REFRACTORY MINERAL RESOURCES IN BRITISH COLUMBIA, CANADA
A Fresh Look

By:
G.J. Simandl, D. Jakobsen and P.S. Fischl
British Columbia Ministry of Energy,
Mines and Petroleum Resources
Geological Survey Branch
553 Superior Street
Victoria, British Columbia
V8V 1X4

INTRODUCTION

The term refractory mineral, as applied in this paper, refers to an industrial mineral that can withstand high temperatures, or may be transformed into a refractory material that can withstand high temperatures, in a specific industrial environment without losing the desired properties. The industrial mineral may have other applications in addition to its refractory uses.

In British Columbia refractory minerals, with the exception of fireclays, have historically received little attention. This was due to the lack of major local industries that use refractory materials, such as steel producers and heavy industry in general. The majority of operations involved in the refractory business in British Columbia acted as agents for larger Canadian or American concerns by importing refractory materials in ready-to-use form. As a result, exploration for refractory minerals in British Columbia did not increase significantly until the late 1980s.

Today, most of the refractory materials consumed in British Columbia are specialized products used in the linings of tanks in the pulp and paper industry. Large quantities are also used in chemical plants, petrochemical, aluminum and steel industries and in nonferrous metallurgical refining furnaces, ovens, boilers, incinerators, heaters, cement and lime kilns, and in fireproofing applications. Many of the processes, involved in the transformation of refractory minerals into value-added products, are energy intensive and since energy in British Columbia is relatively inexpensive, on-site transformation is feasible.

Industrial minerals, with the exception of those commodities with low per unit value, are traded internationally and therefore geographic location, accessibility and transportation are important factors affecting the viability of all industrial mineral projects.

British Columbia has the geological potential to host world-class industrial mineral

Industrial Minerals No. 296 (May 1992), pp 67-77

deposits which could supply high-performance refractory products able to compete on domestic and international markets.

The highest geological potential exists for magnesite, olivine and kyanite-group aluminosilicates with good potential for graphite, silica, refractory clays and pyrophyllite.

British Columbia comprises five distinct tectono-stratigraphic belts as illustrated in Figure 1. A description of the general geology of British Columbia is presented by Z.D. Hora (Industrial Minerals in Western Canada) in this issue.

MAGNESITE

Over 70 magnesite occurrences are reported in British Columbia (Figure 2). The significant deposits are hosted by ultramafic rocks or by sedimentary rocks deposited in a shallow marine environment[1]. Major sparry magnesite deposits, hosted in sedimentary rocks, have been documented in detail[2,3,4] and their descriptions are summarized below.

The large and high-grade Mount Brussilof deposit (082JNW001)*, hosted by Cambrian dolomites of the Cathedral Formation and mined by Baymag Mines Co. Ltd., provides the bulk of Canadian magnesite production (Figure 2). Geological mapping indicates that the magnesite belt hosting the Mount Brussilof deposit is more extensive than previously suspected[2].

Several other sparry magnesite deposits are located in the Brisco-Driftwood Creek area, west of Radium Hot Springs (Figure 2). These deposits follow paleo-evaporitic stratigraphic horizons of the Precambrian Mount Nelson Formation[3], which has been disrupted by structural and tectonic events. Typical chemical analyses of surface samples, collected in 1991 from these deposits, are listed in Table 1. The most common mineralogical impurities are quartz, chert and dolomite. Talc, calcite, pyrite, chlorite, clay and iron oxides which occur along fractures are the most common trace minerals. Although the deposits have, in general, lower magnesia and higher silica content than the Mount Brussilof deposit, they are similar in the sparry textures and mineralogy. These deposits have equivalent or higher grades than magnesite deposits currently mined in Europe. The potential of these deposits has been enhanced since the increase in non-refractory uses of magnesite and magnesia in both environmental applications and the production of magnesium metal.

The Anzak or Chuyazega Creek deposit (093J 008) is located 120 kilometres north of Prince George (Figure 2). The deposit, hosted by dolomites of the Gog Group believed to be Lower Cambrian in age, is currently being investigated by Norsk Hydro[5]. The magnesite-bearing rocks of this deposit are similar to those described at Mount Brussilof. The analyses of grab samples from this deposit are reported in Table 1.

Other magnesite deposits, hosted by the Cranbrook Formation of Lower Cambrian age, are reported near Cranbrook[1]. The best known is Cominco's Marysville occurrence (082GNW005) where the magnesite horizon has been traced over a distance

* The number in brackets following the name of the occurrence is the MINFILE number[28]

of 8 kilometres (Figure 2). Typical chemical analyses of the magnesite-bearing rock from the Marysville occurrence, are reported in Table 1. The mineralogy of the magnesite beds varies considerably across the stratigraphy, the central part of the occurrence has the highest grade. These magnesite beds are similar to those found in the Mount Nelson Formation in the Brisco-Driftwood area. The principal impurities within the magnesite beds are quartz (1-20%), dolomite (<10%), chlorite (0-2%), sericite (0-1 %) and pyrite (trace). Although the Marysville deposit may be lower in grade than previously described deposits, its potential would be enhanced if the magnesite could meet the specifications for the production of magnesium metal or environmental applications. The occurrence is located near the tailings of a large base metal mining operation.

OLIVINE

Three zones of fresh dunite rock, with loss on ignition of less than 2 per cent, have been documented in the core of the Tulameen Ultramafic Complex, located in southern British Columbia (Figure 3), on Grasshopper Mountain (092HNE189) approximately 32 kilometres northwest of Princeton[6]. Metallurgical tests of the dunite potential, for foundry sand applications, were positive[7,8,9,10]. A sample evaluation was performed using Hadfield manganese steel "scab blocks" as the test casting and the results were compared with those obtained by using standard foundry sand.

In addition to traditional foundry sand applications, olivine is used for the production of olivine based panels. These panels are used in the manufacturing of wood and sanitary waste incinerators, commonly referred to as "silo-type burners". The silo-type burners, are gradually replacing traditional steel "beehive" burners and are better environmentally. In British Columbia, the panels for silo-type burners are currently imported from the U.S. in a prefabricated form. Olivine could also be used in applications such as marine ballast, heavy aggregate, in heat exchangers or as an environmentally friendly sand blasting agent. Ideally, a future olivine developer in British Columbia should attempt to supply all segments of the potential olivine market and develop new applications.

REFRACTORY CLAYS, DIATOMITE AND PYROPHYLLITE

There are several documented diatomite[11,12,13] occurrences in British Columbia and the economically interesting deposits occur between Kamloops and Quesnel (Figure 3).

At present, the only pyrophyllite production is from the Pyro group of claims which produced approximately 140 tonnes in 1990. Past or present pyrophyllite producers are shown on Figure 3[17].

Clay and shale deposits[14,16] also occur in British Columbia. The only producing deposit, used as a primary component in refractory bricks, is quarried and processed by Clayburn Industries Ltd. at Sumas Mountain (092GSE024). Clayburn Industries also mines pyrophyllite from the Pyro deposit (092HSE131) near Princeton (Figure 3) and diatomite at Quesnel. Other primary constituents of the refractories produced by Clayburn Industries Ltd., such as bauxite and ball clay, are imported.

