British Columbia Geological Survey
Geological Fieldwork 1991

GEOLOGY OF DOLOMITE-HOSTED MAGNESITE DEPOSITS OF THE BRISCO AND DRIFTWOOD CREEK AREAS, BRITISH COLUMBIA

By George J. Simandl and Kirk D. Hancock

KEYWORDS: Economic geology, industrial minerals, magnesite, Mount Nelson Formation, Evaporites, Precambrian.

LOCATION AND HISTORY

The magnesite deposits of the Brisco and Driftwood Creek areas are located approximately 30 and 50 kilometres, respectively, northwest of Radium Hot Springs (Figure 4-9-1). Most of the deposits are accessible by forestry roads. The first magnesite discovery in the area dates back to the early Sixties. Some of the deposits have been investigated by drilling, trenching and bulk sampling. Up to the present, no commercial production has resulted from these activities.

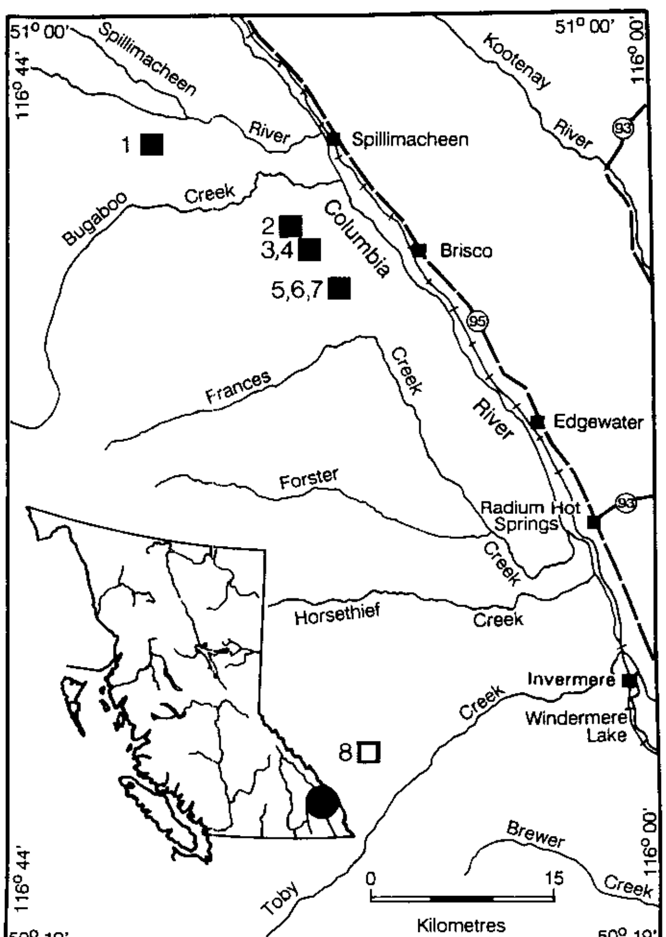


Figure 4-9-1. Location of the Brisco and Driftwood Creek magnesite deposits. 1-Driftwood Creek, 2-Red Mountain, 3-Topaz Lake, 4-Cleland Lake, 5-Dunbar, 6-Jab, 7-Botts Lake, 8-deposits described by Pope (1990).

REGIONAL GEOLOGIC SETTING

The Brisco and Driftwood Creek deposits are situated west of the Rocky Mountain Trench fault Figure 4-9-2). They are hosted by dolomites of the Helikian Mount Nelson Formation of the Purcell Supergroup within the Purcell anticlinorium. Stratigraphic sections applicable to the area of the magnesite deposits were established by Walker (1926), Reesor (1973) and Bennett (1985). The geology of the Toby and Horsethief Creek areas has been described by Pope (1989, 1990). Only the Mount Nelson and Toby Creek formations will be described below. The upper part of the Mount Nelson Formation hosts the magnesite deposits.

The Mount Nelson Formation is separated from the overlying Toby Formation of the Windermere Supergroup (Hadrinian) by an unconformity (Reesor 1973, Pope 1989). This unconformity records the East Kootenay orogenic event which consisted of regional uplift and thermal metamorphism dated at 750–850 Ma and submarine volcanic activity within the Purcell anticlinorium (Pope, 1989).

The magnesite deposits are located within an area affected by low-grade regional metamorphism (Reesor, 1973; Bennett, 1985). All known magnesite occurrences are located outside the contact metamorphic aureole of Middle Cretaceous intrusions (Figure 4-9-2).

STRATIGRAPHY OF THE MOUNT NELSON AND TOBY FORMATIONS

MOUNT NELSON FORMATION

In the Toby – Horsethief Creek map area, the Mount Nelson Formation (Figure 4-9-3) is at least 1320 metres thick and is the uppermost unit of the Purcell Supergroup (Pope, 1990). It is divided into seven members. The descriptions below, in order from oldest to youngest are summarized from Pope (1990).

The "lower quartzite" is 50 to 150 metres thick, white, well-sorted, thin-bedded (<20 cm), ripple-laminated, fine to medium-grained quartz arenite.

The "lower dolomite sequence" is characterized by its grey colour and a light grey weathered surface, laminated beds 20 to 50 centimetres thick, soft sediment features, cryptalgal laminations and laterally linked hemispherical stromatolites. This dolomite also contains black argillite layers 1 to 2 centimetres thick and oolitic laminae. The top of the sequence is the cream-coloured, cherty "cream marker dolomite", 20 metres thick.

The "middle dolomite sequence" comprises the "middle quartzite", "orange dolomite" and "white markers". The "middle quartzite" has a characteristic apple-green colour. It consists of graded, crossbedded and massive arenites, siltstones and argillites. Beds are 10 to 50 centimetres thick

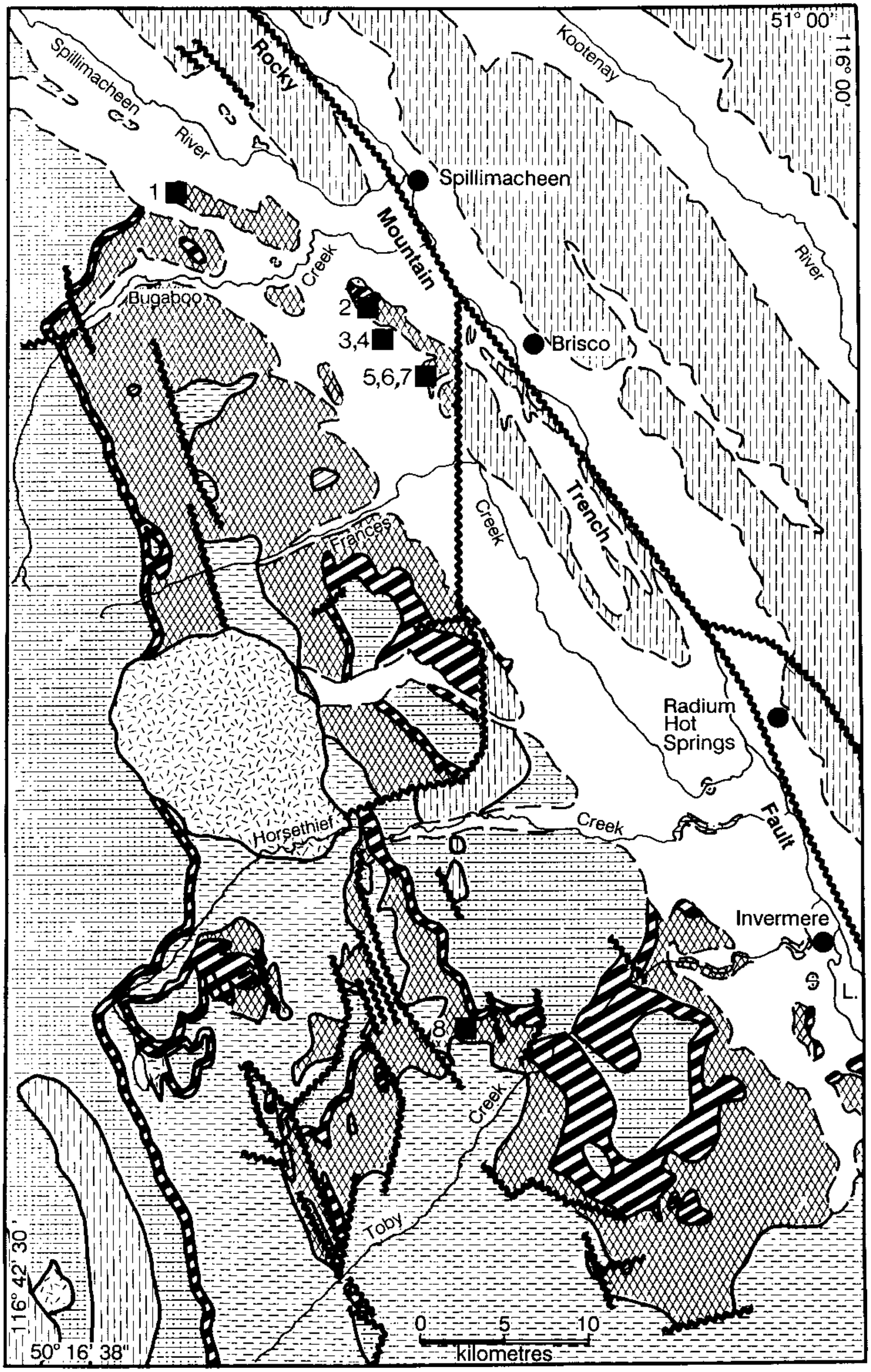
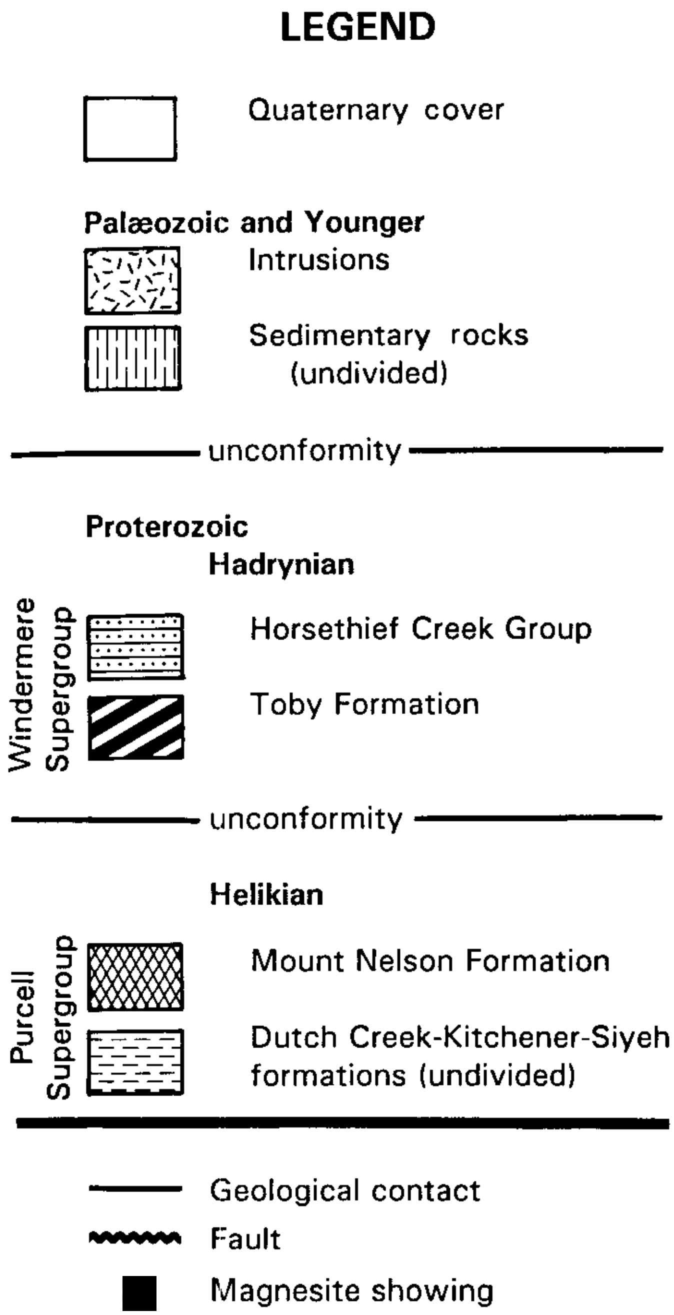


