

## VANADIUM MINERALIZATION AND ITS INDUSTRY IN CANADA

Mehmet F. Taner, Robert A. Gault, and T. Scott Ercit

Canadian Museum of Nature  
Research Division, PO Box 3443, Stn.  
"D", Ottawa, Ontario, Canada K1P 6P4

### Introduction

Vanadium is a strategic metal and is used in the production of high-quality metal alloys, like strengthened steel, for its property as an active grain refiner and as a strong deoxidant. It can also impart strength, hardness and wear resistance to steels. Vanadium is mostly used in industry for the production of (i) high-strength steel (85%), e.g. pipelines; (ii) titanium-aluminum-vanadium alloys (10%) (Ti-6Al-4V), used in the aerospace industry; (iii) for the production of catalysts, ceramics, glasses and pigments, electronics and batteries in the chemical industry (5%). The vanadium industry is only about 40 years old. New uses are continually being discovered for this metal. Vanadium is relatively abundant in the Earth's crust, but few economic deposits are known. Up to now, South Africa has produced 43% of the world's vanadium, while the rest is split between Russia (19%), the Far East (mostly China, 23%), and the United States (15%). Australia will become a producer of vanadium with the Windamura project by Precious Metals Australia Lim-

ited (in production by 1999), and will contribute approximately 10% of the world's production. World demand for vanadium is estimated at about 46 000 tV in 1997 (it was about 20 000 tV in 1991) and consumption is expected to rise at 5% per annum to 2005. Vanadium has gained some new markets and will find some new applications over the next few years. For example, Japan and Australia are currently developing the next generation of vanadium redox batteries to power electric vehicles. The next generation of high-capacity wide body jets is also expected to offer growing markets for aluminum/vanadium/titanium alloys. New catalytic applications are also being developed for vanadium. NASA selected vanadium foil for use in experimental high temperature superconducting cables. Vanadium is also used for the production of superconductive magnets.

Vanadium mineralization typically occurs in oxide-rich horizons within the upper parts of layered complexes such as the Bushveld (Willemsse, 1969; Von Gruenewaldt *et al.*, 1985a, b; Reynolds, 1985a,b). The distribution and geological relationships of these oxide-rich layers clearly indicate that they are magmatic ore deposits and that their genesis is directly related to processes that were operating during the late stages of fractional crystallization. Although there is a substantial potential for vanadium in Canada, there is currently no vanadium production. However, McKenzie Bay Resources Ltd. expects to deliver a feasibility study before the end of 1999 for development of the Lac Doré vanadium deposit, Chibougamau, Québec (Girard & Allard, 1998). Most of the vanadium deposits in Canada are associated with: (1) layered mafic intrusions, such as the Lac Doré Complex at Chibougamau,

Québec (Allard, 1976), the Bell River Complex at Matagami, Québec (Taner & Allard, 1998; Taner *et al.*, 2000); (2) Anorthosite complexes, such as the Sept Îles complex, Québec (Cimon, 1998) and (3) anorthosite complexes, such as the Pipestone Lake Complex, Manitoba (Jobin-Bevans *et al.*, 1997); (4) there also is a substantial vanadium potential in the Athabaskan tar sands, Alberta.

The present report summarizes our findings on the geology and mineralogy of vanadium deposits in the Bell River and Lac Doré Complexes, Abitibi, Quebec (Fig. 1).

### The Bell River Complex, Matagami Mining District

The Bell River Complex (Fig. 1) is a large, layered intrusion of Archean age in the Matagami mining district. It consists of eastern and western lobes separated by the Olga granodioritic pluton (Sharp 1968; Scott, 1980; Maier *et al.*, 1996). Although the complex played an important role as a heat source for the mineralization of a number of massive sulfide deposits in the Matagami mining district (Sharp 1968; Beaudry & Gaucher, 1986; MacLean, 1984; Piché *et al.*, 1993), it is poorly documented compared to similar layered intrusions in the Abitibi belt, such as the Lac Doré Complex in the Chibougamau area (Allard, 1976). The Bell River Complex has been divided into three main zones (Fig. 2): (1) a basal anorthosite zone (Main Zone), (2) a layered gabbro zone (Layered Zone), and (3) a zone consisting of apophyses and subsidiary intrusions (Granophyre/ Border Zone). The basal anorthosite zone lacks a defined stratigraphy. The layered gabbro zone consists of distinctly layered Fe-Ti-oxide-rich gabbro, ±

(Continued on page 4)

### Inside this issue:

Message from President	3
Comment & Reply	10
Mobility of Geoscientists	15
Looking Back at MDD	17
Calendar of Events	18

## 1999-2000 MINERAL DEPOSITS DIVISION EXECUTIVE LIST

### **Chairperson:** *Jason Dunning*

Hudson Bay Exploration and Development Co.  
800-700 Pender St. W., Vancouver, BC V6C 1G8;  
Tel: (604) 684-1454; FAX: (604) 689-3480; email: hbed@istar.ca

### **Past Chairperson:** *Catherine Farrow*

INCO Ltd., Highway 17W, Copper Cliff, ON, P0M 1N0;  
Tel: (705) 682-8383; Fax: (705) 682-8243; email: farrowc@exploration.incoltd.com

### **Vice Chairperson:** *Andrew Conly*

Dept. of Geology, Univ. of Toronto, 22 Russell St., Toronto, ON M5S 3B1; Tel: (416) 978-0657; FAX: (416) 978-3938; email: aconly@quartz.geology.utoronto.ca

### **Secretary:** *Gary S. Wells*

Inmet Mining Corporation, 1300 Blvd. Sagunay, Rouyn-Noranda, QC J9X 7C3;  
Tel: (819) 764-6666 ext. 223; Fax: (819) 764-6404;  
email: inmet-rouyn@sympatico.ca

### **Treasurer:** *Robert J. Cathro*

Cathro Exploration Corp, RR#1, Site U-39, Bowen Is., BC, V0N 1G0;  
Tel: (604) 947-0038; Fax: (604) 947-0038  
or, Arizona, Tel/Fax: (602) 423-1006; email: bobcat@direct.ca

### **Publications:** *Dirk Tempelman-Kluit*

4697 West 4th St., Vancouver, BC;  
Tel/FAX: (604) 224-5582; Fax: (604) 224-6903; email: dirktk@direct.ca

### **Professional Development – Short Courses:** *Iain M. Samson*

Dept. of Earth Sciences, Univ. of Windsor, Windsor, ON N9B 3P4;  
Tel: (519) 253-4232 ext 2489; FAX: (519) 973-7081; email: ims@uwindsor.ca

### **Professional Development – Field Trips:** *Dani Alldrick*

BC Geological Survey, 5 - 1810 Blanshard Street, Victoria, BC V8T 4J1;  
Tel: (250) 952-0412; Fax: (250) 952-0381;  
email: Dani.Alldrick@gems6.gov.bc.ca

### **Program Chair: GEOCANADA 2000:** *Michael Marchand*

Madrona Mining Ltd., Calgary, AB; Tel/Fax: (403) 282-5105;  
email: marchand@ibm.net

### **Medals Committee:** *Charlie Jefferson*

Geological Survey of Canada, 601 Booth St., Ottawa, ON K1A 0E8;  
Tel: (613) 996-4561; Fax: (613) 996-9820; email: cjeffers@NRCan.gc.ca

**PLEASE CHECK OUT OUR Internet Website:**  
[www.northfacesoftware.com/mdd](http://www.northfacesoftware.com/mdd)

The Gangue is published quarterly by the Mineral Deposits Division of GAC and is distributed to its members.



## MDD Goals and Objectives

The Mineral Deposits Division of the Geological Association of Canada is Canada's foremost society for promoting the study of mineral deposits by supporting local and national meetings, symposia, short courses and field trips. We sponsor the publication of research relating to ore deposits and metallogeny, and recognize the contributions of outstanding Canadian economic geologists by annually awarding the Duncan Derry and William Harvey Gross medals and the Julian Boldy Certificate.

### **Publication Schedule:**

SUBMISSION	DATE
December 15	January
March 15	April
June 15	July
September 15	October

### **Information for contributors:**

The objective of this newsletter is primarily to provide a forum for members and other professionals to voice new ideas, describe interesting mineral occurrences or expound on deposit models. Articles on ore deposits, deposit models, news events, field trips, book reviews, conferences, reprints of presentations to companies, mining groups or conferences, or other material which may be of interest to the economic geology community are welcome. Manuscripts should be submitted by email in WP or WORD format. A printed version should be mailed or FAXed. Illustrations should be camera-ready (ideally as CDR digital files); photos should be of good quality. Short items dealing with news events or meetings can be submitted by FAX, postal mail or email. Contributions may be edited for clarity or brevity.

### **For Information & Submissions:**

**David Lentz** – THE GANGUE  
Dept. of Geology, Univ. of New Brunswick,  
Fredericton, NB E3B 5A3  
Email: dlentz@unb.ca

**Steven McCutcheon** – THE GANGUE  
N.B. Geological Survey, PO Box 50,  
495 Riverside Drive, Bathurst, NB E2A 3Z1

## MDD DIRECTORS

### • **Dan Marshall (1999-2002)**

Dept. of Earth Sciences, Simon Fraser Univ., Vancouver, BC; Tel: (604) 291-5474; Fax: (604) 291-4198; email: marshall@sfu.ca

### • **Dave Peck (1999-2002)**

Manitoba Energy and Mines, Winnipeg, MB; Tel: (204) 945-6545; Fax: (204) 945-1406; email: dpeck@em.gov.mb.ca

### • **Jeremy Richards (1999-2002)**

Dept. of Earth Sciences, Univ. of Alberta, Edmonton, AB; Tel: (403) 492-3430; Fax: (403) 492-2030; email: Jeremy\_Richards@ualberta.ca

### • **Derek Wilton (1999-2002)**

Dept. of Earth Sciences, Memorial Univ. of Nfld., St. John's, NF; Tel: (709) 737-8389; Fax: (709) 737-2589; email: dwilton@kean.ucs.mun.ca

### • **Bob Friesen (1998-2001)**

Teck Exploration, Kamloops, BC; Tel: (250) 372-0032; Fax: (250) 372-1285; email: gfriesen@wkpowlink.com

### • **Mike Sweeney (1998-2001)**

Falconbridge Exploration, Falconbridge, ON; Tel: (705) 693-2761 ext. 3655; Fax: (705) 699-3600; email: Mike\_Sweeney@sudbury.falconbridge.com

### • **Kevin Ansdell (1997-2000)**

Univ Saskatchewan, Saskatoon, SK; Tel: (306) 966-55698; Fax: (306) 966-8593; email: kevin.ansdell@usask.ca

### • **Harold Gibson (1997-2000)**

Laurentian Univ, Sudbury, ON P3E 2C6; Tel: 705-675-1151 ext 2337; FAX: 705-675-4898; email: hgibson@nickel.laurentian.ca

### • **Baxter Kean (1997-2000)**

Dept of Mines & Energy, St. John's, NF A1A 5A8; Tel: (709) 729-5946; Fax: (709) 729-3493; email: bjk@zeppo.geosurv.gov.nf.ca

## President's Message

As my term as the Chairperson for the Mineral Deposits Division (MDD) draws to a close, I am proud to say that the MDD continued to show why we are a strong presence in both the national and international geoscience community and that the MDD had an incredibly successful year. Although the mining industry as a whole has seen more profitable times, there is now a light at the end of the tunnel, as evidenced by recent staking rushes in Central BC south of Prince George and around Sudbury, Ontario. Although these local staking rushes do not signal a complete reversal of the mining industry's recent misfortunes worldwide, I am sure that many of our colleagues across the country now share a cautious optimism about the coming year. With that cautious optimism in mind, the MDD shall continue to build towards a stronger presence in the not so far off future through increased visibility on both a national and international stage. MDD's active role in the GEOCANADA 2000 Conference provides the MDD with an excellent opportunity to disseminate valuable information to our membership and the geoscience community at large. To that end, the MDD is sponsoring 6 special thematic sessions, a field trip to the Purcell Supergroup, which includes a visit to the soon to be closing Zn-Pb Sullivan Mine, and a short course on kimberlite indicator minerals.

