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MINERAL POTENTIEL OF THE CHIBOUGAMAU MINING DISTRICT

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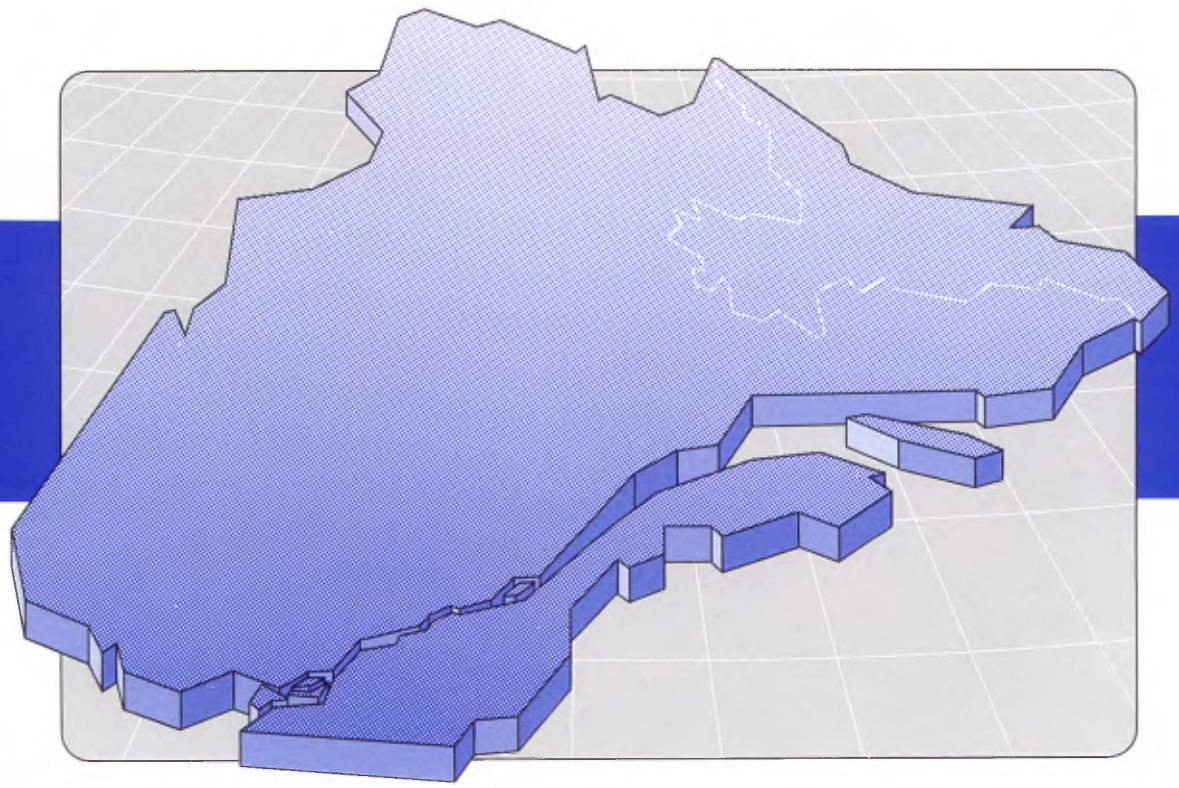

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PRO 99-05 : Mineral Potential of the Chibougamau Mining District

Rémy Morin, Pierre Pilote et Charles Gosselin[1]

The Chibougamau-Caopatina region

REGIONAL GEOLOGY

The Chibougamau-Caopatina region (CCR) is located in the eastern portion of the Abitibi Subprovince (Figure 1). It forms part of the Northern Volcanic Belt (Chown *et al.*, 1992, 1998; Mortensen, 1993), which is bounded to the north by the Opatica Subprovince and to the east by the Grenville Province. The boundary between the Abitibi Subprovince and the Grenville Province, i.e. the Grenville Front, is marked by a break in the E-W regional tectonic grain, where the metamorphic grade changes from the greenschist to the amphibolite facies near the Grenville Front.

The Archean rocks in the Chibougamau region (Figures 2, 3 et 4) have been divided into two groups (Allard, 1976; Allard *et al.*, 1985), i.e. the Roy Group, forming the base of the stratigraphic pile, and the Opemisca Group, which generally lies in unconformity on the Roy Group. The Roy Group comprises four formations: the Obatogamau and Waconichi formations, which constitute the first mafic-felsic volcanic cycle, and the Gilman and Blondeau formations, which represent the second mafic-felsic volcanic cycle. Caty (1978) also attaches a fifth formation to this group, known as the Bordeleau Formation, which lies on top of the Blondeau Formation in the Waconichi Lake region to the north of Chibougamau.

The Opemisca Group comprises two formations: the Stella Formation at its base and the Haüy Formation at its summit. Caty (1978) attaches a third formation, the Chebistuan Formation, which is probably joined to the Stella Formation. In the southern portion of the CCR (Figure 3), the rocks have been grouped into three formations: 1) the Obatogamau Formation, including the lac des Vents Complex and the Wachibagau Member (mafic and felsic volcanic rocks); 2) the Dalime Formation (Brisson and Guha, 1993); and 3) the Caopatina Formation. The latter two formations are composed mainly of sedimentary rock.

