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Projet d'exploitation éventuelle d'une mine et d'une usine de niobium à Oka
Oka 6211-08-002

Étude des processus magmatiques et post-magmatiques responsables des minéralisations niobifères dans la carbonatite d'Oka, Québec.

par André Proulx
superviseurs : Georges Beaudoin et Réjean Hébert
Université Laval

Résumé

La carbonatite d'Oka contient plusieurs zones de minéralisation en Nb dont les zones S-60, HWM1 et HWM2 sur la propriété de Niocan. La zone HWM1 contient de la niocalite, de la latrappite et du pyrochlore. La zone HWM2 est composée des carbonatites à richtérite, à magnétite et à phlogopite rubanée. Le pyrochlore, la latrappite et la niocalite sont présent. La zone S-60 (14.37 Mt à 0.66 % Nb_2O_5) est caractérisée par les carbonatites à forstérite-magnétite-apatite, à diopside-magnétite-apatite et à forstérite. Le niobium se trouve dans le pyrochlore (1 à 5 %).

La géochimie des éléments majeurs montre l'évolution d'une carbonatite calcitique vers une ferrocarbonatite (carbonatites à forstérite-magnétite-apatite et à diopside-magnétite-apatite). La cristallisation fractionnée de la calcite enrichie le magma en Fe et Mn ce qui cause la cristallisation de la magnétite dans des stades plus tardifs. L'enrichissement en Nb se corrèle avec une augmentation de la teneur en F piégé dans l'apatite fluorifère (3 à 4 % F). Les terres rares (TR) montrent des valeurs élevées de 1 000 à 10 000 fois chondrite pour les TR légères et de 10 à 100 fois chondrite pour les TR lourdes. Les TR sont principalement associées au pyrochlore et à l'apatite fluorifère.

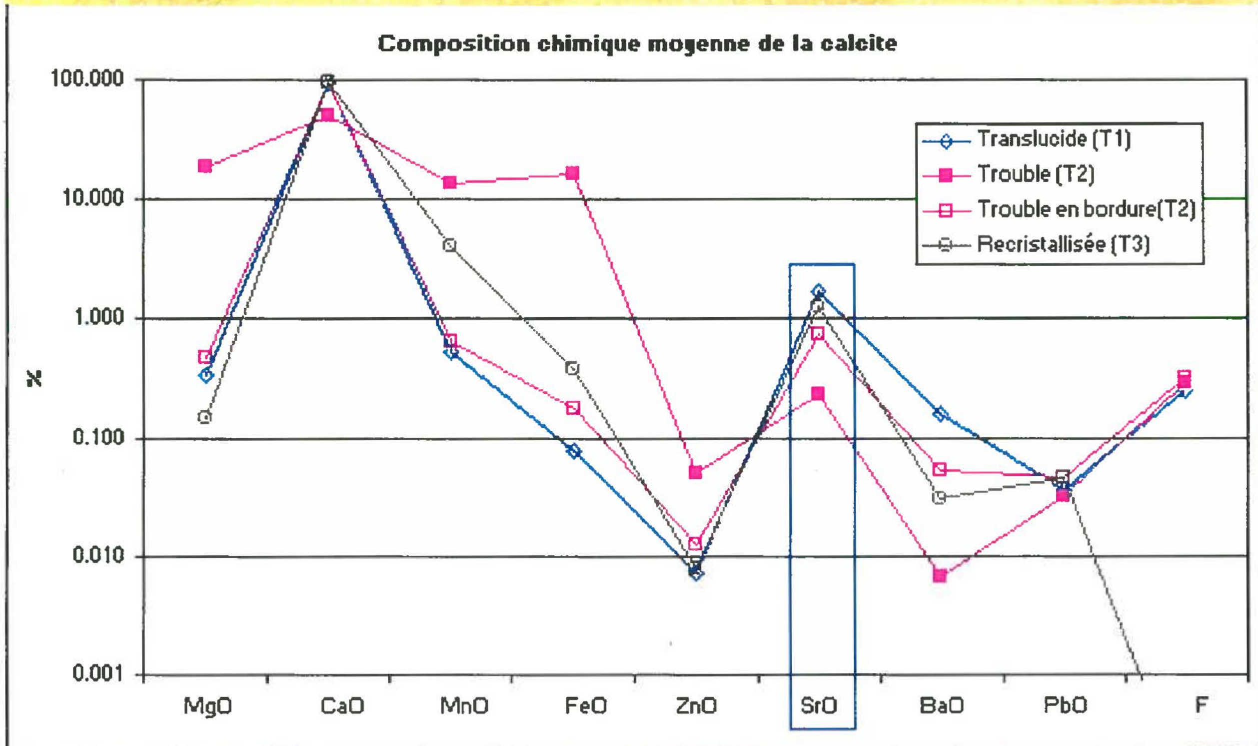
Quatre types de pyrochlore sont définis. Le type 1 est idiomorphe en inclusion dans la calcite et l'apatite fluorifère. Le type 2 est idiomorphe, interstitiel entre la calcite et l'apatite fluorifère. Le type 3 est xénomorphe en inclusion dans le diopside. Le type 4 est hypidiomorphe, parfois poecilitique et il remplace l'apatite fluorifère et la calcite. Le type 4 se retrouve dans les carbonatites à forstérite, à forstérite-magnétite-apatite et à diopside-magnétite-apatite. Le pyrochlore montre quatre compositions chimiques différentes qui se corrèlent avec la lithologie encaissante peu importe la position paragénétique. Le type A est riche en Ta, U, pauvre en Th et il est typique de la carbonatite et des carbonatites à phlogopite et à diopside. Le type B est riche en Th, pauvre en U et on le trouve dans les carbonatites à forstérite, à forstérite-magnétite-apatite et à diopside-magnétite-apatite. Le type C est pauvre en Ta, U et Th et il est caractéristique de la carbonatite et de la carbonatite à phlogopite rubanée tandis que le type D est riche en Ta et pauvre en Th. Le type D se trouve dans les carbonatites à phlogopite et à diopside.

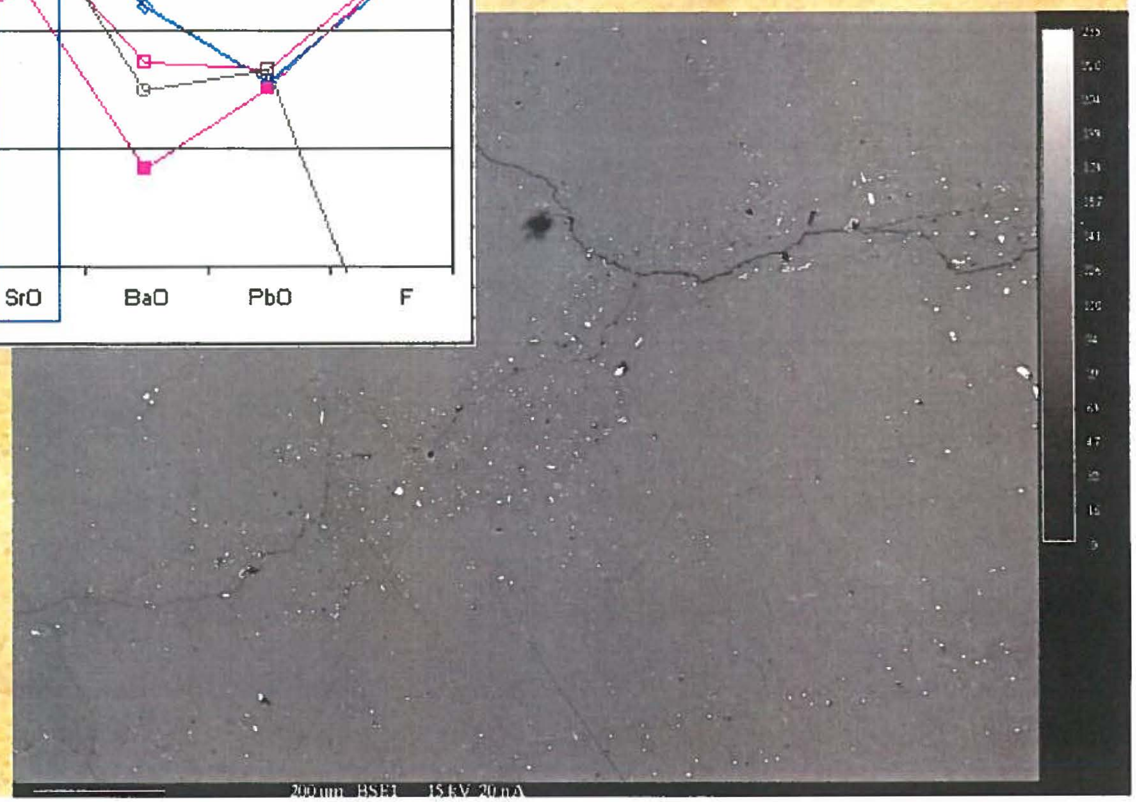
Le pyrochlore (types 1, 2 et 3), la niocalite et la latrappite cristallisent en équilibre avec la carbonatite encaissante et la composition chimique de cette dernière influence directement la composition chimique du pyrochlore. Les zones enrichies en pyrochlore sont plus riches en apatite fluorifère car la cristallisation de l'apatite fluorifère réduit la fugacité du fluor ce qui cause la cristallisation du pyrochlore (type 4).

ANNEXE

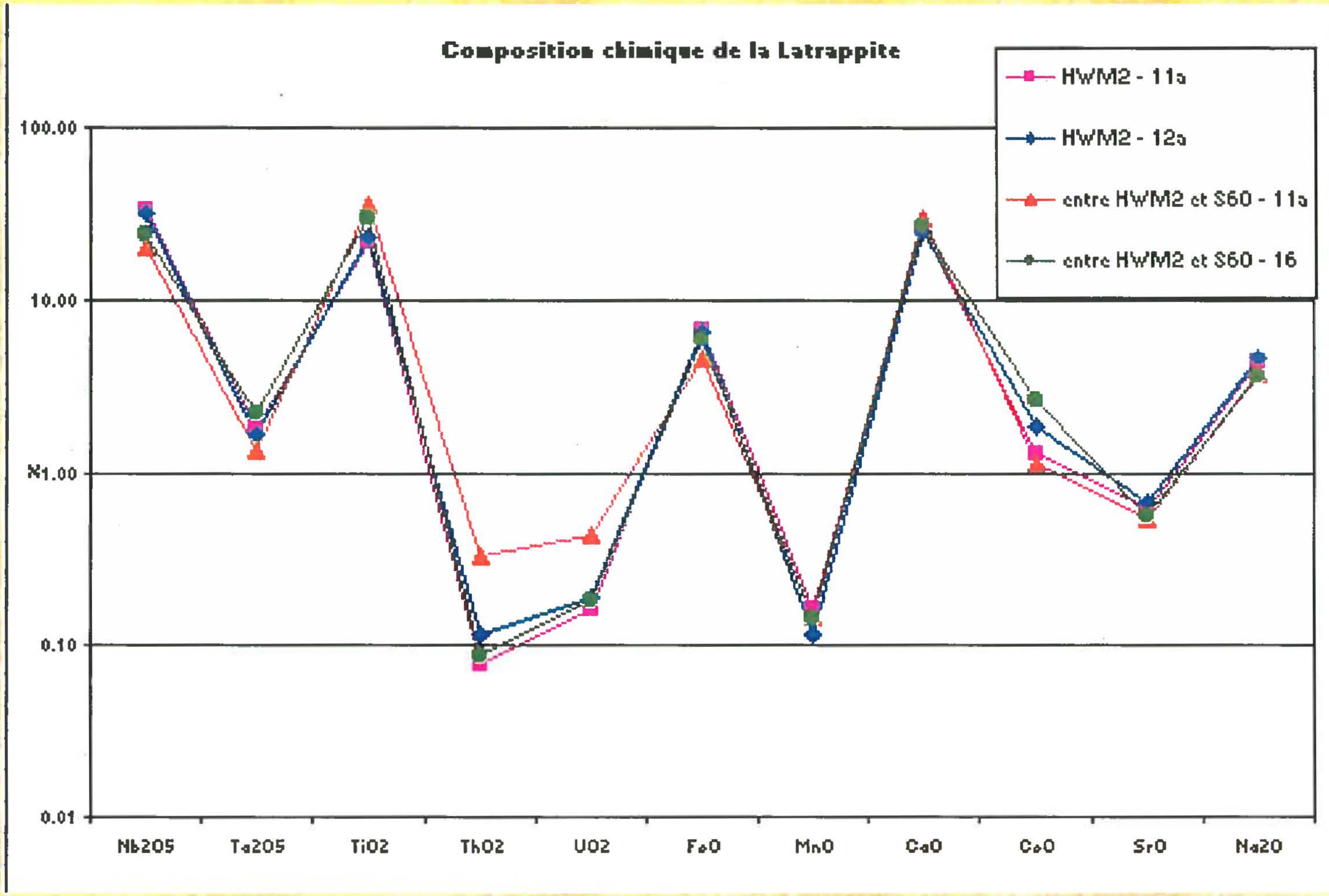
Chimie des autres minéraux

Calcite:



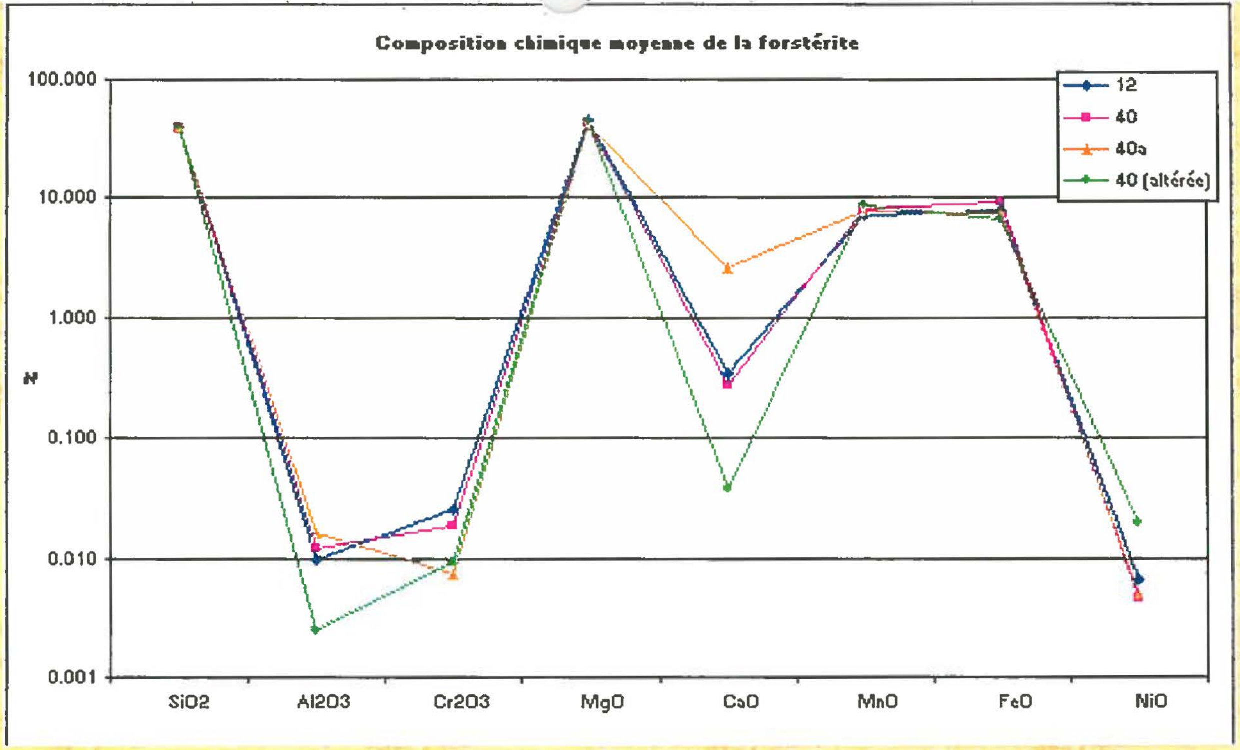


Latrappite

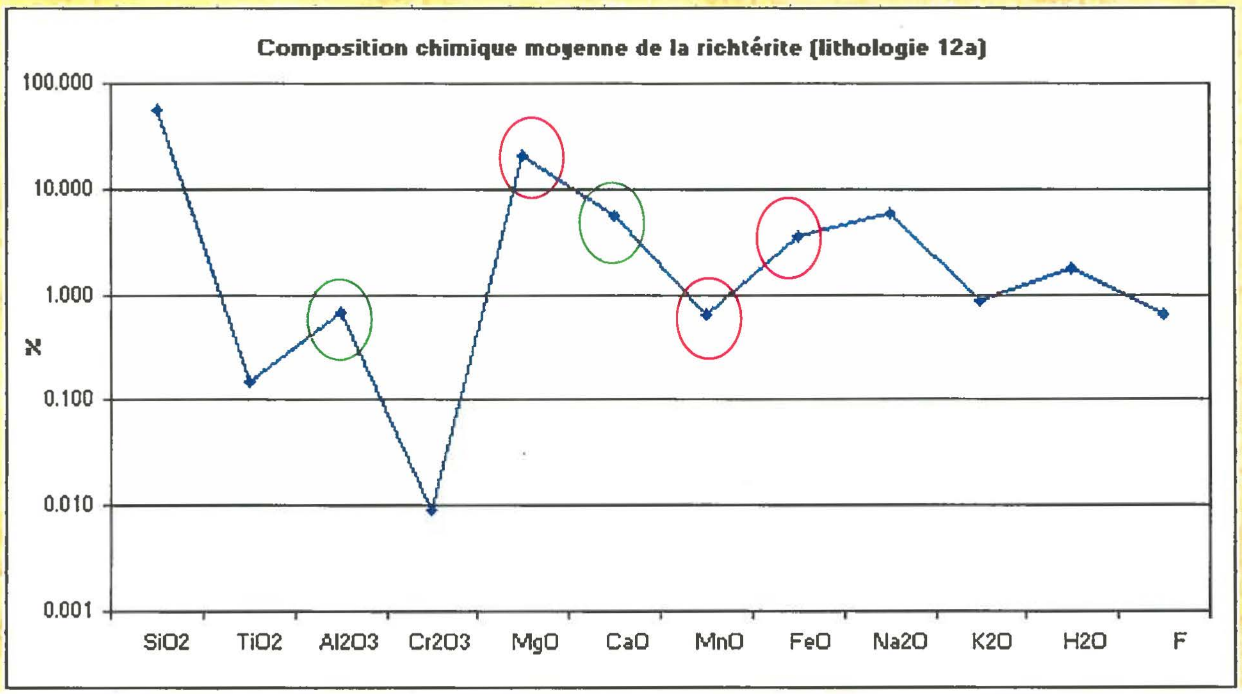


(Bernier, 1997)

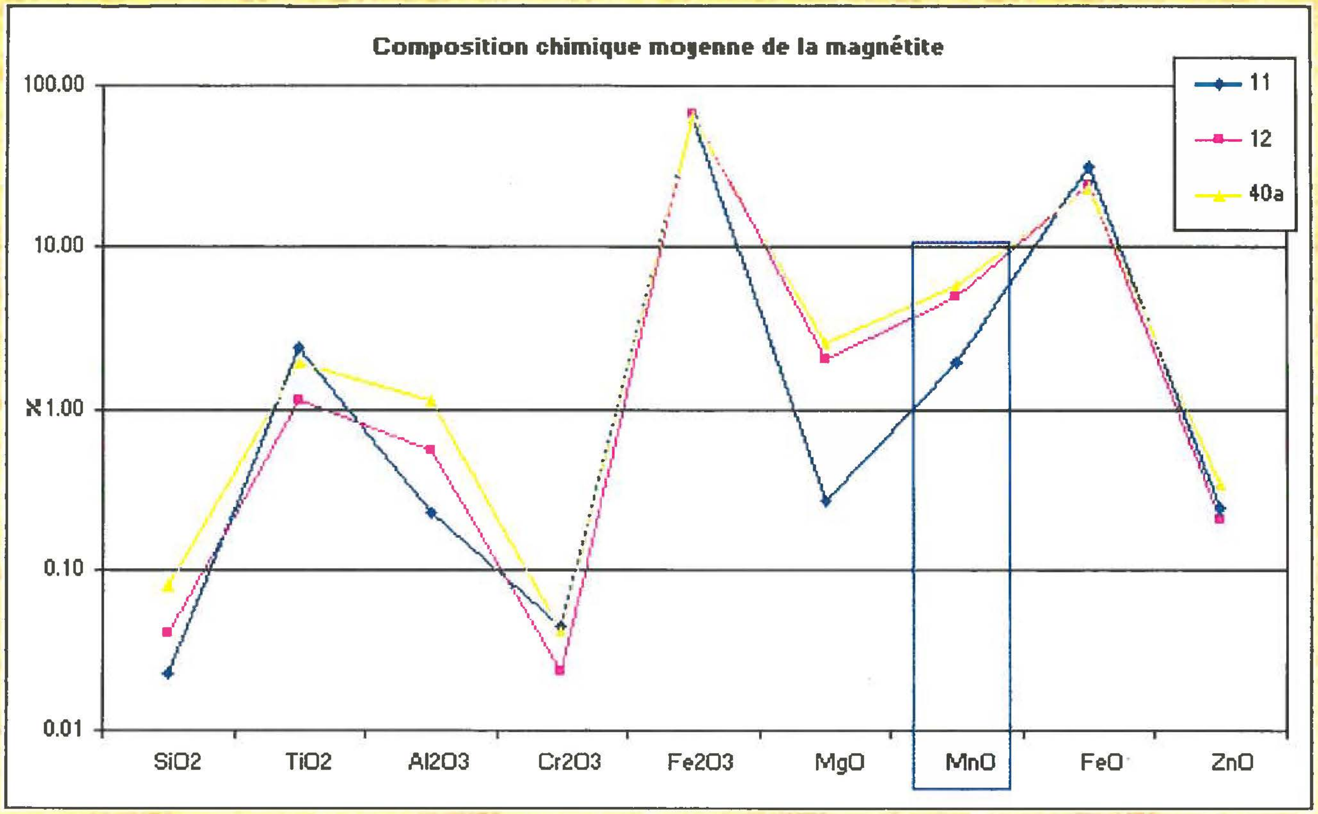
Forstérite:



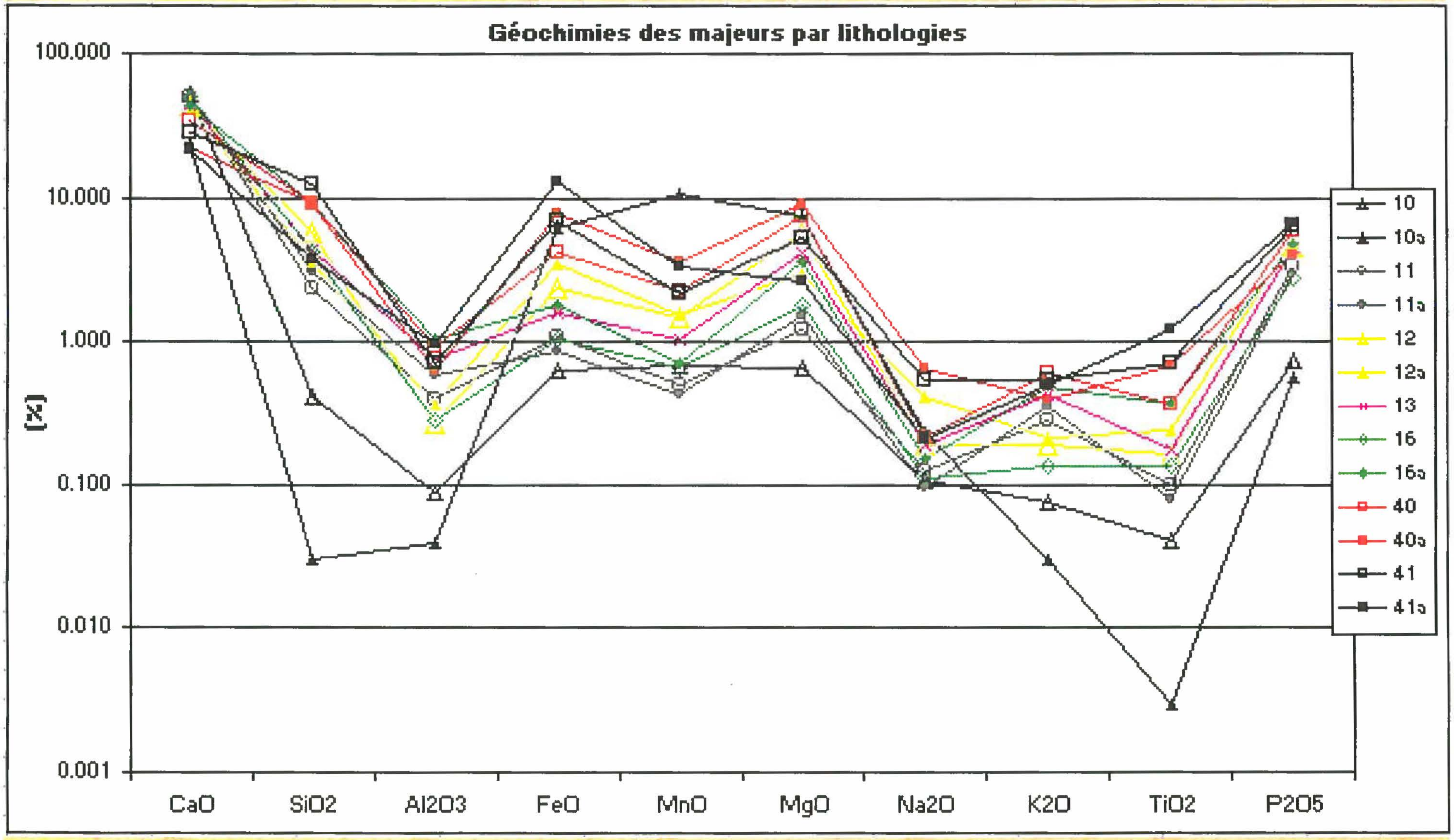
Richtérite:



Magnétite:

