British Columbia Hydromagnesite-Magnesite Resources: Potential Flame Retardant Material

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INTRODUCTION

Hydromagnesite occurrences in British Columbia have been recognized since the beginning of the 19th century (Reinecke, 1920; Young, 1915). However, the known occurrences of hydromagnesite are too small to compete with the large sparry magnesite deposits in British Columbia (Grant, 1987; Simandl *et al.*, 1996 a,b and Simandl, 2000) as potential sources of raw materials for the production of industrial grade caustic, dead-burned and fused magnesia or magnesium metal.

This paper summarizes the information on British Columbia's hydromagnesite occurrences based on published data and 2 days of property examination in the 1997 field season. It also identifies a possible market for brucite and these hydrated carbonates as flame retardants. It is the first document that addresses the potential use of hydromagnesite raw material for flame retardants. Also highlighted are the difficulties in developing similar European hydromagnesite-huntite deposits over the last 20 years. Although much effort and focus has been put into the development of these deposits, they still only account for a very small portion of the flame retardant market.

In British Columbia, exploration and/or re-evaluation of known hydromagnesite occurrences may result in the discovery of deposits with a potential as a source of natural flame retardants. Rapid growth of the inorganic, natural flame retardant market or participation of the developer with the existing captive market are essential for the successful development of these resources.

FLAME RETARDANTS - BACKGROUND

Flame retardants are materials incorporated or applied to products (including plastics and textiles) to increase their resistance to fire. The current demand for flame retardant additives is driven largely by recent product liability concerns, more stringent flammability codes and intensified legislative pressures in Europe and North America. Currently there are at least three hundred and fifty substances that are used and listed as flame retar-

dants according to the Danish Environmental Protection Agency. They can be divided into two fundamental categories: a) reactive retardants where molecules already contain flame retarding groups in their polymeric chain, and b) additive retardants which are essentially functional inorganic fillers.

In the mid 1990s, inorganic flame retardants had a share of about 70% of the consumption in the USA. Aluminium hydroxide (ATH), accounted for more than 50% of the total demand by volume (Kirschbaum, 1995). More recent data (Weber, 2000) indicates that flame retardant markets in the USA and Europe account for 344 800 and 339 900 tonnes, respectively (Figure 1). ATH still represents the lion's share of the total market. ATH is manufactured by digestion of bauxite in an alkaline media to produce a solution of sodium aluminate, from which it is crystallized.

Other commonly used flame retardants are magnesium hydroxide, antimony trioxide (Sb_2O_3), zinc compounds such as zinc borate and tin containing minerals such as zinc stannate and zinc hydroxystannate (Kirschbaum, 1995).

It is expected that major concerns about environmental issues will favor inorganic substances not containing any halogens or antimony compounds. Antimony by itself is ineffective, but it becomes very effective in combination with halogens.

The flame retardant efficiency of ATH, magnesium hydroxide ($Mg(OH)_2$), and similar materials like hydromagnesite and huntite is based largely on endothermic decomposition into an oxide and water. In addition to this, the released water vapor isolates flames and dilutes flammable gases. Chemical composition of these magnesium compounds is shown schematically in Figure 2.

Magnesium-based compounds are a rather new flame retardant in the market. Magnesium hydroxide has a higher temperature stability field (up to 340°C) than ATH (200°C). Therefore, ATH is only applicable to polymer systems compounded and processed at low temperatures such as PVC (polyvinyl chloride), EVA (ethylene vinyl acetate copolymer), PE (polyethylene), whereas, $Mg(OH)_2$ can be applied in polypropylene, nylons and thermoplastic polyesters such as PET (polyethylene terephthalate), PA 6 (polyamide) and PBT (polybutylene terephthalate) (Figure 3).

In addition to mined and processed brucite, $Mg(OH)_2$ can be obtained from brines or sea water processing, or

[1] *British Columbia Ministry of Energy and Mines*
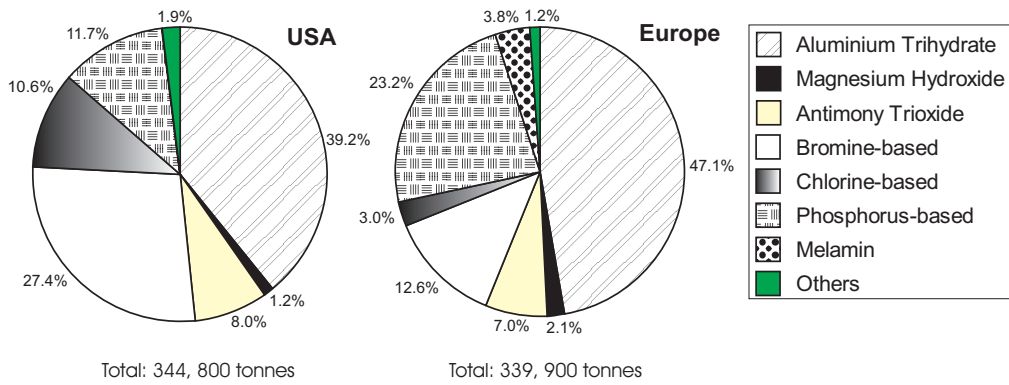
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Figure 1. Flame retardant consumption in the USA and Europe for 1998 from Business Communications Co. Inc. Alusuisse Martinswerk GmbH. Figure modified from Weber (2000).
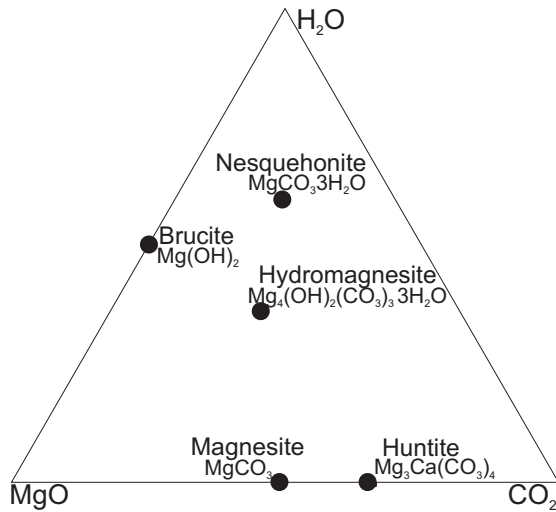