Several mafic to ultramafic layered intrusions are present in the region, the main ones being the Doré Lake Complex and the Cummings Complex (Figure 2). The Doré Lake Complex (Allard, 1976; Daigneault and Allard, 1990) is a differentiated layered intrusion subdivided into four zones. From base to summit, these are the Anorthositic Zone, the Layered Zone, the Granophyric Zone and the Upper Border Zone. Most of the copper-gold mines in the Doré Lake mining camp (Pilote *et al.*, 1998) are located in the Anorthositic Zone. The Layered Zone, 900 m thick, contains pyroxenite and gabbro units rich in iron oxide, titanium and vanadium (the Doré Lake vanadium deposit; Gobeil, 1976; Girard and Allard, 1998) alternating with anorthositic units. The Cummings Complex comprises three separate but genetically related sills: the Roberge sill at its base, the Ventures sill and the Bourbeau sill at its summit. These sills are composed of dunite, pyroxenite and gabbro. The Ventures sill hosts the Springer, Perry and Robitaille copper mines at Chapais (Watkins and Riverin, 1982). The Bourbeau sill hosts the former Cooke gold mine at Chapais and the Norbeau gold mine at Chibougamau (Dubé and Guha, 1989).

A large number of granitic intrusions are injected into the volcano-sedimentary sequence of this region (Figures 2 and 3). These intrusions are classified into three groups: 1) synvolcanic, 2) syntectonic and 3) post-tectonic plutons (Racicot *et al.*, 1984). The synvolcanic plutons are polyphased in appearance and generally of dioritic composition in their early phases. They exhibit a development towards tonalitic to leucotonalitic and, locally, granodioritic compositions. The Chibougamau Pluton, synvolcanic in age, is responsible for the porphyry copper-gold mineralizations located in the Doré Lake mining camp (Pilote *et al.*, 1995, 1997, 1998; Kirkham *et al.*, 1998). The syntectonic plutons, subparallel to the belt's dominant tectonic fabric, exhibit a development in several phases, commonly progressing from a meladiorite on the borders of the intrusions to a granodiorite towards the central portions. The post-tectonic plutons are represented by leucogranodiorite stocks evolving into a syenite in the centre of the intrusion.

The CCR's rocks were deformed during the Kenoran Orogeny. Four deformation events have been identified in the region. The first three occurred in the Archean age, and are included in the main regional deformation continuum (Daigneault and Allard, 1990). E-W isoclinal folds, generally associated with a well-developed schistosity, give the regional tectonic grain. The folds are referred to as P_2, since the region's rocks underwent a deformation phase P_1 prior to or synchronous with parts of the formation of the P_2 folds (Daigneault, 1983). The third event, D_3, is illustrated by intense deformation corridors or shear zones.

The CCR is crosscut by a large number of faults (Figures 2, 3 and 4) which can be subdivided into four families (E-W, SE, NE and NNE). The E-W family shears represent large corridors or shear zones of ductile deformation varying in width between 100 and 1 000 m. These shears, showing mostly a reverse movement, are responsible for

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the repetition of some portions of the stratigraphic sequence. The SE faults, which occur more particularly on the northern flank of the Doré Lake Complex, are shears of up to 300 m wide with lateral extensions varying between 2 000 and 5 000 m (Figure 2). They contain most of the Chibougamau mining camp's copper and gold mineralizations and are interpreted as synvolcanic structures taken up by regional deformation (Allard, 1976; Pilote *et al.*, 1995 and 1998; Magnan *et al.*, 1996; Kirkham *et al.*, 1998). The NE-SW shears, including the Gwillim fault, occurred later than the E-W faults (Dimroth *et al.*, 1984). The Gwillim fault (Figure 2), which exhibits a quartz-chlorite-carbonate assembly, can be followed over a minimum distance of 100 km. The NNE family of faults is linked in particular to the Grenville deformation that affects the rocks in the eastern portion of the Chibougamau region (Figure 2; Daigneault and Allard, 1994).

MINERALIZATIONS

CCR mineralizations are classified into five types (Brisson and Guha, 1993; Dion and Guha, 1994, Pilote and Guha, 1998): 1) mineralizations (oxides and sulphides of magmatic origin) related to the emplacement of mafic intrusions (vanadium deposit in the Doré Lake Complex); 2) volcanogenic massive sulphide mineralizations associated mainly with the felsic rocks in the Waconichi Formation, i.e. the Lemoine mine (728 000 t at 4,2% Cu, 9,6% Zn, 4,5 g/t Au and 83,85 g/t Ag; Gobeil, 1980) and the Scott Lake deposit (reserves of 680 000 t at 0,55% Cu, 6,9% Zn and 13,3 g/t Ag; Saunders and Allard, 1990) and the Blondeau Formation; 3) porphyry-type mineralizations associated with the emplacement of later phases of the Chibougamau Pluton (Cimon, 1973; Pilote *et al.*, 1995, 1997, 1998; Kirkham *et al.*, 1998), and which potentially generated epithermal-type deposits in the upper parts of the stratigraphic pile (Pilote, 1987); 4) mesothermal-type mineralizations associated with E-W shear zones (Joe Mann mine, Dion and Guha, 1994); and 5) Opemisca-type copper veins (chalcopyrite veins within the Cummings Complex; Watkins and Riverin, 1982).