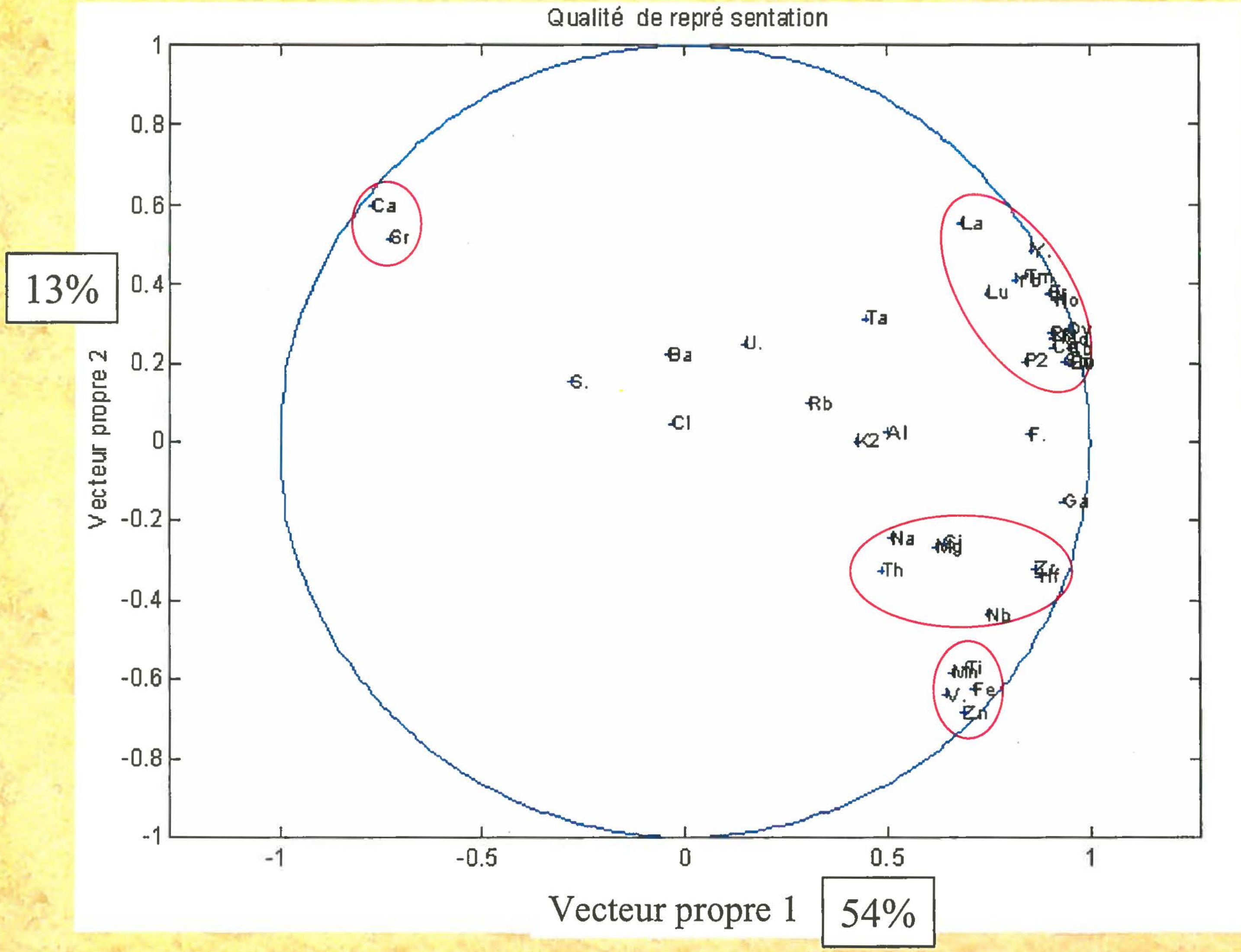


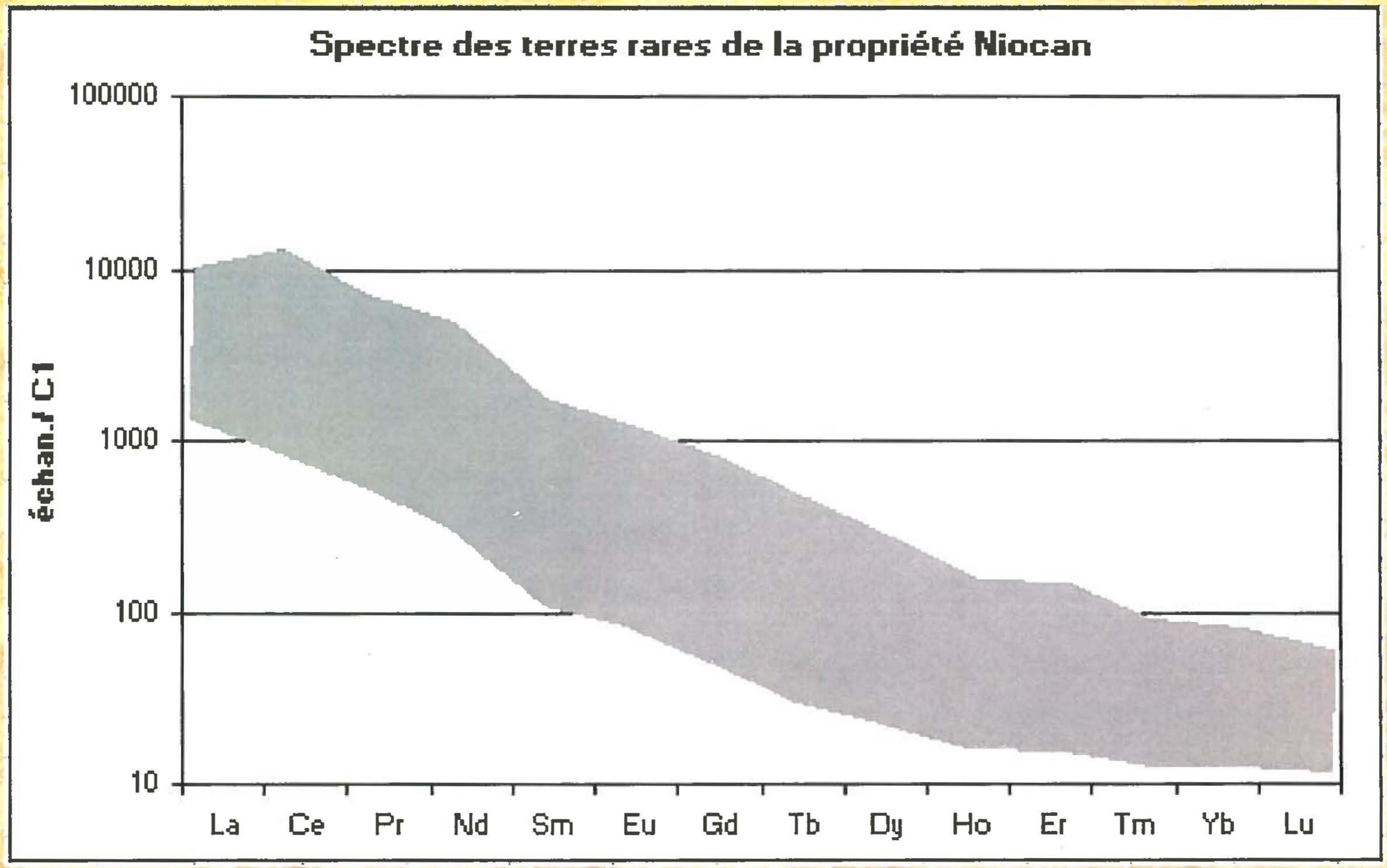
Phlogopite : à venir

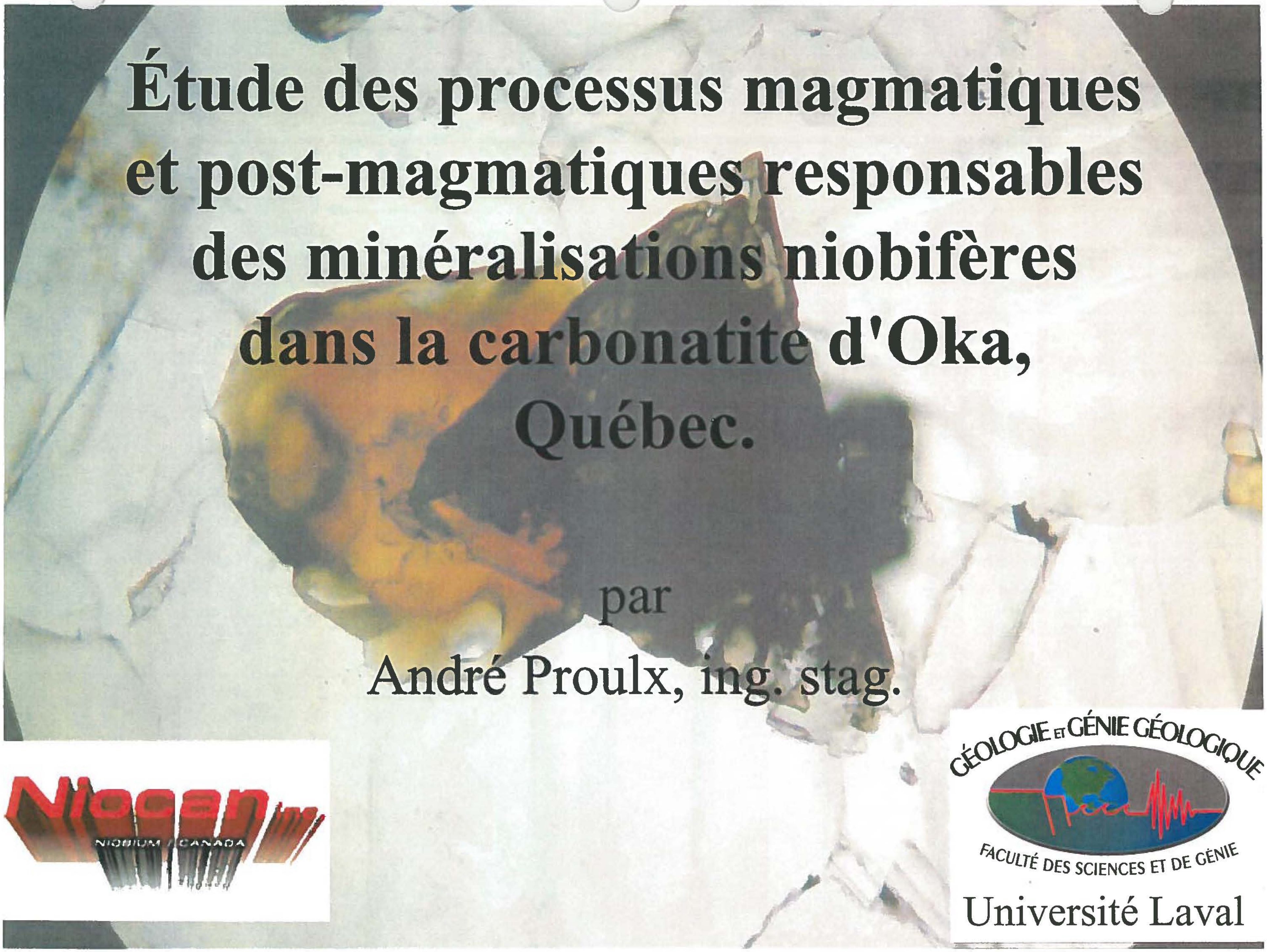


Géochimies des majeurs par lithologies
100.000
10.000
1.000
0.100
0.010
0.001
(%)
CaO
SiO2
Al2O3
FeO
MnO
MgO
Na2O
K2O
TiO2
P2O5
10
10a
11
11a
12
12a
13
16
16a
40
40a
41
41a

Statistique (ACP)




Spectre des terres rares de la propriété Niocan
100000
10000
1000
100
10
échan./ C1
La
Ce
Pr
Nd
Sm
Eu
Gd
Tb
Dy
Ho
Er
Tm
Yb
Lu


Étude des processus magmatiques
et post-magmatiques responsables
des minéralisations niobifères
dans la carbonatite d'Oka,
Québec.
par
André Proulx, ing. stag.
Niocan inc.
NIOBIUM CANADA
GÉOLOGIE ET GÉNIE GÉOLOGIQUE
FACULTÉ DES SCIENCES ET DE GÉNIE
Université Laval

Plan de la présentation

- Problématique, but et objectifs de l'étude
- Méthodologie
- Géologie régionale
- Géologie de la propriété
- Type de pyrochlore
- Chimie et géochimie
- Interprétations préliminaires

Problématique, but et objectifs de l'étude

- **Problématique:**

1) Pour quelle raison certaines zones (HWM1, HWM2 et S-60) sont plus riches en niobium que le reste de la carbonatite ?
2) Pour quelle raison la zone S-60 est-elle si différente des autres zones minéralisées ?

- **But:**

Comprendre les processus magmatiques et post-magmatiques qui ont permis l'enrichissement en niobium.

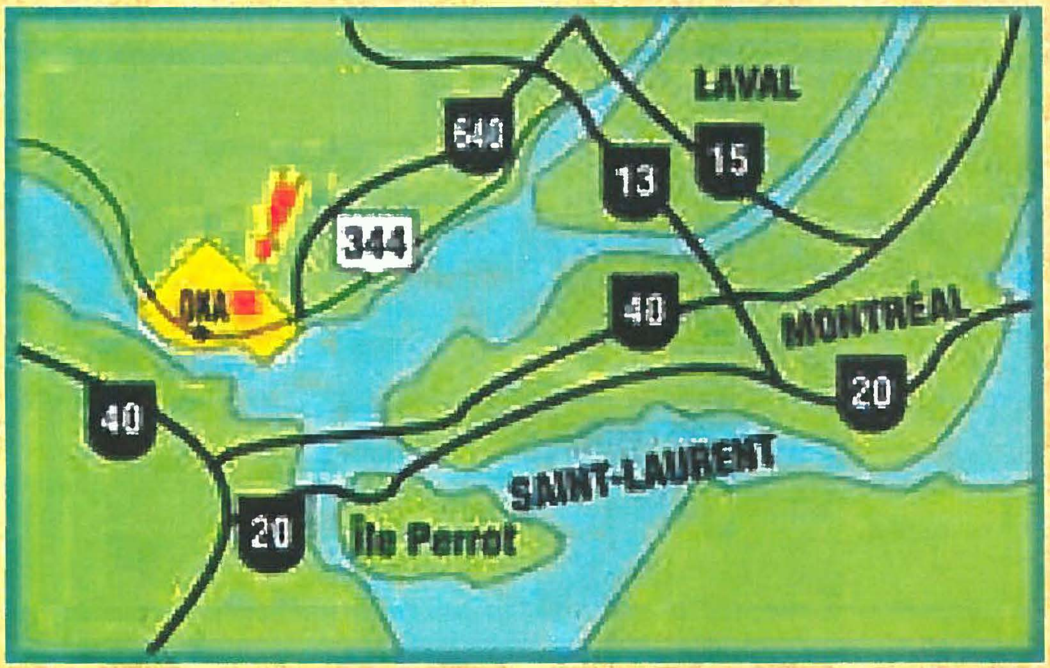
- **Objectifs:**

1) Décrire et échantillonner en détail les zones minéralisées et leurs enveloppes ;
2) Établir la pétrologie de la roche encaissante et la minéralisation;
3) Déterminer l'importance relative des processus magmatiques et hydrothermaux;
4) Formuler un modèle métallogénique dans le but de mieux comprendre l'origine des zones niobifères de la carbonatite d'Oka.

Méthodologie

- 15 trous de forage;
- 91 lames minces polies;
- 52 analyses chimiques des majeurs, des mineurs et des traces;
- Microsonde sur le pyrochlore, l 'apatite, la calcite, la forstérite, la richtérite, le diopside, la phlogopite et la magnétite.

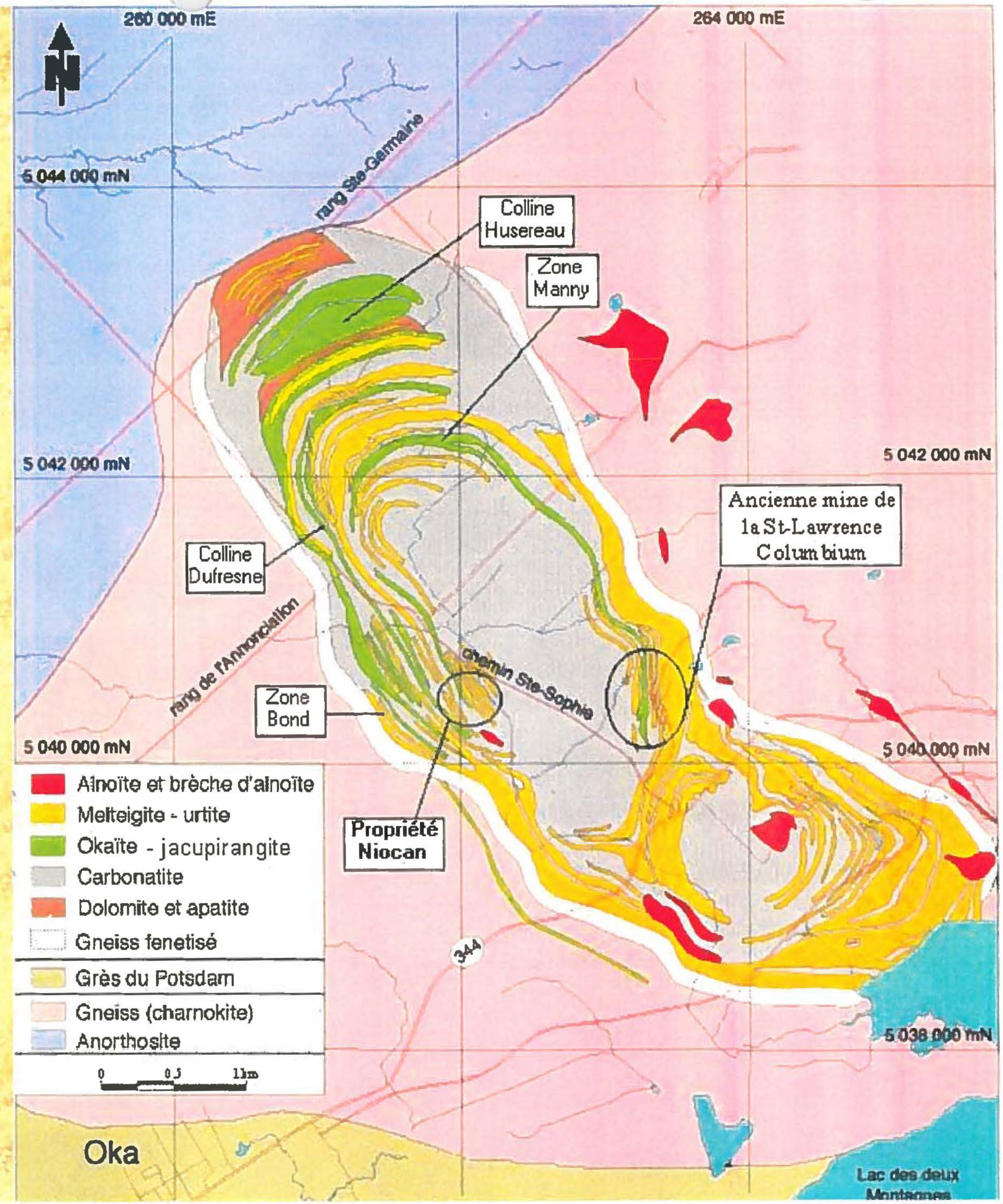
Localisation du complexe carbonatitique



Géologie régionale

- 7.2 par 2.4 km
- Âge : Crétacé précoce
- Mise en place (Gold et Vallée, 1969):

1) Fénitisation, carbonatite précoce;
2) Série okaïte - jacupirangite;
3)Carbonatite principale;
4) Série melteigite - urtite;
5) Circulation de solutions hydrothermales;
6) Carbonatite blanche
7) Diabase, lamprophyre et d'alnoïte



Géologie de la propriété

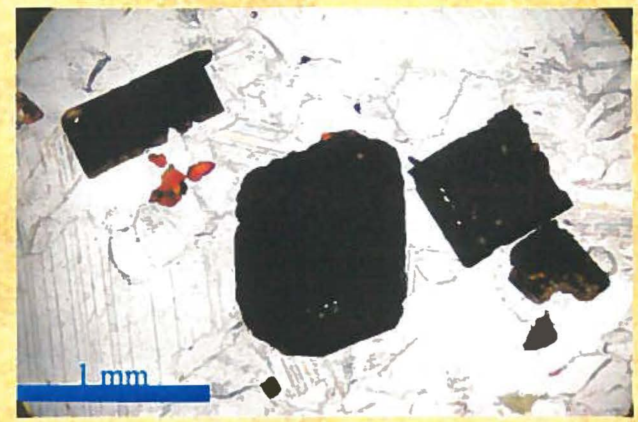
- <u>Minéraux d 'intérêts:</u>

1) Pyrochlore:

- $(NaCaUThRe)_{16x}(Nb,Tc,TaTi)_{16}(O,OH)_{48}(F,OH)_1$
- 40 à 60 % Nb_2O_5 (Gold, 1963, Bernier, 1997)
- Forme variable, jaune, rouge, brun et noir.

2) Latrappite:

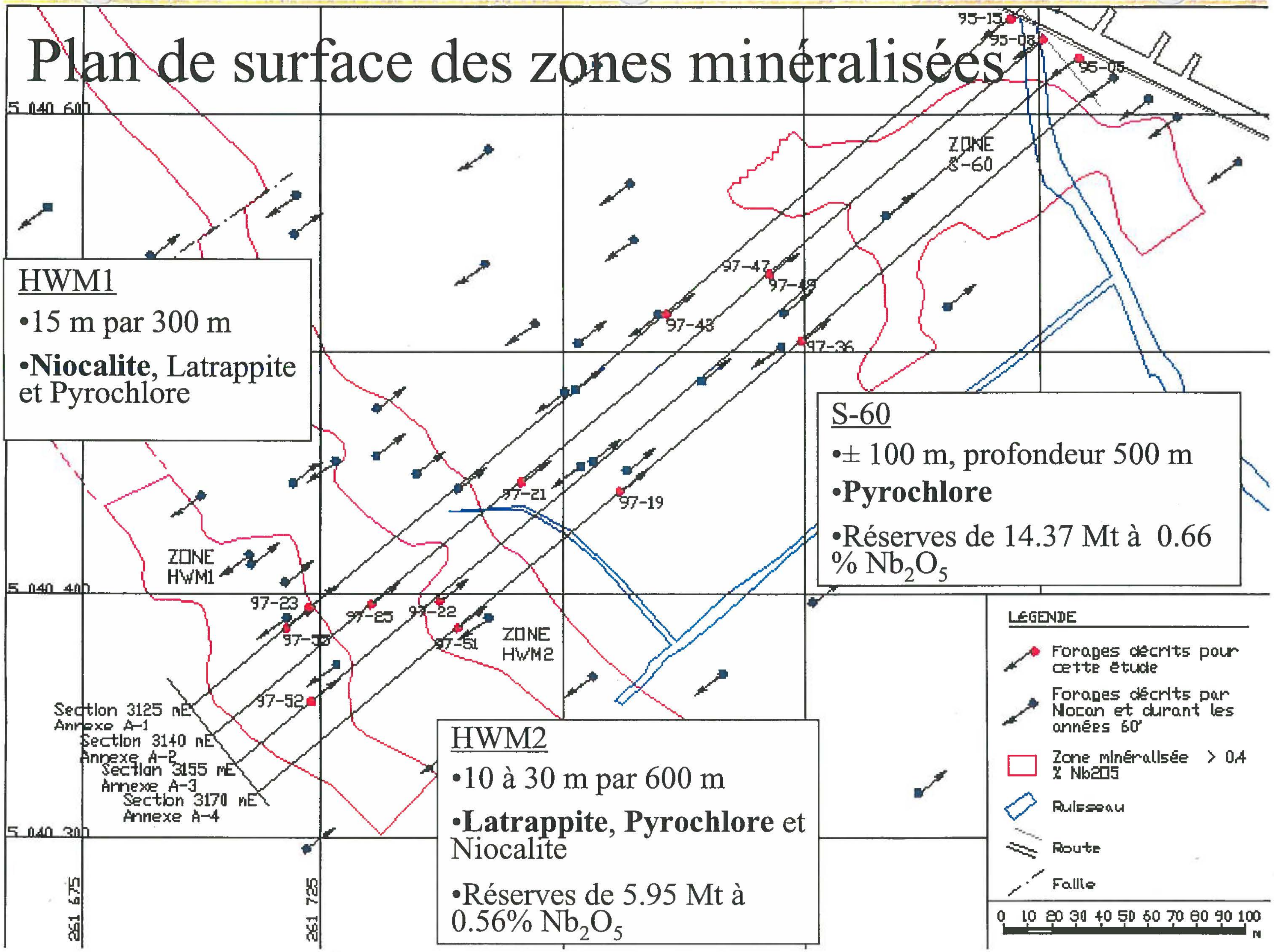
- $(CaNaFeCe)(TiNb)O_3$
- 20 à 40 % Nb_2O_5 (Gold, 1963)
- Cube noir



3) Niocalite:

- $(CaNb)_{16}Si_8(O,OH,F)_{36}$
- ~ 20 % Nb_2O_5 (Nickel, 1958)
- Prisme jaune

Plan de surface des zones minéralisées



HWM1

- 15 m par 300 m
- **Niocalite**, Latrappite et Pyrochlore

S-60

- ± 100 m, profondeur 500 m
- **Pyrochlore**
- Réserves de 14.37 Mt à 0.66 % Nb_2O_5

HWM2

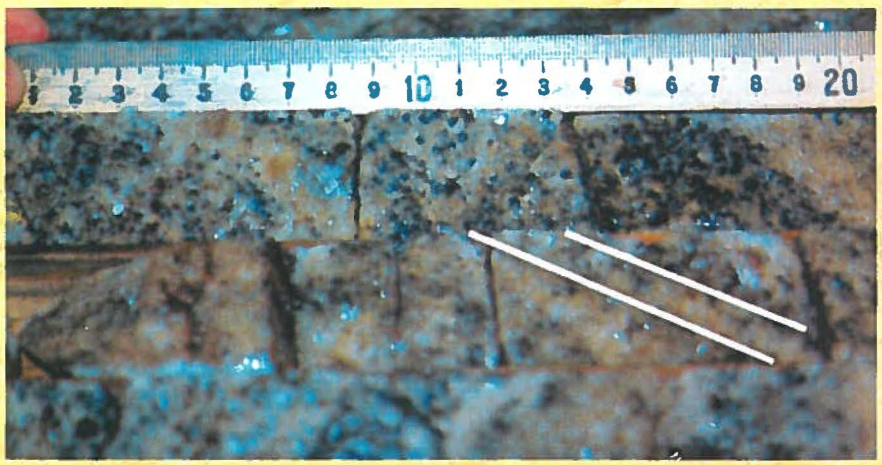
- 10 à 30 m par 600 m
- **Latrappite**, **Pyrochlore** et Niocalite
- Réserves de 5.95 Mt à 0.56% Nb_2O_5

