Field Evaluation of Prospective Filler-Grade Limestones in Alberta

by

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1. EXECUTIVE SUMMARY

1.1 Background

This study is a follow-up to a literature study of Alberta limestones for potential paper filler use. The study is in support of efforts by the Government of Alberta to attract a fine-paper industry to the province. Its objective is to evaluate prospective limestone (and dolomite) occurrences identified in the literature study, by field checking, sampling and laboratory testing.

1.2 Fieldwork and Testing

Four prospective occurrences were included for field evaluation: (1) "white" limestones reported in the Precambrian Waterton Formation, in the Clark Range north of Waterton Park; (2) "white" dolomites in the Peechee reef member of the Devonian Fairholme Group, Phillipps Pass; (3) light-coloured limestones in the Cambrian Eldon Formation at Kananaskis in the Bow River valley; (4) the thick Cambrian carbonate succession exposed in the David Thompson Corridor.

Each locality was thoroughly investigated geologically and carbonate beds that appeared to meet the evaluation criteria were systematically sampled. The main evaluation criteria are colour (whiteness) and carbonate purity. Colour evaluations in the field were aided with the use of the Munsell rock colour chart. Laboratory testing involved determination of Brightness (measured and expressed as a percentage on a standardized scale), chemical analysis, and estimation of grindability. Petrographic and X-ray diffraction analyses were also done for lithology and texture determinations in relation to grindability.

1.3 Summary of Results

The results of field observations and laboratory tests conducted for this study are summarized in table 1. The best test results are obtained for Eldon Formation limestones, at Kananaskis in Bow Valley and also at Windy Point in the David Thompson Corridor. Brightness values average 76% at Kananaskis, 74% at Windy Point. The limestones are lithologically similar at both localities, have very high purity of around 98% $CaCO_3$, and good grindability.

The next best Brightness values are for dolomites in the Altyn Formation overlying the Waterton Formation in the Clark Range. These measured up to 74.8%, but the rocks are siliceous and difficult to grind. Other carbonates tested in this study have Brightness values below 65%.

1.4 Conclusions

None of the prospective carbonates tested meets the Brightness specifications for a calcium carbonate paper filler (i.e., minimum 85%). However, the Eldon limestones (76% and 74%) come close, and otherwise have excellent characteristics. These limestones may be considered for use as an extender for paper filler, or for other less stringent filler applications.

1.5 Other Potential Filler Sources

Several mineral fillers that can be used in paper-making may be available in Alberta, as possible alternative sources. These include kaolin, titanium dioxide, gypsum, phosphogypsum, and waste calcium carbonate. Others that include talc, barite and diatomite are not known to occur in Alberta, but the geological conditions exist for the possibility that they might yet be found.

Alberta kaolin deposits investigated previously were found to be of sub-marginal quality, due to clay and quartz impurities well above specification limits. However, since that investigation, beneficiation experiments on an equivalent Saskatchewan deposit are reported to have been successful in upgrading the kaolin to filler quality. In view of this, further and more intensive testing of Alberta kaolin deposits may be in order.

1.6 Recommendations

(1) Conduct further tests of Eldon limestones to evaluate their potential use as an extender for paper filler. This should include blending tests with commercial calcium carbonate fillers, and economic evaluation of cost factors.

(2) Follow a similar procedure for kaolin, submitting the best material identified from previous study for beneficiation testing, followed by blending tests using the beneficiated product with commercial kaolin filler, and economic analyses of results.

(3) Undertake a strategic study of minerals availability for Alberta forest products industries. This should be broadly based, examining the whole spectrum of potential mineral raw materials from the standpoint of requirements, current sources, Alberta resources, economic factors, and information needs.

(4) If studies in (1) and (2) yield economically positive results, undertake further geological fieldwork to establish quarriable reserves, and check out possibilities for better sites in more remote areas. Includes test drilling.

2. INTRODUCTION

2.1 Background

This study is a follow-up to a literature study of Alberta limestones to evaluate their potential as a source of calcium carbonate paper filler. The Government of Alberta is encouraging the establishment of a fine-paper mill in the province, and one of the principal raw material requirements is a white mineral filler. The province lacks kaolin, the most common paper filler used, but has extensive deposits of limestone, which can substitute for kaolin in the alkaline paper-making process.

The literature study (Hamilton, 1986a) determined that Alberta limestones in general are grey-coloured and of insufficient purity for filler use. However, a few localized carbonate rock occurrences of exceptionally light colour were identified. These were recommended for field checking, sampling and laboratory tests to evaluate their filler potential. The present study carries out those recommendations.

The prospective occurrences identified are as follows:

1) Outcrops of the Precambrian Waterton Formation - reported to contain beds of white limestone - in the Clark Range area between Crowsnest Pass and Waterton Park.

2) A local reef dolomite development in the Devonian Fairholme Group (Peechee Member), outcropping in Phillipps Pass adjacent to Crowsnest Pass.

3) Limestones of the Cambrian Eldon Formation in the Bow Valley, near the old Kananaskis quarries, where bands of light-coloured, very pure limestone are reported.

4) The thick Cambrian carbonate succession exposed in the David Thompson Corridor, between Windy Point and Banff Park gate, where data on carbonate lithologies are scanty.

2.2 Previous Work

Prospective localities examined in this study have all been mapped in detail by the Geological Survey of Canada (Price, 1961; Price and Mountjoy, 1970; Mountjoy and Price, 1974). Part of the David Thompson Corridor region, from Whirlpool Point west to Banff Park gate, has had only reconnaissance-scale mapping (CSPG, 1968) but even that is sufficient to establish a lack of prospects in this part of the Corridor.

Previous limestone resource studies are summarized in Hamilton (1986a). Data from these studies were oriented to the conventional end uses for limestone (i.e., cement and lime) and did not allow a direct evaluation for filler use, though they indicated promise for some limestones. No previous testing of Alberta limestones for filler potential has been done.

2.3 Specifications

Specifications for calcium carbonate filler used in paper making are outlined in Hamilton (1986a). The critical requirements pertain to colour (whiteness), particle size distribution, and carbonate purity.

Colour, or whiteness, is specified in terms of Brightness - generally a minimum 85% for paper filler, 90% for coating. These specifications differ slightly from those given for paper-grade kaolin clays - minimum 80% for filler and 85% for coating clay (Scafe and Hamilton, 1985). The difference is unreconciled, but may be due to generally higher Brightness values available in calcium carbonate filler products.

Particle size distribution is for the ground product, but depends on the physical structure of the rock and its carbonate purity as they relate to grindability. Specifications call for 30-40% of the product to be finer than 2μm in filler and 80-90% finer than 2μm in coating.

Carbonate purity is commonly specified as limestone purity, with a minimum $CaCO_3$ content of 96-98%. However, dolomitic limestones and dolomites could substitute for high calcium limestones (Guillet and Kriens, 1984). $MgCO_3$ is not deleterious to white paper filler, even though specifications call for high-calcium limestone. More important is the content of non-carbonate impurities, mainly silica, which must be minimal to ensure "freedom from grit" in the ground filler product.

3. METHOD OF STUDY

3.1 Fieldwork

Fieldwork was carried out in late September 1986. At each locality, the site was reconnoitered with regard to physiographic and geologic setting. The "float" in each area was noted as an indicator of the presence of white limestone. Outcrop and quarry exposures were investigated and prospective carbonates identified with the aid of a rock colour chart for the Munsell color system. The field criteria established for colour evaluations were: Lightness value $\geq$ 8, Chroma $\leq$ 2; these values were considered likely to yield Brightness values approaching 80% in the powdered rock. The Munsell rock colour chart was used to remove any subjectivity in field observation of rock colour.

The other main field criterion for selecting prospective limestone beds was carbonate purity. Prospective limestones that appeared to meet the criteria were systematically sampled to provide representative material of each unit. Marginal or submarginal limestones were also sampled to insure that no possibly was overlooked. The sampling method involved taking representative samples at 0.5 m intervals across the bedding of selected zones, then combining the samples into stratigraphic intervals of uniform character and colour. In this way, minor colour variations would be measured quantitatively in subsequent laboratory tests.

3.2 Laboratory Testing

Samples collected in the field were ground and passed through a 65-mesh sieve. During this process, observations were made on the hardness and ease of grinding of the material as a preliminary indication of its grindability, an important characteristic of filler-grade limestones. These estimates are qualitative only, expressed as the relative ease with which the rock was ground to pass a 65-mesh sieve. They provide some indication of the amenability of the rock to commercial fine-grinding techniques, where a much finer grain size (-325 mesh) must be achieved. Thin-sections were cut from some of the rock samples for microscopic examination, to determine the degree of crystallinity and other petrographic characteristics that might affect grindability.

The powdered samples were tested for Brightness (also termed whiteness, or Reflectance), which is measured and expressed as a percentage on a standardized scale. The standard material defining the scale is magnesium oxide, with 100% Reflectance. For this study, the procedure was as follows. The powdered sample was strewn out on paper and pressed to form a flat surface. Measurements were made directly on the flat powder surface, using a Photovolt reflectometer with a tristimulus green filter in the search unit. The standard was a porcelain plate of trigreen reflectance 77. All measurements were performed by J. H. Hudson at the Saskatchewan Research Council laboratory[1].

Selected samples were subjected to chemical analysis, to determine carbonate purity and the nature of the impurities present. Some samples were subjected also to X-ray diffraction analysis, to identify the mineral forms of impurities.

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1 The procedure is one commonly used for testing kaolin. For limestone, Hudson suggests the samples should be ground finer than 65-mesh for a truer measurement. These measurements would tend to be low and therefore can be considered minimum values.

4. TEST LOCALITIES

4.1 Clark Range, Waterton Area

4.1.1 Location and Physiographic Setting

South of Crowsnest Pass in southwestern Alberta, a prominent eastward salient occurs in the Rocky Mountain front to form the Clark Range, which extends from the Flathead Range southeastward into Waterton National Park (figure 1). The Clark Range comprises the whole of the Front Ranges at this latitude and is dissected by north flowing streams and tributaries of the Castle, West Castle and Carbondale Rivers, whose deep valleys give rise to rugged topography. Relief in the area is up to 1100 m, with maximum elevations of 2640 m. NTS sheet "Fernie 82G" (1:250,000) covers the area.

Access to the area is mainly from Highway 3 to the north, on secondary roads which follow the major river valleys. Access is also available from Highway 6 to the east, via Secondary Highway 507 from Pincher Creek to Beaver Mines. However, local access is limited and none is available from Waterton Park. The main test locality is along the West Castle River (WCR-4,5 in figure 1), reached by Secondary Highway 774 from Beaver Mines.

4.1.2 Geologic Setting

The regional geology of the Clark Range is shown in figure 1. The Clark Range is a broad synclinorium of Proterozoic rocks, 160 km long and 30 km wide, thrust eastward over Mesozoic rocks by the Lewis thrust fault, which is the major structural feature of the area. The Lewis fault marks the eastern boundary of the Front Ranges in southern Alberta and extends for more than 200 km, also underlying the Flathead and High Rock Ranges to the north. At the southern terminus of Flathead Range the Lewis fault trace swings sharply to the east, around the projecting front of the Clark Range.

The Proterozoic rocks form a series known as the Purcell Supergroup,

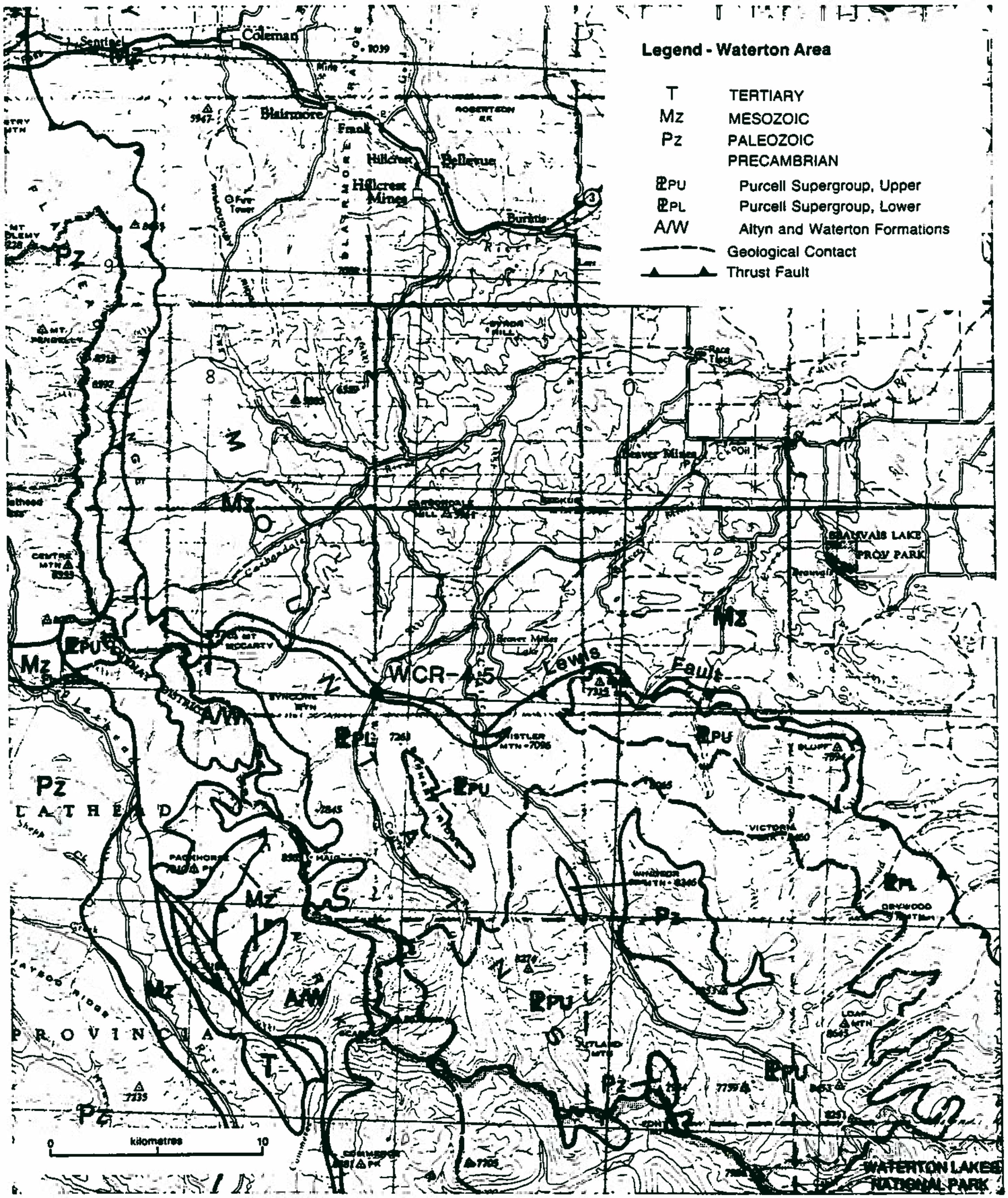

Figure 1. Regional geology of the Clark Range, Waterton area.

comprised of quartzites, argillites and carbonates with an aggregate thickness of 3350 m (Douglas, 1977). The succession of formations and their lithologies are shown in figure 2. The succession is subdivided broadly into upper and lower units (ⱣPU , ⱣPL), the mapped distribution of which is shown in figure 1. In their broad synclinal setting the strata are relatively undisturbed and the outcrop pattern is controlled largely by topography, with younger strata at higher elevations and older strata at lower.

The formation of primary interest for this study is the Waterton Formation, oldest unit of the series. The Waterton is an assortment of varicoloured limestones and dolomites, with one of its characteristic rocks types described as "dense white limestone" (Price, 1964). Above the Waterton, the Altyn Formation is comprised of thinly bedded dolomite and massive, cliff forming sandy dolomite, with minor argillite and limestone. Some of the dolomites are very light grey coloured, weathering almost white in outcrop, and were considered a secondary prospective source.

