Open-File Report 90-2

Geology and Mineral Evaluation of Mineral Claims within the Snowmass Wilderness Area in the Vicinity of The Colorado-Highland Marble Quarry, Conundrum Creek, Pitkin County, Colorado

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with a section about Rock Sample Descriptions

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EXECUTIVE SUMMARY

The Colorado Geological Survey (CGS) was contracted by the U.S. Geological Survey and the U.S. Forest Service to conduct an evaluation of privately held mineral rights located within the Snowmass Wilderness Area along Conundrum Creek. The CGS spent three man months in the 472 acre project area mapping, sampling, and studying the regional geology with emphasis on the extensive marble deposits of the Belden Formation and the potential for gold in gravels of Conundrum Creek. The CGS has estimated the mineral estate to have a net present value of $555,000 based on sustained production for five months per year for 30 years. The Net PresentValue ranges from $189,000 for a four month production season to $1,019,000 for a six month production season. This is consistent with the rough rule of thumb used by quarry experts of $.10 per saved cubic foot which yields a value of $696,400. The resources of value are the gray marble deposit, as situated on the east side of Conundrum Creek in the vicinity of the lower water fall, and the white marble in the south portion of the claim block. The gray marble and the white marble have a combined minable reserve of 3,046,000 tons. CGS has found upper marble beds in the upper portion of the claim block, white, gray, and dark gray beds above hornfels in the south portion of the claim block, and upper falls marble beds to have no value due to the thin nature of the beds and the preponderence of closely spaced bedding plane joints. Although there is a good possibility that lower falls marble can be projected westward across Conundrum Creek, the projection steepens the beds and covers them with an unknown thickness of Quaternary cover. Furthermore, this projection is well over 1500 feet and exceeds any strike or dip length of marble which has not been folded, thickened, thinned or otherwise affected such that a projection is unsupportable.

The CGS mapping and sampling program for base and precious metals found no indications of resources of economic value in the many prospect holes examined or in the placer gravels of Conundrum Creek.

Although the minable reserve is far less than the estimated tonnage of marble on the subject property, the economics of this project are not sensitive to the quantity of in place rock. By far the most important aspect of this evaluation is the market side of the marble business. The CGS has had to rely on often contradictory opinions of the sales potential of the product from various experts from the marketing side. The CGS believes from the results of ASTM testing and the inquiries to experts that the product will be a specialty item of low demand, and at the low end of the market in price. The projected low sales volume is consistent with the weather driven low production rate of 6500 tons to 17,850 tons per year.

The CGS recommends that further work on this project should involve continued market analysis of the potential products, the marbles, and the waste products generated from a quarry operation. This may involve the quarrying of blocks and toll fabrication. The CGS believes that there is little need for drilling on the project because the type of information gained will contribute only minor adjustments to the accuracy of the economic evaluation. However, it would be prudent to consider drilling several holes to justify the eastward projection of the proposed gray quarry unit.

INTRODUCTION

SITE BACKGROUND

Site Setting

The Conundrum Creek—Colorado Highland property is located in Township 11 South, Range 85 West, of the 6th Principle Meridian, in the eastern portion of the 174,329 acre Maroon Bells-Snowmass Wilderness exclusion of the White River and Gunnison National Forests, Pitkin and Gunnison Counties, Colorado. The city of Aspen, Colorado lies eight miles to the north.

The property can be reached by traveling southeast on Colorado Highway 82 from Glenwood Springs to just above Aspen, and then proceeding south on the Castle Creek Road to the Conundrum Creek turnoff. From the Castle Creek Road, a County dirt road leads to U.S. Forest Service (USFS) Trail No. 1981 which accesses the Conundrum Valley. USFS Trail No. 1981 climbs at a gentle to moderate grade paralleling Conundrum Creek. The trail follows a road for the first 2.25 miles, at which point it crosses the creek. The remaining six or more miles of the trail, which proceeds to Conundrum Hot Springs and over Triangle pass, is a single track path. The central portion of the claim block is reached at about the 2.5 mile mark from the trailhead at the Wilderness boundary.

The Conundrum Creek drainage basin is roughly 8.7 miles in length and 2.6 miles wide. Topography is striking in this steep-walled valley with elevation differences ranging between 8,500 feet at the confluence with Castle Creek, and 14,265 feet at the summit of Castle Peak (Figure 1). Topographic map coverage is the Hayden Peak and Maroon Bells 7.5 Minute Quadrangle Maps published by the U. S. Geological Survey. Avalanche chutes are numerous and highly active during winter months.

The climate in the Elk Mountains is typical of the Colorado high country. During the winter the Elk Mountains receive more than 350 inches of snowfall annually on the average (Colorado Geological Survey-CAIC, 1989). Fluctuation in temperature between day and

Figure 1: View of Conundrum Creek Valley —looking south. The photo was taken during first CGS visit in April of 1989.

night can be more pronounced in winter due to solar warming of air and thermal inversion.

Tree cover in the Conundrum Valley is restricted to elevations below about 10,800 feet. Mature stands of coniferous trees are few but do occur in certain areas. Large aspen groves thrive on the valley floor and up either valley slope. Due to the number of avalanche chutes, a large percentage of the lower valley supports ground vegetation only. Much of the terrain is above timberline and is sparsely vegetated.

Area History

Pitkin County and the Aspen area were originally developed as a mining center in the 1880s when rich silver-lead-zinc ore was discovered nearby. The mines of Aspen flourished for a time until the demonetization of silver in 1893 caused a gradual decline in activity.

Other areas in and around the Elk Mountains were also being settled to exploit the rich mineral wealth which was becoming evident. In the Crystal River valley to the west, potentially economic deposits of copper, iron, gold, sulphur, coal, slate, and marble were being recognized, in addition to silver-lead-zinc. By 1897, two smelters were processing the variety of ores being mined in the valley. This rejuvenated the crippled economy in the aftermath of the silver panic for a time. The revival of metal mining was to be short lived, prompting the local inhabitants to look to the deposits of white marble known to occur in the valley for the next "boom".

The first claims located on the white marble deposits of Yule Creek were staked in 1886, with some minor development commencing immediately (Vandenbusche and Myers, 1970). Production was hampered by harsh working and transportation conditions and by a lack of capital to develop the quarries properly. It would be another seven years before any substantial capital was attracted to the marble operations and another 15 years before they were fully developed (Vandenbusche and Myers, 1970). Yule Creek marble proved to be of a superior quality, rivaling that of any marble found in the world. Its extreme strength and aesthetic quality placed a high demand on Yule Creek stone, and it was eventually used in numerous constructions in the United States and abroad, including the Lincoln Memorial in Washington D.C.

The blue-gray marble of Conundrum Creek, which is subject of this report, was slated for development in the years 1911–1912. The placer claims: Edith M, Vera, and Vermont, all patented in February 1899, were laid out adjacent to and contiguous with the California placer, patented April 1891. These four claims, comprising 472 acres, were the major holding of the Colorado-Highland Marble Corporation, incorporated in 1912 under the laws of Colorado with a capital stock of $10,000,000 (Rocky Mountain News, 1912). The company did manage to receive and install equipment at the site including a boiler, two hoists, and two channeling machines. Production was limited to two small quarry benches and no record exists of marble being shipped from the property (see Figure 2). The property has remained idle except for some minor attempts at gold placering on the California claim.

INVESTIGATIONS SUMMARY

Project Objectives

The Colorado Geological Survey (CGS) was contracted by the U.S. Forest Service through the U.S. Geological Survey to conduct a mineral appraisal of privately held mineral rights located in the Snowmass Wilderness Area. The contract calls for an economic analysis to determine the Net Present Value (NPV) using the Discounted Cash Flow Rate of Return (DCFROR). The objective of this study was to arrive at a valuation for the U.S. Forest Service of this mineral estate or to identify and recommend courses of action which would lead to the completion of such a valuation. The CGS understood that time is of the essence, and that the project must be completed immediately following the 1989 field season. No motorized equipment would be used to collect samples by rotary drilling, core drilling, trenching, mining, or any other methods generally used when conducting a mineral appraisal.

Figure 2:
A view, looking down-valley to the north, from the upper bench of the Colorado - Highland quarry which operated on site in 1912. Not visible in this photo is a four foot cutwall at back of quarry cut and old cable used to lower blocks to loading area below. Bench also extends to south of photo vantage-point.

Initial Investigations

Colorado Geological Survey began preliminary research on this project in March of 1989. It was initially important to make as many industry contacts as possible to begin formulating some concepts concerning current trends in marble products, physical and aesthetic constraints on specific marble products, mining technology and associated costs, processing technology and associated costs, and industry structure. CGS initial investigations also included a review of available literature on the geology of the Elk Mountains and surrounding region. CGS visited and questioned quarry operators, marble dealers, architects, consultants, and marble craftsmen to gain a better understanding of the marble industry. CGS also investigated the mineral potential of placer gold and base metals.

Report Overview

This report is designed to enable a reader with no prior knowledge of the Conundrum Creek Property to gain an understanding of the mineral potential and evaluation. The report contains maps, diagrams, and photographs designed to enhance the reader's understanding of the subject matter. Also included are various correspondences and documentation of verbal conversations conducted by CGS during the investigation.

GEOLOGIC CHARACTERIZATION

INVESTIGATION ACTIVITIES

Literature Review

The earliest written account of the geology of the Elk Mountain region was produced by the Hayden Survey in the early 1870s. Reports of their work in the Aspen area, including a 1:125,000 scale geologic map on a topographic base, are given in the United States Geological and Geographical Survey Annual Reports of 1874–1876 (Hayden, 1874; Peale, 1874; Hayden, 1876; Holmes,1876). The map documents early impressions of the complex structural features of the area. This work remained the only published geologic map of the Elk Mountain region until those of Bryant in 1969–1971 (Bryant, 1969, 1970, 1971a). Bryant's studies of the area have appeared in various publications and are culminated in Geology of the Aspen 15 Minute Quadrangle, Pitkin and Gunnison Counties, Colorado, published in 1979 (Bryant, 1966, 1971b, 1972a, 1972b, 1979). Bruce Bryant's personal input was extremely helpful throughout this evaluation. Numerous other workers have also written on the various aspects of the geology of the Elk Range and their studies were consulted. An extensive bibliography accompanies this report.

Aerial Photography

Black and white aerial coverage of the Conundrum-Colorado Highland property at a scale of 1:24,000 was produced by Merrick and Company, under contract to CGS, during June of 1989. The most recent color aerial photography coverage was produced by the USFS, flight line No. 1081, photos 201–203, dated September 24, 1982 at 1:24,000 scale. Stereo images from the 1989 photography were digitized by computer to produce a topographic base map of the area at a scale of 1 inch equals 400 feet, with a contour interval of 10 feet. Ground control for aerial mapping was provided by CGS.

Aerial photography was utilized throughout the geologic investigation to verify ground observations and to assist in field location. Ground textures of the Conundrum Valley as seen on the aerial photographs have provided insight into the structural complexity of this area.

Survey Control

CGS received all survey notes from USFS in April of 1989. The Forest Service has not conducted an official survey of the claim block, but has recovered existing corners where possible. The 472.46 acre claim block is comprised of:

- The California Placer—MS No. 4928, 153.023 acres, patented April 1891
- The Edith M. Placer—MS No. 12334, 160.0 acres, patented February 1899
- The Vera Placer—MS No. 12335, 20 acres, patented February 1899
- The Vermont Placer—MS No. 12393, 139.434 acres, patented February 1899 (see Plate 3).

The California Placer was surveyed by Lee Hayes, U.S. Mineral Surveyor, on September 13, 1887. The Edith M., Vera, and Vermont Placers were surveyed by George W. Wyce, U.S. Deputy Mineral Surveyor, in mid December, 1897. No record of any subsequent boundary survey for this claim block is in existence. Original claim corners constructed of rock markers scribed with claim number and corner designation have been recovered at various locations on the property (see Plate 3). CGS has copies of all original survey notes.

