THE QUARTZITE BUILDING STONE INDUSTRY OF THE RAFT RIVER AND GROUSE CREEK MOUNTAINS, BOX ELDER COUNTY, UTAH

by
Bryce T. Tripp
Utah Geological Survey

Special Study 84 **1994**
UTAH GEOLOGICAL SURVEY
a division of
UTAH DEPARTMENT OF NATURAL RESOURCES
in cooperation with
DEPARTMENT OF COMMUNITY AND ECONOMIC DEVELOPMENT

Tripp THE QUARTZITE BUILDING STONE INDUSTRY OF RAFT RIVER AND GROUSE CREEK MOUNTAINS Utah Geological Survey Special Study 84

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COVER PHOTOGRAPH - White Elba Quartzite stone veneer on east end of the Boy Scouts of America Building, 525 South Foothill Boulevard, Salt Lake City, Utah.

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THE QUARTZITE BUILDING STONE INDUSTRY OF THE RAFT RIVER AND GROUSE CREEK MOUNTAINS, BOX ELDER COUNTY, UTAH

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ABSTRACT

A well-established building stone industry exists in the Raft River - Grouse Creek Mountains area of Box Elder County, Utah. Six companies mine micaceous quartzite and mica-quartz schist flagstone and ashlar from some of the 29 quarries in the area. A high percentage of the flagstone ranges from 1/4 to 2 inches (0.6 to 5 cm) thick. Stone colors include white, light grey, dark grey, gold, and light green, all with varying degrees of micaceous surface sheen and decorative iron staining along fractures and in irregular bands. Quarry employees hand split the rock and sort it according to split thickness, color, and size of slab. The Precambrian (Proterozoic) Elba Quartzite and the Cambrian (?) quartzite of Clarks Basin provide most of the stone. The desirable thin layering of the stone is due to metamorphic schistosity formed during middle Mesozoic metamorphism and development of the Raft River - Grouse Creek metamorphic core complex. Stone masons use the stone primarily for veneering walls and paving floors, walkways, and pool decks. Stone producers market stone from this area to dealers nationwide. Recent industry innovations such as the manufacture of stone tile should expand the market for this material.

INTRODUCTION

Background and Purpose

An important but little known stone industry has existed in the Raft River - Grouse Creek Mountains area of Box Elder County, Utah (figure 1) since the mid-1950s. Quarry operators mine micaceous quartzite and mica-quartz schist from Precambrian and Cambrian metamorphic rocks exposed in the area. All of this stone is referred to as "quartzite" in the stone trade and that convention will be used here for brevity. The quartzite is an uncommon variety of stone due to its very thin layering, very flat parting surfaces, distinctive appearance, and durability. It sells for a premium over other competing stone types. The premium price allows the stone to be shipped long distances profitably. The same stone units quarried in Utah also crop out across the state line in Idaho. Similar stone is quarried in Maryland, USA and Norway, Sweden, South Africa, India, Brazil, and China. Operations generally are small, shallow open pits. Few explosives are used and heavy equipment is typically used only for overburden removal; the actual mining of the stone

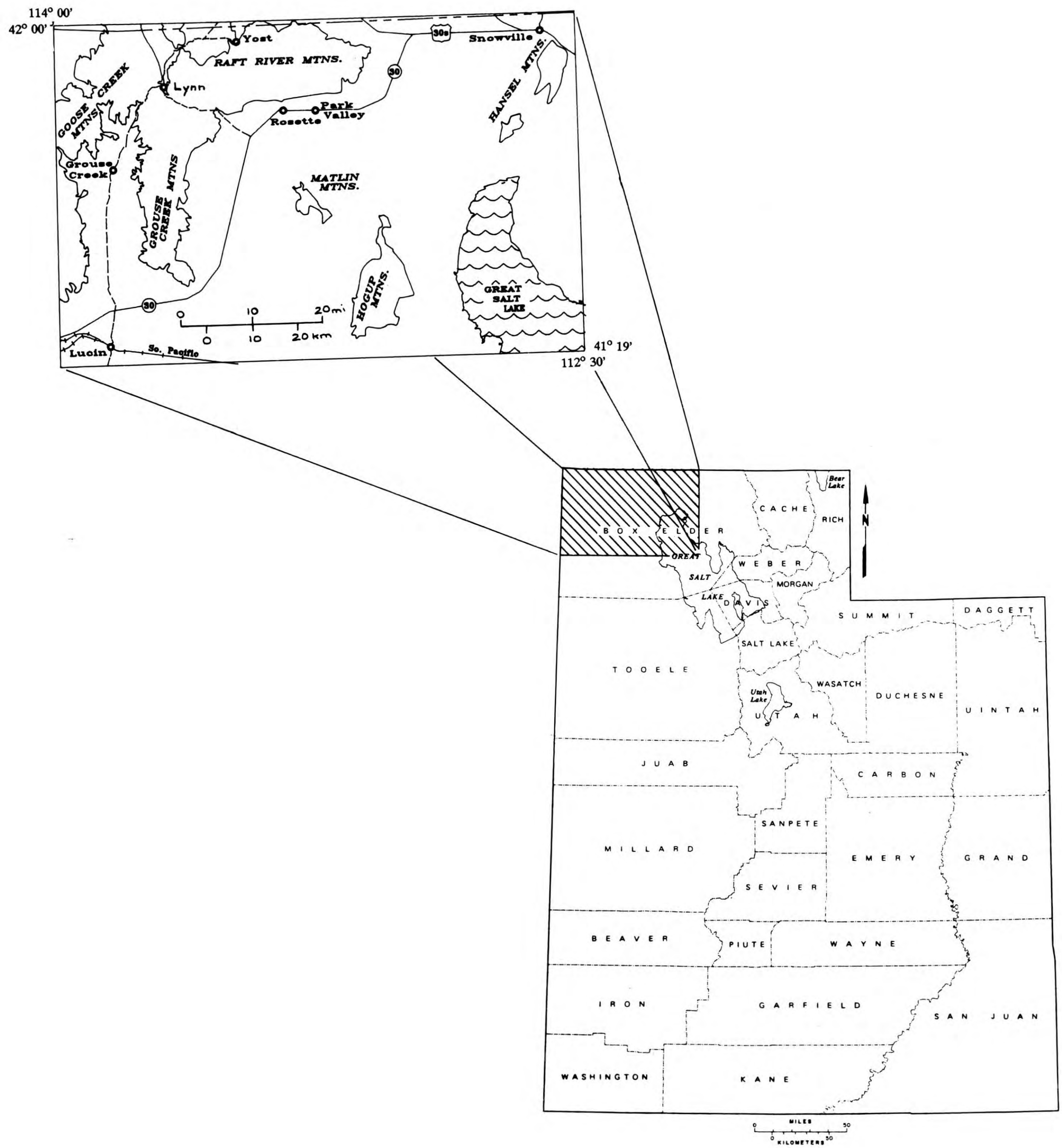

Figure 1. *Location of the quartzite building stone study area, Box Elder County, Utah.*

is very labor intensive. Laborers manually split and sort flagstone, veneer stone, and ashlar by size, shape, and color. Individual quarries often produce several categories of stone. Operators market the stone through their own retail stone yards, through wholesaling to other operator\dealers, and through brokers. Operators ship quartzite to stone dealers nationwide. Increased sales reflect a recent international increase in dimension stone demand.

Despite a long history of production and a currently expanding market, little has been written about the Utah quartzite building stone industry. This special study presents the history and current (1993) status of the quartzite building stone industry in Box Elder County. Funding for this study came, in part, from the Utah Department of Community and Economic Development (DCED); this work is part of a DCED-funded project to compile a Utah dimension stone catalog which was published in April (*Utah Stone*; Tripp, 1993) as a full-color brochure of Utah building stone with examples of their use. Improved knowledge of the stone deposits and industry of Box Elder County should: (1) allow land-use planners to balance stone extraction against other land-use actions, (2) enable the Utah Geological Survey (UGS) to provide better information to out-of-state stone buyers, and (3) help Utah promote its building stone industry.

Scope of Work

This report complements the *Utah Stone* brochure by providing stone producers, land-use planners, and potential stone buyers with detailed information on the quartzite building stone industry of the Raft River - Grouse Creek Mountains area of Box Elder County. It gives an overview of current stone producers, quarries, and quarry geology of the micaceous quartzite and mica-quartz schist operations. The study consisted of a field examination and sampling of distinct stone types at each known, accessible quarry in the study area. Some important aspects of stone occurrences were not addressed due to time limitations and lack of adequate exposures. Additional study is needed to determine variations in stone quality with respect to stratigraphic position and geographic location. Also, the exact role of metamorphism and tectonism in producing favorable foliation and fracturing is poorly understood. Consequently, a regional exploration model for additional sources of high-quality stone can not be constructed based solely upon the work completed to date. Additional study of the quartzite is merited. Although there is a large resource of stone remaining at existing quarries, additional sites containing easily mineable stone with thin layering and unusual color characteristics could be profitable.

REGIONAL GEOLOGY

The Raft River - Grouse Creek Mountains area contains some of Utah's most complex geology and has been studied by many geologists. Geoscientists involved in mapping and interpreting this difficult terrain include Felix (1956), Compton (1972, 1975, 1980, 1983), Todd (1973, 1980, 1983), Doelling and others (1980), and Snoke and Miller (1988) (figure 2).

