Province of British Columbia
Ministry of Energy, Mines and
Petroleum Resources

MINERAL RESOURCES DIVISION
Geological Survey Branch

GYPSUM IN BRITISH COLUMBIA

By S.B. Butrenchuk

OPEN FILE 1991-15

Canadian Cataloguing in Publication Data
Butrenchuk, S.B.
Gypsum in British Columbia

(Open file, ISSN 0835-3530 ; 1991-15)
Includes bibliographical references.
ISBN 0-7726-1419-9

1. Gypsum - British Columbia. 2. Geology, Economic - British Columbia. I. British Columbia. Geological Survey Branch. II. Title. III. Series: Open file (British Columbia. Geological Survey Branch) ; 1991-15.

TN946.B87 1991 553.6'35'09711 C91-092292-6

VICTORIA
BRITISH COLUMBIA
CANADA

SEPTEMBER 1991

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Gypsum, a hydrous calcium sulphate, is a low-cost ($11.50/tonne) bulk commodity with major applications in the manufacture of wallboard and cement. Demand is therefore closely related to the construction industry. Two mines in British Columbia currently produce in excess of 500 000 tonnes annually. Markets for this production are located in Alberta and Vancouver with very minor amounts of anhydrite shipped to the United States. British Columbia currently imports in excess of 200 000 tonnes of gypsum annually from Mexico and Spain.

At present there are sufficient reserves for 200 years based on current production rates. Westroc Industries Limited and Domtar Construction Materials control both the local source and market for gypsum. Another potential source is the O'Connor River deposit located in the northwestern corner of the province. This deposit can deliver gypsum to the Vancouver area at a competitive price and conceivably replace the imports provided suitable contracts with present producers can be achieved. Gypsum deposits at Falkland are nearly depleted although a substantial reserve of anhydrite remains. A deposit at Forgetmenot Creek is not likely to be developed because of its location with respect to the Willmore Wilderness Area in Alberta and has no road access from British Columbia. Most of British Columbia's production will continue to come from the East Kootenay region, in particular, the Stanford Range.

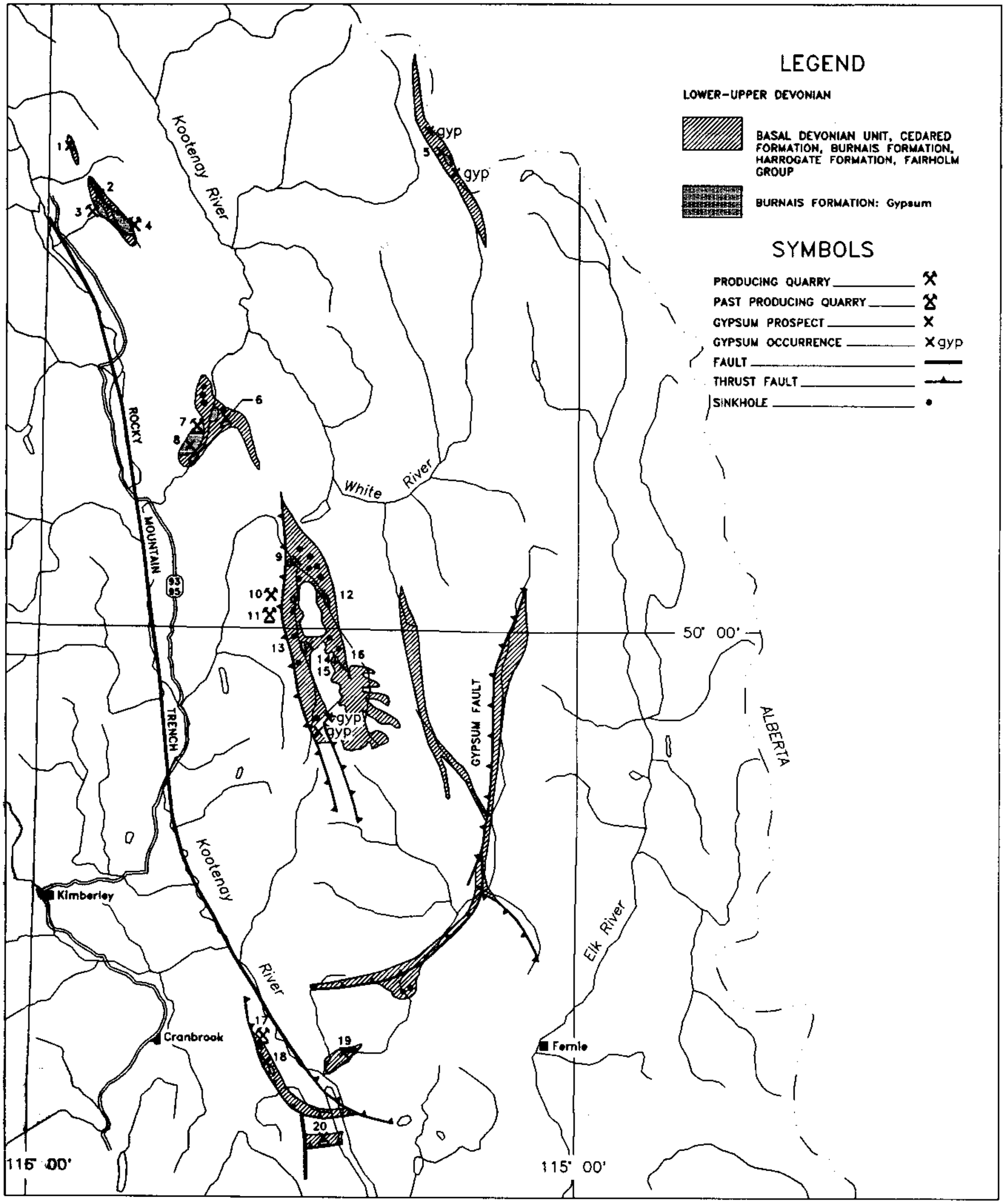

Figure 4. Distribution of Devonian strata and associated gypsum deposits in southeastern British Columbia.

INTRODUCTION

In British Columbia the first claims for gypsum were staked in 1894 in the Salmon River area southeast of Kamloops on what are now known as the Falkland deposits. The first production of gypsum was in 1911 when 700 tonnes were shipped to Vancouver for use in the manufacture of cement. Gypsum deposits near Spatsum were first staked in 1896 while deposits in the Mayook - Wardner - Bull River were not staked until the 1920s. In 1926 there was a substantial increase in the production of gypsum from both the Falkland and Mayook deposits.

It was not until 1947 that gypsum was discovered in the Windermere Creek area although sinkholes were first reported in 1926 (Henderson, 1954). Some gypsum was produced in 1949 but steady production began in 1950 from the Windermere No. 1 quarry. Production totalled 81 450 tonnes by 1953 and by 1988 had exceeded 7 million tonnes, produced from five quarries.

Gypsum in the Lussier River area was known prior to 1954 but significant production only began in 1984.

Gypsum ranks third in value of production, behind asbestos and sulphur, among industrial minerals produced in British Columbia. During the 1970s there was a steady increase in gypsum produced reaching a maximum in 1980 (Figures 1 and 2). Production declined during the period 1981-1984 but has since been slowly increasing. In 1986, 527 000 tonnes of gypsum valued at $5.5 million was produced, primarily from quarries located on Windermere Creek operated by Westroc Industries Limited and on the Lussier River operated by Domtar Construction Materials. There has also been some intermittent production by Canada Cement Lafarge Limited from its quarries near Falkland. In addition, British Columbia currently imports in excess of 230 000 tonnes of gypsum from Mexico and Spain for use in the manufacture of wallboard and cement in the Vancouver area.

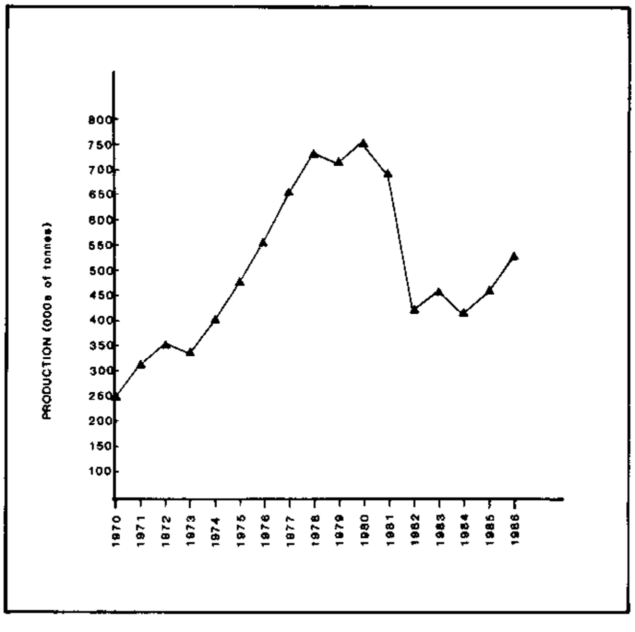

Figure 1. Production of gypsum in British Columbia, 1970-1986.

Only four regions of British Columbia contain gypsum deposits of significance: the East Kootenays, Falkland, the Forgetmenot Creek area astride the British Columbia - Alberta boundary and the O'Connor River area in the northwestern corner of the province. Minor occurrences are present elsewhere but none are considered suitable for exploitation (Figure 3).

Although gypsum has been known in the province since the early 1900s no comprehensive report on gypsum deposits has been published prior to this study initiated during the summer of 1988. Fieldwork supplemented by office investigation focused on the Stanford Range with its existing production centres and where extensive gypsum is present in the Devonian Burnais Formation. Some time was spent examining Devonian gypsum in the Joffre

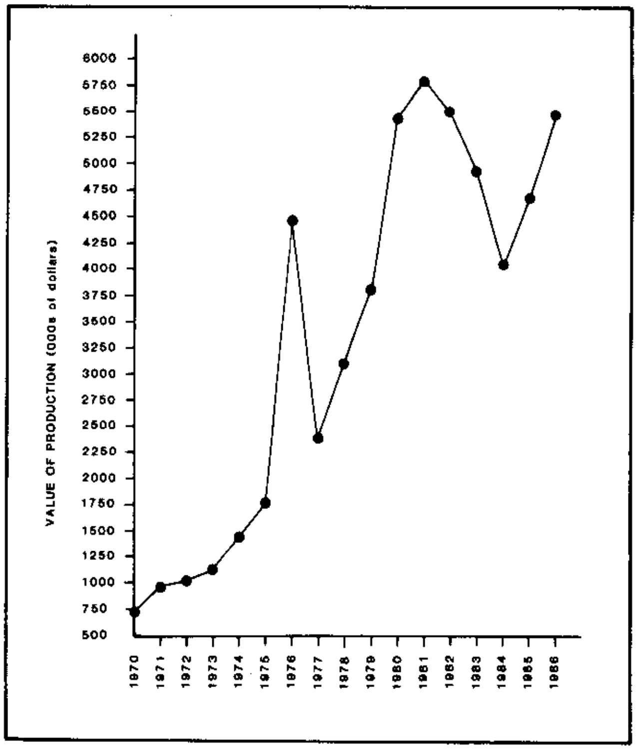

Figure 2. Value of production of gypsum in British Columbia, 1970-1986.

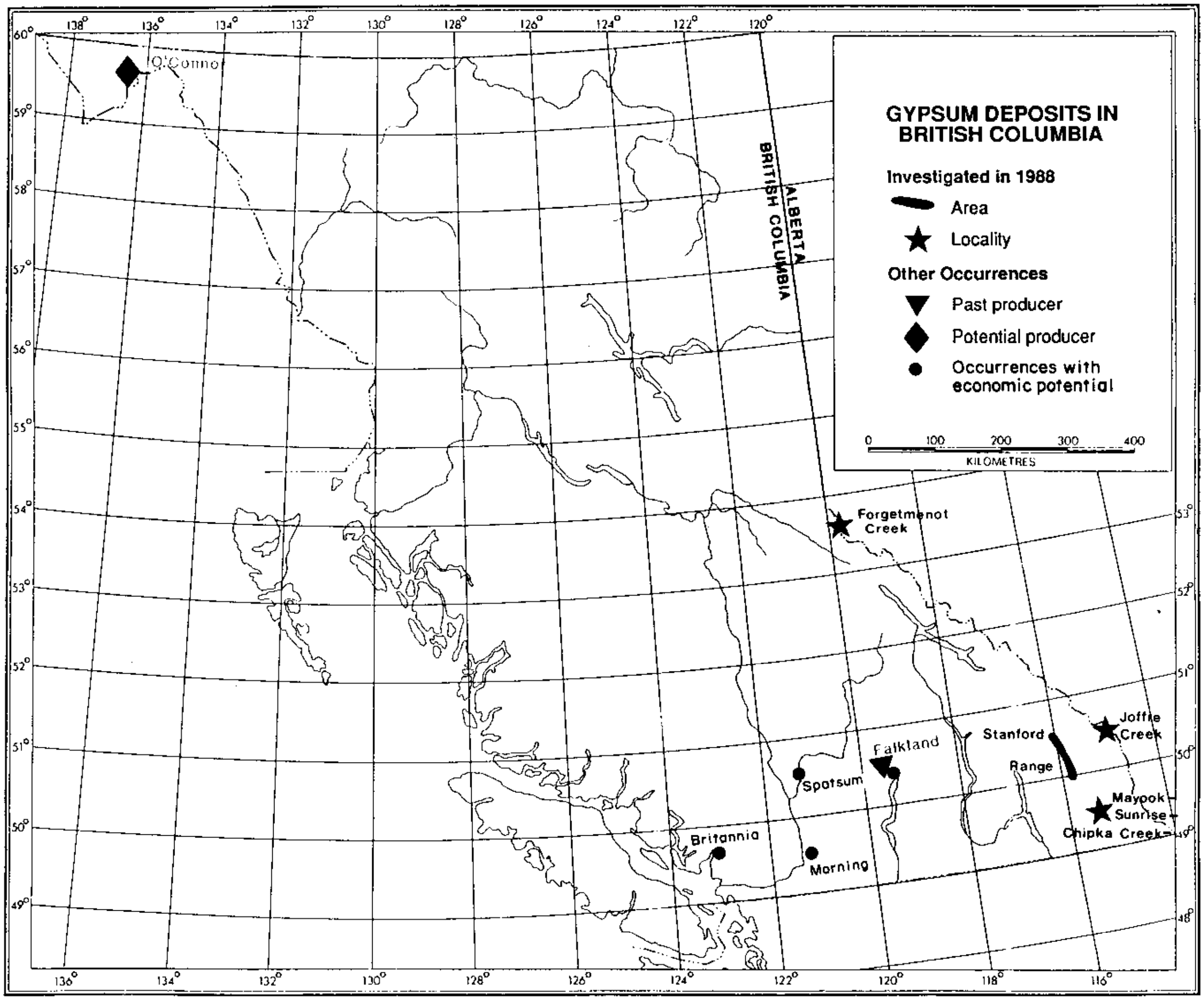

Figure 3. Location of gypsum deposits and occurrences in British Columbia.

Creek and Mayook, Bull River and Chipka Creek localities (Figure 4, in pocket). In addition to the work in southeastern British Columbia, a single occurrence of Triassic age in the Forgetmenot Creek area east of Prince George was evaluated. Information on other deposits was compiled from various reports and government publications.

Gypsum occurrences were assessed for their resource potential and quality. Wherever possible stratigraphic relationships and structural controls were also examined. Samples were taken to assess the quality of the gypsum and its trace element content. Analytical results for the Stanford Range are tabulated in Appendix 1 and sample localities for southeastern British Columbia are shown in Figure 5. Chemical analyses were done by Chemex Labs. In addition four samples from the Coyote Creek area were analyzed by Bondar-Clegg.

The objective of this report is to provide an inventory and an estimate of the resource potential of gypsum in British Columbia.

PROPERTIES OF GYPSUM

Gypsum is a hydrous calcium sulphate ($CaSO_4 2H_2O$) with a theoretical composition of 46.6 per cent SO_3, 32.5 per cent CaO and, 20.9 per cent H_2O. Its hardness is 1.5 to 2.0 and its specific gravity 2.314 to 2.328. Colour varies from white through various shades of grey to occasionally pale pink. Most gypsum deposits, including those in British Columbia, contain between 10 and 15 per cent impurities, some may contain as much as 20 per cent or as little as 5 per cent. Impurities include insoluble material, chloride salts and hydrous minerals (sulphate salts). Each of these impurities affects the gypsum differently.

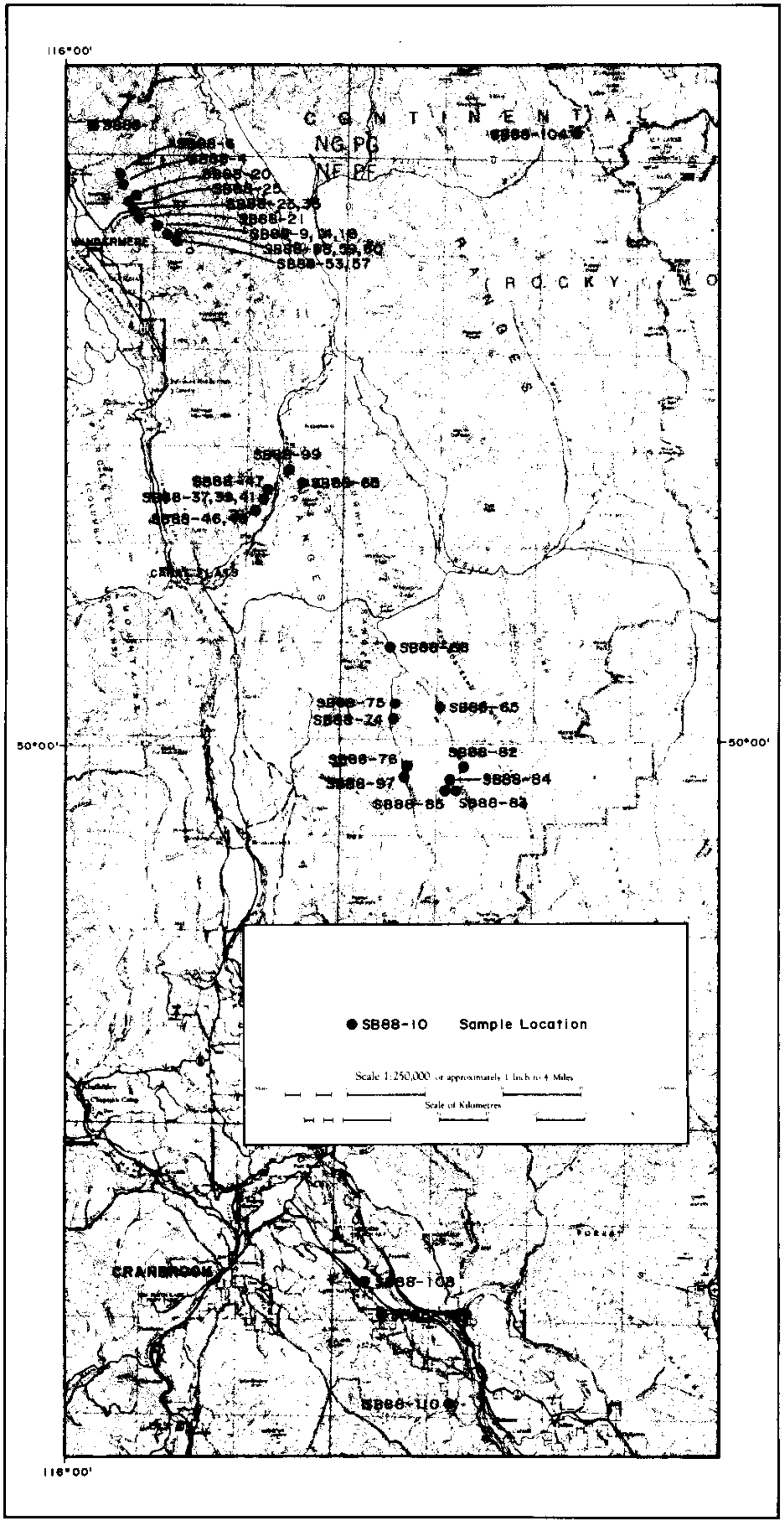

Figure 5. Sample location map.

USES OF GYPSUM

Gypsum has the unique characteristic of being able to lose water upon heating. It is this ability to lose water that allows it to be an excellent fireproofing material. Because gypsum is economical and can be used in a variety of forms it sees wide application in the construction industry.

The majority of gypsum produced is calcined before being used in the manufacture of various end products. In the calcining process ground gypsum is heated to temperatures between 150 and 165° centigrade for 2 to 3 hours and is converted to hemihydrate ($2CaSO_4H_2O$) otherwise known as plaster of paris or stucco in the construction industry. Addition of water to hemihydrate forms a product that can be shaped and molded and that will harden in a short period of time. Hemihydrate is the basis for over 90 per cent of the value of all calcium sulphate end products.

Products manufactured from gypsum can be grouped into three major categories. In the United States construction and industrial applications account for 93 per cent of consumption and almost 100 per cent of the value of all gypsum products. Agricultural usage accounts for 6 to 7 per cent of consumption and less than 1 per cent of the value.

By far the most important use for gypsum in the construction industry is in the manufacture of wallboard, accounting for 65 to 70 per cent of all gypsum consumed. Wallboard is produced by adding water to hemihydrate to form a slurry and then casting the slurry between specially prepared paper. The bond between the paper and the gypsum core is produced by the gypsum crystals locking into the fibres of the paper (Appleyard, 1983). Plaster continues to be used to meet special needs and slurry gypsum can be used to produce fireproof roofs and floors.

Wallboard manufacturers require certain specifications to ensure good bonding of the gypsum to the paper and to maintain a low weight. Insoluble material reduces the strength of the rehydrated stucco and increases the weight of finished plaster or wallboard. The amount of this material should be consistent, generally less than 20 per cent. Chloride salts affect the calcining temperature and must be less than 0.02 to 0.03 per cent. Sodium chloride is corrosive and hygroscopic and causes efflervescent staining on the finished wallboard product. Hydrous minerals affect the bonding characteristics of the gypsum core to its paper covering and are also limited to 0.02 to 0.03 per cent. White gypsum is preferred.

Industrial applications make use of both calcined and uncalcined gypsum. The major industrial application of calcined gypsum is for mold making in metal casting and the manufacture of sanitary ware, pottery and decorative objects. Plaster of paris is used in orthopedic casts. Gypsum that has been heated to 204°C, a process known as dead-burning, is used as a drying agent because of its strong affinity for water. Dead-burning produces a whiter product sometimes used as a source of calcium in food products. It is also used as an extender in pharmaceutical pills, rubber, artificial wood, plastics, paper and pigments.

Terra alba is a term used for high-quality finely ground raw gypsum. It has much the same uses as dead-burned gypsum but is not interchangeable with anhydrous gypsum. Terra alba is also used in the brewing industry; it assists in the proper development of yeast fermentation and helps settling out of the yeast and clarification of the beer.

Next to wallboard the largest use of gypsum is as a retarder in portland cement. Uncalcined gypsum is used to control the setting time, the rate at which cement paste develops strength, and the shrinkage of cement products during drying (Appleyard, 1983). The amount of gypsum used averages about 5 per cent by weight of finished cement. The product specifications by the cement industry required are:

Insolubles should be less than 2%.
SO_3 content must be greater than 41%.
Moisture content must be less than 4%.

The product should meet these size parameters:
Maximum size - 100% must be less than 6 to 3.5 cm.
Minimum size - less than 10%can be finer than 0.8 cm.

Gypsum is used in the pulp-and-paper industry as a filler in the manufacture of paper. Fillers are used to provide the paper with strength, whiteness, opaqueness, surface texture and to increase its ability to accept ink. The properties required include brightness and whiteness, easy dispersability and disintegration, low abrasion and high flow properties.

Some uncalcined, finely ground gypsum is used in the manufacture of container glass. Gypsum is used for agricultural purposes both as a soil conditioner and as a supplement in cattle feed.

