

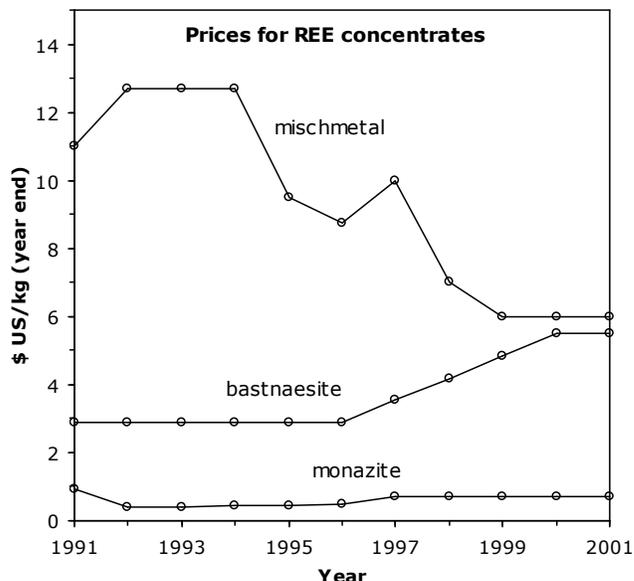
1. ECONOMICS

The world demand for REE is growing and applications tend to diversify. China dominates the world supply and the market remains competitive, but prices and purity specifications are on the rise.

In 2001, China accounted for 88% of the world production of REE totaling an estimated 85,500 metric tons of contained rare earth oxides (REO). The United States produced about 6% (e.g., the Mountain Pass mine in California), whereas India accounted for 3% and the former Soviet Union about 2%. The world REE reserves amount to 110 Mt (USGS reserve base), of which China claims 42.5%, the former Soviet Union 18.6%, the U.S. 12.4%, Australia 5.1%, and Canada 0.9%.

Lanthanides are sold as monazite or bastnaesite concentrates, or as mischmetal - a natural blend of rare earth elements (~53% Ce, 25% La, 16% Nd, 4% Pr and 2% others). The price for monazite concentrates remains depressed since many treatment plants only process thorium-free ores to avoid environmental problems (monazite is a thorium-bearing mineral). Monazite was not imported into the United States during the year 2000. The price of bastnaesite concentrates, on the other hand, has been rising steadily since 1996, from \$2.87 US to \$5.51 US per kilogram. In 2000, the prices per kilogram for isolated and purified rare earth oxides ranged from \$20.85 US for cerium (Ce, 99.5% pure), an element whose crustal abundance (60 ppm) surpasses that of copper, to \$3,500 US for lutetium (Lu, 99.99% pure), whose crustal abundance is 0.5 ppm.

Long term growth of REE consumption will be stimulated by new applications and the rising demand for some existing applications, such as permanent magnets (annual increase of 25% since 1990), catalytic converters in automobiles (anti-pollution systems) and rechargeable Ni-MH batteries (cellular phones, portable computers, personal data assistants



and other portable electronic devices). On the other hand, some end-uses are declining, such as REE phosphors (lighting, televisions, computer monitors, radars, X-ray intensifying films) and petroleum refining catalysts. The world REE market will remain competitive because of the low manpower costs and less stringent environment regulations in developing countries. China is expected to remain the dominant world producer.

2. GEOLOGY-EXPLORATION

Two types of deposits presently produce almost all REE concentrates: carbonatite-related bastnaesite deposits and heavy mineral sands (placers) operations extracting monazite as a by-product. Polymetallic iron oxide deposits could become an important source of lanthanides in the future.

Historic and current light rare earth element (LREE) production mainly comes from the minerals monazite and bastnaesite. Monazite concentrates contain 55-60% REO, 3-10% thorium, and lesser amounts of yttrium and uranium. Bastnaesite concentrates contain more REO but no thorium or yttrium. Heavy rare earth element (HREE) production is

mainly from the mineral xenotime, which is present in granitic rocks and placer deposits derived from their breakdown. Apatite associated with alkaline rocks may be REE-enriched, and it is sometimes possible to extract lanthanides during phosphoric acid production.

REE deposits are either primary (carbonatite deposits, vein-type deposits, polymetallic iron oxide deposits) or secondary (residual carbonatite deposits, monazite-bearing placers and paleoplacers).

