Study of Alberta Limestones for Potential Use as Paper Filler

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Table of Contents

ILLUSTRATIONS

TABLES

1. EXECUTIVE SUMMARY

1.1. Background

Establishment of a fine-paper mill in Alberta requires a source of white mineral filler. The province lacks economic deposits of kaolin, the most common filler used, but has extensive deposits of limestone. White, filler-grade limestone can substitute for kaolin if suitable deposits can be located in Alberta. The objective of this study is to evaluate known limestone deposits in the province for potential use as paper coating/filler material and identify prospective occurrences for follow-up fieldwork and testing.

1.2. Calcium Carbonate Fillers

Limestones and marbles are the most common sources of white fillers, and generally yield higher whiteness values than kaolin. Most existing North American paper plants use kaolin because they employ an acid sizing process, with which calcium carbonate is not compatible. However, the paper industry is tending toward conversion to an alkaline sizing process because of major economic advantages, and new plants generally are designed for an alkaline system. Such a system allows the use of calcium carbonate filler, which is cheaper and more available than kaolin in many areas. The quality requirements for calcium carbonate in the paper industry are stringent, with colour and ground particle fineness being the most important.

1.3. Limestone Distribution and Prospective Areas

Limestones occur abundantly in Alberta, exposed in two main regions -- the mountain belt in the southwest, and in the vicinity of Fort McMurray on the northeast plains. Industrial potential is greatest in the mountains, in areas where major valleys transect mountain ranges formed of limestone-bearing formations. Six such areas are evaluated in this study, along with the Fort McMurray area;

these are Crowsnest Pass, Bow Valley, Nordegg, Cadomin, Brule, and Grande Cache. In addition, two areas not previously investigated -- the David Thompson Corridor and the Clark Range -- are included for preliminary assessment.

1.4. Summary of Evaluations

(1) The characteristic colour of Paleozoic carbonate rocks in Alberta is grey. White colours are rarely seen.

(2) In the Crowsnest Pass area, one prospect is identified for further study -- the Peechee dolomite member of the Devonian Fairholme Group -- locally exposed in Phillipps Pass.

(3) In the Bow Valley area, a "cream coloured" limestone bed reported in the Cambrian Eldon Formation, near the old quarry at Kananaskis, warrants further study.

(4) No prospects are noted in the Nordegg, Cadomin, Brule or Grande Cache areas, though the areas are rich in high calcium limestones.

(5) Carbonates exposed in the Fort McMurray area generally are of inferior quality to those in the mountains. No prospects exist.

(6) The best prospects for white carbonates seem to be in areas previously untested. In the Clark Range, the Precambrian Waterton Formation is reported to include beds of white limestone. In the David Thompson Corridor, the great thickness of Cambrian carbonate strata exposed makes the area prime exploration gorund for carbonates with special attributes.

1.5. Conclusions

Alberta is not an ideal geological environment for the occurrence of white limestone. The shallow marine origin of most Paleozoic carbonates has resulted in significant organic content and a characteristic grey colour. Nevertheless, localized beds of exceptionally light colour have been noted as worthy of further study. Previously unstudied areas offer good prospects in some Precambrian and Cambrian strata.

1.6. Recommendations

Fieldwork, sampling and laboratory tests are recommended as follows, for a conclusive evaluation of Alberta's filler-grade limestone potential.

(1) Reexamine prospective occurrences in the Crowsnest Pass area (Peechee dolomite outcrop in Phillipps Pass), and the Bow Valley area (Eldon limestone bed near old Kananaskis quarry).

(2) Evaluate Waterton Formation prospects in the Clark Range area by locating and testing beds of white limestone reported in the formation.

(3) Explore the untested, thick Cambrian carbonate succession in the David Thompson Corridor area; locate, map and test any light coloured beds.

2. INTRODUCTION

2.1 Background

Establishment of a fine-paper mill in Alberta is a goal of the Alberta Government. Fine-paper products require significant quantities of white mineral filler in the pulp fibre (see Appendix). Previous study has shown that kaolin, the most common filler used, is not present in potentially economic deposits in the province (Scafe and Hamilton, 1985). However, a possible substitute for kaolin is limestone if the alkaline paper making process is used. Limestone deposits are extensive in Alberta and British Columbia, and at least two deposits of white limestone are developed in B.C. for the filler market (Appendix). If a suitable white limestone deposit could be located in Alberta, it would be helpful in attracting a paper mill to the province. The objective of this study is to evaluate known limestone deposits in Alberta for potential use as coating/filler material in paper making.

2.2 Method and Scope of Study

This study is basically a review of existing information on limestone deposits in Alberta, to identify prospective occurrences for follow-up fieldwork and testing. Because previous limestone studies were oriented largely toward conventional industrial use of limestone (i.e., cement and lime manufacture), no data exist that would permit a direct evaluation of any deposits for filler use.

The study involves a geological analysis of seven principal limestone areas in Alberta and evaluation of filler-grade prospects for each, plus a preliminary assessment of two untested areas. Evaluations are based largely on previous limestone studies by the Alberta Research Council (Holter, 1976; Macdonald and Hamilton, 1979, 1981) and on geological mapping by the Geological Survey of Canada. Data from these studies are captured in the Alberta Mineral Deposits and Occurrences (AMD/O) file, which includes approximately 150 documented deposits of limestone and dolomite.

The study also includes a review of the technology of industrial limestone and its use as filler in the alkaline paper making process.

3. USE OF LIMESTONE AS FILLER

3.1 Limestone Rock Characteristics

Limestone is a sedimentary rock composed primarily of calcium carbonate or combinations of calcium and magnesium carbonate with varying amounts of impurities. Pure limestone consists entirely of the mineral calcite ($CaCO_3$). Its counterpart at the other end of the carbonate rock spectrum is dolomite (or "dolostone"), in which the mineral dolomite ($CaMg[CO_3]_2$) predominates. Pure dolomite is 54.3 percent $CaCO_3$ and 45.7 percent $MgCO_3$. All gradations in $CaCO_3$ content can exist between these two extremes.

Limestone has a wide variety of industrial uses depending on the purity of the rock, the textural characteristics, and the colour. Most industrial limestone (other than crushed stone used for construction aggregate) is a high purity rock, at least 95 percent $CaCO_3$, termed high calcium limestone. This type of limestone consists of interlocking grains of calcite, formed largely of shell fragments and other calcareous detritus cemented by clear calcite cement (Harben and Bates, 1984).

The major impurities found in limestones include clays, silica in the form of chert or quartz sand/silt, and organic matter. High calcium limestones commonly are of biogenic origin, formed in high energy environments rich in marine life, with little or no mud or terrigenous debris. In these limestones the principal impurity is organic matter, which is significant as it affects the colour of the rock.

Although calcite in its pure mineral form is white, most high calcium limestones are coloured grey or tan. Tan colours are due to small amounts of iron, which also give related hues of buff, red or brown. Grey colours are due mainly to organic matter. Even minute amounts of less than 1 percent can colour the rock light grey; with higher amounts, high calcium limestones are coloured dark grey or even black. Organic content is probably derived from residues of organisms not completely oxidized or decomposed.

Limestones that have been subjected to moderate degrees of metamorphorism are generally lighter in colour, an indication that the organic matter has been purged. If metamorphism is advanced, the limestone rock is transformed into marble, still a rock comprised essentially of $CaCO_3$ but now recrystallized and reconstituted. White limestones and marbles are found most commonly in areas of pronounced igneous activity where forces of alteration and metamorphism have been at work.

For most industrial uses of high calcium limestone, the colour of the rock is inconsequential. However, in limestones considered for use as filler the colour is a key factor. Mineral fillers is a specialized application of limestones that has grown substantially in recent years and opened up new markets and new demands for white limestone and marble.

3.2 Mineral Fillers

The first purpose of mineral fillers is to add bulk to a product at reduced cost. Good white colour is one of the key requirements that many product uses demand. The others are good grindability for uniform fineness, and chemical stability. For fillers in general, almost any white mineral will do that is chemically inert and can be readily ground to the required fineness. Minerals that are used include kaolin, calcium carbonate, gypsum, talc, pyrophyllite, mica, barite, asbestos and silica flour. Of these, the most common is calcium carbonate, because it is generally the most available (Freas, 1985).