The outcrop of Waterton and Altyn Formations is shown in figure 1. Outside Waterton National Park the Waterton has limited outcrop, its only exposure being just above the Lewis thrust fault along the north front of Clark Range between Castle and Carbondale Rivers, and in small isolated (and inaccessible) fensters on the west flank. The outcrop band along the north front was the locality prospected for white limestones in this study.

4.1.3 Site Sampling

The best exposures of Waterton and Altyn Formations are in Waterton National Park. Outcrops of the formations were examined initially in the Park, along Cameron Lake Road, to gain an appreciation of the type lithologies and to attempt to locate white carbonates in the successions.

No beds of white limestone could be found in Waterton Formation outcrops. The Altyn, however, has some very light-coloured dolomites that weather almost white (plate 1). Small pieces of the rock taken from rubble at two points along the road are representative of middle Altyn dolomites

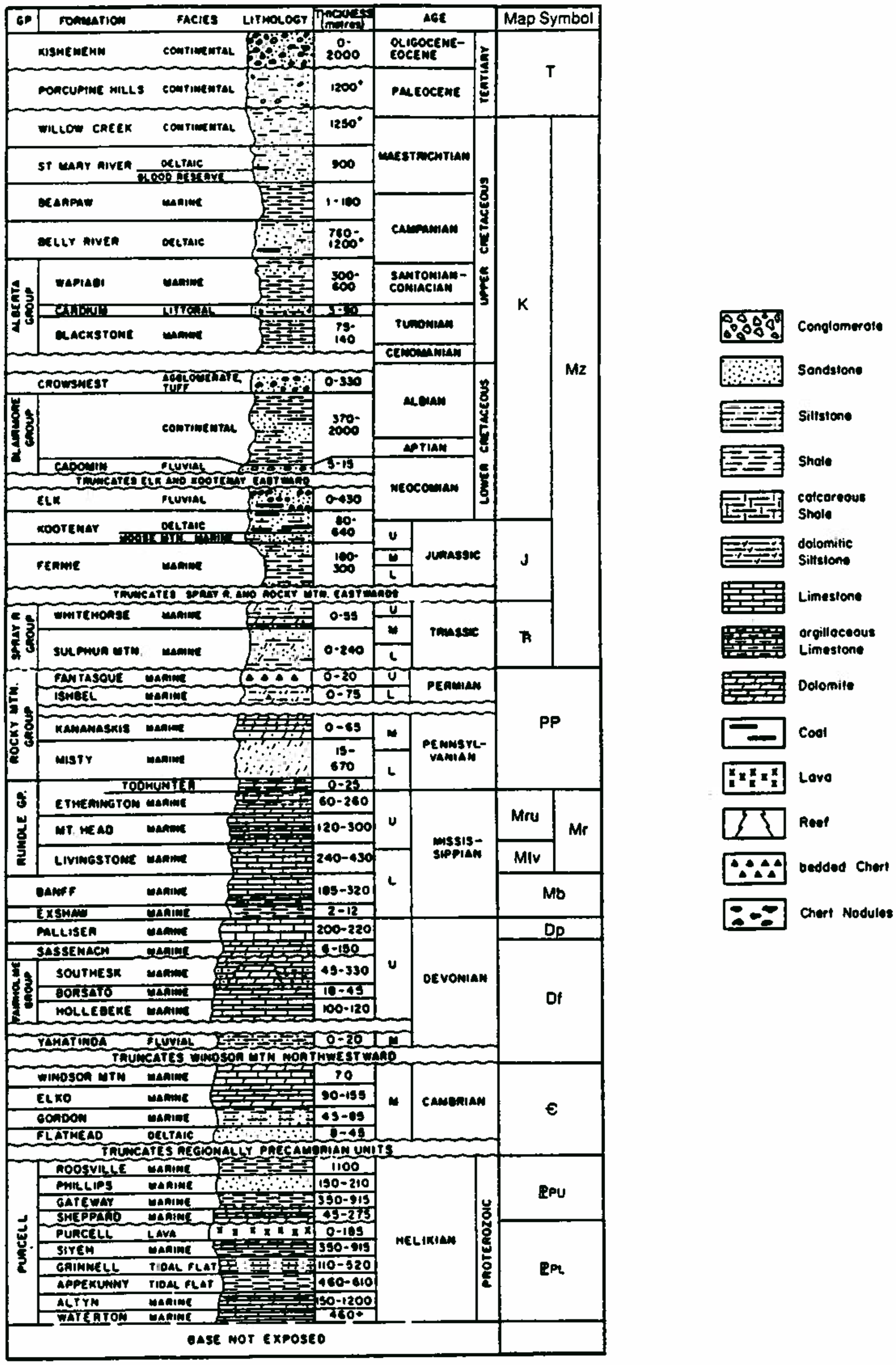

Figure 2. Stratigraphic column for Waterton and Crowsnest Pass areas (from Norris, in Gordy, et al, 1977).

(WTN-2 and 3, figure 3). Another representing the lower Altyn was taken at the north end of Upper Waterton Lake (WTN-1). The dolomites are siliceous and quite hard.

Outside the Park, the Waterton Formation was examined at its outcrop on West Castle River (figure 1). No distinct beds of white limestone were noted, although the formation is not completely exposed here. What was noted, however, were some thin bands of white cryptocrystalline limestone interlaminated with grey limestones and dolomites. This may be the form of occurrence of the "dense white limestone" reported in the formation.

The Altyn Formation at West Castle River shows similar characteristics to that in the Park. A bed of white weathering, very light grey dolomite was sampled in a roadside exposure near the middle of the formation (WCR-4 and 5, figures 1, 3).

4.1.4 Test Results

Brightness values for the middle Altyn dolomites range from 68.6 to 74.8%. For the lower Altyn dolomites it is less, 58.8% in the single sample tested. Detailed test results are given in table 1. Typical rock colour and powder Brightness of Altyn dolomites are displayed in the appendix (samples WTN-2 and WCR-5).

Chemical analyses confirm the siliceous character of Altyn dolomites. Results of analyses (samples WTN-2, WCR-4 and 5, table 2) show SiO_2 contents ranging from 12 to 23%. This and the compact crystalline texture of the dolomites (observed in thin section examination) account for the high degree of hardness and toughness of the rocks, and the difficult grindability.

4.2 Phillipps Pass, Crowsnest Pass Area

4.2.1 Location and Physiographic Setting

Phillipps Pass lies 2 to 3 km north of the Crowsnest Pass (figure 4).

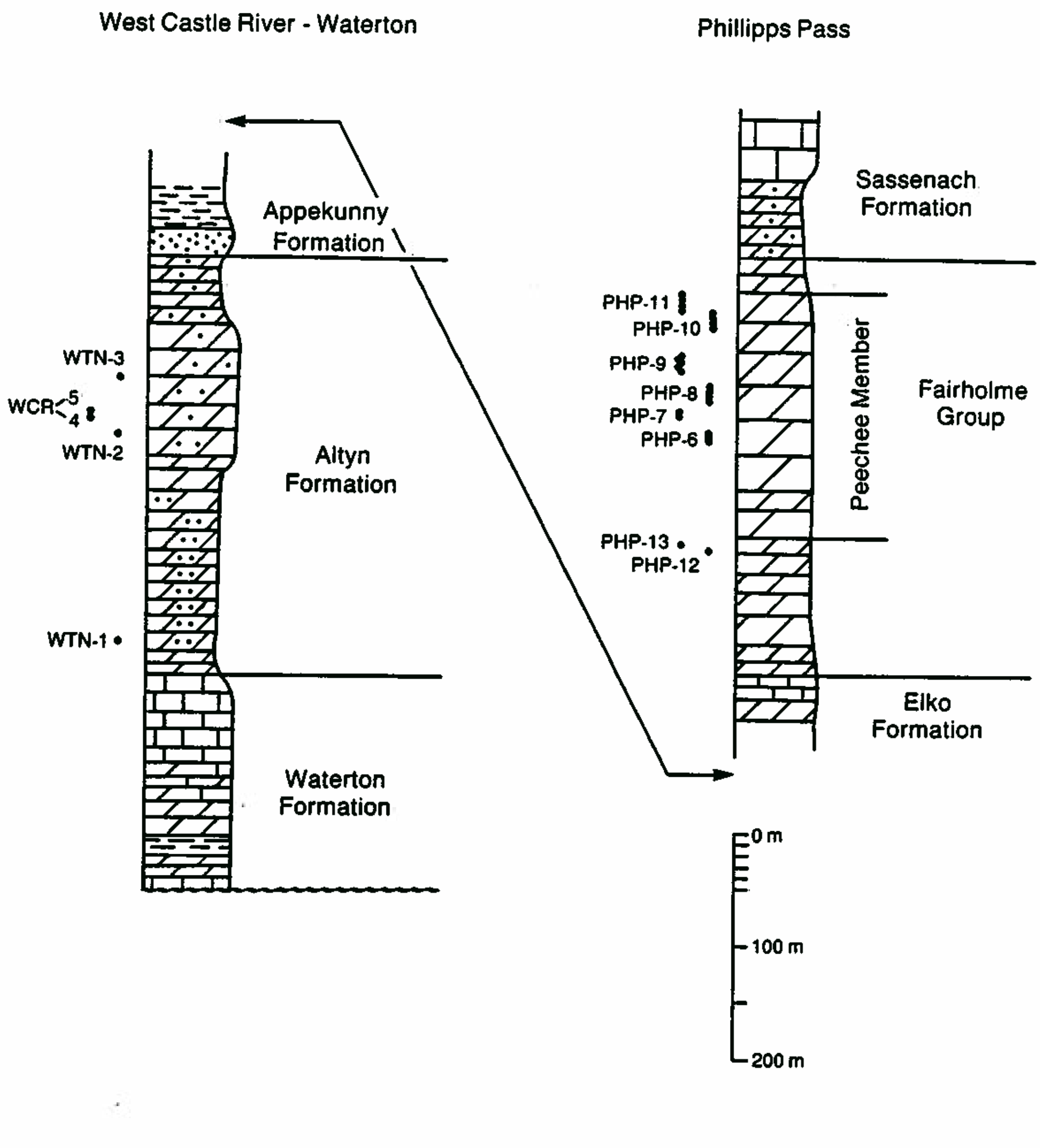

Figure 3. Stratigraphic distribution of sampling, Waterton and Crowsnest Pass areas.

It cuts through the High Rock Range, which is the easternmost of the Front Ranges at this latitude. The High Rock Range has a north-south trend and runs for 50 km northward from the Crowsnest Pass: south of the Pass, it continues southward as the Flathead Range. The area has rugged topography with maximum elevations over 2500 m. Phillipps Pass summit is 1600 m, Crowsnest Pass only 1350 m. NTS sheet "Crowsnest 82G/10" (1:50,000) covers the area.

Crowsnest Pass is serviced by Highway 3 and the southern CPR mainline. Phillipps Pass has access directly from Highway 3 by a secondary road. A gas pipeline and a major power transmission line also run through Phillipps Pass.

4.2.2 Geologic Setting

The geology of the area is shown in detail in figure 4. The succession of formations and their lithologies are given in the stratigraphic column of figure 2, although not all units are exposed within the map area. The High Rock Range exposes Paleozoic rocks, Cambrian to Mississippian in age (plate 2A), thrust eastward along the Lewis Fault onto Mesozoic strata of the adjoining Foothills. The surface trace of the Lewis Fault is shown on figure 4 along the front of the High Rock Range, marking the boundary between the Front Ranges and the Foothills.

The formation of primary interest for this study is the Devonian Fairholme Group. It includes a local reef mound development termed the Peechee Member (of the Southesk Formation, figure 2), a dolomite unit of white to light grey colour identified as the lightest coloured rock in the area (Hamilton, 1986a). The member is developed in Phillipps Pass, and also farther south locally in the Flathead Range (Price, 1961), although it is not seen in the Fairholme Group strata in Crowsnest Pass.

The Peechee Member forms reef-like masses that intertongue with and replace Fairholme limestones in localized areas (plate 2B). In Phillipps Pass, the Peechee dolomite is 220 m thick and consists of massive, medium crystalline calcareous dolomite, with abundant fine to coarse vugs lined or

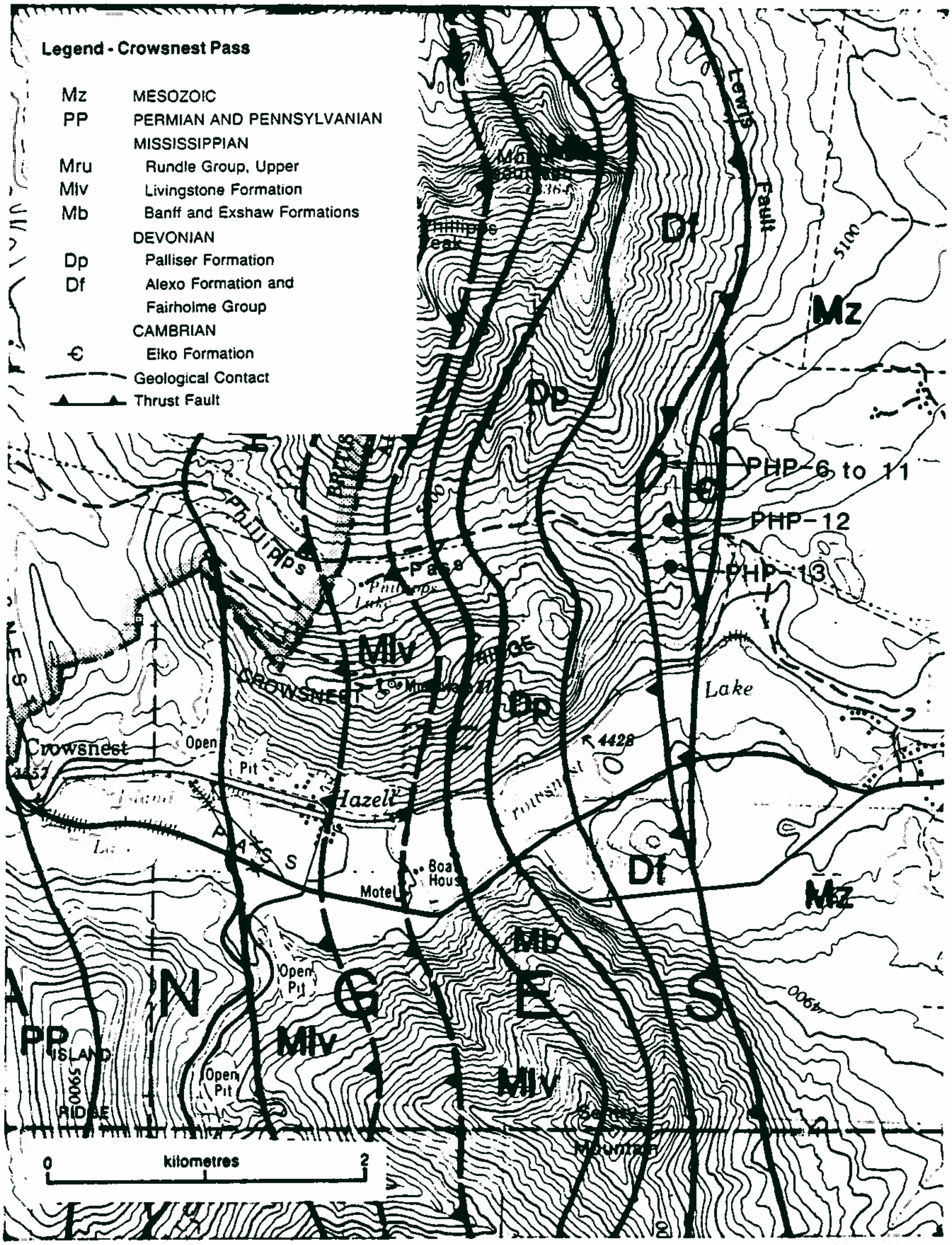

Figure 4. Geology of Phillipps Pass, Crowsnest Pass area.

filled with calcite. It is a very pure carbonate, with only minute amounts of non-carbonate material (Hamilton, 1986a).