A potential use of gypsum or anhydrite is the production of sulphur. This usage could become more important as present supplies of sulphur are depleted. Gypsum deposits in British Columbia contain between 13 and 24 per cent sulphur. At present the cost of recovering sulphur from gypsum is prohibitive even with the value of calcium that may be recovered for use in the cement industry.

MARKET STUDY

Gypsum is a low-cost, high-bulk mineral commodity with consumption very closely related to the fortunes of the housing industry. Markets are intrinsically associated with large urban areas, especially those where the housing construction industry is flourishing, as the largest market for gypsum is in wood-frame buildings. This market is expected to experience a growth rate between 1.9 and 3.2 per cent into the 1990s.

A recent market study completed on behalf of Queenstake Resources Ltd. (King *et al.*, 1987) identified wallboard and cement plants in Vancouver, Seattle and Tacoma as the best market opportunity for British Columbia gypsum. Markets for gypsum and gypsum products are dominated by a few large vertically integrated manufacturers with their own mines, transportation equipment, manufacturing facilities and distribution network. In British Columbia the industry is controlled by Westroc Industries Limited and Domtar Construction Materials. New producers of gypsum for the wallboard industry would have to negotiate sales contracts for gypsum with one or other of these companies.

There is an opportunity for a coastal producer to supply 200 000 tonnes annually to the wallboard market providing a long-term contract can be negotiated. This production would replace imports from Spain and Mexico. Similarly there is a potential market for 100 000 tonnes annually in the cement industry. A large part of this could be captured by a low-cost producer. New producers would have to demonstrate that they have a reliable source of gypsum meeting quality specifications and an advantageous price relative to current domestic sources or gypsum imported from abroad. Potential secondary markets include agricultural uses, extenders and fillers and specialty markets. There is long-term potential for high purity gypsum in the pulp and paper industry once it adopts gypsum in place of kaolin for paper filler.

The authors of the Queenstake market study predict that a future producer could capture almost 100 per cent of the cement industry demand and approximately 30 per cent of the wallboard industry demand in the Pacific Northwest, providing the cost to deliver the gypsum to the plants is less than that of the present imports.

GENESIS OF GYPSUM AND ANHYDRITE DEPOSITS

Gypsum and anhydrite are typically found in deposits that are the result of chemical precipitation of calcium sulphate from saturated brines. They may also form by the replacement of carbonate by sulphate or in a volcanogenic environment. Minor to trace amounts are also present as alteration products in many porphyry copper deposits.

The most important deposits commercially are the chemical precipitates. They form by precipitation from concentrated brines that have resulted from evaporation at the air-water interface.

Gypsum will begin to precipitate when normal seawater is concentrated to approximately 3.35 times the original salinity. This concentration will take place when the net evaporation effect exceeds the influx of fresh seawater or rainwater and the loss of brine is restricted. High temperatures promote this process.

Environments in which these deposits occur vary from deep water to shallow evaporite basins or sabkha. Each has its own characteristics. Deep-water evaporites are believed to result from crystals, generated at the air-water interface gradually settling to the sea floor. The depth of water in which these deposits may form can be as much as 40 metres as is suggested by studies of the Muskeg - Prairie Evaporite Formations (Kendall, 1984). The most common form of deep water evaporite facies is laminar sulphate together with laminations of carbonate and/or organic matter. Individual laminae may be 1 to 10 millimetres thick. They may be crenulated or plastically deformed and be traceable over long distances.

Shallow water evaporites form in environments that may be subjected to wave or current action. They most commonly form in water about 5 metres in depth. These deposits are also commonly laminated and similar in origin and character to deep water evaporites. However, they may exhibit such shallow water features as cross-bedding, ripple marks, rip-up breccias or basal scoured surfaces (Kendall, 1984).

There are three depositional models that are currently accepted for evaporite formation. These are: a deep water, deep basin model; a shallow water, shallow basin model and a shallow water, deep basin model (*see* Figure 6).

The shallow water, deep basin model was developed to account for those deposits that developed in pre-existing deep basins but contain evidence for shallow water or

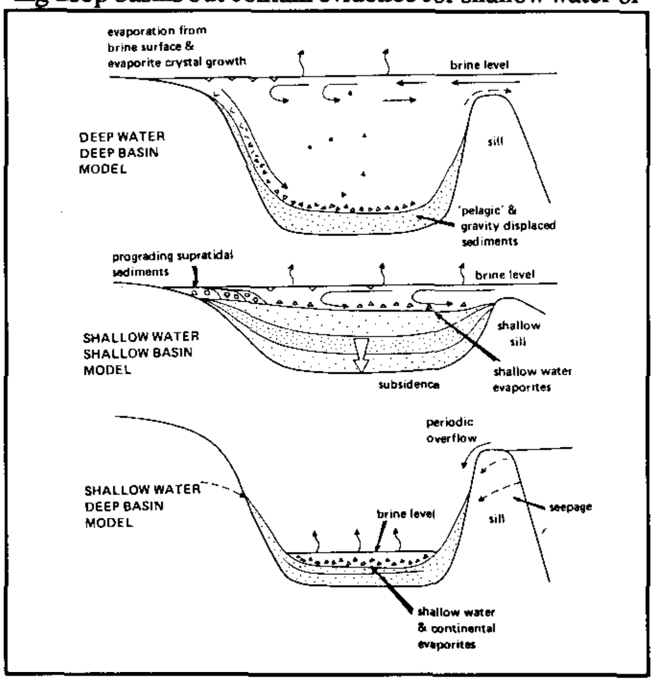

Figure 6. Depositional models for evaporite formation (Kendal, 1984).

subaerial depositional environments. This model is especially applicable to the Middle Devonian Elk Point evaporites of western Canada. This same model may be applicable to the gypsum deposits of the Burnais Formation.

Triassic evaporites of the Whitehorse Formation are interpreted to have been deposited in a shallow-water environment. Further north, the extensive anhydrite deposits of the Charlie Lake Formation were probably formed in a near-shore environment. The anhydrite is massive and is associated with red dolomitic siltstone, dolomite and minor halite.

Kuroko-type and related volcanogenic massive sulphide deposits are also known to contain gypsum and anhydrite along with other sulphate minerals, in particular barite. Deposits of gypsum and anhydrite generally occur in stratigraphically equivalent strata to or overlying the massive sulphide portion of the deposits. In British Columbia deposits formed in the volcanogenic environment, with the possible exception of Falkland, do not represent a significant source of gypsum.

The deposition of gypsum and anhydrite deposits has been the subject of much discussion in the literature. In recent sediments gypsum is the only form of calcium sulphate evaporite that is forming. This is to be expected as gypsum is the most stable form of sulphate in the surface environment. With depth, generally around 600 metres, and increased temperature, around 42 degrees centigrade, gypsum is converted to anhydrite. Murray (1964) suggested that there is a diagenetic cycle in which gypsum is first formed and subsequently diagenetically converted to anhydrite with burial. Later uplift, removal of covering rocks and presence of meteoric water reverses the reaction and anhydrite is converted to gypsum. As a result gypsum is present in outcrop or at shallow depths in older rocks while anhydrite commonly occurs beneath gypsum at depths varying between 30 and 60 metres.

Henderson (1954) concluded that gypsum deposits in the Stanford Range were primary; he based his conclusions on the absence of anhydrite and the lack of expansionary structures. He further argued that the gypsum was never buried deep enough for it to be converted to anhydrite. Most of his work was done prior to any mining having taken place.

Subsequent work has shown that anhydrite underlies the gypsum deposits in the Stanford Range at relatively shallow depths. Also, some of the structures present can be interpreted as expansionary, as evidenced by the presence of enterolithic folding. However, the absence of these structures does not necessarily preclude the gypsum having formed from anhydrite. Work by Holliday (1970) and Mossop and Shearman (1973) suggests that anhydrite can alter to gypsum without expansion. This may be explained by the fact that some of the sulphate is lost in solution. Also, the volume of water required to hydrate anhydrite is larger than the additional volume of the gypsum that is produced. In a closed system the gypsum occupies the space formerly occupied by water. Where there is macroscopic evidence of distortion caused by expansion, hydration probably took place very close to the surface.

Gypsum deposits in the Stanford Range are interpreted by the author to be secondary. In addition to macroscopic expansionary structures there is petrographic evidence of anhydrite being converted to gypsum. Relict anhydrite in thin section can be identified, although rare hydration or alabastine and textures similar to those described by Holliday (1970) are present. Hydration by meteoric water is interpreted to have taken place near surface, during uplift and erosion of sediments overlying the anhydrite.

Similarly, gypsum at Forgetmenot Creek, Falkland and O'Connor River formed as a result of the hydration of anhydrite. At these deposits the confining pressure was low enough to permit the gypsum to form and expand without restriction. As a result the expansionary structures observed throughout the Stanford Range are not present.

SEDIMENTARY GYPSUM DEPOSITS

GEOLOGY AND STRATIGRAPHY OF THE STANFORD RANGE

Gypsum in the Stanford Range occurs in rocks of Devonian age (Figure 7). 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 Devonian quartzite, argillaceous limestone and limestone 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 illustrated in Figure 8.

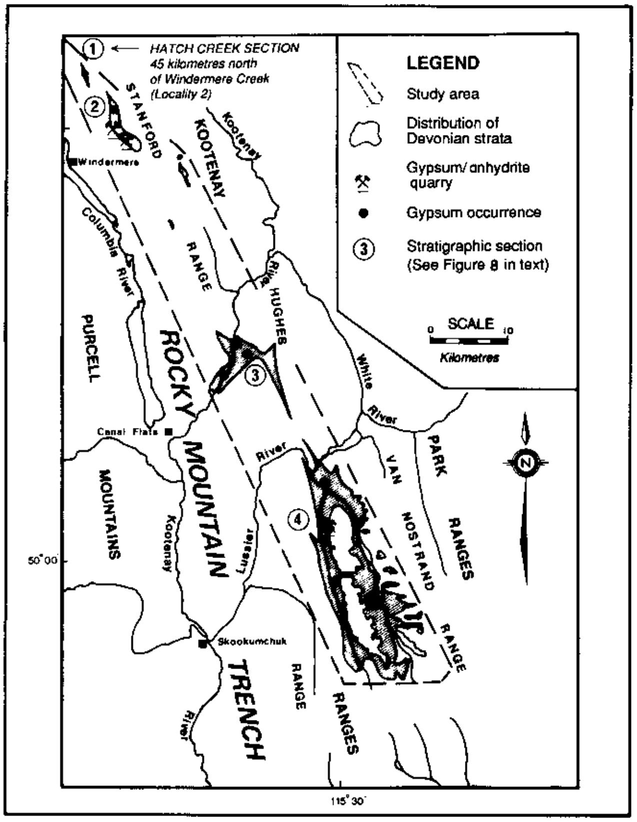

Figure 7. Location map showing the distribution of Devonian strata and gypsum occurrences in the Stanford Range.

This study attempted to delineate areas underlain by gypsum from those underlain by carbonate rocks. Most 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, and ovular chert nodules and lenses in a carbonate matrix are characteristic. The upper contact was not seen in the study area.

Strata of the basal Devonian unit were only observed in the Coyote Creek area. They consist of orthoquartzite and sandstone low in the section and limestone, argillaceous limestone, dolomite and minor shale in the upper part. Argillaceous limestones are easily recognized by their pale maroon to pale green colour. Lithologically similar rocks, tentatively assigned to the Cedared Formation, outcrop in the Windermere Creek area east and northeast of 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 devoid of fossils.

The Cedared Formation, at its type locality at Hatch Creek, Beaverfoot Range, 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, anhydrite and minor limestone that occurs at a number of localities throughout the Stanford Range. Although anhydrite does not outcrop, it has been intersected in drill holes. Very little is known about its thickness as very few holes penetrate the entire anhydrite section. Black fetid limestone and thin grey aphanitic limestone bands in fault contact with the gypsum are also included in the Burnais Formation. Estimates of stratigraphic thickness range from 50 to 100

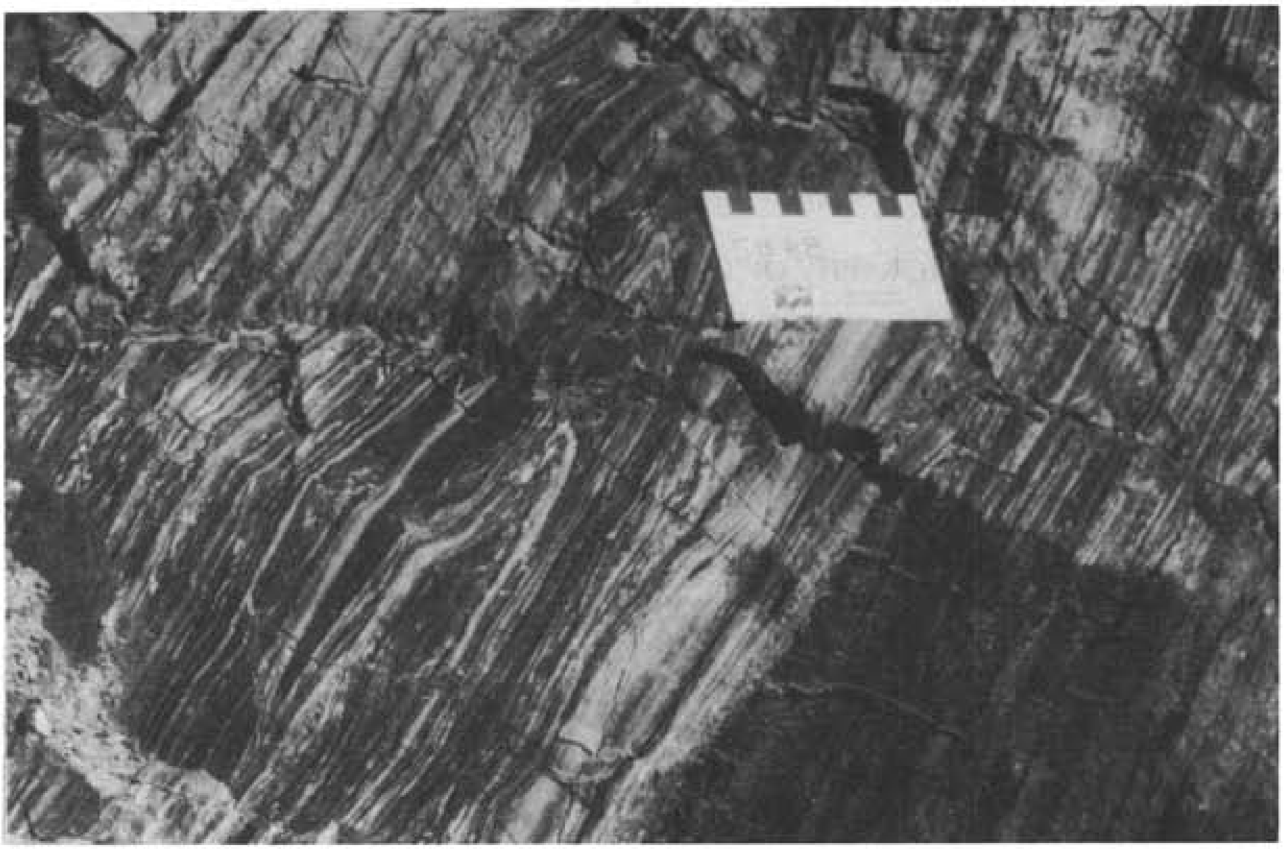

Plate 1. Example of laminated gypsum typical of deposits in the Stanford Range.

Plate 2. Enterolithic folding of gypsum laminae from Elkhorn No. 1 quarry.

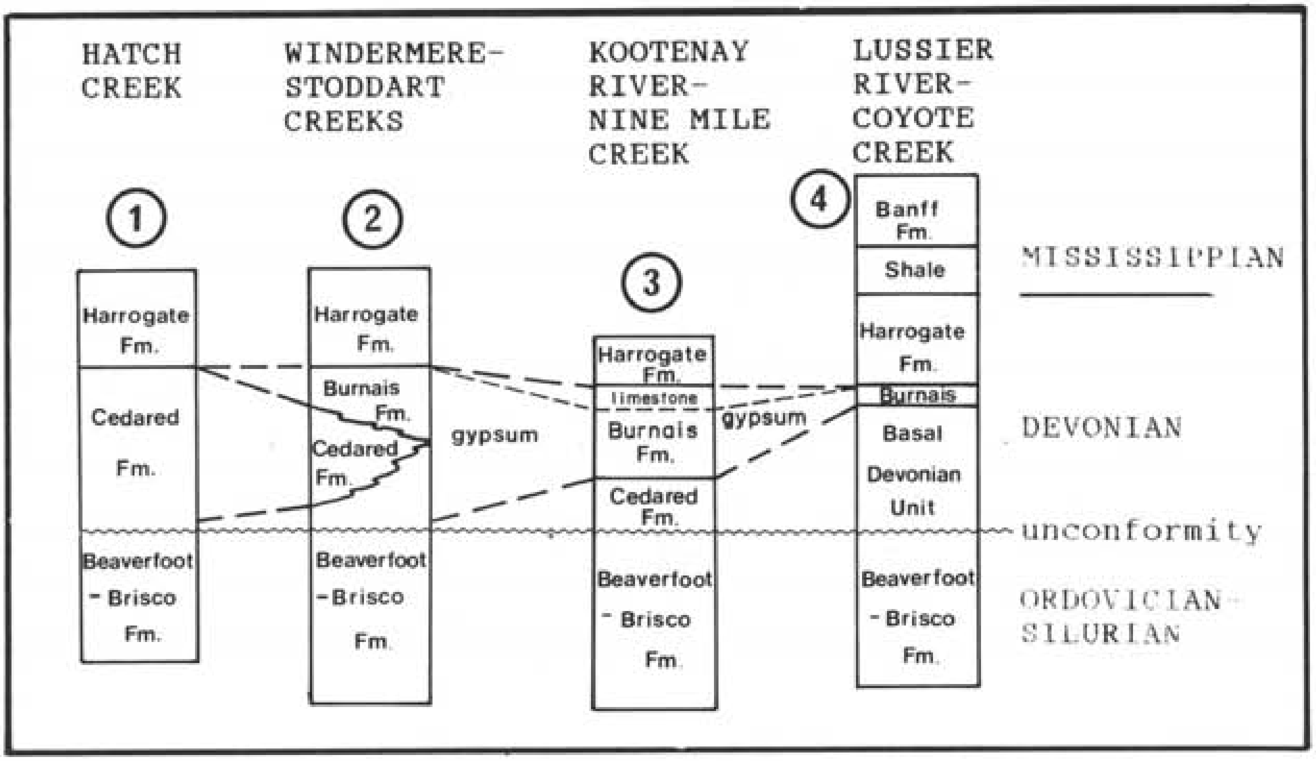

Figure 8. Nomenclature and correlation of Devonian stratigraphy in the Stanford Range.

metres or more, with the thickest sections occurring in the Windermere Creek area. There is a general thinning of the formation southward towards 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.

Seven areas underlain by the Burnais Formation were identified by Henderson in the Stanford Range. 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 1), with laminations and bedding varying in thickness from a fraction of a millimetre to 4 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 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 environment, 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.

Gypsum deposits are more structurally complex than the enclosing carbonate rocks. Some of the small-scale structural features may be the result of soft-sediment deformation occurring at the time of deposition; others are interpreted as enterolithic (Plate 2) and related to swelling and expansion during conversion of anhydrite to gypsum. This process involves a volume increase of 30 to 50 per cent. Microfaults are also believed to be the result of expansionary forces.

Large-scale concentric, open and chevron folds preceded the conversion of anhydrite to gypsum as the anhydrite/gypsum boundary crosscuts fold axis. Transverse faults with an east-west orientation appear to be a late stage event and may even postdate the formation of the gypsum. This late stage faulting may account for the large variation in thickness of gypsum north and south of the fault in the Elkhorn quarry.

Anhydrite is distinguished from gypsum by its hardness and light blue colour. In the Windermere Creek area anhydrite occurs at an average depth of 30 to 40 metres while in the Lussier River area it occurs 20 to 25 metres below surface. Very often there is an accumulation of hydrous salts with sodium or potassium at or very near the anhydrite-gypsum contact.

Gypsum-anhydrite evaporite deposits commonly form in either standing bodies of water or within the vadose zone and upper phreatic zone on supratidal flats and in desert playas. Characteristics of the former include

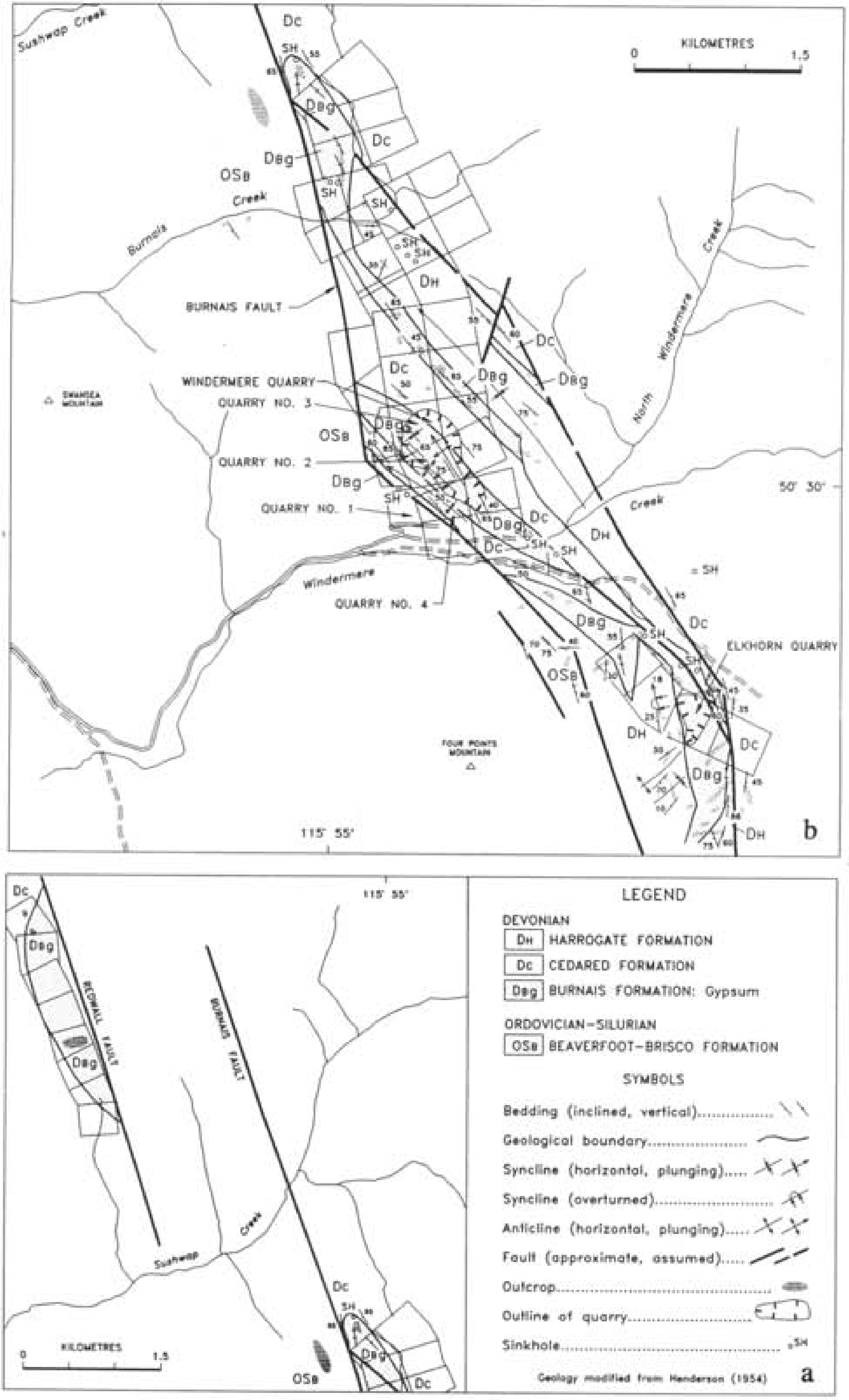

Figure 9a and b. Location of Windermere quarries. Geology and distribution of gypsum in the Windermere - Stoddart Creek area. Figure 9a shows area northeast of Figure 9b. Note the variation in scale between the two figures.

laminated or bedded evaporites and soft sediment deformation with small faults. They are usually devoid of fossils. Based on these criteria it is interpreted that gypsum deposits in the Stanford Range formed in a standing body of water. Water depths were probably shallow, ranging from a few centimetres to a few metres. This is evidenced by the presence of crosslaminations, cut-and-fill structures and rip-up breccias. The presence of selenite is also indicative of a shallow water environment.

