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GYPSUM IN BRITISH COLUMBIA (82G, J, 83E)

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KEYWORDS: Industrial minerals, gypsum, Stanford Range, Mayook, Joffre Creek, Forgetmenot Creek, Burnais Formation, Starlight evaporite.

INTRODUCTION

Gypsum ranks third in value of production, behind asbestos and sulphur, among industrial minerals produced in British Columbia. In 1986, 527 200 tonnes of gypsum valued at $5,460,700 were produced. Production comes primarily from quarries located on Windermere Creek operated by Westroc Industries Limited (Plate 3-4-1) and on the Lussier River operated by Domtar Construction Materials (Plate 3-4-2). There is also some intermittent production by Canada Cement Lafarge Limited from its quarries near Falkland. Most of the gypsum produced is used in the manufacture of wallboard; smaller quantities are used in the cement industry. Gypsum is shipped by rail and truck to plants in Vancouver, Calgary and Edmonton. Minor tonnages of anhydrite-gypsum mixture are also produced by Westroc Industries at Windermere and are exported to the United States to be used in the manufacture of portland cement.

While gypsum has been known in the province since the early 1900s, there has been no comprehensive report on gypsum deposits in British Columbia. A program to study gypsum deposits in the province was initiated during the summer of 1988. Fieldwork focused on the Stanford Range where extensive gypsum is present in the Devonian Burnais Formation. Some time was spent examining Devonian gypsum in the Joffre Creek and Mayook, Bull River and Chipka Creek areas (Figure 3-4-1). In addition to the work in southeastern British Columbia, a gypsum occurrence of Triassic age in the Forgetmenot Creek area was evaluated.

Gypsum occurrences were assessed for their resource potential and quality. Wherever possible, stratigraphic relationships and structural controls were also examined. Samples were routinely collected for major oxide analyses and specimens were collected for petrographic study. In addition to evaluating known deposits the fieldwork also involved a search for new occurrences. The program was successful in locating three major, previously undocumented, gypsum localities in the Coyote Creek area.

STRATIGRAPHY OF THE STANFORD RANGE

Gypsum in the Stanford Range occurs in rocks of Devonian age (Figure 3-4-2). Early work by Henderson (1954) assigned the name Burnais Formation to a sequence of evaporites and associated carbonate rocks and Harrogate Formation to the overlying limestone and shale sequence. Leech (1958, 1960) retained the same nomenclature and added the term "basal Devonian unit" to a sequence of quartzites, argillaceous limestone and limestone of Devonian age underlying the evaporites. More recent work by Belyea and Norford (1967) proposed the term "Cedared Formation" for a sequence of dolomites, sandstones and limestones that is, in part, stratigraphically equivalent to the Burnais Formation and possibly part of the basal Devonian unit. They retained the name Harrogate Formation. These stratigraphic relationships are shown in Figure 3-4-3.

This study attempted to delinate areas underlain by gypsum from those underlain by carbonate rocks. Much of the carbonate strata previously included in the Burnais Formation are now tentatively assigned to either the Cedared or Harrogate formations. This designation is primarily based on lithological similarities.

Devonian strata unconformably overlie or are in structural contact with the Ordovician-Silurian Beaverfoot-Brisco Formation. This unit consists primarily of thin to medium-bedded light grey dolomite and limestone. Ovular chert nodules and lenses in a carbonate matrix are characteristic of the unit. The upper contact was not seen in the study area.

Strata of the basal Devonian unit were only observed in the Coyote Creek area. It consists of orthoquartzite and sandstone low in the section and limestone, argillaceous limestone, dolomite and minor shale in the upper part. Ar-

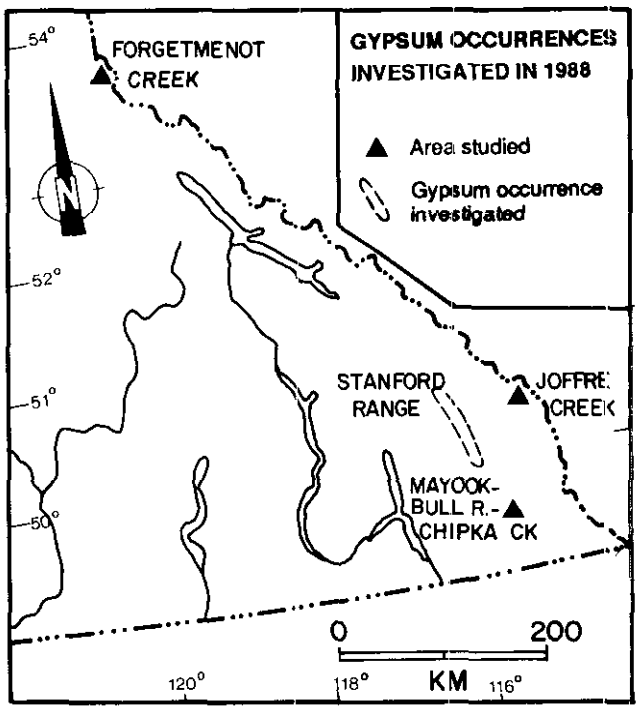

Figure 3-4-1. Location map showing areas studied.

British Columbia Ministry of Energy, Mines and Petroleum Resources, Geological Fieldwork, 1988, Paper 1989-1.

