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Energy Resources Conservation Board

Alberta Geological Survey

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Abstract

This report contains a general discussion on what building stone is, the types of rocks used, its properties and applications, and the locations of prospective sources in Alberta. Its focus is on the geological aspects of the rocks, because how the rocks were deposited can help determine how suitable they are for building stone. The following characteristics determine the suitability of stone for building purposes: strength, durability, weathering, appearance, size, jointing and abundance. The report describes these characteristics in detail for each rock formation of interest. It describes rocks that are productive or potentially productive for building stone, mining techniques used to extract the rocks, product types that can be used once the rock has been extracted, the different types and locations of markets, the feasibility of transportation, and the future potential of building stone. It also discusses current production statistics for building stone, as well as surface-land-access reservations. The report is based mainly on previous publications and quarry visits carried out in 2006–2008.

1 Overview

Alberta began producing building stone during the 1890s after a devastating fire destroyed many of the wooden buildings on Calgary's main street. Calgarians were determined to rebuild but this time with a fireproof, more durable material—stone. A readily available source was the Paskapoo sandstone outcrops along the Bow and Elbow rivers. Since then, many stone structures have been erected throughout Alberta, including banks, churches, schools, libraries and railway stations. These buildings have created a sense of stability and community for Albertans.

Alberta produces sandstone, siltstone, limestone and fieldstone, and there is potential for granite, slate and volcanic rocks. Each stone has its own unique properties and uses. The purpose of this report is to document the different types of building stone used in Alberta; to outline the unique properties and uses of each type of stone; and to analyze past, current and future potential of the building-stone industry in Alberta. We present basic geological concepts and descriptions in nontechnical language to better understand the building stone industry.

1.1 What is Building Stone?

Building stone is used primarily as a construction material in place of wood, metal or concrete. It can take the form of blocks for walls, sills for windows or archways for doors. It can also be used for decorative purposes; although stone is not normally extracted for this purpose, it is usually a byproduct.

There is no easy way to define and separate the types of building stone because the classification can change depending on the purpose. 'Building stone' is sold in natural or broken sizes and shapes that can be used as material for building (Figure 1), rough construction, landscaping and erosion control. 'Dimension stone' is cut and finished to a specified size (Figure 2) and can be used for buildings, monuments, paving or decorative pieces. Sometimes called 'cut stone,' dimension stone is typically quarried in rectangular blocks, then sawed and finished to a specified size. Industry uses the terms 'building stone' and 'dimension stone' synonymously.

Figure 1. Building stone (Paskapoo sandstone), Alberta Provincial Legislature building, Edmonton.

Figure 2. Dimension stone (Rundlestone) from the Thunderstone quarry near Canmore.

Decorative stone, also called 'ornamental stone,' can be a byproduct of dimension- and building-stone production. Decorative stone is sought for its colour, texture and general appearance (Figure 3). There are many ingenious ways to use stone in a decorative way: in flower beds, fountains, large carvings, signage, park benches and table tops. Austin and Mead (2006) and Austin et al. (2006) have provided in-depth reviews of dimension- and decorative-stone characteristics. In this report, 'building stone' is defined as stone used for building, rough construction or decorative purposes.

Figure 3. Decorative stone (Rundlestone) from the Kamenka quarry near Canmore.

The most common applications of building stone in Alberta are the following:

- Buildings: columns, lintels, roofing, flooring, electrical panels, mantels, chimney hearths, countertops, tabletops, desktops and tiles
- Rough construction: retaining walls for erosion control, weight retention in dams and power generating stations, and rip-rap or rubble for fill material
- Landscaping: signage, curbs, edging borders around lawns or gardens, and walls
- Paving: flagstone for patios and driveways, crushed stone for pathways and baseball diamonds

- Monuments: tombstones, historical markers
- Artistry: carvings, picture frames

1.2 Types of Rocks Used as Building Stone

Alberta has produced a variety of rock types for building stone that include sandstone, siltstone, limestone, travertine and fieldstone. There is also the potential to produce granite, slate and volcanic rock.

In Alberta, sandstone is the most widely used stone material due to its abundance and ease of workability. Sandstone consists primarily of quartz, feldspar and mafic minerals (i.e., dark-coloured minerals containing iron and magnesium). The minerals vary in grain size, composition, shape, roughness and degree of dissolution. Sand grains are usually laid down in bands or layers and are cemented with silica and/or calcium carbonate. Typical grain size for sandstone is between 2 and 0.06 mm. The quality and type of cement binding the grains will naturally affect how the sandstone performs as a building stone. Several buildings throughout the province are made of sandstone; examples include the Alberta Provincial Legislature building in Edmonton, Calgary's city hall and Lethbridge's courthouse.

Siltstone, comprising silt-sized mineral grains (<0.06 mm), has typically smaller pore sizes and higher clay content than sandstone. Siltstone may also have numerous laminations and may contain concretions and fossils. The historic Banff Springs Hotel and the restored 1914 Banff Springs swimming pool used siltstone.

Limestone forms from precipitation of calcium carbonate and/or accumulation of shell material, and contains variable amounts of silica, commonly in the form of chert. It has variable grain sizes and crystalline textures, and can contain fossils or shell fragments. Limestone is commonly used as a decorative stone for landscaping.

Travertine is a sedimentary rock that forms as calcium carbonate deposited from the water of mineral springs. The Utilities Building in Calgary used travertine tile.

Granite is a coarse-grained igneous rock consisting mainly of quartz, feldspar and plagioclase. Although Alberta does not currently produce granite, there is potential for production near Lake Athabasca in the northeastern part of the province.

Fieldstone is best described as boulders or cobbles found in or upon the soil in glaciated or alluvial environments. These stones, which sometimes occur in cultivated fields, are often rounded and can consist of sedimentary, metamorphic or igneous rocks. The best area of known use is in the town of Jasper, where fieldstone is used in building foundations and retaining walls.

Slate is a fine-grained metamorphic rock derived from the heating and compaction of shale (grain size <0.004 mm). Slate can be quarried as thin sheets (<1 cm thick). Alberta is not currently producing slate, but there are potentially productive occurrences situated within the Rocky Mountain national parks.

Volcanic rocks contain a wide variety of mineral grain types, colours, sizes and textures. There is potential to produce volcanic rock from limited exposures in the foothills and mountains of southwestern Alberta.

1.3 Building Stone Properties

There are several factors to consider when determining what makes a good building stone: strength and durability, resistance to weathering, abrasion resistance, block size, jointing, abundance, workability and appearance.

A compressive-strength test measures the strength of a rock. A piece of the rock is compressed between two plates and the pressure at which failure occurs is the maximum strength of that rock. Parks (1916) measured the compressive strengths of a variety of building stones in Alberta and found that sandstone ranged between 34 500 and 155 000 kPa, limestone between 122 000 and 360 000 kPa, and granite between 138 000 and 320 500 kPa. For comparison, the compressive strength of wood ranges between 22 750 and 25 500 kPa, and that of structural steel between 248 000 and 400 000 kPa. The strength of a rock could determine its intended use.

A rock's resistance to weathering can be an important factor in its suitability for use as building stone. Water penetration can lead to fracturing or spalling during freeze-thaw cycles. Water expands when frozen and pushes the rock apart, thus increasing the size of fractures. An absorption test can be performed on a sample to determine if the mineral matrix will allow water to penetrate the rock. Fracturing and spalling have been noted in many of the buildings in Alberta that are faced with Paskapoo sandstone. Spalling does not pose a major threat to the structural integrity of a building but can affect its aesthetic appeal.

Abrasion resistance refers to the rock's ability to withstand friction; whether the friction comes from the soles of shoes or the blade of a snowplough, the stone must be durable. This is an important factor in selecting a suitable flagstone, which is a flat stone typically used as paving slabs for patios and walkways.

When quarrying stone for building purposes, it is always preferable to extract the largest blocks possible because larger blocks allow for greater variety in usage. Larger blocks are more difficult to obtain because of the jointing and bedding plane directions and impurities that could cause the rock to crack in undesired places. Joints are the natural breaks in the stone at regularly spaced intervals due to fracturing. These natural breaks are the result of such factors as the type of material that constitutes the rock and how it was deposited, and the amount of stress on the rock. Joints at regular intervals can be a positive factor for building stone because they can aid in extraction and give regular stone thicknesses. They can also be a negative factor if they limit the block size that can be produced. Abundance of a rock can determine whether it makes a suitable building stone. If it meets all other criteria but produces little excellent quality stone because it has thin laminations or joints at irregular intervals, then it is less marketable. The key is to have a consistent grade. Stone workability takes into consideration all of the above-mentioned rock characteristics and determines if the stone can be worked by stonemasons.

Inclusions are material, usually plant or clay matter, that have been incorporated in the rock during deposition. The impurities in the resulting stone layers are in the form of plant material, mud spots and clay inclusions. These inclusions affect the finished surface of the stone and therefore the desired visual appearance. Although inclusions are present to some extent in almost all building stones, they have little effect on the overall suitability.

Building stone has a wide range of colours, grain sizes, textures and patterns. These visual differences can influence the buyer in the architecture or landscaping market. Often the 'look' that a person is trying to achieve will determine if the stone is right for the purpose.

2 Alberta Geological Formations with Building Stone Potential

Geology is the study of the origin, history and composition of rocks. Understanding how rocks were deposited and deformed, and their mineralogy and cementing material will help determine their suitability for use as building stone. Rock packages are commonly grouped into lithostratigraphic units called formations. Rocks within a given formation were derived from similar geological settings or depositional environments, and may have similar compositions and ages. Figure 4 presents the rock formations in Alberta, along with their ages and building stone potential. The following sections provide details of the rocks and how they can be used as building stone.

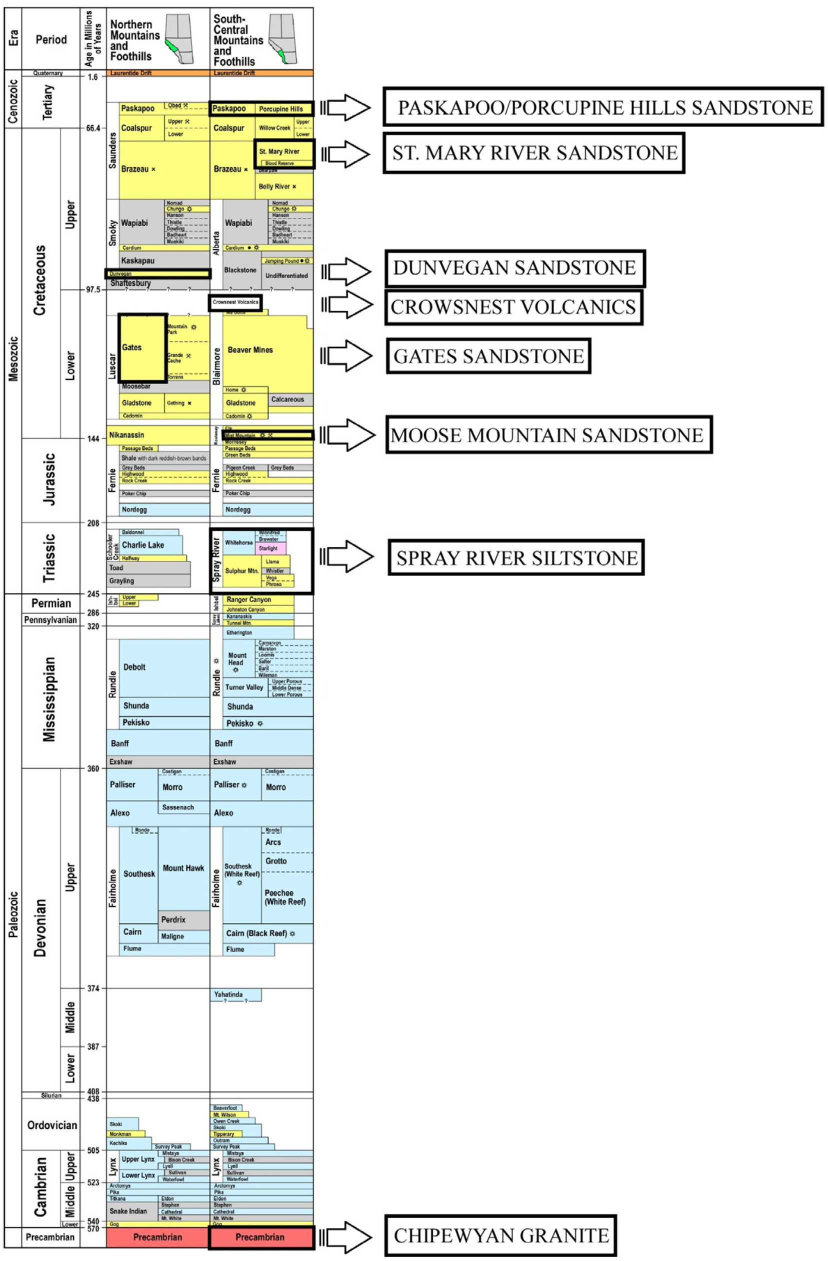

Figure 4. Rock formations in Alberta, highlighting those with building-stone potential (Alberta Energy and Utilities Board, 2002). See Appendix 1 for larger version.

2.1 Paskapoo and Porcupine Hills Formations

The Paskapoo Formation was historically Alberta's most productive formation for building stone. Although there are no current Paskapoo sandstone quarrying operations, there is huge potential for production. The Paskapoo Formation consists of a series of thick, tabular, buff-coloured sandstone beds with interbedded siltstone and mudstone layers. The sandstone beds can be in excess of 15 m thick and are commonly stacked into successions greater than 60 m thick (see Glass, 1990, p. 481). Rivers and streams in a fluvial environment deposited the Paskapoo sediments. Fluvial environments transport and deposit coarse- to fine-grained sediments. Landforms associated with fluvial environments include deltas, flood plains, point bars and braided streams. These landforms may develop sedimentary structures such as crossbedding, bedding planes, laminations, ripple marks and variations in grain size, all of which will give different characteristics to the rock (e.g., appearance and strength). The Paskapoo Formation can be seen in outcrops along the Rocky Mountain foothills and in the banks of most of the major rivers in west-central and southwestern Alberta (Figure 5).

The Porcupine Hills Formation consists of poorly exposed siltstone and mudstone (70%), which are typically well-exposed, resistant, interbedded sandstone units (30%). The sandstone units are usually cross-stratified and form numerous cliffs on the slopes of the Porcupine Hills (Jerzykiewicz, 1997). The formation was deposited as channel fills (averaging 12 m thick) and crevasse-splay sheets (up to 2 m thick) in a fluvial system thought to have been dominated by multiple, interconnected sand-bed channels encased by mud and silt deposited in interchannel lake and overbank areas (anastomosing river system; Smith and Putnam, 2008).

Parks (1916) did not differentiate between the Paskapoo and Porcupine Hills formations, possibly due to similarities in rock properties, appearance, their similar stratigraphic positions and the general public opinion that the Paskapoo and Porcupine Hills were essentially the same building-stone package. Past-producing quarries in the Paskapoo and Porcupine Hills formations can be grouped into four geographic areas, in part based on historical production, as indicated by Parks (1916): the Fort Macleod, Calgary, Red Deer and Entwistle areas (Figure 6, Table 1).