Calcium carbonate fillers are produced from limestone, marble, chalk, and vein calcite, and also as precipitated calcium carbonate (PCC) from the reaction of CO_2 with milk of lime (Power, 1985). Chalk has long been a favourite filler source because it is soft and easily comminuted, consisting of smooth, rounded, weakly bonded coccolith structures. Crystalline carbonates are more widely available, but are more difficult to grind and -- depending on the degree of crystallinity -- require a much higher energy input to achieve the desired fineness (minus 325 mesh). Higher whiteness values generally are obtainable with ground crystalline rocks. The whitest fillers with the finest and most uniform particle sizes are achieved with precipitated calcium carbonates (PCC's), but these are costly to produce. Improvements in grinding technology and new ultrafine grinding techniques have made ground limestones a cost-effective substitute for PCC's in markets for superfine fillers.

The main uses of calcium carbonate filler are in paints, paper, plastics and floor covering applications, but there are many more (see table 1). The market in Canada and USA is proportioned to the major uses as shown in table 2. Production currently comes from the localities shown on figure 1. Prices for calcium carbonate fillers range from about US $20 to $175 per tonne depending on whiteness and fineness of grain (Guillet and Kriens, 1985).

3.3 Calcium Carbonate as Paper Filler

The functional use of fillers and coatings in paper making is described by Scafe and Hamilton (1985), excerpts from which are reproduced in the Appendix. Kaolin is used for 80 percent of current paper filler requirements in North America, where most existing paper plants use an acid sizing process. Calcium carbonate can be used instead of kaolin where the paper making process uses alkaline sizing. It is cheaper, whiter, and more available than kaolin in most regions. However, calcium carbonate is not compatible with an acid medium.

With development of neutral or alkaline sizing agents in the 1960's, the door was opened to the use of calcium carbonate. The paper industry has since shown a growing interest towards conversion of paper plants to an alkaline sizing process, because of a number of economic factors that favour this conversion (North, 1985):

1. Permits use of less expensive pulps
2. Higher filler loadings
3. Reduced maintenance costs
4. Reduced cost of effluent treatment

Table 1. Primary Uses for Carbonate Fillers (from Guillet and Kriens, 1985).

Application	Function	General Specifications
Paint	Extender of prime pigments in interior and exterior paint formulations.	High whiteness; controlled particle size, 44 microns to 8 microns top size.
Plastics	As a resin extender in a wide range of polymer systems.	High whiteness; controlled particle size, 30 to 5 microns top size; fillers treated with coatings and coupling agents are used.
Paper	As a filler or for paper coating. Partial displacement of kaolin.	High whiteness; controlled particle size, low abrasion, very fine products with top sizes ranging from 10 to 4 microns.
Putty, Caulking, Sealing		White, medium to fine. 90–99% passing 325 mesh (44 microns).
Vinyl Floor Covering	As a filler in vinyl tile	Coarse granular (– 40 mesh) to fine (– 325 mesh); good white colour; controlled particle size and bulk density.
Carpet Backing		White to gray colour; 90%–99% passing 325 mesh.
Asphaltic Products	Filler in roofing materials and asphalt sealers.	Off-color buff to gray; coarse ranging from 80% passing 325 to 80% passing 200 mesh.
Rubber	Filler pigment in footwear, automotive goods, non-reinforced rubber, wire and cable coatings.	White to off-colour; Fine to medium fine products.
Construction	Filler in jointing compounds for gypsum board.	Lower grade white products; 90–95% passing 325 mesh.
Other	Synthetic Marble	White, coarse products; 80–85% finer than 200 mesh, and granular grades.
	Coal Dusting	White to buff, coarse filler used in coal mining.

Table 2. Estimated Carbonate Filler Market, 1980-1985 (from Guillet and Kriens, 1985).

	Total Canada and United States
	Tonnes annually
Putty, caulks, sealants	480.000
Carpet backing	500.000
Plastics	400.000
Paint	250.000
Paper	125.000
Rubber	100.000
Adhesives	25.000
	1.880.000

5. Lower energy costs
6. Higher brightness
7. Higher strength paper
8. More permanent paper

Savings of U.S. $20 per tonne or more have been estimated (North, 1985), which for an average size paper plant producing 80,000 tpa can be very significant. New plants now in the planning works are being designed for an alkaline system or for ready conversion from acid to alkaline. The limiting factor in the use of calcium carbonate filler will be the availability of grinding capacity to supply the market.

Requirements for the paper industry are stringent. Colour (92 percent brightness) and proper particle size distribution are the most important. There are basically two grades, one with average particle size of 1.5 to 2 µm used for filler, and a finer product with average particle size 0.6 to 0.8 µm used for coating. Typical commercial product specifications for these two applications are given in table 3.

Table 3. Chemical and physical characteristics of calcium carbonate whitings used in paper making (from Power, 1985).

Typical Applications	PAPER FILLER	PAPER	COATING
$CaCO_3$ %	96.15	98.5	98.1
Water soluble salt content %	0.13	0.14	-
Moisture content %	15%*	-	-
Particle size distribution			
plus 53 microns	0.75	0.02	0.01
plus 10 microns	18	1.0	1.0
plus 5 microns	35	2.5	4.0
minus 2 microns	40	80(±3%)	90
minus 1 micron	-	42	70
Specific surface area m^2/g	2.2	8.0	5-16
Brightness	85.5	89.0	96.0

*slurry form

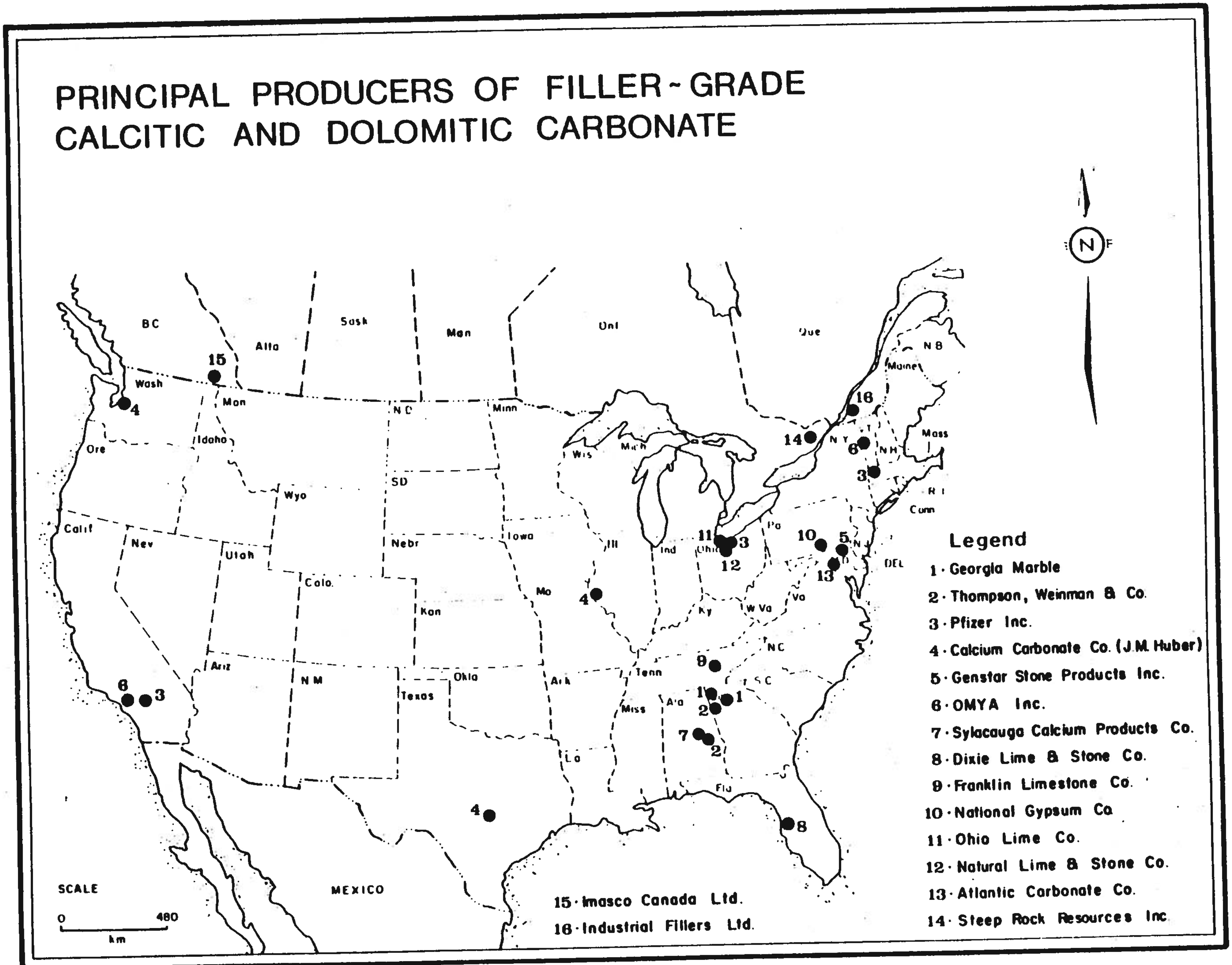


Figure 1 (From Guillet and Kriens, 1985)

The most promising market area for paper filler-grade calcium carbonate is the Pacific Northwest (North, 1985). At present, as shown on figure 1 this region has just two producers, and considerable pressure exists to find more suitable deposits in anticipation of market growth in the paper industry. Scattered deposits of white limestone and marble are known to exist in British Columbia and the northwestern USA states, but are poorly explored. The potential for finding deposits in Alberta is the subject of this report.