The major products marketed by Clayburn Industries are acid refractories used in the aluminum, base metal and oil refining industries, in incinerators, lime kilns, industrial furnaces, and in pulp and paper industries. The refractories are used in high alumina (50-85%) brick, fireclay brick, light-weight machine-ground insulating brick, castables, plastic insulating brick and mortars. Most of the production is exported.

A deposit, similar to Sumas Mountain, was reported on Blue Mountain (092GSE028), approximately 20 kilometres northwest of Mission (Figure 3). Tests carried out on samples of the mudstone, which is 15 to 30 metres thick, from this location indicate that it is less refractory than materials mined at Sumas Mountain.

A number of brown or dark-grey mudstone and claystone beds, intersected during the exploration for residual kaolin deposits of Late Cretaceous age, have been reported in the Lang Bay area (092F 137; Figure 3). These beds can be classified as medium to high duty fireclay[18].

A claystone bed with good refractory properties (pyrometric cone equivalent of 31.5)[18] is reported in association with the No. 1 coal seam at the Quinsam colliery (092F 319) near Campbell River (Figure 3).

KYANITE, ANDALUSITE AND SILLIMANITE

Over 50 kyanite, 23 sillimanite and 8 andalusite occurrences are reported in British Columbia. A large majority of the showings are associated with high-grade regional metamorphism within the Coast and Omineca belts (Figure 4). These aluminosilicate showings are primarily hosted by metapelitic rocks, however, in some cases, they are associated with quartz sweats or pegmatites.
Many of the aluminosilicate occurrences hosted in metapelitic schists also contain garnet and mica; these are summarized in Table 2.

Favorable exploration areas, those affected by amphibolite facies metamorphism, are extensive, and the reported grades of the individual aluminosilicate showings are of economic interest.

The crystal size of the aluminosilicates varies from a few millimetres to several centimetres, depending on the showing. Sillimanite occurs mainly in the form of fibrolite which is considered very difficult to extract, however prismatic sillimanite is also reported (Table 2).

The high garnet concentrations, coexisting with refractory aluminosilicates, may constitute a recoverable byproduct. Past investigations did not specify the variety of the mica which coexists with the garnet and aluminosilicates. If some of the showings contain a pale colored, highly prized mica, which may be used as a filler, then the economic potential of these showings would be strengthened. Recovery of refractory aluminosilicates in conjunction with garnet, and possibly filler-grade mica, is an interesting proposition.

Large scale grassroots exploration for refractory aluminosilicates has not been documented or attempted yet.

SILICA

There are large resources of silica known in British Columbia[19,20,21] but only three deposits are presently in production.

The Nicholson Silica deposit (082N 043), massive quartzite of the Mt. Wilson Formation, is located approximately 11 kilometres from Golden (Figure 5). The property is owned by Silicon Metaltech of Seattle and operated by Bert Miller Trucking and Contracting Ltd. Annual production has fluctuated from 30 000 to 60 000 tonnes per year; grades of the silica ore are listed in Table 3. The lump silica is used for ferrosilicon and silicon production in northeast Washington State.

The Mt. Moberly silica (082N 001) operation (Figure 5) is owned and operated by Mountain Minerals Company Ltd. of Lethbridge, Alberta. The ore consists of friable, uniform, massive, silica-cemented, quartz arenite also of the Mount Wilson Formation. The majority of the production is directed to the glass manufacturing industry, however, the operation also supplies silica for a variety of other applications, including blasting and foundry sand.

The Fs quartz vein (082LNW031), located about 40 kilometres northeast of Kamloops, is at least 400 metres long and from 3.5 to 15 metres wide[25]. Production from this vein supplied milky quartz for a silicon carbide plant in Oregon[21].

Many quartz veins (082ESW008,090) cut the Late Jurassic Oliver Plutonic Complex located near the town of Oliver in southern British Columbia (Figure 5). The veins vary from 0.3 to 4 metres in thickness with the thicker veins occurring exclusively in the porphyritic quartz monzonite phase of the pluton. Several of these veins were mined in the past for their precious, base metal or silica content[20]. Production from one of these veins was used in the manufacturing of ferrosilicon and production from the other veins was used as flux[26].

The Gypo quartz deposit (082ESW084), near Oliver, owned by Pacific Silica Ltd., is currently producing on a small scale (less than 10 000 tonnes a year) and is being evaluated for underground development.

GRAPHITE

Thirty-four graphite occurrences are reported in British Columbia, however, most of the occurrences have never been investigated. Selected showings, of possible economic interest by eastern Canadian standards, are located on Figure 6 and described in the following paragraphs.

A graphite deposit[28], hosted in metasediments that occur as roof pendants within the Coast Plutonic Complex of the Coast Belt, has been reported by Wind River Resources. Available information indicates 2.98 to 17.9 per cent total carbon in assayed samples. The high degree of metamorphism suggests that the graphite will have good crystallinity, however, the size and shape of the deposit has not been established.

The Skeena showing (103I 203) is hosted within amphibolites and biotite-hornblende gneisses. A sample, taken across a gneissic band, is reported to contain 3 per cent graphite over 120 metres. Other samples assayed up to 3.0 grams per tonne gold[22] but these grades have not been independently confirmed.

The Payroll showing (103H 035) is reported to consist of a 3 to 4.5 metres thick graphitic horizon, concordant with the adjacent schists and hosted in amphibolite facies rocks.

The Mon occurrence (093N 203) reportedly contains disseminated graphite flakes in marbles and calcsilicates or biotite schists of the Wolverine Complex metamorphosed to amphibolite facies.

The above mentioned graphite deposits and showings indicate a favourable geological environment and require additional exploration. Furthermore, as exemplified by the Skeena showing, metamorphosed organic material is commonly associated with many metallic elements[3]. The possibility of recovering metals as a byproduct of graphite should be further investigated.

British Columbia also has the geological potential to host microcrystalline graphite deposits. Prospective areas correspond to localities where coal beds are affected by contact or medium-grade regional metamorphism, however, only meta-anthracite has been reported from these areas.

CHROMITE

Chromite is used in refractory bricks, castables, mortar, ramming and gunning compounds, as well as foundry sand. Refractory grade chromite concentrates traditionally contain 30-40 per cent Cr_2O_3, high Al_2O_3 content (25-30%), Cr to Fe ratio of 2.0 - 2.5:1 and a total iron, expressed as FeO, of less than 15 per cent.

Chromite deposits are commonly subdivided into two major categories: stratiform and podiform. Stratiform deposits are hosted by layered intrusions typified by the Bushveld Complex in South Africa. This type of deposit accounts for more than 80 per cent of world chromite reserves and is not known to occur in British Columbia. Podiform occurrences are primarily hosted in Alpine-type (ophiolite-type) and Alaskan-type intrusions.