The stone found in these areas is similar in strength but can differ in colour. Sandstone quarries vary in size. Most quarries were along rivers, scarped banks, buttes, coulees, escarpments and the weathered side of small knolls. The commonality of these landforms is that the rock is exposed and overburden is minimal. There are currently no Paskapoo quarries known to be producing, but the many successful examples of Paskapoo stone used throughout Alberta should help in marketing the stone.

The Porcupine Hills Formation is currently being mined for decorative stone in Alberta. The Lewis quarry, near the town of Cowley, is on the north side of the Oldman Dam and is approximately 1 ha (2.5 acres) in size (Figure 6). Appendix 2, Table 8 gives the locations of the Paskapoo and Porcupine Hills quarries.

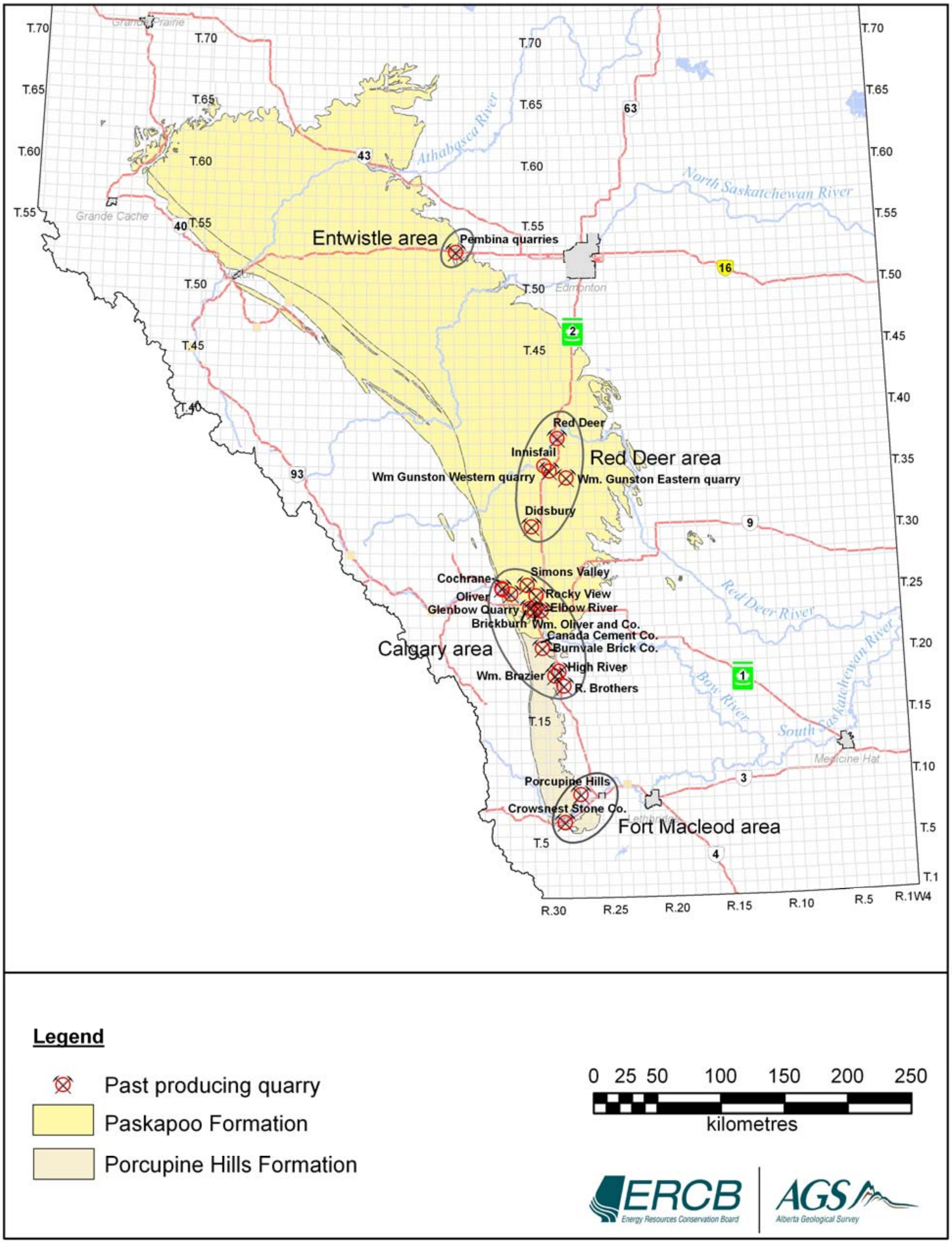

Figure 5. Areal extent of the Paskapoo and Porcupine Hills formations and past-producing quarries.

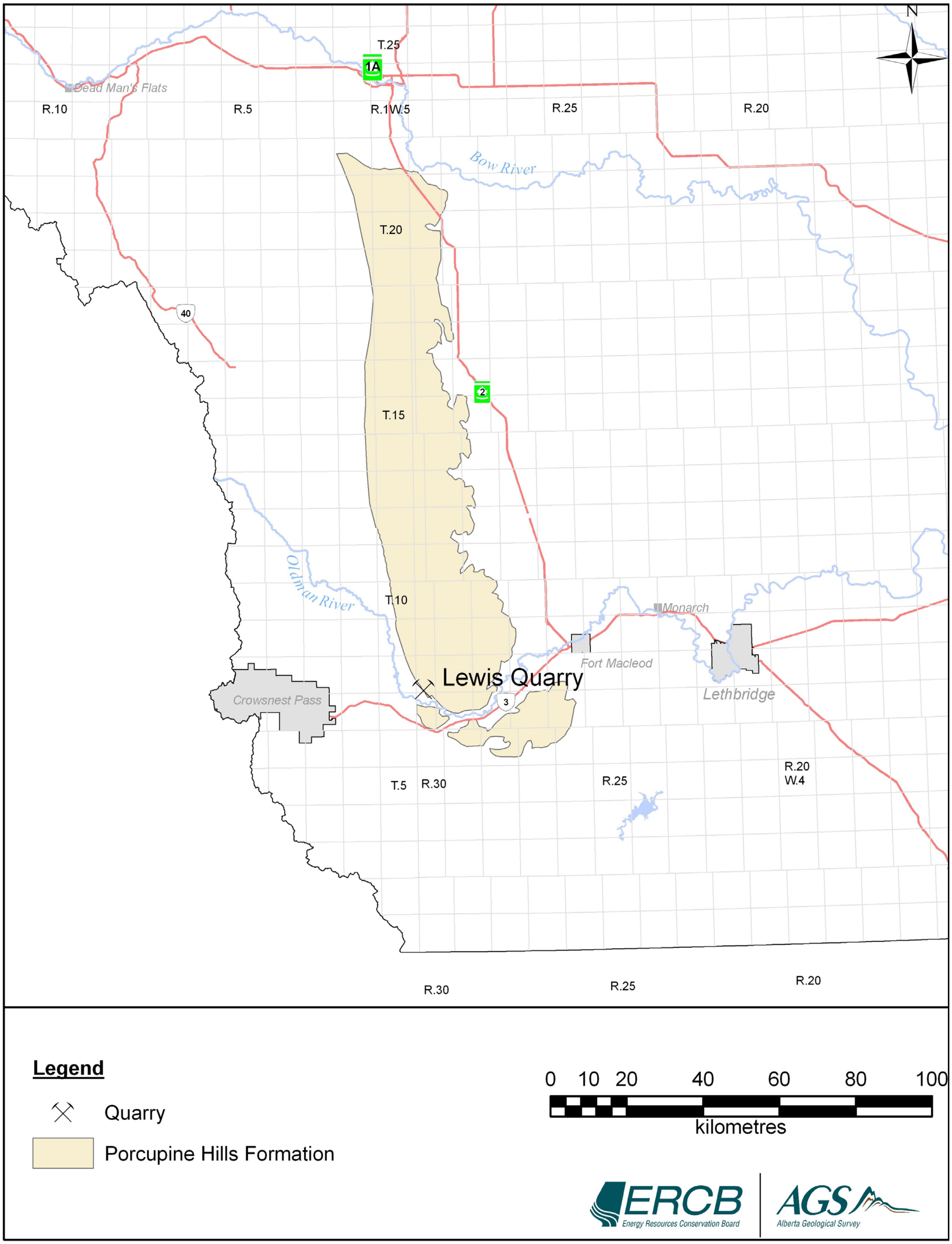

Figure 6. Porcupine Hills Formation areal extent and producing quarry.

Table 1. Geographic areas with quarries and/or outcrops in the Paskapoo and Porcupine Hills formations.

Area	Local Name	Company or Property Name	Location Type
Fort Macleod	Cowley	Lewis quarry	Quarry
Fort Macleod	Porcupine Hills	Porcupine Hills	Quarry
Fort Macleod	Brocket	Crowsnest Stone Co. Ltd.	Quarry
Fort Macleod	Brocket	Brocket	Outcrop
Calgary	High River	Wm. Brazier	Quarry
Calgary	High River	R. Brothers	Quarry
Calgary	Sandstone	Canada Cement Co.	Quarry
Calgary	Sandstone	Sandstone Brick and Sewer Pipe Co.	Quarry
Calgary	Sandstone	Burnvale Brick Co.	Quarry
Calgary	Calgary	Wm. Oliver and Co.	Quarry
Calgary	Calgary	Elbow River	Quarry
Calgary	Calgary	Bone and Leblanc	Quarry
Calgary	Rocky View	J.A. Lewis	Quarry
Calgary	Simons Valley	James Hay	Outcrop
Calgary	Glenbow	C. de Lavergne	Quarry
Calgary	Cochrane	Shelly Quarry Co.	Quarry
Red Deer	Didsbury	Peter P. Dick	Quarry
Red Deer	Didsbury	Christopher Lorine	Quarry
Red Deer	Innisfail	Wm. Gunston	Quarry
Red Deer	Innisfail	Frank F. Malcolm	Outcrop
Red Deer	Red Deer	Red Deer River	Outcrop
Red Deer	Red Deer	John T. Moore estate	Quarry
Entwistle	Entwistle	Pembina Quarries Ltd.	Quarry and outcrop

2.1.1 Rock Descriptions

The majority of this section is summarized from Parks (1916) and seven days of field observations of Paskapoo and/or Porcupine Hills building-stone quarries (Table 1). Sedimentary structures include crossbedding, irregular bedding, pinch-outs, ripple marks and massive bedding. Massive bedding observed at a few quarries enables extraction of large blocks and consistent grain size, both of which are beneficial in quarrying a consistent stone. Examples of massively bedded sandstone occur at the quarries in the Fort Macleod area. Observed pinch-outs, false bedding, laminations and crossbedding of the formation have limited the consistency of producible building stone. Typical quarries have a producing bed thickness ranging between 1.0 and 15.0 m.

The sandstone is typically fine to medium grained and generally consists of one-third quartz, one-third feldspar and one-third ferromagnesian minerals. This grain assortment gives the visual appearance of ‘salt and pepper' evident in most Paskapoo sandstone. Observations have shown a fine- to medium-grained stone in the Fort Macleod and Calgary areas, whereas a more medium-grained stone occurs in the Red Deer and Entwistle areas.

Paskapoo sandstone has a unique yellow to buff colour, with occasional bluish hues. This colour variation is derived from weathering, variations in mineral matrix composition or oxidation zones. Weathering occurs when the stone is exposed to natural processes, such as water absorption or freeze-thaw cycles. When water is absorbed into the stone, the matrix can be altered. The matrix, which binds the mineral grains together, consists of calcium carbonate, clay and magnesia. Lime, which is the main bonding element, can undergo a natural chemical process that can either soften or harden the stone. The zone of oxidation is the depth to which water and air have penetrated into the subsurface. The stone within the 'zone of oxidation' is commonly softer, thus making it easier to extract. Oxidation can also change the original colour of the stone. Table 2 gives the stone colours typical of the various areas in which the Paskapoo and Porcupine Hills formations occur.

Table 2. Colour variations in sandstone from the Paskapoo and Porcupine Hills formations by geographic area (Godfrey, 1986).

Paskapoo and Porcupine Hills Sandstone Colour	Geographic Area						
	Macleod-Brocket	High River	Sandstone – Calgary (south)	Calgary (northwest)	Glenbow-Cochrane	Red Deer	Entwistle
Very yellow							X
Yellow				X			
Buff							
Grey-yellow		X	X		X	X	
Grey	X						
Blue			X				X

According to Parks (1916), 25 known outcrops and quarry locations of the Paskapoo and Porcupine Hills formations yielded commercial stones:

Stone 1 The yellow Calgary stone (Wm. Oliver and Co. and J.A. Lewis, Calgary; Figure 7)

Stone 2 The grey-yellow Glenbow stone (C. de Lavergne, Calgary) used in the Alberta Provincial Legislature building (Figure 1) and Athabasca Hall, University of Alberta (Figure 8)

Stone 3 The grey-yellow Cochrane stone (Shelly Quarry Co., Calgary; Figure 7)

Stone 4 The grey Macleod-Brocket stone (Porcupine Hills and Crowsnest Stone Co. Ltd., Fort Macleod; Figure 9)

The railway station at Claresholm is an example of the use of stones from different quarries (Figure 7). The station "…was built partly of Cochrane stone, and partly of the stone taken from the old station at Calgary which I believe was quarried at the Elbow" (Parks, 1916, p. 200–201).

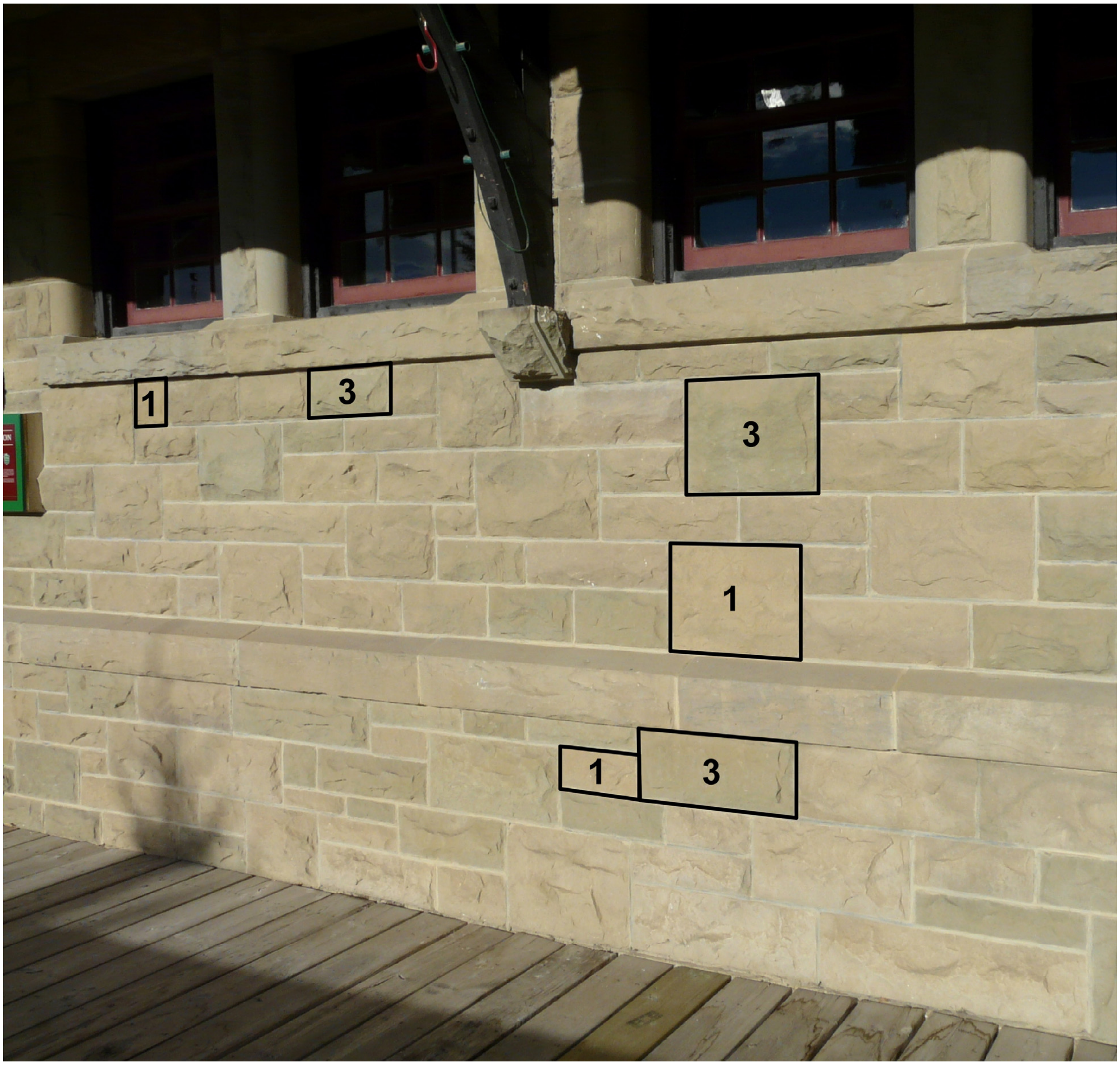

Figure 7. West-facing wall of the railway station in Claresholm, showing stone types 1 and 3 from the Paskapoo and Porcupine Hills formations (Parks, 1916).