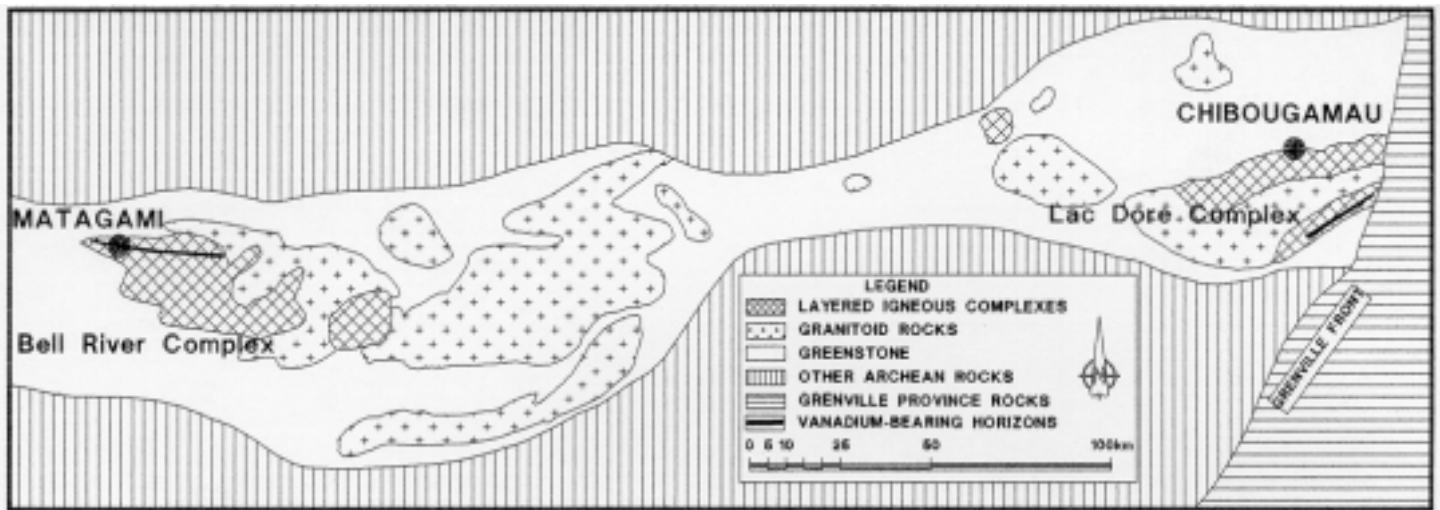
Our main highlights in 1999 included a renewing of our profitable relationship with the Mineral Deposits Research Unit of the University of British Columbia through a joint short course prior to the Cordilleran Round-Up Conference in Vancouver, BC. This short course focused on the genetic and geochemical aspects of the Carlin-type deposits with respect to their possible occurrence in the Canadian Cordillera and was attended by over 80 persons from academia, government, and industry. In terms of Publications, 1999-2000 proved to be a challenging year for MDD; however, through diligent efforts of our editors and the respective steering committees, the MDD will now see the publication of two world-class publications this upcoming summer, namely in the Latin American VMS and Sullivan volumes. Both of these volumes will be on display at GEOCANADA 2000 in Calgary along with order forms. Two other publications that came out during the 1999 calendar year were the short course notes volume from the 1999 GAC Annual Meeting in Sudbury. As for future publication projects for the MDD, there are currently plans for two new additions to our very successful Atlas Series family, which is especially important knowing that the Alteration Atlas continues to be one of the strongest selling publications for the GAC across the geoscience spectrum.

This year, like every year, there is a changing of the guard in the Executive Council of the MDD. Therefore, I would like to take this opportunity to announce the incoming changes. Andrew Conly, a Ph. D. student from the University of Toronto will be our new Chairperson for 2000-2001. He is coming off a great year as our Vice-Chairperson and it should be noted that Andrew's contributions have been an invaluable asset to a number of MDD projects. To fill the role as Vice-Chair, the MDD Executive Council selected Stephen Piercey, a Ph.D. student from the Mineral Deposit Research Unit (MDRU) at the University of British Columbia. Like Andrew, Stephen has solid links with many other geoscience organizations such as the Society of Economic Geologists (SEG) and is also well connected with several of the geological surveys and the mining industry. I hold out great hope for this new dynamic duo and cannot wait to see them both in action in the very near future.

In closing, I want to once again extend my congratulations to everyone who participated in the MDD this past year. If not for them, 1999 and the beginning of 2000 would not have been such an incredible year of growth for the MDD. I would also like to thank all of our returning members, who continue to support the MDD and those new members, whose journey with the MDD is only just beginning. So as I move into the role of the Past President on the Executive Council of the MDD, my role may become slightly less active, but I know that I eagerly await the challenges of the upcoming year, as I foresee only positive growth for the MDD into 2001.

Yours sincerely,

**Jason K. Dunning**, B.Sc., M.Sc., FGAC – 1999-2000 Chairperson  
*Mineral Deposits Division, Geological Association of Canada*



**Figure 1.** Simplified geological map of the Matagami-Chibougamau area, the Northern part of the Abitibi greenstone belt, Quebec (modified from MacLean, 1984).

(Continued from page 1)

leucogabbro, minor anorthosite and pyroxenite. Vanadium mineralization within the Bell River Complex occurs within Fe-Ti-oxide-rich horizons (Fig. 3A) in the layered ferrogabbro zone of the upper part of the Complex (Fig. 2). This horizon is well defined on the ground and in aeromagnetic survey maps by its high magnetic susceptibility.

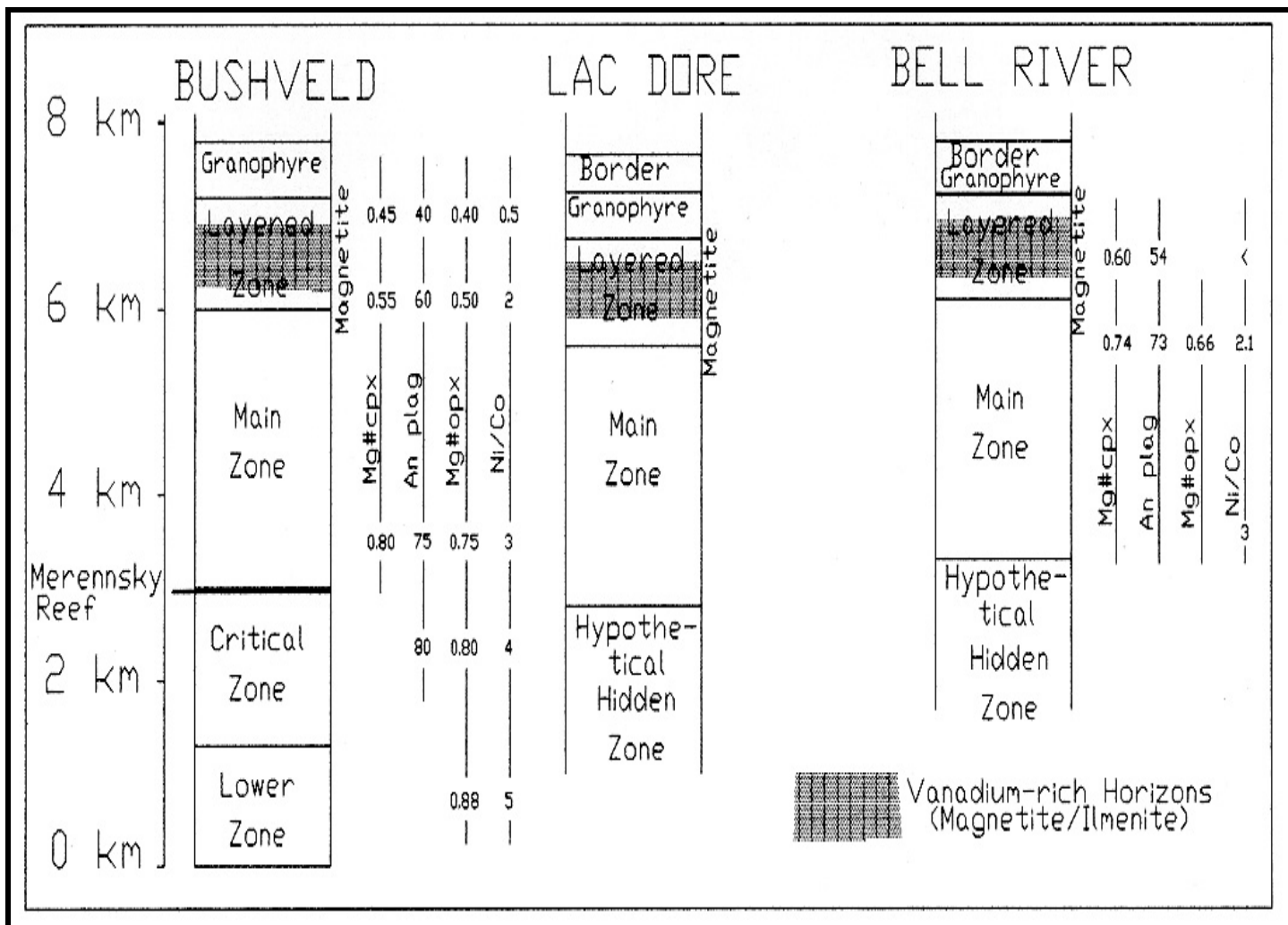
#### Lac Doré Complex, Chibougamau mining district

The Lac Doré Complex (Allard, 1976; Girard & Allard, 1998) is located about 250 km east of Matagami (Fig. 1). According to Allard (1976), the Lac Doré Complex is a Bushveld-type layered complex, folded into a large anticline and metamorphosed to greenschist facies like the enclosing volcanic rocks, with which it is coeval and comagmatic. From bottom to top (Fig. 2), the Complex has been divided into the following zones: Anorthosite Zone (Main Zone), Layered Zone, and Upper Border Zone (including Soda-granophyre and Ferrodiorite Zones). The vanadium mineralization in the Lac Doré Complex (Allard, 1976) is contained in the lower-most part of the Layered Zone (Fig. 2) in Rinfret and Lemoine Townships and in the Cache Lake - David Lake area. The vanadium horizon consists of rhythmically layered units (50 to 200 meter-thick layered zones) rich in ferroaugite, magnetite and ilmenite, intercalated with layers of leucogabbro. The Fe-Ti oxides at Lac Doré (Fig. 3B) are heterogeneously and rhythmically distributed, with Fe-Ti-oxide-rich horizons intercalated with oxide-free horizons. Total evaluated resources estimated by McKenzie Bay Resources Ltd. (Girard & Allard, 1998) are about 100 million tonnes of ore with a grade of 0.49%  $V_2O_5$ , including 32.2 million tonnes of measured resources with a tenor of 0.65%  $V_2O_5$ . The concentrated ore (vanadian magnetite) contains between 1.4% and 1.6%  $V_2O_5$ .

