Preliminary Study Of The Economic Feasibility Of Producing Crushed Stone From Fort Chipewyan Red Granite

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Executive summary

Attempts in 1988 to quarry commercial size dimension stone blocks from the Fort Chipewyan Red Granite failed. Currently, two Alberta companies are attempting to quarry commercial size dimension stone blocks from other parts of the pluton. Using an economic model, certain assumptions, and the data outlined in this report, it is shown that crushing the waste material from a block quarrying operation, manufacturing agglomerated granite tile in an 800 000 tile/year plant built for $5M, and wholesaling the product for $7.50 would be profitable. It also would be profitable to quarry granite and crush it solely for agglomerated granite tile, but profit would not be as high. Crushed waste granite could be sold at a profit for landscape rock, concrete deck topping, poultry grit and exposed aggregate concrete by selling all of the material produced at the production rate assumed for this model. The markets are small. Granite crushed solely for crushed stone only could be sold at a profit for concrete deck topping and exposed aggregate concrete under similar circumstances.

Use of alternate input data in the model may change the conclusions reached concerning profitability.

Introduction

The failure to successfully quarry commercial size dimension stone blocks from the Fort Chipewyan Red Granite in 1988 resulted in abundant broken material at the quarry site. This study investigates potential uses for stone that could be crushed from this or other sources of similar broken material. New attempts by two Alberta companies to quarry commercial size dimension stone blocks at other locations in the granite pluton may provide additional sources of the broken material that is the inevitable byproduct of any quarrying operation. An economic model is developed for calculating the potential profitability of a crushed stone operation that either uses the waste from a block quarrying operation, or that quarries material solely for crushing.

Previous work

Bedrock geological mapping in 1970 by John Godfrey of the Alberta Research Council delineated a body of red granite approximately 24 km by 6.5 km in size northwest of Fort Chipewyan. He called the pluton Chipewyan Red Granite (Godfrey, 1986) (map in pocket). A helicopter reconnaissance geological mapping of the southern section of the pluton, adjacent to the commercial tug and barge route along the Slave River, was performed in 1971. Blocks as large as 0.03 m^3 were collected, cut and polished, and shown to exhibit potential for use as ornamental building stone. Additional reconnaissance mapping of the entire pluton was performed in 1972, to assess the gross lithologic and structural characteristics and to outline specific areas for more detailed work. Eight areas showed promise, and after further investigation one site in the southern part of the pluton was chosen for detailed study (Godfrey,

1972). This site is 17.5 km northwest of Fort Chipewyan, is 3.5 km from the barge route, and has relief of ~6 m in the area of interest, . Six cores of ~7.5 m length were drilled at the site in 1975 (Godfrey, 1976a) to further evaluate color, texture, fractures, etc.. It was concluded that an area of only 12 m by 30 m is suitable for building stone.

Another site ~245 m north of the first site was chosen for further investigation. The bedding joint spacing of 1 to 2 m was considered encouraging for production of building stone blocks, the vertical joint frequency was expected to diminish with depth, mineralogical defects were considered to be within commercially acceptable limits, the volume of granite available was considered more than adequate, and an ~7 m scarp would provide a good opportunity for the initial development of a side hill quarry (Godfrey, 1976b). In 1988, a quarrying operation began on a small parcel of reserve land after construction of a 10 km road to the site. the ~$1 million project was funded primarily by the Northern Development Agreement of the Western Economic Diversification Project. The Fort Chipewyan Development Corporation with representatives from the Metis, Cree and Fort Chipewyan bands had a 5% equity contribution. Other federal programs contributed funds for employment assistance and the quarry supervisor was seconded at no cost from Alberta Public Works. Blocks of industry standard size ~1.5 x 1.2 x 2.7 m were impossible to quarry, because the rock broke into smaller pieces on what appeared to be natural surfaces. A review of data published previously concluded that the close joint and fracture spacings should have suggested that large blocks would be difficult to quarry (Geo-Engineering, 1988). It was recommended that a program of drilling to 20 m be performed to determine whether fracturing decreases with depth. Two holes were drilled successfully in 1989, and

evaluation of the cores obtained indicated that fracturing does not decrease with depth. The production of industry standard sized blocks therefore was considered unlikely. In addition, color variation from red to gray-pink and gray was encountered in one borehole (Geo-Engineering, 1989). Further investigation in the vicinity of the quarry was discontinued.

Present study

The failure of the initial dimension stone project does not mean that alternate uses of this deep red material could not be considered. Moreover, if it were possible to quarry industry standard size dimension stone blocks from another part of the pluton, as currently is being attempted, the waste material generated from that operation also could be sold for alternates uses. Such uses employ either blocks smaller than the standard size dimension stone block or crushed material. Small blocks can be used for tile, pavers, curbing, rough wall facing blocks or slabs, lapidary memorabilia, and small burial headstones. Crushed material can be used to make agglomerated granite tile, landscape rock, bridge deck topping, poultry grit, exposed aggregate panels, roofing granules, railroad ballast, and roadstone.

This study investigates the economic feasibility of using Fort Chipewyan Red Granite for crushed granite products. After identifying uses and their markets an economic model was constructed to determine the potential profitability of serving those markets.

A contact for input made with the office of Chief Lawrence Vermilion of the Cree Band in Fort Chipewyan received no response. Dave McConnell of Northern Alberta Granite Company Ltd., one of the companies currently

attempting to quarry commercial blocks, was generous with data.

The raw material

Godfrey (1980) identified three geologic terrains in an area covered by four map sheets northwest of Fort Chipewyan. Granite gneisses are the oldest rocks, metasediments are younger, and granitoid plutons intrude the older materials. The Chipewyan Red Granite, one of four granitoid plutons in the area, is noted for its rare, deep red color. The pluton is approximately 24 km by 6.5 km in size, with its long axis conforming to the regional northeast structural grain of the area (map in pocket). The rock 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 minor minerals forming the remainder (Godfrey, 1976b). Although medium red to dark red is the dominant rock coloring, a gray to gray-pink variety was encountered below 7.5 m in one borehole. Few xenoliths (inclusions) are present in the southern part of the pluton. Crude banding of dark minerals is prominent toward the north end of the pluton. Minor quartz veins and pegmatites from 7 to 10 cm thick, and 0.6 to 3 m amphibolite dykes cut the granite.

Two major subvertical joint sets and a series of subhorizontal fractures, together with random joints and minor shear zones, dissect the rock mass at the sites previously investigated. The average spacing of the subvertical joint sets is 0.8 and 1.1 m respectively and the average spacing of the subhorizontal defects is 0.2 to 0.25 m in the upper 20 m of the pluton. These data suggest that the average block size which could be produced from the upper 20 m of the southern part of the pluton is in the

order of 0.2 x 0.75 x 1.0 m.

Potential broken stone products

Blocks smaller than the industry standard ~1.5 x 1.2 x 2.7 m size for dimension stone operations, which inevitably are a byproduct of quarrying, could be used for tile, pavers, curbing, rough wall facing blocks or slabs, lapidary memorabilia, and small burial headstones. Although the markets for such products would be of interest to a dimension stone producer they are not considered in this report. This investigation pertains to the crushing of these smaller blocks and broken waste to make agglomerated granite tile, landscape rock, bridge deck topping, poultry grit, exposed aggregate panels, roofing granules, railroad ballast, and roadstone.

Agglomerated tile

Agglomerated granite tile is a product manufactured by block casting or precasting. The block casting method involves mixing graded, granite chips with cement, polyester resin or epoxy. The mix is poured into forms of large blocks and either vibrated or pressed until the desired density is achieved. The hardened blocks are removed from the forms, left to cure, then sawn into slabs and ground to finishes from rough grind to high polish. The finished slabs are cut into tiles of various sizes or sold as slabs. Precast agglomerated tile use similar mixes to the block cast method, but each tile is cast in its own mold, mechanically vibrated, and hydraulically compressed during manufacture. The tiles subsequently are steam cured to further strengthen the product. Due to their high compressive strength, they commonly are "ground in place" to produce a smooth floor. A high polish bevelled edge tile also is produced for laid-only appications (Terrazzo, Tile and Marble Assoc. of Canada, 1991).