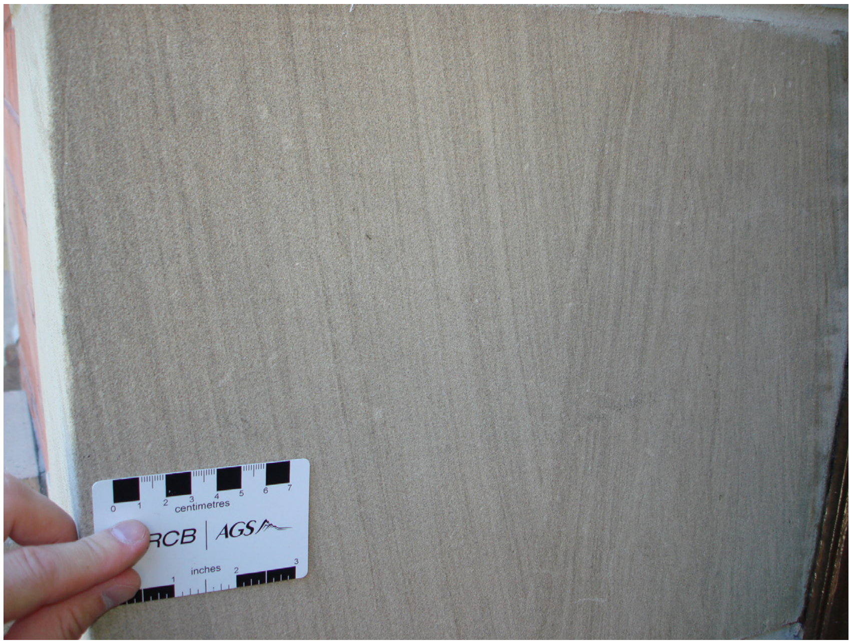

Figure 8. Paskapoo Formation grey-yellow, crossbedded sandstone (type 2 of Parks, 1916) used as a cut block on the Athabasca Hall, University of Alberta in Edmonton. Note that the stone was installed with bedding oriented vertically instead of the typical horizontal orientation.

Figure 9. Grey sandstone (type 4 of Parks, 1916) from the Porcupine Hills Formation in the wall of the Queens Hotel in Fort Macleod.

Parks (1916, p. 206) gave a description and the weathering characteristics of Paskapoo and Porcupine Hills stone type 4, the grey Macleod-Brocket stone:

> "The Queens hotel in Macleod was built of the grey stone in 1903. The walls are laid up in good uniform 14-inch rock face coursing which has preserved its original colour remarkably well. In very exposed positions only has a slight yellow colouration appeared. Some mud holes are apparent but they are small and confined to a few blocks. Cut work standing in vertical position is still sharp but in horizontal position it shows a superficial disintegration. The surface of the stone can scarcely be abraded by the thumb nail even on sharp points of the rock face and in no place was any evidence of powdering observed. The general appearance of the building is very satisfactory as it lacks the variation in colour of different blocks which is a feature not uncommon in many buildings constructed of Paskapoo sandstone."

Current observations (2008) of the Queens Hotel in Fort Macleod indicate that the stone is holding up rather well (Figure 9), although the lower foundation blocks are showing signs of spalling due to stagnant water and snow on the sidewalks infiltrating the stone.

Stone hardness is a major factor in its durability. Geological deposition, degree of weathering, grain size and matrix determine the hardness. A few of the Calgary quarries have examples of hard Paskapoo sandstone (Parks, 1916). Carving the stone into the desired shape or size with ease can determine if the stone is usable for building purposes. Overall, sandstone from the Paskapoo and Porcupine Hills formations is soft enough to be shaped into a desired form, yet hard enough to be a durable, long-lasting stone.

Typical sandstone from the Paskapoo and Porcupine Hills formations has a specific gravity of 2.6, 16%–22% pore volume, a saturation coefficient of 0.68–0.79 and cohesive strength ranging from 41 350 to 75 850 kPa. Appendix 2, Table 9 presents general physical characteristics for a variety of sandstone building-stone types.

Field observations describe the Porcupine Hills Formation as a light grey, fine-grained sandstone. The bedding is uniform and regular but has some clayey/shaly layers. The Lewis stone is soft and easily worked. This unit is synonymous with the "Paskapoo stone type 4" sandstone of Parks (1916).

Table 3 summarizes the characteristics of sandstone from the Paskapoo and Porcupine Hills formations.

Table 3. Characteristics of stone from the Paskapoo and Porcupine Hills formations (Parks, 1916). Abbreviation: n/a, not available.

Quarry Name and Location	Total Mineable Thickness (m)	Overburden Thickness (m)	Sedimentary Structures	Fresh and Weathered Colours	Grain Size	Mineral Framework	Cement Content	Durability (Soft to Hard)
Lewis quarry, Cowley	8.5	Minimal	Ripple marks, massive bedding	Light grey to light tan, brown	Fine	Quartz, mafic minerals	Calcite	Soft to medium
Fort Macleod–Porcupine Hills	1.2–6.0	n/a	n/a	Grey to slightly brown; no difference on weathered surface	Fine to medium	33% quartz	Calcite and iron oxide	Soft
Crowsnest Stone Co. Ltd., Fort Macleod	6.5	5.0	Crossbedding and massive bedding	Grey to slightly brown; weathers slightly yellow	Fine to medium	Quartz, feldspar	n/a	Slightly hard
Brocket, Fort Macleod	1.0	n/a	False bedding	Grey	Fine to medium	n/a	n/a	Slightly hard
Wm. Brazier, Calgary	1.0	n/a	Crossbedding	Mainly grey but also yellow and blue; weathers to slightly yellow	Medium to coarse	Quartz, feldspar	Lime and iron oxide	Moderately hard
Canada Cement Co., Calgary	1.0	4.5	n/a	Light greyish with a cast of yellow	Fine to medium	Quartz, feldspar	Lime	Moderately hard
Sandstone Brick and Sewer Pipe Co., Calgary	1.0–3.0	n/a	n/a	Bluish	Fine	Quartz, feldspar	Lime	Moderately hard
Burnvale Brick Co., Calgary	6.0	Minimal	Wavy	Greyish; weathers to yellow or yellow and bluish	Fine to medium	n/a	n/a	Slightly hard
Wm. Oliver and Co., Calgary	3.0–6.0	3.0	n/a	Blue, yellow to buff, grey	Medium	25% quartz, remainder undetermined	Lime and iron oxide	Moderately hard
Elbow River, Calgary	6.0	Up to 15.0	False bedding	Grey, greyish yellow	Medium	Quartz, feldspar, mica	Lime	Soft
Bone and Leblanc, Calgary	7.5	2.0	n/a	Buff, grey and slightly yellow	Fine, medium	n/a	n/a	Soft
J.A. Lewis, Calgary	1.0–3.0	6.0	False bedding	Buff, light blue, yellow	Fine to medium	Quartz, feldspar	Lime and calcite	Soft
C. de Lavergne, Calgary	6.0	7.5	False bedding, crossbedding	Grey, yellow-buff	Fine, medium, coarse	Quartz, feldspar,	Lime, calcite and iron oxide)	Soft
Shelly Quarry Co., Calgary	6.0	3.0	False bedding, laminations	Blue, grey, grey with a brownish cast	Fine, fine to medium	Quartz, feldspar,	n/a	Soft
Peter P. Dick, Red Deer	1.3	1.5	Lenticular, false bedding	Greyish yellow	Medium to fine	n/a	n/a	n/a
Christopher Lorine, Red Deer	4.5	Minimal	Crossbedding	Greyish yellow; weathers yellow	Medium	n/a	n/a	n/a
Wm. Gunston, Red Deer	3.0	Minimal to 6.0	False bedding, lenticular	Bluish grey, greyish; weathers yellow	Fine	n/a	n/a	Soft
Frank F. Malcolm, Red Deer	3.0	n/a	n/a	Greyish green, light grey; weathers yellow	Very fine	n/a	n/a	Very hard
John T. Moore estate, Red Deer	2.0	4.5	Lenticular, false bedding	Grey; weathers slight yellow	Fine	n/a	n/a	Very soft
Pembina Quarries Ltd., Entwistle	15.0	6.0	n/a	Blue, buff, grey, yellow	Medium to coarse	Quartz, feldspar,	n/a	Soft

2.1.2 Mining Techniques

Methods used for extracting sandstone from the Paskapoo and Porcupine Hills formations included blasting, gang saws and extraction by hand (crowbars and wedges). Parks (1916, p. 222) recorded the following blasting method at the Wm. Oliver and Co. quarry in Calgary: "Powder is occasionally used in 1.5 inch rimmed holes in small charges with an air chamber: fairly straight breaks 10 feet long are thus produced." Gang saws were able to cut 8.9–20.3 cm (3.5–8 in.) per hour with 5–6 and 7–8 blades (Parks 1916, p. 199). Quarries that used gang saws included those of the Crowsnest Stone Co. Ltd., Wm. Oliver and Co. and C. de Lavergne. Crowbars and wedges were commonly used along bedding and jointing planes where extraction would be done by hand. Once a sizable block was removed, a derrick with a steam or friction hoist was used to elevate and move the blocks. The blocks were hauled out of the quarry on tracked cars to a finishing area, where they were prepared for market.

In the Lewis quarry, saws cut the stone in place and an excavator lifts the stone out. Figure 10 shows benches where the stone has been cut and extracted. Bench thicknesses vary from 1 to 1.5 m and bench length is continuous. The quarry dimensions are approximately 8.5 m high by 50 m long by 25 m wide.

2.1.3 Products, Market and Transportation

Sandstone from the Paskapoo and Porcupine Hills formations has been used as dimension stone, building blocks (sawed or rough), pillars, windowsills, lintels, carvings and mill blocks. See Appendix 2, Table 10 for a listing of buildings that have used sandstone from the Paskapoo and Porcupine Hills formations.

Most of the sandstone produced was used in building construction. Local quarries supplied stone to local buildings, except in some cases where the stone was transported for a large building project. For example, the Alberta Provincial Legislature building in Edmonton was constructed of stone hauled from the C. de Lavergne quarry in Calgary (Appendix 2, Table 10). Railways were used for transportation, with spur lines being built off the main rail lines to the quarries to accommodate the transportation of the stone to market. Haul distances from the quarries to the main rail lines were relatively short, ranging from 0.8 km (0.5 mi.) at the Crowsnest Stone Co. Ltd. quarry to 11.3 km (7 mi.) at the Porcupine Hills quarry and averaging 5.6 km (3.5 mi.).

The primary product of the Lewis quarry are blocks for retaining walls, due to the 'saw-in-place' extraction method. The market for Porcupine Hills Formation sandstone is local. Nearby communities, such as Lethbridge, Pincher Creek and Crowsnest Pass, use the stone for retaining walls and landscaping. Stone has been sold as far away as Red Deer, Calgary, Fernie and even Vancouver. Although transportation for local markets is minimal, the cost to access larger urban areas increases significantly.

2.1.4 Future Potential

Paskapoo sandstone has already demonstrated its worth in the Alberta economy. There are currently no Paskapoo quarries known to be producing, but the many successful examples of Paskapoo stone used throughout Alberta should help in marketing the stone. The Lewis quarry in the Porcupine Hills Formation operates within a small outcrop on the tops of low hills. The success of this quarry warrants further exploration for this type of stone.

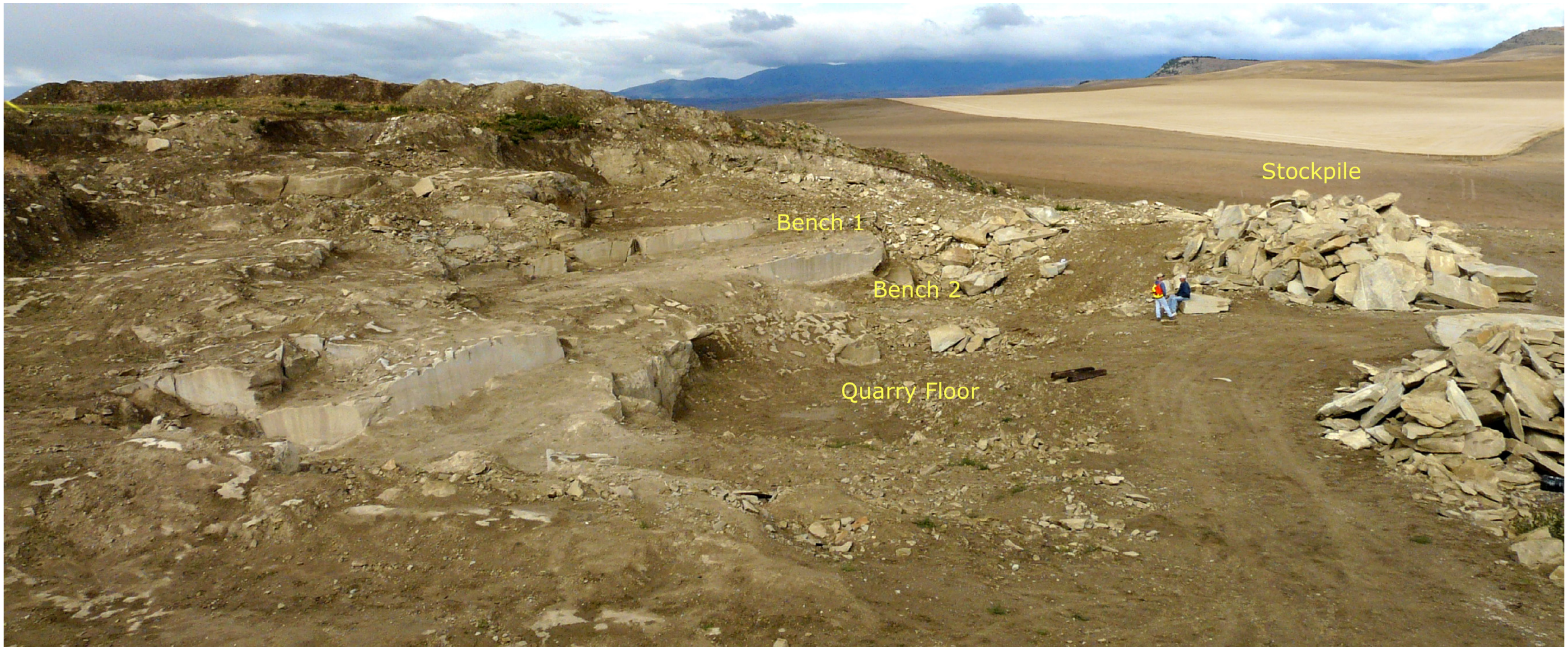

Figure 10. Lewis quarry, Fort Macleod, showing cut benches (looking west).

