Open File Report 1990-11

An Evaluation of Alberta Limestones for Use as Paper Filler Materials

Prepared for: Alberta Forestry, Lands and Wildlife
Forestry Industry Development

By:

ALBERTA RESEARCH COUNCIL

Alberta Geological Survey

MINPROBE Consultants Ltd.

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EXECUTIVE SUMMARY

Limestone is found in Alberta along the entire length of the Foothills and Front Ranges trend of the western side of the province as well as within northeastern Alberta in the Fort McMurray area (see Figure 1-4). None of the limestones tested from seven of the nine major localities of accessible outcrops is capable of producing ground calcium carbonate (GCC) paper fillers of acceptable quality due to low brightness characteristics. Two deposits (one at Kananaskis, the other at Windy Point; see Figures 3-3 and 3-5b) may be of suffiient quality to be blended in reasonably high proportions with industry standard GCC from outside the province to yield an acceptable filler.

The best possibility for the extensive use of Alberta limestone as paper filler material seems to be through the production of precipitated calcium carbonate (PCC). This material is currently being produced from lime manufactured from limestone quarried by Continental Lime in the Bow Corridor.

A comparison of GCC and PCC products indicates that the latter form of filler will be favored by the pulp and paper industry in the future. The PCC materials are less expensive to produce, yield a high brightness, may have more consistent fine size ranges, possess high surface area characteristics, and demonstrate many other properties favorable to the manufacturing of fine paper. The trend towards establishment of alkaline systems in pulp and paper operations will result in an increased use of calcium carbonate as a paper filler media.

Several deposits of limestone in Alberta may be worthy of further consideration as lime and PCC plant feedstock. As proven by the experience of Continental Lime a rock which has good calcining properties as well

as low contents of dolomite, silica, iron oxides, alumina, and sulfur may be suitable.

Additional work is recommended to further define the quality of Alberta limestones for use as paper filler materials. Tests should be carried out to document lime-making and PCC production capabilities of rock from selected deposits within the province.

ACKNOWLEDGEMENTS

The writer is indebted to several individuals and firms which have contributed to the collection and preparation of the data contained herein. Mr. W.N. Hamilton of the Alberta Geological Survey was largely responsible for formulating the scope of study and provided considerable support during the preparation of the report. Mr. M.R. Baaske prepared all samples for analysis and completed the sedigraph testing. Brightness tests were preformed by J. Laidler, chemical analyses were run by J. Nelson, and S.E.M. photomicrographs were prepared by E. Zacharuk, all of the Alberta Research Council.

The following company and agency representatives are to be acknowledged for their cooperation:

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Saskatchewan Recreation and Parks (Forestry Division):

J. Benson
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Summit Lime Works:

N. Clairingbone
Sentinel, Alberta

Westmin Resources Limited:

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A considerable amount of information was also obtained through a series of telephone conversations and correspondence with additional miscellaneous contacts.

1. INTRODUCTION

1.1 Background and Scope

The projected expansion of pulp and paper production in western Canada provides for considerable additional demand for associated mineral commodities into this industrial sector. The status of plant development to this point in time is summarized in Figure 1-1, including data from some recently announced programs for new development. Of particular interest in connection with the growing Alberta pulp and paper industry is the potential for supply of limestone as a paper filler from local deposits. This report is intended to achieve three major tasks in an attempt to expand the current knowledge of paper filler technology as it may prove to be applied to the Alberta industry in the near future:

1.) Briefly review the respective potential of using ultra-fine ground calcium carbonate (GCC) and precipitated calcium carbonate (PCC) in future paper mill developments.
2.) Evaluate the currently available data on Alberta limestones with respect to GCC and PCC useage.
3.) Report on recent field studies which update the information on Alberta deposits.

In order to properly determine the best possibilities of using either GCC or PCC products several operating facilities were visited during the course of the study. The plant operations of International Marble and Stone Company Limited (IMASCO) near Creston and at Surrey, British Columbia were toured to learn of procedures necessary to produce a fine-ground product. The production of precipitated calcium carbonate was reviewed through visiting plants operated by Continental Lime Inc. at Tacoma, Washington and Prince Alberta, Saskatchewan. Lime-making facilities of Continental Lime Ltd. at Exshaw, Alberta and Summit Lime Works at Sentinel, Alberta were briefly

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examined. The pulp and fine paper plant operated by Weyerhaeuser Canada Ltd. at Prince Albert, Saskatchewan was also visited.

An extensive review was carried out of all previous evaluation work completed on limestone deposits in Alberta and selected sites were revisited to obtain samples which were subjected to analytical procedures unique to the testing of filler-grade materials. Previously unreported field work carried out by W.N. Hamilton in 1988 has also been included herein and this information constitutes a very significant contribution to the existing data base.

1.2 Limestone Production Areas

The current distribution of limestone production sites in Alberta is shown in Figure 1-2 in relationship to proposed paper production facilities. All indicated limestone quarries, with the exception of the Cadomin operations of Inland Cement, were visited in order to obtain samples for testing for filler quality. Quarry rock from Cadomin was sampled at the Inland Cement plant in Edmonton. Two other localities which are not under production at this time were also sampled (the Kananaskis and Windy Point sites). The abandoned quarries of Loders Lime near Kananaskis and outcrops at Windy Point along the David Thompson Highway were previously determined by Hamilton (1986) to include light-colored rock which could be considered for filler useage.

Properties which are presently producing limestone in British Columbia are indicated in Figure 1-3. Sites in the northeastern sector of the province may be considered to be in favorable geographical locations to serve at least the western part of Alberta. In view of this, it may be anticipated that some competitive marketing of such limestones into Alberta may be a real possibility in the near future.

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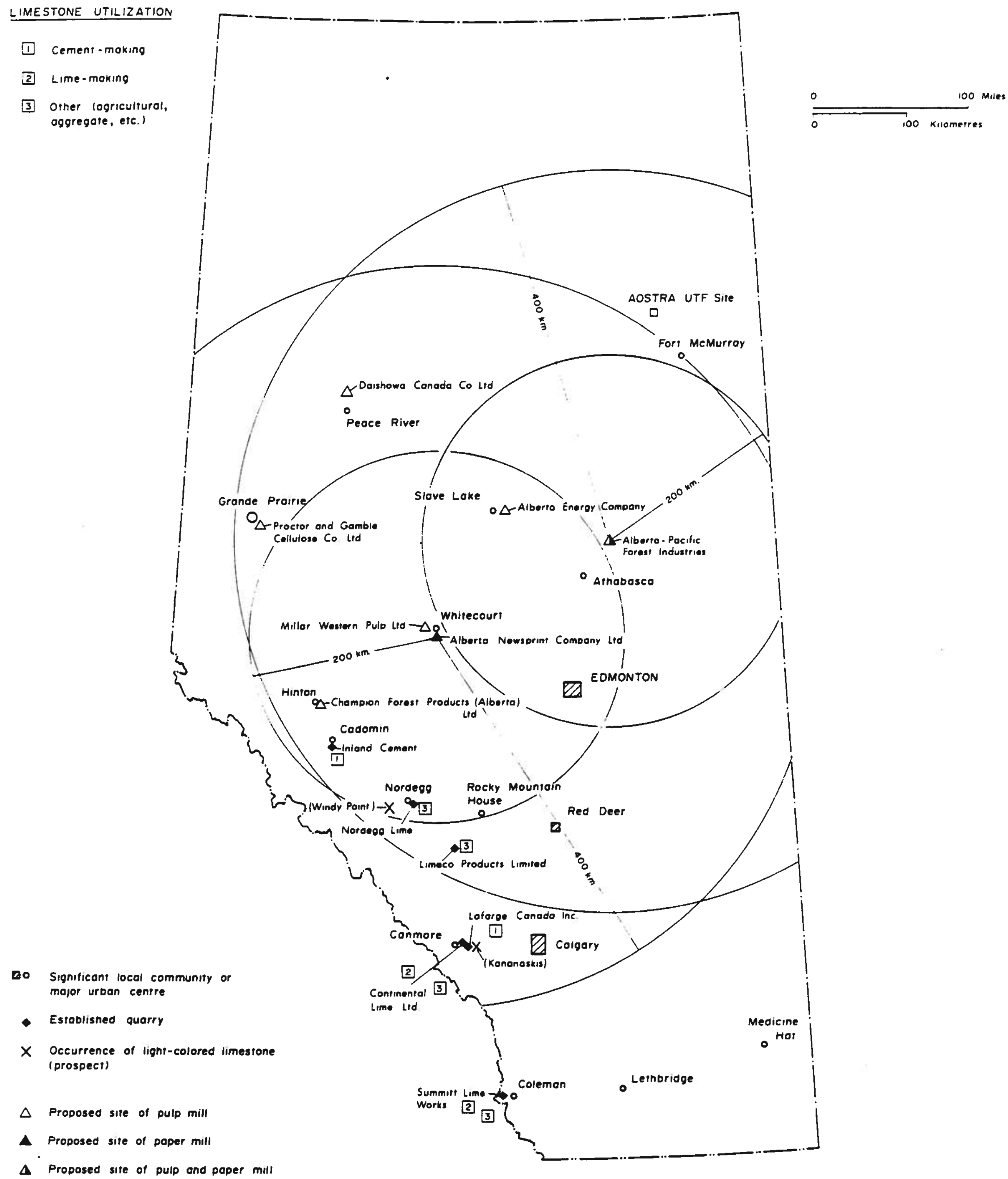

FIGURE 1-2

Alberta Limestone Quarries

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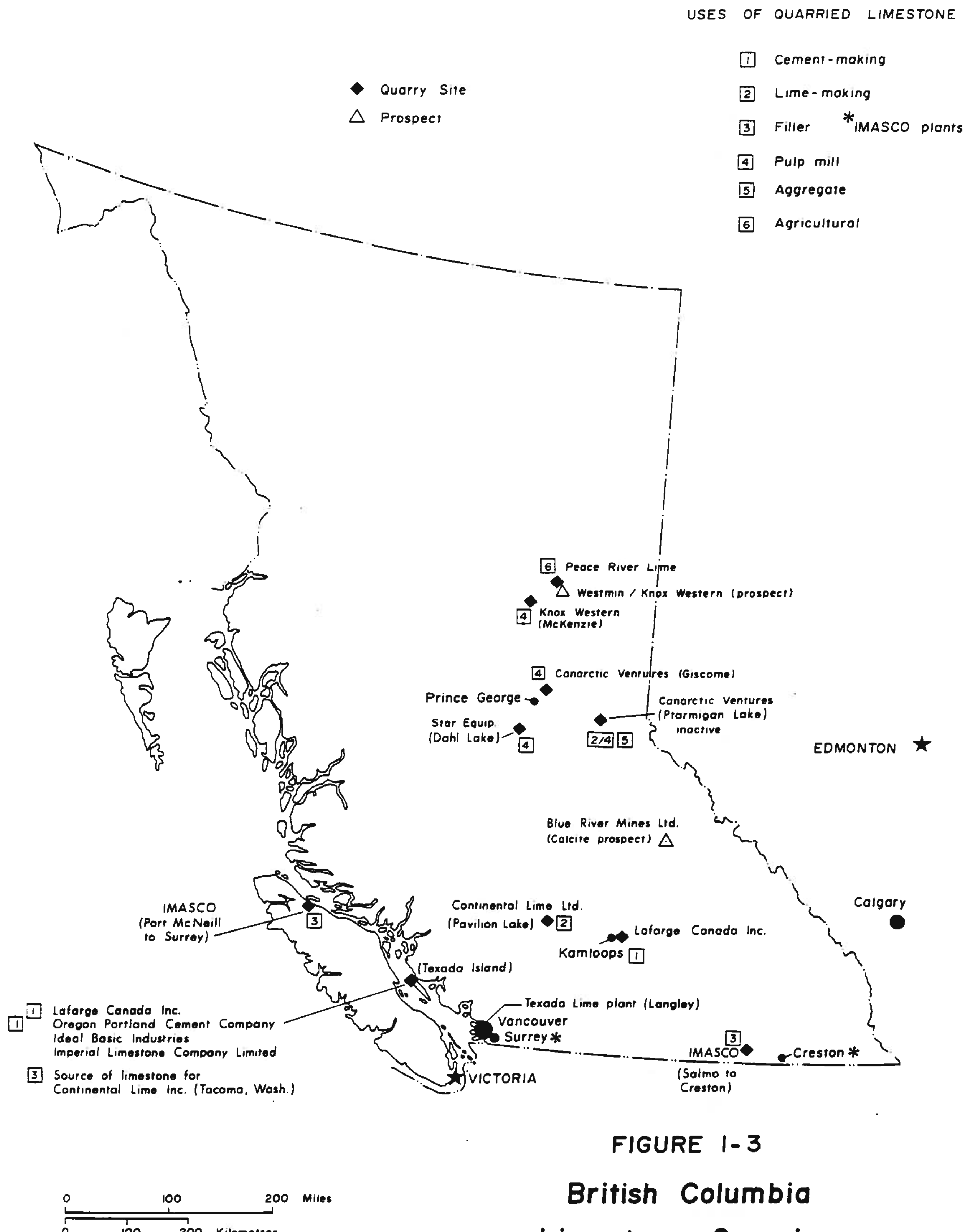

FIGURE 1-3

British Columbia Limestone Quarries

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1.3 Regional Distribution of Limestone

Limestone deposits are widespread throughout western Alberta as well as to the northeast in the Fort McMurray area (Figure 1-4). Current production is exclusively from beds of the Rundle Group (Mississippian age) and the Palliser Formation (Devonian age). A more extensive consideration of geological conditions, quarry locations, and accessible areas for future development will be considered later in the report.

1.4 Limestone Fillers

The selection of a filler and/or coating in paper production is primarily dependent upon the manufacturing process involved. It is imperative, for example, that a paper plant operate on an alkaline sizing process if calcium carbonate is to be used. Although there is a current trend towards the use of the alkaline technique some existing plants operate on an acidic system and must therefore employ more inert minerals such as kaolin, talc, barite, mica, or silica. It has been estimated that 35 percent of North American fine paper production is presently based on alkaline process and by 1998 this will increase to 90 percent (Continental Lime, pers. comm.).

Any mineral employed as a filler material is usually added to the basic mixture of wood pulp at the start of the paper-making process. The mineral particles are retained within the resultant paper sheet and help to fill the voids created where the cellulose fibres overlap, thus producing a smoother paper which takes print better. Alternatively, as a coating pigment, the mineral is applied to the surface of a finished paper as a slurry containing a binder which adheres to the paper. A smoother, glossier surface results which is preferable for high quality color printing. The printing is thus done on the mineral itself and not on a mixture of mineral and fibre

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as in the case of filled paper. The net result of utilizing a satisfactory calcium carbonate filler and coating is to increase the opacity and brightness of the paper, provide better ink receptivity, and to improve surface smoothness (Scafe and Hamilton, 1985).

Calcium carbonate filler results in a strong paper that allows mineral loadings as high as 50 percent (Scafe and Hamilton (op. cit.). Typical filler levels in uncoated papers may, in fact, range from 5 to 15 percent and coated papers usually have 3 to 9 percent mineral loading. Ground calcium carbonate is suitable for filler purposes if average size ranges are between about 1 to 3 microns and the top sizes do not exceed 10 to 15 microns. Superfine grades are used for coating if they achieve an average size classification of about 1 micron with a top size of 4 microns. It is commonly noted that the finer a given filler or coating is ground the whiter it will appear. The brightness factor is normally determined by TAPPI (The Technical Association of the Pulp and Paper Industry) or ASTM (American Society of Testing and Materials) standards of testing and is expressed as a percentage. A brightness of at least 92 percent is generally regarded to be necessary for fine paper production although values as low as 80 percent may be tolerated in some circuits.

The main criteria applied in the choice of the best filler source normally include the following (Guillet and Kriens, 1984):

1.) Whiteness (brightness).
2.) Particle shape.
3.) Particle size.
4.) Cost.

Secondarily, there are other physical and chemical properties to be considered, such as:

1.) Weight.
2.) Opacity.

3.) Hardness.
4.) Chemical inertness.
5.) Refractive index.
6.) Mineral purity.
7.) Receptivity to ink.
8.) Retention characteristics in the paper web.
9.) Rheological properties affecting flow and application.

Calcium carbonate is commonly preferred as a mineral filler in a nonacidic system for several reasons:

1.) It may provide excellent whiteness.
2.) Equidimensional particle sizes may be achieved.
3.) Calcium carbonate produces low absorption behavior (generally, an indicator of particle size, size distribution, and surface area).
4.) It may be readilly available and at a relatively low cost.
5.) These materials are normally free of troublesome grit.
6.) A precipitated product is especially noted for good ink absorption.

The use of either ground calcium carbonate or precipitated product is relative to several factors among those noted above. The PCC materials tend to be favored for the following specific reasons:

1.) A more consistent product may result in terms of brightness, size ranges, and chemical purity.
2.) The cost of production is reported to be lower ($100 or less per tonne for PCC versus costs as high as $200 per tonne for ultra-fine GCC).
3.) Transportation costs may be less if lime rather than limestone quarry rock must be delivered to on-site facilities.
4.) Elimination of large volumes of CO_2 from the pulp mill or lime-making operations may be realized

by recirculting gaseous effluents through the PCC production process thus alleviating any negative impact on the environment.

1.5 Limestone Specifications for PCC

The use of limestone for PCC production is related more or less to the ability of a limestone to make a high quality lime product. At a temperature approaching 900°C the CO_2 begins to be driven off resulting in a general weight loss of 40 to 44 percent. During calcination impurities within the limestone remain unaltered and are effectively doubled in content in the lime. Several natural contaminants impede the degree of usefulness of the lime. Any SiO_2 present will, for example, react with the CaO (quicklime) to form a dicalcium silicate, bonding two molecules of CaO with every one of SiO_2 thus leaving them unavailable for hydration. Similarly, iron, alumina, and sulfur yield other mineral forms such as ferrites and aluminates which reduce the available CaO.

Dolomite in the limestone will result in slower lime reaction time for completion of hydration and is therefore not normally tolerated in contents exceeding 5 percent (MgO equivalents).

The ideal lime product is one produced from limestone having a minimum of 97 percent combined carbonate content resulting in production of pure CaO with high porosity. The large amount of internal surface area of this so-called soft burned material is directly related to high chemical purity. If limestone is burned at excessively high temperatures the lime shrinks, a denser product results (hard burn), and the chemical reactivity is more limited.

The rate of calcination is effected by the ability of the CO_2 to diffuse to the surface of the burned material, the presence of impurities, differences in crystallinity, grain boundary conditions, density variability, and atomic lattice inperfections (O'Driscoll, 1988). A given limestone can only be verified for use in lime production after successful completion of adequate burn tests designed to evaluate the various limiting factors (Boynton <u>et</u> <u>al</u>, 1983).

The effectiveness of a given lime in production of acceptable PCC materials for paper use is less well documented. It is purported by some operators that most lime products will suffice to manufacture PCC. Others strongly express the opinion that not every lime will make a satisfactory precipitated product for filler use.

2. PROCESSING

The use of limestone and limestone by-products is implicated in a number of ways within the circuitry of a pulp and fine paper plant. Besides the application of PCC or GCC filler materials to the pulp sheet through the head box in the paper mill there is additional utilization of calcium carbonate within the recovery process (Figure 2-1). Slaked lime is introduced to the caustic reactor system to recover sodium hydroxide and sodium sulfide from the green liquor reagents and to consequently produce fresh cooking chemical for utilization in the digester unit (Figure 2-2). The lime is commonly produced in kilns on site from calcium carbonate mud recovered from the caustic reactors. Approximately 5 percent make-up lime must be added to the system, usually from bulk material delivered to the plant from outside commercial sources. Alternatively, additional limestone rock may be passed through for calcining along with the recovered reactor mud.

An on-site PCC plant is capable of utilizing CO_2 generated within the plant for reconstitution of calcium carbonate. The gas may be drawn directly from the lime kiln or from stack gases emanating from the boiler systems.

The production of GCC involves a series of grinding, screening, and air classification stages, each of which includes return circuits for oversize materials (Figure 2-3) The initial stages of processing normally follow dry procedures but ultra-fine grinding may require wet grinding. These final stages of GCC production employ sophisticated and relatively expensive equipment and result in a slurried product.

North American processes for manufacturing PCC materials begin with the treatment of lime. The production sequence for a lime plant is shown in Figure 2-4 indicating

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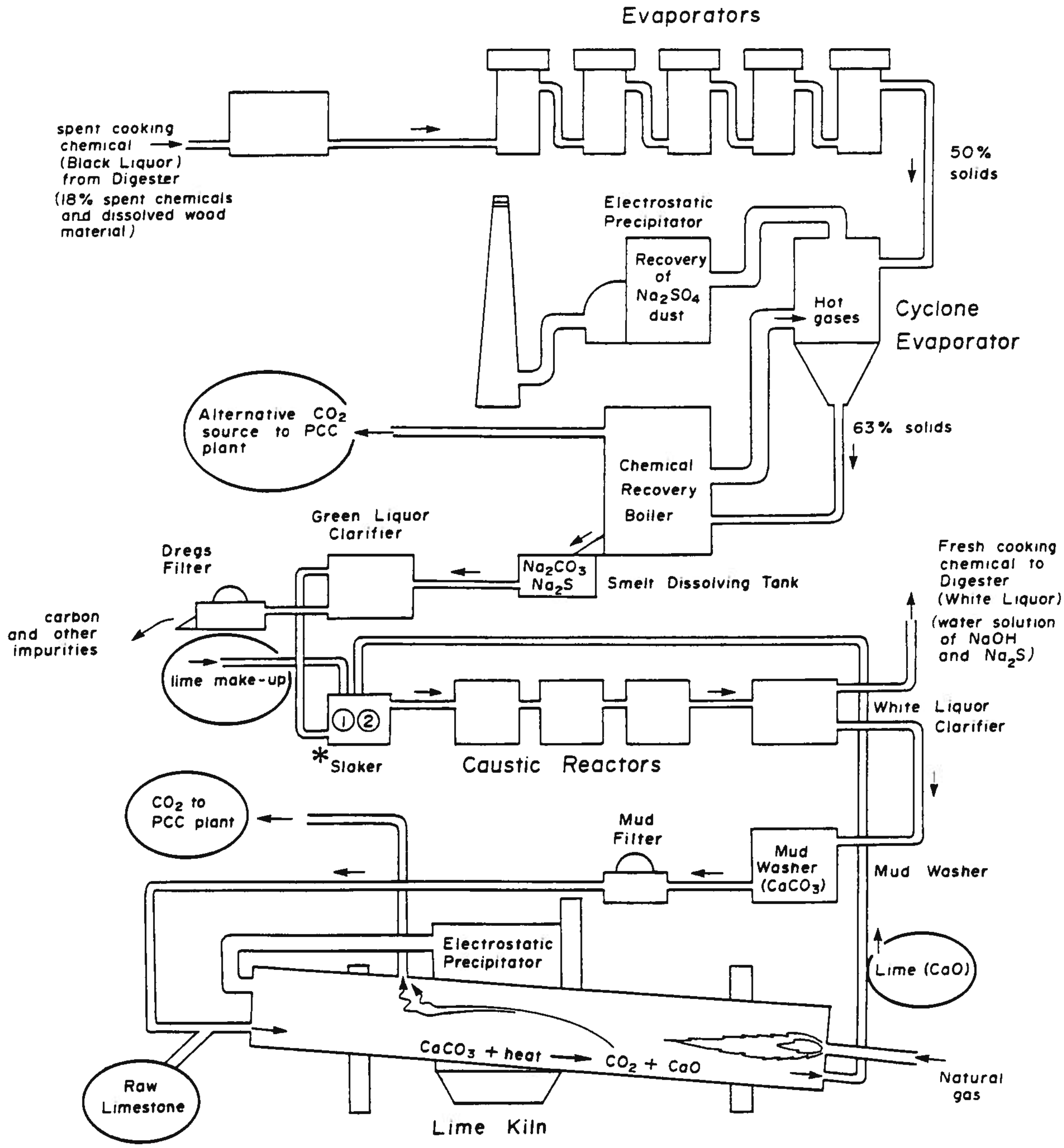

* ① $CaO + H_2O \rightarrow Ca(OH)_2$

② $Ca(OH)_2 + Na_2CO_3 \rightleftharpoons 2NaOH + CaCO_3$

FIGURE 2-2

Chemical Recovery Process in a Pulp Mill

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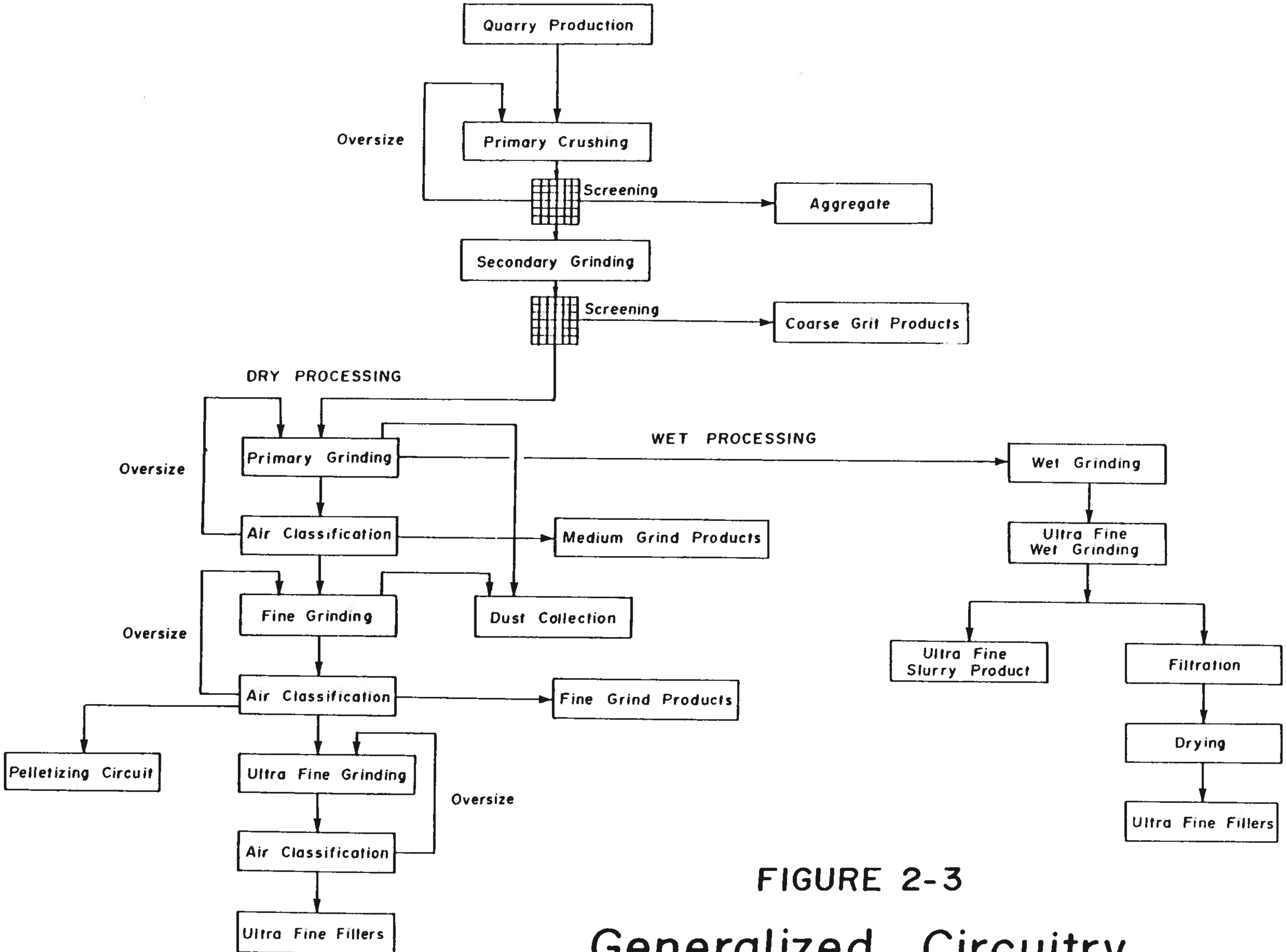

FIGURE 2-3

Generalized Circuitry for GCC Production

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the progression from quarry-run deliveries, through calcining, to the screening, grinding, and distribution to storage and loadout of the various by-products and sizes. Although the PCC production process is considered proprietary information by all current manufacturers the general circuitry is well known. Limestone passes through calcining, hydration, and carbonation stages as shown in Figure 2-5 at the combined lime and PCC plant (from which a slurried product may be delivered some distance to the paper mill) or, alternatively, lime is delivered to a PCC production unit on site for continuous production of slurry feed to the adjacent paper plant. The PCC may be dewatered for convenience of storage. A slurry made up of 17 to 30 percent solids may normally be pumped and is therefore readily transportable. A solids concentration of about 17 percent is commonly fed to the headbox in the paper mill.