Forty podiform or nodular chromite occurrences, related to Alpine-type and Alaskan-type intrusions, are known in British Columbia (Figure 7)[24]. Some of these occurrences have been tested while others are essentially untouched. Past production is reported from five occurrences (named on Figure 7).

OTHER MINERALS

Other minerals that have refractory applications, but are not produced for this purpose in British Columbia, are dolomite, zircon and brucite. Zircon requires a special mention, since it could possibly, in some cases, be recovered as a byproduct of placer mining.

CONCLUSION

Magnesite, kyanite-family minerals, and olivine represent unique exploration opportunities. Magnesite is mined, by Baymag Mines Ltd., from an unusually pure sparry magnesite deposit. Other magnesite deposits, especially those located in southeastern British Columbia, have excellent potential to become producers. The Omineca and Coast belts have excellent potential to host world-class kyanite-family deposits. The small but growing market for silo-type incinerators, with or without electricity generating equipment, will probably contribute to the use of olivine or other refractory materials in British Columbia.

Alpine-type ultramafic intrusions host podiform refractory grade chromite in a number of locations. Good geological potential exists for the discovery of flake graphite deposits within the metasedimentary roof pendants of the Coast Plutonic Complex of the Coast Belt and within highly metamorphosed pelitic rocks.

Clays, pyrophyllite and diatomite are mined and used by Clayburn Industries Ltd. in the production of acidic, medium temperature range, products with high resistance to abrasion and corrosive environments.

The above described commodities are primary sources for a wide range of refractory products including Al_2O_3-graphite, MgO-graphite and dolomite-graphite bricks, which are part of the high performance segment of the refractory market. This segment is currently handling the recession better than the rest of the refractory industry and has good potential for expansion.

Low energy costs in British Columbia favor immediate upgrading and transformation of refractory products, for example mullite production from aluminosilicates and production of the calcined, dead burned or fused magnesia.

British Columbia has excellent geological potential to host world-class refractory mineral deposits. New applications have been developed for some industrial minerals traditionally considered purely refractory. The existing and newly developing markets for use of these minerals in other applications may lead to horizontal integration. This may increase the size of the potential market and also protect future producers against the highly cyclical nature of refractory product use. Furthermore, recovery of byproducts, as exemplified by the kyanite-garnet-mica and graphite-gold associations, may lead to further enhancement of the potential of the refractory minerals in British Columbia.

Additional information on the specific commodities or occurrences may be obtained from the authors or from the B.C. Geological Survey's computerized mineral inventory database (MINFILE).

ACKNOWLEDGEMENTS

Enriching discussions, of the chromite and micro-crystalline graphite deposits with G. Nixon and of the prospective areas for micro-crystalline graphite with W. Kilby, B. Ryan and D. Grieve of the B.C. Ministry of Energy Mines and Petroleum Resources, Geological Survey Branch, are acknowledged. The suggestions and information received from Z. D. Hora of the B.C. Ministry of Energy Mines and Petroleum Resources, Geological Survey Branch are greatly appreciated

D. Lefebure and B. Grant of the B.C. Ministry of Energy, Mines and Petroleum Resources, Geological Survey Branch, improved this manuscript. This manuscript is published with the permission of W. R. Smyth, the Chief Geologist of the B.C. Ministry of Energy, Mines and Petroleum Resources, Geological Survey Branch.

REFERENCES

1 Grant, B. (1987): Magnesite, Brucite and Hydromagnesite Occurrences in British Columbia, B.C. Ministry of Energy, Mines and Petroleum Resources, Open File 1987-13, 68 pages.

2 Simandl G.J. and Hancock K.D.(1991): Geology of the Mount Brussilof Magnesite Deposit, Southeastern British Columbia, B.C. Ministry of Energy, Mines and Petroleum Resources, Geological Fieldwork 1990, Paper 1991-1, pp. 269-278

3 Simandl, G.J. and Hancock K.D. (1992): Geology of Dolomite-Hosted Magnesite Deposits of the Brisco and Driftwood Creek Areas, British Columbia, B.C. Ministry of Energy, Mines and Petroleum Resources, Geological Fieldwork 1991, Paper 1992-1, pp. 461-481

4 Gourlay, A.W. (1989): Anzac Magnesite Property, Report for Norsk Hydro, B.C. Ministry of Energy, Mines and Petroleum Resources, Assessment Report 19213

5 McCammon, J.W.(1964): The Brisco Magnesite Area; B.C. Ministry of Energy, Mines and Petroleum Resources, Annual Report, 1964, pages 194-199.

6 White, G.V.(1987): Olivine Potential in the Tulameen Ultramafic Complex, Preliminary Report (92H/10), B.C. Ministry of Energy, Mines and Petroleum Resources, Geological Fieldwork 1986, Paper 1987-1, pages 303-307.

7 Szabo, E.I. and Kular, A.C.(1987): Evaluation of Olivine Type Sand Sample for Foundry Use; Physical Metallurgy Research Laboratories, CANMET/ Energy, Mines and Resources Canada, unpublished report PMRL 87-20 (INT), 6 pages.

8 Whiting, L.V., Warda, R.D., Collings, R.K. and Darke, E.F.(1987): Evaluation of Olivine Sand from Grasshopper Mountain, Princeton, B.C.; Physical Metallurgy Research Laboratories, CANMET/Energy, Mines and Resources Canada, Unpublished report, PMPL 87-24 (CF), 16 pages.

9 Hora, Z.D. and White, G.V. (1988): The Evaluation of Olivine Sand prepared from Tulameen Dunite, B.C. Ministry of Energy, Mines and Petroleum Resources, Geological Fieldwork 1987, Paper 1988-1, pages 381-385.

10 Hancock K.D., Hora, Z.D. and White, G.V. (1990): Olivine Potential of the Tulameen Ultramafic Complex; B.C. Ministry of Energy, Mines and Petroleum Resources, Open File 1991-9, 19 pages.

11 Cockfield,W.E.(1948): Geology and Mineral Deposits of Nicola map-area, Geological Survey of Canada, Memoir 249.

12 Tipper, H.W.(1978): Taseko Lakes (92-O) map area, Geological Survey of Canada, Open File 534, Ottawa.

13 Hora, Z.D.(1984): Diatomite in British Columbia; in: The Geology of Industrial Minerals in Canada, ed. G.R.Guillet and W. Martin, The Canadian Institute of Mining and Metallurgy Special Volume 29, 350 pages.

14 Hora, Z.D. (1984): Clay and shale in British Columbia; in: The Geology of Industrial Minerals in Canada, ed G.R.Guillet and W. Martin, The Canadian Institute of Mining and Metallurgy Special Volume 29, 350 pages.

15 MacLean, M.,(1990): Talc and Pyrophyllite in British Columbia; B.C. Ministry of Energy, Mines and Petroleum Resources, Open File 1988-19, 108 pages.

16 Cummings, J.M., and McCammon, J.W.(1952): Clay and shale deposits of British Columbia, B.C. Ministry of Energy, Mines and Petroleum Resources, Bulletin 30.

17 MacLean, M. (1990): Talc and Pyrophyllite in British Columbia, B.C. Ministry of Energy, Mines and Petroleum Resources, Open File 1988-19, 108 pages.