4.2.3 Site Sampling

The Peechee dolomite was sampled through most of its exposure on the north side of Phillipps Pass, at the site indicated in figure 4 (PHP-6 to 11). The outcrop consists throughout of very light grey dolomite, in places appearing almost white, with massive, very poorly defined bedding. An interval of 134 m of more-or-less continuous exposure was sampled (plate 2B), the samples grouped into six sample intervals as indicated in figure 3.

Another sample taken just above road level (PHP-12) is lithologically similar to, but stratigraphically below the above samples. The sampled interval, about 20 m, includes reefoid beds similar to above, interlayered with medium bedded, blocky dolomite of light to medium grey colour. It appears to represent lower Fairholme Group beds.

On the south side of Phillipps Pass, a similar dolomite unit that also appears to underlie the Peechee dolomite was sampled across a narrow ridge running down almost to the road (PHP-13, figure 4). The sample represents about 20 m of thickness (figure 3). On the same site, a sample of white calcite (PHP-13V) was collected from the talus, presumably from a calcite vein that cuts Fairholme Group strata in the immediate vicinity. The sample was taken to provide a pure white carbonate rock as a standard for comparison purposes.

4.2.4 Test Results

Brightness values for the Peechee dolomite range from 57.2 to 69.7%, with a weighted average value of about 63%. Samples of lower Fairholme dolomites (i.e., below the Peechee) have values both lower (PHP-12, 57.6%) and higher (PHP-13, 68.5%). For the sample of white calcite the Brightness measured 87.2%. Detailed test results are given in table 1. The typical rock colours and powder Brightness are displayed in the appendix (samples

PHP-7,8,13 and 13V).

The high carbonate purity of Peechee dolomites is indicated by chemical analyses, table 2. Combined samples PHP-6,7,8 and PHP-9,10,11 have carbonate purities of 98.7% and 96.9% respectively. Low SiO_2 content and the porous, loosely compacted crystalline texture make for a relatively soft, easily grindable rock.

4.3 Kananaskis, Bow Valley Area

4.3.1 Location and Physiographic Setting

Kananaskis lies in the Bow River valley on the eastern margin of the Front Ranges (figure 5). The Front Ranges, trending in a northwest-southeast direction, are transected at right angles by the valley. The valley floor lies at an elevation of approximately 1300 m and the surrounding mountains rise to a maximum of 2750 m. NTS topographic sheet "Canmore 820/3" (1:50,000) covers the area.

Highways 1 and 1A and the CPR mainline pass through the valley, servicing the industries at Kananaskis and Exshaw. The area is a major limestone producing area in the province, for lime and cement manufacture respectively at the two sites. The lime plant at Kananaskis (Steele Bros.) is supplied by quarries west of the area, but its predecessor (Loder's Lime) plant was supplied from the old Kananaskis quarries outlined in figure 5.

4.3.2 Geologic Setting

The geology of the Kananaskis-Bow Valley area is mapped in detail in figure 5. The stratigraphic succession is shown in figure 6, although not all the formations are exposed here. Within the area, strata from Cambrian to Mississippian age form a continuous, west dipping succession from Kananaskis to Exshaw, on a fault block thrusted onto Mesozoic strata by the McConnell thrust fault. The McConnell Fault, surfacing at the base of the mountain front, marks the boundary between Front Ranges and Foothills.

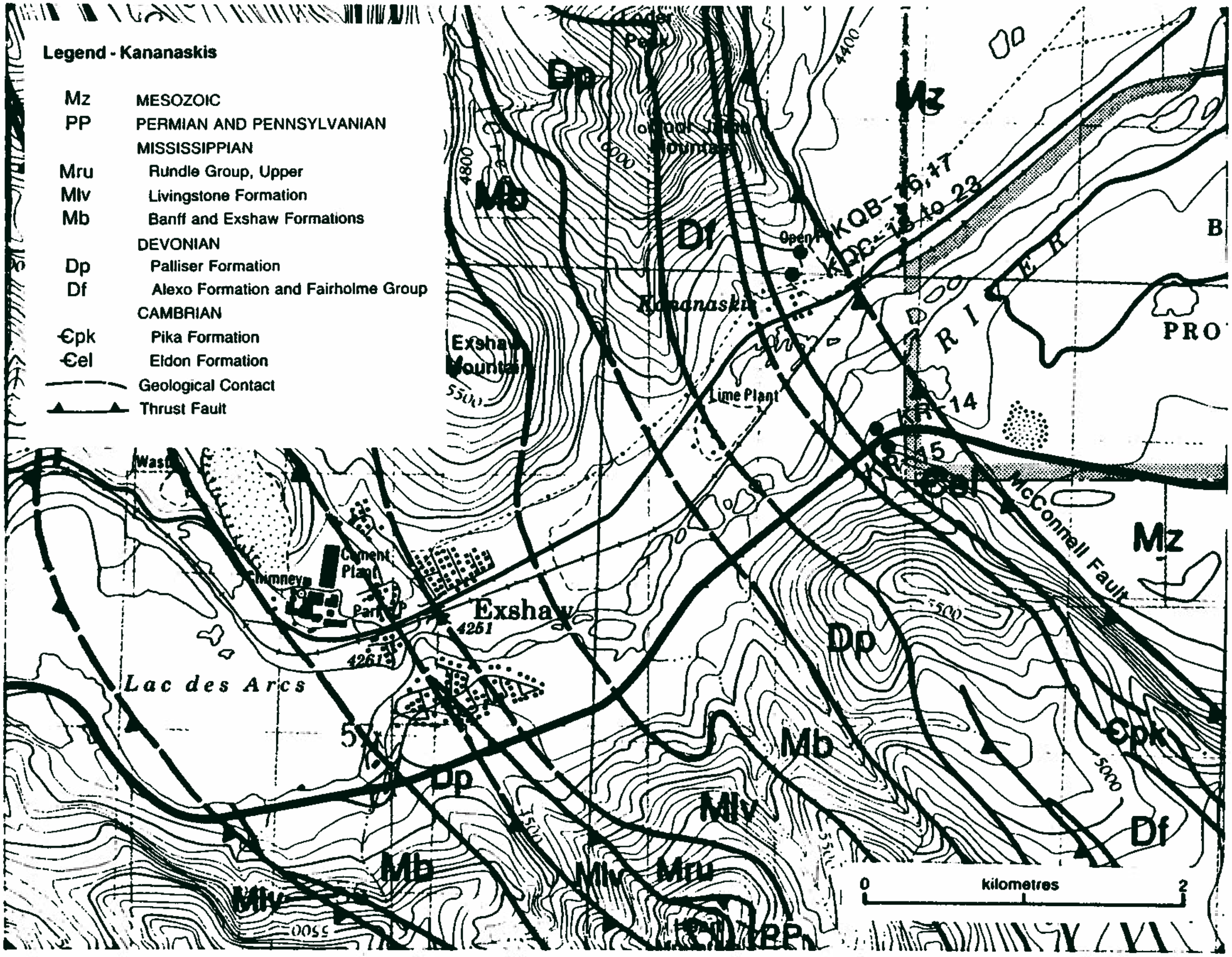

Figure 5. Geology of Kananaskis, Bow Valley area.

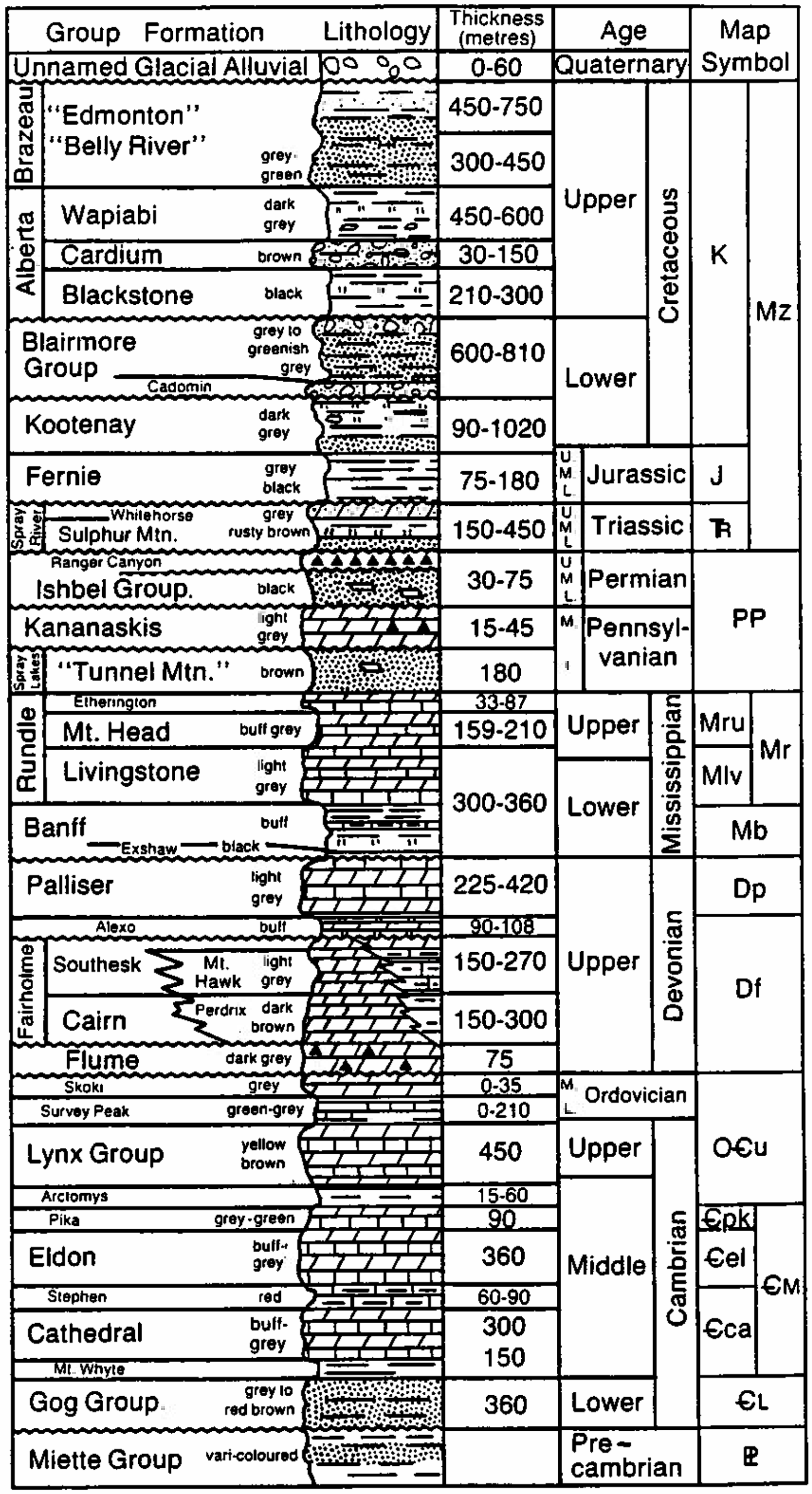

Figure 6. Stratigraphic column for Bow Valley and David Thompson Corridor areas.

Other major thrust faults repeat the successions of west dipping Paleozoic strata westward, the next two being the Exshaw fault (passing through Exshaw) and the Lac des Arcs fault (passing near the western end of Lac des Arcs).

For this study, the Cambrian Eldon Formation is the prospective unit. Its outcrop band is shown in figure 5 just above the McConnell fault trace. The Eldon comprises dark grey, finely crystalline variegated and mottled limestone and interbedded dolomite, in a thickness of more than 240 m (Hamilton, 1986a). Some of the purer limestone beds are much lighter coloured, and were quarried selectively in the past for lime manufacture (plate 4A). One bed is described as "an irregular band, 66 ft wide of cream-coloured, very pure high-calcium limestone" (Goudge, 1945), which seems to apply to the rock subsequently quarried in the main Kananaskis quarries (plate 5A).

4.3.3 <u>Site Sampling</u>

Sample sites in the Kananaskis area are shown in figure 6. Stratigraphic distribution of sampling is summarized in figure 7. Sampling of the Eldon limestone was done first on the south side of Bow Valley, opposite the Kananaskis quarries, where the formation outcrops in a white-weathering ridge that descends to and is intersected in a roadcut on the TransCanada Highway (plate 3A). White surface weathering is a prominent feature of the outcrop, although most of the beds exposed in the roadcut are medium grey. One band of very light coloured limestone at least 5 m thick is present in the exposure and was sampled on both sides of the road; KR-14 from the north side, and KR-15 from the south (plate 3B).

The major sampling was carried out in the Kananaskis quarries, from the middle (B) and the westernmost (C) quarries (plate 4A). Both quarries are in steeply dipping bands of very light coloured limestone, which appear to run oblique to the bedding. The easternmost (A) quarry follows a zone of grey coloured limestone. All quarries are the slot-trench type and are fault bounded on at least one side.

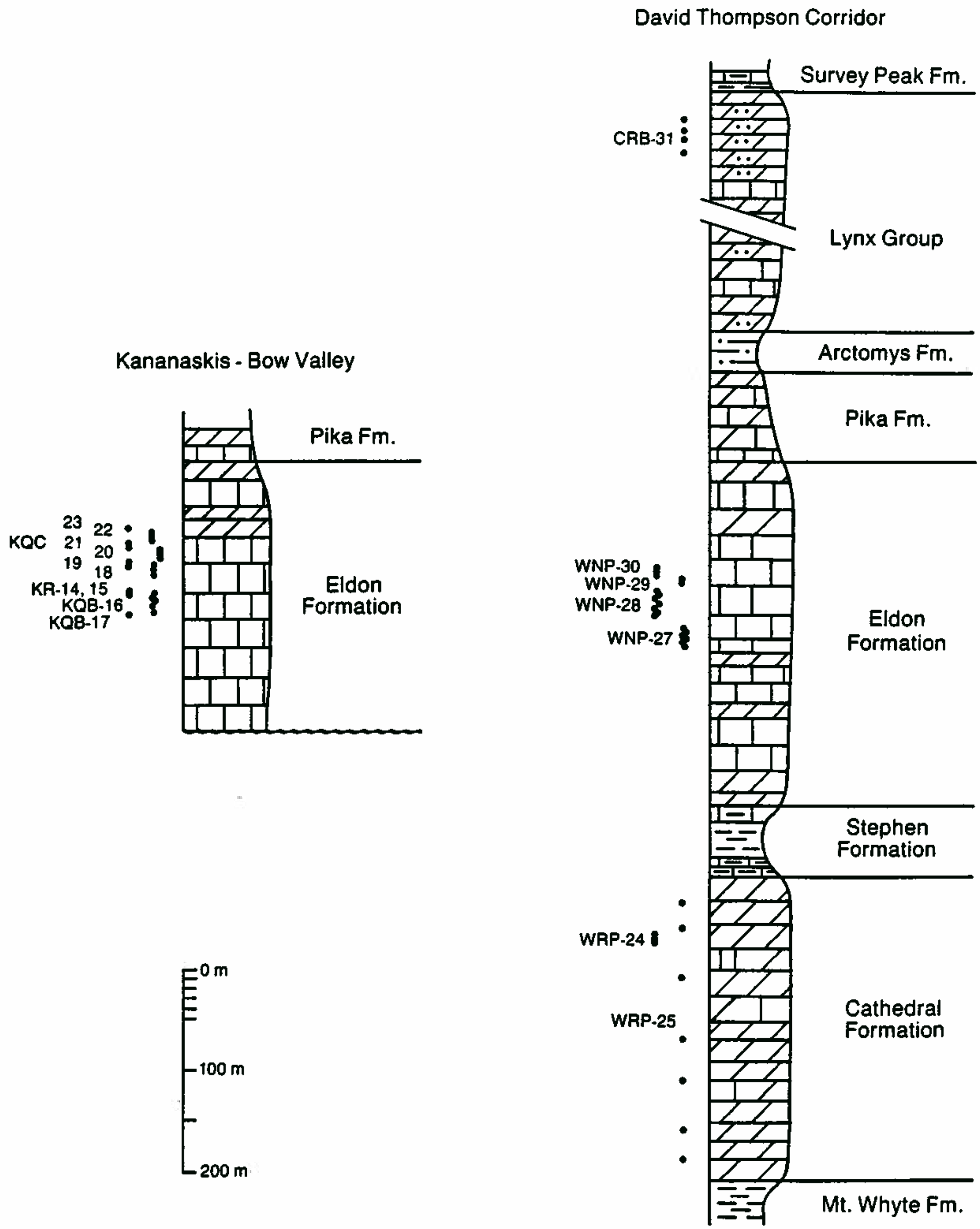

Figure 7. Stratigraphic distribution of sampling, Bow Valley and David Thompson Corridor areas.