EXPLOITATION

The first exploitation operations took place in December of 1953, with the bringing into production of the Springer mine belonging to Opemiska Copper (today Inmet Mining Corporation). It was followed by Campbell Chibougamau in 1955, Merrill Island in 1958 and Patino in 1960 (now MSV Resources Inc.). Approximately 30 mines have been developed since 1953, producing more than 74 Mt of ore, including 1,3 Mt of copper, 133 t of gold, 700 t of silver, 115 000 t of zinc and 4 400 t of lead. Annual mined tonnage peaked in 1972, at 3 150 000 t, and stabilised at around 2 000 000 t in the early 1980s. By the end of the 1980s, the reserves of several mines had been depleted, and the annual tonnage fell to 1 385 130 t in 1991. It subsequently stabilised at around 750 000 t. Copper production peaked in 1971, at 61 576 t of copper metal. It then dropped substantially, and although it rose slightly between 1975 and 1977, it has continued to decline ever since. By 1991, it was just 13 602 t, less than 22% of the record 1971 tonnage. The major causes of the decline were the gradual depletion of reserves, a drop in ore grade, rising production costs and low copper prices. During the same period, gold underwent an opposite trend in response to the positive interaction of various factors. These factors were: 1) a significant gold price increase in the mid-1970s; 2) the bivalent nature (copper and gold) of the region's deposits; 3) the bringing into production of two new mines in the Desmaraisville sector (Bachelor Lake and Shortt Lake; Figure 4); and 4) the resumption of production at the Joe Mann mine.

As a result, by the early 1970s gold production had reached 2 000 kg. It peaked in 1988, at 7 045 kg, and subsequently stabilized at around 6 000 kg. For comparative purposes, the Val-d'Or district produced 7 889 kg of gold in 1988. In the period from 1984 to 1988, Chibougamau produced 21,8% of Québec's gold, compared with 26,8% for the Val-d'Or region. The relative importance of the value of gold as opposed to copper has increased steadily since the late 1970s. In 1970, 95% of the region's revenues came from the sale of copper and 5% from the sale of gold. By 1991, copper generated just 29% of revenues, and gold, 71%.

EXPLORATION ACTIVITIES: REVIEW AND FUTURE PROSPECTS

In the 1980s, exploration expenses in the Chibougamau district were much lower than those in the Val-d'Or and Rouyn-Noranda districts, which benefited significantly from flow-through share investments. The Chibougamau region attracted only a small percentage of this funding, with the result that exploration expenditures were insufficient to maintain mineral production levels. Exploration levels peaked in 1987, at $38 000 000, and fell to $14 000 000 in 1989, after the stock market crash. This downward trend observed in 1987 has continued up to the present day everywhere in Québec.

Since 1989, however, the region has undergone a recovery. Exploration expenses increased to $16 000 000 in 1990, and have been stable at around this level since then. We believe that this leveling of mining exploration is due to a number of factors. For example, despite the low level of exploration investments, several discoveries have recently been made in the region (the Philibert, Doré Lake, Chevrier, Pusticamica Lake deposits, etc., and the Troilus mine). Most of these discoveries lie on or close to the surface. A second factor is that the area can be accessed by a large number of new forest roads. This is

especially true of the Caopatina Segment, the Urban-Barry belt and the Frotet-Troilus region (Figure 5), with the recent opening of the year-round Northern Road. A number of new sectors and new metallogenic contexts have also emerged. These include the porphyry-gold context in the Frotet-Troilus belt (Fraser, 1993; Boily, 1998); the identification of the Doré Lake mining camp mineralizations as belonging to a vast porphyry-type copper-gold system; the recognition of a major lode gold system in the Fancamp sector (Legault *et al.*, 1997; de Corta, 1998); the discovery of gold showings located in the Pustamica Lake area and the Philibert and Fenton gold deposits.

The last decade has been marked by three major events in the region: the resumption of production at the Joe Mann mine by Meston Resources Inc. in 1987 (Figure 3), the discovery of the Troilus porphyry copper-gold deposit (Fraser, 1993; Boily, 1998) in the Frotet-Troilus sector (Figure 5), and the termination of mining operations in the Doré Lake mining camp late in 1997. The Joe Mann mine (Dion and Guha, 1994) has been in operation twice in the past – the first time between 1956 and 1959, under the name of Key Anacon Mines, and the second time in the period 1974-1975, under the name of Chibex. When the mine was reopened in 1987, its reserves totalled 845 000 t (0,35% Cu and 7,57 g/t Au). By early 1992, they had increased to 3 011 676 t (0,29% Cu, 8,70 g/t Au and 4,79 g/t Ag). Although 260 000 t of ore has been extracted every year since then, the mine's current (1998) reserves are still above 3 Mt. In the Doré Lake sector, MSV Resources is considering the possibility of resuming mining operations at the Copper Rand mine by extending the main shaft to a depth of 5 000 feet.

In the last year, SOQUEM has made an interesting discovery in the McKenzie township, near Chibougamau. The best values, obtained in a sheared, altered belt of the Gilman Formation, were 39,17 g/t of gold over 0,5 m and 23,52 g/t of silver over 1 m. SOQUEM and Northern Mining Explorations have also uncovered a mineralized corridor in Le Tac township, located about ten kilometres SW of Desmaraisville. An intersection in drill hole 4041-98-20 contains 7,44 g/t Au, 4,82% Zn and 40,4 g/t of Ag over a length of 4 m. Drill hole 4041-97-11, located approximately 500 m to the SE, had given 9,43 g/t Au, 0,56% Cu, 3,37% Zn and 35,5 g/t Ag in a 0,8 m intersection.

The possibilities for acquiring new holdings and initiating joint ventures are also excellent. A Symposium held in Chibougamau in September of 1998 (Pilote, 1998) led to the signature of several agreements between corporations and companies. Most of the junior companies involved have succeeded in obtaining funding in order to carry out their work in 1999.