Figure 4-9-2. Regional geology and geological setting of the magnesite deposits hosted by Mount Nelson Formation. Simplified from Reesor (1973).



with undulate bases and truncated tops. The orange dolomite consists of well-bedded silty or light beige to dark grey dolomites weathering orange-brown or orange-buff. Stromatolitic textures, cryptalgal laminations, chert intercalations, halite casts, solution-collapse breccias and dewatering features have been described in this unit.

The "white markers" sequence is less than 70 metres thick and comformably overlies the orange dolomite. It consists of cream to medium grey dolomites and locally contains white magnesite beds up to 1 metre thick as well as purple, green and buff dolomitic mudstones and beds with dolomite-replaced halite crystals.

The "purple sequence" comformably overlies the white markers. It consists of dolomites as well as dolomitic siltstones and sandstones consisting of 20 per cent quartz, 70 per cent dolomicrite and 10 per cent hematite. These rocks contain halite casts and grade upward into purple shales with green reduction spots. Several mudchip breccias and monomictic conglomerates occur within this sequence. The upper part of the purple sequence is referred to as "purple shale unit". It consist of purple argillites with or without green reduction spots and laminae. The purple sequence is separated from the overlying upper middle dolomite by a conglomerate consisting of angular to rounded dolomite and quartzite clasts of variable dimensions, cemented by purple sandy argillite.

The "upper middle dolomite" is 80 metres thick and similar to the lower main dolomite, however, it contains abundant allochems (oncolites and oolitic peloidal and pisolitic laminations) replaced by chert.

The "upper quartzite" is over 260 metres thick. It is a cliff-forming, well-sorted, quartz-cemented and medium to coarse-grained arenite, characterized by massive bedding and poorly preserved sedimentary features.

The "upper dolomite" has a conformable gradational contact with the upper quartzite. Pale beige to dark grey, dolomite beds, 10 to 50 centimetres thick, are interbedded with quartz and dolomite-pebble conglomerates and dolomitic sandstones. The unit is characterized by abundant chert layers, cryptalgal structures replaced by black chert and by a distinctive, laminated, strongly contorted and locally brecciated blue-grey dolomite. The contact with underlying quartzite is transitional and consists of interbeds of purple argillite, quartzite and dolomite.

Toby Formation

The Toby Formation forms the base of the Windermere Supergroup. It consists of five major lithofacies: boulder breccia, diamictite, sparse-clast diamictite, siltstone and argillite, and submarine basic volcanics which are described by Reesor (1973) and Pope (1989). These lithofacies exhibit rapid facies changes.

The boulder breccia facies forms lenticular bodies at the base of the Toby Formation. Clasts are of local provenance and consist of underlying lithologies of the Mount Nelson Formation (Pope, 1989).

The diamictite facies consists of rounded quartzite and subangular dolomite clasts supported by a sandy argillite matrix. The sparse clast diamictite consists of graded, poorly sorted argillites that contain isolated, rounded quartzite clasts.

The volcanic component of the Toby Formation is a "conglomerate" containing clasts of the same range of composition and size as previously described lithofacies, but the matrix is vesicular andesite flow (Reesor, 1973; Bennett, 1985). The Toby Formation is commonly interpreted as a "syn-rift" deposit (Pope, 1989).

GEOLOGY OF THE MAGNESITE DEPOSITS

The descriptions of the Driftwood Creek – Brisco magnesite deposits presented below are based mainly on the 1991

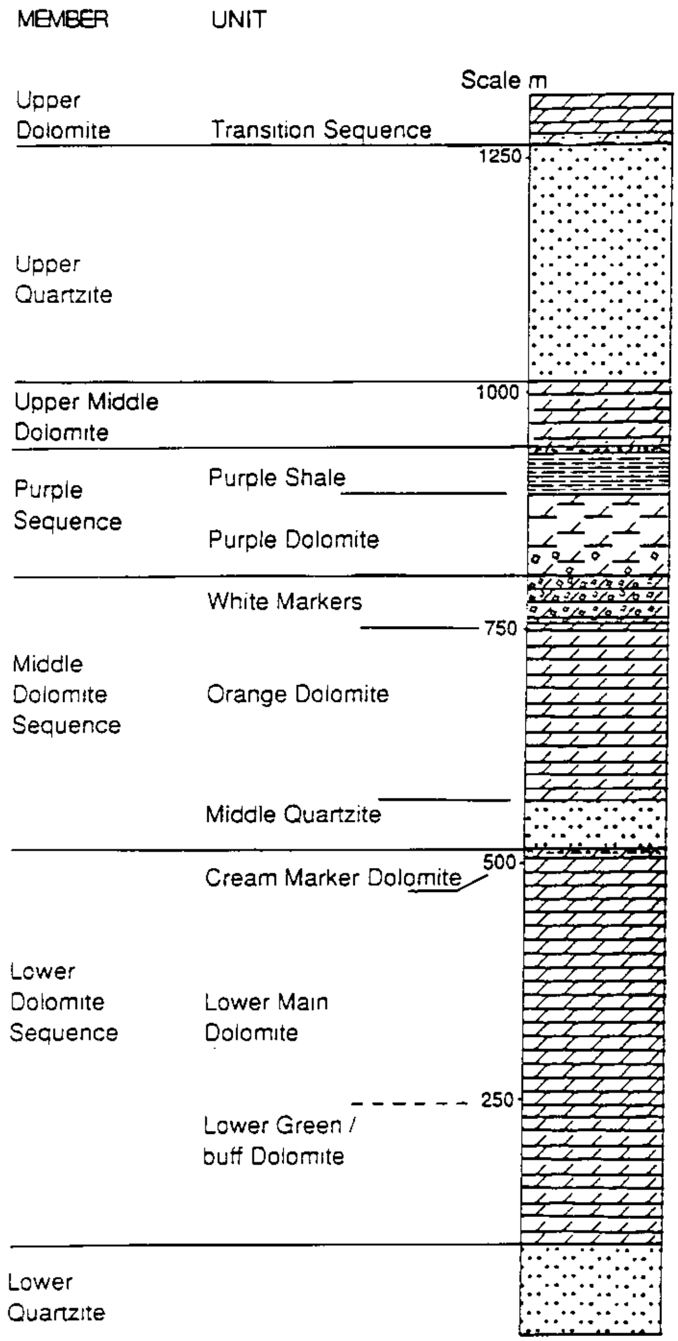


Figure 4-9-3. Stratigraphy of the Mount Nelson Formation. (Pope, 1990)

field investigations, however, where required, deposit descriptions are supplemented by published information by McCammon (1964) and Grant (1987). Mineralogical descriptions are based on field observations. The deposits were extensively sampled in 1991. Chemical analyses of these samples are not available at the time of writing and all quoted analyses are from Grant (1987).

All deposits are hosted by dolomites of the Mount Nelson Formation. The mineralization consists of sparry or coarse-grained magnesite. With the exception of the Red Mountain deposit, detailed stratigraphy in the proximity of magnesite deposits is impossible to establish due to the poor exposure.

Driftwood Creek

The Driftwood Creek deposit is exposed on ridges, on the east side of Driftwood Creek (Figure 4-9-2). The northern part of the deposit was drilled and test pitted by Kaiser Resources Ltd. in 1978 (Morris, 1978) and mapped by Hora (1983). Present work documents a string of stratabound magnesite lenses over a distance of 4 kilometres (Figure 4-9-4). The magnesite-hosting horizon continues farther south and is covered by overburden to the north. The sparry carbonate with least silica impurities lies south of the area investigated by Kaiser Resources. The geology of the Driftwood Creek deposit is illustrated by Figure 4-9-4 and lithologies are described below:

Phyllite and quartzite (Unit D1, Figure 4-9-4) outcrop in the southeastern part of the map area. This unit consists mainly of dark grey argillite with moderately well developed planar cleavage and phyllitic sheen. Grain size is usually smaller than 0.062 millimetre, however, locally white mica specks up to 0.5 millimetre appear on some cleavage faces. Interbeds of soft, probably feldspathic, greenish sandstone (0.062–0.125 mm), less than 50 centimetres thick, are common.

Massive orthoquartzite (Unit D2) is typically white but locally greenish. It consists mainly of rounded, silica-cemented grains measuring 0.125 to 0.5 millimetre in diameter. It is crosscut by numerous, white quartz veins, up to several centimetres wide, and by narrow iron oxide stained fractures less than 0.5 millimetre wide.

Green or buff-weathering dolomitic argillites and siltstones (Unit D3) overlie the massive orthoquartzite. Individual beds are usually 10 to 25 centimetres thick. Both the green and buff-weathering rocks contain dolomite.

Black dolomite (Unit D4) is generally massive and aphanitic and weathers buff. However, some of the beds, 10 centimetres to 2 metres thick, may weather pale grey or greyish white. This rock may contain cryptalgal laminations or isolated stromatolites up to 20 centimetres in diameter (Plate 4-9-1). The dolomite reacts moderately with hydrochloric acid when powdered and is crosscut by abundant quartz veinlets a few millimetres to several centimetres wide.