Control for topographic mapping and claim location was established by CGS in June of 1989. A closed loop traverse of 11,500 feet was run through panel points and selected claim corners where available. Horizontal closure error in the traverse yielded an accuracy ratio of 1:14,200. This corresponds to a maximum error of plus or minus 0.814 feet for X and Y coordinates. Vertical closure error yields an accuracy ratio of 1:1000, corresponding to a maximum error of 0.535 feet for elevations. Vertical control was established from topographic benchmarks and is referenced to the mean sea level (MSL) datum.

Claim corners were plotted from CGS survey coordinates or by reference to original survey notes. The high degree of consistency which exists in corner locations and claim geometry between the unofficial CGS survey and the original, indicates accurate location of property boundaries.

Field Mapping

Field mapping was conducted by CGS during July through September 1989. Surface features within the claim block were located by survey from existing CGS ground control. Where geologic mapping extended into areas lacking in ground control, location was by altimeter, aerial photography, and topographic base map. Availability of outcrop exposure on this property ranges from moderate to poor, depending on location. Field map compilation was greatly aided by extensive color photo-documentation.

This report includes a regional geologic map at 1 inch equals 400 feet scale (Plate 1). The geology inside and immediately adjacent to the claim block is from mapping conducted by CGS. The remainder of the regional geologic information is the work of Bruce Bryant of the U.S. Geological Survey (Bryant, 1969, 1970). Also at 1 inch equals 400 feet scale are maps of mining claims and sample locations (Plate 3). A detailed geologic map of the marble resource area cross-sections, and longitudinal sections produced by CGS have been reproduced at a scale of 1 inch equals 100 feet (see Plate 2).

Sampling

Sampling of marble was extremely difficult due to the "low impact" restriction placed on this project. The lack of mechanized sampling equipment and vehicular support virtually ruled out obtaining a recommended three cubic foot sample from below the weathered zone. A number of sizeable blocks were, however; removed from the weathered zone by Mr. Stefan Albouy, owner of the property. These specimens were examined by CGS personnel. Product quality tests on these bulk samples, including gang saw testing, were performed by Valley Marble and Slate Corporation of New Milford, Connecticut, for Mr. Albouy.

CGS obtained a number of smaller blocks for engineering tests. These marble samples were selected from a small stock pile of material which was quarried during the 1912 Colorado-Highland operation. Two blocks of dark gray marble, totaling 195 pounds, were shipped to The Indiana Geological Survey for testing. Some of this same stock pile material was given to The Denver Marble Company and the Aspen Marble Company for polishing tests and aesthetic evaluation. Test results and aesthetic considerations will be discussed in a following section of this report. Numerous hand-size samples of various types of marble from the property have also been collected.

Metal potential of the Conundrum Valley was tested for by both outcrop and stream sediment sampling. Rock chip samples were analyzed by fire assay or atomic absorption methods. Stream sediments were collected from areas of favorable stream geometry. Stream sediment samples were hand concentrated by pan from known volumes of gravel. These samples were tested by multi-element suite analysis for gold, silver, copper, lead, zinc, and molybdenum. Results are given in parts per million (ppm). Samples were selected from areas most likely to contain metal values.

Select marble samples were tested for uranium by geochemical analysis for U_3O_8 and for asbestos type minerals by optical methods. No deleterious minerals were encountered. Marble was also tested for possible use as chemical grade calcium carbonate. Results are reported as weight percentage $CaCO_3$, $MgCO_3$, and SiO_2.

Sample locations and parameters are documented on Plate 3.

Radiometric Investigation

A radiometric survey was run over the main marble zone to further check for uranium content. A Geometrics GS 101A scintillometer with a 1.25 sodium iodide crystal was used in the survey. No readings were encountered that would indicate an elevated uranium content.

BEDROCK STRATIGRAPHY

A thick sequence of sediments, deposited in the Central Colorado trough (Eagle Basin) during the Paleozoic Era displays changing depositional conditions from thin, relatively uniform quartz-carbonate sequences to thicker, less geochemically mature, more variable sedimentation (Bryant, 1979). Early to Middle Paleozoic sediments of the Aspen area are not exposed at the surface in the Conundrum valley but probably exist in the subsurface. Upper Paleozoic and Tertiary rocks are exposed in the Conundrum Valley and are the main focus of this report.

Early Paleozoic sediments of the Aspen-Conundrum area were deposited in the offshore shelf environment of a shallow sea, consisting of pure quartzites and relatively pure limestones. Middle to Upper Mississippian strata consist of widespread sequences of carbonates of the Leadville Formation. The lower units of the Leadville contain thinly bedded dolomite and limestone with dark grey chert lenses and stringers. Upper Leadville sequences are dominated by massive limestones and dolomites with a characteristic blue-gray color. The "blue limestone", as this series is commonly known, has been much studied because it is a common host rock for important metal deposits in many Colorado mining districts.

Following deposition of the Leadville Limestone, the pattern of sedimentation in the Aspen-Conundrum area changed substantially, but not before a period of erosion in which some of the Upper Leadville was removed. The upper contact of the Leadville locally displays karst solution features and breccia development. This fossilized erosion surface can serve as a marker bed for the contact between Mississippian and Pennsylvanian rocks. Overlying the Leadville Formation are thick bedded sequences of increasingly more clastic sediments. The next phase of sedimentation in the basin began in Lower Pennsylvanian time with the deposition of carbonates and shales of the Belden Formation. With increased relief of the Umcompahgre upland to the southwest deposition produced the arkoses, siltstones, and shales of the Middle Pennsylvanian Gothic Formation and the coarse conglomerates and sandstones of the Maroon Formation. Further uplift of the Umcompahgre led to deposition of conglomerate, sandstone, and siltstone of the Permian-Triassic State Bridge Formation and the Upper Triassic Chinle Formation.

This report will discuss only the Pennsylvanian, and Lower Permian sedimentary rocks, their metamorphic equivalents, and the Tertiary intrusive rocks, as they are the only bedrock units exposed in the Conundrum valley. Other rock units of the Aspen area, although not specifically described, are important in understanding the regional geologic framework.

Maroon Formation

The Upper Pennsylvanian-Lower Permian Maroon Formation is the most prevalent rock type of the Aspen-Conundrum area. Both the east and west ridges of the Conundrum valley are composed predominantly of Maroon rocks. Four of the five 14,000 feet peaks in the Elk Mountains-Aspen area are composed almost entirely of the distinctive, red strata. Even though the Maroon Formation is very well exposed in the Aspen area, its great thickness and gentle angle of regional dip make true thickness calculations difficult. In the Aspen-Conundrum area, the calculated thickness based on measured sections is 10,500 feet (Bryant, 1979).

The Maroon Formation is composed of arkosic sandstone, conglomerate, siltstone, mudstone, and local limestone, all of which are interbedded. Lateral extension of beds is limited, restricting stratigraphic correlation between outcrops. A few sandstone, conglomerate, or limestone beds can be traced for as much as a mile, but in general many beds tend to lens out in just a few feet. Occasionally, sequences of beds are recognizable from one place to another where outcrop exposure is substantial, or the entire nature of the stratigraphic section can change in a short distance along strike. Color gradation in the Maroon Formation, where unmetamorphased, is from grayish-red to pale-red in the lower sequences through reddish-brown and moderate-red colors in the upper sections. These rocks are greatly discolored by even slight metamorphism, adding additional correlation problems to the formation as a whole (Bryant, 1979).

Maroon Formation rocks, range in composition from limestone to arkose. The limestone beds account for only a small percentage of the Maroon Formation but are common in the lower sequences. Dolomite is rare in the formation but does occur locally. Beds of evaporite occur in the lower part of the formation in the Conundrum Creek area. Maroon Formation siltstones and mudstones are typically thick bedded to massive, and frequently grade to fine grained sandstone. Carbonate cementing of grains is most common. Maroon sandstones are composed of poor to well sorted, angular to sub angular grains of quartz, plagioclase, microcline, carbonate, and flakes of muscovite and biotite. Some of the more poorly sorted, coarser grained sandstones grade into conglomerates with large contained portions of rock fragments. The matrix is mostly carbonate. The distinctive red color of the Maroon Formation is due to hematitic alteration of biotite and other iron rich minerals (Bryant,1979).

Maroon Formation rocks are conspicuous in the Conundrum valley, both in outcrop high on either valley wall, and as colluvium and stream gravel in the valley bottom. The majority of Maroon Formation rocks of the valley have been altered chemically and texturally by contact metamorphism to a recrystallized, greenish-gray hornfels. The exception is near the head of the valley in the vicinity of Conundrum Hot Springs where unmetamorphased Maroon Formation rocks occur. The Maroon Formation is of no economic importance.

Gothic Formation

The Gothic Formation of the Aspen-Conundrum area is a gray, tan, and brown calcareous sandstone and siltstone with zones of silty-sandy limestone, and limestone.

Rocks of the Gothic Formation have very limited surface exposure in the Conundrum valley, outcropping only where the lower plate of the Elk Range thrust fault has been exposed by erosion in the Conundrum Creek window (Plate 1). The Gothic Formation is of no economic importance.

Belden Formation

The Belden Formation is a thin bedded sequence of carbonaceous limestone, dolomite, and shale with a small number of sandstone and sandy shale horizons. In general the sand content of the formation increases toward the upper sections. Sandstone, carbonaceous shale, and sandy limestone in the Upper Belden are displaced by limestones and minor dolomite toward the base of the formation, which is dominated by carbonates. Breccias and evaporite horizons are common in the Belden.

Surface exposure of Belden rocks is poor except in areas where they have been converted to marble and hornfels by contact metamorphism. Total thickness of the Belden is difficult to calculate but has been estimated by Bryant at between 400–1900 feet in the Aspen-Conundrum area. Upper Belden rocks are transitional with the Gothic Formation above. In the Aspen-Conundrum area, the contact is distinguished by a color change, due to the lack of a marker bed of sandstone which marks the contact elsewhere. The lower contact of the Belden Formation is more difficult to define. The base of the Belden Formation rests unconformably on an erosion surface of the Leadville Limestone. The stratigraphic base of the Belden Formation in the Aspen-Conundrum area has been observed by Bryant to consist locally of about three feet of gray dolomite, a one foot bed of sandy dolomite, another three feet of grey dolomite, and a sandstone lens. This basal sequence, if sufficiently extensive, is too poorly exposed to be used as a marker horizon elsewhere. More reliable as a lower Belden contact, at least in adjacent areas, is a horizon of residium at the top of the Leadville which has been mapped as a separate rock unit known as the Molas Formation. This formation, which has been mapped as being up to 50 feet thick southwest of the area, is missing in the Aspen-Conundrum area. Where lower Belden rocks are sufficiently exposed due to contact metamorphism, as at the Conundrum Creek property recrystallization and deformation have destroyed necessary indicators for determination of a lower Belden contact.

The Belden Formation is of importance economically, as this is the zone of marble being considered in this report.

IGNEOUS ROCKS

Overview

Laramide and Middle Tertiary age igneous rocks have been emplaced throughout the Elk Mountains in the form of dikes, sills, lacoliths, and plutons. Laramide age intrusive rocks of both mafic and felsic affinity occur predominantly as sills. Laramide igneous rocks described thus far in the Aspen area include hornblende quartz diorite, quartz porphyry, aplite, and aplite porphyry. All of these intrusive rocks have been recognized in the Conundrum Creek area. None of these rock types were mapped in the vicinity of the Colorado Highland Marble quarry property by CGS. Middle Tertiary age (Oligocene) calc-alkalic igneous rocks comprise a number of large plutons and associated dikes, sills, and lacoliths. The major rock types are granodiorite, granodiorite porphyry, and hornblende porphyry. The Oligocene plutons have been emplaced along a regional zone of weakness (the Elk Range Thrust Fault) with which they are generally concordant. The plutons are also concordant with bedding in gross aspect, but occasionally cross-cut strata. Figure 3 shows the outcrop pattern, and some structural relationships of the Oligocene plutons. The White Rock pluton is of particular interest because of extensive areas of associated contact metamorphism which have produced the marble and hornfels of the Conundrum valley (Bryant, 1979).