Rocks exposed in the study area range in age from Archean (rocks older than 2.5 billion years) to Tertiary (rocks 66 to 1.6 million years old), but tectonic thinning and erosion eliminated as much as 9,000 feet (2,743 m) of the Paleozoic stratigraphic section (rocks 570 to 240 million years old) and most of the Mesozoic section (rocks 240 to 66 million years old) (figure 3). Most of the quartzite produced comes from the Elba Quartzite (figure 4) of Proterozoic age (rocks 2.5 billion to 570 million years old), and the quartzite of Clarks Basin (figure 5) of Cambrian (?) age (rocks 570 to 505 million years old). The Proterozoic quartzite of Yost is mined at one small quarry. Doelling and others (1980) describe the productive units as follows:

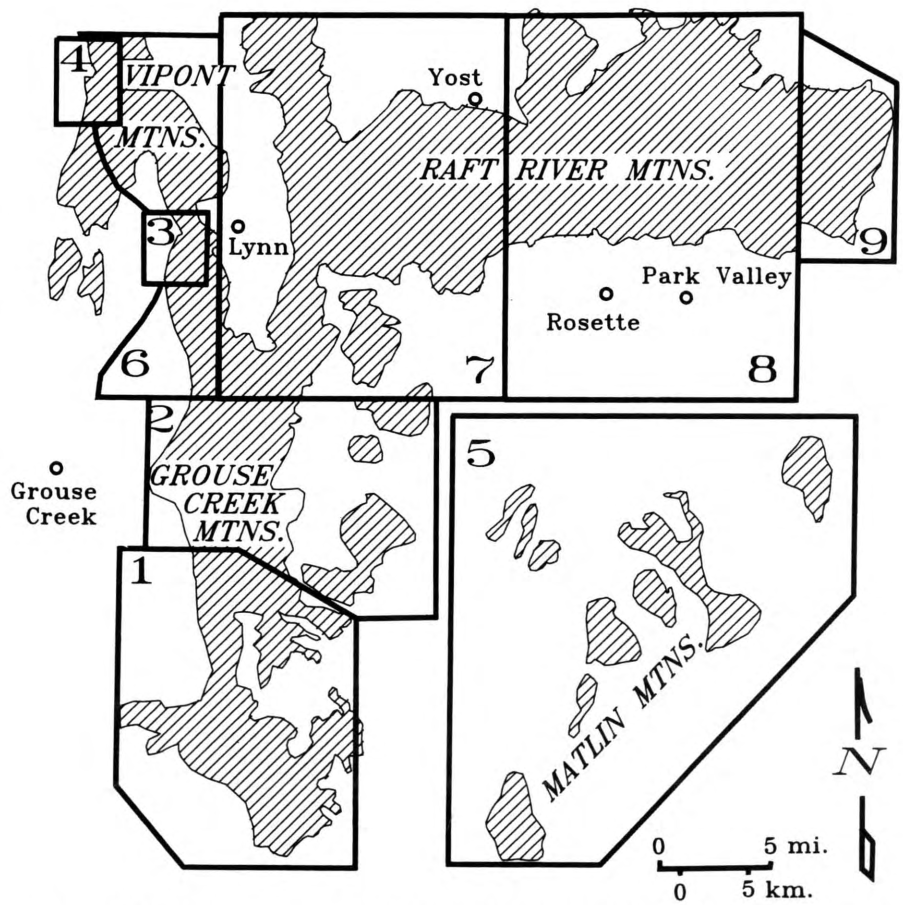

Figure 2. Geologic map coverage of the Raft River-Grouse Creek Mountains. Areas 1, 3, 4=Compton (1983), 2 =Todd (1973), 5=Todd (1983), 6=Doelling (1975), 7=Compton (1972), 8=Compton (1975), and 9=Stanford University (1967). Only the latest mapping at the largest scale is shown (after Compton, 1983).

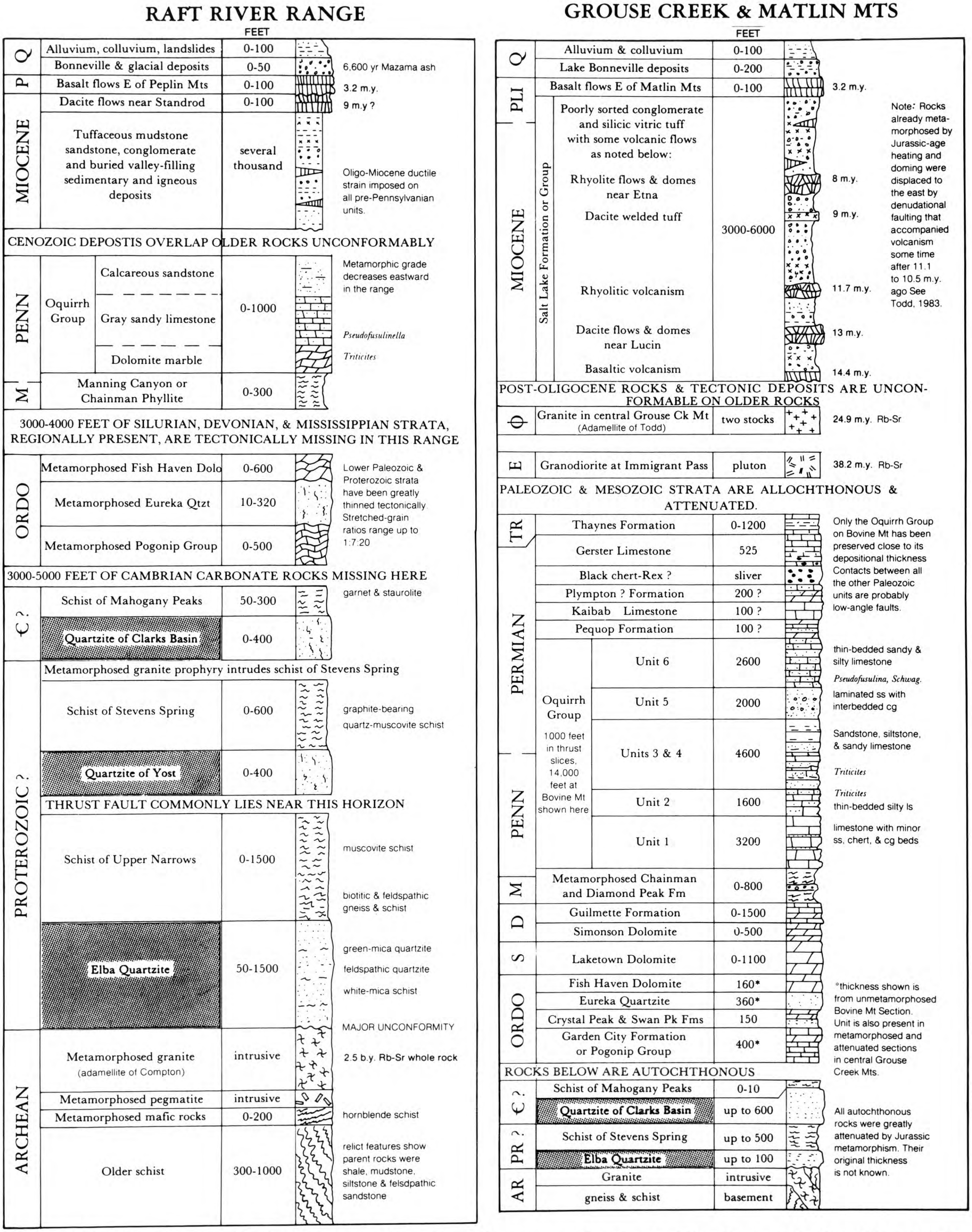

Figure 3. *Stratigraphic sections for the Raft River and Grouse Creek Mountains, northwestern Box Elder County, Utah. Quartzite-producing formations are shaded. After Hintze (1988).*

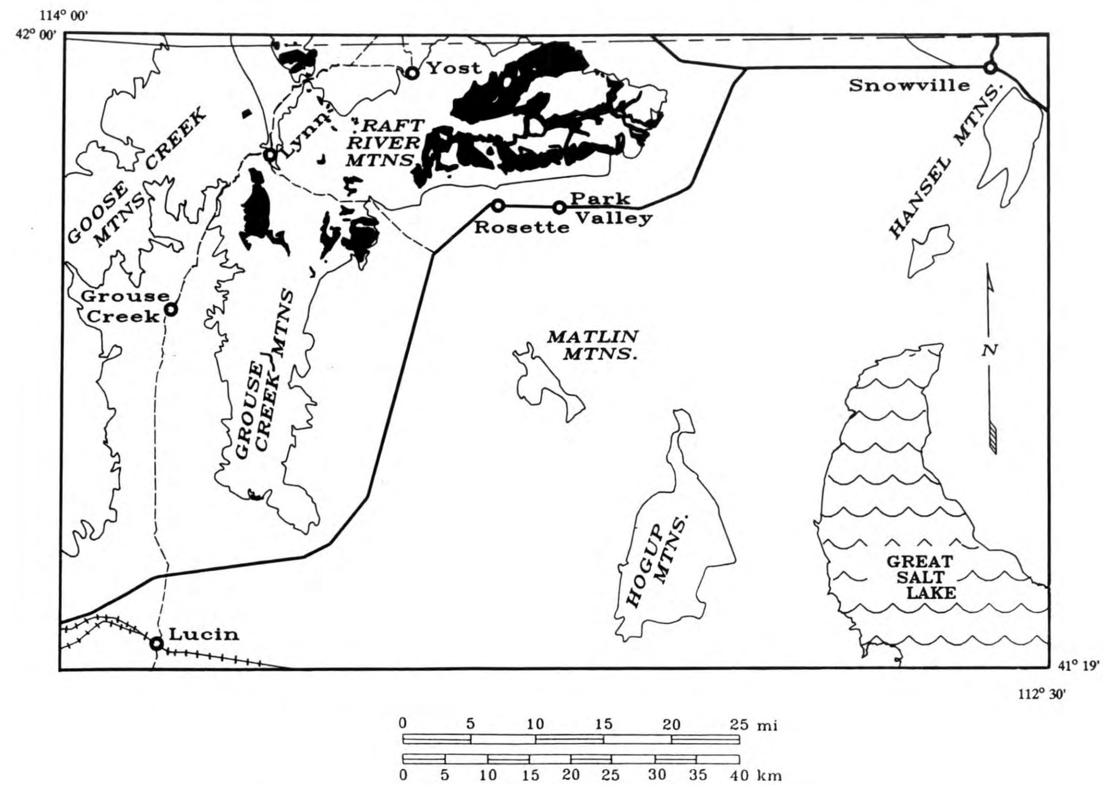

Figure 4. *Outcrops of the Precambrian Elba Quartzite (in black), northwestern Box Elder County, Utah. Outcrop pattern from Doelling and others (1980).*