2.2 St. Mary River Formation

The St. Mary River Formation is currently being mined for decorative stone in Alberta. The Windmill quarry is the only St. Mary River Formation quarry known to be producing in Alberta. It is in southern Alberta, near the town of Cowley, on the northwest corner of Cowley ridge. There is a row of large electricity-generating windmills in the area, hence the name Windmill quarry. The quarry is approximately 1 ha (2.5 acres) in size.

In the basal member of the St. Mary River Formation is a 30 m thick sandstone that is commonly lenticular in shape and interbedded with alternating green and grey friable silty shale, very thin coal and limestone (Glass, 1990, p. 600). The St. Mary River sediments were deposited in marginal marine conditions, generally a low-energy sedimentary environment comprising clay, silt, sand, plant matter and limestone. Parks (1916) had described the Monarch, Mrs. Arnold and Duncan Maclean locations in the Fort Macleod area as Paskapoo Formation. Since 1916, geological mapping has indicated that these three quarries are in the St. Mary River Formation. Appendix 2, Table 8 gives the location of the St. Mary River quarries.

The mined stone is a soft, fine-grained, greenish grey sandstone that typically comes from the basal member of the formation. The St. Mary River Formation can be seen in outcrops along the Rocky Mountain foothills and in most of the major rivers along a thin band in southern Alberta (Figure 11). Exposures at the tops of knolls, in abandoned coulees or in the rivers valleys could be an excellent place to explore for sources of St. Mary River stone.

2.2.1 Rock Descriptions

Figure 12 shows a geological section of the Windmill quarry wall, divided into five units for description. Unit 1, the uppermost layer, is a 0.5 m thick, fine-grained sandstone that is olive grey and iron stained; at the base of the unit is a 0.35 m mud mixed in the sand. Unit 2 is a 1.4 m thick layer of alternating shale and mudstone. Unit 3 is a 1.2 m thick, fine-grained, hard, buff sandstone. Unit 4 is a 3.4 m layer of alternating sandstone, shale and mudstone. Unit 5, the bottom layer, is a 7.2 m thick, massive, medium-grained sandstone that is grey to light olive grey and iron stained. The bulk of the production comes from the equivalent of unit 5. The quarry floor consists of hard, coarse-grained, bluish grey sandstone, which is not mined. The overall length of the quarry is 62 m.

The exposed quarry face shows visible bedding planes, ripple marks along the bedding planes, visible iron staining (Figure 13) and calcite stringers along fracture zones. Inclusions in the marketable stone consist of organic matter and mud blebs. Table 4 summarizes the characteristics of St. Mary River stone in the Windmill quarry and Fort Macleod area.

Figure 14 shows thick, soft sandstone in a coulee that enters the Oldman River valley at the Mrs. Arnold location.

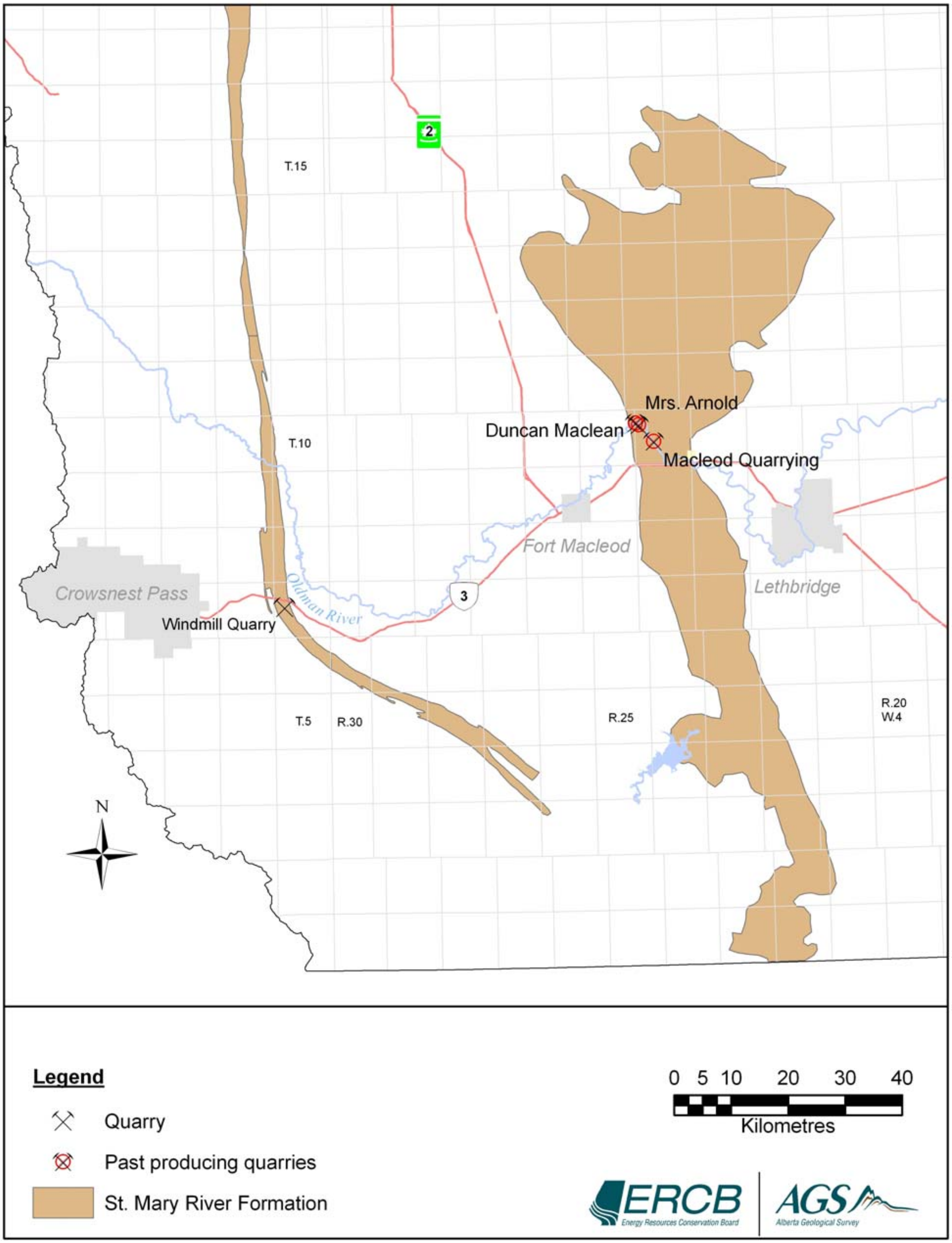

Figure 11. St. Mary River Formation aerial extent and current producing quarry.

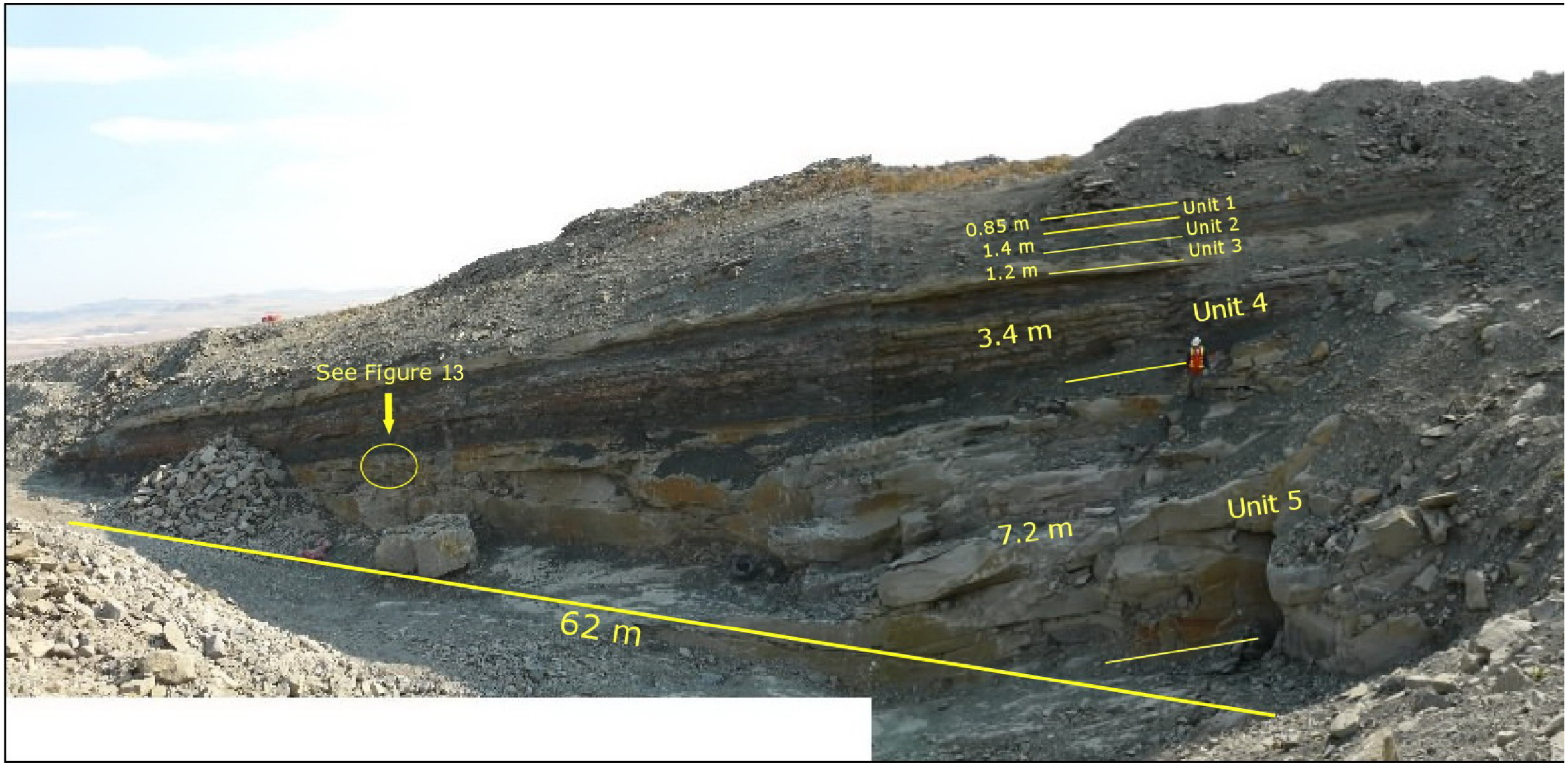

Figure 12. Face of the Windmill quarry in the St. Mary River Formation (looking north).

Figure 13. Iron staining and blast fracturing of unit 5, Windmill quarry, St. Mary River Formation.

Figure 14. Thick, soft sandstone bedding, the Mrs. Arnold property, St. Mary River Formation.

Table 4. Characteristics of St. Mary River Formation stone.

Quarry Name and Location	Total Mineable Thickness (m)	Overburden Thickness (m)	Sedimentary Structures	Fresh and Weathered Colours	Grain Size	Mineral Framework	Cement Content	Durability (Soft to Hard)
Windmill quarry, Cowley	8.4	Minimal	Ripple marks, massive bedding	Grey to light olive grey, iron staining	Medium	Quartz, mafic minerals	Calcite	Soft to medium
Macleod Quarrying and Contracting Co., Fort Macleod	4.6 m bed thickness; extracting 1 m blocks	1.5–10.0	Thin crossbedding	Blue and buff; weathers slightly yellow	Fine to medium	33% quartz, remainder feldspar, ferromagnesian minerals, plus black mica and white mica	24% (lime, clay and magnesia)	Soft, hardens on exposure
Mrs. Arnold, Fort Macleod	3.0–9.0	3.0–9.0	Crossbedding and massive bedding	Light greyish buff	Fine	25% quartz, remainder n/a	Lime, clay and magnesia	Very soft
Duncan Maclean, Fort Macleod	1.5	3.0	n/a	Light greyish buff; weathers slightly yellow	Fine	25% quartz, remainder n/a	Lime, clay and magnesia	Soft

2.2.2 Mining Techniques

The Windmill quarry uses a blasting-and-excavator method for stone extraction. A charge of dynamite and fertilizer, set off in a drillhole, fractures the bedrock enough that the excavator can remove the stone from the blast area (Figure 13). The Monarch quarry used gangsaws to cut the blocks and derricks with steam hoists to lift the blocks onto tracked cars.

2.2.3 Products, Market and Transportation

The Windmill quarry uses a rock-etching technique to make customized stone products for signage and monuments (Figure 15). Products also include flagstone for patios and driveways, and larger blocks used as decorative centrepieces and retaining walls. The market for St. Mary River stone is nearby communities, such as Lethbridge (Figure 16), Pincher Creek and Crowsnest Pass. Products have been sold as far away as Red Deer, Calgary and Fernie. Although transportation for local markets is minimal, the cost to access larger urban areas increases significantly.

2.2.4 Future Potential

The St. Mary River quarry operates within a small outcrop on the top of low hills. The Windmill quarry had a crushed-stone test done on some of the extracted material. The results indicated that the stone would be moderately favourable for ice control on roadways. The success of this quarry and the historical Monarch quarry warrants further exploration for this type of stone.

Figure 15. Decorative stone: 'sign rock' from the Windmill quarry.

Figure 16. St. Mary River buff-coloured sandstone used as a pillar on the courthouse in Lethbridge.

2.3 Dunvegan Formation

The Dunvegan Formation is currently being mined for decorative stone in Alberta. It is a marine and nonmarine, delta-sourced sandstone that is light grey to yellowish buff in colour. Thin beds of shale, fossiliferous limestone and coal also occur in the Dunvegan (Glass, 1990). Its depositional environment is considered to be deltaic. Deltas are shallow-slope, low-wave-energy environments that deposit fine- to coarse-grained sediments.

The Dunvegan Formation, part of the Lower Mesozoic–Lower Cretaceous strata, is visible in outcrops along the Rocky Mountain foothills and along several of the major rivers in west-central Alberta (Figure 17). The 'Kakwa quarry' is the only known producing quarry in the Dunvegan Formation of Alberta. Appendix 2, Table 8 gives the location of the Kakwa quarry.