Precipitated calcium carbonate may be produced by at least two other processes. One such system is based on the ammonia process developed by Solvay for the production of Na_2CO_3. The essential part of the process for development of PCC is as follows:

$$CaCO_3 \xrightarrow{heat} CO_2 + CaO \xrightarrow{H_2O} Ca(OH)_2$$

$$Ca(OH)_2 + 2NH_4Cl \longrightarrow 2NH_3 + 2H_2O + CaCl_2$$

$$\xrightarrow{CO_2} H_2O + 2NH_4Cl + CaCO_3$$

The precipitated $CaCO_3$ must then be washed to remove soluble salts, dried, and micropulverized. Particle sizes are controlled by temperature, concentrations of constituents, rate and order of additions of reactive materials, and the mode of agitation.

In the NaOH process the $CaCO_3$ is calcined, as before, to form CaO which is reacted with water to form $Ca(OH)_2$. The reaction continues as follows:

$$NaCO_3 + Ca(OH)_2 \longrightarrow 2NaOH + CaCO_3$$

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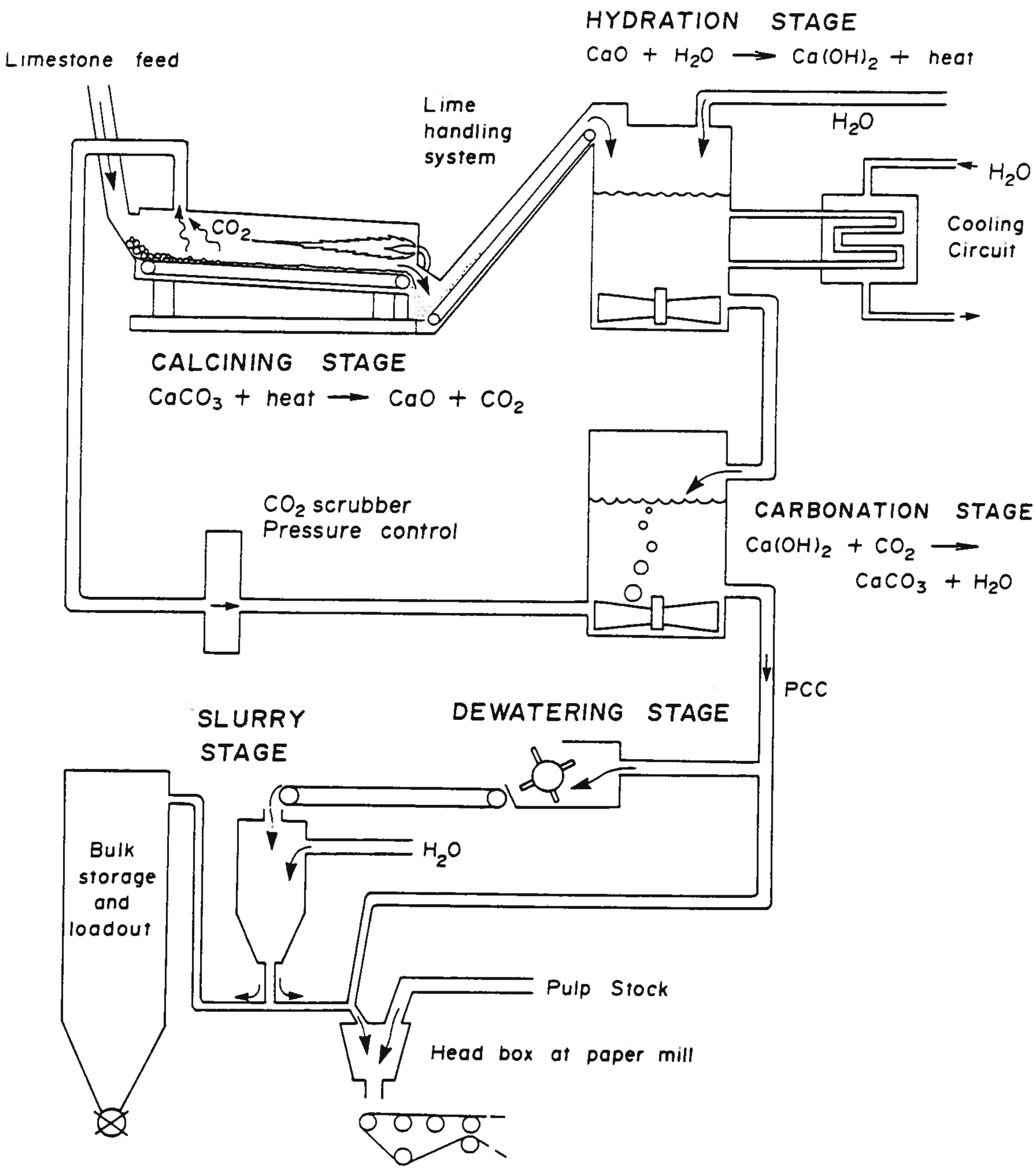

FIGURE 2-5

Generalized Circuitry for PCC Production

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Neither of the above two processes are considered to be preferable to the recarbonization procedures due to economic restrictions and the more limited access to the reactive additives.

3. GEOLOGY

Extensive work has been carried out previously on limestone deposits in Alberta. Studies by Goudge (1945) defined earlier developments and updated information was later provided by Holter (1976). Investigations since that time are included in discussions that follow for major accessible areas of limestone occurrences within the province (refer to Figure 1-4):

1.) Southwestern Alberta
2.) Crowsnest Corridor
3.) Bow Corridor
4.) Corkscrew Mountain Area
5.) David Thompson Corridor
6.) Cadomin Area
7.) Entrance Area
8.) Northern Foothills
9.) Fort McMurray Area

The geological setting of the Cordilleran and Foothills limestone deposits is typically characterized by strata which dip to the west at medium to high angles. Broad folding and intense inbricate thrust faulting is commonly present thus resulting in preservation of erosionally resistant units which strike northwest-southeast and may be repeated two or more times across the disturbed belt. Quarriable positions of any high grade deposit are limited by severe topographic restaints which prove to be problematic for access and proper quarry face development. Well established transportation routes through the western side of the province are few and environmentally sensitive areas have been recognized over much of this area. Little consideration is given herein to potential deposits which may lie within the boundaries of federal or provincial parks.

Carbonate beds that occur stratigraphically below the Devonian Palliser Formation are dolomitic over most of the Foothills and Front Ranges. The Palliser demonstrates relatively consistent stratigraphy and chemical composition along the entire length of the disturbed belt. Although the limestone grades are generally high there are some variations in the degree of dolomitization of this material. Beds of the Mississippian Banff Formation tend to be both argillaceous and dolomitic. The Mississippian Rundle Group is comprised of variable quality rock both laterally as well as vertically at any one location. Some of the highest quality limestones are quarried from this unit.

Strata in the Fort McMurray area are relatively flat-lying and the local relief is low. The beds are therefore mainly exposed along the more deeply incised parts of the main river courses. Folding and faulting influences are minimal and lateral stratigraphic or compositional changes are not significant.

3.1 Southwestern Alberta

The area of the province south of Highway 3 and west of the Fifth Meridian is included for consideration within the southwestern study sector (Figure 3-1). The geology was mapped by Price (1961) and the only published field work carried out to date to evaluate filler-grade limestones in this region is that of Hamilton (1987). Two samples of the Proterozoic Altyn Formation were collected by Hamilton from outcrops of white-weathering, very light grey dolomite outside the Waterton Lakes Park along the West Castle River.

For details concerning the stratigraphy and structure of the area the reader is referred to the above-noted publications. Reference will be made to results of the analytical work later in this report.

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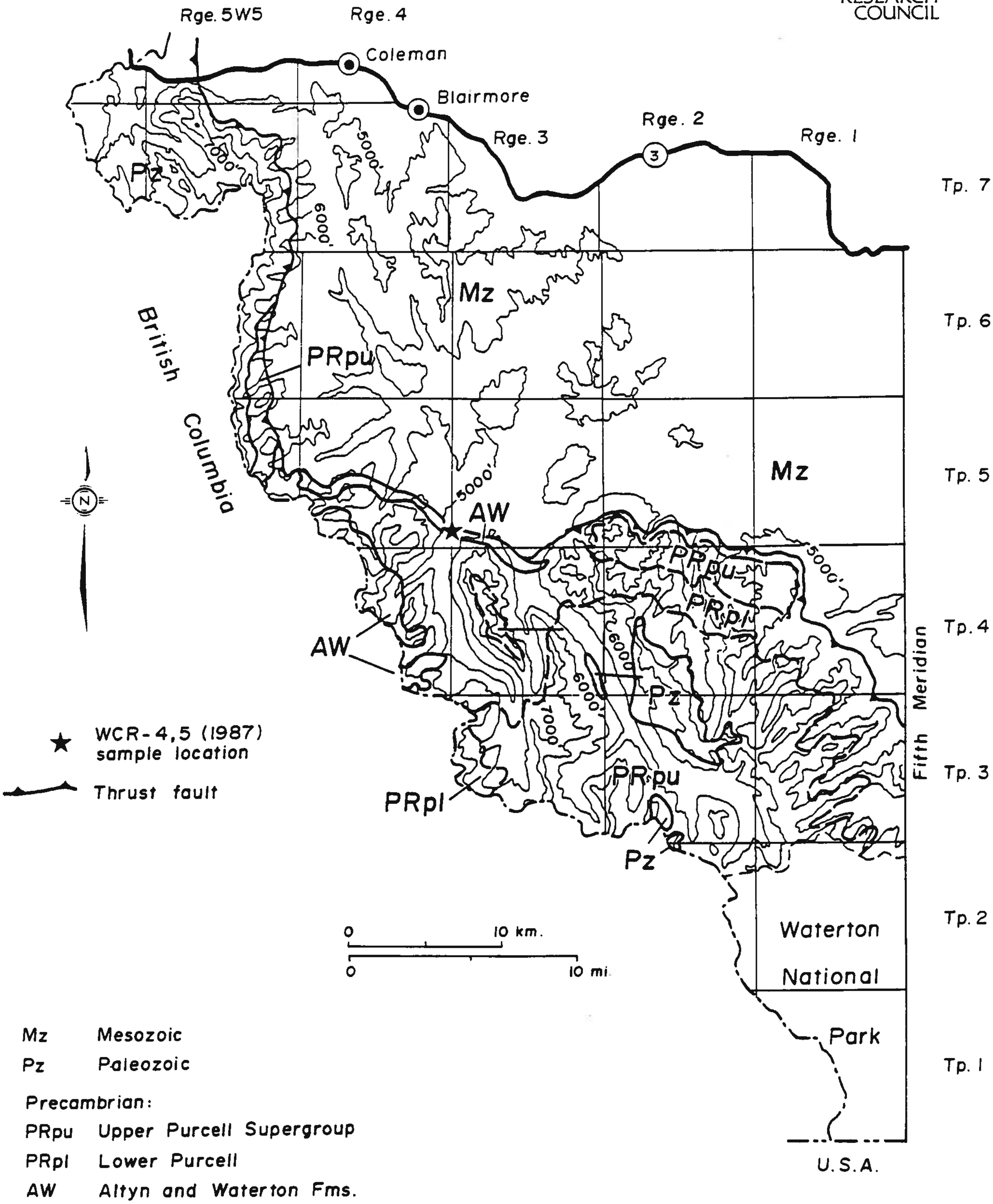

FIGURE 3-1

Geology of Southwestern Alberta

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3.2 The Crowsnest Corridor

Geological mapping of the limestone-bearing Paleozoic formations is derived from Norris (1955) in the Blairmore area and from Price (1961) through the Crowsnest Pass region to the west (see Figure 3-2). MacDonald and Hamilton (1981) carried out a more recent assessment of the limestone prospects in the area in order to define possible additional reserves for Summit Lime Works Ltd. operations near Crowsnest Lake. As a result of this work Hamilton (1987) carried out additional testing of the rocks of the Devonian Fairholme Group in the adjacent Phillipps Pass to investigate the potential use of these strata as filler materials. Samples of light-colored dolomite were obtained from within and immediately below the reefoid Peechee Member of the Southesk Formation (PHP-6 to 13). The Summit Lime Works was visited by the writer in February, 1989 and limestone samples were obtained from quarry operations at the west end of the deposit, on the north side of the Pass (SL-89-1).

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3.3 The Bow Corridor

Geology of the Bow River valley indicated in Figure 3-3 is from compilations by Price (1970). Extensive industrial development of the local limestones has taken place over many years. Quarries were opened in the Cambrian Eldon Formation by Loders Lime at the east entrance of the corridor near Kananaskis but these now lie abandoned. The property is currently controlled by Continental Lime Ltd. A lime plant near Exshaw operated by Continental Lime obtains rock from a quarry near Highway 1A east of Canmore within beds of the Mississippian Livingstone Formation. Lafarge Canada Inc. quarries rock from the Devonian Palliser Formation near Exshaw for local cement production.

Hamilton (1987) sampled the light-colored Eldon limestones both within the old quarries at Kananaskis as well as along Highway 1 (KQB, KQC, and KR sample series). The writer was able to revisit the area in February, 1989 to sample Quarry B (the middle opening) at the abandoned Loders Lime site (samples LL-89-1 to -10). Limestone feedstock was also obtained from the Continental and Lafarge Canada operations (CL-89-2 and LCI-89-1, respectively).

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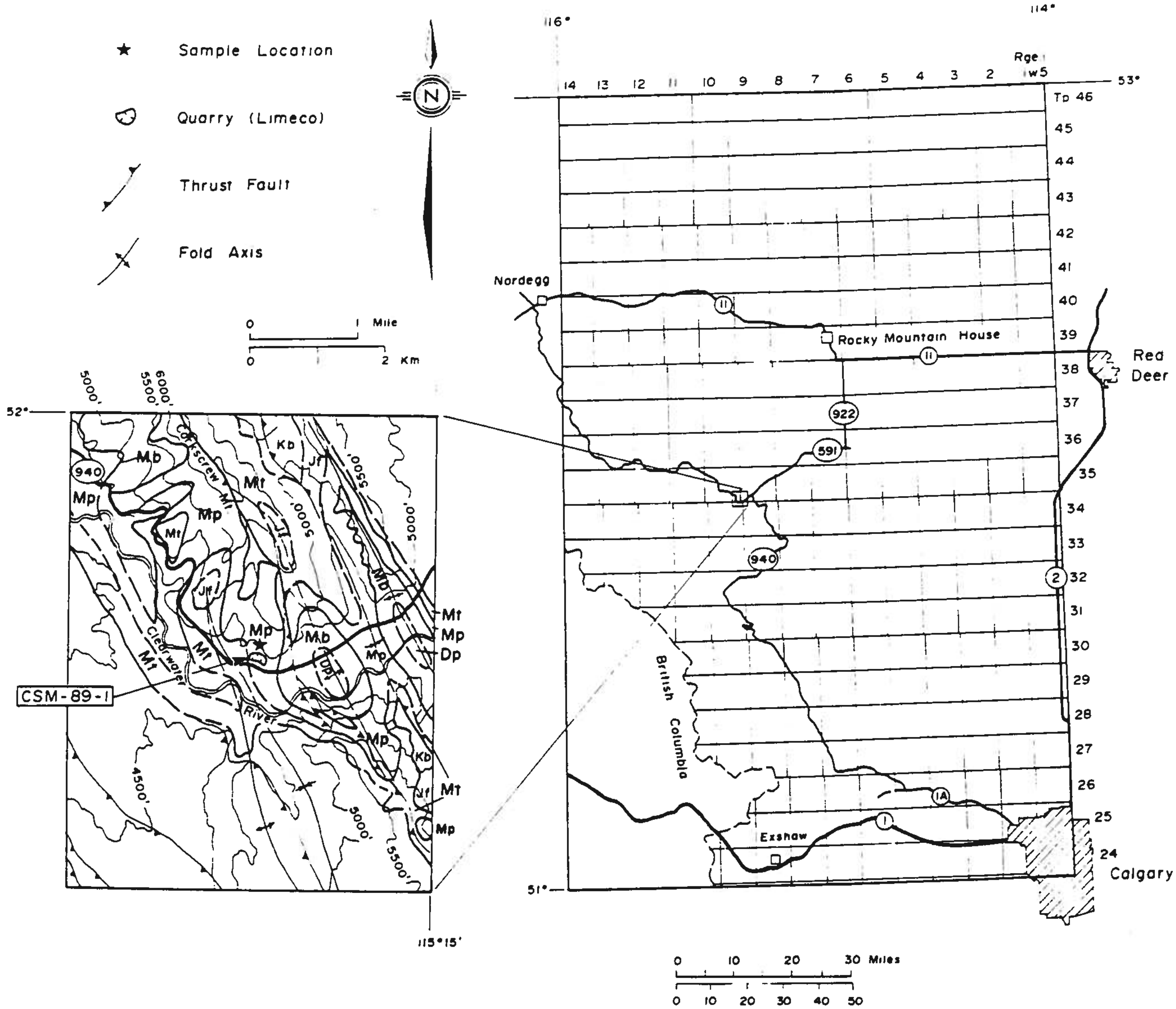
3.4 Corkscrew Mountain

Limeco Products Limited of Rocky Mountain House holds quarry rights on a property on the southwest flank of Corkscrew Mountain along the Forestry Trunk road (Highway 940; see Figure 3-4). The indicated Paleozoic geology is from Ollerenshaw (1968). This rock, which belongs to the Mississippian Rundle Group, is trucked to Rocky Mountain House where it is processed into a number of products including poutry grits and livestock pellets (Berg, 1988). Samples were obtained from the quarry during the duration of the study (CMS-89-1) as well as previously by W.N. Hamilton (WH-88-6).



LOWER CRETACEOUS

Kb	Blairmore Group

JURASSIC

Jf	Fernie Group

MISSISSIPPIAN

Mt	Turner Valley and Mount Head Fms
Mp	Pekisko and Shunda Fms
Mb	Banff and Exshaw Fms

DEVONIAN

Dp	Palliser Fm

FIGURE 3-4

Geology of the Corkscrew Mountain Area

3.5 David Thompson Corridor

Geological map coverage of the David Thompson Corridor has been obtained from a number of sources including Douglas (1956, 1958) and Mountjoy and Price (1974). Paleozoic outcrops are shown in Figure 3-5a and 3-5b. One sample from the Mississippian Rundle Group was obtained from the Nordegg Lime aggregate quarry specifically for the testing of filler characteristics (NL-89-4A). Samples of Cambrian rock were earlier obtained from exposures at Whirlpool Point, the Cline River crossing, and Windy Point by Hamilton (1987; the WRP, CRB, and WNP series). The Windy Point outcrop of the Eldon Formation was sampled again in February, 1989 by this writer (WP-89-1 to -23).

Hamilton inspected and sampled five outcrops during the 1988 field season immediately west of Abraham Lake. These intervals were not previously tested for limestone quality. Sections WH-88-1, -2, and -5 occur approximately 4 kilometres (2.5 miles) southwest of Windy Point within the Devonian Alexo and Palliser Formations. Section WH-88-3 is located within Palliser strata on the north side of the Cline River valley along Highway 11 and section WH-88-4 was established at the south end of Abraham Lake within Mississippian Rundle Group beds. Details of Hamilton's work is included in Appendix A of this report.

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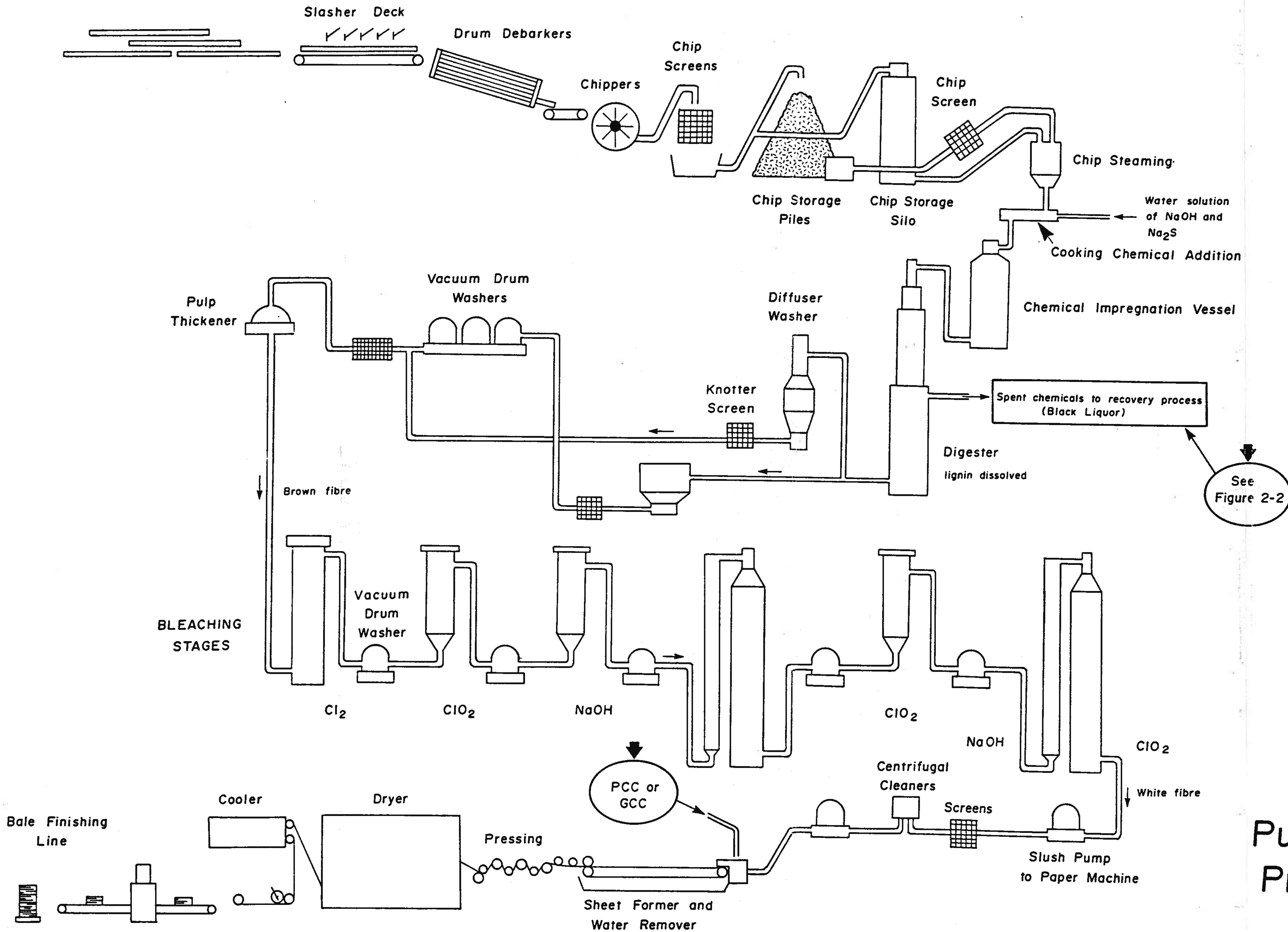

Drawing modified from public information brochure produced by: Weyerhaeuser Canada Ltd.

FIGURE 2-1

Pulp and Fine Paper Production Sequence

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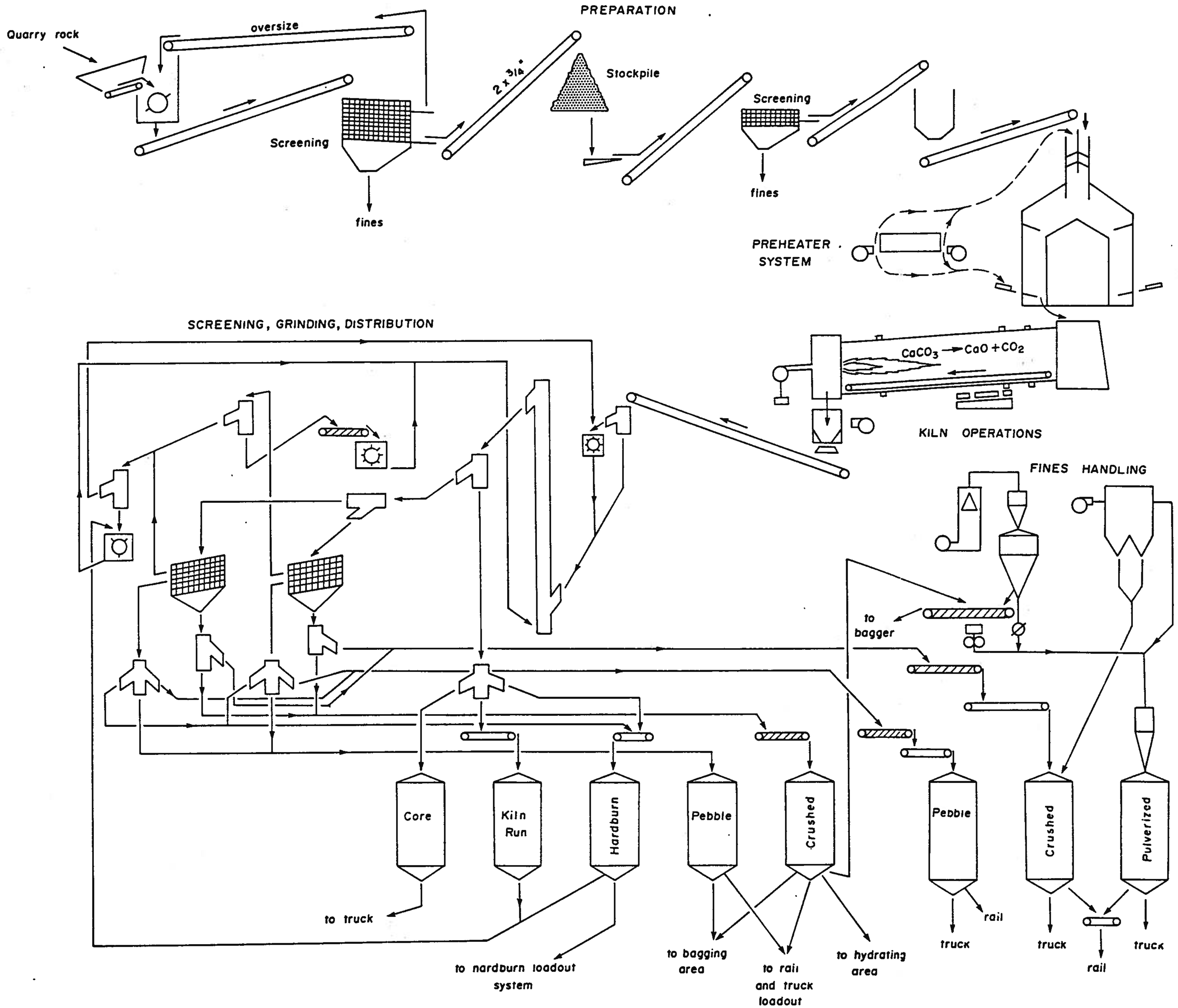

Modified from flow sheets provided by: Continental Lime Ltd. for the Exshaw lime plant.