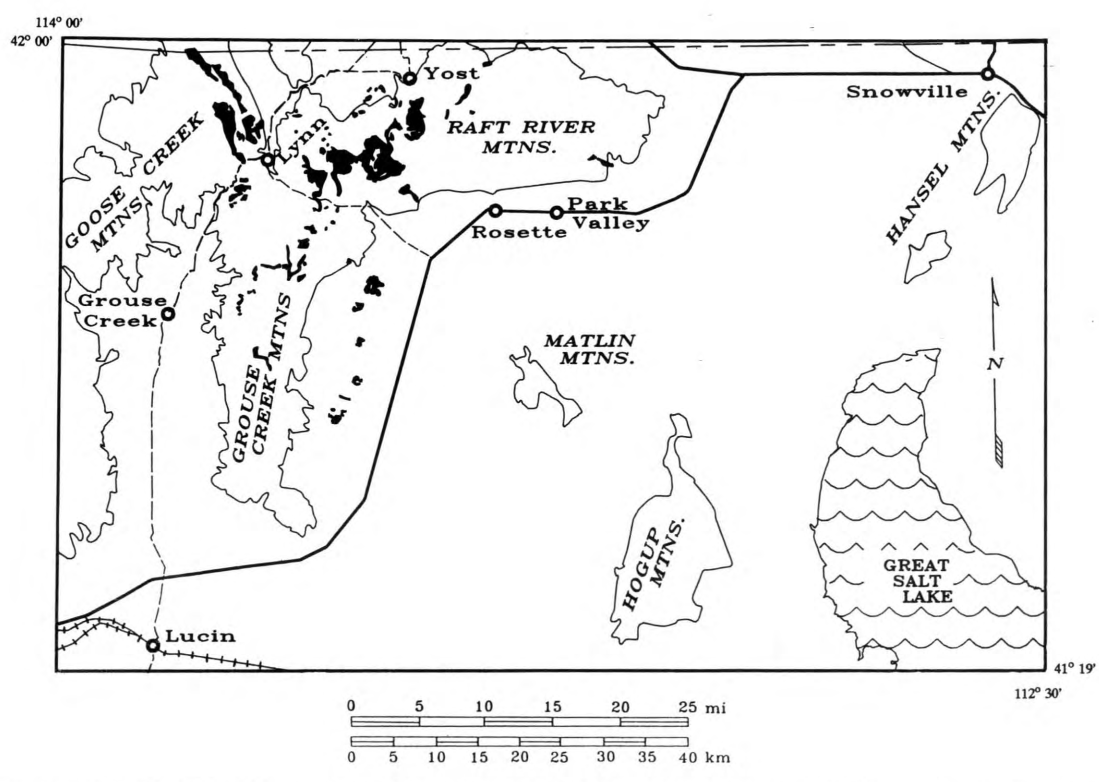

Figure 5. *Outcrops of the Cambrian (?) quartzite of Clarks Basin (in black), northwestern Box Elder County, Utah. Outcrop pattern from Doelling and others (1980).*

Elba Quartzite - lenticular and variable in lithology and ranges in thickness from 50 to 1,500 feet (15 to 457 m), averaging 500 feet (152 m). Typically the unit is white, tan, or in places green micaceous quartzite that is especially well displayed on the flanks of the Raft River Range. The bedding is thin to thick, some beds are cross-bedded, and muscovite-quartz schist forms thin partings between some of the beds. There are a number of quartzite pebble conglomerate beds as well. In the eastern part of the Raft River Mountains the Elba Quartzite has a lens-shaped, fine-grained mica-feldspar-quartz schist member up to 600 feet (183 m) thick in the middle.

Quartzite of Clarks Basin - about 400 to 600 feet (122 to 183 m) thick, mostly thin bedded with white micaceous partings. The lowermost strata appear to interfinger with Precambrian rocks.

Quartzite of Yost - outcrops ... are restricted to smaller areas in the western Raft River Range and in the Dove Creek Mountains. The formation ranges from 0 to 400 feet (0 to 122 m) thick and pinches to the southwest. The quartzite is mostly white, thin-bedded, and contains sparse to moderate amounts of muscovite mica. In local areas, such as in the Upper Narrows of the Raft River in the Dove Creek Mountains, there are beds of green, chromium mica-bearing quartzite. In some areas the quartzite contains up to 10 percent feldspar and small quartzite pebbles.

The chromium mica mentioned by Doelling and others (1980) also occurs at numerous places in the Elba Quartzite. A sample taken in section 18, T. 13 N., R. 13 W. contained 555 ppm chromium.

The thin layering of the quartzite building stone is due to the effects of middle to late Mesozoic metamorphism in the Raft River - Grouse Creek area. The heat and pressure of metamorphism altered and recrystallized the minerals in the sediments, originally deposited more than 500 million years ago, causing a planar orientation of minerals. Quartz and mica tended to segregate into alternating tabular layers. Such a tabular arrangement of minerals is termed schistosity; it permits splitting into sheets, a desirable characteristic for building stone. The quartzite building stone in which these alternating layers are well developed is called mica-quartz schist. Quartzite containing less mica and having a less well-developed layering is called micaceous quartzite.

An understanding of variations in degree of metamorphism in the area helps to predict where commercial-quality stone might occur. The rock units of the area can be roughly "lumped" into four groups: a very old core group of rocks overlain by three successively younger, thick "sheets" of rocks that slid independently over the old, central core rocks. The uppermost sheet is unmetamorphosed; the middle sheet is locally metamorphosed with metamorphic grade increasing downward and the lowest sheet and the core rocks are metamorphosed with grade increasing downward (Compton and others, 1977). Two of the sources of quartzite building stone; the Elba Quartzite and the quartzite of Yost are restricted to the core rocks while the quartzite of Clarks Basin is found both in the core rocks and in the lowest sheet. Metamorphic grade also changes laterally, with low-grade metamorphism in the southern Grouse Creek Mountains and eastern Raft River Range and higher metamorphic grade near the junction of the two mountain ranges (Snoke and Miller, 1988). The stone quarries are probably clustered in the area of the junction because the better-developed metamorphic fabric yields thinner, more uniform stone slabs. The locations of the quarries are plotted on figure 6; precise locations, and other site-specific quarry information are contained in table 1. Local variations in metamorphism, folding and fracturing, and the composition of the precursor sandstones affect stone quality. More detailed information on metamorphism in the Raft River - Grouse Creek area is contained in Compton and others (1977), Coney (1980), and Snoke and Miller (1988).

CHARACTERISTICS OF BOX ELDER COUNTY QUARTZITE BUILDING STONE

The "quartzites" of Box Elder County possess desirable qualities for building stone, including low porosity, low permeability, high compressive and flexural strength, good hardness, and good slip resistance. There is wide variation in stone color, surface color patterns and sheen, smoothness of split surfaces, splitting thickness, and size of slabs. Different combinations of these characteristics yield a wide range of marketable "quartzite" varieties. Low porosity and permeability is indicated by a 0.38 percent water absorption determined by ASTM test C-97 (Rocktile Specialty Products Inc., 1992). The low absorption value means that the stone is resistant to freeze-thaw damage, is unlikely to suffer from surface coatings of dissolved minerals, and will resist stains from oil in paving applications. The high compressive strength [20,000 - 50,000 psi (137,900 - 344,750 kPa), ASTM C-170] and high flexural strength [3,696 psi (25,480 kPa), ASTM C-99] (Idaho Quartzite Corp., 1987) makes the stone durable in transit and suitable for heavy pedestrian traffic and occasional vehicular traffic. This great strength also means that thinner slabs can be used in these applications as compared to other weaker stone types. A hardness of 6-7 (Mohs scale) (Idaho Quartzite Corp., 1987) translates into a very durable, maintenance-free surface even in high traffic paving applications. The slight roughness of the stone ((0.71 coefficient of friction) (Idaho Quartzite Corp., 1987)) provides good slip resistance, an important feature for paving around swimming pools and on stairs. Stone colors include white, light grey, charcoal grey, sage green, and light to medium bluish green. The bulk of the stone mined from the quartzite of Clarks Basin is white. Lesser amounts of light-grey and charcoal-grey stone are also mined. A light-sage-green stone is mined from the quartzite of Clarks Basin at the Rosebud Creek quarry (quarry 20 of figure 6) and at the Green Beetle quarry (quarry 19 of figure 6). Color of the stone in the Elba Quartzite is predominantly white with isolated pockets of a light- to medium-bluish-green stone. Five quarries (23, 25, 26, 27, and 29 of figure 6) contain this unusual green stone and additional undeveloped bodies of green stone occur elsewhere in the Raft River Range. Considerable variation in surface sheen and coloration modify

Table 1. *Quartzite building stone quarries and prospects, Box Elder County, Utah*

QUARTZITE OF CLARKS BASIN QUARRIES

LOCATION NO.	QUARRY NAME	TWN.	RNG.	SEC.	OPERATOR	STATUS\SIZE[1]
1	STARLIGHT STONE	014N	017W	NE1/4SE1/4NE1/4, 21	STATE STONE	ACTIVE \ LARGE
2	HOLT BASIN EAST	014N	017W	NE1/4NW1/4SE1/4, 22	STATE STONE	ACTIVE \ SMALL
3	AMERICAN STONE NORTH	014N	017W	NE1/4NW1/4NE1/4, 28	AMERICAN STONE	ACTIVE \ LARGE
4	RIDGE CREST	014N	017W	SE1/4NW1/4NE1/4, 28	DON AND KEITH NELSON	INACTIVE \ LARGE
5	AMERICAN STONE SOUTH	014N	017W	SW1/4NE1/4SE1/4, 33	AMERICAN STONE	INACTIVE \ SMALL
6	SOUTH HOLT BASIN (POLE CREEK)	014N	017W	SE1/4NW1/4SE1/4, 34	STATE STONE	ACTIVE \ LARGE
7	BASIN CREEK GORGE	013N	017W	NE1/4SE1/4SE1/4, 04	UNKNOWN	INACTIVE \ MEDIUM
8	LYNN PASS	013N	017W	SW1/4SW1/4SE1/4, 03	UNKNOWN	INACTIVE \ MEDIUM
9	LOWER BASIN CREEK	013N	017W	SE1/4SW1/4SE1/4, 02	DON AND KEITH NELSON	INTERMITTENT \ MEDIUM
10	UPPER NARROWS	014N	016W	SE1/4SE1/4SE1/4, 08	UTAH BUILDING STONE SUPPLY	ACTIVE \ SMALL
11	LYNN CREEK	014N	016W	NE1/4NE1/4NW1/4, 29	UTAH BUILDING STONE SUPPLY	ACTIVE \ MEDIUM
12	PINE SPRING	013N	016W	NE1/4NW1/4SW1/4, 01	STONE ART CO.	INACTIVE \ SMALL
13	SOUTH CLARKS BASIN	013N	016W	SW1/4SE1/4NW1/4, 14	UTAH BUILDING STONE SUPPLY	ACTIVE \ MEDIUM
14	GOLD SHEEN QUARTZITE	013N	016W	NE1/4NW1/4NE1/4, 23	UTAH BUILDING STONE SUPPLY	ACTIVE \ MEDIUM
15	CLARKS BASIN CREEK SW	013N	016W	NW1/4NE1/4SE1/4, 23	IMPERIAL STONE	ACTIVE \ LARGE
16	DOVE CREEK PASS	013N	016W	NW1/4SW1/4SW1/4, 22	MR. PICKET	INTERMITTENT \ MEDIUM
17	UPPER BLACK HILLS CREEK	013N	015W	NE1/4NE1/4SW1/4, 23	IMPERIAL STONE	INACTIVE \ SMALL
18	BLACK HILLS QUARTZITE	013N	015W	SE1/4SW1/4NE1/4, 23	IMPERIAL STONE	ACTIVE \ MEDIUM
19	GREEN BEETLE	011N	016W	SE1/4,SE1/4, 36	UTAH BUILDING STONE SUPPLY	ACTIVE\ SMALL
20	ROSEBUD CREEK (LAZY GREEN)	010N	016W	SE1/4SE1/4SE1/4, 02	NORTHERN STONE SUPPLY	ACTIVE \ SMALL
21	ROSEBUD RIDGE	010N	016W	NE1/4SE1/4SW1/4, 11	UTAH BUILDING STONE SUPPLY	INTERMITTENT \ SMALL