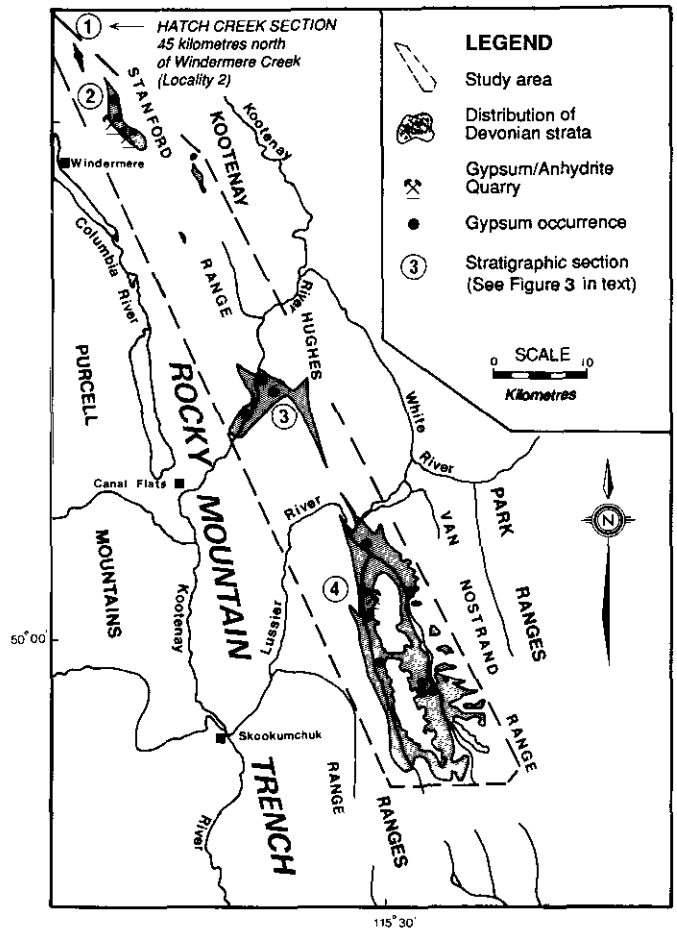

Figure 3-4-2. Location map showing the distribution of Devonian strata and gypsum occurrences in the Stanford Range.

Plate 3-4-1. Elkhorn quarry operated by Westroc Industries Limited, Windermere Creek.

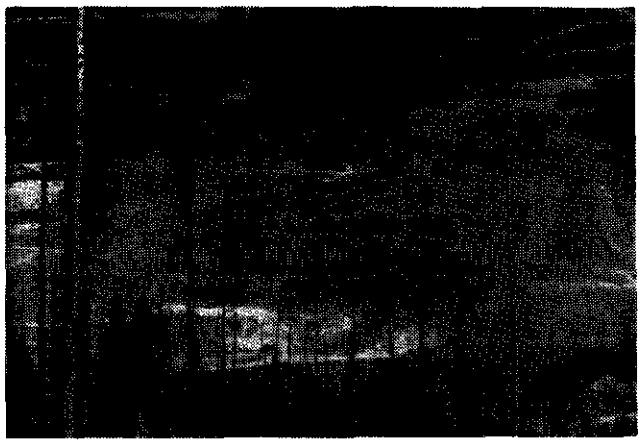

Plate 3-4-2. Lussier quarry operated by Domtar Construction Materials, Lussier River.

gillaceous limestones are easily recognized by their pale maroon to pale green colour. Lithologically similar strata, tentatively assigned to the Cedared Formation, outcrop in the Windermere Creek area near the Elkhorn deposits. Limestone and dolomite in the upper part of the section are generally grey to dark grey, thin to medium bedded, aphanitic and void of fossils.

The Cedared Formation, at its type locality, consists of a sequence of dolomite, limestone, argillaceous limestone, mudstone, sandstone and breccia. These rocks are typically grey to yellowish brown and weather light grey, light yellowish grey and light brownish grey to light brown (Belyea and Norford, 1967). In the Stanford Range the Cedared Formation comprises dolomite with minor limestone and argillaceous limestone. These rocks are generally light grey to grey and weather grey to pale maroon and green. They are thin to medium bedded and aphanitic to finely crystalline. No fossils were found.

The Burnais Formation is restricted to an evaporite sequence consisting of gypsum and anhydrite that occurs at a number of localities throughout the Stanford Range. Although anhydrite does not outcrop, it occurs in drill holes at depths ranging from 20 to 40 metres. Very little is known about the thickness of the anhydrite as very few holes penetrate its entire thickness. A black fetid limestone and thin grey aphanitic limestone bands in fault contact with the gypsum are also included in the Burnais Formation. Estimates of thickness range from 50 to 300 metres, with the thickest sections occurring in the Windermere Creek area. There is a general thinning of the formation southward toward Coyote Creek where thickness rarely exceeds 60 metres. This study suggests gypsum deposits are not as widespread as previously thought. Much of the area previously mapped as Burnais Formation is now interpreted as underlain by carbonate rocks of the Cedared and Harrogate formations.

The Harrogate Formation is the youngest Devonian unit in the Stanford Range. It consists of a sequence of dark grey to black, typically nodular limestones. Minor shale and dolomite are present locally. The nodular limestone unit, which can be traced throughout the study area, is a useful marker horizon. Fossils, mainly brachiopods, were found at two localities, near the Elkhorn quarry and in the Coyote Creek area. In the Coyote Creek–Lussier River area, the Devonian sequence is overlain by a shale unit and carbonate strata of the Banff Formation. These rocks are Mississippian in age.

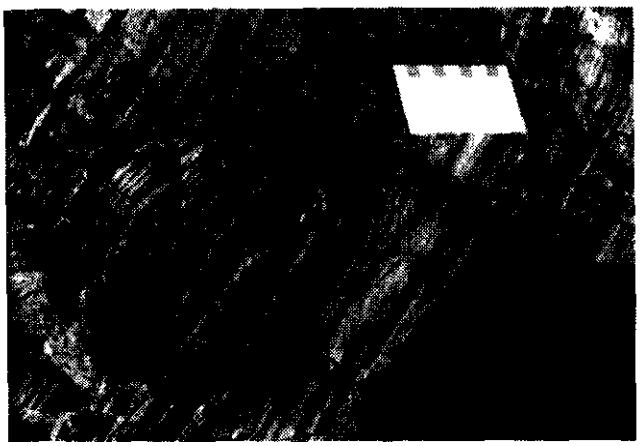

Plate 3-4-3. Laminated gypsum from the Windermere quarry on Windermere Creek.

GYPSUM DEPOSITS

Primary gypsum was discovered on Windermere Creek in 1947 (Henderson, 1954). Production, which began in 1950, has been continuous to the present day totalling in excess of 6.8 million tonnes.