Figure 2. Ternary MgO - CO_2 - H_2O diagram showing chemical composition of magnesium compounds used as flame retardants (Molecular %).

Figure 3. Decomposition/dehydration temperatures of ATH, huntite/hydromagnesite, $Mg(OH)_2$ and processing temperatures of selected polymers. Modified from Georgiades et al.,1995.

can be manufactured via specific synthetic routes from magnesite and other Mg-rich minerals such as serpentinite. The market for $Mg(OH)_2$ is estimated at 10 000 to 15 000 tonnes depending on the source of information and Figure 1 suggests that it is over 11 000 metric tonnes for Europe and the USA combined. The price for synthetic $Mg(OH)_2$ is estimated at 3000 to 4500 AU$ /tonne. (<http://www.minerals.csiro.au/public/work/stories/magnesit.htm>).

There is no published market data for natural hydromagnesite-huntite ore used as a flame retardant, but the market is much lower than that for $Mg(OH)_2$.

Mixtures of huntite-hydromagnesite were first seriously studied and examined in the '70s as part of a geological study of the magnesium carbonate minerals of the Serbia basin of Kozani (Georgiades et al., 1996). These investigations were followed up by applied research on huntite-hydromagnesite for commercial scale production and exploitation. The relative volume/cost relations between the aluminium hydroxide, huntite-hydromagnesite and magnesium hydroxide at filling levels of 60%, 65% and 70% are shown in Figure 4. The diagram shows that,
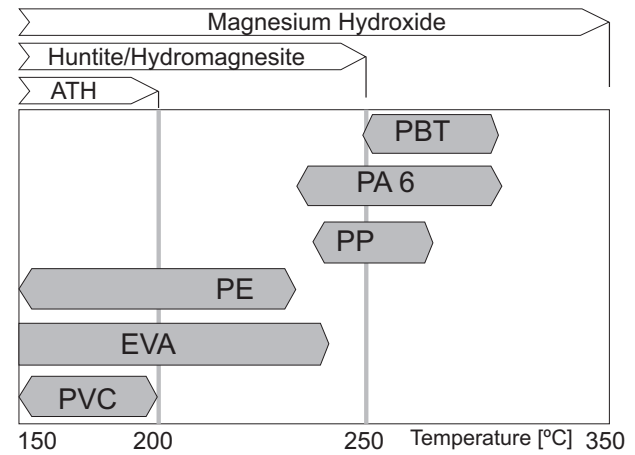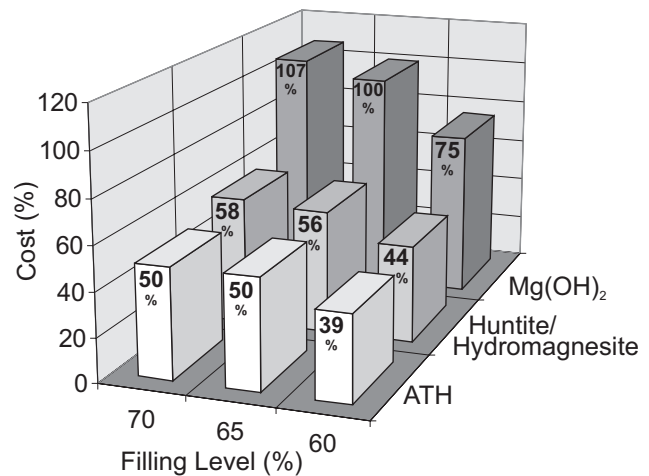

Figure 4. Volume-cost relations between ATH, huntite/ hydromagnesite and $Mg(OH)_2$ filled products based on actual European prices. Modified from Georgiades et al., 1995.

for example, at 60% filling of ATH, huntite-hydromagnesite and $M_g(OH)_2$ levels, the cost of the retardant accounts for 39%, 44% and 75% of the total product, respectively. Overall the market for ATH, $Mg(OH)_2$ and similar products such as huntite- hydromagnesite, is increasing as a result of their substitution for brominated flame retardants.

HYDROMAGNESITE ORE AND PRODUCT SPECIFICATIONS

There are a number of hydromagnesite ($Mg_4(OH)_2(CO_3)_3 3H_2O$) and huntite ($Mg_3Ca(CO_3)_4$) occurrences worldwide. The major impurities in these deposits are magnesite, aragonite, calcite and dolomite. Only a few of these occurrences have material commercially exploited for their flame retarding properties.

The ore in the producing deposits from the Serbia basin of Kozani consists of a mixture of huntite-hydromagnesite with very low iron contents ($Fe_2O_3 < 0.03\%$), high whiteness (~95% in comparison with chemically produced MgO) and total impurities (aragonite, calcite, magnesite, etc.) less than 8% (Georgiades *et al*., 1996).