Lithologies

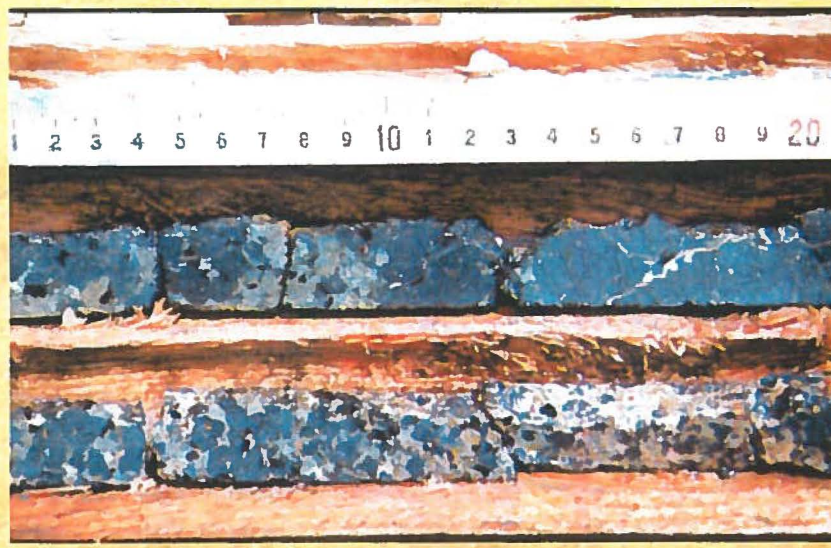
S-60	HWM2	Roches fraîches	Roches équivalentes altérées	
		Roches carbonatitiques		
		Carbonatite	Carbonatite altérée	
	X	Carbonatite à phlogopite	-	≤ 1 % Pc,La et Nio
X	X	Carbonatite à forstérite	Carbonatite à richtérite	1 à 3 % Pc , ≤ 1 % La et Nio
		Carbonatite à magnétite	-	
		Carbonatite à mélilite	-	
		Carbonatite à diopside	-	
X		Carbonatite à forstérite-magnétite-apatite	Carbonatite à richtérite-magnétite-apatite	1 à 5 % Pc
X		Carbonatite à diopside-magnétite-apatite	Carbonatite à diopside-altéré-magnétite-apatite	1 à 5 % Pc
		-	Carbonatite ankéritique	
		-	Zones météorisées	
		Roches alcalines et alnoïte		
		Ijolite	Ijolite biotitisée	
		Okaïte	-	
		Dyke d'alnoïte	-	

Carbonatite et carbonatite à phlogopite

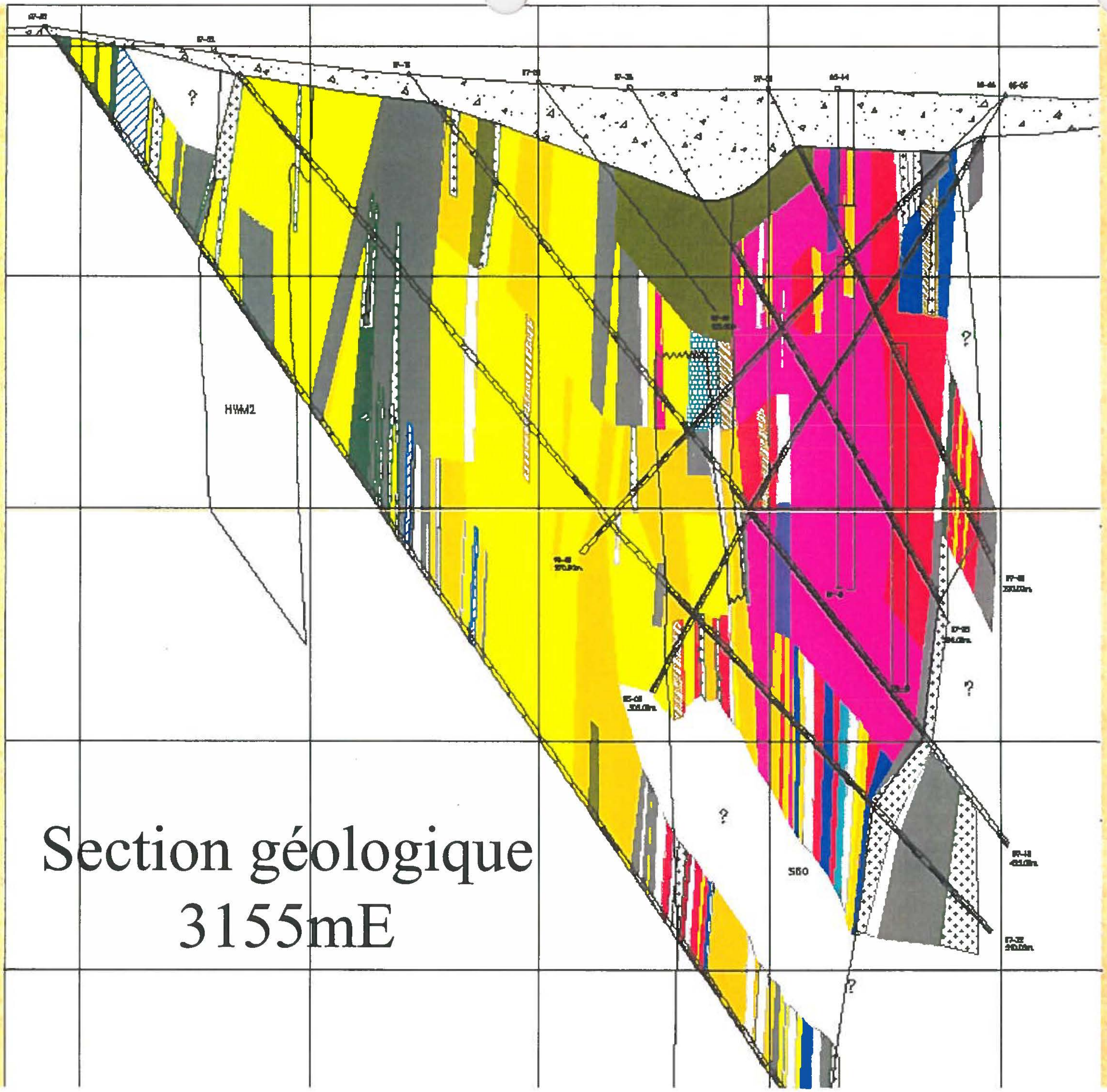
Carbonatite à forstérite



Carbonatite à forstérite
avec rubanement

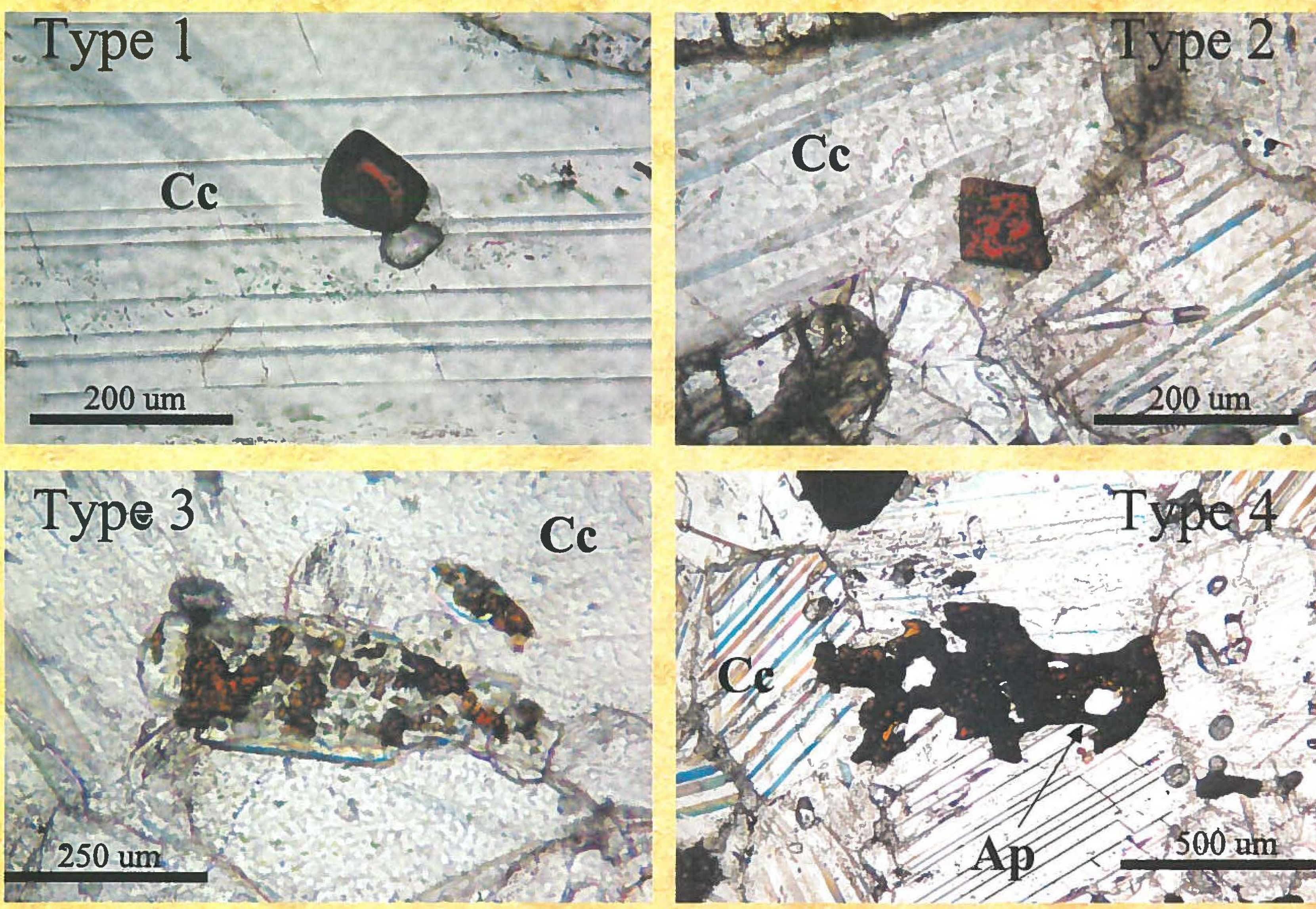


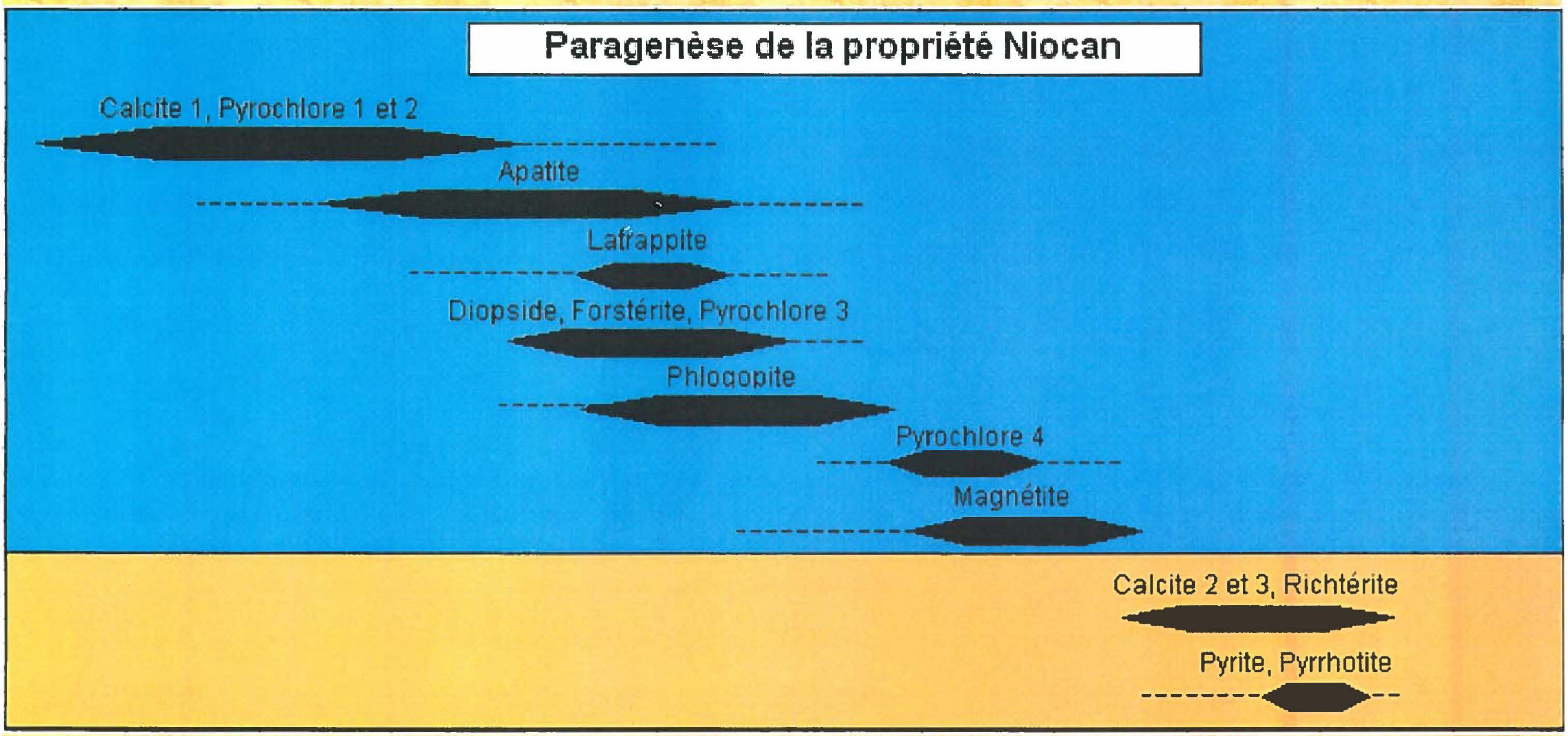
Carbonatite à diopside-magnétite-apatite



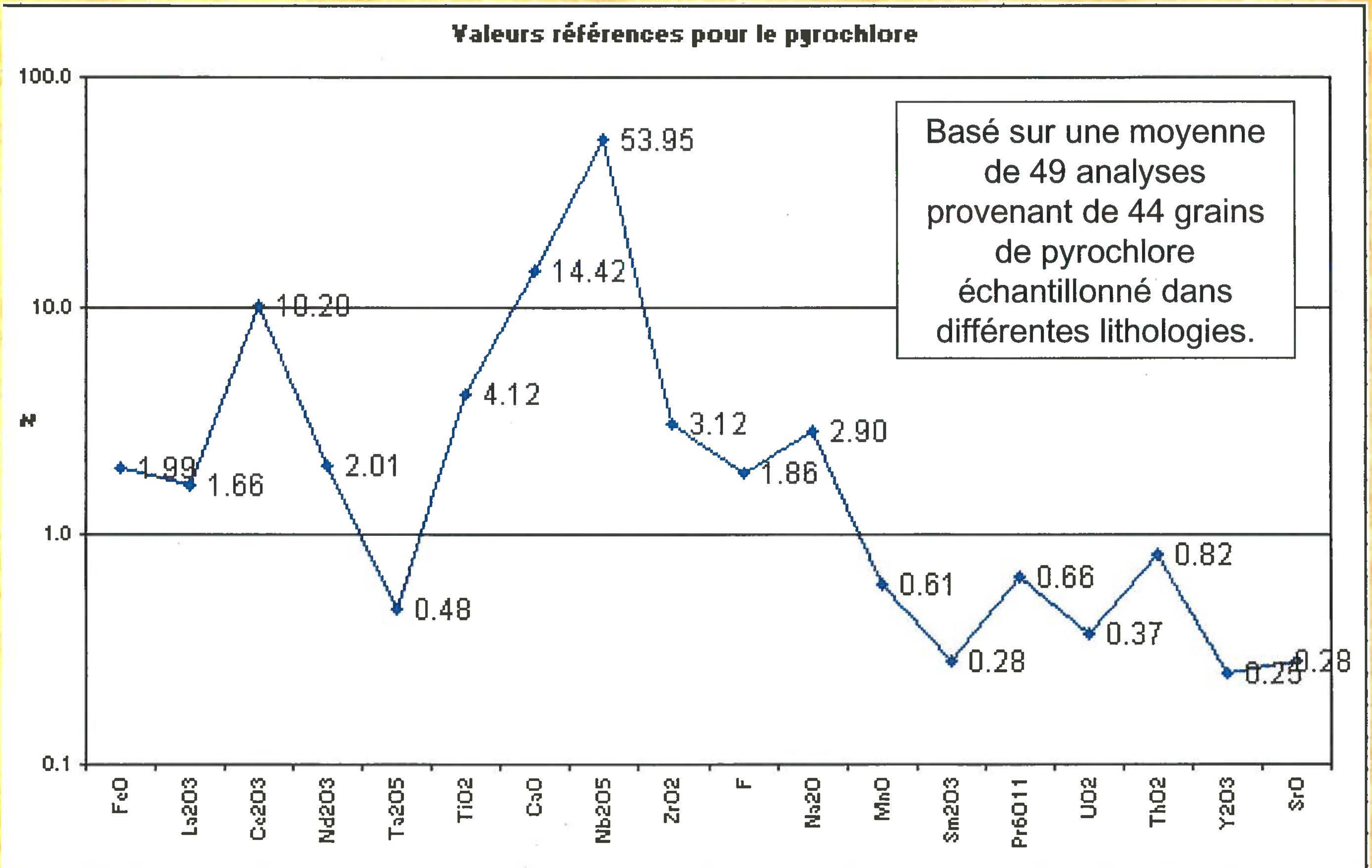
Section géologique 3155mE

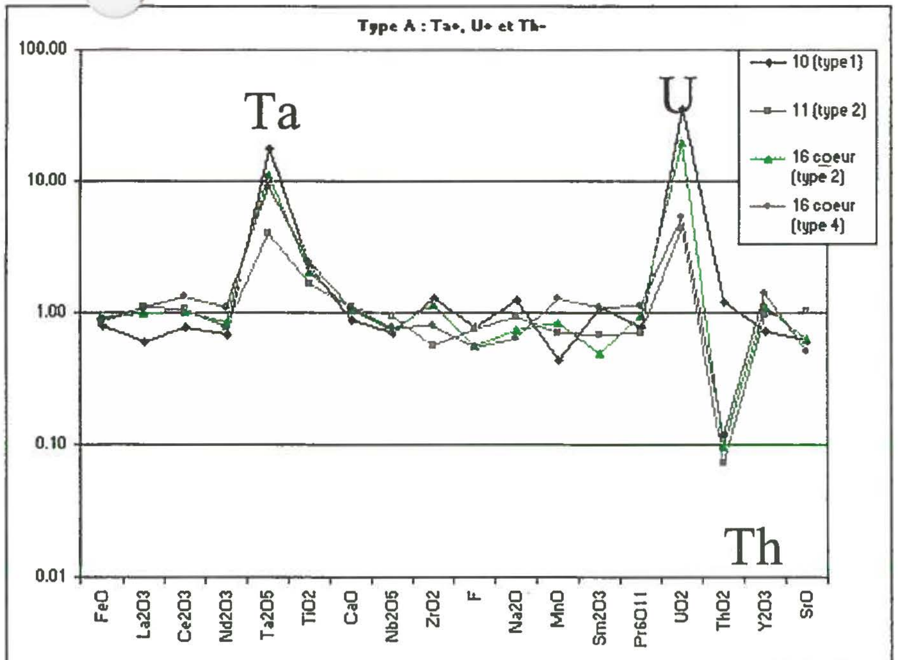
Type de pyrochlore (en se basant sur la paragenèse)

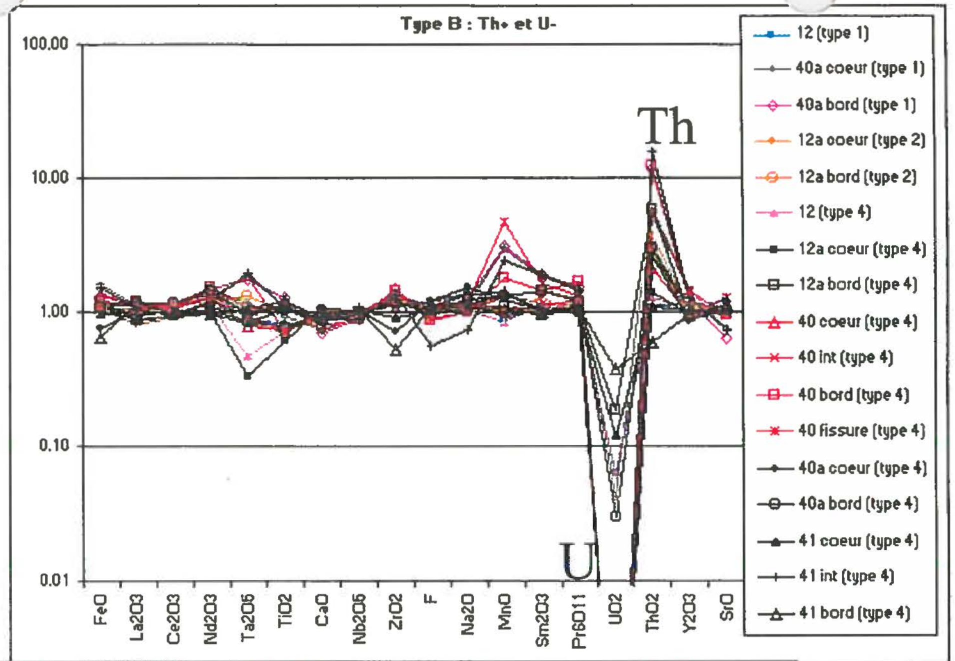



Paragenèse de la propriété Niocan
Calcite 1, Pyrochlore 1 et 2
Apatite
Lafrappite
Diopside, Forstérite, Pyrochlore 3
Phlogopite
Pyrochlore 4
Magnétite
Calcite 2 et 3, Richtérite
Pyrite, Pyrrhotite

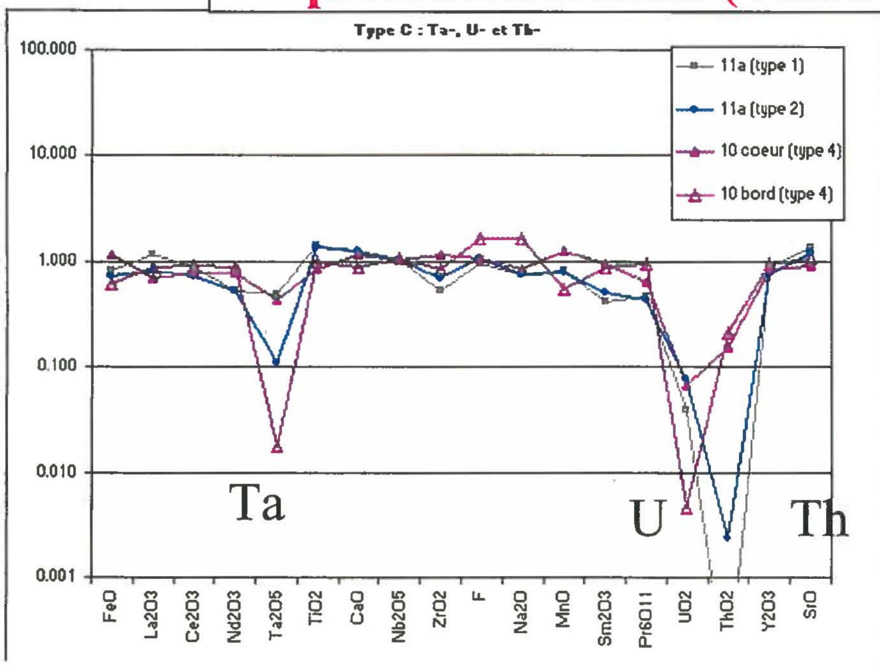
Chimie du pyrochlore

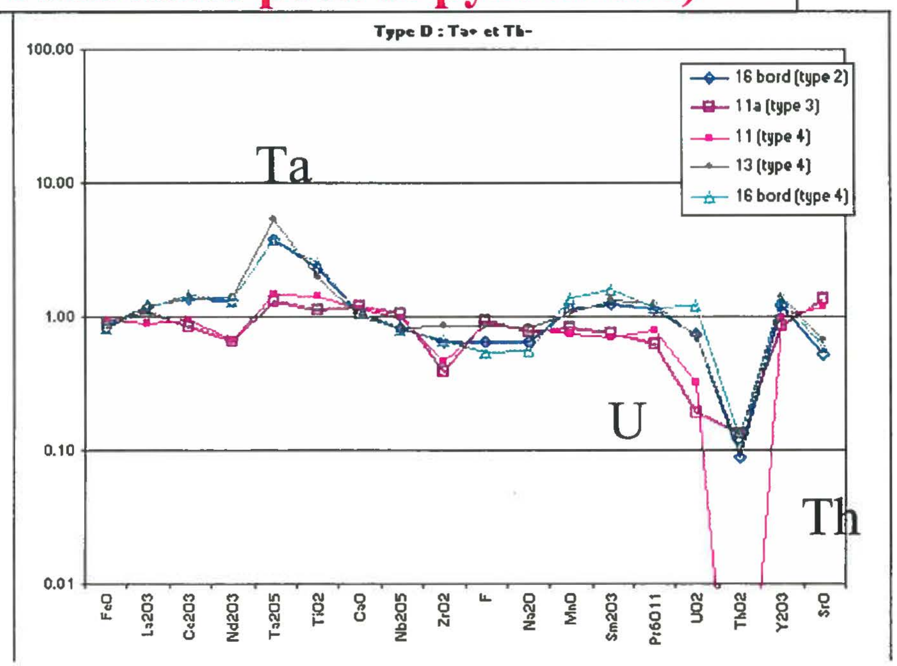






Valeurs normalisées avec les valeurs de références du graphique précédent intitulé (Valeurs références pour le pyrochlore)





Pyrochlore:

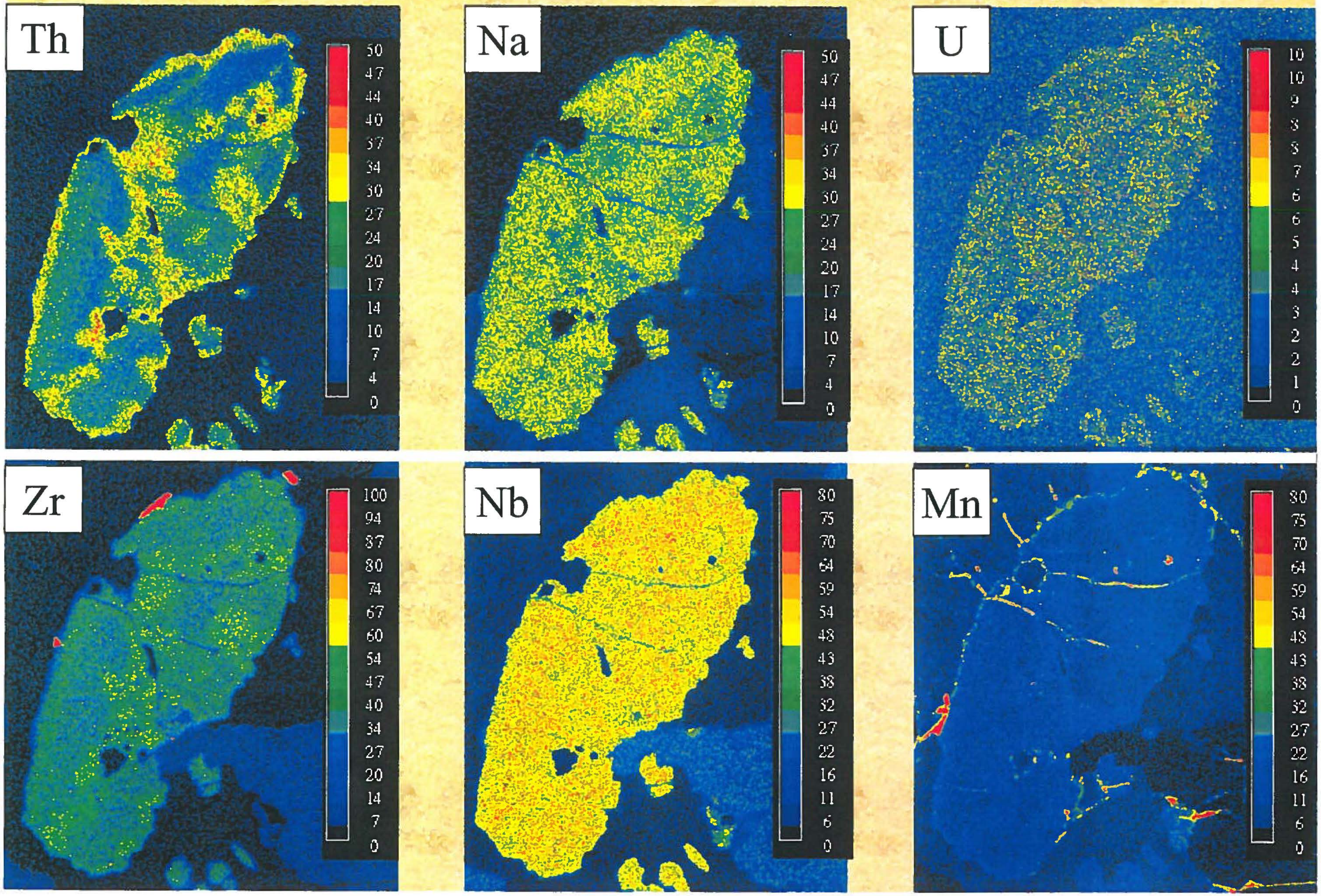
•Le pyrochlore montre quatre compositions chimiques différentes qui se corrèlent avec la lithologie encaissante peu importe la position paragénétique.