Seven areas underlain by the Burnais Formation were identified by Henderson (1954) and Leech (1958) mapped the formation over a large area near the Lussier River. Much of the subcrop of the Burnais Formation is inferred from the presence of sinkholes; the scarcity of outcrop makes interpretation of the gypsum distribution extremely difficult.

Gypsum throughout the Stanford Range is typically laminar to thin bedded (Plate 3-4-3), with laminations and bedding varying in thickness from a fraction of a millimetre to 3 millimetres. Laminations are generally crenulated or intricately folded. The colour of the gypsum varies from white through various shades of grey to occasionally black. Pale brown to pale brownish grey laminae are very often present. White selenite is common as massive blebs but may also occur as well-formed crystals or along fractures and fault surfaces. Crosslaminations and cut-and-fill structures, indicative of periodic high-energy events in an overall shallow-water facies, are observed locally. Native sulphur is present in trace amounts at many localities, most commonly as crystalline masses associated with selenite along fractures. Occasionally it is smeared along slickenside surfaces giving the impression of greater abundance.

Anhydrite is rarely observed in outcrop. In the Windermere Creek area anhydrite occurs at an average depth of 30 to 40 metres while in the Lussier River area it occurs at a depth of 20 to 25 metres. Very often there is an accumulation of salts at or very near the anhydrite-gypsum contact.

Gypsum deposits are more structurally complex than the enclosing carbonate rocks. Some of the structural features may have formed at the time of deposition, others are interpreted as enterolithic (Plate 3-4-4) and related to swelling and expansion during conversion of anhydrite to gypsum. This process involves a volume increase of 30 to 50 per cent.

WINDERMERE CREEK

Gypsum deposits are best developed in the Windermere Creek area where thicknesses in excess of 100 metres have been reported. These deposits trend northwesterly along a strike length of 3 kilometres (Figure 3-4-4). Two gypsum horizons are interpreted, separated by dolomite and limestone tentatively assigned to the Cedared Formation. The lower gypsum bed has a minimum thickness of 50 metres

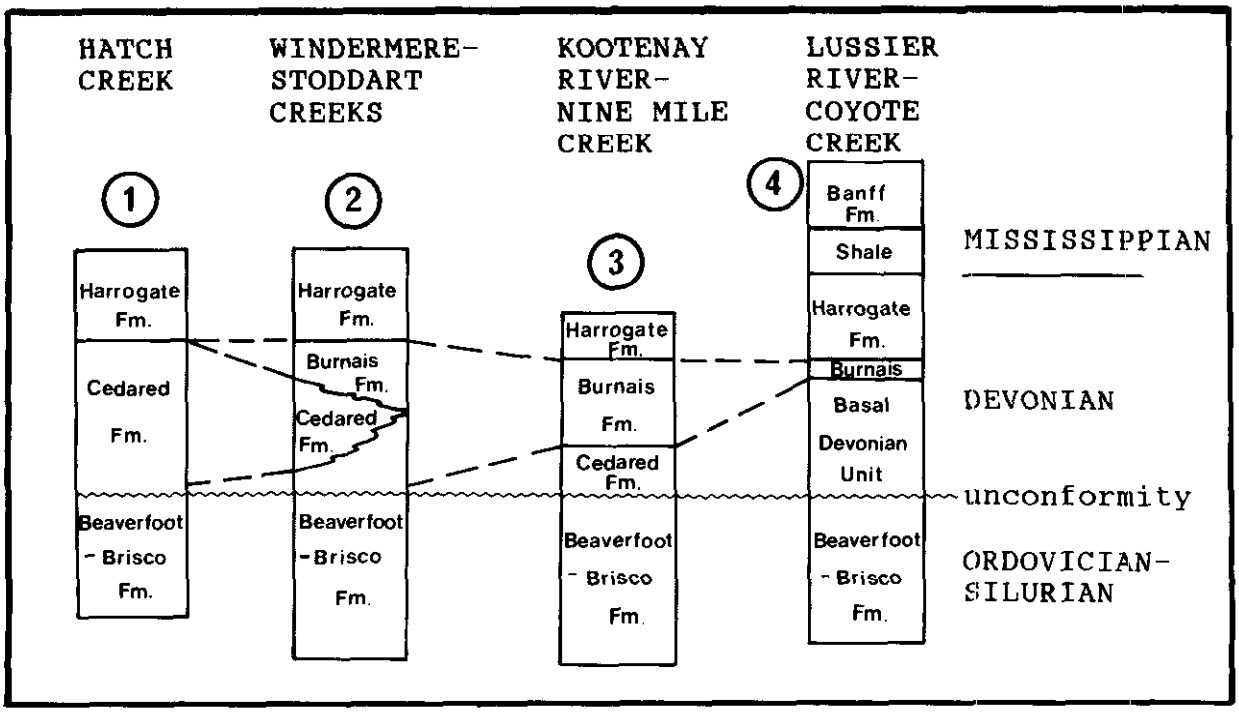

Figure 3-4-3. Nomenclature and correlation of Devonian stratigraphy in the Stanford Range.