Greenish grey and locally purplish orthoquartzite (Unit D5) weathers grey, greenish or beige. Massive beds are up to 50 centimetres thick and laminated beds are up to 30 centimetres thick. Quartz grains are moderately well sorted, rounded, less than 0.25 millimetre in diameter and silica cemented. Loadcast textures indicate the sequence is upright.

Dark grey dolomite (Unit D6) is similar to unit D4. It weathers beige or light grey.

Fine-grained, dolomitic siltstone and silty dolomites (Unit D7) are characterized by diffuse centimetre-scale, greenish to purplish or almost salmon-pink rainbow-like colour transitions. Broken rock has sharp edges and nearly conchoidal fractures. The rock is hard and in most cases can not be scratched by a hammer. It reacts strongly with hydrochloric acid if crushed and consists mainly of quartz and dolomite. Softer, more weathered, purplish beds also con-

Plate 4-9-1. Stromatolite in the dolomite which hosts and underlies magnesite; Driftwood Creek deposit.

Plate 4-9-2. Dolomite breccia; pale grey dolomite fragments cemented by sparry dolomite. Sulphide grains appear black; Driftwood Creek deposit.

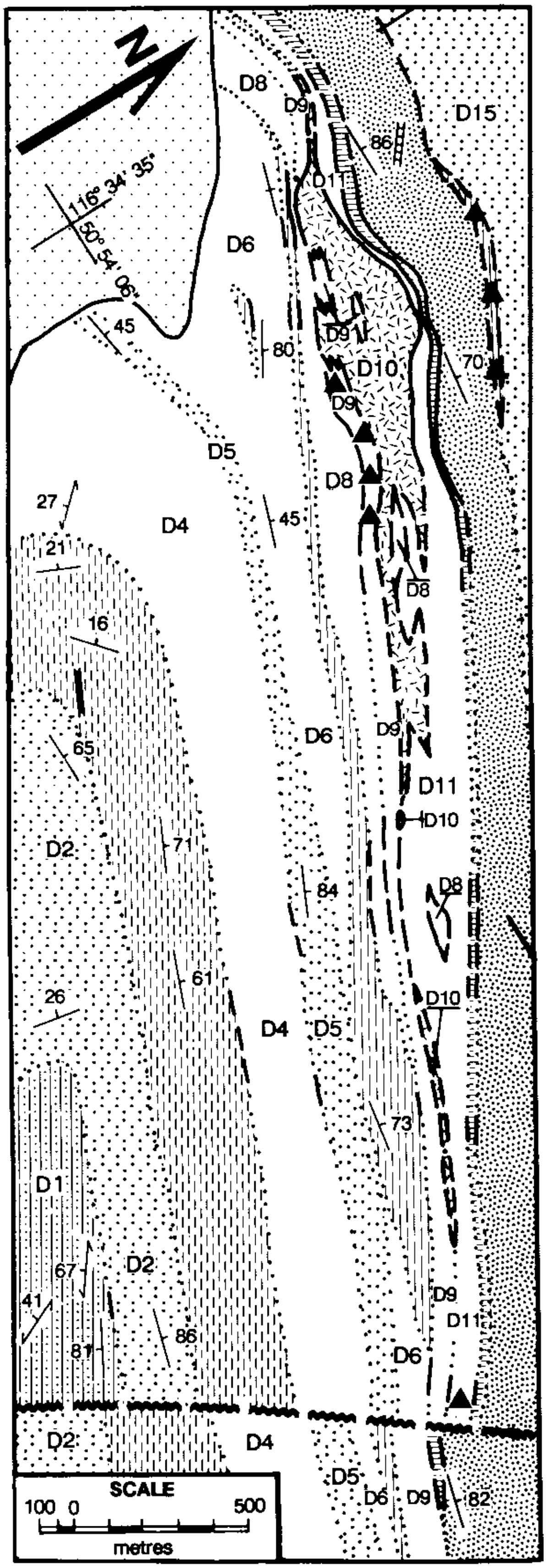
tain chlorite. Proportions of rock-forming minerals are highly variable from bed to bed.

Laminated dark grey dolomite (Unit D8) is medium to dark grey and weathers buff. It is commonly massive and aphanitic to fine grained, however, where locally recrystalized it is coarser (0.25-0.5 mm). When crushed, it reacts with hydrochloric acid. Differential weathering emphasizes fine, sub-millimetre laminations.

Stromatolitic dolomite (Unit D9) most commonly forms the footwall of the magnesite deposit. It is pale grey in colour and weathers orange-brown or red-brown. A feature characteristic of this unit is an abundance of hemispherical stromatolites measuring 10 to 40 centimetres across, commonly discernible only on the weathered surface. When crushed, the rock reacts strongly with hydrochloric acid. It consists of dolomite (<0.125 mm, >90 %) and calcite (<0.125 mm, 0–5%). Commonly it is cut by silica veinlets up to 3 millimetres wide which form less than 10 per cent of the rock. Sparry calcite veins up to 10 centimetres wide were observed in one outcrop only. This rock is locally brecciated where it outcrops adjacent to or below the magnesite lenses. The angular breccia clasts may be elongate or equidimensional and vary in size from a few millimetres to 20 centimetres across. These are interpreted as dissolution and collapse breccias. Clasts are cemented by light grey or white, sparry dolomite (Plate 4-9-2). The sparry cement commonly contains 1 to 3 per cent pyrite crystals up to 4 millimetres across. The dolomite fragments also contain fine-grained, disseminated sulphides.

Magnesite and sparry carbonate (Unit D10) form stratabound lenses and pockets. They are either white, pale grey or beige and weather buff. The unit is characterized by coarse to sparry crystals (Plate 4-9-3) and locally contains light green interbeds less than 1 centimetre in thickness. The interbeds are either regular or disrupted by growth of sparry magnesite crystals within the coarsest magnesite-rich zones. Vestiges of hemispherical stromatolites are observed locally in finer grained magnesite-bearing rocks. Chert, quartz veinlets and dolomite are the most common impurities. Calcite, pyrite, and talc (?) are typically present in trace amounts. The abundance and proportion of impurities change irregularly both along strike and across bedding.

Cherty dolomite (Unit D11) occupies the hangingwall of the magnesite deposits and locally forms parts of the footwall. The chert is generally dark grey to black and weathers either grey or beige. It forms either lenses (Plate 4-9-4) and layers 0.5 to 20 centimetres thick or angular clasts 0.5 to 2 centimetres across. Where interbedded with dolomite,



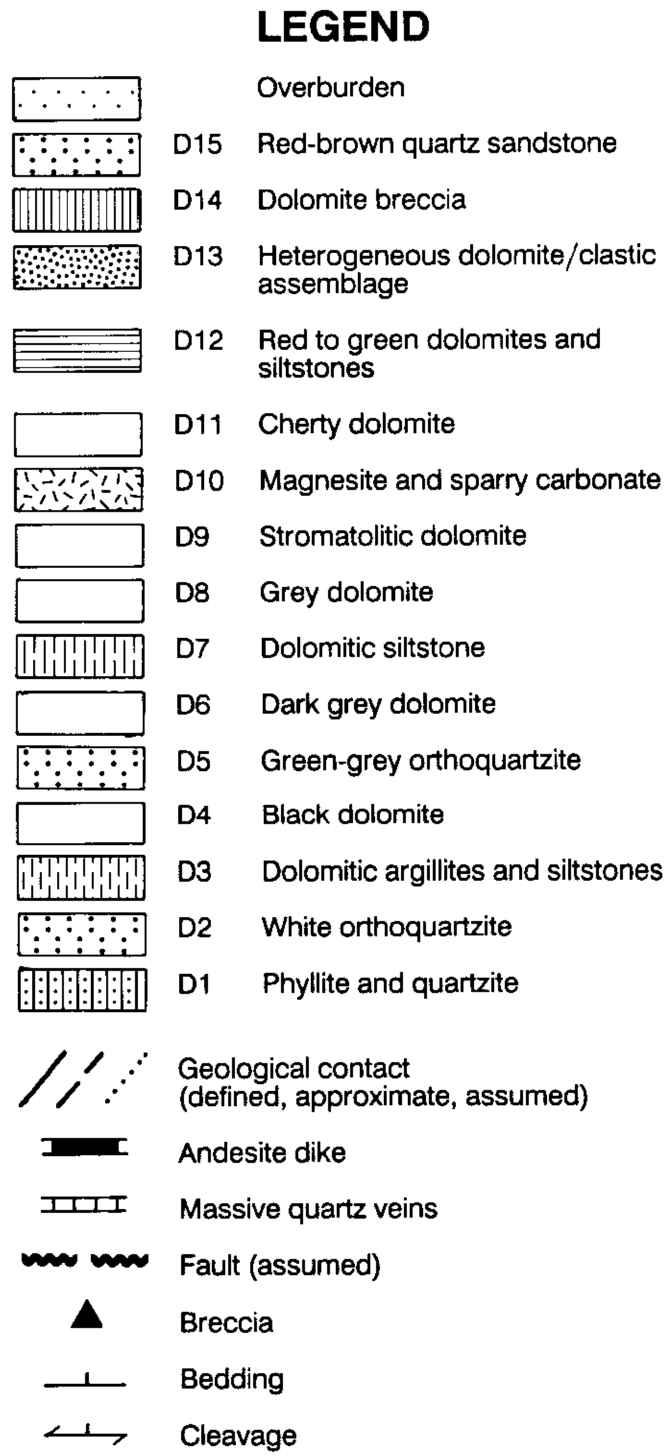


Figure 4-9-4. Geology of the Driftwood Creek deposit.

chert has distinctive positive relief on weathered surfaces. Dolomite is pale to medium grey and weathers beige, light grey or buff. It reacts strongly with hydrochloric acid if crushed.

Red to green dolomites and siltstones (Unit D12) overlie cherty dolomite. The fine-grained red to purple dolomites, minor limestones, silty dolomites, and dolomitic siltstones and shales are characterized by brown to red and pitted weathered surfaces (Plate 4-9-5). These rocks may be inter-

Plate 4-9-3. Sparry magnesite, granola-like texture; Driftwood Creek deposit.

Plate 4-9-4. Chert lenses interbedded with dolomites immediately overlying magnesite; Driftwood Creek deposit.

bedded on centimetre to decimetre scale. Dolomite pseudomorphs after halite are the most distinctive features. Shales and siltstones, and to some extent dolomites, change colour along strike from red-purple in the south to green in the north.

The heterogeneous dolomite-siltstone assemblage (Unit D13) consists of a wide variety of lithologies such as cherty dolomites, red to purple dolomites, dark grey massive dolomites and a variety of dolomitic siltstones either purple, brown or green in colour. Due to poor exposure, the correlation between these units on the map scale is impossible.