FIGURE 2-4

Typical Lime Production Sequence

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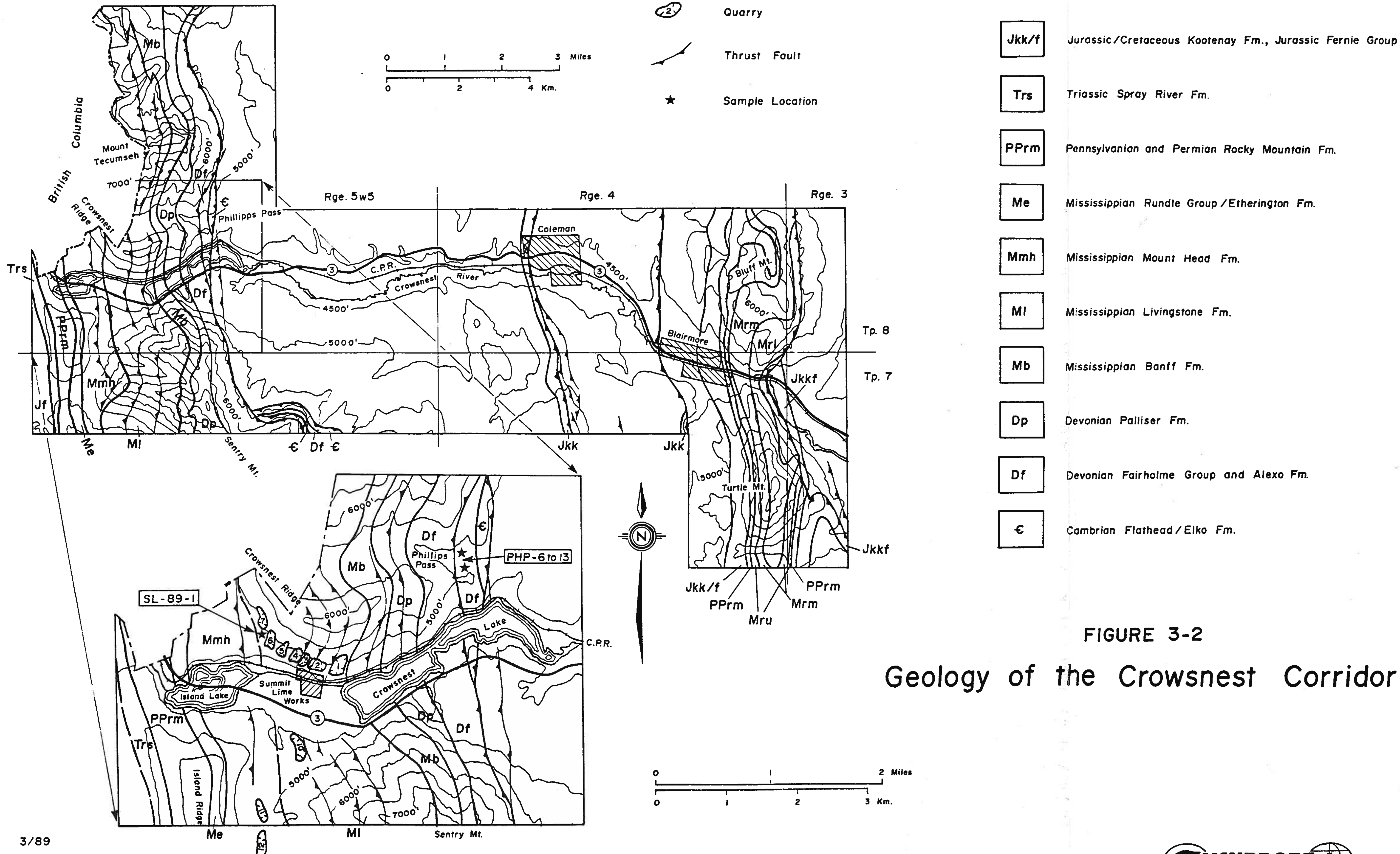

FIGURE 3-2

Geology of the Crowsnest Corridor

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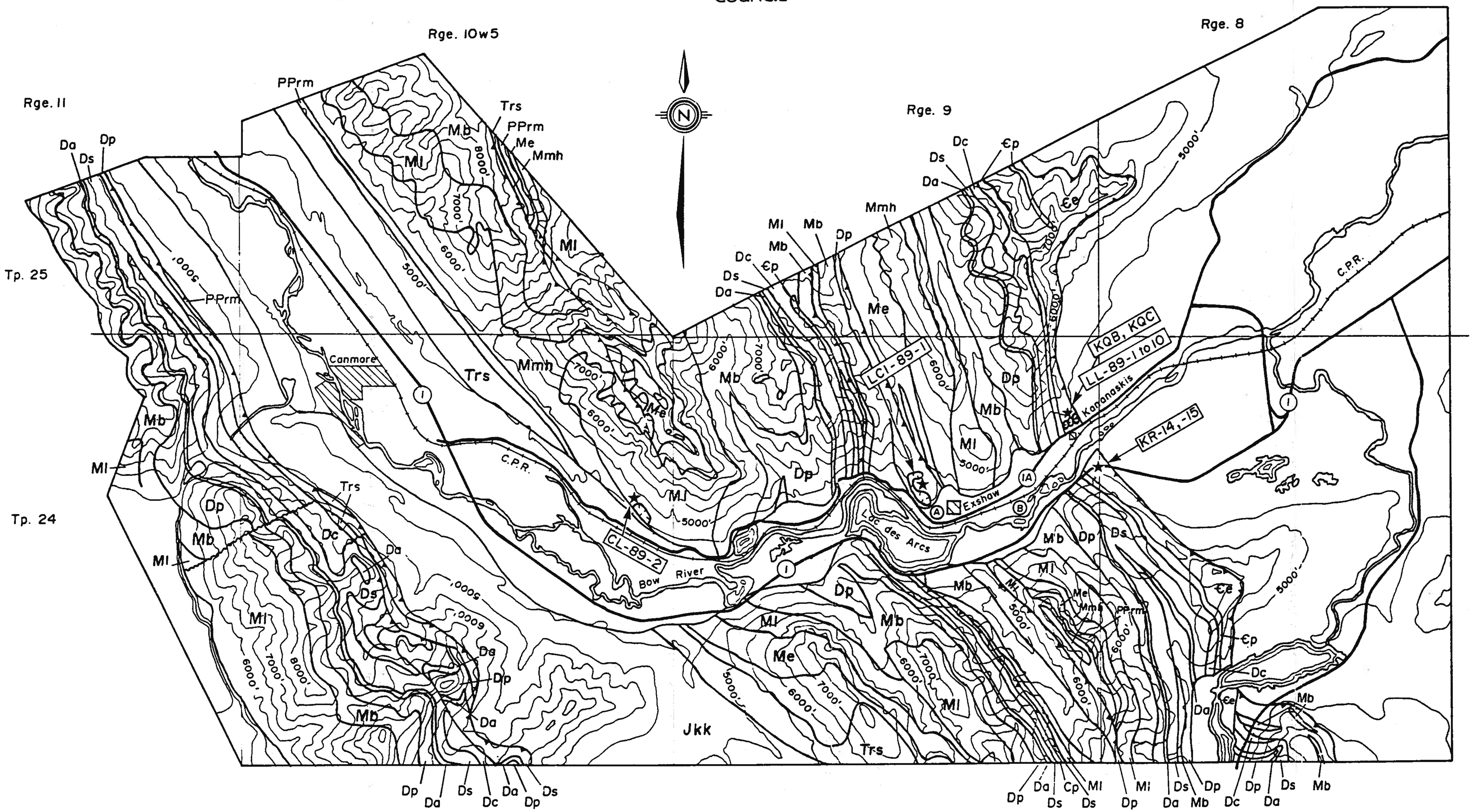

Jkk	Jurassic/Cretaceous Kootenay Fm.
Trs	Triassic Sulfur Mt. Fm.
PPrm	Permian/Pennsylvanian Rocky Mt. Group
Me	Mississippian Etherington Fm.
Mmh	Mississippian Mount Head Fm.
Ml	Mississippian Livingstone Fm.
Mb	Mississippian Banff Fm.
Dp	Devonian Palliser Fm.
Da	Devonian Alexo Fm.
Ds	Devonian Southesk Fm.
Dc	Devonian Cairn Fm.
€p	Cambrian Pika Fm.
€e	Cambrian Eldon Fm.

0 1 2 3 Miles
0 1 2 3 4 Km.

(A) Lafarge Canada Inc.
(B) Continental Lime Ltd.
Quarry
Thrust fault
★ Sample location

FIGURE 3-3

Geology of the Bow Corridor

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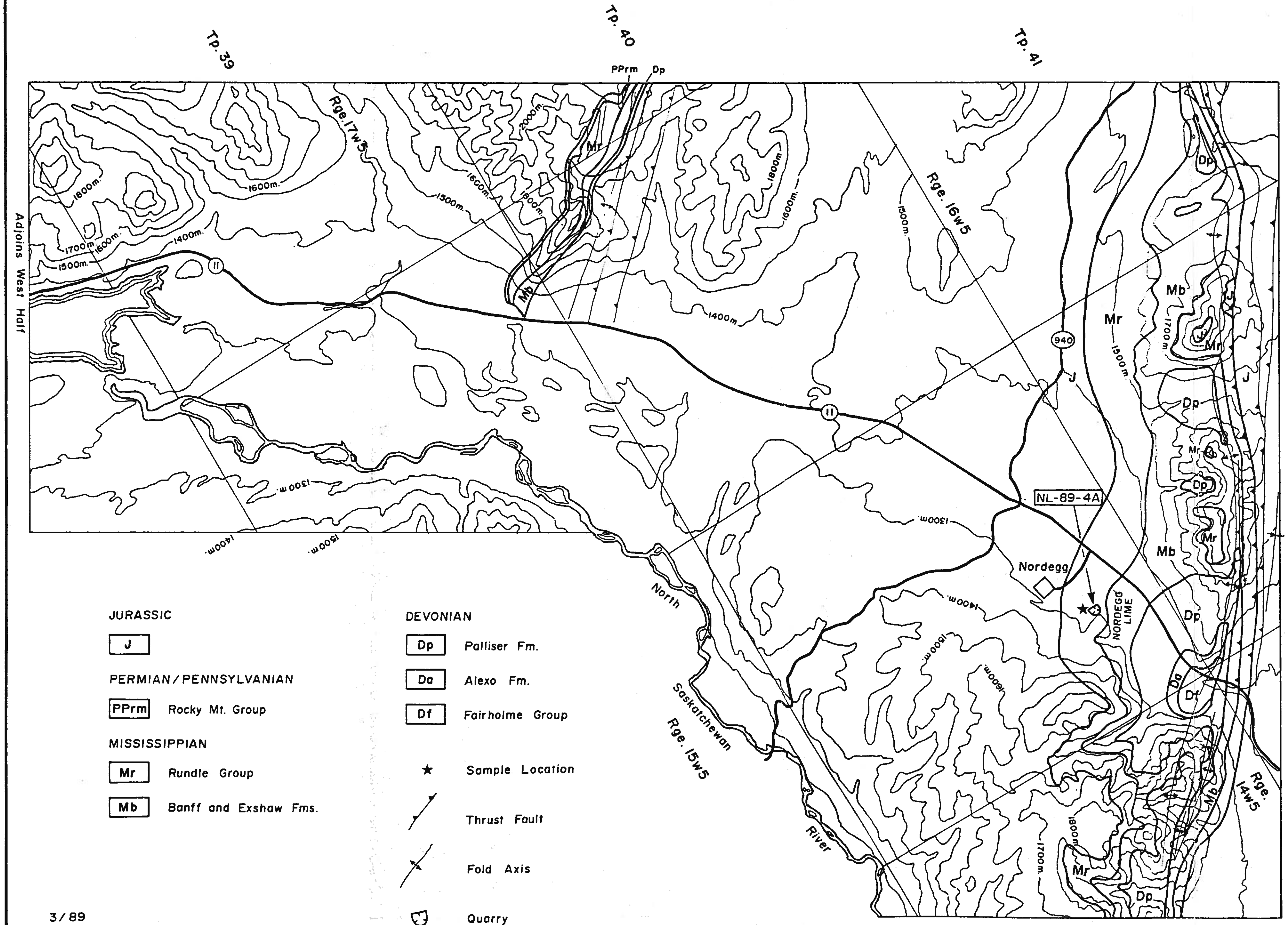

0 1 2 3 Miles
0 1 2 3 4 Km.

FIGURE 3-5a
Geology of the David Thompson Corridor (East Half)

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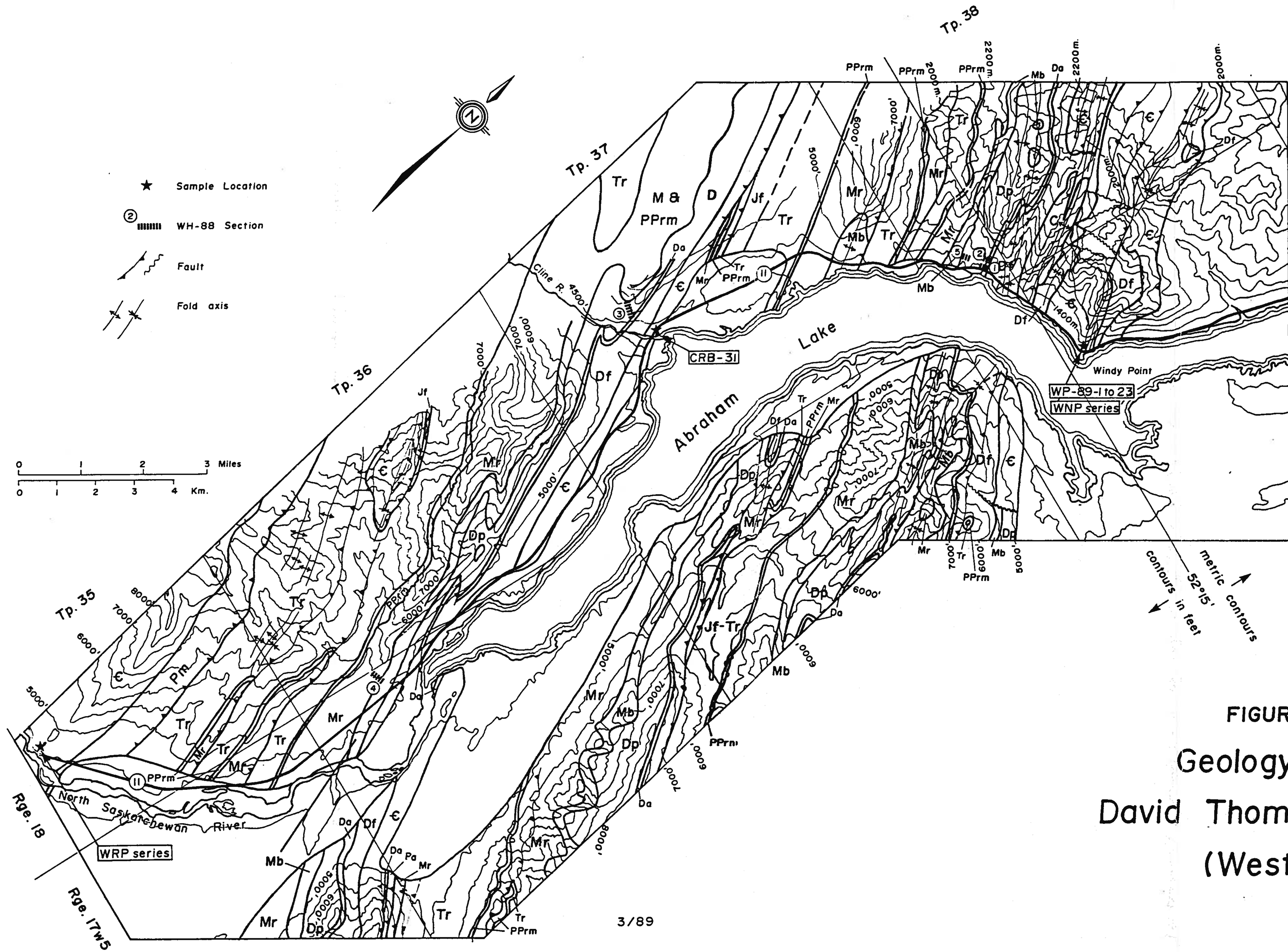

FIGURE 3-5b

Geology of the David Thompson Corridor (West Half)

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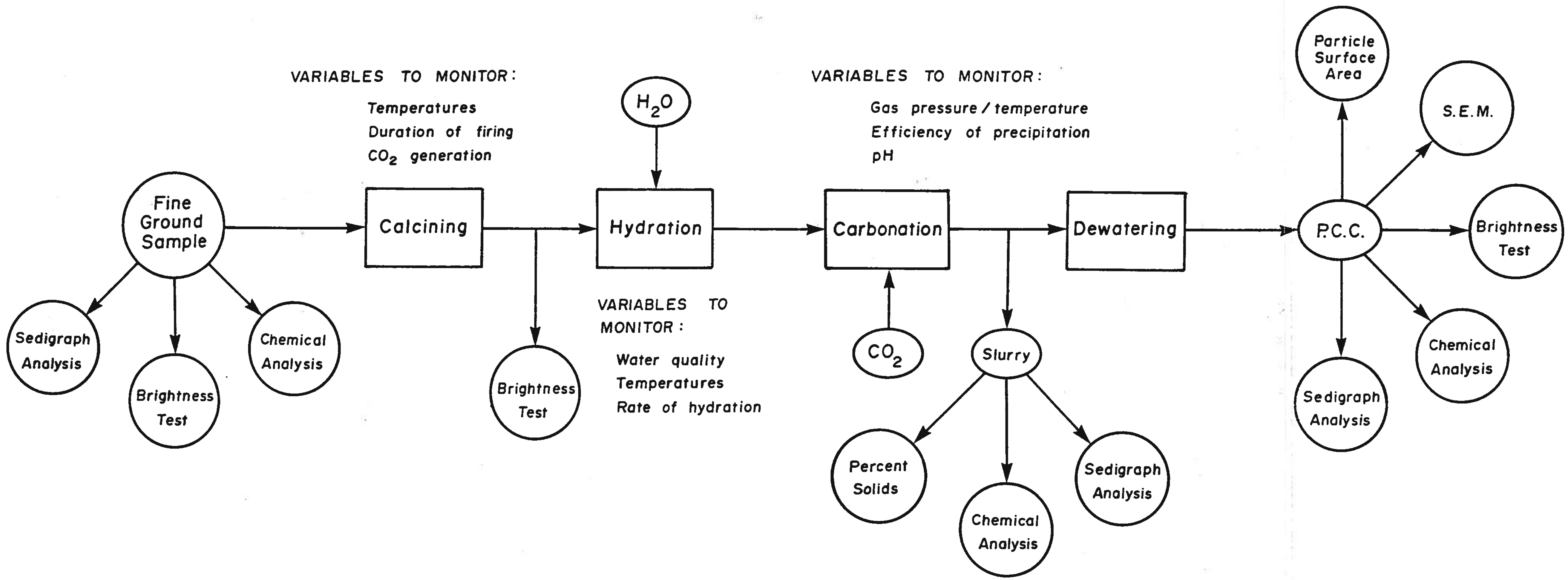

FIGURE 6-1

Recommended Analytical Program

3/89

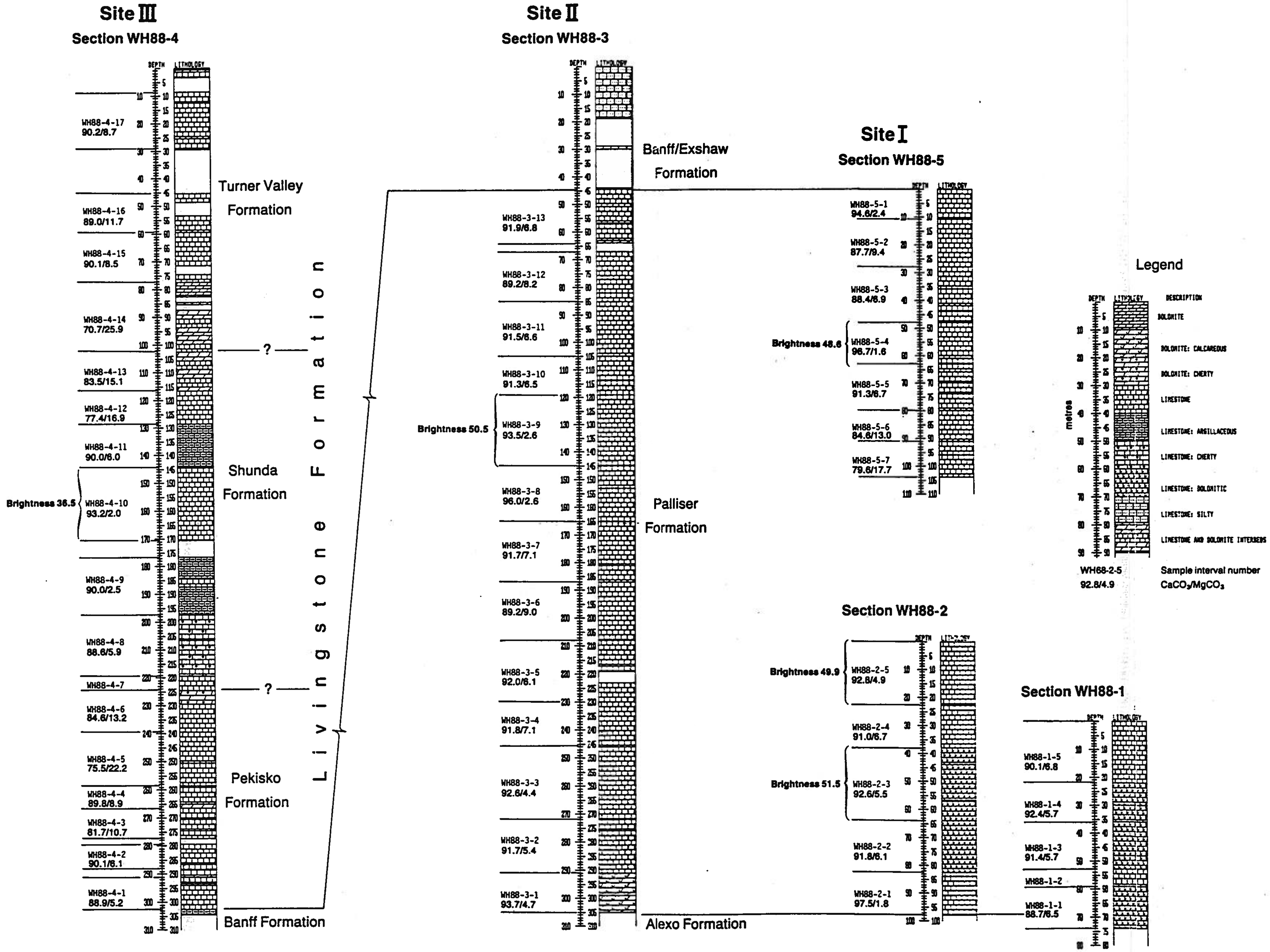

Figure . Stratigraphic sections and sampled intervals, Devonian and Mississippian strata, David Thompson Corridor area.

Figure 8-3

Stratigraphic sections and sampled intervals, Devonian and Mississippian strata, David Thompson Corridor area.

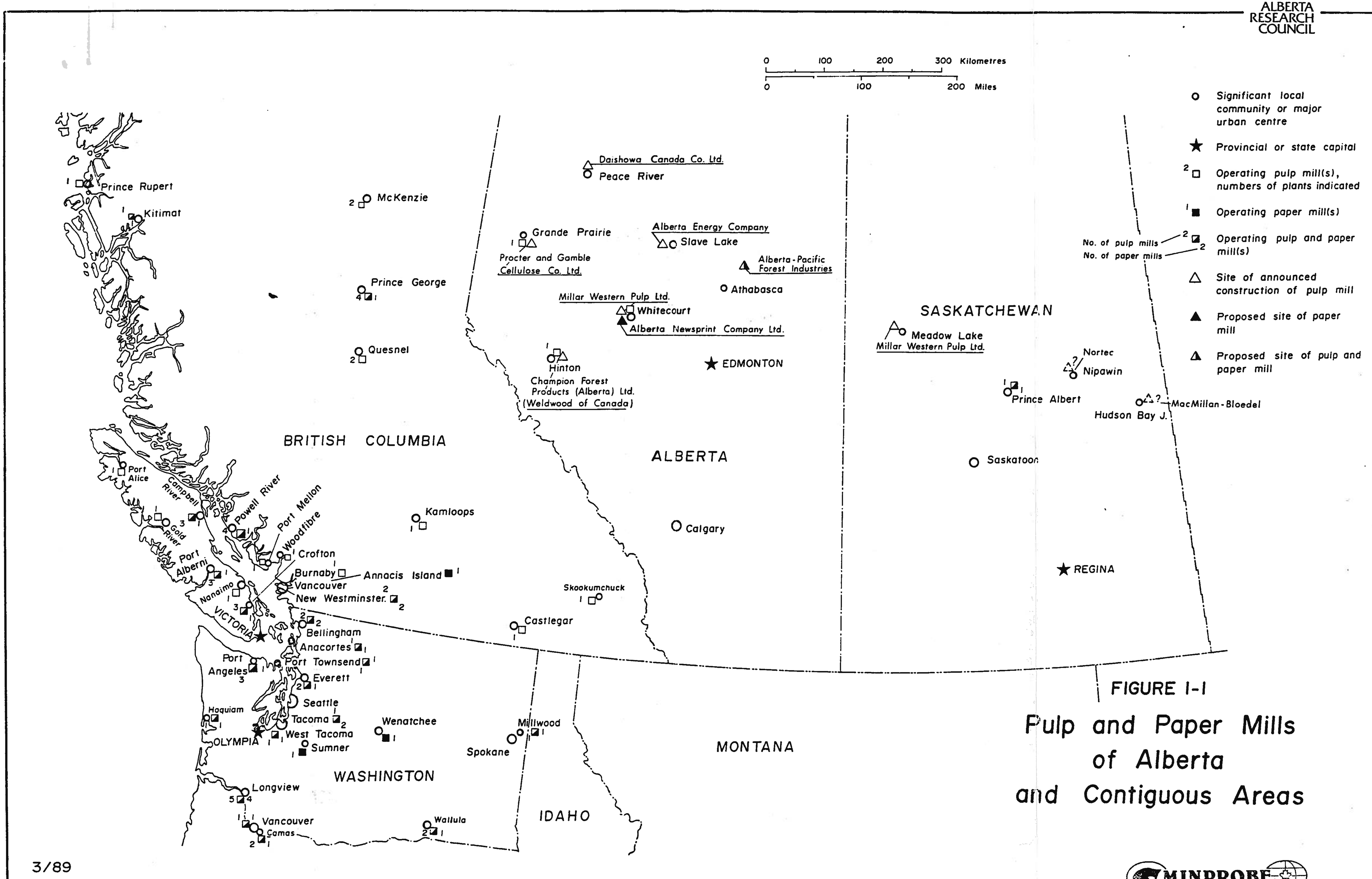

FIGURE 1-1

Pulp and Paper Mills of Alberta and Contiguous Areas

Insert 3.11 & 3.12 in back pocket

3.6 The Cadomin Area

The geology of the area was initally mapped by MacKay (1929) and more recently in unpublished form by C.W. Langenberg of the Alberta Research Council. Results of the latter mapping are included in a review study of the region by MacDonald and Hamilton (1979). Generalized Paleozoic geology is indicated in Figure 3-6 and for details of the distribution of formational units of the Mississippian Rundle Group the reader is referred to MacDonald and Hamilton (*op. cit.*)

One sample of Devonian Palliser rock from the Cadomin quarry was obtained from the stockpiles of Inland Cement in Edmonton during February, 1989 (IC-89-1) for analytical testing of filler quality.

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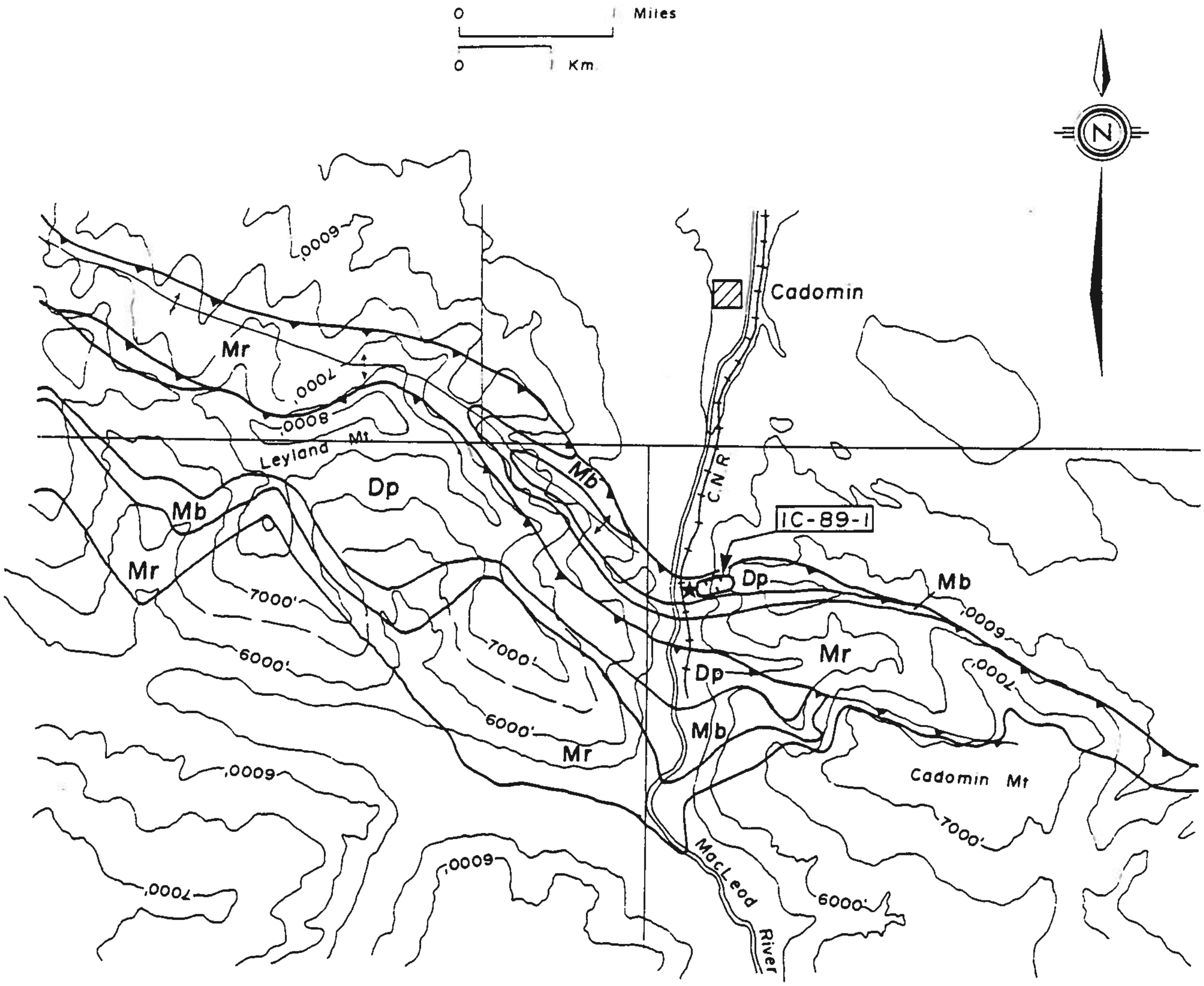

MISSISSIPPIAN

Mr Rundle Group

Mb Banff and Exshaw Fms.