2.3.1 Rock Descriptions

Field observations describe the Dunvegan Formation as a fine- to medium-grained sandstone, grey in colour and weathering to brown. Ripple marks and visible laminations, as well as shale and mudstone beds, occur in the quarry face. The geological section shown in Figure 18 is divided into three units. Unit 1, the lowermost, is 1 m of fine- to medium-grained sandstone broken by a ripple-marked shaly unit at the 0.6 m mark. Unit 2 comprises 1 m of interbedded shale and mudstone with 0.10 m of coarse-grained sandstone in the middle. Unit 3, at the top, is 1.8 m of jointed, fine-grained grey sandstone interbedded with thin carbonaceous layers. The stone extracted from unit 1 is thicker and heavier than that extracted from unit 3. Table 5 summarizes the characteristics of Kakwa Formation stone.

Table 5. Characteristics of 'Kakwa Stone' from the Dunvegan Formation.

Quarry name and Location	Total Mineable Thickness (m)	Overburden Thickness (m)	Sedimentary Structures	Fresh and Weathered Colours	Grain Size	Mineral Framework	Cement Content	Durability (soft to hard)
Kakwa quarry, Two Lakes	2.8	Minimal	Laminations, ripple marks	Grey; weathers brown	Fine to medium	Quartz	Calcite	Medium to hard

2.3.2 Mining Techniques

The Kakwa quarry is a roadcut-style quarry rather than a traditional pit quarry. It was 'discovered' during construction of access roads for the oil and gas, and forestry industries. An excavator extracts the stone; the stone is then stacked by hand onto pallets.

2.3.3 Products, Market and Transportation

The trade name 'Kakwa Stone' was chosen for the Dunvegan Formation stone because Kakwa is the name of the area where the quarry is located. Kakwa Stone products are mainly flagstone and art rock that are sold to local markets for landscaping. Transportation is a major consideration for this stone, as the quarry is 161 km from the sales office in Grande Prairie.

2.3.4 Future Potential

The Kakwa quarry is an established stone producer. A location closer to an urban centre would greatly help reduce the cost of transportation. The producer of Kakwa stone would also like to test for 1-inch or 2-inch crushed stone to augment the current landscaping use.

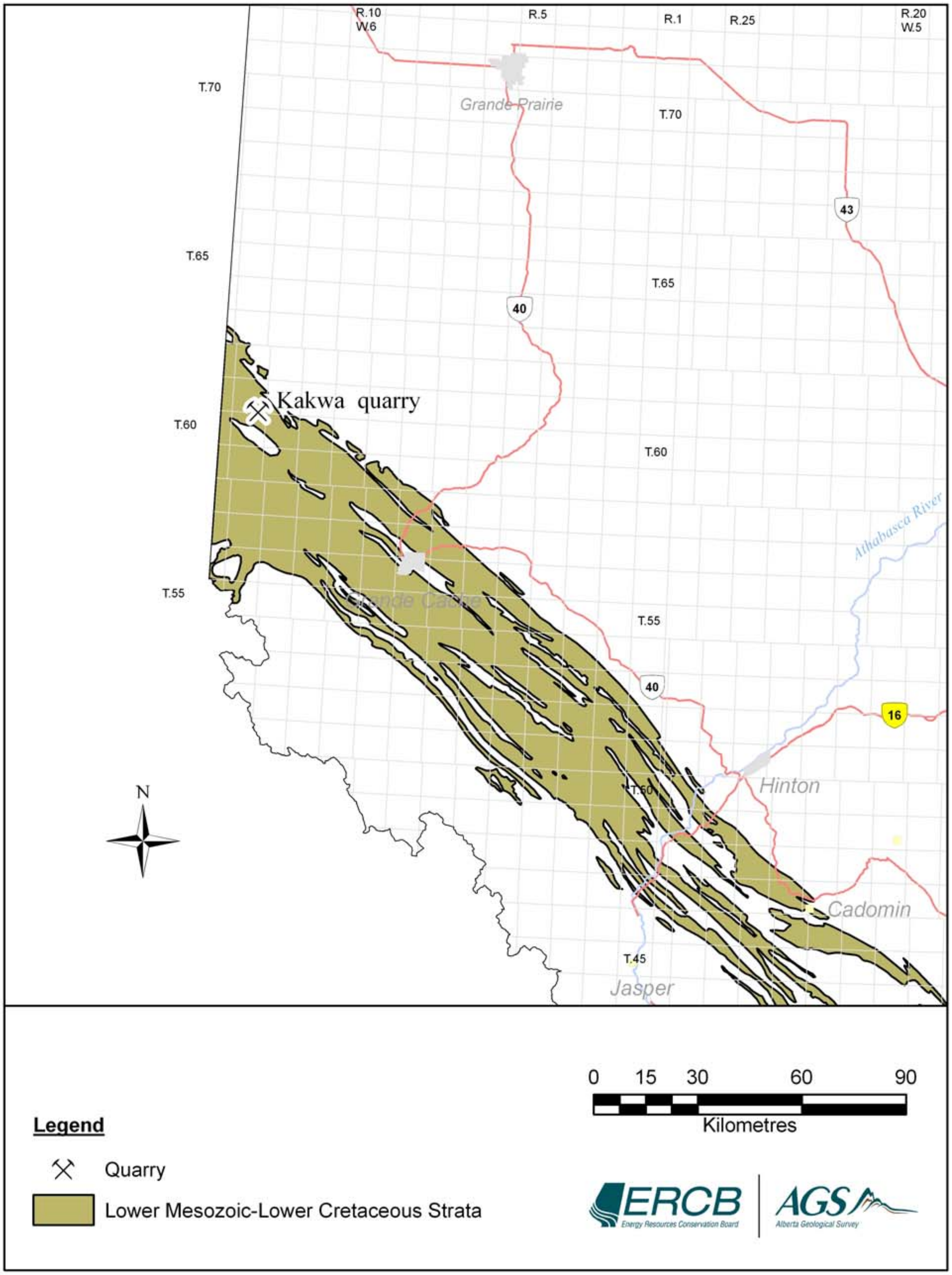

Figure 17. Location of the Kakwa quarry (Dunvegan Formation) in the Lower Mesozoic–Lower Cretaceous strata.

Figure 18. Geological section in the Kakwa quarry (looking north).

2.4 Gates Formation (Luscar Group) and Moose Mountain Member (Kootenay Group)

The Gates Formation and Moose Mountain Member can be seen in outcrops along the Rocky Mountain foothills in Alberta. Figure 19 is a subcrop map showing the areal extent of the Lower Mesozoic–Lower Cretaceous strata, including the Kootenay and Luscar groups.

The basal part of the Gates Formation, part of the Luscar Group, is characterized by well-sorted, fine-grained sandstone. The upper part of the formation consists of a cyclic succession of carbonaceous sandstone, mudstone, coal and some conglomerate (Glass, 1990).

The Moose Mountain Member, part of the Kootenay Group, contains silt and shale, as well as a medium grey–weathering, fine- to coarse-grained, quartz-chert sandstone (Glass, 1990).

The Gates Formation and the Moose Mountain Member are potentially productive for building stone. Coal-mining operations must move the overburden to get to the underlying coal. The overburden, sometimes called waste rock, can be sold as decorative stone. (see Horachek, 1996). Appendix 2, Table 8 gives the locations of the waste-rock mine sites.

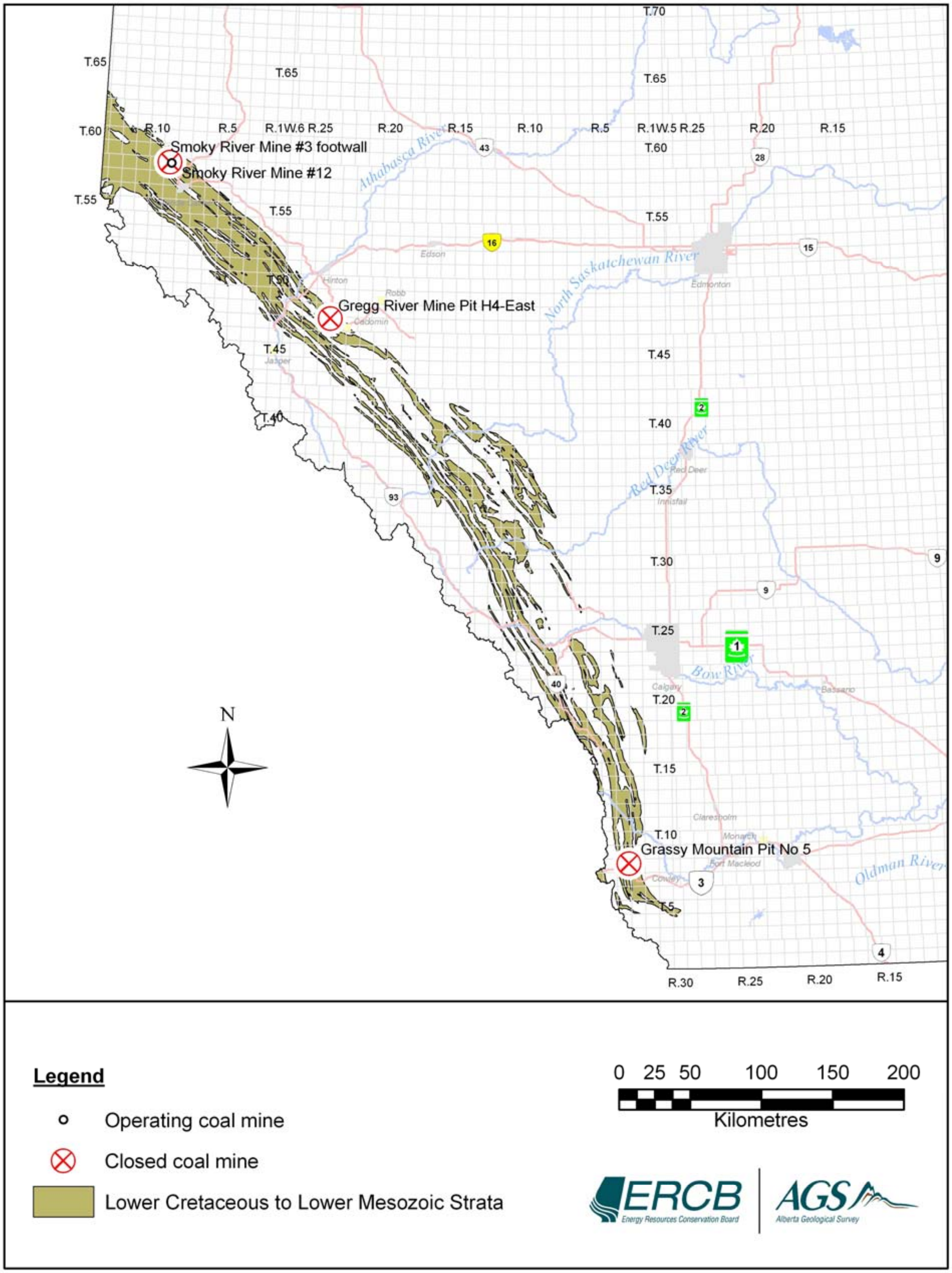

Figure 19. Locations of mined waste-rock pits (Gates Formation and Moose Mountain Member) in the Lower Mesozoic–Lower Cretaceous strata.

2.4.1 Rock Descriptions

'Greggstone' is a potentially productive building stone from the Gates Formation near Cadomin. According to Horachek (1996), Greggstone "is a hard, argillaceous, slightly calcareous, medium to coarse grained, quartz sandstone, with a moderate amount of carbon particles. It is grey when fresh and ochre-grey to greyish light brown when weathered; the overall colour of this rock is greyish light brown." (Figure 20). 'Smokystone' is also a potentially productive building stone from the Gates Formation near Grande Cache. It was described by Horachek (1996) as "a medium dark to dark grey, very fine-grained, non-calcareous, siliceous, flaggy sandstone. The top and bottom of the stone are greyish-black to black due to the presence of carbonaceous to coaly material on the bedding planes…joints have a cream-white yellow orange weathered dolomitic siderite" (Figure 21).

'Lillestone' is a potentially productive building stone from the Moose Mountain Member near Blairmore. Horachek (1996) described Lillestone as "a hard, medium to coarse-grained, siliceous sandstone. It consists mainly of quartz and chert. On a fresh surface it is light to medium grey. Some weathered surfaces are light grey to greyish-brown, some are orange brown to rusty brown and occasionally it is mottled grey and brown in colour" (Figure 22). Table 6 summarizes the characteristics of Greggstone, Smokystone and Lillestone.

2.4.2 Mining Techniques

Greggstone, Smokystone and Lillestone could be produced as waste rock from the associated coal-mining operations. Extraction of the stone would consist of sorting through the waste piles created by the coal mining. Sorting could be done by hand and the stone stacked on pallets for shipment. This type of stone extraction would simply require able-bodied personnel and a forklift to load the pallets.

2.4.3 Products, Market and Transportation

Waste rock has only limited use as a building stone due to the manual sorting and stacking used by the coal-mining companies, which results in broken rock of mixed sizes and quality. However, waste rock could be used in landscaping as flagstone, in construction for erosion control (such as retaining walls) or as fill for reclamation. Greggstone, Smokystone and Lillestone all have similar characteristics and are located in the Rocky Mountains, so the markets for the three stones could be similar. Transportation to local markets could be feasible due to the relatively short haul distance (approximately 50 km) between the mine site and nearby towns.

2.4.4 Future Potential

After coal mining is completed, the land must be returned to its original state, a process called reclamation. During reclamation, potentially productive waste rock could be used as fill, thereby reducing or eliminating the supply of waste rock for sale. An advantage of using waste rock as building stone is that it has already been extracted, so the need for heavy equipment is minimal.

Figure 20. 'Greggstone' from the Gregg River coal mine near Cadomin (Horachek, 1996).

Figure 21. 'Smokystone' from the Smoky River coal mine near Grande Cache (Horachek, 1996).

Figure 22. 'Lillestone' from the Grassy Mountain coal mine near Blairmore (Horachek, 1996).

Table 6. Characteristics of 'Greggstone' and 'Smokystone' from the Gates Formation, and 'Lillestone' from the Moose Mountain Member.

Quarry Name and Location	Total Mineable Thickness (m)	Overburden Thickness (m)	Sedimentary Structures	Fresh and Weathered Colours	Grain Size	Mineral Framework	Cement Content	Durability (Soft to Hard)
Gregg River mine, pit H4-East (outcrop), Cadomin	8	Nil	Some crossbedding	Grey; weathers greyish light brown	Medium to coarse	Chert and quartz	Silica and calcite	Hard
Smoky River mine #12 (outcrop), Grande Cache	1	Nil	Ripple marks and significant fracturing	Dark grey; weathers reddish grey	Fine	Quartz and chert	Silica	Hard
Grassy Mountain pit #5 (mine), Blairmore	1.5	Nil	n/a	Light to medium grey; weathers greyish brown and rusty brown	Medium to coarse	Quartz and chert	Silica	Hard

2.5 Spray River Group

The Spray River Group is Alberta's most productive building-stone formation. The Kamenka and Thunderstone quarries are the only known producing quarries in Alberta. They are close to one another, near the town of Canmore. The Spray River Group is divided into a lower Sulphur Mountain Formation and an upper Whitehorse Formation. The Sulphur Mountain Formation is a dark grey– to brown-weathering siltstone, silty dolostone and silty carbonaceous shale (Glass, 1990). Its depositional environment is considered to be open-shelf marine. Figure 23 is a subcrop map showing the areal extent of the Lower Mesozoic–Lower Cretaceous strata, including the Spray River Group. Appendix 2, Table 8 gives the locations of the Thunderstone and Kamenka quarries.

