SIDEX

1. ECONOMY

Exploring for cobalt in Québec

Co

Cobalt is a chemical element in demand since ancient times for its deep blue compounds used, for example, to colour Chinese porcelain. To German miners, it was known as the goblin element. It is one of only three naturally magnetic metals, the other two being iron and nickel, and it is very resistant to heat.

Cobalt is used in metallurgy and chemistry. In metallurgy, it is a component of alloys and superalloys with high mechanical and heat resistance used mainly in the aerospace industry, nuclear reactors, dental prostheses and permanent magnets. In chemistry, cobalt has applications in colouring agents, catalysts and animal food, but it is the metal's role in lithium batteries that drives demand. The world market for cobalt rebounded with the development of electric batteries for smart phones, each of which uses 5 to 25 g of Co in the form of Li-Co oxide. Today, the market is energized by the growth of electric vehicles that use batteries containing up to 15 kg of cobalt per vehicle in the form of a Li-Ni-Co (Mn or Al) alloy.

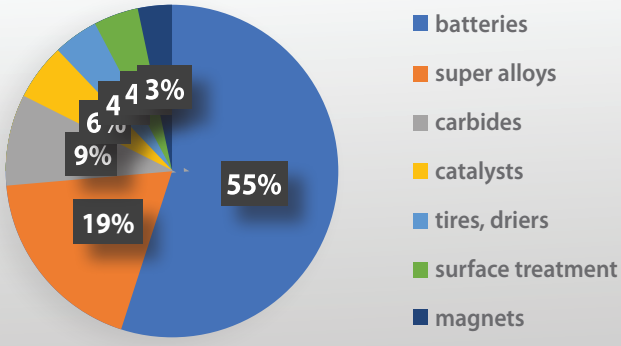

Figure 1: Uses of cobalt (source: Darton Commodities)

In 2016, world production was 109,500 t of cobalt, with 60% from copper mines, 38% from nickel mines, and 2% from cobalt mines in Morocco (Bou Azzer) and Uganda. Ore grades range from 0.5 to 2.5% Co, in rare cases exceeding 10% Co. Recovery rates are often low. The DRC has produced more than half the world's cobalt (66,000 t), of which 20% is artisanally mined. It is extracted by hydro- and pyro-metallurgical processes. Other producing countries include China (7,700 t), Zambia (4,600 t), Australia (5,100 t), Canada (7,300 t), Russia (6,200 t) and Cuba (4,200 t). More than 50% of the world's cobalt is processed in China, with the rest in Finland, Zambia and Belgium.

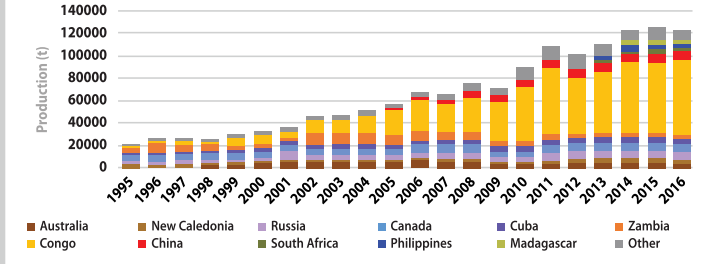

Figure 2: Production by country from 1995 to 2016 (USGS)

The world's largest producers are Glencore (30% of global production), China Molybdenum Co, Vale, Umicore and Gécamines. In Canada, Cobalt27 Capital Corp. has built a strategic inventory of nearly 3,000 t of cobalt.

The current price of cobalt hovers around US$80,000/t after tripling over the past two years. It reached a new high of US$34.25/lb in January 2018. There was a market shortage in 2016, partly due to lower copper production from the DRC. An increased demand for batteries, estimated at 11.7% per year until 2022, would lead to a 6.9% rise in cobalt demand until 2020.

2. GEOLOGY- METALLOGENY

Cobalt is a rare metal and does not exist naturally as a native element. There are roughly thirty principal minerals of cobalt in the form of oxides, carbonates, sulphides, arsenides and thioarsenides (Table 1).

TABLE 1: PRINCIPAL COBALT MINERALS

Asbolane	Ni, Co oxide	Koniambo (New Caledonia)
Carrollite	$Cu(Co,Ni)_2S_4$	Chambishi (Zambia)
Cobaltite	CoAsS	Sudbury (Ontario)
Erythrine	$Co_3(AsO4)_2.8H_2O$	Bou Azzer (Morocco)
Heterogenite	CoO(OH)	Copperbelt (DRC)
Linnaeite	Co_3S_4	Noril'sk (Russia)
Safflorite	$(Co,Fe)\ As_2$	Schneeberg (Germany)
Skutterudite	$(Co,Ni)As_3$	Skutterud (Norway)
Smaltite	$(Co,Fe,Ni)As_2$	Cobalt (Ontario)

The bulk of production, however, is the result of cobalt substitution in other sulphides (arsenopyrite, pyrrhotite, pyrite or pentlandite).