Quarry B was sampled in a single composite sample (KQB-16) collected across the quarry face over an interval of about 20 m (plate 5). The interval is fault-bounded on the east wall (plate 5A). Sample KQB-17 is from an exceptionally light coloured bed at the base of the quarried section, just above the fault contact.

Quarry C is a similar situation to B, in a steeply dipping band of light coloured limestone, fault-bounded on the east side. Samples KQC-18 to 20 were taken across the quarry face over an interval of about 24 m. Sample KQC-19 represents a 4-m bed of somewhat darker coloured limestone in the middle of the unit.

Quarry C had an upper level developed at its northern end, which was also sampled across the quarry face. Sample KQC-21 is from the lower 2 m interval and overlaps beds of the lower level. Samples KQC-22 and 23 are from overlying beds of dolomite, somewhat darker in colour, spanning 10 m and 2 m intervals.

Outcrops of the Eldon Formation were also examined along strike from the quarries, where they display prominent white surface weathering (plate 4B). The white weathering seems most pronounced in, but is not exclusive to the lighter coloured limestone bands.

4.3.4 Test Results

Brightness values for the Eldon limestones in this locality range from 73.3 to 79.5% (table 1), averaging about 76%. The dolomites in Quarry C (KQC-22 and 23) have considerably lower values, 55.8% and 65.5%. Typical rock colours and powder Brightness are displayed in the apprendix (samples KR-14 and 15, KQB-16 and 17, KQC-20 and 22).

Chemical analyses of Eldon limestones show very high purity, averaging about 98% pure carbonate. The dolomite beds in Quarry C analyzed 96% carbonate purity or better. Detailed analytical results are given in table 2.

The Eldon limestones generally have a dense microcrystalline texture and tend to be somewhat brittle. They grind readily to a powder, aided undoubtedly by their carbonate purity.

4.4 David Thompson Corridor

4.4.1 Location and Physiographic Setting

The gap cut by the North Saskatchewan River through the central Alberta Rockies is referred to as the David Thompson Corridor, so named for the highway route traversing the gap. The David Thompson Highway (Highway 11) runs from Nordegg to Saskatchewan Crossing, across the Foothills, Front Ranges and into the Main Ranges of the Rockies (figure 8). In this study, the area of interest is primarily in the Front Ranges, from Windy Point westward to Banff Park gate.

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 bridge crossings of the river (or Abraham Lake) for vehicles, and no roads exist on the south side.

4.4.2 Geologic Setting

The regional geology and major structural divisions of the Rocky Mountains in the David Thompson Corridor are shown in figure 8. The stratigraphic succession is shown in figure 6. 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 Ranges, thrusting Paleozoic rocks onto Mesozoic rocks of the Foothills. The Front Ranges

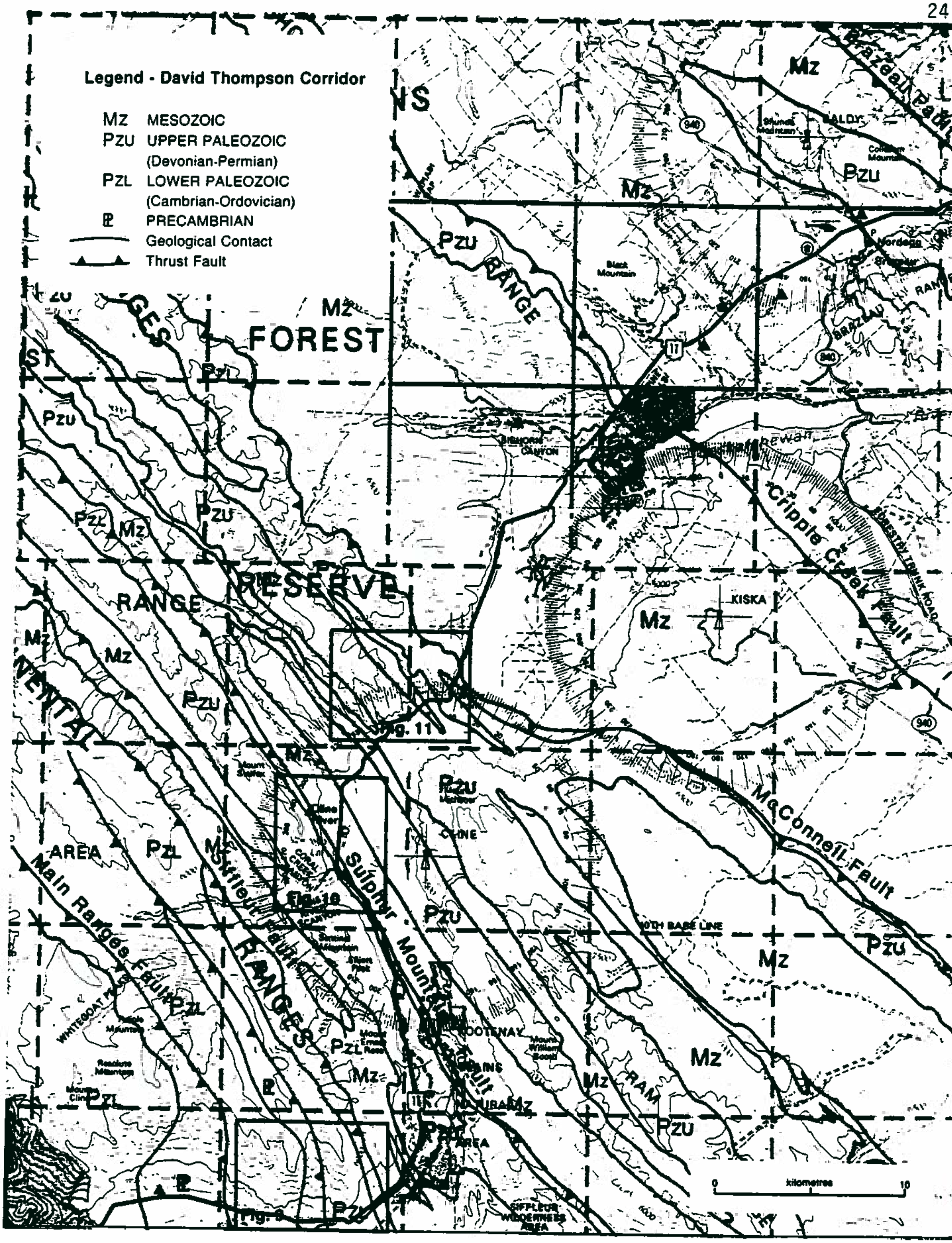

Figure 8. Regional geology of the David Thompson Corridor.

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 plates) with strata dipping moderately to steeply southwest (Verrall, 1968). Lower Paleozoics outcrop in narrow bands just above the major thrusts, and extensively above the Siffleur Fault on the west.

The Lower Paleozoic rocks are mainly the thick carbonates of the Cambrian formations (figure 6). These carbonate units, up to 1200 m in aggregate thickness, are the rocks of primary interest for this study. These rocks were examined and sampled at three sites in the Corridor where exposed in the three major thrust sheets (figure 8): at Windy Point, above the McConnell Thrust; at Cline River, above the Sulphur Mountain Thrust; and at Whirlpool Point, above the Siffleur Thrust.

4.4.3 Geology and Site Sampling, Whirlpool Point

The geology at Whirlpool Point is shown in detail in figure 9. The area encloses a block of west-dipping Precambrian and Cambrian strata of the Siffleur thrust sheet. The Siffleur Fault, running northwesterly through the area, thrusts Precambrian strata onto Triassic. Above the Precambrian and Lower Cambrian (Miette and Gog Groups), the Middle Cambrian carbonates of the Cathedral and Eldon Formations are exposed.

The Cathedral Formation outcrops in a prominent ridge that extends down to valley bottom and forms a projecting spur known as Whirlpool Point. The formation is predominantly dolomite at this locality, with a thickness of about 300 m. The dolomites are grey-coloured with finely interlayered white dolomite and irregularly scattered zones and patches of white dolomite veins and stockworks. Some dolomite beds are recrystallized to a marble-like texture, but without any alteration of the grey colour.

Minimal sampling of the Cathedral dolomite was done because of the predominant grey colour. The formation was traversed across its full outcrop width, but no distinct beds of light-coloured carbonate were observed. A roadcut on Highway 11 was sampled over an 8-m interval (WRP-24)

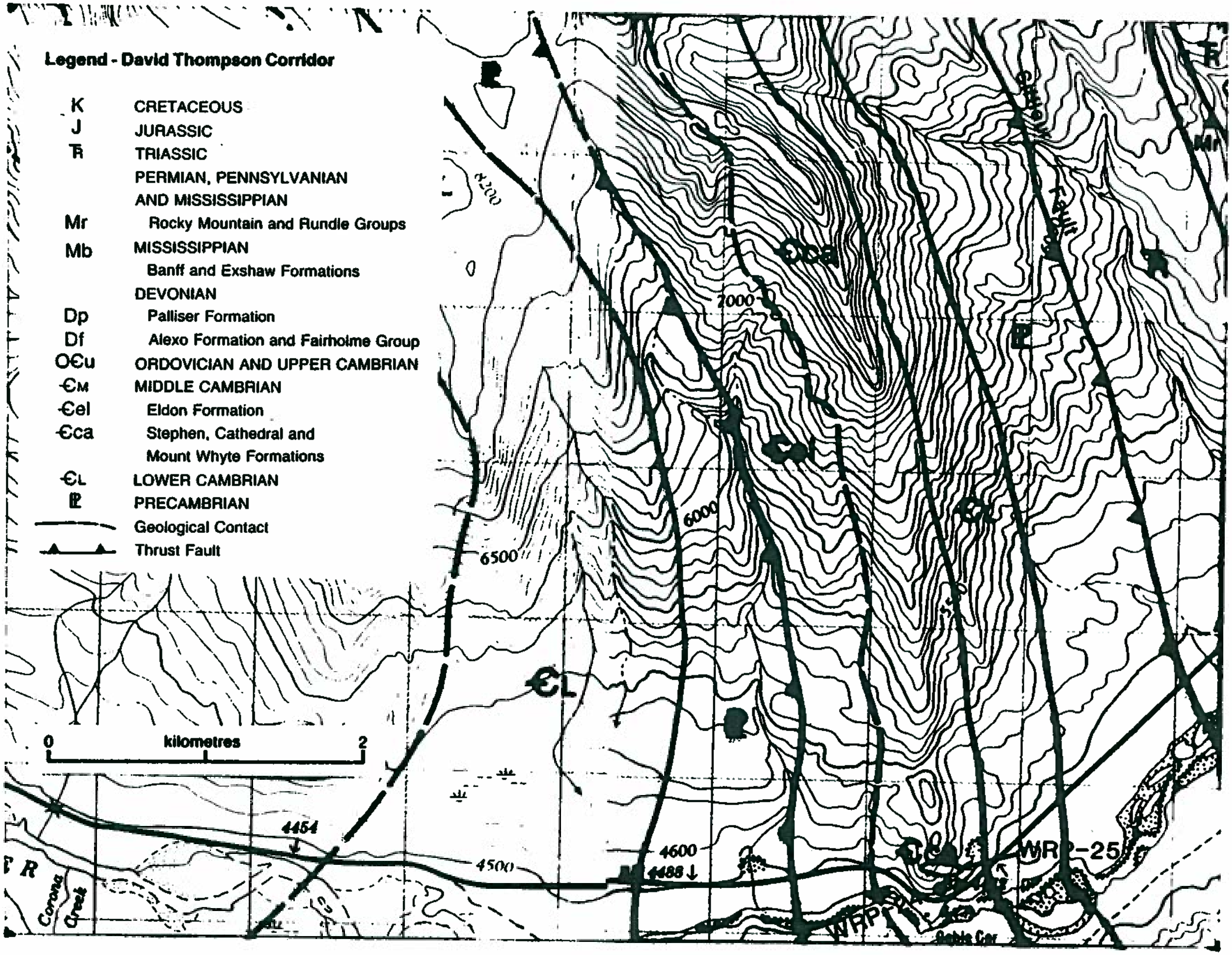

Figure 9. Geology of Whirlpool Point, David Thompson Corridor.

of dolomite beds near the top of the formation that seemed characteristic of the whole. Grab samples were also collected across the formation, from discontinuous exposure on the ridge above the road, and lumped into a composite sample (WRP-25). The white dolomite vein material was sampled as well (WRP-26), to provide a colour standard for comparison purposes. Figure 7 summarizes the stratigraphic distribution of sampling in the Cathedral Formation.

The Eldon Formation is not exposed at Whirlpool Point except at higher elevations, which present difficult access. The Eldon is partly overridden by Precambrian rocks along a subsidiary fault that repeats the succession to the west (figure 9). However, no outcrops of the Middle Cambrian carbonates occur (except at higher elevations) west to the Banff Park gate.

4.4.4 Geology and Site Sampling, Cline River

The geology at Cline River is shown in detail in figure 10. The Sulphur Mountain Fault runs diagonally through the area, thrusting Paleozoic strata onto Jurassic, and exposing Upper Cambrian (and Ordovician) formations in a narrow band just above the fault.

The Upper Cambrian strata are dolomites belonging to the Lynx Group, the upper part of which is exposed beneath the bridge on Cline River. The dolomites are mainly light grey in colour with some beds very light grey, microcrystalline, siliceous in part and quite hard. About 35 m of section outcrop along the Cline River in west dipping beds (plate 7). No detailed sampling was done, but grab samples were collected over the interval and lumped into a composite sample (CRB-31) representative of the upper Lynx Group carbonates (figure 7).

4.4.5 Geology and Site Sampling, Windy Point

The geology at Windy Point is shown in detail in figure 11. The area embraces a segment of the McConnell thrust plate, which has a broad band of complexly faulted and folded Lower Paleozoic strata at its leading edge, thrusted onto Cretaceous rocks. This complex structure forms the First

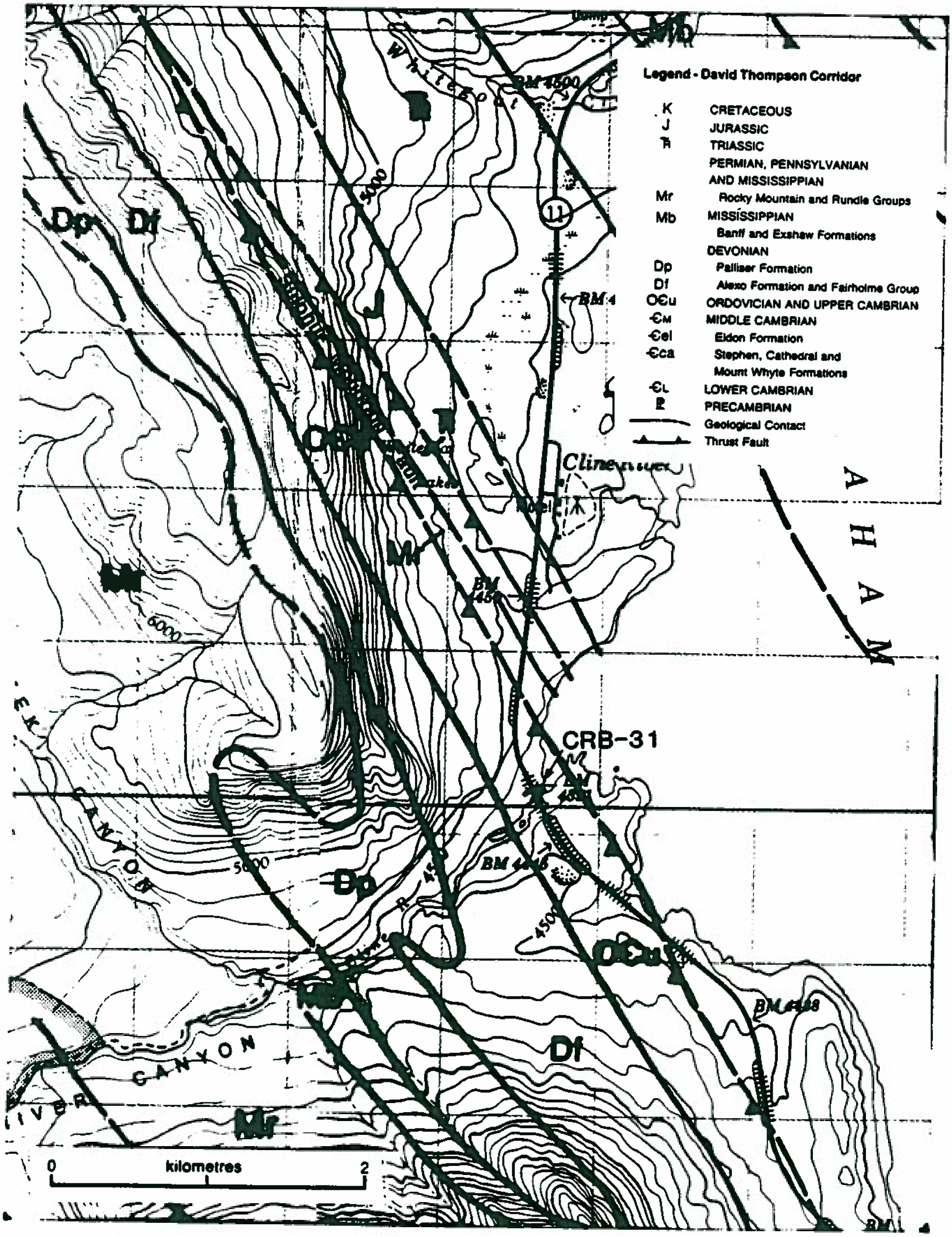

Figure 10. Geology of Cline River, David Thompson Corridor.

