Feldspathic Sandstone Flagstone from Near Hudson Hope, Northern British Columbia - Potential for Sandstone Production in British Columbia

By Z.D. Hora

INTRODUCTION

Throughout the fall of 2001 and following winter months I had the opportunity to study the sandstone quarry site located about 15 kilometres southwest of Hudson Hope in northeastern British Columbia.

This report summarizes my observations and conclusions on the potential for producing flagstone and sandstone dimension stone in the province of British Columbia.

DIMENSION STONE AND FLAGSTONE

Dimension stone is natural stone which has been selected and fabricated to specific sizes or shapes. In British Columbia it means a rock or stone product that is cut or split on 2 or more sides and includes, without limitations, tiles, facing stone, monument and ornamental stone, but does not include stone in structural applications.

Flagstone is a type of dimension stone usually of sedimentary origin (but may also be metamorphic), which splits into thin slabs from 1 to 5 cm (0.4 to 2 inches) in thickness.

There are a number of well-established flagstone and dimension stone producers supplying the existing market in Western Canada and adjacent US states. Such products are distributed in pallets of approximately 1 cubic metre (around 2 metric tonnes) (Photos 1, 2), sorted by thickness and degree of processing, such as with or without sharp edges, random or square shapes, etc. The BC and Alberta products are complemented by imported stone types not available from local producers.

Photo 1. Typical pallets of split stone – lithified volcanic ash from the Okanagan area. Kettle Valley Stone Ltd product.

Photo 2. Typical pallets of split stone – granite from Beaverdell Quadra Stone Company Ltd product.

The basic requirements for any building stone are durability, soundness, uniformity and chemical stability. Dimension stone should also be attractive and easy to process and shaped according to specifications, without producing uneconomic quantities of waste.

Chemical stability means that the stone should not react with mortars or cement. When exposed to weather, it should not produce unsightly stains (rust for example), nor be susceptible to crystallization of soluble salts. A recently published article on the restoration of the Parliament Buildings in Ottawa describes how, for example, the Ohio sandstone, which had been used , exhibits salt crystallization damage resulting in fracturing, surface erosion and overall crumbling (exfoliation).

The decision to use a particular stone may be dictated by price, but very often is based on personal taste. Even construction fashion of the time may play an important role.

SANDSTONE AND ITS USE IN BRITISH COLUMBIA

Sandstone was the first building stone used commercially in this province and its use dates to about 1870; varieties of blue, brown and yellow types were quarried from