ELBA QUARTZITE QUARRIES

LOCATION NO.	QUARRY NAME	TWN.	RNG.	SEC.	OPERATOR	STATUS\SIZE[1]
22	BLM COMMUNITY PIT	013N	017W	23, 25, 26	U.S. BUREAU OF LAND MGT.	INTERMITTENT \ SMALL
23	ROCK CANYON (TURQUOISE)	013N	013W	NE1/4SE1/4NW1/4, 18	NORTHERN STONE SUPPLY	ACTIVE \ LARGE
24	UPPER FISHER CREEK	013N	013W	NE1/4SE1/4NW1/4, 08	UTAH BUILDING STONE SUPPLY	ACTIVE \ MEDIUM
25	LOWER FISHER CREEK	013N	013W	NW1/4SW1/4SE1/4, 08	UTAH BUILDING STONE SUPPLY	ACTIVE \ LARGE
26	LEFT FORK DUNN CANYON	013N	013W	SE1/4SE1/4SE1/4, 09	AMERICAN STONE	INACTIVE? \ SMALL
27	RIGHT FORK DUNN CANYON	013N	013W	SE1/4SE1/4SW1/4, 10	AMERICAN STONE	INACTIVE? \ SMALL
28	UPPER INDIAN CREEK	013N	012W	SE1/4SW1/4SW1/4, 05	UNKNOWN	INACTIVE? \ SMALL
29	LOWER INDIAN CREEK	013N	012W	SE1/4SW1/4, 05	UNKNOWN	INACTIVE? \ SMALL

[1] Quarry size refers to the total estimated volume of all pits and prospects at a property. The quarries were grouped into three categories: LARGE - >10,000 cu. yd. (7,650 m^3), MEDIUM - > 2,000 cu. yds. (1,530 m^3) and < 10,000 cu. yds. (7,650 m^3), and SMALL < 2,000 cu. yds (1,530 m^3). The volume estimate can not be used to calculate stone production since the quarry volume was only roughly estimated and amount of excavation due to overburden, waste, and produced stone was not determined.

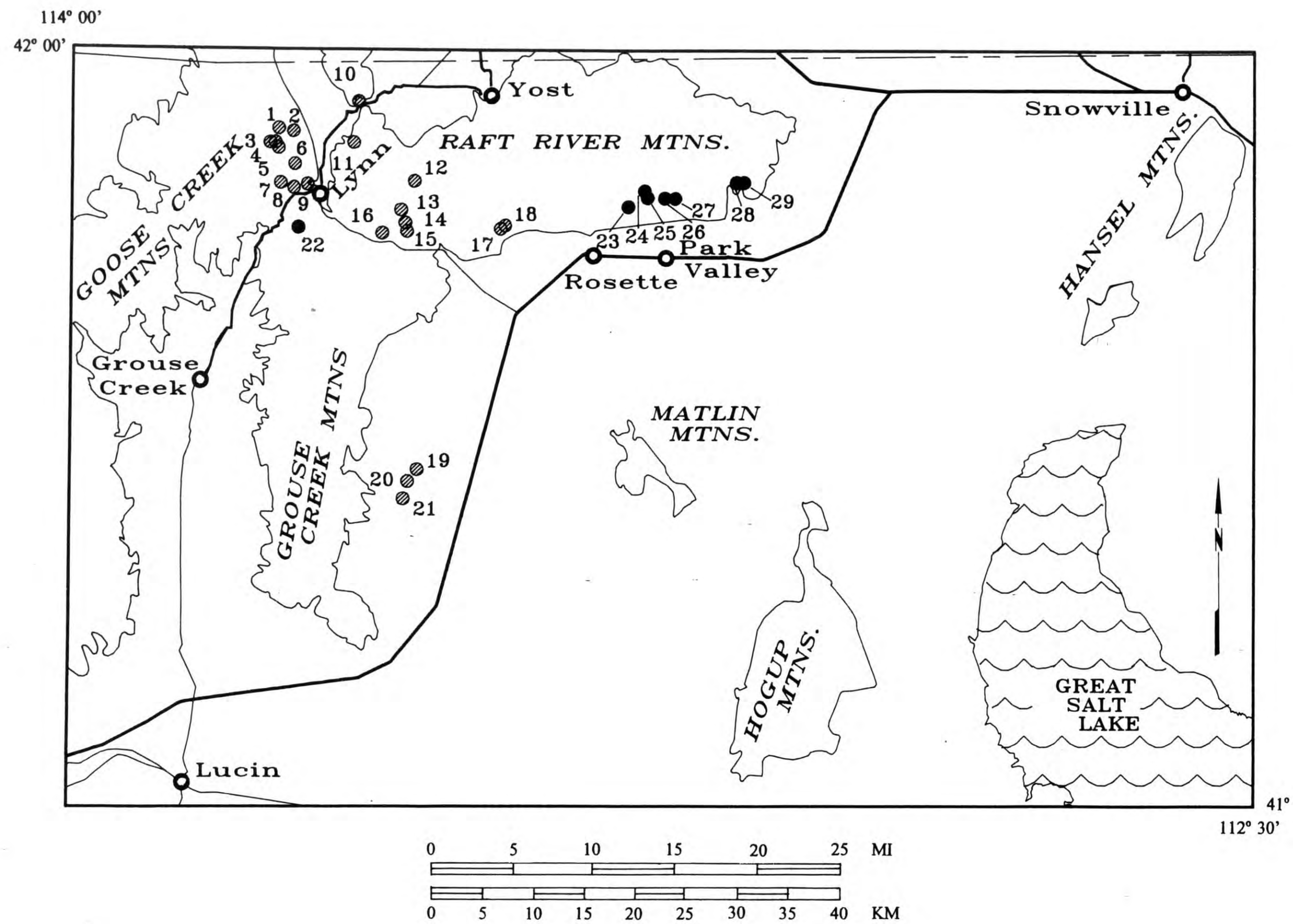

***Figure 6.** Location of quartzite quarries, northwestern Box Elder County, Utah. Quarries in the Elba Quartzite are shown as solid black dots. Quarries in the quartzite of Clarks Basin are shown as grey dots. Quarry numbers are keyed to table 1.*

the basic stone colors in both the quartzite of Clarks Basin and the Elba Quartzite. Variable amounts of mica on the parting surfaces and different amounts of iron staining create an infinite range of colors from orange to brown to bronze with varying degrees of sheen. Iron staining can be uniform to concentrically banded or concentrated along fracture planes. Split stone surfaces vary from somewhat rough to very smooth. The Elba Quartzite has a higher percentage of stone with significant surface roughness while the quartzite of Clarks Basin is generally much smoother. In an extreme example, a slab 5 by 9 feet (1.5 by 2.7 m) from the Rosebud Creek quarry (quarry 19 of figure 6) had an estimated surface relief of only about 1/8 inch (0.3 cm). The quartzite in all three formations splits into slabs ranging in thickness from 1/4 to 9 inches (0.6 to 23 cm) or greater. The quartzite of Clarks Basin generally splits into thinner sheets than the Elba Quartzite. Thin stone slabs are desirable since a ton of thin stone will veneer or pave a larger area than a ton of thick stone, effectively lowering shipping costs. Thin slabs are also very valuable since they can be cut into tile most economically. A substantial amount of stone at many of the quarries splits to 2 inches (5 cm) or less, the desirable thickness range for paving and building veneer. An informal stone classification used by the local industry is shown below:

Thickness Range (inches/cm)	**Informal Designation**	**Coverage PerTon** (sq ft/sq m)
¼ - ¾ / 0.64 - 1.9	"Slate"	250 / 23
¾ - 1¼ / 1.9 - 3.2	"Patio"	150 / 14
1¼ - 2 / 3.2 - 5.1	"Stepping Stone"	110 / 10

Other non-quartzite veneer stones, used nationally, cover only about 60 square feet (5.6 sq m) or less per ton. Thin veneer stone is a premium product because it is less expensive to ship and is easier for stone masons to install.

Fracture patterns vary from quarry to quarry, but some generalizations can be drawn. Closely spaced fractures, perpendicular to the foliation planes, are almost universally present. In many quarries two sets of these fractures cut the stone at 60° to 90° angles to each other and are spaced from 2 to 6 feet (0.6 to 1.8 m) apart. Depth of penetration of the fractures is variable. At the Starlight quarry (quarry 1 of figure 6) many fractures penetrate the whole 40-foot (15 m) quarried interval. At the Rosebud Creek quarry (quarry 20 of figure 6) the fracture pattern is more widely spaced, more irregular, and fractures tend to terminate at shallow depths in mica layers (M. Cooper, quarry operator, personal communication, 1991).

Table 2.
Directory of stone companies who are currently quarrying Utah quartzite or who process and market Utah quartzite.