Dolomite breccia (Unit D14) consists of dolomitic chert and quartz arenite fragments in a matrix dark grey, fine-grained dolomite weathering grey. When powdered it reacts strongly with hydrochloric acid. In general the breccia is clast supported and polymictic, with fragments consisting of laminated or massive dark grey dolomite. Dark grey chert and white arenite fragments are angular and less than one centimetre in diameter. Over 75 per cent of dolomite fragments are also angular, but some of the clasts larger than 3 centimetres are subrounded. Both matrix and fragments are locally crosscut by fibrous quartz veinlets. Where the breccia is monomictic, the fragments consist exclusively of dolomite. This breccia is at least 25 metres thick.

Massive, white, grey or beige sandstone (Unit D15) weathers light shades of red-brown. Locally it contains silty, olive-coloured layers with well-developed, planar, paper-thin, spaced cleavage. Near the contact with the underlying dolomitic unit this rock consists of well-rounded quartz grains 0.25 to 0.5 millimetre in diameter. Outcrops higher in the sequence contain well-rounded quartz grains up to 6 millimetres in diameter and lithic clasts up to 2 centimetres across. In some outcrops quartz grains are at least partially recrystallized and the rock could be called quartzite. Regardless of size, the grains are, at least in part, cemented or stained by iron oxides and/or coated by clay. Quartz constitutes over 85 per cent of the rock, lithic fragments from 0 to 14 per cent, clays and iron oxides 1 per cent.

Based on the above information, the magnesite-bearing horizon (Unit D10) in the Driftwood Creek area probably corresponds to the white markers unit underlying the purple sequence of the Mount Nelson Formation (Figure 4-9-3).

Red Mountain Deposit

The Red Mountain deposit is located on Figures 4-9-1 and 2. The coarse to sparry magnesite-bearing zone outcrops near the top of Red Mountain. It was traced over 400 metres along strike and has an orientation of approximately 075° with a dip of 45° south. Thickness of the zone is variable and locally exceeds 20 metres.

Two stratigraphic sections were measured perpendicular to the strike near the easternmost limit of the deposit. Section A is correlated with section B along the twin conglomerate marker (Figure 4-9-5). Section B, which is not mineralized, is longer and will be described first. It includes the top of the Mount Nelson Formation and the base of the Toby Formation.

The base of the section consists of pale grey or beige quartzite which weathers beige, grey or white (Unit I). It is exposed for 51 metres. The coarser grained portion of this unit, 37 metres thick, appears at least partly recrystallized and is characterized by a blocky appearance. The longest fracture faces are perpendicular to the bedding. The quartzite consists of well-sorted, well-rounded quartz grains from 0.125 to 0.5 millimetre in diameter depending on individual beds. Other minerals observed in trace quantities are disseminated pyrite (1 mm, <0.5%), iron oxide stains and clays coating or cementing quartz grains (<0.5%).

The upper part of this unit consists mainly of beds, 0.5 metre thick, containing quartz grains varying from 0.125 to 0.75 millimetre in diameter. These beds are interbedded with fine-grained sandstone and siltstone beds from 2 to 20 centimetres thick with grain sizes of less than 0.125 millimetre. Other characteristics are similar to the basal portion of the unit.

A red to purple sequence of shales and siltstones (Unit II), identified on Figure 4-9-5b as red beds, overlies the quartzite. The grain size is typically less than 0.065 milli-

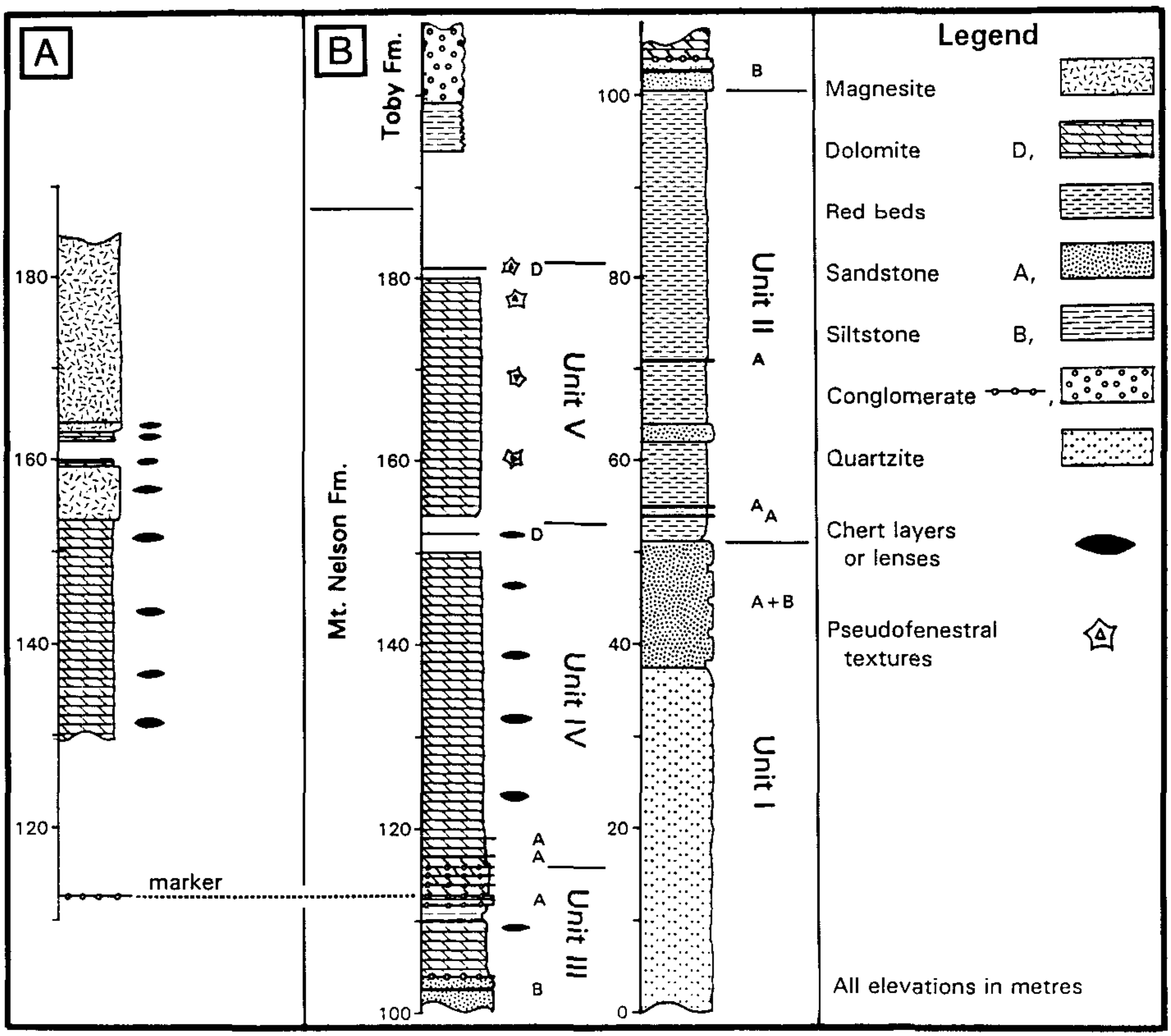


Figure 4-9-5. Stratigraphic setting of the Red Mountain deposit. Section A is magnesite-bearing equivalent of Section B.

metre. However, locally, rounded quartz grains up to 0.75 millimetre in diameter form layers less than 1 centimetre thick within the siltstones. The rock does not react with hydrochloric acid even if crushed. A few thicker and isolated quartzite beds are present within this unit. The first sign of a change from an oxidizing to a reducing environment appears at 87.5 metres above the base of the section, in the form of irregular green patches and lenses within the red-purple shales.

Unit III extends from 100.2 metres to 118.8 metres above the base of the section. It consists of a variety of sandstones, siltstones, conglomerates and minor argillite interbedded with dolomite.

Sandstone dominates the stratigraphic interval from 100.2 to 104.0 metres. The first continuous bed of green shale appears at 102.1 metres. This bed contains four dolomitic layers 1 centimetre thick marking the first appearance of dolomite in the section. Isolated angular clasts of white quartzite, measuring approximately 3 centimetres across, are observed within the dolomite at 104 metres. These clasts consist of arenite (99% quartz) with grain size of 0.125 millimetres.

Fine-grained green siltstone is exposed from 109.9 to 111.7 metres. It weathers light green. The grain size does

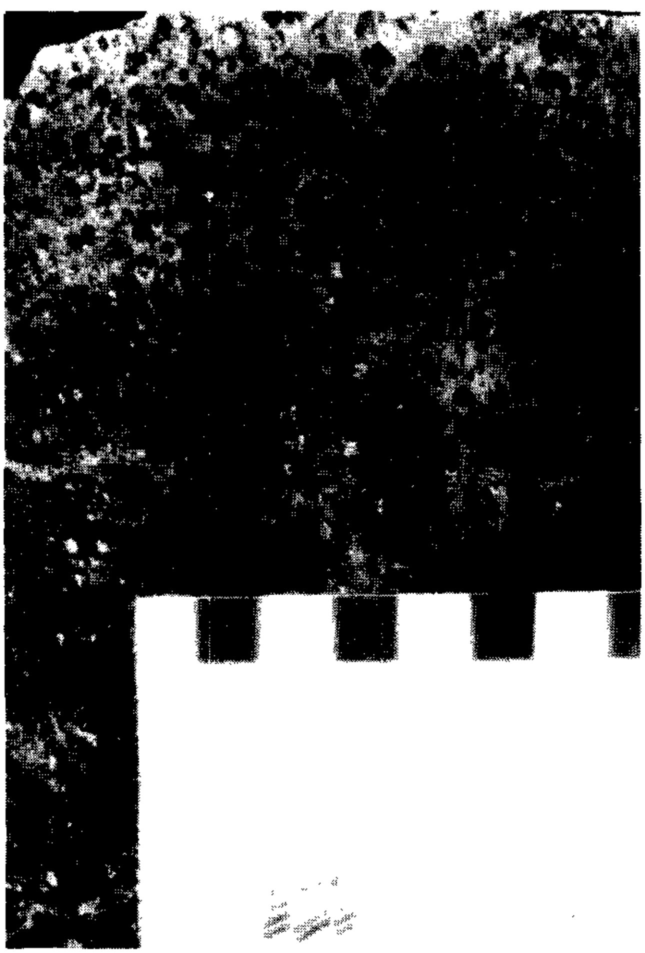


Plate 4-9-5. Weathered-out dolomite cast after halite; Driftwood Creek deposit.

not exceed 0.062 millimetre except for scattered feldspathic and lithic grains of up to 0.125 millimetre in diameter

A sequence of conglomerate and siltstone beds enclosed by dolomite overlies the fine-grained green siltstone. The conglomerates are matrix supported with angular to subrounded clasts ranging from 0.5 to 20 centimetres across. The clasts are quartz arenite with grain sizes of 0.25 to 0.5 millimetre. The matrix is a coarse, 0.25 to 1.0-millimetre quartz sand. Iron oxides and calcite stain or cement the matrix. A twin quartz-conglomerate marker, 1.1 metres thick, consists of two conglomerate beds separated by a thin green siltstone layer approximately 10 centimetres thick. The top of the twin conglomerate marker was used to relate sections A and B (Figure 4-9-5). Three other conglomerate beds, each about 10 centimetres thick, are present at 113.7, 114.8 and 115.9 metres.