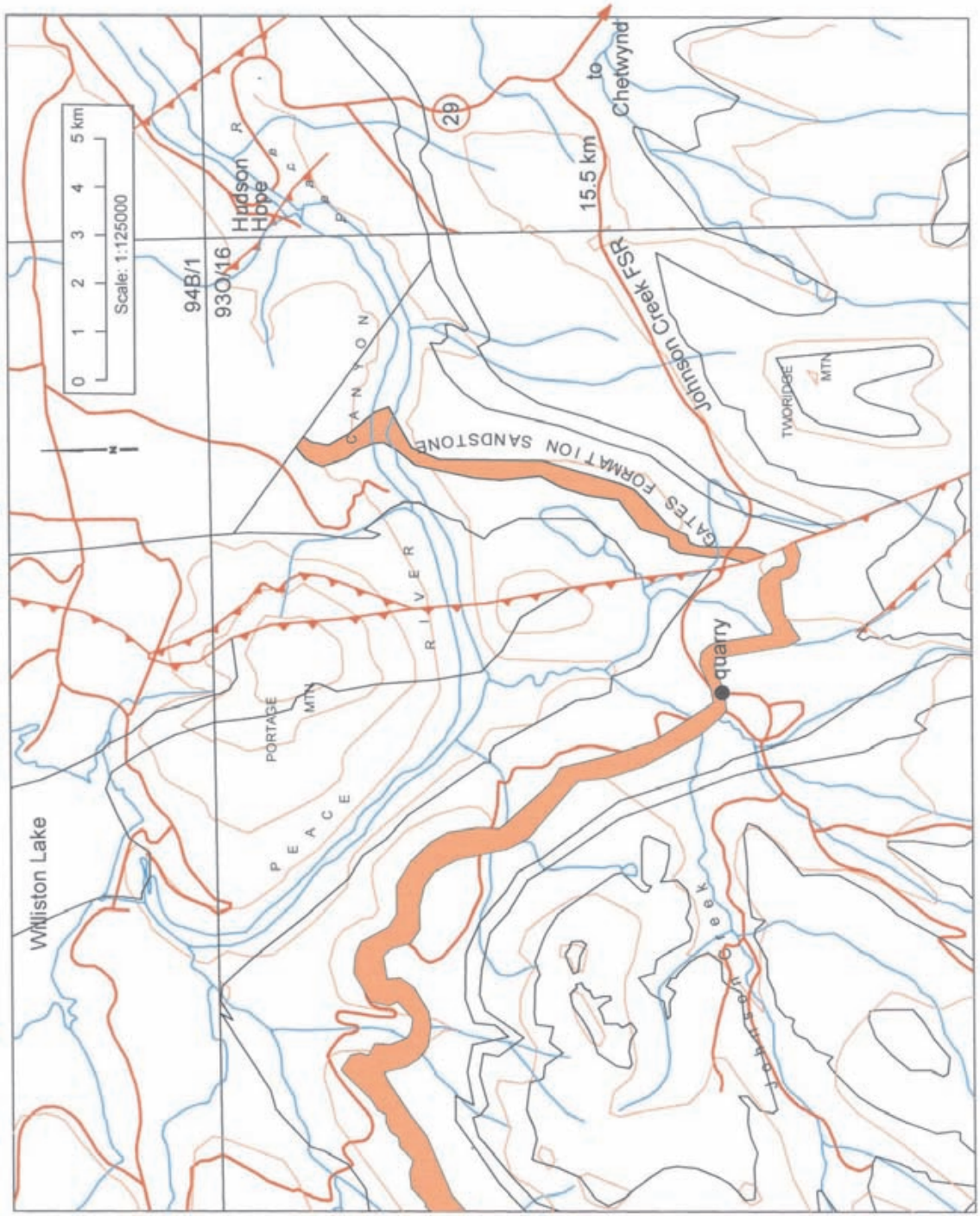

Figure 1. Gates sandstone and Johnson Creek quarry location.

sites on Vancouver Island and most of the Gulf Islands. The quarry locations, quality and performance records of these sandstones are well documented. Many of the structures in which these sandstones were used are still standing in downtown areas of Vancouver, Nanaimo and Victoria (Parks,1917).

In Alberta, similar sandstones were quarried in the Foothills from sites located between Red Deer and Lethbridge. Edmonton and Calgary still have buildings with sandstone from these Alberta quarries. These sandstones were used as masonry blocks and ashlar, lintels, sills, window and door frames and similar products. However, it was not split in sheets for general flagstone applications. Stone producers one hundred years ago concentrated their attention to produce a sound structural sandstone and completely ignored sites with stone of flaggy development.

This once flourishing industry was replaced by the use of quarried granite, andesite (a volcanic rock from Haddington Island north of Nanaimo), concrete and steel, and the quarries were abandoned many years ago with plenty of resource still available.

Commercially available sandstone in the Pacific Northwest currently comes from the Hercules Quarry in Washington State through Marenacos Stone Center, Issaquah, WA. It can be obtained in up to 10-ton blocks and is marketed as cut and split product in a variety of shapes and sizes. Some sandstone is also produced by Wilkeson Sandstone Quarry LLC. located in Wilkeson, WA.

Recent geological studies of Nanaimo Group sandstones on Vancouver and Gulf Islands by Peter Mustard, and his graduate students of Simon Fraser University in Vancouver, identified a number of sites, where the sandstone splits readily into thin slabs. With the increased industry interest in flaggy sandstones, some of those sites merit examination for development potential.