Cobalt resources are considerable but they depend on the production of Cu and Ni. It is estimated that global resources are between 5 and 25 Mt, without taking into account the more than 120 Mt of cobalt in manganese nodules on the seafloor. The greatest resources are contained in the Copperbelt of DRC and Zambia. Additional resources are found in the nickel laterites of Australia, the Southwest Pacific and Cuba. Ultramafic rocks in Canada, Australia, Russia and the USA also have good potential.

THERE ARE FIVE MAIN TYPES OF DEPOSITS:

1. Stratiform deposits in cupriferous sandstones and shales, primarily in the Copperbelt. Cobalt appears to be associated with zones with abundant mafic rocks and evaporites; the Co/Cu ratio is highly variable;

2. Magmatic Ni, Cu (Co, PGE) sulphide deposits, such as Sudbury, Noril'sk, Voisey's Bay and Bushveld: these may be layered igneous complexes or komatiite-type submarine volcanoes; cobalt may be associated with scandium in dunites;

3. Polymetallic veins, known as "five-element veins" (Ni-Co-Bi-Ag-U+As,REE), such as those in Cobalt (Ontario), Bou Azzer (Morocco), and the cobalt belt of Idaho;

4. Sulphide bodies in Besshi-type basic sedimentary settings, with variable degrees of deformation, such as Outokumpu (Finland); these deposits have been recognized up to amphibolite and granulite facies in Archean settings (Modum, Norway; Werner Lake, Ontario);

5. Ni-Co laterite deposits, formed in an equatorial climate on peridotite substrata during the Tertiary, notably in New Caledonia, Cuba and Australia. Some deposits are found in arid climates (USA, Russia, Australia). These deposits are not likely to be found in Québec.

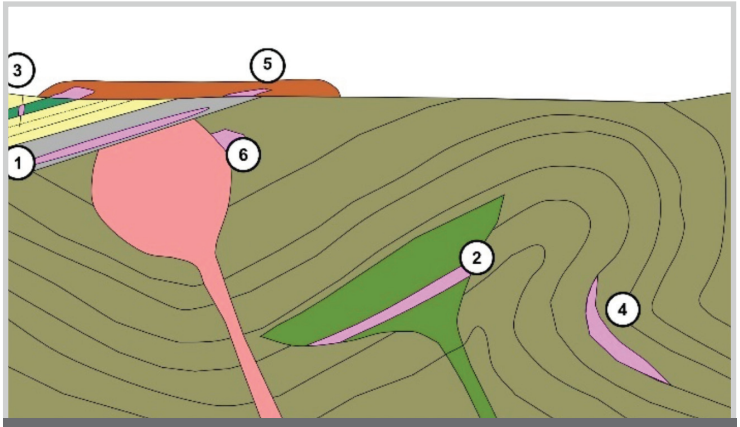

Figure 3: The main types of cobalt deposits

Cobalt has also been extracted from several other types of geological environments: black shales, Co-Cu-Au deposits in metasedimentary rocks (Idaho), Mississippi Valley-type Pb-Zn-Co deposits, unconformity uranium deposits, and polymetallic IOCG and skarns (NICO, 0.12% Co – type 6 on Figure 3). The genesis of most of these deposits is not well understood and the cobalt metallogeny remains somewhat unclear (Hitzman et al. 2017).

Exploration tools for these deposits rely on the analysis of the geological context (mafic and ultramafic rocks, black shales), Cu-Ni geochemistry and geophysical signatures, particularly magnetics.

The economic and geological characteristics of these types of deposits are summarized in table 3.

3. QUÉBEC'S POTENTIAL

Cobalt exploration in Québec has been neglected in the past. Available data support a strong discovery potential.

PRODUCTION

In 2013, two mines produced cobalt alongside Ni, Cu and PGE: Raglan and Nunavik Nickel. Total production reached 1,155 t in 2014. Globe Metal, based in Montréal, is the main cobalt recycler in North America.

PROJECTS

The following table summarizes some of the active projects in Québec.