#### Petrography

Vanadium-bearing Fe-Ti-oxide zones form specific layers at the upper part of the Bell River and Lac Doré layered complexes. Layering is sharply defined by leucocratic laminae, which constitute a thin 2- to 20-cm layer, by the orientation of cumulate minerals, or by oxide-rich bands (Figs. 3A, and 3B). In both complexes, these layers are concordant with the igneous layering of the Upper Zone. The continuity and lateral extent of these horizons are well-characterized by magnetic anomalies. In the Bell River Complex, oxide-rich gabbro horizons are about 10 to 150 m wide, with a subvertical dip. The gabbro is a mineralized cumulate with (1) homogeneously disseminated oxide mineral contents of 20 to 60 modal %, or (2) homogeneous, massive bands with widths of several cm to tens of cm, with oxide mineral contents of 50 to 90 modal % (Fig. 3A). These mineralized bands form 60-80% of the layered gabbro zone. There is a sharp contact between mineralized oxide-rich gabbro and host gabbro-anorthosite sequences in the Bell River Complex. A similar occurrence (Fig. 3B) was also described for the Lac Doré Complex (Allard, 1976; Girard & Allard, 1998). Table 1 contains whole rock analyses of selected vanadium ore samples from the Bell River and Lac Doré Complexes.

Optical microscopy of selected samples from these complexes indicates that the oxide-rich mineralized zones are medium-grained magnetite-ilmenite ferrogabbro. These rocks may be defined as mesocumulates to adcumulates. They consist of silicate minerals (30-80%), principally laths of plagioclase (1-3 mm in length) and subhedral elongated augite along with interstitial Fe-Ti oxide minerals (20-70%). Rutile and titanite are dominant accessory minerals. The main oxide minerals are ilmenite and magnetite. They range in size from 1-2 mm to less than 5  $\mu$ m, occurring as coarse- to medium-grained subhedral crystals intergrown with cumulus silicate gangue. The magnetite: ilmenite



**Figure 2.** Comparison of the schematic stratigraphic column, mineral chemistry, and Ni/Co ratio of the Bushveld, Lac Doré, and Bell River layered complexes (modified from Maier *et al.*, 1996).

ratio ranges from about 1:1 to 2:1. Most magnetite crystals contain tiny lamellae of ilmenite (Fig. 4A and 4B) that account for 20-40% of their volume.

### Oxide Mineralogy

#### Ilmenite

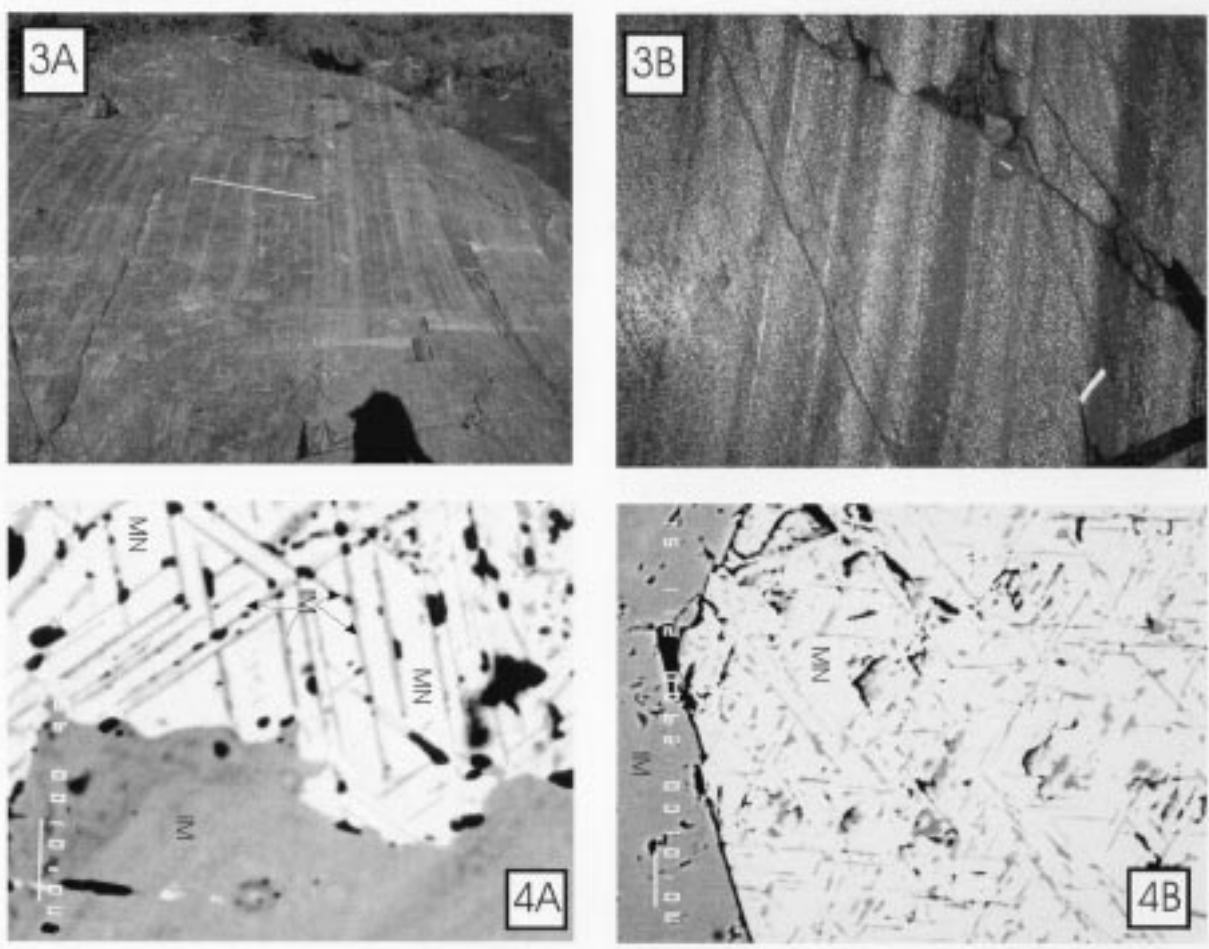
Ilmenite,  $\text{FeTiO}_3$ , as titanium ore, occurs as separate grains 0.4-2 mm across, intergrown with titanian magnetite, which occupy interstices between cumulus minerals. The grains may occur alone or as aggregates that have smooth or irregular, sharp contacts with adjoining magnetite (Fig. 4A). A textural variety of the ilmenite occurs as exsolution laths with titanian magnetite (Figs. 4A, 4B) and, in some cases, constitutes irregular grains within magnetite. This lamellar textural variety was observed in both complexes. The vanadium content of ilmenite grains is very low (the average value of 21 analyses is 0.18 equivalent  $\text{V}_2\text{O}_5$  %), relative to magnetite samples (1.41% equiv.  $\text{V}_2\text{O}_5$  for 20 analyses). In addition to analysing discrete ilmenite grains, we

attempted to analyze ilmenite laths in magnetite grains. Most laths are too narrow for electron-microprobe analysis; however, one large lath within a magnetite grain was suitable. Its composition compares well with that of the discrete grains of ilmenite (Table 2).

#### Magnetite

Magnetite,  $\text{Fe}^{2+}\text{Fe}^{3+}_2\text{O}_4$ , is the principal host for vanadium in magmatic ores. Trivalent iron in magnetite may be replaced by Al, Ti, V and, more rarely, by Cr. A number of exsolution products can be found in magnetite formed at high temperature, most commonly ilmenite, but also other spinels, including spinel *sensu stricto* ( $\text{MgAl}_2\text{O}_4$ ), hercynite ( $\text{FeAl}_2\text{O}_4$ ), and magnesioferrite ( $\text{MgFe}_2\text{O}_4$ ).

The ilmenite laths occur in two distinct widths that differ by a factor of 10. The wider laths, 10 to 30  $\mu\text{m}$  are rare. The narrow laths are 1 to 3  $\mu\text{m}$  wide (Figs. 4A and 4B) lie within {111} octahedral crystallographic planes of the magnetite host. Sections



**Figure 3.** Photographs of vanadium-bearing oxide-rich gabbroic rocks from the Bell River Complex and Lac Doré Complex: (3A) Outcrop, Matagami, showing mineralized bands that host 50-90% magnetite + ilmenite and form 60-80% of the whole layered gabbroic unit. (3B) Outcrop in Rincret Tp., Chibougamau, showing rhythmic layering with magnetite + ilmenite rich horizons (scale: camera lens cover = 5 cm diameter).

**Figure 4.** Backscattered-electron microprobe images of vanadium-rich samples: (4A) Bell River Complex, variable contacts between homogeneous ilmenite (IM) grains and grains of vanadium-bearing magnetite (MN) plus trellis-textured ilmenite (section cut subparallel to  $\{111\}_{MN}$ , 10µm scale bar); (4B) Lac Doré Complex, sharp contact between a homogeneous ilmenite (IM) grain and a magnetite (MN) grain containing trellis-textured ilmenite lamellae (10µm scale bar).

cut parallel to  $\{111\}$  have a characteristic distribution of ilmenite laths in equilateral triangles forming a trellis texture. Trellis lamellae are generally attributed to "oxidation-exsolution", whereas other ilmenite can be products of either oxidation or primary crystallization (Buddington & Lindsley, 1964; Haggerty, 1991). Sections cut parallel to  $\{100\}$  planes in magnetite have ilmenite laths distributed in a square pattern. The wide laths are usually more widely spaced and continuous than the narrower ones that occur between them. The magnetite grain boundary with any adjoining grain of ilmenite is invariably very irregular (Fig. 4A). These textural relationships are well established in the literature, as illustrated by Ramdohr (1953,1969), Lindsley (1991), and Haggerty (1991).

Our electron-microprobe data indicate that the Ti contents of

the magnetite in the intergrowths is low, generally less than 2 wt. %  $TiO_2$ . For comparison, compositions of mixtures (Table 2) represent the magnetite containing the ilmenite lamellae, which can be taken as crude approximations of the bulk composition. The analyses have  $TiO_2$  contents in the range 11 to 32 wt. %, which are comparable to those given in the literature for macroscopic "titanomagnetite" and "Ti magnetite" (Reynolds, 1985a,b; Von Gruenewaldt *et al.*, 1985a, respectively). The vanadium contents of titanian magnetite quoted in the literature (20-analysis average of 1.41% equiv.  $V_2O_5$ , Table 2) are lower than our results for the Ti-poor magnetite of the intergrowth. The distinction is important because only the magnetite portion of the intergrowths hosts significant amounts of vanadium. A recent study in the vanadium deposits of the Windimurra Complex,

**Table 1.** Whole rock analyses of vanadium-rich selected samples from the Bell River and Lac Doré Complexes (vanadium ores)

Sample	54	99	56	57
SiO <sub>2</sub>	19.97	6.42	8.84	7.19
TiO <sub>2</sub>	8.49	14.21	14.36	15.21
Al <sub>2</sub> O <sub>3</sub>	9.64	2.99	6.45	6.33
V <sub>2</sub> O <sub>3</sub> *	0.49	0.59	0.52	0.66
Fe <sub>2</sub> O <sub>3</sub> **	50.37	69.38	60.71	64.17
MnO	0.24	0.32	0.28	0.32
MgO	2.94	3.53	2.45	2.25
CaO	4.13	1.28	1.72	1.38
K <sub>2</sub> O	0.05	0.01	0.03	0.04
Na <sub>2</sub> O	0.69	0.01	0.2	0.1
P <sub>2</sub> O <sub>5</sub>	0.02	0.01	0.01	0.01
S	0.94	-	0.18	0.19
LOI	1.53	1.23	0.45	0.74
Total%	99.5	99.97	96.2	98.59
Selected trace elements (ppm)				
Cr	18	126	203	213
Mn	1758	2870	2134	2210
As	15	<5	32	42
Sc	22	7	23	23
Co	127	111	115	143
Ni	60	193	69	83
Pb	19	<2	10	19
Cu	145	406	42	30
Zn	275	57	234	274
Selected trace elements (ppb)				
Au	2	38	<1	<1
Pt	<20	<5	<5	<5
Pd	<20	<1	<1	<1
*Equiv.V <sub>2</sub> O <sub>5</sub> %	0.59	0.71	0.63	0.8

Samples 54 and 99: Matagami; Samples 56 and 57: Chibougamau.