White Rock Pluton

The White Rock pluton outcrops in a roughly circular pattern in the southeastern part of the Elk Mountains. Rocks of the pluton make up the jagged peaks at the head of Castle Creek, part of Conundrum Peak, the ridge north of Hayden Peak, Keefe Peak, and the crest of the Elk Mountains at the head of East Maroon Creek. Major exposures of the pluton in the study area are the north ridge of Hayden Peak, a large mass on hill 12,146 between Cataract and Conundrum Creeks, and along the plane of the Elk Range Thrust which cuts the western side of the Vermont Placer on the west side of Conundrum Creek. Just north of the Vermont Placer claim, rocks of the White Rock pluton form the prominent cliffs on the west side of the valley.

Rocks of the White Rock pluton are granodioritic. The granodiorite is white to gray rock composed mostly of plagioclase feldspar, with lesser amounts of quartz and potassic feldspar. Accessory minerals are biotite, hornblende, pyroxene, and magnetite. The pluton displays chemical variation with small areas of more mafic phases occurring at or near margins of the pluton.

Country rocks at the contacts of the pluton lack chilled margins and are generally not deformed due to intrusion. An exception is rocks of the Belden Formation which are highly deformed near contact with White Rock plutonic rocks. Country rocks have been subjected to contact metamorphism, especially in areas where the intrusive contact is discordant.

Exposures of the White Rock pluton south of the Colorado-Highland Marble Quarry contain substantial quantities of pyrite which is generally disseminated, but can occur as micro-fracture fillings or in large masses up to four inches in diameter (Figure 4). Where sulfides occur in the pluton, alteration is most pronounced. Fluid inclusion studies conducted by J.T. Nash and C.G. Cunningham, Jr. show this to be post-magmatic alteration which most likely occurred a million to a few million years after emplacement of the pluton. Also associated with this late stage alteration are mineralized fracture zones containing quartz and/or carbonate, and pyrite. Some of these zones are reported to

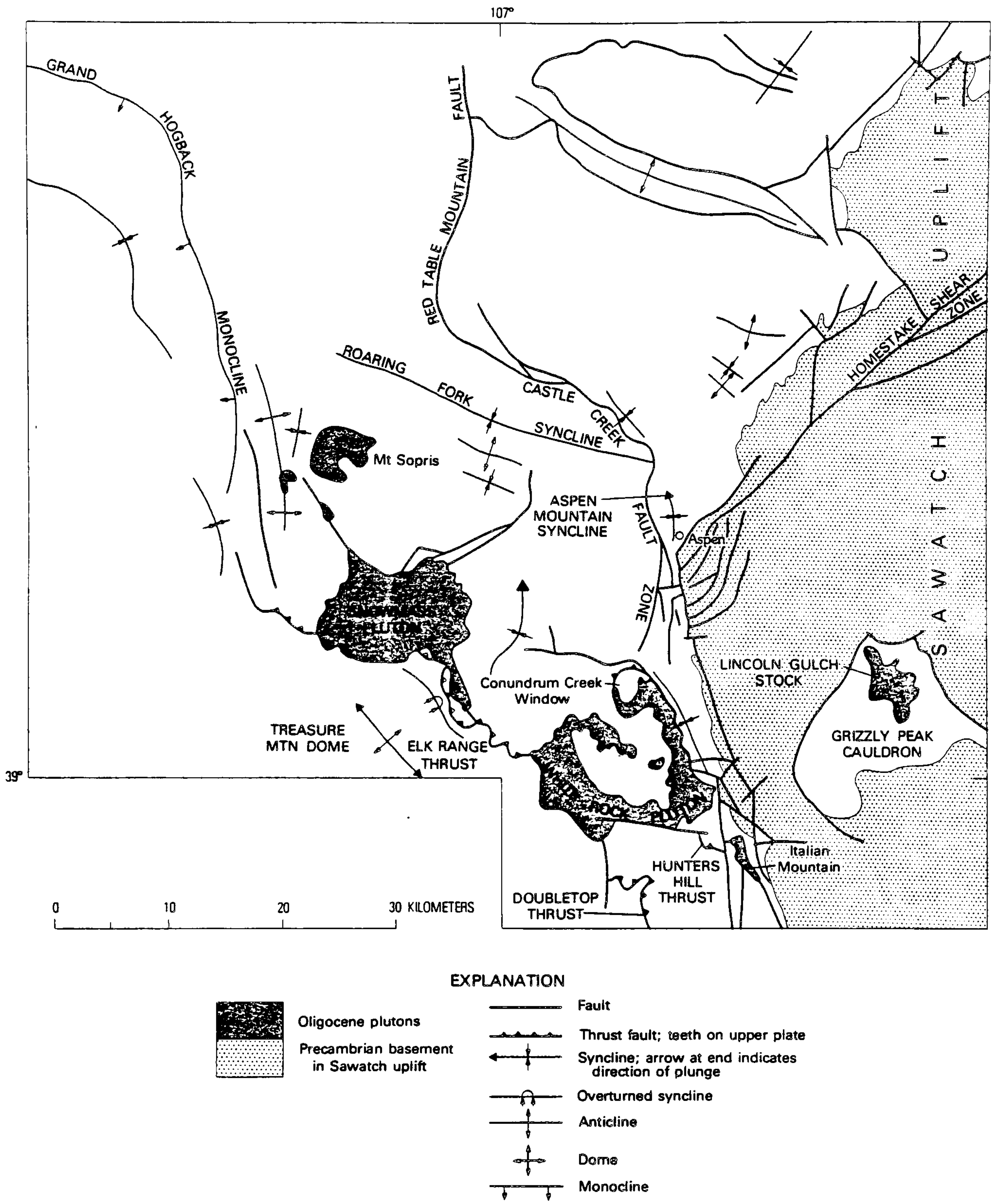

Figure 3: Structural and spatial relationship of Oligocene plutons in the Elk Mountains. White Rock and Snowmass plutons have been emplaced along the Elk Range Thrust Fault. Zone of contact metamorphism associated with the White Rock pluton is extensive and has produced marbles and hornfels. These metamorphic rocks are exposed in the Conundrum Creek window (from Bryant, 1979).

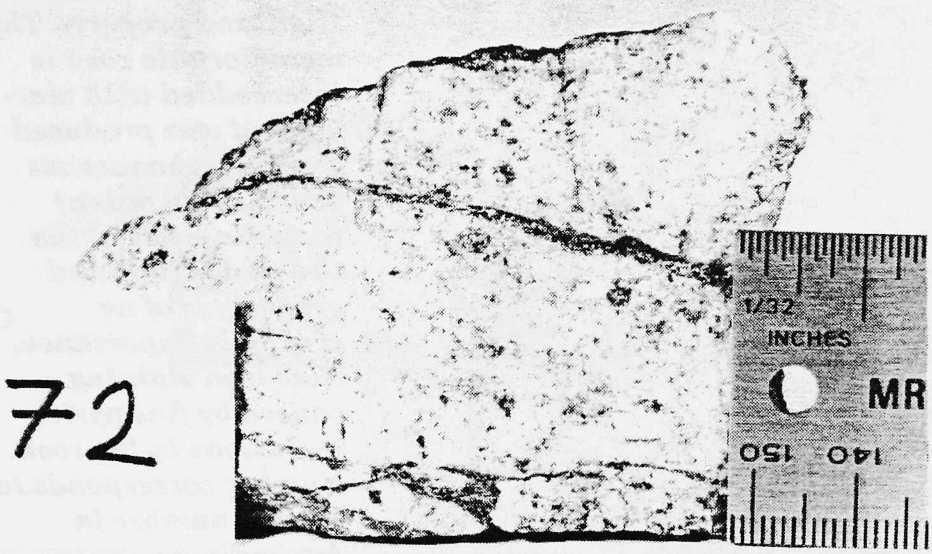

Figure 4:* *Pyrite disseminated in granodiorite of the Oligocene White Rock pluton. Sample was taken from south of the Colorado-Highland Claim block. Samples taken from this area contain no economic values in gold or silver. Number corresponds to sample collection number. See Appendix A.

contain galena, sphalerite, and chalcopyrite with local values in gold and silver (Bryant 1979). This type of mineralization was not observed directly on or near the claim block.

METAMORPHIC ROCKS

Rocks adjacent to the White Rock pluton have been chemically altered and recrystallized to varying degrees by heat of intrusion. Clastic sediments and mudstones have been converted to hornfels. Limestone and other high carbonate sediments have been marblized. Mineralogy in the contact metamorphic zone of the White Rock pluton is that of the hornblende-hornfels facies, with mineral assemblage indicating temperatures of metamorphism on the order of 500–600 degrees Centigrade, under pressure conditions of not more than one kbar. This would place ground surface at the time of metamorphism, at or just above, the current elevation of the highest peaks (Bryant, 1979).

The zone of contact metamorphism ranges from 200–300 feet to over 3000 feet for calculated thickness of metamorphic rocks. Dikes, sills, and lacoliths associated with the pluton have metamorphosed their wall rocks for lesser distances. Change from original country rock mineralogy through metamorphic equivalents in the contact aureole is gradational. Field distinction of metamorphic units is enhanced by distinct color changes of rocks in the contact aureole (Bryant, 1979).

Belden Hornfels

Dominant metamorphic minerals of the hornfels and associated rocks are diopsidic pyroxene, amphibole, garnet, idocrase, scapolite, and biotite. Original sedimentary textures are well preserved in the hornfels. Original detrital grains of silicate mineral are preserved in a recrystallized matrix of calcium and calcium-aluminum silicate. Hornfels in the study area, especially those of the Belden Formation, are frequently pyritized. The probable source of pyrite in hornfels is late stage hydrothermal fluids associated with the White Rock pluton. Weathering of pyritized hornfels has given them a red-yellow colored hematite and limonite staining (Bryant, 1979). Figure 5 is coarse-grained hornfels from the Conundrum Creek Colorado-Highland property.

Belden Marble

Limestone beds in the contact aureole have been completely recrystallized to marble. Original sedimentary textures have generally been

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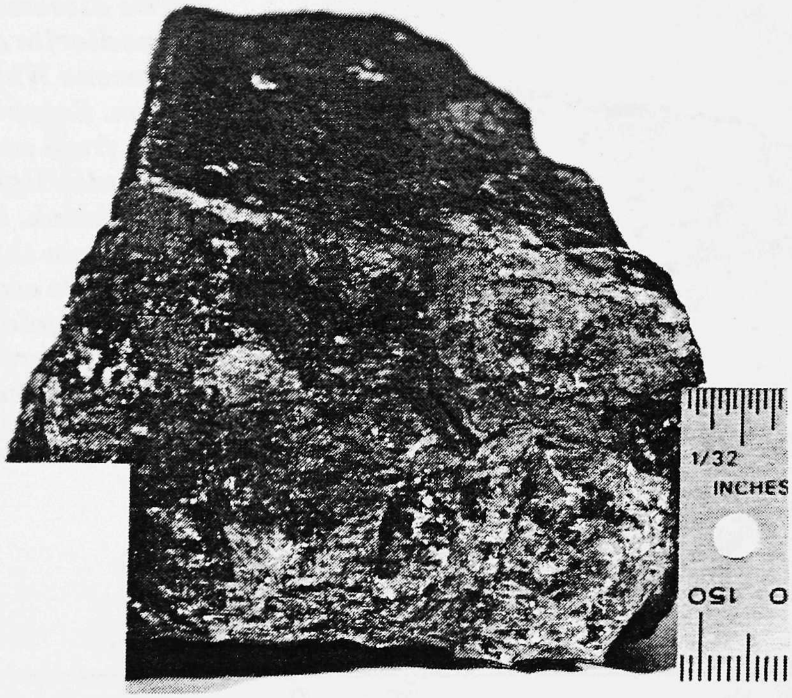


Figure 5. Hornfels from the Conundrum-Colorado Highland property. This metamorphic rock is interbedded with marble and was produced from a carbonaceous sandy shale parent rock. Hornfels at the Colorado-Highland property is of no economic importance. Note iron staining caused by fine pyrite inclusions in the rock. Number corresponds to sample number in Appendix A.

destroyed, although banding in some Conundrum Creek marbles may relate back to original bedding. Chemical analyses of marbles conducted by CGS for this study reveal $CaCO_3$ concentrations upwards of 95 percent for marble sampled.