TABLE 2: SELECTED ACTIVE PROJECTS IN QUÉBEC

NOM	RÉGION	INDICE	GÉOLOGIE	ENTREPRISE
Roberge	Appalachian	Soil geochemistry 1.06% Co	DV 84-16	King's Bay
Lac Paradis	North Shore (Manic 5)	Ni-Cu showings; drilling 0.12% Co	Paragneiss, mafic rocks, UB	Berkwood Resources Ltd
Cobalt Bay	Abitibi (Windfall Lake)	Drilling 0.17% Co		Secova
Broadback River	Opatica, Frotet Evans	Ni-Cu showings; drilling 0.09% Co	Semi-massive sulphides, gabbro	King's Bay
Moria	La Grande	Ni showings 0.09% Co	Pyrite, pentl., pyroxenite	Midland/Altius
Ninuk Lake	Minto	Ni-Cu showings 0.27% Co	Massive sulphides, UB	King's Bay
Dumont Nickel	Abitibi	Deposit under development, 107 ppm Co	Magmatic sulphides, dunite	RNC-Waterton GRM
Fabre	Témiscamingue	Co, Bi, Ag veins	Cobalt type	Volt Energy

TARGETS

Québec has many favourable settings for cobalt deposits that can be identified through geochemistry (>3,500 ppm Co in rocks, >300 ppm Co in stream sediments). The map shows the distribution of anomalous values, primarily associated with magmatic Ni-Cu and Cu deposits. Details of the targets are presented in Table 4.

Numerous cobalt showings in Québec, particularly in the Grenville Province, the Labrador Trough, the New Québec Orogen and the Ashuanipi area.

More than 100 showings of Ni-Cu (Co, PGE) have been discovered in the Québec parts of the Grenville Province. They are associated with mafic-ultramafic intrusions: the Matamec and Bostonais complexes, the Shabogamo gabbro, the Lac St-Jean anorthosite and the Manicouagan plateau. The Taureau Reservoir showing is distinguished by its Ni-Co arsenides, drawing comparison to the Cobalt District of Ontario. In Labrador, the Lynx Lake massive sulphide deposit is associated with an IOCG-type deposit.

The cobalt potential of the Superior Province lies in the komatiites and dunites of its greenstone belts. The Cape Smith and Labrador belts contain cobalt showings hosted in ultrabasic rocks and sedimentary rocks associated with iron formations, and there is also potential for Besshi-type deposits (Soucy, Prud'homme showings).

4. SELECTED REFERENCES

Clark, T. (1998) An overview of the Ni-Cu±Co±PGE potential of the Grenville Province in Québec, Géologie Québec, PRO 98-02, 10 p.

Clark, T. (2001) Distribution and exploration potential of platinum-group elements in Québec. Géologie Québec, PRO 2001-06, 17 p.

Hitzman, MW et al. (2017) Cobalt—Styles of deposits and the search for primary deposits. USGS OPF 2017-1155, 53 p.

www.ecobalt.com/cobalt/cobalt-facts

Mudd, GM et al. (2017) Quantifying the recoverable resources of by-product metals: The case of cobalt. Ore Geology Reviews, 55: 87-90.

Naldrett, AJ (2004) Magmatic sulfide deposits—Geology, geochemistry, and exploration: Berlin, Springer-Verlag, 727 p.

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Main types of cobalt deposits

TABLE 3.