18 Hora, Z.D. (1989): Lang Bay. Exploration in B.C. 1988, B.C. Ministry of Energy, Mines and Petroleum Resources, Part B. pages B69-B68.

19 Evans, C.S. (1932): Brisco - Dogtooth Area, Geological Survey of Canada Summary Report 1932, Part AII

20 Sinclair, A.J., Moore D. and Reinsbakken, A. (1984): Geology of the Gypo quartz vein, Oliver, British Columbia; The Geology of Industrial Minerals in Canada, Ed: Guillet, G.R. and W. Martin. Special Volume 29. The Canadian Institute of Mining and Metallurgy, pp 279-285.

21 Foye, G. (1987): Silica occurrences in British Columbia. B.C. Ministry of Energy, Mines and Petroleum Resources, Open File 1987-15, 55 pages.

22 Clothier, A. (1922): Graphite Group, B.C. Ministry of Energy, Mines and Petroleum Resources, Annual Report 1921, p. 41.

23 Mikami, H.M. (1983): Chromite; in: ed: S.J. Lefond, Industrial Minerals and Rocks, 5th Edition, American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., p. 567-587.

24 Hancock, K.D. (1990): Ultramafic Associated Chromite and Nickel Occurrences in British Columbia, B.C. Ministry of Energy, Mines and Petroleum Resources, Open File 1990-27, 62 pages.

25 Hora, Z.D. (1982): Mapping of Silica Occurrences in British Columbia, B.C. Ministry of Energy, Mines and Petroleum Resources, Geological Fieldwork 1982, Paper 1983-1, p. 197.

26 Pell, J. (1988): The Industrial Mineral Potential of Kyanite and Garnet in British Columbia, B.C. Ministry of Energy, Mines and Petroleum Resources, Open File 1988-26, 43 pages.

27 MINFILE (1992): Provincial Database, B.C. Ministry of Energy, Mines and Petroleum Resources, MINFILE data released Jan. 1992.

28 Demczuk, L. and Zbitnoff, G.W. (1991): Geochemical Report on the AA 1-22 Claims, Wind River Resources, B.C. Ministry of Energy, Mines and Petroleum Resources, Assessment Report 21649.

TABLE 1 - CHEMICAL COMPOSITION OF SURFACE SAMPLES FROM SEDIMENTARY-HOSTED MAGNESITE DEPOSITS

DEPOSIT	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	TOTAL
Anzak	0.44	<0.01	0.21	1.16	0.02	43.79	3.14	0.01	0.01	1.04	50.36	100.19
	0.39	<0.01	0.08	0.76	0.02	34.23	16.70	0.01	0.01	0.82	48.95	101.98
	2.23	<0.01	0.11	0.98	0.02	48.99	0.72	0.01	0.01	0.86	50.01	98.95
Driftwood Creek	7.32	0.09	1.01	0.75	0.01	39.57	0.60	0.27	0.04	<0.01	47.61	97.28
	2.05	<0.01	<0.01	0.86	0.02	37.27	8.08	0.09	0.00	<0.01	50.02	98.42
	15.97	<0.01	0.08	0.52	0.01	38.62	0.10	0.04	0.03	<0.01	43.56	98.95
Topaz Lake	7.11	0.02	0.51	1.37	0.02	42.16	0.61	0.02	0.00	<0.01	46.68	98.51
	7.43	<0.01	0.20	1.34	0.02	41.03	0.31	0.02	0.01	<0.01	48.27	98.65
	4.18	0.03	0.70	1.60	0.02	43.00	0.32	0.02	0.15	<0.01	49.41	99.44
Red Mtn.	10.64	0.01	0.52	1.64	0.03	38.74	0.92	0.10	0.03	<0.01	45.54	98.18
	8.09	0.01	0.33	0.82	0.01	40.14	0.32	0.02	0.03	<0.01	47.91	97.69
JAB	4.67	<0.01	0.13	1.35	0.02	41.99	0.57	0.04	0.00	<0.01	48.66	97.45
	5.56	<0.01	0.13	1.27	0.02	42.55	0.52	0.04	0.01	<0.01	47.37	97.49
	4.43	0.01	0.20	2.02	0.03	41.85	0.35	0.04	0.00	<0.01	48.60	97.54
Clelland Lake	2.80	<0.01	0.12	1.66	0.03	41.12	1.14	0.05	0.01	<0.01	50.36	97.31
Dunbar Creek	2.53	<0.01	0.20	2.11	0.04	41.48	1.36	0.04	0.02	<0.01	50.30	98.10
Botts Lake	3.62	<0.01	0.03	0.27	0.01	38.82	6.68	0.09	0.08	<0.01	48.85	98.47
Marysville	2.59	0.02	0.64	1.71	0.03	46.00	0.92	<0.01	0.01	<0.01	49.50	101.44
	5.90	0.04	0.84	1.12	0.02	43.42	1.09	<0.01	0.03	0.28	47.28	100.03
	3.59	0.05	0.92	0.72	0.01	45.11	1.02	<0.01	0.15	0.02	49.02	100.62
Mt. Brussilof *	<0.01	<0.01	<0.01	0.35	0.01	48.00	0.82	0.01	0.03	<0.02	51.96	101.23
	0.10	<0.01	<0.01	0.38	0.01	47.00	1.41	<0.01	0.02	0.03	51.44	100.42
	<0.01	<0.01	<0.01	0.37	0.01	48.12	1.02	<0.01	0.01	0.01	51.86	101.44
	<0.01	<0.01	<0.01	0.51	<0.01	47.74	0.85	<0.01	0.01	0.02	51.88	101.06
	<0.01	<0.01	<0.01	0.42	0.01	47.89	0.87	0.00	0.00	0.01	52.02	101.31

* Samples from the mine

TABLE 2 - SUMMARY OF PUBLISHED INFORMATION ON KYANITE, ANDALUSITE AND SILLIMANITE (Source: Pell 1988)

AREA	ALUMINOSILICATE			POSSIBLE BY-PRODUCTS
	Ky	Sill	And	
Southern Shuswap		20 - 25		<30 Gr, (Mi?)
Revelstoke - Big Bend	20 - 30			(Mi?)
Canoe River	20 - 25			15 - 20 Gr, (Mi?)
Hope-Yale (Settler Schist)	23 (L)	24 (L), 15 (P)		<30% Gr, (Mi?)
Hope-Yale (Breakenridge Fm.)	<40		Minor	<50 Gr
Hope-Yale (Cairn Needle)	15 (av.)			20 (av.) Gr, (Mi?)
Kwinamass Peek		<50		15 - 20 Gr, (Mi?)
1 km east of Kwinitsa		5 - 30		5 - 30 Gr
Hawksbury Island	<20			<20 Gr

Abbreviations: And - andalusite, Gr - garnet, Ky - kyanite, p - prismatic, Sill - sillimanite, L - Locally, av. - average, (Mi?) - type of mica is not specified