	Enrichi	Appauvri	Cristallisation	Lithologies associées	Zones
Type A	Ta U	Th	Type 1, 2 et 4	Carbonatite Carbonatite à phlogopite Carbonatite à diopside (coeur)	entre HWM1 et HWM2 HWM2
Type B	Th	U	Type 1, 2 et 4	Carbonatite à forstérite Carbonatite à forstérite-magnétite-apatite Carbonatite à diopside-magnétite-apatite	S-60
Type C		Ta U Th	Type 1, 2 et 4	Carbonatite Cabonatite à phlogopite	HWM2 S-60
Type D	Ta	U Th	Type 2, 3 et 4	Carbonatite à phlogopite Carbonatite à magnétite Carbonatite à diopside (bordure)	entre HWM1 et HWM2 HWM2 entre HWM2 et S-60

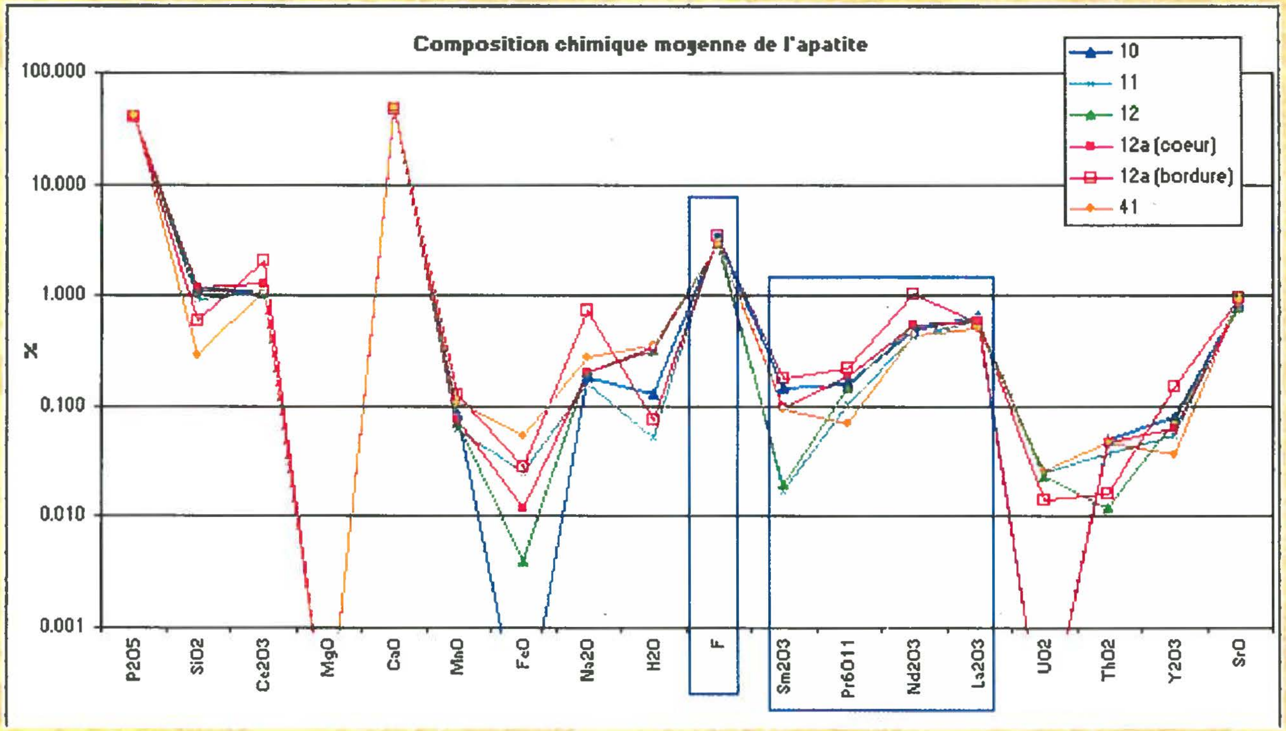
Gold (1963) conclu que le pyrochlore à thorium appartient à un stade tardif.

Cartographie du Pc

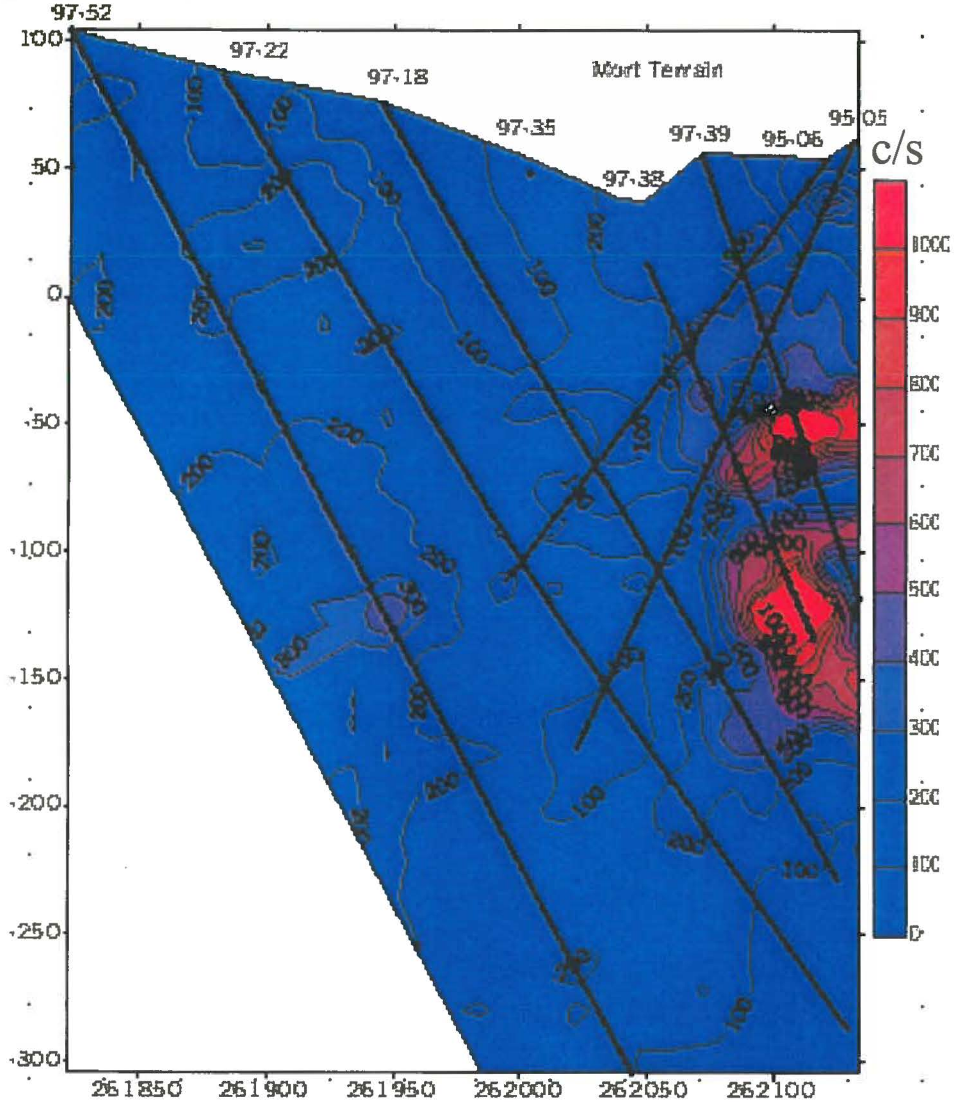
litho 40 / S-60 / 100um / 15kv, 40nA / Ce, F, Ca et Fe



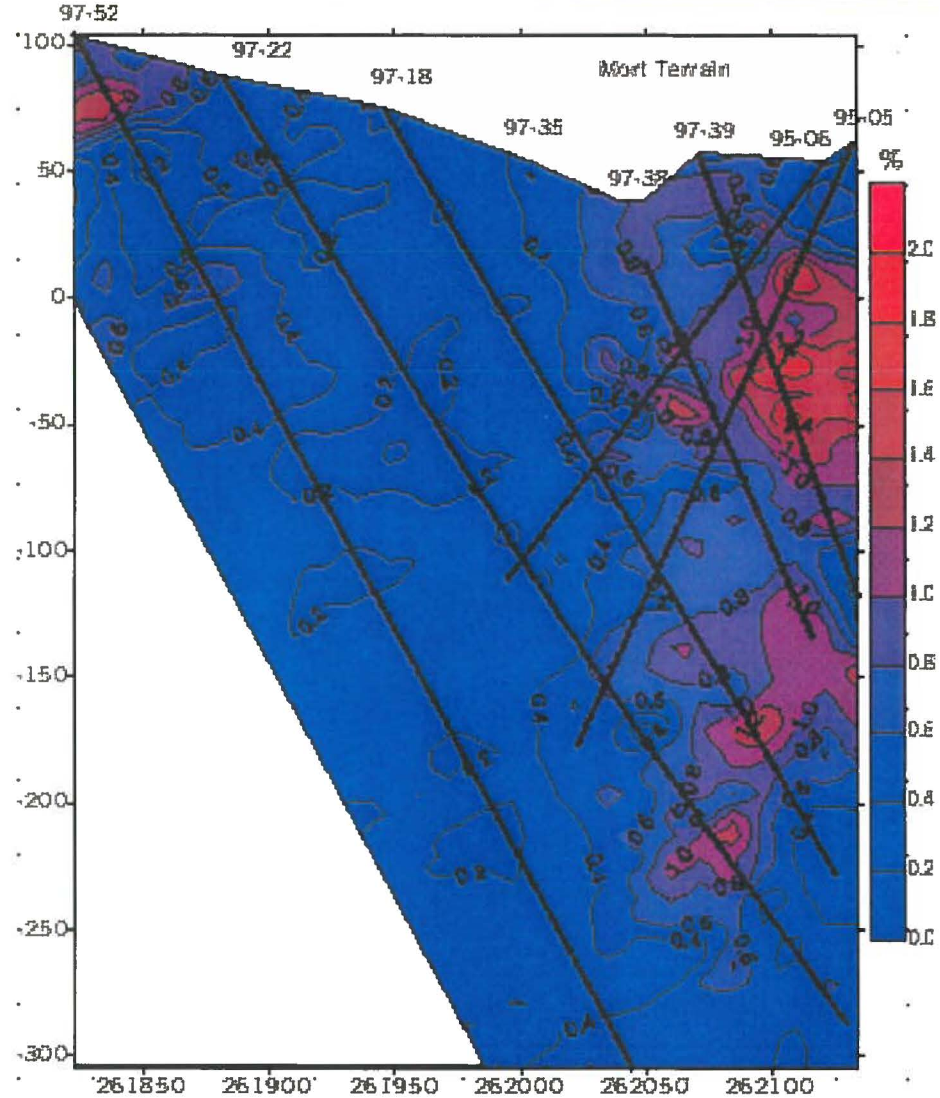
Apatite fluorifère:



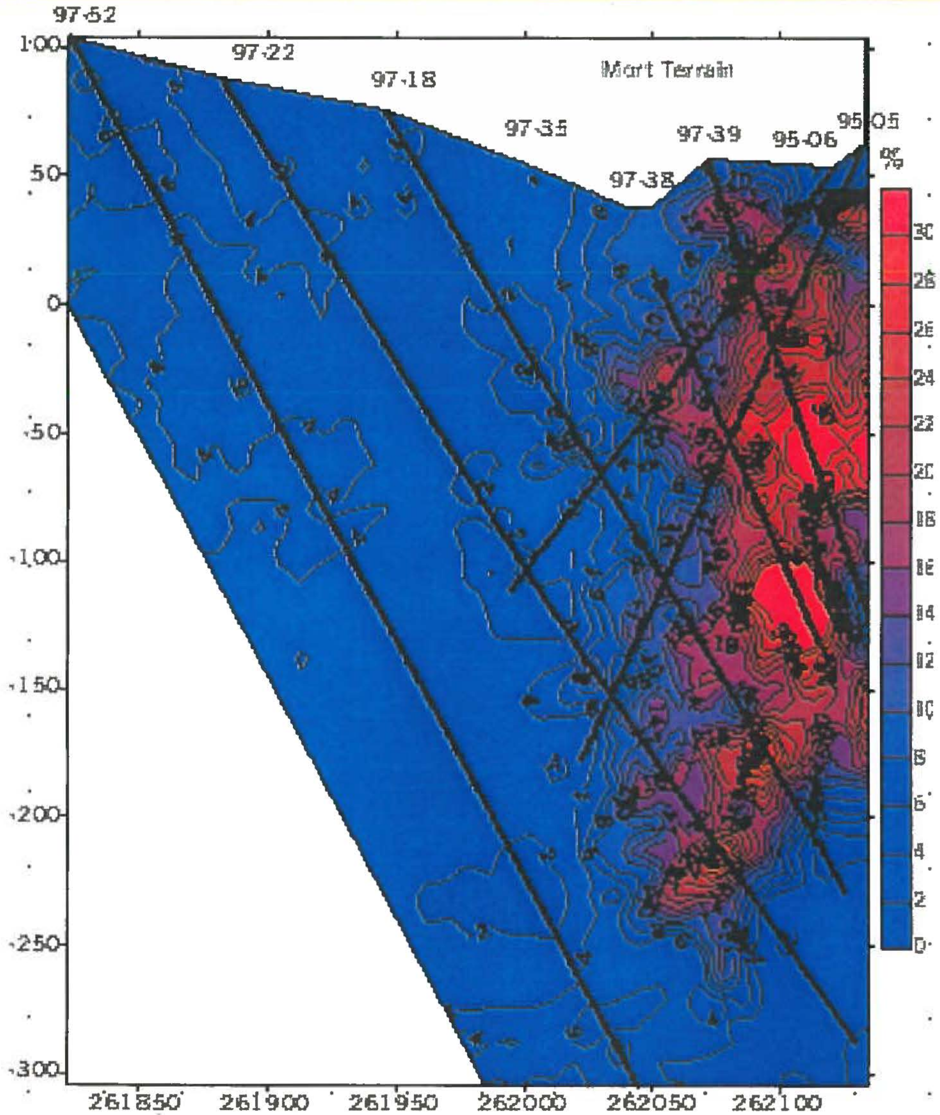
Géochimie (ex. section 3155)



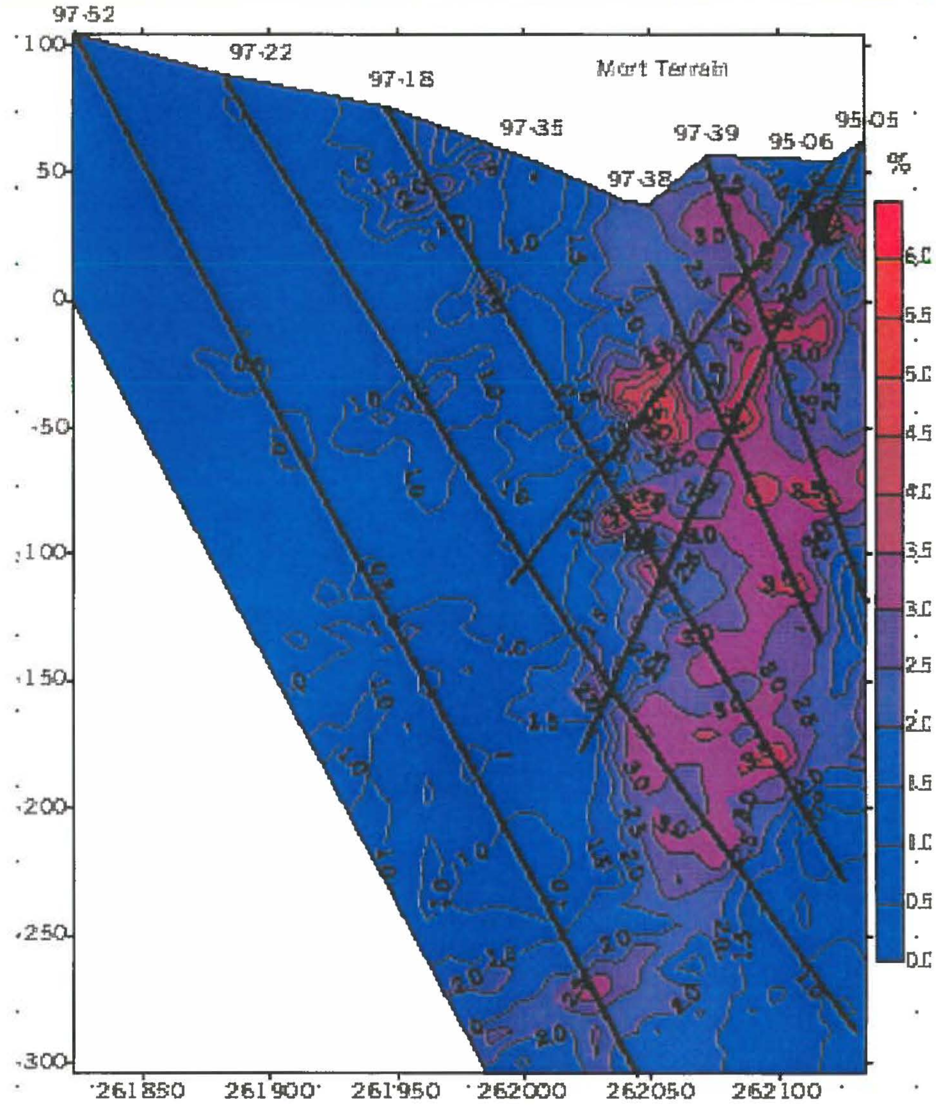
Radioactivité



Nb2O5


97-52
97-22
97-18
97-35
97-39
97-38
95-06
95-05
Mort Terrain
%
261850
261900
261950
262000
262050
262100

Fe2O3


97-52
97-22
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Mort Terrain
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261850
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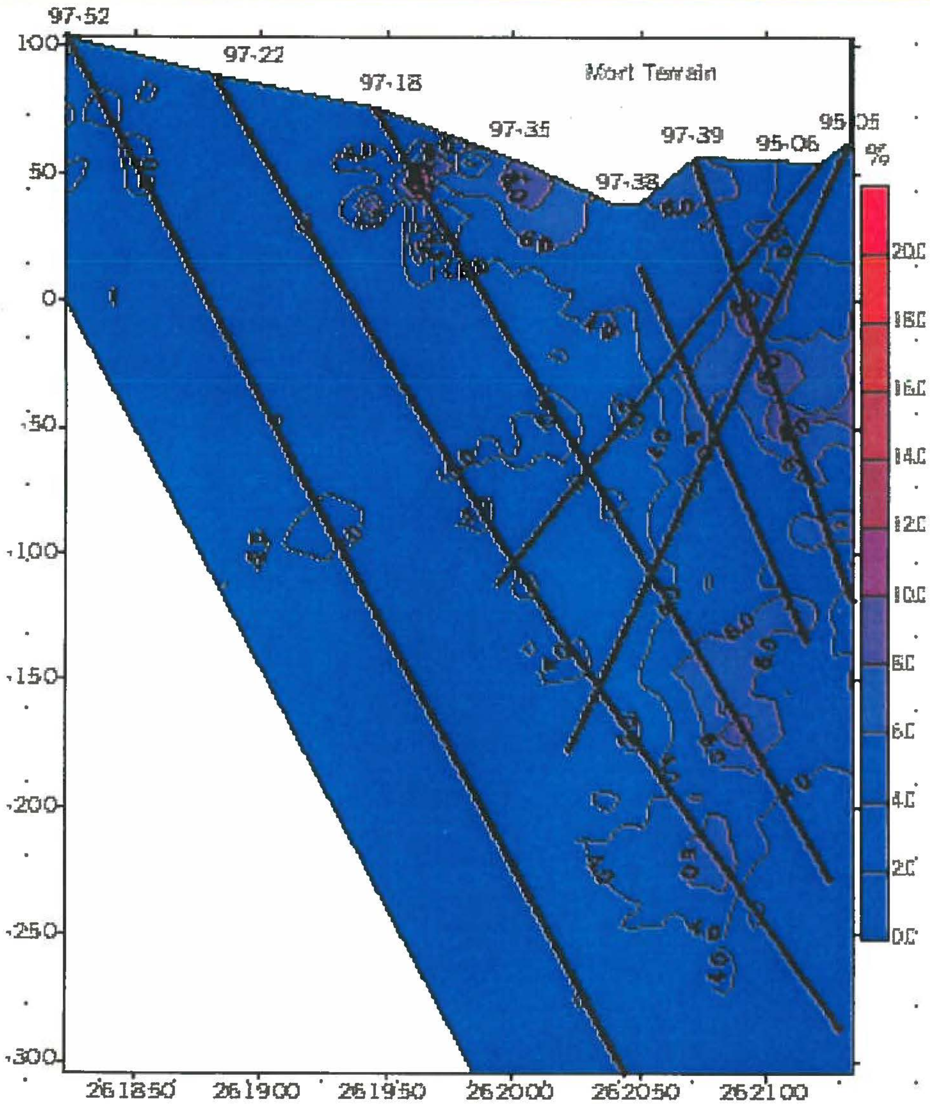
MnO



97-52
97-22
97-18
97-35
97-38
97-39
95-06
95-05
Mort Terrain
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261850
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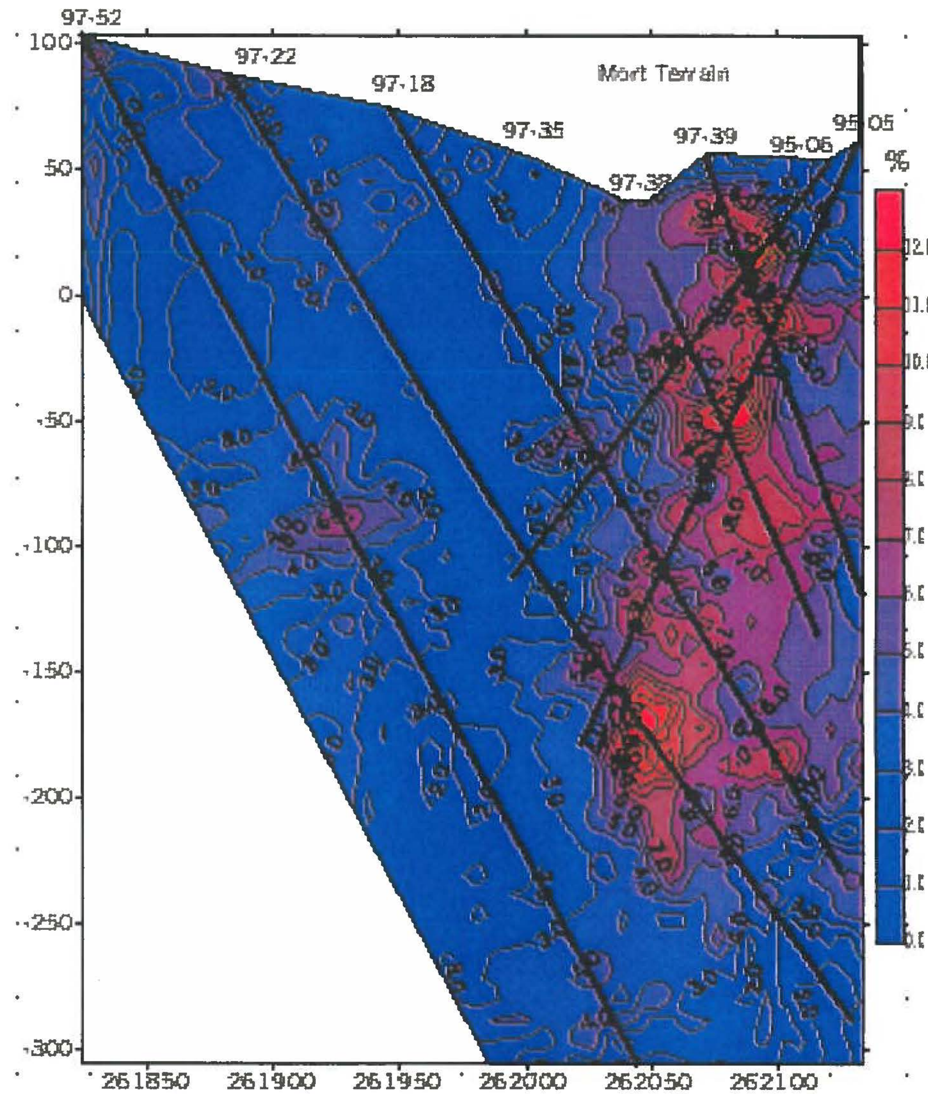
262000
262050
262100