4. ALBERTA LIMESTONES

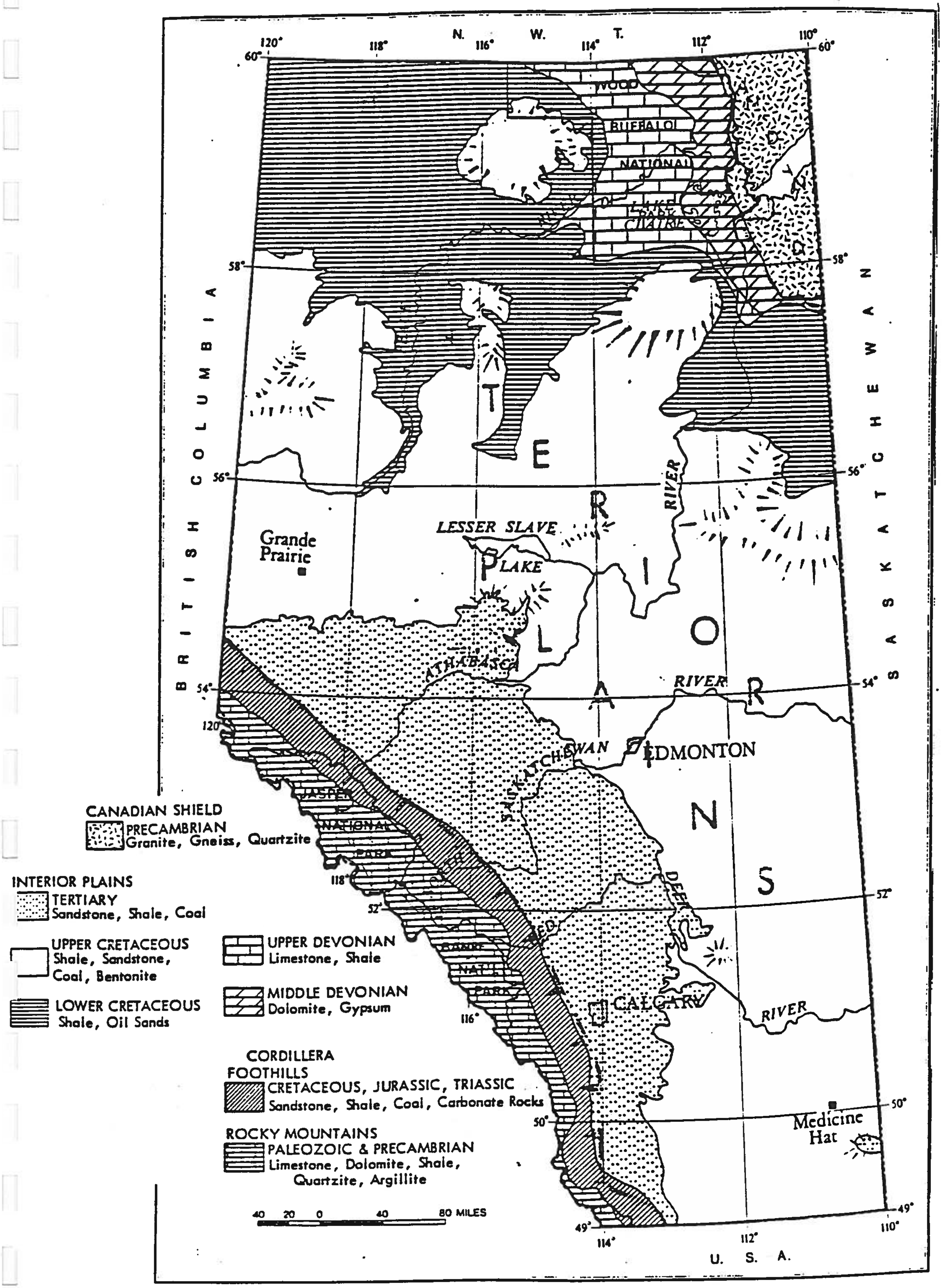
4.1 Occurrence and Distribution

Limestones occur abundantly in Alberta. The Paleozoic section of up to 4000 m thickness is comprised dominantly of limestone and dolomite, in approximately equal proportions. These rocks are exposed in two main regions of the province -- the mountain belt in the southwest, and at the margin of the Canadian Shield in the northeast (Figs. 2,3). Limestones also extend throughout the subsurface, but mostly at depths below 1000 m (Fig. 2).

Industrial potential for limestone is greatest in the mountain belt. The purest limestones are found in formations of Cambrian, Devonian and Mississippian ages, exposed almost continuously along the Front Ranges of the Rocky Mountains. These strata are deformed and uplifted in a series of west-tilted fault blocks, giving rise to elongated outcrops (Fig. 3). In this setting, limestone deposits occur typically as thick units with moderately to steeply dipping beds. By contrast, limestone strata exposed in the northeast, marginal to the Canadian Shield, are nearly flat-lying and thin.

4.2 Prospective Areas

Despite the abundance of limestone in Alberta, its existence in



N. W. T.
120° 118° 116° 114° 112° 110°
60° 58° 56° 54° 52° 50° 49°
WOOD BUFFALO NATIONAL PARK
LAKE CLAIRE
BRITISH COLUMBIA
SASKATCHEWAN
T E R R I O R N S
L A
P
RIVER
LESSER SLAVE LAKE
Grande Prairie
ATHABASCA
RIVER
SASKATCHEWAN
EDMONTON
JASPER NATIONAL PARK
BANFF NAT'L PARK
RED
DEER
RIVER
CALGARY
Medicine Hat
U. S. A.
CANADIAN SHIELD
PRECAMBRIAN
Granite, Gneiss, Quartzite
INTERIOR PLAINS
TERTIARY
Sandstone, Shale, Coal
UPPER CRETACEOUS
Shale, Sandstone, Coal, Bentonite
LOWER CRETACEOUS
Shale, Oil Sands
UPPER DEVONIAN
Limestone, Shale
MIDDLE DEVONIAN
Dolomite, Gypsum
CORDILLERA
FOOTHILLS
CRETACEOUS, JURASSIC, TRIASSIC
Sandstone, Shale, Coal, Carbonate Rocks
ROCKY MOUNTAINS
PALEOZOIC & PRECAMBRIAN
Limestone, Dolomite, Shale, Quartzite, Argillite
40 20 0 40 80 MILES