TABLE 3 - ANALYSES OF THE SILICA ORE

LOCATION	SiO_2	Al_2O_3	MgO	K_2O	Fe_2O_3	CaO	Na_2O	TiO_2	LOI	TOTAL
Nicholson Silica	99.85	0.10	<0.05	<0.10	0.04	<0.05	<0.10	<0.05	0.32	100.31
	99.90	0.10	0.05	<0.10	0.04	<0.05	<0.10	<0.05	0.31	100.36
Mt. Moberly Silica	99.67	0.06	0.02	0.02	0.02	0.06	0.01	0.01	0.12	99.9

(Source: Foye, 1987)

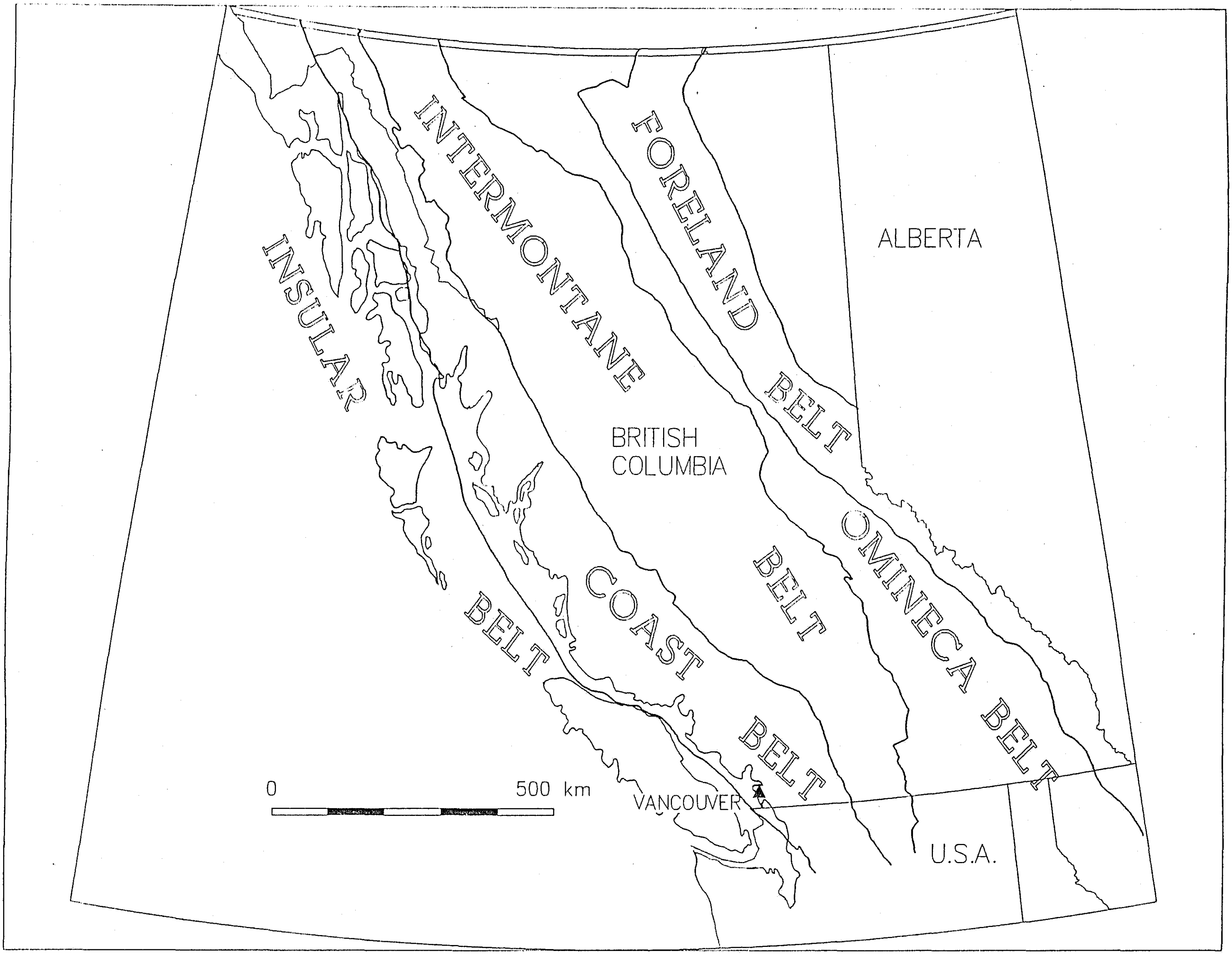

FIGURE 1: TECTONIC BELTS OF BRITISH COLUMBIA

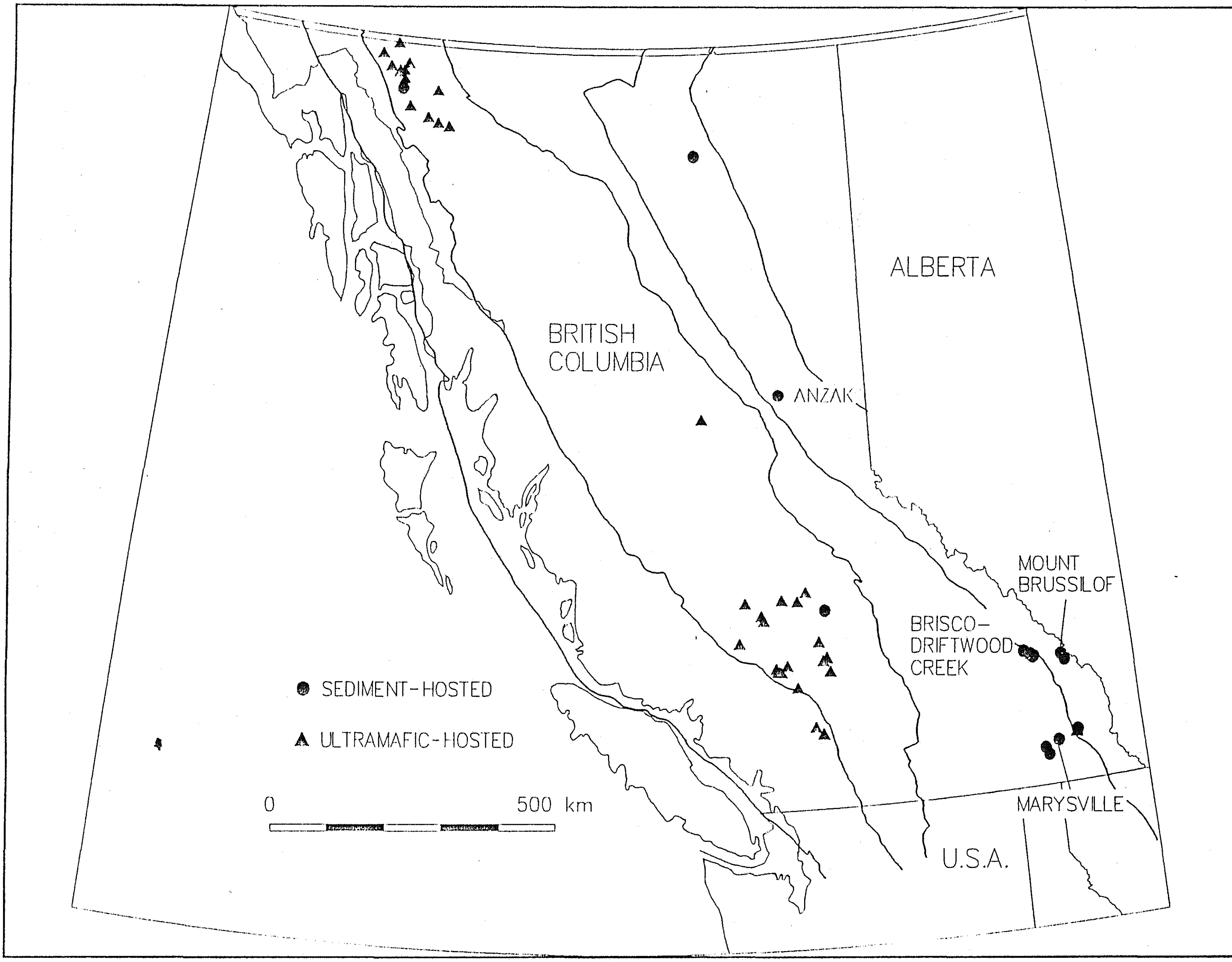

FIGURE 2: MAGNESITE DEPOSITS IN BRITISH COLUMBIA

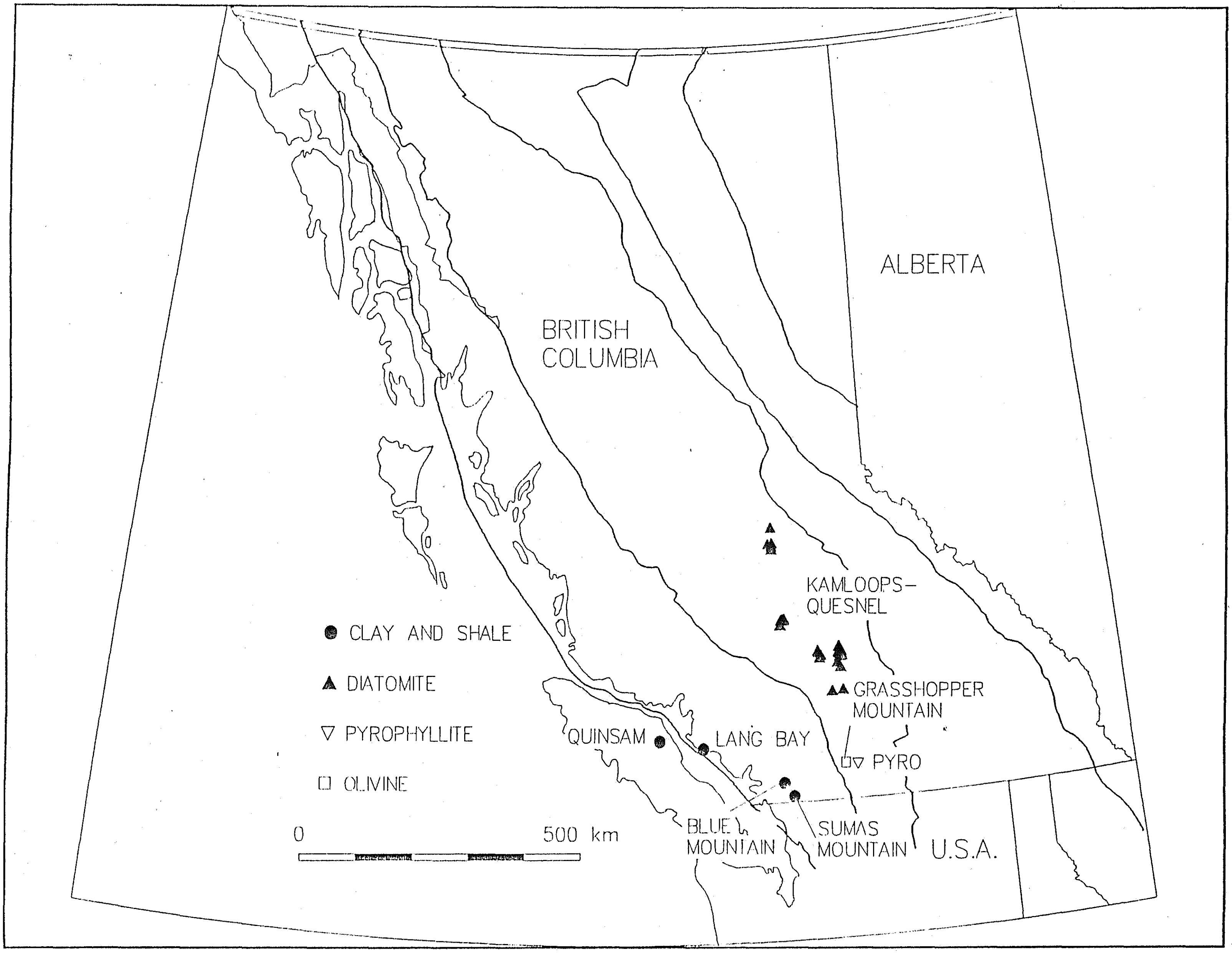