2.5.1 Rock Descriptions

The produced stone is called 'Rundle Rock' or 'Rundlestone,' named after Mount Rundle, which overlooks the town of Canmore. The quarries produce a very dark grey to black, fine-grained marine siltstone to sandstone. Rundlestone contains numerous laminations and beds ranging in thickness from 0.5 m to >1 m. Ripple marks, fossils (Figure 24) and fossil traces are common on many bedding surfaces. The rock has been subjected to deformational stresses, resulting in a regular joint pattern perpendicular to the bedding plane that results in square or rectangular breaking patterns with smooth surfaces. Table 7 summarizes the characteristics of Rundlestone from the Kamenka and Thunderstone quarries.

2.5.2 Mining Techniques

The Kamenka quarry uses an excavator for extraction and then hand-dressing to obtain the desired shape. The Thunderstone quarry uses blasting and excavators to extract the stone, which is then mechanically cut to the desired size using a guillotine (Figure 2). Figure 25 shows the Thunderstone quarry operation, including pallets of stone ready for shipping, the stone-cutting shop and some of the quarry benches.

2.5.3 Products, Market and Transportation

The Kamenka quarry has unique products, including specialty rocks such as fossil imprints and sedimentary structures that can be used for tables (see Figure 3), benches and mantles. They also produce flagstone and boulders.

The Thunderstone quarry has an assortment of products used mainly for landscaping or masonry: ledgestone (1–3 inch and 3–5 inch cut stone), flagstone (1 or 2 inch and 1 or 2 inch oversize) and crush (2 inch and smaller, boulders and steps).

Rundlestone is well known throughout Alberta in the landscaping market, with stone being sold in most cities at a variety of building stores. Rundlestone has also been shipped to most provinces in Canada, and to the western United States. The location of the quarries is excellent with respect to transportation of the products because both are on the Trans-Canada Highway less than an hour's drive from Calgary; a railway is also nearby.

2.5.4 Future Potential

The Spray River Group is already an established producer of building stone with an existing market. The current quarries both have significant reserves of Rundlestone at their current rate of production. Production of Rundlestone could easily be increased, but the limitations of a small market and proximity to an environmentally sensitive area could be detrimental factors in expanding the existing operations or opening a new quarry.

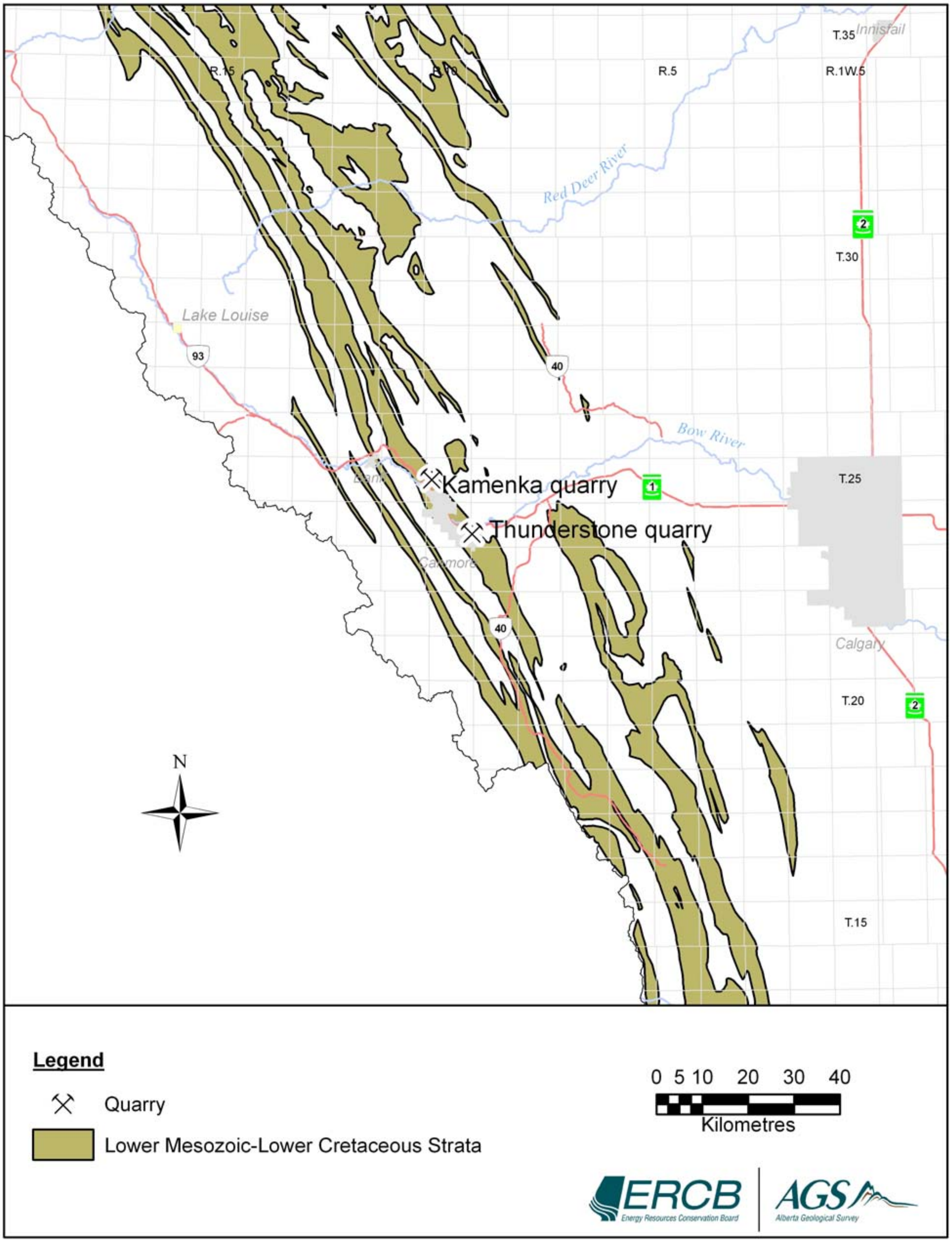

Figure 23. Location of the Thunderstone and Kamenka quarries (Spray River Formation) in the Lower Mesozoic–Lower Cretaceous strata, near Deadman Flats and Canmore, respectively.

Figure 24. Ammonite cast (left) and mould (right) in 'Rundlestone,' Kamenka quarry.

Table 7. Characteristics of 'Rundlestone' from the Spray River Group.

Quarry Name and Location	Total Mineable Thickness (m)	Overburden Thickness (m)	Sedimentary Structures	Fresh and Weathered Colours	Grain Size	Mineral Framework	Cement Content	Durability (Soft to Hard)
Kamenka quarry, Canmore	30–100	Minimal	Folding, ripple marks, laminations, fossils	Dark grey	Fine	Quartz	Calcite and clay	Hard
Thunderstone quarry, Deadman Flats	30–100	Minimal	Folding, ripple marks, laminations, fossils	Dark grey	Fine	Quartz	Calcite and clay	Hard

Figure 25. Thunderstone quarry operations, near Deadman Flats.

2.6 Chipewyan Granite

Granite is an igneous rock that formed from cooling of magma deep in the Earth's crust. In the northeastern part of Alberta lies a portion of the Canadian Shield. The granites bodies of the Canadian Shield were formed by the collision of continental plates. During this process, the continents were pushed together, creating fiction that caused the rocks at surface to form mountains and at depth to melt into magma. The magma formed granitic intrusions, which possibly created volcanoes at the surface. Over time, these mountains and volcanoes eroded to their roots. Gneiss is a coarse-grained metamorphic rock formed from pressure and temperature. The portion of the Canadian Shield within Alberta is composed of granite and gneiss, and is exposed either at surface or covered with a very thin layer of soil. This exposure of bedrock makes quarrying significantly easier than in other parts of the province, where the bedrock can be overlain by tens of metres of overburden.

There have been many studies on the suitability for building stone of granites in the Fort Chipewyan area; the Alberta Research Council conducted most of them (Godfrey, 1972, 1976, 1984, 1986; Scafe, 1994). The majority of this section is a summary of these studies. The location of the Devil's Gate sluice site in the Chipewyan granite has been interpreted from the paper maps of Godfrey (1972) and is therefore a general location (Figure 26). See Appendix 2, Table 8 for the co-ordinates.

2.6.1 Rock Descriptions

According to Scafe (1994), the Chipewyan red granite "is of medium grained texture, is locally fine grained and massive to faintly lineated. Mineralogically, the granite is composed of 34% mostly pink to red potash feldspar, 31% quartz, 29% plagioclase, 2.7% biotite, 0.9% chlorite with other minor minerals forming the remainder (Godfrey, 1976)." At test sites investigated by Scafe (1994), "two major subvertical joint sets and a series of subhorizontal fractures, together with random joints and minor shear zones, dissect the rock mass…." Documentation suggests that Scafe was referring to the Devils Gate sluice outcrop-drillhole site.

Godfrey (1972) mentioned a white granite of medium- to coarse-grained texture, white to grey to colourless grey-blue in colour and composed of white feldspar, grey quartz and mafic minerals. He evaluated hand-sized samples for colour and textural characteristics to see if the rock met commercial stone standards at the time. National Marble and Tile Ltd. deemed the white granite unsuitable as ornamental stone because it requires a high polish.

2.6.2 Mining Techniques

Attempts have been made to quarry the granites of the Fort Chipewyan area, but there has been no commercial stone production to date. Work to assess their potential for quarrying has included helicopter reconnaissance geological mapping, ground checking and hand sampling (Godfrey, 1972). To delineate the extent of granite where the site was desirable, the outcrop was cleaned by hydraulic sluicing, and numerous hand samples and large blocks were collected for cutting and polish testing. In 1975, six holes were drilled to a depth of 7.6 m (25 feet) on sluice site 1 to obtain continuous core. Core sampling evaluated the fracture quality as well as the texture, colour and structural-mineralogical characteristics of the granite. Godfrey concluded that an area of only 12 m by 30 m was suitable for dimension stone. Since this would not provide the necessary quantity of dimension stone, he explored other sites to find a larger deposit of suitable granite.

Godfrey (1976) obtained favourable results at a second sluice site that was further delineated for building-stone potential in 1988 when a company attempted to quarry the stone. Two holes drilled to a depth of 18.3 m (60 feet) showed that fracturing did not decrease in depth. Due to the extensive fracturing of the stone, obtaining blocks of industry-standard size was unlikely, and the company discontinued the investigation.

2.6.3 Products, Market and Transportation

The Devil's Gate sluice site in the Chipewyan granite was investigated for its dimension-stone potential, but suitable material could not be found. However, there still may be potential for other granite products. Small blocks could be used for tile, pavers, curbing, rough wall-facing blocks or slabs, and small burial headstones. The crushed material could be used to make agglomerated granite tile, landscape rock, bridge-deck topping, poultry grit, exposed aggregate panels, roofing granules, railroad ballast and road stone.

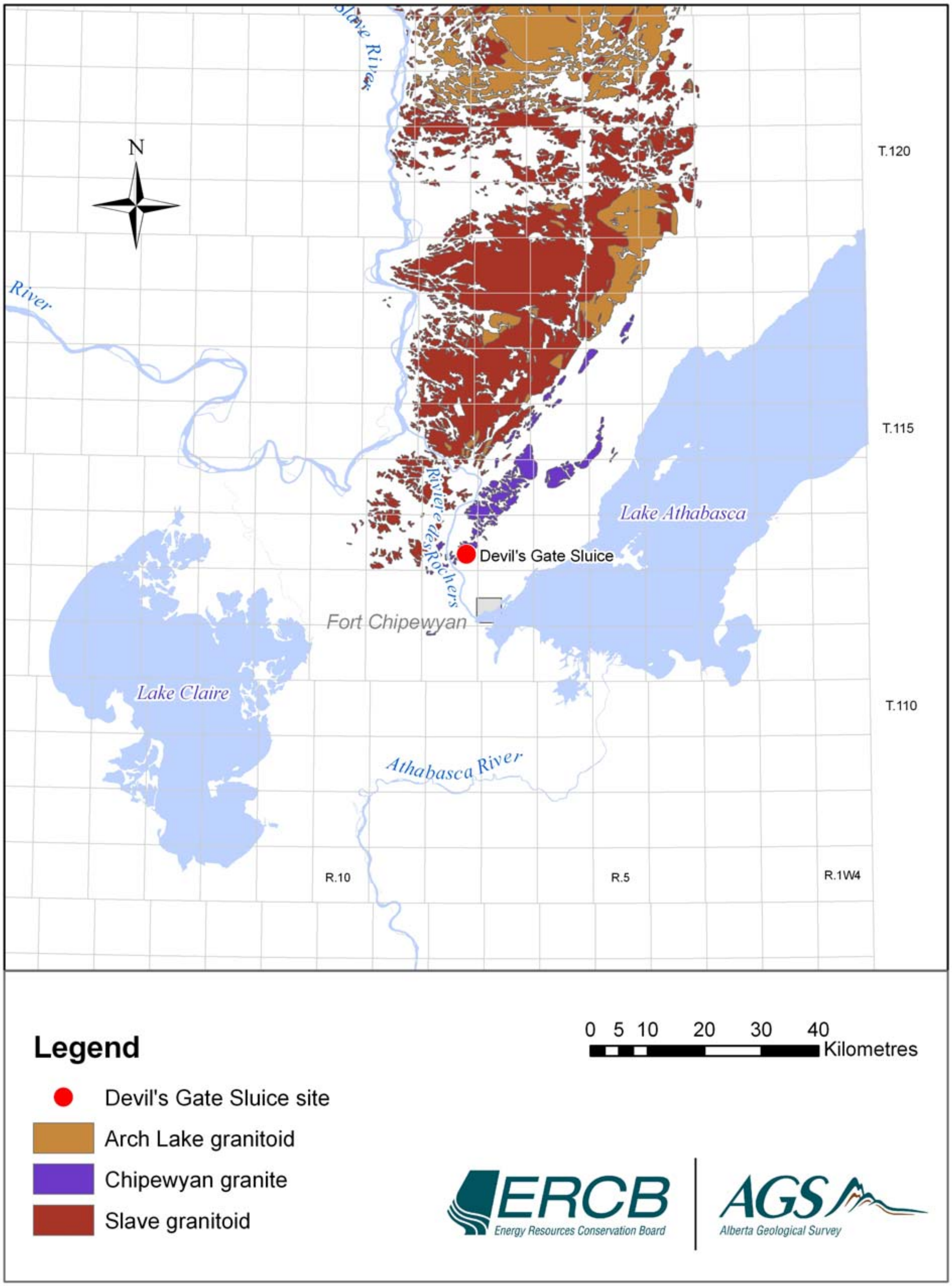

Figure 26. Location of Devil's Gate sluice site in the Chipewyan granite.