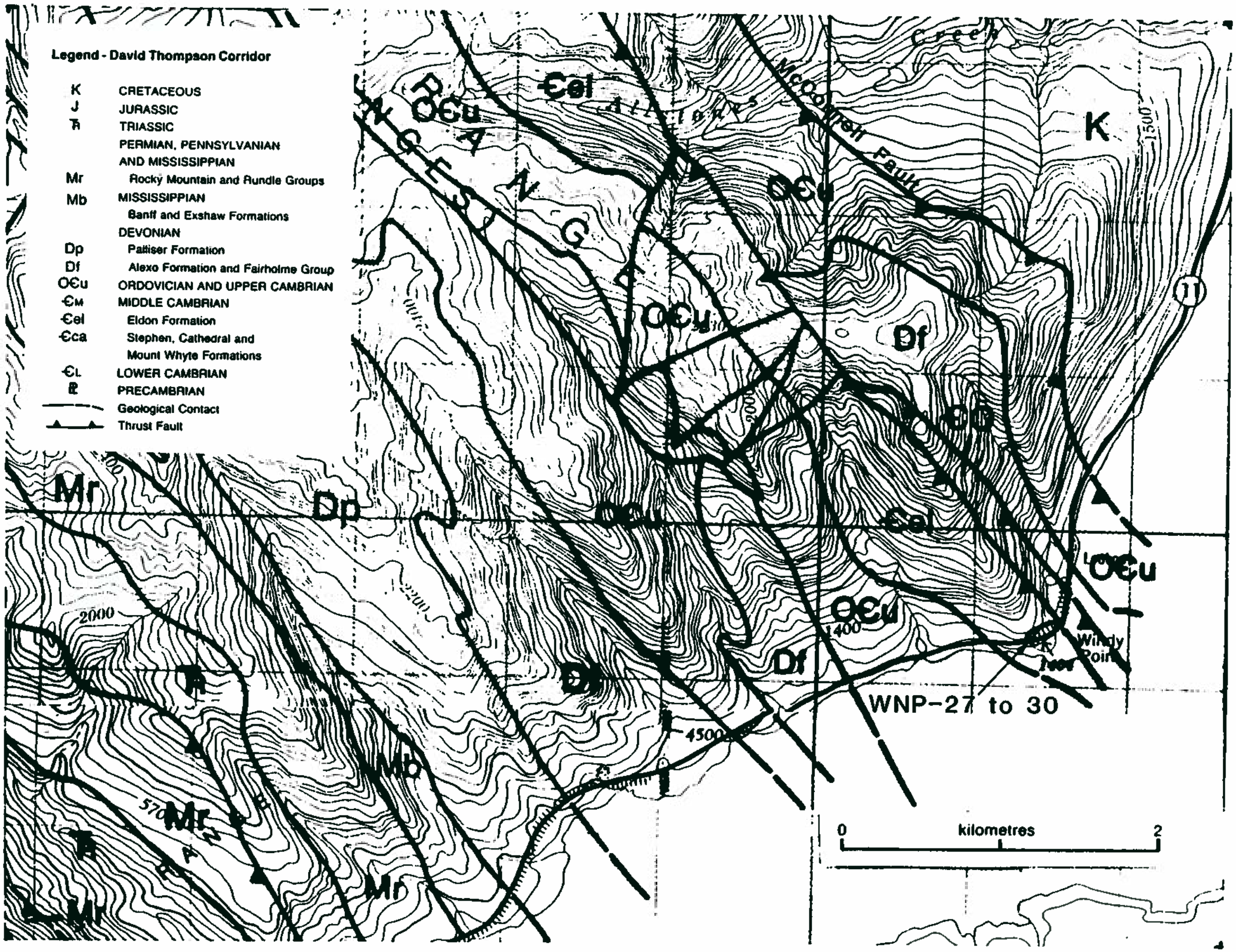

Figure 11. Geology of Windy Point, David Thompson Corridor.

Range of the Front Ranges. To the west, younger Paleozoic and Triassic strata are exposed in a steeply southwest-dipping succession.

The McConnell Fault surfaces at the base of the mountain front just east of Windy Point. Upper Cambrian strata are exposed above the fault, forming a tight syncline with overlying Ordovician and Devonian strata. These are overridden on the southwest by Middle Cambrian strata of the Eldon Formation, thrust upwards along a steeply inclined subsidiary fault. The Eldon Formation consists dominantly of limestone at this locality and is the rock unit of primary interest. It forms the main massive ridge of the First Range, projecting outwards on the valley floor in the prominent feature called Windy Point. The formation is composed of massive bedded, cliff-forming limestone with microcrystalline texture (peloidal in part), light pinkish to brownish grey in colour, streaked with dark grey bands. About 370 m of the formation are present here, the base being underlain by a fault (Douglas, 1956).

The Eldon limestone is well exposed in a major roadcut at Windy Point on Highway 11 (plate 6A). The roadcut is about 150 m long and cuts across 70 m of the middle part of the formation. The beds dip steeply to the west but with some variability and possibly some repetition through faulting. Beds at the west end of the roadcut are highly contorted.

Sampling of Eldon limestones was carried out in the roadcut (figure 11). Stratigraphic distribution of sampling is summarized in figure 7. The samples were taken across four main intervals of massive, light coloured limestones, separated by bands of medium to dark grey limestone generally about 1.5 m thick. The sample intervals, from the east end of the roadcut through to the west ranged in thickness as follows: WNP-27, 21 m (Plate 6B); WNP-28, 28 m; WNP-29, 2 m; WNP-30, 9 m. Contorted beds at the west end of the roadcut were not sampled.

4.4.6 Test Results

Brightness values for Cambrian carbonates in the David Thompson Corridor differ widely for the different formations (table 1), but are fairly consistent within a formation. Samples of the Cathedral Formation dolomite at Whirlpool Point (WRP-24,25) gave values of 52.1% and 52.4%. The white dolomite vein material collected at this site measured 82.9%. The Eldon Formation limestones at Windy Point (WNP-27 to 30) had considerably higher brightness values, ranging from 72.4 to 76.2 % with a weighted value of about 74%. Dolomites of the Lynx Group have a value in between, 64.9%, measured for a single composite sample of beds exposed at the Cline River bridge site. Detailed test results are given in table 1. The typical rock colours and powder Brightness are displayed in the appendix (WRP-25,26; WNP-27,28).

Chemical analyses of Cambrian carbonates are presented in table 2. The Cathedral dolomites and the Eldon limestones both show high carbonate purity; generally 96 to 97% for the dolomites, 98 to 99% for the limestones. Both rock types have good grindability, the limestones in particular, possibly because of their slightly higher purity and finer crystalline texture (table 1).

The Lynx Group dolomite (CRB-31) has considerbly lesser carbonate purity, 91.1%, due to its silty nature. This rock ground with some difficulty.

5. SUMMARY OF RESULTS

The results of laboratory tests conducted for this study are summarized in table 1. The table gives results of Brightness measurements and chemical analyses; it also includes observations on the grindability of the rock samples, data on field determinations of lithology and rock colour, and thin-section determinations of rock textures. Detailed results of chemical analyses are given in table 2.

The best results are obtained for Eldon Formation limestones, in the Kananaskis-Bow Valley area and also at Windy Point in the David Thompson Corridor. Brightness values average about 76% at Kananaskis, 74% at Windy Point. The limestones are lithologically similiar at both localities, with very high carbonate purity of around 98%, and very low SiO_2 contents in the range of 0.13 to 0.27%. Grindability of the rock is good.

The Precambrian carbonates of the Waterton area show the next best results in terms of Brightness, ranging up to 74.8% in Altyn Formation dolomites. However, the high silica contents (up to 22.7% SiO_2) render these carbonates very tough and difficult to grind.

Other carbonates tested in this study have significantly lower Brightness values. The Peechee dolomites in the Crowsnest Pass area measured only about 63% Brightness on average, even though these rocks are the lightest coloured of all the carbonates investigated in the field (as indicated by Munsell rock colour values).

Selected samples from table 1 are displayed in the appendix as mounted rock slabs, showing the typical rock colours of the sample assemblage. The rock slabs are partly coated with epoxy to show the true "wetted" colour of the rock as well as the dry colour. Each sample is displayed also in powdered form, for a visual comparison of its powder Brightness with actual commercial calcium carbonate fillers.

Samples of two commercial fillers are included in the appendix. One of these, 200X, was tested for Brightness following the same procedure used for other samples in this study and measured 89.5%. The other, 6HX is from the same source (Creston, British Columbia), but is much finer grained[2] and has a higher Brightness, 94.8% (quoted from a product specification sheet). The only comparable materials in this study are the two white carbonate vein samples, PHP-13V (87.2%) and WRP-26 (82.9%).

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[2] Generally, the finer the grind, the higher the Brightness. For this reason, the Brightness values of carbonate sample powders (-65 mesh) cannot be compared absolutely with the filler products (-325 mesh). Finer grinding of the samples to actual filler size specifications may increase the Brightness by 2 or 3 points, but is not practical for normal laboratory testing purposes.

Table 1. Summary of Properties of Alberta Carbonates Tested For Paper Filler Potential

Sample Number	Formation and Age	Lithology	Munsell Rock Color	Texture* and Hardness	Grindability	Brightness	Carbonate** Purity $CaCO_3$	$MgCO_3$
CLARK RANGE, WATERTON AREA								
WTN-1	Altyn, lower (Precambrian)	dolomite, siliceous	N 7.5 very light grey	fine crystalline with detrital quartz grains, compact; very hard, tough	grinds with difficulty, gritty particles remain	58.8		
WTN-2	Altyn, middle (Precambrian)	dolomite, siliceous	N 7.5 very light grey	microcrystalline with detrital quartz grains, compact; very hard, tough	grinds with difficulty, gritty particles remain	73.9	41.9	35.7
WTN-3	Altyn, upper (Precambrian)	dolomite	5 YR 7.5/1 very light pinkish grey	medium to fine crystalline, sub-compact, porous; hard, brittle	grinds with moderate ease, no grit residue	68.6		
WCR-4	Altyn (Precambrian)	dolomite, siliceous	5 B 8/1 very light bluish grey	microcrystalline (peloidal) with quartz and chert clasts, compact; very hard, tough	grinds with difficulty, gritty particles remain	74.8	46.0	39.7
WCR-5	"	dolomite, siliceous	N 7.5 very light grey	microcrystalline with detrital quartz grains, compact; very hard, tough	grinds with difficulty, gritty particles remain	71.1	39.9	32.5
PHILLIPPS PASS, CROWSNEST PASS AREA								
PHP-6	Peechee Member, Fairholme Group (Devonian)	dolomite, calcareous	10 YR 7.5/2 very pale yellowish brown	medium crystalline, subcompact, porous; moderately hard, brittle	grinds readily, no grit residue	62.3		
PHP-7	"	dolomite, calcareous	N 8 very light grey	medium crystalline, subcompact, porous; moderately hard, brittle	grinds readily, no grit residue	69.7	59.8	38.9
PHP-8	"	dolomite, calcareous	10 YR 8/1 white	medium crystalline, subcompact, porous; moderately hard, brittle	grinds readily, no grit residue	68.9		
PHP-9	"	dolomite, calcareous	10 YR 7.5/1 very light brownish grey	medium crystalline, loose granular, porous; soft and crumbly	grinds readily, no grit residue	63.2		
PHP-10	"	dolomite	10 YR 7.5/1 very light brownish grey	medium crystalline, subcompact, porous; moderately soft	grinds readily, no grit residue	61.5	54.7	42.2
PHP-11	"	dolomite	10 YR 7.5/1 very light brownish grey	medium crystalline, subcompact, porous; moderately soft	grinds readily, no grit residue	57.2		

PHP-12	Fairholme Group, lower (Devonian)	dolomite, calcareous	10 YR 7.5/1 very light brownish grey	medium to coarse crystalline, sub-compact, porous; moderately soft	grinds readily, no grit residue	57.6		
PHP-13	"	dolomite, calcareous	N 8 very light grey	medium crystalline, compact, porous; moderate soft	grinds readily, no grit residue	68.5		
PHP-13V	Fairholme Group?	calcite (vein)	N 9 white	medium to coarse crystalline; compact; moderately hard, brittle	grinds readily	87.2		
KANANASKIS, BOW VALLEY AREA								
KR-14	Eldon (Cambrian)	limestone	N 7 light grey	microcrystalline, dense; moderately hard, brittle	grinds readily, no grit residue	73.3		
KR-15	"	limestone	N 7.5 very light grey	microcrystalline (peloidal), dense; moderately hard, brittle	grinds readily, no grit residue	78.0		
KQB-16	"	limestone	5 YR 7.5/1 very light pinkish grey	microcrystalline (peloidal) with coarse crystalline spar, dense; moderately hard, brittle	grinds readily, no grit residue	76.1	97.1	0.7
KQB-17	"	limestone	5 YR 7.5/1 very light pinkish grey	microcrystalline, dense; moderately hard, brittle	grinds readily, no grit residue	79.5		
KQC-18	"	limestone	5 YR 7.5/1 very light pinkish grey	microcrystalline (peloidal), dense; moderately hard, brittle	grinds readily, no grit residue	76.7		
KQC-19	"	limestone	5 YR 6/1 light brownish grey	microcrystalline (peloidal) and fine crystalline, dense; moderately hard, brittle	grinds readily, no grit residue	74.2	96.8	1.3
KQC-20	"	limestone	5 YR 7.5/1 very light pinkish grey	microcrystalline, dense; moderately hard, brittle	grinds readily, no grit residue	78.0		
KQC-21	"	limestone	5 YR 7.5/1 very light pinkish grey	microcrystalline, dense; moderately hard, brittle	grinds readily, no grit residue	77.8		
KQC-22	"	dolomite	10 YR 6.5/1 light brownish grey	medium crystalline, subcompact, porous; moderately hard, brittle	grinds readily, no grit residue	55.8	52.7	43.4
KQC-23	"	dolomite, calcareous	N 6.5 light grey	fine crystalline (peloidal) to medium crystalline, compact; moderately hard, brittle	grinds readily, no grit residue	65.5	71.3	27.5

DAVID THOMPSON CORRIDOR

WRP-24	Cathedral (Cambrian)	dolomite	N 5.5 medium light grey	medium crystalline with coarse crystalline spar, dense; hard, brittle	grinds with moderate ease, no grit residue	52.1	53.3	43.9
WRP-25	"	dolomite	N 6.5 light grey	medium crystalline (peloidal) with coarse crystalline spar, dense; hard, brittle	grinds with moderate ease, no grit residue	52.4	53.4	42.1
WRP-26	"	dolomite (vein)	N 8.5 white	coarse crystalline, compact; moderately hard, brittle	grinds readily	82.9	55.6	42.1
WNP-27	Eldon (Cambrian)	limestone	5 YR 7.5/1 very light pinkish grey	microcrystalline (peloidal) and fine crystalline, dense; moderately hard, brittle	grinds readily, no grit residue	72.4		
WNP-28	"	limestone	5 YR 7/1 light pinkish grey	microcrystalline, dense; moderately hard, brittle	grinds readily, no grit residue	76.2	97.1 97.6	1.0 1.0
WNP-29	"	limestone	5 YR 7/1 light pinkish grey	microcrystalline (peloidal), dense; moderately hard, brittle	grinds readily, no grit residue	72.4	99.1	0.7
WNP-30	"	limestone	5 YR 6.5/1 light brownish grey	microcrystalline with medium crystalline spar, compact; moderately hard, brittle	grinds readily, no grit residue	73.6		
CRB-31	Lynx Group (Cambrian)	dolomite, silty	5 YR 6/1 light brownish grey	medium crystalline, compact; hard, tough	grinds with moderate difficulty, some gritty particles remain	64.9	51.1	40.0

*Crystalline texture expressed in terms of dominant crystal size: microcrystalline <.016 mm; fine, between .016 and .062 mm; medium, between .062 and .5 mm; coarse, between .5 and 2.0 mm. Some textures are "peloidal", i.e. comprised of peloids (rounded clasts) which have internal microcrystalline texture.