**Analytical methods:** whole-rock analyses were done by Intertek Testing Services-Chimitec at Val d'Or, Québec, Canada; major elements by XRF, selected trace elements by ICP-AES, S by Leco, V, Cu and Zn by atomic absorption (AA), and Au, Pt and Pd by pyroanalysis.

Western Australia by Habteselassie *et al.* (1996) also shows similar results to Lac Doré and Bell River vanadium deposits.

## Discussion

### Vanadium in magnetite

Electron microprobe analyses of ore samples from both complexes (Table 2) indicate that vanadium is more strongly partitioned into magnetite than into ilmenite. This behavior most likely reflects the nearly identical ionic radius and charge of V<sup>3+</sup> (0.64 Å) and Fe<sup>3+</sup> (0.645 Å, Shannon, 1976). Consequently, magnetite, a mineral rich in Fe<sup>3+</sup>, is expected to have higher V contents than ilmenite, a mineral poor in Fe<sup>3+</sup>. Coulsonite

**Table 2.** Electron-microprobe analyses of magnetite, ilmenite and mixture of magnetite/ilmenite within magnetite containing ilmenite lamellae

Min.	magnetite	Ilmenite	Mixture	
MnO	0.06	1.05	0.88	0.37
FeO	33.45	44.01	28.17	42.92
ZnO	0.20	0.00	0.19	1.02
Al <sub>2</sub> O <sub>3</sub>	0.97	0.01	0.68	2.21
Fe <sub>2</sub> O <sub>3</sub>	62.23	3.62	34.58	38.33
V <sub>2</sub> O <sub>3</sub> *	1.16	0.15	0.77	1.00
TiO <sub>2</sub>	2.43	50.56	32.44	13.77
SiO <sub>2</sub>	0.05	0.01	0.05	0.06
Total %	100.65	99.63	97.76	99.68
Formula Contents				
Mn	0.00	0.02	0.02	0.01
Fe <sup>2+</sup>	1.06	0.93	0.62	1.35
Zn	0.01	0.00	0.04	0.03
Al	0.04	0.00	0.02	0.10
Fe <sup>3+</sup>	1.78	0.09	0.68	1.09
V <sup>3+</sup>	0.04	0.00	0.02	0.03
Ti	0.07	0.96	0.64	0.39
Si	0.00	0.00	0.00	0.00
Sum	3.00	2.00	2.00	3.00
O	4.00	3.00	3.00	4.00

\*Equiv.V<sub>2</sub>O<sub>5</sub>%

1.41                      0.18    0.93    1.21

Magnetite (average of 20 samples): Formula contents per 3 cations and 4 anions Ilmenite (average of 21 samples): Formula contents per 2 cations and 3 anions. Selected analyses of magnetite/ilmenite mixtures (magnetite with ilmenite lamellae).

Fe<sup>2+</sup>V<sup>3+</sup><sub>2</sub>O<sub>4</sub>, the vanadium analogue of magnetite (Radtke, 1962), found in titaniferous magnetite ores at Singhum, Bihar India, represents the ultimate in Fe<sup>3+</sup> → V<sup>3+</sup> substitution in magnetite.

It is likely that the vanadium in magnetite is trivalent, not pentavalent. On the basis of both charge and size considerations, V<sup>5+</sup> will not readily substitute for Fe<sup>2+</sup>, yet it can substitute for Fe<sup>3+</sup>. However, substitution of V<sup>5+</sup> for Fe<sup>3+</sup> introduces a charge imbalance in the magnetite structure which can only be offset by substitution of a small monovalent cation for Fe<sup>3+</sup>, by means of a substitution mechanism like 2Fe<sup>3+</sup> ↔ R<sup>+</sup> + V<sup>5+</sup>. Routine beneficiation of vanadium ores results in an oxidized product, hence the reporting of refined vanadium ore concentrates in wt. % V<sub>2</sub>O<sub>5</sub>. This has led previous researchers to erroneously report vanadium concentrations of unrefined magnetite-bearing ore and ore minerals in wt. % V<sub>2</sub>O<sub>5</sub> (e.g., Klemm *et al.*, 1985; Reynolds, 1985a,b; Von Gruenewaldt *et al.*, 1985a). For scientific accuracy, analyses of unrefined vanadian magnetite ore and ore minerals should be reported in wt. % V<sub>2</sub>O<sub>3</sub>. Nonetheless, we advocate supplementing analytical results with *equivalent* V<sub>2</sub>O<sub>5</sub> (= V<sub>2</sub>O<sub>3</sub> × 1.2135), for a tie to previously published data and to provide a measure of vanadium concentration preferred by industry (cf. Table 2).

### **Ore benefaction**

Several technological advances have had a positive effect on the profitability of vanadium projects. For example, advances in Wet High Intensity Magnetic Separation (WHIMS) technologies in recent years have led to substantial improvements in vanadium recovery. With the current study, we now have the mineralogical data needed to complete the process of commercial extraction of vanadium from vanadium ore.

The main vanadium-bearing mineral in both complexes is magnetite. These vanadium ores also contain economic quantities of ilmenite. Accordingly, we suggest as a schematic flow sheet: (1) Grinding of the ore to an average grain-size of 40-50 µm, for a good initial degree of liberation. (2) Gravimetric separation of oxide ore minerals (ilmenite and magnetite) from silicate gangue minerals (plagioclase, pyroxene, chlorite, etc.), resulting in a medium-grade V-Ti ore and an environmentally safe waste. (3) Concentration of vanadium ore (magnetite) by magnetic separation and of titanium ore (ilmenite) by floatation. Because of the extremely fine grain-size of the ilmenite laths in the magnetite, it is not practical to attempt physical separation of the intergrowth. Consequently, the final step is (4) the application of conventional vanadium-extraction process on the vanadian ore.

### **Conclusion**

It is concluded that Canada may have the potential to become a large scale vanadium producer with the industrial applications in North America. Therefore, it is recommended that Canada seek to develop new industries related to vanadium in order to give greater values to its substantial vanadium potential. Thus, multi-disciplinary team work is needed in collaboration with people from industry, governments (Federal and Provincial), and universities. This team must evaluate the profitability of projects, including marketing, feasibility and possibly industrial applications. During the first stage of projects, intense research and development activities are necessary with the involvement of the National Research Council.

### **Acknowledgements**

We wish thank the editors for suggesting to us to submit this contribution. Constructive comments provided by G. Woods (NOREX-Bathurst) and D. Peck (Manitoba government) during their review were also appreciated.

### **References**

- Allard, G.O., 1976. Doré Lake Complex and its importance to Chibougamau geology and metallogeny. Ministère des Richesses Naturelles du Québec, DP-368, 446 pages.
- Beaudry, C. & Gaucher, E., 1986. Cartographie géologique dans la région de Matagami. Ministère de l'Énergie et des Ressources du Québec. MB86-32, 147 pages.
- Buddington, A.F., & Lindsley, D.H., 1964. Iron titanium oxide minerals and their synthetic equivalents. *Journal of Petrology*, v. 5, p. 310-357.
- Cimon, J., 1998. L'unité à apatite de rivière de Rapides, Complexe de Sept-Îles: localisation stratigraphique et facteurs à l'origine de sa formation. Ministère des Ressources Naturelles du Québec, ET97-05, Part I, p. 1-32.
- Girard, R. & Allard, G.O., 1998. The lac Doré vanadium deposits, Chibougamau. In " Geology and Metallogeny of the Chapais-Chibougamau Mining District: a new vision of the discovery potential", Proceedings of the Chapais-Chibougamau 1998 symposium, edited by P. Pilote, p. 99-102.
- Habtelelassie, M.M., Mathison, C.I., & Gilkes, R.J., 1996. Vanadium in magnetite gabbros and its behaviour during lateritic weathering, Windimurra Complex, Western Australia. *Australian Journal of Earth Sciences*, v. 43, p. 555-566
- Haggerty, S.E., 1991. Oxide textures- a mini-atlas. In *Oxide minerals: petrologic and magnetic significance*, edited by D. H. Lindsley, *Reviews in Mineralogy*, v. 25, p.129-219.
- Jobin-Bevans, L.S., Halden, N.M., Peck, D.C., & Cameron, H.D. M. 1997. Geology and oxide mineralization of the Pipestone Lake anorthosite complex, Manitoba. *Exploration and Mining Geology*, v. 6, p. 35-61.
- Klemm, D.D., Henckel, J., Dehm, R., & Von Gruenewaldt, G., 1985. The geochemistry of titanomagnetite in magnetite layers and their host rocks of the eastern Bushveld Complex. *Economic Geology*, v. 80, p.1075-1088.
- Lindsley, D.H., 1991. Experimental studies of oxide minerals. In *Oxide minerals: petrologic and magnetic significance*, edited by D.H. Lindsley, *Reviews in Mineralogy*, v. 25, p.69-106.
- MacLean, W.H., 1984. Geology and ore deposits of the Matagami District. In *Chibougamau-Stratigraphy and Mineralization*, edited by J. Guha and E.H. Chown, the Canadian Institute of Mining and Metallurgy, Special volume 34, p.483-495.
- Maier, W .D., Barnes S.-J., & Pellet, T., 1996. The economic significance of the Bell River Complex, Abitibi Subprovince, Québec, *Canadian Journal of Earth Sciences*, v. 33, p. 967-980.
- Piché, M., Guha, J., & Daigneault, R., 1993. Stratigraphic and structural aspects of the volcanic rocks of the Matagami mining camp, Québec: implication for the Norita ore deposits. *Economic Geology*, v. 88, p. 1542-1558.
- Radtke, A.S., 1962. Coulsonite, FeV<sub>2</sub>O<sub>4</sub>, a spinel-type mineral from Lovelock, Nevada. *The American Mineralogist*, v. 47, p. 1284-1291.
- Ramdohr, P., 1953. Ulvöspinel and its significance in titaniferous iron ores. *Economic Geology*, v. 48, p. 677-687.
- Ramdohr, P., 1969. *The ore minerals and their intergrowths*. Pergamon Press, London, 1174 pages.
- Reynolds, I.M., 1985a. Contrasted mineralogy and textural relationships in the Uppermost titaniferous magnetite layers of the Bushveld Complex in the Bierkraal area north of Rustenburg, v. 80, p. 1027-1048.
- Reynolds, I.M., 1985b. The nature and origin of titaniferous magnetite-rich layers in the upper zone of the Bushveld Complex: a review and synthesis. *Economic Geology*, v. 80, p. 1089-1108.

- Scott, R.W., 1980. The geology and petrography of a portion of the Bell river complex in Bourbaux township, Québec. Master of Science thesis, University of Toronto, 163 p.
- Shannon, R.D., 1976. Revised effective ionic radii and systematic studies of interatomic distances in halides and chalcogenides. *Acta Crystallographica*, v. A32, p. 751-767.
- Sharp, J.I., 1968. Géologie et gisements de sulfures de la région de Matagami, Comté d'Abitibi-Est. Rapport Géologique 137. Ministère des Richesses Naturelles du Québec.
- Taner, M.F., & Allard, M., 1998. Évaluation du Potentiel en vanadium dans la partie sommitale du complexe de la rivière Bell. Noranda Inc. Ministère des Ressources Naturelles du Québec, 45 p (GM56921 and GM56292).
- Taner, M.F., Ercit. T.S., and Gault R.A., 2000. Vanadium-bearing magnetite from the Matagami and Chibougamau mining districts, Abitibi, Québec, Canada. *Exploration of Mining Geology*, v. 9 (in press).
- Von Gruenewaldt, G., Klemm, D.D., Henckel, J., & Dehm, R. M., 1985a. Exsolution features in titanomagnetites from massive magnetite layers and their host rocks of the upper zone, eastern Bushveld Complex. *Economic Geology*, v. 80, p. 1049-1061.
- Von Gruenewaldt, G., Sharpes, M.R., & Hatton, C.J., 1985b. The Bushveld Complex: introduction and review. *Economic Geology*, v. 80, p. 803-812.
- Willemse, J., 1969. The vanadiferous magnetic iron ore of the Bushveld igneous complex. *Economic Geology, Monograph* 4, p. 187-208.