Due to the remoteness of the potential quarry site, transportation is a significant factor when evaluating the economic benefits of a profitable stone quarry. According to Scafe (1994), sluice site 2 is 17.5 km northwest of Fort Chipewyan, 3.5 km from a barge route and 9.6 km from the public airport. Fort Chipewyan, with a population of 915, is the closest settlement. Access to the area is by winter roads, by boat via Fort McMurray and by air via Fort McMurray or Edmonton. Weather is a consideration for quarry operations in the remote northeastern part of Alberta, with stone extraction and transport via barge to southern commercial destinations most likely occurring during the summer months. Refer to Scafe (1994) for an economic feasibility study on the Chipewyan red granite.

2.6.4 Future Potential

Geological mapping of the Fort Chipewyan area has generated interest in the red granite, and other igneous rocks on the Shield that could be productive for building stone. This area is attractive because of the shallow overburden, the unique colours and the potential for large reserves. The remote location is a significant deterrent because markets are hundreds of kilometres away and transportation costs would therefore be high.

2.7 Other Geological Formations with Building-Stone Potential

Other geological formations in Alberta have the potential to produce building stone. Prospectors have explored some of them, whereas others have produced stone for local construction projects. These formations are worthy of mention because they have the potential to be productive as decorative or building stone.

Travertine is a sedimentary rock that forms when calcium carbonate is deposited from the water of mineral springs. It is used as building material, usually in the form of tiles for wall cladding and flooring. Exploration work on travertine during the 1930s and 1940s was mentioned in newspaper articles, university letters and an Alberta Geological Survey internal report. The report mentioned an outcrop on freehold land (minerals not owned by the province) west of the hamlet of Radnor and a few miles northwest of Ghost Lake, in Twp. 26, Rge., 5, W 5th Mer. E.J. Crouch discovered and quarried the outcrop in the 1920s. An article in the newspaper *The Albertan*, dated December 2, 1939, mentioned that “Alberta golden travertine marble” was used for the base and capping of the wainscoted walls in a civic utilities building in Calgary. It was also used as flooring in the T. Eaton Co. store in Edmonton. Typical travertine from a deposit in Tivoli, Italy is slightly browner in colour and deeper in tone. The quality and richness of colour and its ability to take a high polish make the Alberta travertine an equal of the typical Italian stone. It is not known why the quarry did not continue production.

The Crowsnest Formation was formed by volcanic activity. The lower member is recessive and consists of thinly to thickly bedded airfall pyroclastic flow, surge and lahar deposits. The upper member is a resistant ridge-former dominated by coarse-grained pyroclastic breccia. The upper unit has the most potential for decorative stone because it is thicker, better consolidated and less fractured. It is crystal rich and ranges in colour from pink and green to purple (Figure 27). Mineral assessment work has been carried out on the “Crowsnest volcanics” for decorative stone and rip-rap (Bryant, 2006). The Crowsnest Formation could have potential for this type of stone, as it is the only known volcanic rock that can produce the colour variations and stone quantities to make such an operation feasible.

The Lower Cambrian St. Piran Formation is a very hard quartzite that ranges in colour from white to blotched pink to uniform pink to pink and white banded. This formation was quarried at the southwest corner of Lake Louise, where it is exposed in vertical cliffs. The beds at this location vary in thickness from 0.1 to 0.6 m (a few inches to 2 feet or more). According to Parks (1916, p. 264–265), “It has been quarried, largely from the talus, and used in the construction of the chalet on Lake Louise. The stone is much too hard to be chiselled but it makes attractive and unique rock face work.” Large quantities of stone are available at this location, although quarrying into the side of a mountain would prove an engineering challenge and obtaining mining rights in Banff National Park would be very difficult.

Figure 27. Outcrop of Crowsnest volcanics.

The Gladstone Formation in the Blairmore Group is a medium- to fine-grained sandstone with a light grey to greenish grey colour. It was used as building stone in the construction of the powerhouse and the mine manager's residence at the Leitch Collieries (Provincial Historic Site) in the Crowsnest Pass (Figure 28). Since the stone has had some historical use as building material, the Gladstone Formation could have potential for future production.

Limestone is produced from a number of quarries along the foothills. These quarries are extracting limestone for lime, cement and agricultural products. Some of the quarries also market small quantities of crushed stone for decorative purposes and large blocks for erosion control. Limestone is quarried from, but is not limited to, the Mount Head, Pekisko and Palliser formations.

Figure 28. Leitch Collieries stone quarry, Crowsnest Pass (looking north).

3 Production and Surface Land Access

3.1 Building-Stone Production

Natural Resources Canada has been capturing mineral statistics on Alberta's stone industry since 1909. These statistics are based on data provided voluntarily by companies, which can lead to some inconsistencies. Alberta's stone production within the last 10 years has been fairly consistent (Figure 29), considering that the stone industry is limited to a few producing quarries. Most stone production in Alberta is for local consumption, although some is shipped to neighbouring provinces and states.

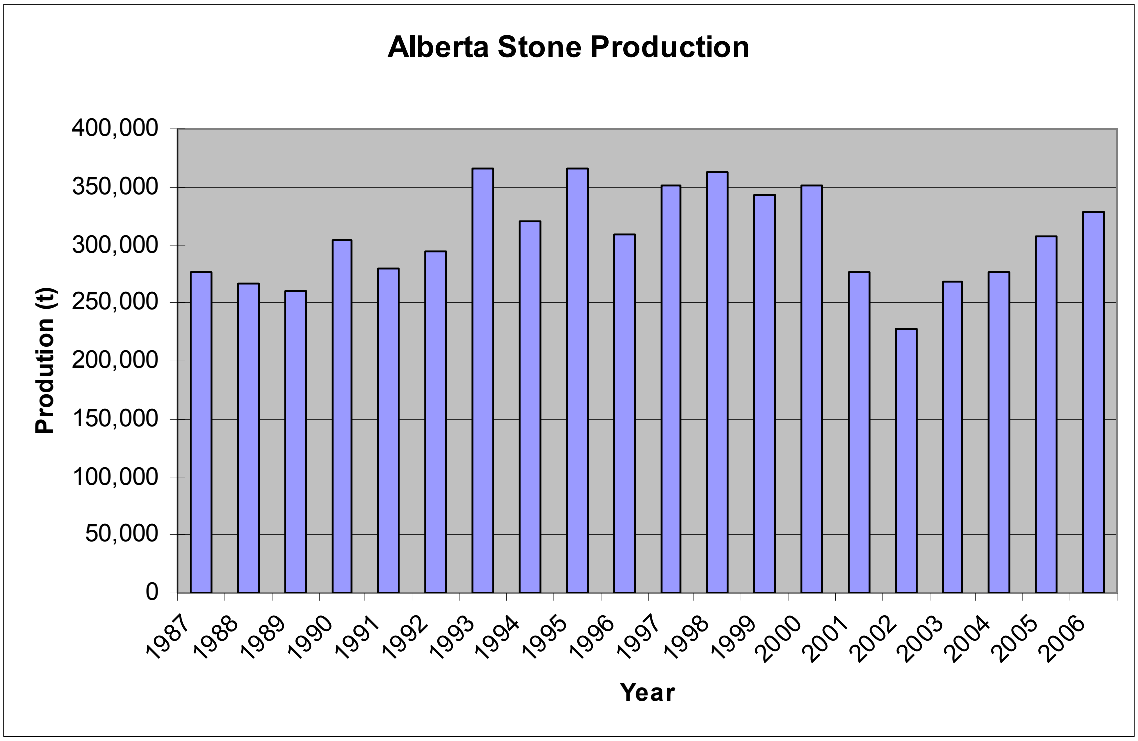

Figure 29. Alberta stone production (data provided by Natural Resources Canada).

3.2 Surface-Land-Access and Lease Information

Significant parts of Alberta have geological potential for building stone, but there are areas where development could be very difficult due to surface-land-access reservation. These reservations have several purposes: some are intended to keep the land in its natural state, whereas others set aside land for historical reasons. Regardless of the reservation, there is a process of application to the Alberta and/or federal government that companies must follow if they wish to develop resources in certain areas.

Figure 30 shows the areas within Alberta that have surface-land-access reservations. Special reservation areas are lands for which the Crown has specific resource-development policies (e.g., Integrated Resource Plan Land Use and Eastern Slopes Policy). Historical areas are lands that have historical significance (e.g., world heritage sites, archeological sites). Ecological areas are lands that are ecologically sensitive (e.g., provincial parks, sensitive habitat areas, Wetlands For Tomorrow Project). Federal areas are lands over which the federal government has jurisdiction, in this case the Canadian Forces bases and national parks. Infrastructure areas are lands set aside for resource use (e.g., oil sands surface mineable areas, proposed dam reservoirs, power development). Métis areas are lands that have Métis settlements. These surface-land-access restrictions do not preclude exploration for building stone. They simply mean that

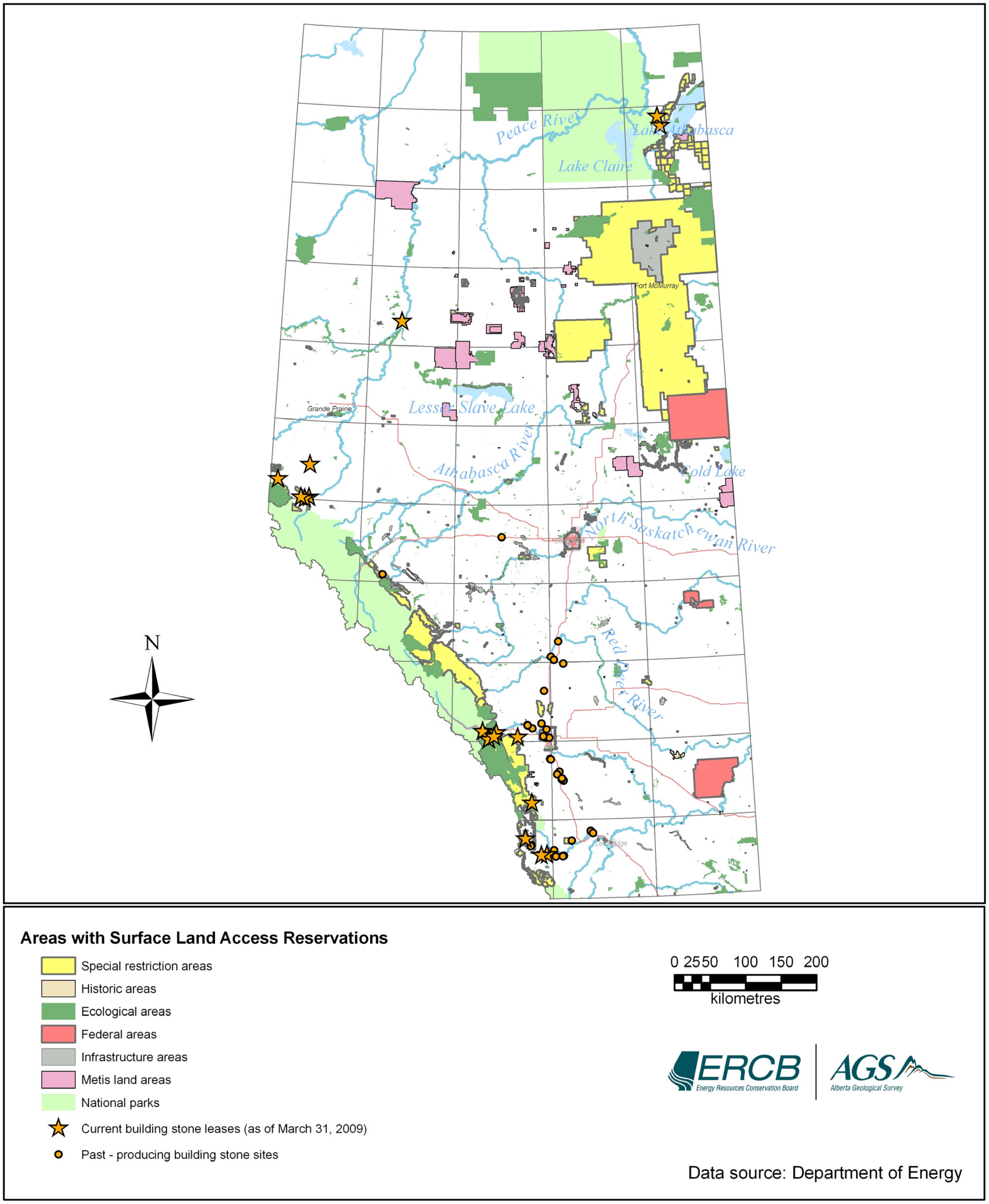

Figure 30. Areas with building-stone leases and surface-land-access reservations.

companies must exercise great care in these areas. The building-stone leases (current to March 31, 2009), shown on Figure 30 with orange stars, make up a very small geographic area of the province. The leases are typically within the foothills or front ranges of the Rocky Mountains, with the exception of the Lake Athabasca area in the north. For more information on building-stone development, contact the Alberta Department of Energy, which regulates mineral development in the province, at http://www.energy.gov.ab.ca/minerals/547.asp.

4 Conclusion

Building stone in Alberta comes from many different geological formations that yield a variety of stones for various purposes. Several geological formations have successfully produced building stone. The key element in producing building stone is that it must meet certain standards in terms of strength, durability, workability, abundance, appearance, abrasion resistance and weathering.

Current building-stone quarries are operated by entrepreneurs who are very passionate about working with stone. Employing a handful of people with one or two pieces of heavy machinery is the norm for most quarries in Alberta. Building-stone markets in Alberta are primarily for local landscaping suppliers, where consumers can buy the stone for buildings, rough construction, paving, monuments, artistry or erosion control. Transporting the stone to market is one of the most costly parts of the operation due to the distance of the quarries from urban centres.

The potential to grow the building-stone industry in Alberta is enormous. Most building-stone quarries occur where the stone outcrops in a valley, on a knoll or escarpment, or anywhere that there is minimal overburden. Alberta has vast areas of exposed rocks where numerous geological formations are present, many of which can produce building stone.