Agglomerated tile are prone to attack by acid rain and ultraviolet radiation, and therefore are used for interior installations on walls, floors, stairs, and window or door sills. In Canada at present, only one plant in Quebec produces agglomerated granite tile. It expects world sales to be 1.85 million tiles/year (Rogan, 1993). Alberta requirements are unlikely to be more than the current 40 000 tiles/year demand for its competitor, agglomerated marble.

Landscape rock

Crushed granite and other natural rocks are crushed into 75 x 150 mm size and sold packaged or in bulk to garden and landscape suppliers. Use is typically for walkways, and ground cover around trees and shrubs. The superior durability and consistent color of granite should allow it to compete well with the red burned shale commonly used in Alberta for paths or ground cover. White quartzite and dolostone are major competitors that sell for ~$65/t in bulk. Total demand in Alberta is estimated to be ~200 t/yr.

Concrete deck topping

Concrete bridges, overpasses, and parking structure deck surfaces are very susceptible to penetration of moisture, oxygen, and corrosive chemicals such as deicing salts. The deck surfaces also are subjected to high stress loads, movement due to climatic changes, and abrasion from traffic. To counteract these problems, an aggregate-resin mix may be applied to the deck surface. The compressive strength of the aggregate must exceed 200 MPa, water absorption must not exceed 0.75%. decrease in sulfate soundness for 15 cycles must not exceed 0.75%, and no more than 12% loss in the LA abrasion test. The aggregate also must be properly graded, dry, very clean, durable, and contaminant free. Granite

easily meets these requirements. Future demand is estimated at 100 t/yr. Current price is $250/t in bags (Rogan, 1993). At present, one Alberta and two out-of-province companies have material to supply this market.

Poultry grit

The poultry industry uses a large amount of premixed feed that commonly contains supplements. Granite grit is a supplement added because of its durablity. The hard granite grit enhances nutrient uptake by further grinding mineral and organic components in the crop of the bird to release additional nutrients. The grit must be free of elements deemed hazardous to health. Latest Canadian demand and value figures are 1000 t/yr and $90/t respectively (Vagt, 1993). Alberta demand is estimated to be ~50 t/yr.

Exposed aggregate concrete

A popular way to add color and texture to concrete buildings is to attach precast panels that have the aggregate exposed at the outer surface. This is accomplished either by sandblasting off the surface cement or by brushing a setting retarder on the surface then washing off the affected cement with water. The aggregate must be clean, evenly sized, and of uniform color. Specific colored precast panels require 100 to 250 t/yr of decorative aggregate. Such material currently is imported into Alberta at a landed cost of ~$225/t vs $5.60/t for local aggregate.

Roofing granules

Roofing granules are stone particles that have been crushed and screened to <10 and >35 mesh and then spread over asphalt impregnated paper felt that commonly is fashioned into a strip shingle. Most granules are coated with a mixture of sodium silicate, clay and inorganic colored

pigments then fired in a rotary kiln. One supplier in Quebec uses gray basalt as the raw stock for pigmenting. Some blacks are merely ground slag, whereas others are pigmented basalt. The chief purposes of the granules are to prevent ultrviolet radiation from breaking down the asphalt and to fireproof the roof surface. Roofing gravels or "chips" are stone particles crushed and screened to >6 mm that are pressed into the top dressing of hot asphalt commonly used on flat or low pitched roofs and serve the same purposes as the granules of asphalt shingles. White is a common color preference in warmer climates and marble, dolostone, limestone, quartzite, and coquina are some of the materials used. Currently in Alberta, the stone chips are screened from local deposits and the resultant color commonly is grey/brown; the deep red color of Fort Chipewyan Red Granite would make an unique addition to the market. Latest Canadian demand and value figures are 278 000 t/yr and $21.90/t respectively (Vagt, 1993). Alberta demand is estimated to be ~30 000 t/yr. Alberta demand for red material is estimated to be ~300 t/yr.

Railroad ballast

Railroad ballast is composed of crushed rock, nickel slag or crushed gravel, composed of hard, strong and durable particles, free from injurious amounts of deleterious substances (Klassen, Clifton and Waters, 1987). Particle size ranges from 4.75-63.5 mm. CN Rail experience indicates that fine grained igneous rocks have a longer performance life than coarser textured rocks such as granite. Sources seldom are more than a kilometre from trackside. Long haul distances are acceptable only if they are on the home railway. Transportation costs preclude use of material located on a competing railway. Latest western Canadian demand and

value figures are 817 000 t/yr and $8.20/t respectively (Vagt, 1993). Alberta demand is estimated to be ~163 400 t/yr.

Roadstone

Roadstone, a major use of crushed and broken stone in some other parts of Canada, is the 25 cm or more of material above the subgrade that provides the protective bulk and the wearing surface, of an asphalt or concrete surfaced highway. Specifications are similar to those for railroad ballast. Latest western Canadian demand and value figures are 84 770 000 t/yr and $5.25/t respectively (Vagt, 1993). Alberta demand for crushed granite roadstone could be 847 700 t/yr if the crushed granite were to replace the gravels that currently meet the demand.

Fort Chipewyan red granite economic model

The economic model outlined here uses the Lotus 1 2 3 software program. Most of the input data are from Rogan (1993). Readers, using the disk enclosed, can substitute different data for any of the assumptions used in the examples to calculate alternate results. The disk duplicates what follows in this section of the report. The numbers calculated by the computer program may not match exactly the numbers in this report because some rounding occurs in the computer program. Figure 1 is a schematic flow sheet of the operation modelled and Figure 2 is a schematic flow sheet of the calculations made in the model.

Currently two companies are attempting to quarry standard 1.5 x 1.2 x 2.7 m commercial blocks from northwest of Fort Chipewyan. The examples that follow employ the economic model first to determine the feasibility of using the waste from such a block quarrying operation as crushing stone; second to determine the feasibility of quarrying material

Option 1 **Option 2** **Option 3**
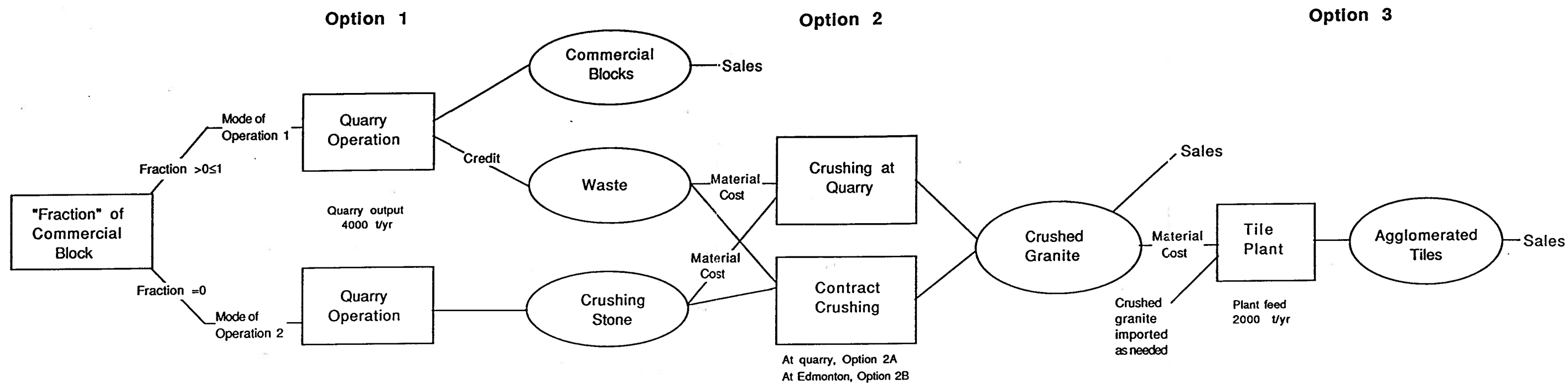
Figure 1.   Schematic flow sheet for Fort Chipewyan granite operations