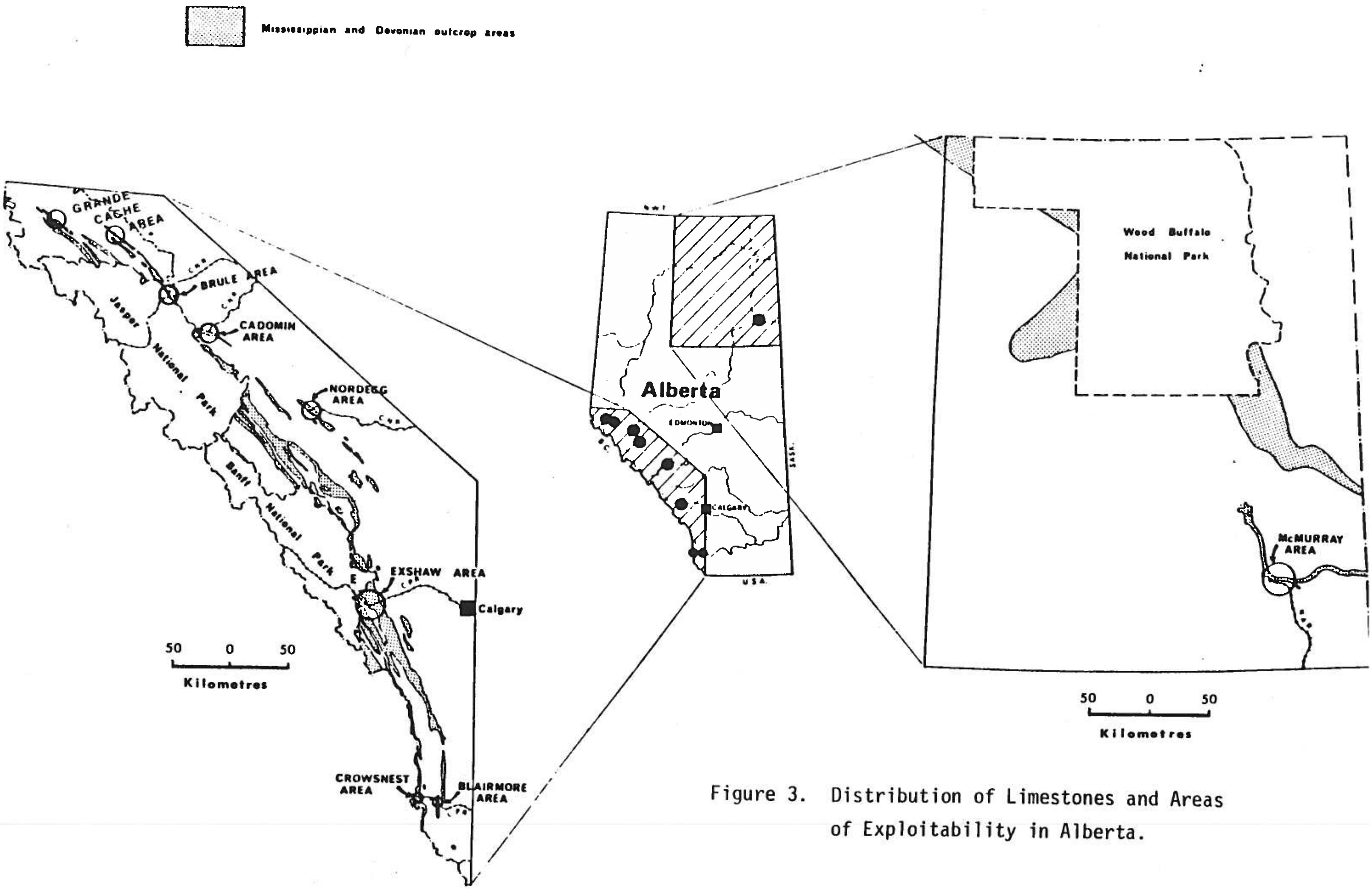


Figure 3. Distribution of Limestones and Areas of Exploitability in Alberta.

many places is negated by economic inaccessibility. Limestone exploitation hinges on two conditions, ease of access and quarriability. In the mountain region, these conditions occur only in the passes, i.e., where major river valleys transect the ranges. The passes provide the access routes and expose the limestone formations at low (and potentially quarriable) elevations.

This study focuses on six such areas of the Foothills and Front Ranges, and in addition, an area in northeastern Alberta near Fort McMurray. The six mountain areas are Crowsnest Pass, Bow Valley, Nordegg, Cadomin, Brule and Grande Cache (Fig. 3).

In addition to the above, a preliminary assessment is made of two areas previously untested; the David Thompson Corridor west of Nordegg, and the Clark Range north of Waterton National Park. These areas are remote from the conventional industrial markets for Alberta limestone, but are worthy of study for a specialized market such as white filler.

The principal evaluation criteria for this study are limestone quality and colour. Limestone quality means essentially carbonate purity, inasmuch as dolomitic limestones and dolomites are also considered. $MgCO_3$ is not deleterious to white paper filler, even though specifications call for high calcium limestone.

4.3 Crowsnest Pass Area

The Crowsnest Pass area includes both Blairmore and Crowsnest areas shown in Figure 3, which were discussed separately by Holter (1976). Crowsnest Pass is the southernmost of the major passes in the Alberta Rocky Mountains. Two lesser passes within the area, Phillipps Pass and Deadman Pass, lie 3 km and 8 km to the north and give added exploitability to the limestones in this area.

The Crowsnest Pass transects two main ranges exposing Paleozoic strata; the High Rock Range at Crowsnest Lake and the Blairmore Range near the town of Blairmore. Figure 4 is a stratigraphic column for the region showing the complete succession of formations, although not all are represented within the limits of the study area.

The oldest carbonate-bearing formation exposed in the area is the Cambrian Elko Formation, which outcrops as an isolated wedge in the High Rock Range near the east entrance to Phillipps Pass. It consists mainly of grey microcrystalline dolomites and limestones.

The Devonian Fairholme Group, exposed in the High Rock Range, comprises dark grey limestones and light to dark grey dolomites. In Phillipps Pass, a local reef development of white to light grey dolomite occurs near the middle part of the Fairholme. The dolomite, apparently belonging to the Peechee Member (Price, 1961), is the lightest coloured rock in the area and may be worthy of further investigation.

The Peechee Member is a sub unit of the Southesk Formation and forms reef-like masses that intertongue with and replace Fairholme limestones in localized areas (Price, 1962). In Phillipps Pass, the Peechee is 220 m thick and consists of massive, coarse crystalline, calcareous dolomite, saccharoidal in appearance, with abundant fine to coarse vugs lined or filled with calcite (Hamilton, 1969). It is a very pure carbonate, with only minute amounts of non-carbonate matter.

The Alexo Formation consists of buff and grey sandy dolomites, with minor amounts of limestone.

The Palliser Formation is a dark grey limestone, in part mottled with brownish grey dolomite. It is a massively bedded cliff-forming unit, 200 m plus in thickness, that has industrial potential in the area for use as cement or lime raw material