MAIN TYPES OF COBALT DEPOSITS	CUPRIFEROUS SANDSTONES AND SHALES	MAGMATIC NI-CU SULPHIDE DEPOSITS	FIVE-ELEMENT VEIN-TYPE	BESSHI-TYPE SULPHIDES
ECONOMY				
Ore tonnage	5 - 500 Mt	1 - 1000 Mt	0.1-10 kt	10-160 Mt
Typical grades	0.1 - 3% Co	0.03-0.2% Co	0.2 - 10% Co	0.05 - 1% Co
Proportion of global resource	40%	7%	11 % (with IOCG)	0.1-1%
Canadian examples	Redstone (NWT); up to 0.12% Co	Raglan (QC), 0.06% Co; Sudbury 0.04 % Co (ON), Voisey Bay 0.12% Co (NL)	Keeley-Frontier Mine (Cobalt, ON) 1500 Mt at 0.5% Co, Thunder Bay	Windy Craggy (0.07 % Co) (BC)
International examples	Tenke Fugurume, (0.3%), Kisanfu (1.1%), Nchanga (0.4%), Kamoto (0.49% Co), DRC and Zambia Talvivaara (Finland) 0.02 % Co	Noril'sk-Talnakh (Russia), Bushveld (SA), Duluth (MN), Jinchuan (China) 0.01% Co, Kambalda (WA) 0.06% Co	Bou Azzer (Morocco; 1% Co), Idaho (USA), Erzgebirge (Germany), Konsberg (Norway)	Outokumpu (0.25% Co, Finland), Kilembe-Kasese (16 Mt at 2% Cu 0.2% Co, Uganda), Ducktown (Tennessee)
GEOLOGY				
Tectonic context	rift involved in an orogeny	pre- to syn-orogenic mafic to ultramafic setting	post-orogenic mafic to ultramafic setting	ophiolite or rift
Host rock lithology	reduced sandstones and shales overlying oxidized sandstones, black shales, carbonates	layered igneous complexes, komatiite flows	basic to ultrabasic rocks	basic volcanics and sediments (argillites, black shales)
Host rock deformation	diapiric breccia	tilted with little deformation; deformed komatiites	undeformed to shear zones	deformed
Host rock age	Upper Proterozoic, Permo-Triassic, Cenozoic	Archean, Proterozoic	Proterozoic, Paleozoic	Proterozoic, Paleozoic, Mesozoic
Alteration	chloritization, carbonatization	none	chloritization	serpentinization, chloritization
Geometry	conformable layer	lens at the base of intrusions and flows, magmatic pipes, magmatic layers	veins or selvage replacement	massive sulphide lens, variable degree of deformation
Mineralogy	Cu-Co sulphides	pyrrhotite, pentlandite, chalcopyrite, linnaeite	pyrite, native Ag, Ni-Co arsenide, native Bi, calcite, quartz	pyrite, chalcopyrite, pyrrhotite, linnaeite
Geochemistry	Cu-Co (Pb, Zn, Mo, V, U, Ag)	Ni, Cu, Co, PGE	Ni-Co-Bi-Ag-U+As,REE	Cu-Co-Zn-Ni-Ag-Au
Co to Ni ratio	< 1	0.1 to 0.01	> 1	> 1

SIDEX

Selection of favourable areas in Québec for cobalt based on rock geochemistry (source: SIGEOM)

TABLE 4.

TARGETS	EASTING	NORTHING	UTM	SAMPLE	GEOLOGY	CO (%) AND ASSOCIATIONS	GEOFICHE DOCUMENT (EXAMINE)
1	590771	6839092	18	1988001930	Paleoprot. sandstone, silstone	0.41% Co, Cu, Ni	R233348
2	449176	6465570	19	1988015447	Paleoprot. Montagnais gneiss and sill, gabbro	0.43% Co, Cu, Au, Fe, Zn	MB 88 05
3	527833	6255303	19	1906021062	Paleoprot. dolomite	0.42% Co, Cu, Ni, U, Ag	GM 64155
3	527740	6255716	19	1906031287	Paleoprot. dolomite	0.57% Co, Ni. Cu. Pb, Zn	GM 62471
3	527810	6255579	19	1906021037	Paleoprot. dolomite	1.32% Co, Cu, U, Ag	GM 64155
3	527810	6255580	19	1906021036	Paleoprot. dolomite	1.41% Co, Cu, Ni, U, Ag	GM 64155
3	527746	6255728	19	1985024702	Paleoprot. mudshale, dolomite	1.68% Co, Cu, U, V	
4	326864	6137637	20	1988011727	Paleoprot. sulphide BIF, basalts	0.46% Co, Fe	RG 301BZ
5	632836	6075998	19	1989025686	Paleoprot. chert BIF (Sokoman)	0.42% Co, Fe	
6	617844	5855478	19	1991000526	BIF (Wabush)	8.97-8.85% Co, Ni	
Walsh	617844	5855478	19	Walsh Prospect	Sediment lenses, Wabush Formation (Paleoprot.)	6% Co, Ni	Gobeil, 1991
7	548946	5706675	19	1995005332	Norite, Manicouagan Complex	0.36% Co, Cu, Ni, PGE	
8	333912	5645922	20	999912330	Massive sulphides in anorthosite, norite	0.35% Co, Cu, PGE	GM 55953
9	318745	5406973	19	1993013552	Anorthosite, norite (Lac St-Jean)	0.53% Co, Au	
10	704840	5467535	18	1988011907	Anorthosite, norite (Lac St-Jean) 4pts	0.9% Co, Cu, Ni, PGE	
11	556963	5511921	18	2007045298	Chibougamau Pluton vein, Archean	0.36% Co. Fe	
11	557238	5512295	18	2005100017	Massive sulphides, Lac Doré Anorthosite, Archean	0.39% Co	EGP2002-VP50
12	316827	5326838	18	1986000237	Sill, Vicour diorite	0.49% Co, Au	MB 86-67
Fabre	626041	5229691	17	Fabre Rang V (north) - lot 3	Archean andesite, diorite (Baby)	7.3% Co, Au, Ag, Cu, Ni, Bi	GM 03956