An average mineralogical composition established by a combination of XRD and chemical analyses of current ores is as follows: huntite (46%), hydromagnesite (46%), magnesite (4%), aragonite (3%), calcite (1%). Typical chemical analysis of the ores consist of MgO (38.0%), CaO (9.5%), H_2O (9.1%), CO_2 (43.4%) and LOI (52.5%).

MINING AND PROCESSING

In the Serbia basin of Kozani, beds with known ratios of huntite/hydromagnesite are selectively mined and blended to obtain a marketable product of constant composition and quality. The primary processing consists of crushing to less than 10mm and drying to less than 1% moisture. Final processing consists of de-agglomeration and air classification to obtain desirable particle shape and particle size distribution. Depending on the final product, additional drying and surface treatment may be required (Georgiades *et al*., 1996).

CHARACTERISTIC PHYSICAL PROPERTIES

The typical end product has a huntite/hydromagnesite ratio of 1:1 and median diameter d_{50}=0.5-0.7 microns. The high huntite material has d_{50} 0.3-0.4 microns. The d_{97} of both products is below 5 microns (Sedigraph 5000D) and TAPPI brightness is over 95% (Georgiades *et al*., 1996). The stability of the product is intermediate between that of magnesium hydroxide and ATH (Figure 3).

HYDROMAGNESITE IN BRITISH COLUMBIA

The hydromagnesite occurrences in British Columbia were documented by Reinecke (1920); Cummings (1940) and reviewed by Grant (1987). In those studies the occurrences were considered chiefly as a potential source of magnesia and the flame retardant potential was not considered. The geological setting and sedimentation within Cariboo area playas and saline lakes is described by Renault and Long (1987, 1989) and Renault and Stead (1991). The last study suggests that hydromagnesite-magnesite in these environments are found: 1) as major constituents in carbonate playa basins where they precipitated subaqueously or in zones of shallow groundwater discharge; 2) in mudflats surrounding closed perennial lakes; 3) in marshy valley-bottoms and in saline mudflats of ephemeral lake complexes. In the last environment they occur in peripheral mudflats or near spring water discharges. The detailed genesis of hydromagnesite-magnesite accumulations in British Columbia is beyond the scope of the present study and the reader is invited to consult Renault and Stead (1990) and Calvo *et al.* (1995). Huntite was not reported in British Columbia deposits prior to the early 1990's (Renault, 1993), since most of the attempts to characterize hydromagnesite deposits in British Columbia predate the first description of huntite by Faust (1953).

All known British Columbia hydromagnesite occurrences reported in Minfile (http://www.em.gov.bc.ca/Mining/Geolsurv/Minfile/default.htm) are listed below and are located in Figure 5. Should the market for huntite-hydromagnesite increase, satellite photo interpretation, which was not available for early explorers, may become the best reconnaissance exploration tool.

61 Mile Creek (MINFILE 092P 078)

Hydromagnesite deposits are located within a swampy area in the headwaters of 61 Mile Creek and about 3 km east of Goose Lake, and approximately 15 km SE of Clinton. The deposits adjoin a small swampy lake (Cummings, 1940).

White hydromagnesite with a cauliflower-like surface texture covers about 1.1 hectares. The material has been test pitted to a depth of 30 cm but no data is available to indicate its total thickness (Cummings, 1940). Chemical analyses from Cummings (1940) are shown in Table 1, samples MC1, MC2 and MC3.

Barnhart Vale (MINFILE 092INE049)

A deposit of hydromagnesite occurs within a depression near the road to Campbell Range about 2 km north of the Campbell Range deposit and approximately 3.2 km east of the community of Barnhart Vale.

The depression is about 183 m long by 153 m wide and a second depression about 430 m to the east is also reported to contain hydromagnesite. Auger drilling indi-
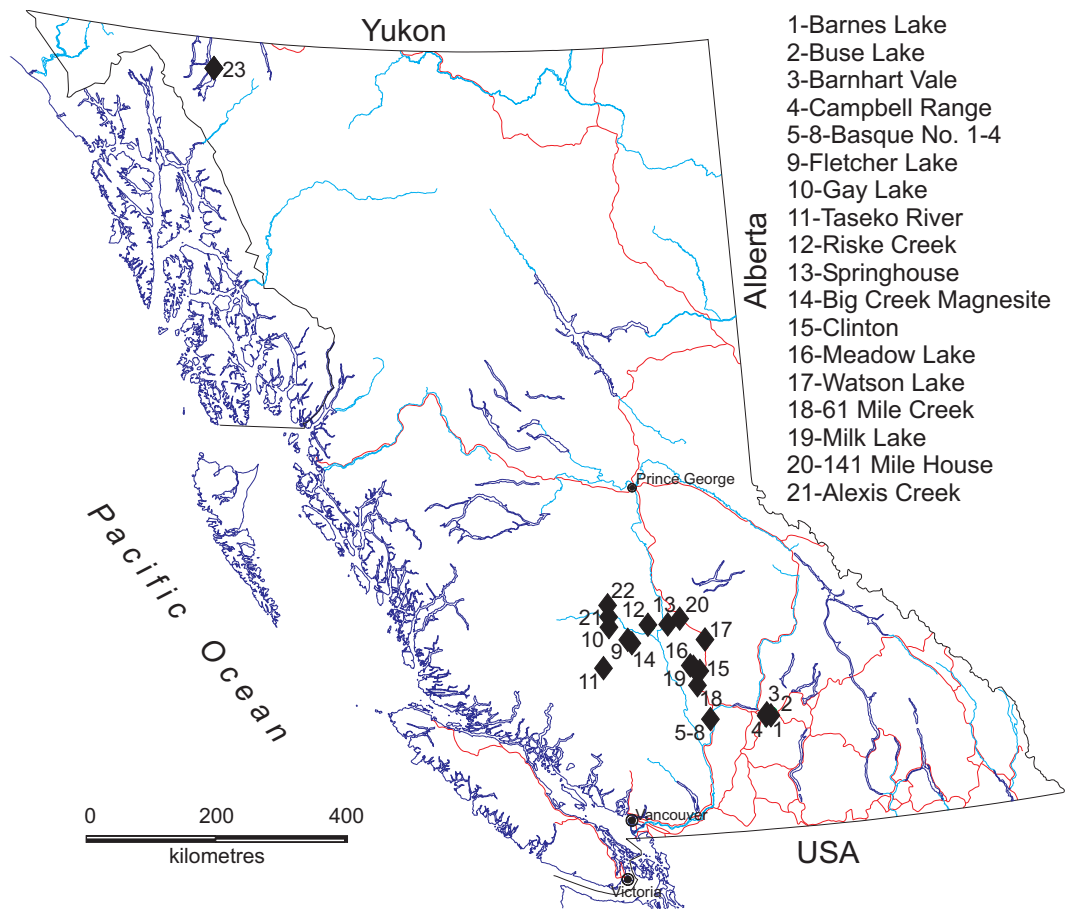
Figure 5. Hydromagnesite occurrences in British Columbia.