Dolomite is present throughout this unit and contains minor, thin, green siltstone and sandstone layers. The dolomite is medium grey and weathers beige or pale grey. It reacts strongly with hydrochloric acid if crushed. Grain size varies from aphanitic to 0.062 millimeter. The first isolated lens of chert, less than 3 centimetres thick, appears at 107.6 metres.

The thick succession of cherty dolomite (Unit IV) starts at 118.8 metres and extends to 150 metres with one more metre exposed at 151.8 metres. The dolomite is medium to dark grey, fine grained to aphanitic and thickly bedded to laminated. Parallel ripple marks are preserved in some of the dolomite beds. Black chert forms interbeds and discontinuous, lobate lenses within the dolomite. Thickness of chert beds and lenses is from a few millimetres to a maximum of 20 centimetres.

Overburden covers the interval 152.8 to 154.0 metres. Distinctive pseudofenestral dolomite (Unit V) extends from 154.0 to 181.0 metres. This dolomite is grey on fresh surface and weathers white to light grey. It is fine grained and generally massive. The pseudofenestral texture is seen as very irregular, complexly shaped features commonly outlined by a thin, black or dark grey border with a core of white or medium grey dolomite or rarely calcite. Concentric layers of dolomite, in shades of grey, are present within some of these pseudofenestrae. Locally the pseudofenestrae have polygonal outlines and are interpreted as fillings within a dissolution breccia.

The Toby Formation is exposed from 94 metres to 208 metres. The lower 5.3 metres consists of brown-weathering, well-cleaved shale. On fresh surfaces the rock is dark to medium grey with grain size less than 0.062 millimetre. Calcite forms a thin coating on the planar cleavage. Scattered, discontinuous layers of dolomite, less than 2 centimetres thick, are present in the shale. They are grey, weather light buff and have a slight positive relief above the surrounding shale.

Above the brown shale to the top of the exposure is a polymictic conglomerate, typical of the Toby Formation. The conglomerate is matrix supported. The clasts form 40 per cent of the rock, range from 1 to 20 centimetres in diameter and are subangular to rounded. Clasts consist of fragments of rocks from the underlying Mount Nelson Formation. They consist of black chert, pseudofenestral dolomite and grey dolomite together with green, grey and white quartz arenite. Magnesite clasts were were not observed. The matrix is the same as the underlying shale. Cleavage is developed exclusively in the matrix.

Comparison between Sections A and B clearly indicates that cherty dolomite and pseudofenestral dolomite are host-rocks and stratigraphic equivalents of the magnesite. This relationship is further supported by the preservation of the cherty layers and lenses within the sparry magnesite-bearing rock. The footwall contact between sparry magnesite and cherty dolomite is irregular. Carbonate pseudomomorphs after lenticular gypsum crystals are present within the dolomite near this contact. The lateral lithological change between sparry magnesite and cherty and pseudofenestral dolomite is not exposed.

Magnesite-bearing rock is sparry and light grey on fresh surface. It is characterized by a knobby, rough, buff-coloured weathered surface. When crushed, the rock reacts moderately with hydrochloric acid. Grain size varies from 0.1 millimetre to 2 centimetres. The rock consists mainly of magnesite. Typical impurities are dolomite (1-25%), calcite, rusty stains along fractures and occasional shaly layers. Near contacts with dolomite, magnesite-bearing rock contains layers of black chert 1 to 15 centimetres thick which form up to 30 per cent of the rock. The chemical composition of the rock is given in Table 4-9-1.

The Red Mountain deposit overlies the purple and green shales of the Mount Nelson Formation (Figure 4-9-5), indicating that it is located higher in the stratigraphy than the Driftwood Creek deposit.

Topaz Lake Deposit

This magnesite deposit, located south of Topaz Lake, was staked in 1960 and 61 and consists of several showings

Plate 4-9-6. Pseudofenestral features. Open spaces filled be white dolomite separated from the host dolomite by dark gray rims. Topaz Lake deposit.

TABLE 4-9-1
CHEMICAL COMPOSITION OF THE MAGNESITE-BEARING ROCKS OF THE BRISCO AND DRIFTWOOD CREEK AREAS

DEPOSIT	MgO	CaO	SiO_2	Fe_2O_3	Fe (Total)	Al_2O_3	CO_2
Red Mountain	39.50	0.76	14.72	0.88	-	-	43.40
Topaz Lake	42.79	1.04	6.48	0.87	-	-	46.72
	43.34	0.51	5.54	1.02	-	-	47.60
	44.85	0.73	3.47	0.95	-	-	49.20
Cleland Lake	38.20	7.89	4.51	1.00	-	-	47.74
Jab	44.02	0.47	8.99	0.99	-	-	43.82
Botts Lake	35.97	8.57	8.69	0.12	-	-	46.02
Dunbar Creek	41.41	2.84	3.97	2.07	-	-	47.48
	42.28	2.67	3.22	1.03	-	-	48.28
Driftwood Creek	42.50	4.20	2.50	-	0.77	0.06	-
	40.00	6.00	4.60	-	0.82	0.13	-

(McCammon, 1964; Grant 1987). The largest is exposed over an area of 38 800 square metres (Figure 4-9-6). The contact between magnesite-bearing rock and the footwall is irregular and subhorizontal. Drilling indicates a thickness of magnesite of up to 30 metres (Grant, 1987). The footwall of the deposit, where exposed, consists of dark grey to black, fine-grained dolomite. When powdered, this dolomite effervesces strongly on contact with hydrochloric acid. It commonly displays spectacular pseudofenestral textures (Plate 4-9-6). However, drilling indicated that outcropping magnesite is underlain by cherty dolomite (Grant, 1987), suggesting that the footwall contact is discordant.

Sparry magnesite-bearing rock is white to light grey and weathers beige. Crystal size varies from 1 to 20 millimetres. Observed impurities are dolomite (0-20%), calcite veinlets and fracture fillings (<5%), disseminated pyrite (<0.5 mm, trace) and quartz grain aggregates (1-2 cm, <1%). It reacts weakly or not at all with hydrochloric acid even if crushed. However, near the contact with fine-grained dolomite, powdered sparry carbonate reacts moderately with acid when crushed, indicating a substantial dolomite component. These sparry zones with lower magnesite content are identified on Figure 4-9-6 as a distinct unit. The chemical composition of the magnesite-bearing rock from the main showing is given in Table 4-9-1. Smaller magnesite occurrences nearby are described by Grant (1987).

Based solely on textural and lithologic similarities, both the Cleland Lake and Red Mountain deposits are tentatively interpreted as part of the same magnesite horizon.

Cleland Lake Deposit

This magnesite deposit is exposed along a low ridge at the south end of Cleland Lake (Figure 4-9-7). The minimum thickness of the magnesite zone is 20 metres (Figure 4-9-8). Most of the sparry magnesite rock is coarse grained and, when crushed, reacts moderately with hydrochloric acid. It is beige to pale grey and weathers buff. It consists of magnesite (1-5 mm, 60-95%), sparry dolomite (1-10 mm, 3-40%), local silica concentrations in the form of veinlets and sandy layers (<5%) and disseminated pyrite (<2 mm, <0.5%). Composition of the magnesite-bearing rock is given in Table 4-9-1. Some sparry carbonate zones have a high dolomitic component and are referred to as sparry carbonate (Figure 4-9-7). Near the contact of magnesite with overlying red or grey fine-grained dolomite, the magnesite zone is fine grained and layered.

Fine-grained, pale grey dolomite is a stratigraphic equivalent of the sparry magnesite in the southern part of the study area.

The hangingwall consists of a thin layer of pale to dark grey, fine-grained carbonate, which is in turn overlain by a thick sequence of red to purple dolomites and dolomitic siltstones (Figure 4-9-8). These purple rocks contain abundant dolomite casts after halite and dolomite-replaced halite hopper crystals. They are reduced in the northwestern part of the map area, where their colour changes to green and they contain pyrite crystals up to 1 centimetre in size.

Disseminated fine-grained sphalerite, bornite and an unidentified opaque mineral were observed approximately 620 metres southeast of the magnesite showing. This metalliferous mineralization is hosted by silicified, light grey dolomite which is believed to be the stratigraphic equivalent of the magnesite horizon.

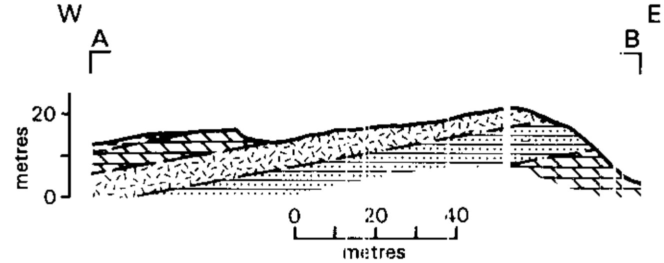


Figure 4-9-8. Cleland Lake deposit; vertical cross-section; for location and legend see Figure 4-9-7.

Based on the lithologic succession: magnesite and red silty dolomite containing halite hopper crystals, the Cleland Lake deposit is probably hosted by the stratigraphic equivalent of the white markers unit described by Pope (1989) which underlies the purple sequence (Figure 4-9-3).

Jab Deposit

Staked in 1961, the Jab deposit is the oldest known magnesite showing in the Brisco area. Magnesite-bearing rocks form a knoll about 130 metres long, up to 55 metres wide and up to 20 metres high (Figures 4-9-9 and 10). The magnesite-bearing rock is white on fresh surfaces and weathers beige. It is sparry, however, the size of magnesite crystals diminishes progressively from several centimetres in the north to finer and sugary (1-3 mm) in the south part of the knob. Most of the primary sedimentary features of the protolith were destroyed during recrystallization, however relicts of hemispherical, laterally linked stromatolites are preserved in two fine-grained outcrops. In the southern part of the knoll, magnesite layers 2 to 5 centimetres thick are separated by vestiges of thin (<5 mm) silty beds now partially transformed to talc or serpentine.

Visual examination indicates that magnesite-bearing rock consists mainly of magnesite (>85%). Impurities are dolomite (<10%), disseminated pyrite (trace) and vestiges of the talc or serpentinized green silt layers (0-5%). Silica veinlets and quartz crystals (0-3%) are less abundant than in other deposits of the Brisco area.