The pure calcitic nature of marble units indicates that metamorphism was not accompanied by circulation of hydrothermal fluids. Metamorphism of limestones, accompanied by exchange of elements, would tend to produce skarn and hornfels rather than chemically pure marble. Marble units are, however, pyritized locally. Alteration of marble is less extensive and of decreased intensity to that of hornfels, due to very low permeabilities in marble.

The Belden marbles are variable in color, ranging from dark gray to white. Intermediate colors exists, as do zones of alternating layers of dark and light banding. The marbles are composed of fairly large grained, euhedral to subhedral crystals, although some zones of more fine grained marble occur. All marbles observed in the Conundrum Creek area are pyritized to some degree. Small pyrite grains (less than one mm) are aligned on fractures and other permeable layers (Figures 6, 7, and 8).

Marble beds are of variable thickness due to plastic deformation. Rift if present is generally parallel to bedding. Folding of beds has tended to align mineral grains in direction of deformation. Some marble beds, especially the basal sections of the gray marbles contain significant quantities of chert. The white marbles have some breccia zones.

Detailed descriptions of representative rock samples from across the Colorado-Highland claim block are reprinted in Appendix A of this report. Locations of 65 collected samples are shown on Plate 2. These samples are available for inspection at the Colorado Geological Survey offices.

STRUCTURAL GEOLOGY

Regional Setting

The Sawatch Range of central Colorado was uplifted during the Laramide Orogeny. The gentle eastern side of the Sawatch Range Uplift has been truncated by a fault, emplaced along the trend of the Rio Grande Trough, forming the Upper Arkansas Valley. In the vicinity of Aspen, the steeper and structurally more com-

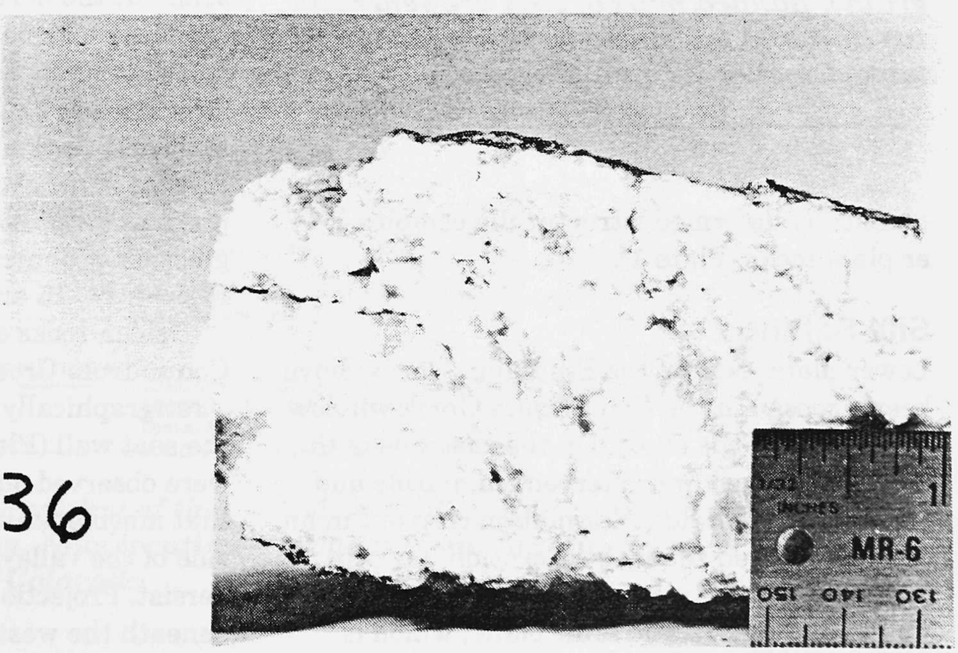
6

Figure 6:
Gray marble from the Colorado-Highland property. Note variable grain size and color variation. Some pseudo-banding is visible in sample. No original bedding features discernible. Number in photo correlates to sample number in Appendix A.

plex western margin of the Sawatch Uplift takes a pronounced change in strike. Intrusive rocks and associated Ag, Pb, and Zn mineralization have been localized where this major change in the trend of the west margin of the Sawatch Uplift intersects the Colorado mineral belt (Figure 9).

The Elk Mountains are a northwest trending offshoot from the asymetrical western limb of the large Sawatch Range uplift. During the Laramide Orogeny, it is postulated that a sequence of Paleozoic-Mesozoic rocks, on the order of 2.5 to 4.0 miles in thickness, slid to the southwest off of the emerging Sawatch Range Uplift (Bryant, 1966, 1979). The plane of movement, known as the Elk Range Thrust, was probably a bedding plane fault in the Belden Formation. Direct field observation of the thrust fault is limited due to Tertiary intrusive rocks which have been emplaced along the fault plane in many locations. Where exposures are sufficient, as in the Conundrum Creek window, non-deformed, structurally simple upper plate rocks unconformably overly highly folded and

Figure 7:
White marble from the southern end of the Colorado-Highland property. White marble tends to contain less pyrite than do the gray marbles. Green mineral is probably chlorite. Number in photo correlates with descriptions in Appendix A.



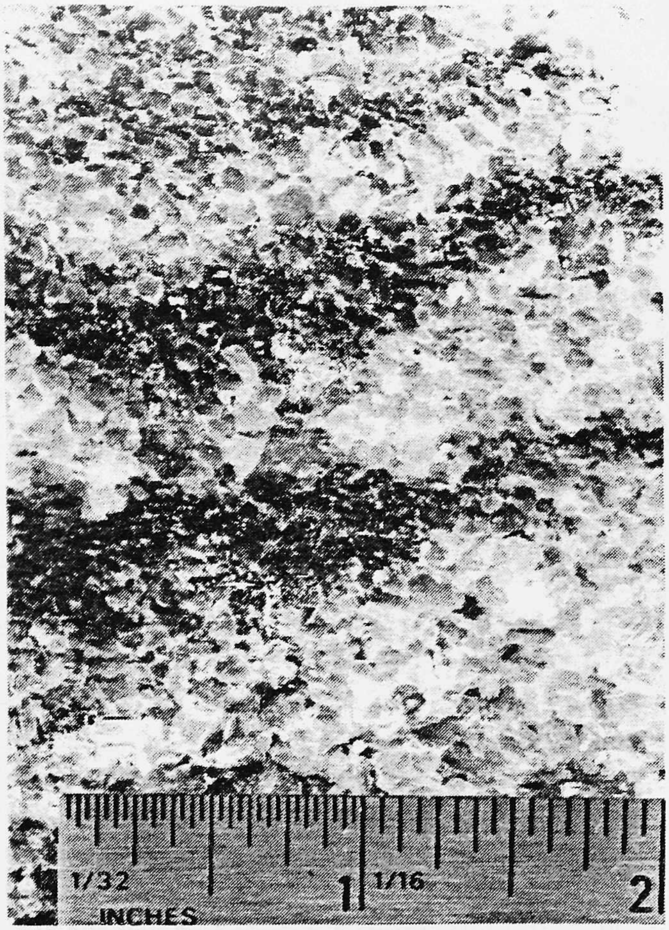


Figure 8: Close-up of banded marble. Note variable grain size and alternating coloration. Brown staining is due to the weathering of fine pyrite located between grains. Banded marble beds are generally too thin and too folded to be of economic importance.

plastically deformed, structurally complex lower plate rocks (Plate 1).

Site Setting

Lower plate rocks of the Elk Range Thrust have been exposed in the Conundrum Creek window in the area of the study. On the east side of the valley, deformed and interbedded marble and hornfels of the Belden Formation crop out in an eliptical shaped zone where erosion has proceeded below the plane of the Elk Range Thrust Fault (Figure 10). The fault plane, which is high on the west slope of Hayden Peak, is not recognizable because of a large intrusive mass which occupies the fault zone. The plane of the thrust fault is recognizable on the west wall of the valley where it brings rocks of the Maroon Formation above into contact with upper Belden rocks below. A sill of granodiorite was emplaced just above the thrust plane in rocks of the Maroon Formation.

Detailed mapping by CGS of lower plate rocks exposed on the east side of Conundrum Creek reveals complicated structure characterized by intense folding and plastic deformation. Alternating beds of marble and hornfels have been in some places overturned, with thinning and thickening of beds common (Plate 2). Exposure of the stratigraphic section is locally sufficient enough to make estimates of bedding thicknesses. Projection of structures and bedding contacts is subjective due to complex structure. Folding of beds has not been accompanied by major faulting due to plastic deformation. The jointing pattern is highly variable throughout the exposed marble area.

Belden rocks in outcrop above creek level on the Conundrum Creek property manifest as a dissected view of the east limb of an asymetrical, plunging syncline in gross aspect (see Figure 11 and Plates 1 and 2). Appreciable thickening of strata is evident in the "waterfall zone", at the north end of the outcrop, where the black marble unit of the lower bench is estimated to be 80 feet thick (see Figures 12 and 13 and Plate 2). This same unit was measured at 20 feet thick at the south end of the outcrop. Intense folding and thinning of "waterfall zone" marbles to the south limit the southern progression of quarrying of these marble (See Figures 14, 15 and 16 and Plate 2).

Belden rocks exposed on the west side of Conundrum Creek are postulated to be higher stratigraphically than marble and hornfels of the east wall (Plate 1). No major beds of marble were observed on the west wall, suggesting that marble units which outcrop on the east side of the valley may be found at depth if they persist. Projection of marble and hornfels units beneath the west side of the valley is consistent with our observations and corroborates the map

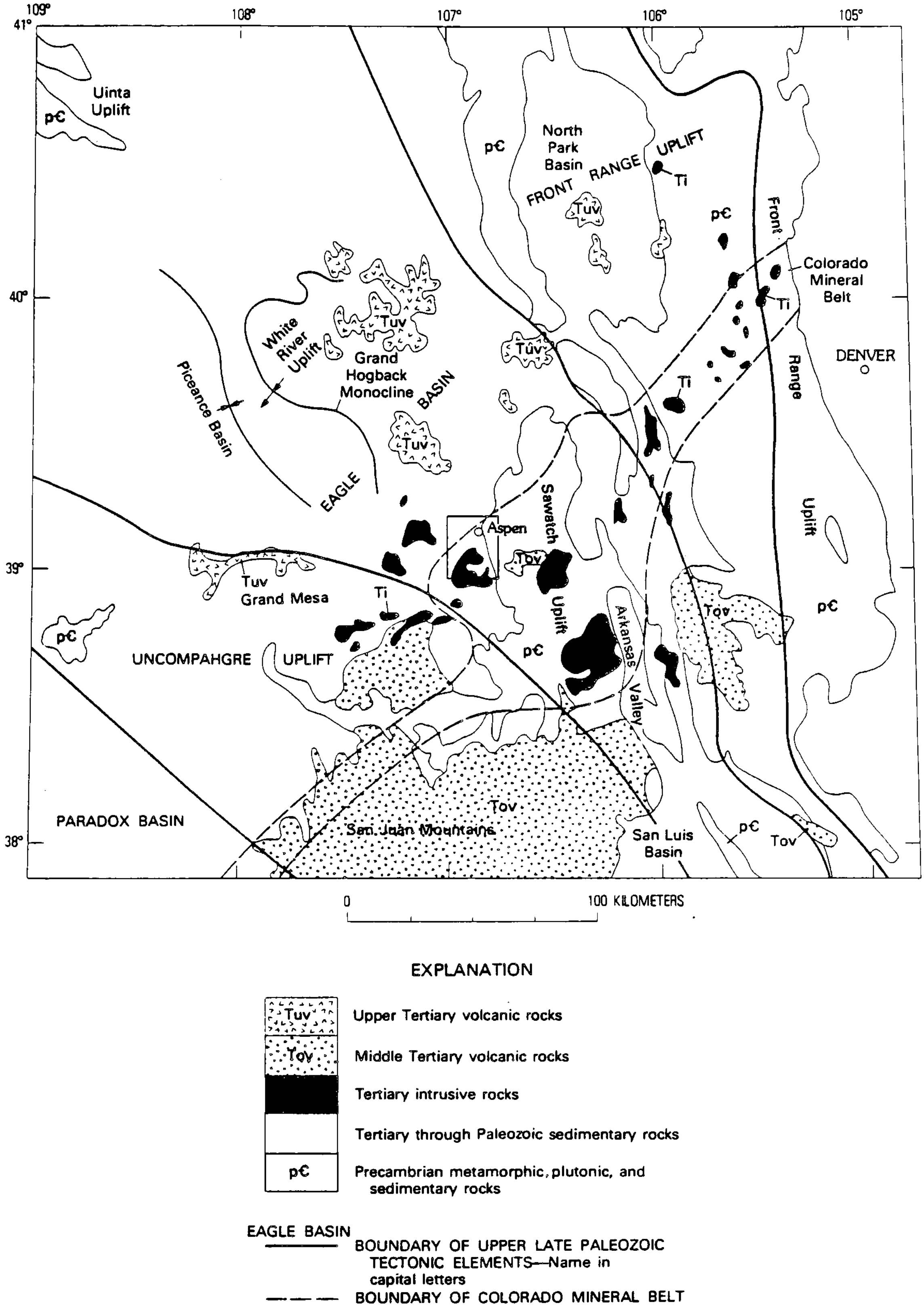


Figure 9: Regional geologic setting of the Aspen - Elk Mountains area. Note location of Aspen at intersection of Colorado Mineral Belt and west margin of Sawatch Uplift (from Bryant, 1979).