Other than precious metals and basic metals, the region offers potential for vanadium (Gobeil, 1976; Girard and Allard, 1998). Mapping by G.O. Allard in 1966 revealed interesting vanadium contents associated with the iron-titanium deposit discovered in the mid-1950s by Dominion Gulf on the southern flank of the Doré Lake Complex, in the Layered Zone. In 1978, the mining rights for the deposit were transferred to SOQUEM, which carried out metallurgical tests. In 1997, McKenzie Bay Resources optioned the property from SOQUEM, and carried out additional field work (Girard and Allard, 1998), including systematic surface sampling of the mineralized areas. In April of 1998, the combined preliminary reserves defined in six zones had been established at 450 Mt grading 0,45% V_2O_5. Vanadium is used mainly in the metallurgical industry for the production of light, highly resistant steels that have gradually replaced carbon steels.

In short, there are many reasons why the Chibougamau region, wrongly neglected in the past, offers a high potential that should encourage companies to increase their exploration work. These reasons include the numerous recent mineral discoveries, their proximity to the surface (and hence lower exploration costs), the presence of infrastructures, of new roads and of qualified manpower in the region, and the possibility of partnerships agreements and the acquisition of properties. All these elements, taken together, help increase the potential for new discoveries.

The Frotet-Troilus Belt

The Frotet-Troilus Archean volcano-sedimentary belt (Figure 5) is located approximately 100 km North of Chibougamau. It includes four main volcanic cycles (Simard, 1987; Gosselin, 1996 and 1998). Cycle 1 corresponds to a period of tholeiitic volcanism represented by the De Maurès, La Fourche and Dompierre formations. Cycle 2 is composed mainly of the pyroclastic calc-alkaline units of the Frotet Formation.

Cycle 3 corresponds to a highly complex period of volcanism resulting in alternate volcanic units of different origins, showing a transitional geochemical affinity for the lavas located in the Châtillon, Parker, South Domergue and North Domergue formations (Gosselin, 1996 and 1998), komatiitic basalts for the Crochet Member in the southern Troilus sector, and numerous calc-alkaline pyroclastic units and sedimentary rocks in the Testard member and the median member of the Parker formation. Primitive basalts of tholeiitic affinity are also found in the Châtillon formation (Figure 5).

Cycle 4 corresponds to a period of tholeiitic volcanism represented by the Mésière Formation in the northern part of the region, and by the Oudiette Formation to the South. These formations are composed mainly of basalts showing a remarkably homogeneous geochemical composition. The basaltic sequences are interrupted only occasionally by narrow pyroclastic units and sedimentary rocks, sometimes hosting generally sterile iron sulphides. One of these sulphide-bearing horizons, the Habitation

Member, exhibits a regional extension (Gosselin, 1996 and 1998).

Exploration of the region began in 1957, with the discovery of an erratic block mineralized in Cu-Ni. The first mineralizations to be discovered (1958-1959) were of the vein-type and were suggestive of a significant copper-gold or gold potential, especially in the southern Troilus sector. By 1961, exploration work had diminished considerably, and most of the permits issued had expired. The discovery of the Moléon deposit (184 000 t at 3,4% Zn and 1,56% Cu) triggered a new round of exploration. Some volcanogenic showings and massive sulphides deposits were soon discovered (Yorbeau and Diléo prospects), as was the Domergue deposit (1,2 Mt at 3,35% Zn, 1,96% Cu, 42,9 g/t Ag and 0,72 g/t Au).

In 1987, Kerr Adisson discovered a large porphyry gold deposit, thanks to a dispersion of erratic blocks (Fraser, 1993; Boily, 1998). This deposit became the Troilus mine operated by Inmet Mining Corporation. It is located in the eastern part of the Frotet-Evans Belt (Figure 5) and is composed of two zones, Zone 87 (including zones 87 and 87 South) and Zone J-4. The geological reserves are estimated at 49 590 000 t grading 1,38 g/t Au, 0,12% Cu and 1,23 g/t Ag.

The interest of exploration companies in seeking out volcanogenic massive sulphide mineralizations has also been maintained in the region. This interest led recently to the discovery of the PK zone by Inco Exploration, the Tortigny deposit (531 000 t grading 6,49% Zn, 3,59% Cu, 85,23 g/t Ag and 0,43 g/t Au) by Noranda Inc., and the De Maurès deposit (350 000 t grading 7,8% Zn, 1,4% Cu and 22,0 g/t Ag) by SOQUEM.

Conclusion

The Chibougamau mining district is a fairly young mining area. For the first thirty years, exploration works were concentrated around the mines. It is therefore still possible to discover surface mineralizations elsewhere in the area, and even in proximity to infrastructures. Despite the low level of investment, a number of discoveries have been made in recent years (Joe Mann, Chevrier, Troilus, etc.). In addition to its copper and gold potential, this mining district offers potential for other metals, including vanadium. The possibilities for partnership agreements and property acquisition are also excellent.