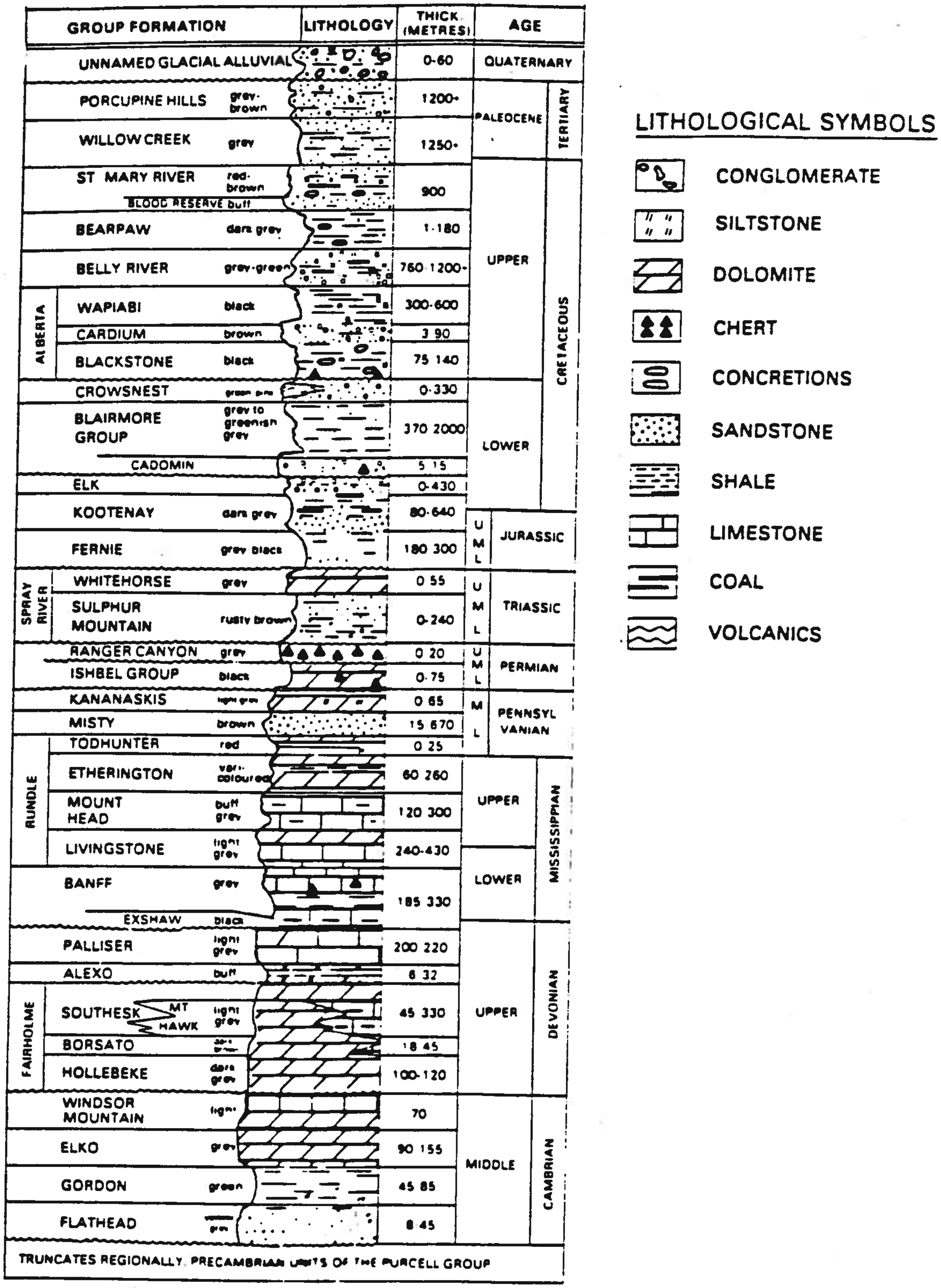


Figure 4. Stratigraphic column for the Crowsnest Pass area.

(Macdonald and Hamilton, 1981). No exploitation of this limestone has occurred, although quarriable sites are identified in Phillipps and Deadman Passes.

The basal Mississippian formations are the Exshaw, a thin black shale unit that marks the top of the Palliser, and the Banff, which varies from black shales and limestones in the lower part to dark grey, cherty limestones above.

The Livingstone Formation is the basal unit of the Mississippian Rundle Group and an important economic unit for the area. It consists of light grey, bioclastic limestone and finely crystalline limestone, with interbeds of finely crystalline dolomite. The limestone is quarried extensively in the Crowsnest Pass for lime manufacture (Holter, 1976). However, its grey colour disqualifies it for use as filler.

Other carbonates of the Rundle Group and the overlying Permo-Pennsylvanian Formations generally are too siliceous or argillaceous for consideration as potential filler. No carbonates of any significance occur in the Mesozoic section in this area.

4.4 Bow Valley Area

The Bow Valley area (or Exshaw area as indicated on Fig. 3) lies due west of Calgary between the eastern margin of the Front Ranges and Banff National Park, and is a major limestone-producing area of Alberta (Holter, 1976).

The stratigraphic column for the Bow Valley area is illustrated in figure 5. Bow Valley transects a series of tilted fault blocks uplifted by four major thrust faults, exposing repeated successions of carbonate strata from Cambrian to Mississippian in age. Not all the formations shown in figure 5 are exposed in the area, the older ones being restricted to the Main Ranges in Banff National Park.

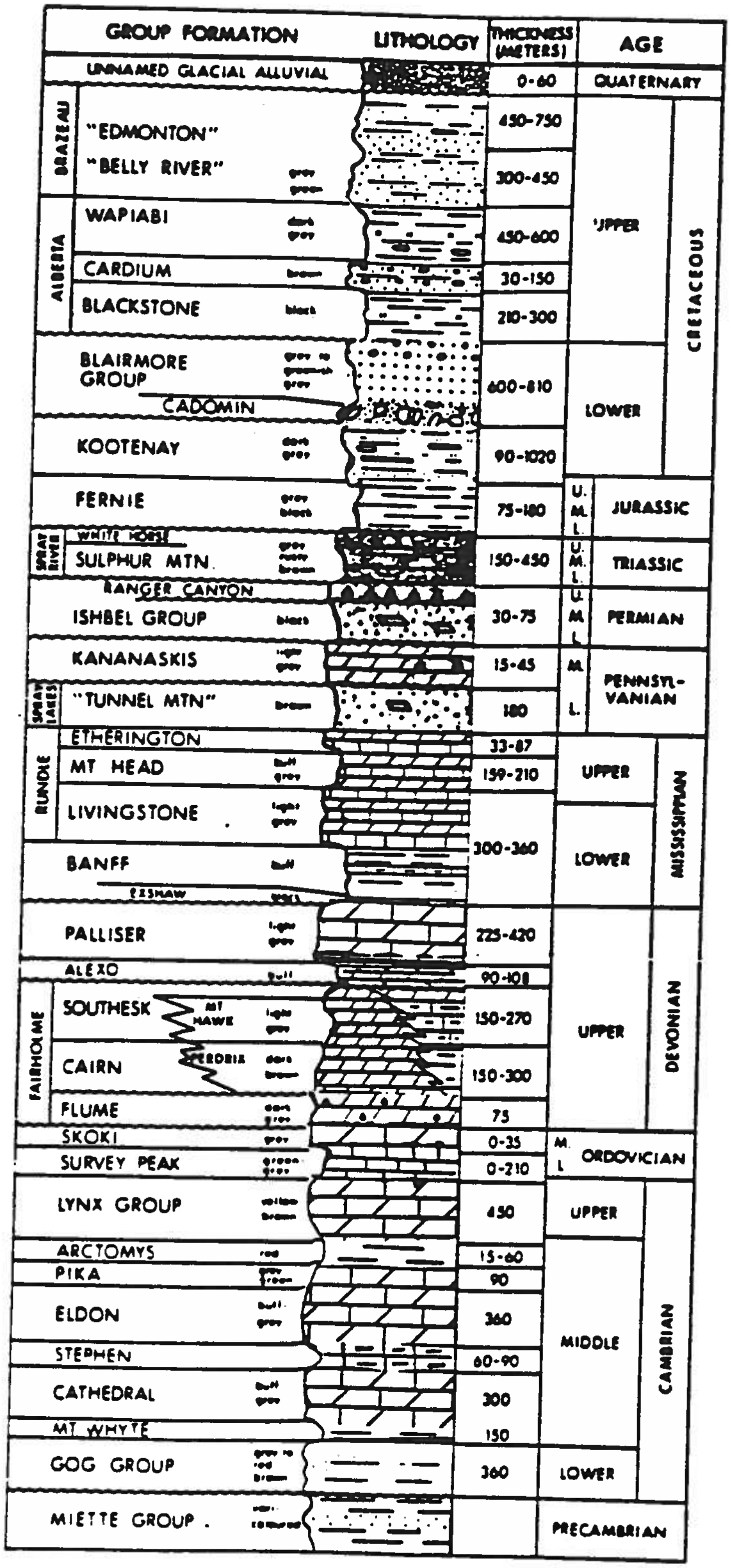


Figure 5. Stratigraphic column for the Bow Valley area.

The oldest formation exposed is the Cambrian Eldon Formation, on the eastern Front Ranges margin. The Eldon comprises dark grey, finely crystalline variegated and mottled limestone and interbedded dolomite, in a thickness of more than 240 m. Some of the purer limestone beds were quarried in the past for lime manufacture. One band is described as "an irregular band, 66 ft wide of cream-coloured, very pure high-calcium limestone", and another as "pure, cream-coloured limestone", in which a small quarry once operated (Goudge, 1945). These light coloured bands were said to be "irregular in their trend and cut across the stratification". Field investigation is needed to confirm whether these bands are light enough in colour for potential use as white filler.

Cambrian Formations overlying the Eldon (Pika, Arctomys, and Lynx Group) are exposed on the Spray Lakes Road above Canmore. These rock units are medium to dark grey dolomites and siliceous dolomites, with no industrial potential (Hamilton, 1969).

The Devonian Fairholme Group consists largely of grey to brown reefal dolomites. Overlying these are buff-coloured silty dolomites of the Alexo Formation.

Strata of the Devonian Palliser Formation contain much of the reserves of high calcium limestone in the area, and are quarried at Exshaw for cement manufacture. The rock is typically dark grey in colour, with no prospects for use as a source of white filler.

Mississippian Banff Formation carbonates are mostly grey coloured argillaceous and cherty limestones. The overlying Livingstone Formation is typically light grey, medium crystalline limestone, much of which is biofragmental. This unit is another excellent source of high calcium limestone for the area and is quarried in high tonnages for lime manufacture. However, the grey colour is not light enough to warrant consideration of the rock for filler use. The same comment applies to the remaining Mississippian carbonates exposed in the area (Mount Head and Etherington

Formations) which in addition, are cherty.