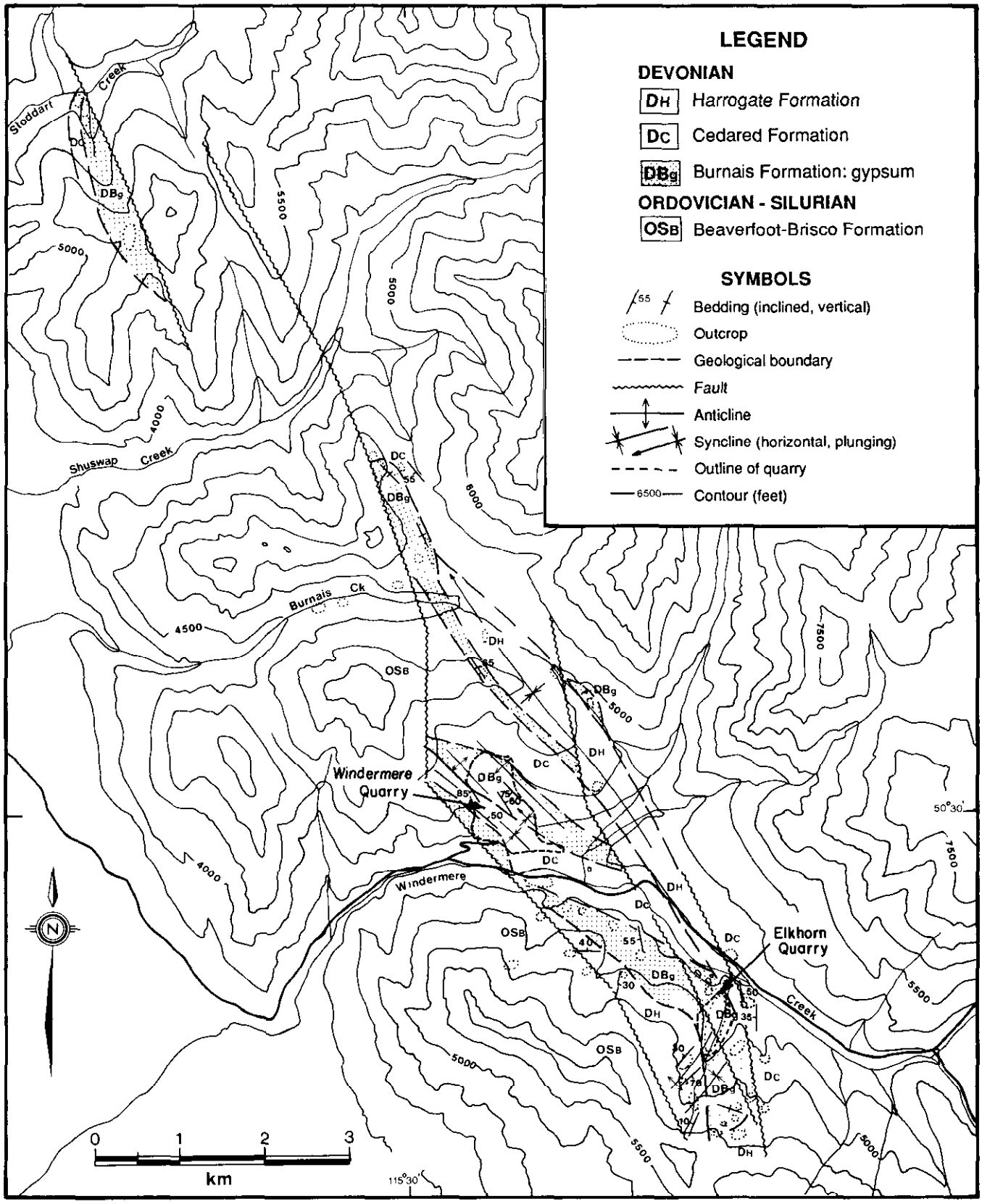

Figure 3-4-4. Geological setting of gypsum deposits in the Windermere Creek area, Stanford Range.

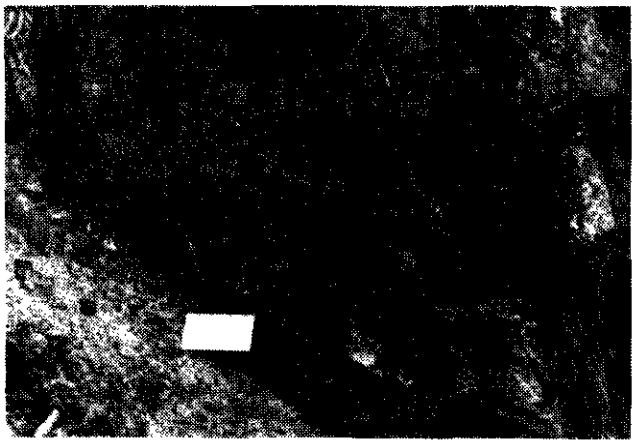

Plate 3-4-4. Enterolithic folding of gypsum, Lussier River quarry.

while the upper bed ranges from 50 to 100 metres thick. The upper bed is structurally more complex and therefore determining an accurate thickness is difficult. Contact relationships between the gypsum and underlying strata were not observed but it is inferred the lower gypsum bed is in fault contact with the underlying Beaverfoot-Brisco Formation. Contacts with the Cedared Formation and overlying Harrogate Formation, where observed, appear to be conformable. The quality of the ore is good, ranging between 83 and 93 per cent gypsum.

Gypsum can be traced northward from Windermere Creek to north of Burnais Creek where it thins and disappears under thick overburden and carbonate strata of the Cedared Formation. Further north a small lens of gypsum outcrops south of Stoddart Creek. Here the rock is of lower quality, containing approximately 75 per cent gypsum (F.W. Jarrett, Westroc Industries Ltd., personal communication, 1988). No gypsum is known to occur north of Stoddart Creek.

Anhydrite is distinguished from gypsum by its hardness and light blue colour. At the nearly depleted Windermere quarry anhydrite is present in a breccia zone that is 30 metres