1-Barnes Lake
2-Buse Lake
3-Barnhart Vale
4-Campbell Range
5-8-Basque No. 1-4
9-Fletcher Lake
10-Gay Lake
11-Taseko River
12-Riske Creek
13-Springhouse
14-Big Creek Magnesite
15-Clinton
16-Meadow Lake
17-Watson Lake
18-61 Mile Creek
19-Milk Lake
20-141 Mile House
21-Alexis Creek

TABLE 1
CHEMICAL COMPOSITION OF SAMPLES FROM 61 MILE CREEK; BARNHART VALE,
BUSE LAKE, CAMPBELL RANGE AND SPRINGHOUSE
[COMPILED FROM COCKFIELD (1948), CUMMINGS (1940)]

Sample No.	Deposit Thickness (m)	Sample Depth (cm)	MgO (%)	CaO (%)	Fe+Al (%)	MnO (%)	SiO_2 (%)	SO_3 (%)	Insol-ubles (%)	LOI (%)
MC1*	-	surface	38.00	1.60	1.70	-	9.80	-	-	48.90
MC2	-	surface	34.40	1.76	0.69	-	11.60	-	-	48.16
MC3	-	surface	32.75	3.32	0.67	-	12.40	-	-	47.74
BA1	1.83	-	27.44	5.71	3.58	0.05	-	-	23.28	nd
BU1	0.60	180	34.20	1.76	3.91	0.07	-	0.05	20.74	38.45
CA1	0.90	-	37.44	0.66	0.93	-	-	-	7.37	nd
CA2	0.90	-	41.00	nil	0.78		-	-	2.40	59.00
SP1	-	-	33.10	4.90	4.30	-	-	-	14.80	42.00

*MC - 61 Mile Creek; BA - Barnhart Vale; BU - Buse Lake; CA - Campbell Range; SP - Springhouse

cated hydromagnesite to a depth of 1.83 m with about 15 cm of overburden (Cockfield, 1948). The chemical analysis from Cockfield (1948) is shown in Table 1, sample BA1. This sample has a relatively high content of insoluble (non-carbonate) minerals.

Buse Lake (MINFILE 092INE048)

The material lies in a depression which is about 430 m long and 60 to 125 m wide. Auger drilling indicated a hydromagnesite thickness of 30 to 76 cm which is overlain by 25 to 75 cm of drift material. The sample contains 77.9% hydromagnesite based on the MgO content (Cockfield, 1948; Cummings, 1940). The chemical analysis from Cockfield (1948) is shown in Table 1, sample BU1. The sample may have been contaminated by the overlying soil since it has a high content of insoluble (non-carbonate) minerals.

Campbell Range (MINFILE 092INE050)

About 550 tonnes of white hydromagnesite are reported in a small, 75 m diameter depression west of the Campbell Road about 19 km southeast of Kamloops. One auger hole indicated a thickness of about 90 cm of hydromagnesite while others intersected only sand and gravel (Cockfield, 1948; Cummings, 1940). Chemical analyses from Cockfield (1948) and Cummings (1940) are shown in Table 1, samples CA1 and CA2, respectively from the same drill hole.

Springhouse (MINFILE 092O 088)

The Springhouse hydromagnesite showing is probably older than other occurrences of the Chilcotin Plateau, where hydromagnesite is being formed in modern lakes, since it is covered in soil.

White, clay-like material is reported to underlie 10 to 30 cm of soil in scattered locations (Cockfield, 1948; Cummings, 1940). One occurrence close to the Williams Lake-springhouse Road, near Boitano Lake was sampled and the chemical analysis from Cummings (1940) is shown in Table 1, sample SP1.

141 MILE HOUSE (MINFILE 093A 156)

Hydromagnesite is deposited in an area over 30 m across and down-slope from a mineral spring near 141 Mile House and east of the railway tracks. The material contains freshwater shells and is predominantly calcium and magnesia and a small amount of alkalic carbonates (Reinecke, 1920). Samples 141A and 141B (Table 2) were collected 6 m and 30 m, respectively, downstream. However, the analysis of the two samples does not support the presence of hydromagnesite in the deposit. The CaO content of these samples is too high, while the H_2O content is too low.