STONE PRODUCERS

American Stone and Building, Inc.
Attn. Lon Thomas
4040 South 300 West
Murray, Utah 84107
(801) 262-4300

Imperial Stone Company
Attn. James C. Petersen
P.O. Box 298
Clarkston, Utah 84305
(801) 563-9086

Northern Stone Supply, Inc.
Attn. Gary Mullard
Box 249
Oakley, Idaho 83346
(208) 862-3353

Stone Art Company
Attn. John D. Hechtle
2100 West Center
Provo, Utah 84601
(801) 373-0719

State Stone Corp., Inc.
Attn. Keith P. Mackay
4640 South 300 West
Salt Lake City, Utah 84107
(801) 262-9323

Utah Building Stone Supply
Attn. Preston Bown
707 South 950 West
Woods Cross, Utah
(801) 295-0601

Don, Keith, and Curtis Nelson
RT3 Box 247
Burley, Idaho 83318

QUARTZITE TILE MANUFACTURERS

Idaho Quartzite Corp.
Attn. Bill Hamm
311 4th Street, North Extension
Nampa, Idaho 83687
(208) 466-3550

Rocktile Specialty Products Inc.
Attn. Kenneth V. Franklin
220 South Avenue A
Boise, Idaho 83702
(208) 342-7700

QUARTZITE BUILDING STONE INDUSTRY IN UTAH

Marketing efforts by stone producers expanded the Utah quartzite business from initial local sales in 1948 to national exposure by the mid-1950s, to an international business by the mid-1970s. Three large building stone companies and numerous smaller ones are active in the quartzite industry in Utah (table 2). Recent shipments of stone have gone to such distant locations as Hawaii, Japan, Fiji, and Europe. One recent large construction project was the Hilton Hawaiian Village where 170,000 square feet (15,800 sq m) of Utah and Idaho quartzite was used for sidewalks and pool decking (Idaho Quartzite Corp., 1987).

Only sparse information is available on the stone companies operating in the region. Maley (1985) provides the only detailed information on the quartzite industry. He performed a market study of Northern Stone Supply (one of the larger quartzite companies) which gives some insights into the industry as a whole. Northern Stone Supply, a long-time Idaho quartzite producer, expanded their operations into Utah by buying the Rock Canyon quarry (quarry 23 of figure 6) from Glen Fuller and the Rosebud Creek quarry (quarry 20 of figure 6) from Max Cooper. The following summary describing Northern Stone Supply was largely extracted from Maley (1985). Northern paid contractors by the ton to quarry "slate" sized slabs. Northern relied on foreign laborers due to a lack of experienced local labor. Marketing, promotion, road and quarry maintenance, and development costs were about equal to labor costs. Production of this "slate" accounted for about 60 percent of Northern's production, the balance being "patio" stone, "stepping" stone, and ashlar. The average retail price of this stone in 1985 at stone yards in six western cities was $324 per ton. The quartzite was marketed primarily on the west coast and in the Rocky Mountain states.

The number of dealers per state, who distributed Northern's quartzite in 1985, is as follows:

Alaska	3	Montana	6
California	17	Nebraska	2
Colorado	3	Nevada	6
Florida	3	New Jersey	1
Idaho	8	New Mexico	1
Illinois	1	Oregon	9
Indiana	1	Pennsylvania	1
Kansas	2	Utah	3
Michigan	2	Washington	10
Minnesota	2	Wisconsin	1

Northern also shipped sizable quantities of stone to Canada and Europe. Northern's annual production increased steadily as shown below:

Year	Production (short tons)	Year	Production (short tons)
1974	1,300	1980	5,300
1975	2,200	1981	6,100
1976	2,700	1982	4,500
1977	3,625	1983	5,000 (est.)
1978	4,725	1984	5,000 (est.)
1979	no data		

The Utah quartzite industry has grown steadily, although interrupted by periodic building industry recessions. The outlook for the future is positive; quartzite production should increase through more aggressive marketing, especially of quartzite tile.

Uses of Utah Quartzite Building Stone

Box Elder County quartzite quarry operators market quartzite primarily for residential and commercial building material. Landscaping and various other ornamental uses consume a smaller amount of stone.

Stone masons use this stone primarily as a decorative veneer over load-bearing walls and for paving material. The most common quartzite veneering method involves applying the quartzite with the foliation surface paralleling the wall. The stone can be in irregular polygon shapes, as it comes from the quarry, or sawed into regular rectangular shapes. Figures 7 through 10 show examples of veneer stone used on Salt Lake City buildings. A second method is to lay thick, blocky, brick-

Figure 7. *Stone veneer at Olympus High School, 4055 South 2300 East, Salt Lake City, Utah. Veneer stone is mixed sandstone and quartzite laid in a "planking" pattern.*

Figure 8. *Close-up of stone veneer at Olympus High School.*

Figure 9. *Stone veneer at the ZCMI building (Cottonwood Mall), 4835 South Highland Drive, Holladay, Utah.*

Figure 10. *Close-up of veneer stone at ZCMI building.*

Figure 11. *Typical quartzite ashlar.*

Figure 12. *An ashlar-faced office building, 637 East 400 South, Salt Lake City, Utah.*

Figure 13. *Close-up of crushed Elba Quartzite used in precast panels on a building, 530 East 400 South, Salt Lake City, Utah. Individual "chunks" average 3 inches (8 cm) in diameter.*

Figure 14. *Quartzite tile flooring used in a bank in El Paso, Texas. Photograph courtesy of Idaho Quartzite Corporation.*

Figure 15. Landscape granules of Elba Quartzite used on a parking strip, 2925 South Melbourne Street, Salt Lake City, Utah. Individual granules are 1/4 inch (6 mm) in diameter.

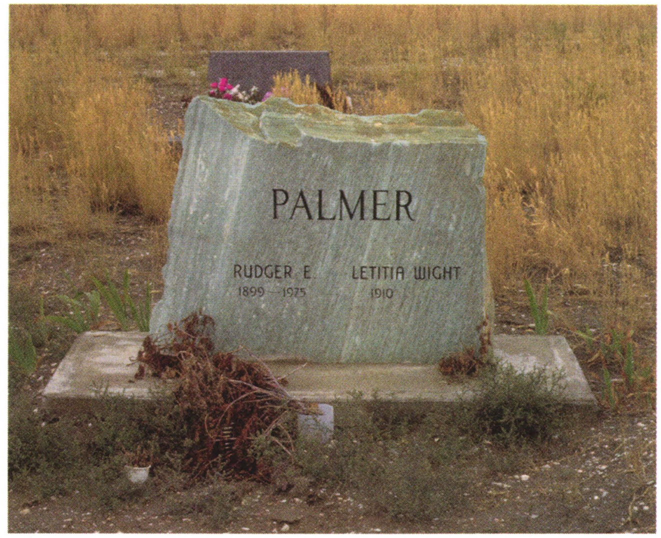

Figure 16. Quartzite used as a cemetary monument in Park Valley Cemetary, Box Elder County, Utah.

Figure 17. A typical, small quartzite quarrying operation, the Rosebud Creek (Lazy Green) quarry (quarry 19 of figure 6).

Figure 18. Small stone slabs stacked horizontally on a pallet.

Figure 19. Large, thin sheets of quartzite stacked vertically in shipping crates to prevent breakage during shipping.

like pieces of quartzite (figures 11 and 12) with foliation planes perpendicular to the wall. Stone laid in this manner is called ashlar. Still another method uses quartzite slabs or granules as veneer on concrete panels which are cast either at a plant or on site then attached to the building frame (figure 13). Stone masons also use thin slabs of quartzite for interior and exterior paving of building floors (figure 14), sidewalks, patios, and swimming pool decks. The stone is laid with the foliation surface parallel to the ground in a bed of mortar, usually over a concrete slab. In the past, masons used mostly polygonal rock slabs as they came from the quarry, however the trend is now toward the use of rectangular sawed tiles. Rocktile Specialty Products Inc., State Stone Corp., and Idaho Quartzite Corp. have produced sawed quartzite stone tiles. Quartzite tile retails for roughly \$9-\$11 per square foot (\$97- \$118 per m^2). Stone producers have also investigated grinding down (or gauging) the backs of quartzite slabs to create a flat stone tile of uniform thickness. Sawing and gauging should help quartzite stone dealers capture some of the large granite or marble tile and ceramic tile business.

Landscapers utilize quartzite for decorative granules, decorative boulders, and stepping stones. At least one operator, Northern Stone Supply, crushes quartzite at their quarry (quarry 23 of figure 6) and sells it for landscape granules. The granules are typically installed over a polyethylene sheet, in areas such as parking strips (figure 15), creating an attractive, low-maintenance area. Landscapers also incorporate large quartzite boulders for decorations in flower beds and gardens. Quartzite finds additional landscape use as stepping stones which are stone slabs thick enough to be laid directly on soil, creating walkways through gardens or across high traffic areas of lawns.

Utah quartzite is used in smaller quantities for a variety of miscellaneous uses. Figure 16 shows a cemetery monument made of quartzite. Quartzite is seldom used in this role; granite and marble dominate the monument business. One reason that quartzite has not been traditionally used is its extreme hardness; it is difficult to saw and engrave. Recent advances in diamond rock cutting equipment could minimize this problem. Box Elder County quartzites could be made into extremely durable, attractive headstones. Selected pieces of green Elba Quartzite have been cut, polished, and sold as the semi-precious gemstone chrome aventurine (or green aventurine). Jewelers shape these stones into convex disks called cabochons sized to fit rings and necklaces. Stone operators also market some quartzite as decorative stone for home aquariums.

Mining Methods

The bulk of the quartzite production in Box Elder County comes from surface quarrying with a smaller amount of stone collected from the extensive amounts of "float" which blanket areas of the Raft River and Grouse Creek Mountains. Workers often use heavy equipment, such as backhoes and bulldozers, to remove shallow overburden during exploration and quarry preparation and to clear waste rock during quarrying. The actual production of the stone, however, is a very labor-intensive process. Workers employ pry bars, chisels, and hammers to split the stone (figure 17). The stone is then hand sorted according to color, thickness, and slab size. Small, thicker slabs are stacked horizontally on pallets (figure 18) while larger, thinner, fragile sheets are placed vertically on end in pallets with wooden sides (figure 19). A pallet typically contains 3,500 pounds (1,590 kg) of stone. Stone is stored at the quarry site and eventually loaded by forklift onto trucks to be hauled to market. Explosives are seldom used since the bulk of the stone is easy to remove and explosives can damage the stone. Explosives appear to have been used at quarries 23 and 24 (figure 6). These quarries are in the Elba Quartzite which, in general, does not split as cleanly as the quartzite of Clarks Basin. Stone workers also gather substantial amounts of float stone. In this method, a four-wheel drive truck is driven along secondary roads or cross-county and selected slabs of stone are collected. Much of this surface float has variable orange and brown oxidized iron staining on the surfaces.