Thinly bedded sandstone turbidites are observed at following sites (Mustard, personal communication, 2002):

Denman Island:

- Cedar District Formation along southwest shoreline near the ferry dock, and for about 5 kilometres to the southeast.
- Northcumberland Formation along the northeast shoreline, from about 1 kilometre southeast of Fillongley Park to about 2 kilometres northwest of the Hornby Island ferry dock.

Hornby Island:

- Spray Formation on east side of the island. In particular the Sandpiper Beach area and the northeast facing coastline on southwest side of Tribune Bay near Dunlop Point and the coast to the northwest.

Mayne Island:

- Bennett Bay and Horton Bay on the east side of the island.
- Gabriola Island:
- Gabriola Formation at Descano Bay, to the southwest of ferry dock.
- Northcumberland Formation near beach along False Narrows on the south coast.

The required material characteristics, physical requirements and testing procedures for building stone are covered by industry standards specified in American Society for Testing and Materials (ASTM) and Canadian Standards Association (CSA) designations.

ASTM and CSA specifications are very often identical and ASTM standards are widely used by industry in Canada. These designations apply to dimension stone used for general building and structural purposes. Minimum characteristics of sandstone suitable for commercial use are listed in “Standard Specification for Quartz-Based Dimension Stone, ASTM C 616-99.

JOHNSON CREEK QUARRY

The quarry site is located east of Williston Lake within the Rocky Mountains Foothills, the eastern part of the Rocky Mountains Thrust and Fold Belt.This eastern part of the Thrust and Fold Belt is more distal of the maximum deformation and adjacent to the tectonically undisturbed Interior Platform. But it is still affected by wide, low angle folds and subsequent faulting. A major north to south thrust fault truncates the Gates sandstone only 3 kilometres east of the quarry (Figure1). Such deformations cause the close jointing pattern observed on the quarry face.

The site was opened in 1981 as a quarry to provide stone for construction of Johnson Creek Forest Service Road (FSR). During 1995 some stone was removed for flagstone application and in 1996 the site was a source of riprap for local use. Since 1996 the site has been left inactive. Some of B.C. stonesmasons compared the Hudson Hope sandstone to the so called “Pennsylvania Bluestone”, a very popular feldspathic flagstone produced in New York state and Pennsylvania and sold all over the USA and Canada.

The Johnson Creek quarry can be accessed from Highway 29 driving west 15.5 kilometres on Johnson Creek Forest Service Road (FSR) (Fig.1).

There are a variety of sandstones exposed in the quarry which belong to the “Gates Formation” sandstones of the Early Cretaceous age. This sandstone unit has been named after The Gates - a site on the Peace River 5 kilometres downstream of Hudson Hope, where the sandstone outcrop was first described in detail.

The Gates Formation is described as fine-grained, marine and non-marine sandstones (Stott,1982). The sandstones extend upstream from The Gates to Steamboat Island at the lower end of the Peace River canyon. From there they can be traced southward to Pine River and as far south as Deadhorse Meadows, near Kakwa River, over a distance of over 300 kilometres.

Sandstone beds of 18 – metres thickness, are exposed at The Gates; over 61 metres are present at Steamboat Island, and the Formation increases to a maximum of 263 metres thickness at Mount Belcourt.

Gates sandstones are described as generally brownish grey, and they weather to a light brown to lightly rusty colour. Most are laminated, the brittle laminations developed by mica minerals, clay, or finely comminuted carbonaceous material. The most common occurrence is in thin to thick - bedded units which weather in stacks of plates.

Sedimentary structures found within the Gates sandstones include cross-bedding, ripplemarks, mud cracks and various irregular forms called "tracks and trails". These include rounded, elongated features which are artifacts of the burrows and castings of worm-like animals (Stott, 1975; 1982). These features can also be found on the Johnson Creek quarry site.

The quarry face consists of a main rock cut with a vertical wall of varied height rising from about 1 metre at each end to approximately 7 metres in the centre. The length of this wall is approximately 30 metres (Photo 3). Numerous important geological features are exposed on the quarry face.