DEVONIAN

Dp Palliser Fm.

Quarry (Inland Cement)

★ Sample Location

Thrust Fault

Fold Axis

FIGURE 3-6

Geology of the Cadomin Area

3/89

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3.7 The Entrance Corridor

The area immediately outside the east entrance of Jasper National Park, both north and south of Highway 16, has been geologically mapped by Lang (1947) and Mountjoy (1959). A summary of this work is indicated in Figure 3-7. Four limestone sections were examined and tested by MacDonald and Hamilton (1979) to provide information additional to that contributed earlier by Goudge (1945) and Holter (1976). No quarries are currently operating in this region and no samples were collected to define potential filler-grade materials from this area.

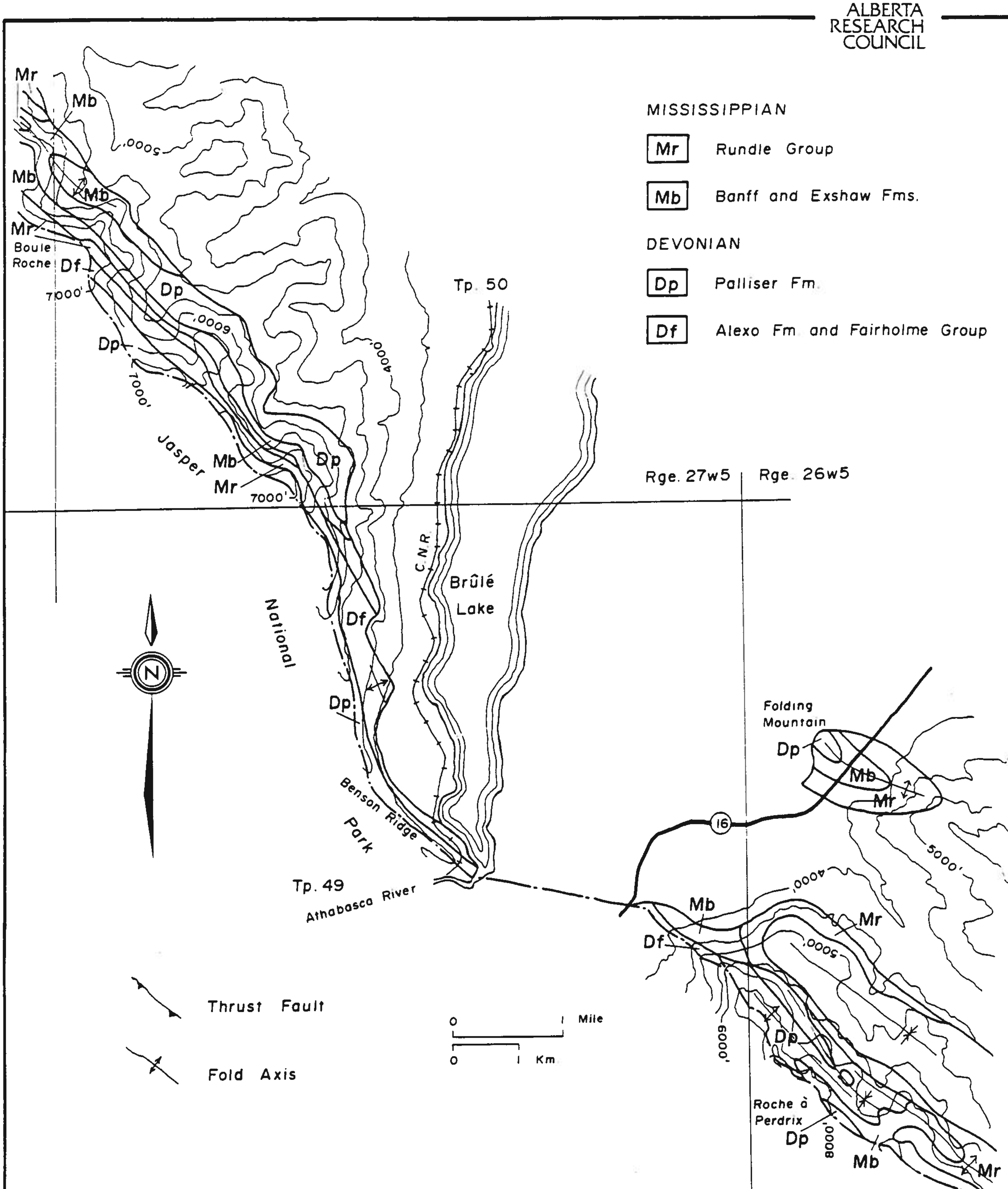

FIGURE 3-7

Geology of the Entrance Corridor

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3.8 Northern Foothills

Extensive investigations of limestone occurrences have been carried out by MacDonald and Hamilton (1979) northwest of Highway 16 to an area west of Grande Cache (see Figure 3-8). Three principal localities were studied: Rock Lake, Adams Lookout, and Smoky River-Clarks Crossing. The latter two outcrop areas occur within the Willmore Wilderness Park.

Relatively high-calcium limestones were defined within thin intervals of the Mississippian Shunda Formation near Rock Lake. Encouragingly high analyses of $CaCO_3$ were obtained for rock from the Devonian Palliser Formation and Mississippian Pekisko Formation in the Adams Lookout area. High grade limestone appears to be mainly confined to the Devonian Palliser Formation at the Smoky River-Clarks Crossing exposures. The geological coverage of these areas was derived from Irish (1965) and Mountjoy (1963, 1980).

No limestone samples from the area were collected for testing of filler quality.

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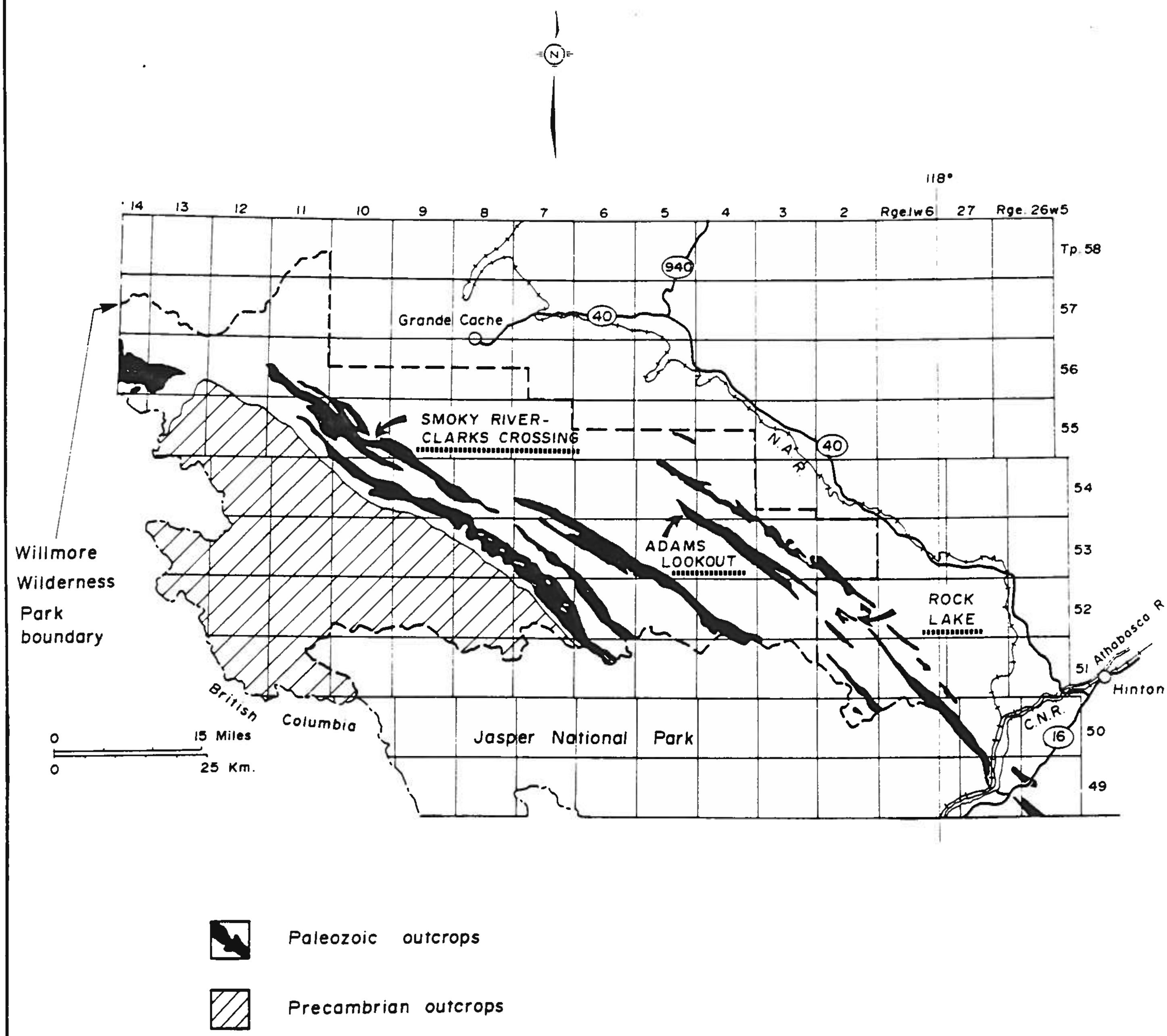

FIGURE 3-8

Geology of the Northern Foothills

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3.9 The Fort McMurray Area

Upper Devonian outcrops of the Waterways Formation are exposed along the Athabasca and Clearwater Rivers in the Fort McMurray area (Figure 3-9). Details regarding the geology of the region are available in Carrigy (1959) and Norris (1963). The development of the AOSTRA underground oil sands test facility northwest of Fort McMurray provided access to samples of the Mildred Member (sample UTF-89-1). Selection of typical or representative sample from the mined out rock was carried out by B. Rottenfusser. No testing of this member of the Waterways for determination of limestone quality has been done previously.

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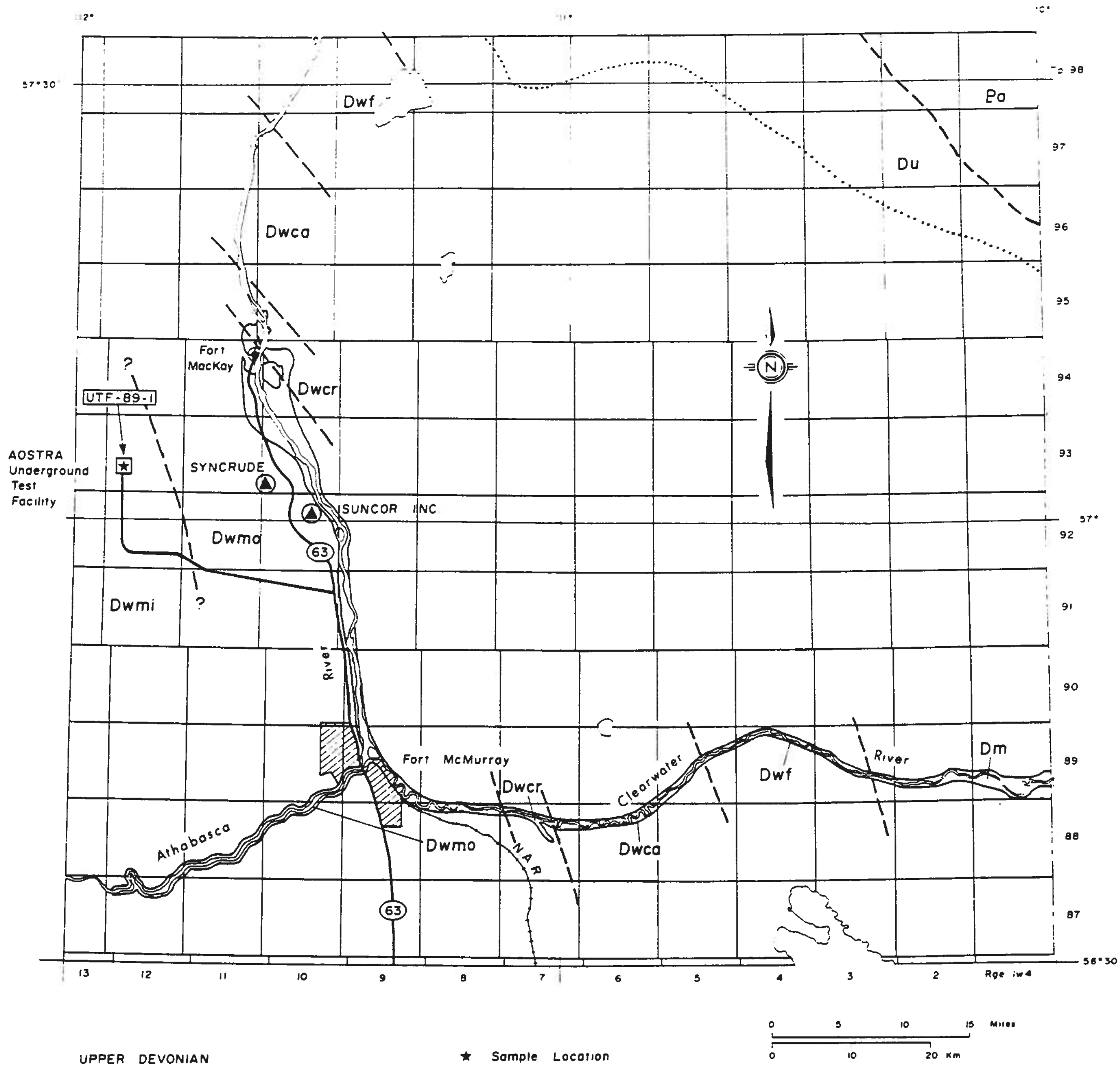

UPPER DEVONIAN
Waterways Fm

Dwmi	Mildred Mbr
Dwmo	Moberly Mbr
Dwcr	Christina Mbr
Dwca	Calumet Mbr
Dwf	Firebag Mbr

MIDDLE DEVONIAN

Dm	Methy Fm
Du	undivided

PRECAMBRIAN

Pa	Archaean, undivided

FIGURE 3-9

Geology of the Fort McMurray Area

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4. ANALYSES

Limestone samples obtained during the early part of the 1989 season were collected under adverse weather conditions and within a very limited period of time available to completion of the project. The results of the analyses must accordingly be regarded as more or less representative of the deposit characteristics but are not necessarily definitive. There was a bias directed towards sampling producing properties in view of the fact that immediate production could be realized if any filler-grade materials were so defined. The Kananaskis quarries and the Windy Point outcrop locations were exceptions in this regards. The Loders Lime quarries at Kananaskis are essentially exhausted of open face reserves and further development here could only be considered by underground operations. This mode of quarrying has been successfully adopted by International Marble and Stone Company Limited (IMASCO) in the Creston area to develop deposits of limestone, quartzite, and granite. The resultant quarries yield rock that is uncontaminated by overburden, lesser problems are faced with inclement weather conditions, and the sites are more aesthetically acceptable. Such quarry operations could prove to be financially prohibitive unless the by-product value is higher than normally realized for such commodities as aggregates, lime, and cement. A high quality filler may be a market success in this regards. Both the Kananaskis and Windy Point localities were sampled and tested because they indicated the presence of light-colored material upon previous study.

The basic analysis program adopted for all the limestone samples collected is shown in Figure 4-1. A raw sample split of about 2 000 grams (4.4 pounds) was subjected to crushing first by a Chipmunk jaw crusher before being passed through a BICO disc grinder. A split of this material was fine ground in an eccentric ring (swing)

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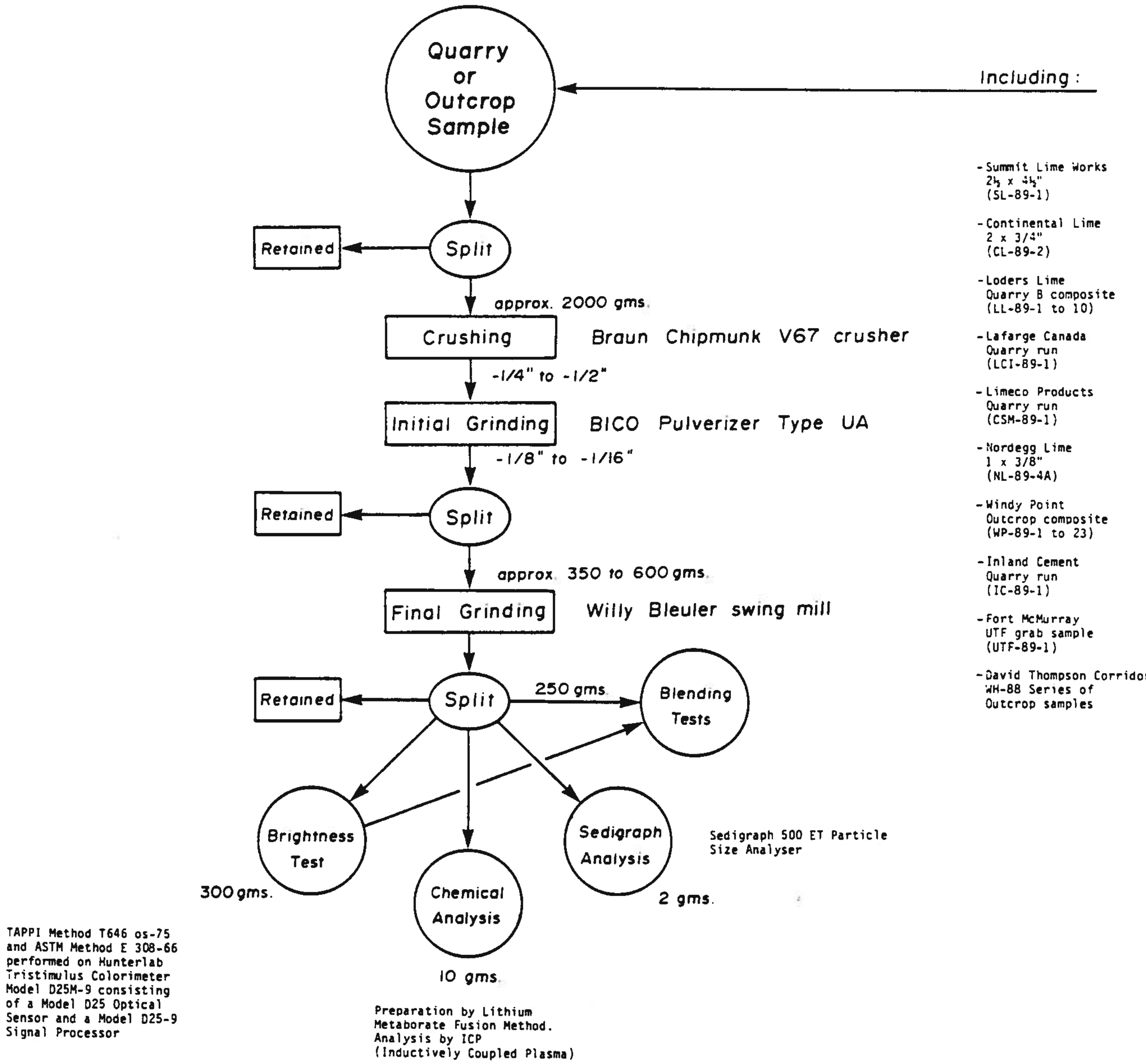

FIGURE 4-1

Analysis Program

3/89

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mill before being further subdivided into portions for brightness testing, chemical analysis, and sedigraph charting. Selected samples were also subjected to blending tests.

Fine limestone sizes are generated at several Alberta plants but none, with the exception of those resulting from operations at Limeco Products, are produced for a specific market. As noted earlier, the processing cycle at the Rocky Mountain House facilities of Limeco Products incorporates fine material into several agricultural products. The sedigraphs of three fine limestone by-products are shown in Figure 4-2. In the case of the Nordegg and Continental operations the fines are the result of dust collection circuits. The Nordegg material is remarkably fine (3 microns, average) but is only produced in small volumes and would not fulfill paper filler brightness specifications with its rating of 50.7 percent.

Other results obtained during the course of this study on raw quarry and outcrop rock are summarized in Figure 4-3 and Table 4-1. All samples were subjected to a similar degree of final grinding during laboratory preparation but a wide range of particle sizes was generated. Some samples achieved sizes as low as 10 microns whereas others were in excess of 30 microns on average. It is possible that there may be a correlation between these observations and the relative performance to be expected of each rock type in a commercial production circuit. Brightness values recorded may be considered as conservative since none of the samples were processed to ultra-fine sizings.

All results obtained to date for brightness testing and chemical purity may be considered in terms of area and stratigraphy. To the southwest, the Precambrian Altyn Formation samples of Hamilton (1987, see Figure 3-1) analysed 71.1 to 74.8 percent brightness and $CaCO_3$ values were low (40 to 46 percent). Further north, in the Crowsnest

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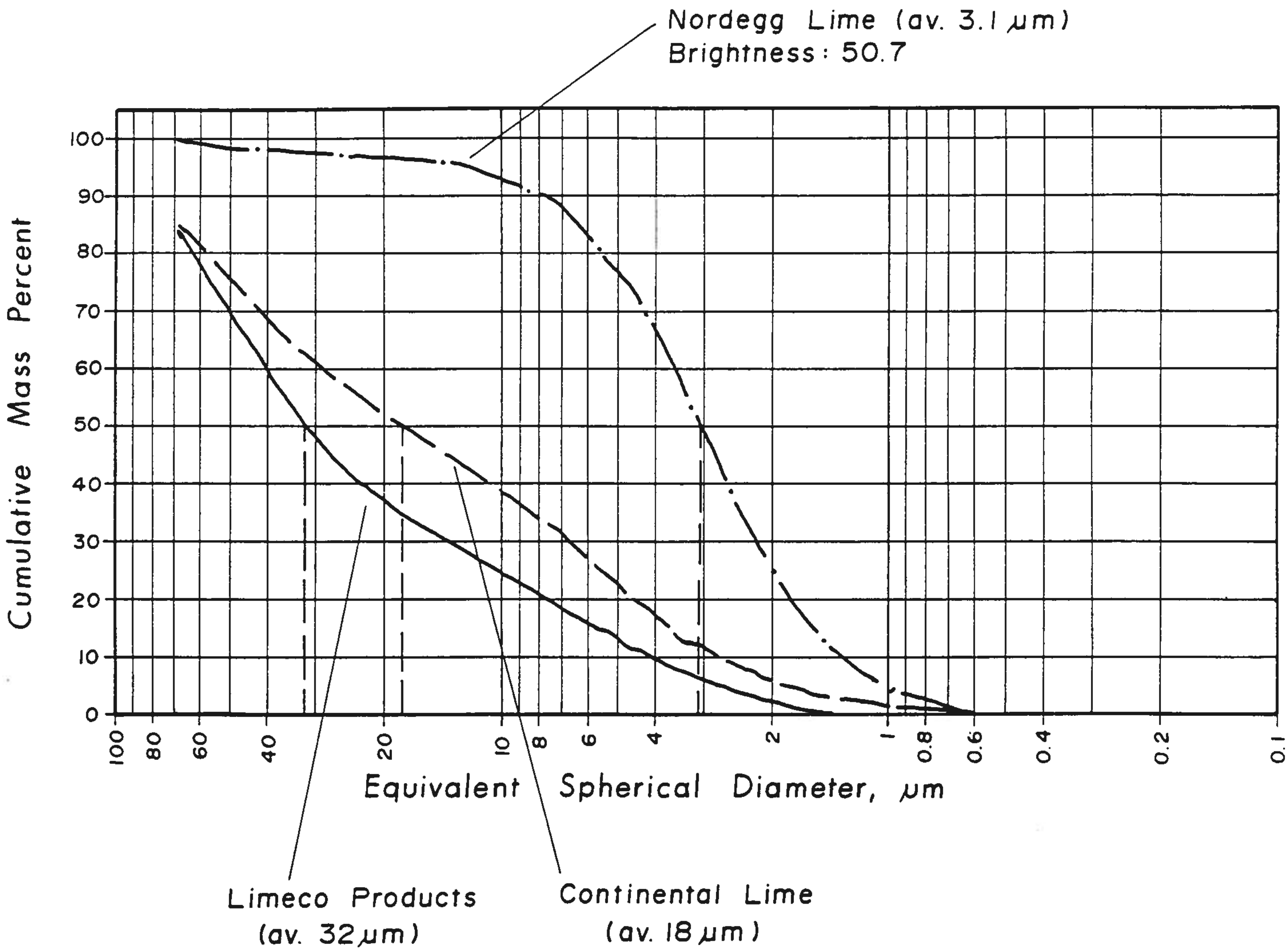

FIGURE 4-2

Fine Product Specifications for Alberta Plants

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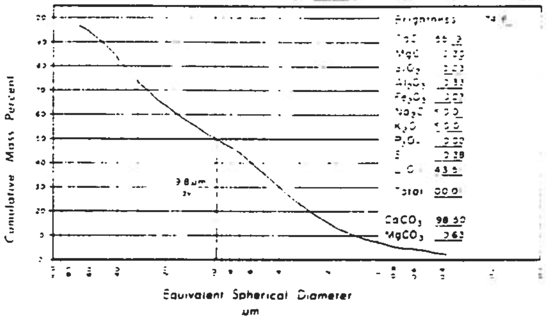
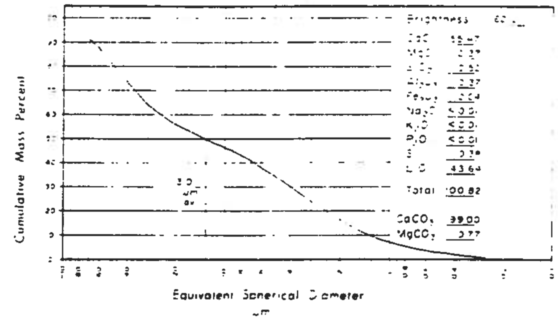
Sample No SL-89-

Source Summit Lime Works
quarry run
Miss Head Fm



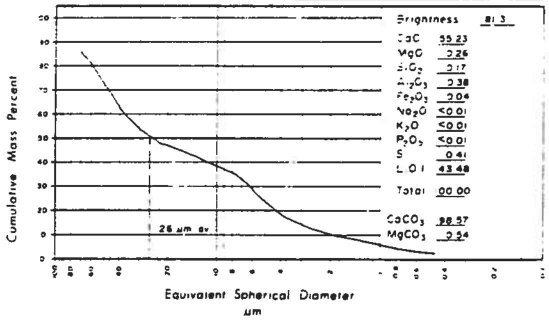
Sample No

Source Continental Lime, Exshaw
quarry run
Miss Livingstone Fm



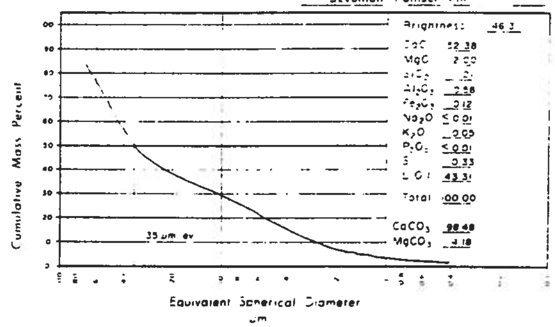
Sample No. LL-89-1 to 10

Source Loders (Continental) Lime
Quarry B face composite
Cambrian Eldon Fm (abandoned)