**Editors Note:** This is an invited contribution.

## Geological Survey of Canada Open File 3791a,b

### World distribution of nickel deposits

*Compiled by: O.R. Eckstrand and D.J. Good*

**GSC-OF 3791a – 19 page report + 3 diskettes**

**Price: \$41.40 (Canada), \$53.82 (outside Canada)**

**GSC-OF 3791b – 1 colour map, scale 1:35 000 000.**

**Price: \$15.00 (Canada), \$19.50 (outside Canada)**

[http://www.NRCan.gc.ca/gsc/gicd/pubs/circular/2000\\_04/ofiles\\_e.htm#3791](http://www.NRCan.gc.ca/gsc/gicd/pubs/circular/2000_04/ofiles_e.htm#3791)



## Geological Survey of Canada Open File 3792a,b

### World distribution of porphyry, porphyry-associated skarn, and bulk-tonnage epithermal deposits and occurrences

*Compiled by R.V. Kirkham and K.P.E. Dunne*

**GSC-OF 3792a – 26 page report + 1 diskette**

**Price: \$22.10 (Canada), \$28.73 (outside Canada)**

**GSC-OF 3792b – colour map, scale 1:35 000 000**

**Price: \$15.00 (Canada), \$19.50 (outside Canada)**

[http://www.nrcan.gc.ca/gsc/gicd/pubs/circular/2000\\_02/ofiles\\_e.htm](http://www.nrcan.gc.ca/gsc/gicd/pubs/circular/2000_02/ofiles_e.htm)



## The metallogeny of volcanogenic massive sulphide deposits accompanying the Antler Cycle, Finlayson Lake belt, Yukon-Tanana – A Comment

\*Donald C. Murphy<sup>1</sup> Maurice Colpron<sup>1</sup>, Stephen J. Piercey<sup>2</sup> and James K. Mortensen<sup>2</sup>

<sup>1</sup> Yukon Geology Program, Yukon Government, Box 2703 (F-3), Whitehorse, Yukon Y1A 2C6

<sup>2</sup> Department of Earth and Ocean Sciences, The University of British Columbia, Vancouver, BC V6T 1Z4

\*Corresponding author: don.murphy@gov.yk.ca

It was with great interest that we read Duke and Terry's (2000) account of the metallogeny of the Finlayson Lake massive sulphide district. Unfortunately, in our view, the paper is an incomplete summary of the state of knowledge of the area and, in our view, an inaccurate portrayal of the geology and evolution of the district.

Although their article would have been a commendable attempt at interpreting the complex geological setting of the district in the early 1980's, it mostly disregards a large and publicly available body of geological information that has been produced since then and which shows little support for an 'Antler cycle' model. This includes two syntheses of the geological evolution of Yukon-Tanana Terrane (YTT, Mortensen and Jilson, 1985; Mortensen, 1992); the first igneous petrochemical studies of the tectonic setting of the meta-volcanic rocks of YTT in the Finlayson Lake area (Grant et al., 1996; Grant, 1997); systematic 1:50 000-scale regional mapping of the heart of the district (Murphy and Timmerman, 1997; Murphy, 1997, 1998; Hunt and Murphy, 1998; Murphy and Piercey, 1998, 1999a,b,c); and the first igneous petrochemical studies on stratigraphically and geologically constrained samples from the district (Piercey et al., 1999; Sebert and Hunt, 1999). These new data have led to a substantial revision of the 1970's-vintage geological interpretation of YTT, which is the interpretation that underpins Duke and Terry's (2000) main conclusions.

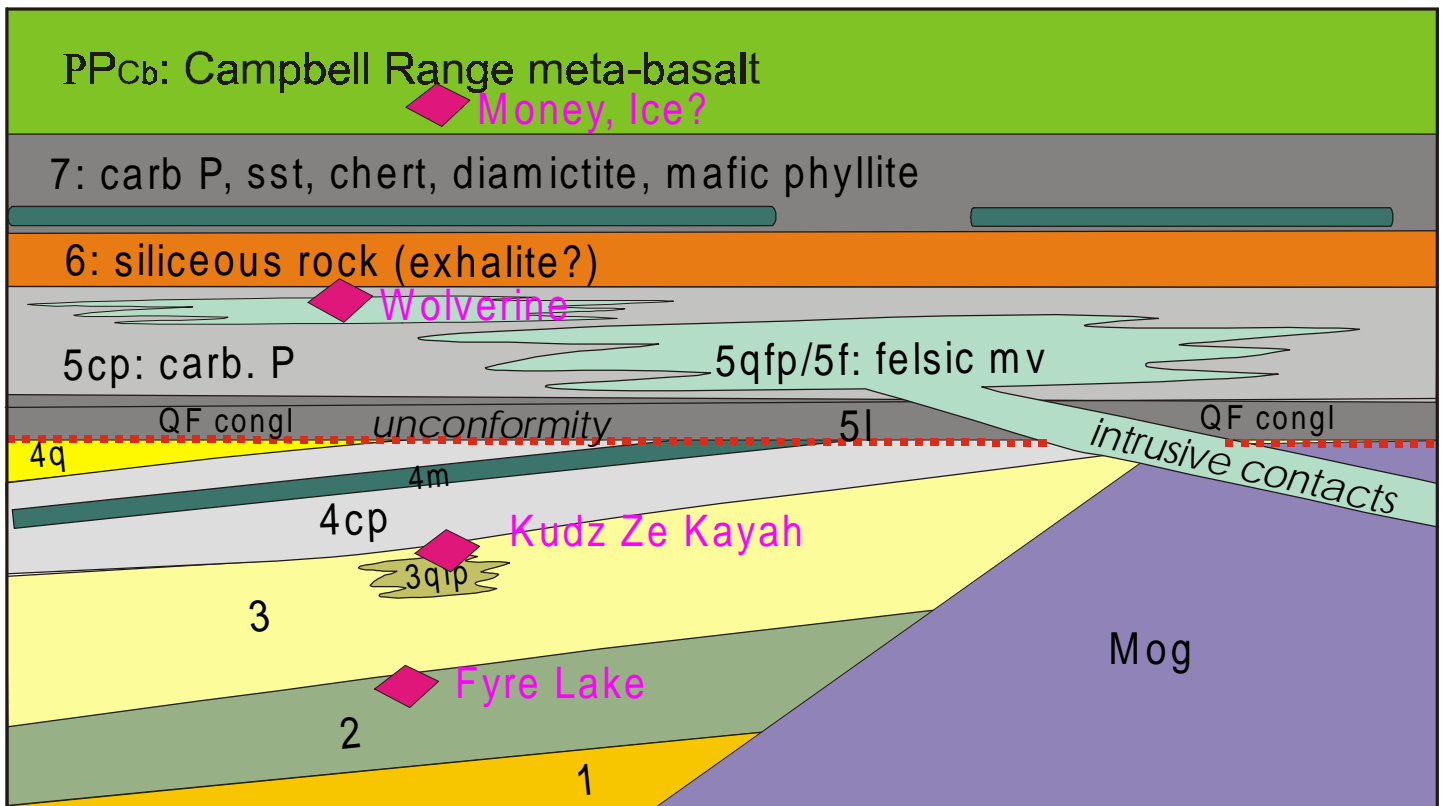
We would like to address three aspects of their synthesis: (1) the stratigraphic context of the deposits, (2) the proposed rift setting for the deposits (opening of the 'Antler ocean') and (3) the proposed closing of the 'Antler Ocean'. Figure 1 is a summary of the stratigraphic units that have been traced over the equivalent of four 1:50 000-scale map areas and the locations of the various deposits within the stratigraphic succession (Murphy and Piercey, 1999c). The Fyre Lake deposit occurs at the top of a Latest Devonian mafic schist unit with primitive arc (boninitic) through calc-alkalic chemistry (Piercey et al., 1999; Sebert and Hunt, 1999), which is **low** in the stratigraphic succession, not high in the succession as asserted by Duke and Terry (2000). Kudz Ze Kayah occurs in a slightly younger felsic metavolcanic unit with a geochemical character that is compatible with intra-arc- or back-arc rifting (Piercey et al., 1999, 2000). Wolverine Lake occurs in an even younger succession that is inferred to

*unconformably* overlie the succession that hosts Kudz Ze Kayah and Fyre Lake. Its chemistry is identical to that of Kudz Ze Kayah and likely reflects the persistence of the same geological setting. Finally, the Campbell Range meta-basalt, which contains mid-Pennsylvanian to Early Permian radiolaria near its base (Harms, in Plint and Gordon, 1997) and hosts the Money prospect (and likely the Ice deposit) belongs to a succession that is inferred to *stratigraphically, not structurally*, overlie the Wolverine succession, not structurally as had been interpreted by all previous workers. We interpret this stratigraphic evolution as a record of the evolution from arc magmatism to arc- or back-arc rifting culminating in the formation of oceanic crust.

Although sounding somewhat like the opening of an ocean, our interpretation differs in that much, but perhaps not all, of the rifting is thought to have occurred in a back-arc setting. In contrast to Duke and Terry's (2000) assertions to the contrary, intermediate calc-alkalic plutonism of Early to Late Mississippian age is well documented throughout YTT, mainly occurring south and west of the core of the Finlayson Lake district (Simpson Range Plutonic Suite of Mortensen, 1992; Grant et al., 1996; Grant, 1997; Piercey et al., 1999, 2000). Also, volcanic centres have been identified, including Fyre Lake, Kudz Ze Kayah, and Wolverine Lake. Hence, it is reasonable to conclude that Fyre Lake, the southernmost of the deposits, formed in a nascent arc setting and Kudz Ze Kayah and Wolverine Lake formed in a back-arc rift environment. Whether or not the Campbell Range succession formed in a back-arc setting is less clear as a coeval arc has yet to be identified.

In terms of the closing of the 'Antler Ocean', our work has challenged the widely held notion that all occurrences of mafic meta-volcanic rocks, mafic and ultramafic meta-plutonic rocks, and dark argillite and chert are oceanic allochthons belonging to Slide Mountain Terrane (Murphy, 1998; Murphy and Piercey, 1999a). As mentioned above, our observations in the Campbell Range suggest that the base of the Campbell Range succession (Duke and Terry's (2000) Campbell Range allochthon (*sic*)) is a stratigraphic contact, not a thrust and especially not a thrust representing the closure of an ocean basin. This notwithstanding, parts of YTT, mainly to the southeast and west of the Finlayson Lake area, were exposed to eclogite facies metamorphism in the Mississippian and Permian. These sites are where ocean closure may have taken place but we find no evidence, either structural or stratigraphic, for such a suture in the area of the known deposits.