The rock is a well-stratified fine-grained arenite. Individual bed thickness is very irregular, from less that 1 centimetre up to approximately 20 centimetres.

They are separated by fragile, thin layers of clay, mica and detrital coal (Photo 4), and split easily in slabs and sheets along these layers. Some layers appear to be sealed to percolating meteoric water, but many have brown zones as a result of ground water *see*page (Photo 5). The units exhibit almost horizontal bedding dipping 5 to 10 degrees to the southeast in some parts of the quarry face, to 5 to 10 degrees to the south and southwest in others. Some beds contain cross- stratification features; wedge shaped layers resulting from deposition in a deltaic environment. Some beds exhibit a very rough, irregular surface with ripplemarks, worm burrows, mud cracks, carbonized root and wood remnants and similar irregularities. There is no uniformity in the appearance of the bed surface.

The sandstone weathers brown where it has been in contact with percolating meteoric waters. This is due to slow, but gradual oxidation of iron originally present in bi-valent form and causing "blue" (or to some people "green") coloration, into the tri-valent form, which is rusty brown. Water and frost have also softened the less solidified partings and finely laminated layers. Therefore, close to the surface, the Gates sandstone in the quarry area occurs in stacks of easily separable slabs and plates (Photo 7).

White stains occur locally on the quarry face (Photo 6, 7). These are clearly recent features and are located along coal - rich ledges where water percolating through the strata

Photo 3. Johnson Creek quarry. Horizontal and vertical continuity of steep fractures and bedding plane system. View from the south.

Photo 4. Fracture frequency results in quarrying slabs up to 1 metre in size. Hammer for scale is approximately 30 centimetres.

Photo 5. Brown colouration (oxidation) from percolating water along bedding planes.

Photo 6. Large patches of white staining, below some bedding planes, indicate soluble salts problem in the sandstone . Seepage comes periodically from many bedding planes after the spring break-up or rainy periods.

Photo 7. Detail look as above.

seeps out from the quarry wall. This white substance is probably leachate from coal layers, rich in pyrite, which is precipitated when water comes in contact with air.

When examined closely, the individual beds exposed in the quarry face, while having a very similar look, exhibit distinct properties. Some, when hit by a standard geological hammer have a sharp, metallic sound, while others sound dull and hollow. Some are hard, while others scratch easily. Six samples, taken at about 50 - centimetre intervals from bottom up, and numbered #1 to #6, were collected from the quarry face. The samples were tested for absorption, to identify the stone's porosity, which can provide clues as to homogeneity, and how the stone produced from the quarry site will potentially perform. The absorption test was done by Thurber Engineering Ltd geotechnical laboratory in Victoria and results confirmed the lack of homogeneity, as suspected from the hollow to metallic sound of the stone. The values range from 0.3 % in sample #1 to 3.3 % in sample # 6 (Table 1). This is well within the ASTM limits for quartz – based dimension stone.

TABLE 1
ASTM ABSORPTION TESTS ON SAMPLES FROM HUDSON HOPE

Sample #	As Received Weight	Oven Dry Weight	Soaked Weight	Percent Absorption
1	634.6	632.5	634.6	0.3
2	211.7	208.7	214.7	2.9
3	1539.9	1521.8	1543.7	1.4
4	165.2	163.1	166.3	2
5	505.8	498.8	510.3	2.3
6	155.6	153.5	158.6	3.3

Note: The unit of measurement for all weights shown above is grams.

The thin section study was undertaken by Vancouver Petrographics Ltd. of Langley, BC. The study identified the rocks as feldspathic sandstone lithified mostly by compaction; only sample # 1 has a calcite matrix. A carbonaceous substance and very fine-grained pyrite are identified, disseminated throughout the rock . No evidence of microfractures or enhanced cleavage in feldspar was noticed in any of the samples.