No carbonates occur in the Mesozoic section exposed in this area.

4.5 Nordegg Area

The Nordegg area lies in the central Alberta Foothills, about 160 km northwest of Bow Valley (Fig. 3). In this area, Devonian and Mississippian carbonates are exposed in an anticlinal structure on the Brazeau Range, a Paleozoic inlier in the Foothills. The Brazeau Range is breached at Nordegg by the Shunda Creek Valley, which links up with the North Saskatchewan Valley and David Thompson Pass to the west.

The oldest rocks exposed are uppermost beds of the Devonian Fairholme Group. These beds are mapped as the Mount Hawk Formation and consist of black argillaceous dolomites. The overlying Alexo Formation consists of silty and argillaceous limestones and dolomites with interbedded siltstones and shales.

The Palliser Formation is primarily dolomite in this area, a fairly pure carbonate rock in the lower part (lower 150 m) but medium brown in colour; the upper 110 m of the formation includes some dark grey limestone interbeds (Holter, 1976). Above the Palliser, the Mississippian Banff Formation has black shales grading upward into thin bedded cherty limestones and argillaceous limestones. Little economic potential exists for these or the underlying Devonian rocks.

The Pekisko Formation, lowest subunit of the Mississippian Rundle Group, consists of medium to coarse crystalline, crinoidal limestone. It is a high-purity carbonate rock and has been quarried on a small scale for agricultural and miscellaneous uses. However, the colour is buff to grey, not light enough for filler use.

The Shunda Formation overlying the Pekisko consists also of buff limestone but is fine grained and argillaceous, with some interbedded shale. The upper strata of the Rundle Group (Turner Valley and Mount Head Formations) comprise mainly of dolomites of buff to brown colour. No other carbonates rocks are exposed in the area.

4.6 Cadomin Area

The Cadomin area lies within the Foothills belt west of Edmonton, about 100 km northeast of Nordegg (Fig. 3). Geologically, the area is a segment of a Paleozoic inlier, the Nikanassin Range, in which Devonian and Mississippian carbonates are exposed in an anticlinal structure. At Cadomin, the Nikanassin Range is transected by the McLeod River.

The stratigraphic succession for this area is shown in Figure 6, although rock units older than Devonian are not exposed. The oldest carbonates in the Nikanassin Range belong to the Devonian Palliser Formation. Older rocks of the Fairholme Group are exposed in Miette Range (Front Ranges) to the southwest but are not readily accessible. These rocks are mainly dolomites with grey and brown colours.

The Palliser Formation is the source of the high calcium limestone quarried in large tonnages in the area (Holter, 1976). The rock is used for cement making and is hauled 300 km by train to a plant in Edmonton. Colour of the rock is medium to light grey, unsuitable for filler use.

The Mississippian Banff Formation comprises mostly shales and shaley dolomites with brown silty dolomites at the top. The Rundle Group, subdivided into four formations (Fig. 6), consists mainly of dolomites and limestones with colours ranging from grey to brown. No exceptionally pure or light coloured carbonates are noted in these Mississippian rocks (Macdonald and Hamilton, 1979).

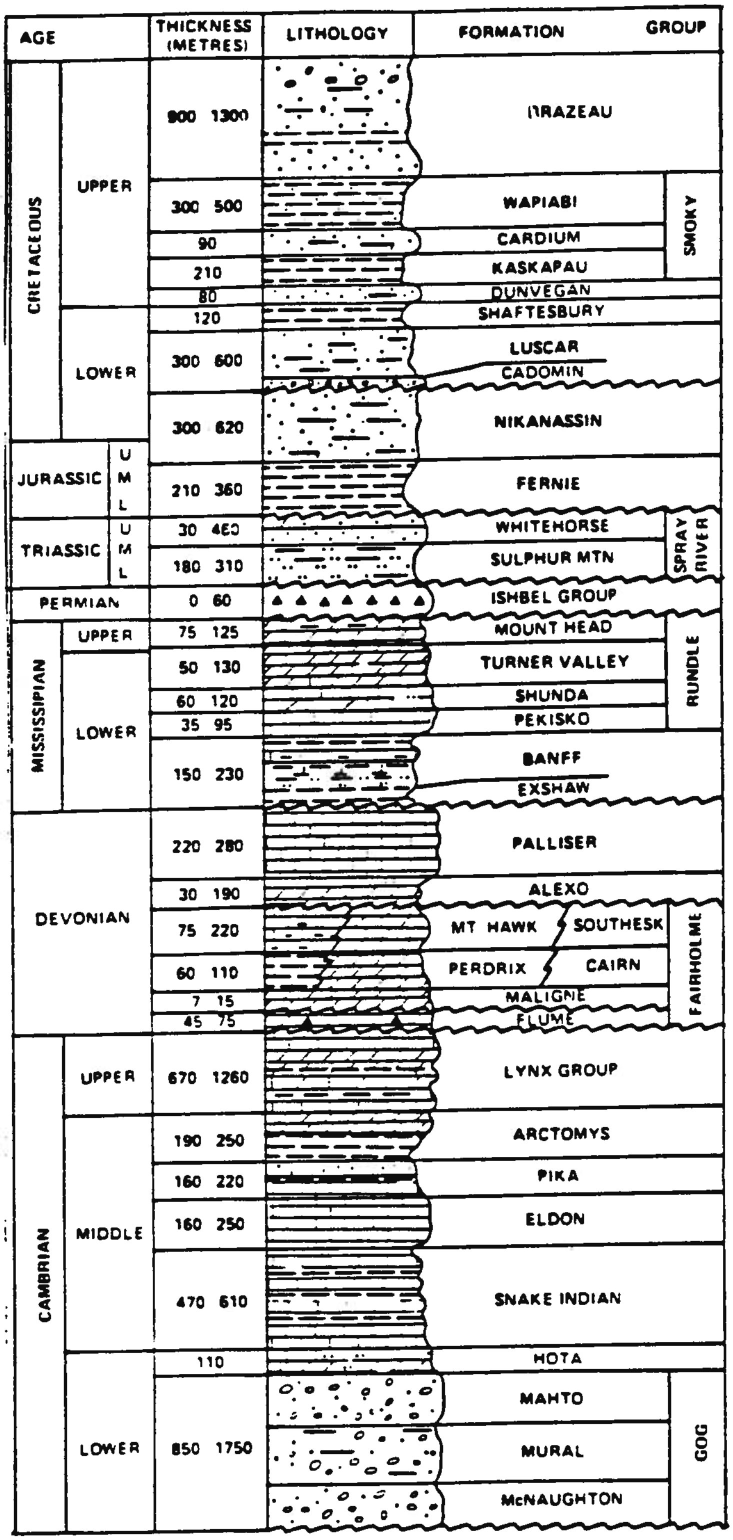


Figure 6. Stratigraphic Column for the Cadomin-Grande Cache areas.

Overlying the Mississippian in the Cadomin area is the Triassic Spray River Group. It comprises mostly clastic rocks, but has a carbonate unit at the top called the Whitehorse Formation (Fig. 6). The Whitehorse is the only significant carbonate found in the Mesozoic section of Alberta, and is thickly developed in this area. It consists mainly of dolomite that actually has good white colour in some beds, but is quite sandy (Hamilton, 1967). This renders an otherwise promising rock useless as a source of filler.

4.7 Brule Area

The Brule area lies at the eastern entrance to Yellowhead Pass, where the Athabasca River cuts through the Front Ranges. The area borders directly on Jasper National Park and only a narrow band of the Front Ranges lies outside the park to offer exploitable limestone prospects. Nevertheless, some high purity limestones are available.

Figure 6 illustrates the vertical succession of rock types found in this area. Devonian and Mississippian carbonates are exposed in the Boule and Fiddle Ranges, and in the core of the Folding Mountain anticline, a Paleozoic outlier about 3 km east of the mountain front. The lowest stratigraphic unit present is the Devonian Mount Hawk Formation, consisting of dark grey argillaceous limestone with some shale. Above it, the Alexo Formation comprises siltstones and silty dolomites.

The Palliser Formation contains massive beds of high calcium limestones which are typically dark grey coloured. Limited quarrying of this unit has occurred, though only for constructional use (riprap), despite the excellent grades available (Holter, 1976). The dark colour disqualifies it for use as filler.