The Burnais and Cedared formations are interpreted by Belyea and Norford (1967) to have been deposited in a slowly 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 periodically emergent. Deposition took place on a fairly broad shelf west of the Western Alberta ridge (Norford, 1981). Contemporaneous deposition of the Burnais Formation evaporites was limited to areas with restricted circulation.

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. Deposition of the Harrogate Formation took place in a deeper water environment as is evidenced by the presence of open-marine carbonates and shales (Norford, 1981).

In the Coyote Creek - Lussier River area, the Devonian sequence is overlain by a shale unit and carbonate strata of the Mississippian Banff Formation.

Sinkholes, although commonly associated with gypsum deposits can also be formed in carbonate terrains. It is possible for sinkholes to form along contacts between carbonate rocks of varying solubility. Sinkholes following distinct linear trends are therefore generally indicative of contact or fault zones. This characteristic is often observed in the Stanford Range. Sinkholes which have formed directly over gypsum tend to have a random pattern. This is most evident in the vicinity of Coyote Creek. Areas where there is no distinct pattern to the distribution of sinkholes may therefore provide good exploration targets.

PETROLOGY AND PETROGRAPHY

Textures observed in thin sections of samples collected in the Stanford Range are similar to those of alabastine secondary gypsum described by Holliday (1970), Mossop and Shearman (1973) and Ogniben (1957). Alabastine textures are defined as those in which individual grains are poorly defined or diffuse and have irregular or undulose extinction. Well-defined, intricately interlocking equidimensional anhedral grains form with further recrystallization. Gypsum varies in habit from granoblastic texture consisting of very fine-grained anhedral to subhedral crystals to mosaics of ill-defined anhedral crystals. Relic anhydrite is only rarely observed. In some thin sections subhedral crystals, generally coarser grained, are observed. These are interpreted to have formed in the late stages of the hydration and recrystallization process. In those specimens in which anhydrite is prevalent, one can observe the initial stages of the conversion to gypsum either as alteration of individual crystals or as veinlets of gypsum formed along fractures or microfaults.

GYPSUM DEPOSITS

WINDERMERE CREEK AREA

MINFILE: 082JSW021, 082JSW028

Gypsum deposits are best developed in the Windermere Creek area where stratigraphic thicknesses in excess of 100 metres have been reported. Primary gypsum was discovered in this area in 1947 (Henderson, 1954). Production, which began in 1950 from Windermere No. 1, has been continuous to the present day, totalling in excess of 6.8 million tonnes. Gypsum was mined from four quarries (Windermere Nos. 1 to 4) (Figure 9) on the north side of Windermere Creek until 1981 (Plate 3). It is currently being produced from the Elkhorn 1 quarry south of the creek (Plate 4). Production from this quarry is primarily for the wallboard industry. Minor production of mixed gypsum and anhydrite from the Windermere quarries continues, as required by the cement industry.

Production from the Elkhorn 1 deposit began in 1982. The orebody is tabular conforming to the slope of the hill on which it crops out over a vertical height of approximately 120 metres. It varies in width from 120 to 250 metres with the depth of the gypsum varying from 12 to 70 metres (Clow, 1981). Initial reserves were estimated to be 3.3 to 4.0 million tonnes with the gypsum grade averaging better than 80 per cent.

Immediately to the southeast and across a north-trending draw is the Elkhorn 2 deposit. It is expected that production from this deposit will follow production from the Elkhorn 1 quarry. Reserves are estimated to be sufficient to last well into the next century.

The gypsum is mined by open-pit methods, processed through a portable crushing and screening unit and then hauled by truck over a private road approximately 20 kilometres to the plant at Wilmer where the gypsum is further crushed and screened. The final product, 7.5 centimetres or less in size, is then shipped to plants in Vancouver and Calgary.

Gypsum occurs along a northwesterly trend which has strike length of 5 kilometres (Figure 9) north and south of Windermere Creek. The main gypsum unit is host to the Windermere 2 to 4 and Elkhorn deposits. The

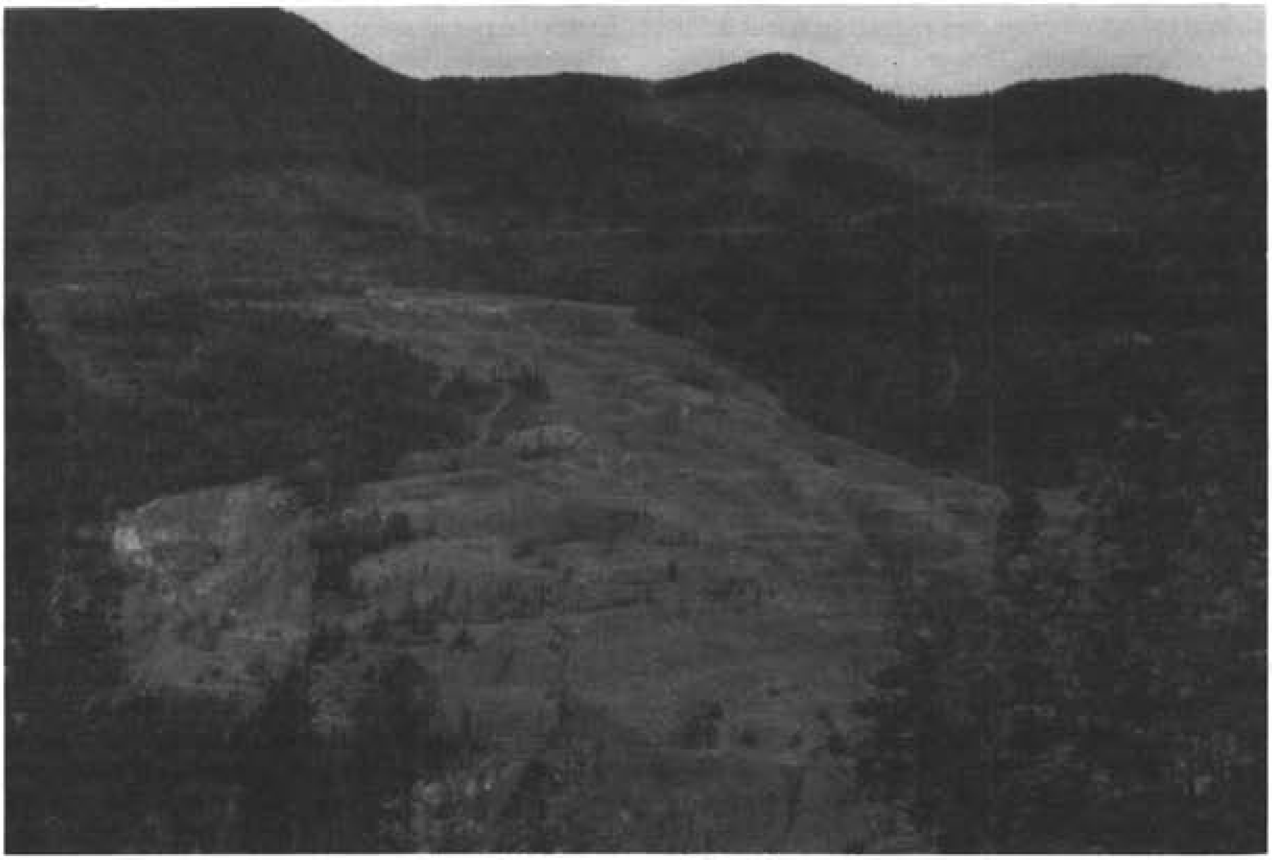

Plate 3. View of Windermere quarries looking northwest.

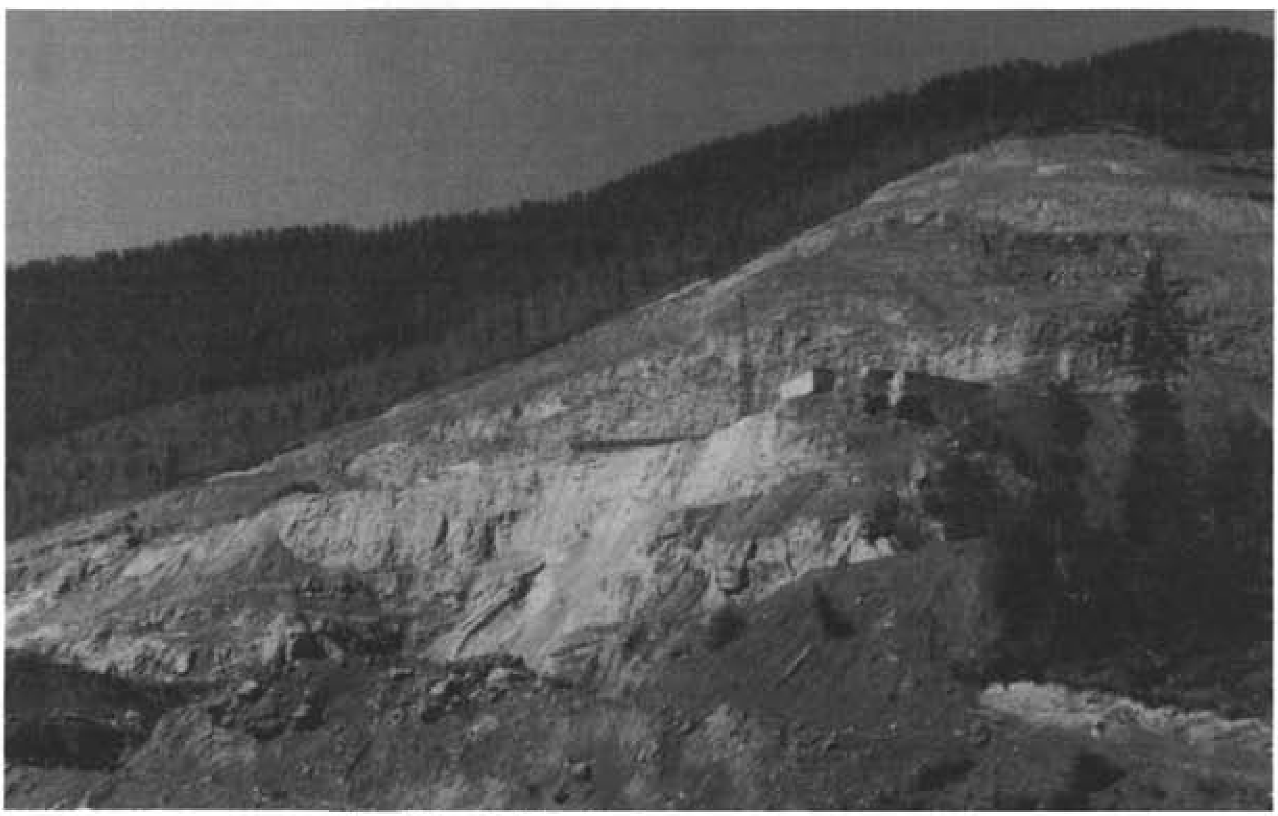

Plate 4. View of Elkhorn No. 1 quarry looking southeast.

Windermere No. 1 quarry is hosted by a separate lens of gypsum or represents a folded or faulted repetition of the main gypsum unit.

The lower gypsum bed has a minimum thickness of 50 metres and may be as much as 100 metres thick. The upper or main bed is structurally more complex and determining an accurate thickness is difficult. Contact relationships between the gypsum and enclosing strata are rarely observed. It is inferred that gypsum of the Burnais Formation is in fault contact with the underlying Beaverfoot-Brisco Formation or in conformable contact with the Cedared Formation. Contact with the overlying Harrogate Formation also appears conformable.

The gypsum in the Windermere Creek area is good quality, ranging between 83 and 93 per cent gypsum. It varies in colour from pale grey to grey with brownish grey, dark grey to black, or cream-coloured laminae also present. The rock is distinctly laminated or thin bedded with bedding and laminae very often severely contorted or enterolithically folded.

The gypsum-anhydrite sequence has been folded into a series of northwest-plunging folds. Their plunge varies from 18 to 40° degrees. Small-scale faulting with minimal displacement is present west of the Elkhorn quarry in the west-dipping overturned limb of a syncline. Both bedding and axial planes dip westerly. Henderson (1954) suggested that beds on the eastern margin of the Windermere No. 1 quarry may also be overturned. Faulting on a larger scale and with indeterminate displacement is more prevalent to the southeast. A large northwest-trending fault cuts through the lower portion of the Elkhorn quarry.

At the Windermere quarry anhydrite is present in a breccia zone that is 30 metres wide. The breccia consists of angular anhydrite and gypsum fragments in an anhydrite matrix. The anhydrite tends to be more massive than the surrounding gypsum.

A second gypsum bed can be traced over a strike length of 4.2 kilometres northward from Windermere Creek to north of Burnais Creek where it thins and disappears under thick overburden and carbonate strata of the Cedared Formation (MINFILE 082JNW004). Drilling on the ridge north of Windermere Creek intersected gypsum to depths varying from 17 to 43 metres and underlain by anhydrite (Clow, 1980). Gypsum is similar to that observed elsewhere in the area. Its quality varies from 74 to 94 per cent, averaging better than 85 per cent gypsum.

Further north a small lens of gypsum outcrops south of Stoddart Creek (MINFILE 082JNW005). Here the rock is of lower quality, containing 75 per cent gypsum (F.W. Jarret, Westrock Industries Limited, personal communication, 1988). Gypsum, which can be traced intermittently along strike for approximately 3 kilometres, is confined to a downdropped fault block that abuts against the Redwall fault to the east. The contact between the gypsum and the fault is not observed. Gypsum is cream to pale grey and laminated. In thin section it is seen to be composed of very fine-grained, anhedral to diffuse gypsum grains. Also present are distinct stringers of gypsum, probably selenite. Dolomite occurring as a very fine-grained clastic component is the principal impurity with trace amounts of quartz and orthoclase also present. No gypsum is known north of Stoddart Creek.

Kootenay River - Nine Mile Creek Area

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 10). Gypsum is very well exposed in an area approximately 1.5 kilometres in length across an average width of 400 metres and an elevation difference of up to 30 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 (Little Joan; MINFILE 082JSW005) where gypsum has been exposed in trenches and other workings over a stratigraphic interval of approximately 125 metres. Shipments of gypsum from this location, containing 85 per cent or less gypsum, were made by Western Gypsum Products Limited in 1951.

Further to the north there are several large exposures of gypsum along the east bank of the Kootenay River and in the immediate vicinity of Nine Mile Creek. Away from the valleys of these two watercourses outcrop is scarce or absent. Overburden cover in excess of 25 metres thick has been determined from diamond drilling done along the access road into Nine Mile Creek (Blender, 1987a). The gypsum is intercalated with carbonate rocks 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. Bedding strikes east to northeasterly with moderate dips to the northwest, north and south. A syncline, with or without associated faulting, may be present along the Kootenay River.

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

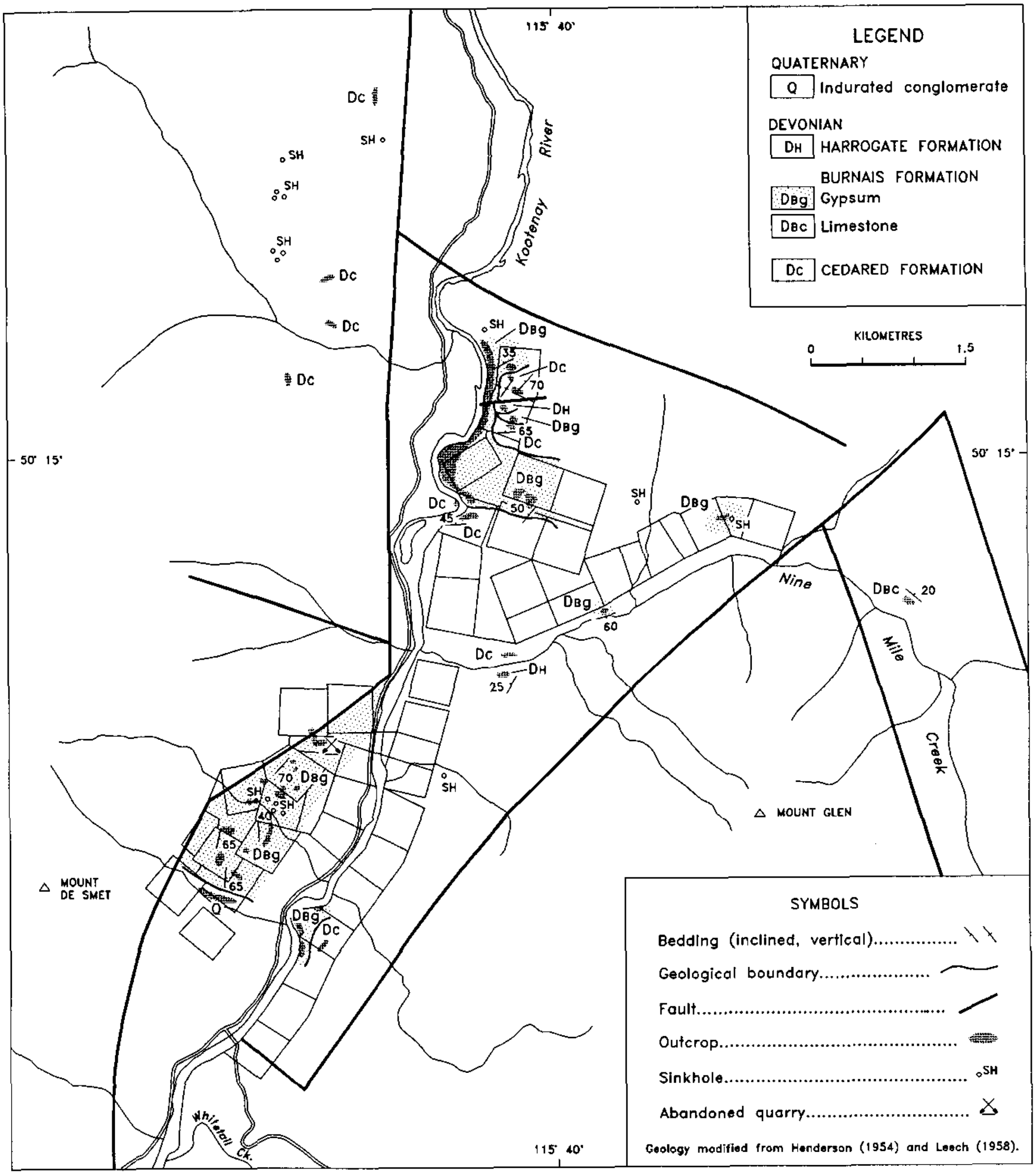

Figure 10. Geology and distribution of gypsum in the Kootenay River - Nine Mile Creek area.

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 ranging from 44 to 94 per cent (Henderson, 1954). Sampling by the author indicated gypsum contents between 81 and 97 per cent.

LUSSIER RIVER - COYOTE CREEK AREA

The southernmost exposures of gypsum in the Stanford Range occur in the Lussier River - Coyote Creek area (Figure 11). In the Lussier River valley the majority of occurrences are located east of the river. Extensive and very thick overburden preclude tracing the gypsum over any significant distance. Where observed, the gypsum is steeply dipping to vertical. Faulting may have played an important role in the localization and preservation of these deposits. The dominant structural feature in the area is a north-trending syncline with shallow-dipping limbs. Its axis is located along the height of land separating the Lussier River and Coyote Creek and gypsum is present along both limbs.

Isolated occurrences of gypsum have been traced from a locality approximately 2 kilometres north of the confluence of the Lussier River and Coyote Creek, south to the northern boundary of the Top of the World Park. A single gypsum outcrop is present east of Coyote Creek at the same latitude as the Lussier River quarry. Further to the south three new occurrences of gypsum were located immediately east of the height of land separating the Lussier River from Coyote Creek. These showings were first reported by Butrenchuk (1989) although nearby sinkholes were mapped by Leech (1960). Two of the gypsum occurrences are located on a logging road locally known as Branch F; the third outcrops north of the westernmost of these two showings.

Following are descriptions of the various deposits and occurrences present in the Lussier River - Coyote Creek area.

LUSSIER QUARRY - MINFILE 082JSW009

Latitude: 50°03′00″ Longitude: 115°31′00″ NTS: 82J/4E

Gypsum is presently mined from a quarry located on the Lussier River approximately 2.5 kilometres south of its confluence with Coyote Creek. The quarry, which began producing in 1984, is owned by Domtar Inc. and operated by Domtar Gypsum. Original reserves were calculated to be approximately 7 million tonnes (Rodgers and Kovacs, 1984). Gypsum is hauled a distance of 32 kilometres over logging roads to a loading bin at Canal Flats. Unlike the quarries on Winderemere Creek there is no primary crushing at the quarry site, the crushing facility is located along a railroad spur at Canal Flats.

The deposit, which outcrops across a width of 156 metres and a vertical height of approximately 100 metres, occurs in a northeast-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 the contacts exposed. 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 enterolithic 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 within the deposit.

Gypsum varies in colour from pale grey to black with some cream to white laminae present. It is very well laminated with laminae ranging in thickness from 0.1 to 4 millimetres. Locally thicker laminae are present. White selenite occurs as blebs along fractures and fault zones. Native sulphur is present locally but is rare, as is pyrite. Anhydrite occurs as pods or thin layers within the deposit. These increase in frequency and extent with depth (Rodgers and Kovacs, 1984).

In thin section the gypsum is observed to have a fine-grained granular texture. The texture varies from distinct well-formed grains to those having diffuse boundaries giving the rock a felted appearance. Carbonate material, generally in the form of dolomite, constitutes approximately 10 to 15 per cent of the rock while minor amounts of quartz and lesser anhydrite are also present.

BEAVER (LUSSIER SOUTH) - MINFILE 082JSW017

Latitude: 50°02′15″ Longitude: 115°30′15″ NTS: 82J/4W

The Lussier South quarry is located 3 kilometres south of Coyote Creek and 1025 metres south of the presently producing gypsum quarry on the Lussier River. There has been some minor production from this quarry although details are lacking.

Gypsum is exposed along the quarry walls across a width of 80 metres. It is laminated to thin bedded, pale grey to grey with some dark grey laminae. At the south end of the outcrop numerous faults are exposed and some brecciated gypsum is present. Minor amounts of selenite occur as blebs and stringers throughout. Trace amounts of native sulphur were also observed. Dolomite and minor amounts of quartz and anhydrite also occur. Trace amounts of albite, chlorite and syngenite, a hydrous calcium-potassium sulphate, were identified by x-ray diffraction. A high salt content in the deposit caused cessation of production (R. Banting, oral communication, 1989).