Samples 2 to 6 were found to be fine - grained lithic arenites, texturally mature in that they are generally well sorted and contain little or no original clay component, however, clasts are angular. Composition consists of approximately 30 – 40 % angular lithic fragments, 25 – 30 % angular quartz fragments and roughly 15 – 25 % feldspar or clay and sericite after feldspar. Minor mica as individual flakes and fragments of carbonaceous material are also noted. The rocks appear lithified by compaction, with a pseudomatrix consisting of altered and squashed (compacted) lithic and feldspar clasts.

Sample 4 is finely laminated.

Sample 1 differs from the others as it has a calcite matrix (visually estimated at slightly more that 20 % of the sample) and shows little if any evidence of compaction prior to introduction of the cement. Relative proportions of lithic fragments, quartz and feldspar are approximately the same as other samples of the suite, and clasts have similar size range and are similarly angular.

Opaque materials cannot be positively identified in thin section, as the slides are covered.

However examination of offcuts indicates that most of the opaque material is carbonaceous matter. There are also traces of very fine pyrite (grains <0.1 mm in diameter) scattered in each sample, most commonly observed within lithic or feldspathic fragments. The pyrite appears to be most abundant in sample 3, where it is estimated at less than 0.5 %. In many cases pyrite shows some partial oxidation to hematite around grain edges.

Other than bedding features, the quarry face exhibits numerous steeply dipping fractures (Photo 3). The most prominent is about 20 degrees to the general direction of the quarry wall. It consists of continuous parallel faults, approximately 5 to 7 metres apart (Photo 3). These faults have a direction from 60 to 70 degrees and dip at 70 to 80 degrees northwest. The faults are exposed on the quarry wall and can be traced along the quarry floor. There are numerous less pronounced and less continuous subordinate parallel fractures as a part of the system, together with many irregular fractures in all directions without a pattern. But all show the rusty brown coating. The rusty brown staining demonstrates that the Gates sandstone in the Johnson Creek quarry area had a well developed system of vertical fractures and open bedding planes through which the ground water circulated for many millennia, well before the quarry was opened.

The stone has been used on a trial basis in construction of a house built 5 years ago on Bowen Island, which was described in Canadian House and Home magazine. A variety of stone was used in its construction, and for landscaping.

While the retaining walls, chimneys and other structures use irregular size and shape blocks of imported "Montana Stone" – a mixture of crystalline igneous and metamorphic rocks, the deck around the house is paved with approximately 5 centimetre (2 inches) thick slabs of cut sandstone taken from the Hudson Hope site. The slabs are of very irregular size and shape (Photo 8). The average size is approximately 1 square foot (900 square centimeters); some of the slabs are smaller, some may be up to 2 square feet in size. The colour is not uniform, ranging from light bluish green to dark brown. The surface is not uniformly smooth; some slabs are very smooth, but many have slight irregularities like small blobs sticking out or irregular hollows (Photo 8). Many slabs exhibit a coarse, pitted, and almost rasp - like surface. Physical deterioration was noted in several places as a result of chipped out fragments along the edges of individual slabs. The size of such holes is in the order of a quarter to a one - dollar coin. In general, the stone has a very pleasing look.

Photo 8. Bowen Island home patio floor. Cut, irregular shape slabs of 1 to 2 square feet (900 to 1800 square centimeters) in size.

The availability of Gates sandstone in this part of BC is practically unlimited. It outcrops over a large area of the Rocky Mountain Foothills from Peace River southeast to the BC – Alberta border, and similar deltaic development is certainly not unique.

Within the quarry area there is no doubt that flaggy sandstone can be produced from the existing site by opening an east – west oriented face at the south end of the present quarry wall and gradually progressing to the north. That will offer the advantage of processing first, the easily separable stacks of slabs and plates in the surficial layer.

Aside from aesthetic appeal, responsible marketability of the Hudson Hope sandstone will depend on its physical and chemical properties, long-term performance in potential end use and competitive pricing with alternative products available from stone distributors.