Atlin (MINFILE 104N 079)

Hydromagnesite is located within topographic lows immediately east of Atlin. In addition to the two main bodies, a number of small, isolated patches of hydromagnesite occur along the lakeshore in the vicinity of Atlin (Grant, 1987 *see* also Figure 6).

Estimated resource is 107,037 tonnes grading 41% hydromagnesite; 83% of the resource would grade 41 to 42% MgO (Aitken, 1959).

The largest deposit is about 7.29 hectares with an average thickness of 81 cm and it has several smaller satellitic bodies.

Near the base of the deposit the hydromagnesite may be more porous and is cut by irregular vein-like, glassy hydromagnesite. The hydromagnesite is white, powdery and massive with no evidence of bedding or structure and its composition is homogeneous. The white surface color assumes a yellow tinge at a depth of about 30 cm below the surface. The tinge disappears with exposure to air. The material becomes quite plastic, like clay, when wet (Young, 1915).

Two holes drilled in the deposit were sampled and analyzed. Hole No. 1 indicated a hydromagnesite thickness of 66 cm and was sampled at depths of 8, 33 and 58 cm. Hole No. 2 indicated a thickness of 107 cm and was sampled at 10, 42 and 71 cm. Results of this sampling are presented in Table 2.

A second hydromagnesite deposit lies directly east of Atlin and southwest of the main deposit. It consists of three bodies within topographic depressions and is associated with larger areas of impure hydromagnesite. The first body covers about 1.82 hectares with an average thickness of about 1 m, but which varies from 0.3 to 1.5 m. Sample AT3 was collected at a depth of 53 cm near the center of the body. Sample AT4 was collected at a depth of 41 cm, about 30 m from sample AT3.

The second body underlies about 0.3 hectares with a thickness of 1 to 2.14 m. Near the northeast corner of this body the thickness is about 1.73 m and sample AT5 was collected from a depth of 46 cm. The material is partly granular and some-what clay-like with walnut sized, or smaller, pieces of hardened hydromagnesite. Sample AT6 is a surface sample where the thickness of the deposit is >1.8 m.

The third body is exposed over 0.4 hectares with a thickness of 0.3 to 1 m. Sample AT7 was collected about 10 cm above the base of the deposit at a depth of 51 cm. The material sampled is compact and traversed by thin micro-veinlets of hydromagnesite (Cummings, 1940; Fraser, 1904; Reinecke, 1920). Chemical analyses of all the above mentioned samples, from Young (1915), are shown in Table 2. One of these bodies was recently promoted by Stralak Resources as a potential source of magnesia.

TABLE 2
CHEMICAL COMPOSITION OF SAMPLES FROM 141 MILE HOUSE; ATLIN; BIG CREEK; CLINTON; MEADOW LAKE; RISKE CREEK AND WATSON LAKE

(NOTE: SAMPLES FROM THE ATLIN OCCURRENCE DATA ARE FROM HOLE 1 AND ATB FROM HOLE 2)

Sample No.	Deposit Thick-ness (m)	Sample Depth (cm)	MgO (%)	CaO (%)	SiO₂ (%)	Al₂O₃ (%)	Fe₂O₃ (%)	SO₃ (%)	Na₂O (%)	K₂O (%)	CO₂ (%)	H₂O (%)	H₂O +105
141A*	-	-	12.14	34.31	8.78	-	5.05	tr	0.10	0.58	36.84	3.10	-
141B**	-	-	5.00	43.32	5.22	-	1.45	tr	0.02	0.36	35.10	6.06	-
ATA1	0.66	8	41.13	2.04	1.86	0.67	0.82	-	-	-	35.98	18.02	-
ATA2	0.66	33	42.35	0.82	0.9	0.10	0.59	-	-	-	36.10	18.95	-
ATA3	0.66	58	42.19	0.68	0.54	0.17	0.82	-	-	-	36.17	19.05	-
ATB1	1.07	10	40.56	1.26	1.22	0.67	0.88	-	-	-	35.96	19.04	-
ATB2	1.07	42	41.93	1.5	1.96	0.14	1.17	-	-	-	36.04	17.66	-
ATB3	1.07	71	35.23	6.44	9.22	0.94	1.6	-	-	-	37.70	8.20	-
AT3	1	53	42.85	0.32	0.74	0.35	0.88	-	-	-	36.35	19.10	-
AT4	1	41	38.94	0.42	3.48	2.85	1.46	-	-	-	34.31	18.10	-
AT5	1.73	46	43.04	0.16	0.96	0.23	0.71	-	-	-	36.21	19.26	-
AT6	>1.83	surface	42.45	0.26	0.62	0.41	0.49	-	-	-	36.23	18.95	-
AT7	0.61	51	42.12	0.48	1.18	0.33	0.89	-	-	-	35.89	19.42	-
BI1***	-	-	43.19	4.10	-	0.60	1.00	0.04	0.64	-	36.47	11.00	-
CL1	1.45	0-61	41.60	0.22	2.30	0.63	0.13	0.36	-	-	35.88	18.65	17.53
ME1	0.2-0.81	0-38	41.38	1.32	4.00	1.36	0.40	-	-	-	37.67	13.60	12.12
ME2	0.9-1.25	38-130	35.68	6.38	11.33	2.88	0.46	-	-	-	36.63	6.44	4.15
ME3	-	130-168	20.34	25.55	7.60	-	0.24	-	-	-	-	-	-
ME4	0.2-0.81	0-99	36.63	2.86	13.10	1.34	0.30	-	-	-	35.64	9.58	7.00
ME5	0.9-1.25	99-153	24.32	20.12	10.32	1.35	0.49	-	-	-	38.64	4.38	2.93
ME6	0.7	0-30	20.14	9.20	36.78	1.54	2.47	-	-	-	20.24	10.32	6.80
ME7	-	composite	40.56	1.26	1.22	0.67	0.87	-	-	-	35.96	19.45	18.00
ME8	-	composite	38.80	0.80	7.40	2.50		-	-	-	38.70	11.50	11.50
RI1	75	0-66	41.14	0.10	1.22	0.48	0.19	0.08	-	-	37.70	19.06	17.78
RI2	composite	0-90	42.30	0.70	4.40	1.00		-	-	-	41.90	9.20	9.20
RI3	0.84	0-61	41.74	0.17	1.85	0.48	0.62	0.11	-	-	40.85	14.65	12.98
WA1	0.5-1.0	66	41.06	1.62	6.36	0.20	0.12	-	-	-	38.04	12.57	11.25
WA2	1	0-92	43.17	1.14	4.62	0.16	0.16	-	-	-	43.64	6.68	5.26
WA3	-	-	39.40	2.10	5.70	1.30		-	-	-	50.50	-	-
WA4	-	-	36.70	1.54	8.62	0.33	0.57	-	-	-	31.08	17.07	14.86