FIGURE 3: SELECTED CLAY, SHALE, DIATOMITE, PYROPHYLLITE AND OLIVINE DEPOSITS IN BRITISH COLUMBI

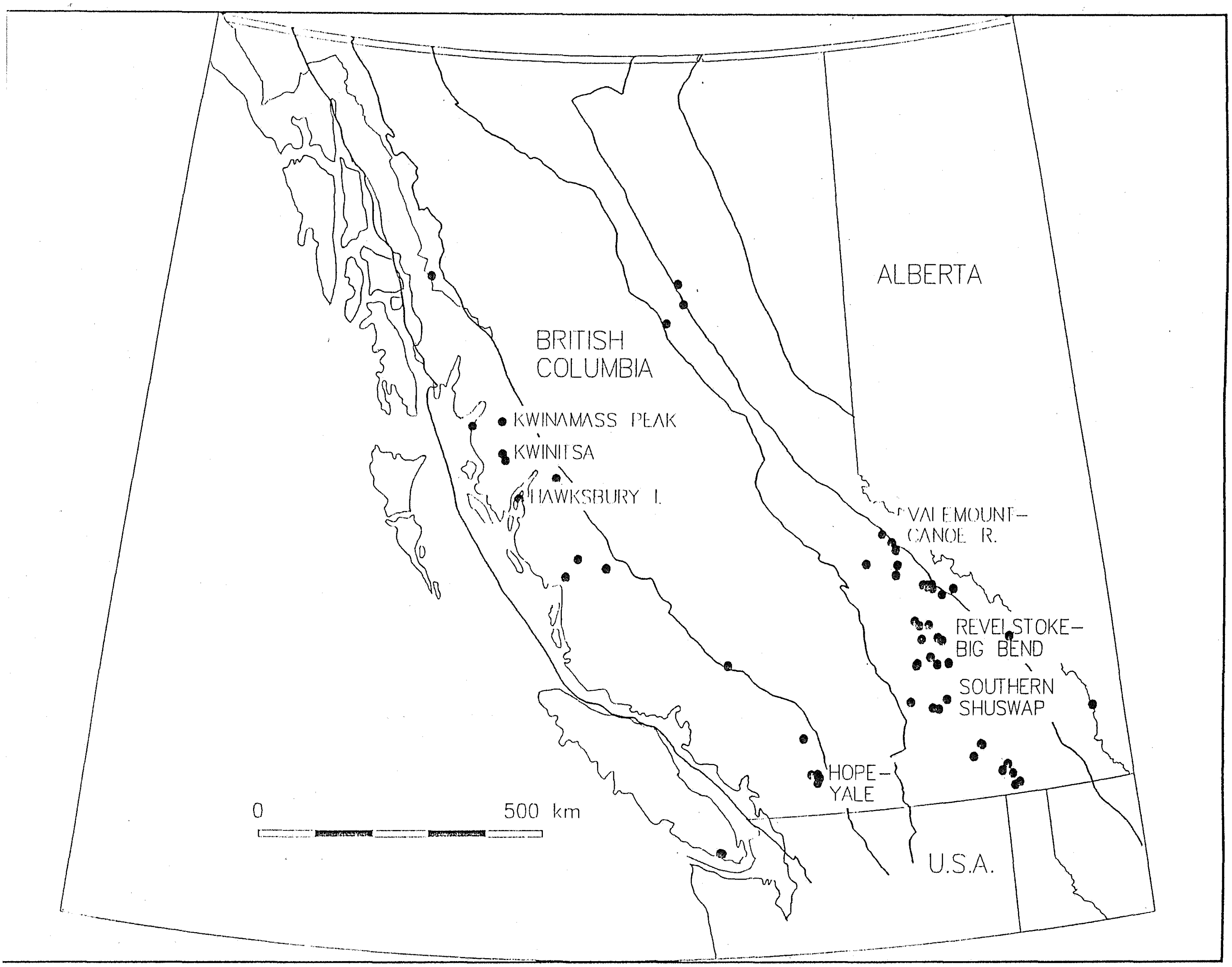

FIGURE 4: KYANITE, ANDALUSITE AND ~~STILLIMANITE~~ SILLIMANITE OCCURRENCES IN BRITISH COLUMBIA