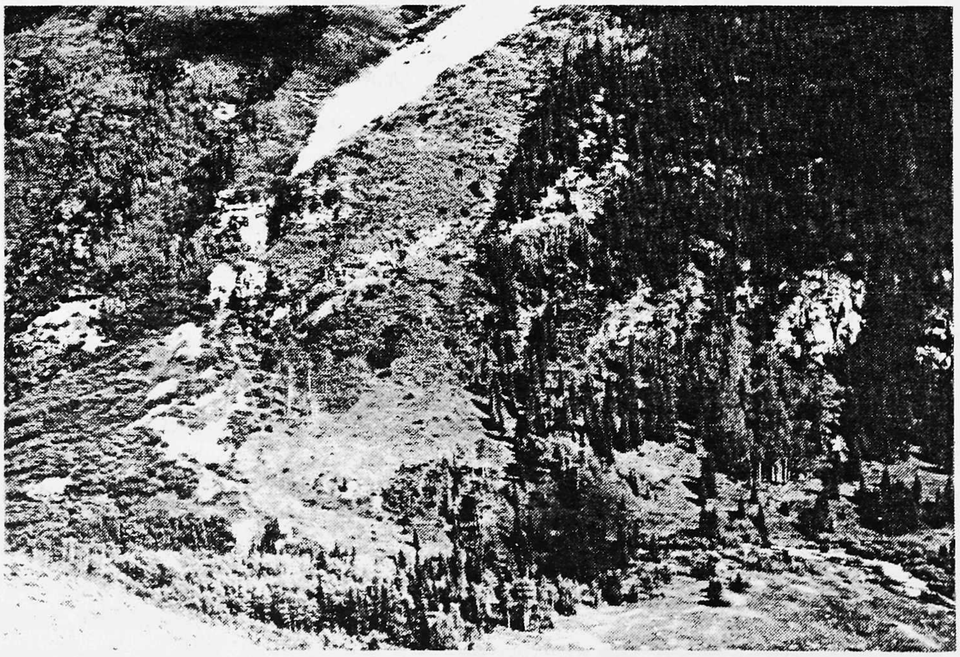
Figure 10: Outcropping of Belden marbles on east side of Conundrum Creek. Old Colorado-Highland quarry bench is visible at left. Note large avalanche catchment basin above marble outcrop. Lower waterfall bench at center is massive gray marble. Initial open-pit quarry operation would be centered near 1912 bench at left of photo. See Plate 2 for geologic detail.

ping of Bryant. Depth of marble on the west side of the valley is difficult to estimate due to low confidence in projectability of geology.

ECONOMIC GEOLOGY

Important silver-lead-zinc deposits, associated with igneous activity of the Laramide Orogeny, occur in the vicinity of Aspen and the surrounding districts of Lenado, and Richmond Hill. Production reported for the area is 101,000,000 ounces of silver, 294,000 tons of lead, and 11,000 tons of zinc (Henderson, 1926). The most favorable horizons for the discovery of ore have been in carbonate units of the Mississippian Leadville and Pennsylvanian Belden Formations. The erosion surface between the Leadville and the Belden, which is frequently brecciated, has also been a productive ore zone. No significant amount of production from this type of ore deposit has been recorded since the

Figure 11: Panoramic view of marble zone on east side of Conundrum Creek. Waterfall and Colorado - Highland quarry are at left. Outcrop of white marble is clearly visible at center. See longitudinal section F-F' Plate 2 for geologic detail.



closing of the Midnight Mine near Richmond Hill in 1952.

A number of ore deposits are associated with the Middle Tertiary plutons of the Elk Mountains. Deposits of contact metasomatic iron, disseminated sulfide, and fissure-vein lead-zinc-silver occur in and adjacent to granodiorite intrusives. Except for iron produced by Pitkin Iron Corporation during the 1960s, and possibly some sporadic precious and base metal production from fissure-veins, no significant metal production can be attributed to the Middle Tertiary deposits.

At the head of Cooper Creek in the southeast corner of the Hayden Peak quadrangle, a contact metasomatic deposit of iron has been mined by open pit methods. The iron deposit occurs in highly recrystallized limestones of the Belden Formation adjacent to Tertiary intrusive rocks. The ore was emplaced in steeply dipping fractures which are most likely associated with intrusion of the White Rock pluton. The ore consists of massive magnetite with some pyrite.

As previously mentioned, disseminated sulfides are a common occurrence in granodiorites of the White Rock pluton, as well as in adjacent hornfels and to a lesser extent, marbles. The deposits are mostly pyrite, but local occurrences of disseminated molybdenum and copper have been reported. There are no records of metal production from altered granodiorite or other pyritized units. CGS observed an old prospect adit and dump which was developed on an outcrop of pyritized hornfels unit at the southern end of the California placer. Assay results and panned concentrates from the dump contained low metal values. These deposits are not economically important.

Minor, non-extensive quartz-carbonate-pyrite veins cut red-beds, hornfels and other strata above and adjacent to the White Rock pluton remote from the subject property. These fissure-veins locally contain sphalerite, silver bearing galena, and very rarely gold. Fluid inclusion data from veins of this type indicate they are related to post-magmatic alteration and mineralization associated with the intrusion of granodiorite, as in disseminated deposits. Production from these structures has been minimal. The most noteworthy mine developed on this type of deposit is the Montezuma mine just northeast of Castle Peak. Records show a total production of 6,700 tons of ore. No grades are available for ore mined or shipped. Fissure type veins have been reported to occur in the upper Conundrum valley. The Cummings property, on the west side of Conundrum gulch, has been alleged to contain fair values in silver. CGS did observe and sample a number of pieces of "vein float" which were picked up in the stream bed. No veins were observed on the subject property. Assay values on "vein float" were low for both gold and silver (Plate 3, Table 1).

Geochemical analysis of samples taken in "reconnaissance" fashion by CGS are documented in (Plate 3, Table 1). Whole rock and panned stream sediments were tested for multiple elements. Fire assay and atomic absorption analyses for gold and silver on select whole rock samples gave low results. Several high values for copper, both in pan concentrates and rock samples are interesting, but are not considered to be indicative of high mineral potential within the claim boundary. Assay and atomic absorption analyses mineralization from the property were also consistently low.

Although Leadville Limestone represents favorable host rock in known mining districts. No Leadville rocks were observed on or immediately adjacent to the property. This fact, combined with the complex structure in the area and the extreme variation in the thickness of the Belden Formation, make accurate estimation of depth to this horizon difficult.

Placer gold potential of the claim block was tested by hand panning methods. This technique will only test the immediate surface and cannot lend insight into placer potential of deep gravels or bedrock surface where most of the gold would accumulate. The original placer claims along Conundrum Creek extend for approximately 6,000 feet and from an elevation at the north of 8,600 feet AMSL to 9,800 feet at the southern end. The extreme southern end of the claim block was considered by CGS to have

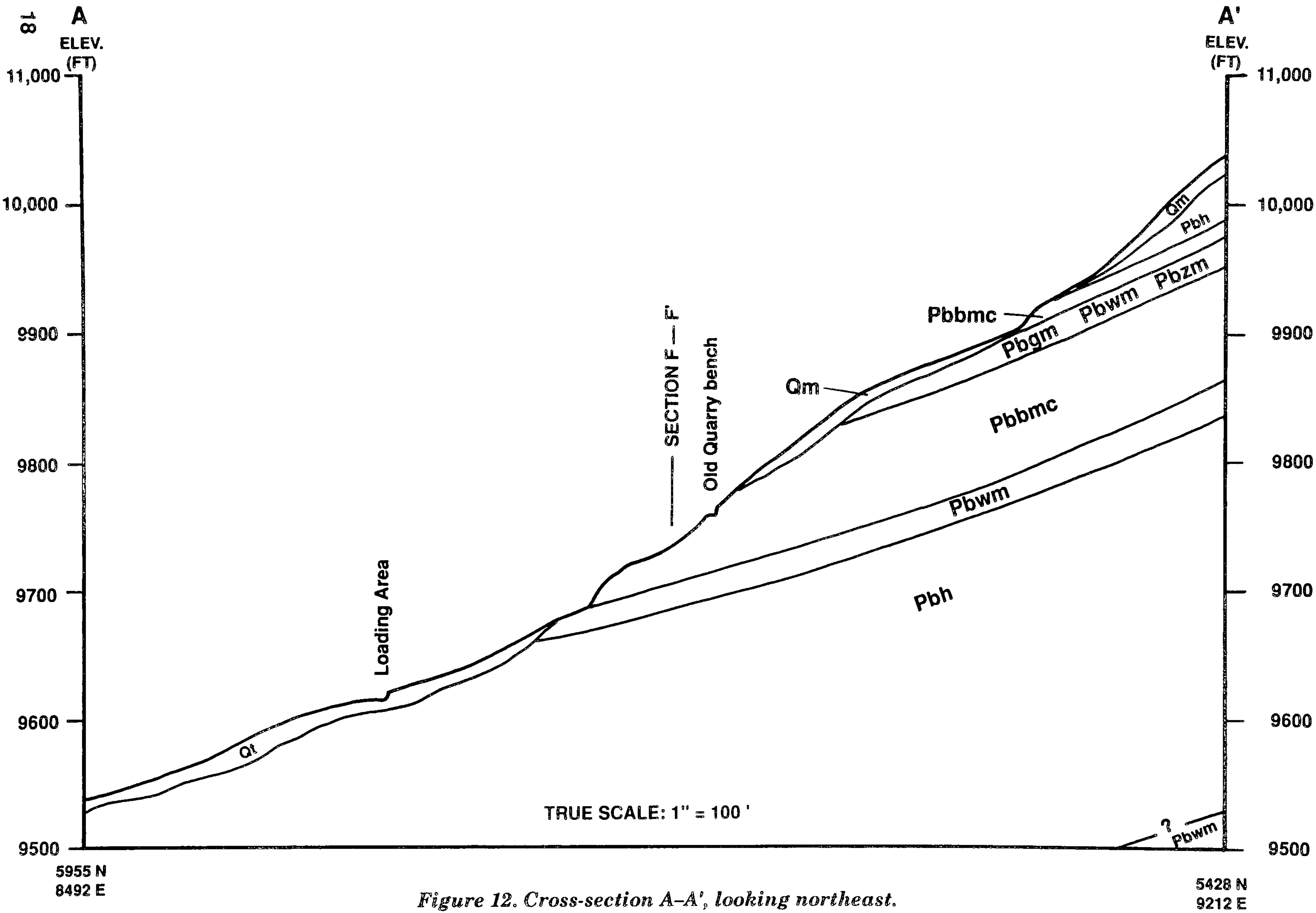


Figure 12. Cross-section A–A', looking northeast.