Section I

Wholesale price

Revenue

Financial parameters

Total cost

Production

Profit

Transportation cost

Section II

Equipment cost

Material cost

Operating cost

Section III

Operating costs

Capital cost

Transportation costs
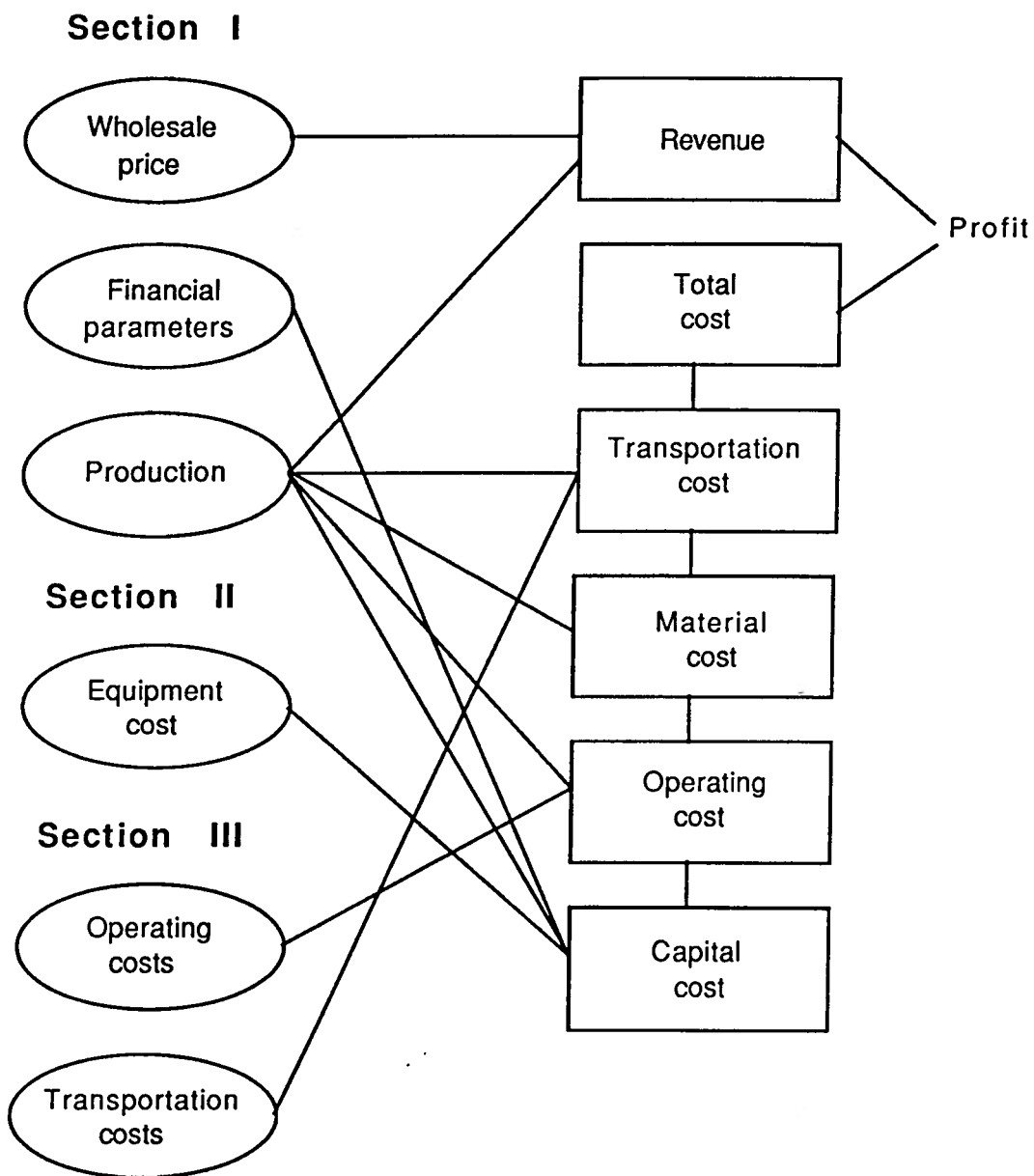
Figure 2. Model calculation for each option

solely to produce crushing stone. In the first example, quarrying costs are charged to block production and a nominal charge for the waste material is levied. Five options are considered for each example. In Example 1 Option 1 the commercial blocks are sold and the waste blocks are sold for crushing stone. In Option 2 the waste blocks are purchased, and equipment is purchased to crush the stone at the quarry. In Option 2A crushing is contracted at the quarry. In Option 2B crushing is contracted in Edmonton. In Option 3 an agglomerated granite tile plant is constructed at Fort Chipewyan and uses the stone crushed from waste. It is assumed that a single commercial block quarrying enterprise, quarrying 4 000 t/yr, attains the Canadian average of 50% successful recovery of commercial rough blocks and has 2 000 t/yr waste available for sale to crush for manufacturing agglomerated tile. Should the block quarrying operation be more efficient than 50% recovery, it is assumed that waste blocks can be imported, at the same price, from a neighboring block operation to compensate for the shortfall to the tile plant (Figure 1).

By selling the entire production of granite crushed from waste of a commercial block operation, current economic data suggest a profit could be made by selling it for decorative landscape rock, concrete deck topping, poultry grit, and exposed aggregate concrete. Available markets are smaller than the total production so it is more profitable to use all the waste to make agglomerated tile.

In the second example, all of the quarrying costs are charged to crushing stone production. In Example 2 Option 2 there are no commercial blocks, all stone is quarried as crushing stone, and crushed at the quarry. In Option 2A crushing is contracted at the quarry. In Option 2B crushing is contracted in Edmonton. In Option 3 an agglomerated granite tile plant is

constructed and uses 2 000 t of stone crushed from the crushing stone. The remaining 2 000 t are available for sale in other markets.

By selling these 2 000 t, current economic data suggest a profit could be made only by selling for concrete deck topping and exposed aggregate concrete. Available markets are much smaller than the total production so orders probably could be filled from a small inventory built from crushiing a little more than needed for tile production each year.

If an 800 000 tiles/year agglomerated tile plant could be built for $5 million and its tiles wholesaled for $7.50 each in Edmonton, the operation would be profitable in the growing granite tile market. Since raw material cost is only a small fraction of the tile cost, the difference between using granite crushed from waste of a commercial block operation and granite quarried exclusively as crushing stone is only about $0.22/tile. The tile operation using granite quarried solely as crushing stone would still be economically viable.