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Appendix 1 – Rock Formations in Alberta (Figure 4)

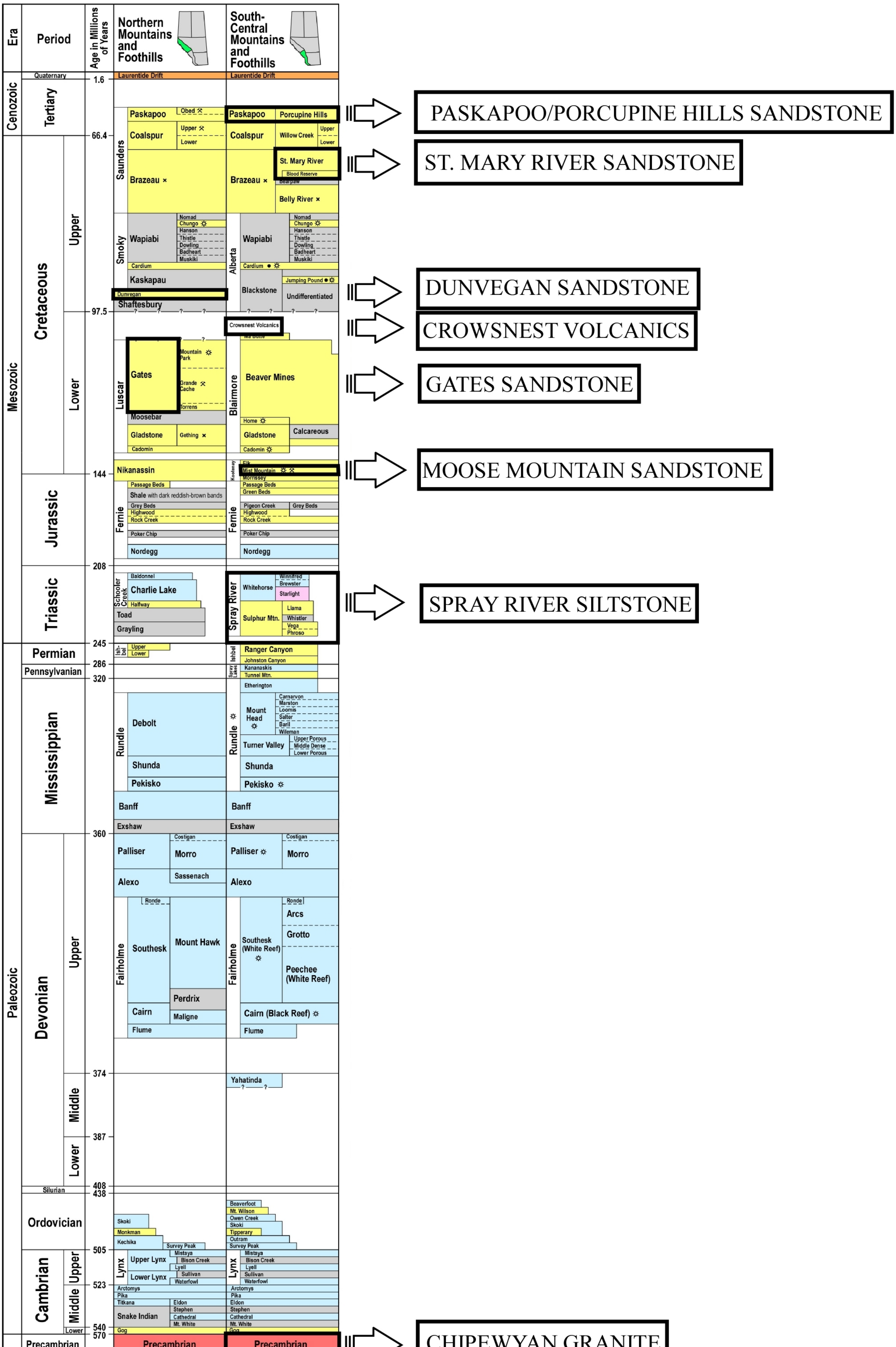

Figure 31. Rock formations in Alberta, highlighting those with building-stone potential (Alberta Energy and Utilities Board, 2002).

Appendix 2 — Alberta Building-Stone Quarry and/or Outcrop Locations (Table 8); Physical Characteristics of Paskapoo Sandstone (Table 9); and Alberta Building Stones Sorted by City, Building and Quarry (Table 10)

Table 8. Alberta building-stone quarry and/or outcrop locations.

Formation	Location Name	NAD83		How Obtained
		Latitude	Longitude	
Paskapoo	Porcupine Hills	49.734861	–113.62527	GPS reading at site
Paskapoo	Crowsnest Stone Co. Ltd.	49.536674	–113.801399	GPS reading at site
Paskapoo	Brocket	49.4856	–113.9364	GPS reading close to site
Paskapoo	Wm. Brazier	50.579336	–113.89267	Parks (1916)
Paskapoo	R. Brothers	50.506362	–113.79238	Parks (1916)
Paskapoo	Canada Cement Co.	50.773802	–114.02679	Parks (1916)
Paskapoo	Sandstone Brick and Sewer Pipe Co.	50.7661	–114.0269	Parks (1916)
Paskapoo	Burnvale Brick Co.	50.768377	–114.01224	Parks (1916)
Paskapoo	Wm. Oliver and Co.	51.043284	–114.10823	Parks (1916)
Paskapoo	Elbow River	51.043399	–114.039216	Parks (1916)
Paskapoo	Bone and Leblanc	51.060992	–114.159998	Parks (1916)
Paskapoo	J.A. Lewis	51.149281	–114.092306	Parks (1916)
Paskapoo	James Hay	51.224955	–114.18974	Parks (1916)
Paskapoo	C. de Lavergne	51.163262	–114.37573	Parks (1916)
Paskapoo	Shelly Quarry Co.	51.204961	–114.47736	Parks (1916)
Paskapoo	Peter P. Dick	51.640255	–114.13347	Parks (1916)
Paskapoo	Christopher Lorine	51.6419	–114.1314	Parks (1916)
Paskapoo	Wm. Gunston	52.032598	–113.92291	Parks (1916)
Paskapoo	Frank F. Malcolm	52.069437	–113.98239	Parks (1916)
Paskapoo	Red Deer River	51.369759	–113.802494	Parks (1916)
Paskapoo	John T. Moore estate	52.264975	–113.82783	Parks (1916)
Paskapoo	Pembina Quarries Ltd.	53.590563	–114.9983	Parks (1916)
Porcupine Hills	Cowley – Lewis quarry	49.59704	–115.975115	GPS reading at site
St. Mary River	Macleod Quarrying and Contracting Co.	49.823222	–113.208074	GPS reading at site
St. Mary River	Mrs. Arnold	49.852481	–113.251343	GPS reading at site
St. Mary River	Duncan Maclean	49.849867	–113.24369	Parks (1916)
St. Mary River	Cowley – Windmill quarry	49.572202	–114.110638	GPS reading at site
Dunvegan	Kakwa quarry	54.242897	–119.834477	GPS reading at site
Dunvegan	Dunvegan outcrop	54.320773	–119.831649	GPS reading at site
Gates	Smoky River mine #3 footwall (mined-out pit)	54.035721	–119.276607	Horachek (1996)
Gates	Smoky River mine #12 (outcrop)	54.028496	–119.258024	Horachek (1996)
Gates	Gregg River mine, pit H4-East (outcrop)	53.094193	–117.505631	Horachek (1996)
Moose Mountain	Grassy Mountain pit #5 (mine)	49.669726	–114.424804	Horachek (1996)
Spray River	Kamenka quarry	51.142567	–115.380445	GPS reading at site
Spray River	Thunderstone	51.035897	–115.25316	GPS reading at site
Fort Chipewyan granite	Devil's Gate sluice (outcrop/drillhole)	58.80179	–111.22196	Godfrey (1971), (1972), (1976), (1980), Godfrey and Langenberg (1978)

Table 9. Physical characteristics of Paskapoo Formation sandstone (Parks, 1916).

Characteristic	1	2	3	4	5
Specific gravity	2.678	2.665	2.672	2.677	2.679
Weight per cubic foot (lbs.)	131.48	134.19	136.24	144.66	137.54
Pore space (%)	21.72	19.34	18.26	12.83	17.66
Coefficient of saturation	0.69	0.68	0.72	0.76	0.72
Dry crushing strength (lbs/sq. in.)	5,985	7,631	9,617	11,119	8,306
Wet crushing strength (lbs/ sq. in.)	3,874	5,640	7,007	7,224	5,613
Frozen crushing strength (lbs/sq. in.)	2,782	3,896	4,212	6,524	4,065
Transverse strength (lbs/sq. in.)	398	554	658	582	521
Shearing strength (lbs/sq. in.)	431	497	642	586	531
Loss on corrosion (grams/sq. in.)	0.06746	0.04301	0.05031	0.04194	0.04558
Drilling factor (mm)	25.2	21.0	26.6	17.8	22.7
Chiselling factor (grams)	9.44	6.87	14.66	4.72	11.16

Stone types:
1. Yellow Calgary stone (Wm. Oliver and Co. and J.A. Lewis, Calgary)
2. Grey-yellow Glenbow stone, Alberta Provincial Legislature building (C. de Lavergne, Calgary)
3. Grey-yellow Cochrane stone (Shelly Quarry Co., Calgary)
4. Grey Macleod-Brocket stone (Porcupine Hills and Crowsnest Stone Co. Ltd., Fort Macleod)
5. Average of the above six commercial stones

Table 10. Alberta building stones sorted by city, building and quarry.

City	Building	Address	Quarry	Stone	Formation
Banff	Banff Springs Hotel	405 Spray Avenue	Kamenka and Thunderstone	Siltstone	Spray River
Banff	Historical Banff National Park swimming pool	P.O. Box 900, T1L 1K2	Kamenka and Thunderstone	Siltstone	Spray River
Bassano	Post office		Wm. Oliver and Co.	Sandstone	Paskapoo
Calgary	Alberta hotel	804 – 1st Street SW	Bone and Leblanc	Sandstone	Paskapoo
Calgary	Balmoral school (all except the base)	220 – 16th Avenue NW	Bone and Leblanc	Sandstone	Paskapoo
Calgary	Bank of British North America building	Assimilated into Bank of Montreal	N/A	Sandstone	Paskapoo
Calgary	Bank of Commerce building		N/A	Sandstone	Paskapoo
Calgary	Calgary Grain Exchange	815 – 1st Street SW	N/A	Sandstone	Paskapoo
Calgary	Canadian Pacific Railway station		Shelley Quarry Co.	Sandstone	Paskapoo
Calgary	Carnegie Public Library	223 – 12th Avenue SW	Wm. Oliver and Co.	Sandstone	Paskapoo
Calgary	Cathedral of the Redeemer	218 – 7th Avenue SE	N/A	Sandstone	Paskapoo
Calgary	Central Methodist church	1st Street SW and 7th Avenue	Bone and Leblanc	Sandstone	Paskapoo
Calgary	City hall	800 Macleod Trail SE	Wm Oliver and Co. and partly Lewis	Sandstone	Paskapoo
Calgary	Department of Natural Resources of the Canadian Pacific Railway Company		Macleod Quarrying and Contracting Co.	Sandstone	St. Mary River
Calgary	Dominion Trust Company building	200 – 8th Avenue SE	N/A	Sandstone	Paskapoo
Calgary	Fire hall	18th Avenue and 2nd Street	Bone and Leblanc	Sandstone	Paskapoo
Calgary	Imperial Bank building	100 – 8th Avenue SE	Lewis	Sandstone	Paskapoo
Calgary	Knox church	506 – 4th street SW	Bone and Leblanc	Sandstone	Paskapoo
Calgary	Land Titles building		Wm. Oliver and Co.	Sandstone	Paskapoo
Calgary	McDougall block.	455 – 6th Street SW	N/A	Sandstone	Paskapoo
Calgary	School		N/A	Sandstone	Paskapoo
Calgary	Numerous churches, schools and business blocks		N/A	Sandstone	Paskapoo
Calgary	Riverside school	107 – 6A Street NE	Bone and Leblanc	Sandstone	Paskapoo
Calgary	Royal Bank building		Elbow River	Sandstone	Paskapoo
Calgary	Victoria school (addition)		Bone and Leblanc	Sandstone	Paskapoo
Calgary	Young Men's Christian Association building		N/A	Sandstone	Paskapoo
Claresholm	Canadian Pacific Railway station		Macleod Quarrying and Contracting Co.	Sandstone	St. Mary River
Didsbury	Grist mill and building foundations in Didsbury		Peter P. Dick	Sandstone	Paskapoo
Edmonton	Assiniboia Hall, University of Alberta	114th Street and 89th Avenue	Macleod Quarrying and Contracting Co.	Sandstone	St. Mary River
Edmonton	Athabasca Hall, University of Alberta (trimmings)	114th Street and 89th Avenue	Glenbow	Sandstone	Paskapoo
Edmonton	Bank of Commerce (base)	10102 Jasper Avenue	N/A	Sandstone	Paskapoo
Edmonton	Bank of Montreal		N/A	Sandstone	Paskapoo
Edmonton	Bank of Nova Scotia (base)		N/A	Sandstone	Paskapoo
Edmonton	Courthouse	Demolished 1972	Calgary Quarries	Sandstone	Paskapoo
Edmonton	Government House (cut stone is partially Ohio sandstone)	12845 – 102nd Avenue	N/A	Sandstone	Paskapoo
Edmonton	Imperial Bank (base of Tyndall stone)	9990 Jasper Avenue	N/A	Sandstone	Paskapoo
Edmonton	Merchants Bank		N/A	Sandstone	Paskapoo
Edmonton	Alberta Provincial Legislature building (some Ohio sandstone and some Indiana limestone)	10801 – 97th Avenue	Glenbow	Sandstone	Paskapoo
Fort Macleod	Hudson’s Bay Company building (mullions)		Duncan Maclean	Sandstone	St. Mary River
Fort Macleod	Hudson’s Bay Company building		Pincher	Sandstone	Paskapoo
Fort Macleod	Macdonell's block		Duncan Maclean	Sandstone	St. Mary River
Fort Macleod	Numerous business blocks: Leather, Anderton, Struthers and Bryan blocks		Macleod Quarrying and Contracting Co.	Sandstone	St. Mary River
Fort Macleod	Pioneer furniture store		Porcupine Hills	Sandstone	Paskapoo
Fort Macleod	Power house		Duncan Maclean	Sandstone	St. Mary River
Fort Macleod	Queen's Hotel	207 Colonel Macleod Blvd.	Porcupine Hills	Sandstone	Paskapoo
Fort Macleod	Reach block		Pincher	Sandstone	Paskapoo
High River	High River Trading Co.		R. Brothers	Sandstone	Paskapoo
High River	Public school		Macleod Quarrying and Contracting Co.	Sandstone	St. Mary River
High River	Union Bank		Wm. Brazier	Sandstone	Paskapoo
Innisfail	Bank of Commerce		Frank F. Malcolm	Sandstone	Paskapoo
Innisfail	Basement of the school in Innisfail		Wm. Gunston western quarry	Sandstone	Paskapoo
Innisfail	Mr. Gunston's barn		Wm. Gunston eastern quarry	Sandstone	Paskapoo
Innisfail	Simpson block		Wm. Gunston western quarry	Sandstone	Paskapoo

City	Building	Address	Quarry	Stone	Formation
Lacombe	Royal Bank		Crowsnest Stone Co. Ltd. quarry	Sandstone	Paskapoo
Lake Louise	Chalet	111 Lake Louise Drive	N/A	Quartzite	St. Piran
Lethbridge	Bank of Montreal		Macleod Quarrying and Contracting Co.	Sandstone	St. Mary River
Lethbridge	Brewery	Demolished 1991	Macleod Quarrying and Contracting Co.	Sandstone	St. Mary River
Lethbridge	Courthouse	320 – 4th Street South	Macleod Quarrying and Contracting Co.	Sandstone	St. Mary River
Lethbridge	Wesley Methodist church	1011 – 4th Street South	Macleod Quarrying and Contracting Co.	Sandstone	St. Mary River
Medicine Hat	Post office		Wm. Oliver and Co.	Sandstone	Paskapoo
Medicine Hat	Royal Bank		Crowsnest Stone Co. Ltd. quarry	Sandstone	Paskapoo
Okotoks	School		Canada Cement Co.	Sandstone	Paskapoo
Red Deer	Arlington Hotel	405 – 51st Street	Red Deer area	Sandstone	Paskapoo
Red Deer	Green's block		John T. Moore estate	Sandstone	Paskapoo

Appendix 3 — Additional Building-Stone References

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