P2O5



97-52
97-22
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97-35
97-38
97-39
95-06
95-05
Mort Terrain
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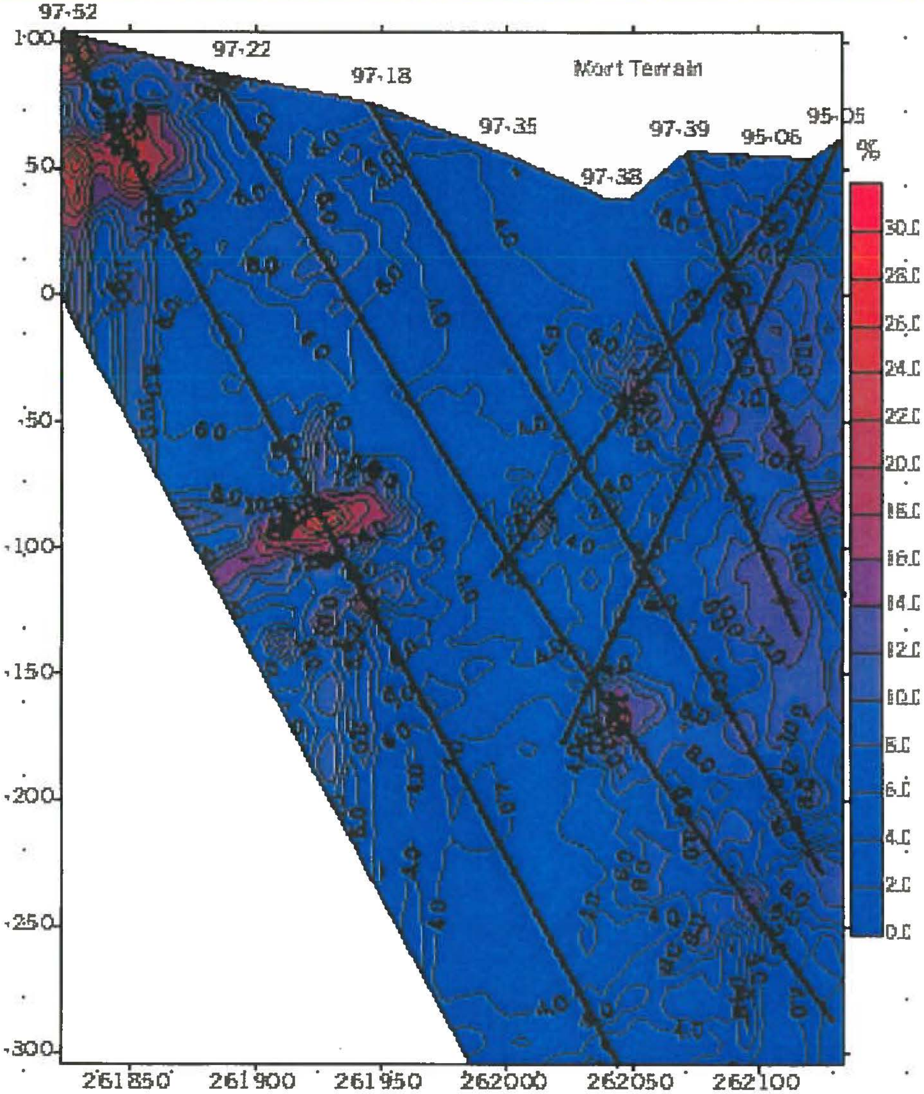
261850
261900
261950
262000
262050
262100

MgO


97-52
97-22
97-18
97-35
97-38
97-39
95-06
95-05
Mort Terrain
%
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28.0
26.0
24.0
22.0
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16.0
14.0
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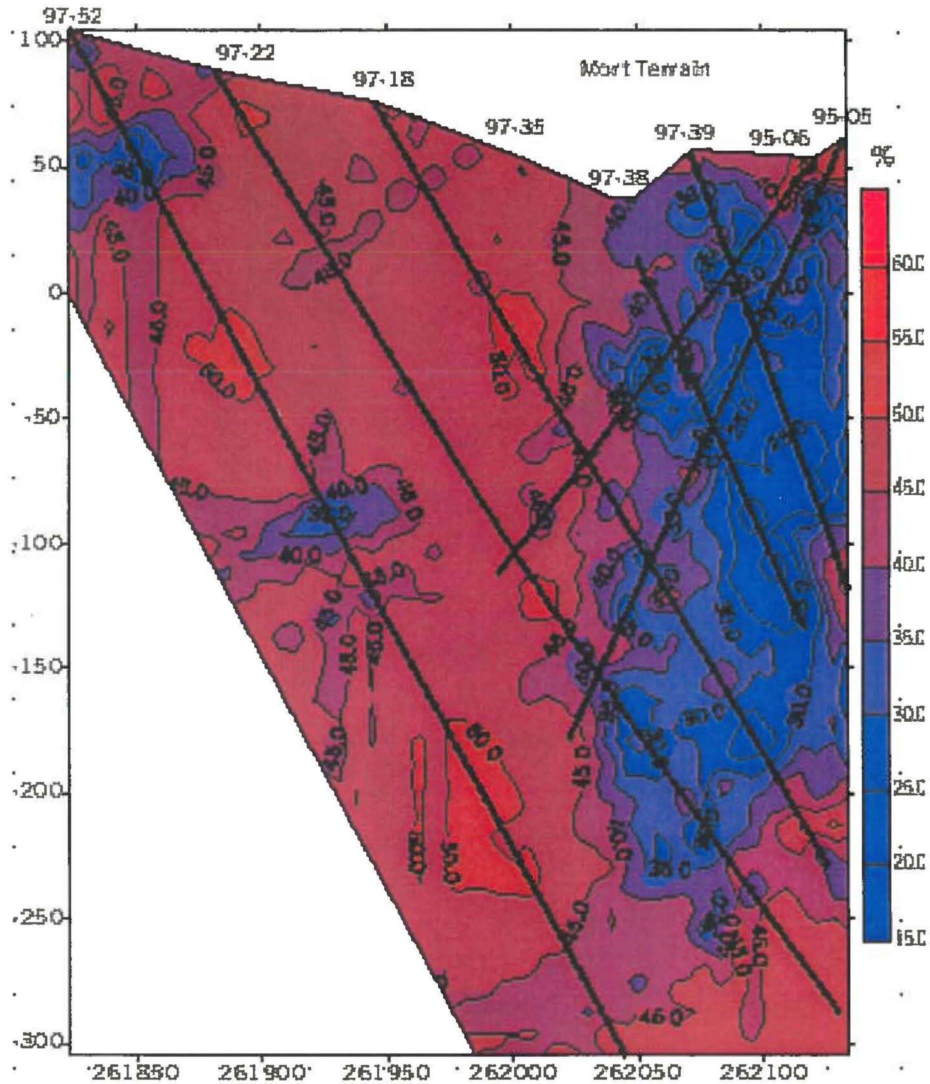
262100
SiO2


97-52
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97-38
97-39
95-06
95-05
Mort Terrain
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261850
261900
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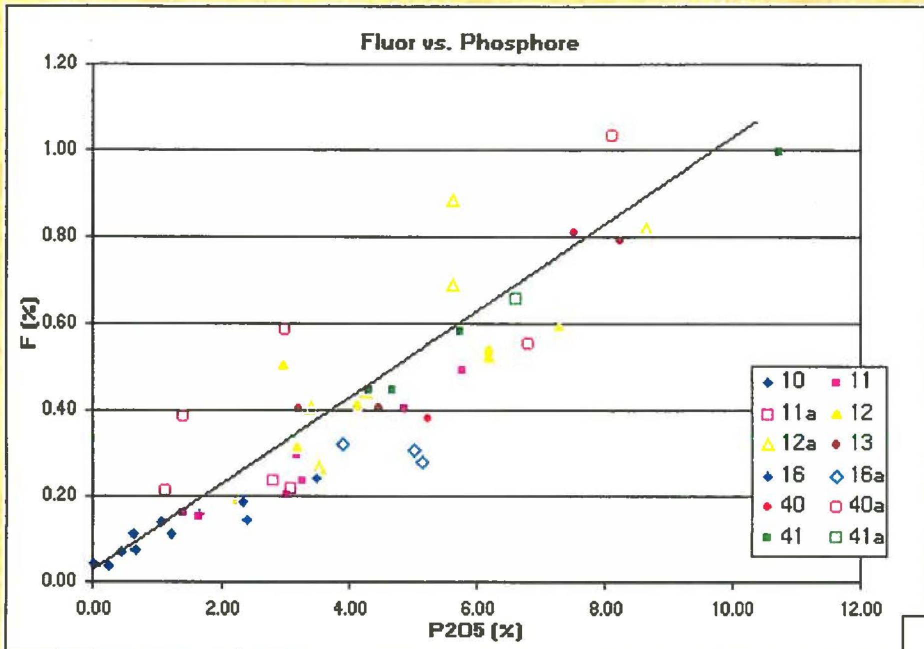
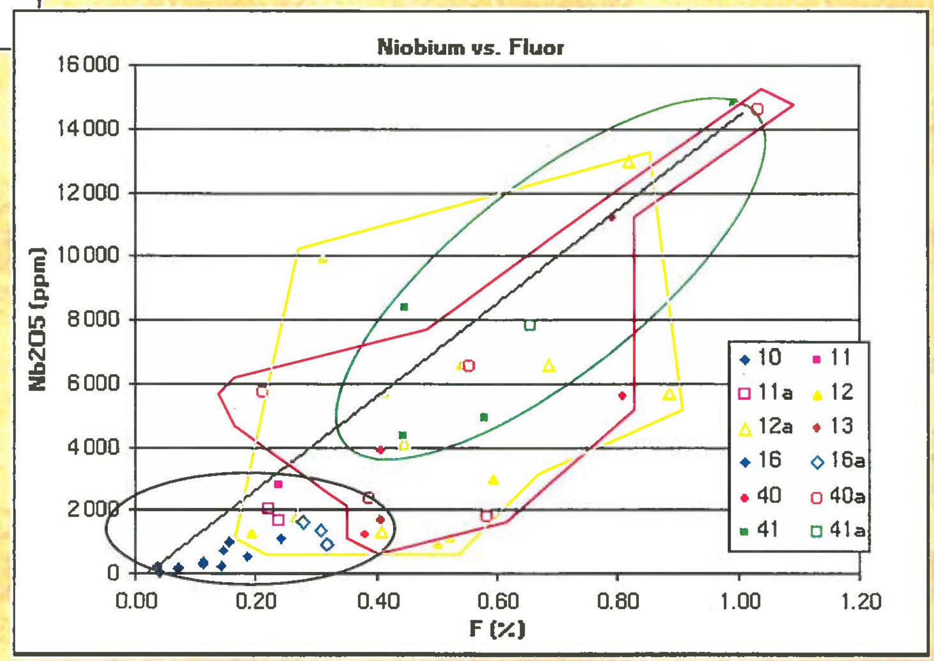
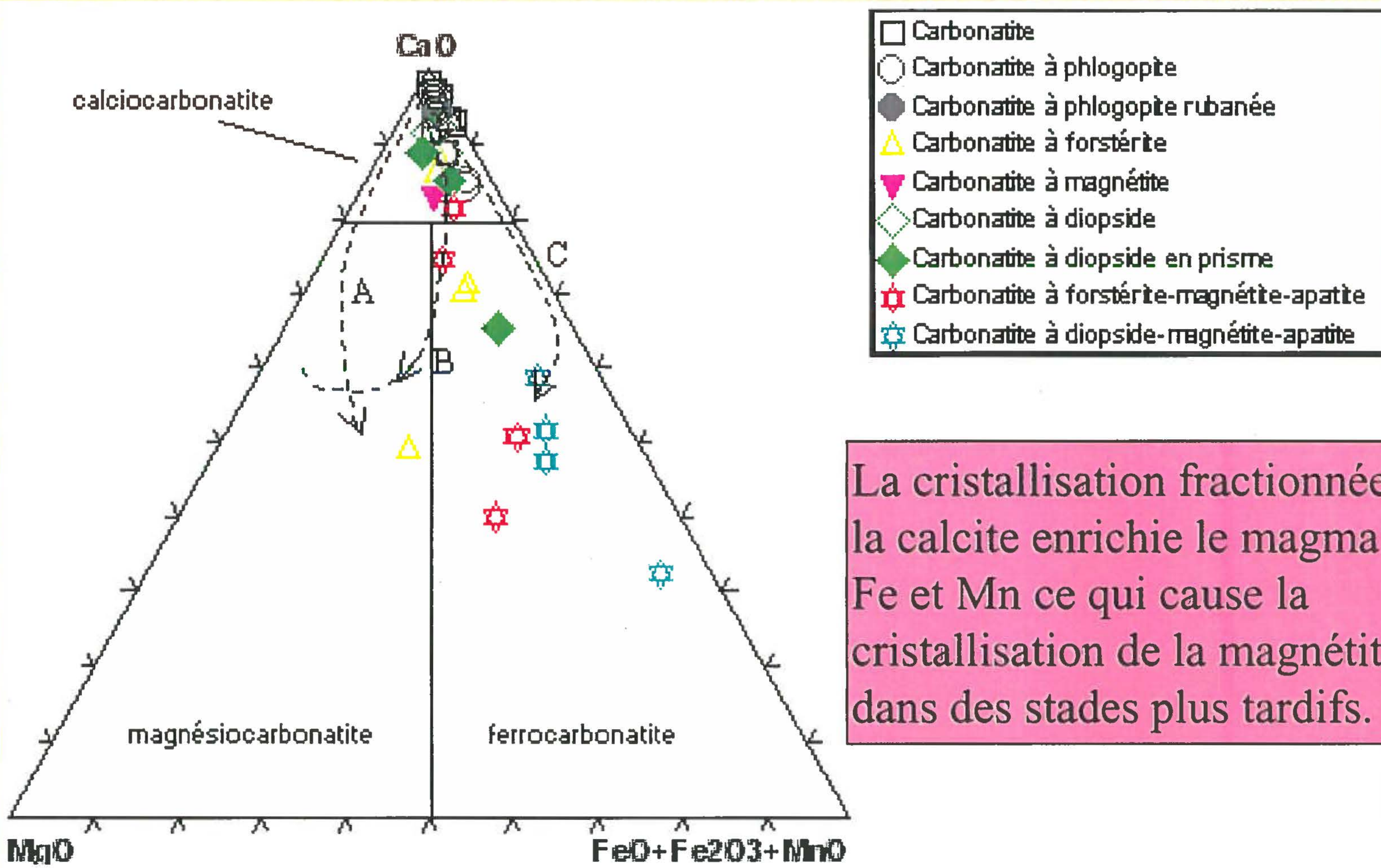
262000
262050
262100
CaO

Covariations chimiques





Interprétations préliminaires



La cristallisation fractionnée de la calcite enrichie le magma en Fe et Mn ce qui cause la cristallisation de la magnétite dans des stades plus tardifs.

Diagramme CMF des roches carbonatitiques fraîches. Les flèches illustrent l'évolution de la cristallisation fractionnée d'un magma carbonatitique dans un environnement à haut (A), moyenne (B) et faible (C) fugacité de l'oxygène selon Le Bas, 1989.

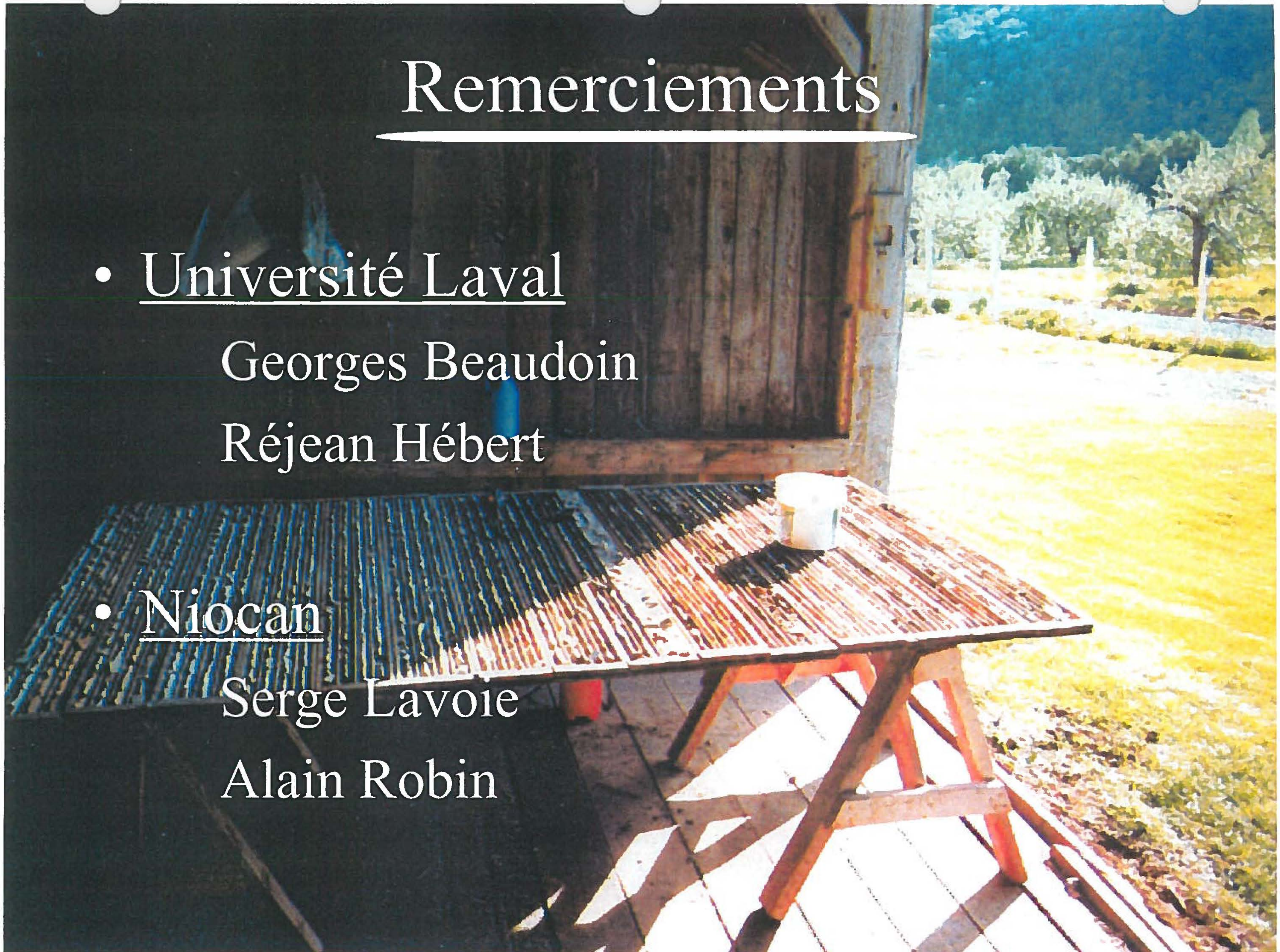
Zone S-60

- Le **F** joue un rôle très important sur la solubilité du **pyrochlore** (Gold,1963; Gittins, 1992).
- F est principalement dans l'apatite fluorifère (3 à 4 % F).
- Lithologies du S-60 possèdent entre 1 à 30 % d '**apatite**.
- L'enrichissement en Nb se corrèle avec une augmentation de la teneur en F.
- Observations semblables dans les zones niobifères sur l'ancien site de la St-Lawrence (Kalogeropoulos, 1977).

Cristallisation de l'apatite → diminution du fluor → précipitation du pyrochlore (type 4)

Zone HWM 2

- Pas de zone riche en apatite.
- Entre HWM2 et S-60: 1) pyrochlore
  2) latrappite et niocalite
- Concentration du pyrochlore légèrement plus élevé que entre les zones HWM2 et S-60.
- **Présence du pyrochlore, de la latrappite et de la niocalite.**
- Pourquoi ces 3 minéraux niobifères se retrouvent seulement dans le HWM2 et HWM1 ?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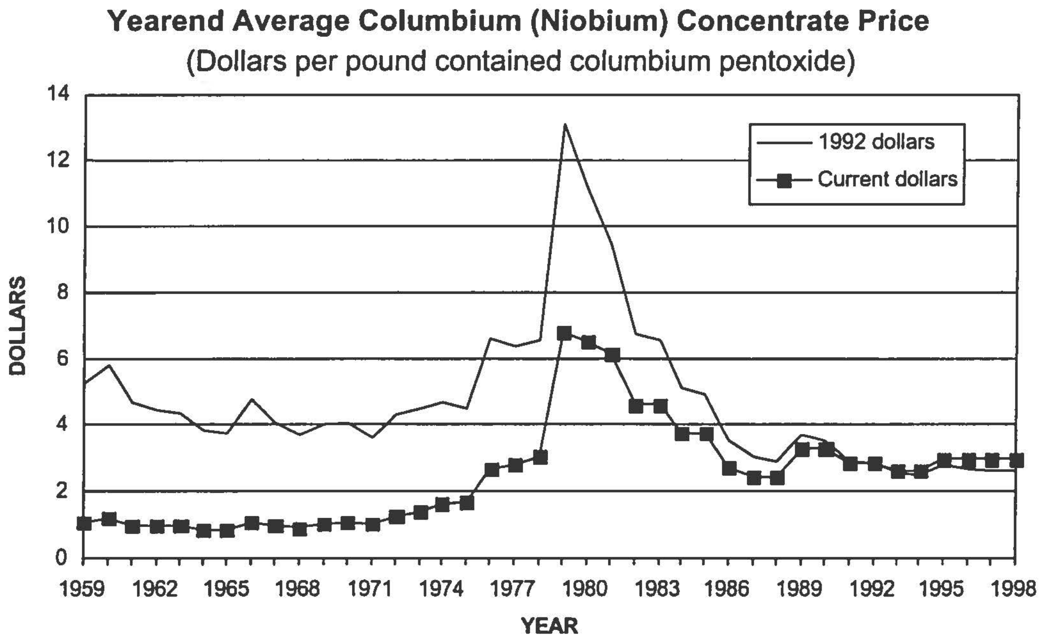
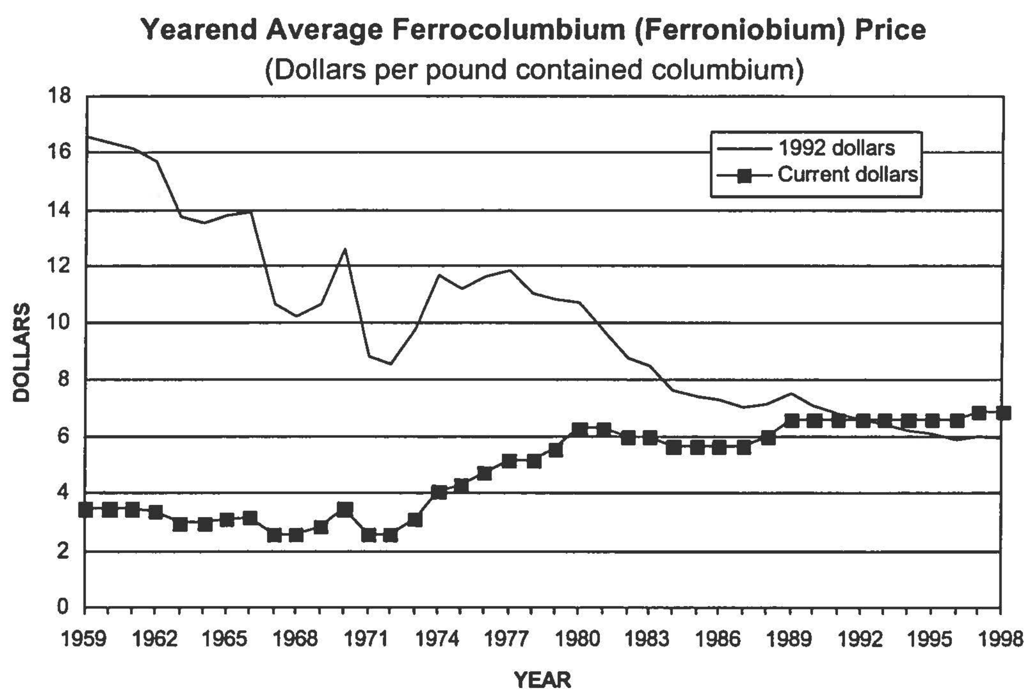
• Niocan
Serge Lavoie
Alain Robin

Columbium (Niobium)

by Larry D. Cunningham





Significant events affecting columbium prices since 1958

1960-70	Development of pyrochlore deposits in Brazil and Canada
1970-79	Increased demand
1980	Columbium oxide produced from pyrochlore-based feed material
1981	Exports of Brazilian pyrochlore ceased
1994	Production of ferrocolumbium began in Canada
1997-98	Sales of ferrocolumbium from the National Defense Stockpile (NDS)
1998	Expansion of ferrocolumbium production capacity in Brazil

Columbium is a refractory metal that conducts heat and electricity well and is characterized by a high melting point, resistance to corrosion, and ease of fabrication. Columbium, in the form of ferrocolumbium, is used worldwide mostly as an alloying element in steels and in superalloys. Little commercial application was found for columbium until the 1930's, when metallurgists began using it in the form of ferrocolumbium in steel and as columbium carbide in high-speed cutting tools (Cunningham, 1985a). Acceptable substitutes, such as molybdenum, tantalum, titanium, tungsten, and vanadium, are available for some columbium applications, but substitution may lower performance and/or cost-effectiveness.