Key assumptions

Rough commercial blocks wholesale selling price	160.00 $/t
Crushed granite wholesale selling price	80.00 $/t
Agglomerated granite tiles wholesale selling price	7.50 $/tile
Economic life of capital assets	15 years
Required rate of return on investment	10 %
Capital recovery factor	0.131

$$\frac{(1+r)^n}{(1+r)^n - 1} \times r = 0.131$$

r = return on investment (10%)
n = depreciation period (15 years)

Drilling capacity (40t/wk/drill x 2 drills x 50 wks)	4 000 t/yr
Commercial block recovery (@ 50%)	2 000 t/yr
Commercial waste	2 000 t/yr
Contract crushing at quarry	$12/t
Contract crushing at Edmonton	$5/t
Tile plant capacity	800 000 tiles
Tile production loss	10.0%
Tile weight	2.268 kg
Granite (available)	2 000 t/yr

Actual production (2000 x 0.9) ÷ 2.268   793 650 tiles
Finishing cost $5/tile
Weight of tile shipped   1 800 t/yr

Capital costs
Capital equipment to quarry blocks or crushing stone

Quantity	Equipment	Price	Total
2	Blast hole drilling rigs	40 000	80 000
1	D-7 dozer	70 000	70 000
1	Wheeled loader (3-4 yd^3)	80 000	80 000
1	Compressor (350 CFM)	36 000	36 000
1	Tandem dump truck (used)	20 000	20 000
1	Pickup truck	20 000	20 000
1	Air tank	2 500	2 500
2	Fuel tanks with stands	750	1 500
1	Small drill	6 000	6 000
1	Tools	10 000	10 000
1	Electrical generator	1 500	1 500
1	Office trailer	2 000	2 000
			329 500
	Freight charges		9 500
	Total capital		$339 000

$000/yr
Yearly quarrying capital cost ($339 000 x 0.131)   44.4

Capital equipment to crush

Quantity	Equipment	Unit Price	Total
1	35 t/hr crusher with 2 deck screen	35 000	35 000
1	2 deck screen plus conveyor	20 000	20 000
4	Conveyors	10 000	40 000
			95 000
	Freight		5 000
	Total capital		$100 000

	$000/yr
Yearly crushing capital cost ($100 000 x 0.131)	13.1

Capital cost to contract crush waste or crushing stone at quarry
$0

Capital cost to contract crush waste or crushing stone at Edmonton
$0

Capital cost for agglomerated tile plant
$5 000 000

	($000)
Yearly plant capital cost ($5 000 000 x 0.131)	655.0

Operating costs
Operating costs to quarry blocks or crushing stone

	$000/yr	$000/yr
Maintenance (2% of equipment capital)	6.8	
Fuel ($50/day/250 days)	12.5	
Foreman ($21/hr/250 days)	42.0	
Drillers (2 @ $18/hr/250 days)	72.0	
Loader operator ($15/hr/250 days)	30.0	
		163.3

Operating costs to quarry blocks if waste sold as crushing stone
$163 300 - ($5/t x 2 000 t)   153.3

Operating costs to crush waste at quarry

Crusher capacity (30 t/hr/8 hr)	240 t/day
Granite available for crusher	2 000 t
Operating days required	8.3

	$000/yr	$000/yr
Maintenance (2% of equipment capital)	2.0	
Fuel ($2/t x 2 000 t)	4.0	
Operators (2 @ $16.50/hr/8.3 days)	2.2	
		8.2

Operating costs to crush crushing stone at quarry

Crusher capacity (30 t/hr/8 hr)	240 t/day
Granite available for crusher	4 000 t
Operating days required	16.6

	$000/yr	$000/yr
Maintenance (2% of equipment capital)	2.0	
Fuel ($2/t x 4 000 t)	8.0	
Operators (2 @ $16.50/hr/16.6 days)	4.4	
		14.4

Operating costs to contract crush waste at quarry

	$000/yr
$12/t x 2 000 t	24.0

Operating costs to contract crush crushing stone at quarry

	$000/yr
$12/t x 4 000 t	48.0

Operating costs to contract crush waste at Edmonton

	$000/yr
$5/t x 2 000 t	10.0

Operating costs to contract crush crushing stone at Edmonton

	$000/yr
$5/t x 4 000 t	20.0

Operating costs for agglomerated tile plant

	$000/yr	$000/yr
Finishing (793 650 tiles x $5/tile)	3 968.3	
Administration	250.0	
Marketing	100.0	
		4 318.3

Material costs

Material costs for commercial blocks

$0 (assume no royalties)

Material costs for waste crushed at quarry

	$000/yr
$5/t x 2 000 t	10.0

Material costs for crushing stone crushed at quarry

	$000/yr
Annual quarrying capital cost + operating costs (163.3 + 44.4)	207.7

Material costs for waste contract crushed at quarry

	$000/yr
$5 x 2 000 t	10.0

Material costs for crushing stone contract crushed at quarry

	$000/yr
Annual quarrying capital cost + operating costs (163.3 + 44.4)	207.7

Material costs for waste contract crushed at Edmonton

	$000/yr
$5 x 2 000 t	10.0

Material costs for waste contract crushed at Edmonton

	$000/yr
Annual quarrying capital cost + operating costs (163.3 + 44.4)	207.7

Material costs to agglomerated tile plant using waste crushed at quarry

	$000/yr
($5 + $10.65) x 2 000 t	31.3

(Granite cost + total crushing costs) x 2 000 t

Total crushing costs = (annual crushing equipment capital costs + operating costs) ÷
2 000 t
= (13 100 + 8 200) ÷ 2 000
= $10.65/t

Material costs to agglomerated tile plant using waste contract crushed at quarry

	$000/yr
($5 + $12) x 2 000 t	34.0

The plant will use the less expensive ($15.65) waste material crushed at the quarry.

Material cost to agglomerated tile plant using crushing stone crushed at quarry

	$000/yr
$58.82/t x 2 000 t	117.6

Granite cost = total crushing costs x 2 000 t

Total crushing costs = (yearly crushing costs + yearly crushing operating costs +
material costs) ÷ 4 000 t
= (13.1 + 14.4 + 207.7) ÷ 4 000
= $58.82

Material cost to agglomerated tile plant using crushing stone contract crushed at quarry

	$000/yr
$63.95/t x 2 000 t	127.90

Granite cost = total crushing costs x 2 000 t

Total crushing costs = (contract crushing costs + material costs) ÷ 4 000 t
= (48.0 + 207.7) ÷ 4 000
= $63.95

The plant will use the less expensive ($58.82) crushing stone material crushed at the quarry.

Transportation costs

Transportation cost assumptions

Commercial blocks weigh ~23 tonnes. A $10/block (or equivalent weight of crushed stone) charge is assumed for transport to the barge from the quarry and a $30/block (or equivalent weight of crushed stone) charge is assumed thereafter for each transfer between modes of transport.

Quarry to barge ($10 ÷ 23 t)	$0.43/t
Transfer between transport modes ($30 ÷ 23 t)	$1.30/t
Summer barge transport to Ft. McMurray	$28.00/t
Winter truck transport to Ft. McKay	$17.00/t
Summer/winter truck to Edmonton	$26.50/t

Blocks or crushed granite transportation costs to Edmonton

Currently the only overland route, from the south, to the Fort Chipewyan area is the winter road from Fort McKay that usually is available between December and March. Material can be loaded onto a truck at the quarry in winter and continue to Edmonton via Fort McKay. Summer traffic is by barge to Fort McMurray then by truck, or the more expensive rail, to Edmonton. The $17/t winter truck rate to Ft. McKay is a special winter backhaul rate.