Our final comments have to do with the appropriateness of the use of the phrase 'Antler cycle' to describe the events recorded in YTT. The Antler Orogeny refers to a very specific thrusting event of Early Mississippian age in the Great Basin that places rocks of deep water basinal character onto the ancient North American continental margin sequence. Although evidence is growing for localized Mississippian deformation in YTT (Murphy, 1998), it is, for the most part, younger than the tightly bracketed Antler Orogeny in the western United States, it occurred during the evolution of the arc-back-arc system; it does not involve the North American continental margin and it does



**Figure 1.** Schematic summary diagram showing the massive sulphide deposits of the Finlayson Lake district in a stratigraphic context. Grass Lakes succession (Late Devonian to Early Mississippian): **unit 1**, quartz-rich metaclastic rocks, marble and meta-pelite; **unit 2**, chlorite schist of boninitic and tholeiitic chemistry, host of the Fyre Lake deposit; **unit 3**, felsic metavolcanic rocks with laterally and vertically varying amounts of carbonaceous schist, quartzite and locally quartzofeldspathic psammite, host of Kudz Ze Kayah deposit and numerous prospects; **unit 4**: carbonaceous phyllite, quartzite and chloritic phyllite. The Grass Lakes succession is intruded by granitic metaplutonic rocks as old as ca. 360 Ma (Mog). Wolverine succession (Early Mississippian, unconformably overlying Grass Lakes succession): **unit 5l**, basal quartz-feldspar conglomerate and sandstone and carbonaceous phyllite; **unit 5cp**, mainly carbonaceous phyllite with lesser carbonaceous quartz sandstone, laterally interfingering with **unit 5qfp/5f**; **unit 5qfp/5f**, felsic meta-igneous rocks of volcanic and subvolcanic intrusive protoliths in footwall of Wolverine deposit and satellite bodies; **unit 6**, barite-magnetite iron formation and aphyric felsic phyllite. Campbell Range succession (Pennsylvanian and Permian), disconformably deposited on Wolverine succession: PPCb1 (not indicated in Figure), pillowed, fragmental and massive basalt of NMORB and EMORB chemistry; **unit 7**, carbonaceous phyllite, sandstone, diamictite, chert, chert-pebble conglomerate, limestone; PPCb, pillowed, fragmental and massive basalt of NMORB and EMORB chemistry, host of MONEY prospect and probable host of ICE deposit. All of the metamorphic successions are intruded by weakly foliated mid-Cretaceous granite.

not seem to merit the distinction as an 'orogeny'. Ocean closure may have taken place throughout the evolution of YTT but it appears to have occurred by typical B-type subduction at the margins of the terrane as evidenced by the local occurrences of high-pressure metamorphic mineral assemblages (e.g. Erdmer et al, 1998). Furthermore, the tectonic setting of the Antler Orogeny in Nevada has been heavily debated and a simple model of ocean-opening and ocean-closing likely does not apply. Recent models (Burchfiel and Royden, 1991; Dickinson, 1999) put the thrusting in a Mediterranean-like back-arc setting. Neither the timing nor character of the Antler Orogeny of Nevada applies to YTT.

In summary, through increasingly more detailed and diverse studies, Yukon-Tanana Terrane is starting to reveal a complex Late Paleozoic and Mesozoic geological history – a history that is not reflected in the 'Antler Cycle' model.

#### References

Burchfiel, B.C. and Royden, L.H., 1991. Antler orogeny: A Mediterranean-type orogeny. *Geology*. v. 19, p. 66-69.  
 Dickinson, W.R., 1999. Antler-Sonoma orogenesis in light of Apennine analogy. *Geological Society of America Abstracts with*

Programs, v. 31, no. 6, p. A-50.

- Duke, N.A. and Terry, D.A., 2000. The metallogeny of volcanogenic massive sulphide deposits accompanying the Antler Cycle, Finlayson Lake belt, Yukon-Tanana. *The Gangue*, No. 64, p. 1-7.
- Erdmer, P., Ghent, E.D., Archibald, D.A., and Stout, M.Z., 1998. Paleozoic and Mesozoic high-pressure metamorphism at the margin of ancestral North America in central Yukon. *Geological Society of America, Bulletin* v. 110, p. 615-629.
- Grant, S.L., 1997. Geochemical, radiogenic tracer isotopic, and U-Pb geochronological studies of Yukon-Tanana Terrane rocks from the Money Klippe, southeastern Yukon. Unpublished M.Sc. thesis, University of Alberta, 177p.
- Grant, S.L., Creaser, R., and Erdmer, P., 1996. Isotopic, geochemical and kinematic studies of the Yukon-Tanana Terrane in the Money Klippe, SE Yukon. *Slave-Northern Cordilleran Lithospheric Experiment (SNORCLE) – Lithoprobe Report 50*, p. 27-30.
- Hunt, J.A. and Murphy, D.C., 1998. A note on preliminary bedrock mapping in the Fire Lake area. In *Yukon Exploration and Geology 1997*. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 59-68.
- Mortensen, J.K., 1992. Pre-mid-Mesozoic tectonic evolution of the Yukon-Tanana Terrane, Yukon and Alaska. *Tectonics*, v. 11, p. 836-853.
- Mortensen, J.K. and Jilson, G.A., 1985. Evolution of the Yukon-Tanana terrane: evidence from southeastern Yukon Territory. *Geology*, v. 13, p. 806-810.
- Murphy, D.C., 1997. Preliminary geological map of Grass Lakes area, Pelly Mountains, southeastern Yukon (105G/7). Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Open File 1997-3, 1:50 000-scale.
- Murphy, D.C., 1998. Stratigraphic framework for syngenetic mineral occurrences, Yukon-Tanana Terrane south of Finlayson Lake: A progress report. In: *Yukon Exploration and Geology 1997*, Exploration and Geological Services Division, Indian and Northern Affairs Canada, p. 51-58.
- Murphy, D.C. and Piercey, S.J., 1998. Preliminary geological map of northern Wolverine Lake area (NTS 105G/8, north half). Exploration and Geological Services Division, Indian and Northern Affairs Canada, Open File 1998-4.
- Murphy, D.C. and Piercey, S.J., 1999a. Finlayson Project: Geological evolution of Yukon-Tanana Terrane and its relationship to the Campbell Range belt, northern Wolverine Lake map area, southeastern Yukon. In: *Yukon Exploration and Geology 1998*, D.S. Emond and C.F. Roots (eds.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 47-62.
- Murphy, D.C. and Piercey, S.J., 1999b. Geological map of Wolverine Lake area, Pelly Mountains (NTS 105G/8), southeastern Yukon. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Open-File 1999-3 (1:50 000-scale).
- Murphy, D.C. and Piercey, S.J., 1999c. Geological map of parts of Finlayson Lake (105G/7, 8 and parts of 1, 2, and 9) and Frances Lake (parts of 105H/5 and 12) areas, southeastern Yukon. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Open-File 1999-4 (1:100 000-scale).
- Murphy, D.C. and Timmerman, J.R.M., 1997. Preliminary geology of the northeast third of Grass Lakes map area (105G/7), Pelly Mountains, southeastern Yukon. In: *Yukon Exploration and Geology 1996*, Exploration and Geological Services Division, Indian and Northern Affairs Canada, p. 62-73.
- Piercey, S.J., Hunt, J.A., and Murphy, D.C., 1999. Litho-geochemistry of meta-volcanic rocks from Yukon-Tanana terrane, Finlayson Lake region, Yukon: preliminary results. In: *Yukon Exploration and Geology 1998*, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 125-138.
- Piercey, S.J., Murphy, D.C., Mortensen, J.K., and Paradis, S., 2000. Arc-rifting and ensialic Back-arc basin magmatism in the northern Canadian Cordillera: evidence from the Yukon-Tanana Terrane, Finlayson Lake region, Yukon. *Slave-Northern Cordilleran Lithospheric Experiment (SNORCLE) – Lithoprobe Report 72*, pp. 129-138.
- Plint, H.E. and Gordon, T.M., 1997. The Slide Mountain Terrane and the structural evolution of the Finlayson Lake Fault Zone, southeastern Yukon. *Canadian Journal of Earth Sciences*, v. 34, p. 105-126.
- Sebert, C. and Hunt, J.A., 1999. A note on preliminary litho-geochemistry of the Fire Lake area. In: *Yukon Exploration and Geology 1998*, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 139-142.

---

## CHECKOUT :

**GAC's website** - <http://www.gac.ca> & **MAC's website** - <http://www.mineralogicalassociation.ca>

## **The Metallogeny of volcanogenic massive sulphide deposits accompanying the Antler Cycle, Finlayson Lake Belt, Yukon-Tanana Terrane – A Reply**

Norman A. Duke and David A. Terry  
*Dept. of Earth Sciences, University of Western Ontario,  
London, ON*

We are gratified that our metallogenic framework for the Finlayson Lake Belt (FLB) has not gone unnoticed by those active in the field. We hope that it stimulates similarly incisive criticism by explorationists working more regionally in the Yukon Tanana Terrane (YTT). In light of the response received from Donald Murphy et al., however, we are concerned that there may have been some misunderstanding about both the purpose and the basis of our article. When we began working on this topic, we saw it as contributing to a common enterprise, not throwing down a gauntlet. It may perhaps help clear the air if we fill in a bit of what necessarily got left out of the *Gangue* article.

The first misconception that needs to be corrected concerns our alleged lack of familiarity with the literature on the FLB. None of the information brought to our attention by Murphy and his colleagues is new to us. If this body of data did not figure centrally in our synthesis, it was by choice, not by oversight. One obvious reason for the omission was simply the limitations of the venue. The material published in the *Gangue* was an expanded abstract, not a fully fleshed-out scientific paper. In the circumstances, it was necessary to be selective in both our coverage and our focus. A second misconception had to do with what we were attempting to achieve with this presentation. It was not our goal either to summarize or to critique extant research findings but to offer a new perspective for interpreting such findings. It is important to understand the route that led to our involvement with this topic. The geotectonic model offered in the *Gangue* article was neither derived from nor conceived in reaction to the literature referenced by Murphy et al. It grew out of more than twenty years of active exploration in the Alaskan segments of the Yukon-Tanana Terrane, in the course of which we grappled with many of the same features and puzzles which Murphy and his colleagues are now tackling in the FLB. Duke's work (Duke, 1997, Duke et al., 1994a,b, 1995) on the YTT dates back to the mid-seventies. The idea of a northern "Antler Cycle" syndates Terry's Ph.D. (1997), and aspects of the general model have been presented at several previous GSA and GAC/MAC meetings (see references). One might also note that we do not purport to offer final answers in our article — indeed, considering the present state of knowledge (as opposed to speculation) about the FLB, we feel it is premature to fix on any particular interpretation as definitive. What we offer, rather, is a working hypothesis based on what we feel are persuasive parallels. On the information currently available, we believe that our model well accounts for the regional make-up of the FLB and supplies a better explanation for the widely differing VMS settings in the district.

When it comes to specifics, the most critical issue raised by

Murphy et al. concerns our interpretation of "tectonostratigraphy." Given the space constraints, we thought it best not to get into the thorny issue of structural/stratigraphic relationships in this polymetamorphic setting. Overprinting in the FLB is deceptively complex. Although bedding is generally discernable, it is variably obscured and locally obliterated by multiple foliation fabrics. The "autochthonous" YTT elements, those occurring below the Campbell Range allochthons, are characterized by a penetrative  $S_1$  foliation subparalleling  $S_0$ . The allochthons themselves, as well as immediately underlying olistostromal deposits, lack this penetrative  $S_1$  foliation, thus indicating that the  $S_1$  foliation relates to obduction. Stratigraphically, the structural break from  $S_0/S_1$  to nonfoliated  $S_0$  occurs at the Pennsylvanian limestone marker. Both  $S_0$  and  $S_1$  have been transposed by a subhorizontal  $S_2$  foliation. The regional structural grain is dominated by recumbent chevron-style minor folds with highly attenuated limbs. Locally, these  $F_2$  fold sets are bound by subhorizontal mylonitic  $S_2$  schists. The best locale for viewing this late phase of subhorizontal flattening is on the Pak Claim Group where the  $S_2$  fabrics are strongly injected by sheets of Cretaceous-age 2-mica felsite. These sheeted dyke sets are themselves openly to tightly folded by the subhorizontal  $S_2$ -cleavage, indicating that  $S_2$  syn- and post-dated the emplacement and unroofing of Cretaceous granitoid plutons occurring throughout the FLB and greater YTT.