Mississippian strata overlying the Palliser have little industrial potential in this area. The Banff Formation comprises shales and argillaceous limestones. The Rundle Group consists of grey limestones and dolomites subdivided into four formations

(Fig. 6). Some high calcium limestone beds are present in the Pekisko and Shunda Formations, but are lacking in good colour attributes.

4.8 Grande Cache Area

The Grande Cache area includes two areas, Adams Lookout and Clarks Crossing (Fig. 3). These areas are remote and have neither road nor rail access, but were explored initially (Macdonald and Hamilton, 1979) because of proximity to the Alberta Resources Railway, which passes within 30 km to the east. In both areas, the Front Ranges are breached by major river valleys, to bring Paleozoic carbonates into potentially exploitable situations.

The stratigraphic column for the Grande Cache area is as given in Figure 6. Devonian and Mississippian strata are exposed into anticlinal structures in the Hoff and Berland Ranges, which are cut by the Berland River near Adams Lookout; and in the de Smet Range, cut by the Smoky River at Clarks Crossing.

The oldest rocks exposed in the area belong to the Devonian Fairholme Group, consisting of argillaceous limestones and shales, with some dolomites. The overlying Palliser Formation consists of massive bedded high calcium limestones up to 260 m thick. Although the rock is very pure, the colour is typically dark grey, making it unsuitable for use as filler.

Mississippian strata of the Banff Formation and Rundle Group are essentially the same as described for the Cadomin and Brule areas, ie comprised of impure carbonates with grey and brown colours. At Adams Lookout, the Pekisko Formation consists of exceptionally pure limestone at one locality, but the olive grey colour negates any prospects for the rock as a source of filler. No other carbonates are exposed in the area (apart from the sandy dolomites of the Triassic Whitehorse Formation).

4.9 Fort McMurray Area

The Fort McMurray area lies in the northeastern Alberta plains, centred at the junction of the Athabasca and Clearwater Rivers. The valleys of these two rivers are incised through the Cretaceous rocks of the region to expose flat-lying Devonian strata. The strata also form a broad near-surface subcrop belt across northeast Alberta (and Wood Buffalo National Park) as shown in Figure 3. Thus are formed the only surface deposits of carbonate rocks in Alberta outside the mountain belt.

The stratigraphic column for the Fort McMurray area is shown in figure 7. The oldest carbonates exposed are reefal dolomites of the Methy Formation of Middle Devonian age. This unit forms the resistant rock outcrops that give rise to Whitemud Falls on the Clearwater River, near the Saskatchewan border (Hamilton and Mellon, 1973). The dominant rock type is a coarse crystalline, vuggy dolomite with a very pure carbonate content, but with colours ranging from light grey to brown. Whitemud Falls is remote, 80 km east of Fort McMurray, with no road access.

Units above the Methy are exposed discontinuously along the Clearwater and Athabasca valleys. The evaporitic Nyarling Formation does not outcrop, but the Upper Devonian Waterways Formation is seen in numerous low outcrops of nearly flat-lying beds. The Waterways consists generally of grey to brown argillaceous limestones and grey shales. The limestones have rather low carbonate purity and little potential for industrial development (Holter, 1976).

4.10 Untested Areas

In previous studies of Alberta limestone resources, some areas known from geological mapping to contain high purity carbonates were not surveyed. These included protected areas, remote or inaccessible areas, and some areas beyond the economic range for conventional industrial limestone markets. Areas of the latter category are

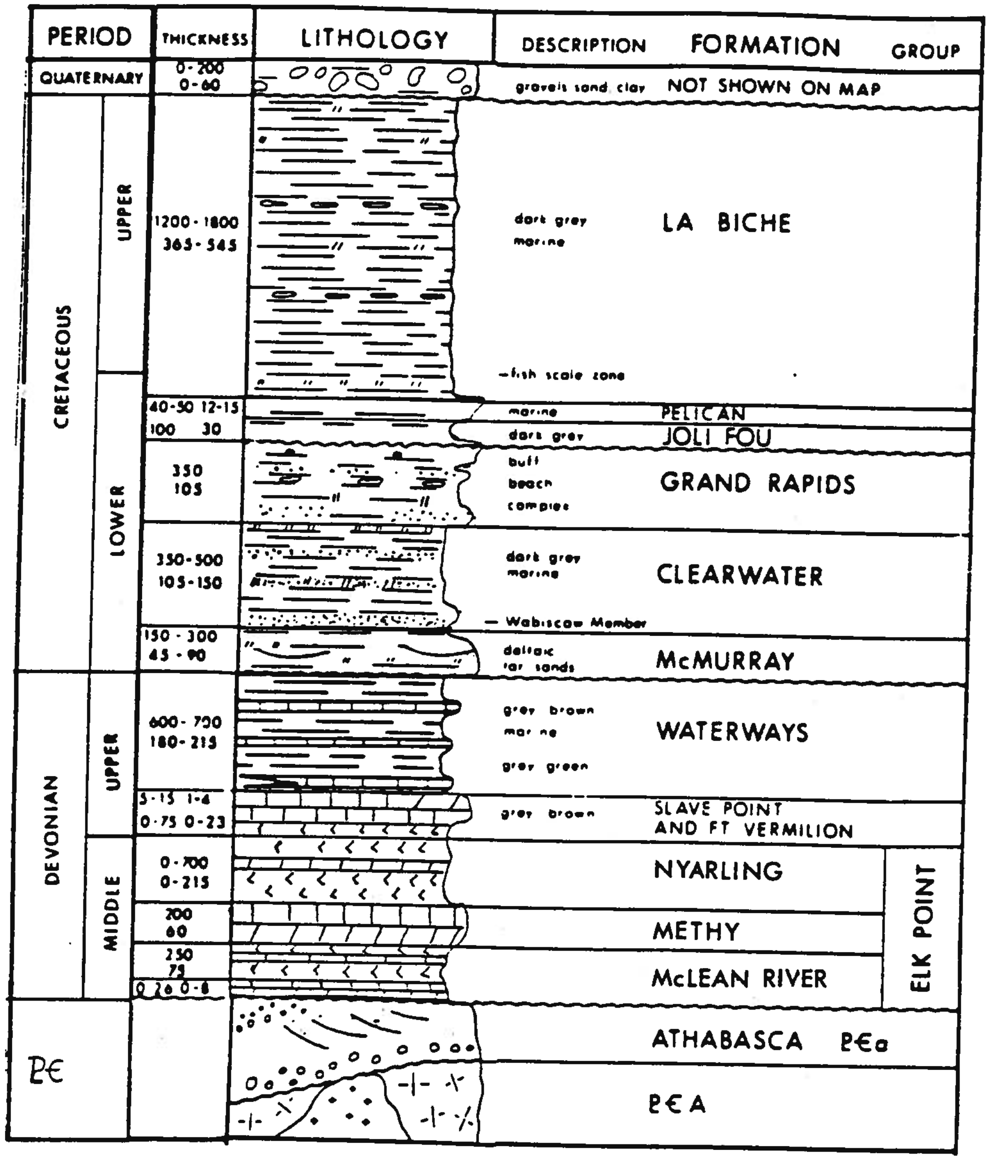


Figure 7. Stratigraphic column for the Fort McMurray area

reconsidered for this study, because of the higher market value that fillers hold for limestone.

One prospective area is in the Clark Range between Crowsnest Pass and Waterton Park. This area has rugged terrain, with limited road access provided along the valleys of Castle and Carbondale Rivers. Much of the area is underlain by Precambrian rocks of the Purcell Supergroup. Of particular interest is the basal unit of this series, the Waterton Formation. In mapped exposures of this formation, one of its principal rock types is described as "white, very fine crystalline and cryptocrystalline limestone" (Douglas, 1952). This unit deserves field investigation as a potential filler source.

In other parts of the area, the Devonian Fairholme Group may offer some prospects for its reefal members, Peechee and Arcs, both described as "white and light grey, coarse crystalline dolomite" (Price, 1962). Further geological analysis and some field checking is needed to evaluate the potential for these units.

Another untested area is the David Thompson Corridor west of Nordegg, where the North Saskatchewan River transects the Front Ranges and eastern Main Ranges of the Rockies. Paleozoic strata are well exposed along here. The Devonian and Mississippian successions illustrated in Figure 6 are completely exposed in the eastern part of the corridor. In addition, older strata normally seen only in the Main Ranges (in the National Parks) are exposed in the western part of the corridor. These strata include the complete Precambrian and Cambrian successions illustrated in Figure 5, which is representative of the lower Paleozoics for this area.