**Chemical analyses (see Table 2).

Table 2. Chemical Analyses of Selected Carbonate Samples

Sample Number	CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3	Na_2O	K_2O	P_2O_5	S	LOI	Total	$CaCO_3$	$MgCO_3$
WTN-2	23.45	17.06	20.41	0.62	0.32	0.02	0.18	<0.01	0.05	36.72	98.84	41.9	35.7
WCR-4	25.78	18.98	12.04	1.42	0.83	0.04	0.64	0.03	0.00	40.59	100.35	46.0	39.7
WCR-5	22.37	15.56	22.70	1.47	0.78	0.04	0.91	0.04	0.00	35.14	99.01	39.9	32.5
PHP-6,7,8	33.49	18.60	0.15	0.20	0.03	0.03	0.01	<0.01	0.00	46.51	99.03	59.8	38.9
PHP-9,10,11	30.63	20.17	1.01	0.49	0.20	0.04	0.09	<0.01	0.00	46.65	99.29	54.7	42.2
KQB-16	54.39	0.32	0.16	0.34	0.04	0.01	0.02	<0.01	0.00	43.27	98.56	97.1	0.7
KQC-18,19,20	54.24	0.61	0.27	0.37	0.08	0.01	0.02	<0.01	0.00	43.24	98.85	96.8	1.3
KQC-22	29.52	20.75	0.65	0.44	0.11	0.06	0.09	<0.01	0.00	47.85	99.48	52.7	43.4
KQC-23	39.93	13.16	0.24	0.28	0.30	0.03	0.04	<0.01	0.00	45.71	99.70	71.3	27.5
WRP-24	29.87	21.00	0.74	0.34	0.88	0.02	0.04	<0.01	0.00	46.83	99.73	53.3	43.9
WRP-25	29.93	20.14	1.19	0.41	1.65	0.04	0.06	<0.01	0.00	46.34	99.77	53.4	42.1
WRP-26	31.17	20.12	0.10	0.25	0.89	0.04	0.01	<0.01	0.00	47.58	100.17	55.6	42.1
WNP-27,28,29,30	54.71	0.47	0.19	0.34	0.08	0.01	0.04	<0.01	0.00	43.40	99.25	97.6	1.0
WNP-28	54.40	0.46	0.13	0.32	0.09	0.02	0.04	<0.01	0.00	43.42	98.89	97.1	1.0
WNP-29	55.52	0.35	0.15	0.34	0.11	0.02	0.04	<0.01	0.00	43.42	99.96	99.1	0.7
CRB-31	28.63	19.15	5.16	1.39	0.56	0.04	0.70	0.02	0.00	43.38	99.03	51.1	40.0

6. CONCLUSIONS

None of the prospective carbonates tested in this study meets the Brightness specifications for a white paper filler. Some have excellent characteristics in terms of purity and grindability, but the powdered colours are "off white" and short of the minimum requirement. Two samples of calcite and dolomite vein material (collected for comparison purposes) do yield high Brightness values, but veins or stockworks rarely occur in Alberta carbonates and have no significant extent. Vein carbonates are not a potential source in Alberta.

The Eldon limestones yield the highest Brightness values and are also the purest carbonates tested. Although not of paper filler grade, these limestones might be considered for other less stringent filler applications. They might also be useful as an extender in calcium carbonate paper filler. With an average Brightness of 76%, the limestones possibly could be blended cost-effectively with high-grade filler to yield an acceptable product.

Eldon limestone deposits are not evaluated specifically here in terms of quarriability and reserves. In the Kananaskis quarries, reserves are essentially exhausted, but the geological setting indicates that more could be identified in the area. At Windy Point the Eldon Formation is present in a very large quarriable situation which could provide huge reserves of limestone. Test drilling would be required to establish reserves at either site.

Other carbonates tested show little promise. Precambrian dolomites of the Waterton area are too siliceous and therefore too abrasive for paper filler use. The Peechee dolomite of the Crowsnest Pass area has a low Brightness, and is downgraded further by limited recoverability due to recent construction of major power transmission lines over the deposit. Other Cambrian carbonates in the David Thompson Corridor similarly are too siliceous (Lynx Group) or low in Brightness (Cathedral Formation).

The carbonates sampled in this study were carefully chosen from the best potential source rocks known in Alberta, based on a previous literature study (Hamilton, 1986a). The possibly of unknown occurrences of better quality rocks in more remote locations does exist, but must be considered unlikely in the given geological context. The results of this study can be taken, therefore, as a conclusive evaluation of Alberta's filler-grade limestone potential.

7. OTHER POTENTIAL FILLER SOURCES IN ALBERTA

A number of different mineral fillers can be used in paper making. The ones most abundantly used by far are kaolin, talc and calcium carbonate (Harben, 1984). Others include titanium dioxide (rutile and anatase), barite, gypsum, and diatomite. Potential exists for occurrence of some of these minerals in Alberta, as possible alternative sources of paper filler. In addition, certain industrial waste byproducts that have the compositions of natural minerals may have potential as sources of filler.

Known kaolin deposits in Alberta have been investigated for filler potential and found to be of sub-marginal quality (Scafe and Hamilton, 1985). Mineralogical analyses show the kaolin to contain deleterious clay and quartz impurities in amounts well above specification limits. However, no beneficiation studies and no actual Brightness tests were made on the Alberta material. Since that investigation was completed, beneficiation experiments on a geologically equivalent kaolin deposit in Saskatchewan are reported to have been successful in upgrading the kaolin to a filler quality (L. E. W. Hogg, personal communication). In view of this, it is now suggested that further and more intensive testing of the Alberta kaolin deposits is required for an unequivocal evaluation.

Titanium dioxide is potentially available in Alberta as a byproduct of oil sands processing (Hamilton and Hora, 1987). Titanium-rich minerals (ilmenite, rutile and brookite) are concentrated in the secondary tailings stream of the oil sands extraction process and form a potential commercial source of TiO_2. The combined output from the two existing oil sands plants represents a world-class-size deposit, although no development has occurred as yet.

Several gypsum deposits known to exist in Alberta are undeveloped owing to remote or restricted locations or difficult access (Hamilton, 1986b). None has been evaluated specifically for filler use. For conventional (high tonnage, low value) industrial use, the deposits are sub-economic under present market conditions because of their location. However, if the gypsum is of paper filler quality (i.e., high Brightness and purity) then for a higher valued product the location factor becomes less important.

Phosphogypsum is byproduct calcium sulphate from phosphoric acid manufacture. Alberta's four fertilizer plants produce 1.3 million t annually of phosphogypsum in waste tailings ponds (Hamilton, 1986b). No use is made of the material in Alberta, nor in Canada, because of impurities (residual phosphates and uranium) that are difficult to remove economically. However, phosphogypsum has been in commercial use for years in Europe and Japan for standard gypsum product applications. It is noteworthy that in France, recent experiments have been successful in using phosphogypsum as paper filler in amounts up to 20% (Hamilton, 1986b).

Calcium carbonate is a waste byproduct of the Kraft pulping process, formed when quicklime is used to convert sodium carbonate back to caustic soda (Harben, 1984). There has been experimental use by some Kraft pulp producers, which have integrated operations, to use their own waste precipated $CaCO_3$ as a paper filler (Boynton, 1980). In spite of the obvious economy, only limited application has occurred for this more heterogenous, lower quality material. The potential savings would seem to warrant a research effort.

The minerals talc, barite and diatomite are not known to occur in Alberta (except for a talc occurrence reported in Banff National Park). However, in British Columbia all three are found in deposits with existing or potential production (Hamilton and Hora, 1987). The geological conditions exist for the possibility that they might be found in Alberta as well.

8. RECOMMENDATIONS

Based on this study, the following recommendations are made to provide a more comprehensive evaluation of the potential for use of Alberta materials as paper filler.

1. Conduct further tests of Eldon Formation limestones to evaluate their prospective use as an extender for paper filler. The study would involve blending of the limestones (re-ground to filler- grade particle size) with commercial calcium carbonate filler to determine the proportions required to achieve an acceptable Brightness value. The study should also include an economic evaluation of cost factors and potential savings, using materials from both the Kananaskis and Windy Point localities. Finally, optimum blend samples should be sent to a paper filler company for a complete suite of standard product tests, to develop comparative data sheets for the materials.

2. Follow a similar procedure as in (1) for kaolin. Select the best Alberta deposit of Whitemud Formation kaolin identified in the previous study (Scafe and Hamilton, 1985), re-sample the material and submit for beneficiation testing to a laboratory with established expertise. Conduct blending tests using the beneficiated kaolin with commercial kaolin filler, and do economic analyses of the results. Obtain a complete suite of test data for Alberta kaolin (and blends), employing the testing facilities of a Georgia kaolin company.

3. Undertake a broadly based, strategic study of availability of mineral raw materials for Alberta forest products industries. This study would examine the whole spectrum of minerals used in forest products development, including those discussed in Section 7 (other potential filler sources), from the standpoint of requirements, current sources, Alberta resources, economic factors and information needs. The results would be used to formulate research programs for specific commodities (e.g.,

gypsum) where resource information is needed in the pursuit of industry development opportunities.

4. If the studies in (1) or (2) yield economically positive results, undertake further geological fieldwork to establish quarriable reserves, of the Eldon limestones at both the Kananaskis and Windy Point localities, and/or the Whitemud Formation kaolins in southeastern Alberta. Fieldwork should also check out possibilities for better sites in more remote areas. These studies would include test drilling.

9. REFERENCES

Boynton, R.S. (1980): Chemistry and technology of lime and limestone, John Wiley & Sons, Inc., Toronto (2nd edition), 578 pages.

CSPG (1968): Central Canadian Rockies and Foothills of Alberta, 16th Field conference guidebook; Canadian Society of Petroleum Geologists, Calgary, 168 pages.

Douglas, R.J.W. (1956): Nordegg, Alberta; Geological Survey of Canada Paper 55-34, 31 pages.

______________ (1977): Waterton Lakes National Park, in Geological guide for the CSPG 1977 Waterton - Glacier Park field conference; Canadian Society of Petroleum Geologists, p. 35-40, 63-74.

Gordy, P.L., Frey, F.R. and Norris, D. K. (1977): Geological guide for the CSPG 1977 Waterton - Glacier Park field conference; Canadian Society of Petroleum Geologists, 93 pages.

Goudge, M.F. (1945): Limestones of Canada, Part 5, Western Canada; Canada Mines Branch Report 811, 233 pages.

Guillet, G.R. and Kriens, J. (1984): Ontario and the mineral filler industry; Ontario Ministry of Natural Resources, Industrial Mineral Background Paper No. 5, 175 pages.

Hamilton, W.N. (1986a): Study of Alberta limestones for potential use as paper filler; Alberta Research Council open file report, 37 pages.

______________ (1986b): Gypsum - mineral commodity profile, in The metallic and industrial minerals of Alberta; Alberta Research Council Contribution #1409, 18 pages.

Hamilton, W.N. and Hora, Z.D. (1987): Industrial mineral opportnities in British Columbia and Alberta, Canada; Society of Mining Engineers Preprint #87-111, 13 pages.

Harben, P. (1984): Introduction to paper, in Raw materials for the pulp and paper industry; Metal Bulletin, Inc., New York, p. 4-13.

Mountjoy, E.W. and Price, R.A. (1974): Geology, Whiterabbit Creek 83C/1 (west half); Geological Survey of Canada Map 1389A.

Price, R.A. (1961): Fernie map-area, east half, Alberta and British Columbia 82G E1/2; Geological Survey of Canada Paper 61-24, 65 pages.

______________ (1964): The Precambrian Purcell system in the Rocky Mountains of southern Alberta and British Columbia; Bulletin of Canadian Petroleum Geology, vol. 12, Field conference guidebook issue (August 1964), p. 399-426.

Price, R.A. and Mountjoy, E.W. (1970): Geology, Canmore 820/3 (east half); Geological Survey of Canada Map 1265A.

Scafe, D.W. and Hamilton, W.N. (1985): Study of potential sources of paper coating/filler materials for Alberta; Alberta Research Council open file report, 47 pages.

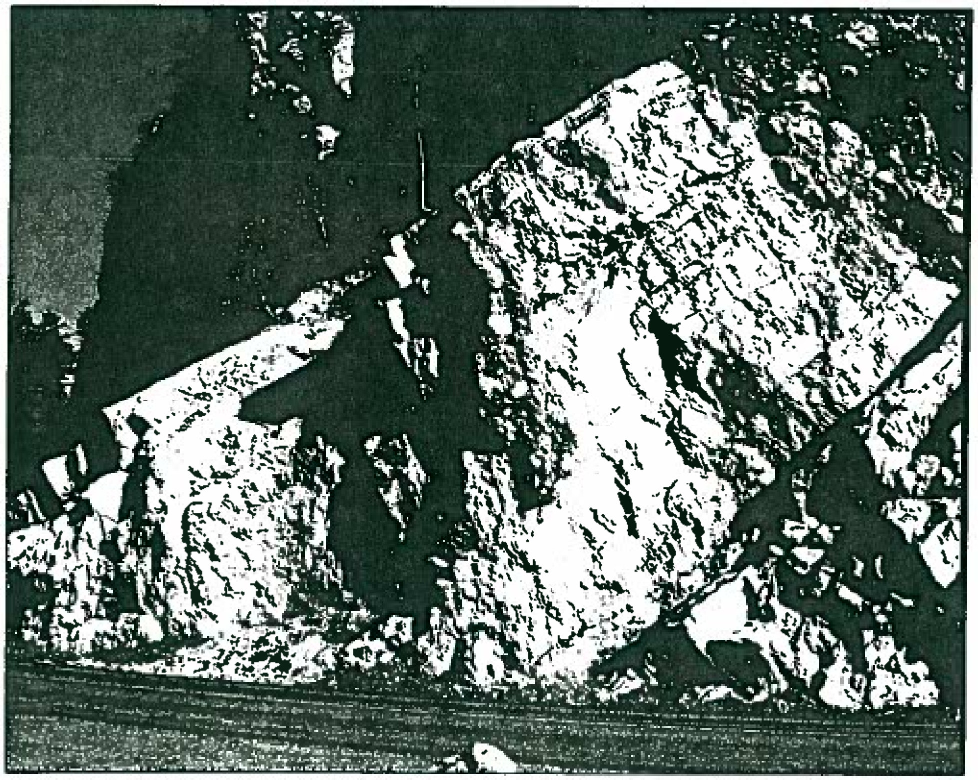
Verrall, P. (1968): Observations on geological structure between the Bow and North Saskatchewan Rivers, in 16th Field conference guidebook; Canadian Society of Petroleum Geologists, p. 106-118.