Current Issues

An important question currently facing the Box Elder County quartzite stone industry is whether the quartzite building stone is an "uncommon" variety and therefore subject to claim and patent under mining law or a "common" variety for which mineral producers must pay the federal government. If quartzite is found to be a common variety, production at some of the quarries may cease due to the increased cost. The definition of what constitutes an uncommon variety was established in McClarty vs. Secretary of the Interior, 408 F.2d 907, 906 (9th Cir. 1969). The decision outlines several criteria to be applied when deciding if a commodity is an uncommon variety: (1) there must be a comparison of the mineral deposit in question with other deposits of such minerals generally, (2) the mineral deposit in question must have a unique property, (3) the unique property must give the deposit a distinct and special value, (4) if the special value is for uses to which ordinary varieties of the mineral are put, the deposit must have some distinct and special value for such use; and, (5) the distinct and special value must be reflected by the higher price which the material commands in the market place. Also the "special economic value of a deposit, due to a unique property, might be based on reduced costs or overhead resulting in a greater margin of profit" (Parnell, 1990). Maley's 1985 study for the U.S. Bureau of Land Management (USBLM) established that the quartzite building stone at one quarry site in Idaho met all of the criteria for an "uncommon" variety and therefore was claimable and patentable. In 1990, the U.S. Forest Service (USFS) reinterpreted existing mining law and precedence setting lawsuits to modify their regulations concerning mineral disposal on Forest Service land. In modifying 36 CFR Part 228, the USFS decided that the only building stone that is "uncommon" is stone which is suitable for structural (or load-bearing) use in construction, a use that is now nearly non-existent. However, Roland Robison, former Utah state director of the USBLM, opposed the Forest Service decision in a 1988 letter to F. Dale Robertson, the Chief of the U.S. Forest Service. Mr. Robison questioned the USFS interpretation of mining law and even if USFS had jurisdiction since by prior agreement the USBLM administers locatable minerals even on Forest lands. As of August, 1993 the two agencies still interpreted the locatability of building stone differently.

SUMMARY AND CONCLUSIONS

Six companies mine several varieties of an unusual quartzite building stone from Precambrian and Cambrian rocks of Box Elder County and ship it to most states and several foreign countries. This little publicized industry has grown steadily since the 1950s due to the desirability of the stone that they produce. Micaceous quartzite from the Elba Quartzite and mica-quartz schist from the quartzite of Clarks Basin were altered and recrystallized by middle Mesozoic metamorphism and endowed with desirable qualities for premium building stone. The quartzite has the following characteristics: it splits into large, thin sheets that are relatively inexpensive to ship and easy to install; it is durable due to its strength, hardness, and impermeability; and it occurs in a range of colors with varying degrees of micaceous surface sheen and decorative iron staining along fractures and in irregular bands. The best quality building stone is found where the rock is most metamorphosed. These rocks occur along the contact between Cambrian and Precambrian rocks especially near the junction of the Raft River and Grouse Creek Mountains. Mining of quartzite is very labor intensive; machinery is used to remove overburden but splitting and extraction of the stone is done manually. Workers use pry bars, hammers, and chisels to separate the stone slabs. The stone is then sorted according to color, thickness, and slab size. Thin slabs are widely used for building veneer and paving. Large thin sheets are especially valuable since they are suitable for cutting into tile. Thick blocky chunks are less expensive and are used for ashlar building veneer.

The quartzite industry of Box Elder County has a bright future for several reasons: (1) the market for quartzite is expanding, (2) the trend toward sawing the quartzite into tile is making it more competitive with granite and marble and with ceramic tile, and (3) stronger, better capitalized companies have bought out or formed joint ventures with smaller companies. Three factors which could negatively affect the industry are difficulty of finding skilled help in this labor-intensive business; competition from foreign quartzite dealers (Europe, India, China, and Brazil); and government regulations exempting this stone from claim under federal mining law.

ACKNOWLEDGMENTS

A large number of industry and non-industry people were very helpful during the study. Industry personnel spent substantial amounts of time answering questions and providing company literature. They include (in alphabetical order): Preston Bown, Hugh Buchanan, Max Cooper, Ken Franklin, Glen Fuller, Ernie Hale, Bill Hamm, Keith Mackay, Gary Mullard, and Don Seehusen. Doug Bauer, Terry Maley, and Daniel Washington of the U.S. Bureau of Land Management were also helpful. Mr. Bauer provided information pertaining to the Forest Service regulations on disposal of building stone from Forest Service lands. Mr. Maley provided a copy of the mineral land appraisal report that he wrote on the Northern Stone Supply claims. Mr. Washington provided access to an unpublished BLM map showing stone claim locations. Reviews by the following people greatly improved this report: Glen Fuller; Gary Mullard of Northern Stone Supply; Harold Taylor of the U.S. Bureau of Mines; and Bob Blackett, Mike Shubat, Bob Gloyn, and Bill Lund all of the Utah Geological Survey. Additionally, thanks are due to Brigham Young University for permission to use an illustration from Hintze (1988) in figure 3 and to Idaho Quartzite for permission to use their photograph for figure 14. Financial support from the Utah Department of Community and Economic Development is appreciated.

GLOSSARY*

Ashlar - Rectangular pieces of stone of uniform or non-uniform size that are set in regular or uneven courses or laid randomly in a wall.

Archean - The time period during which earth's oldest rocks were emplaced; more than 2.5 billion years ago.

Cambrian - The oldest of the periods of the Paleozoic Era, currently defined as the time period from 570 to 500 million years ago.

Dimension Stone - Natural stone which is split, sawed, or trimmed to specified or indicated shapes or sizes, with or without one or more mechanically dressed surfaces.

Flagstone - A rock that splits naturally into tabular pieces ranging in thickness from roughly 0.4 to 2 inches (1 to 5 cm). The rock may split along bedding planes or along foliation planes.

Float - Fragments of stone covering the hillsides below outcropping beds of the same stone.

Foliation - A general term for a planar arrangement of textural or structural features in any type of rock, especially the planar structure that results from flattening of the constituent grains of a metamorphic rock.

Mesozoic -The third youngest era into which geologic time is divided (as recorded by the stratified rocks of earth's crust). This era is currently defined as the time from 240 to 66 million years ago.

Micaceous Quartzite - A metamorphic rock composed of tightly interlocked quartz grains with small amounts of mica segregated into irregular, thin, parallel layers.

Mica-Quartz Schist - A medium- or coarse-grained metamorphic rock with subparallel orientation of its constituent minerals which are segregated into discrete layers. Quartz is the dominant mineral with smaller amounts of mica present.

Precambrian - The period of geologic time before the Paleozoic Era; currently defined as the period from the origin of the earth to 570 million years ago. Contains Proterozoic and Archean eons.

Proterozoic - The youngest geological time eon of Precambrian time; currently defined as the time from 2.5 billion to 570 million years ago.

Veneer Stone - A thin decorative layer of stone applied over a load-bearing wall.

** Definitions derived in part from Bates and Jackson (1987), Palmer (1983), Power (1983), and Thrush (1968).*

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APPENDIX A

Detailed descriptions of Box Elder County quartzite quarries. The quarry numbers correspond to the numbering system used in table 1 and figure 6.

Location 1. Starlight Stone Quarry. The quarry is roughly 450 by 300 feet (137 by 91 m) with a maximum depth of 70 feet (21 m) (figure A1). It was active in the fall of 1991. Several buildings at the quarry site house workers. The operators have been stripping increasing amounts of overburden because the deposit dips gently into the hillside. As much as 35 feet (11 m) of overburden have been stripped to expose the 40-foot-thick (12 m) ore body. Foliation planes (N. 80° W., 08° SW.) are closely spaced and uniform. A high percentage of the stone is in the 1/4 to 3/4 inch (0.6 to 1.9 cm) thickness range. Vertical fractures cut the stone at 2- to 3-foot-intervals (0.6-0.9 m). Some fractures parallel the quarry face and aid quarrying. Rock slabs measuring 2 by 3 feet (0.6 to 0.9 m) are common. The majority of the stone is a light silvery yellowish orange and is sold under the trade name "Klondike Gold." The quarry produces smaller amounts of silvery-white and silvery-light-grey stone. The top few feet of quartzite are weathered; the next interval is a silvery-white stone, and the lowest is a gold stone which comprises the bulk of the deposit. In 1991, the white and grey stones were in vogue, but the quarry operator reported that the gold stone has had the best long-term demand. Stone from this quarry wholesaled for roughly $130 per ton FOB quarry in 1992.

Location 2. Holt Basin East Quarry. One quarry, roughly 100 feet (30 m) in diameter, occupies part of a large stripped area. This quarry was active in the fall of 1991. The quarry produces thin sheets of a silvery-medium-grey stone with intricate bronze and gold concentric banding.