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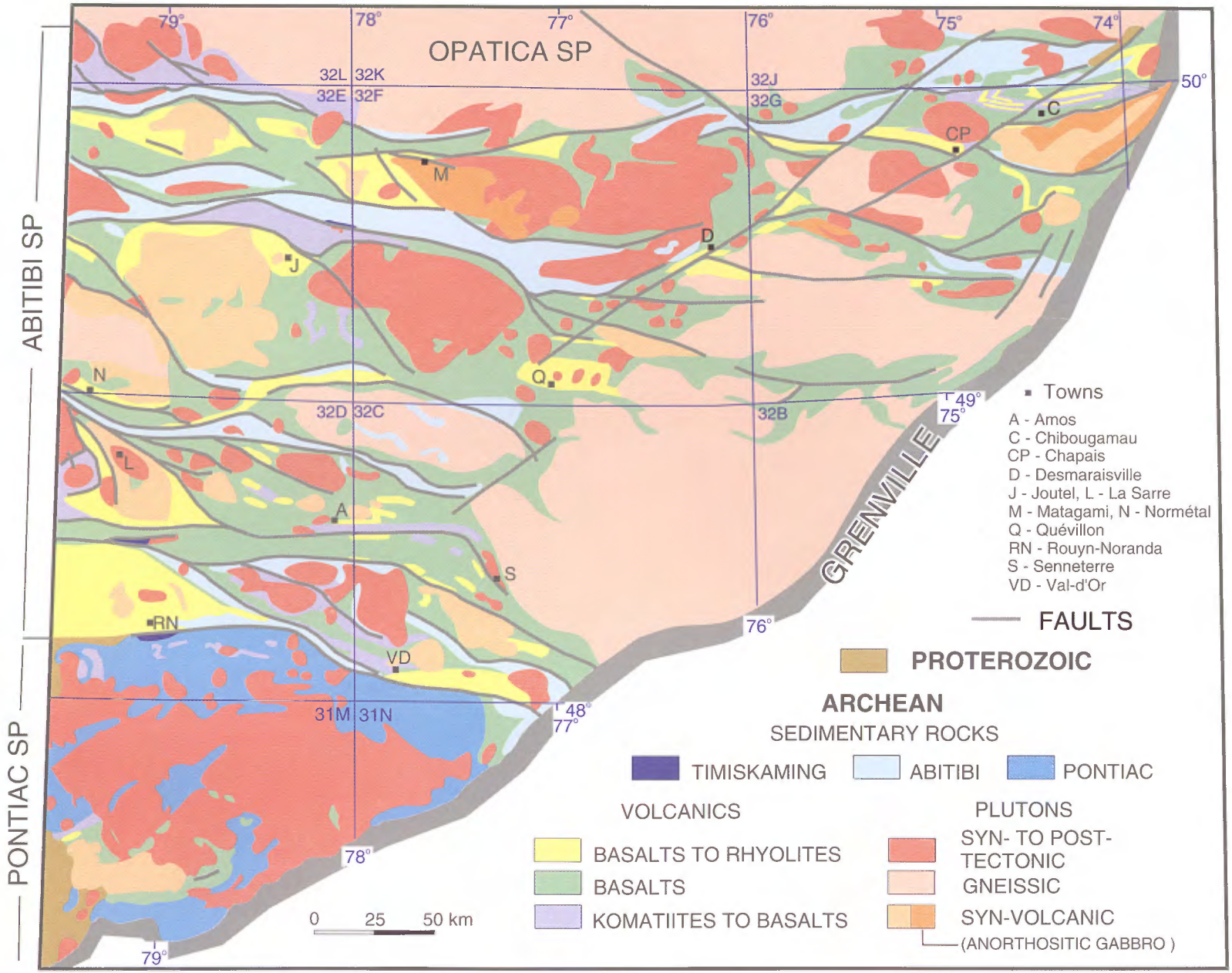


FIGURE 1 – Simplified geology of the Abitibi and Pontiac Subprovinces (modified from Hocq and Verpaelst, 1994).