Characteristics of two types of primary REE deposits (see web site for examples)

	Carbonatite	Polymetallic iron oxide (Olympic Dam type)*
GEOLOGY		
Tectonic context	Generally intraplate regions, some along plate margins (orogenies or rifts)	Late-orogenic to post-orogenic, within cratons or contin. margins; extensional or transtensional regimes
Age	Four major periods: (a) 1800-1550 Ma; (b) ~1100 Ma; (c) 750-500 Ma; (d) <200 Ma	Proterozoic (<1.9 Ga) to Holocene
Related intrusive rocks		
Chemistry/ Mineralogy	Carbonatites: >50% carbonates (calcite, dolomite, ankerite, sodic/potassic carbonates), + sodic pyroxenes, amphiboles, phlogopite, apatite, olivine and rare/exotic minerals containing F, Nb, Ta, Th, REE, U, V or Zr; very late phases may bear REE	Alkaline intrusive complexes of generally intermediate composition; Rapakivi granites, diorites
Size	Small intrusive bodies (3-5 km in diameter) within larger alkaline complexes	Intrusions may not be obvious or may be absent
Host rocks		
Lithology	Host rock for carbonatite-bearing alkaline complex: not important	Sedimentary rocks, volcanic and intrusive rocks (felsic to intermediate), metamorphic rocks
Alteration	Fenitization aureoles around the alkaline complex: SiO ₂ loss, Fe ³⁺ , Na and K gain; high concentr. of LREE, large lithophile elements and other incompatible elements	The largest deposits are accompanied by large hydrothermal systems characterized by magnetite, hematite, chlorite, epidote, carbonates and albite
Mineralization		
Position and shape	Magmatic deposits: REE concentrated in the core of the carbonatite; metasomatic deposits: veins, stockworks or replacement zones outside carbonatite body (veins and dikes occupy radial and concentric structures)	Breccias/diatremes near surface; replacement zones in specific horizons; veins, pegmatites; iron skarns near the intrusion at depth
Mineralogy	Pyrochlore, REE fluorocarbonates or phosphates (bastnaesite, parisite, monazite), apatite; gangue minerals include calcite, dolomite, strontianite, quartz, barite, hematite, magnetite, zircon, allanite, etc.	LREE in florencite, bastnaesite, monazite; HREE and yttrium as cation substitution in uraninite and coffinite; sulfides = chalcopyrite, pyrite, less commonly bornite and hypogene gold-bearing chalcosite; abundant iron oxides (hematite, magnetite); fluorite may be present
EXPLORATION		
Geology	1- Carbonatite intrusions are often located in the central part of rather small (<50 km ²) alkaline complexes; 2- circular topographic features (e.g., lakes with circular shapes); 3- lineament intersections; 4- fenite alteration of host rocks	1- Large volcano-intrusive complexes in extensional or intraplate contexts; 2- Large volumes of low-Ti iron oxides; 3- Large-scale potassic, sodic or sericitic alteration; 4- Remote sensing: major structures
Geochemistry	1- Within a carbonatite intrusion, trace intrusive contacts and systematically analyze for Nb, REE, P, U and F; 2- REE-enriched Intrusive phases have lower P, Ti, Zr and Nb relative to earlier phases; 3- Pyrochlore and monazite are detectable in heavy min. concentr. (soils, streams)	Anomalous concentrations of Cu, Au, U, Ag, Ce, La, Co, P, F, Ba, Sr and REE
Geophysics	1- Magnetite-bearing carbonatites appear on aeromagnetic maps as small circular to elliptical positive anomalies; 2- Fenitized host rocks can create a negative anomaly due to magnetite destruction; 3- Near-surface carbonatites have a positive radiometric signal (Th-bearing pyrochlore, monazite)	1- Coincident magnetic and gravimetric anomalies, but sulfides not associated with magnetic high 2- Radiometric data (K, U and Th) ± I.P. and TEM (e.g., Ernest Henry deposit, Australia)

* Excluding Kiruna-type deposits, which are tabular magnetite-apatite-actinolite bodies mined exclusively for iron.

Characteristics of two types of secondary REE deposits (see web site for examples)

	Residual carbonatite deposits	Monazite-bearing placers
GEOLOGY		
Age	See carbonatite ages (residual deposits are younger than primary deposits)	Mined placers: Holocene and end of Tertiary
Mineralogy	During surface alteration, calcite, dolomite and apatite are dissolved; REE are mobilized into supergene monazite during intense alteration; pyrochlore⇒florencite and pérovskite⇒anastase	REE hosted by monazite (++), xenotime (+) and anastase (-); other heavy minerals: ilmenite, zircon and rutile (economic), plus magnetite, staurolite and garnet (not exploited)
Genesis	Long exposure to wet tropical climates (e.g., Amazon Basin) can result in alteration and erosion of outcropping carbonatites to create exploitable accumulations of P, Nb, Ti and REE; favorable conditions = absence of karstic system and basin-style topography	Monazite, xenotime and anastase are dense minerals that are resistant to physical degradation; they accumulate in beach and dune deposits (++) as well as fluvial (stream), lacustrine (lake) and deltaic sediments (-)
EXPLORATION		
Geology	Topography: circular shapes indicate small alkaline complexes (<50 km ²) with steep borders; radial and concentric drainage patterns due to carbonatite-related fracture system	The majority of monazite-bearing placers are located along shorelines (beach deposits); REE minerals are derived from adjacent granitic or high-grade metamorphic rocks
Geochemistry	Once an alkaline complex with residual soils has been identified, soil/stream sediment geochemistry (REE, Nb, Ti, P) and heavy mineral concentrations in soils (anastase, pyrochlore, monazite) can be used to trace mineralized zones	Analyze potential deposit for Ti, Zr and REE
Geophysics	Intense radiometric anomaly (10-20 times background) possibly coincident with (1) positive magnetic anomaly of circular shape and high gradient, or (2) gravimetric anomaly when residual soils are thick enough and of sufficiently different density	Seismic profiles and auger drilling can be used to measure thickness