Location 3. American Stone North Quarries. Workings consist of four quarries on the west-facing slope and ridge directly east of upper Mahogany Creek. The *west quarry* is 200 feet (61 m) by 75 feet (23 m) with a 12 foot (3.7 m) maximum depth and an 8 foot (2.4 m) average depth. It appears to be intermittently active. Layering (N. 38° W., 14° SW.) is notably

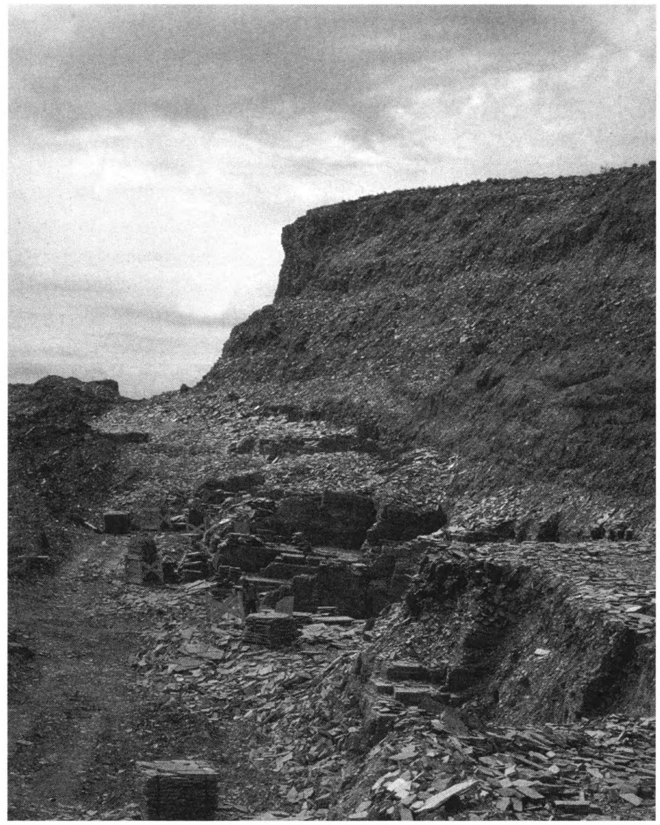

Figure A1. *The Starlight Stone quarry (quarry 1 of figure 6). The loaded pallet in the foreground is about 4 x 4 feet (1.2 x 1.2 m).*

thin and uniform, most being in the range of 3/8 to 1 1/4 inch (1 to 3 cm) thick. Vertical fractures cut the rock, limiting the size of recoverable slabs to about 1 foot (0.3 m) by 2 feet (0.6 m). The majority of the exposed stone is silvery white to deep golden in color. The *south quarry* is 90 feet (27 m) long by 90 feet (27 m) wide with a 5 foot (1.5 m) maximum depth and a 3 foot (0.9 m) average depth. It is operated intermittently. Layering (N. 49° W., 16° SW.) thickness commonly ranges from 1/2 to 3/4 inch (1.3 to 1.9 cm). Occasional vertical fractures strike N. 05° E. The largest slabs seen were about 1 by 2 feet (0.3 by 0.6 m), but slabs average 1 by 1 foot (0.3 by 0.3 m). Stone removed from near the surface is weathered to a reddish brown to brownish black with little surface sheen. Stone deeper in the deposit is silvery white. In 1991, the *north quarry* was actively being worked with a bulldozer, a forklift, and a truck. It is roughly 160 feet (49 m) long by 100 feet (30 m) wide. The *ridge quarry* was active in 1991. It is approximately 400 feet (122 m) long by 300 feet (91 m) wide.

Location 4. Ridge Crest Quarry. The property consists of one quarry on the ridge east of Mahogany Creek. It is 900 feet (274 m) by 300 feet (91 m) with a maximum depth of 20 feet (6 m) and an average depth of 10 feet (3 m). The layering (N. 30° W., 13° SW.) thickness ranges from 3/4 to 2 inches (1.9 to 5 cm), but some slabs are as much as 8 inches (20 cm) thick. Abundant near-vertical fractures, some striking N. 78° E., break the stone into slabs as large as 1 by 2 feet (0.3 by 0.6 m). Material from the hilltop at the south end of the quarry is as much as 3 square feet (0.3 sq m) in area. Dark-gold and light-gold stone predominates. Some of the rock in the quarry has a pronounced surface ripple and/or sparse mica.

Location 5. American Stone South Prospects. The property consists of several shallow bulldozer cuts as much as 225 feet (68 m) in diameter and about 1 foot (0.3 m) deep. The bulk of the stone is silvery white with smaller amounts of gold and rusty brown.

Location 6. South Holt Basin (Pole Creek) Quarry. The quarry is about 320 feet (98 m) long by 280 feet (85 m) wide with an average depth of about 12 feet (3.7 m). Layering (N. 36° E., 13° SE.) yields a high percentage of slabs in the 1/2 to 1 1/4 inch (1.3 to 3 cm) thickness range. Vertical fractures strike predominantly N. 60° E. Fracturing is less intense than at some localities and this yields a good proportion of large slabs with maximum dimensions of 2 by 3 feet (0.6 by 0.9 m). The quarry produces gold to silvery-light-grey stone with decorative iron staining along fractures and in irregular bands.

Location 7. Basin Creek Gorge Quarry. The quarry is 150 feet (46 m) in diameter and 3 feet (0.9 m) deep. Parting surfaces (N. 78° W., 07° SW.) are spaced 4 to 6 inches (10 to 15 cm) apart. Abundant vertical fractures through the rock are spaced 1 foot (0.3 m) or less apart. A notable set of fractures strikes N. 03° W. Stone is reddish brown with irregular iron staining. This quarry has some potential for ashlar production.

Location 8. Lynn Pass Quarry. The property consists of a main quarry and several prospect pits southeast of the main quarry. The main quarry is 375 feet (114 m) long by 300 feet (91 m) wide with a 5-foot (1.5 m) average depth. The quarry floor is irregular containing pits as much as 10 feet (3 m) deep. The quarry is probably intermittently operated. Parting planes (N. 65° W., 04° SW.) are closely spaced; a high percentage of the stone splits into 1/4-to 3/4-inch thick (0.6 to 1.9 cm) slabs. The thickest quartzite slabs are about 6 inches (15 cm) thick. Vertical fractures are common, a notable set strikes N. 08° W. Fractures are closely spaced, 1 foot (0.3 m) or less apart so the quarry yields mostly small slabs and ashlar. The quarry contains some small-amplitude folds and rusty bull quartz veins. Fracturing and layering in parts of the quarry combine to yield high-quality ashlar. Stone color is highly variable. The most common color is a light silver grey with medium-reddish-brown staining. Lesser amounts of silvery-white quartzite also occur.

Location 9. Lower Basin Creek Quarry. The property consists of two quarries. The *north quarry* is 300 feet (91 m) by 54 feet (16 m) with an average depth of 10 feet (3 m) and a maximum depth of 15 feet (4.6 m). The quarry is probably active. Layering (N. 05° W., 16° NE.) thickness varies from 1/4 to 3 inches (0.6 to 7.6 m) but averages about 1/2 inch (1.3 cm). A dominant set of vertical fractures strikes N. 02° E. Fracture spacing is 2 to 5 feet (0.6 to 1.5 m). Rocks slabs as large as 4 by 4 feet (1.2 by 1.2 m) are recoverable. Small folds with a 3-inch (7.6-cm) maximum amplitude make a small amount of the stone unsuitable for flagstone. The axes of the folds are aligned parallel to the strike of foliation. Stone is silvery light grey to silvery medium grey with some light-reddish-brown stains, some in concentric rings. The *south quarry* is 180 feet (55 m) by 54 feet (16.5 m) with a maximum depth of 20 feet (6 m) and an average depth of 10 feet (3 m). The stone at this quarry resembles that of the north quarry.

Location 10. Upper Narrows Quarry. Workings consist of a small quarry and a hillside where float rock is collected. The quarry is 21 by 135 feet (6.4 by 41 m) with a 12 foot (3.7 m) maximum depth and a 5-foot (1.5 m) average depth. This property appears to be intermittently active. Layering (N. 82° W., 36° SE.) thickness ranges from 3/4 to 9 inches (1.9 to 23 cm) with a 2 to 4 inch (5 to 10 cm) average. High-angle fractures strike N. 30° E. to N. 50° E. and are, at most, 3 feet (0.9 m) apart. The largest slabs seen were 3 by 3 feet (0.9 by 0.9 m). Color varies from a silvery light tan to a silvery white. Some stone is white with almost no micaceous sheen or white with a slight greenish cast or with iron-stained bands.

Location 11. Lynn Creek Quarry. The quarry is 150 by 150 feet (46 by 46 m) with a 4-foot (1.2 m) average depth and a 6 foot (1.8 m) maximum depth. The quarry was being worked in the fall of 1991. Parting (N. 26° W., 31° SW.) thickness ranges from 1/4 to 4 inches (0.6 to 10 cm) with a 1 inch (2.5 cm) average. High-angle fractures cut the stone at roughly 3-foot (0.9 m) intervals. Slabs as large as 2 by 3 1/2 feet (0.6 by 1.1 m) are quarried. Stone color is a silvery orangish light grey. This stone has decorative surface features including intricate iron-stained bands and irregular micaceous streaks on foliation planes.

Location 12. Pine Spring Quarry. The quarry is at the top of a prominent ledge and is 36 by 87 feet (11 by 27 m) with a 3-foot (0.9 m) average depth. Parting (N. 36° W., 37° SW.) thickness ranges from 1 to 8 inches (2.5 to 20 cm) but most slabs average 2 to 2 1/2 inches (5 to 6.4 cm) thick. Dominant vertical fractures strike N. 53° E. and are spaced 2 to 6 feet (0.6 to 1.8 m) apart. Most of the stone present is silvery white, some with a slight greenish tint. A small amount of silvery-charcoal-grey stone is present in the quarry.

Location 13. South Clarks Basin Quarry. Workings consist of two recent bulldozer cuts each about 150 by 150 feet (46 by 46 m) and a maximum of 4 feet (1.2 m) deep. The quarry operators were using a bulldozer and backhoe to remove overburden from the west quarry in the fall of 1991. The stone at this quarry is thinly layered. Widely spaced vertical fractures permit recovery of a fairly high percentage of large slabs. The largest quarried slab observed was 2 1/2 by 4 1/2 feet (0.8 by 1.4 m). White is the predominant stone color with lesser amounts of light orangish silvery white (palomino), light silvery grey, and silvery charcoal grey.

Location 14. Gold Sheen Quartzite Quarry. This prospect is 240 by 480 feet (73 by 146 m) by 2 feet (0.6 m) deep. The stone present is a fractured and blocky, silvery-white stone. A small quantity of material has been removed.