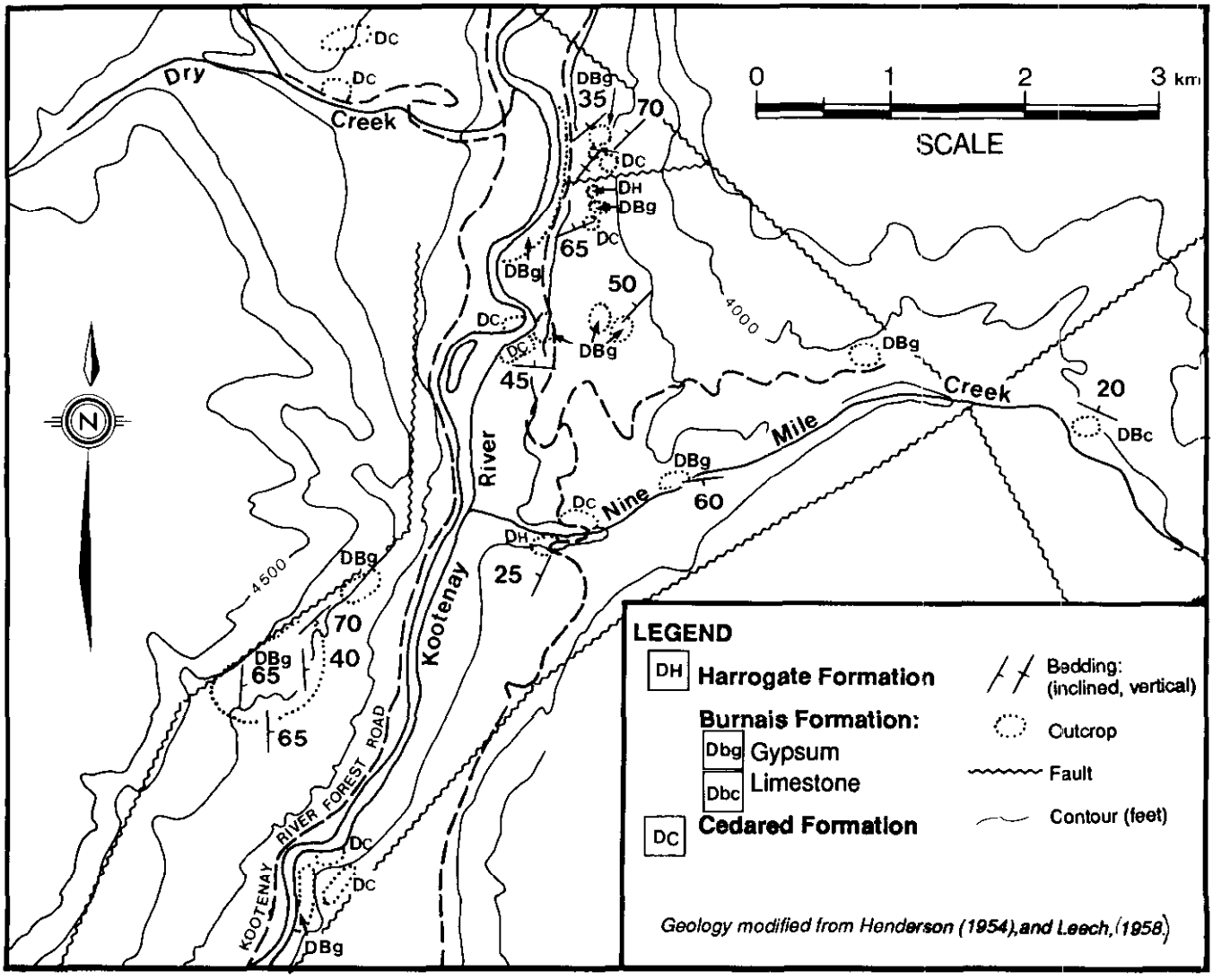

Figure 3-4-5. Geological setting of the Kootenay River–Nine Mile Creek area, Stanford Range.

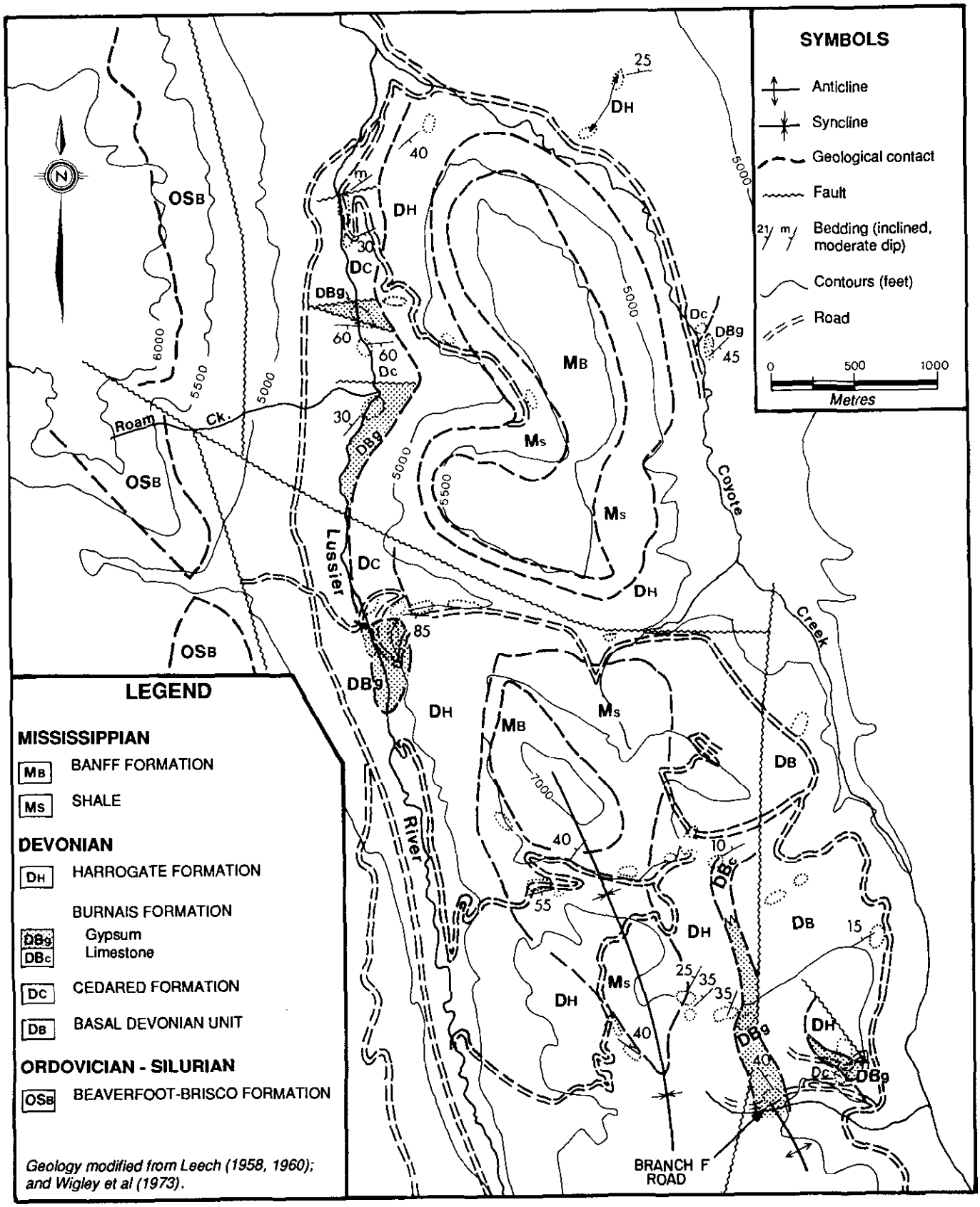

Figure 3-4-6. Geological setting of the Lussier River–Coyote Creek area, Stanford Range.

wide. The breccia consists of angular anhydrite and gypsum fragments in an anhydrite matrix. Also, the anhydrite tends to be more massive than the surrounding gypsum.