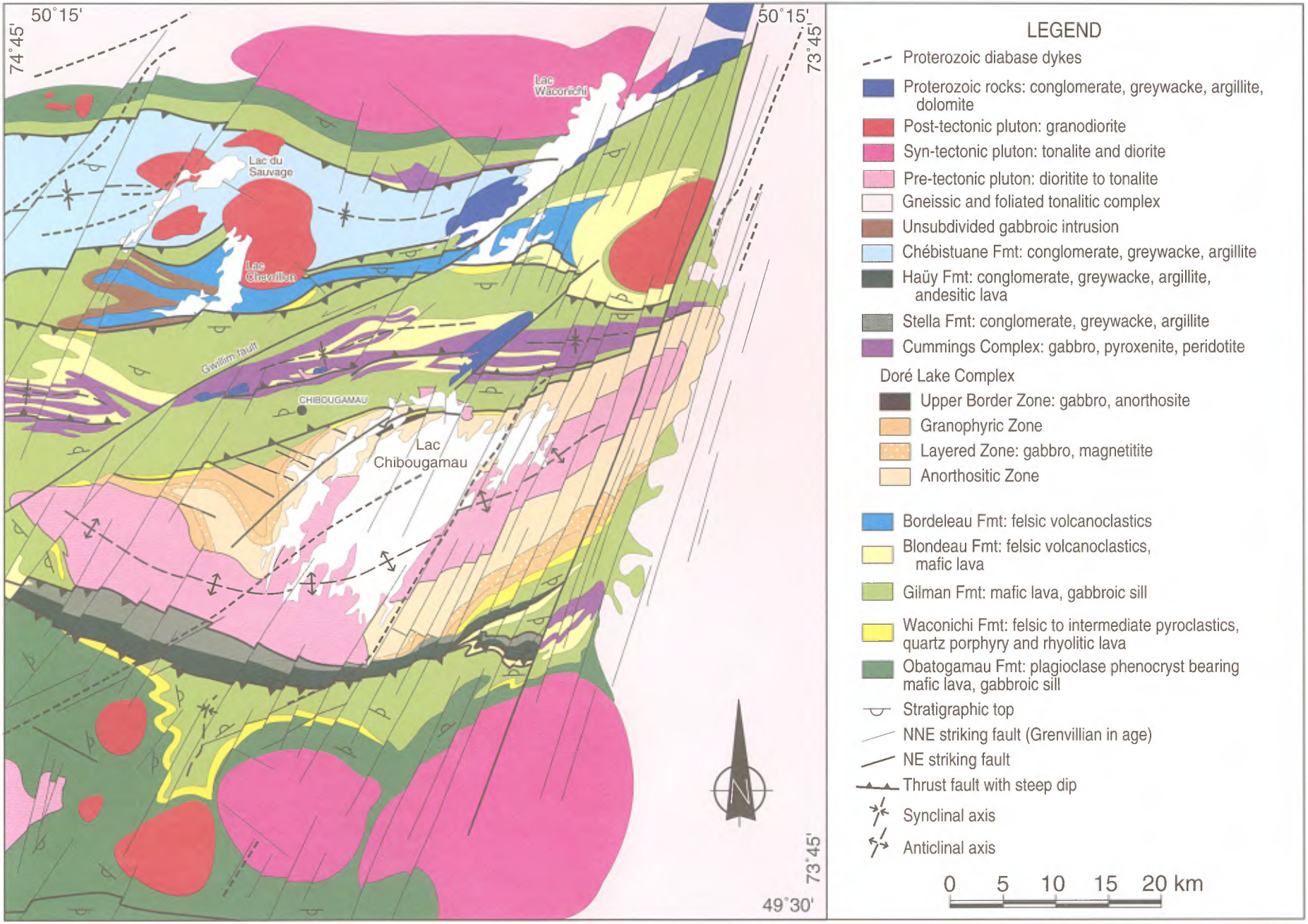
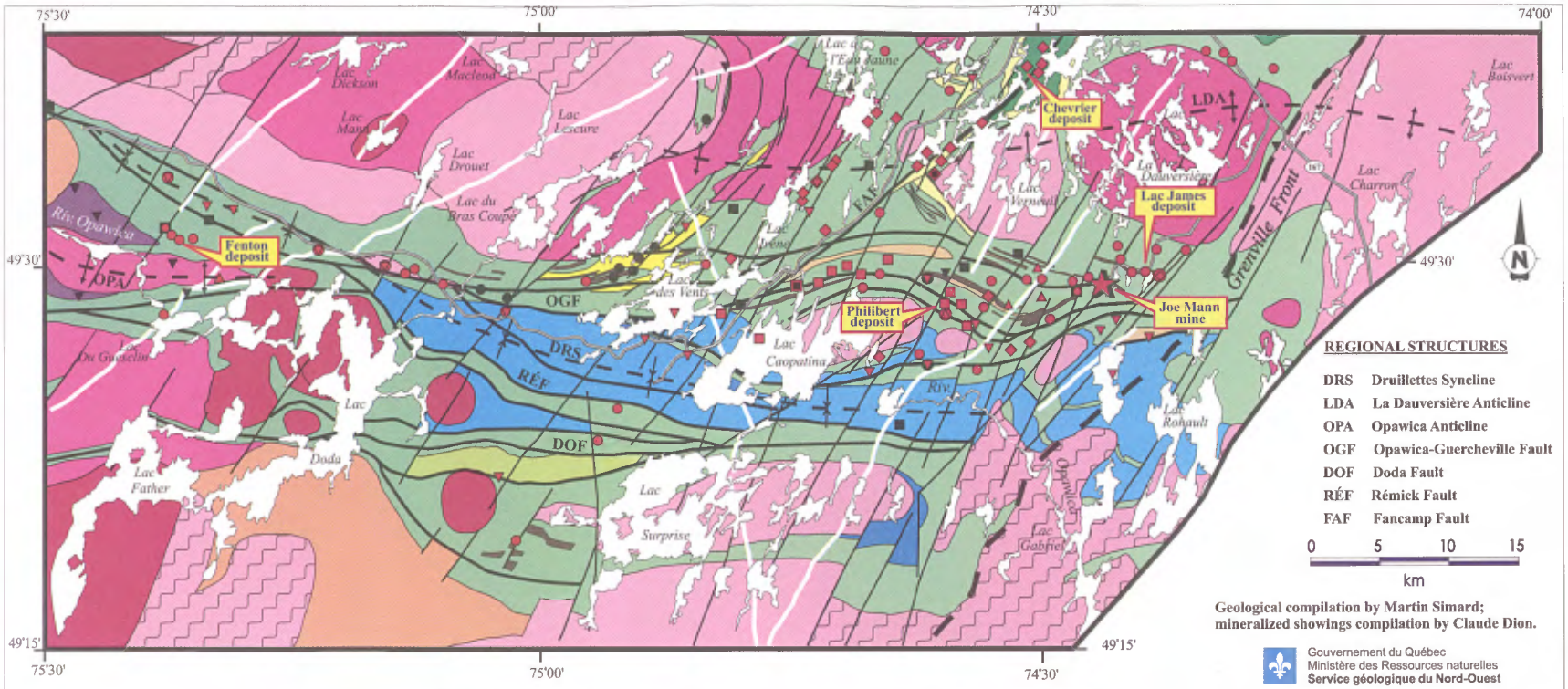


FIGURE 2 - Simplified geological map of the Chibougamau ara (modified from Daigneault and Allard, 1990).