Location 15. Clarks Basin Creek SW Quarry. Workings consist of a large central quarry with a smaller quarry to the south and a prospect trench to the north. The *central quarry* is 600 by 210 feet (183 by 64 m) with a 10-foot (3 m) average depth. It was being worked in the fall of 1991. Parting (N. 05° W., 37° SW.) thickness ranges from 1 1/2 to 4 inches (3.8 to 10 cm) although there is a sizable amount of thinner stone present. Vertical fractures are abundant, limiting average slab size to 1 square foot (0.09 sq m) although some slabs measure as much as

2 by 3 feet (0.6 by 0.9 m). A dominant fracture set strikes N. 65° E. Silvery-white (some with a slight green tint) to silvery-light-grey stone predominates. Several other color varieties are present: silvery medium grey, silvery charcoal grey (some with irregular limonitic iron staining), silvery light grey with orange iron banding, and some white with almost no micaceous sheen. A significant amount of stone from this quarry would be suitable for ashlar. The *south quarry* is 165 by 48 feet (50 by 15 m) with a 3-foot (0.9 m) average depth. The quarry is active (1991). Layering (N. 23° W., 48° SW.) thickness ranges from 1/2 to 4 inches (1.3 to 10 cm) with the majority measuring 3/4 to 1 inch (1.9 to 2.5 cm). Two conspicuous sets of vertical joints strike N. 68° E. and N. 45° W. Silvery-light-grey stone (some with a light orangish tint) predominates with smaller amounts of silvery-medium-grey, silvery-dark-grey, and rusty-dark-grey stone. The *north prospect* is a 75 by 30 foot (23 by 9 m) shallow bulldozer trench.

Location 16. Dove Creek Pass Quarry. The quarry is 165 by 210 feet (50 by 64 m) with a maximum depth of 10 feet (3 m). The quarry floor is very irregular. The quarry may be worked intermittently. Parting (N. 03° E., 18° NW.) thickness ranges from 4 to 12 inches (10 to 30.5 cm). Strong vertical fractures cut the rock; the dominant sets strike N. 48° W. and N. 25° E. The fracturing has broken the stone into slabs usually less than 1 1/2 feet (0.1 m) square. The combination of closely spaced fractures and thick parting results in a significant amount of brick-like slabs which can be used for ashlar. Several different stone color variations are present: silvery light grey with orange-brown concentric bands and stains along fractures, silvery medium grey, and silvery white.

Location 17. Upper Black Hills Creek Quarry. Workings consist of one small pit 25 by 38 feet (7.6 by 11.6 m) by 6 feet (1.8 m) deep. Layering (N. 82° E., 19° SE.) thickness ranges from 2 1/2 to 8 inches (6.4 to 20.3 cm) and averages 4 to 6 inches (10 to 15 cm). Vertical fractures are spaced 2 to 3 feet (0.6 to 0.9 m) apart and predominantly strike N. 14° W. and N. 31° W. The largest slab visible in the quarry was 2 1/2 by 5 feet (0.8 by 1.5 m), but most slabs are much smaller. Stone surfaces are generally smooth, but some have a noticeable ripple. Foliation planes vary from non-micaceous to moderately micaceous. Roughly half of the rock exposed is silvery white with a slight reddish-brown stain. A lesser amount is pale silvery reddish orange and a small amount is silvery light grey.

Location 18. Black Hills Quartzite Quarry. Workings consist of a main quarry, a bulldozer cut, and a backhoe trench. The *main quarry* is cut into the west side of a small drainage. It is 230 by 60 feet (70 by 18 m) with a maximum depth of 20 feet (6 m). The *bulldozer cut* is on the east side of the small drainage. It is 130 by 45 feet (40 by 14 m) with an average depth of 2 1/2 feet (0.8 m). The *backhoe trench* is immediately south of the bulldozer cut; it was being excavated at the time of the field investigation. It is 50 by 15 feet (15 by 5 m) and about 5 feet (1.5 m) deep. The property was being worked in the fall of 1991. The development plan seems to be to produce the stone on the east side of the drainage in preference to the quarry on the west side where the stone dips into the hillside requiring stripping and benching. Layering (N. 84° W., 21° SW.) appears to be fairly thick, but the thick slabs can be easily split with chisel and hammer into sheets 3/4 to 1 1/2 inches (1.9 to 3.8 cm) thick. Vertical fractures, striking N. 21° E. and N. 19° W., break the stone into slabs averaging slightly less than 1 square foot. Predominant color of stone in the quarry is silvery white. Small amounts of the silvery-white stone have an uneven orange staining. Some stone is dark orangish brown to reddish purple with a micaceous sheen.

Location 19. Green Beetle Quarry. Three small quarries produce light-grey stone and sage-green stone similar to stone from the Rosebud Creek Quarry (quarry 19, figure 6). The property was active in 1993.

Location 20. Rosebud Creek (Lazy Green) Quarry. The quarry is roughly 75 by 75 feet (23 by 23 m) with a maximum depth of 5 feet (1.5 m). It was being worked in the fall of 1991. Parting (N. 11° W., 15° NE.) thickness ranges from 1/4 to 3/4 inch (0.6 to 1.9 m). The parting surfaces are very smooth. Irregular weak vertical fractures, many striking N. 88° E., leave large slabs of stone intact. Much of the stone can be quarried in sheets averaging 2 1/2 by 4 feet (0.8 by 1.2 m). The largest sheet seen was 9 by 5 feet (2.7 by 1.5 m) and only 1 1/2 inches (3.8 cm) thick (figure A2). The stone has a unique silvery-sage-green color which appears to be quite uniform throughout the quarry exposures.

Location 21. Rosebud Ridge Quarry. This quarry is about 190 by 80 feet (60 by 24 m) with a 2-foot (0.6 m) maximum depth. Layering (N. 73° E., 20° SE.) thickness ranges from 3/4 to 2 inches (1.9 to 5 cm). Strong dominant subvertical fractures strike N. 23° E. and N. 42° W. and are spaced widely enough to yield some sizable slabs. Two-square-foot (0.2 sq m) slabs are common and slabs 3 by 4 foot (0.9 by 1.2 m) occur locally. Medium-silver-grey colored stone predominates.

Location 22. BLM Community Pit. There are no actual workings; small amounts of stone have probably been gathered here from the quantities of "float" that are associated with the prominent quartzite ledges. The collecting area covers most of section 23, the northeastern part of section 26 and the western part of section. 25, T. 13 N., R. 17 W. Parting (N. 17° W., 9° SW) thickness ranges from 2 to 24 inches (5 to 61 cm) but averages about 5 inches (13 cm). Foliation surfaces are notably wavy in parts of the deposit and are interspersed with micaceous lenses. Foliation surfaces are generally sparsely micaceous to non-micaceous. Strong subvertical fractures strike N. 90° W. and N. 30° W. and are irregularly spaced from 1 to 9 feet apart (0.3 to 2.7 m). Slabs as large as 3 by 9 feet (0.9 by 2.7 m) occur in the deposit, but the average size is approximately 1 by 1.5 feet (0.3 by 0.46 m). A strong lineation strikes N. 66° W. Color is predominantly a lightly orange stained white to very light grey. The BLM sells stone from this location for $2.50/ton with a $10.00 minimum charge.

Location 23. Rock Canyon (Turquoise) Stone Quarry. The quarry consists of a series of benches cut into a steep slope in a conspicuous outcrop of green quartzite. The quarry extends roughly 400 feet (122 m) up the slope. Substantial quantities of rock have been removed. Property improvements include on-site housing and crushing facilities. This quarry is the source of much of the green Elba Quartzite that is produced. The layering tends to be somewhat thick and irregular; much of the stone splits

Figure A2. *Quarrying at the Lazy Green locality (quarry 20 of figure 6). The slab standing on end is 9 feet by 5 feet (2.7 m by 1.5 m).*

into slabs thicker than 1 1/2 inches (3.8 cm). Vertical fractures are common. Stone color varies from a dark green to a very pale green and is only moderately micaceous. There is a gradual color transition from the green stone of the deposit to the regular white color of the Elba Quartzite in the area surrounding the quarry.

Location 24. Upper Fisher Creek Quarry. The property consists of a disturbed area about 450 feet (137 m) long by 105 feet (32 m) wide and contains several small pits. The bulk of the stone splits to 1 1/2 inches (3.8 cm) or more thick. Vertical fractures are spaced 1 to 4 feet (0.3 to 1.2 m) apart, and most recoverable slabs are less than 2 by 2 feet (0.6 by 0.6 m). Stone color is white to light orangish tan with abundant limonitic iron staining along fractures. Explosives appear to have been used for quarrying.

Location 25. Lower Fisher Creek Quarry. The quarry is 255 feet (78 m) long by 120 feet (37 m) wide with a 20-foot (6 m) average depth and a 35-foot (11 m) maximum depth. Parting (N. 82° E., 13° SE.) appears somewhat thick and uneven; most stone splits into slabs thicker than 1 1/2 inches (3.8 cm). Vertical fractures are spaced 1 to 4 feet (0.3 to 1.2 m) apart and have two dominant strikes: N. 35° W. and N. 15° E. Abundant fracturing limits the maximum size of slabs to about 2 by 2 feet (0.6 by 0.6 m). The moderately micaceous stone varies in color from a deep green to a very pale green. The stone color changes gradually from green in the quarry to the regular white color of the Elba Quartzite in the area surrounding the quarry. This quarry has a higher percentage of stone suitable for ashlar than for flagstone or veneer stone. The stone appears to have been blasted.

Location 26. Left Fork Dunn Canyon Quarry. This quarry could not be examined in 1991 due to a washed-out road and locked gates. Doelling (unpublished file information), however, examined this 20- by 30-foot (6 by 9 m) quarry in 1979. Foliation strikes east-west with a 20° south dip. Some of the micaceous quartzite present is light green and separates into slabs measuring as much as 2 by 2 feet (0.6 by 0.6 m).

Location 27. Right Fork Dunn Canyon Quarry. This quarry could not be examined in 1991 due to a washed out road and locked gates. Doelling (unpublished file information), however, examined this property in 1979. It consisted of a 20-foot adit and a few small test pits. Foliation strikes east-west with a 20°south dip. Some of the micaceous quartzite present was light green and separated into slabs as large as 2 by 2 feet (0.6 by 0.6 m).

Location 28. Upper Indian Creek Quarry. This quarry could not be examined in 1991 due to locked gates. Doelling (unpublished file information), however, examined the quarry in 1979 and described a 200- by 50-foot (61 by 15 m) quarry in micaceous quartzite.

Location 29. Lower Indian Creek Quarry. This quarry could not be examined in 1991 due to locked gates. Doelling (unpublished file information), however, examined the quarry in 1979 and described an 80- by 35-foot (24 by 11 m) quarry containing light-green, micaceous quartzite.