The columbium price is driven by the availability of columbium mineral feed materials, recycling being an insignificant source of supply. Thus, the events affecting the supply of columbium mineral concentrates are discussed herein. A price table and graph, however, are included for standard-grade ferrocolumbium, the dominant form in which columbium is consumed. In 1979, the increase in demand for "high-purity" ferrocolumbium in superalloys was significant. This increased columbium demand affected the prices for high-purity ferrocolumbium and for columbite, but had no real impact on the price for standard ferrocolumbium. The feed material for production of high-purity ferrocolumbium was columbite, and standard ferrocolumbium was produced from pyrochlore. In 1998, the price for columbium contained in concentrate was $4.29 per pound compared with $6.88 per pound for columbium contained in standard ferrocolumbium.

Brazil and Canada are the major producers of columbium mineral concentrates and converters of the material to ferrocolumbium. The U.S. columbium-mining industry has not been significant since 1959. The United States satisfies its columbium requirements primarily by importing ferrocolumbium and columbium oxide from Brazil, ferrocolumbium from Canada, and lesser amounts of columbium concentrates for processing from various countries. Many of the applications for columbium are either directly or indirectly defense related because of its use in the aerospace, communications, energy, and transportation industries. Thus, columbium is classified as critical and strategic, and, over the years, various columbium materials have been purchased for the NDS.

A significant activity during the 1950's was the U.S. Government's worldwide program for the purchase of about 6,800 metric tons (t) of combined columbium and tantalum oxides contained in columbium-tantalum ores and concentrates. The purchase program was terminated in 1959 (Cunningham, 1985a, b). The program, which was initiated to encourage increased production of columbium-tantalum ores and concentrates of domestic and foreign origin, largely governed the market price for columbium ores and concentrates. It also resulted in the discovery of large low-grade domestic and foreign deposits of columbium minerals. The program, however, was less successful in developing domestic columbium mineral production. The low grade of the discoveries precluded their development at current or expected future prices. Termination of the program was followed by lower market prices, resulting in reduced production worldwide. Marginal producers, who could not operate profitably at lower prices, halted production.

Reshaping of columbium supply and demand began in the 1960's. Discovery of the strengthening effect of small amounts of columbium in structural carbon steel eventually led to a widespread and growing use for columbium in high-strength low-alloy steels. Until the mid-1960's, the world's needs for columbium were provided for mostly by columbite concentrates mined in Nigeria; the Nigerian columbite was produced as a byproduct of tin mining. Development of pyrochlore deposits in Brazil and Canada during this period, however, greatly increased columbium availability (Cunningham, 1985a; Miller, Fantel, and Buckingham, 1986, p. 8; Crockett and Sutphin, 1993, p. 4-5). Pyrochlore deposits are mined primarily for columbium, and columbite and tantalite are recovered mostly as a byproduct/coproduct of other minerals, principally tin. The shift in columbium supply from Nigeria to Brazil and Canada did not have an adverse impact on the columbium price, which changed little or not at all during the 1960's owing to the readily available supplies of pyrochlore.

During the 1970's, increased demand, mostly in the form of ferrocolumbium for steelmaking, continued to be met by the large quantities of pyrochlore concentrates produced in Brazil and Canada. Pyrochlore became the standard material for the manufacture of ferrocolumbium for steelmaking.

Columbite-tantalite remained as the source material for the production of columbium oxide used in high-purity columbium products. As demand increased in the 1970's, prices began to escalate for columbium concentrates and columbium products. With continued strong demand for columbium in the manufacture of steels and especially high-purity columbium products, the price for columbium concentrates peaked in 1979.

In 1980, an important change in columbium supply took place when plants that produced columbium oxide from pyrochlore-based feed materials were established in Brazil and the United States, which resulted in lower prices for columbium oxide and high-purity columbium products (Jones, 1981). This change greatly diminished the need for columbite ores. Until 1980, columbium oxide had been produced mostly from columbite- and tantalite-based materials. Columbium concentrate prices fell during most of the 1980's owing to the large quantities of pyrochlore produced in Brazil and Canada and the columbium products produced from this feed material, especially in Brazil.

Brazil's production of columbium concentrates, mostly pyrochlore, accounts for more than 85% of total world production of columbium. Pyrochlore concentrates, however, have not been exported from Brazil since 1981. Pyrochlore concentrates produced in Brazil are processed locally, and some of the upgraded columbium products are consumed domestically, with the majority of the products exported. As the dominant columbium producer/supplier, Brazil has maintained a marketing strategy of stable supply and moderate price changes.

A significant change took place in the columbium industry in late 1994. The sole Canadian columbium concentrate producer began ferrocolumbium production at its columbium mine in Quebec (Teck Corp., 1994, p. 13, 32). The plant converts basically all pyrochlore concentrates produced at the mine to ferrocolumbium. Prior to commissioning of the plant, columbium concentrates produced at the mine were shipped mostly to the United States, Europe, and Japan for conversion to ferrocolumbium.

In 1997, the U.S. Department of Defense initiated the sale of ferrocolumbium from the NDS. From March 1997 through December 1998, the Defense Logistics Agency sold about 211 t of columbium contained in ferrocolumbium valued at about $2.98 million (Cunningham, 1998a, b, p. 1; Defense National Stockpile Center, 1998a, b). The overall average unit price for the sales, about $6.40 per pound of contained columbium, was somewhat less than that quoted for ferrocolumbium, $6.88 per pound of contained columbium.

In 1998, the leading Brazilian columbium producer initiated plans to raise its ferrocolumbium production capacity by about 50% by 2000. The expansion is aimed at maintaining the stability of world supply and pricing of ferrocolumbium in response to growing international demand (Metal Bulletin, 1998).

For most of the 1990's, the price for columbium remained stable as the demand for and supply of columbium continued to increase.

References Cited

Crockett, R.N., and Sutphin, D.M., 1993, International Strategic Minerals Inventory summary report—Niobium (columbium) and tantalum: U.S. Geological Survey Circular 930-M, 36 p.

Cunningham, L.D., 1985a, Columbium, *in* Mineral facts and problems: U.S. Bureau of Mines Bulletin 675, p. 185-196.

———1985b, Tantalum, *in* Mineral facts and problems: U.S. Bureau of Mines Bulletin 675, p. 811-822.

———1998a, Columbium (niobium), *in* Mineral Commodity Summaries 1998: U.S. Geological Survey, p. 50-51.

———1998b, Columbium (niobium) and tantalum in 1997—Annual review: U.S. Geological Survey Mineral Industry Surveys, August, 12 p.

Defense National Stockpile Center, 1998a, Stockpile accepts ferrocolumbium offers: Fort Belvoir, VA, Defense National Stockpile Center news release, November 13, 1 p.

———1998b, Stockpile accepts ferrocolumbium offers: Fort Belvoir, VA, Defense National Stockpile Center news release, December 10, 1 p.

Jones, T.S., 1981, Columbium and tantalum, *in* Minerals Yearbook 1980, v. I: U.S. Bureau of Mines, p. 249-260.

Metal Bulletin, 1998, CBMM expands to maintain ferro-niobium stability: Metal Bulletin, no. 8311, September 21, p. 11.

Miller, F.W., Fantel, R.J., and Buckingham, D.A., 1986, Columbium availability—Market economy countries—A minerals availability appraisal: U.S. Bureau of Mines Information Circular 9085, 20 p.

Teck Corp., 1994, Teck Corp. annual report 1994: Vancouver, British Columbia, Canada, Teck Corp., 60 p.

Yearend Average Columbium (Niobium) Concentrate Price
(Dollars per pound contained columbium pentoxide[1])

Year	Price	Year	Price	Year	Price	Year	Price
1940	0.35	1955	3.40	1970	1.12	1985	3.75
1941	0.35	1956	3.40	1971	1.04	1986	2.75
1942	0.53	1957	3.40	1972	1.29	1987	2.43
1943	0.25	1958	3.40	1973	1.42	1988	2.43
1944	0.25	1959	1.08	1974	1.64	1989	3.25
1945	0.60	1960	1.22	1975	1.71	1990	3.25
1946	0.54	1961	1.00	1976	2.69	1991	2.83
1947	0.65	1962	0.95	1977	2.76	1992	2.83
1948	0.73	1963	0.95	1978	3.03	1993	2.60
1949	1.13	1964	0.85	1979	6.78	1994	2.60
1950	2.55	1965	0.85	1980	6.50	1995	3.00
1951	2.56	1966	1.11	1981	6.13	1996	3.00
1952	3.40	1967	0.97	1982	4.63	1997	3.00
1953	3.40	1968	0.92	1983	4.63	1998	3.00
1954	3.40	1969	1.05	1984	3.75		

[1] To convert to dollars per kilogram, multiply by 2.20462.

Sources: Metal Bulletin (1946-51), U.S. Government purchase (1952-58), E&MJ Metal and Mineral Markets (1959-66), Metals Week (1967-90), and Metal Bulletin (1991-98). Prices before 1946 were published by the U.S. Bureau of Mines; origins are unknown.

Yearend Average Ferrocolumbium (Ferroniobium) Price[1]
(Dollars per pound contained columbium[2])

Year	Price	Year	Price	Year	Price	Year	Price
1940	2.30	1955	6.90	1970	3.49	1985	5.66
1941	2.30	1956	6.90	1971	2.55	1986	5.66
1942	2.28	1957	4.90	1972	2.55	1987	5.66
1943	2.28	1958	3.73	1973	3.10	1988	6.00
1944	2.28	1959	3.45	1974	4.12	1989	6.58
1945	2.28	1960	3.45	1975	4.30	1990	6.58
1946	2.28	1961	3.45	1976	4.73	1991	6.58
1947	2.55	1962	3.40	1977	5.12	1992	6.58
1948	2.90	1963	3.00	1978	5.12	1993	6.58
1949	2.90	1964	3.00	1979	5.58	1994	6.58
1950	4.90	1965	3.10	1980	6.29	1995	6.58
1951	4.90	1966	3.21	1981	6.29	1996	6.58
1952	4.90	1967	2.53	1982	6.00	1997	6.88
1953	6.40	1968	2.53	1983	6.00	1998	6.88
1954	12.00	1969	2.79	1984	5.66		

[1] Standard (steelmaking) grade, 65% contained columbium (1997-98).

[2] To convert to dollars per kilogram, multiply by 2.20462.

Sources: Mostly E&MJ Metal and Mineral Markets (1940-66), Metals Week (1967-92), Platt's Metals Week (1993-96), and American Metal Market (1997-98).

COLUMBIUM (NIOBIUM)

(Data in metric tons of columbium content, unless otherwise noted)

Domestic Production and Use: There has been no significant domestic columbium mining since 1959. Domestic columbium resources are of low grade, some mineralogically complex, and most are not commercially recoverable. Most metal, ferrocolumbium, other alloys, and compounds were produced by six companies. Feed for these plants included imported concentrates, columbium oxide, and ferrocolumbium. Consumption was mainly as ferrocolumbium by the steel industry and as columbium alloys and metal by the aerospace industry, with plants in the Eastern and Midwestern United States, California, and Washington. The estimated value of reported columbium consumption, in the form of ferrocolumbium and nickel columbium, in 2001 was about $85 million. Major end-use distribution of reported columbium consumption was as follows: carbon steels, 33%; superalloys, 23%; stainless and heat-resisting steels, 18%; high-strength low-alloy steels, 16%; alloy steels, 9%; and other, 1%.

Salient Statistics—United States:	1997	1998	1999	2000	2001[e]
Production, mine	—	—	—	—	—
Imports for consumption:					
Concentrates, tin slags, other[1]	NA	NA	NA	NA	NA
Ferrocolumbium[e]	4,260	4,900	4,450	4,400	4,100
Exports, concentrate, metal, alloys[e]	70	50	160	100	110
Government stockpile releases[e 2]	126	145	280	217	(14)
Consumption, reported, ferrocolumbium[e 3]	3,770	3,640	3,460	4,090	4,100
Consumption, apparent	4,030	4,150	4,100	4,300	4,300
Price:					
Columbite, dollars per pound[4]	3.00	3.00	3.00	6.25	NA
Pyrochlore, dollars per pound[5]	NA	NA	NA	NA	NA
Stocks, industry, processor and consumer, yearend	NA	NA	NA	NA	NA
Employment	NA	NA	NA	NA	NA
Net import reliance[6] as a percentage of apparent consumption	100	100	100	100	100

Recycling: While columbium is not recovered from scrap steel and superalloys containing it, recycling of these alloys is significant, and columbium content is reused. Data on the quantities of columbium recycled in this manner are not available.

Import Sources (1997-2000): Brazil, 75%; Canada, 9%; Germany, 4%; Russia, 2%; and other, 10%.

Tariff: Item	Number	Normal Trade Relations 12/31/01
Columbium ores and concentrates	2615.90.6030	Free.
Columbium oxide	2825.90.1500	3.7% ad val.
Ferrocolumbium	7202.93.0000	5.0% ad val.
Columbium, unwrought:		
Waste and scrap	8112.91.0500	Free.
Alloys, metal, powders	8112.91.4000	4.9% ad val.
Columbium, wrought	8112.99.0000	4.0% ad val.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

Government Stockpile: For fiscal year 2001, ending September 30, 2001, the Defense National Stockpile Center (DNSC) sold about 48 tons of columbium contained in ferrocolumbium valued at about $1.29 million and about 9 tons of columbium metal ingots valued at about $323,000 from the National Defense Stockpile (NDS). The DNSC disposed of about 3 tons of columbium contained in tantalum minerals that were sold in fiscal year 2001; no value obtained as columbium was contained within the tantalum minerals. There were no sales of columbium carbide powder in fiscal year 2001. The DNSC also proposed maximum disposal limits in fiscal year 2002 of about 10 tons[7] of columbium contained in columbium carbide powder, about 254 tons of columbium contained in columbium concentrates, and about 9 tons of columbium metal ingots. The NDS uncommitted inventories shown below include about 244 tons of columbium contained in nonstockpile-grade concentrates.

Prepared by **Larry D. Cunningham [(703) 648-4977, lcunning@usgs.gov, fax: (703) 648-7757]**

COLUMBIUM (NIOBIUM)

Stockpile Status—9-30-01[8]

Material	Uncommitted inventory	Committed inventory	Authorized for disposal	Disposal plan FY 2001	Disposals FY 2001
Columbium:					
Carbide powder	10	—	10	[7]10	—
Concentrates	594	—	594	254	[9]3
Ferrocolumbium	—	—	—	[7]68	48
Metal	46	—	46	9	9

Events, Trends, and Issues: For the first one-half year, domestic demand for columbium ferroalloys in steelmaking and demand for columbium in superalloys (mostly for aircraft engine components) increased slightly compared with the similar period of 2000. For the same period, overall columbium imports increased; Brazil accounted for more than 70% of quantity and about 65% of value. Exports increased, with Canada, Italy, Mexico, and the United Kingdom receiving most of the columbium materials. The published price for columbite ore was discontinued in October at a range of $5.50 to $7 per pound of pentoxide content. Unchanged since September 1997, the published price for steelmaking-grade ferrocolumbium was quoted at a range of $6.75 to $7 per pound of columbium content and high-purity ferrocolumbium was quoted at a range of $17.50 to $18 per pound of columbium content. Industry sources indicated in December 1999 that nickel columbium sold at about $18.50 per pound of columbium content, columbium metal products sold in the range of about $24 to $100 per pound in ingot and special shape forms, and columbium oxide for master alloy production sold for about $8.80 per pound. Public information on current prices for these products was not available. No domestic columbium mine production is expected in 2002, and it is estimated that U.S. apparent consumption will be about 4,400 tons. Most of total U.S. demand will be met by columbium imports in upgraded forms.

World Mine Production, Reserves, and Reserve Base:

	Mine production 2000	Mine production 2001[e]	Reserves[10]	Reserve base[10]
United States	—	—	—	Negligible
Australia	160	200	16,000	NA
Brazil	30,000	30,000	4,400,000	5,200,000
Canada	2,290	2,300	140,000	400,000
Ethiopia	7	5	NA	NA
Nigeria	35	30	60,000	90,000
Rwanda	28	25	NA	NA
Other countries[11]	—	—	NA	NA
World total (rounded)	32,600	32,600	4,600,000	5,700,000

World Resources: Most of the world's identified resources of columbium are outside the United States and occur mainly as pyrochlore in carbonatite deposits. On a worldwide basis, resources are more than adequate to supply projected needs. The United States has approximately 150,000 tons of columbium resources in identified deposits, all of which were considered uneconomic at 2001 prices for columbium.

Substitutes: The following materials can be substituted for columbium, but a performance or cost penalty may ensue: molybdenum and vanadium as alloying elements in high-strength low-alloy steels; tantalum and titanium as alloying elements in stainless and high-strength steels; and ceramics, molybdenum, tantalum, and tungsten in high-temperature applications.

[e]Estimated. NA Not available. — Zero.
[1]Metal, alloys, synthetic concentrates, and columbium oxide.
[2]Net quantity (uncommitted inventory). Parentheses indicate negative number (increase in inventory).
[3]Includes nickel columbium.
[4]Yearend average value, contained pentoxides for material having a Nb_2O_5 to Ta_2O_5 ratio of 10 to 1.
[5]Yearend average value, contained pentoxide.
[6]Defined as imports - exports + adjustments for Government and industry stock changes.
[7]Actual quantity limited to remaining sales authority or inventory.
[8]See Appendix B for definitions.
[9]Columbium units contained in the disposal of tantalum minerals.
[10]See Appendix C for definitions.
[11]Bolivia, China, Congo (Kinshasa), Russia, and Zambia also produce (or are thought to produce) columbium, but available information is inadequate to make reliable estimates of output levels.

COLUMBIUM (NIOBIUM) AND TANTALUM

By Larry D. Cunningham

Domestic survey data and tables were prepared by Robin C. Kaiser, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

Columbium [Niobium (Nb)] is vital as an alloying element in steels and in superalloys for aircraft turbine engines and is in greatest demand in industrialized countries. It is critical to the United States because of its defense-related uses in the aerospace, energy, and transportation industries. Substitutes are available for some columbium applications, but, in most cases, they are less desirable.

Tantalum (Ta) is a refractory metal that is ductile, easily fabricated, highly resistant to corrosion by acids, a good conductor of heat and electricity, and has a high melting point. It is critical to the United States because of its defense-related applications in aircraft, missiles, and radio communications. Substitution for tantalum is made at either a performance or economic penalty in most applications. Neither columbium nor

Columbium (Niobium) and Tantalum in the 20th Century

Columbium.—Columbium (niobium) was discovered in 1801; prior to 1918, however, most U.S. interest in columbium was for experimental purposes. Commercial columbium usage began around 1925 when it was added to tool steel as a substitute for tungsten. In 1933, columbium (in the form of ferrocolumbium) was first used in stainless steel, and about 1935, columbium was added to superalloys for use in gas turbines. About 3.5 metric tons of columbium-bearing minerals valued at about $4,520 was reported shipped from domestic mines in 1935. Imports of columbium-bearing minerals were about 540 tons valued at about $107,000, with Nigeria accounting for most of the imports. Nigeria was the leading source for columbium-bearing minerals, and the country shipped its entire output to the United States.

In 2000, there was no domestic columbium mining, and the United States satisfied its columbium requirements primarily by importing ferrocolumbium and columbium oxide from Brazil, ferrocolumbium from Canada, and columbium-bearing mineral concentrates for processing mainly from Australia and Nigeria. U.S. columbium imports totaled about 6,500 tons of contained columbium valued at about $110 million. Brazil and Canada were the world's largest producers of columbium minerals, together accounting for more than 95% of the total. Ferrocolumbium and columbium metal, alloys, and compounds were produced in the United States by six companies located mostly in the eastern United States. Columbium consumption in the United States was mainly as ferrocolumbium by the steel industry and as high-purity columbium alloys and metal by the aerospace industry. Steelmaking accounted for more than 75% of reported columbium consumption, with the value of consumption estimated to be about $70 million.

Tantalum.—Tantalum was discovered in 1802. Commercial use of tantalum began in Germany in 1903 with the production of tantalum wire to replace carbon in incandescent light filaments. By 1909, tungsten began to replace tantalum in filaments, and by 1912, the substitution was complete. During this period, U.S. tantalum requirements were imported from Germany. By 1918, U.S. demand for tantalum for experimental purposes was large enough that about 2 metric tons of tantalum-bearing minerals valued at about $2,250 was marketed from material mined in South Dakota. Tantalum carbide was produced in the United States in 1929, and the tantalum capacitor was developed in 1940. There was no reported domestic tantalum mine production in 1940, and U.S. imports of tantalum minerals totaled about 222 tons valued at about $260,000. Australia was thought to be the major producer of tantalum minerals at that time.

In 2000, there was no domestic tantalum mining, and the United States satisfied its tantalum requirements by importing alloys, metal, and powder from China, Japan, and Thailand, and tantalum-bearing mineral concentrates for processing mainly from Australia, Canada, and Nigeria. U.S. tantalum imports totaled more than 900 tons of contained tantalum valued at more than $190 million. Australia was the world's largest producer of tantalum mineral concentrates and accounted for more than 60% of U.S. imports. Tantalum metal, alloys, and powders were produced in the United States by three companies located in the eastern part of the United States. The major use (more than 60%) for tantalum as tantalum metal powder was in the production of electronic components, mainly tantalum capacitors. Tantalum was also consumed in cemented carbides and in superalloys. The value of tantalum consumed in the United States in 2000 was estimated to be about $200 million.

tantalum was mined domestically because U.S. resources are of low grade. Some resources are mineralogically complex, and most are not currently (2000) recoverable. The last significant mining of columbium and tantalum in the United States was during the Korean Conflict, when increased military demand resulted in columbium and tantalum ore shortages.

Pyrochlore was the principal columbium mineral mined worldwide. Brazil and Canada, which were the dominant pyrochlore producers, accounted for most of total estimated columbium mine production in 2000. The two countries, however, no longer export pyrochlore—only columbium in upgraded valued-added forms produced from pyrochlore. Brazil exported mostly regular-grade ferrocolumbium and columbium oxide, and Canada exported regular-grade ferrocolumbium. The remaining columbium mineral supply came from the mining of columbite in Nigeria and tantalite-columbite, mostly in Australia, Brazil, and certain African countries. Tantalum mineral was produced mostly from tantalite-columbite mining operations in Australia, which was almost 60% of total estimated tantalum mine production in 2000, and from other tantalum mine operations in Brazil, Burundi, Canada, Congo (Kinshasa), Ethiopia, Nigeria, and Rwanda. The reliance on tantalum-containing tin slags as a source of tantalum supply remained low.

The United States remained dependent on imports of columbium and tantalum materials; Brazil was the major source for columbium, and Australia, the major source for tantalum. The Defense National Stockpile Center (DNSC) offered and sold selected columbium and tantalum materials from the National Defense Stockpile (NDS). The Generalized System of Preferences (GSP), a renewable preferential trade program, was extended to September 30, 2001. Columbium price quotations remained stable. Tantalum price quotations for tantalite ore escalated amidst concerns about the status of the world tantalum supply. Overall reported consumption of columbium in the form of ferrocolumbium and nickel columbium increased, with demand for columbium in superalloys up significantly. Tantalum consumption increased.

Legislation and Government Programs

Summaries of important columbium and tantalum statistics are listed in tables 1 and 2, respectively. To ensure supplies of columbium and tantalum during an emergency, various materials have been purchased for the NDS. The Stockpile goals, effective as of October 5, 1999, for tantalum metal powder and tantalum metal (contained tantalum) were about 16 metric tons (t) and about 55 t, respectively (table 3). The NDS had no goals for columbium materials. For fiscal year (FY) 2000 (October 1, 1999, through September 30, 2000), the DNSC sold about 182 t of columbium contained in ferrocolumbium valued at about $2.8 million, and about 9 t of columbium contained in columbium metal ingots valued at about $567,000 and disposed of about 80 t of columbium contained in tantalum minerals that were sold in FY 2000; no columbium value was obtained, as the columbium was contained within the tantalum minerals. Additionally, the DNSC sold about 2 t of tantalum contained in tantalum carbide powder valued at about $254,000, about 23 t of tantalum contained in tantalum metal powder valued at about $3.67 million, about 18 t of tantalum contained in tantalum metal ingots valued at about $3.84 million, about 134 t of tantalum contained in tantalum minerals valued at about $42.7 million, and about 9 t of tantalum contained in tantalum oxide valued at about $1.32 million. As of September 30, 2000, columbium and tantalum inventory sold but not shipped from the NDS included about 37 t of columbium contained in ferrocolumbium and about 106 t of tantalum contained in tantalum minerals (U.S. Department of Defense, 2001, p. 14, 15, 43, 45, 47, 48).

In its revised Annual Materials Plan (AMP) for FY 2001 (October 1, 2000, through September 30, 2001) and proposed AMP for FY 2002 (October 1, 2001, through September 30, 2002), the DNSC had authority to sell about 10 t of columbium contained in columbium carbide powder (actual quantity limited to the remaining sales authority or inventory), about 254 t of columbium contained in columbium concentrates, about 68 t of columbium contained in ferrocolumbium (actual quantity limited to the remaining sales authority or inventory), about 9 t of columbium contained in columbium metal ingots, about 2 t of tantalum contained in tantalum carbide powder, about 23 t of tantalum contained in tantalum metal powder (actual quantity limited to the remaining sales authority or inventory for FY 2002), about 18 t of tantalum contained in tantalum metal ingots (actual quantity limited to the remaining sales authority or inventory for FY 2002), about 227 t of tantalum contained in tantalum minerals, and about 9 t of tantalum contained in tantalum oxide (Defense National Stockpile Center, 2001a, b). For FY 2001, through June 30, 2001, the DNSC sold about 48 t of columbium contained in ferrocolumbium valued at about $1.29 million, about 9 t of columbium contained in columbium metal ingots valued at about $142,000, about 20 t of tantalum contained in tantalum capacitor-grade metal powder valued at about $14.3 million, about 18 t of tantalum contained in tantalum metal ingots valued at about $16.1 million, about 2 t of tantalum contained in tantalum carbide powder valued at about $1.34 million, and about 11 t of tantalum oxide valued at about $2.55 million.

Under the GSP, the United States grants duty-free access to eligible products from designated developing countries. In 2000, U.S. import duties for selected columbium and tantalum materials ranged from duty free to 8.5% ad valorem for normal-trade-relations (NTR) status and from duty free to 45% ad valorem for non-NTR status (U.S. International Trade Commission, 1999). In March, the GSP program, which expired on June 30, 1999, was renewed through September 30, 2001, retroactive to July 1, 1999, by a provision in the Ticket To Work and Work Incentives Improvement Act of 1999. Customs began processing refunds due to the renewal on January 7, 2000 (U.S. Customs Service, 2000). Categories of U.S. imports from developing countries affected by the GSP included all columbium and tantalum tariff articles except columbium and tantalum ores and concentrates, synthetic tantalum-columbium concentrates, and columbium and tantalum unwrought waste and scrap, for which the general rate of duty already was zero.