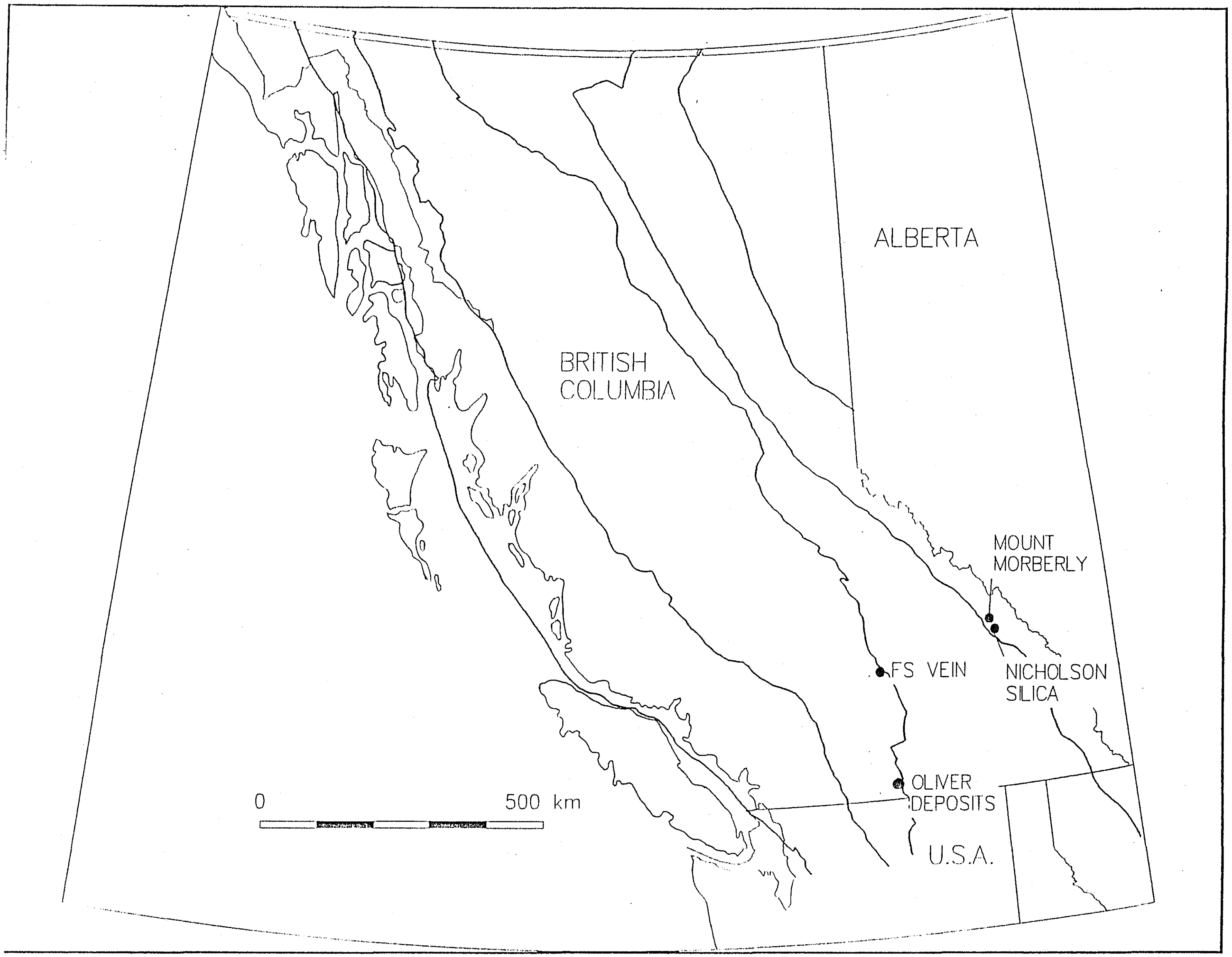

FIGURE 5: SELECTED SILICA DEPOSITS IN BRITISH COLUMBIA

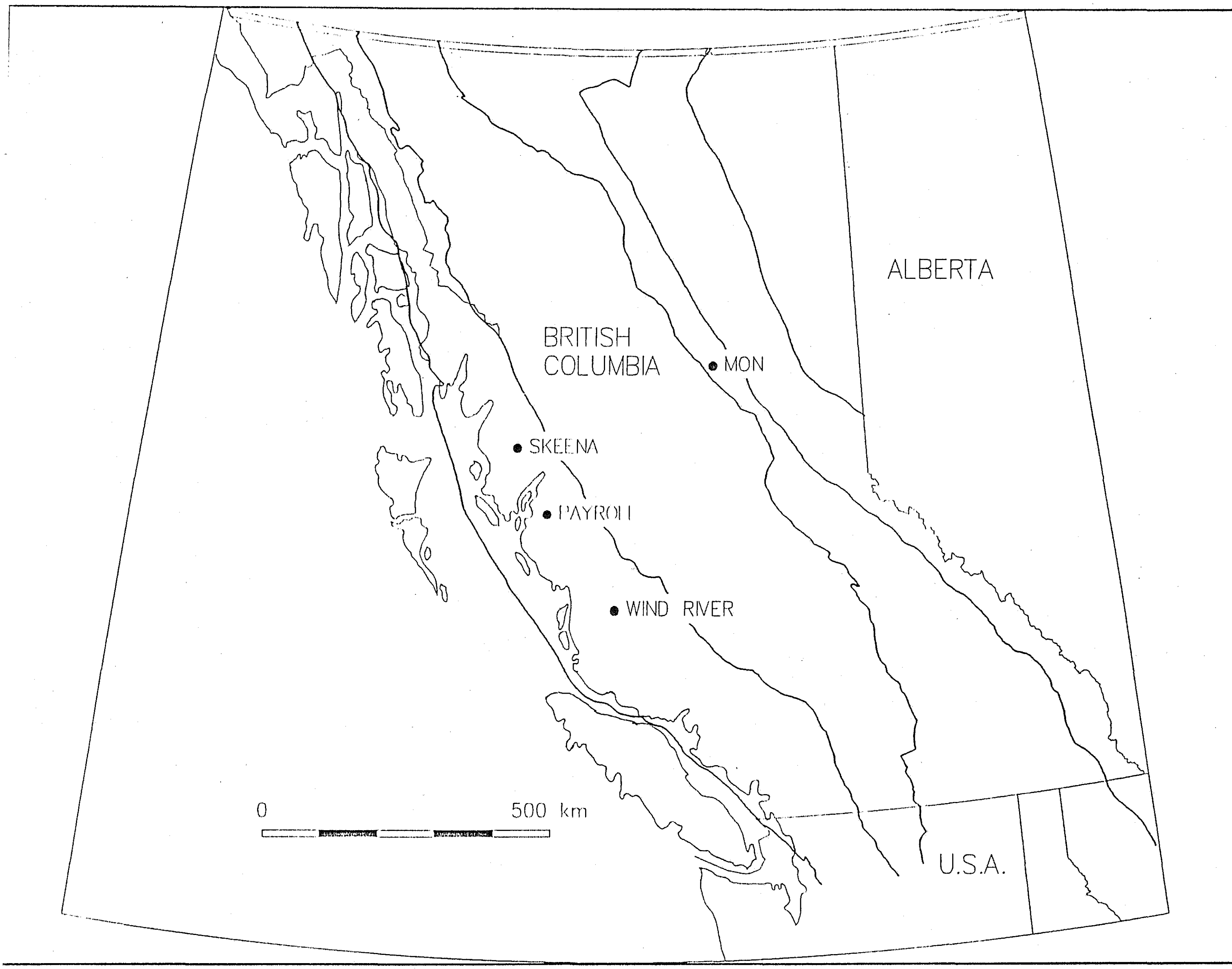

FIGURE 6: SELECTED GRAPHITE SHOWINGS IN BRITISH COLUMBIA

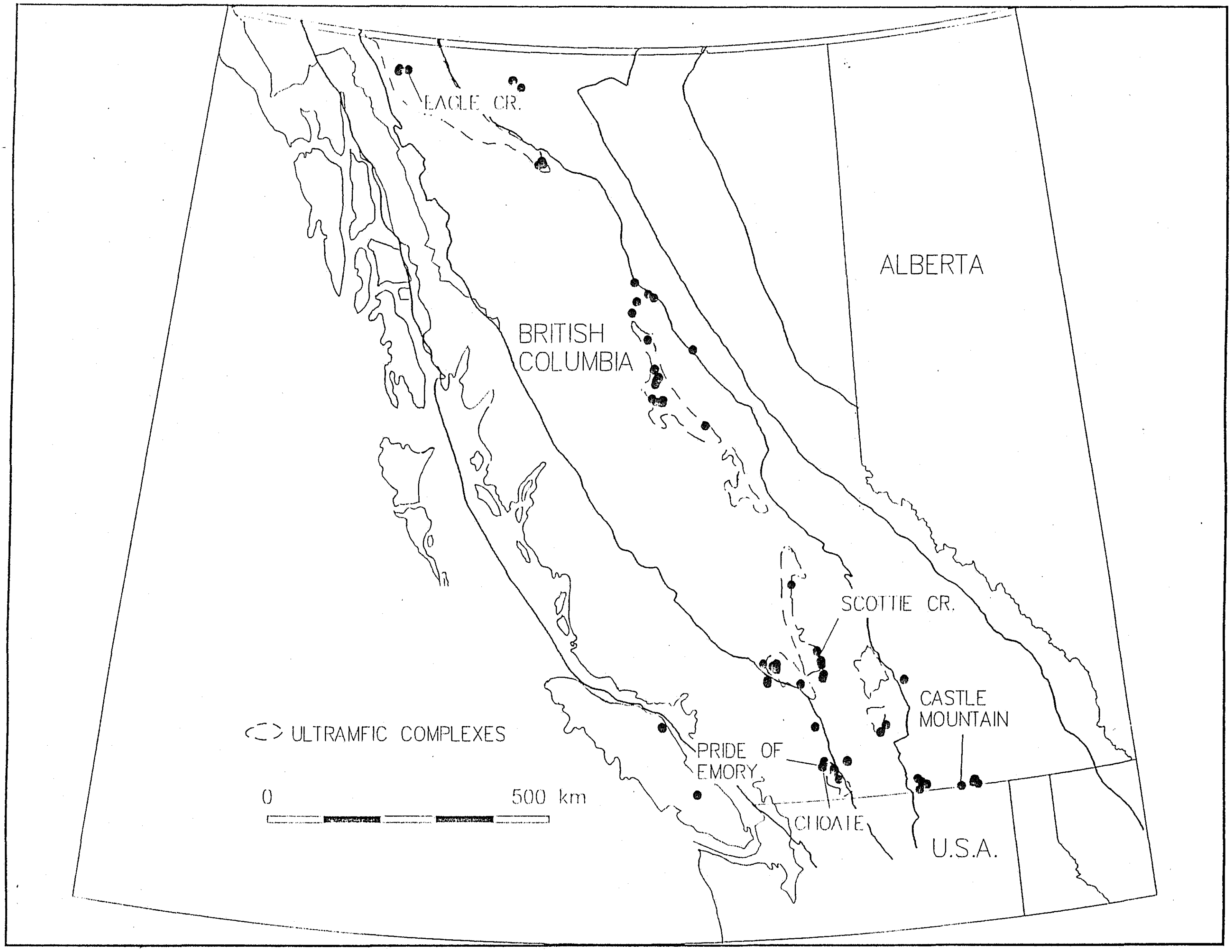

FIGURE 7: CHROMITE OCCURRENCES IN BRITISH COLUMBIA