KOOTENAY RIVER–NINE MILE CREEK

In the Kootenay River–Nine Mile Creek area gypsum outcrops extensively on the west side of the river north of the bridge at kilometre 10.5 on the Kootenay River logging road (Figure 3-4-5). Gypsum is very well exposed in an area approximately 1.5 kilometres in length across an average width of 400 metres. Bedding generally strikes north to northeasterly with moderate to steep dips to the east. The gypsum is pale grey to grey in colour and is typically laminated to thin bedded. Pure white gypsum is present locally. To the west the gypsum is in fault contact with older rocks; to the east it disappears under extensive overburden in the Kootenay River valley. A minor amount of gypsum has been produced from a small quarry at the north end of this deposit.

There are several large exposures of gypsum along the east bank of the Kootenay River and in the Nine Mile Creek area. The gypsum is intercalated with carbonate strata of the Cedared Formation. A black fetid limestone of the Burnais Formation is present in more easterly localities. Nodular limestone of the Harrogate Formation is also present. East of the Kootenay River the structure is more complex and the bedding strikes east to northeasterly with moderate dips to the northwest, north and south. Structural relationships east and west of the Kootenay River suggest that a synclinal axis, with or without associated faulting, may be present.

In the Nine Mile Creek area laminated to thin-bedded gypsum varies from cream to pure white in the north to the more typical pale grey to grey in southerly exposures. Northern exposures contain abundant white selenite with lesser rounded gypsum fragments and a few angular limestone fragments. To the south the gypsum retains its laminar appearance but does not contain any gypsum or carbonate fragments. Bedding thickness ranges up to 5 centimetres, but thicknesses less than 1 centimetre are more usual. Native sulphur was observed in a single outcrop immediately north of Nine Mile Creek. The quality of the rock is variable with gypsum content varying from 44 to 94 per cent (Henderson, 1954).

LUSSIER RIVER–COYOTE CREEK

The southernmost exposures of gypsum in the Stanford Range occur in the Lussier River–Coyote Creek area (Figure 3-4-6). In the Lussier River valley all known occurrences are located east of the river. Extensive and very thick overburden preclude tracing the gypsum over any significant distance, but drilling by Domtar Construction Materials in recent years has helped to delineate its distribution. Where observed, the gypsum is steeply dipping to vertical. Faulting may have played an important role in the localization and preservation of these deposits.

Domtar's Lussier River gypsum deposit occurs in a northwest-trending anticline. It is truncated on the south by a fault and probably abuts a fault to the north, although evidence for this is lacking. Carbonate strata of the Cedared Formation outcrop immediately north and south of the deposit but nowhere are contact relationships observed. The deposit is overlain by nodular limestone of the Harrogate Formation. Structure within the deposit is complicated by numerous faults with minimal displacement and intricate small-scale folds. A fault with considerable but undetermined displacement near the southern end of the quarry has a carbonate band adjacent to it. These structures are the locus of sinkholes and other karst features.

There are two other significant gypsum occurrences on the east side of the Lussier River south of the Lussier quarry. The South quarry is a small deposit located 750 metres south of the main producing quarry, but there has been limited production from this locality. Gypsum is again exposed south of Roam Creek, over a length of 200 metres, in steep bluffs 60 to 90 metres high along the east side of the Lussier River. The gypsum is steeply dipping and cut by numerous near-vertical faults. Some breccia material and a thin limestone band adjacent to a fault are present at the northern end. Traces of native sulphur occur locally. Work by Trurock Gypsum Products Ltd. on this deposit suggests a reserve potential of 40 million tonnes with a gypsum content averaging 80 per cent (Korun, 1980).

Three occurrences of gypsum were located immediately east of the height of land separating the Lussier River from Coyote Creek. To the author's knowledge these are new discoveries although nearby sinkholes were mapped by Leech (1960). Two of them are located on a logging road locally known as Branch F; the third outcrops north of the westernmost of these two showings. Gypsum is similar in appearance to that seen elsewhere in the Stanford Range and is probably of similar quality. The easternmost showing is exposed in an outcrop measuring 45 by 20 metres. Small sinkholes, many of which contain gypsum or possibly anhydrite, are present over an area measuring 300 by 100 metres. It is estimated that the gypsum bed is approximately 30 metres thick, suggesting potential for a 2 to 3-million-tonne deposit.

To the west gypsum is exposed in two outcrops approximately 1 kilometre apart along a northerly trend, and small sinkholes, some of which contain gypsum, are commonly present in the intervening area. The northern occurrence is exposed across an outcrop width in excess of 30 metres and 60 metres of elevation. Gypsum is laminated, pale grey to dark grey with some black laminations. Traces of native sulphur are also present. The southern occurrence is exposed in a roadcut across a width of 60 metres in the nose of an anticline. The gypsum is similar in appearance to the northern showing. These two localities are estimated to have a combined potential for 6 million tonnes and all three of these occurrences are ideally situated for future exploitation.

MAYOOK–CHIPKA CREEK–BULL RIVER AREA (82G)

There are four gypsum occurrences in the Rocky Mountain Trench area east of Cranbrook and they represent the southernmost occurrences of gypsum in southeastern British Columbia. Two of them, Sunrise and Mayook, are located north and south respectively of Highway 3 near Mayook and the third is along Chipka Creek, south of Wardner. Gypsum is also reported from a locality on the Bull River approximately 4 kilometres from its mouth.