Three samples of sound, massive sandstone beds collected from the present face of the quarry were subjected to compressive strength test according to ASTM specifications. The sandstone slabs were drilled with a 2 inch (5 centimeter) bit (Photo 9) and the resulting core was cut into cylinders of equal length. Five cylinders from each sample were then crushed to measure the load under which they fail. The result gives the strength of the stone, which is com-

Photo 9. Compressive strength sample # B-04 with drilled core segments.

TABLE 2
COMPRESSIVE STRENGTHS OF CORED SANDSTONE

Location	Core No	Tested Length (mm)	Diameter (mm)	Corr. Factor	Load kN	Uncorrected Strength mPa	Corrected Strength mPa	Corrected Strength psi
B-04	1	47.5	45.6	1.000	295	180.7	180.7	26,211
	2	48.5	45.6	1.000	318.4	195.1	195.1	28,290
	3	48.7	45.6	1.000	330.4	202.4	202.4	29,357
	4	50.7	45.6	1.000	314.4	192.6	192.6	27,935
	5	50.2	45.6	1.000	319.8	195.9	195.9	28,415

Location	Core No	Tested Length (mm)	Diameter (mm)	Corr. Factor	Load kN	Uncorrected Strength mPa	Corrected Strength mPa	Corrected Strength psi
B-05	1	52.6	45.6	1.000	340.5	208.6	208.6	30,254
	2	52.8	45.6	1.000	325.3	199.3	199.3	28,904
	3	50.1	45.6	1.000	307.6	188.4	188.4	27,331
	4	50.1	45.6	1.000	334.7	205	205	29,739
	5	50.4	45.6	1.000	319.5	195.7	195.7	28,388

Location	Core No	Tested Length (mm)	Diameter (mm)	Corr. Factor	Load kN	Uncorrected Strength mPa	Corrected Strength mPa	Corrected Strength psi
B-06	1	48	45.6	1.000	360.5	220.9	220.9	32,031
	2	49.7	45.6	1.000	342.6	209.9	209.9	30,441
	3	50.4	45.6	1.000	364.2	223.1	223.1	32,360
	4	49.3	45.6	1.000	335.9	205.8	205.8	29,845
	5	51.2	45.6	1.000	348.6	213.6	213.6	30,974

parable with other stones and specifications required for a particular application.

All 15 samples produced very similar results, which are provided in Table 2.

The average strength measured was 193 megapascals (mPa) in metric units or 28042 pounds per square inch (psi) for sample B-04; 199.4 mPa or 28923 psi for sample B-05; and, 214.7 mPa or 31130 psi for sample B-06 (Table 2).

These values are the highest, ever recorded in British Columbia. Most of B.C. sandstone quarried in the past has a reported strength between 8256 psi and 16505 psi. Only the stone from Saltspring Island has a similar strength of 27229 psi (Parks, 1917).

FLAGSTONE AND BRITISH COLUMBIA MARKETS

Producing flagstone is a labour- intensive enterprise. In a typical scenario, one central BC producer brings stone blasted by standard explosive from the quarry site to the yard by truck, for further splitting and sorting. Split and sorted by thickness, the stone is stacked onto 1- square - metre wooden pallets. Depending on the slab thickness, a complete pallet weights between 1.5 and 2 metric tones (Photos 1, 2). It takes an average skilled worker one day to split and sort one pallet. At the quarry site, about 50 % of the blasted rock is rejected as waste; at the yard, rejected unusable stone is about 25 % of the processed material.

In another case the quarry is easily reached by a flat bed truck. There, the blasted rock is split, sorted and stacked on the quarry floor. Total stone recovery in this example is about 50 %, but this is mainly because the stone splits more evenly. Productivity here is about the same – one pallet a day per person.

There are a number of well-established flagstone/facing stone producers supplying the existing market in Western Canada and adjacent US states.

- Kootenay Stone Centre of Salmo is producing quartzite in a variety of brown, beige, yellow or green colours, in thicknesses of 0.25 to 0.5 inch (0.8 to 1.25 centimetres), 1 inch (2.5 centimetres), 2 inches and 4 inches thick, at a price of $ 2 to $ 4 per square foot.
- Revelstoke Flagstone Quarries Ltd. of Revelstoke is producing a silvery grey, mica schist, in thicknesses of 0.5 inch, 1 inch, 2 inches, at a price of $ 4 per square foot.