*141 - 141 Mile House; AT - Atlin; BI - Big Creek Magnesite; CL - Clinton; ME - Meadow Lake; RI - Riske Creek; WA - Watson Lake

**This sample also contained 4.01% carbonaceous matter

***This sample also contained 16% insolubles

Big Creek Magnesite (MINFILE 092O 089)

The Big Creek showing occurs about six km south of the Fletcher Lake showing (Minfile #092O 084). It contains about 500 tonnes of hydromagnesite (Cummings, 1940; Grant, 1987). Chemical analysis from Grant (1987) is shown in Table 2, sample BI1.

Clinton (MINFILE 092P 072)

The three pure hydromagnesite deposits occur about 1 km east of Clinton in the valley of Clinton Creek, within a larger area of impure hydromagnesite, covering a combined area of about 0.28 hectares. The material is 0.6 to 1.4 m thick and is underlain by a brown hydromagnesite to a depth of about 1.5 m. Sand and clay underlie the deposit (Reinecke, 1920).

Chemical analyses from Reinecke (1920) are shown in Table 2, sample CL1.

Meadow Lake (MINFILE 092P 074)

The area contains two main and a number of smaller areas of pure and impure hydromagnesite. The total area covered is about 20.4 hectares (Figure 7).

All occurrences have irregular outlines and a typical cauliflower-like surface which is raised 10 to 60 cm above the surrounding swamp. The impure hydromagnesite occurrences have a flat, cracked surface of dense, gray material. They occur east and west of Meadow Lake and the individual deposits vary widely in
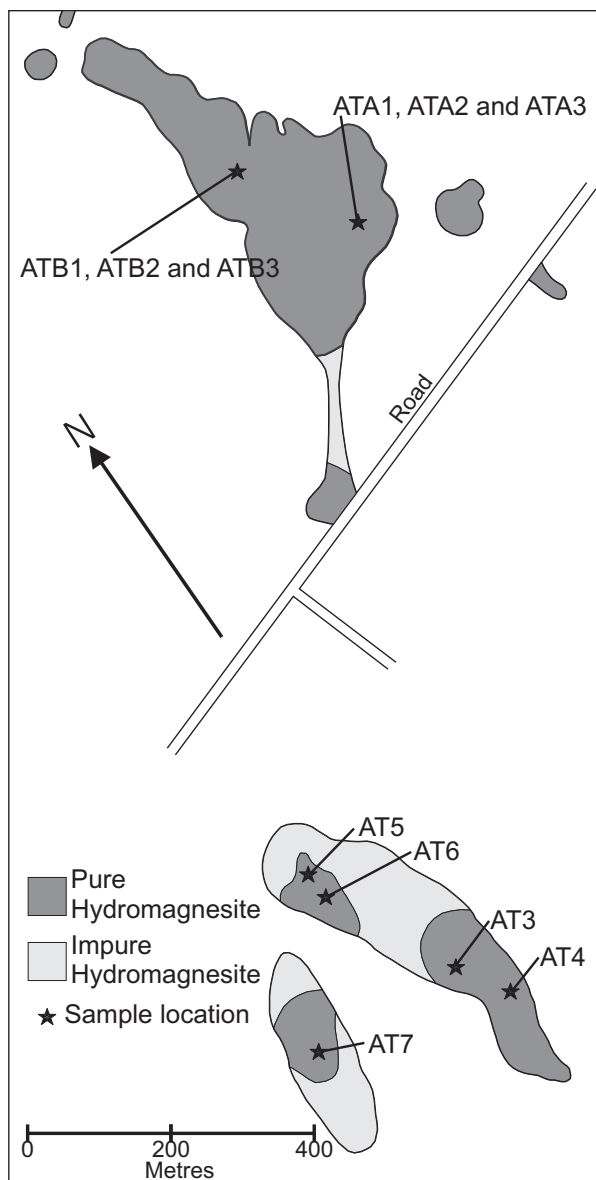
Figure 6. Atlin hydromagnesite deposit. Source: Young, 1915.

sample ME4 is from 99 to 153 cm and is entirely within yellow hydromagnesite (Grant, 1987).