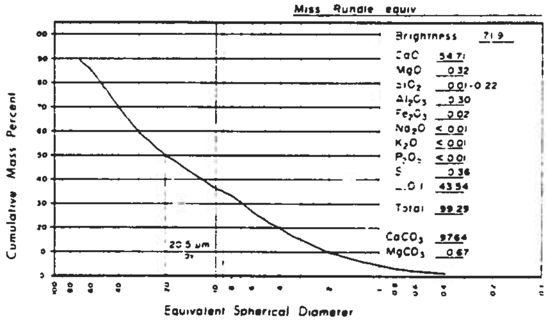
Sample No. LC-89-1

Source Lafarge Canada
raw quarry run
Devonian Palliser Fm



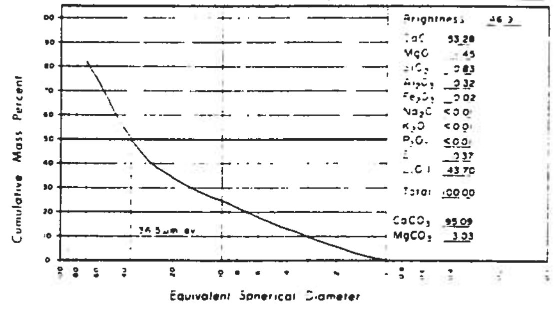
Sample No. CSM-89-1

Source Limeco Products
Corkscrew Mt quarry, raw quarry run
Miss Rundle equiv



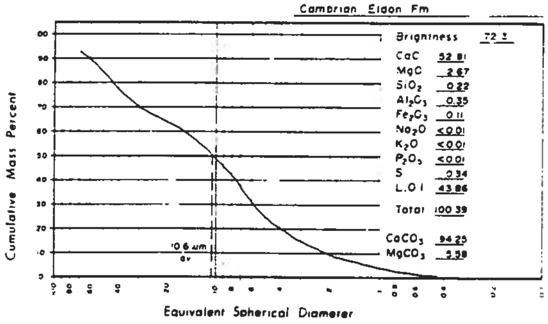
Sample No. NL-89-4A

Source Nordegg Lime
1 x 3/8" quarry run, upper limestone
Miss Pekisko Fm



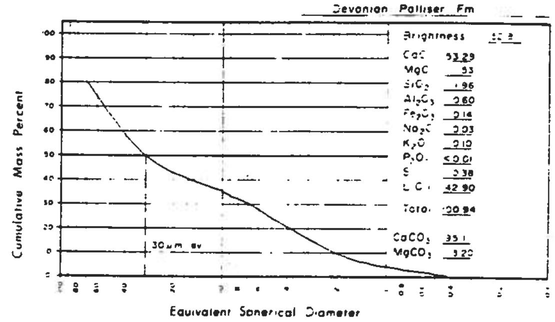
Sample No. WP-89-1 to 23

Source Windy Point, David Thompson
Corridor, composite of outcrop samples
Cambrian Eldon Fm



Sample No. C-89-1

Source Inland Cement
quarry run
Devonian Palliser Fm



Sample No. UTF-89-1

Source AOSTRA Underground Test
facility, grab sample
Devonian Waterways Fm

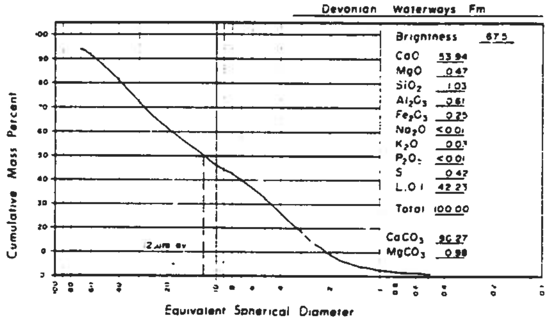


FIGURE 4-3

Summary of Analyses, Alberta Limestones

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	SL-89-1	CL-89-2	LL-89	LCI-89-1	CSM-89-1	NL-89-4A	WP-89	IC-89-1	UTF-89-1
CaO	55.19	55.47	55.23	52.38	54.71	53.28	52.81	53.29	53.94
MgO	0.30	0.37	0.26	2.00	0.32	1.45	2.67	1.53	0.47
S	0.38	0.38	0.41	0.33	0.36	0.37	0.34	0.38	0.42
P_2O_5	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Na_2O	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	<0.01
K_2O	<0.01	<0.01	<0.01	0.05	<0.01	<0.01	<0.01	0.10	0.03
Al_2O_3	0.33	0.37	0.38	0.58	0.30	0.32	0.35	0.60	0.61
Fe_2O_3	0.03	0.04	0.04	0.12	0.02	0.02	0.11	0.14	0.25
SiO_2	0.23	0.52	0.17	1.21	0.01	0.83	0.22	1.96	1.03
L.O.I.	43.51	43.64	43.48	43.31	43.54	43.70	43.86	42.90	43.23
Total	100.01	100.82	100.00	100.00	99.29	100.00	100.39	100.94	100.00
$CaCO_3$	98.50	99.00	98.57	93.48	97.64	95.09	94.25	95.11	96.27
$MgCO_3$	0.63	0.77	0.54	4.18	0.67	3.03	5.58	3.20	0.98
Brightness	74.83	62.42	81.34	46.34	71.85	46.92	72.25	52.84	67.52

TABLE 4-1 Summary of 1989 Analyses

Pass area (Figure 3-2) the Peechee Member of the Devonian Fairholme Group showed brightess values of 57.2 to 69.7 percent and $CaCO_3$ contents of less than 60 percent (Hamilton, op. cit.) The Summit Lime Works sample collected for this study (SL-89-1) showed nearly 75 percent brightness for a very high grade limestone (98.5 percent $CaCO_3$).

The potential for filler grade limestones in the Bow Corridor (Figure 3-3) was reviewed by Hamilton (1987) to indicate that the Cambrian Eldon Formation may show brightnesses as high as 79.5 in quarry beds that contain as much as 97 percent $CaCO_3$. Dolomitic interbeds showed lesser brightness values. Samples taken from along Highway No. 1 were also relatively light in color (73 to 78 percent brightness). Testing of the 1989 sample suite (LL-89-1 to -10) confirmed the previously established values for Quarry B (81.3 percent brightness, 98.6 percent $CaCO_3$). The Mississippian quarry-run material collected in early 1989 from Continental Lime facilities indicated a brightness of 62 percent and extremely high $CaCO_3$ values (99 percent; sample CL-89-2). The Lafarge Canada rock (LCI-89-1) ran very low in brightness (46 percent) and contained 93.5 percent $CaCO_3$.

Materials from the Corkscrew Mountain quarry of Limeco Products showed promising results (72 percent brightness, 97.6 percent $CaCO_3$) but would not be satisfactory alone for fine paper filler specifications (refer to Figure 3-4 for site location).

Previous work by Hamilton (1987) in the David Thompson Corridor (see Figures 3-5a and 3-5b) concentrated on the evaluation of Cambrian deposits. Rock from the Cathedral dolomites at Whirlpool Point (the WRP test series) analyzed 52 percent brightness and 53 percent $CaCO_3$. Outcrops of the Lynx Group at the Cline River crossing (CRB-31) were noted to yield rock which is both highly dolomitic and silty with brightness values rated at 65 percent.

The Eldon beds at Windy Point (the WNP series) varied in brightness from 72 to 76 percent and $CaCo_3$ grades were high (97 to 99 percent). Analyses from the 1989 suite at the same locality (WP-89-1 to -23) were towards the lower end of this range of values (72 percent brightness, 94 percent $CaCO_3$).

The upper limestone beds of the Nordegg Lime quarry showed surprisingly low brightness values of its visual appearance (47 percent) in quarry run rock and 51 percent from fines from the aggregate plant. The $CaCO_3$ values were relatively high (95 percent) and the only constituents that would otherwise prove to be detrimental were the slightly higher SiO_2 contents (0.83 percent) and the small but visual amounts of organics.

A stratigraphically lower limestone bed on the same property which has not been exploited to date indicated a brightness of 58.4 percent from drill cuttings. Chemical analyses run on these samples in a commercial laboratory by the company were similar to those obtained for the upper bed.

To the north, at Cadomin (Figure 3-6, the single Palliser Formation sample originating from the Inland Cement quarry (IC-89-1) showed a low brightness (53 percent) with relatively high silica (1.96, as tested).

The material obtained from the Devonian Waterways Formation in the Fort McMurray area (UTF-89-1, Figure 3-9) tested a 68 percent brightness, over 96 percent $CaCO_3$ and noteably, an SiO_2 content of over one percent.

None of the Alberta limestones investigated meet the brightness requirements of a GCC paper filler material by most current standards. However, one procedure which may allow for some use of local material is one of blending with a high-grade product from outside the province. Commercially produced ground limestone from the IMASCO plants near Creston and at Surrey were obtained to act as test blend standards in this regards. These were rated as 6H and 7H company products respectively (see Figure 4-4).

The program to determine the influences of blending the IMASCO 6H material and a number of Alberta limestones is shown in Figure 4-5. It was arbitrarilly considered that the use of at least 50 percent Alberta GCC product should be anticipated in any one blend such that laboratory batching with the standard was carried out in percent proportions of 50:50, 60:40, and 70:30. The resultant blended samples were each subjected to brightness and size analyses. Two of the brightest limestones were chosen for blending: the Kananaskis (LL-89-1) quarry rock and the Windy Point outcrop strata (WP-89-1 to -23). In addition, the Continental Lime (CL-89-2) and Inland Cement (IC-89-1) materials were also included in the program in order to represent Alberta limestones of both intermediate and low brightness. Graphical presentations of all four test series are provided in Figure 4-6 and data listings are given in Table 4-2.

A further synopsis of the effects of blending on brightness values is shown in Figure 4-7. A family of curves has been plotted in an attempt to accomodate limestones with various percentages of the IMASCO 6H material. Blending with a different standard of brightness would obviously alter the plots. Assuming cuttoffs of 80 percent minimum brightness and 50 percent or more Alberta limestone content in a given blend it is possible to delineate an area of the family of curves within which a more acceptable product would result. The Kananaskis limestone could achieve an increase in brightness to about 88 percent at the 50 percent mix limit. The Windy Point limestone would also be rated at an 80 percent brightness if blended at a ratio of approximately 63:37. At the 50 percent blend level the same rock would have a brightness value of about 83 percent.

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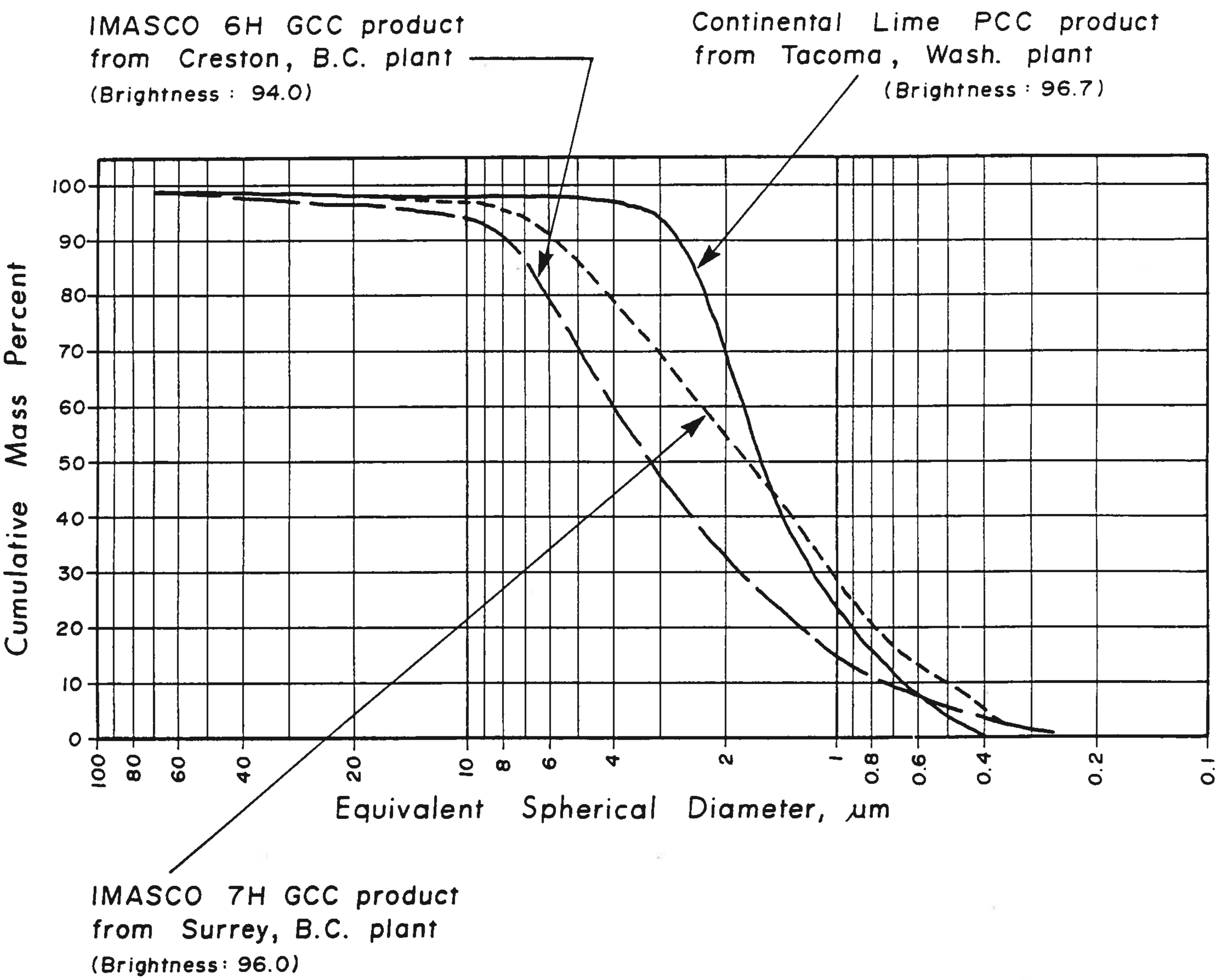

FIGURE 4-4

Size Analyses for Standard Products

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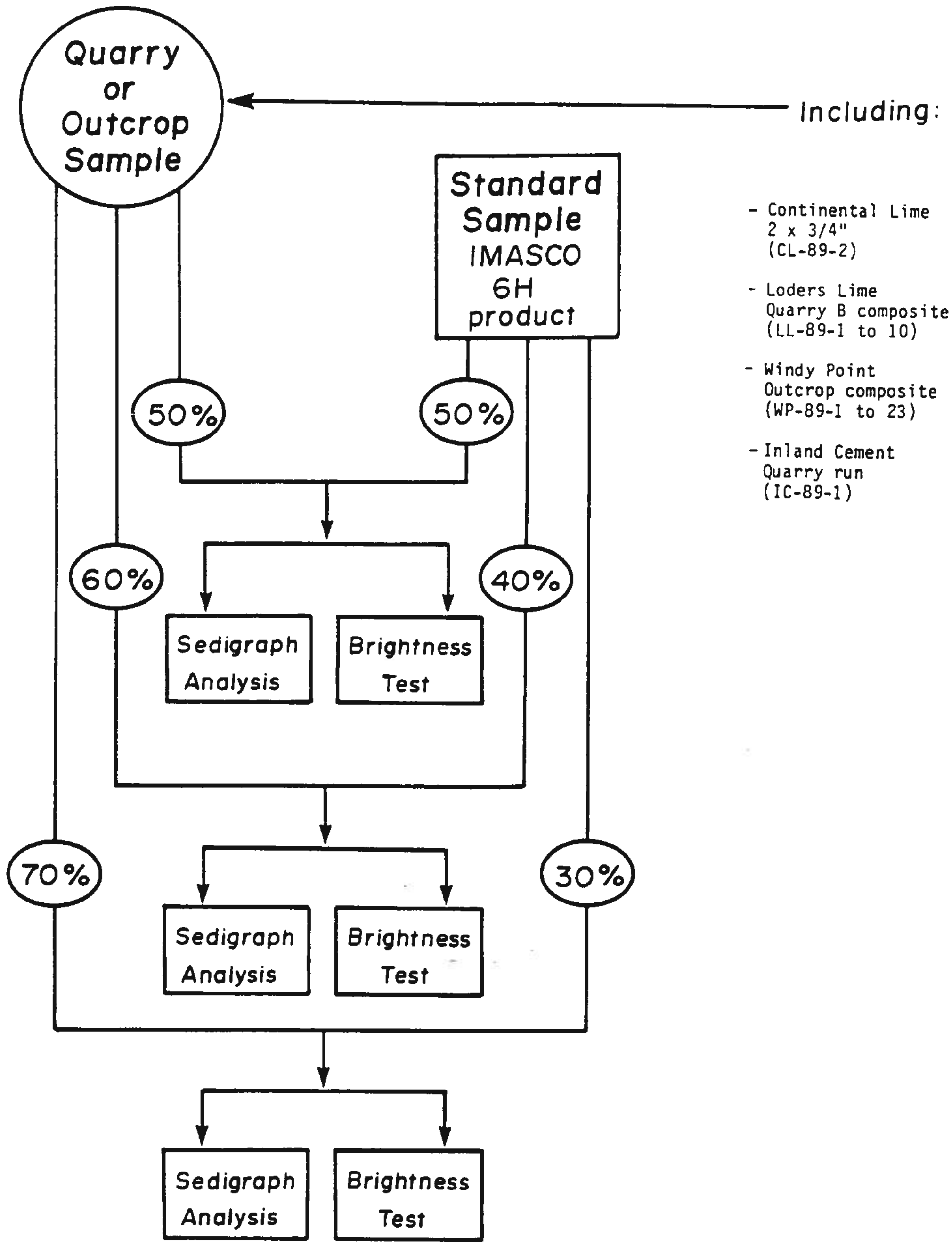

FIGURE 4-5

Analysis Program for Blended Samples

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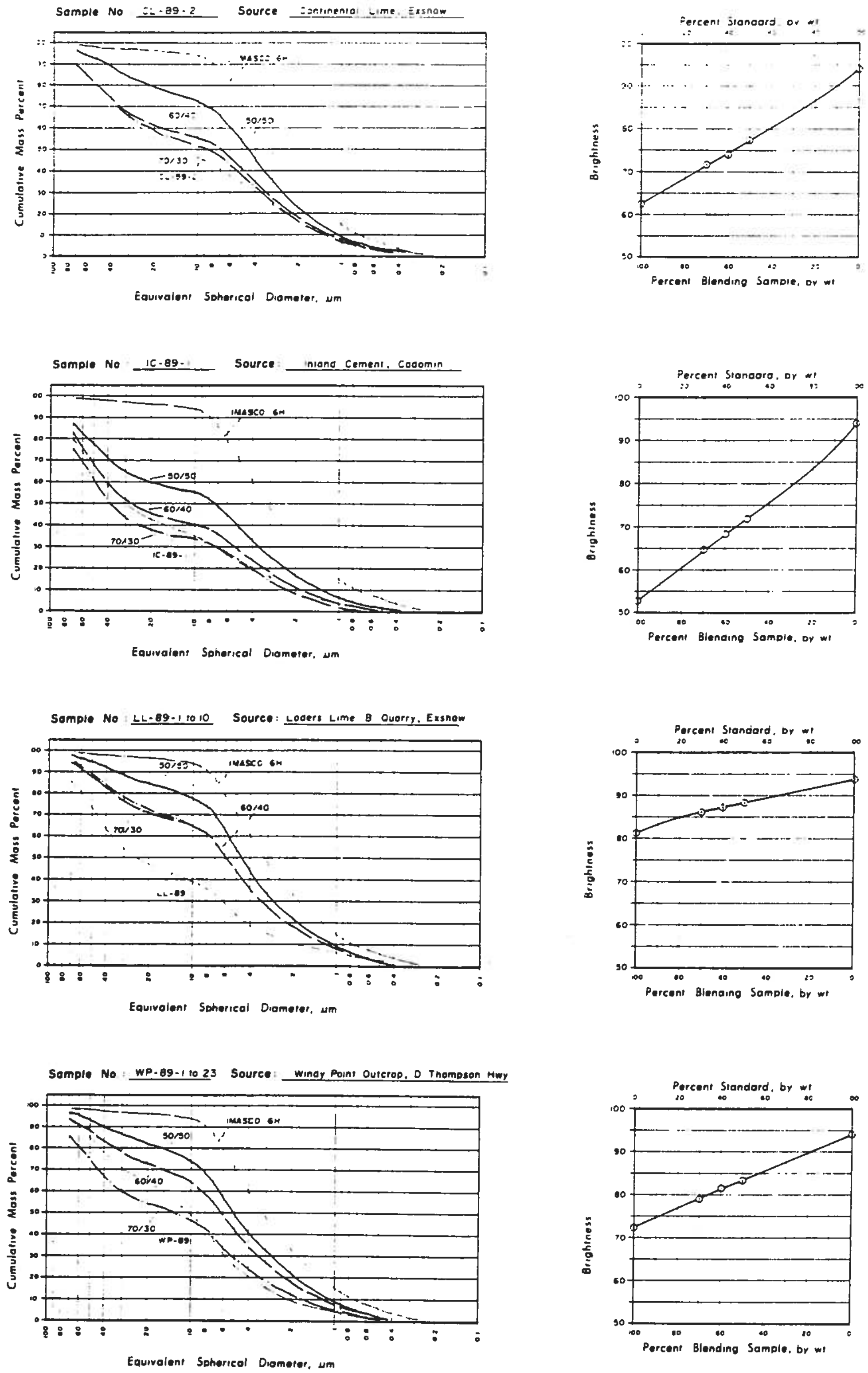

NOTE All samples were blended with IMASCO 6H (Creston) product as standard

FIGURE 4-6

Results of Blending Tests of GCC

3/89

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SAMPLE	BLEND RATIO, Raw:Standard	BRIGHTNESS
IMASCO 6H		94.19
CL-89-2		62.42
	70:30	71.74
	60:40	73.95
	50:50	77.26
IC-89-1		52.84
	70:30	64.66
	60:40	68.30
	50:50	71.93
LL-89-1 to -10		81.34
	70:30	86.10
	60:40	87.19
	50:50	88.33
WP-89-1 to -23		72.25
	70:30	79.08
	60:40	81.53
	50:50	83.44

TABLE 4-2 Summary of analyses of 1989 blended samples

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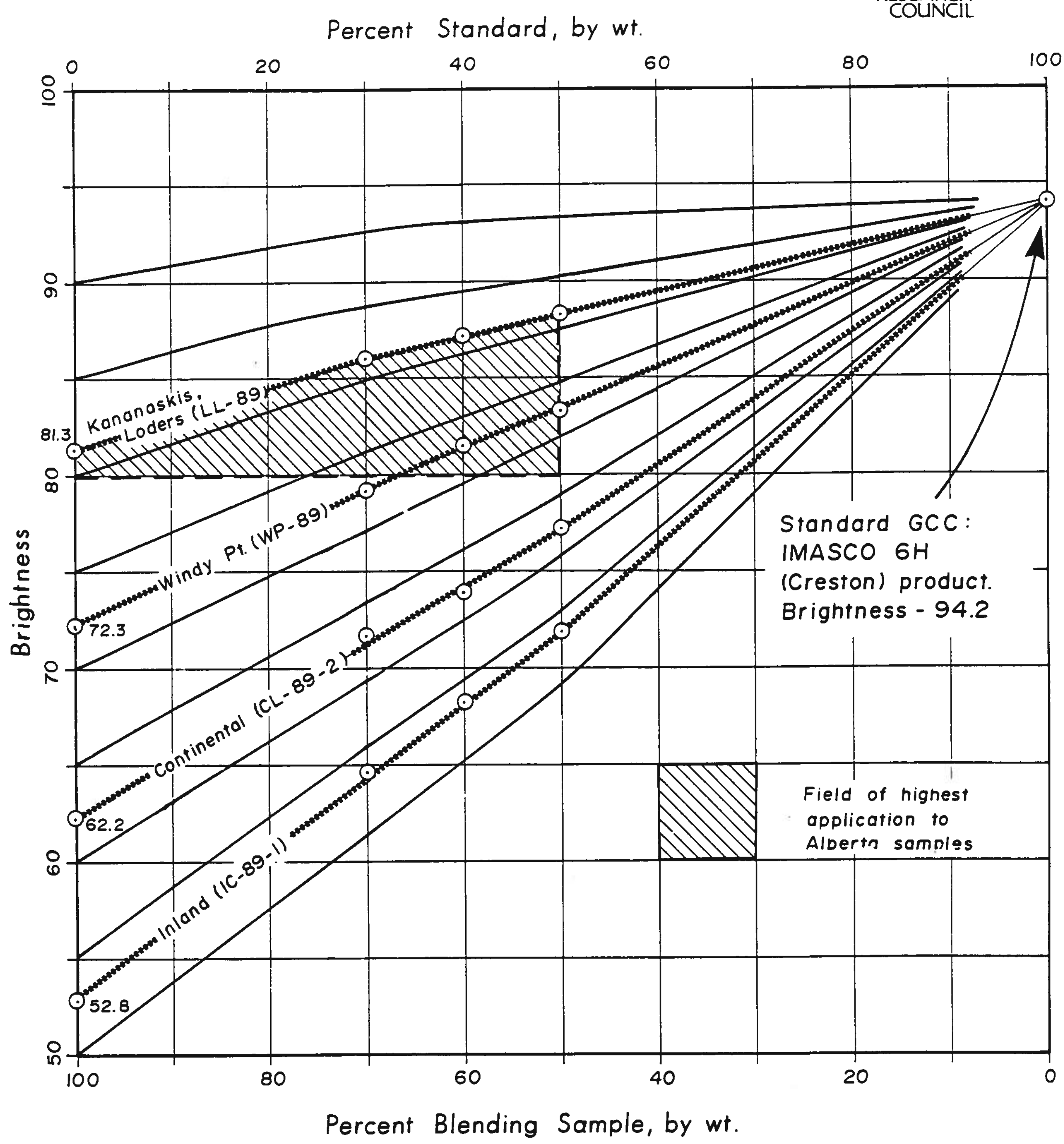

FIGURE 4-7

Family of Curves for Blended Samples

3/89

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A comparison of GCC and PCC analysis data is relevant to the choice of filler types to be used. As may be noted in Figure 4-4 the PCC product of Continental Lime has an extremely narrow range of particle sizes in comparison to the GCC plots. It should be reiterated here however, that the IMASCO products are not ground to ultra-fine sizes and are not intended for, nor are they currently being utilized within, the paper manufacturing industry. The chemical analyses of the processed products are listed in Table 4-3. Although the IMASCO limestone has very high purity the precipitated product of Continental Lime is almost virtually pure $CaCO_3$.

Scanning electron micrographs of the selected standards also provide additional useful observations (see Plates 4-1, 4-2, and 4-3). The IMASCO 6H and 7H products are predictably comprised of highly angular fragments of various dimensions within the size ranges achieved by final grinding in a dry ball mill. The Continental Lime PCC material is made up of loose clusters or rosettes of calcite crystals of uniform size and shape.