	Summer Barge ($/t)	Winter Road ($/t)
Quarry to river	0.43	
Load to barge	1.30	
Barge to Ft. McMurray	28.00	
Transfer to truck	1.30	
Truck to Edmonton	26.50	
Unload at Edmonton	1.30	
Quarry to truck		1.30
Truck to Ft. McKay		17.00
Truck to Edmonton		26.50
Unload at Edmonton		1.30
Total transport cost	58.83	46.11

Average year round transport cost = $52.47/t

Transport costs for commercial blocks

	$000/yr
$52.47/t x 2 000 t/yr	104.9

Transport costs for crushed stone from waste or crushing stone

	$000/yr
$46.11/t x 2 000 t/yr	92.2
$46.11/t x 4 000 t/yr	184.4

(only least expensive [winter] transport assumed)

Transport costs for agglomerated tile

	$000/yr
$52.47/t x 1 800 t	94.4

Revenue

Total revenue = wholesale price x production volume (if all production sold)

Total revenue for block and waste crushing stone production

Option	Particulars	Revenue $000/yr
1	Rough commercial blocks ($160/t x 2 000 t)	320.0
2	Crushed stone ($80/t x 2000 t)	160.0
2A	Site contract crushing ($80/t x 2 000 t)	160.0
2B	Edmonton contract crushing ($80/t x 2 000 t)	160.0
3	Agglomerated tile ($7.50 x 793 650 tiles)	5 952.4

Total revenue for crushing stone production

Option	Particulars	Revenue $000/yr
1	Rough commercial blocks	0.0
2	Crushed stone ($80/t x 4 000 t)	320.0
2A	Site contract crushing ($80/t x 4 000 t)	320.0
2B	Edmonton contract crushing ($80/t x 4 000 t)	320.0
3	Agglomerated tile ($7.50 x 793 650 tiles)	5 952.4

Evaluation summaries
Total evaluation summary when using waste from commercial block operations

Option	Particulars	Capacity
1	Rough commercial blocks	2 000 t/yr
2	Crushed granite	2 000 t/yr
2A	Site contract crushing	as needed
2B	Edmonton contract crushing	as needed
3	Agglomerated tile production	800 000 tiles/yr

Option	Total Revenue	Capital Costs	Oper. Costs	Mat'l Costs	Transp. Costs	Total Costs	Surplus (Deficit)
			(All figures $000/yr)				
1	320.0	44.4	153.3	0.0	104.9	302.6	17.4
2	160.0	13.1	8.2	10.0	92.2	123.6	36.4
2A	160.0	0.0	24.0	10.0	92.2	126.2	33.8
2B	160.0	0.0	10.0	10.0	92.2	112.2	47.8
3	5 952.4	655.0	4 318.3	31.3	94.5	5 099.1	853.3

A project is economically viable if total revenue exceeds total cost.

Total evalutation summary when quarrying entirely for crushing stone

Option	Particulars	Capacity
1	Crushing stone	4 000 t/yr
2	Crushed granite	4 000 t/yr
2A	Site contract crushing	as needed
2B	Edmonton contract crushing	as needed
3	Agglomerated tile production	800 000 tiles/yr

Option	Total Revenue	Capital Costs	Oper. Costs	Mat'l Costs	Transp. Costs	Total Costs	Surplus (Deficit)
			(All figures $000/yr)				
1	0.0	44.4	163.3	0.0	0.0	207.7	(207.7)
2	320.0	13.1	14.4	207.7	184.4	419.6	(99.6)
2A	320.0	0.0	48.0	207.7	184.4	440.1	(120.1)
2B	320.0	0.0	20.0	207.7	184.4	412.3	(92.1)
3	5 952.4	655.0	4 318.3	117.6	94.4	5 275.4	677.0

A project is economically viable if total revenue exceeds total cost.

Product unit cost vs wholesale price summary during commercial block production

	FOB Quarry	Transport	Delivered Edmonton	Wholesale Edmonton
	($/t or $/tile)			
Rough commercial blocks	98.85	52.47	151.32	160.00
Crushed granite	15.65	46.11	61.76	80.00
Agglomerated granite tile	6.31	0.12	6.43	7.50

Block quarried cost = net quarrying costs ÷ production
$$= (\$153\ 300 + \$44\ 400) \div 2\ 000\ t$$
Block transport = average annual transportation cost/t
Crushed cost = granite cost/t + crushing cost/t
$$= \$5 + \$10.65$$
Crushed transport = least expensive (winter) transport
Tile cost = total manufacturing costs ÷ production
$$= \$5\ 004\ 600 \div 793\ 650\ tiles$$
Tile transport = (actual production weight x average annual transport cost/t) ÷ tile production
$$= (1\ 800\ t \times \$52.47) \div 793\ 500$$

A project is economically viable if the wholesale price exceeds delivered cost.

Product unit cost vs wholesale price summary for crushing stone production

	FOB Quarry	Transport	Delivered Edmonton	Wholesale Edmonton
	($/t or $/tile)			
Crushed granite	58.88	46.11	104.99	80.00
Agglomerated granite tile	6.53	0.12	6.65	7.50

Crushed cost = (capital costs + operating costs + material costs) ÷ production
$$= (\$13\ 100 + \$14\ 400 - \$207\ 700) \div 4\ 000\ t$$
Crushed transport = least expensive (winter) transport
Tile cost = total manufacturing costs ÷ production
$$= (\$655\ 000 + \$4\ 318\ 300 + \$207\ 700) \div 793\ 650\ tiles$$
Tile transport = (actual production weight x average annual transport cost/t) ÷ tile production
$$= (1\ 800\ t \times \$52.47) \div 793\ 650$$

A project is economically viable if the wholesale price exceeds delivered cost.

Discussion

The rare deep red color of the Fort Chipewyan Red Granite would make it an attractive addition to the world stone market. Its distance from markets, combined with the high costs dictated by a limited transportation infrastructure, requires that products made from this granite must command a premium price. The current efforts by two local companies to quarry commercial size blocks from the deposit suggest that such a price would be paid for dimension stone product. Figures from the economic model suggest that agglomerated granite tile also could be produced at a profit. Manufacture of the tile appears to be profitable both for using waste material from the quarrying of commercial blocks, and from quarrying the granite exclusively for tile production. Data from Table 1 suggest that sales of stone crushed from waste for poultry grit, landscape rock, concrete deck topping, and exposed aggregate concrete products also could be profitable, using the assumptions in the economic model. However, the markets are smaller than assumed in the model so using all the stone crushed from waste for manufacture of agglomerated granite tile is a much more profitable option.

The data in Table 1 also show that construction aggregates such as rubble and rip rap, concrete aggregate, asphalt aggregate, roadstone, and railroad ballast normally are high volume and low priced commodities that could not be sold at a profit using the assumptions in the economic model. However,the paucity of construction aggregate in northeast Alberta could dramatically alter the economics locally if there was a surge of resource development with its commensurate demand for roads and buildings.

Table 1. Consumption and selling prices of crushed stone

Product	Market (t)	$/t
Roofing granules	278 000 *	21.90
Poultry grit	1 000 *	90.00
Rubble and rip rap	588 000 *	6.60
Concrete aggregate	12 670 000 * *	5.60
Asphalt aggregate	7 339 000 * *	6.40
Roadstone	77 431 000 * *	5.25
Railroad ballast	817 000 * *	8.20
Landscape rock	200 * * *	65.00
Concrete deck aggregate	100 * * *	250.00
Exposed concrete aggregate	250 * * *	225.00

   * Canadian consumption (Vagt, 1993)
  ** Western provinces consumption (Vagt, 1993)
 *** Alberta consumption (Rogan, 1993)

Conclusions

1. An economic model to assess preliminary economics of quarrying granite near Fort Chipewyan has been constructed and tested using data from the literature. User data can be substituted for those currently contained on the disk with this report to obtain alternate economic assessments.

2. If an 800 000 tiles/year agglomerated tile plant could be built for $5 million and its tiles wholesaled for $7.50 each in Edmonton, the operation would be profitable in the growing granite tile market. Since raw material cost is only a small fraction of the tile cost, the difference between using granite crushed from waste of a commercial block operation and granite quarried exclusively for crushing stone is only about $0.22/tile. The operation using granite quarried solely for manufacturing agglomerated tiles would still be economically viable.

3. By selling the entire 2 000 t production of granite crushed from waste of a commercial block operation, current economic data

suggest a profit could be made by selling it for decorative landscape rock, concrete deck topping, poultry grit, and exposed aggregate concrete. However, available markets are smaller than the total production so using all the stone crushed from waste for manufacture of agglomerated granite tile is a much more profitable option..