Area B, the second largest occurrence, consists of white hydromagnesite covering about 5.85 hectares of swampy terrain, roughly 325 m southeast of Area A, the main deposit. In Area B, the hydromagnesite is 30 to 90 cm thick with an average thickness of 41 cm (Reinecke, 1920). Sample ME6 (Reinecke, 1920) represents a composite of white hydromagnesite from a number of the Meadow Lake occurrences. Sample ME8 is a similar composite, but is limited to white material from drill holes in areas A and B. Chemical analyses of the above-mentioned samples, from Reinecke (1920), are shown in Table 2.

Riske Creek (MINFILE 092O 087)

Deposits of hydromagnesite are contained within recent sediments that occur on low swampy terrain along the Riske Creek drainage, south of the Chilcotin Road.

The western deposit is estimated to cover 0.65 hectares. White hydromagnesite, 60 to 90 cm thick, grades downwards to a brown clayey soil at a depth of about one meter. Sample RI1 was collected from the eastern end of the deposit, as well as Sample RI3 which consisted of a composite from five drill holes throughout the deposit.

The eastern deposit is estimated to be about 0.84 hectares. It is white to cream hydromagnesite to about 84 cm depth and grades into brown clay at 1.27 m. Sample RI2 was collected from the center of this deposit (Cummings, 1940; Reinecke, 1920). Chemical analyses of these samples are shown in Table 2.

Watson Lake (MINFILE 092P 077)

Deposits of hydromagnesite are located in a swampy depression about 500 m to the southwest of Watson Lake and about 1.5 m above the lake level.

The larger area, is about 200 by 60 m along a northeast trend. It has a variable depth, to an underlying dark gray mud, up to about 2.16 m. The hydromagnesite has a white superficial layer which is 50 to 100 cm thick with an average of 58 cm. Underlying this layer is a 1.5 m thick, cream to brown Ca-rich hydromagnesite layer (Reinecke, 1920). Sample WA1 (Reinecke, 1920) is of 66 cm of white hydromagnesite and part of the layer of cream-colored hydromagnesite.

The second significant area is about 180 m southeast of the first. The white surface layer of hydromagnesite is about one meter thick. Sample WA2 is of white hydromagnesite collected from 0 to 92 cm from the surface. Sample WA3 (Cummings, 1940) is a composite sample of white hydromagnesite collected from seven drill holes representing all occurrences in this area. Sample WA4 (Reinecke, 1920) was collected from an isolated of hydromagnesite located about 1.5 km northeast of the main occurrence.

In total, the Watson Lake deposits cover approximately two hectares and contain slightly more than

composition but generally contain elevated values of calcium and silica.

Area A, is about 1.5 km east of Meadow Lake. Drilling confirmed that the 11.87 hectares of white hydromagnesite has a thickness of 20 to 81 cm with an average of about 46 cm. Creamy yellow granular material underlies the white hydromagnesite in a layer which is in the order of 90 to 125 cm thick and is underlain in turn by impure hydromagnesite. Sample ME1 is of material from 0 to 38 cm depth within the white hydromagnesite at the center of the deposit. Sample ME2 is from 38 to 130 cm, below sample ME1, and consists of cream-colored hydromagnesite. Sample ME3 is cemented soil taken from 130 to 168 cm depth. Sample ME4 was collected near sample ME1 and is from 0 to 99 cm, but includes some yellow hydromagnesite. Sample ME5, taken below
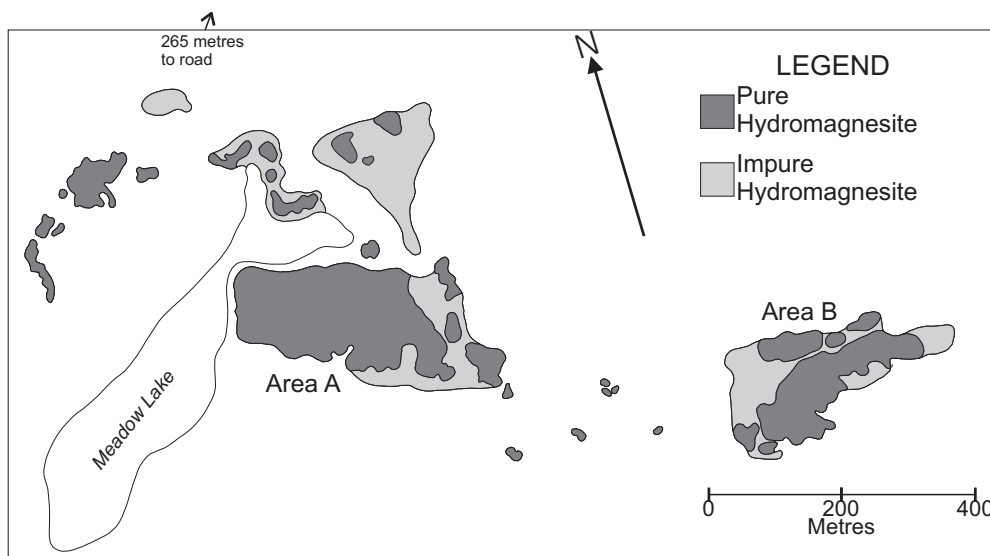
Figure 7. Meadow Lake hydromagnesite deposit. Source: Cummings, 1940.

20,000 tonnes of hydromagnesite (Cummings, 1940; Reinecke, 1920). Chemical analyses of the above samples, from Reinecke (1920), are shown in Table 2.

Alexis Creek (L.561) (MINFILE 093B 041)

The Alexis Creek showing may contain 900 tonnes of hydromagnesite resource. The showing is located 3 km west of the town of Alexis Creek along the Chilcotin River (Cummings, 1940). The chemical analysis from Cummings (1940) is shown in Table 3, sample AC1.