AMOS - MINFILE 082JSW004

Latitude: 50°05′15″ Longitude: 115°32′10″ NTS: 82J/4E

Two small gypsum showings are exposed in a roadcut on the east bank of the Lussier River, 2.2 kilometres north of its confluence with Coyote Creek. Outcrop is rare except for a third outcrop of gypsum to the south along

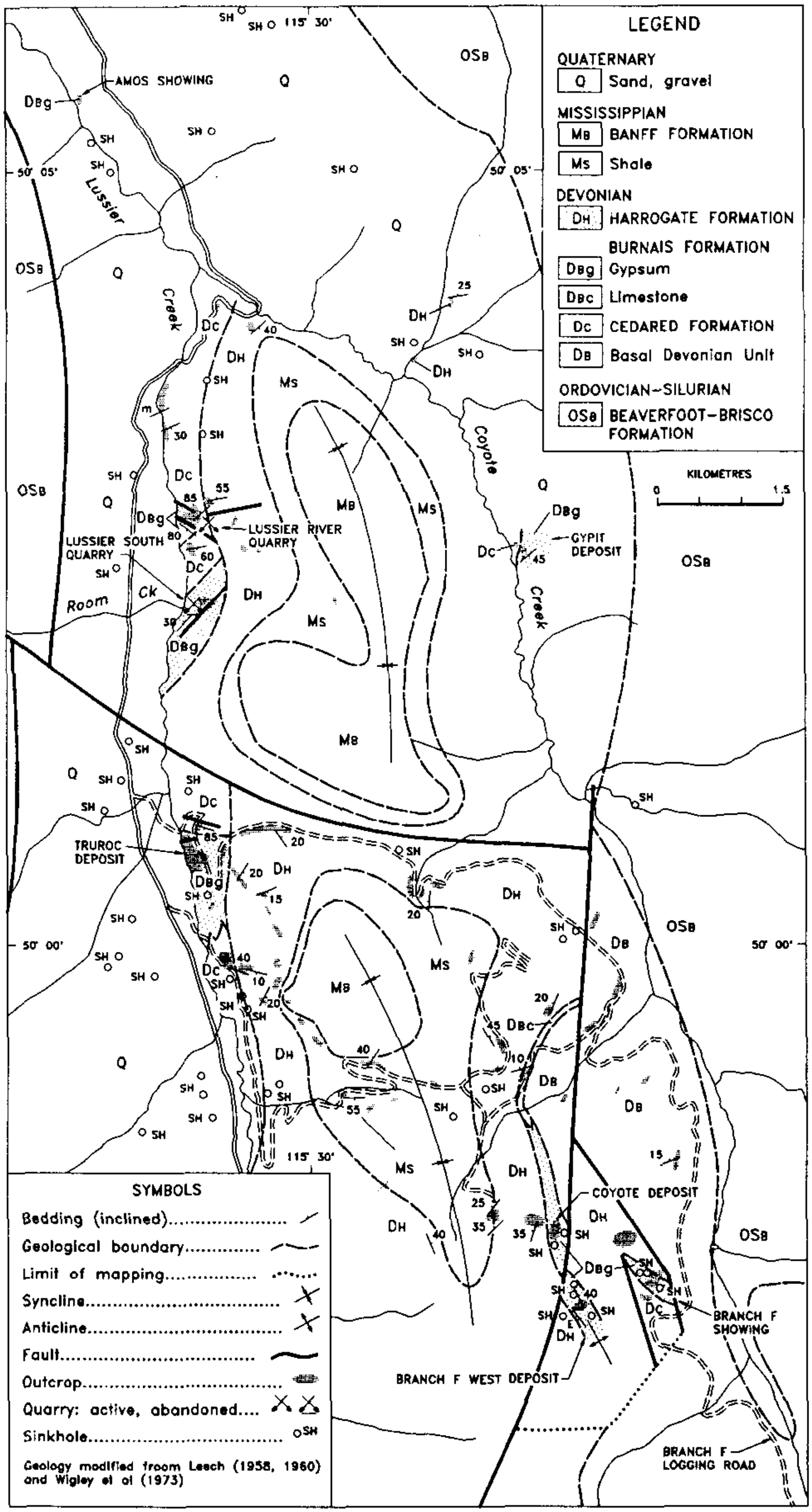

Figure 11. Geology and distribution of gypsum in the Lussier River - Coyote Creek area.

the river and two outcrops of limestone east of Coyote Creek. Sinkholes are common. A seismic survey completed in this area in 1961 indicated that the thickness of overburden varied from 15 to 76 metres (Millar, 1961). Drilling by Domtar Inc. in 1987 (Blender, 1986) confirmed the presence of thick overburden cover.

Where exposed the gypsum is pale grey, grey and pale brownish grey. It is laminated with the laminae contorted and folded. Some brecciated gypsum is present locally. Drilling in the immediate vicinity of these outcrops failed to intersect any gypsum. Holes that were able to penetrate the overburden intersected either anhydrite or limestone (Blender, 1986). Gypsum appears to be restricted to a small area along the bank of the Lussier River. To the north limestone is present while anhydrite replaces gypsum to the northeast. There may be potential for the gypsum to extend southwards to the southernmost of the gypsum outcrops.

East of the Lussier River logging road several sinkholes are randomly distributed. While there may be potential for the presence of gypsum, limestone is present in at least part of the area (Blender, 1986).

GYPIT - MINFILE 082JSW019

Latitude: 50°02'30" Longitude: 115°28'00" NTS: 82J/3W

A solitary outcrop of gypsum is exposed along a roadcut immediately east of Coyote Creek, approximately 5 kilometres south of the junction of the Lussier and Lower Coyote Creek logging roads. Gypsum is present over a length of 115 metres with thicknesses varying between 10 and 20 metres. This occurrence is owned by Domtar Inc. and was the subject of an exploration program in 1987. Trenching and percussion drilling using an air-trac drill failed to extend the gypsum beyond the outcrop limits (Blender, 1987).

The gypsum is dark grey to black with some pale grey and cream-coloured laminae; laminations are contorted and folded. Small-scale faults with negligible displacement are also common. On a larger scale it appears that the gypsum occurs on the southern limb of an east-trending anticline.

A granular texture consisting of very fine-grained to fine-grained gypsum is observed in thin section. Very fine-grained dolomite with minor amounts of anhydrite and quartz is associated with the gypsum. Traces of an unidentified amphibole mineral were identified by x-ray diffraction.

Contacts with surrounding rock are not exposed. A small outcrop of dark grey to black dolomite to the northwest is assigned to the Cedared Formation.

TRUROC - MINFILE 082JSW022

Latitude: 50°00'40" Longitude: 115°31'00" NTS: 82J/4E

Gypsum is exposed along the east bank of the Lussier River 2.5 kilometres south of its confluence with Roam Creek. It is exposed over a length of 200 metres in steep bluffs in excess of 30 metres high. Sinkholes on both sides of the river suggest that gypsum may be present over a much larger area than observed in outcrop (Figure 12).

The property on which the gypsum occurs is owned by Westroc Industries Limited. Past exploration has consisted of diamond drilling, geological mapping (Korun, 1980) and geophysics (Reimchen and Bakker, 1982).

The gypsum is pale grey and thinly bedded to laminar. Bedding and laminations are generally steep dipping and very often severely contorted. Fault-related breccia zones are observed in both outcrop and in drill core. Native sulphur is present in trace amounts. Results of the drilling program indicate that the gypsum is 33 metres thick at its centre and 20 metres thick near its northern end.

Overlying the gypsum is a black to dark grey limestone of the Harrogate Formation. To the south the gypsum abuts against a calcareous tufa. North of the gypsum outcrop is a black, aphanitic, steeply dipping limestone of the Cedared Formation. Its contact with the gypsum is not exposed. Faulting is common and this contact may be a fault.

Korun (1980) suggested that there is a potential for 40 million tonnes of gypsum with a purity in excess of 80 per cent. A more conservative estimate by the author suggests the potential for 20 million tonnes. No gypsum has been mapped on the west side of the Lussier River at this locality; drilling was unsuccessful in penetrating the overburden in this area. While the presence of sinkholes suggests that gypsum may be present at depth it is very doubtful that it could be exploited.

BRANCH F - MINFILE 082GNW071

Latitude: 49°58'10" Longitude: 115°27'00" NTS: 82G/14W

Gypsum, tentatively assigned to the Burnais Formation, is exposed in an outcrop measuring 45 by 20 metres along a logging road locally named Branch F. Small sinkholes, many of which have exposed gypsum, are present over an area measuring 300 by 100 metres. To the northwest the gypsum disappears under overburden while to the southeast it appears to terminate against a fault.

The gypsum is grey to dark grey to black, laminated and occasionally massive. Its thickness is unknown but is estimated to be a minimum of 30 metres. Grey limestone and dolomite of the basal Devonian unit underlie the gypsum; overlying the gypsum is a black limestone breccia. This breccia may be a collapse structure caused by solution of the underlying gypsum; it is also interpreted as part of the Burnais Formation. This unit is overlain in turn by dark grey to black, nodular limestone of the Harrogate Formation.

Two analyses by Bondar-Clegg on samples of gypsum taken at this locality are presented in Table 1.

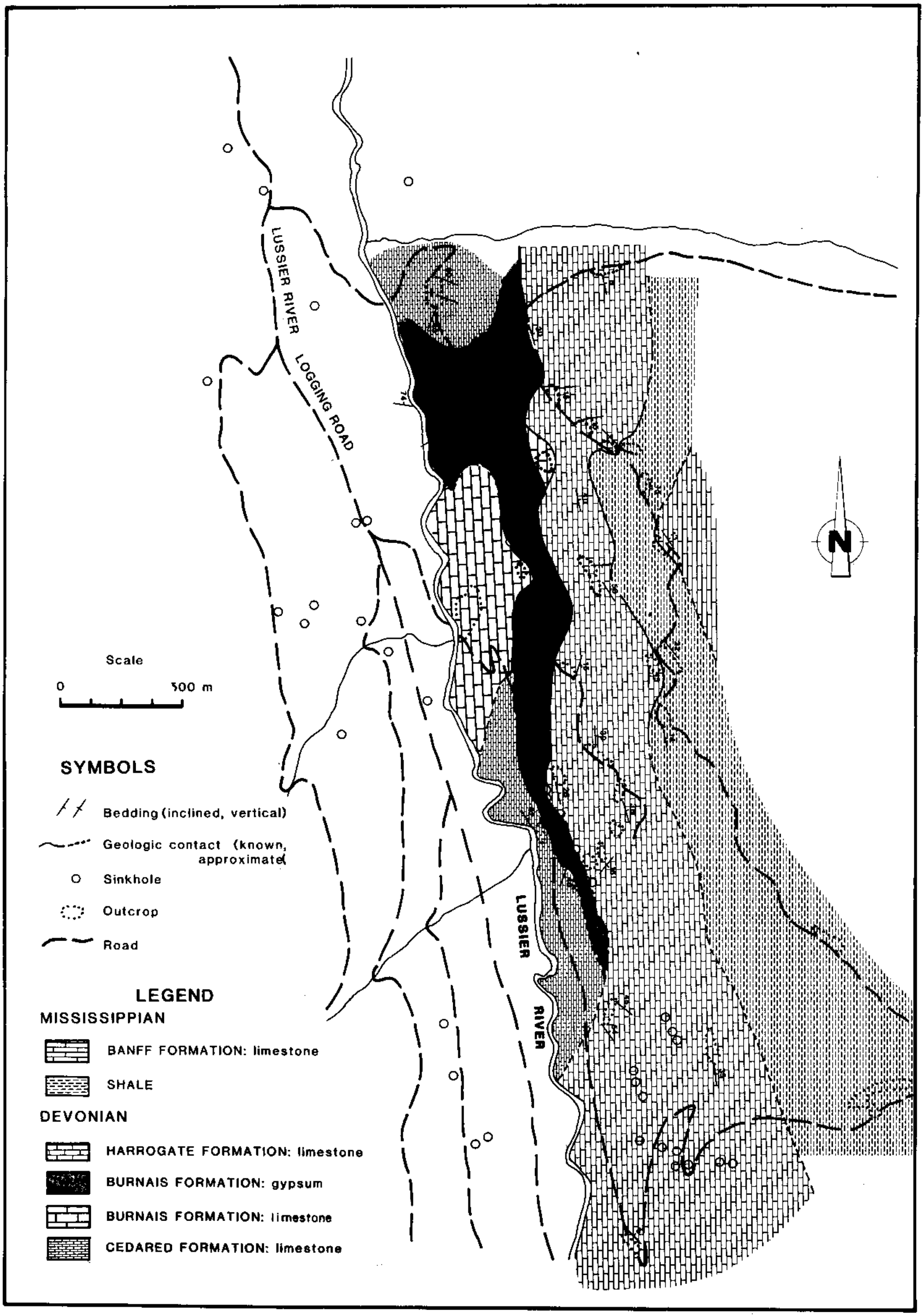

Figure 12. Geology of the Truroc gypsum deposit.

TABLE 1
CHEMICAL ANALYSES OF GYPSUM - BRANCH F SHOWING
(all values in per cent)

Sample No.	Al_2O_3	CaO	Fe_2O_3	K_2O	MgO	MnO	Na_2O	P_2O_5	SiO_2	TiO_2	SO_3	H_2O^+	Cl
SB88-83A	0.10	35.00	0.05	<0.03	0.79	<0.01	0.02	<0.03	0.62	<0.01	44.36	19.25	<0.01
SB88-83B	0.19	35.52	0.09	<0.03	2.19	<0.01	0.03	0.04	1.04	<0.01	40.52	17.84	<0.01

The gypsum varies from 85 to 92 per cent pure. Minor amounts of dolomite and quartz were identified by x-ray diffraction.

There appears to be a potential for approximately 2 to 3 million tonnes of gypsum at this locality.

BRANCH F WEST - MINFILE 082GNW077

Latitude: 49°57′45″ Longitude: 115°27′30″ NTS: 82G/14W

A new occurrence of gypsum, first reported by Butrenchuk (1989), is exposed near the west end of the Branch F logging road 2 kilometres west of Coyote Creek. Gypsum crops out over a length of 60 metres and is also exposed in sinkholes and small outcrops for a distance of 300 metres north from the main showing.

The gypsum is present in the Burnais Formation and is overlain by a thin, black limestone breccia probably belonging to the same formation. A black nodular limestone of the Harrogate Formation conformably overlies strata of the Burnais Formation. Underlying strata are limestone, dolomite, sandstone and orthoquartzite of the basal Devonian unit.

Gypsum is typically laminated to thin bedded and pale grey to grey. Bedding and laminae are locally contorted. White selenite is present in minor quantities as irregular lenses and blebs. Minor amounts of dolomite, quartz and anhydrite are also present. An analyses by Bondar-Clegg on a sample taken across a width of 25 metres at this locality is given in Table 2.

The gypsum has a purity in excess of 87 per cent. Impurities, identified petrographically and by X-ray diffraction, consist of minor dolomite, quartz and anhydrite.

COYOTE - MINFILE 082GNW078

Latitude: 49°57′55″ Longitude: 115°28′00″ NTS: 82G/14W

Gypsum is exposed in outcrop and sinkholes between two logging roads in a logged-off area approximately 2 kilometres west of Coyote Creek. This occurrence which is located 1000 metres north of the Branch F West occurrence, was first reported by Butrenchuk (1989).

In the best exposure gypsum occurs across an outcrop width in excess of 30 metres and 60 metres of elevation. Overlying the gypsum is a thin black limestone breccia. Both the limestone and gypsum are assigned to the Burnais Formation. These units are in turn overlain by a dark grey to black nodular limestone of the Harrogate Formation. Gypsum is laminated, pale grey to dark grey with some black laminations. Traces of native sulphur are also present. Table 3 presents an analysis by Bondar-Clegg of a sample collected across a width of 20 metres from this locality.

The gypsum is better than 90 per cent pure. Similar results were obtained by Chemex Labs (Appendix 1). Minor amounts of calcite, dolomite and quartz were identified petrographically and by x-ray diffraction.

This occurrence is believed to be the northern extension of the Branch F West occurrence. These two areas are estimated to have a combined potential for 6 million tonnes of gypsum.

CRANBROOK - ROCKY MOUNTAIN TRENCH AREA

There are four gypsum occurrences in the Rocky Mountain Trench area east of Cranbrook representing

TABLE 2
CHEMICAL ANALYSIS OF GYPSUM - BRANCH F WEST SHOWING
(all values in per cent)

Sample No.	Al_2O_3	CaO	Fe_2O_3	K_2O	MgO	MnO	Na_2O	P_2O_5	SiO_2	TiO_2	SO_3	H_2O^+	Cl
SB88-85	0.19	39.61	0.11	0.07	1.79	<0.01	<0.02	0.08	1.23	<0.01	42.17	18.32	<0.01

TABLE 3
CHEMICAL ANALYSIS OF GYPSUM - COYOTE SHOWING
(all values in per cent)

Sample No.	Al_2O_3	CaO	Fe_2O_3	K_2O	MgO	MnO	Na_2O	P_2O_5	SiO_2	TiO_2	SO_3	H_2O^+	Cl
SB88-84	0.18	36.52	0.09	0.07	1.05	0.01	0.02	0.08	0.86	0.01	43.45	18.88	0.01

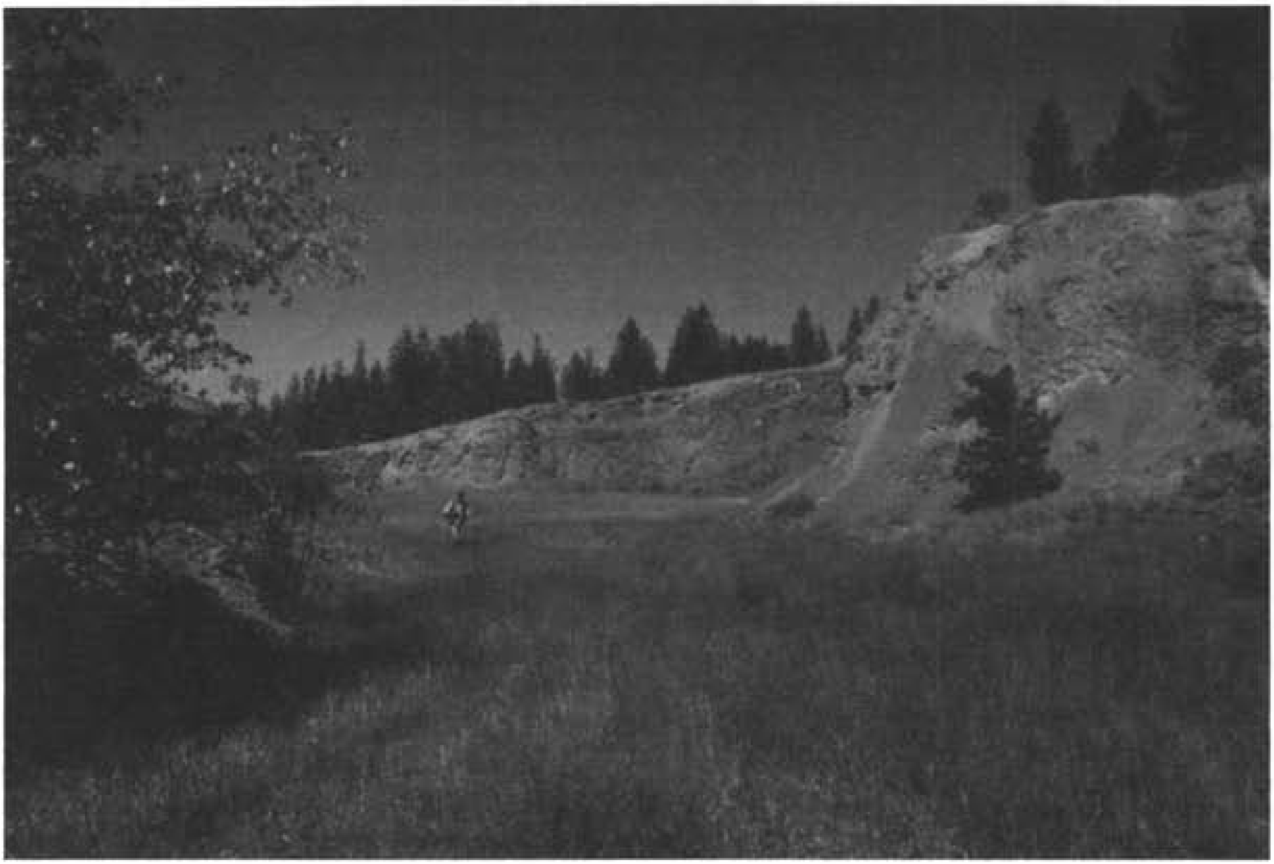

Plate 5. Sunrise gypsum quarry east of Cranbrook.

TABLE 4
CHEMICAL ANALYSES OF GYPSUM - MAYOOK - CHIPKA CREEK AREA

Sample No.	Location	SiO_2 %	CaO %	Na_2O %	K_2O %	MgO %	H_2O %	SO_3 %	S %	Sr ppm
SB88-108A	Sunrise	5.12	28.52	0.05	0.37	5.12	14.80	33.63	13.5	620
SB88-108B	Sunrise	4.51	28.53	0.03	0.16	4.35	15.80	35.77	14.4	305
SB88-109A	Mayook	5.46	29.19	0.02	0.30	4.10	16.00	36.35	14.4	500
SB88-109B	Mayook	5.59	28.92	0.02	0.33	4.14	15.70	35.88	14.3	275
SB88-109C	Mayook	5.28	28.23	0.02	0.30	4.24	15.70	35.81	14.3	400
SB88-109D	Mayook	5.19	28.37	0.02	0.33	4.00	15.90	36.06	14.6	300
SB88-110A	Chipka Ck.	4.01	29.97	0.03	0.29	2.22	17.80	40.44	16.3	755

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 a 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.

Gypsum in these deposits varies from white to grey and is bedded to laminated, although bedding is poorly defined; 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 enterolithic structures, present throughout much of the Stanford Range further to the north, are not as common 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 remains uncertain but they are believed to be of Devonian age and may be equivalent to the Burnais Formation.

SUNRISE - MINFILE 082GSW045

Latitude: 49°29′20″ Longitude: 115°32′50″ NTS: 82G/5E

The Sunrise gypsum deposit is located along Highway 3, 26 kilometres east of Cranbrook. Gypsum is exposed in a quarry (Plate 5), a few small pits and sinkholes over an area measuring 550 by 200 metres (Figure 13). The quarry itself is 125 metres long and 15 to 60 metres wide. Gypsum is exposed over a height of 36.5 metres decreasing to 2 to 4 metres along the south wall. Approximately 95 000 tonnes of gypsum were produced by Canada Cement Company of Exshaw, Alberta from this quarry during the periods 1926-1929 and 1948-1954.

Gypsum at this location is pale grey to dark grey and occasionally black, sucrosic and laminated to thin bedded. Locally, it is cut by stringers of white fibrous selenite 1 centimetre or less in width. Dolomite beds 2 to 4 centimetres thick are intercalated with the gypsum. Results of sampling by the author indicate the quality of gypsum varies between 72 and 77 per cent (Table 4).

The main structural feature is a northeast-plunging anticline, the north limb of which is cut by a fault. Near the fault gypsum is brecciated and contains clasts of both gypsum and limestone.

A thin-bedded, fine-grained black limestone that weathers light grey is exposed east of the quarry. Bedding varies from 1 to 5 centimetres thick. Dolomite outcrops north of the gypsum deposit.

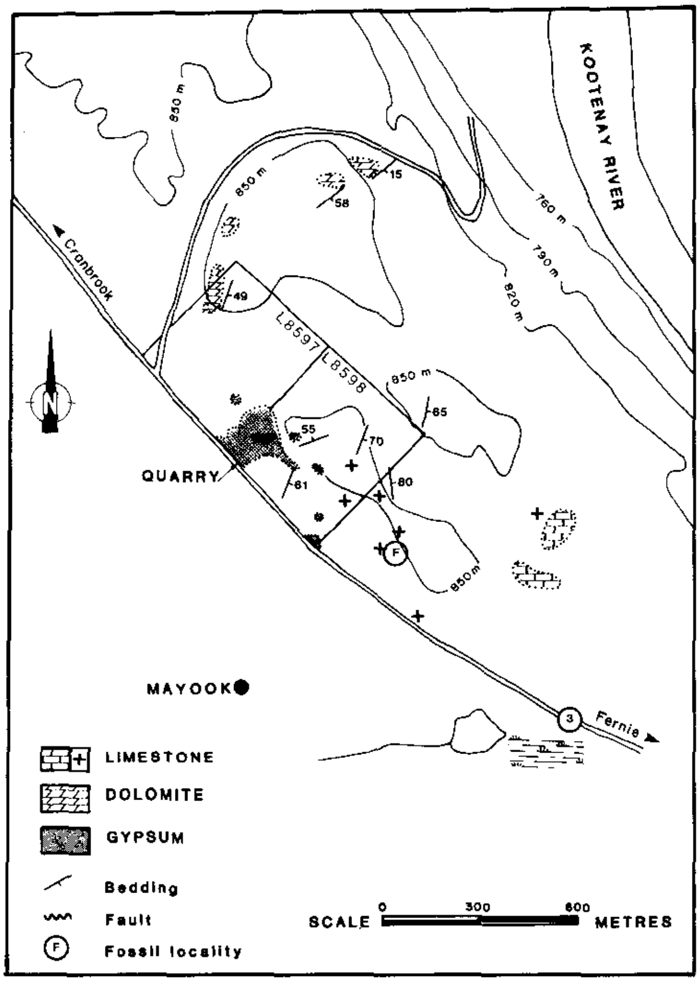

Figure 13. Sunrise gypsum deposit, north of Mayook.