The magnesite-bearing knoll (Figure 4-9-9) is isolated and none of the nearby trenches reached bedrock. The knoll was bulk sampled and drilled. A drill hole over 80 metres deep terminated in magnesite (McCammon, 1962). The orientation of the borehole is not known. Although the overburden in the area appears to be thick, this deposit warrants further exploration and testing. The interpretation of structural measurements taken on the vestiges of bedding planes suggests that the magnesite knoll is part of a larger fold structure plunging 16° towards 324°.

The lack of outcrops in the immediate area of the deposit precludes stratigraphic correlation, however stromatolitic textures and green centimetre-scale layers of sedimentary origin were also observed in magnesite-bearing rocks of the

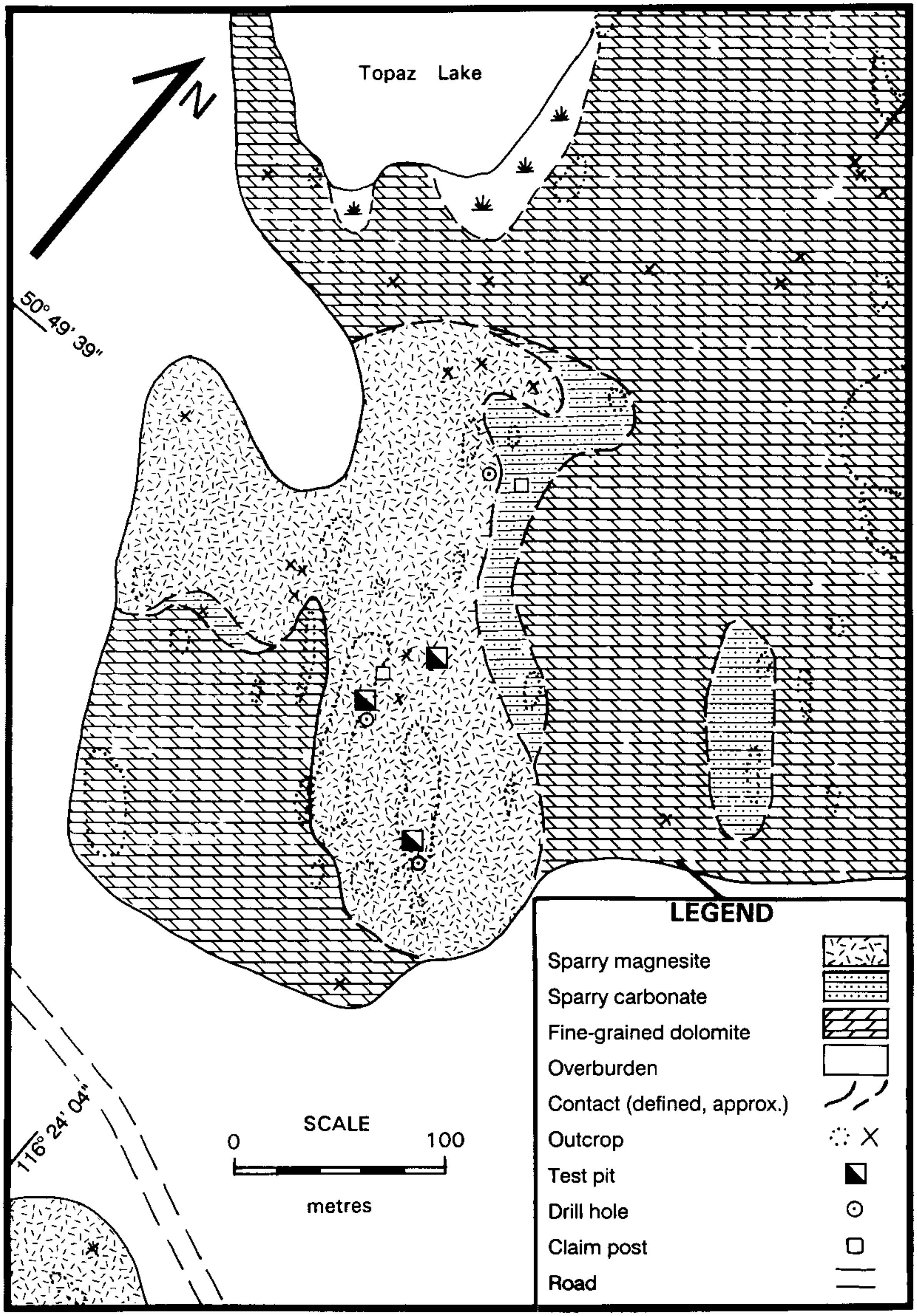


Figure 4-9-6. Geology of the Topaz Lake deposit.

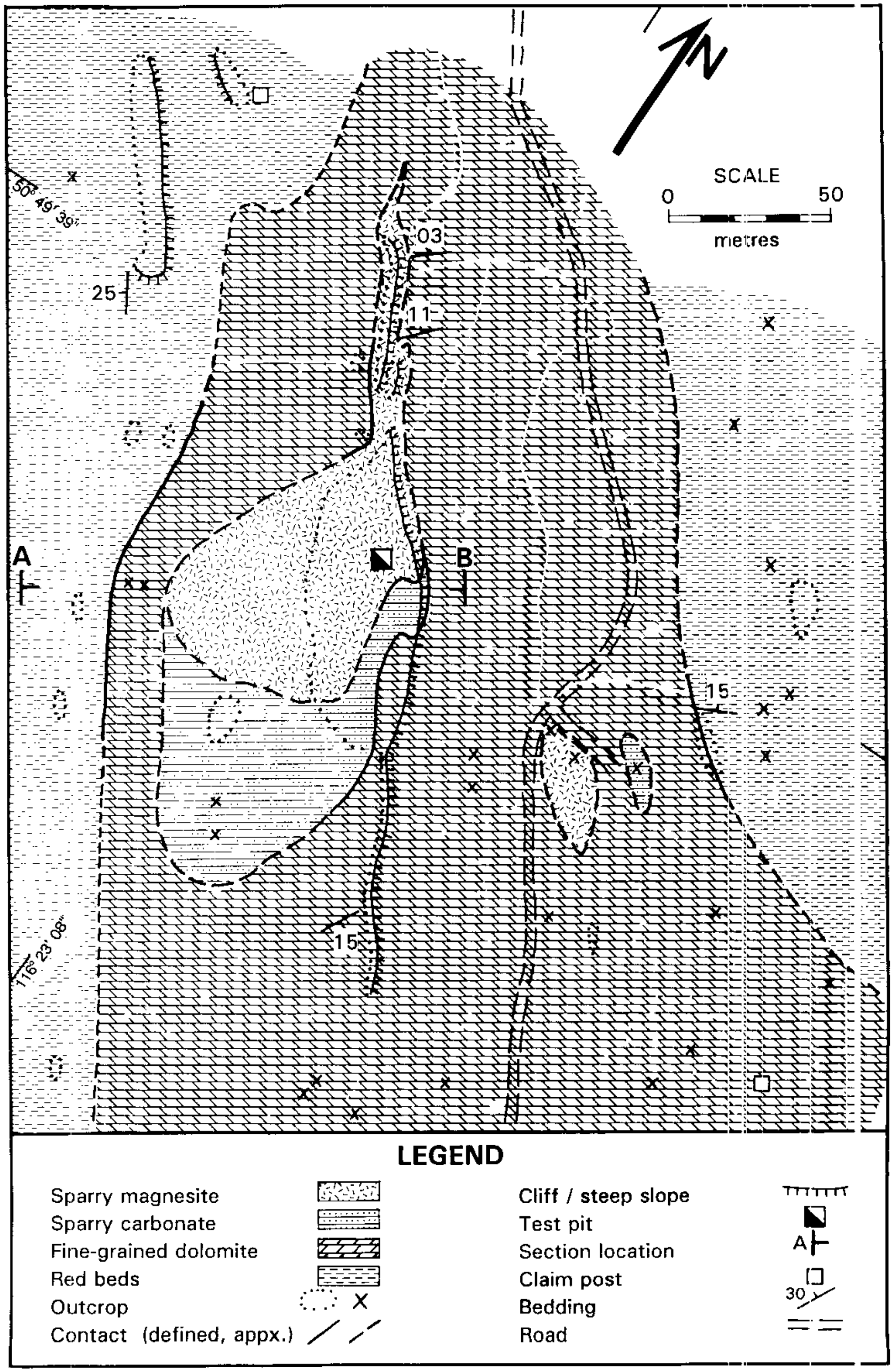


Figure 4-9-7. Geology of the Cleland Lake deposit.

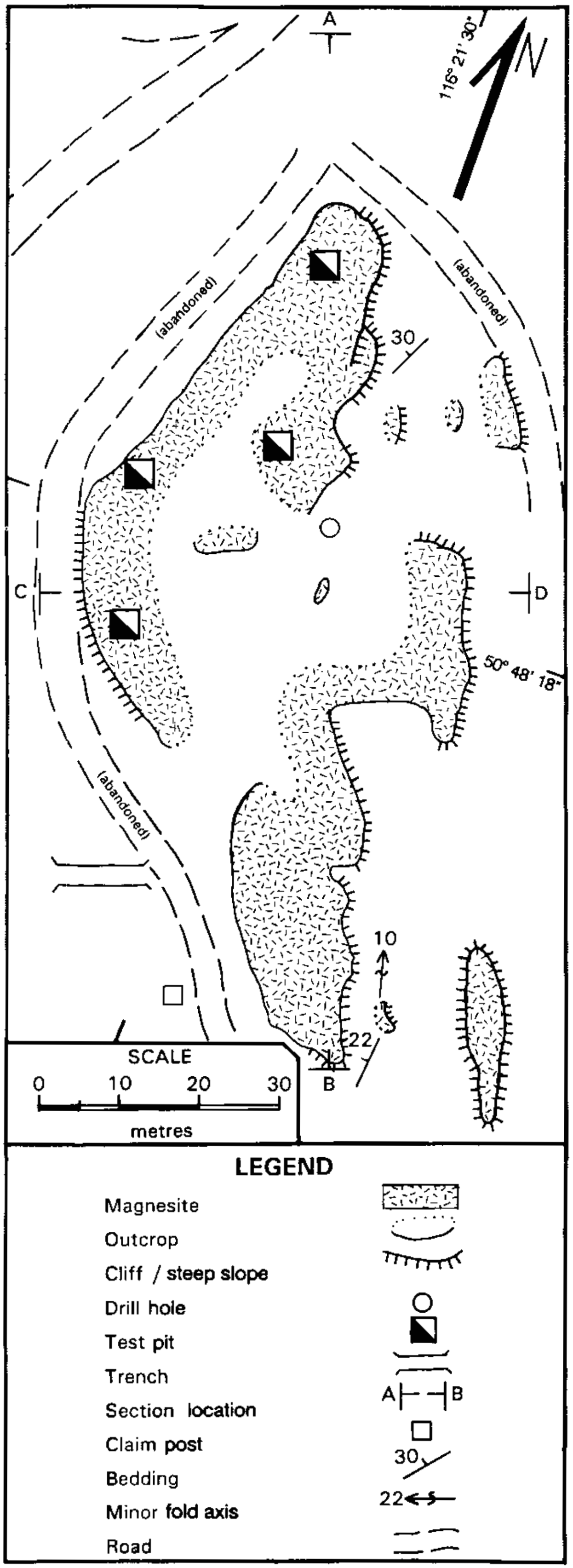


Figure 4-9-9. Geology of the Jab deposit.