Approximately 95 000 tonnes of gypsum has been produced from the Sunrise quarry and there has been limited production from the Mayook occurrence.

Gypsum in these deposits varies from white to grey and is bedded to laminated, although bedding is largely obscured; surface exposures are generally soft and granular and very often covered by a coating of gypsite. Angular, pale brownish grey fragments of limestone are present locally. At the Chipka Creek locality limestone and chert are reported in sufficient quantities to make parts of the deposit unworkable (Cole, 1930). Intricate minor structures, present throughout much of the Stanford Range further to the north, are rare in this area. Native sulphur was observed only at Chipka Creek although Cole reports native sulphur at the Mayook and Sunrise deposits.

The stratigraphic position of these deposits is still uncertain but it is believed they are Devonian and may be equivalent to the Burnais Formation.

Gypsum in the Bull River area is described as dark grey in colour with indistinct bedding. Rocks are reported to be highly folded. A small bulk sample was taken from this locality in 1937 for testing.

JOFFRE CREEK (82J/11)

Gypsum was reported in the basal Devonian unit in the Joffre Creek area by Leech (1979) and Mott *et al.*, (1986). The basal Devonian unit consists of brown to orange dolostone with white orthoquartzite. Minor sandstone and shale are also present.

A single gypsum occurrence located along a westerly flowing tributary of Joffre Creek was examined during this study. Gypsum is exposed along the bank of the creek at an elevation of 1830 metres.

Gypsum varies from cream to grey in colour and is laminated to thin bedded. Both the laminations and bedding are highly contorted, possibly the result of soft-sediment deformation. Thin black laminae are present locally. Selenite is locally abundant but native sulphur is absent. Approximately 20 metres above the base of the gypsum, the rock is distinctly conglomeratic in appearance. This unit is 5 metres thick and consists of egg-shaped gypsum fragments in a gypsum matrix, possibly representing a period of emergence of the evaporite deposit. Above this horizon the gypsum reverts to its normal appearance.

The gypsum has a minimum thickness of 40 metres and a strike length of less than 100 metres. Bedding strikes east-northeast with shallow north dips into the mountain. The area is structurally complex with several faults. Neither the upper nor lower gypsum contacts were observed and therefore stratigraphic relationships could not be determined. The gypsum is probably equivalent to the Burnais Formation.

FORGETMENOT CREEK (83E/13)

Gypsum of Triassic age occurs at a single locality straddling the Alberta boundary at the headwaters of Forgetmenot and Fetherstonhaugh creeks. This occurrence was first reported by Henderson (1954) and later described in detail by Govett (1961). Gypsum intercalated with dolomite and minor limestone is present in several beds in the Starlight evaporite member of the Whitehorse Formation. This unit is assigned a Karnian age and is correlated with the Charlie Lake Formation which is host to extensive anhydrite deposits further north (Figure 3-4-7).

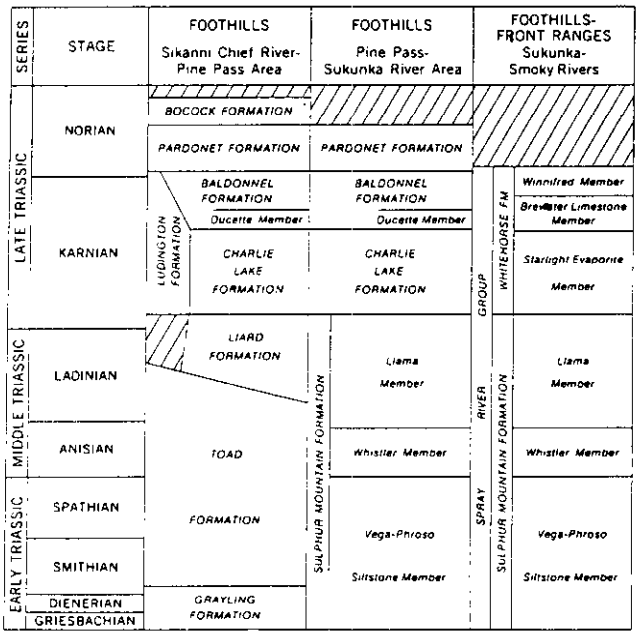

Figure 3-4-7. Nomenclature and correlation chart of Triassic stratigraphy (from Gibson, 1972).

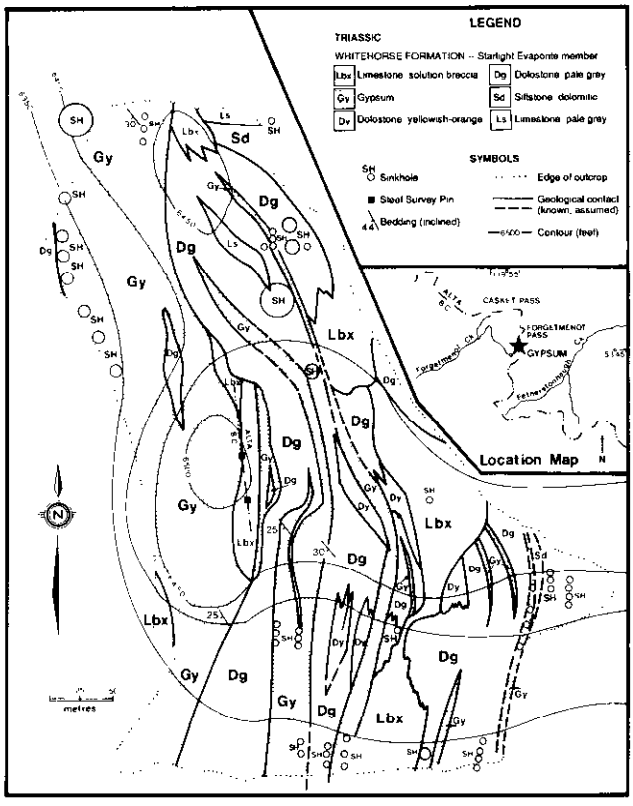

Figure 3-4-8. Geological setting of the gypsum deposit in the Forgetmenot Creek area.