MAYOOK - MINFILE 082GSW044

Latitude: 49°28′40″ Longitude: 115°32′50″ NTS: 82G/5E

The Mayook gypsum deposit is located south of Highway 3, 26 kilometres east of Cranbrook. Gypsum is exposed in four outcrops over an area measuring 800 by 300 metres (Figure 14). Three small test quarries have been opened on Lot 10213 and a 21-metre adit driven along the boundary between Lots 10220 and 10219 (Ministry of Mines Annual Report, 1968). Gypsum has been known at this location since before 1926. In 1946 the Western Gypsum Company shipped 6950 tonnes to its Calgary plant and there has been no production reported since that time.

Outcrops are highly weathered and decomposed and partially coated with gypsite. The gypsum is typically pale grey to grey and sucrosic. Bedding is indistinct except to the south where it dips steeply to the east. Locally the gypsum is distinctly conglomeratic or brecciated, containing fragments of both gypsum and limestone. The quality

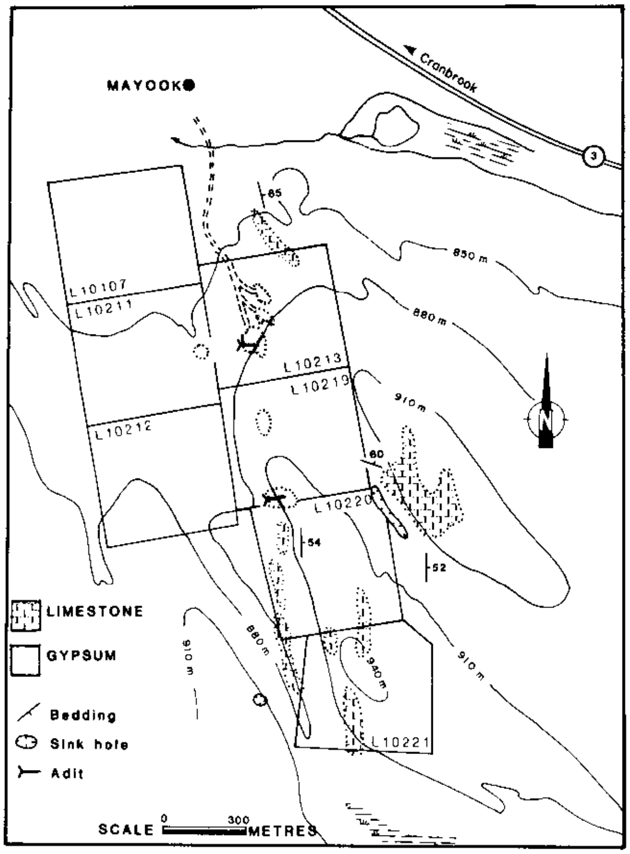

Figure 14. Gypsum deposit at Mayook.

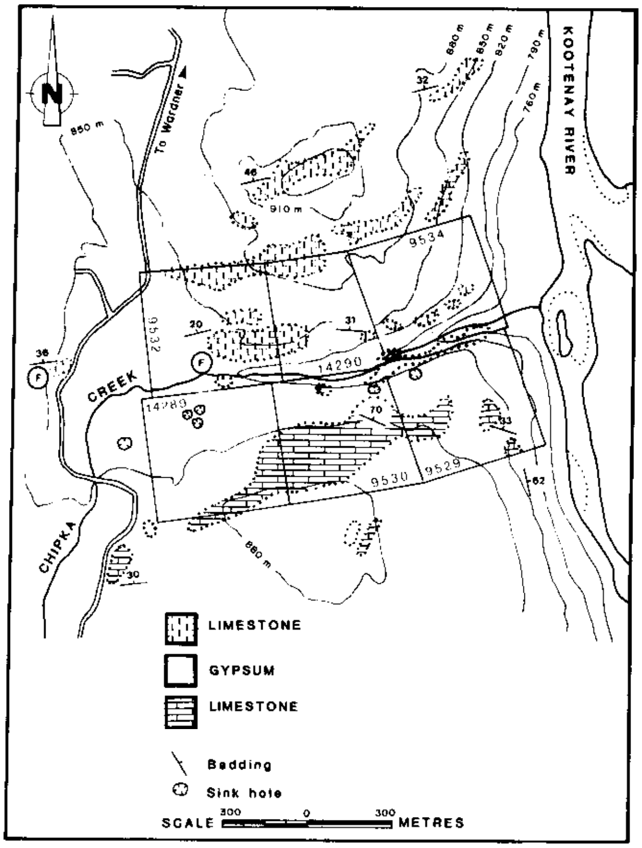

Figure 15. Chipka Creek gypsum deposit.

of the gypsum as indicated by sampling is consistently 77 per cent (Table 4).

Limestone also outcrops in the area but nowhere are contact relationships observed. The limestone is fine grained, dark grey to black, weathers light grey and is locally brecciated. Exposures north of the gypsum are lithologically similar to the Harrogate Formation in the Stanford Range.

CHIPKA CREEK - MINFILE 082GSW009

Latitude: 49°24′00″ Longitude: 115°25′00″ NTS: 82G/6W

Gypsum occurs over a wide area along Chipka Creek, 2.5 kilometres south of Wardner. The main showing forms steep cliffs along the southern bank of the creek. Smaller exposures are present to the west and sinkholes occur over a wide area on the bench south of Chipka Creek (Figure 15).

Gypsum varies from dark grey to black in colour with lighter streaks or laminae occasionally present. It is laminated to thin bedded and in part brecciated. Limestone is mixed with the gypsum and traces of native sulphur are also present.

The area north of Chipka Creek is underlain by a brecciated, fossiliferous limestone that weathers light grey. Many of the exposures are nodular. Limestone to the south of the creek is massive, black and light grey weathering. Locally it is thin bedded and light grey in colour. Bedding in the area trends east with moderate to steep northerly dips. The stratigraphic sequence containing the gypsum is interpreted to be truncated by a thrust fault to the south and forms a conformable sequence with younger strata to the north (Höy and Carter, 1988).

BULL RIVER - MINFILE 082GSW031

Latitude: 49°29′30″ Longitude: 115°24′23″ NTS: 82G/6W

Gypsum is exposed along the Bull River 4 kilometres upstream from the Bull River townsite; outcrops are restricted to the banks of the river, although a few sinkholes are present to the north and south (Figure 16).

The following description is summarized from the Ministry of Mines Annual Report 1968. Gypsum is highly contorted, light grey to white-streaked in the upper part, grading to darker shades of grey towards the bottom. Some carbonate occurs within the gypsum.

Limestone crops out extensively in the area but nowhere are contacts with the gypsum exposed. North of the river the limestone is black, nodular and interbedded with argillaceous limestone and is lithologically similar to the Harrogate Formation in the Stanford Range. South of the river the limestone is brecciated and tightly folded.

In 1937 Mountain Minerals Limited, then Summit Lime Works, shipped 315 tonnes of gypsum to Lethbridge for testing. There has been no production recorded from this site since that time.

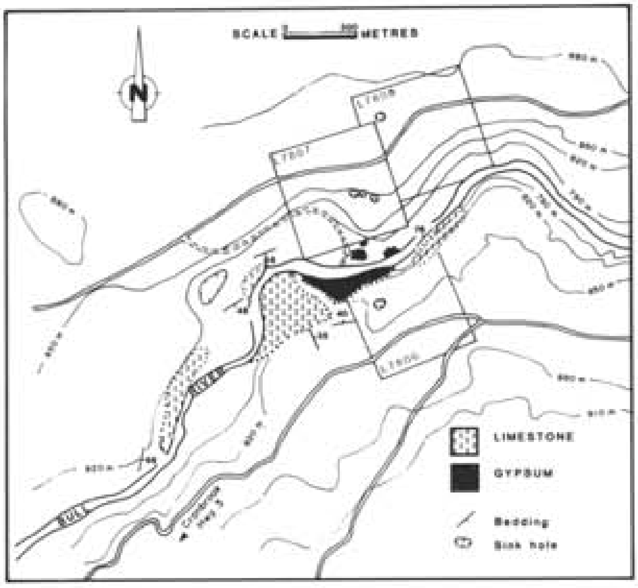

Figure 16. Bull River gypsum occurrences.

Plate 6. Gypsum exposure in the Joffre Creek area.

KANANASKIS LAKES AREA

JOFFRE CREEK - MINFILE 082JSW003

Latitude: 50°34′45″ Longitude: 115°15′30″ NTS: 82J/11

Gypsum was reported in the basal Devonian unit in the Joffre Creek area east of the Palliser River by Leech (1979) and Mott *et al.* (1986). The basal Devonian unit consists of brown to orange dolomite 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 (Plate 6). Gypsum is exposed along the bank of the creek at an elevation of 1830 metres (Figure 17). Two other gypsum occurrences are also reported from this area (Leech, 1979).

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 are exposed and therefore stratigraphic relationships could not be determined. The gypsum is probably equivalent to the Burnais Formation.

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. It possibly represents a period of emergence of the evaporite deposit. Above this horizon the gypsum reverts to its normal appearance. Initial results suggest a purity of gypsum ranging from 62 to 87 per cent (Table 5).

TABLE 5
CHEMICAL ANALYSES OF GYPSUM - JOFFRE CREEK

Sample No.	SiO_2 %	CaO %	Na_2O %	K_2O %	MgO %	H_2O %	SO_3 %	S %	Sr ppm
SB88-104A	4.01	28.52	0.04	0.30	6.89	17.80	40.44	11.9	285
SB88-104B	4.93	29.26	0.06	0.23	5.60	12.60	28.81	13.0	295
SB88-104C	3.74	30.32	0.050	.09	3.54	14.40	32.72	15.3	385
SB88-104D	1.90	29.48	0.05	0.16	3.84	16.80	38.19	15.0	370

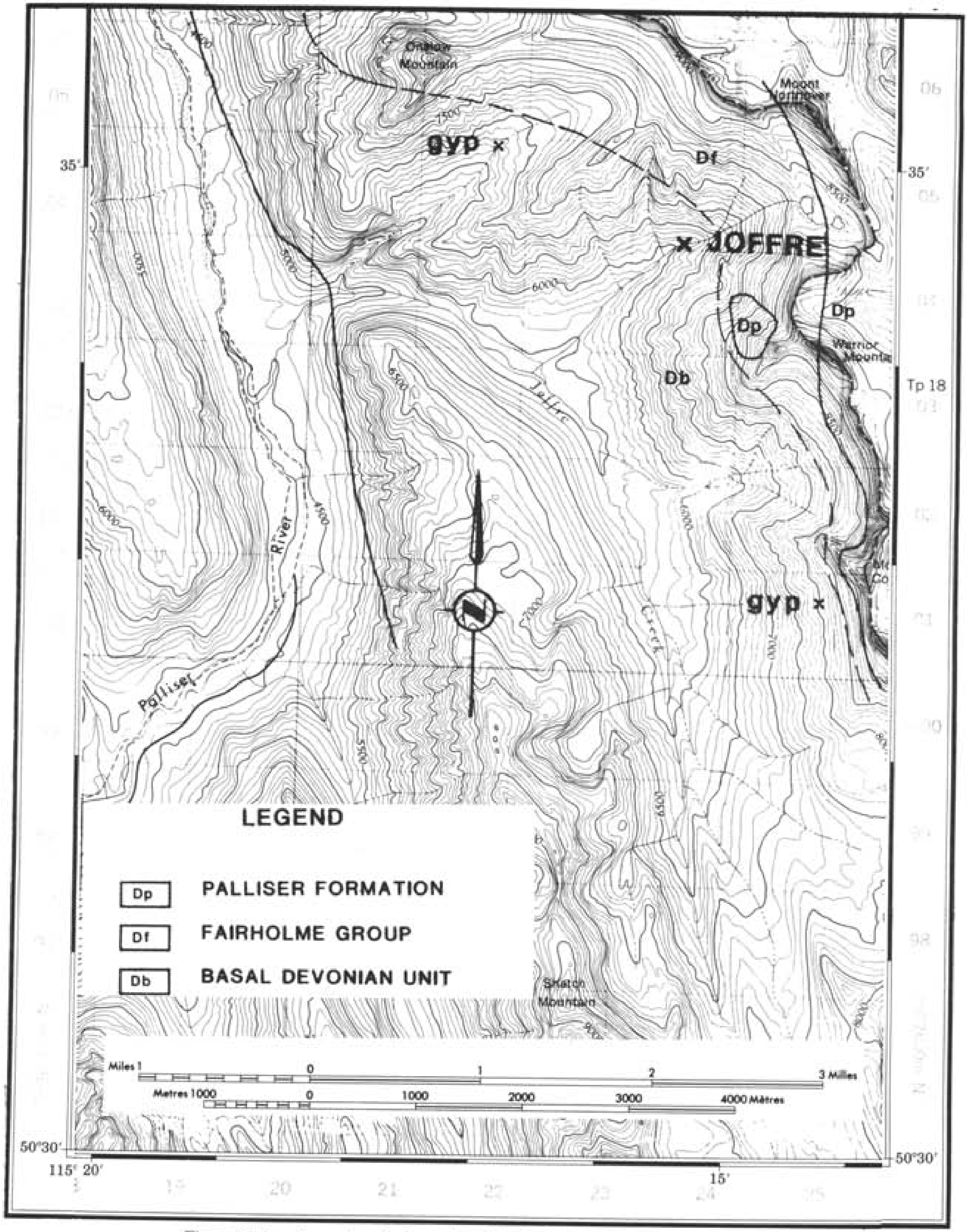

Figure 17. Location and geologic setting of the Joffre gypsum occurrence.

Plate 7. Uppermost gypsum bed from the Forgetmenot Creek locality.

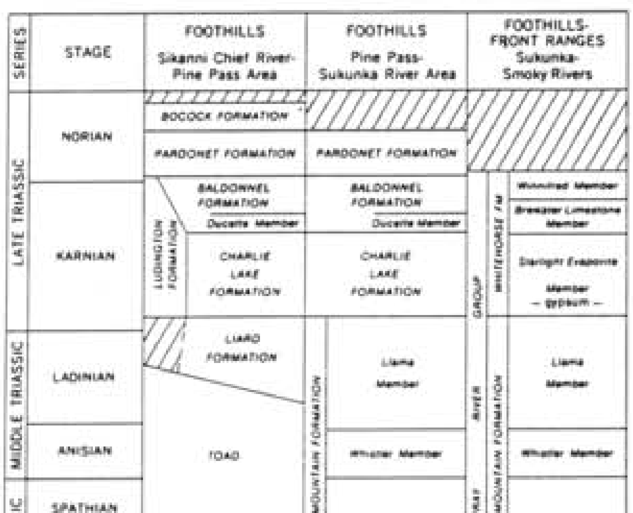

Figure 18. Nomenclature and correlation chart of Triassic stratigraphy.

Gypsum Deposits in Northeastern British Columbia

FORGETMENOT CREEK - MINFILE 083E 001

Latitude: 53°45′50″ Longitude: 119°53′20″ NTS: 83E/13

Gypsum of Triassic age occurs at a single locality straddling the Alberta boundary at the headwaters of Forgetmenot and Fetherstonhaugh creeks (Plate 7). This occurrence was first 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 (Figure 18) which is host to extensive anhydrite deposits further north. The presence of anhydrite is known from oil and gas drilling; it is not exposed at surface.

The Starlight evaporite member, 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 dolomites, limestones, siltstones and intraformational or solution breccias. In the Forgetmenot Creek area pale grey and yellowish brown to orange dolomite is intercalated with several gypsum beds (Figure 19). Also present are lenses of dolomitic and calcareous siltstone and pale grey lime-

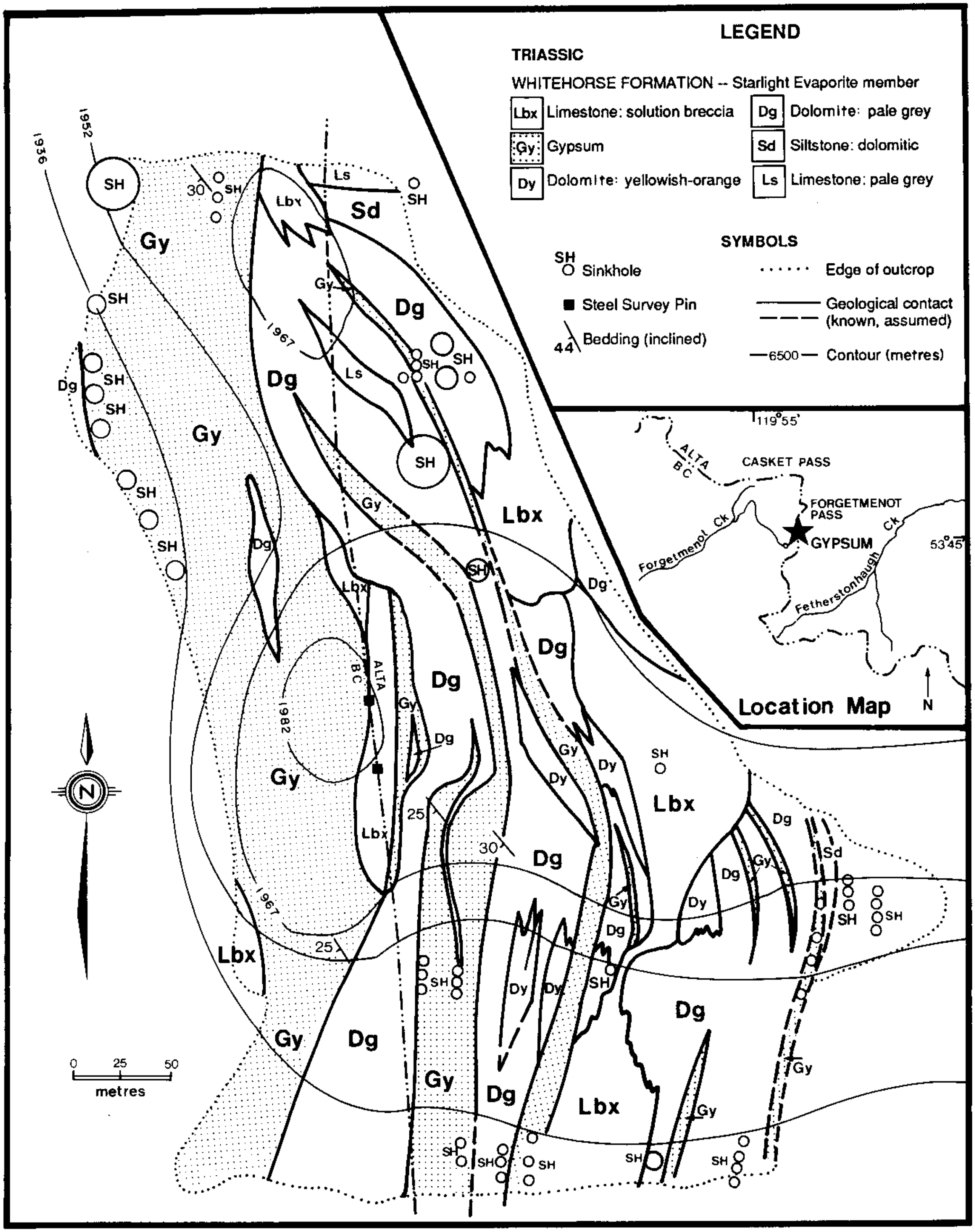

Figure 19. Geological setting of the gypsum deposit in the Forgetmenot Creek area.

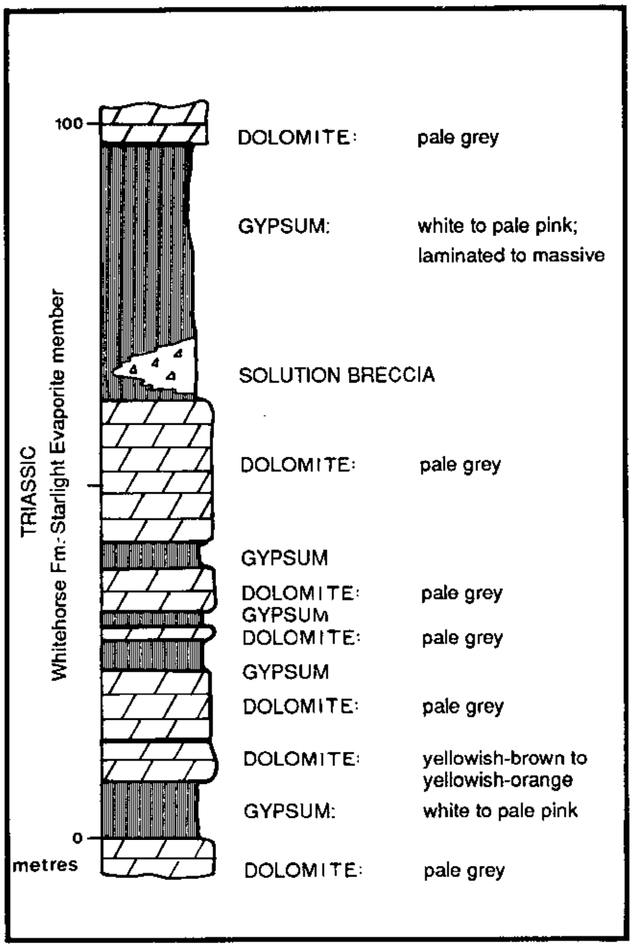

Figure 20. Stratigraphic section of upper portion of gypsum-bearing sequence, Forgetmenot Creek.

stone. 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 20) 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 stike northwest with dips of 25° to 30° southwest. Gypsum is exposed in outcrop for 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.

Drilling by Domtar Chemicals Ltd. (1968) indicated that the gypsum grade is more variable at depth than in surface exposures. Gypsum content in the subsurface varied between 75 and 80 per cent while surface sampling indicated a purity greater than 90 per cent gypsum (Table 6). Sampling of the uppermost gypsum bed by the author confirmed the high purity of the gypsum, varying from 84 to 98 per cent. 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.