Study of the David Thompson Corridor is warranted particularly for its unique exposure of lower Paleozoics and the great carbonate formations of the middle and upper Cambrian (see Fig. 5). The area has not been geologically mapped at detailed scale, and practically no data exists on the industrial quality of these carbonates, though they exceed 1500 m in total thickness. With such a great thickness of carbonates, the probability of finding white limestone seems better for this area than for any other in Alberta.

4.11 Summary of Evaluations

This study evaluates limestones for potential white filler use in seven areas of Alberta where previous field studies and detailed analyses were conducted. In addition, preliminary assessments are made of two areas where the limestones were not previously investigated. A summary of these evaluations is as follows:

(1) Although limestones and dolomites are abundant in all areas studied, the characteristic colour of the rocks is grey. White colours are rarely seen in the typical Paleozoic carbonates exposed in the mountains.

(2) In the Crowsnest Pass area, one prospect is identified for further study. The Peechee reef dolomite member (Devonian Fairholme Group) has localized exposure in Phillipps Pass, with very light grey to white colours.

(3) In the Bow Valley area, the only possible prospect identified is a "cream coloured" limestone bed of localized extent in the Cambrian El~~ko~~don Formation, near the old quarries at Kananaskis.

(4) The Nordegg, Cadomin, Brule and Grande Cache areas all have abundant high purity limestones but no indications of white carbonate rocks.

(5) Limestones exposed in the Fort McMurray area are generally of inferior carbonate quality. The Devonian Methy Formation is a very pure dolomite but with grey and brown colours, and its outcrop is quite remote.

(6) The best prospects for white carbonates seem to be in areas

previously untested. In the Clark Range area, the Precambrian Waterton Formation is reported to include beds of white limestone. In the David Thompson Corridor, the great thickness of Cambrian carbonate strata exposed makes the area prime exploration ground for carbonates with special attributes.

5. CONCLUSIONS

Alberta is not an ideal geological environment for the occurrence of white limestone. The areas evaluated for this study have abundant carbonate rocks of high purity, but with colours mostly of grey. The colour is due to organic content, reflecting the shallow marine environments (with their great abundances of marine organisms) that these carbonates formed in during Paleozoic time. Since deposition, no metamorphic events have occurred in Alberta's geological history that would transform the carbonates into marble, a common type of white carbonate rock.

Nevertheless, localized beds of exceptionally light colour have been noted in some of the areas studied and warrant further investigation. So do the areas not previously studied, which seem to offer the best prospects for white limestone. These prospects are in some of the oldest sedimentary rocks of the province. In the Clark Range, the Precambrian Waterton Formation, reported to include white limestones, is the oldest carbonate-bearing unit mapped in Alberta. In the David Thompson Corridor, the great thicknesses of Cambrian carbonates have their only full exposure outside of National Parks, but are unmapped in detail and unstudied from an industrial use standpoint. A conclusive evaluation of Alberta's filler-grade limestone potential requires specific field studies of all these prospects.

6. RECOMMENDATIONS

Fieldwork, sampling and laboratory tests are recommended as below, to check out prospective occurrences identified from previous studies, and to investigate prospects in unstudied areas. In these studies, laboratory tests would include routine chemical analysis, and whiteness tests performed on finely ground material using standard brightness measuring instruments. Field observations would include estimates of recoverability of material and potential reserves in each prospective locality.

1. Re-examine prospective occurrences in the Crowsnest Pass area (Peechee dolomite outcrop in Phillipps Pass), and the Bow Valley area (Eldon limestone bed near old Kananaskis quarry).

2. Evaluate Waterton Formation prospects in the Clark Range area by traversing the mapped formation outcrop belt at accessible points, to locate and test reported beds of white limestone.

3. Explore the thick Cambrian carbonate succession in the David Thompson Corridor area; locate and map* any light coloured zones and test prospective beds.

*Note - Geological maps at detailed scale are not available for this area.

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APPENDIX

Excerpts from Scafe and Hamilton (1985): Study of Potential Sources of Paper Coating/Filler Materials for Alberta

2. MINERAL COATING AND FILLER MATERIALS IN PAPER MAKING

2.1. TECHNOLOGY OF PAPER MAKING

Paper consists of a mass of fibres, arranged in all directions, with numerous air spaces between them. Cellulose, the principal component of papermaking fibres, may be extracted from nearly all plants but the most common fibre source is wood (see Appendix 1 for a summary of the papermaking process). Cellulose fibres are nearly transparent, but massed in a sheet of paper the light striking the sheet is scattered, making the paper appear opaque with a white matte surface. The extent of this opacity depends on the number of light absorptive or reflective fibre surfaces. Opacity may be improved by the addition of mineral fillers whose small particles impregnating the sheet help to scatter the light. Minerals also may be applied as a thin film or coating on the surface of the paper to mask microscopic imperfections of the paper surface, improve its receptivity to printing ink, apply a moisture resistant film, reduce abrasion, and limit fluffing to produce a high grade product.

2.2. GENERAL REQUIREMENTS FOR FILLERS AND COATERS

Any filling or coating material must have:

- high reflectance at all wavelengths of light to give maximum brightness and whiteness
- high refractive index to increase opacity and brightness
- rheological properties that permit easy flow and application
- chemical inertness and insolubility
- freedom from impurities (especially grit)
- particle size distribution around 0.3 μm (half the wavelength of light)
- a soft, nonabrasive nature
- a surface flexible enough to form either a matte or gloss finish with processing
- good retention in the cellulose fibre web

- low specific gravity preferable
- low price

Kaolin goes further than any other mineral in fulfilling the points outlined above to make the perfect filling or coating material and accounts for 80% of the white minerals used in the paper industry.

5. CALCIUM CARBONATE COATER/FILLER

Calcium carbonate serves the similar functions to kaolin in paper filling and coating , i.e. of increasing opacity and brightness, providing better ink receptivity, and improving surface smoothness. As calcium carbonate is potentially reactive, its use as a filler in an acid paper system that uses alum-rosin sizing is quite limited, confined mainly to a filler in unsized paper such as bible and cigarette paper. However, in alkaline paper-making systems its use is extensive. Assuming the required whiteness, the physical size and shape of the particles and freedom from abrasive impurities are the main factors affecting the coating performance (MacGugan, 1971). By combining a diffusely reflecting and double refracting crystal with an extremely small particle size, high opacity can be obtained even in thin layers (Hagemeyer and Brooks, 1966). Calcium carbonates for coating primarily range in size from 5-0.1μm. In this size range proper dispersion is necessary for the material to perform satisfactorily.

Calcium carbonate filler produces a strong paper that allows calcium carbonate loadings as high as 50%. Typical filler levels in uncoated paper, however, range from 5-15% and coated paper usually has 3-9% filler. Natural, ground calcium carbonate (limestone or marble) with an average particle size of 1-3μm and a top size of 10-15μm (called fine grades), are suitable for filling purposes and sell for prices ranging from US $95/tonne (for grades with an average particle size of 3μm) to US $145/tonne (for grades with an average particle size of 1μm). Superfine grades used for coating have a top size of 4μm, an average size of less than 1μm and sell for US

\$128/tonne in slurry form or US \$175/tonne dry. In North America the superfine grades are produced only in the United States (Guillet and Kriens, 1984). Only Washington, of the western bordering states, produces limestone material that could be used as filler/coater in the paper industry. Near Seattle, J.A. Jack and Sons process 4μm material with a minimum brightness of 88 for the Calcium Carbonate Co., a subsidiary of J.M. Huber Co. one of the largest producers of kaolin. At present no material is sold to the paper industry, because no mills in the area use the alkaline process, although the plant was built in anticipation of construction of such a plant.

In western Canada, International Marble and Stone Co. Ltd. mines limestone that has brightness of 94.85 from the Reeves Member of the Laib Formation of Early Cambrian age near Salmo, in southeastern B.C. The company also mines limestone that has brightness of 94.95 from the Quatsino Formation of Late Triassic age near Port McNeill, on Vancouver Island, B.C. At present, the company cannot grind to superfine sizes but does produce the fine grade. This company is the only one in western Canada currently producing white limestone filler material. Other deposits of white limestone or marble are scattered in several localities in B.C. but are poorly documented. The full potential for coater/filler grade calcium carbonate in B.C., although promising, largely is unexplored.