5. COBALT TARGETS IN QUEBEC

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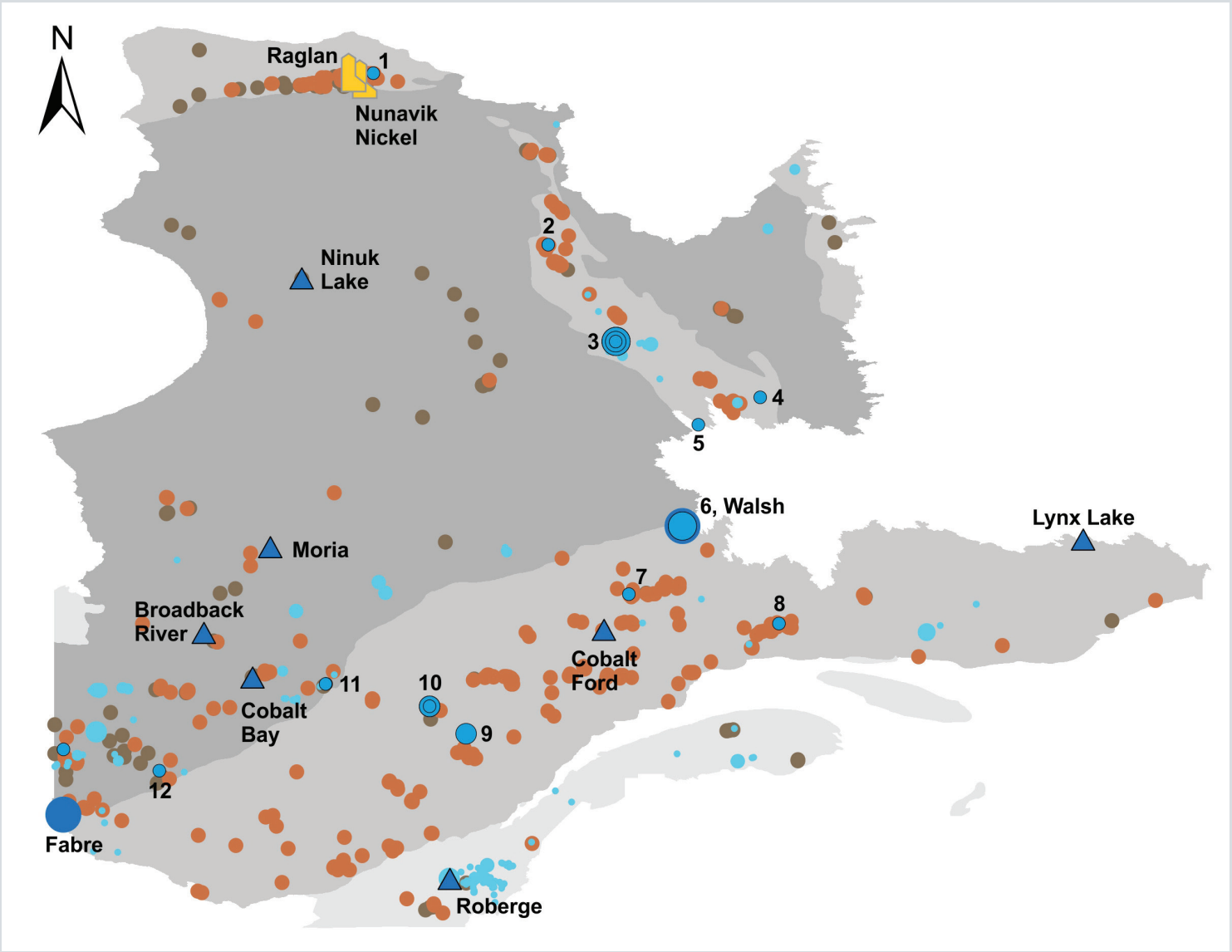

Mines Ni-Cu-Co

Exploration projects

Mineralized bodies

Prospects Ni-Cu

Prospects Ni

Prospects Co

Steam sediments - Co

300 - 500 ppm

500 - 1,000 ppm

1,000 - 3,000 ppm

3,000 - 6,000 ppm

6,000 - 12,000 ppm

Rocks - Co

3,500 - 5,000 ppm

5,000 - 10,000 ppm

10,000 - 100,000 ppm

0 250 500 Km