TABLE 6
CHEMICAL ANALYSIS OF GYPSUM
FETHERSTONHAUGH AND FORGETMENOT CREEKS

Sample No.	SiO_2 %	R_2O_3* %	CaO %	MgO %	Na_2O %	K_2O %	SO_3 %	H_2O^+ %	Sr ppm
1	n.d.φ	0.27	32.64	0.58	n.d.	0.03	45.61	20.34	
2	0.05	0.18	32.79	1.77	0.02	n.d.	45.10	20.28	
3	n.d.	0.30	32.74	0.75	0.03	0.02	44.88	19.90	
4	n.d.	0.30	32.63	0.17	0.03	0.02	46.03	20.53	
5	n.d.	0.19	32.84	0.41	0.01	n.d.	45.49	20.51	
6	0.20	0.54	32.60	0.71	0.02	n.d.	44.60	20.07	
7	0.65	0.56	32.52	0.25	0.07	0.10	45.56	20.16	
8	n.d.	0.20	32.90	0.32	0.02	n.d.	45.81	20.46	
9	0.13	0.45	32.53	3.22	0.04	0.05	38.01	16.82	
SB88-103A	0.98		31.07	1.02	0.04	0.06	44.51	19.50	1300
SB88-103B	0.52		31.31	0.70	0.02	0.03	45.31	19.90	1200
SB88-103C	0.64		32.17	0.55	0.01	0.03	45.50	20.00	1600
SB88-103D	0.75		32.21	0.56	0.03	0.04	45.21	20.10	1100
SB88-103E	0.84		32.06	0.74	0.03	0.05	44.93	19.80	1200
SB88-103F	0.87		32.12	3.46	0.02	0.06	39.06	17.10	1300

Note: Samples No. 1-9 from Fetherstonehaugh Creek analyzed by H. Wagenbauer, Researcher Council of Alberta (modified from Govett, 1961). Samples SB88-103A to F are from Forgetmenot Creek (1988).
$*R_2O_3 = Al_2O_3, Fe_2O_3, TiO_2, P_2O_5$
$^+H_2O+$ determined at 200°
φn.d. - not detected
Samples 1, 2, 3 - from uppermost bed
Sample 4 - from next lower bed
Samples 5, 6, 7, 8 - from middle bed
Sample 9 - from next to lowest bed
Samples SB88-103A, SB88-103B, SB88-103C, SB88-103D, SB88-103E, SB88-103F - from uppermost gypsum bed
Samples SB88-103A, SB88-103B, SB88-103C, SB88-103D, SB88-103E - from northwestern end of outcrop
Sample SB88-103F - from central part of outcrop area

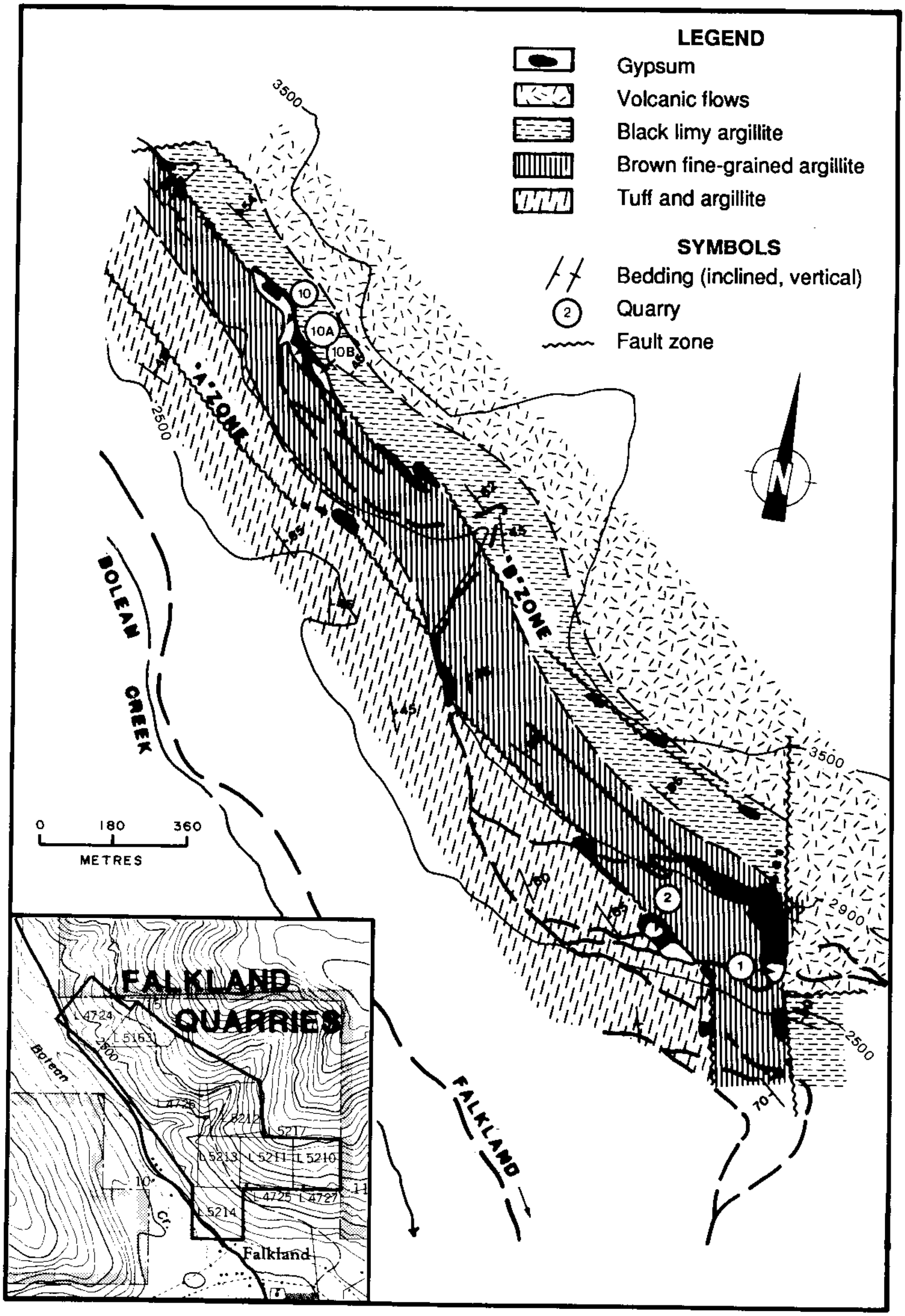

Figure 21. Geology of the Falkland gypsum deposits.

MISCELLANEOUS DEPOSITS AND OCCURRENCES

FALKLAND - MINFILE 082LNW001

Latitude: 50°31′00″ Longitude: 119°34′00″ NTS: 82L/12E

The Falkland gypsum deposits comprise a series of lenses along the northeast side of Bolean Creek valley north of Falkland (Figure 21). They were first staked in 1894 with production beginning in 1926. Production was continuous through to 1956 during which time 1 125 000 tonnes were produced. During the period 1976-1980 gypsum and anhydrite were mined intermittently from seven quarries and trucked to the Canada Lafarge Cement plant 18 kilometres east of Kamloops. There is still intermittent production from these quarries although gypsum reserves are virtually mined out. Anhydrite is still present in the deeper part of the quarries.

The deposits have been described by various authors (Baird, 1964; Cummings, 1940; Jones, 1959). Gypsum occurs along two parallel shear zones that are slightly discordant with a northwesterly striking and northeast-dipping sequence of interbedded volcanic and argillaceous rocks. These rocks belong to the Cache Creek Group of Carboniferous to Permian age.

Volcanic rocks consist of a series of flows that are dark green to grey to black, medium grained, slightly schistose and composed primarily of amphibole. Beneath the flows are thin-bedded, fine-grained, limy argillites. Alteration of the argillite close to the gypsum is manifest by colour changes from black to reddish brown. Pyrite and quartz stringers and veinlets are common within the alteration zone. Underlying this unit are thin-bedded, light green to greyish brown, brown-weathering argillites. The oldest rocks consist of bedded tuffs and a lower sequence of interbedded black argillite and tuff.

Gypsum is conformable with the enclosing rocks and occurs in a series of irregular, discontinuous lenses along a strike length of 2.4 kilometres (Figure 21). The irregular shape of these lenses, both in plan and section, is partly attributed to displacement along the shear zones. The gypsum varies in colour from pure white through various shades of grey, grey-and-white banded and brown-and-white banded to reddish brown. Locally, the siliceous and argillaceous component reaches significant proportions especially in certain banded and brecciated material. Variations are sharp but generally unpredictable. Inclusions of dark red-brown to orange-brown, severely fractured argillaceous rocks, ranging in size from masses measuring 10 by 15 metres down to dust size, are present within the gypsum. These inclusions consist of fine-grained aggregates of quartz and albite, pyrite cubes, tiny tourmaline prisms and calcite in masses and small rhombs. At depths ranging between 20 and 35 metres gypsum grades abruptly into anhydrite. Mineable gypsum was generally confined to depths less than 25 metres.

In thin section the gypsum is seen to consist of subhedral crystals, fibrous masses and aggregates of gypsum with various impurities. Replacement of anhydrite by gypsum has also been observed (McCammon, 1952). The gypsum remaining appears to be of high purity (Table 7).

McCammon (1952) believed that the gypsum formed by the hydrothermal replacement of argillites and tuffs along shear zones. In thin section he observed that gypsum was the last mineral to form and that it replaces all other minerals. The mineral assemblage observed was at least partially a hydrothermal suite. Cummings (1940) interpreted the gypsum to have formed by the replacement of limestone by sulphate solutions. This replacement was believed to have been related to volcanic activity. Baird (1964) concluded that the gypsum-anhydrite bodies were deposited pre-Cache Creek as part of a sedimentary sequence and were later squeezed into their present position by plastic flow. The author favours a volcanogenic origin for these deposits although evidence, other than an association with volcanic rocks, is lacking.

TABLE 7
CHEMICAL ANALYSES OF GYPSUM - FALKLAND DEPOSITS

Lab No.	SiO_2 %	CaO %	Na_2O %	K_2O %	MgO %	H_2O %	SO_3 %	S %	Sr ppm
37651	2.58	30.89	0.30	0.02	0.22	18.60	42.51	17.3	1200
37652*	0.38	38.85	0.05	0.01	0.15	0.32	59.02	23.6	1300
37653	0.47	31.15	0.02	0.01	0.14	20.40	46.69	18.6	1000
38427	0.57	40.08	0.14	0.04	0.07			23.4	1400

**Denotes anhydrite.*

Plate 8. Exposure of gypsum in the O'Connor River area.

Figure 22. Location of the O'Connor River gypsum deposit.

O'CONNOR RIVER GYPSUM - MINFILE 114P 005

Latitude: 59°39'00" Longitude: 136°34'00" NTS: 114P/10E

The O'Connor River gypsum deposit (Plate 8) is located in northwestern British Columbia, 96 kilometres northwest of Haines, Alaska. Gypsum occurs in rugged terrain above tree line on both sides of the river near the headwaters of its north fork. The nearest major transportation route is the Haines Road 12 kilometres east of the deposit. A haul distance of 104 kilometres will be required to transport the gypsum to tidewater at Haines.

This deposit was discovered in 1958 by J.J. McDougall while working for Ventures Ltd. A little work was done on the property in 1959 and again in 1964 when Falconbridge Limited did some trenching. Some drilling was done in 1965. In 1984 a bulk sample was taken by Haines Gypsum Inc. and further drilling was completed in 1986 by Queenstake Resources Ltd.

Gypsum occurs in complexly deformed Paleozoic sedimentary rocks and Triassic basic flows and related volcaniclastic rocks within the Alexander Terrane of the Insular tectonic belt (Figure 22). The following description is summarized from White (1986), McDougall (1959) and Kootenay Geo-Services (1986).

Hostrocks to the gypsum are limestone, limestone breccia and black calcareous argillite. Sill-like dioritic intrusions are also present in the area. Sediments adjacent to these sills have been silicified and metamorphosed. Better quality gypsum is described as snow white with no visible impurities and occurring in massive continuous beds. Traces of anhydrite may be present. Brown or buff-coloured gypsum or gypsiferous carbonate is present near the edges of the pure white material (McDougall, 1959). A sample of pure-white gypsum taken by G.V. White indicates a purity in excess of 90 per cent gypsum (Table 8).

TABLE 8
CHEMICAL ANALYSIS OF GYPSUM - O'CONNOR RIVER

Lab No.	SiO_2 %	CaO %	Na_2O %	K_2O %	MgO %	H_2O %	SO_3 %	S %	Sr ppm
37650	0.47	31.06	0.01	0.02	0.62	19.50	45.77	17.9	1300

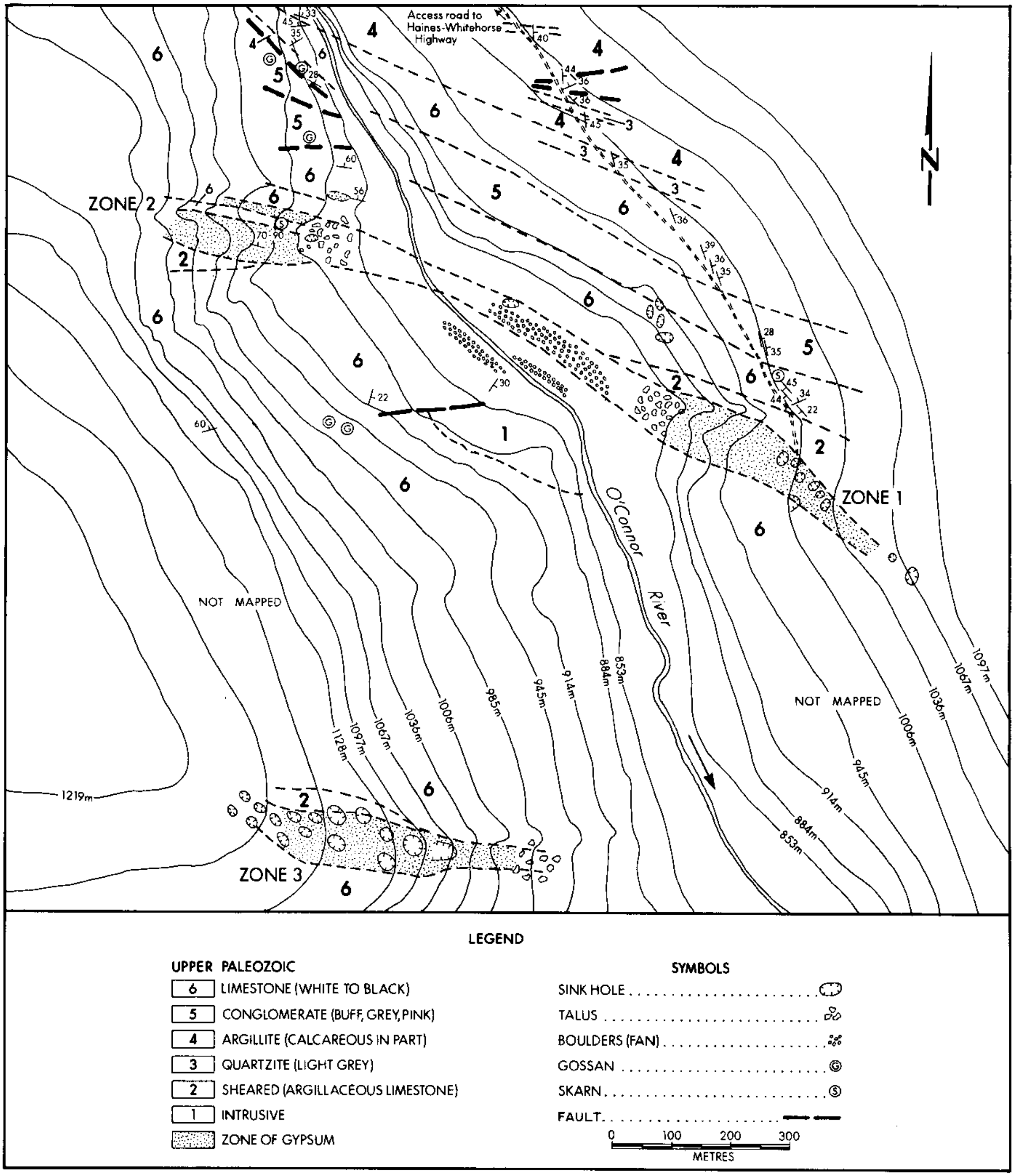

Figure 23. The O'Connor River gypsum showing (from White, 1986).

Tuffaceous layers consisting of biotite, chlorite, amphibole and sericite are commonly found concordant with bedding within the gypsum. Other impurities include strontianite, siderite, ankerite, limonite and scapolite. There are remnants of anhydrite the size and shape of footballs within the gypsum at surface. Hydration is estimated to have taken place to a depth of 40 metres from the paleosurface. The absence of enterolithic folding implies a recent origin with unconfined swelling.

Gypsum is exposed in three zones (Figure 23) of which two may in fact be the same, with the central portion eroded away by the O'Connor River. Zone 1, described as irregular in shape, is exposed along strike for 400 metres over a vertical height (Plate 8) of 122 metres (White, 1986). It strikes northwest with steep dips to the northeast. The gypsum is generally pure containing only minor anhydrite. Contacts with the surrounding rocks are sharp. Locally it appears that the gypsum crosscuts the sedimentary rocks. Sinkholes, 10 to 20 metres in diameter and 10 to 15 metres deep, are present at the southeast end of zone; gypsum is exposed in the walls of some of them.

Zone 2 or West zone is believed to be an extension of Zone 1. It is exposed along strike for 220 metres across widths of 60 to 100 metres and a vertical component of 200 metres. The gypsum is white, massive and finely crystalline. There is a 30-metre-wide argillaceous limestone exposed within the gypsum at the southeast end of the zone. Contacts are sharp although there are a few inclusions of argillaceous limestone, up to 15 centimetres in size, in the gypsum.

Zone 3, located 1200 metres south of Zone 2, strikes east and dips to the north. It is exposed along strike for 550 metres across widths of 50 to 110 metres and a height of 120 metres. The gypsum is white and is in sharp contact with a limestone unit. Sinkholes are present along the entire length of the zone.

Reserves for Zone 1 are estimated to be 2.5 million tonnes grading 79 per cent gypsum (Kootenay Geo-Services, 1986). The SO_3 content averages 40 per cent and the oxide and insoluble content is fairly high making the gypsum suitable for wallboard manufacture but not for the cement industry. There is a potential for 10 million tonnes in the three zones combined.

Other areas containing sinkholes occur between the O'Connor River gypsum deposit and the Haines Road and east of the Haines Road (J.J. McDougall, oral communication, 1989). Both localities contain no outcrop.

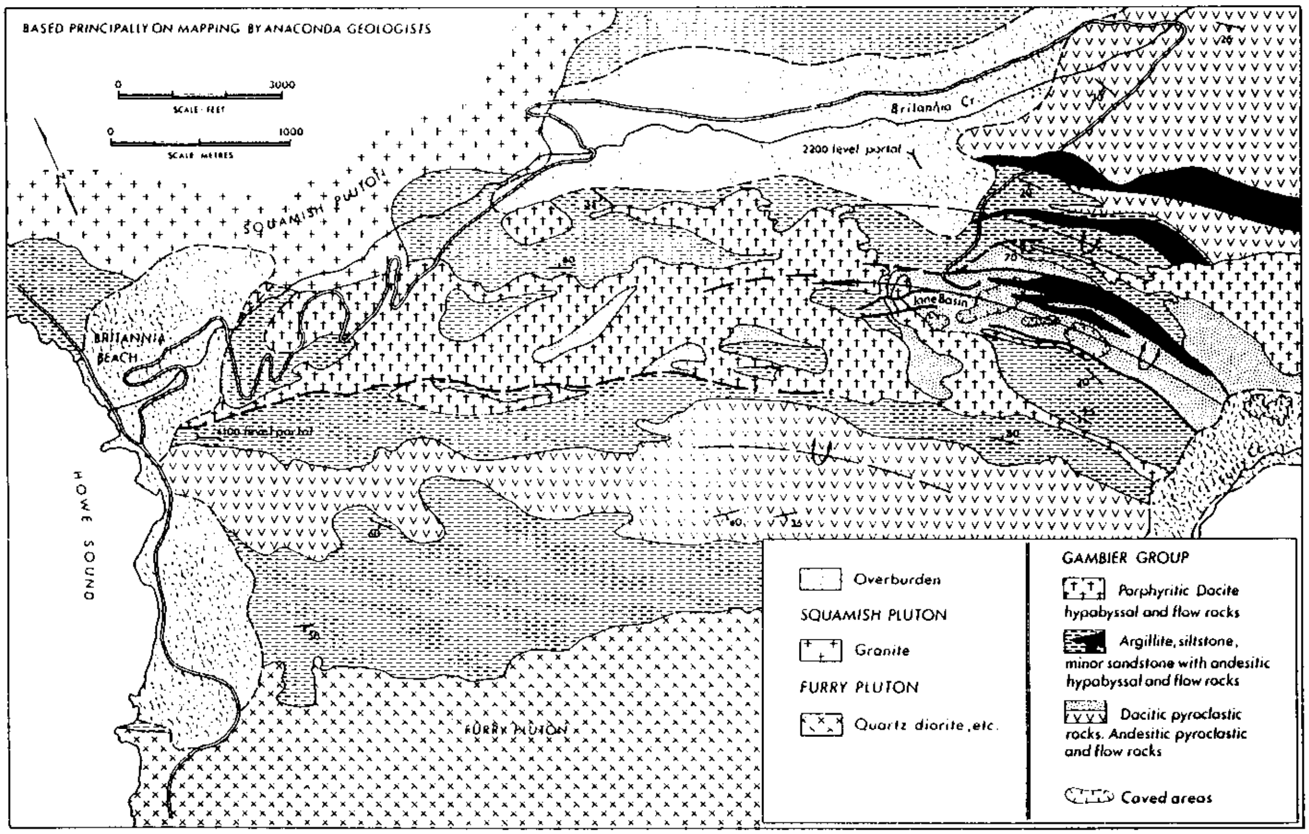

Figure 24. Generalized geology of Britannia mine area, Anaconda Canada Limited (from Sutherland-Brown 1974).

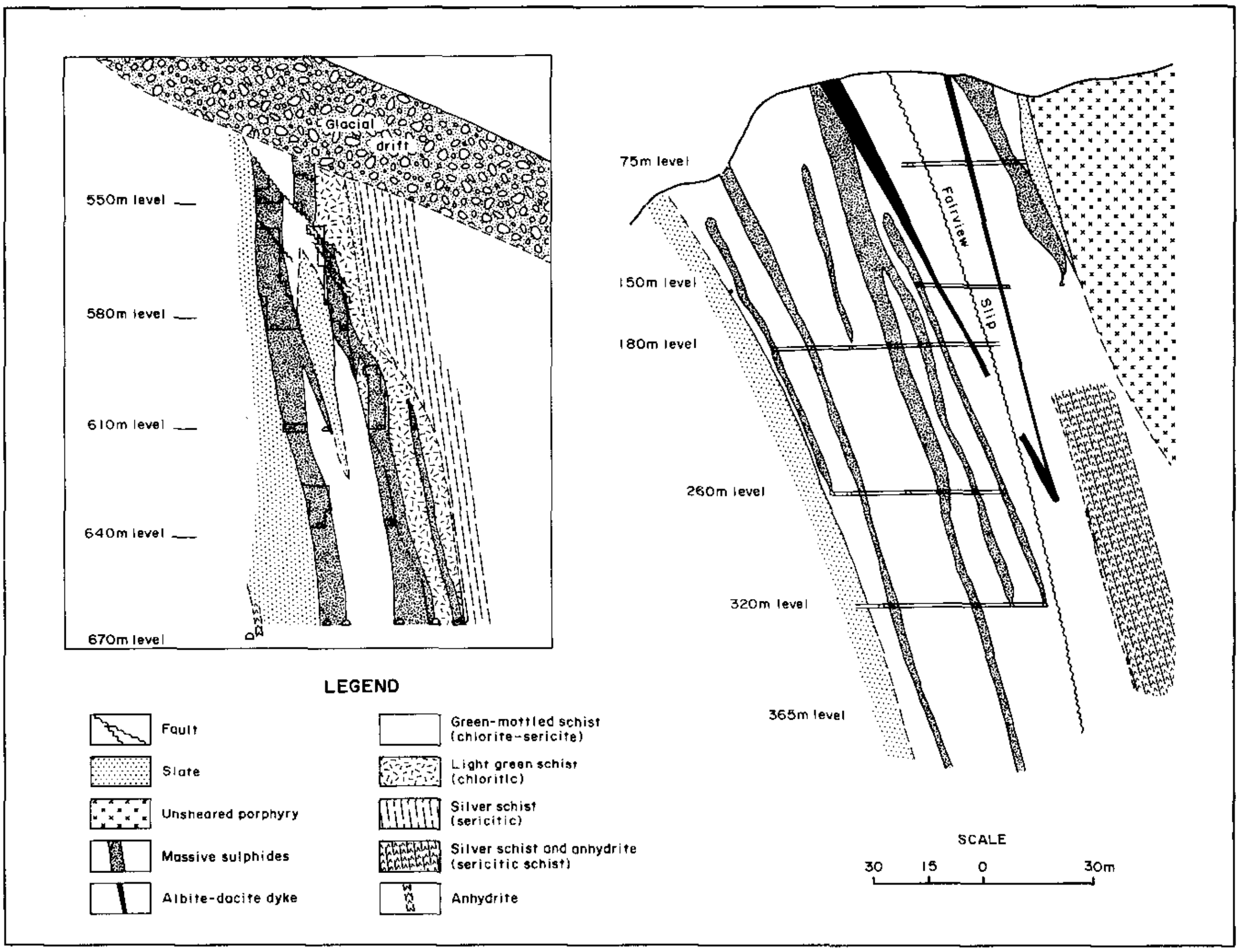

Figure 25. Transverse section of Victoria and Fairview Mines. Longitudinal section, Britannia mine, Anaconda Canada Limited.