Production

Neither columbium nor tantalum was mined domestically in 2000. Domestic production data for ferrocolumbium are developed by the U.S. Geological Survey from the annual voluntary domestic survey for ferroalloys. Ferrocolumbium production data for 2000 were, however, incomplete at the time this report was prepared.

Cabot Performance Materials, Boyertown, PA, had production capability that ranged from raw material processing through the production of columbium and tantalum end products. In September, Cabot proceeded with the company's decision to close its Revere, PA, plant, which had produced high-purity ferrocolumbium and nickel columbium. Shieldalloy Metallurgical Corp., Newfield, NJ, was a producer of ferrocolumbium. H.C. Starck Inc. was a major supplier of tantalum and columbium products. Reading Alloys Inc., Robesonia, PA, and Wah Chang, Albany, OR, were major producers of high-purity columbium products. Kennametal Inc., Latrobe, PA, was a major supplier of columbium and tantalum carbides (table 9).

In July, KEMET Corp., Greenville, SC, announced planned expansion of more than 7,900 square meters (m^2) of manufacturing floor space in South Carolina and Mexico dedicated to the production of solid tantalum and conductive polymer tantalum capacitors. With increasing customer demand for capacitors, KEMET, a major world maufacturer of tantalum capacitors, indicated that the capacity expansions would ensure the company's ability to provide high-value tantalum and high-frequency organic tantalum capacitors to meet its customers' needs. About 1,000 m^2 of manufacturing space would be created with additions in Mauldin and Greenwood, SC; relocation of support functions in Simpsonville, SC, would add 418 m^2; and construction of a new facility in Matamoros, Mexico, would add 6,500 m^2. The new capacity at each facility would be used to increase production rates for solid tantalum surface-mount capacitors. New capacity in Mauldin and Simpsonville would also increase production rates for KEMET's new high-performance conductive polymer tantalum capacitor. The expansions were expected to add approximately 1,100 new jobs (KEMET Corp., 2000b).

In November, KEMET announced a memorandum of understanding with Australasian Gold Mines NL (AGM) to establish a 50-50 joint venture, which would own and fund development of AGM's existing tantalum projects, including a pilot-processing plant at Dalgaranga, Australia. The feasibility of future mining and commissioning of full-scale plants would be determined. KEMET would purchase processed tantalum products from the pilot plant and any future processing development. The material would be toll converted into tantalum powder necessary for the production of capacitors. In February 2001, KEMET announced completion of the joint-venture agreement with AGM. KEMET's initial investment in the venture would be approximately $5.5 million, and KEMET would acquire a 10% interest in AGM for approximately $2.5 million. When full-scale mining operation is achieved, KEMET anticipates that the venture could ultimately provide up to 10% to 15% of its total annual tantalum requirements (KEMET Corp., 2000a; 2001).

Consumption

Overall U.S. reported consumption of columbium as ferrocolumbium and nickel columbium rose by almost 20% compared with that of 1999 (table 4). Consumption of columbium by the steelmaking industry increased by more than 10% as a result of an increase in raw steel production, with consumption up in all major reported steel end-use categories. Demand for columbium in superalloys increased significantly to more than 940 t, reflecting strong demand from the aerospace industry. That portion used in the form of nickel columbium increased to about 600 t. Overall U.S. apparent consumption of all columbium materials was estimated to be about 4,300 t, compared with about 4,100 t in 1999.

Estimated overall U.S. apparent consumption of all tantalum materials increased by more than 15% to about 650 t, owing to continued strong demand for tantalum powder for the production of tantalum capacitors. More than 60% of total tantalum consumed was in the electronics industry. Major end uses for tantalum capacitors included portable telephones, pagers, personal computers, and automotive electronics. Tantalum consumption was also affected by increased demand for tantalum-containing superalloys for jet engine and gas turbine components.

Columbium.—"Columbium" and "niobium" are synonymous names for the chemical element with atomic number 41; "columbium" was the name given in 1801, and "niobium" was the name officially designated by the International Union of Pure and Applied Chemistry in 1950. The metal conducts heat and electricity well and is characterized by a high melting point (about 2,470 C), resistance to corrosion, and ease of fabrication.

Columbium in the form of ferrocolumbium is used worldwide, mostly as an alloying element in steels and in superalloys. Because of its refractory nature, appreciable amounts of columbium in the form of high-purity ferrocolumbium and nickel columbium are used in nickel-, cobalt-, and iron-base superalloys for such applications as jet engine components, rocket subassemblies, and heat-resisting and combustion equipment. Columbium carbide is used in cemented carbides to modify the properties of the cobalt-bonded tungsten carbide-based material. It is usually used with carbides of such metals as tantalum and titanium. Columbium oxide is the intermediate product used in the manufacture of high-purity ferrocolumbium, nickel columbium, columbium metal, and columbium carbide. Acceptable substitutes, such as molybdenum, tantalum, titanium, tungsten, and vanadium, are available for some columbium applications, but substitution may lower performance and/or cost effectiveness.

Tantalum.—The major use for tantalum as tantalum metal powder is in the production of electronic components, mainly tantalum capacitors. The tantalum capacitor exhibits reliable performance and combines compactness and high efficiency with good shelf life. Applications for tantalum capacitors include computers, communication systems, and instruments and controls for aircraft, missiles, ships, and weapon systems. Because of its high melting point (about 3,000 C), good strength at elevated temperatures, and good corrosion resistance, tantalum is combined with cobalt, iron, and nickel to produce superalloys that are used in aerospace structures and jet engine components. Tantalum carbide, which is used mostly in mixtures with carbides of such metals as columbium, titanium, and tungsten, is used in cemented-carbide cutting tools, wear-resistant parts, farm tools, and turning and boring tools. Because of tantalum's excellent corrosion-resistant properties, tantalum mill and fabricated products are used in the chemical industry in such applications as heat exchangers, evaporators, condensers, pumps, and liners for reactors and tanks. Substitutes, such as aluminum, rhenium, titanium, tungsten, and zirconium, can be used in place of tantalum but are usually used at either a performance or economic penalty.

Prices

Published prices for pyrochlore concentrates produced in Brazil and Canada were not available because these concentrates were consumed internally by producers of regular-grade ferrocolumbium in Brazil and Canada and are no longer being exported. A price for Brazilian pyrochlore has not been available since 1981, and the published price for pyrochlore produced in Canada was discontinued in early 1989. The columbium price is affected most by the availability of regular-grade ferrocolumbium produced from pyrochlore. The American Metal Market published price for regular-grade ferrocolumbium ranged from $6.75 to $7 per pound of contained columbium and has not changed since September 1997.

The Metal Bulletin price for columbite ore, which is based on a minimum 65% contained columbium oxide (Nb_2O_5) and tantalum oxide (Ta_2O_5), quoted since February 1995 at a range of $2.80 to $3.20 per pound, rose to a range of $5.50 to $7 in late November, where it remained through December. The American Metal Market published price for high-purity (vacuum-grade) ferrocolumbium ranged from $17.50 to $18 per pound of contained columbium and has not changed since September 1997. Industry sources indicated in December 1999 that nickel columbium sold at about $18.50 per pound of contained columbium, columbium metal products sold in the range of about $24 to $100 per pound in ingot and special shape forms, and columbium oxide for master alloy production sold for about $8.80 per pound (Mining Journal, 1999a; Tantalum-Niobium International Study Center, 1999a, p. 5). Significant events affecting columbium prices since 1958 include the following: 1960-70, development of pyrochlore deposits in Brazil and Canada; 1970-79, increased demand and rising prices; 1980, columbium oxide produced from pyrochlore-based feed material; 1981, exports of Brazilian pyrochlore ceased; 1994, production of ferrocolumbium began in Canada; 1997-98, sales of ferrocolumbium from the NDS; and 1998, expansion of ferrocolumbium production capacity in Brazil (Cunningham, 1999a).

The price for tantalum products is affected most by events in the supply of and demand for tantalum minerals. During 2000, published prices for tantalite ore (per pound contained oxide) rose significantly: Platt's Metals Week, rose to a range of $145 to $175 from a range of $33 to $35; Metal Bulletin, rose to a range of $180 to $240 from a range of $28 to $31.50; and Ryan's Notes, rose to a range of $250 to $300 from a range of $45 to $48. Strong global demand and an apparent shortage of tantalum source materials for processing contributed to the price increase. In 2000, sales of tantalum minerals from the NDS averaged about $118 per pound contained tantalum oxide. In July 2001, published prices for tantalite ore (per pound contained oxide) were as follows: Platt's Metals Week, a range of $75 to $100; Metal Bulletin, a range of $55 to $75; Ryan's Notes, a range of $48 to $55. The decrease in price reportedly was due in part to excess tantalum inventories and a downturn in tantalum demand from the electronics sector. The Metal Bulletin published price for Greenbushes tantalite ore, Australia, was $40 per pound contained oxide and has not changed since April 1991. The most recent industry source (August 1999) on tantalum product prices indicated that the average selling prices per pound of contained tantalum for some tantalum products were as follows: capacitor-grade powder, $135 to $260; capacitor wire, $180 to $270; and vacuum-grade metal for superalloys, $75 to $100 (Mining Journal, 1999b). Presumably these prices increased in 2000, based on the escalating price for tantalum ore, but public information on prices for these products was not available. Significant events affecting tantalum prices since 1958 include the following: 1979-80, tantalum price accelerates to record levels; 1982, industry's accumulation of large tantalum material inventories; 1988, drawdown of tantalum material inventories by processors; 1990, purchase of tantalum materials for the NDS; 1991, long-term tantalum supply contracts between major producer and processors; and 1998, sales of tantalum minerals from the NDS (Cunningham, 1999b).

Foreign Trade

Table 5 lists columbium and tantalum export and import data. Net trade for columbium and tantalum continued at a deficit. Overall trade value for exports increased significantly with total volume down slightly. In descending order, Israel, the United Kingdom, Japan, Germany, and China were the major recipients of the columbium and tantalum materials, on the basis of value, with more than 80% of the total. For imports, overall trade value was up by about 35%, with total volume up by more than 10%. In descending order, Brazil, Japan, Australia, China, Germany, and Canada were the major sources of columbium and tantalum imports, on the basis of value, with more than 70% of the total.

Imports for consumption of columbium ores and concentrates increased by about 60% (table 6); imports from China accounted for more than 20% of quantity and value. Imports at an average grade of approximately 30% Nb_2O_5 and 31% Ta_2O_5 were estimated to contain about 30 t of columbium and about 40 t of tantalum. Ferrocolumbium and columbium oxide imports were down slightly; Brazil accounted for more than 80% of U.S. ferrocolumbium imports and about 40% of columbium oxide imports.

Imports for consumption of tantalum ores and concentrates increased twofold (table 7); imports from Australia accounted for more than 60% of quantity and about 55% of value. Imports at an average grade of approximately 37% Ta_2O_5 and 18% Nb_2O_5 were estimated to contain about 610 t of tantalum and about 270 t of columbium.

The schedule of tariffs applied during 2000 to U.S. imports of selected columbium and tantalum materials is found in the Harmonized Tariff Schedule of the United States—2000 (U.S. International Trade Commission, 1999). Brazil, which was the major source for U.S. columbium imports, accounted for about 68% of total, in units of contained columbium (figure 1), and Australia, which was the major source for U.S. tantalum imports, accounted for about 48% of total, in units of contained tantalum (figure 2).

Net import reliance as a percent of apparent consumption is used to measure the adequacy of current domestic columbium and tantalum production to meet U.S. demand. For columbium in 2000, net import reliance as a percent of apparent consumption was 100%. For tantalum, net import reliance as a percent of apparent consumption was estimated to be about 80%.

World Review

Industry Structure.—Principal world columbium and tantalum raw material and product producers are listed in tables 8 and 9, respectively. Annual world production of columbium and tantalum mineral concentrates, by country, is listed in table 10. Brazil and Canada were the major producers of columbium mineral concentrates, and Australia, Brazil, Canada, and Congo (Kinshasa) were the major producers of tantalum mineral concentrates. The importance of tantalum-containing tin slags as a source of tantalum supply has decreased owing to structural changes in the tin industry. Tantalum-containing tin slags account for about 18% of tantalum supply compared with about 70% 20 years ago (Mining Journal, 2000b; Tantalum-Niobium International Study Center, 1998, p. 2-6).

Australia.—For its 1999-2000 financial year ending June 30, 2000, Sons of Gwalia Ltd., West Perth, Western Australia, reported that tantalum production (tantalum oxide contained in mineral concentrates) totaled about 505 t at its Greenbushes and Wodgina Mines and that tantalum sales totaled about 500 t. Greenbushes production was about 315 t, and sales, about 314 t. Production at Wodgina was about 190 t, and sales, about 186 t. Existing "main production" at Greenbushes will be exhausted in 1993. Annual production capacity at Greenbushes is planned to be expanded from about 320 t to about 590 t. The existing processing facility will be expanded from about 1.6 million metric tons (Mt) of ore to more than 2.75 Mt. Preproduction capital cost for underground development at the mine, and capital cost for expansion of the existing processing facilities, total about $65 million. At Wodgina, annual production capacity will be increased over the next 2 years to more than 450 t, with plant processing capacity increasing to at least 2 Mt of ore. Capital cost for the Wodgina expansion will be approximately $35 million. By 2003, total company annual sales of contained tantalum oxide were expected to build to at least about 1,040 t. Forecast production increases from development of an underground operation at Greenbushes and the plant expansions at Greenbushes and Wodgina were expected within 3 years, with construction activities scheduled to commence in early 2001. Greenbushes existing production and the increased production from the Wodgina expansion were committed to Cabot Corp. and H.C. Starck of Germany under long-term contracts through to calender year 2005 (Sons of Gwalia Ltd., 2000, p. 7, 22-26).

In its quarterly report for March 31, 2001, Sons of Gwalia reported that Greenbushes tantalum "resource base" was about 44,000 t of contained tantalum oxide, including about 20,400 t classified as tantalum reserves. As a result of a successful drilling program, Wodgina's tantalum "resource base" doubled to about 27,200 t of contained tantalum oxide, including about 24,000 t classified as tantalum reserves (Sons of Gwalia Ltd., 2001, p. 9, 10).

Brazil.—Cia. Brasileira de Metalurgia e Mineração (CBMM), which was the world's largest columbium producer, completed its $80 million expansion program that was initiated in 1998. Annual columbium ore concentration capacity was increased to about 84,000 t of concentrate, and annual ferrocolumbium capacity increased to about 45,000 t. The new concentration plant uses a pyrometallurgical process, which replaced a leaching plant. In 2000, CBMM was expected to produce about 51,000 t of concentrate, about 30,000 t of ferrocolumbium, and about 2,000 t of columbium oxide for use in the aerospace industry. In 1999, CBMM reportedly produced about 40,000 t of concentrate and about 25,000 t of ferrocolumbium. For 2001, CBMM planned to increase concentrate output to about 55,000 t and to increase ferrocolumbium output to about 33,000 t. CBMM was said to export 95% of its ferrocolumbium production, mostly to Europe and North America, 35% each, and to Japan, 16% (American Metal Market, 2000; TEX Report, 2000).

Canada.—Production of columbium oxide contained in pyrochlore concentrate at the Niobec Mine near Chicoutimi, Quebec, was about 3,270 t compared with about 3,370 t in 1999. Niobec was a 50-50 joint venture between Cambior Inc. (product marketing), and Teck Corp. (operator). Columbium contained in ferrocolumbium production was about 2,170 t compared with about 2,290 t in 1999. Pyrochlore-to-ferrocolumbium converter recovery was 96.2% compared with 97.1% in 1999. Ore milled increased to 907,000 t as the mill operated, on the average, at about 2,480 metric tons per day. Average recovery decreased to 54.6%, with the Nb_2O_5 grade of concentrate at 66%. Operating cost, dollars per metric ton of ore milled, was about $37.30 compared with about $36.10 in 1999. Capital expenditures were $9 million, including $7 million for expansion of mill and converter capacities. For 2001, capital costs were forecast at $3 million, including $2 million for underground development and equipment. Teck reported proven and probable ore reserves of 11.5 Mt grading 0.51% columbium. In November, Teck reached an agreement to sell its 50% interest in Niobec to Mazarin Inc., Quebec, for $47 million. The transaction was expected to be closed in the first half of 2001, with Teck expecting to record a pretax gain of $25 million on the sale (Cambior Inc., 2001, p. 11; Teck Corp., 2001, p. 24, 32, 58). As part of its financial restructuring, Cambior entered into an agreement with Jipangu Inc., a Japanese investment company, and a financial institution for a mortgage loan on its 50% interest in Niobec for $13 million. The term was for 4.5 years repayable in 16 consecutive quarterly installments commencing on March 30, 2001, with a maturity date of December 31, 2004. The mortgage was secured by Cambior's 50% interest in Niobec and its share of the cash flow generated by the mine. On January 18, 2001, Jipangu agreed to a $6.3 million private placement to subscribe to 15 million common shares of Cambior at a price of $0.42 per share, with proceeds from the private placement used to repay in part Jipangu's mortgage loan (Cambior Inc., 2001, p. 24, 25, 37).

In 2000, about 69 t of tantalum oxide contained in concentrate was produced at the Bernic Lake, Manitoba, tantalum operation, compared with about 66 t in 1999.

In October, it was reported that Avalon Ventures Ltd., Toronto, had finalized a joint-venture agreement with Global Canada Co., a private Nova Scotia company controlled by BSAV Inc., a private Delaware company. Global would have the right to earn up to 75% interest in any of Avalon's Canadian tantalum exploration properties, Lilypad Lakes, Raleigh Lake, and East Braintree. Global would have the right to earn an initial 50% interest in any of the properties by providing $5 million in exploration and development funding before December 31, 2002, or upon delivery of a feasibility study. The interest in any one property could be increased to 75% by Global arranging financing to bring a tantalum mine into production. Initial commitment by Global was to provide $1 million to fund work programs on the properties and to provide working capital. The program had a budget of $750,000 to be spent by December 31, 2000. Avalon would be the operator of the exploration programs, and Global would have the right to participate in any other tantalum exploration properties acquired by Avalon in Canada. Lilypad Lakes near Pickle Lake, Ontario, had top priority with a program budget of $580,000. A preliminary diamond drilling program completed in April intersected tantalum mineralization occurrences averaging 0.05 % Ta_2O_5 across 11.5 meters (m), 0.036% Ta_2O_5 across 24 m, and 0.076% Ta_2O_5 across 7 m. In addition, a surface program involving mapping, sampling, lithogeochemistry, and a gravity survey discovered a new high-grade tantalum occurrence. Assays of 10 random samples indicated tantalum ranging from 0.131% to 0.422% Ta_2O_5. A minimum 1,100-m diamond drilling program was scheduled to begin on the property in November (Avalon Ventures Ltd., 2000a, b; Skillings Mining Review, 2000).

China.—China's Jiujiang Nonferrous Metals Smelter, eastern Jiangxi Province, completed an upgrade to its tantalum production line which increased annual production capacity to about 20 t from 2 t to 3 t. Existing production ceased in January and new production started in mid-August. However, owing to raw material shortages, output was expected to reach only about 4 t by January 2001. Jiujiang's annual columbium production capacity was about 20 t, with output in 2000 expected to be about 15 t. Annual production capacity for tantalum oxide and columbium oxide was about 100 t and 300 t, respectively, with tantalum oxide output in 2000 expected to be about 70 t and columbium oxide output about 100 t. In 1999, tantalum oxide output was about 60 t and columbium oxide output about 100 t (Platt's Metals Week, 2000).

Congo (Kinshasa).—In June, the President of the Security Council, United Nations, requested the Secretary-General to establish a panel of experts on the illegal exploitation of natural resources and other forms of wealth of the Democratic Republic of the Congo for a period of 6 months. The report of the panel was transmitted to the President on April 12, 2001. The panel's recommendations revolved around six broad themes: "(1) sanctions against countries and individuals involved in the illegal activities; (2) preventive measures to avoid a recurrence of the current situation; (3) reparations to the victims of the illegal exploitation of natural resources; (4) design of a framework for reconstruction; (5) improvement of international mechanisms and regulations governing some natural resources; and (6) security issues." Categories that were of primary consideration included coltan (columbium and tantalum). Some of the panel's recommendations for Security Council action included an immediate temporary embargo on the import or export of coltan and pyrochlore; the freezing of financial assets of the rebel movements and their leaders; the freezing of financial assets of the companies or individuals who continue to participate in the illegal exploitation of the natural resources of the Congo immediately after publication of the report; and the declaration of an immediate embargo on supply of weapons and all military material to rebel groups operating in Congo (United Nations, 2001).

Greenland.—Angus and Ross plc, a United Kingdom company with tantalum interest in Ireland, received a licence from the Greenland Government for rights to explore for tantalum in southern Greenland centered in an area 20 kilometers east of the southern capitol of Narsarsuaq. The area of interest is the Motzfeld Centre, an alkaline igneous ring complex, with pyrochlore the most important economic mineral phase. Data suggest that resources could be about 50 Mt of ore grading in the range of 0.03% to 0.1% Ta_2O_5, and about 130 Mt of ore grading in the range of 0.4% to 1% Nb_2O_5, with some zones in the range of 1% to 1.5% Nb_2O_5. Mineralogy of the area was said to be complex and mineral processing problems remain to be addressed (Mining Journal, 2000a).

Japan.—In 2000, Japan's demand for tantalum was about 552 t; powder, 269 t; compounds, 157 t; and products, 126 t. Demand for tantalum powder was met by imports from China, Thailand, the United States, and domestic production from imported potassium fluotantalate. Imports of potassium fluotantalate totaled about 1,140 t, sufficient for the production of about 378 t of tantalum powder. Production of tantalum powder for the electronics sector was about 386 t. Demand for tantalum wire used in tantalum capacitors was met entirely by imports, about 68 t, mostly from the United States. Tantalum imports (powder, compounds, and products) in 2000 were about 139 t compared with about 98 t in 1999. In 2000, apparent consumption of tantalum powder, wire, and products was 269 t, 69 t, and 57 t, respectively. In 2001, tantalum demand is forecast to fall to about 462 t; powder, 225 t; compounds, 127 t; and products, 110 t (Roskill's Letter from Japan, 2001b). Tantalum scrap imported for the production of tantalum powder, compounds, and products was about 203 t; Portugal, the United Kingdom, and the United States accounted for about 75% of the imports. In 2000, Japan's production of tantalum capacitors totaled about 8.67 billion units compared with about 6.54 billion units in 1999. Tantalum capacitor exports in 2000 were about 3.24 billion units compared with about 2.56 billion units in 1999 (Roskill's Letter from Japan, 2001a).

Russia.—At yearend 1999, the Chita region made a decision to join a federal program named Libton for the creation of a scientific production center for rare metals, including tantalum, in the Trans-Baikal region. The Chita region and TVEL, a producer and supplier of nuclear fuel controlled by the Russian Ministry of Atomic Energy, signed an agreement on liaison with the Priargunsky Mining and Chemicals Production Association, a uranium producer controlled by TVEL, and the Zabaikalsky Mining and Beneficiation Plant, a rare metal producer. The Ministry was to finance the program and coordinate efforts by Priargunsky and Zabaikalsky to produce materials for the nuclear sector (Interfax International, Ltd., 2000).

Outlook

Columbium.—The principal use for columbium will continue as an additive in steelmaking, mostly in the manufacture of microalloyed steels used for pipelines, bridges, automobiles, etc. The production of high-strength low-alloy steel is the leading use for columbium, and the trend for columbium demand, domestically and globally, will continue to follow closely that of steel production (see the Outlook section of the Iron and Steel chapter for a discussion of the future of the steel industry). The October 2000 medium-term forecast of the International Iron and Steel Institute projected an annual growth rate in steel consumption between 2000 and 2005 for the world of 2%; the North American Free Trade Agreement countries, 0.9%; European Union countries, 0.8%; China, 3.8%; and total Asian countries, 2.6%. Japan was the only major steel consumer where steel usage was expected to fall, by about 1% (Ian Christmas, Secretary General, International Iron and Steel Institute, October 3, 2000, IISI survey reveals renewed world steel consumption growth, annual report of the Secretary General, accessed June 1, 2001, at URL http://www.worldsteel.org/trends_indicators/demand.html).

The outlook for columbium also will be dependent on the performance of the aerospace industry and the use of columbium-bearing alloys in it. Columbium consumption in the production of superalloys, which is the second largest end use for columbium, will be most dependent on the market for aircraft engines. Because nickel-base superalloys (such as alloy 718, which contains about 5% columbium) can account for about 40% to 50% of engine weight, they are expected to be the materials of choice for the future owing to their high temperature operating capability (Tantalum-Niobium International Study Center, 1999b). The Aerospace Industries Association (2001, p. 3) forecast that U.S. aerospace industry sales will rise to $145 billion in 2001 from $144 billion in 2000 owing to the strength of Department of Defense increases.

The majority of U.S. demand for columbium units will continue to be met by imports. Brazil will continue as the leading source for U.S. imports of columbium, and Canada will also be a major source of supply.

Tantalum.—U.S. apparent consumption of tantalum totaled about 650 t in 2000 compared with about 555 t in 1999. More than 60% of the tantalum consumed was used to produce electronic components, mainly tantalum capacitors. This market sector is expected to be stimulated by the growth in the use of cellular telephones; each phone may contain from 10 to 20 capacitors (Mining Journal, 2000b). Tantalum consumption in superalloys, mostly in the aircraft industry, is expected to grow by about 3% per year. Tantalum carbide in the metal cutting industry and tantalum in the chemical processing industry will be dependent on the growth of the general economy, and both are expected to grow at an estimated 2% per year (Tantalum-Niobium International Study Center, 1998).

In 2000, world tantalum supply was estimated to be about 1.8 Mt of contained tantalum. For 2001, world tantalum supply was projected to be about 2.1 Mt of contained tantalum. World tantalum supply will come mostly from Australia, Brazil, Canada, China, Southeast Asia, and certain African countries (including Burundi, Congo (Kinshasa), Ethiopia, Mozambique, Nigeria, Rwanda, Uganda, and Zimbabwe) (Tantalum-Niobium International Study Center, 2001). Another important component of world supply is the U.S. Government sales of tantalum materials from the NDS. As of June 30, 2001, tantalum materials authorized for disposal from the NDS totaled about 910 t of contained tantalum, including about 860 t contained in tantalum minerals.

References Cited

Aerospace Industries Association Update, 2001, AIA projects rise in aerospace sales: Aerospace Industries Association Update, v. 5, no. 7, January-February, 7 p.