	Typical Chemical Analysis of IMASCO GCC Product	Typical Chemical Analysis of Continental Lime quarry rock from Exshaw	Chemical Analysis of Continental Lime (Tacoma) PCC Product by Alberta Research Council
CaO	54.65	55.1	55.87
MgO	0.54	0.4	0.26
SiO_2	0.44	0.7	0.14
Fe_2O_3	0.35		0.08
Al_2O_3	0.35		0.02
TiO_2	0.01		
Na_2O	0.03		
K_2O	0.02		
S			0.01
P_2O_5			0.29
MnO			0.01
Pb		0.008	
R_2O_3		0.2	
L.O.I.		43.4	43.3
$CaCO_3$	97.53	98.34	99.71
$MgCO_3$	1.13	0.84	0.54
Brightness:	93.98 (6H) 96.04 (7H)	62.42	96.68

TABLE 4-3 Comparison of analyses of GCC and PCC Products

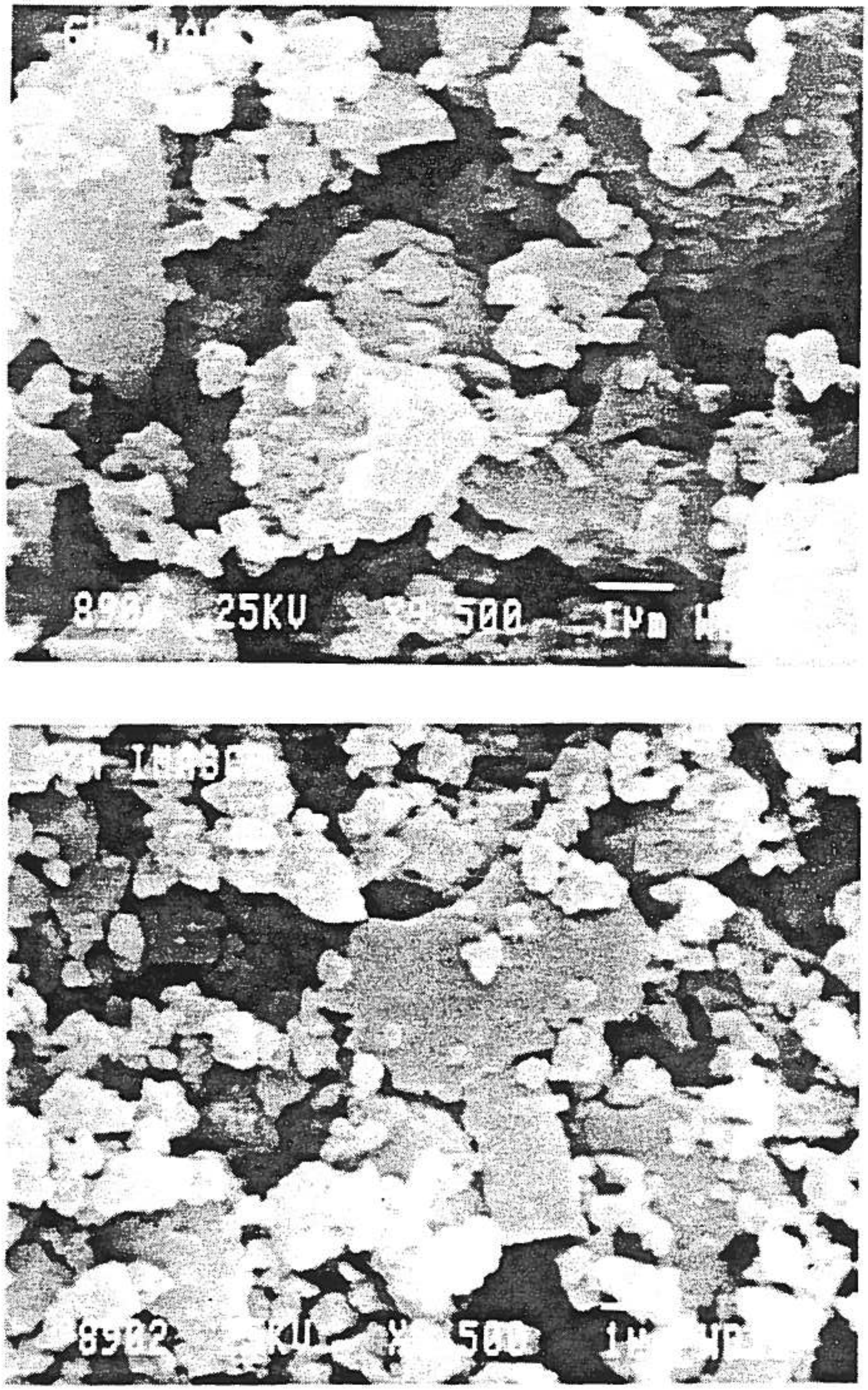

PLATE 4-1 Scanning electron micrographs of two IMASCO grades of GCC product.

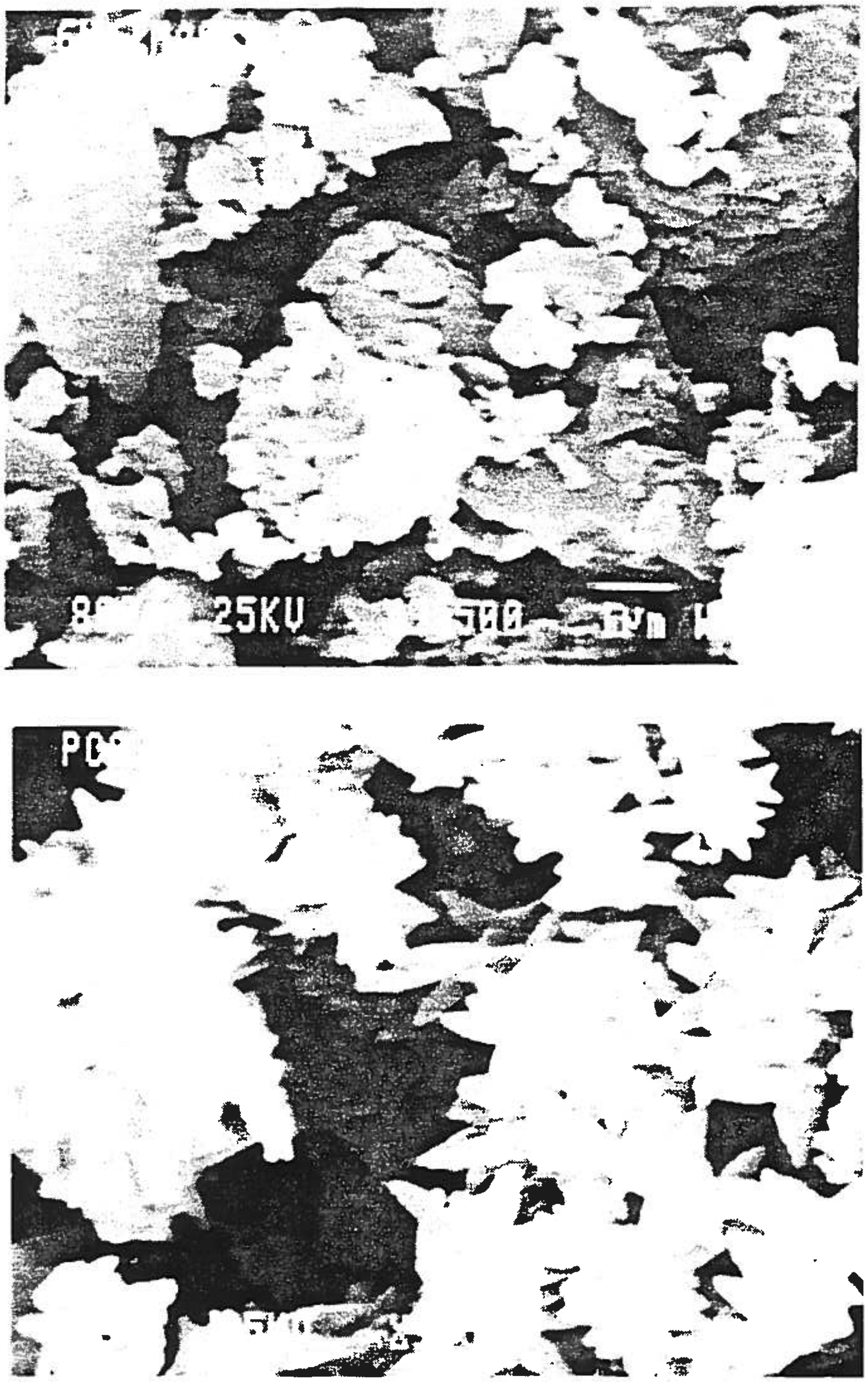

PLATE 4-2 Scanning electron micrographs comparing IMASCO 6H grade of GCC product with Continental Lime PCC product

10 μm 2000 ×

PLATE 4-3

Scanning electron micrographs of Continental Lime PCC product.

(S.E.M.s courtesy of Continental Lime)

1 μm 8000 ×

5. CONCLUSIONS

The testing of Alberta limestones to date indicates that fine paper fillers cannot be produced by ultra-fine grinding utilizing rock from local sources due to inherent low brightness factors. However, it may be feasible to exploit at least two occurrences (the Kananaskis and Windy Point deposits of Cambrian age) for blending with high grade GCC products from outside the province.

Current trends in the industry strongly suggest that PCC will be favored over GCC (and other mineral fillers) for future paper filler requirements in mills operating under alkaline conditions, for several technical and economic reasons. It is reasonable to expect that Alberta limestones may be further developed as feedstock for such production.

Data summarized in Table 4-1 indicate that Alberta limestones would generally be potentially suitable for production of precipitated calcium carbonate. However, as pointed out elsewhere herein, the ability of a given limestone to produce a high grade lime can only be determined with certainty through a kiln-burn test utilizing a full charge sample.

The Continental Lime plant at Exshaw produces lime from limestone locally quarried from beds of the Mississippian Livingstone Formation. The lime has been successfully used in the satellite PCC plant at the Weyerhaeuser pulp and paper mill at Prince Albert, Saskatchewan, where PCC is a constituent in the production of fine paper.

6. RECOMMENDATIONS

Any future programs devoted to the study of Alberta limestones should include analytical procedures designed to define filler specifications. Attention should be specifically given to the development of a comprehensive laboratory program for testing high calcium limestones for PCC production characteristics. A suggested format for evaluation of a rock to determine its potential for successful manufacture of a precipitated product is outlined in Figure 6-1. In order to effectively carry out this program laboratory procedures may require further modification and sophistication to match or even exceed industry standards. Contact should be maintained with manufacturers and users outside the province to ensure that all current aspects of PCC utilization are understood. Any future project undertaken should involve extensive literature searches for published information regarding developments in filler production and useage.

It is proposed that at least two high quality Alberta limestones be subjected to testing for possible PCC production through a program carried out in consultation with knowledgeable industrial firms. By this means an understanding of the potential for expanding the use of limestone resources of the province into this market may be realized.

Preparation of filler-grade materials on a pilot plant scale may be justified to more conclusively prove the viability of using limestones suspected to be of favorable quality.

Insert ___6.2___ in back pocket

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8. APPENDIX A

Prospective Limestones in the David Thompson Corridor

Results of the 1988 Field Work Carried out in the David Thompson Corridor by W.N. Hamilton

8. APPENDIX A. PROSPECTIVE LIMESTONES IN THE DAVID THOMPSON CORRIDOR

This section presents the results of field sampling and analyses of limestones that were not tested previously in limestone resource studies for Alberta. These are limestones exposed in the David Thompson Corridor, the last of the major mountain pass regions in Alberta where data were lacking.

Location and Physiographic Setting

The David Thompson Corridor is the region adjoining the North Saskatchewan River where it transects the Foothills, Front Ranges and Main Ranges of the Alberta Rocky Mountains, as shown in figure 8-1. The David Thompson Highway (Highway 11) traverses the Corridor from Nordegg west to Saskatchewan Crossing.

The mountains in this area have a northwest-southeast structural grain and form rugged topography, rising to 2550 m in average elevation. The valley bottom has an elevation of about 1330 m and is flooded in large part by Abraham Lake, formed by the Bighorn Dam on North Saskatchewan River. NTS sheet "Brazeau 83C" (1:250 000) covers the area.

Access in the Corridor (from Windy Point west) is restricted to the north side of the valley, along Highway 11. There are no vehicle bridge crossings of the North Saskatchewan River (or Abraham Lake) and no roads exist on the south side. The Corridor is not serviced by rail.

Geologic Setting

The regional geology and major structural divisions of the Rocky Mountains in the David Thompson Corridor are shown in figure 8-1. Detailed geology is presented in figures 3-5a and 3-5b. Geologically, the area includes three broad structural segments corresponding to the Foothills, Front Ranges and Main Ranges, all bounded by major thrust faults. The McConnell Fault marks the eastern boundary of the Front

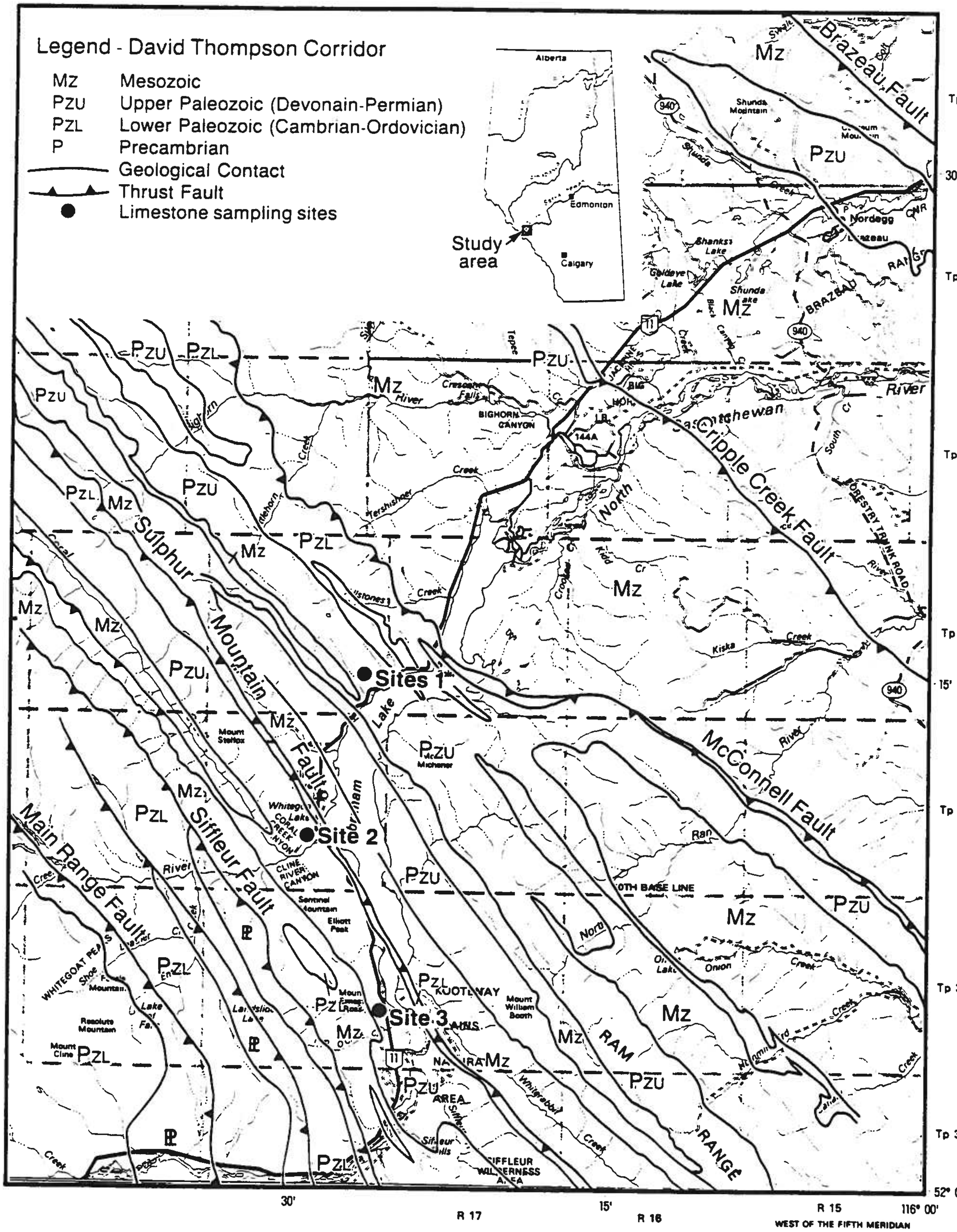

FIGURE 8-1. Regional geology of the David Thompson Corridor

Ranges, thrusting Paleozoic rocks onto Mesozoic rocks of the Foothills. The Front Ranges extend westward 40 to 45 km to the Main Ranges thrust, exposing mostly Upper Paleozoic rocks in three major thrust sheets (McConnell, Sulphur Mountain and Siffleur sheets), with strata dipping moderately to steeply southwest.

The Lower Paleozoic rocks comprise mainly thick carbonates of the Cambrian Formations (figure 8-2). These rocks were assessed previously for limestone quality with respect to ground calcium carbonate (GCC) potential, the primary assessment criterion being Brightness. Upper Paleozoic carbonates, because of their characteristic gray colour (i.e., low Brightness), were not included in that investigation.

In the present study, attention is focussed on the Upper Paleozoic carbonates for potential as source material for precipitated calcium carbonate (PCC). The Upper Paleozoic formations also consist dominantly of carbonates, as shown in figure 8-2. Of particular interest are the Devonian Palliser and the Mississippian Livingstone Formations, limestone-bearing units with proven capability for high-grade limestone production in other areas.

Previous Study

Until relatively recently (last 25 years) the David Thompson Corridor region was somewhat remote from Alberta's industrial markets and had only minimal road access. As a result, resource studies for the region are deficient. The geology is mapped on a reconnaissance scale (Verrall, 1968), but detailed mapping exists only for NTS map sheets 83C/1 (Mountjoy and Price, 1974) and 83C/8 (Douglas, 1955). The stratigraphy of the region is not well documented.

Previous limestone investigations focussed on the Cambrian Cathedral and Eldon Formations (Hamilton, 1987). These formations were prospected as potential host units of light coloured limestone suitable for ground calcium carbonate (GCC) paper filler. For GCC, the primary assessment criterion is Brightness and the Cambrian carbonates seemed to

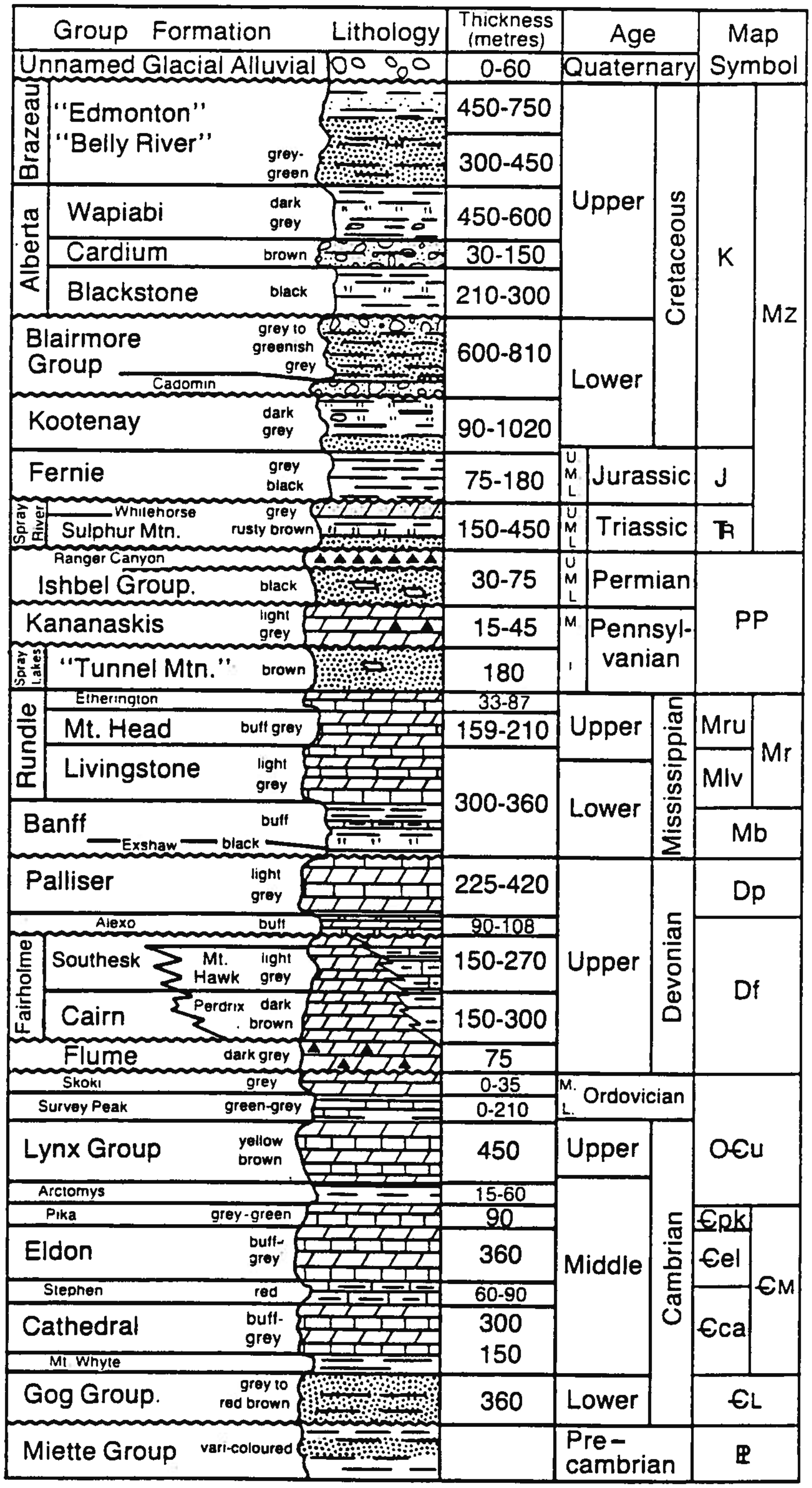

FIGURE 8-2. Stratigraphic succession in the David Thompson Corridor

offer the best prospects. In fact, the Eldon Formation limestones yielded among the highest Brightness values obtained for Alberta limestones, although still well below required levels. Chemical analyses data also indicate very high purity for the Eldon limestones at Windy Point. In the Cathedral Formation, however, the carbonates are mainly dark coloured dolomites.

Fieldwork and Testing

Palliser and Livingstone Formations were examined and sampled at three sites in the Corridor (figure 8-1), two for the Palliser and one for the Livingstone. Fieldwork was carried out in August 1988. Sections of the formations were measured and sampled completely through available exposures, with samples taken at 1.0 m intervals across the bedding. The samples were then combined into intervals of uniform lithology, for subsequent laboratory processing and analysis.

The principal evaluation criterion for limestone as PCC source rock is calcium carbonate purity. This is not a perfect indicator. The end quality being sought is amenability to calcining, with a high yield of high-purity calcium oxide. Some very pure limestones, for various reasons (Boynton, 1980), will not calcine satisfactorily in actual lime kiln operations. However, short of full scale kiln-burn trials with bulk tonnage samples, the chemical analysis is the best available test. Samples obtained in this study were subjected to standard analyses for calcium carbonate purity.

Selected sample intervals were also tested for Brightness. Although not a test criterion for PCC limestone, it is potentially useful data for other limestone applications.

Test Localities

Site I—Palliser Formation

Geology and site sampling

The Palliser Formation is exposed on the McConnell thrust sheet in an outcrop band that intersects the Corridor about 3.5 km west of Windy Point (figure 3-5b). A fault runs along the outcrop band near the middle of the formation, so that no complete section of the Palliser is available at this site. Total thickness of the formation is not determined.

The lower part of the formation (east of the fault trace) forms a prominent ridge that descends to the valley floor into a slight projecting spur. Palliser beds, and beds of the underlying Alexo Formation are exposed in a roadcut where Highway 11 crosses the toe of the spur (figure 3-5b). This exposure was measured and sampled as Section WH88-1. A similar interval sampled from ridge outcrop just above the road is Section WH88-2.

The upper part of the Palliser Formation (west of the fault trace) also forms a projecting ridge feature. On this ridge, the strata are folded in an anticlinal structure, the east limb truncated by the fault. On the west limb, the succession forms a dipslope to the ridge. A section of these strata exposed on the nose of the ridge, about 500 m north of Highway 11, was measured and sampled as Section WH88-5.

Lithologic descriptions of the sections at Site I are given in appendix B.

Analytical results

Chemical analyses of the Palliser limestones at this site are presented in appendix C, samples WH88-1, WH88-2 and WH88-5. The selected sample intervals and carbonate purities are shown on the lithology logs, figure 8-3.

The lower Palliser limestones all show high carbonate purity, generally 98 percent or higher, with significant content of $MgCO_3$. Values for $MgCO_3$ run fairly constant at between 5 and 7 percent, except in the basal 16 m interval of Section WH88-2 where it drops to less than 2 percent. The equivalent interval sample for Section WH88-1 includes some argillaceous beds from the underlying Alexo Formation, so the analyses are not directly comparable.

The Upper Palliser limestones (section WH88-5) also show high carbonate purity but with greater variability in $MgCO_3$, ranging from as low as 1.6 percent to 17.7 percent.

A single Brightness test of a selected interval of upper Palliser limestones yielded a value of 48.6 percent (figure 8-3).

Quarriabilty

Site I presents moderately favourable quarrying situations. At Sections WH88-1 and WH88-2, massive bedded limestones dipping steeply (70°) southwest form a sloping ridge mass up to 100 m wide over a strike length of 200 m, directly adjoining Highway 11. However, recoverable reserves are small due to limited depth of quarriability, probably less than 2 million tonnes.

At Section WH88-5, the upper Palliser limestone beds in a dipslope situation present ideal quarrying conditions. However, the inconsistency in quality makes quarriability of commercial grade tonnages uncertain.

Site II—Palliser Formation

Geology and site sampling

A second band of Palliser Formation is exposed in the Corridor, on

Insert 8.8 in back pocket

the Sulphur Mountain thrust sheet. The Palliser outcrops on a range that runs parallel to the Corridor in this sector, but is transected by the Cline River to expose a complete section of the formation at the mouth of Cline River Canyon, about 1 km west of Highway 11 (figure 3-5b). This section was measured and sampled as Section WH88-3. The section is on the flank of a synclinal fold structure, with the beds dipping southwest at 50°. Total thickness of 260 m was measured for the Palliser Formation. A lithologic description is given in appendix B.

Analytical results

Chemical analysis of Palliser limestones at Site II are presented in appendix C, samples WH88-3. A lithology log of Section WH88-3 showing selected sample intervals and carbonate purities is given in figure 8-3.

The analytical results are comparable with those for the Palliser limestones at Site I. The limestones show high carbonate purity throughout the formation, generally 98 percent or higher, with $MgCO_3$ contents ranging from 2.6 to 9.0 percent (though mostly in the 5 to 7 percent range). Only one zone, near the middle of the formation, tested as low-magnesium, high-purity limestone. This zone is 45 m thick, represented by samples WH88-3-8 and 9 (figure 8-3). The zone was also tested for Brightness and measured 50.5 percent.

Quarriability

Site II is the nose of a ridge formed of west-dipping limestone beds, presenting a favourable quarrying situation on the ridge as it descends to the floor of the Cline River valley. However, the limiting factor to quarriability could be limestone quality. If the only exploitable zone in the Palliser was the high-purity limestone near the middle of the succession, its recovery could be hampered by excessive overburden.

Site III—Livingstone Formation

Geology and site sampling

The Livingstone Formation (lower unit of the Rundle Group) lies above the Palliser, separated by a 300 m interval of shaly strata of the Banff and Exshaw Formations (figure 8-2). The Livingstone occurs in broad outcrop bands on both the McConnell and Sulphur Mountain thrust sheets, repeated on both sheets by subsidiary thrust faulting (figure 3-5b). However, accessible sections are rare. No suitable sampling site was found on the McConnell sheet, but a site on the Sulphur Mountain sheet is present opposite the south end of Abraham Lake. Here, a fairly complete section is exposed at the end of a ridge that plunges into the North Saskatchewan River valley (figure 3-5b). This section was measured and sampled as Section WH88-4. The strata dip southwest at about 50° over the measured interval of 310 m. A lithologic description is given appendix B.

The Livingstone Formation in this area was subdivided into three map units for geologic mapping (Mountjoy and Price, 1974); the Pekisko, Shunda and Turner Valley formations. The formation boundaries are not clearly defined and could not be identified with certainty in Section WH88-4, but are placed approximately as shown in figure 8-3.

Analytical results

Chemical analyses of Livingstone Formation limestones are presented in appendix C, samples WH88-4. The sample intervals and carbonate purities are shown on the lithology log for Section WH88-4, figure 8-3.

Results of analyses of samples WH88-4 are highly variable, reflecting lithologic variances observed for the Livingstone limestones (appendix B). In the lower part (Pekisko Formation) the limestones are shown to be fairly dolomitic, with $MgCO_3$ contents ranging from 5.2 to 13.2 percent. Carbonate purities vary considerably as well, from 92 to 98 percent, due to siliceous matter in the lower 35 m interval.

The middle Livingstone (Shunda Formation) limestones are also relatively impure, due to siliceous matter throughout, and $MgCO_3$ contents from 15 to 17 percent in the upper 25 m.

The upper Livingstone (Turner Valley Formation) exposure in Section WH88-4 is not complete, the uppermost 100 m or so of formation interval being covered. The exposed beds are dolomitic limestones, with high carbonate purities (98+ percent) and $MgCO_3$ contents from 8.5 to 25.9 percent.

A single Brightness test on Livingstone limestone, from a 26 m interval near the middle of the formation (figure 8-3) yielded a low value of 36.5 percent.

Summary of Results

The results of this study of Upper Paleozoic limestones in the David Thompson Corridor are summarized in table 8-1. Analytical results are presented in appendix C and figure 8-3.

The Palliser Formation is characterized by relatively uniform limestone lithology, and the limestones show consistently high carbonate purity (98+ percent) throughout the formation. The limestones are dolomitic, with $MgCO_3$ contents commonly in the range of 5 to 7 percent. Only one zone of low-magnesium limestone was identified, over a 45 m interval near the middle of the formation, where $MgCO_3$ content dropped to 2.6 percent (figure 8-3). Non-carbonate impurities are mainly silica and alumina, from minor argillaceous content rarely exceeding 2 percent. Low Brightness values, from 48.6 to 51.5, reflect the strong gray colour of the rocks.