PLATE 1

Waterton Area

1A. Light-coloured dolomite of middle Altyn Formation, Cameron Lake Road, Waterton Park. Massive, sandy dolomite beds typical of middle Altyn.

1B. Altyn Formation outcrop on Ruby Ridge above Cameron Lake Road, showing typical white weathering aspect. Altyn dolomites overlain by greenish argillites (Appekunny Formation), with red argillites (Grinnell Formation) on ridge top.



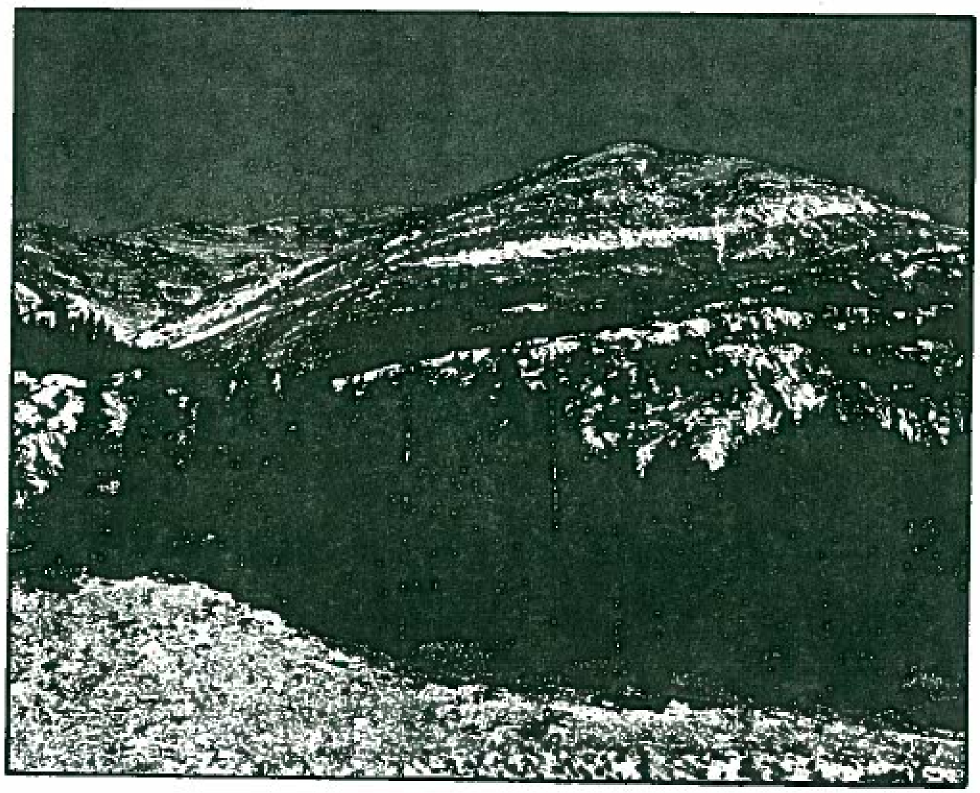


PLATE 2

Phillipps Pass

2A. Phillipps Pass, view looking northwest toward east entrance. Complete section of Paleozoic carbonates (with faulted repetitions) exposed, from Cambrian Elko Formation in middle-ground (lower center of photo) to Mississippian Rundle Group on skyline. Prospective beds are in Devonian Fairholme Group just above the Cambrian (centre of photo).

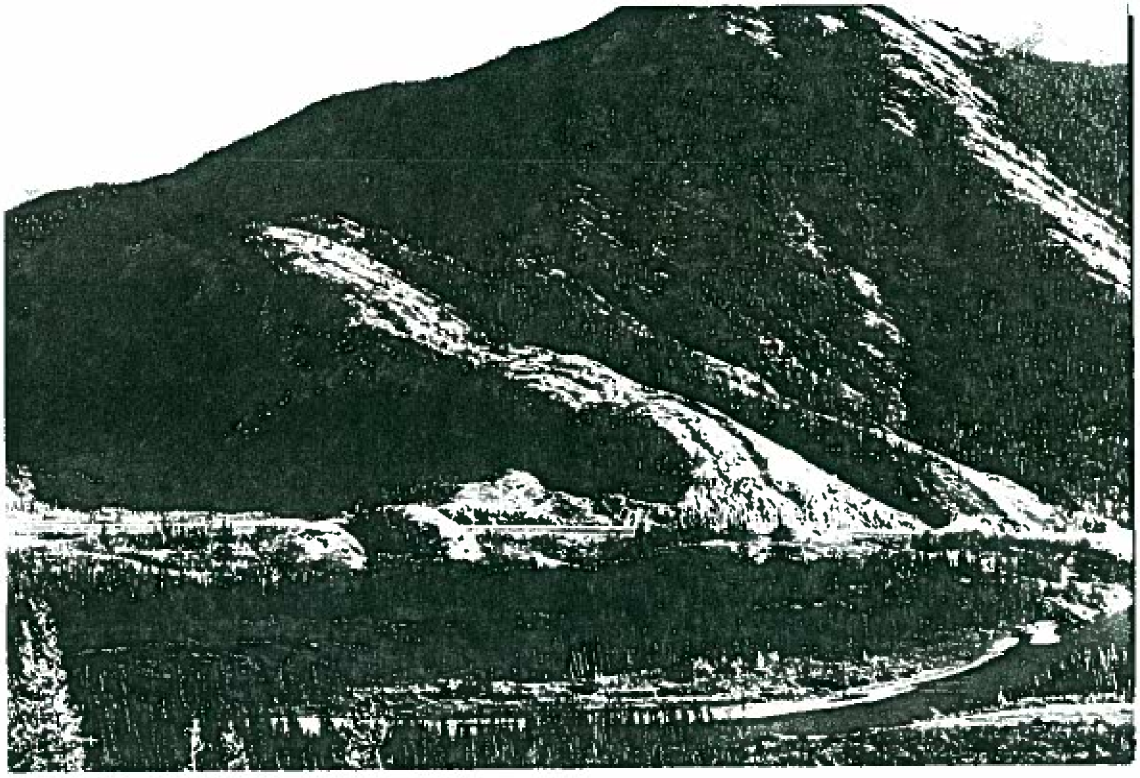
2B. Peechee dolomite member, Fairholme Group. Samples PHP-6 to 11 taken from base to top of whitish dolomite (reef mound) exposure, approximately 120 m interval.

PLATE 3

Kananaskis

3A. Ridge of white weathering Cambrian Eldon Formation terminating in roadcut on TransCanada Highway, south side of Bow Valley opposite Kananaskis. View looking south. Eldon overlain by grey carbonates of Cambrian Pika Formation (covered) and Devonian Fairholme Group (partly covered) to top of mountain.

3B. Roadcut in west dipping beds of Eldon limestone (see Plate 3A). Grey limestones overlie light coloured bed exposed at eastern end of roadcut. Sample KR-15 is of light coloured bed, about 5 m interval.



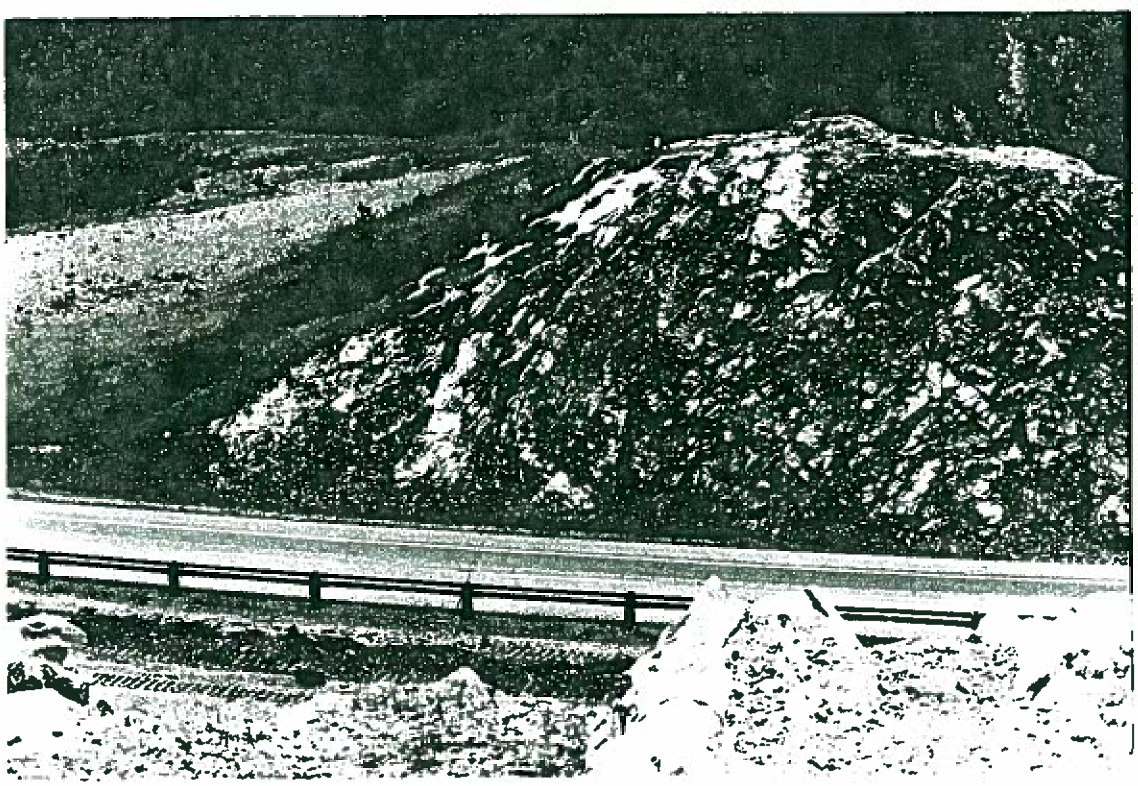
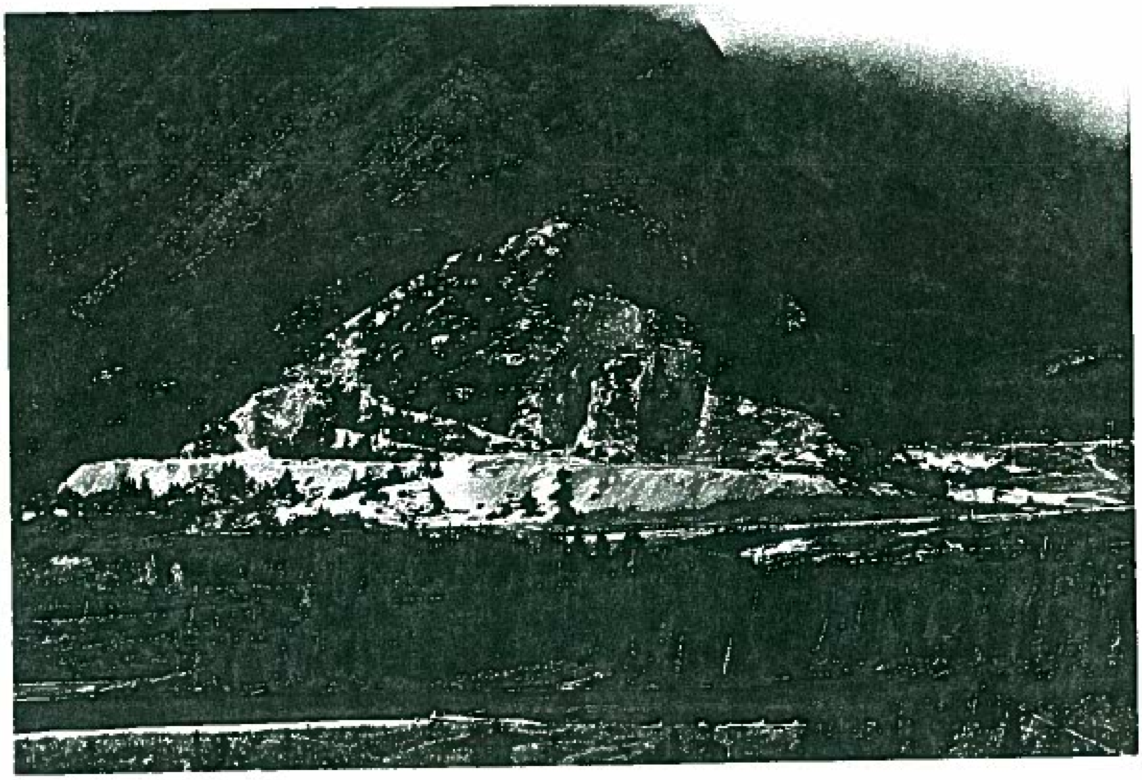


PLATE 4

Kananaskis

4A. Kananaskis quarries, view looking north across Bow Valley. Quarries are in Cambrian Eldon Formation, supplied former Loder's Lime plant located on site at right side of photo. Quarries are slot-trench type, follow zones of high-calcium limestone which run oblique to bedding and are fault-bounded in part.

4B. Outcrop of Eldon limestone above Kananaskis quarries, showing prominent white surface weathering and very light rock colour (evident in large fragment, lower left foreground).



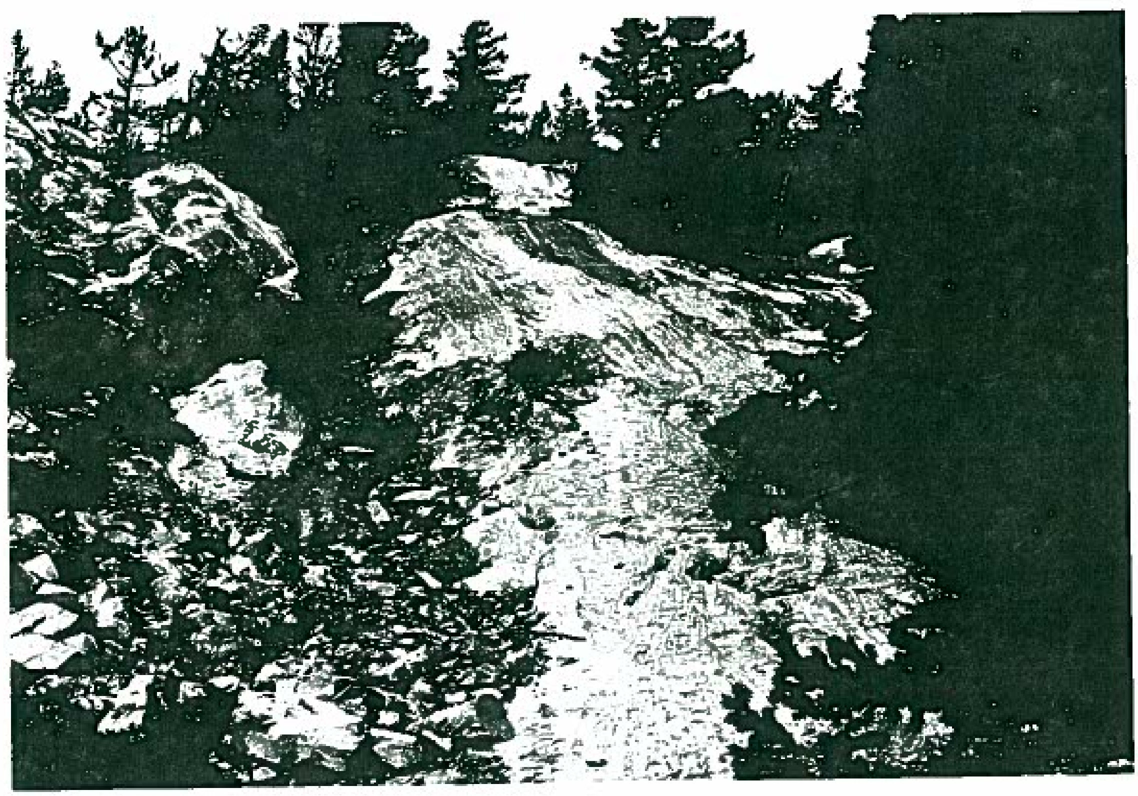


PLATE 5

Kananaskis

5A. Kananaskis quarry B (middle quarry, Plate 4A). Quarry rock is light coloured limestone, overlain by grey limestone. Width of quarry about 20 m. Wall on right side is a fault plane.