The Starlight evaporite, the lowermost unit of the Whitehorse Formation, has been described by Gibson (1972, 1975) as consisting of a recessive buff to light grey weathering sequence of interbedded dolostones, limestones, siltstones and intraformational or solution breccias. In the Forgetmenot Creek area pale grey and yellowish brown to orange dolostone is intercalated with several gypsum beds (Figure 3-4-8). Also present are lenses of dolomitic and calcareous siltstone and pale grey limestone. Solution breccia comprised of a vuggy calcareous matrix with subangular to subrounded fragments of limestone occurs in a number of outcrops.

There are at least four gypsum beds ranging in thickness from 2 metres to greater than 26 metres (Figure 3-4-9) with the uppermost bed being the thickest and most persistent. Locally, it contains solution breccia and lenses of dolostone of variable thickness. The gypsum is typically white to pale pink in colour but may also be pale grey to grey. It is laminated to thin bedded and locally massive. Anhydrite was not observed in outcrop. Trace amounts of pyrite are present but native sulphur is absent. The quality of the gypsum is good.

The beds strike northwest with dips of 25 to 30 degrees southwest; the gypsum outcrop can be traced 500 metres along strike. The presence of sinkholes suggests it may extend some distance further south. Gypsum occurs over a minimum stratigraphic thickness of 100 metres and contacts between gypsum and overlying or underlying rocks are invariably marked by sinkholes up to several metres in diameter.

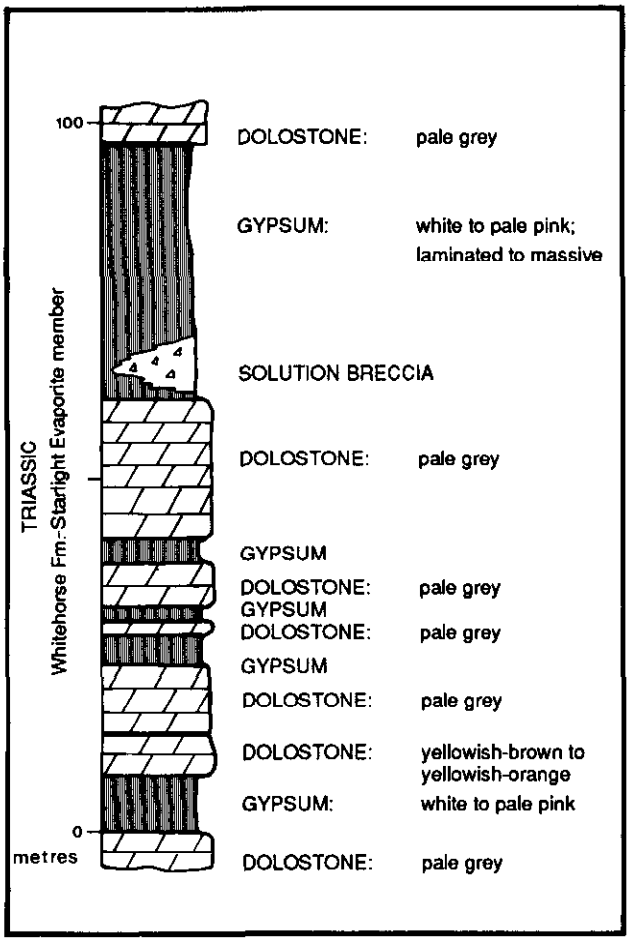

Figure 3-4-9. Stratigraphic section of upper portion of gypsum-bearing sequence, Forgetmenot Creek.

Drilling by Domtar Chemicals Ltd. (1968) indicated that the gypsum grade at depth was more variable than in surface exposures. Gypsum content in the subsurface varied between 75 and 80 per cent while surface sampling yielded assays greater than 90 per cent gypsum. Reserves estimated by Domtar (Hamilton, 1984) are 2.3 million tonnes with a potential for 25 to 30 million tonnes if the gypsum persists along its projected length.

DISCUSSION

Evaporite deposits in the Rocky Mountains are sedimentary in origin. Henderson (1954) concluded that the gypsum deposits in the Stanford Range were primary and not the result of hydration of anhydrite. He based his conclusions on the absence of anhydrite at depth and the absence of expansion-type fold structures. It is now apparent that gypsum only occurs near surface and expansion-related folding is present at many localities. This author concludes that the deposits in the Stanford Range formed by the hydration of anhydrite by the action of meteoric waters.

Further to the south in the Mayook–Chipka Creek–Bull River area, at Joffre Creek, and at Forgetmenot Creek, the enterolithic folding present in the Stanford Range is not present. No anhydrite is seen at surface, but it may be present at depth. Gypsum in these areas may be primary but evidence for this is inconclusive.

CONCLUSIONS

The Burnais and Cedared formations are interpreted by Belyea and Norford (1967) to have been deposited in a gently subsiding basin. Accumulation took place in a long, relatively narrow depression. The Cedared Formation was probably deposited in a tidal-flat environment that may have been emergent at times. Contemporaneous deposition of the Burnais Formation evaporites was limited to areas with restricted circulation.

The gypsum resource potential of the Stanford Range originally estimated at 450 million metric tonnes by Henderson (1954) is now thought to be substantially reduced and may be in the order of 160 million tonnes, including all past production. The most favourable areas for future exploitation are the west side of the Kootenay River, along the Lussier River south of the Lussier quarry, and the area near Coyote Creek which contains the three new occurrences.

There is a potential for 2 to 3 million tonnes of good quality gypsum in the Forgetmenot Creek area, but because of its inaccessibility and location near the Willmore Wilderness Reserve in Alberta it will probably be some time before this deposit is developed.

Deposits in the Joffre Creek area appear to be poddy although probably of good quality. Extensive overburden and rugged terrain will inhibit development and their resource potential is small.

Substantial amounts of gypsum remain in deposits in the Mayook–Chipka Creek–Bull River area, but they contain

varying amounts of carbonate and are subeconomic under current market conditions.

ACKNOWLEDGMENTS

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