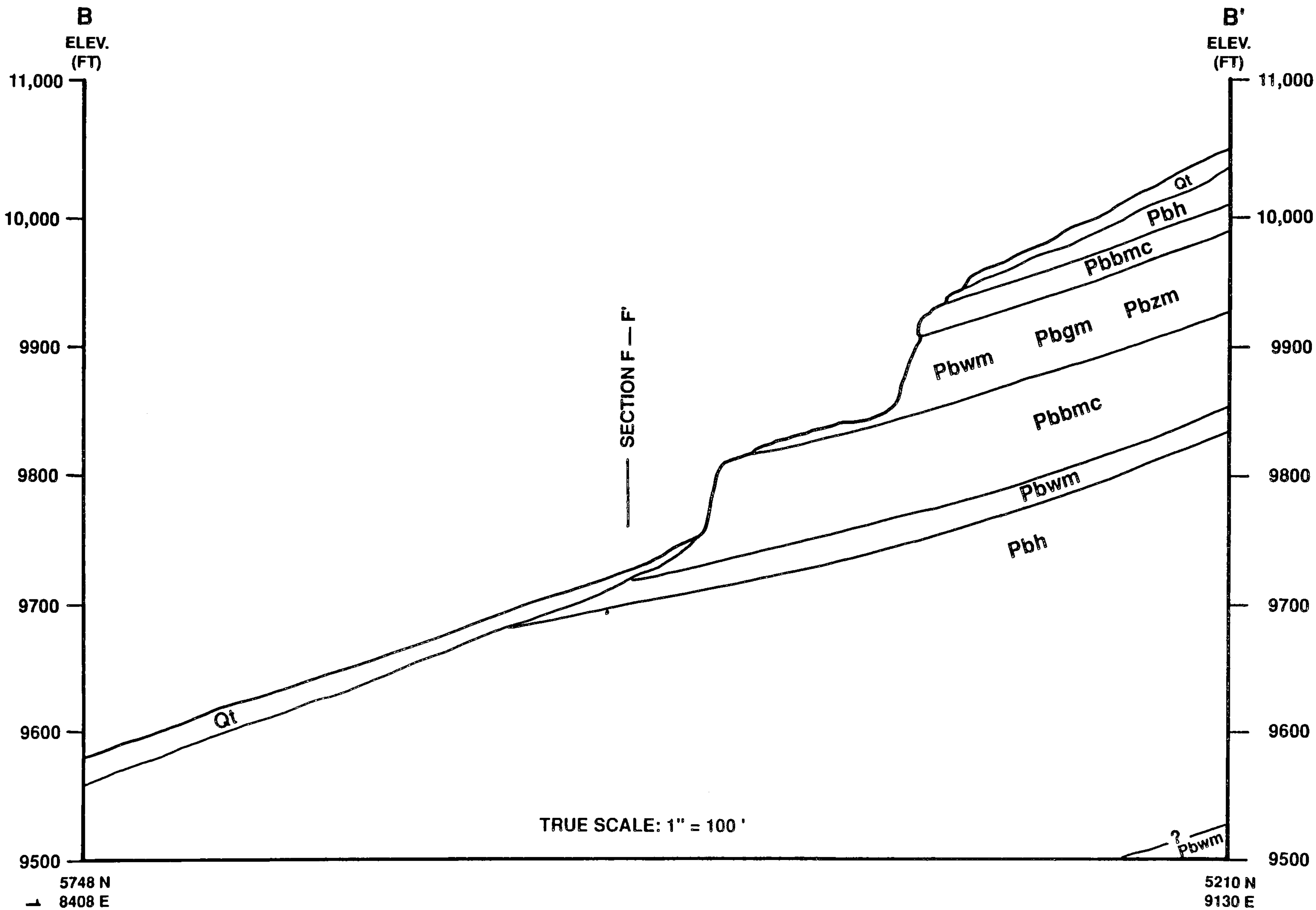


Figure 13. Cross-section B–B′, looking northeast.

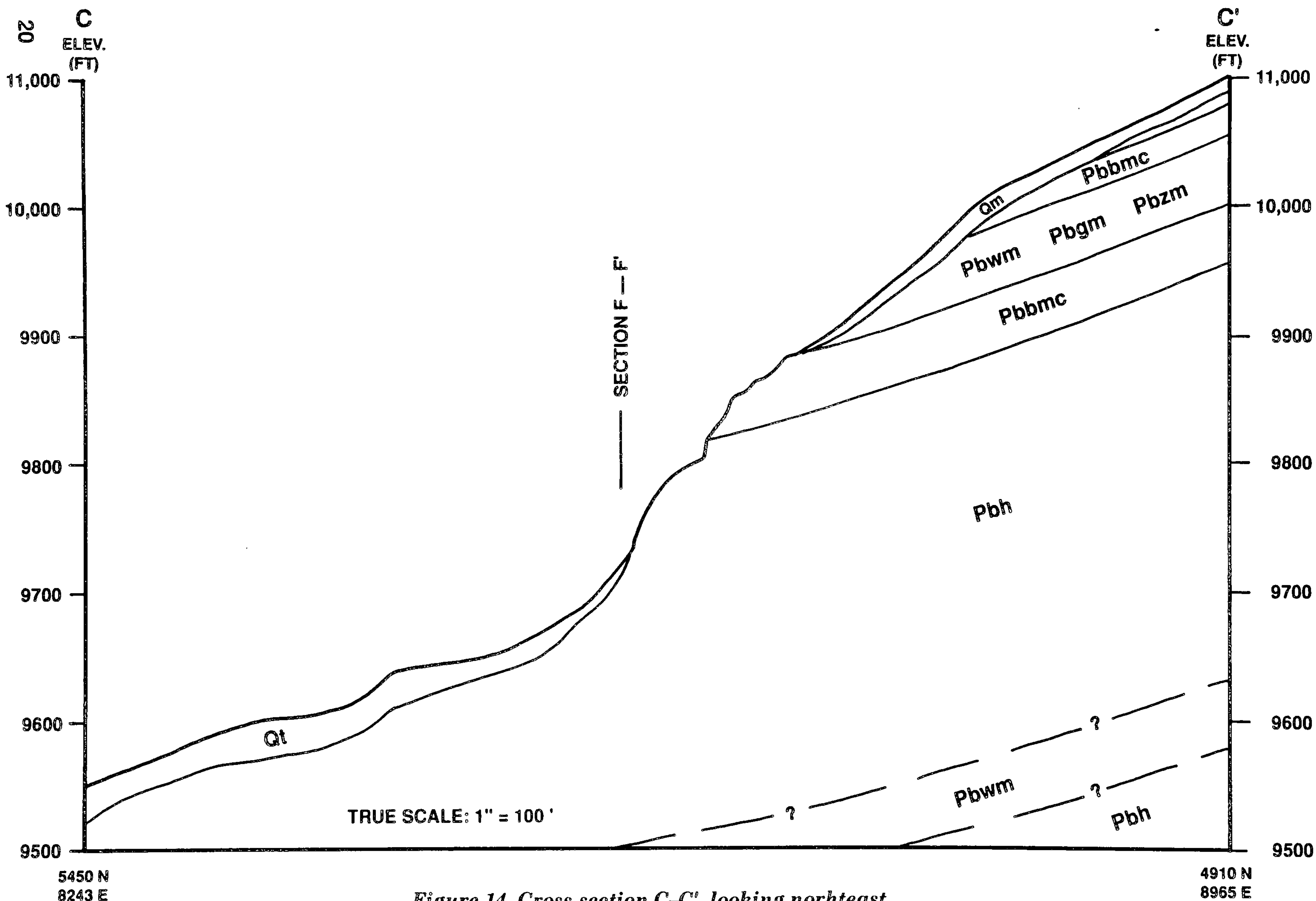


Figure 14. Cross-section C–C′, looking norhteast.

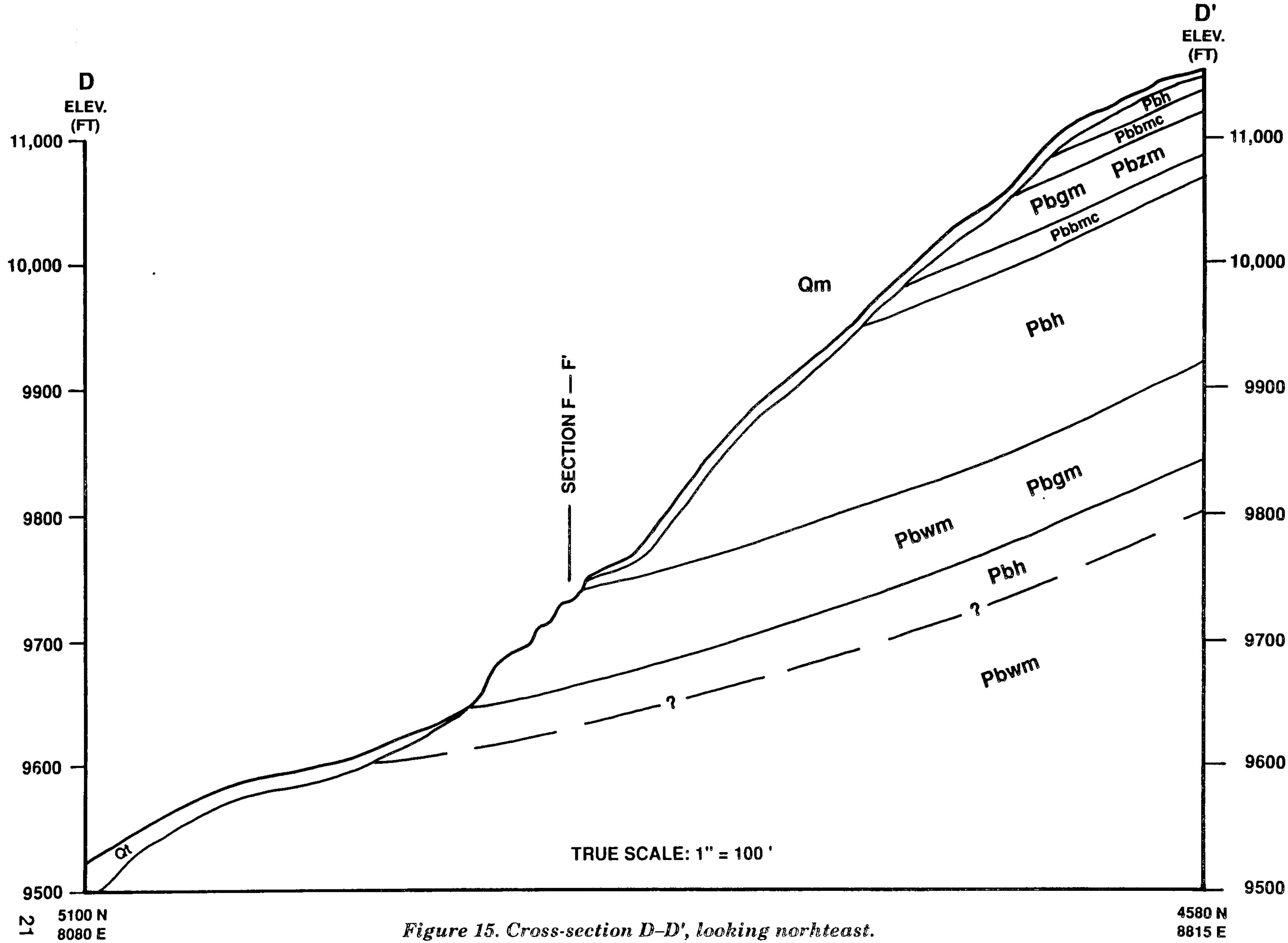


Figure 15. Cross-section D–D', looking norhteast.