4. By selling the 2 000 t of granite quarried exclusively for crushing stone remaining after satisfying the 2 000 t needs of an agglomerated granite tile plant, current economic data suggest a profit could be made only by selling it for concrete deck topping and exposed aggregate concrete. Available markets are considerably smaller than the total production so only a small inventory in excess of the needs of the tile plant should be produced.

5. The known paucity of common construction aggregate in northeastern Alberta suggests that a study of the local economics of using crushed granite as aggregate has merit. Possible metallic resource development on the Canadian Shield northeast of Fort Chipewyan or new production activity in the oil sands east of Fort McKay would require large volumes of aggregate for roads and buildings.

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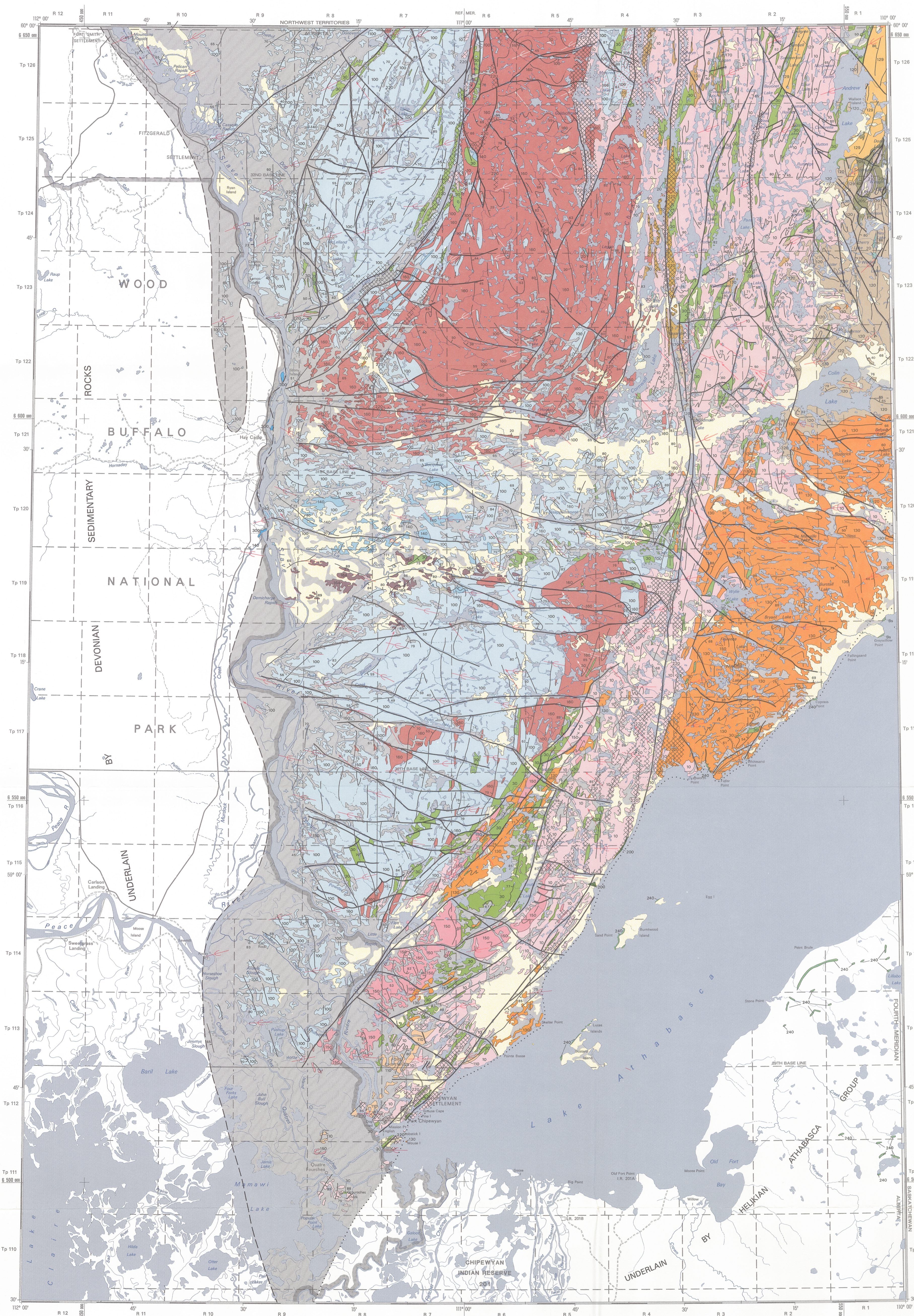
LEGEND

PHANEROZOIC

300 DEVONIAN CARBONATES: a basal regolith grades upwards through poorly sorted conglomerate, arkosic and pebbly sandstone, to sandy dolostone. Overlying strata successively include: rubbly to massive bedded, vuggy, sandy and argillaceous dolostone and dolomitic limestone, gypsiferous, argillaceous, bioclastic, fossiliferous limestone with shale laminations.

HELIKIAN

240 ATHABASCA GROUP: hematite-stained, flaggy to rubbly bedded wacke with pebble bands. Locally includes rubble. South of Lake Athabasca, well indurated, medium-grained subitharenite, locally pebbly, planar crossbedded and quartz overgrowth cemented.

9a Underlain in part by a saprolite on the crystalline basement; intense hematization, fractures and quartz veinlets.

APHEBIAN

210 WAUGH LAKE GROUP (low-grade metavolcanic rocks): greenstone and amphibolite derived from basalt, gabbro and possibly tuff.

205 WAUGH LAKE GROUP (low-grade metasedimentary rocks): quartzite with subordinate biotite chlorite schist, phyllite, phyllonite; locally ferruginous, garnetiferous, graphitic, with quartz-tourmaline veins.

200 BURNTWOOD GROUP (low-grade metasedimentary rocks): arkosic sandstone with pebble bands interbedded with subordinate phyllonitic chloritic argillite.

RECRYSTALLIZED MYLONITIC ROCKS: zones of regional shearing and recrystallization have produced: ultramylonite, mylonite, blastomylonite, and flaser gneiss; locally contains rounded or augen rock clasts or feldspar porphyroclasts. Matrix may be foliated to gneissose, or massive.

160 ARCH LAKE GRANITOIDS*: granite, typically with subhedral to augen, tabular feldspar megacrysts (10 to 30 mm long) in a medium-grained, well-foliated, crushed matrix that includes blue quartz. Locally gradational to Slave Granitoids.

155 ARCH LAKE GRANITOIDS; FRANCIS GRANITE PHASE: pink tabular feldspar megacrysts (25 to 35 mm long) in a medium-grained typically massive matrix.

150 CHIPEWYAN RED GRANITE: equigranular, medium-grained, massive to poorly foliated, locally aplitoid; minor pegmatites and quartz veins.

140 LA BUTTE GRANODIORITE: generally medium gray with feldspar megacrysts (8 to 20 mm long) in a medium-grained matrix.

130 WYLIE LAKE GRANITOIDS: dominated by granodiorite and quartz diorite. Granodiorite is typically equigranular with a medium-grained, poorly foliated to massive matrix. Quartz diorite is light gray, typically with megacrystic feldspars (5 to 10 mm long) in a medium-grained matrix; poorly foliated locally massive or gneissic. Schlieren of biotite concentrations or metasedimentary rocks are present locally.

135 COLIN LAKE GRANITOIDS: lithologies in this group range from granite to quartz diorite and are gradational in character. Feldspar megacryst (ranging from 3 to 10 to 15 to 40 mm long) are in a biotite-rich, well-foliated, quartz-feldspar matrix. Minor aplo-pegmatite masses accompany all of the lithologies.