5B. Quarry face at north end of Kananaskis quarry B. Sample KQB-16 taken across quarry face, about 20 m interval.

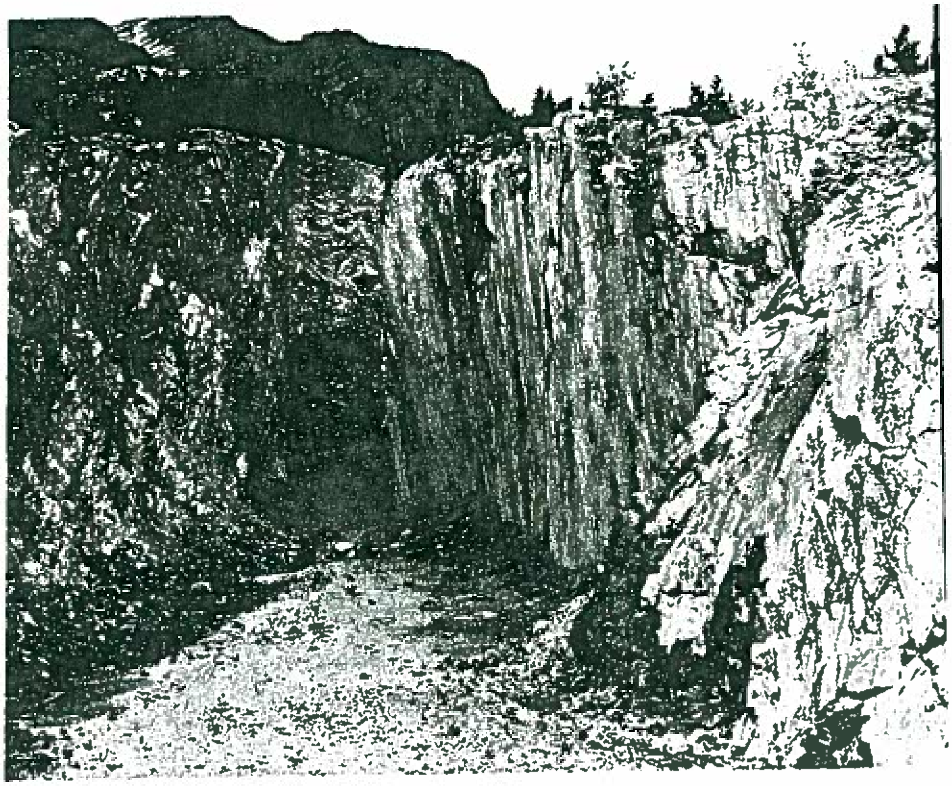


PLATE 6

Windy Point, David Thompson Corridor

6A. Roadcut at Windy Point, David Thompson Highway, in limestones of Cambrian Eldon Formation. View looking west. Roadcut exposes steeply dipping limestone beds over distance of about 150 m. Samples WNP-27 to 30 are from east through to west end of roadcut, about 70 m interval.

6B. Sample site WNP-27, east end of Windy Point roadcut. Sample is of light pinkish grey limestone band 21 m thick, overlying yellowish-coloured silty dolomite bed on left side of photo.

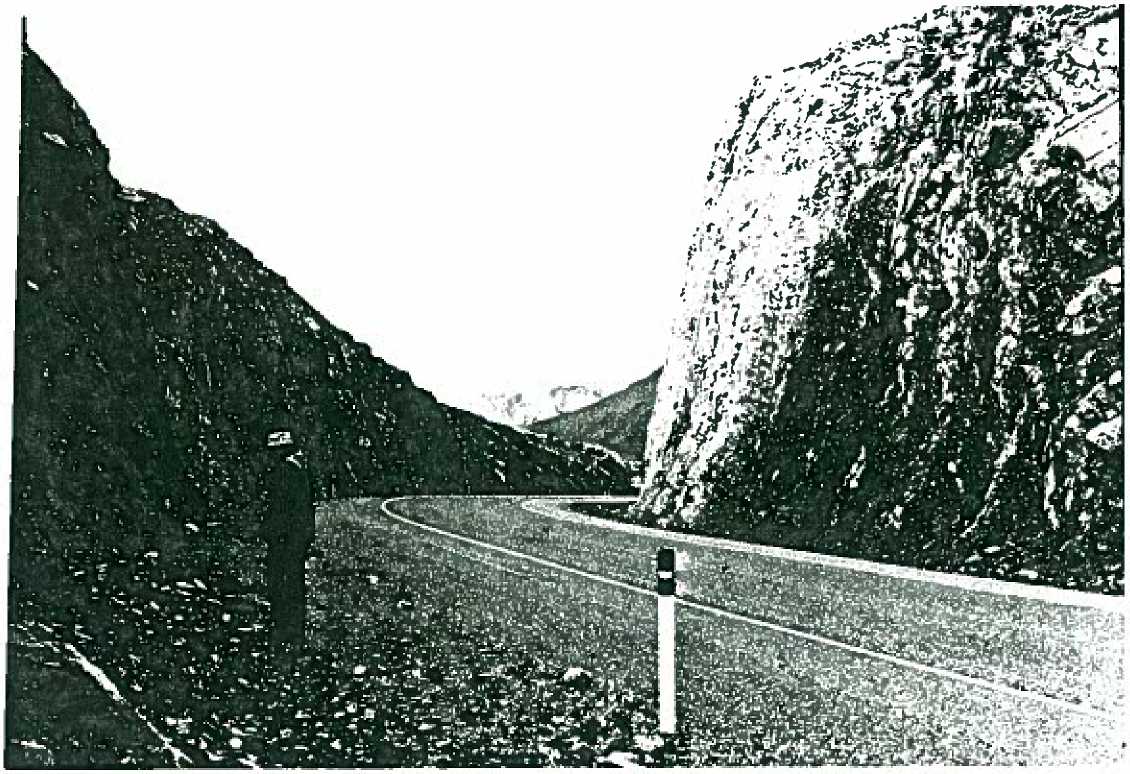


PLATE 7

Cline River, David Thompson Corridor

7A. Outcrop of Cambrian Lynx Group dolomite at Cline River bridge. West dipping dolomite beds outcrop along Cline River for about 150 m. Sample CRB-31 is collection of representative grab samples over interval of about 50 m.

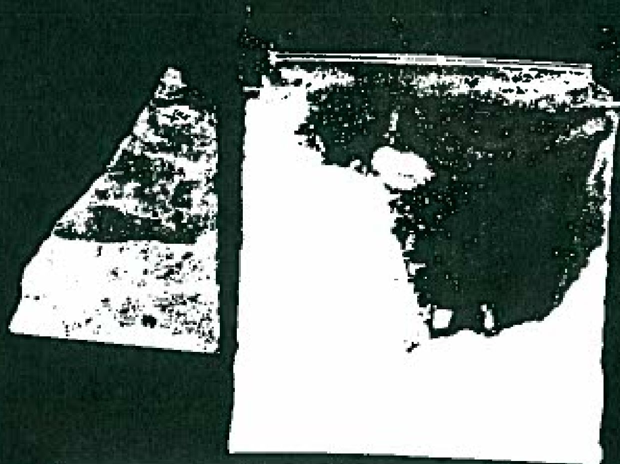
APPENDIX

Carbonate Rock Samples

*Munsell Rock Color

**Brightness (Powdered Sample)

CLARK RANGE - WATERTON AREA
Altyn dolomite (Precambrian)



N7.5* 73.9**
Sample WTN-2

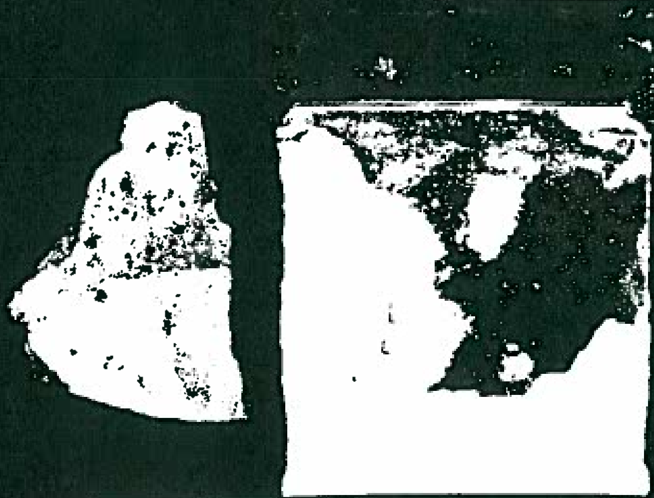
N7.5* 71.1**
Sample WCR-5

PHILLIPPS PASS
Peechee dolomite (Devonian)

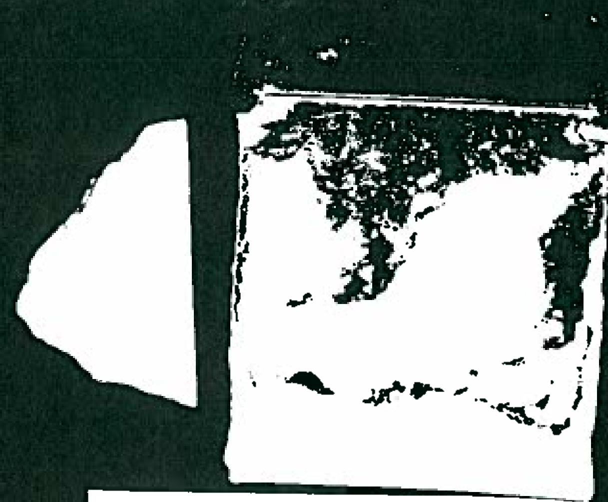
N8* 69.7**
Sample PHP-7

10 YR 8/1* 68.9**
Sample PHP-8

PHILLIPS PASS
Peechee dolomite (Devonian)



N8* 68.5**
Sample PHP-13



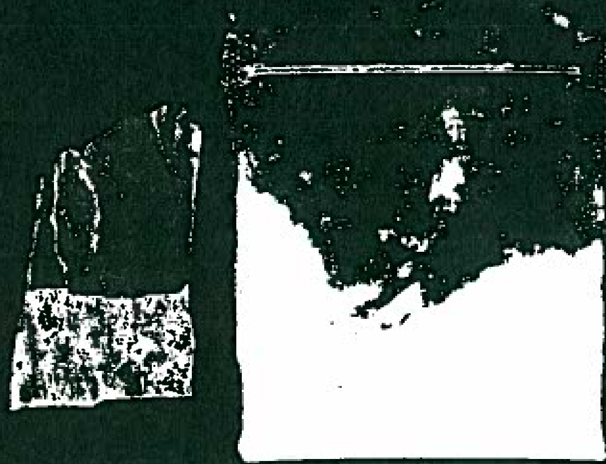
N9* 87.2**
Sample PHP-13V
(calcite vein)

KANANASKIS
Eldon limestone (Cambrian)

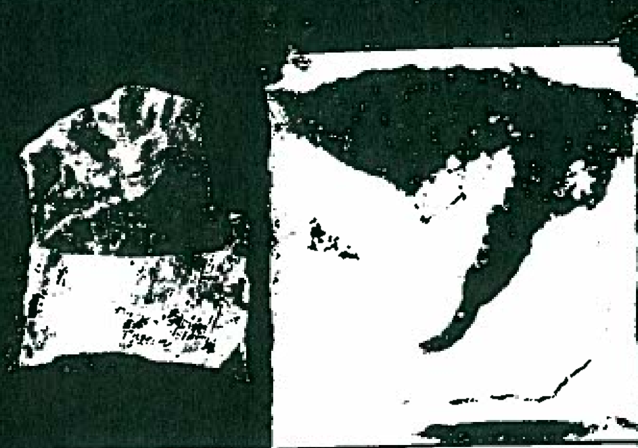
N7* 73.3**
Sample KR-14

N7.5* 78.0**
Sample KR-15

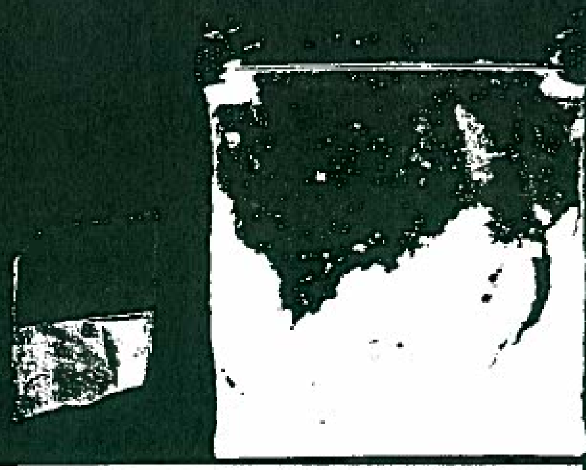
KANANASKIS QUARRIES
Eldon limestone (Cambrian)



5 YR 7.5/1* 76.1**
Sample KQB-16



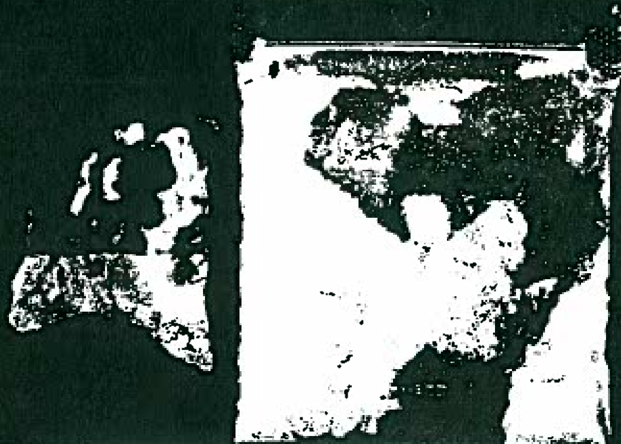
5 YR 7.5/1* 79.5**
Sample KQB-17



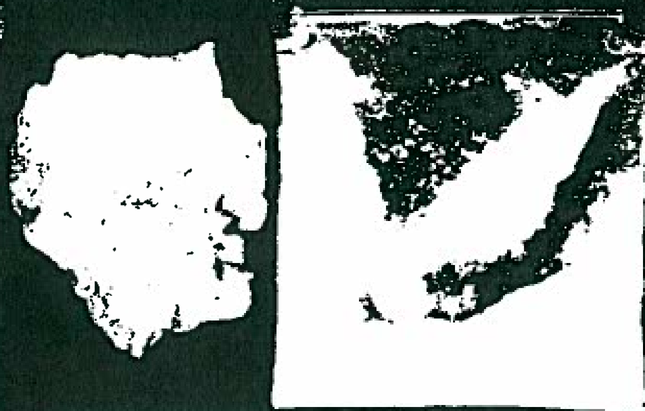
5 YR 7.5/1* 78.0**
Sample KQC-20

10 YR 6.5/1* 55.8**
Sample KQC-22

WHIRLPOOL POINT - DAVID THOMPSON CORRIDOR
Cathedral dolomite (Cambrian)



N6.5* 52.4**
Sample WRP-25



N8.5* 82.9**
Sample WRP-26
(dolomite vein)

WINDY POINT - DAVID THOMPSON CORRIDOR
Eldon limestone (Cambrian)

5 YR 7.5/1* 72.4**
Sample WNP-27

5 YR 7/1 76.2**
Sample WNP-28

IMASCO COMMERCIAL PRODUCTS
Calcium Carbonate Filler

200x
Mean Particle Size 21.8µm
Brightness 89.5%

6HX
Mean Particle Size 3.2µm
Brightness 94.8%