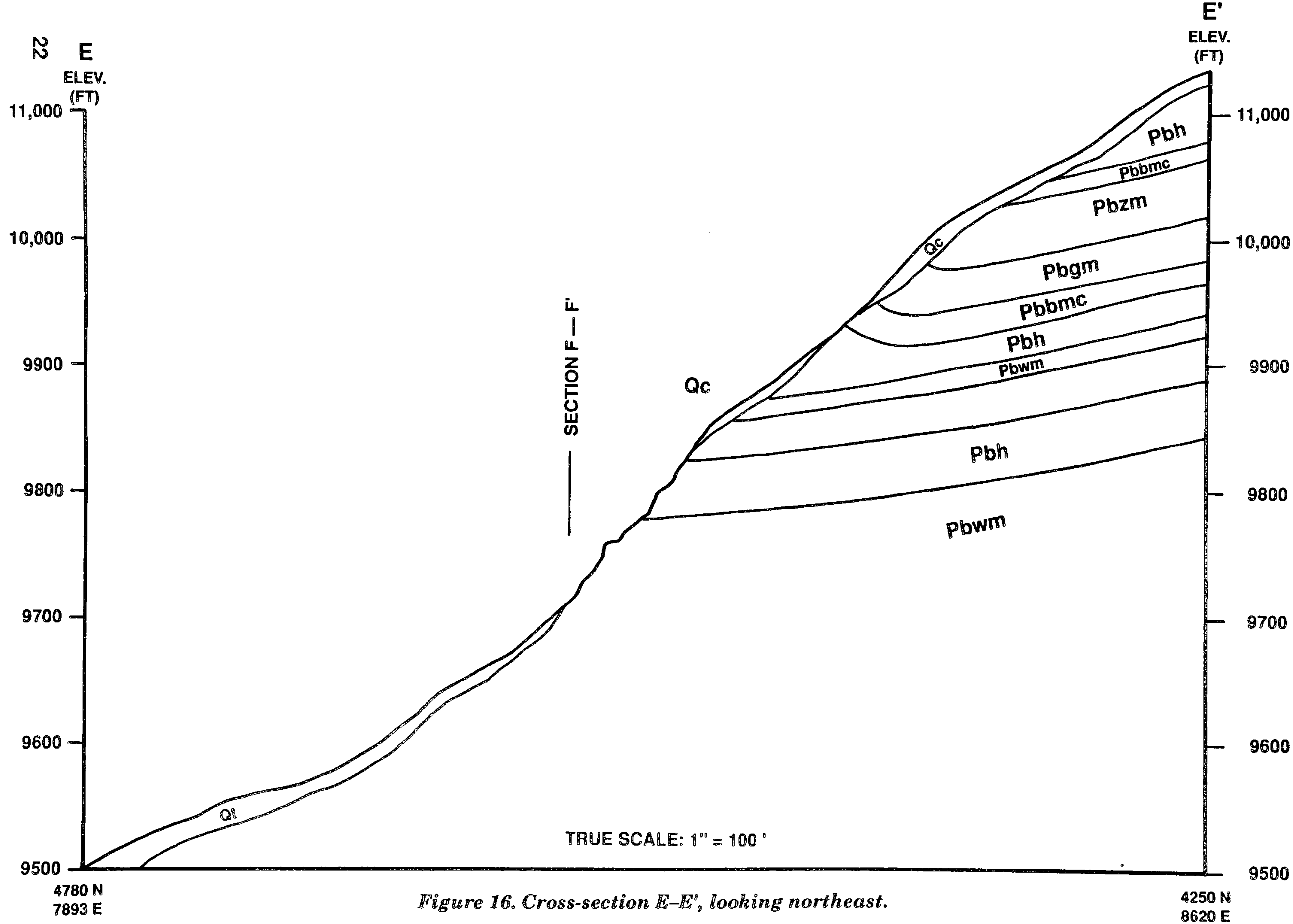


Figure 16. Cross-section E–E', looking northeast.

the greatest potential for gold. This was in part due to the geometry of the basin and the existence of metal mining activities at this point in the basin and southward. CGS concentrated panning activities here and at the location of turn-of-the-century placering efforts near the north-south center of the claims. CGS also panned in many other areas of Conundrum Creek which would be favorable for gold accumulation from the stand point of present day and paleostream hydraulics.

Placer gravels were evaluated both by quantitative and qualitative methods. Panned concentrates were run by AA for gold. The highest value received was six ppm with the average running 2.8 ppm. This value reflects total gold of sample and makes no designation as to amount of contained free gold which would be recoverable by placer mining methods. Very few "colors" were observed in panned concentrates. The great majority of detected gold in samples is probably contained in other minerals as background value. The high ppm concentrations of copper are probably due to the presence of chalcopyrite, often a carrier of gold values. Other panned concentrates were examined by hand lens and visible gold documented. Very few samples contained visible gold. All gold recovered by surface panning was flour gold. No minable placer gold could be delineated on the property from which to devise a mineral value. Furthermore, placer gold potential of the subject property is considered by CGS to be low due to the minor occurrences of observed gold, the small partical size of the gold, and the depth to bedrock which is speculated to be more than forty feet.

SURFICIAL DEPOSITS

A variety of Quaternary deposits occur in the Conundrum valley, all of which are typical of those found in high alpine valleys with varied rock types. The most recent deposits are those of the immediate stream bed of Conundrum Creek. Moderate to poorly sorted alluvium ranging in size from small boulders to fine silt occurs in and immediately adjacent to Conundrum Creek. Alluvial deposits are mostly formed by the reworking of older surface deposits. Glacial moraine deposits occurring in the Conundrum Valley are poorly sorted but display crude bedding in some locations. The lower slopes on the west side of the valley in the vicinity of the Colorado-Highland property are covered with large, lobate fan deposits. These deposits are best developed where short, steep tributaries join the major drainage. Large deposits of colluvium and talus are well developed in the valley. These surficial deposits comprise over 95 percent of the property and made accurate mapping of the bedrock geology difficult.

ENGINEERING GEOLOGY

Avalanches comprise the major engineering geology problem for the development of the marble resources of the Conundrum Valley. A major avalanche path crosses the site of the old Colorado Highland quarry (the most logical site for initial quarry development). Field and color aerial photo evaluation indicate the probability of major avalanche activity across this broad path at least once per year. Parts of the path probably run several times a year. Several avalanche runout zones with indicated annual or more frequent activity cross the access road between the quarry location and the present trail head.

These avalanches would make winter operations expensive and extremely hazardous.

The large avalanche path at the Colorado-Highland quarry site starts in a catchment basin near the ridge top at an elevation of 13,000 feet. The velocity and force developed in its 3,000 vertical drop in the steep run down to the quarry should not be underestimated.

Any permanent shops and buildings would have to be located several hundred feet to the north where they would be out of the path and protected by dense large conifers not far from where the access road leaves the present trail. Detailed engineering and snow studies beyond the scope of this project would be required to determine the feasibility and design of constructing a diversion structure to protect the quarry. The wilderness classification of lands above the claim boundary would prevent avalanche mitigation structures in the catchment basin and release zones. It would be necessary in most years to clear avalanche debris consisting of packed snow and minor rock from the quarry working. Obviously, equipment would need to be removed each fall.

The most logical site for the white marble quarry is south of the avalanche path and protected by a large, dense stand of conifers.

Although highly dependent on the amount and timing of snowfall the avalanche season could be expected to commence between November 1 and December 1 in the fall and continue through April 15 to May 15 in most years. This would effectively allow only seven months work in favorable years and five months in unfavorable years unless the operation grew to where it could afford extensive avalanche defense measures.

Upgrading of the current road sufficient to carry quarry traffic would encounter only minor engineering geology problems. In two or three locations the stability of the cut slopes required to widen the road and improve the grade would need to be addressed.

The economic evaluation for the Colorado-Highland Marble properties on Conundrum Creek is modeled after standard methods and widely accepted practices of the mining industry. The objective is to establish the most economical mine plan which would show the best return on investment over the operating life of the property. In this case the opportunity exists for at least two extremely different mining efforts. First, the property may be mined as a small day-to-day operation, delivering production as the need arises or as a small, select market demands. An example of this would be the demand generated by sculptors who conceivably would be invited into the quarry, offered a block of marble from one of several workable faces. Second, the property may be mined in the manner of a large multinational mining company that anticipates large scale production for many years, mining different colors of marble as the market requires. Both of these vastly different conditions have been examined.

INVESTIGATION ACTIVITIES

Literature Review

There is little published information to assist the evaluator with respect to marble quarry operations. The information which can be obtained includes costs of equipment, retail prices for finished product, transportation rates, and imports. The Colorado Geological Survey studied the trade journals and data supplied by the U.S. Department of Commerce as well as the very few historical documents and publications describing marble mining in the United States.

Site Visits

Personnel from the Colorado Geological Survey toured various sites to gather information on product quality, finishing and distribution techniques, quarry operations and associated costs. These include the Denver Marble Company, Finishing plant, Platte River Drive, Denver Colorado; the Colorado Stone Company of Longmont, Colorado; Aspen Marble Company, Glenwood Springs, Colorado; and the operating quarry and modern fabrication plant of the New Mexico Travertine Company of Belen, New Mexico.

The Yule Quarry located five miles south of Marble, Colorado, was examined to determine the nature of the problems associated with an underground operation in a rugged environment which has certain similarities to the Conundrum Creek area, and to ascertain the changes in quality of the marble as one proceeds through the weathered zone into fresh material.

Telephone Contacts

Telephone contacts were used to establish costs and potential markets. No attempt was made to disqualify information perceived to come from potential competitors. A synopsis of these contacts indicate that there is a market for dimension stone products in the building industries. Many architects are using these products. The most popular now are granites because of their beauty and durability. Marble is also extremely popular but its use is more appropriate for interiors where not subjected to weathering. Black marble is the most sought after of the marbles. Its use is even more limited than lighter marbles because it is generally softer due to the carbonaceous inclusions which give it its color. Therefore only the most durable of the black marbles are used in floors or areas requiring similar abrasion resistance. The marbles in shades of gray are in much less demand. The records obtained from these contacts are included in Appendix D.

Correspondence with State Geological Surveys

The geological surveys of Alabama, Vermont, Tennessee, Georgia, South Carolina, Idaho, and

Montana were contacted for pertinent information with respect to marble production in their respective states. The information obtained was helpful in the understanding of marble occurrences but of no substantial help in the determination of production or volume of sales.

MARKET EVALUATION

Potential Users

The potential users of the marble include builders, architects, fabricators, sculptors and intermediates such as other quarry operations which might want to expand their product line with outside material.

Representatives from these groups were contacted with mixed results. All of the architects contacted showed interest in the black marble product but needed samples of polished tiles for approval by their customers. They also needed test results before any commitment would be made with respect to useage. Fabricators include Idaho Travertine Corporation, Boise, and the New Mexico Travertine Company, Albuquerque, New Mexico. Both of these showed minor interest in the dark gray marble but were cautious because previous toll fabricating arrangements were unsuccessful. These past unsuccessful efforts were due to wide variations in the quality of the stone including equipment damaging chert inclusions and weak material that would fail when machining. An opportunity exists for toll sawing or purchasing of mill blocks by the fabricator but this would eliminate much of the profit margin expected by the quarry operator in a start up mode. Idaho Travertine does toll saw and polish marble from outside quarries.

Foreign Competition

Black and gray marbles are quarried in many countries. At this time France, Belgium, Spain, and Italy all have well established, good quality dark marbles available. Cost are relatively cheap due to the well developed infrastructure enjoyed by European quarriers. In addition to the European producers, China, Australia, and Guatemala have available varieties of black or gray marbles.

The longevity of these operations is one of the largest selling points. The products can be observed in many buildings where questions of resistance to weathering can be answered at a glance. These foreign operations have also demonstrated a continuity of supply which is of major importance to a potential buyer who wants thousands of tons at the present and the assurance that more of the identical material will be available in the future when anticipated maintenance is necessary.

It is a well known fact that labor costs in many foreign countries emerging in the marble business such as China and India are considerably lower than labor costs for new entries in the United States. The savings in labor costs and the proven infrastructure enjoyed by established foreign producers offset shipping and importation costs to some degree.

Other countries are vying for a portion of the favorable U.S. market. China and India are shipping marble to these favorable markets at prices which are below costs in order to capture market share. The effect of this strategy on all the known producers will be to lower prices to remain competitive. A new quarry without a proven product must enter this market with the same competitive posture to get his product into the marketplace. This will necessarily come at a time when establishing cash flow will be of utmost importance.