Photo 10. Typical use of split stone in wall facing. BC granite from Fox Island. Quadra Stone Company Ltd. product.

- Kettle Valley Stone of Kelowna is producing lithified white and red/green banded volcanic ash, in thicknesses of 1 inch and 4 inches, at a price of $ 2 to $ 7 per square foot. Kettle Valley Stone also sells split basalt.
- A variety of split granite is also produced in BC in square shapes and in some areas competes with flagstone (Photo 10).
- Garibaldi Granite Group in Squamish is producing a variety of sizes of 2 and 4- inch -thick slabs of white, grey and beige granite at $ 2.50 to $ 8 per square foot; a specialty product without sharp edges at $ 12 per square foot; and, 4- inch sawn basalt at $ 8 per square foot.
- Margranite Industries Limited of Surrey, Quadra Stone Company Limited of Vancouver and Adera Natural Stone Supply Ltd of Burnaby also offer a small selection of BC split square granite products at a competitive price.
- Margranite Industries Limited is also producing about ten different colours of BC cut and polished or flamed granite tile in two sizes – 1 and 1½ foot squares. The price of BC stone tiles is from $ 12.75 to $ 14.95 per square foot.
- Matrix Marble Corporation of Duncan is selling black and white BC marble varieties as square paving blocks (Photo 11) for $ 9 per square foot and tile for $ 12 per square foot.

The prices quoted are retail, as sold from the producer's yard or a distribution center.

A very popular so called "Rundle Stone" or "Rundle Rock", dark grey to black silty sandstone is quarried in Alberta near Canmore by Thunderstone Quarries Ltd. It is used in rough split pieces as a patio stone, facing stone, etc. It can be seen in Banff on many structures including the Banff Springs Hotel. It retails in Vancouver in 2-inch thick slabs for $ 6.89 per square foot.

The transportation cost of BC flagstone products to Vancouver is between $ 85 to $ 100 per pallet or $ 600 to $ 800 for a 25 tonne trailer from eastern BC locations on Highway #1 or #3.

Photo 11. Vancouver Island marble varieties. Mosaic floor assembled of 10 by 10 cen timetres square cut pavers (tiles). Matrix Marble Corporation product.

Photo 12. Typical use of stone chips (rubble) in wall facing. BC granites from Fox Island (left) and Beaverdell (right). Quadra Stone Company Ltd. product.

Throughout the BC interior, and probably elsewhere, many local contractors operate small-scale intermittent quarries for their own use. Some of the stone comes from blasted rock in road construction, road cuts and natural cliffs and is usually available at no cost. There is no control or documentation of such local stone production and furthermore much of it is not really a flagstone, but just irregular rubble, or "chips" (Photo 12). This type of stone, partic-

Photo 13. Quartzite flagstone, 'Kootenay Rainbow' trade name, as a column facing in Vancouver airport building. Kootenay Stone Centre product.

ularly one used in interior application, is transportation sensitive. Very rarely such stone is shipped to more distant locations. One exception is the so called "Golden Fern" stone from Grand Forks, a coarse - grained crystalline quartzite which is occasionally quarried on the east side of the town and shipped to Vancouver stone distributors. This stone has an unusual look and appeal due to its colour and texture.

Although many highrise structures were built in downtown Vancouver during the last 20 years with an extensive use of natural stone, all is highly processed granite and marble. None of it is split flagstone. One of the few exceptions is the newly expanded Vancouver Airport Terminal with its minor use of quartzite, mica schist, basalt and granite in its interiors (Photo 13, 14).

About 20 000 housing units are built every year in British Columbia. Of those, only a few percent are custom built houses with a demand for stone. Standard houses with a fireplace use stone as wall facing and for the hearth, but due to a 1991 ban against wood burning fireplaces in the Vancouver area, this market disappeared

Photo 14. Split columnar basalt from Whistler as a wall facing, Vancouver airport building. Garibaldi Group product.