BRITANNIA MINE - MINFILE 092GNW003

Latitude: 49°37′00″ Longitude: 123°12′00″ NTS: 92G/11E

The Britannia mine is a massive sulphide deposit consisting of numerous orebodies that occur in a pendant of volcanic and sedimentary rocks within the Coast Plutonic Complex (Figure 24). Comprising the volcanic sequence is a thick pile of andesitic to dacitic pyroclastic rocks with some flows. In detail the geology is complex because of numerous facies changes and the lenticular nature of some of the units.

Mineralized bodies (Figure 25), consisting of massive and stringer deposits, have been mined over a length of 4 kilometres. They are most commonly found between the top of crystal-rich dacitic pyroclastic rocks and andesitic rocks. Within the orebodies there is a zoning of both sulphide and hydrothermal alteration minerals. They generally consist of a chalcopyrite core with a pyrite periphery. Sphalerite is concentrated in the upper parts of some of the orebodies. Silicate minerals grade from an inner quartz-sericite zone to an outer chlorite-epidote zone. Gypsum and anhydrite, commonly associated with a pyritic green siltstone, do not appear to have a systematic distribution. Anhydrite is widespread and abundant in the hangingwall of the ore zones. Locally the anhydrite has been converted to gypsum, especially near permeable zones where the gypsum occurs as narrow replacement veinlets. Within 60 to 90 metres of surface the conversion of anhydrite to gypsum is complete.

James (1929) reports the presence of native sulphur in the mine. While the native sulphur may have gypsum or anhydrite associated with it none is present in the large gypsum masses.

MORNING GROUP - MINFILE 092HSW035

Latitude: 49°28′18″ Longitude: 121°14′30″ NTS: 92H/6W

Gypsum is present on the hangingwall of an andesitic dike on the east side of the Coquihalla River above the mouth of Dewdney Creek (Figure 26). Two dikes, 4 to 5 metres wide and 15 metres apart, intrude slate of the Cache Creek Group. The gypsum is associated with the lower of the two dikes. This locality was initially explored for gold as quartz veins a few centimetres to a metre or

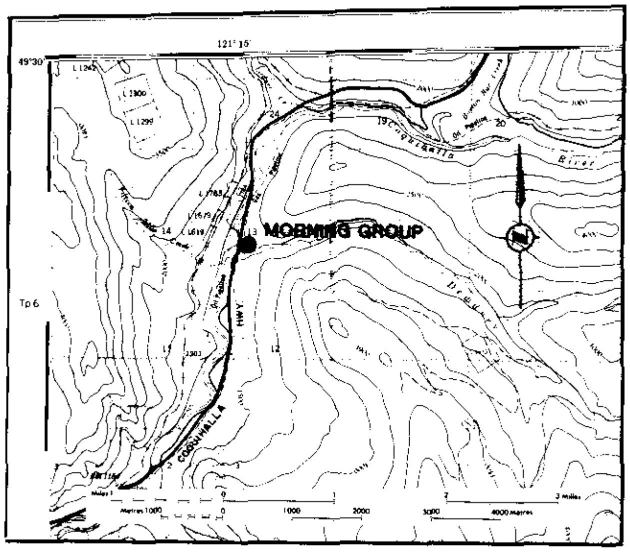

Figure 26. Location map for the Morning Group.

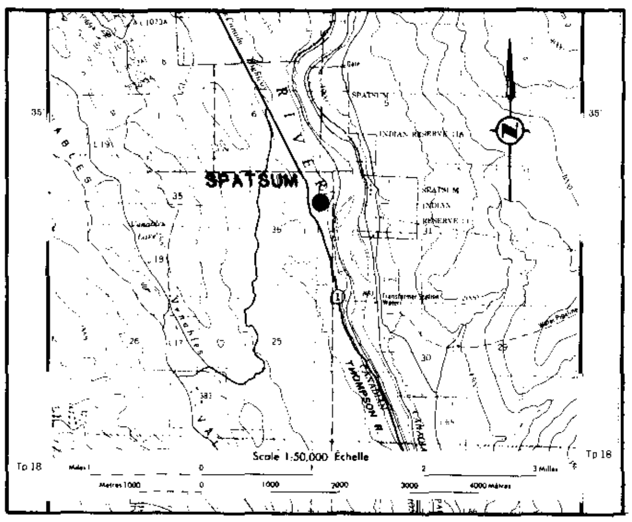

Figure 27. Location map for the Spatsum gypsum occurrence.

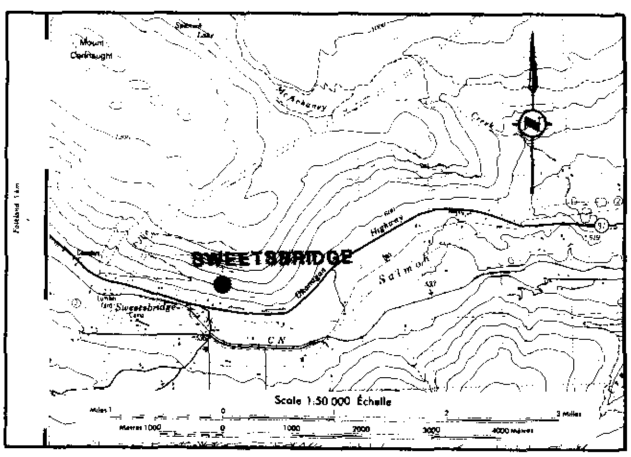

Figure 28. Location map for the Sweetsbridge gypsum occurrence.

more across and containing pyrite and arsenopyrite occur in the area.

SPATSUM - MINFILE 092INW054

Latitude: 50°34'20" Longitude: 121°18'18" NTS: 92I/11

Two outcrops containing gypsum, approximately 600 metres apart, are reported from a locality 180 metres above the Thompson River opposite the Spatsum Indian Reserve (Figure 27). The property was first staked in 1896. In 1913 an 8-metre adit was driven on the showing but there has been no production.

Hostrocks consist of argillaceous schists, greywackes, hydromica schists and minor limestone of the Cache Creek Group of Permo Carboniferous age. Also present are andesite, dacite and rhyolite pyroclastics that are locally intruded by diorite, dacite and rhyolite plugs. Minor gypsum is also associated with these volcanic rocks.

Gypsum is best exposed in the southerly occurrence where it crops out over a strike of 60 metres and a vertical height of 90 metres. The adit driven on this showing intersected a band of nearly pure white, massive gypsum 1.5 metres wide. The gypsum at this locality closely resembles the deposits in the Falkland area. The gypsum strikes north-northeast with a moderate dip to the northwest. The hangingwall consists of hydromica schist and some limestone while mica schist, limestone and shale form the footwall. An analysis from this locality is as follows:

Insoluble	0.04%
CaO	32.70%
SO_3	46.72%
H_2O	20.60%
Total:	100.06%

Casselman (1980) suggests that these gypsum occurrences are volcanogenic and that altered and weakly mineralized rhyolites with associated gypsum represent the gypsum-rich facies of Kuroko-type deposits.

SWEETSBRIDGE - MINFILE 082LSW074

Latitude: 50°27'12" Longitude: 119°28'00" NTS: 82L/6W

An occurrence of white, brown and grey gypsum is reported from a locality 300 metres north of Highway 97 at the abandoned school near Sweetsbridge station, 6.4 kilometres southeast of Falkland (Figure 28). Gypsum is exposed along a hillside for 180 metres across a width of 12 metres. It is very similar to the Falkland deposits but there has been no production from this locality.

ACCESSORY GYPSUM IN PORPHYRY COPPER AND RELATED DEPOSITS

Anhydrite may constitute as much as 20 per cent of porphyry copper deposits. It most commonly occurs as an alteration mineral developed in the late stages of the evolution of a deposit but is rarely preserved because of hydration and subsequent leaching.

VALLEY COPPER - MINFILE 092ISW012

Latitude: 50°29'00" Longitude: 121°03'00" NTS: 92I/6E

The Valley Copper deposit in the Highland Valley is situated 40 kilometres southeast of Ashcroft (Figure 34). It occurs entirely within quartz monzonite of the Bethsaida phase of the Guichon Creek batholith. Original reserves were calculated to be in excess of 850 million tons grading 0.48 per cent copper.

Variations in grade are related to the intensity of alteration and veining. Anhydrite-gypsum veins are described by McMillan (1970) as follows:

"At Valley Copper gypsum is interpreted to be secondary and post ore. It is commonly fibrous and white to orange but locally it forms large platy crystals or may be massive. Anhydrite, which is also present, provide indirect evidence for the secondary nature of the gypsum. It is apparently the same age as and associated with sericitic and potassic alteration. Quartz-gypsum veins and quartz-potash feldspar veins in which gypsum fills interstices provide more direct evidence for its secondary nature. Gypsum is believed to have formed at the expense of anhydrite which was deposited from the ore-forming fluids.

Gypsum veins are common in the lower portion of the orebody below what is termed the gypsum-line. The position of this line was probably controlled by the composition of the ore-forming fluids and pressure-temperature conditions. This line may represent the level at which the ore-forming fluid was depleted in $CaSO_4$. Another possible explanation is that the fluids were moving in a convective cycle. Under these conditions anhydrite in the upper part of the deposit was hydrated and was reconstituted as gypsum veins."

IRON MASK - MINFILE 092INE010

Latitude: 50°39'24" Longitude: 120°26'05" NTS: 92I/9W

The Iron Mask mine, a former copper producer, is located 11 kilometres west of Kamloops city centre (Figure 29). Production ceased in 1928.

The hostrock is diorite of the Sugarloaf Unit of the Iron Mask batholith. Gypsum is reported from a number of localities on the property. Talc and gypsum occur along fracture planes near the bottom of the Iron Mask shaft and along slips in diorite in the Larson workings. In the Norma, Iron Mask and western Erin localities veins of banded gypsum are reported to contain streaks and knots of chalcopyrite. These veins follow shears along lengths up to 30 metres and widths up to a metre or more. The Erin orebody was in a coarse breccia, consisting of altered diorite that graded into banded gypsum at both ends.

LEN - MINFILE: 093E 098

Latitude: 53°41'30" Longitude: 127°09'00" NTS: 93E/11E

The Len property is located on Huckleberry Mountain east of Tahtsa Lake 130 kilometres by road from Houston in central British Columbia (Figure 30). A quartz diorite porphyry stock measuring 300 by 600 metres underlies the major portion of the property. The stock has intruded tuff and tuffaceous sedimentary rocks of the Middle Jurassic Hazelton Group. Hornblende feldspar porphyry dikes cut the stock and adjacent rocks. Quartz veining is also present in and around the stock. Gypsum veins and disseminated anhydrite are also present. These have been observed in drill core to depths of 180 metres. Copper and molybdenum mineralization is present as disseminations, as fracture-fillings and in quartz veins.

ALICE (LIME CREEK) - MINFILE 103P 120

Latitude: 55°23'30" Longitude: 129°25'30" NTS: 103P/6W

The Lime Creek property, a former producer, is located on the southeast fork of Lime Creek approximately 8 kilometres south of Alice Arm (Figure 31). Molybdenum mineralization is associated with a small elliptical stock of quartz monzonite to quartz diorite composition. The stock exhibits varying degrees of alteration and is cut by later dikes. A ring structure, elliptical in outline and elongate in an east-west direction contains the zone of molybdenum mineralization in a closely spaced quartz-vein stockwork. Later quartz veins that cut the molybdenum-bearing quartz veins are barren except for minor amounts of pyrite, galena, sphalerite and scheelite. Minor amounts of chalcopyrite, tetrahedrite, pyrrhotite and gypsum are also present.

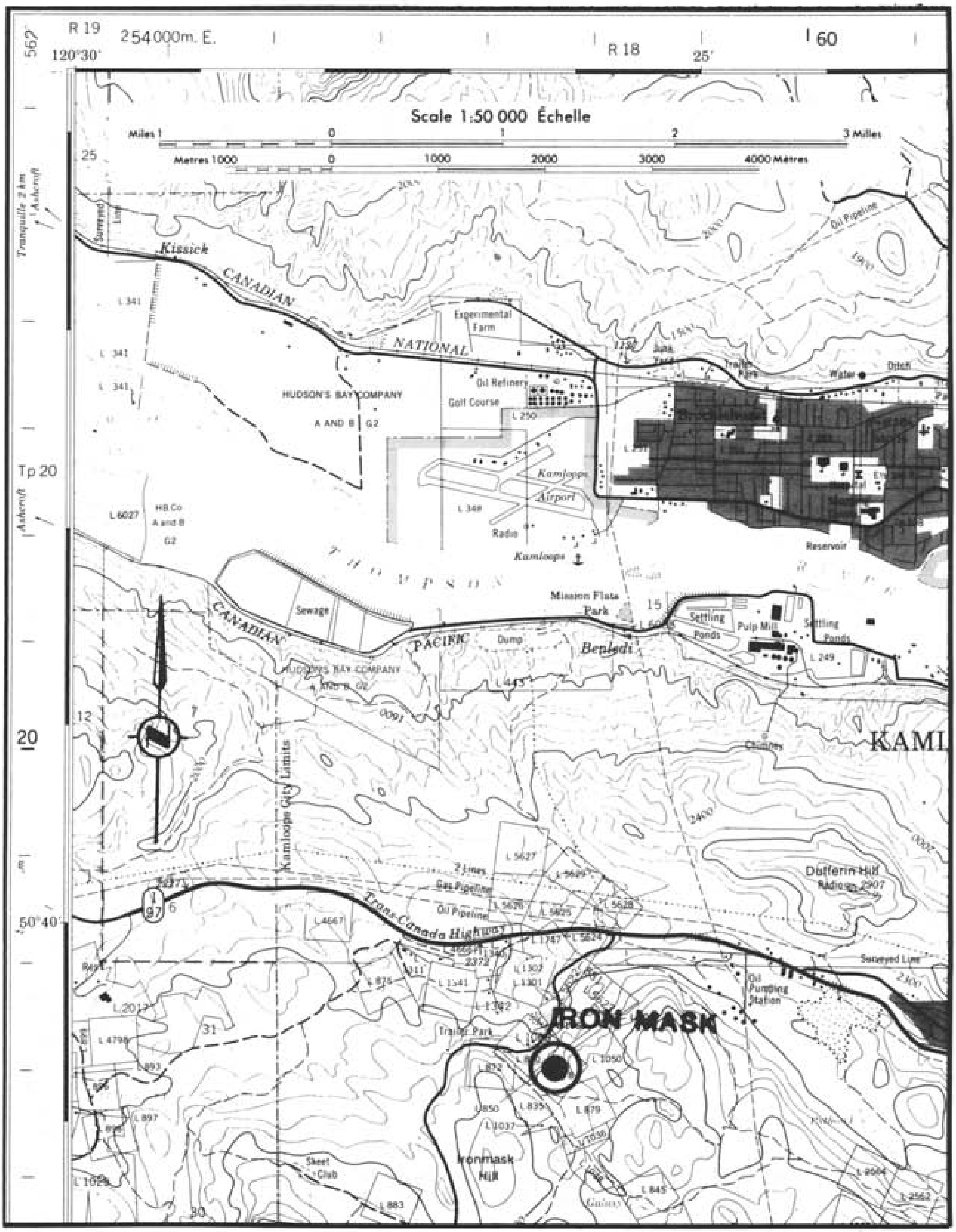

Figure 29. Location map for Iron Mask property.

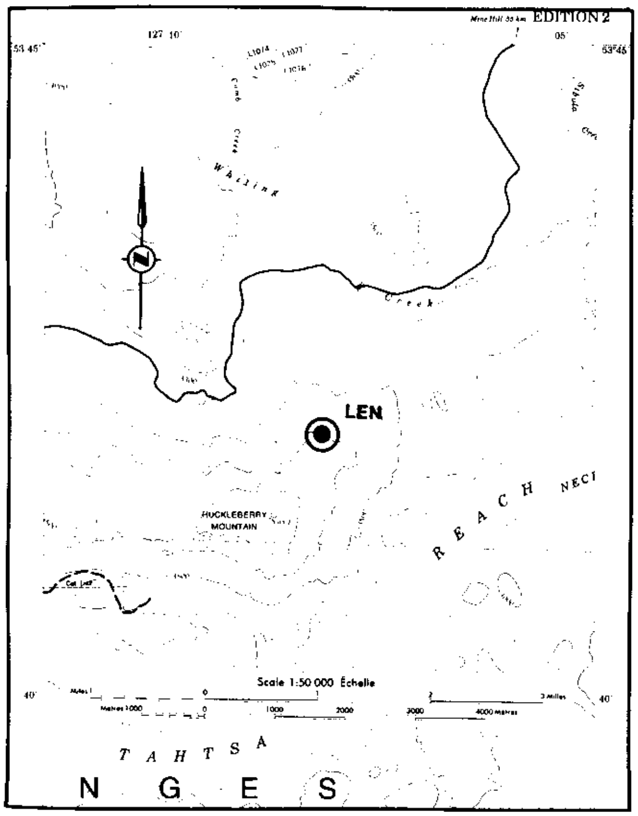

Figure 30. Location map for the Len property.

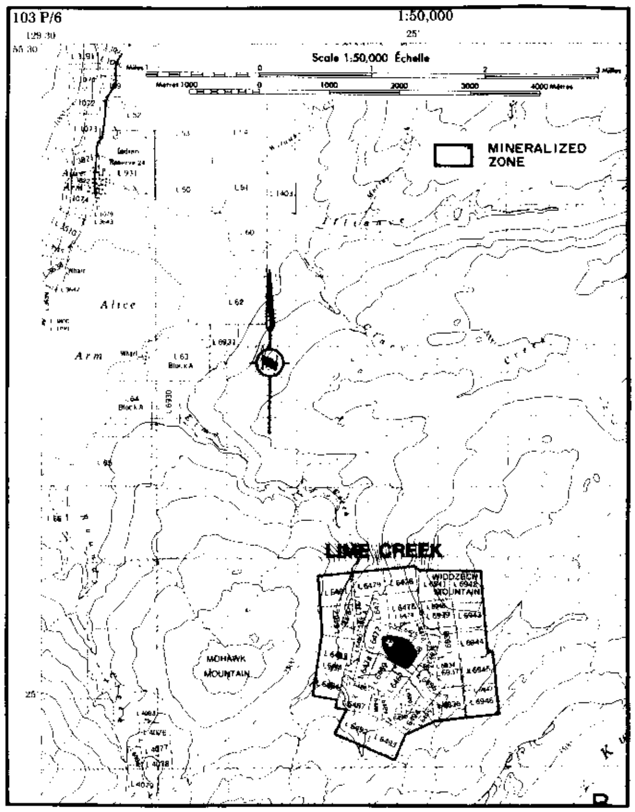

Figure 31. Location map for the B.C. Molybdenum mine, Lime Creek.

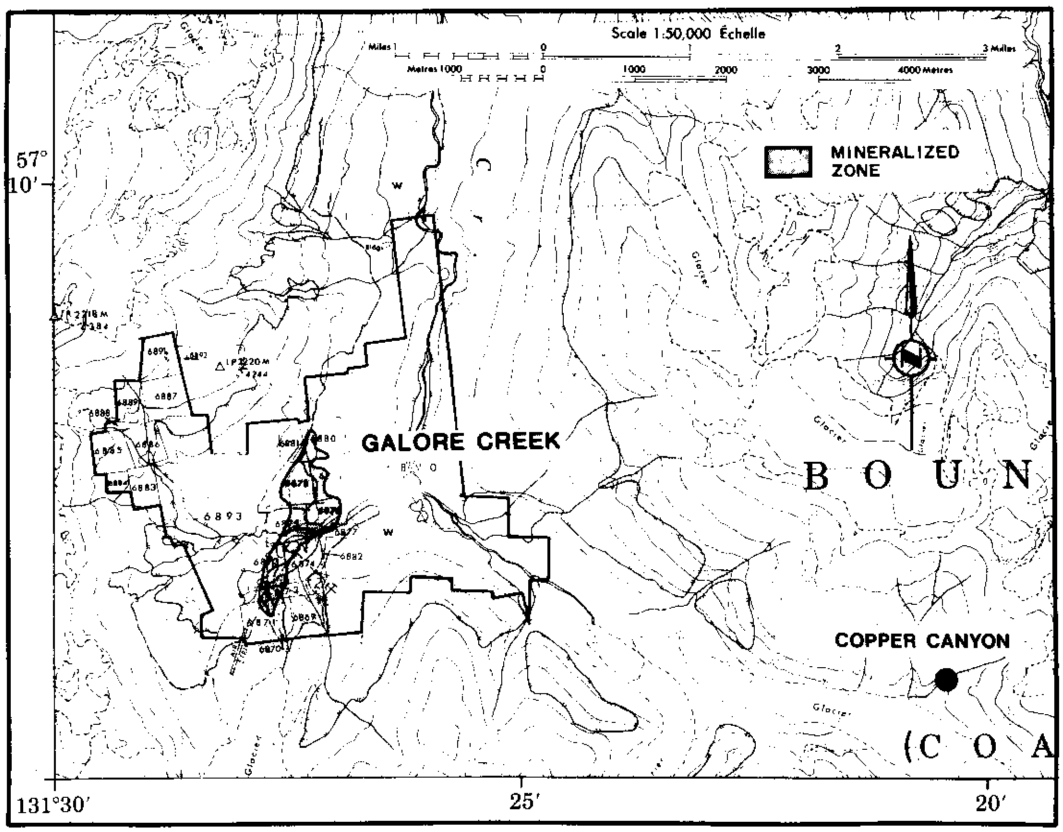

Figure 32. Geology of the Galore Creek property.

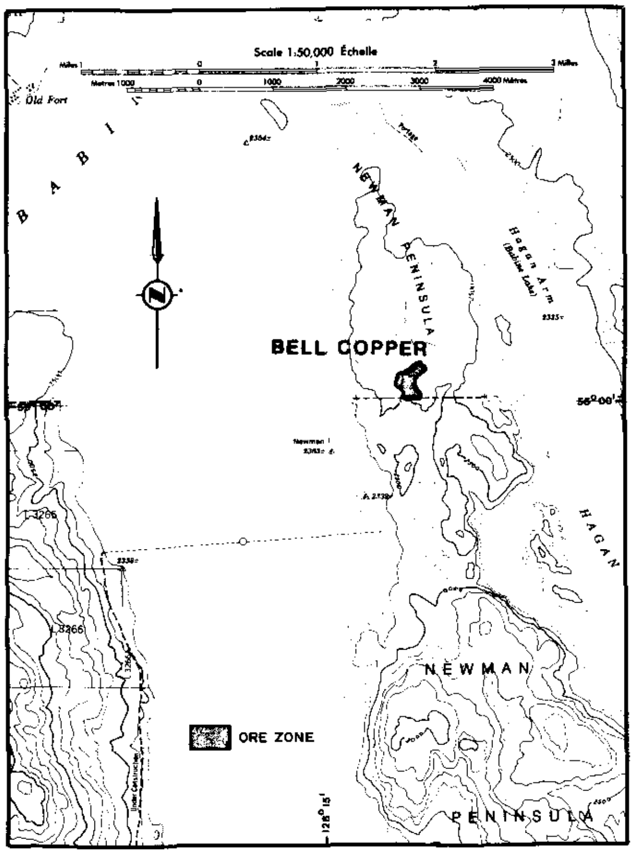

Figure 33. Geology and cross-section of Central Newman Peninsula (Bell Copper Deposit).