Given the polydeformed character of the FLB, we realize that all stratigraphic interpretations are hazardous. Notwithstanding, we feel that there is strong structural (the lack of a penetrative  $S_1$  above the Pennsylvanian limestone marker) and stratigraphic (the preservation of olistostromal deposits) evidence for tectonic emplacement of the Campbell Range "Slide Mountain" allochthons. The controversy regarding the specific stratigraphic position of the Kona greenstone with respect to the productive Wolverine sequence is more difficult to resolve. We placed the Kona greenstone unit higher in the stratigraphy because of proximity to the Slide Mountain klippen, i.e., structural highs preserved near the Tintina Fault Zone. We correlate the Kona greenstone with the greenstone unit capping the Wolverine sequence because both of these greenstone members are immediately overlain by prominent Mississippian-age (?) black phyllite units. Although this interpretation is clearly speculative, we feel that it is the most reasonable one in light of regional structural considerations.

Beyond their differing interpretations of stratigraphy in the FLB, Murphy et al. place considerable weight on volcanic petrochemistry in arguing for an evolving marginal arc setting. Continental margin arc settings have long been invoked on similar geochemical grounds for the volcanic components of the Alaskan segments of the YTT as well (Nokleberg and Aleinikoff, 1985). Unless there is more hard evidence forthcoming, however, we find it difficult to believe that the diagnostic coeval augen granites and rhyolitic button schists relate in any way to subduction. The analytical results on similar rocks in Alaska identify strong crustal components, i.e., both granites and rhyolites stem from melting of crust having a geochemical signature

consistent with Proterozoic North America basement (Hudson, 1994). Whether or not this melting occurred in a back arc setting is moot in the absence of a preserved frontal arc magmatic setting. If the overlying (according to our stratigraphic reconstruction) greenstone is boninitic, a forearc setting might be more plausible, and this would be consistent with our inference of westward subduction/eastward obduction geotectonic polarity. Certainly, both scenarios are consistent with a general evolutionary trend towards more primitive oceanic conditions. But how could oceanic rocks stratigraphically overlie arc volcanics, as argued by Murphy et al.?

If there are normal calcalkaline arc rocks in the YTT, one might expect these to be preserved at higher structural levels than the Slide Mountain allochthons, as with the Simpson Ranges in the FLB. Our hypothesis of the opening and closing of a nascent ocean basin seems to us the simplest way to rationalize the regional basinal stratigraphy. The key feature of arc volcanism is the formation of centralized constructive volcanic edifices, i.e., the island chains. In our work in the YTT we have seen no physical evidence for such environments. The key diagnostic features of these volcanic sequences are their common sedimentary interlayers and their location within sediment dominated successions. Generally speaking, they occur as relatively thin, regionally extensive sequences within basinal depocenters. To identify actual sites of mineralization as arc volcanic centers is to confuse centralized volcanism with centers of hydrothermal activity. In keeping with the basinal setting, the hydrothermal systems we are dealing with in the FLB seem to us much more likely to be structurally controlled by syndepositional faults.

Although Murphy et al. raise many unresolved questions regarding specific structural/stratigraphic relationships, which were glossed over in our "working hypothesis," they have not raised any hard facts to counter this hypothesis. At best they have demonstrated how risky it is to be taking an overly dogmatic position at this point. We are quite ready to concede that the setting may have been back arc, that is, that there may have been an arc out there somewhere. The question still remains, however, whether regional granite/rhyolite magmatism could in fact typify such a setting. It is worth noting that the "missing arc" debate has been a prominent theme in the literature on the Antler Orogeny in Nevada as well. Murphy et al. take exception to our use of this terminology in respect of the YTT. If we have applied the label "Antler" to phenomena beyond its strict definition, we do not feel that our attributions are either misleading or unjustified. On contiguity as well as analogy, one might consider the Cordilleran margin from mid-Devonian through lower Permian as an "Antler" problem. The fact that the usage is unconventional is in our view more than outweighed by the insights it offers. Murphy and his colleagues are, of course, free to disagree.

This brings us to our bottom line for this contretemps. While we welcome alternative views on topics of interest, the umbrage taken by Murphy et al. to our article seems to us counterproductive. Whoever turns out to be "right" about these issues in the long run, the best reason for entertaining alternative, even novel

models in the short run is to avoid prematurely foreclosing research directions. The value of our approach is not that it "solves" the problem of the FLB, but that it offers a testable hypothesis which can be interrogated by future work. One key disparity between our Antler Cycle model and a marginal arc model, for instance, is that the former predicts considerable geological similarity in the mid-Devonian-lower Permian assemblages along the entire Cordilleran while the latter predicts diversity and uniqueness. This is obviously a difference that can be resolved by investigation. Better documentation of the olistostromal deposits preserved at the base of the Campbell Range allochthons is particularly crucial. The best locale known to us for observing olistostromal serpentinite debris is on the Tack Claims. Another prediction implicit in our model is that the Mississippian (?) black phyllite overlying the Kona greenstone not only reflects the opening of an "Antler" ocean basin but represents the global anoxic event coinciding with the deep marine transgression of the externides of Pangea (Joachimski and Buggisch, 1993). This too can be tested. The same would hold for inferences about correlatives. Might the Finlayson Lake black phyllite unit correspond to the Beaver Creek Phyllite in the Brooks Range Ambler District and the Guillet Pass Phyllite in the Delta District of the Eastern Alaska Range? Certainly these units look similar lithologically. Detailed biostratigraphic and chemostratigraphic studies could tell us if the resemblance is more than superficial. Further analytical work might also reveal whether or not the old Phyllite and Quartzite Series has North American shield provenance as our model assumes. We look forward to the elucidation of such questions through new information derived not only from the FLB but from correlative terranes along the Antler seaboard. Hopefully, new results from the ongoing NATMAP project will render the present argument immaterial.

## References

- Duke, N.A., 1997. Bathurst-type polymetallic massive sulphide districts related to displaced Antler-aged back-arc basins in north and central Alaska. GAC/MAC Program with Abstracts, v.22, p. A41.
- Duke, N.A., Terry, D.A. and Newkirk, S.R., 1995. Gabbro/chert association hosting Frasnian Ba-Mn occurrences, Eastern Alaska Range. GAC/MAC Program with Abstracts, v. 20, p. 104.
- Duke, N.A., Terry, D.A. and Newkirk, S.R., 1994a. The metallogenic significance of the Antler Event in the Eastern Alaska Range. GAC/MAC Program with Abstracts, v. 19, p. A31.
- Duke, N.A., Terry, D.A., and Newkirk, S.R., 1994b. Metallogeny of VMS deposits of the Eastern Alaska Range. GSA Abstracts with Program, v. 26(7), p. A28.
- Hudson, T.L., 1994. Crustal melting events in Alaska. In G. Plafker and H. Berg, eds., *The Geology of Alaska: The Geology of North America*, v. G-1, p. 657-670.
- Joachimski, M.M. and Buggisch, W., 1993. "Anoxic events in

the late Frasnian — Causes of the Frasnian-Famennian faunal crisis? *Geology*, v. 21, p. 675-678.

Nokleberg, W.J., and Alienikoff, J.N., 1985. Summary of stratigraphy, structure, and metamorphism of Devonian igneous-arc terranes, northeastern Mount Hayes quadrangle, eastern

Alaska Range. U.S.G.S. Cic. 967, p.66-71.

Terry, D.A., 1997. Lithotectonic setting and metallogenic significance of barite manganese occurrences in the Tetlin District, Eastern Alaska Range. Unpub. PhD. thesis, University of Western Ontario, 362 p.

## Professional Registration of Geoscientists in Canada

### - Mobility -

**F. Dwight Ball**, P.Geo., *Chair-Elect, Canadian Council of Professional Geoscientists*

**William N. Pearson**, P.Geo., *President, Association of Geoscientists of Ontario*

**Gordon D. Williams**, P.Geol., *Past-Chair, Canadian Council of Professional Geoscientists*

### INTRODUCTION

Licensing and regulation of professionals in Canada began over a hundred years ago as a means of ensuring that those who provided certain services to the public possessed appropriate academic, experience and ethical qualifications to provide those services. Protection of the public from unskilled or unethical practice by unqualified individuals was, and still is, paramount.

Under the Canadian Constitution, licensure of professionals is the responsibility of individual provinces and territories. In each jurisdiction, acts of their legislature restrict the practice of the professions to individuals who are registered members of (and therefore licensed by) autonomous, self-governing professional associations established under the legislation. This right-to-practice legislation enables the professional associations to protect the public by preventing unqualified, unskilled or unethical persons from carrying on the restricted professions. Aside from appointing public members to the governing councils and key committees of the professional associations, governments play no direct role in the licensing of practitioners.

The professional associations in each province and territory have legal responsibility and authority to set standards and to evaluate the qualifications of applicants for entry into the profession, to maintain a list of qualified persons in the profession, to ensure that unqualified persons do not practise the profession, and to discipline members of the profession who practise unethically or beyond the level of their qualifications.

Interaction between professionals and the public may be on a direct, one-on-one, professional-to-client basis (e.g., most doctors, lawyers, dentists), or may be indirect, as when members of the public use facilities designed and constructed by professionals or rely on conclusions and opinions expressed by professionals (e.g., most engineers, architects, geoscientists, accountants). Conclusions and opinions expressed by professionals very often have safety, financial, or environmental implications for the public. In both direct and indirect cases, licensure of the professionals involved protects the public by ensuring that the licensed professional possesses appropriate qualifications, as well as providing an avenue of redress should something go wrong.

### HISTORICAL BACKGROUND

The engineering professions were regulated in Canada in the early decades of the twentieth century. From the outset, it was recognized that the work of many geoscientists also affected the public welfare through their involvement in oil, gas and ore reserves estimation, exploration and mining activities, and construction of major engineering works such as dams and bridges. More recently, geoscientists have become major players in the broad area of environmental practice.

Initially, geoscientists whose work impacted the welfare of the public were licensed as engineers, usually as mining engineers. In Alberta, Dr. John A. Allan, a prominent geoscientist and founder of the Geology Department at the University of Alberta, took an active role in establishing the Association of Professional Engineers of Alberta (APEA) in the 1920s and became its president in the 1930s. In the 1950s, the discovery of oil and gas in Alberta focussed attention on the geoscience professions, with the result that geologists, and the practice of geology and geophysics, were explicitly identified in the Engineering Act in Alberta in 1955. Separate designations for geologists and geophysicists (P.Geol. and P.Geoph.) were introduced in 1960 and, in 1966, APEA changed its name to become the Association of Professional Engineers, Geologists and Geophysicists of Alberta (APEGGA).

Following the pattern set in Alberta, geoscientists are now licensed in most Canadian provinces and territories by associations of engineers and geoscientists, established by legislative acts covering the professions of engineering and geoscience.

### CURRENT STATE OF LICENSURE IN CANADA

More than 5,000 geoscientists are now licensed as Professional Geoscientists (P.Geo.), Professional Geologists (P.Geol.) or Professional Geophysicists (P.Geoph.) under combined engineering and geoscience right-to-practice legislation in Alberta, British Columbia, Manitoba, New Brunswick, Newfoundland, Northwest Territories, Nunavut and Saskatchewan.