129 COLIN LAKE GRANITOIDS; ANDREW LAKE GRANITE PHASE: white to gray feldspar megacrysts (10 to 15 mm long) in a foliated matrix. Subordinate aplo-pegmatite patches and dykes are characteristic.

110 THESIS LAKE GRANITE: typically dark with up to 10 percent red to pink megacrystic augen feldspars (6 to 13 mm long) in a medium-grained matrix that includes blue gray quartz; subordinate quartzo-feldspathic aplo-pegmatitic pods, patches and dykes.

100 SLAVE GRANITOIDS: typically whitish gray granite, with feldspar megacrysts (10 to 50 mm long) and abundant mafic knots of garnet in a biotite envelope 5 ± mm across within a medium-grained, massive to poorly foliated matrix. Minor inclusions, patches and lenses of metasedimentary rock, aplo-pegmatite dykes, and quartz veins.

108 SLAVE GRANITOIDS; RAISIN GRANITE PHASE: mottled appearance with abundant white to pink to red rounded to sub-rounded augen feldspars (2 to 6 mm long) in a sheared foliated matrix of lenticular quartz, feldspar, (chloritic) biotite, sericite, and minor epidote.

ARCHEAN

120 CHARLES LAKE GRANITOIDS: a wide range of lithologies is represented in this group. Megacrystic granite has subhedral feldspars (25 to 100 mm long) in a coarse-grained, massive to poorly foliated matrix, with local minor aplo-pegmatite masses. Gray Hornblende Granite is buff to gray with dark specks of hornblende and local feldspar megacrysts (5 to 10 mm long) in a fine- to medium-grained, massive to slightly foliated matrix. Locally well-foliated and equigranular. Leucocratic Granite is equigranular, medium- to coarse-grained, massive to locally foliated, with up to 3 percent mafic minerals.

300 HIGH-GRADE METASEDIMENTARY ROCKS: rock types in this unit are lithologically and texturally gradational. Typically dark greenish gray quartzite is interlayered with subordinate biotite-chlorite-sericite schist and has ferruginous, garnetiferous and graphitic zones, locally scattered pyrite, gossans, and milky quartz pods. Common variations are: (1) metamorphic quartzo-feldspathic phases; (2) retrograde phyllite and schist biotite, chlorite, sericite, and uncommonly hornblende) and phyllonite; (3) minor amphibolite.

20 AMPHIBOLITE: typically medium-grained, biotite common; composition ranges from hornblende pure or rich to a feldspathic biotite amphibolite; commonly foliated or gneissic; minor pyrite common. Note: Some younger amphibolites are included.

10 GRANITE GNEISS: typically pink to reddish, fine- to medium-grained, equigranular, feldspar, quartz, biotite, hornblende composition. Migmatitic where associated with metasedimentary rocks, pegmatite, or amphibolite.

*Nomenclature of granitoids follows Streckeisen (1967): Classification and nomenclature of igneous rocks; Neues Jahrbuch für Mineralogie, Abhandlungen, 107, No. 2, pp. 144–240.

Map unit boundary . . . .
Erosional limit of Athabasca Group . . . .
Inferred edge of Phanerozoic rocks . . . .
General foliation and gneissosity, with dip . . . .
Fault . . . .
Glacial striae . . . .
Wind-cut groove . . . .
Sand . . . .
Muskeg . . . .
Drainage . . . .
Township boundary . . . .
National Park boundary . . . .
Road . . . .

Approximate magnetic declination 25°26' East in 1986 decreasing approximately 4.2' annually for the centre of the map area.

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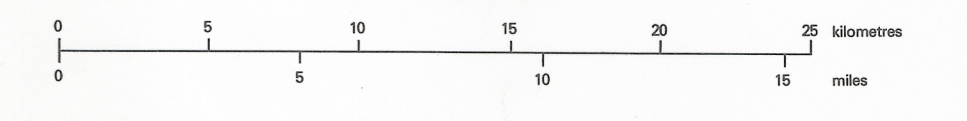
CORRELATION OF ROCK UNITS BETWEEN THIS MAP AND DISTRICT MAPS

| MAP DESIGNATIONS (THIS MAP)	DISTRICT MAP DESIGNATIONS (SEE REFERENCES)		MAP DESIGNATIONS (THIS MAP)	DISTRICT MAP DESIGNATIONS (SEE REFERENCES)	
300 Devonian Carbonates	254 La Butte Fm.	252 Fitzgerald Fm.	120 Colin Lake Granitoids	128 Granite Pegmatite	125 Biotite Granite
	253 Hay Camp Fm.	251 La Loche Fm.		127 Sheared Leucocratic Granite	124 Biotite Granite D
240 Athabasca Group	240 Athabasca Group			126 Leucocratic Granite	123 Quartz Diorite; Biotite Granite C; Biotite Microgranite
210 Waugh Lake Group: low-grade metavolcanic rocks	210 Basic rocks		129 Colin Lake Granitoids; Andrew Lake Granite Phase	121 Biotite Granite A	122 Biotite Granite B
205 Waugh Lake Group: low-grade metasedimentary rocks	202 Quartzite, Biotite Schist, Sericitic	203 porphyroclastic phyllonite	110 Thesis Lake Granite	110 Thesis Lake Granite	
200 Burntwood Group: low-grade metasedimentary	201 Arkosic sandstone, argillite		100 Slave Granitoids	105 Slave PQ Granite	102 Mafic Slave Granite
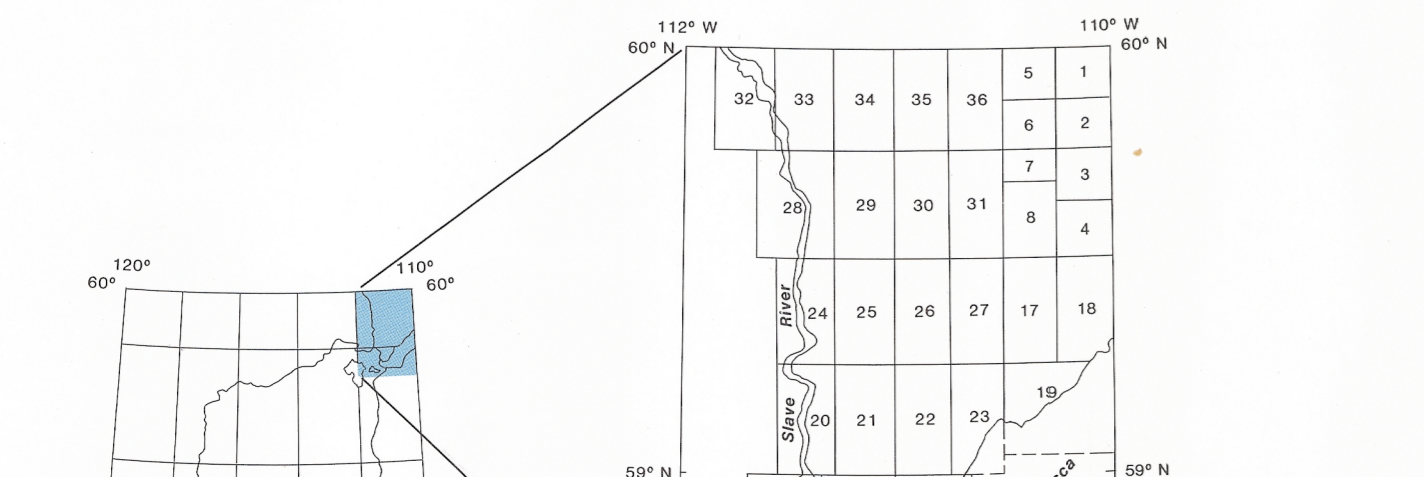
Section II Capital Costs

Total capital for each operation is estimated from the
equipment list and annual capital charges are calculated
using the capital recovery factor. User can change the list
and cost data, when appropriate.