Driftwood Creek deposit. These similarities suggest that the Jab and Driftwood Creek deposits may be part of the same stratigraphic horizon.

Dunbar Creek Deposit

The Dunbar Creek showings are hosted by a sequence of stromatolitic and cherty dolomites. Most of the showings have irregular shape and variable grade. They are described by McCammon (1964). When crushed, the magnesite-bearing rock reacts moderately to poorly with hydrochloric acid. Magnesite content varies from 50 to 90 per cent. Impurities are dolomite (5-30%), calcite veinlets and fracture fillings (0-5%), disseminated pyrite (trace), cherty layers over 1 centimetre thick (0-15%) and disturbed veinlets of quartz less than 5 centimetres wide (0-1%). A thick stromatolitic sequence underlies the deposit and cherty layers are abundant in adjacent dolomite. It is possible that the Dunbar deposit lies on the same stratigraphic horizon as the Driftwood Creek deposit, which is tentatively interpreted as the equivalent of the white markers unit (Figure 4-9-3).

Botts Lake Deposit

The Botts Lake deposit is located on Figures 4-9-1 and 2. Magnesite outcrops were traced over a distance of 118 metres along strike. A magnesite-bearing unit is at least 10 metres thick (Figure 4-9-11), strikes 130° and dips 47° east. The footwall consists of hard, aphanitic to fine-grained, dark grey to black dolomite which weathers pale grey. When crushed, this dolomite reacts moderately to strongly with hydrochloric acid. It appears massive on fresh surfaces, however, careful examination of the weathered surface reveals submillimetre-scale laminations. It is cut by pale grey dolomite and milky white quartz veinlets (<5 mm thick).

Light to medium grey dolomite which weathers pale fawn in colour overlies the dark dolomite. It fractures along irregular, lumpy surfaces. It does not react with hydrochloric acid unless crushed and is cut by hairline fractures containing clay and/or calcite.

Pale grey dolomite, which possibly contains minor amounts of magnesite, may represent the transition between dolomite and the magnesite-bearing horizon. If crushed it reacts moderately with acid. The rock appears massive on the fresh surface, however, suggestions of diffuse 3 to 5-millimetre layers are seen on the weathered surfaces. Grain size does not exceed 0.5 millimetre.

The magnesite-bearing rock is snow white and weathers white or light grey. Crushed rock will effervesce moderately to poorly when in contact with hydrochloric acid. The rock appears textureless on fresh surfaces. Laboratory work is required to identify the origin of local, irregular, "sponge-like" shapes revealed by differential weathering. Field estimates indicate that the rock consists of a mixture of dolomite (40 to 70%) and magnesite (30 to 60%) and is expected to have a lower magnesia content than other magnesite deposits of the Brisco area. Traces of enargite (Cu_3AsS_4) were found in hairline fractures within this horizon.

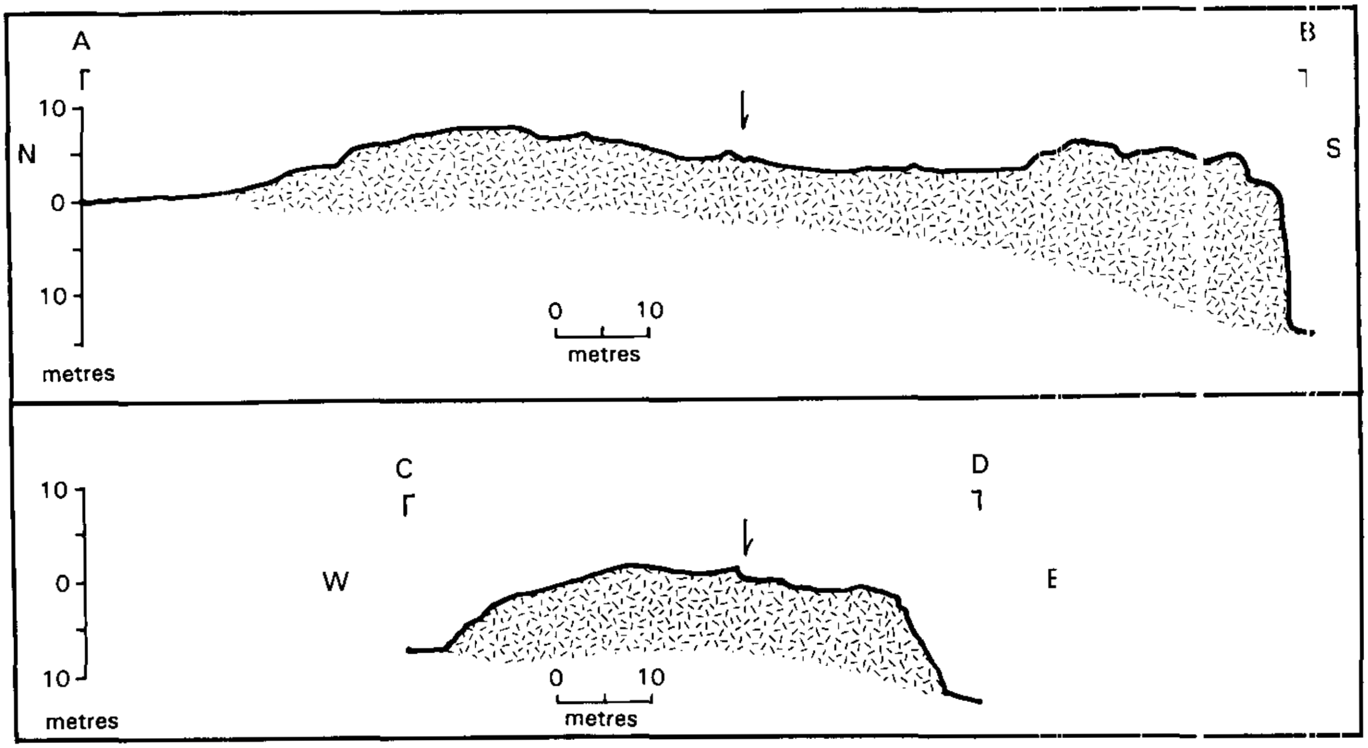


Figure 4-9-10. Vertical sections across the Jab deposit; *see* Figure 4-9-9 for location and legend.

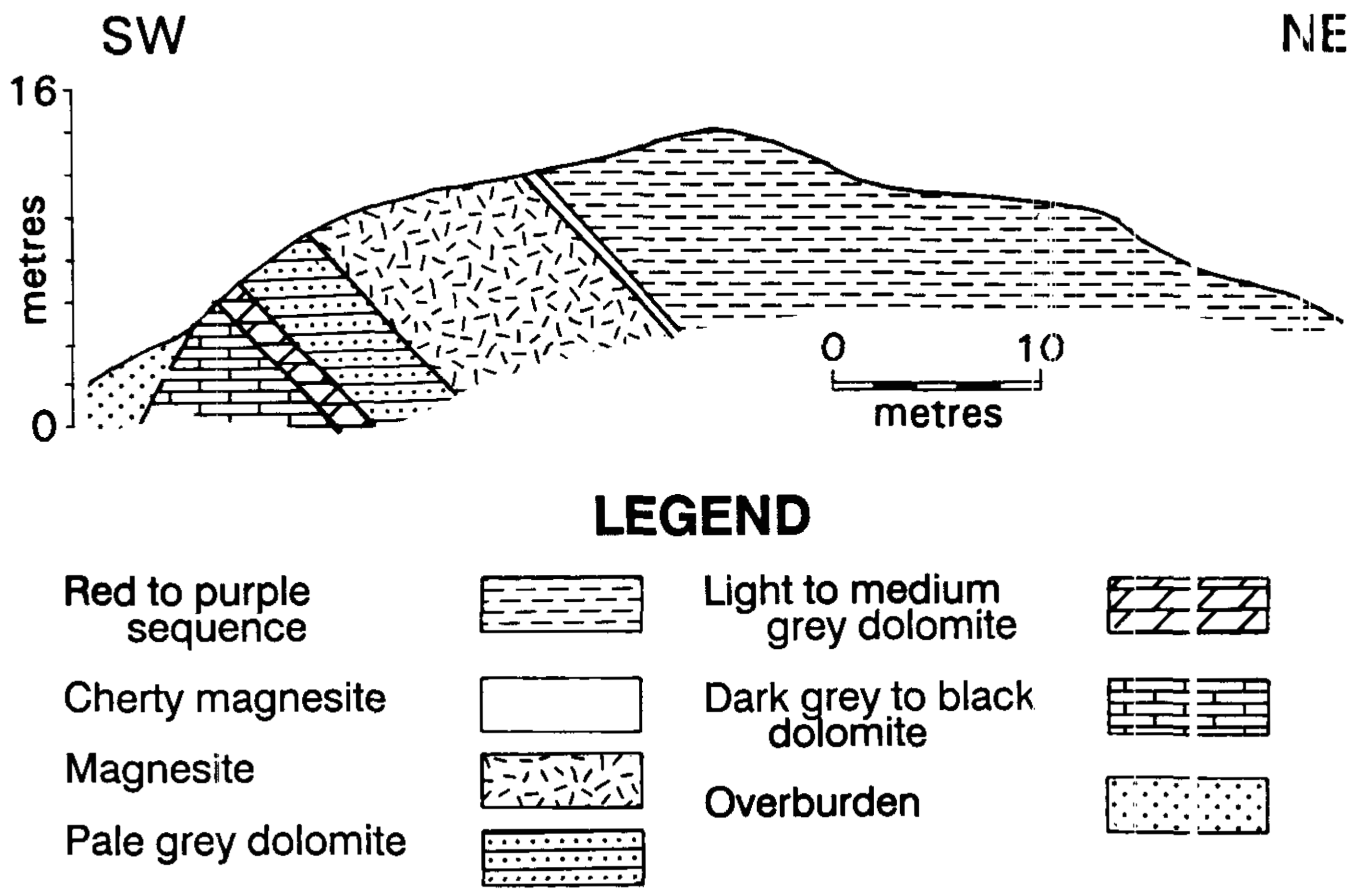


Figure 4-9-11. Geology of the Botts Lake deposit.

Chert is exposed in the hangingwall of the magnesite-bearing unit (Figure 4-9-11). The thickness of this horizon appears to increase along strike to the south.