LITHOSTRATIGRAPHIC LEGEND

PROTEROZOIC

- Diabase dyke

ARCHEAN

SYNTECTONIC INTRUSIONS
- Granodiorites
- Tonalites/granodiorites
- Monzodiorites

SYNVOLCANIC INTRUSIONS
- Diorites and tonalites
- Tonalitic gneiss
- Opawica River : anorthositic Complex

CAOPATINA FORMATION
- Graywackes, shales, conglomerates, iron formations

MESSINE FORMATION
- Paragneiss and biotite-garnet bearing gneiss

GILMAN FORMATION
- Basalts, gabbroic sills

WACONICHI FORMATION
- Felsic to intermediate tuffs, rhyolites

OBATOGAMAU FORMATION
- Intermediate to felsic tuffs
- Gabbros
- Basalts, gabbroic sills

DES VENTS MEMBER
- Pyroclastics, felsic lavas, volcanoclastics, basalts

PHOOEY MEMBER
- Intermediate volcanoclastics

MINERALIZED SHOWINGS

GOLD SHOWINGS

- Type Ia : Quartz-sulphide vein-type mineralizations hosted in E-W striking shear zones
- Type Ib : Disseminated pyrite-type mineralizations hosted in E-W striking shear zones
- Type II : Mineralizations related to NE and NW striking shear zones
- Type III :Mineralizations hosted in intermediate to felsic intrusions
- Type IV : Mineralizations hosted in felsic volcanics, sedimentary rocks and/or iron formations

BASE METALS SHOWINGS

- Type I : Volcanogenic massive sulphide type Cu ± Zn ± Au ± Ag mineralizations related to mafic-felsic volcanic complexes
- Type II : Zn ± Cu ± Au ± Ag mineralizations hosted in mafic sheared lavas, sedimentary rocks or graphitic tuffs
- Type III : Lode-type Cu ± Au ± Ag ± Mo mineralizations related to E-W or NE striking shear zones hosted in mafic volcanic rocks
- Type IV : Cu ± Ni ± PGE mineralizations hosted in mafic volcanic rocks and related intrusions

SYMBOLS

- Regional anticlinal axis
- Regional synclinal axis
- Shear zone
- Brittle fault
- Roads

MAIN DEPOSITS

JOE MANN MINE	type Ia :	Reserves - 3,28 Mt @ 8,78 g/t Au, 5,83 g/t Ag, 0,27 % Cu
CHEVRIER DEPOSIT	type II :	Reserves - 2,36 Mt @ 6,33 g/t Au
PHILIBERT DEPOSIT	type Ib :	Reserves - 1,4 Mt @ 5,32 g/t Au
FENTON DEPOSIT	type Ia :	Reserves - 402 000 t @ 5,01 g/t Au
LAC JAMES DEPOSIT	type Ia :	Reserves - 105 000 t @ 2,06 g/t Au (South Zone) and 66 000 t @ 4,25 g/t Au (North Zone)

FIGURE 3 - Simplified geological map of the Caopatina area, with the locations of the main gold and base metals showings.