II.1 Capital Equipment to Quarry Blocks or Crushing Stone

Equipment Capital

Quant.	Equipment	Unit Price	Total
2	Blast Hole Drilling Rigs	40,000	80,000
1	D-7 Dozer	70,000	70,000
1	Wheeled Loader (3-4 cu.yd.)	80,000	80,000
1	Compressor (350 CFM)	36,000	36,000
1	Tandem Dump Truck (used)	20,000	20,000
1	Pickup Truck	20,000	20,000
1	Air Tank	2,500	2,500
2	Fuel Tanks with Stands	750	1,500
1	Small Drills	6,000	6,000
1	Tools	10,000	10,000
1	Electrical Generator	1,500	1,500
1	Office Trailer	2,000	2,000

```
                                         -------   -------
                                                   329,500
           Freight Charges                           9,500
                                                   -------
           Total Capital                  $339,000  (to Table IV.1)

           Yearly Quarrying Capital Charges   $44,570  (to Table IV.2)
              = Total Capital x Capital Recovery Factor
```

II.2 Capital Equipment to Crush

A. Equipment Capital

Quant.	Equipment	Unit Price	Total
1	35 t/hr Crusher with 2 deck screen	35000	35,000
1	2 Deck Screen plus Conveyor	20000	20,000
4	Conveyors	10000	40,000

```
                                         -------   -------
                                                    95,000
           Freight                                   5,000
```

```
                                 -------
        Total Capital                           $100,000  (to Table IV.1)


        Yearly Crushing Capital Charges          $13,147  (to Table IV.2)
            = Total Capital x Capital Recovery Factor



   B.   Capital Cost to Contract Crush Waste or Crushing Stone
        at Quarry                                    $0  (to Table IV.1)

   C.   Capital Cost to Contract Crush Waste or Crushing Stone
        at Edmonton                                  $0  (to Table IV.1)


II.3 Capital Cost for Agglomerated Tile Plant

Initial estimate: $ 5 MM for a 800,000 tile /yr plant
                  Operating and finishing cost at $ 5/tile
                  (Mervyn Rogan, 1993)

Capital Investment:                       5,000  K$         (to Table IV.1)


        Yearly Quarrying Capital Charges        $657,369  (to Table IV.2)
            = Total Capital x Capital Recovery Factor



        To go to Section IV, press alt c.



Section III Operating Costs

III.1 Operating Costs to Quarry Blocks or Crushing Stone

                                                       K$/yr       K$/yr
                                                       -----       -----
        Maintenance (% Equip. Capital)            2.0%      6.8
        Fuel ($/day)                             50.0      12.5
        Labor
                        No.        $/hr      hr/yr
                        ---        ----      ----
        Foreman                  1     21.00    2000.0      42.0
        Drill Operators          2     18.00    2000.0      72.0
        Loader Operator          1     15.00    2000.0      30.0
                                                           -----
                                                           163.3
     - By product Credit

        Waste granite FOB Quarry               5.00  $/tonne    -10.0
                                                           -----
     Operating Costs to Quarry Blocks
        if Waste Sold to Crushing Operation (to Table IV.2)     153.3


III.2 A. Operating Costs to Crush Waste at Quarry

        Capacity of Crusher              30 t/hr
```

```
                or                      240 t/day
           Max Capacity           60000 t/yr

      Granite to Crusher            2000 tonnes

      Days of Crusher
           Operation                8.3  days
                                                  K$/yr    K$/yr
                                                  -----    -----
      Maintenance (% Equip. Capital)       2.0%     2.0
      Fuel ($/t)                           2.0      4.0
      Labor
                    No.      $/hr      hr/yr
                    ---      ----      ----
      Operators       2     16.50      66.7      2.2
                                                  -----
                                  (to Table IV.2)          8.2

   B. Operating Costs to Contract Crush Waste or Crushing Stone
      at Quarry
                                                           K$/yr
      Contract Price            $12.00  /t
      Quantity                   2000 t
                                                           -----
      Cost = Price x Quantity        (to Table IV.2)        24.0


   C. Operating Costs to Contract Crush Waste or Crushing Stone
      at Edmonton
                                                           K$/yr
      Contract Price             $5.00  /t
      Quantity                   2000 t
                                                           -----
      Cost = Price x Quantity        (to Table IV.2)        10.0


III.3 Operating Costs for Agglomerated Tile Plant       K$/yr    K$/yr
                                                        -----    -----
      Finishing                    5.00  /tile        3964.8

      General and Administration                         250

      Marketing and Selling Expenses                     100
                                       (to Table IV.2)          4314.8




III.4 Granite Material Costs

                                                           K$/yr
                                                           -----
      1. Granite Material Cost for Quarry    (to Table IV.2)      0.0

      2. Granite Material Cost to the Crusher

         It depends on the mode of Operation.
```

For mode of operation 1: Waste granite is a
byproduct of the block operation. It is levied
a nominal charge of $5.00 /t

Production   2000 t

Cost to the Crusher   (to Table IV.2)   10.0

For mode of operation 2: Quarrying solely for
crushed granite. Quarrying cost is charged to
the crushing operation.

Cost to Crusher   (to Table IV.2)   N/A

Note: The cost will the same for contract crushing.

3. Granite Material Cost to the Agglomerated Tile Plant

It is the value of the crushed granite after the
crushing operation.
It is the sum of capital charges, operating cost and
material cost from Table IV.2 - Option 2 or 2A,
whichever is lower. From this, the cost per tonne
is calculated. The plant requires 2000 t/yr.
        Option 2   15.7 $/t x 2000 t
        Option 2A   17.0 $/t x 2000 t

                               (to Table IV.2)   31.3

III.5 Transportation Costs

Currently the only overland route, from the south, to the
Fort Chipewyan area is the winter road from Fort McKay that
usually is available between December and March. Material can
be loaded onto a truck at the quarry in winter and continue to
Edmonton via Fort McKay. Summer traffic is by barge to Fort
McMurray then by truck, or the more expensive rail, to Edmonton.
The $ 17/t winter truck rate to Fort McKay is a special winter
backhaul rate.

                                                    $/tonne

Basis: Weight of Block   23 tonne
          Quarry to River   10 $/Block   0.44
          Crane Charges   30 $/Block   1.30

          Summer Barge Transport to Ft. McMurray   28.00
          Winter Transport to Ft. McKay   17.00
          Summer/Winter Truck to Edmonton   26.50

                     Blocks/Crushed Granite
                     ======================
                          Summer   Winter
From Quarry to Edmonton   Barge   Road
-----------------------   ------   ------
                           ($/t)   ($/t)

```
   Quarry to River                    0.44
   Load to Barge                      1.30
   Barge to Ft McMurray              28.00
   Unload from Barge to Truck         1.30

   Quarry to Truck                                 1.30
   Truck to Ft McMurray                           17.00

   Truck Ft McMurray to Edm          26.50        26.50
   Unloading at Edmonton              1.30         1.30
                                    -------      -------
   Total Transport Cost ($/t)        58.85        46.11


   Average Year Round Transport Cost ($/t)               52.48

   -------------------------------------------------------------
                                                          K$/yr
                                                          -----
A. Transportation Costs for Commercial Blocks

   Average Transport Cost is used ($/t)      52.48

   Production (t/yr)                          2000
                                                        -------
                                      (to Table IV.2)    105.0

B. Transportation Costs for Crushed Stone from Waste or
   Crushing Stone

   The Lower Winter Rate is used ($/t)       46.11

   Production (t/yr)                          2000
                                                        -------
                                      (to Table IV.2)     92.2

C. Transportation Costs for Agglomerated Tiles

   Average Transport Cost is used ($/t)      52.48

   Production (t/yr)                          1800
                                                        -------
                                      (to Table IV.2)     94.5
```