The Livingstone Formation has considerable lithologic variation (figure 8-3, appendix C), and accordingly, wide variation in the chemical composition of the limestones. In general, the Livingstone (Pekisko, Shunda and Turner valley) limestones are relatively impure as a result of their dolomitic and/or siliceous nature. No significant

Table 8-1. Summary of Results, Upper Paleozoic Limestone Study, David Thompson Corridor

Locality	Formation	Quality		Brightness(%)	Thickness(m)	Indicated Reserves(t)	Quarriability
		$CaCO_3$(%)	$MgCO_3$(%)				
Site I	Palliser, upper	88-97 Avg 92	2-9 Avg 6	48.6	80	10M	Good; dipslope
	Palliser, lower	91-98 Avg 93	2-7 Avg 4	49.9-51.5	99	<2M	Good; dipslope
Site II	Palliser, total	89-96 Avg 92	2-9 Avg 6	-	259	>50M	Good; dipslope
	Palliser, middle zone	93-96 Avg 95	2.6	50.5	45	?	Fair/Poor; steeply dipping beds in interval near middle of section
Site III	Livingstone: Turner Valley	71-90 Avg 84	8-26 Avg 15	-	102	-	No limestones encountered of quality suitable for industrial use
	Livingstone: Shunda	77-96 Avg 89	2-17 Avg 7	36.5	115	-	
	Livingstone: Pekisko	76-90 Avg 84	5-22 Avg 13	-	72	-	

zones of high calcium carbonate purity are indicated in any part of the succession. The only Brightness value obtained for Livingstone limestones was 36.5 percent for a zone near the middle of the formation.

Conclusions

Upper Paleozoic limestones of potentially exploitable quality exist in the Devonian Palliser Formation. In the Mississippian Livingstone Formation, the limestones appear to be of submarginal quality for industrial use, particularly as PCC source rock.

The Palliser limestones are dolomitic but generally have high carbonate purity. Argillaceous content ($SiO_2 + Al_2O_3$) is less than 2 percent. The magnesium content (5 to 7 percent $MgCO_3$) is detrimental to the use of limestone for cement making but does not necessarily disqualify it for lime manufacture. Magnesian lime does account for a significant proportion of lime produced for the industrial market (Boynton, 1980). It is not determined, but seems probable that a slightly magnesiam lime could serve as effectively as high-calcium lime for PCC production. More important would be the content of non-carbonate impurites such as iron, silica, and alumina (O"Driscoll, 1988).

Sufficient outcrop and thickness of Palliser limestones exist in the David Thompson Corridor that it should not be difficult to locate quarrying sites with large tonnages. The sections measured and sampled for this study, chosen primarily for accessible exposure, are also sites with good quarriability.

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9. APPENDIX B

Lithologic Descriptions and Logs, David Thompson Corridor

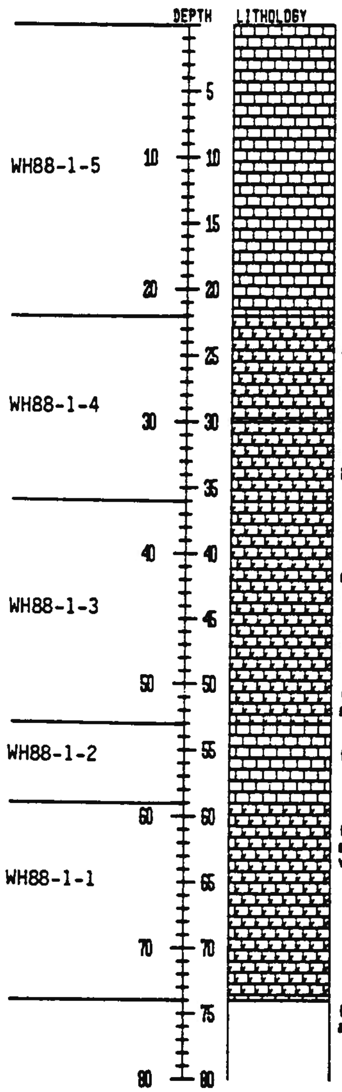
Section WH88-1

W.N. Hamilton

B. Fildes

25 Aug. 1988

Roadcut on David Thompson Highway 3.5 km west of Windy Point. Roadcut in resistant spur formed by lower Palliser and Alexo formation beds intersecting highway. Beds dipping 70 degrees SW.



DESCRIPTION

(0.0-22.0) LIMESTONE: med.-dk. grey mottled, dk. grey more prominent, sl. dolomitic, micro-f.crystalline. Calcite veinlets common, massive bedded.

(22.0-30.0) LIMESTONE: DOLOMITIC, massive, micro-f.crystalline, med.-dk. grey mottled, turbulent bedding structure, wavy laminate, scattered calcite veinlets.

(30.0-36.0) LIMESTONE: DOLOMITIC, similar to above, bedding more pronounced.

(36.0-48.0) LIMESTONE: DOLOMITIC, dk. grey with some med.grey mottling, micro-crystalline, massive, occ.thick bedded.

(48.0-53.0) LIMESTONE: DOLOMITIC, sl.mottled, micro-f.crystalline, pelloidal, med.-dk. grey.

(53.0-59.0) LIMESTONE: dark grey, micro-crystalline, massive.

(59.0-74.0) LIMESTONE: DOLOMITIC, med.-dk. grey, sl.mottled, micro-crystalline, massive-med.bedded, rubbly. @72m, 1m zone vuggy porosity; unit becoming more calcareous upwards.

(74.0-74.0) Middle of roadcut. Strata below are light grey argillaceous dolomites, definitely in Alexo/Fairholme beds.

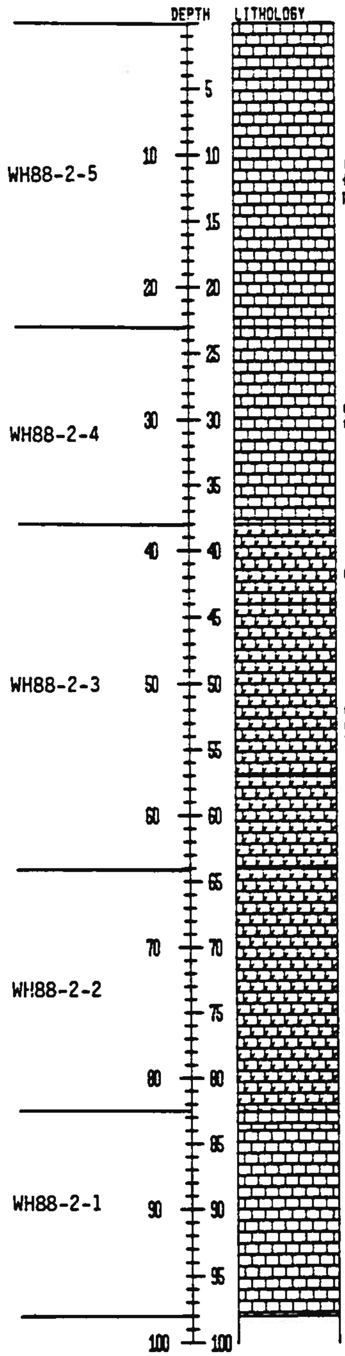
Section WH88-2

W.N. Hamilton

B. Fildes

25 Aug. 1988

Outcrop on spur above roadcut of Section WH88-1, 3.5 km west of Windy Point, David Thompson Highway. Spur formed by lower Palliser and Alexo formation beds. Beds dipping 70 degrees SW.



DESCRIPTION

(0.0-23.0) LIMESTONE: medium grey, as below, f.crystalline/pelloidal, thick bedded, abundant dolomite(?) projections on weathered surface.

(23.0-38.0) LIMESTONE: medium grey, weathered surface medium grey, pelloidal (calcarinite), thick bedded/massive, abundant wispy laminae of resistant (silt?) material, med. grained clastic.

(38.0-44.0) LIMESTONE: DOLOMITIC, irregularly mottled, fine crystalline, thick bedded.

(44.0-57.0) LIMESTONE: DOLOMITIC, med-dark grey, mottled, weathered surface med. grey, occ. med. brn. grey, med. bedded, wispy silt laminae and siliceous pods, f.crystalline, becoming thicker bedded upwards.

(57.0-64.0) LIMESTONE: DOLOMITIC , as below but less mottled, thick bedded/massive, blocky, f.crystalline.

(64.0-82.5) LIMESTONE: DOLOMITIC, med-dark grey, weathered surface med. grey, more mottled than above, micro-f.crystalline, sl. silty with wispy silt laminae, thin-med.bedded.

(82.5-84.0) LIMESTONE: medium grey, weathered surface medium grey, slightly silty, micro-fine crystalline, pelloidal.

(84.0-98.0) LIMESTONE: med.grey, micro-crystalline, sl. sandy/silty pelloidal, scattered clear spar patches, massive bedded. Scattered fossil remains (gastropods?). Above 88m becomes dolomitic, mottled. 84-88m strongly mottled.

(98.0-98.0) Lowest exposure on east side of spur.

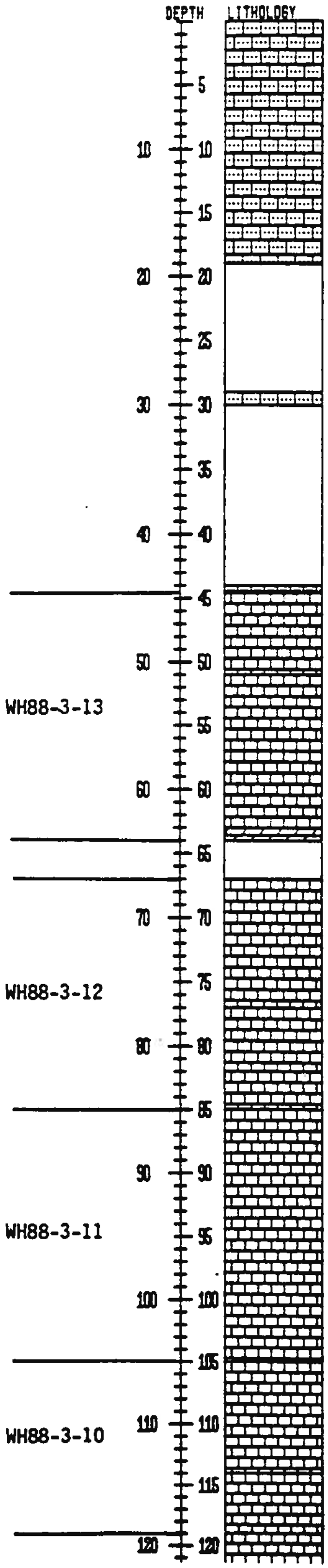
Section WH88-3

W.N. Hamilton

B. Fildes

26 Aug. 1988

Section of Palliser Formation exposed at mouth of Cline River canyon, north side, on spur projecting down to Cline River 1 km above junction with Abraham Lake. Beds dipping 40 degrees SW.



DESCRIPTION

(0.0-19.0) LIMESTONE: SILTY, dol., lt/med gr., wthd.surf. med.gr, thn/med bdd., platy in some zones, distinctly laminated w silt in lower part and v. silty grading to sltst. Zone blk. chert nods. at top of unit, nods.conc. along stratig.lines.

(19.0-29.0) covered interval

(29.0-30.0) LIMESTONE: SILTY, dol.,f./micro xln., thick bdd., lt. grey, wthd.surf. med.grey.

(30.0-44.0) covered interval

(44.0-44.5) LIMESTONE: ARGILLACEOUS, dk. grey, thin bdd./platy, recessive.

(44.5-51.0) LIMESTONE: med./dk. grey, wthd.surf. med grey, micro xln., detrital in part with some f/med g. mat.; some scatt. tubular borings & silt lenses, med bdd., sl. resist. Upper 1m has abnt. tubules with med brn grey mottling.

(51.0-57.0) LIMESTONE: tubular mottled, alternating w med. grey dol. lst., as below. Tubular bands thinner and less frequent upward. Irreg. silty bands throughout.

(57.0-63.0) LIMESTONE: with tubular struct. as below, alt. w. bands silty dol./lst.; bands 0.6m thick, silty bands gen. recessive, finely laminated. Unit moderately resistant.

(63.0-64.0) DOLOMITE: silty, lt. brn. grey, wthd. surf. med./dk. grey, thin bdd., blocky/rubbly.

(64.0-67.0) covered. Outcrop upslope indicates thin/med.bdd., recess. unit.

(67.0-77.0) LIMESTONE: med./dk.grey, med. grey brn. mottling, wthd.surf. med.grey, abnt tubules, micro-xln. w f./med.grained detrital mat. in tubes, scattered silt lenses, med.bdd., resist.

(77.0-82.0) LIMESTONE: med./dk.grey, wthd.surf.med.grey, w. med brn mottling, abnt. tubular structs., massive bdd. alt. to med.bdd. in irreg. manner. @ 71.5m silty band 0.5m thk. w lenses of silt & silty lst./dol.interlayered.

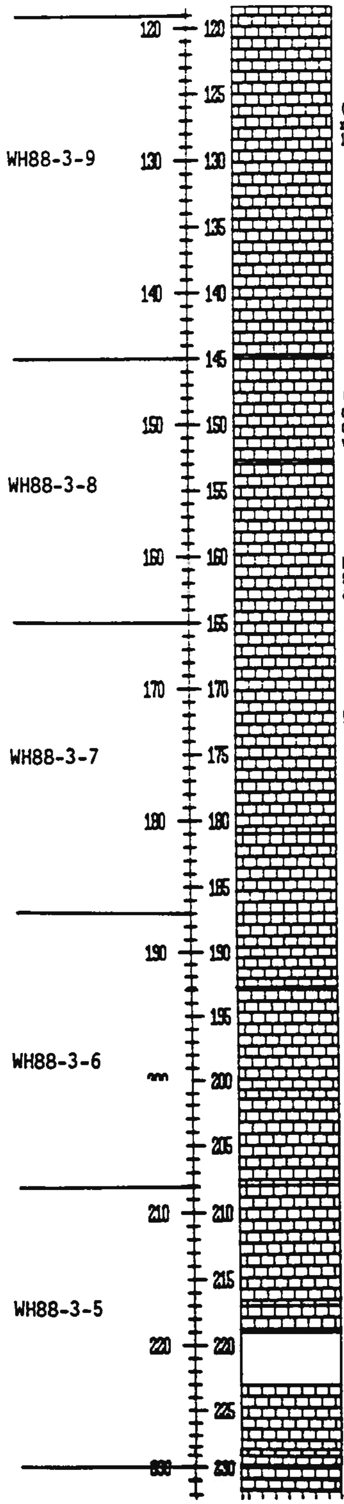
(82.0-85.0) LIMESTONE: med./dk.grey, wthd.surf., med.grey, micro xln., f.g.detrital, some clastic text.in part, thk.bdd./massive, small patches sparry calcite, resist. unit.

(85.0-105.0) LIMESTONE: med./dk.grey, w.med.brn. mottling; abnt. tub. struct. on wthd. surf.; tubes filled w. f. g. det. lst., in micro/f. xln. matrix, med./thk.bdd. @ 93-95m tub. struct. absent. @ 99m zone calc. strings., up to 5 cm thk.

(105.0-114.0) LIMESTONE: med.grey, mottled med./dk. grey and med.brn, f. xln., brecciated in part, med./thk. bdd.

(114.0-119.0) LIMESTONE: as below, but thk./med. bdd.

Section WH-88 -3, Continued



(119.0-145.0) LIMESTONE: med./dk. grey, wthd. surf. med. grey, f. xln., massive. @ 129m zone of calcite stringers: major zone @ 123m, up to 1m thick.

(145.0-153.0) LIMESTONE: med.grey, wthd. surf. med. grey, detrital pelloidal (oolitic) text., med. g., thk. bdd., w scat. calc. stringers, occ. bands of calc.-filled tubes, cavities and vugs.

(153.0-165.0) LIMESTONE: med./dk. grey, detrital, med. g., thk. bdd./massive w.interlayers limestone, dk. grey, f. xln., thk. bdd., sl. recessive. Some beds v. well devlpd. pelloidal text., almost oolitic in places.

(165.0-181.0) LIMESTONE: med./dk. grey, wthd. surf. med. grey; calcarenite, med. g. in part w some beds of dense f. xln. lst. Thk. bdd./massive. 169-171m mottled zone w Amphipora-like tubing.

(181.0-187.0) LIMESTONE: calcarenite, med./dk. grey, wthd. surf. med. grey, med./c. g., thk. bdd./massive. 181-183m mottled zone w worm-like structs. (Amphipora?), mottled brn. & med./dk. grey. Worms (?) infilled with med.xln. dol. lst.

(187.0-208.0) LIMESTONE: calcarenite, med./dk. grey, wthd. surf. med. grey, m./c. g., thk. bdd.; brecciated in part w c. frags. up to 1 cm. Some mottling in dk. grey & med. brn. Scatt. calcite veins up to 5 cm. thk., parallel to bddg.

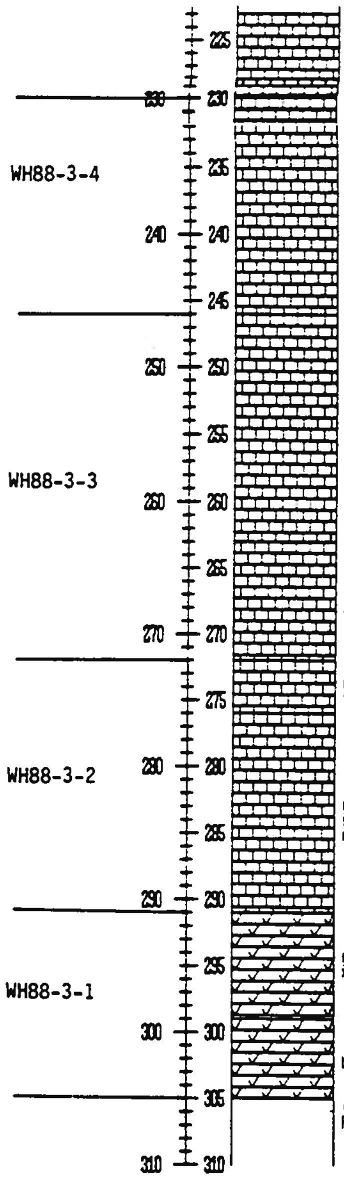
(208.0-217.0) LIMESTONE: med./dk. grey, wthd. surf. med. grey, f. xln., thk./med. bdd., rubbly in part. With occ. interbeds of calcarenite, up to 2 m thick; brecciated zone @ 209m w wthd. vuggy porosity for 1 m.

(217.0-219.0) LIMESTONE: calcarenite, lt./med. grey, med./c. g., med./thk. bdd., rubbly in part.

(219.0-223.0) Covered interval

(223.0-230.0) LIMESTONE: med. grey, wthd. surf. med. grey, f. xln., brecciated in part, med./thk. bdd., rubbly bands w arg. layers. Partly covered interval.

Section WH-88-3, Continued



(223.0-230.0) LIMESTONE: med. grey, wthd. surf. med. grey, f. xln., brecciated in part, med./thk. bdd., rubbly bands w arg. layers. Partly covered interval.

(230.0-246.0) LIMESTONE: as below. Abnt. wthd. laminae of dolomite (?) or silt (?). Alt. thin and thk. bdd. Some mottling in grey and brn. Distinct lamination.

(246.0-263.0) LIMESTONE: sl. dol., med. gr., wthd. surf. med. gr., thk.bdd. w interbdd. zones rubbly, sl. reces. lst., f./med. xln., clastic in part, pelloidal, scat. calc. blebs. Some beds abnt. raised laminae rough xtals. on wthd.surf.(dol?)

(263.0-272.0) LIMESTONE: med. grey, wthd. surf. med. grey, med./thk. bdd., sl. less resistant, somewhat rubbly, f./med. xln., fossil remains.

(272.0-276.0) LIMESTONE: sl. dolomitic, med. grey, wthd. surf. med. grey, med. bdd./mas., f. xln., some intervals more dolomitic than others.

(276.0-291.0) LIMESTONE: sl. dol., dk. grey, wthd. surf. med. grey, f./med. xln., massive, mod. resistant. Occ. bands rubbly, sl. recess. lst. Scatt. patches & veinlets calcite. Recess. rubbly 1 m band @ 282m, w some thn. arg. interlayers.

(291.0-299.0) DOLOMITE: CALCAREOUS, dk. grey, wthd. surf. med. grey, med. bdd., rubbly, sl. recess., f.xln., scat. calcite xtals. Grades upward into dol. limestone.

(299.0-305.0) DOLOMITE: CALCAREOUS, med./dk. grey, micro-f.xln., brecciated, wthd. surf. med. grey, sl. recess., med./thn. bdd.

(305.0-305.0) base may be 5-10m above actual contact with Alexo Formation.

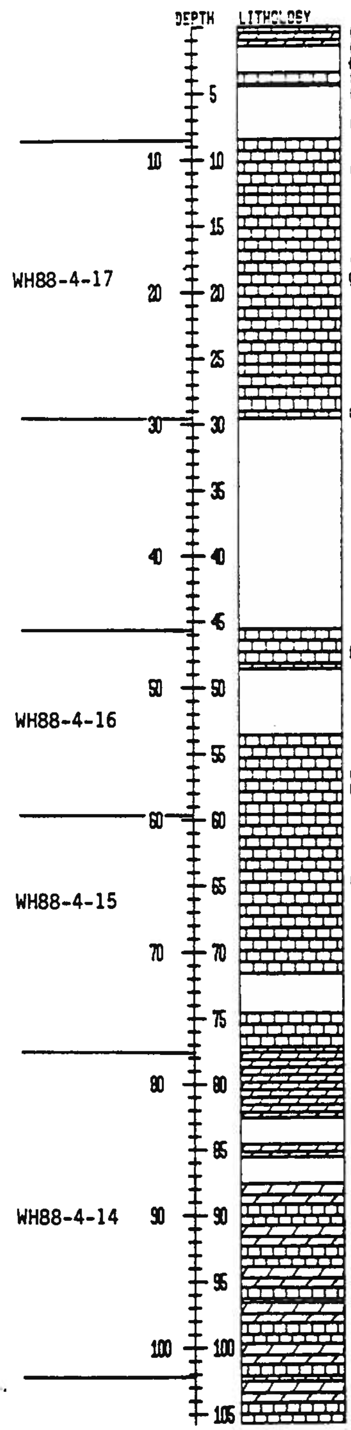
Section WH88-4

W.N. Hamilton

B. Fildes

27 Aug. 1988.

Section of Mississippian Livingstone Fm. at creek crossing David Thompson Highway, 12 km S of Cline R. junction. Section equates with MQ-42 on GSC map 1389A. Beds dipping 42-57 degrees SW.



DESCRIPTION

(0.0-0.5) LIMESTONE: med.gr., med/c.g. biofrag., poorly exposed.
(0.5-1.5) DOLOMITE: lt. gr/lt. crm., wthd.surf. lt. brn. gr., f.xln., thn./med. bdd, rubbly.
(1.5-3.5) Covered interval.
(3.5-4.5) LIMESTONE: med./dk. grey, wthd. surf. med. grey as below.

(4.5-8.5) covered interval.

(8.5-12.5) LIMESTONE: as below.

(12.5-25.5) LIMESTONE: as below, but slightly recessive, med./c. g. biofrag., med. bdd.

(25.5-29.5) LIMESTONE: med./dk. grey, wthd. surf. med./dk. grey, c.g. biofrag., thk.bdd., resistant.

(29.5-45.5) Covered interval.

(45.5-48.5) LIMESTONE: dk. grey, wthd. surf. dk. grey, med. g. biofrag., becoming f./med. g. near top.

(48.5-53.5) Covered interval.

(53.5-59.5) LIMESTONE: as below, but f./med. g., may have arg. unit at base (sharply recessive from underlying bed); unit thk. bdd., becomes med./c. g. in upper part.

(59.5-71.5) LIMESTONE: dk. grey, wthd. surf. med./dk. grey, med./c. g. biofrag., thk. bdd./massive, resistant.

(71.5-74.5) Covered interval.

(74.5-77.5) LIMESTONE: med. grey, wthd. surf. dk. grey, c.g. biofrag., massive bdd., resistant.

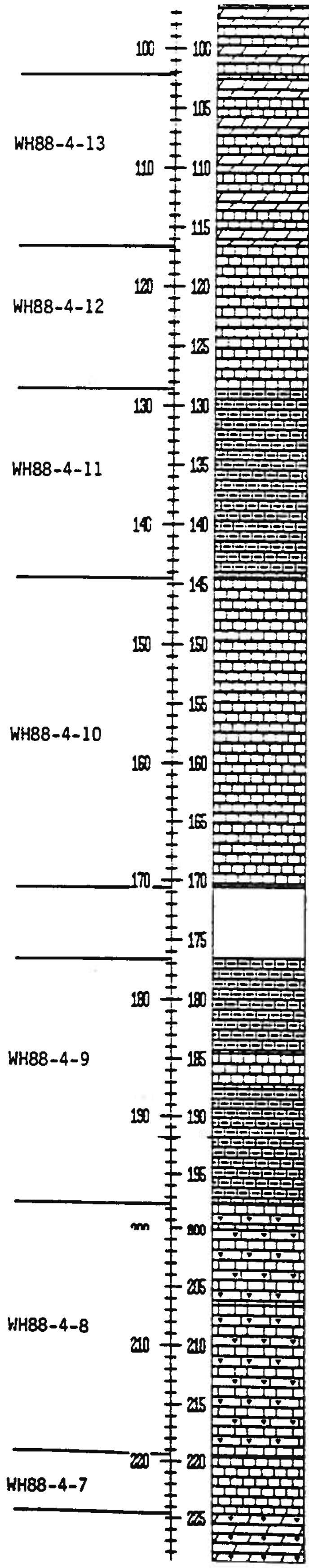
(77.5-82.5) DOLOMITE: lt. grey/lt. brown, wthd. surf. lt. brown, f.xln., sl. silty; interbedd. w dol., med./dk. grey, calc., med. xln. w relics of bioclastics; med. bdd., unit partly covered.

(82.5-84.5) Covered interval.
(84.5-85.5) DOLOMITE: lt. brn. grey, wthd. surf. med./dk. brn. grey, f.xln., scattered fossil frags. dolomitized, med. bdd.
(85.5-87.5) Covered interval.

(87.5-96.5) LIMESTONE AND DOLOMITE INTERBEDS, as below. Some of c.g. biofrag. lst. are partly dolomitized; med. bdd., unit partly covered.

(96.5-102.5) LIMESTONE AND DOLOMITE INTERBEDS, med. bluish grey, wthd. surf. lt. brn./lt. grey, f.xln., med. bdd., in beds 0.4-0.6 m thick; alt. w lst., med./dk. grey, med./c. g. biofrag., med. bdd., unit semi recessive, partly covered.

Section WH-88-4, Continued



(96.5-102.5) LIMESTONE AND DOLOMITE INTERBEDS, med. bluish grey, wthd. surf. lt. brn./lt. grey, f.xln., med. bdd., in beds 0.4-0.6 m thick; alt. w lst., med./dk. grey, med./c. g. biofrag., med. bdd., unit semi recessive, partly covered.

(102.5-116.5) LIMESTONE AND DOLOMITE INTERBEDS: LST. med./dk. gr, wthd. surf. lt./med.& dk. gr, sl. slty, f/med.g.,w interbeds of DOL., med. gr, micro-f.xln., med. bdd., unit semi resistant; scat. interbeds of dk. grey shaly lst.

(116.5-128.5) LIMESTONE: med./dk. grey, wthd. surf. med. grey, f.xln., sl. silty, med./thk.bdd., up to 1 m; interbedded w lst., dk. grey, arg., thin bdd., regularly interbanded; unit semi resistant.

(128.5-144.5) LIMESTONE: ARGILLACEOUS, dk. grey, wthd. surf. lt.grey/lt. brn, f./med.g. biofrag., w interbdd. shaly lst. partings, recessive, partly covered; some beds med. grey, med./c. g. biofrag., <0.3 m thk.; unit thin/med. bdd.

(144.5-170.5) LIMESTONE: med./dk.gr., f./med.g. biofrag., med.bdd., resist.; alt. w lst., dk.gr, arg., f./med.g., recess., in alt. units 1 m thk.; recess. units have partings up to 15cm thk. of dk.gr/blk calc.shale

(170.5-176.5) Covered interval.

(176.5-184.5) LIMESTONE: ARGILLACEOUS, dk.grey, f.g., thin bdd., w shaly zones & partings; interbdd. w lst., med./dk. grey, med. g. bioclastic; scatt. chert nodules.

(184.5-187.5) LIMESTONE: dk. grey, med. g. biofrag., thk. bdd./mass., semi resist.; lense of black chert nodules @ top.

(187.5-197.5) LIMESTONE: ARGILLACEOUS, cherty, dk. grey, wthd. surf. med. grey, f.g., w scat. crinoidal frags., thin/med. bdd., rubbly, semi recess., scatt. nodules black chert.