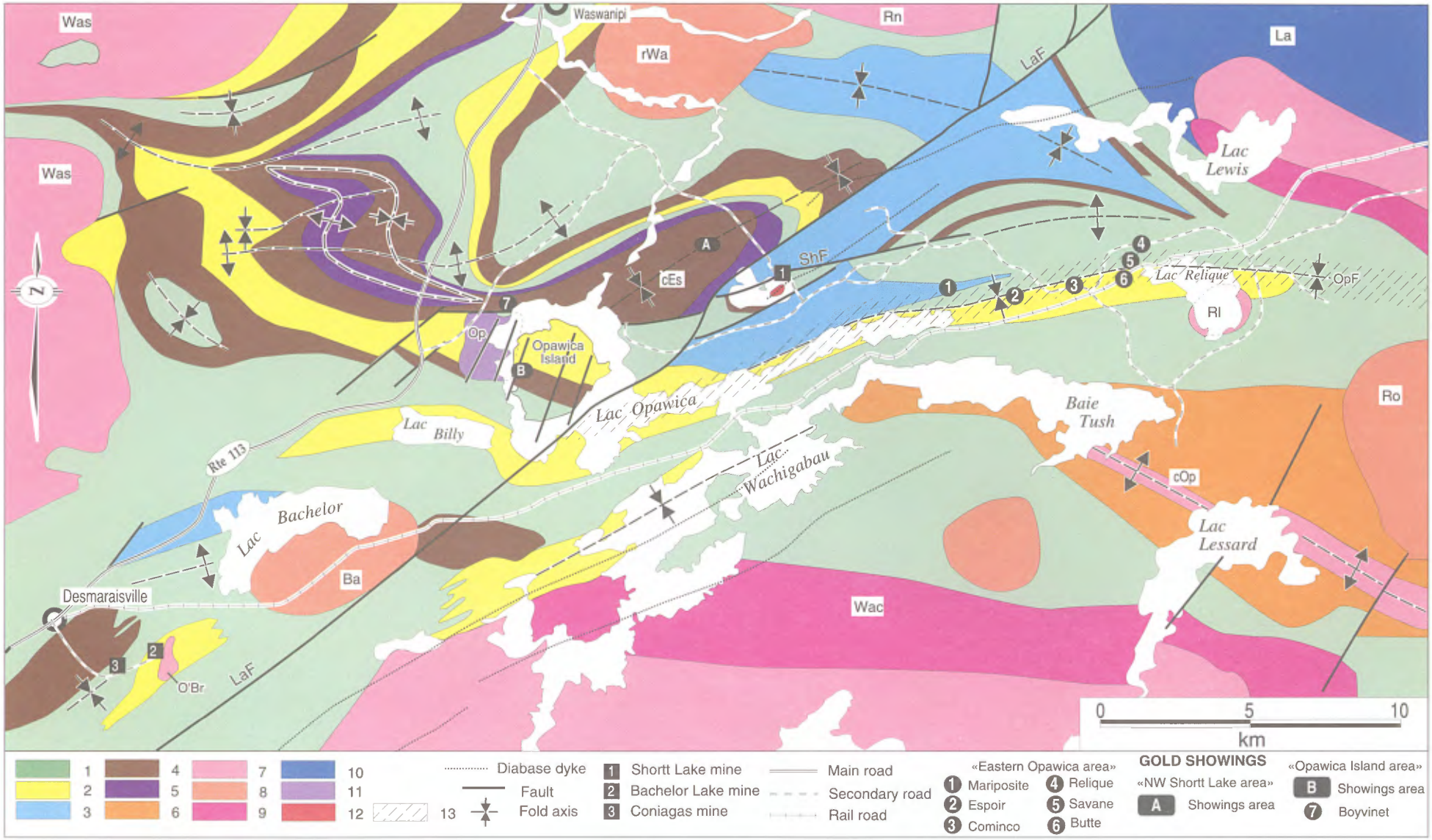


FIGURE 4 - Simplified geology of the Shortt Lake area, with the locations of the main gold showings (modified from Brisson and Guha, 1993). 1: Obatogamau Formation, basalts; 2: Wachigabau member, pyroclastics and felsic; 3: Dalime formation, pyroclastics and volcano-sedimentary rocks; 4: gabbro; 5: pyroxenite; 6: anorthosite; 7: tonalite; 8: granodiorite; 9: monzodiorite; 10: gneiss; 11: syenite; 12: carbonatite; 13: Opawica deformation zone. Plutons and other intrusions: **Ba**, Bachelor; **cEs**, Esturgeon complex; **cOp**: Opawica complex; **La**, Lapparent; **O'Br**, O'Brien; **Op**, Opawica; **RI**, Relique; **Rn**, Renaud; **Ro**, La Ronde; **rWa**, Waswanipi River; **Wac**, Wachigabau; **Was**, Waswanipi. Faults (f): **Laf**, Lamarck; **Opf**, Opawica; **Shf**, Shortt.

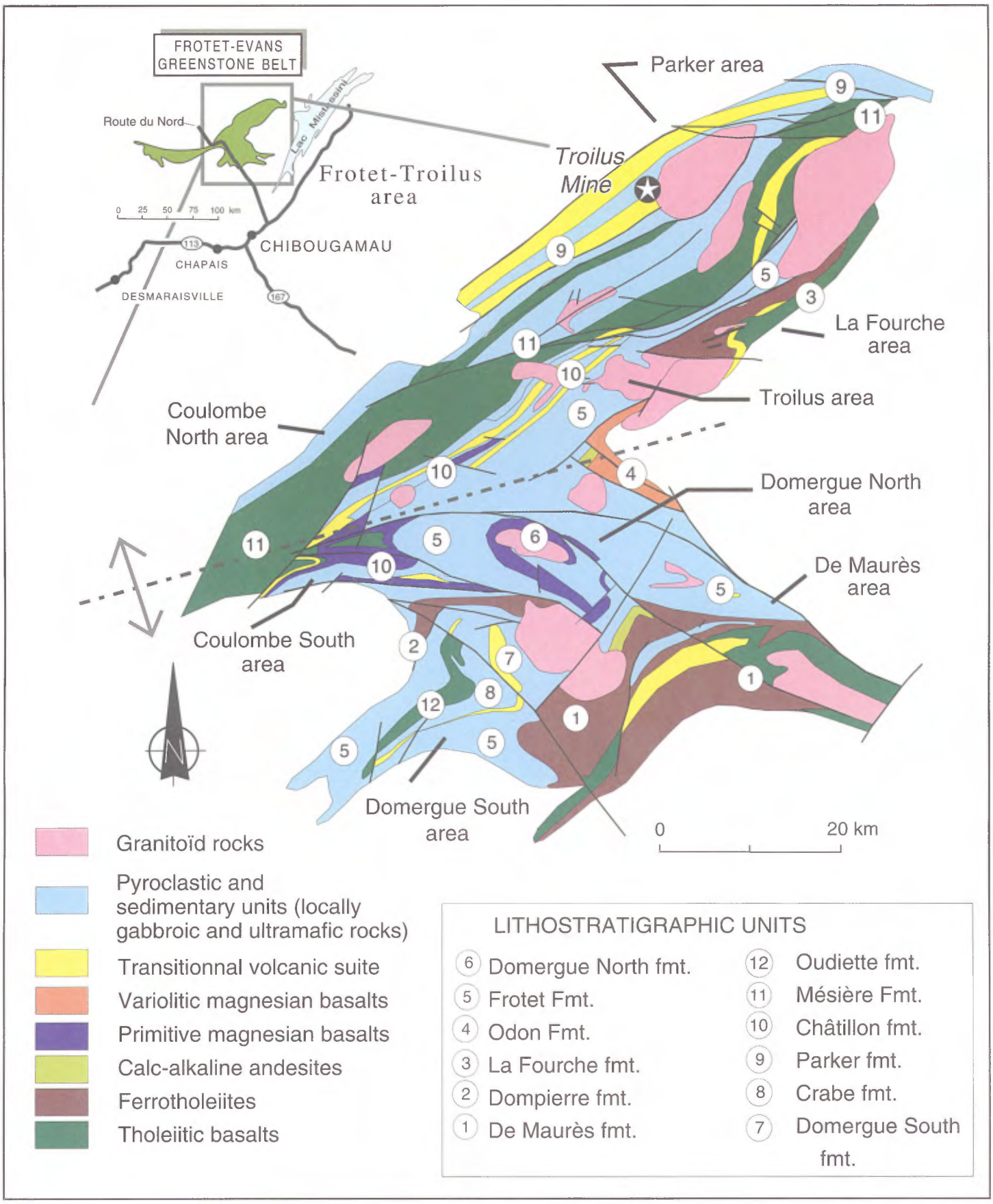


FIGURE 5 - Simplified geology of the Frotet-Troilus area (modified from Gosselin, 1996 and 1998).

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