Alexis Lake (L.2833) (MINFILE 093B 056)

The Alexis Lake showing consists of about 1,800 tonnes of hydromagnesite. The deposit is likely to be a residual precipitate (Cummings, 1940). Chemical analysis from Cummings (1940) is shown in Table 3, sample AL1.

Barnes Lake (MINFILE 082LNW082)

Impure, gray hydromagnesite, up to 60 cm thick, and covered with about 30 cm of soil, underlies a couple of hectares near the north end of Barnes Lake about 43.5 km southeast of Kamloops near the Kamloops-Vernon Road (Grant, 1987). No data is available on the chemistry of the deposit.

Basque No. 1, 2, 3 and 4
(MINFILE 092INW043, 44, 45 and 46)

The Basque salt deposits consist primarily of four small basins or mud-filled ponds 2 km west of Highway 1 and 15 km south of the community of Ashcroft.

The Basque deposits consist primarily of mixed hydrous magnesium sulphate (epsomite or Epsom salt) and hydrous sodium magnesium sulphate (bloedite), as well as hydrous sodium sulphate (mirabilite or Glauber's salt). The top 1 m in all of the deposits is principally epsomite. Mirabilite generally occurs near the surface and the bloedite at depth. There are also small amounts of calcium sulphate, sodium bicarbonate and sodium chloride present. Potassium in detectable levels has been reported in the brines (Goudge, 1924; Grant, 1987).

Shallow, fresh-water ponds and small deposits of impure hydromagnesite and hydrous sodium sulphate (mirabilite) occur in small converging valleys close to and west of the Basque deposits.

Fletcher Lake (MINFILE 092O 084)

The Fletcher Lake hydromagnesite showing occurs within recent lacustrine sediments developed on glacial gravels and Tertiary volcanic rocks. The resource is estimated at 350 tonnes of hydromagnesite (Cummings, 1940). No data is available on the chemistry of the deposit.

TABLE 3
CHEMICAL COMPOSITION OF SAMPLES FROM
ALEXIS CREEK AND ALEXIS LAKE
COMPILED FROM CUMMINGS (1940)

Sample No.	$Mg(HCO_3)_2$ (%)	CaO (%)	$Al_2O_3 + Fe_2O_3$ (%)	Mn (%)	Insol- ubles (%)
AC1*	84.00	nil	0.20	-	13.00
AL1**	80.00	nil	1.20	tr	9.20

*AC - Alexis Creek

**AL - Alexis Lake

Gay Lake (MINFILE 092O 085)

Hydromagnesite of the Gay Lake showing is being deposited within recent lacustrine sediments within a playa developed on older glacial gravels and Tertiary volcanic rocks. Through evaporation of the water of Gay Lake during the summer, hydromagnesite is being concentrated in the clays of the lake bottom and around its margins (Grant, 1987). The deposit is estimated to contain about 100 tonnes of hydromagnesite (Cummings, 1940). No data is available on the chemistry of the deposit.

Milk Lake (MINFILE 092P 173)

A carbonate playa covers 300 m^2, 31 km north of Clinton and 19 km west-northwest of Seventy-mile House. It is underlain by a central mudflat forming a hard flat surface of pale gray mud, comprised mostly of hydromagnesite. A pit dug near the center of the playa encountered 80 cm of massive gray mud comprising magnesite and hydromagnesite underlain by cream-colored magnesite mud. The central mudflat is rimmed by a peripheral mudflat, a few meters to 20 m in width, containing a mixture of massive to crudely bedded siliciclastic detritus, precipitated magnesium carbonates (magnesite, hydromagnesite and dolomite) and organic matter.

The magnesite content increases downward at the expense of hydromagnesite. In two samples, hydromagnesite forms 25 to 30% of the total carbonate, 10 to 20 cm below the central playa surface. Dolomite occurs in the southern peripheral mudflats in association with magnesite, 40 to 80 cm below the surface. Four samples contained 1.2 to 5.4% acid insoluble matter comprised of clay, plagioclase silt, diatom debris and organic detritus (Campbell and Tipper, 1971; Renaut and Stead, 1989). No data is available on the chemistry of the deposit.

Taseko River (MINFILE 092O 086)

The Taseko River hydromagnesite occurrence is hosted by recent sediments deposited within an ephemeral lake system developed, possibly, as a result of meandering of the Taseko River. Hydromagnesite appears to be confined to lacustrine sediments in a small depression in the Taseko River valley (Grant, 1987). The showing is estimated to contain about 55 tonnes of hydromagnesite (Cummings, 1940). No data is available on the chemistry of the deposit.

SUMMARY

British Colombia has a large magnesite resource and quite a number of known hydromagnesite occurrences. While sparry magnesite deposits in British Columbia are relatively well documented, hydromagnesite deposits have received limited attention.

There is not sufficient information about thickness, mineralogy, continuity or the extent of the British Columbia hydromagnesite occurrences. The chemical analyses given in Tables 1, 2 and 3 were compiled from a variety of old sources. In many cases H$_2$O+ analyses, that are one of the essential factors in estimating hydromagnesite and huntite content, are not available. In most cases, the description of the analytical method is not given and no scanning electron or modern X-Ray diffraction data is available.

If the current trends in the application of flame retardants continue, the future market for hydromagnesite products may justify the reassessment of selected known occurrences and the possibity of exploration for new deposits. British Columbia hydromagnesite deposits do represent primary exploration targets for companies with a captive flame retardant market.

ACKNOWLEDGMENTS

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