American Metal Market, 2000, New plant allows CBMM to hike ferrocolumbium yield: American Metal Market, v. 108, no. 117, June 19, p. 12.

Avalon Ventures, Ltd., 2000a, Drilling set to begin at Lilypad Lakes tantalum project, Pickle Lake, Ontario: Toronto, Avalon Ventures, Ltd. news release, November 13, 1 p.

———2000b, Funding arranged and new work program initiated on Avalon's three tantalum exploration projects: Toronto, Avalon Ventures, Ltd. news release, September 11, 2 p.

Cambior Inc., 2001, Annual report—2000: Longueuil, Quebec, Cambior Inc., 64 p.

Cunningham, L.D., 1999a, Columbium (Niobium), *in* Plunkert, P.A., and Jones, T.S., comps., Metal prices in the United States through 1998: U.S. Geological Survey, p. 35-38.

———1999b, Tantalum, *in* Plunkert, P.A., and Jones, T.S., comps., Metal prices in the United States through 1998: U.S. Geological Survey, p. 143-145.

Defense National Stockpile Center, 2001a, FY 2001 revised Annual Materials Plan and FY 2002 Annual Materials Plan sent to Congress: Fort Belvoir, VA, Defense National Stockpile Center news release, February 22, 4 p.

———2001b, Revised FY 2001 Annual Materials Plan: Fort Belvoir, VA, Defense National Stockpile Center news release, April 9, 2 p.

Interfax International, 2000, TVEL completes mine construction at tantalum deposit: Mining & Metals Report, v. 9, issue 40 (445), September 29-October 5, p. 15, 16.

KEMET Corp., 2000a, KEMET announces joint venture with Australasian Gold Mines NL: Greenville, SC, KEMET Corp. news release, November 15, 1 p.

———2000b, KEMET to add an additional 85,000 square feet for the manufacture of tantalum surface-mount capacitors: Greenville, SC, KEMET Corp. news release, July 26, 1 p.

———2001, KEMET completes joint venture agreement with Australasian Gold Mines NL: Greenville, SC, KEMET Corp. news release, February 6, 1 p.

Mining Journal, 1999a, Niobium: Mining Journal, Steel Industry Metals Annual Review Supplement, v. 333, no. 8543, August 6, p. 78.

———1999b, Tantalum: Mining Journal, Speciality Metals Annual Review Supplement, v. 333, no. 8544, August 13, p. 89.

———2000a, Greenland tantalum venture: Mining Journal, v. 334, no. 8569, February 11, p. 113.

———2000b, Tantalum comes of age: Mining Journal, v. 334, no. 8583, May 19, p. 391, 393.

Platt's Metals Week, 2000, China tantalum expansion complete: Platt's Metals Week, v. 71, no. 36, p. 13.

Roskill's Letter from Japan, 2001a, Tantalum—Powder prices rise by 60%: Roskill's Letter from Japan, no. 297, May, p. 10-12.

———2001b, Tantalum—Slow-down in demand forecast for 2001 following two years of growth: Roskill's Letter from Japan, no. 298, June, p. 3-6.
Skillings Mining Review, 2000, Avalon in tantalum JV agreement: Skillings Mining Review, v. 89, no. 43, October 21, p. 17.
Sons of Gwalia Ltd., 2000, Annual report—2000: West Perth, Western Australia, Sons of Gwalia Ltd., 79 p.
———2001, Quarterly report for three months ending 31 March 2001: West Perth, Western Australia, Sons of Gwalia Ltd., 15 p.
Tantalum-Niobium International Study Center, 1998, Tantalum supply and demand: Tantalum-Niobium International Study Center, no. 96, December, 12 p.
———1999a, Overview of the tantalum and niobium industries for 1998 and 1999: Tantalum-Niobium International Study Center, no. 100, December, 12 p.
———1999b, Technical and commercial development of the European niobium market: Tantalum-Niobium International Study Center, no. 98, June, 8 p.
———2001, Tantalum—Raw material supply: Tantalum-Niobium International Study Center, no. 105, March, 8 p.
Teck Corp., 2001, Annual report—2000: Vancouver, Teck Corp., 82 p.
TEX Report, 2000, CBMM/Brazil completes capacity expansion for niobium in May: TEX Report, v. 32, no. 7541, April 26, p. 1.
United Nations, 2001, Letter dated 12 April 2001 from the Secretary-General to the President of the Security Council: United Nations, Security Council, 56 p.
U.S. Customs Service, 2000, Renewal of the Generalized System of Preferences: Federal Register, v. 65, no. 42, March 2, p. 11367, 11368.
U.S. Department of Defense, 2001, Strategic and critical materials report to the Congress—Operations under the Strategic and Critical Materials Stock Piling Act during the period October 1999 through September 2000: Washington, DC, U.S. Department of Defense, 54 p.
U.S. International Trade Commission, 1999, Harmonized tariff schedule of the United States—2000: Washington, DC, U.S. Government Printing Office, U.S. International Trade Commission Publication 3249, variously paginated and unpaginated.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Columbium (niobium) and tantalum. Chs. in Mineral Commodity Summaries, annual.
Columbium (niobium) and tantalum. Ch. in Minerals Yearbook, annual.
Columbium (niobium) and tantalum. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
Columbium (niobium) and tantalum. Mineral Industry Surveys, annual.
Niobium (columbium) and tantalum. International Strategic Minerals Inventory Summary Report, Circular 930-M, 1993.

Other

Aerospace Industries Association.
American Metal Market, daily.
Chemical and Engineering News, weekly.
Columbium (niobium). Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Company annual reports.
Defense National Stockpile Center stockpile reports and news releases.
Electronic Industries Alliance.
Engineering and Mining Journal, monthly.
Federal Register, daily.
Metal Bulletin (London), semiweekly and monthly.
Metal Bulletin Books Ltd.:
  Ferroalloy Directory and Data Book, 5th ed., 1998.
  Ores & Alloys for the Global Steel Industry, 2000.
Mining Journal (London), weekly.
Platt's Metals Week, weekly.
Roskill Information Services Ltd. Reports (London):
  The Economics of Niobium, 8th ed., 1998.
  The Economics of Tantalum, 7th ed., 1999.
Roskill's Letter from Japan, monthly.
Ryan's Notes, weekly.
Skillings Mining Review.
Tantalum. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Tantalum-Niobium International Study Center (Brussels):
  International Symposium-Proceedings.
  Quarterly Bulletin.
The Northern Miner.
The TEX Report (Tokyo: daily issues and annual ferroalloy manual).

TABLE 1
SALIENT COLUMBIUM STATISTICS 1/

(Metric tons of columbium content unless otherwise specified)

	1996	1997	1998	1999	2000
United States:					
Government Stockpile Releases 2/	30	126	145	280	217
Production of ferrocolumbium	NA	NA	NA	NA	NA
Exports: Columbium metal, compounds, alloys (gross weight)	NA	NA	NA	NA	NA
Imports for consumption:					
Mineral concentrates e/	285	220	200	140	300
Columbium metal and columbium-bearing alloys e/	322	423	563	468	607
Columbium oxide	630	1,220	860	1,200	1,190
Ferrocolumbium e/	2,970	4,260	4,900	4,450	4,400
Tin slag	NA	NA	NA	NA	NA
Consumption:					
Raw materials	NA	NA	NA	NA	NA
Ferrocolumbium and nickel columbium e/	3,380	3,770	3,640	3,460 r/	4,090
Apparent e/	3,830 r/	4,030 r/	4,150 r/	4,100 r/	4,300
Prices:					
Columbite, dollars per pound 3/	$3.00	$3.00	$3.00	$3.00	$6.25
Pyrochlore, dollars per pound 4/	NA	NA	NA	NA	NA
World production of columbium-tantalum concentrates e/	16,200	20,600 r/	26,200	32,600 r/	32,600

e/ Estimated. r/ Revised. NA Not available.

1/ Data are rounded to no more than three significant digits, except prices.

2/ Net quantity (uncommited inventory).

3/ Yearend average value, contained pentoxides for material having a columbium pentoxide to tantalum pentoxide ratio of 10 to 1.

4/ Yearend average value, contained pentoxide.

TABLE 2
SALIENT TANTALUM STATISTICS

(Metric tons of tantalum content unless otherwise specified)

	1996	1997	1998	1999	2000
United States:					
Government Stockpile Releases 1/	34	20	213 r/	5 r/	242
Exports:					
Tantalum ores and concentrates (gross weight) 2/	53	91	389	299	263
Tantalum metal, compounds, alloys (gross weight)	342	396	423	460	460
Tantalum and tantalum alloy powder (gross weight)	26	58	61	90	108
Imports for consumption:					
Mineral concentrates e/	360	280	380	320	650
Tantalum metal and tantalum-bearing alloys 3/	203	187	208	244	251
Tin slag	NA	NA	NA	NA	NA
Consumption:					
Raw materials	NA	NA	NA	NA	NA
Apparent e/	524 r/	570 r/	738 r/	555 r/	650
Prices:					
Tantalite, dollars per pound 4/	$27.75	$33.00 r/	$34.00 r/	$34.00	$160.00
World production of columbium-tantalum concentrates e/	436 r/	492 r/	571 r/	569 r/	836

e/ Estimated, r/ Revised. NA Not available.

1/ Net quantity (uncommited inventory).

2/ Includes reexports.

3/ Exclusive of waste and scrap.

4/ Yearend average value, contained pentoxides.

TABLE 3
COLUMBIUM AND TANTALUM MATERIALS IN GOVERNMENT
INVENTORIES AS OF DECEMBER 31, 2000 1/

(Metric tons of columbium or tantalum content)

			National Defense Stockpile inventory			
			Uncommitted			
Material	Stockpile goals	Disposal authority	Stockpile-grade	Nonstockpile-grade	Total	Committed
Columbium:						
Concentrates	--	528	285	244	528	138
Carbide powder	--	10	10	--	10	--
Ferrocolumbium	--	52	52	--	52	37
Metal ingots	--	46	46	--	46	9
Total	--	636	392	244	636	185
Tantalum:						
Minerals	--	778	453	325	778	198
Carbide powder	--	6	6	--	6	2
Metal:						
Capacitor grade	(2/)	23	39	(3/)	39	--
Ingots	(2/)	12	67	--	67	15
Oxide	--	37	37	--	37	--
Total	71 2/	856	601	325	926	215

-- Zero.

1/ Data may not add to totals shown because of independent rounding.

2/ Goals as of October 5, 1999; about 16 tons for tantalum metal powder, and about 55 tons for tantalum metal.

3/ About 60 kilograms.

Source: Defense National Stockpile Center.

TABLE 4
REPORTED CONSUMPTION, BY END USE, AND INDUSTRY STOCKS OF
FERROCOLUMBIUM AND NICKEL COLUMBIUM
IN THE UNITED STATES 1/

(Metric tons of contained columbium)

End use	1999	2000
Steel:		
Carbon	1,270	1,370
Stainless and heat-resisting	603	682
Full alloy	(2/)	(2/)
High-strength low-alloy	938 r/	1,090
Electric	(2/)	(2/)
Tool	(2/)	(2/)
Unspecified	--	--
Total	2,810 r/	3,140
Superalloys	641 r/	942
Alloys (excluding alloy steels and superalloys)	(3/)	(3/)
Miscellaneous and unspecified	9	10
Grand total	3,460 r/	4,090
Stocks, December 31:		
Consumer	NA	NA
Producer 4/	NA	NA
Total	NA	NA

r/ Revised. NA Not available. -- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Included with "Steel: High-strength low alloy."

3/ Included with "Miscellaneous and unspecified."

4/ Ferrocolumbium only.

TABLE 5

U.S. FOREIGN TRADE IN COLUMBIUM AND TANTALUM METAL AND ALLOYS, BY CLASS 1/

Class	1999 Gross weight (metric tons)	1999 Value (thousand dollars)	2000 Gross weight (metric tons)	2000 Value (thousand dollars)	Principal destinations and sources, 2000 (gross weight, metric tons, thousand dollars)
Exports: 2/					
Columbium:					
Ores and concentrates	12	566	55	830	Germany 30, $293; Belgium 2, $218; Switzerland 4, $131; Korea, Republic of 7, $51; Japan 5, $51; China 4, $43.
Ferrocolumbium	166	1,110	60	526	Mexico 51, $408; United Kingdom 6, $96; Canada 3, $22.
Tantalum:					
Synthetic concentrates	18	129	91	174	Japan 14, $101; Venezuela 18, $33; Hong Kong 57, $28; Germany 1, $10; Hungary 1, $3.
Ores and concentrates	299	7,150	263	11,400	China 218, $10,000; Kazakhstan 7, $823; Netherlands 13, $290; Brazil 23, $244; France 1, $17; Japan 1, $13.
Unwrought and waste and scrap	233	11,100	198	16,000	United Kingdom 35, $4,280; Germany 31, $3,380; Austria 12, $1,930; China 15, $1,850; Hong Kong 86, $1,670; Australia 6, $1,280.
Unwrought powders	90	31,900	108	43,100	Israel 88, $36,900; Germany 6, $2,140; Japan 4, $1,630; Austria 5, $1,030; France 2, $565; United Kingdom 1, $332; Sweden 1, $311.
Unwrought alloys and metal	95	22,000	123	40,100	United Kingdom 36, $18,300; Isreal 55, $14,800; France 17, $2,740; Germany 5, $2,110; Barbados 2, $771; Brazil 2, $707.
Wrought	132	43,500	139	47,500	Japan 52, $20,500; Germany 32, $11,000; United Kingdom 10, $5,080; France 10, $2,840; Sweden 3, $1,180; Canada 4, $855.
Total	XX	118,000	XX	160,000	Israel $52,400; United Kingdom $28,100; Japan $22,400; Germany $18,900; China $12,800; France $6,170; Austria $3,580; Hong Kong $1,730.
Imports for consumption:					
Columbium:					
Ores and concentrates	95	1,620	151	1,680	China 117, $1,320; Beligium 9, $155; Brazil 17, $154; Nigeria 7, $47; Germany 1, $3.
Oxide	1,720	30,600	1,700	29,200	Brazil 682, $10,600; Germany 203, $7,610; China 335, $4,180; Russia 244, $3,620; Estonia 190, $2,510; Japan 30, $480.
Ferrocolumbium	6,850	62,200	6,770	62,100	Brazil 5,660, $50,500; Canada 928, $9,650; France 126, $1,000; Germany 55, $901.
Unwrought alloys, metal and powder	468	13,500	606	16,900	Brazil 249, $6,440; Estonia 153, $5,790; Germany 157, $3,490; China 38, $641; Kazakhstan 8, $316; Canada 1, $168.
Tantalum:					
Ores and concentrates	992	33,600	2,080	74,800	Australia 1,280, $41,600; Nigeria 287, $15,800; Canada 178, $6,940; Congo (Kinshasa) 3/ 167, $4,720; Rwanda 68, $2,180; Ethiopia 21, $2,020; China 48, $828.
Unwrought waste and scrap	809	14,500	853	31,400	United Kingdom 268, $10,300; Austria 36, $4,210; Japan 87, $3,410; Taiwan 54, $2,380; Israel 230, $2,190; China 52, $2,140; Kazakhstan 16, $1,520.
Unwrought powders	165	49,800	177	66,900	Japan 64, $36,300; Thailand 57, $15,300; China 47, $13,200; Germany 9, $1,930; France 1, $250; United Kingdom (4/), $31.
Unwrought alloys and metal	23	4,110	31	5,610	Kazakhstan 19, $2,430; Germany 8, $2,200; Russia 1, $246; Canada 1, $226; Brazil 1, $118; China (4/), $114.
Wrought	56	13,000	43	14,900	China 32, $9,590; Japan 5, $2,820; Germany 1, $767; Austria 1, $404; Canada 2, $398; United Kingdom (4/), $260.
Total	XX	223,000	XX	303,000	Brazil $67,800; Japan $43,200; Australia $41,600; China $32,000; Germany $18,300; Canada $17,400; Nigeria $15,800; Thailand $15,300.

XX Not applicable.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ For columbium, data on exports of metal and alloys in unwrought and wrought form, including waste and scrap, are not available; included in nonspecific tariff classification.

3/ Formerly Zaire.

4/ Less than 1/2 unit.

Sources: U.S. Census Bureau and U.S. Geological Survey.

TABLE 6

U.S. IMPORTS FOR CONSUMPTION OF COLUMBIUM ORES AND CONCENTRATES, BY COUNTRY 1/

Country	1999 Gross weight (metric tons)	1999 Value (thousand dollars)	2000 Gross weight (metric tons)	2000 Value (thousand dollars)
Belgium 2/	--	--	9	155
Brazil	--	--	17	154
China	75	1,320	117	1,320
Germany 2/	--	--	1	3
Nigeria	--	--	7	47
Russia	20	291	--	--
Total	95	1,620	151	1,680

-- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Presumably country of transshipment rather than original source.

Sources: U.S. Census Bureau and U.S. Geological Survey.

TABLE 7

U.S. IMPORTS FOR CONSUMPTION OF TANTALUM ORES AND CONCENTRATES, BY COUNTRY 1/

Country	1999 Gross weight (metric tons)	1999 Value (thousand dollars)	2000 Gross weight (metric tons)	2000 Value (thousand dollars)
Australia	597	20,100	1,280	41,600
Belgium 2/	--	--	4	62
Bolivia	11	395	1	45
Burundi	7	186	--	--
Canada	173	6,440	178	6,940
China	3	206	48	828
Congo (Kinshasa) 3/	81	2,000	167	4,720
Ethiopia	20	1,540	21	2,020
Nigeria	8	549	287	15,800
Russia	--	--	1	86
Rwanda	59	1,270	68	2,180
South Africa	--	--	1	23
Tanzania	9	169	15	377
Uganda	24	645	5	140
United Kingdom 2/	(4/)	17	--	--
Total	992	33,600	2,080	74,800

-- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Presumably country of transshipment rather than original source.

3/ Formerly Zaire.

4/ Less than 1/2 unit.

Sources: U.S. Census Bureau and U.S. Geological Survey.

TABLE 8
PRINCIPAL WORLD COLUMBIUM AND TANTALUM RAW MATERIAL PRODUCERS

Country	Company and/or mine	Material type
Mining of columbium- and tantalum-bearing ores:		
Australia	Sons of Gwalia Ltd. (Greenbushes)	Columbium-tantalum.
	Sons of Gwalia Ltd. (Wodgina)	Tantalum.
Brazil	Cia. Brasileira de Metalurgia e Mineracao (CBMM) (Araxa)	Columbium.
	Cia. de Estanho Minas Brasil (MIBRA) 1/	Columbium-tantalum.
	Paranapanema S.A. Mineracao Indústria e Construcao (Pitinga)	Columbium-tantalum.
	Mineracao Catalao de Goias S.A. (Catalao)	Columbium.
Canada	Cambior Inc., and Teck Corp. (Niobec)	Columbium.
	Tantalum Mining Corp. of Canada Ltd. (Tanco) 2/	Tantalum.
China	Government-owned	Columbium-tantalum.
Production of columbium- and tantalum-bearing tin slags:		
Australia	Sons of Gwalia Ltd. (Greenbushes)	Columbium-tantalum.
Brazil	Cia. Industrial Fluminense 1/	Columbium-tantalum.
	Mamoré Mineracao e Metalurgia 3/	Columbium-tantalum.
Thailand	Thailand Smelting and Refining Co. Ltd. (Thaisarco)	Columbium-tantalum.
Production capacity for columbium- and tantalum-bearing synthetic concentrates: Germany: Western States	H.C. Starck GmbH & Co. KG	Columbium-tantalum.

1/ A wholly owned subsidiary of Metallurg Inc., New York, NY.
2/ A wholly owned subsidiary of Cabot Corp.
3/ A subsidiary of Paranapanema S.A. Mineracao Indústria e Construcao.

TABLE 9
PRINCIPAL WORLD PRODUCERS OF COLUMBIUM AND TANTALUM PRODUCTS

Country	Company	Products 1/
Austria	Treibacher Industrie AG	Nb and Ta oxide/carbide, FeNb, NiNb.
Brazil	Cia. Brasileira de Metalurgia e Mineracao (CBMM)	Nb oxide/metal, FeNb, NiNb.
	Cia. Industrial Fluminense 2/	Nb and Ta oxide.
	Mineracao Catalao de Goias S.A. (Catalao)	FeNb.
Canada	Cambior Inc., and Teck Corp. (Niobec)	FeNb.
Estonia	Silmet	Nb oxide/metal.
Germany: Western States	Gesellschaft Fur Elektrometallurgie mbH (GFE) 2/	FeNb, NiNb.
	H.C. Starck GmbH & Co. KG	Nb and Ta oxide/metal/carbide, K-salt, FeNb, NiNb, Ta capacitor powder.
Japan	Mitsui Mining & Smelting Co.	Nb and Ta oxide/metal/carbide.
	Showa Cabot Supermetals 3/	Ta capacitor powder.
	H.C. Starck-V Tech Ltd. 4/	Ta capacitor powder.
Kazakhstan	Ulba Metallurgical	Ta oxide/metal.
	Irtysh Chemical & Metallurgical Works	Nb oxide/metal.
Russia	Solikamsk Magnesium Works	Nb and Ta oxide.
Thailand	H.C. Starck (Thailand) Co. Ltd. 4/	K-salt, Ta metal.
United States	Cabot Performance Materials	Nb and Ta oxide/metal, K-salt, Ta capacitor powder.
	H.C. Starck Inc. 5/	Nb and Ta metal, Ta capacitor powder.
	Kennametal Inc.	Nb and Ta carbide.
	Reading Alloys Inc.	FeNb, NiNb.
	Shieldalloy Metallurgical Corp. 2/	FeNb.
	Wah Chang 6/	Nb metal, FeNb.

1/ Nb, columbium; Ta, tantalum; FeNb, ferrocolumbium; NiNb, nickel columbium; K-salt, potassium fluotantalate; oxide, pentoxide.
2/ A wholly owned subsidiary of Metallurg Inc., New York.
3/ A joint venture between Showa Denko and Cabot Corp.
4/ A subsidiary of H.C. Starck GmbH & Co. KG.
5/ Jointly owned by Bayer Corp. and H.C. Starck GmbH & Co. KG.
6/ A subsidiary of Allegheny Technologies Inc.

TABLE 10

COLUMBIUM AND TANTALUM: ESTIMATED WORLD PRODUCTION OF MINERAL CONCENTRATES, BY COUNTRY 1/ 2/

(Metric tons)

	Gross weight 3/					Columbium content 4/					Tantalum content 4/				
Country 5/	1996	1997	1998	1999	2000	1996	1997	1998	1999	2000	1996	1997	1998	1999	2000
Australia: Columbite-tantalite	920	1,010	1,150	1,230	1,600	112	125	140	140	160	276	302	330	350	485
Brazil:															
Columbite-tantalite	190	190	330	330	330	45	45	70	70	70	55	55	90	90	90
Pyrochlore	32,600	42,900	56,200	71,200 r/	71,400	13,700	18,000	23,600	29,900 r/	30,000	--	--	--	--	--
Burundi	37	46	30	42	42	NA	NA	NA	NA	NA	9	11	7	10	10
Canada:															
Pyrochlore	5,160	5,090	5,110	5,240	5,070	2,320	2,290	2,300	2,360	2,280	--	--	--	--	--
Tantalite	220	196	228	208	228	11	10	11	10	11	55	49	57	54 r/	57
Congo (Kinshasa):															
Columbite-tantalite	NA r/	NA r/	NA r/	NA r/	450	NA r/	NA r/	NA r/	NA r/	NA	NA r/	NA r/	NA r/	NA r/	130
Ethiopia: Tantalite	20	20	40	50	65	2	2	4	5	7	12	12	24	29	38
Nigeria: Columbite	57 6/	60	70	70	80	23	23	30	30	35	3	3	3	3	4
Rwanda	97	224	224	122	83	33	76	76	42	28	26	60	60	33	22
Total	39,300 r/	49,700 r/	63,400 r/	78,500 r/	79,300	16,200	20,600 r/	26,200	32,600 r/	32,600	436 r/	492 r/	571 r/	569 r/	836

r/ Revised. NA Not available. -- Zero.

1/ World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Excludes columbium- and tantalum-bearing tin ores and slags. Production of tantalum contained in tin slags was, in metric tons: 1996--82; 1997--40; 1998-2000--NA according to data from the Tantalum-Niobium International Study Center. Table includes data available through July 9, 2001.

3/ Data on gross weight generally have been presented as reported in official sources of the respective countries, divided into concentrates of columbite, tantalite, and pyrochlore where information is available to do so, and reported in groups, such as columbite and tantalite, where it is not.

4/ Unless otherwise specified, data presented for metal content are estimates based on, in most part, reported gross weight and/or pentoxide content.

5/ In addition to the countries listed, Bolivia, China, Russia, and Zambia also produce, or are believed to produce, columbium and tantalum mineral concentrates, but available information is inadequate to make reliable estimates of output levels.

6/ Reported figure.

FIGURE 1

MAJOR SOURCES OF U.S. COLUMBIUM IMPORTS

(Columbium content)

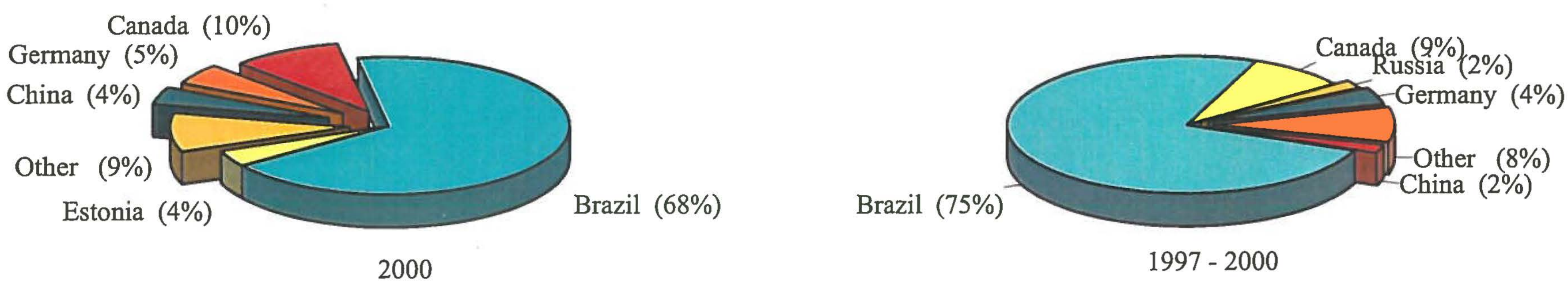


FIGURE 2

MAJOR SOURCES OF U.S. TANTALUM IMPORTS

(Tantalum content)