In these jurisdictions, a person must be a member of (registered by) the appropriate professional association to provide geoscientist services.

tific services (geology, geophysics, geochemistry, etc.) or to use certain restricted professional titles. Over the next few years, it is estimated that approximately 10,000 geoscientists will be licensed in Canada as the remaining jurisdictions (Ontario, Quebec and Nova Scotia) enact similar legislation.

### THE CANADIAN COUNCIL OF PROFESSIONAL GEOSCIENTISTS

In the engineering professions, national coordination and representation has been provided by the Canadian Council of Professional Engineers since the 1930s. A parallel national organization for the geoscience professions, the Canadian Council of Professional Geoscientists/Conseil canadien des géoscientifiques professionnels (CCPG), was established in March, 1997, under federal legislation, and became fully operational on January 1, 1998. The CCPG is a completely autonomous body whose members are those provincial and territorial associations that license geoscientists under right-to-practice legislation, or which are working towards licensure or right-to-title certification.

The CCPG is a federation of the provincial and territorial professional associations; it exists solely to serve its member associations. CCPG does not license or certify geoscientists and has no power of compulsion over its member associations or their existing statutory authority. Individual geoscientists cannot become members of CCPG. Professional geoscientists must be licensed or certified by their provincial or territorial associations which, in turn, hold membership in CCPG.

Recommendations for minimum requirements of knowledge and work experience for the practice of professional geoscience in Canada have been developed by the Canadian Geoscience Standards Board, and have been circulated to the member associations of CCPG for possible adoption as the basis for registration in the associations. The CGSB functions under the CCPG, is Chaired by a CCPG Board member and consists of representatives from each of CCPG's constituent associations.

### MOBILITY

Geoscientists, perhaps to a greater extent than other professionals, often practice outside the jurisdiction in which they are licensed. Increasingly, their practice in Canada spans more than one province or territory and many individuals work internationally.

To facilitate the mobility of professional geoscientists within Canada, CCPG has developed a draft Inter-Association Mobility Agreement for geoscientists that will expedite the transfer of registration among jurisdictions. It is hoped that all CCPG member associations will adopt the Agreement and put it into effect during 2000.

A further objective of CCPG is to develop an agreement that will permit professional geoscientists to practice outside their home province or territory for specified short periods without having to become licensed in each jurisdiction where they might work. Because of legal considerations relating to licensing requirements and disciplinary responsibility, such an agreement will require considerable work and time to develop.

The establishment of reciprocal relationships with licensing and certifying organizations elsewhere in North America and beyond is also an explicit objective of CCPG. Discussions are currently underway with several national geoscience professional associations in North and South America, Australia and Europe.

## Volcanic Environments and Massive Sulfide Deposits

*International Conference and field meeting, Tasmania, Australia*

### CALL FOR PAPERS

**May 30th deadline**

Sponsored by *CODES SRC* and the *Society of Economic Geologists*

**Themes:** Global VHMS belts, Tectonic setting of VHMS deposits, Deposit Description and new discoveries, VHMS-epithermal transition, subaqueous pyroclastic flows, syn-volcanic intrusions and their effects on hydrothermal systems, modern seafloor mineralization, shallow water settings and VHMS deposition, textural modification of glassy submarine volcanics, and volcanology of komatiite successions that host massive sulfides.

**Field Trip:** Mount Read Volcanic Belt, Tasmania (7 days)

**Contact :** +61 (3) 6224 3773; Fax: +61 (3) 6224 3774;

**email:** volcanic@cdesign.com.au; **website:** www.geog.utas.edu.au/codes/home.html

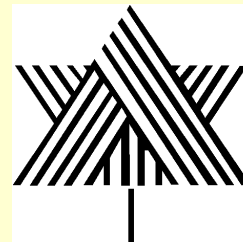


## *Looking Back at MDD*

<u>Name</u>	<u>Year</u>	<u>Employer</u>	<u>Current Address</u>
<b>MDD Chairs:</b>			
Hugh Morris	1978-80	Cominco, Vancouver	Consultant, Vancouver
Steve Scott	1980-81	University of Toronto	Same
Vic Hollister	1981-82	Duval, Vancouver	Retired, Mission BC
Alan Coope	1982-83	Newmont, Toronto	Consultant, Tucson AZ
John McDonald	1983-84	Esso Minerals, Vancouver	Consultant, Vancouver
Bob Hewton	1984-85	Brinco, Vancouver	Deceased
Lee Barker	1985-86	Lacana, Toronto	Southernera, Toronto
Chris Jennings	1986-87	BP/SELCO, Toronto	Southernera, Toronto
John Morganti	1987-88	Placer Dome, Toronto	Teck, Vancouver
Tom Schroeter	1988-89	BCGS, Vancouver	Same
Paul Wojdak	1989-90	Westmin, Vancouver	BCGS, Smithers BC
Ed Debicki	1990-91	INCO, Sudbury	Same
Andy Fyon	1991-92	OGS, Toronto	OGS, Sudbury
James MacDonald	1992-93	MDRU, Vancouver	Billiton, The Hague
Mike Downes	1993-94	Westminer, Toronto	Consultant, Toronto
Scott Swinden	1994-95	Nfld. GS, St. John's	Provincial Gov't, Halifax
Jennifer Pell	1995-96	DIAND, Yellowknife	Trivalence Mining Corp.
Dave Moore	1996-97	Cominco, Vancouver	Same
Al Galley	1997-98	GSC, Ottawa	Same
Catherine Farrow	1998-99	INCO, Sudbury	Same
Jason Dunning	1999-2000	Hudson's Bay Exploration	Same
<b>MDD Publications Chairs:</b>			
J M Allen	1978-80	Cominco, Vancouver	Same
R G Roberts	1980-82	University of Waterloo	Same
Lee Barker	1982-85	Lacana, Toronto	Southernera
Pat Sheahan	1985-92	Consultant, Toronto	Same
Kathryn Dunne	1992-95	MDRU, Vancouver	Consultant, Vancouver Is.
Art Ettlenger	1995-97	Wolverton Securities, Vancouver	Yorkton Securities
Dirk Templeman-Kluit	1997-	Consultant, Vancouver	Same
<b>MDD Secretaries:</b>			
Vic Hollister	1978-80	Duval Corp, Vancouver	Retired. Mission BC
Roy Beavon	1980-81	Can Superior, Vancouver	Consultant, Vancouver
Ian Patterson	1981-82	Cominco, Vancouver	Same
Bob Hewton	1982-83	Brinco, Vancouver	Deceased
Jeff Franzen	1983-86	Billiton, Vancouver	Consultant, Vancouver
Barry Cook	1986-88	Cominco, Toronto	Consultant, Toronto
Linda Thorstad	1988-90	Consultant, Vancouver	Viceroy, Vancouver
Mike Gray	1990-92	Falconbridge, Sudbury	Rubicon, Vancouver
Gary Wells	1992-	Minova/Inmet, Vancouver	Same
<b>Newsletter Editors</b>			
Ken Dawson	1980-85	GSC, Vancouver	Consultant, Vancouver
Giles Peatfield	1985-87	Consultant, Vancouver	Same
Brian Grant	1987-98	BCGS, Victoria	Consultant, Vancouver
Al Galley	1998-99	GSC, Ottawa	Same
Dave Lentz & Steve McCutcheon	1999-	NBGSB, Bathurst	UNB, Fredericton; Same

## MEETINGS, WORKSHOPS, & FIELDTRIPS

2000



- **May 26-29 – GEODE 2000 Workshop** (Geodynamics and Ore Deposit Evolution) of the Alpine-Balkan-Carpathian-Dinaride Province, Borovets, Bulgaria. Contact: [www.erdw.ethz.ch/~td/kbgeode.html](http://www.erdw.ethz.ch/~td/kbgeode.html), or [www.sbg.ac.at/gew/forsch/projects/geode/geode1.html](http://www.sbg.ac.at/gew/forsch/projects/geode/geode1.html).
- **May 29-June 2 – GEOCANADA 2000** (Calgary'00), GAC/MAC/CSPG/CSEG/COOLS joint annual meeting. Contact: Dr. Grant Mossop, Geological Survey of Canada, 3303-33 St. N.W., Calgary, Alberta T2L 2A7, Tel: 403-292-7049, Fax: 403-292-5377, email: [gmossop@nrcan.gc.ca](mailto:gmossop@nrcan.gc.ca)
- **May 30-June 3 – AGU Spring Meeting**, Washington DC. ContactTel; (202) 462-6900; Fax: (202) 328-0566; email: [meeting@kosmos.agu.org](mailto:meeting@kosmos.agu.org); [www.agu.org/meetings](http://www.agu.org/meetings).
- **August 6-17 – 31st INTERNATIONAL GEOLOGICAL CONGRESS**, Riocentro Convention Center, Rio de Janeiro, Brazil; <http://www.31igc.org>.
- **September 3-8 – Goldschmidt 2000**. Oxford, UK. Contact P. Beattie, Cambridge Publications, P.O. Box 27, Cambridge UK CB1 4GL. Tel: 44-1223-333438, Fax: 44-1223-333438, email: [gold2000@campublic.co.uk](mailto:gold2000@campublic.co.uk)
- **September 25 – October 4 – IESCA 2000** (INTERNATIONAL EARTH SCIENCE COLLOQUIUM ON THE AEGEAN REGION), For more detail see: <http://www.deu.edu.tr/Duyuru/iesca2000/iesca2000.htm>.
- **November 16-19 – Volcanic Environments and Massive Sulfide Deposits Conference and field trips**, CODES, Contact : +61 (3) 6224 3773; Fax: +61 (3) 6224 3774; email: [volcanic@cdesign.com.au](mailto:volcanic@cdesign.com.au); [www.geog.utas.edu.au/codes/home.html](http://www.geog.utas.edu.au/codes/home.html)
- **November 13-16 – Geological Society of America (& Society of Economic Geologists) AGM**, Reno, Nevada. Contact Tel: 1-800-472-1988, email: [meetings@geosociety.org](mailto:meetings@geosociety.org).
- **December 15-19 – AGU Fall Meeting**, San Francisco, CA. Contact AGU Meeting Department, 2000 Florida Ave., NW, Washington, DC 20009, Tel: (202) 462-6900, Fax: (202) 328-0566, email: [meetings@kosmos.agu.org](mailto:meetings@kosmos.agu.org)

Please submit your events to Dave Lentz at email: [dlentz@unb.ca](mailto:dlentz@unb.ca)

### Mineralogical Association of Canada – Short Course, Calgary 2000

#### Tracing Fluid Histories of Sedimentary Basins – Kurt Kyser, Editor

May 27-28, 2000 (2 days)

**Speakers:** Eric Hiatt, Department of Geological Sciences and Geological Engineering, Queen's University; Fred Longstaffe, Department of Geological Sciences, University of Western Ontario; Gerry Ross, GSC, Calgary; Ian Hutcheon, Department of Geological Sciences, University of Calgary; Gerry Ross, GSC, Calgary; Bernard Marty, CNRS, Nancy, France; Kurt Kyser, Department of Geological Sciences and Geological Engineering, Queen's University.

The purpose of the course is to illustrate the methods, techniques and approaches used to trace the fluid flow histories of sedimentary basins and demonstrate how to use this information to evaluate the economic potential (both metal and petroleum) of large basins. The results from these studies are prerequisite for constraining large- and restricted-scale flow models, understanding the evolution of the crust, and refining exploration and exploitation strategies for mineral and petroleum deposits. The specific basins to be discussed include Proterozoic basins in Canada and Australia, Phanerozoic and Mesozoic basins in Western Canada, and Mesozoic and Cenozoic basins in Europe.

Cost: \$377 Cnd (\$150 for students) - Please check the website for possible updates.

For additional information, see <http://www.geocanada2000.com/> or contact [kyser@geol.queensu.ca](mailto:kyser@geol.queensu.ca)