Red to purple silty dolomite and dolomitic argillite overly the chert-bearing horizon. These rocks are characterized by a red to rusty brown, locally pitted, weathered surface, halite casts and intraformational breccias. Locally, red argillite contains ellipsoid-shaped reduction features usually less than 5 centimetres along the longest axis. Based on the relative position of the lithologic units, magnesite and red-purple dolomite containing halite pseudomorphs, it is suggested that the Botts Lake showing corresponds stratigraphicaly to the white markers unit (Figure 4-9-3).

Other Magnesite Deposits

Two magnesite showings reported in the Invermere area (Pope, 1989, 1990), are located on Figure 4-9-2. They consist of impure magnesite and are less than 1 metre thick. They are hosted by the white markers unit (Figure 4-9-3) in the upper part of the Mount Nelson Formation (Pope, 1990).

SUMMARY AND DISCUSSION

All the magnesite deposits in the Brisco and Driftwood Creek areas are dolomite hosted and stratabound. They are located within the upper half of the Mount Nelson Formation. Most are lenticular and seem to form chains as illustrated by the Driftwood Creek example (Figure 4-9-4).

All deposits are stratigraphically associated with red to purple dolomites, cherty dolomites (Plate 4-9-4), stromatolitic dolomites (Plate 4-9-1), dissolution breccias (Plate 4-9-2) and other rocks containing dolomite pseudomorphs after halite (Plate 4-9-5) and lenticular gypsum crystals. Locally, stromatolitic textures are preserved, even within magnesite-bearing rocks. Most of the above features are indicative of the evaporitic depositional environment.

Origin

The current working hypothesis for the origin of the magnesite deposits in the Brisco and Driftwood Creek areas is based mainly on the field evidence indicating an evaporitic depositional environment and published information concerning magnesite genesis. The link between the evaporitic environment and magnesite in the Brisco area was first suggested by Bennett (1985).

Although magnesite can not precipitate directly from aqueous solutions under normal near-surface conditions (Lippman, 1973), magnesium hydrates or hydroxyhydrates commonly form in evaporitic environments (Morse and Mackenzie, 1990). The Brisco and Driftwood Creek deposits may have formed by recrystallization of such magnesite precursors, or by cyanobacterial magnesite precipitation in evaporitic basins or lakes having high Ph (8.5-10). The biomineralization of magnesite by cyanobacteria was documented on the laboratory scale by Thompson and Ferris (1990). The presence of magnesite is well documented in modern marine environments for example in Coorong Lakes, South Australia (Warren, 1990) and Sebkha El Melah, Tunisia (Perthuisot, 1980). The evaporitic model was proposed on many occasions in the past to explain the origin of ancient sediment-hosted magnesite deposits. Unfortunately in most cases the analogy was not convincingly documented or the concept was misused. In this case metalliferous minerals would represent an overprint.

Two alternative hypotheses for the formation of the magnesite deposits in the Brisco and Driftwood Creek area should not be discounted before completion of ongoing laboratory studies. They are: (a) formation of magnesite by replacement of dolomite, as proposed for the Mount Brussilof magnesite deposit (Simandl and Hancock, 1991), and (b) formation of magnesite by the inflow of hydrothermal fluids into closed basins as previously proposed for some Yugoslavian deposits (Fallick *et al.*, 1991).

Replacement of dolomite by magnesite can not be prematurely ruled out in the study area. Evaporitic rocks are easier to dissolve than carbonates. Preferential dissolution of evaporitic rock may result in the development of karst features and extensive zones of dissolution breccia along evaporitic horizons. Late diagenetic or hydrothermal fluids similar to those forming Mississippi Valley-type base metal deposits could move preferentially through these highly permeable zones, replacing fine-grained dolomite and evaporitic minerals by sparry magnesite and dolomite, overprinting primary evaporitic textures.

Magnesite deposits of hydrothermal exhalative origin are described in Yugoslavia. These deposits are fine-grained magnesite-dolomite beds and lenses hosted by Miocene lacustrine sediments related to silicic volcanism (Fallick *et al.*, 1991). The hydrothermal model is a viable hypothesis for magnesite deposition in the Brisco area because syn-rift vesicular andesites containing clasts from the Mount Nelson Formation documented along the unconformity separating the Mount Nelson and Toby formations (Reesor, 1973; Bennett, 1985; Pope, 1989). Furthermore the origin of the chert associated with the magnesite deposits is not yet established. Chert may be evaporitic with or without a hydrothermal component.

Exploration Implications

Regardless of the origin of the fluids involved in magnesite genesis (evaporitic, diagenetic or hydrothermal), the carbonates of the Mount Nelson Formation represent a favourable exploration environment for Brisco-type deposits, particularly stratigraphic equivalents of chert-bearing rocks adjacent to red or purple-colored dolomites and dolomitic siltstones with dolomite pseudomorphs after halite.

The Toby conglomerate is a well-documented marker that can be used by prospectors to delimit the Mount Nelson Formation which hosts all known magnesite occurrences in the area (Figure 4-9-2).

Two magnesite showings reported in the Invermere area are also hosted by the white markers sequence of the upper Mount Nelson Formation (Pope, 1990), indicating that the formation is prospective for magnesite at least from Invermere to Driftwood Creek.

Laboratory studies are in progress to test the previously described hypothesis concerning the origin of magnesite deposits in the Brisco and Driftwood Creek areas. A deposit model is required to identify the areas with highest exploration potential.

The occurrence of enargite within magnesite-bearing rock at Botts Lake showing, and of sphalerite and bornite near the Cleland Lake magnesite showing may represent a post-magnesite hydrothermal overprint. However, a possible genetic link with magnesite mineralization should not be discounted. Enargite, sphalerite and bornite are reported in association with a wide variety of geological environments including exhalative hydrothermal deposits (Guilbert and Park, 1985) and Mississippi Valley-type base metal deposits (Hagni, 1976; Vos *et al.*, 1989). The possible metallogenic significance of these new base metal showings should not be overlooked.

Economic Potential

Field investigations indicate that several of the magnesite deposits in the Brisco and Driftwood Creek areas have grades similar to deposits currently mined in Europe, however, their silica content is higher than that of the famous Mount Brussilof deposit.

Magnesite-bearing rocks in the Brisco – Driftwood Creek area have simple mineralogy and coarse textures, suggesting that they may be either upgraded by traditional concentrating methods or used as source material for products not requiring high-purity feed.

Furthermore, as illustrated by the Driftwood Creek example, concentration of impurities such as quartz and chert varies substantially along strike, indicating that extensions of other known deposits may have higher grades than outcropping portions. Most of the deposits are open either along strike or to depth.

Laboratory tests will contribute significantly to determining the possible applications for magnesite from these deposits.

ACKNOWLEDGMENTS

Enriching discussions with Dr. S.Paradis of the Geological Survey of Canada and Dr. A. Panteleyev from the British Columbia Ministry of Energy, Mines and Petroleum Resources are acknowledged. Enargite, sphalerite and bornite were positively identified by Dr. M. Chaudhry of the British Columbia Ministry of Energy, Mines and Petroleum Resources using x-ray diffraction. Mr. J.M. Newell, Dr. D.V. Lefebure, Ms. P. Kelly and Mr. Z.D. Hora of the British Columbia Ministry of Energy, Mines and Petroleum Resources kindly edited this manuscript.

REFERENCES

Bennett, S.M.H. (1985): Tectonics, Sedimentation and Mineralization on the East Flank of the Purcell Anticlinorium, Southeast British Columbia, Canada; unpublished Ph.D. thesis, *University of London*, 461 pages.

Fallick, A.E., Ilich, M. and Russell, M. (1991): A Stable Isotope Study of the Magnesite Deposits Associated with the Alpine-type Ultramafic Rocks of Yugoslavia; *Economic Geology*, Volume 86, pages 847-861.

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.

Guilbert, M.J. and Park, C.F. Jr. (1985): The Geology of Ore Deposits; *W.H. Freeman and Company*, New York, 985 pages.

Hora, Z.D. (1983): Magnesite – Driftwood Creek Area; *in* Geological Fieldwork 1983, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1984-1, pages 213-214.

Hagni, R.D. (1976): Tri-State Ore Deposits: The Character of their Host Rocks and their Genesis; *in* Handbook of Strata-bound and Stratiform Ore Deposits, Volume 6, Wolf, K.H., Editor, *Elsevier Scientific Publishing Company*, Amsterdam, 585 pages.

Lippman, F. (1973): Sedimentary Carbonate Minerals; *Springer-Verlag*, New York, 228 pages.

McCammon, J.W. (1962): untitled map; *B.C. Ministry of Energy, Mines and Petroleum Resources* Property File map 082K-NE-014.

McCammon, J.W. (1965): The Brisco Magnesite Area; *B.C. Ministry of Energy, Mines and Petroleum Resources;* Annual Report 1964, pages 194-199.

Morse, J.W. and Mackenzie, F.T. (1990): Geochemistry of Sedimentary Carbonates; Developments in Sedimentology, Volume 48, *Elsevier*, 707 pages.

Morris, R.J. (1978): Fish Magnesite Deposit; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Assessment Report 8760.

Perthuisot, J.P. (1980): Sebkha El Melah near Zarzis: A Recent Paralic Salt Basin (Tunisia); *in* Evaporite Deposits, *Editions Technip*, Paris, pages 12-17.

Pope, A.J. (1989): The Tectonics and Mineralization of the Toby – Horsethief Creek Area, Purcell Mountains, Southeast British Columbia, Canada; unpublished Ph.D. thesis, *University of London*, 350 pages.

Pope, A.J. (1990): The Geology and Mineral Deposits of the Toby – Horsethief Creek Map Area, Northern Purcell Mountains, Southeastern British Columbia; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Open File 1990-26, 54 pages.

Reesor, J.E. (1973): Geology of the Lardeau Map Area, Purcell Mountains, Southeastern British Columbia; *Geological Survey of Canada*, Memoir 369, 118 pages.

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

Thompson, J.B. and Ferris, F.G. (1990): Cyanobacterial Precipitation of Gypsum, Calcite, and Magnesite from Natural Alkaline Lake Water; *Geology*, Volume 18, pages 995-998.

Vos, R.L., Hagni, R.D. and Gregg, J.M. (1989): Sequential Deposition of Zoned Dolomite and its Relationship to Sulfide Mineral Paragenetic Sequence in the Viburnum Trend, Southeast Missouri; *Carbonates and Evaporites*, Volume 5, pages 195-209.

Walker, J.F. (1926): Geology and Mineral Deposits of the Windermere Map-area, British Columbia; *Geological Survey of Canada*, Memoir 148.

Warren J.K. (1990): Sedimentology and Mineralogy of Dolomitic Coorong Lakes, South Australia; *Journal of Sedimentary Petrology*, Volume 60, pages 843-858.