FLAGSTONE

Kootenay Stone Centre
Revelstoke Flagstone Quarries
Kettle Valley Stone Ltd.
Thunderstone Quarries Ltd
Total ~12000 tonnes

CUT AND SPLIT GRANITE AND MARBLE

Garibaldi Group
Margranite Industries Limited
Adera Natural Stone Supplies Ltd.
Quadra Stone Company Ltd.
Matrix Marble Corporation
Total ~ 5500 tonnes

overnight. Most of the split stone (of all varieties) used in recent years has been in recreational areas, with more rustic architecture. Whistler/Blackcomb and Banff are representative examples of this high-end niche market, not residential dwellings.

The following are estimates of split stone production in BC and Alberta :

The rest of reported production tonnage is in the form of small chips – waste from splitting the stone blocks – sold as landscaping stone, for road maintenance, etc., or possibly as raw material for cement manufacture

Almost all producers sell up to 50 % of their production to other parts of Canada, as well as to the United States.

A significant quantity of stone products is also imported. These are, in part, stone types not available from local producers, or different shapes and sizes produced elsewhere and required for special projects.

In recent years there has been competitive pressure on BC producers from very low priced imports from overseas, particularly from China.

In conclusion, it is my estimate that including imports, the BC market for flagstone and similar facing stone products is approximately 10 thousand tonnes per year.

MARKET POTENTIAL FOR JOHNSON CREEK QUARRY SANDSTONE

Responsible marketing of sandstone from the quarry site near Hudson Hope would require good physical and chemical characterization of the stone to establish its competitive position in the marketplace. The distribution in the deposit of different qualities of the stone, as well as the distribution of its detrimental impurities will have to be established. The production costs need to address issues of selective quarrying and labour intensive processing. Transportation costs from quarry to the marketplace will also be a factor.

It is known the stone varies in some physical properties (namely absorption) and some of it reacts with meteoric water, producing potential problems with unsightly white stains and soluble-salts. While there is always room for a new product, as has been shown most recently by Kettle Valley Stone Ltd., such new product must offer – aside from competitive price - reliability and quality, if it is to replace an already established product with a good reputation. If the product fails only in one of the expected or required properties and specifications, the market potential drops to zero.

The Hudson Hope stone can be used safely in interior applications but outside use, exposed to weather conditions has yet to be established. However, the patio of the Bowen Island home seem to be doing well, considering five years of being exposed to the BC coastal climate.

SUMMARY

The Hudson Hope sandstone is not unique; Gates Formation sandstones outcrop over a large area between the Peace and Kakwa Rivers in northeastern British Columbia.

- 100 years ago, western Canada had a flourishing sandstone industry on the B.C. coast and in the Alberta Foothills. The stone in those quarries has not been depleted and has a reasonable performance record in masonry pieces.
- The use of statistics for market projections may be misleading. Split stone (flagstone and ashlar) can only be 20 to 25% of total reported production volume.
- The petrographic study confirmed that some beds have a different texture or composition from others.
- The fracture pattern and bedding planes exposed in the quarry face exhibit widespread brown coating and staining, which must have developed over many millennia. The spacing between individual fractures clearly indicates, that slabs in the size of several feet long and wide can be easily quarried from this site.
- Three samples taken from different massive beds exposed in the quarry face and tested for compressive strength are proof that the stone has excellent physical properties, superior to most of BC sandstones quarried in the past.

While the Hudson Hope location may have significant logistical drawbacks, a similar sedimentary environment in Lower Cretaceous formations exists over large areas of Rocky Mountains Foothills and farther west. Also, similar flaggy sandstones occur in Triassic rocks of Sulphur Mountain Formation, between Wapiti and Kakwa Lakes of northeastern British Columbia (Pell and Hammack,1992).

Recent studies of Nanaimo Group sandstones on Vancouver and Gulf Island identified a number of potential sites on Gulf Islands, which should be examined by an experienced quarrymaster for flagstone production.

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