GALORE CREEK - MINFILE 104G 090

Latitude: 57°08′00″ Longitude: 131°28′00″ NTS: 104G/3W

This property is located at the headwaters of Galore Creek (Figure 32) approximately 32 kilometres southeast of the confluence of the Scud and Stikine rivers. Claims were first staked in 1956 and the property has been the subject of much exploration over the years.

Most of the copper mineralization is associated with a syenitic complex that is comprised of intrusive syenite porphyry, altered volcanic breccias, tuffs, minor sediments, cataclastic breccias, sulphide zones and numerous dikes. The syenite body and metavolcanic rocks have been pervasively altered. Potash feldspar, epidote, biotite, calcite, chlorite and carbonate, typical alteration products of porphyry copper mineralization are all present. Anhydrite and gypsum are common as veins throughout the area. Colour varies from white, pink to orange.

On the Copper Canyon property, located to the east of the Galore Creek deposit, secondary gypsum is also reported but is not abundant.

BELL COPPER - MINFILE 093M 001

Latitude: 54°59′00″ Longitude: 125°14′00″ NTS: 93M/1E

The Bell Copper deposit, which is located on the Newman Peninsula in Babine Lake (Figure 33) was staked in 1962 and brought to production in 1972. The hostrocks are volcanic and sedimentary strata of Triassic to late Cretaceous and early Tertiary age which are intruded by Eocene intrusions of the Babine igneous suite. The orebody is crescent-shaped with 60 per cent occurring in a biotite-hornblende-plagioclase porphyry plug.

Veinlets of gypsum are present in the upper part of the orebody. Anhydrite is a significant component in the biotite-chalcopyrite zone but is not present in other alteration facies. Monomineralllic veinlets of anhydrite are rare (Carson *et al.*, 1976).

A supergene chalcocite zone caps the deposit and extends to depths of 50 to 70 metres. Some gypsum together with copper-iron sulphate minerals and iron oxides are also present.

OTHER SOURCES OF GYPSUM

PHOSPHOGYPSUM

Phosphogypsum is produced as a byproduct in the manufacture of fertilizers during the acidulation of phosphate rock. For every tonne of phosphoric acid produced five tonnes of phosphogypsum are made. Its physical and chemical characteristics are such that further treatment is necessary before the gypsum can be used. This is a costly procedure and therefore phosphogypsum is only of commercial value if the processing costs are offset by the cost of transportation from a source of natural gypsum. This is rarely the case; there is limited use of this product in Japan both in wallboard and portland cement. In the United States it is mainly used as a soil conditioner. Phosphogypsum has not been used in Canada, primarily because it contains traces of radioactive material. In British Columbia there is a stockpile at Kimberley as a result of the fertilizer operations that have recently shut-down.

FLUE GAS GYPSUM

Byproduct gypsum can be produced by the desulphurization of flue gases in smelters, coal-fired power stations and similar plants. The product is referred to as flue-gas gypsum, scrubber gypsum or desulphogypsum.

Other sources include a variety of chemical processes such as the manufacturing of phosphoric, hydrofluoric or acetic acids and titanium dioxide from ilmenite. The material formed is a wet filter-cake or sludge that settles out in tanks or ponds after the desulphurization process. This product has both higher impurity and moisture levels than crude gypsum and therefore requires further beneficiation. Only a small amount of this material is reclaimed and used for agricultural or wallboard purposes. Byproduct gypsum is not economical at the present time because of the high cost required to make it suitable for wallboard or plaster. Only in Japan is it used in any appreciable quantity. Japan has a well-established industry and a shortage of gypsum. Costs to import crude gypsum are more than those required to recover byproduct gypsum. In Canada the potential use of this material appears to be limited as long as costs remain the same (King, Murphy and Lavalin Consultants, 1987).

SUMMARY

RESOURCE POTENTIAL

The best potential for gypsum in British Columbia is in the Stanford Range where extensive gypsum deposits can be traced from Stoddart Creek to the north end of the Top of the World Park (Figure 4, in pocket). Henderson (1954) originally estimated the resource potential of the Stanford Range at 450 million tonnes. This calculation did not include the deposits in the Lussier River and Coyote Creek areas. The resource potential for the Stanford Range is now estimated to be 210 million tonnes. It is now known that much of the area previously thought to be underlain by gypsum of the Burnais Formation is underlain by carbonate strata of the Cedared Formation or possibly by anhydrite. Elsewhere, the depth of overburden is sufficient to make any underlying gypsum subeconomic. Also, the presence of impurities may make some of the gypsum unsuitable for industrial use.

The best undeveloped potential occurs west of the Kootenay River where there may be a potential for 50 million tonnes. In the Nine Mile Creek area there is a potential for an additional 25 to 30 million tonnes. Within these areas there may be some potential for limited production of white, high-purity gypsum.

In the Windermere Creek area production is expected to continue from the Elkhorn 1 and Elkhorn 2 quarries well into the next century. There is a potential for a reserve of 10 to 20 million tonnes. The Windermere quarries are almost mined out, although a small reserve still exists. There are, however, substantial reserves of anhydrite. The resource potential in the Burnais Creek area is estimated at 40 million tonnes and there is a potential for 15 million tonnes of lower quality gypsum (75 per cent pure) in the Stoddart Creek area.

There is also a substantial resource potential in the Lussier River - Coyote Creek area. The Truroc deposit has an estimated resource of 20 to 40 million tonnes. An additional 5 million tonnes is estimated in the Coyote Creek area. The resource potential could be increased with further exploration. The presently producing Lussier quarry has sufficient reserves for a few more years of production. A new deposit located east of the Lussier River and adjacent to the northern boundary of Top of the World Park is estimated to contain 6 to 10 million tonnes of gypsum. Included in this deposit is a zone of very high purity white gypsum.

Elsewhere in the province there is a potential for 10 million tonnes of ore at the O'Connor River deposit and 3 to 20 million tonnes at Forgetmenot Creek. Because of their locations it may be some time before these deposits are developed. In addition, the location of the Forgetmenot Creek gypsum deposit with respect to the Willmore Wilderness Reserve in Alberta and poor accessibility from the British Columbia side of the border presents an even more significant obstacle to its development.

Deposits in the Joffre Creek are poddy although probably of good quality. They are estimated to have a potential for 1 to 2 million tonnes of production. Extensive overburden and rugged terrain will inhibit development. There may be some potential for discovery of other occurrences in Devonian strata that outcrops along the Bull River to the south (Figure 4, in pocket). Sinkholes have been observed in the vicinity of Sulphur and a small creek north of Iron Creek.

Substantial amounts of gypsum remain in deposits in the Mayook - Chipka Creek - Bull River area. However, they contain varying amounts of carbonate and are subeconomic under current market conditions. The potential for these deposits is probably less than 10 million tonnes.

Gypsum deposits with volcanic affinity may be present in the Cache Creek Group. At present there are no known deposits that are considered economic, however, these rocks host the Falkland deposits and may host other similar deposits. In coastal areas deposits similar to Britannia could represent a potential source of gypsum for the Vancouver market. Gypsum delivered at $28 to $30 per tonne f.o.b. Vancouver can be competitive with both imported gypsum and material from the Kootenay area.

Sources of high-purity, white gypsum are in demand but are not abundant in British Columbia. There may be a modest potential for this type of material at the O'Connor River deposit. At Falkland the gypsum is almost completely depleted. However, there is a substantial reserve of anhydrite, much of which may have the necessary whiteness and purity for some industrial applications.

CONCLUSIONS

There is an estimated resource potential for gypsum in British Columbia of 250 million tonnes which would provide in excess of 300 years reserves based on current production. Those areas with the best potential for development are the Stanford Range and O'Connor River localities. Development of the O'Connor River deposit may depend upon the ability to negotiate a contract with either the cement industry, Westroc Industries or Domtar Construction Materials as these two companies have fully integrated facilities and presently control the gypsum market in British Columbia.

ACKNOWLEDGMENTS

The author gratefully acknowledges Westroc Industries Limited, R. Banting and Kenelly Contracting Limited and Mountain Minerals Ltd. for providing information and logistical support during the last field season. The author also wishes to thank Z.D. Hora for the opportunity to make this study and for many useful suggestions. S. Preto provided able assistance throughout the field season, J. Fontaine helped with the drafting of the figures and D. Butrenchuk typed the manuscript.

REFERENCES

Appleyard, F. (1983): Construction Materials - Gypsum and Anhydrite; Industrial Minerals and Rocks, *AIME*, 5th Edition, pages 183-198.

Baird, D.M. (1964): Origin of Gypsum - Anhydrite Deposits at Falkland, British Columbia; *Canadian Journal of Earth Sciences*, Volume 1, Number 1, pages 1-9.

Belyea, H.R. and Norford, B.S. (1967): The Devonian Cedared and Harrogate Formations in the Beaverfoot, Brisco and Stanford Ranges, Southeast British Columbia; *Geological Survey of Canada*, Bulletin 146, 64 pages.

Blender, D.B. (1987a): Report on the Gypit-2 Claims in the Fort Steele Mining Division; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Assessment Report 16887, 6 pages.

Blender, D.B. (1986): Report on the Domtar Amos Group in the Fort Steele Mining Division; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Assessment Report 16886, 11 pages.

Butrenchuk, S.B. (1989): Gypsum in British Columbia (82G, J, 83E); *B.C. Ministry of Energy, Mines and Petroleum Resources*, Geological Fieldwork 1988, Paper 1989-1, pages 497-506.

Campbell, R.B. and Dodds, C.J. (1983): Geology, Tatshenshini Map-area (114P); *Geological Survey of Canada*, Open File 926.

Carson, J.T., Jambor, J.L., Ogryzlo, P.L. and Richards, T.A. (1976): Bell Copper: Geology, Geochemistry and Genesis of a Supergene-enriched, Biotized Porphyry Copper Deposit with a Superimposed Phyllic Zone; *in* Porphyry Deposits of the Canadian Cordillera, A. Sutherland Brown, Editor, *Canadian Institute of Mining and Metallurgy*, Special Volume 15, pages 245-263.

Casselman, M.J. (1980): Report on Percussion Drilling on the Lofar, Lofar 2 and Orion Claims; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Assessment Report 8263, 3 pages.

Clow, G.G. (1980): Report on the Blue Goose #6 Mining Claim; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Assessment Report 8158, 18 pages.

Clow, G.G. (1981): Report on the Elkhorn and Creek Mining Claims; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Assessment Report 8974, 5 pages.

Cole, L.H. (1930): The Gypsum Industry of Canada; *Department of Mines*, Ottawa, Publication Number 714, pages 64-68.

Cummings, J.M. (1940): Preliminary Geological Report on Falkland Gypsum Deposits; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Industrial Mineral File, 16 pages.

Domtar Chemicals Ltd. (1968): Report on Work Done on the Fetherstonhaugh Creek Gypsum Deposit; *Alberta Research Council*, Unpublished Report, Economic Minerals File GYP-AF-02, 20 pages.

Gibson, D.W. (1972): Triassic Stratigraphy of the Pine Pass - Smoky River Area, Rocky Mountain Foothills and Front Ranges of British Columbia and Alberta; *Geological Survey of Canada*, Paper 71-30, 108 pages.

Gibson D.W. (1975): Triassic Rocks of the Rocky Mountain Foothills and Front Ranges of Northeastern British Columbia and West-central Alberta; *Geological Survey of Canada*, Bulletin 247, 61 pages.

Govett, G.J.S. (1961): Occurrence and Stratigraphy of some Gypsum and Anhydrite Deposits in Alberta; *Alberta Research Council*, Bulletin 7, pages 10-15.

Hamilton, W.N. (1984): Salt and Gypsum in Alberta; *in* The Geology of Industrial Minerals in Canada, *Canadian Institute of Mining and Metallurgy*, Special Volume 29, pages 230-237.

Henderson, G.G.L. (1954): Stanford Range; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Bulletin 35, 84 pages.

Holliday, D.W. (1970): The Petrology of Secondary Gypsum Rocks: A Review; *Journal of Sedimentary Petrology*, Volume 40, pages 734-744.

Höy, T. and Carter, G. (1988): Geology of the Fernie W 1/2 Map Sheet (and Part of Nelson E1/2); *B.C. Ministry of Energy, Mines and Petroleum Resources*, Open File 1988-14.

James, H.T. (1929): Britannia Beach Map-area, British Columbia; *Geological Survey of Canada*, Memoir 158, 139 pages.

Jones, A.G. (1959): Vernon Map Area, British Columbia; *Geological Survey of Canada*, Memoir 296, 186 pages.

Kendall, A.C. (1984): Evaporites; *Geoscience Canada*, R.G. Walker, Editor, Reprint Series 1, Second Edition, pages 159-174.

King, Murphy and Lavalin Consultants (1987): Market Study of British Columbia's Gypsum in the Pacific Rim Area of North America; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Mineral Development Agreement Report, 200 pages.

Kootenay Geo-Services (1986): O'Connor River Gypsum Project 1986 Geological Report; Company Report for *Queenstake Resources Ltd.*, 16 pages.

Korun, B. (1980): Report on Drilling and Geological Evaluation of Mineral Property at Lussier River; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Assessment Report 8076, 27 pages.

Leech, G.B. (1958): Canal Flats; *Geological Survey of Canada*, Map 24-1958.

Leech, G.B. (1960): Fernie (West Half); *Geological Survey of Canada*, Map 11-1960.

Leech, G.B. (1979): Kananaskis Lakes Map Area; *Geological Survey of Canada*, Open File 634.

McCammon, J.W. (1952): Gypsum Lime and Alabastine; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Annual Report 1952, pages A251-A257.

McGammon, J.W. (1969): Gypsum; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Annual Report 1968, pages 300-308.

McDougall, J.J. (1959): Additional Preliminary Report on O'Connor River Gypsum Deposits British Columbia; Company Report for *Ventures Ltd.*, 9 pages.

McMillan, W.J. (1971): Valley Copper; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Geology, Exploration and Mining in British Columbia, 1970, pages 354-369.

Millar, J.V. (1961): Report on Geophysical Work, Aztec-Pyramid Claim Groups; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Assessment Report 422, 3 pages.

Mossop, G.D. and Shearman, D.J. (1973): Origins of Secondary Gypsum Rocks; *Institution of Mining and Metallurgy*, Transactions, Volume B82, pages 147-154.

Mott, J.A., Dixon, J.M. and Helmstaedt, H. (1986): Ordovician Stratigraphy and Structural Style at the Main Ranges - Front Ranges Boundary near Smith Peak, British Columbia; *Geological Survey of Canada*, Paper 86-1B, pages 457-465.

Murray, R.C. (1964): Origin and Diagenesis of Gypsum and Anhydrite; *Journal of Sedimentary Petrology*, Volume 34, Number 3, pages 512-523.

Norford, B.S. (1981): Devonian Stratigraphy at the Margins of the Rocky Mountain Trench, Columbia River, Southeastern British Columbia; *Canadian Society of Petroleum Geologists*, Volume 29, pages 540-560.

Ogniben, L. (1957): Secondary Gypsum of the Sulphur Series, Sicily, and the So-called Integrations; *Journal of Sedimentary Petrology*, Volume 27, pages 64-79.

Reimchen, T. and Bakker, E. (1982): Report on Geophysics, Stripping and Geological Evaluation of Mineral Property at Lussier River; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Assessment Report 10764, 19 pages.

Rodgers, G.M. and Kovacs, J. (1984): Stage One Report, Lussier River Quarry; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Industrial Minerals File, 20 pages.

Sutherland Brown, A. (1975): Britannia Mine; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Geology, Exploration and Mining in British Columbia 1974, pages 190-197.

White, G.V. (1986): Preliminary Report O'Connor River Gypsum Deposit; Geological Fieldwork 1985, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1986-1, pages 279-282.

APPENDIX 1
CHEMICAL ANALYSES OF GYPSUM FROM THE STANFORD RANGE

Sample No.	Latitude	Longitude	Location	SiO_2 %	CaO %	Na_2O %	K_2O %	H_2O %	SO_3 %	S %	MgO %	Sr ppm
SB88-1A	50°34′25″	115°58′15″	Stoddart Ck.	5.78	28.76	0.06	0.24	13.40	32.08	12.7	5.79	620
SB88-4A	50°31′30″	115°54′45″	Burnais Ck.	2.50	31.22	0.03	0.12	18.10	41.98	16.6	1.91	590
SB88-4B	50°31′30″	115°54′45″	Burnais Ck.	2.76	30.72	0.05	0.15	17.10	40.70	15.9	2.34	395
SB88-6A	50°32′00″	115°55′05″	Burnais Ck.	1.40	31.19	0.03	0.07	18.60	44.14	17.7	1.04	505
SB88-9A	50°29′05″	115°52′40″	Elkhorn West	1.63	30.99	0.04	0.06	17.90	41.84	16.2	1.85	880
SB88-14A	50°29′30″	115°53′15″	Elkhorn West	0.71	31.56	0.04	0.03	19.00	45.22	18.0	0.55	840
SB88-18A	50°30′00″	115°54′00″	Windermere	1.40	31.10	0.03	0.06	17.60	42.33	16.5	1.71	440
SB88-20A	50°30′05″	115°54′00″	Windermere	0.87	31.59	0.02	0.06	18.70	44.22	17.3	1.13	735
SB88-20B	50°30′05″	115°54′00″	Windermere	1.33	31.24	0.03	0.05	17.80	42.31	16.8	1.74	860
SB88-20C	50°30′05″	115°54′00″	Windermere	0.74	31.67	0.03	0.03	19.10	44.67	17.6	0.99	765
SB88-21A	50°29′55″	115°54′05″	Windermere	1.63	30.62	0.03	0.08	17.80	42.26	16.6	2.01	1200
SB88-21B	50°29′55″	115°54′05″	Windermere	0.82	31.05	0.02	0.04	18.80	44.65	17.7	1.00	1300
SB88-21C	50°29′55″	115°54′05″	Windermere	0.77	31.26	0.05	0.03	19.10	43.95	18.0	0.85	1100
SB88-23A*	50°29′55″	115°54′05″	Windermere	0.72	37.67	0.04	0.03	2.65	56.06	22.3	0.49	1100
SB88-23B*	50°29′55″	115°54′05″	Windermere	3.31	36.53	0.06	0.03	1.49	48.07	19.0	3.33	1200
SB88-25A	50°29′50″	115°54′15″	Windermere	1.94	30.87	0.04	0.11	17.80	42.85	16.8	1.63	440
SB88-33A	50°29′55″	115°54′10″	Windermere	1.33	30.74	0.05	0.05	16.30	39.05	15.2	3.10	1200
SB88-37A	50°13′20″	115°43′50″	Kootenay R.	1.59	30.45	0.03	0.05	17.40	41.42	16.4	2.43	980
SB88-39A	50°13′20″	115°43′50″	Kootenay R.	1.01	30.63	0.03	0.02	18.80	44.72	18.0	0.99	935
SB88-40A	50°13′20″	115°43′51″	Kootenay R.	1.72	31.29	0.03	0.04	18.70	44.16	17.4	1.33	740
SB88-41A	50°13′20″	115°43′51″	Kootenay R.	1.58	31.14	0.04	0.03	18.60	44.98	17.7	0.93	1200
SB88-46A	50°13′20″	115°43′51″	Kootenay R.	0.98	31.51	0.05	0.02	19.40	45.23	17.7	0.83	1100
SB88-47A	50°13′30″	115°42′30″	Little Joan	0.59	31.47	0.04	0.03	18.60	44.27	17.6	1.24	770
SB88-48A	50°13′15″	115°43′55″	Kootenay R.	1.32	31.11	0.04	0.03	18.80	44.77	17.4	1.07	825
SB88-48B	50°13′15″	115°43′55″	Kootenay R.	3.82	29.72	0.05	0.24	16.60	38.24	14.9	3.30	750
SB88-53	50°28′45″	115°51′45″	Elkhorn 2	1.19	31.24	0.05	0.07	18.90	43.30	16.8	1.32	970
SB88-57A	50°28′45″	115°51′45″	Elkhorn 1	0.79	30.89	0.04	0.04	19.40	44.13	17.2	1.15	1100
SB88-58A	50°28′50″	115°52′00″	Elkhorn 1	0.74	28.78	0.01	0.03	19.40	44.96	17.7	1.01	1200
SB88-58B	50°28′50″	115°52′00″	Elkhorn 1	0.82	26.95	0.01	0.04	19.70	45.04	17.9	0.83	1100
SB88-59A	50°28′50″	115°52′00″	Elkhorn 1	0.74	26.96	0.02	0.03	19.90	45.77	18.0	0.61	1100
SB88-60A	50°28′50″	115°52′00″	Elkhorn 1	0.70	31.20	0.05	0.03	18.50	42.57	16.6	1.93	650
SB88-65A	50°14′30″	115°39′30″	Nine Mile	1.01	31.15	0.05	0.04	19.50	45.07	17.7	0.99	890
SB88-68A	50°05′15″	115°32′10″	Lussier R.	1.37	31.09	0.03	0.04	19.80	42.19	17.9	0.63	790
SB88-74A	50°02′15″	115°30′15″	South Quarry	2.86	29.80	0.07	0.05	18.10	45.74	16.7	2.27	510
SB88-74B	50°02′15″	115°30′15″	South Quarry	1.67	30.18	0.04	0.34	18.60	42.85	16.8	1.77	460
SB88-75A	50°03′00″	115°31′00″	Lussier Quarry	1.06	30.19	0.03	0.06	19.00	43.23	17.3	1.46	1300
SB88-75B	50°03′00″	115°31′00″	Lussier Quarry	1.37	29.25	0.02	0.06	19.40	44.06	17.9	0.79	1200
SB88-75C	50°03′00″	115°31′00″	Lussier Quarry	1.12	30.81	0.04	0.04	19.70	44.92	17.7	0.83	1100
SB88-75D	50°03′00″	115°31′00″	Lussier Quarry	2.56	29.26	0.03	0.14	15.70	35.43	14.4	4.65	855
SB88-76A	50°00′40″	115°31′00″	Truroc	2.81	29.38	0.04	0.09	16.90	38.84	15.4	3.37	610
SB88-83A	49°58′10″	115°27′00″	Branch F	0.91	30.72	0.02	0.04	19.60	44.91	18.1	0.85	610
SB88-83B	49°58′10″	115°27′00″	Branch F	1.24	30.45	<0.01	0.04	18.20	41.60	16.2	2.31	660
SB88-84A	49°59′05″	115°28′20″	Coyote	1.10	31.57	0.03	0.06	19.10	43.87	17.5	1.13	980
SB88-85A	49°57′55″	115°28′00″	Branch F West	1.32	31.25	0.02	0.03	18.50	42.50	16.8	1.81	440
SB88-97A	50°45′00″	115°31′10″	Truroc	0.99	31.33	0.03	0.04	19.00	43.53	17.3	1.53	955
SB88-99A	50°15′40″	115°40′50″	Nine Mile	3.21	30.47	0.02	0.17	17.10	39.16	15.5	3.03	1100
SB88-100A	50°15′35″	115°40′50″	Nine Mile	3.04	30.34	0.03	0.25	16.70	38.15	15.2	3.16	960
SB88-18B	50°30′00″	115°54′00″	Windermere	0.79	32.50	0.02	0.04	19.50	44.50	17.6	0.95	630
SB88-25B	50°29′50″	115°54′15″	Windermere	2.03	32.36	0.05	0.10	17.90	40.98	16.3	2.22	1100
SB88-67A	50°14′30″	115°39′30″	Nine Mile	1.18	31.90	0.02	0.04	19.80	45.30	17.8	0.65	935
SB88-78A	50°02′00″	115°28′00″	Gypit	1.92	31.09	0.02	0.04	18.50	42.60	16.8	1.81	460

**Denotes anhydrite.*