3. QUEBEC'S POTENTIAL

Lanthanides are not amongst substances presently mined in Quebec, and exploration for these elements was marginal over the last years. However, dozens of deposits are known, many of them polymetallic: Nb-Ta-REE in carbonatites, U-Th-REE in pegmatites, Cu-U-Au-Ag-REE in Olympic Dam-type iron oxide deposits. Quebec's potential for lanthanide exploration therefore seems excellent.

Quebec has good potential for carbonatite and Olympic Dam-type REE deposits. In a report by Y. Hébert (MB 94-17), Quebec's alkaline intrusions (**carbonatites**, granites, syenites, diorites, peridotites) are concentrated into five regions: (1) the south-western Grenville Province, (2) the Saint-Lawrence, Ottawa-Bonnechère and Saguenay grabens, (3) the Ungava Bay area, (4) the Greenland-Labrador alkaline province, and (5) the Monteregian Hills. The report concludes that the most favorable area is that between Hull and the Baskatong Reservoir. This region

is covered by a 1987 stream sediment survey (MB 88-35), and the map of REE values from heavy mineral concentrates shows major anomalies east of the Baskatong Reservoir (large anomalous zone, U- and Th-rich), in the Lac David area, south-east of Grand-Remous (no uranium, intrusion-related) and in the Nord-Calumet area proximal to known uranium showings (MB 90-29).

Mineral deposits and showings with affinities to the **Olympic Dam** deposit are known in the Kwyjibo area, north and east of Sept-Îles in the Côte-Nord region. A geochemical survey of lake sediments between Havre St-Pierre and Natashquan reveals several polymetallic anomalies (Cu-U-Th-REE) in the Wakeham Supergroup (MB 95-02). REE anomalies are reportedly associated with U-Mo-Au skarns related to alkaline intrusions in the Mont-Laurier area.

Monazite-bearing placers and paleoplacers may have formed in Quebec; some U-Th-REE pegmatites could also be of interest to prospectors.

REE-bearing iron oxide deposits

- 1 Guido
- 2 505796
- 3 94-14
- 4 543332
- 5 Fluorine
- 6 Malachite
- 7 Andradite
- 8 Josette