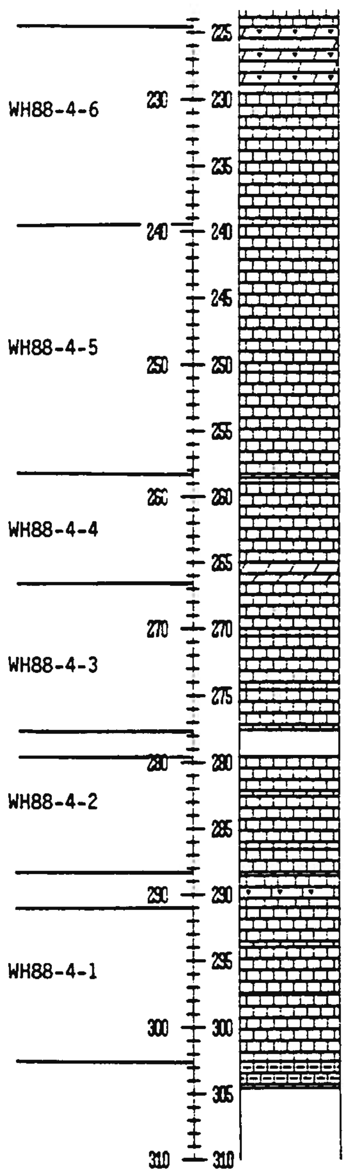
(197.5-206.5) LIMESTONE: CHERTY, arg., dk.gr., f.g., w abnt. scat. chert nods., gen. in distinct bands. Some interlayers c.g. biofrag. lst., thin bdd., platy/rubbly, recess. Biofrag. interbeds ltr., med. bdd. -@ 199.5m band chert masses 0.2m thk.

(206.5-219.5) LIMESTONE: CHERTY, intbdd.; lst. c.g.biofrag., med. gr., in thk. bdd.; chert in zones 0.5m thk, irreg. nods., patches, laminae, imbedded in f.g.dol.lst., but also in some med.g.biofrag. lst. Cherty bands gen. dk. gr. Unit semi res.

(219.5-224.5) LIMESTONE: med. grey, wthd. surf. lt./med.grey, c.g. biofrag. in places v.c.g., thk. bdd., semi resist.

(224.5-229.5) DOLOMITE: CHERTY, m/dk gr, wthd.surf.dk.gr w abnt.nods.,lamin.& irreg.mass. wh.chert; resist., m/dk. bdd.,some blk. cht.nods. At base unit, 0.3m bed of Dol., silic., med.bluish gr, rubbly, in recess. 0.3m bed, wthd.surf. lt. brn.

Section WH-88-4, Continued



(224.5-229.5) DOLOMITE: CHERTY, m/dk gr, wthd.surf.dk.gr w abnt.nods.,lamin.& irreg.mass. wh.chert; resist., m/dk. bdd.,some blk. cht.nods. At base unit, 0.3m bed of Dol., silic., med.bluish gr, rubbly, in recess. 0.3m bed, wthd.surf. lt. brn.

(229.5-239.5) LIMESTONE: as below, but thin bdd., recess. Lst.is . med. g. biofrag., sl. arg. in part, c.g. in part.

(239.5-250.5) LIMESTONE: lt. grey, wthd. surf. med. grey, c.g. biofrag., in parts v.c.g. & friable, abnt. crinoid & shell frags., med. bdd., semi resist.(Top of Pekisko?).

(250.5-258.5) LIMESTONE: lt. grey, wthd. surf. lt. grey, c.g. biofrag., thk. bdd./massive, resist.

(258.5-259.0) LIMESTONE: lt. grey, f.g., silty, wthd. surf. lt. brn., rubbly wthd., recess.
(259.0-265.0) LIMESTONE: lt. grey/lt. brn. grey, wthd. surf. med. grey, c.g. biofrag., massive, resist.

(265.0-266.5) LIMESTONE AND DOLOMITE INTERBEDS; LST.lt. grey, sandy, c.g. biofrag., thin bdd., platy. Intbdd. w DOL., med. blue grey, wthd. surf. lt. grey, silty, med-f.xln., hard, dense; unit thin bdd., recess.
(266.5-270.5) LIMESTONE: med./dk. grey, wthd. surf. med. grey, med./c.g. biofrag, thk. bdd., resist.
(270.5-274.5) LIMESTONE: med.brn.gr, wthd.surf. med. gr, med.g.biofrag., thin bdd.,platy,recess.; w intbds. shaly partings, mostly covered; @ 272.5m, 0.3m bed silty dol., rubbly wthd., f.xln., lt./med. brn., wthd. surf. med. brn.
(274.5-277.5) LIMESTONE: dk. grey, wthd. surf. med. grey, c.g. biofrag., thin/med. bdd., resist.; scatt. thin shaly/silty partings; abnt. small fossils at scat. horizons.
(277.5-279.5) Covered interval.

(279.5-282.5) LIMESTONE: as below, thick bedded, resistant.

(282.5-286.5) LIMESTONE: as below but thin bedded, sl. recessive.

(286.5-288.5) LIMESTONE: dk. grey, wthd. surf. med. grey, med.g.biofrag., med.bdd., resist.
(288.5-291.0) LIMESTONE: CHERTY, w abnt. chert nods. gen. on distinct strat. horizon; both wh. & blk. chert, mostly elongated ellipt. nods. up to 20cm long; lst. as below, resist.
(291.0-293.5) LIMESTONE: dk. grey, wthd.surf. grey, c.g. biofrag., abnt. crinoid frags., thk. bdd., resist.
(293.5-294.0) LIMESTONE: ARGILLACEOUS, dk. grey, w shaly partings.

(294.0-297.5) LIMESTONE: dk. grey, wthd. surf. dk. grey, f.xln., dense, ribbon banded, w thin platy partings of shale between bands, sl. recessive.
(297.5-302.5) LIMESTONE: dk. grey, wthd. surf. dk. grey, c.g. biofrag., w abnt. fossil debris, thk. bdd./mass. resist.

(302.5-304.5) LIMESTONE: ARGILLACEOUS, w thin interlayers blk. calc. shale, dk. grey, silty, f.xln., thin/med. bdd., recess.; contact w Banff Fm., abrupt change from recess. shaly to mass. resist. frag. lst. unit,some ang. truncation at contact

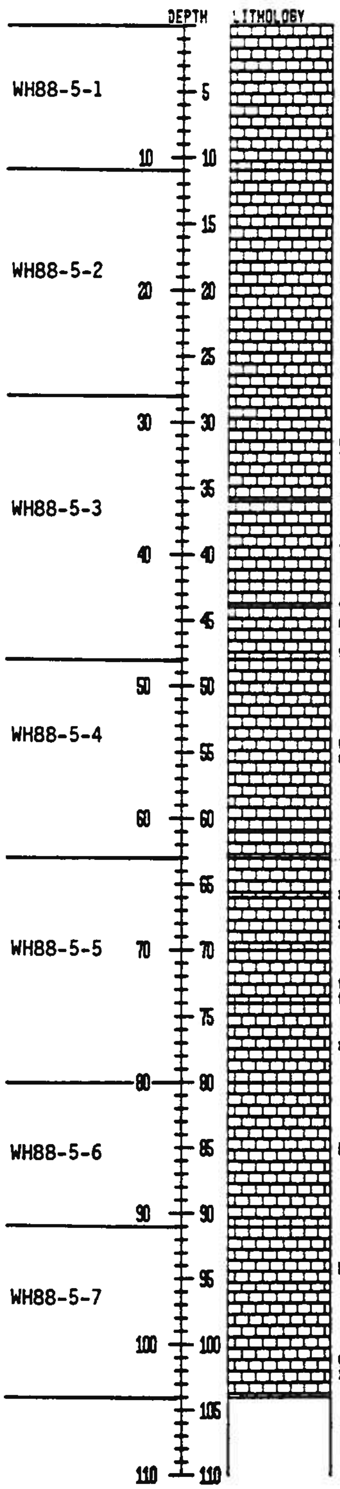
Section WH88-5

W.H. Hamilton

B. Fildes

29 Aug. 1988.

Section of upper Palliser Formation in hanging wall of thrusted Palliser outcrop band, west side of fault from WH88-2, 3.8 km west of Windy Point on David Thompson Highway. Section is on west limb of anticlinal fold (not mapped on GSC Map 1389A), beds dipping 42 degrees SW. Uppermost beds of Palliser Fm. drop off into recessive unit down dip slope. Banff Fm. exposed on opposite side of creek to west.



DESCRIPTION

(0.0-11.0) LIMESTONE: lt./med. grey, f.xln., fragmental in part, thk.bdd./massive.

(11.0-28.0) LIMESTONE: sl. dol. in part, med. gr, sl. mottled w lt./med. brn. gr, f.xln., pelloidal/fragmental in part, med/thk.bdd., resist.; distinct mottling on surface, shows tubular structure. Some intervals thin/med.bdd., slabby, semi-resistant.

(28.0-36.0) LIMESTONE: lt. grey, sl. mottled in lt. brn. grey, micro-f.xln., pelloidal/fragmental, thk. bdd./massive, abnt. tubular structures evident on weathered surface.

(36.0-42.0) LIMESTONE: med. grey, weathered surface med. grey, f.xln.-med. g. clastic in part, thick bdd./massive, resistant.

(42.0-44.0) LIMESTONE: lt. grey, sl. mottled to med. grey, tubular structures abundant, tubules filled w granular material, med. brn. grey. Massive bedd.
(44.0-48.0) LIMESTONE: as above, but less mottling; tubular structures less abundant; massive.

(48.0-61.0) LIMESTONE: med. grey, wthd. surf. lt./med. grey, micro-f.xln., thk. bdd./massive, scattered fossil fragments of white calcite, resistant.

(61.0-63.0) LIMESTONE: med. grey, as above, but f.xln., pelloidal (almost oolitic) in part; thk. bdd./massive.

(63.0-66.0) LIMESTONE: dark grey, wthd. surf. dk. grey, micro xln., massive.
(66.0-70.0) LIMESTONE: med. grey, wthd. surf. med. grey, f./med. xln., thk. bdd./massive. Occ. bands of f.g. clastic lst.

(70.0-74.0) LIMESTONE: med grey w sl. mottling in lt. grey, abnt. tubules at top of unit, decreasing downward; micro xln.-f.gr. in tubules, thk. bdd.

(74.0-80.0) LIMESTONE: med. grey, wthd. surf. med. grey, f.-med. xln., massive.

(80.0-91.0) LIMESTONE: as above, but dk. grey, micro-f. xln., becoming med. grey toward base, thk. bdd./massive.

(91.0-96.0) LIMESTONE: med. grey, micro-f. xln., thk. bdd., blocky, rubbly, strongly fractured, bedding disturbed.

(96.0-104.0) LIMESTONE: as above. Highly fractured zone in core of anticline. Bedding dips east just beyond lowest sample of interval.

10. APPENDIX C

Chemical Analyses of Devonian and Mississippian Limestones, David Thompson Corridor

APPENDIX C. Chemical Analyses of Devonian and Mississippian Limestones, David Thompson Corridor

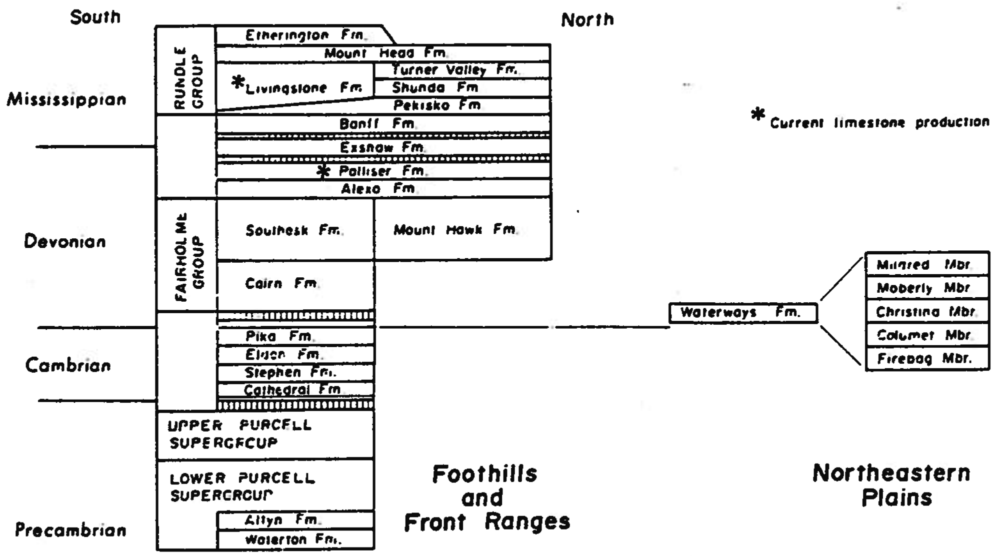
Sample Number	CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3	Na_2O	K_2O	P_2O_5	S	LOI	Total	$CaCO_3$	$MgCO_3$
WH88-1-5	50.97	3.27	1.11	0.60	0.16	0.04	0.25	<0.01	0.42	43.57	100.39	90.97	6.84
WH88-1-4	51.79	2.70	1.07	0.62	0.16	0.05	0.27	<0.01	0.39	43.59	100.73	92.43	5.65
WH88-1-3	51.21	2.70	1.13	0.61	0.16	0.04	0.27	<0.01	0.40	43.51	100.03	91.39	5.65
WH88-1-2	50.47	2.87	1.40	0.75	0.21	0.05	0.30	<0.01	0.42	43.13	99.60	90.07	6.00
WH88-1-1	49.72	3.09	2.09	0.86	0.21	0.07	0.25	<0.01	0.39	42.96	99.64	88.74	6.46
WH88-2-5	51.99	2.32	0.79	0.50	0.11	0.05	0.21	<0.01	0.40	43.43	99.80	92.79	4.85
WH88-2-4	51.01	3.18	1.14	0.62	0.15	0.06	0.24	<0.01	0.43	43.50	100.33	91.04	6.65
WH88-2-3	51.88	2.63	1.07	0.56	0.14	0.04	0.21	<0.01	0.40	43.58	100.51	92.59	5.50
WH88-2-2	51.45	2.90	1.07	0.57	0.13	0.04	0.25	<0.01	0.39	43.54	100.34	91.82	6.07
WH88-2-1	54.63	0.84	0.33	0.39	0.06	0.04	0.17	<0.01	0.45	43.63	100.54	97.50	1.76
WH88-3-13	51.51	3.23	0.84	0.48	0.08	0.03	0.13	<0.01	0.41	43.95	100.66	91.93	6.76
WH88-3-12	49.45	3.91	1.06	0.49	0.10	0.04	0.14	<0.01	0.43	44.00	100.12	89.15	8.18
WH88-3-11	51.29	3.17	1.29	0.58	0.12	0.03	0.15	<0.01	0.43	43.71	100.77	91.54	6.63
WH88-3-10	51.18	3.12	1.52	0.64	0.14	0.04	0.21	<0.01	0.42	43.57	100.84	91.34	6.53
WH88-3-9	52.39	1.23	1.04	0.53	0.10	0.04	0.17	<0.01	0.44	43.59	99.53	93.50	2.57
WH88-3-8	53.77	1.24	1.05	0.57	0.13	0.05	0.17	<0.01	0.45	43.52	100.95	95.96	2.59

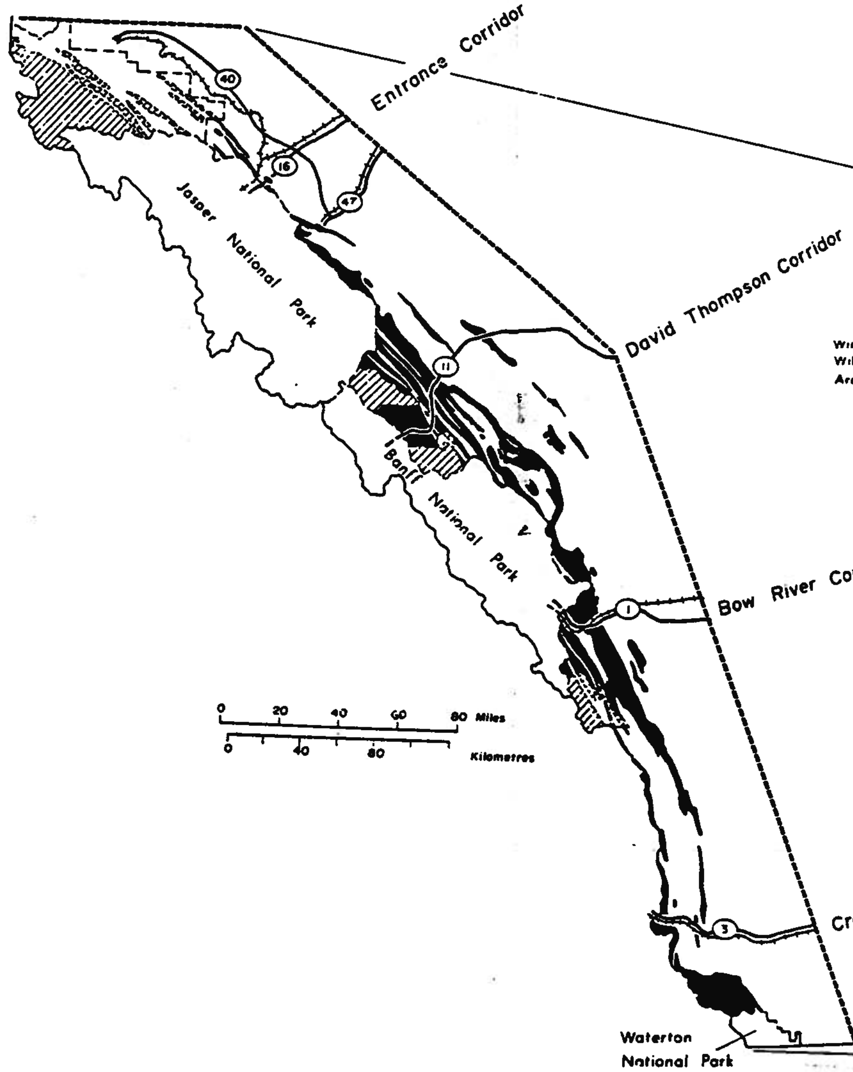
APPENDIX C (continued). Chemical Analyses of Devonian and Mississippian Limestones, David Thompson Corridor

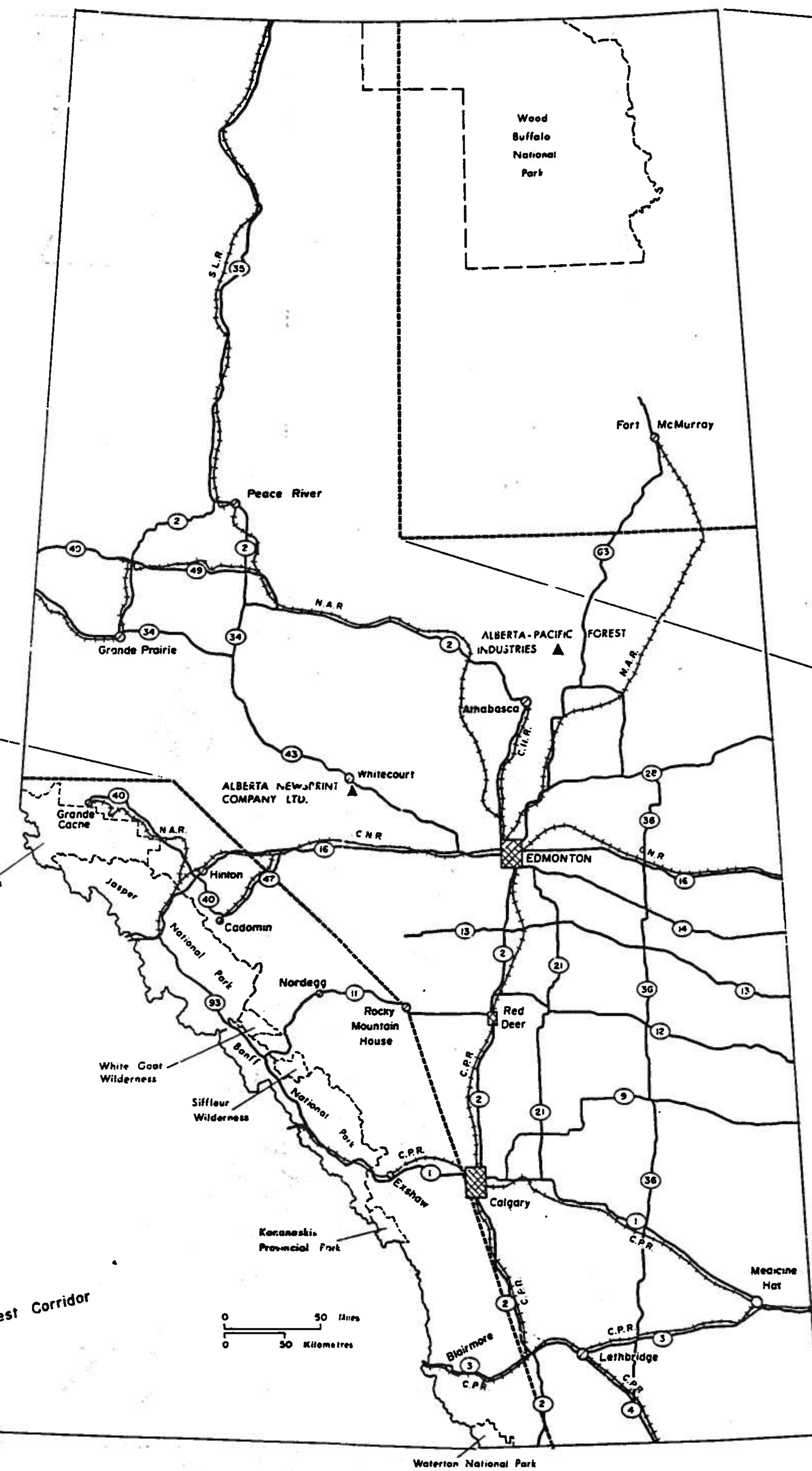
Sample Number	CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3	Na_2O	K_2O	P_2O_5	S	LOI	Total	$CaCO_3$	$MgCO_3$
WH88-3-7	51.39	3.39	0.79	0.49	0.10	0.04	0.16	<0.01	0.40	44.03	100.79	91.72	7.09
WH88-3-6	49.95	4.31	0.65	0.44	0.07	0.04	0.16	<0.01	0.40	44.02	100.04	89.15	9.02
WH88-3-5	51.54	2.92	0.65	0.45	0.08	0.04	0.15	<0.01	0.42	43.86	100.11	91.98	6.11
WH88-3-4	51.42	3.39	0.74	0.48	0.11	0.04	0.17	<0.01	0.41	44.05	100.81	91.77	7.09
WH88-3-3	51.88	2.21	0.88	0.55	0.14	0.05	0.20	<0.01	0.41	43.66	99.98	92.59	4.43
WH88-3-2	51.37	2.60	1.01	0.56	0.13	0.05	0.18	<0.01	0.43	43.60	99.93	91.68	5.44
WH88-3-1	52.48	2.24	1.02	0.59	0.15	0.05	0.22	<0.01	0.42	43.51	100.68	93.66	4.69
WH88-4-17	50.53	4.18	0.75	0.40	0.08	0.02	0.06	<0.01	0.41	44.21	100.64	90.18	8.74
WH88-4-16	49.88	5.58	0.34	0.30	0.06	0.02	0.01	<0.01	0.40	45.23	101.82	89.02	11.67
WH88-4-15	50.97	4.06	0.18	0.30	0.05	0.03	0.01	<0.01	0.43	44.61	100.64	90.97	8.49
WH88-4-14	39.63	12.40	1.20	0.47	0.13	0.04	0.01	<0.01	0.34	45.27	99.49	70.73	25.94
WH88-4-13	46.78	7.24	0.92	0.32	0.11	0.04	0.15	<0.01	0.37	44.61	100.54	83.49	15.14
WH88-4-12	43.38	8.09	4.04	1.08	0.30	0.05	0.41	<0.01	0.37	42.86	100.58	77.42	16.92
WH88-4-11	50.41	2.85	2.77	0.82	0.49	0.04	0.32	<0.01	0.43	42.67	100.80	89.97	5.96
WH88-4-10	52.22	0.95	2.08	0.68	0.21	0.04	0.23	<0.01	0.43	42.91	99.75	93.20	1.99
WH88-4-9	50.40	1.21	6.13	0.73	0.30	0.04	0.26	<0.01	0.44	40.87	100.38	89.95	2.53
WH88-5-3	49.55	3.30	1.34	0.57	0.09	0.01	0.11	<0.01	0.40	[illegible]	[illegible]	[illegible]	[illegible]

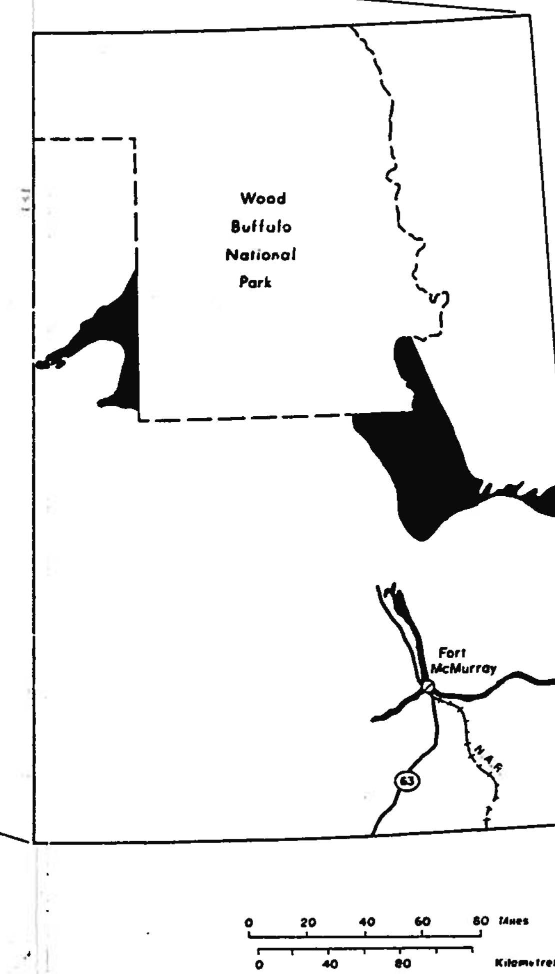
APPENDIX C (continued). Chemical Analyses of Devonian and Mississippian Limestones, David Thompson Corridor

Sample Number	CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3	Na_2O	K_2O	P_2O_5	S	LOI	Total	$CaCO_3$	$MgCO_3$
WH88-4-8	49.66	2.81	4.30	0.66	0.18	0.03	0.19	0.03	0.42	42.04	100.26	88.63	5.88
WH88-4-7	53.97	1.33	0.36	0.34	0.06	0.03	0.03	<0.01	0.44	43.80	100.36	96.32	2.78
WH88-4-6	47.38	6.32	1.86	0.34	0.08	0.03	0.06	<0.01	0.39	43.99	100.45	84.56	13.22
WH88-4-5	42.28	10.61	0.34	0.31	0.09	0.04	0.05	<0.01	0.36	45.45	99.53	75.46	22.19
WH88-4-4	50.32	4.27	0.68	0.40	0.20	0.04	0.09	<0.01	0.41	44.15	100.56	89.81	8.93
WH88-4-3	45.75	5.12	4.11	0.40	0.43	0.05	0.43	<0.01	0.40	42.25	98.94	81.65	10.71
WH88-4-2	50.48	2.92	2.87	0.63	0.27	0.05	0.24	<0.01	0.44	42.80	100.70	90.09	6.11
WH88-4-1	49.79	2.47	4.12	1.01	0.41	0.05	0.44	<0.01	0.43	41.77	100.49	88.86	5.17
WH88-5-1	53.00	1.16	0.73	0.49	0.10	0.01	0.06	<0.01	0.46	43.73	99.74	94.59	2.43
WH88-5-2	49.11	4.47	1.37	0.58	0.13	0.01	0.12	<0.01	0.42	43.92	100.13	87.65	9.35
WH88-5-3	49.55	3.30	1.34	0.52	0.09	0.01	0.11	<0.01	0.40	43.85	99.17	88.43	6.90
WH88-5-4	54.18	0.78	1.30	0.56	0.08	0.01	0.09	<0.01	0.44	43.37	100.81	96.70	1.63
WH88-5-5	51.16	3.19	1.45	0.50	0.09	0.03	0.10	<0.01	0.43	43.63	100.49	91.31	6.67
WH88-5-6	47.42	6.19	1.16	0.41	0.07	0.01	0.07	<0.01	0.38	44.35	100.06	84.63	12.95
WH88-5-7	44.58	8.46	1.37	0.45	0.09	0.02	0.12	<0.01	0.37	44.61	100.07	79.56	17.70









Limestone outcrop area outside Park boundaries

Limestone outcrop area within Provincial Park or Wilderness Area

▲ Location of proposed paper mill

FIGURE 1-4

LOCATION MAP

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