Monazite-bearing placers and paleoplacers

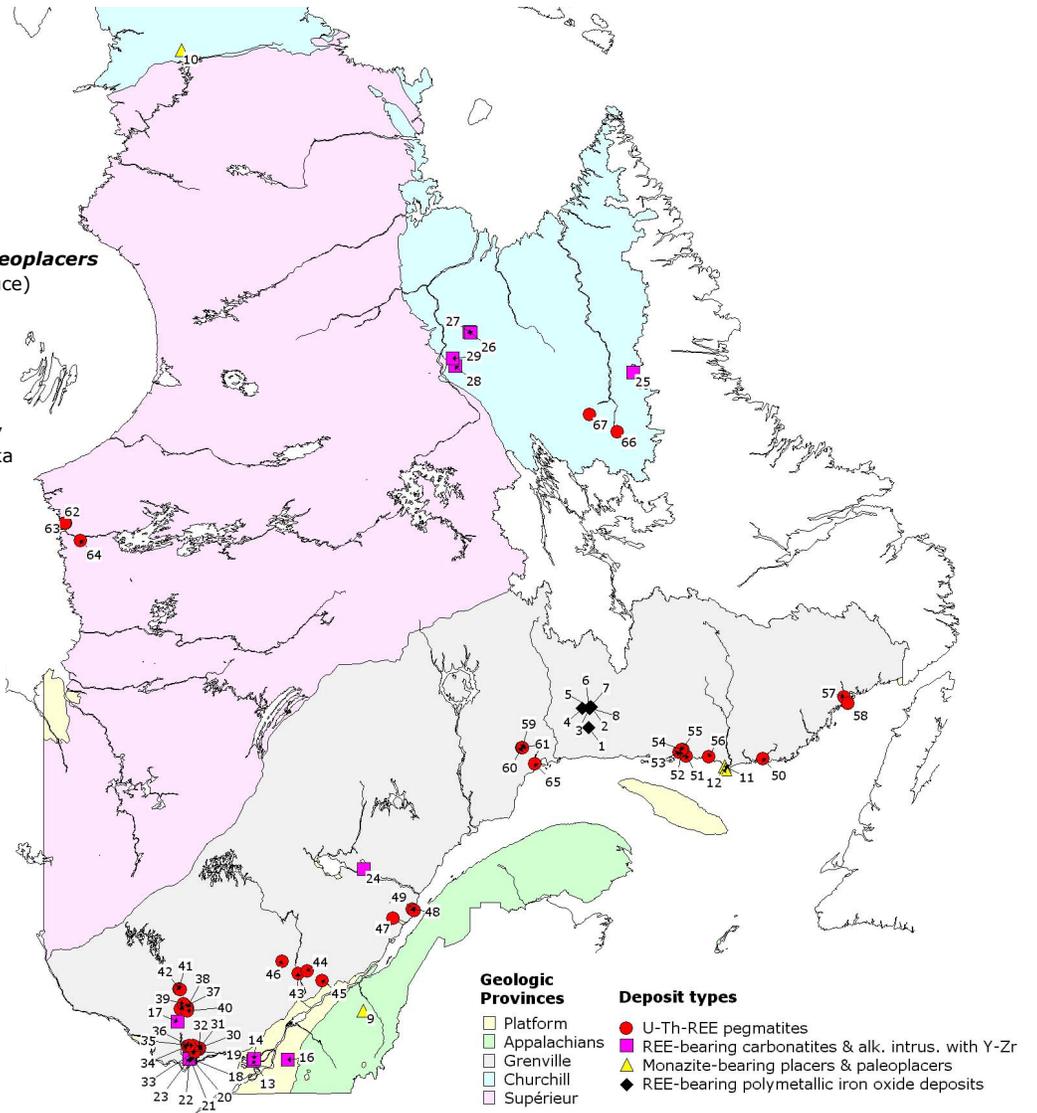
- 9 Wares (Sainte-Marie-de-Beauce)
- 10 Lac Chukotat
- 11 Natashquan-Nord
- 12 Natashquan-Sud

REE-bearing carbonatites

- 13 Complexe d'Oka: zone Manny
- 14 Complexe d'Oka: zone Manoka
- 15 St-André
- 16 Mont St-Hilaire
- 17 Lac du Castor Blanc
- 18 Mine Haycock
- 19 Fénite du Lac McGregor
- 20 Quinville
- 21 Templeton
- 22 Carbonatite de Cantley
- 23 Fénite de Cantley
- 24 St-Honoré (Niobec)
- 25 Lac Brisson (granite alcalin)
- 26 Erlandson No 1
- 27 Erlandson No 2
- 28 Lac Savigny
- 29 Lac de l'Hématite

U-Th-REE pegmatites

- 30 Mine Derry
- 31 Mine Pednaud
- 32 Mine Black
- 33 Carrière du lac Battle
- 34 Mine Lachaine
- 35 Mine Lapointe-Portland
- 36 Mine Evans-Lou
- 37 Rapide Tête des Six
- 38 Lac Malboeuf
- 39 Acme Molybdénite
- 40 Lac des Trente et un Milles
- 41 Ragnar
- 42 Lac A (Grand-Remous)
- 43 Lac Canard
- 44 Rivière Bouchard
- 45 Lac Ricard-SW
- 46 Lac Baude
- 47 Mine du Lac du Pied-des-Monts
- 48 Anomalie N13L1 (St-Siméon)
- 49 Groupe Callières
- 50 Lac Couillard
- 51 Baie Quetachou



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|----|-------------------------------------|----|------------------------------------|
| 52 | Projet K-8, Lac Turgeon (zone Est) | 60 | Anomalie J6-1 - ouest (Lac Walker) |
| 53 | Zone 1 (Lac Turgeon) | 61 | Anomalie J6-1 - est (Lac Walker) |
| 54 | Camp 1 (Lac Turgeon) | 62 | Baie Paul P (Bouro) |
| 55 | Est (Lac Turgeon) | 63 | Baie Paul T |
| 56 | Rivière Nabisibi | 64 | Route Fort-George (km 34) |
| 57 | Village Saint-Augustin | 65 | Anomalie J2R1 |
| 58 | Ile de la Grande Passe - ouest | 66 | Lac Advance nord |
| 59 | Anomalie J6-1 - centre (Lac Walker) | 67 | Lac Tudor |

Simplified geologic map of Quebec (modified from DV 2001-07) showing the locations of known REE deposits (based on SIGEOM and MB 94-17).

To learn more, check out the complete web site on www.sidex.ca