Current Import Situation

U.S. Department of Commerce records display total imports of various marble products yearly by country of origin. Imported marble is in the form of finished or unfinished slabs, rough blocks, or chips. Total import of rough block is understandably small. The majority of recorded import for the past four years has been as finished or unfinished slabs (See Table 1). Department of Commerce tables for marble also include onyx and breccia but still are useful in establishing trends.

The data reflect the expected trend of Italy being the leading exporter of marble slabs to

Table 1. Marble imports to the United States in 1988.

Country of Origin	Product (in square feet) Slabs (finished)	Slabs (unfinished)	Estimated Value (in thousands of dollars)
Italy	39,958,634	760,128	$ 128,482
Spain	11,907,794	57,384	25,034
Greece	4,385,910	141,932	15,142
China	2,432,082	177,478	6,873
Mexico	2,407,978	101,824	4,564
Subtotal:	61,092,398	1,238,746	180,095
Other Countries	10,002,254	166,905	26,417
Grand Total:	71,094,652	1,405,651	$ 206,512

(from U.S. Department of Commerce FT135: U.S. General Imports and Imports for Consumption, 1988)

the U.S.A. Spain is a strong second with Greece, China, and Mexico all recording significant exports. A great majority of the product supplied by Mexico is probably onyx, for which that country is famous.

Local Markets

No definite local markets of any large proportion were identified by CGS. Marble counter tops and interior finish are somewhat popular in the Aspen area according to a number of local architects.

Local Competition

There are no direct competitors selling comparable material however the Colorado Yule Marble Company has applied for permits to reopen the Yule Quarry which by its name alone should overcome the problems of buyer education.

PRODUCT QUALITY PARAMETERS

Physical and Aesthetic Properties of Marble

Marble is defined geologically as a metamorphic rock composed of calcite, dolomite, or a combination of the two (U.S. Bureau of Mines, 1968). Marble is distinguished by its crystalline nature, as there are frequently no compositional differences between marbles and their granular parent rocks limestone and dolomite. In the quarry industry, the term "marble" takes on a much broader definition and includes any calcareous rock of sufficient hardness to take a high polish. This broad, non-geological classification not only includes true crystalline marbles but also onyx and travertine, which are sedimentary precipitates of calcium carbonate.

Marbles often occur in distinctive colors and textures to a degree that certain varieties are sufficiently unique to be identifiable by location. Because of this aspect, marbles are frequently marketed under romantic product names such as; "Belgian Noir", "Napoleon Grand-Melange", and "Valencia Rose". Textural and color differences are a function of the geologic history of the deposit. The engineering parameters of a particular marble are also related to geology.

Color

The color of a marble is related to the species and relative percentages of secondary minerals (impurities) present. Impurities can be original constituents of the parent rock or can be introduced from an outside source during formation. Impurities can be evenly distributed, rendering a uniform color, or may be concentrated in bands to give a more "veined" appearance to a marble. Some highly colored marbles are the result of brecciation, or fracturing, which has allowed an influx of foreign material into a body of marble. In general, the white marbles are derived from pure calcitic or dolomitic limestones and tend to be the most free of impurities. Red, pink, or red-brown coloration is generally caused by manganese oxides or hematite. Yellow, yellow-brown, or cream color variations are usually due to limonite. Gray to black tints are caused by carbonaceous material contained in the rock matrix (Bowles, 1958). Green shades are due to the presence of micas, chlorite, and/or silicates (MIA, 1985). A list of secondary minerals frequently found in marbles would include: brucite, diopside, epidote, feldspars, forsterite, graphite, grossularite, humite, periclase, phlogopite, pyrite, quartz, scapolite, serpentine, sphene, spinel, talc, tremolite, vesuvianite, and wollastonite (Dietrich and Skinner, 1979). The marble which occurs on the subject property can be subdivided into many different colors. The most prevalent is white marble followed by a medium gray marble which was previously mined. The amount of white marble is misleading to even the casual field observer because much of the white marble outcrops have a medium gray stained or weathered rind .5 inch to 1 inch thick. CGS also encountered other marble of various shades of gray, green, and a fine grained dark gray which was the closest to black. None of the marbles were a true black and no such true black is expected.

Texture

The texture of marble is the size, degree of uniformity, and arrangement of constituent minerals. Grain sizes may range from fine (greater than one milimeter), to medium (one to five milimeters), to coarse (greater than five milimeters) for both calcitic and dolomitic marbles. The marbles of the project area all appear to fall into the medium grain category. Where calcite and dolomite marbles occur together, the calcite grains tend to be the more coarse. Also, calcitic marbles tend to display anhedral, interlocking grains with mosaic or sutured boundaries whereas the dolomitic marbles tend to be more granular or saccharoidal (Dietrich and Skinner, 1979). Degree of uniformity can be variable, ranging from equigranular, to non-equigranular, to porphyritic textures in which large euhedral grains are enclosed in a smaller grained ground mass. None of the marbles mapped fell into this category. All were equigranular throughout the thickness of the bed but might grade into finer or coarser grain size over a long strike distance. The type, distribution, and geometry of grains, along with the nature of grain boundaries, is important in that they will determine the relative physical properties of a marble.

Translucence

Certain varieties of marble will allow light to penetrate into the rock structure, creating a very aesthetic "glow". This is a most desirable quality in statuary marbles, some of which have light penetration ranges on the order of .5 to 1.5 inch (Bowles, 1958). Some marbles have a "waxy" luster which may also be attributable to translucence. None of the polished samples of the Colorado-Highland Marble quarry appear to have significant translucence.

Rift-grain

The terms "rift" and "grain", when applied to marble, are essentially synonymous and refer to the direction(s) of easiest breakage or cleavage. Frequently rift parallels bedding and is probably caused by elongation of grains due to pressure. The presence of platy or fibrous secondary minerals, such as micas or actinolite, will enhance rift because of preferred orientations along axes of grain elongation (Bowles, 1958). Rift direction has been an historically important consideration in quarry planning but is recently becoming less important because of the advent of modern diamond saws in the separation of quarry blocks. As previously mentioned, rift in Colorado-Highland marbles is parallel to bedding, where present.

Soundness

The dimension of blocks to be quarried from a particular deposit is greatly controlled by joint spacing. Joints which are encountered in most quarries, may be nothing more than planes of weakness or may be well developed, open cracks. Joint spacing is variable, ranging from tens of feet down to inches. Uniform, wide spacing of parallel joints can add to the value of a deposit as production costs will be decreased as waste may be minimized by running cut walls parallel with the major joint system.

Joints were mapped within the project area to obtain the prevalent direction and orientation for quarry planning. Most of the major joints were oriented vertically in the old quarry area and have an easterly strike. The verticality is an advantage but the easterly strike requires that the blocks will be oriented at an angle to the strike of the outcrop and hillside. Joints to the south in the outcrops of white marble are random and more prevalent. Experts in the field and CGS's examination of the Yule Quarry indicate that jointing decreases with distance from surface weathering. However, there are beds of marble that are so severely jointed that no blocks could be successfully quarried. Specifically, these areas include the white beds above the previously quarried marble, and the upper beds along the south property line.

Soundness is also a function of mineral constituents and texture when considering the competence of marble when slabbed. Variable cohesion between non-uniform size and type of mineral grains can place restrictions on product use or may require slabs to be reinforced. Open voids, veins, or flow structures can also decrease the competence of marble when slabbed. Based on knowledge gained through years of practical experience, marble has been universally classified into four groups based on characteristics encountered upon fabrication. The system indicates required fabrication techniques which are considered necessary, as based on standard trade practice (MIA, 1987):

Group A: Sound marbles and stones, with uniform and favorable working qualities.

Group B: Marbles and stones similar in character to the preceding group, but with working qualities somewhat less favorable; may have natural faults; a limited amount of waxing and sticking necessary.

Group C: Marbles and stones with some variation in working qualities; geologic flaws, voids, veins, and lines of separation are common; it is standard practice to repair these variations by sticking, waxing, and filling; liners and other forms of reinforcement employed when necessary.

Group D: Marbles and stones similar to the preceding group, but containing a larger portion of natural faults, and a maximum variaion in working qualities; requires more of the afore mentioned finishing techniques. This group comprises many of highly colored marbles prized for their decorative qualities.(After MIA, 1985)

Colorado-Highland marbles generally fall into Group B. Polished slabs are fairly competent except for a few scattered grains which may spall out during finishing. All material collected and finished is from the weathered zone of the deposit. Soundness and polishability are expected to increase with depth.

All of the above mentioned characteristics of a building stone can affect market value. It is the aesthetic qualities of polishability and general attractiveness though which will ultimately place a particular stone in high demand.

Engineering Constraints of Marble

Modern building design and construction requires increased knowledge of the physical limitations of building materials. As performance requirements become more demanding, so does increased need for quantitative data on construction materials. The Natural Building Stone Committee of the American Society for Testing and Materials (ASTM) has established standards for the testing and documentation of the physical properties of marble. The recommended tests are:

C97	Absorption and Specific gravity
C99	Modulus of Rupture
C170	Compressive Strength
C241	Abrasion Resistance
C880	Flexural Strength

Standard specifications for marble building stone (exterior), and descriptions of test methods from the Annual Book of ASTM Standards are referenced at the end of this report. It should be noted here that the results of these tests will not necessarily determine the relative value of a marble, but do give insight into its general use.

Gray marble from the old Colorado-Highland quarry was tested by the Indiana Geological Survey for all of the above mentioned ASTM tests except flexural Strength (C880). Test report forms submitted to CGS by IGS are reprinted in Appendix C. To avoid the problem of running tests on severely weathered product, fairly large blocks were submitted enabling IGS to obtain relatively fresh marble from below the weathering rind. All tests were run in two phases. Material from the exterior portion of blocks was cut and tested initially. Less weathered material from the interior portions of the samples was subsequently run to check initial results. Weathering of blocks in the 70 years since they were quarried has weakened the external material. This is reflected both in megascopic observation once blocks are cut, and by increase in test results on internal samples.

Sample test results from exterior material are substandard or marginal for Absorption (C97), Abrasion Resistance (C241), and Compressive Strength (C170). Test results for these parameters when run again on less weathered sample all improve into the acceptable category according to ASTM recommendations. CGS has been advised by the Indiana Geological Survey and is under the opinion that test results from the interior, unweathered zone are more representative of Conundrum Creek marble physical properties. The marble tested meets or exceeds required ASTM standards.

POTENTIAL CONUNDRUM CREEK PRODUCTS

The products listed below are described from the field mapping and sampling investigations which were greatly hindered by lack of outcrop, from extreme contortion of beds and from gradation of one marble color into another. The representative samples have been described in Appendix A.

Black Marble (Pbbmc)

The marble identified as black marble in previous reports and newspaper articles is in fact a medium to coarse grained, medium gray. There is also a fine grained, thin bedded, dark gray marble occurrence interbedded with hornfels. This darker marble was not observed to outcrop in sufficient thicknesses nor in continuous enough beds to mine. The medium gray marble was previously mined from the northern most exposure of marble outcrop from two benches separated by 30 feet. Approximately 400 tons were taken from this area, skidded down to a loading bench and removed from the property. Very little waste remains from this operation. This area is proposed to be the phase one mining area. The outcrop here is approximately 100 feet long, north to south, and the same in an east to west direction. This bed of uniform marble can be projected southward to the lower waterfall giving it a strike length of 500 feet. The true thickness of this bed is 80 feet but chert beds in the lower portion reduce the mining thickness to 65 feet. These beds change from fairly flat lying (a slight westerly dip) to a considerable northerly dip just north of the old quarry. CGS projects these beds into the hillside 500 feet which would yield 16 million cubic feet or 1.4 million tons at 175 pounds per cubic foot (pcf). Figure 17 is a photo of a polished slab of gray marble cut from an old stockpile block from the 1912 Colorado-Highland operation. CGS recovered the block and had a polished finish put on a face by Denver Marble Company.

Gray Marble (Pbgm)

Beds of gray marble have been observed on the property in various stratigraphic intervals. These gray beds range in color from light gray to light blue. They also range from coarse to fine grained. They are seen in outcrop at the southern portion of the property and where they are interbedded in thin beds with the previously mined dark gray marble and with beds of white marble throughout the property. These beds appear to be too thin, discontinuous, and jointed to be mined for quarry blocks (Figure 18).

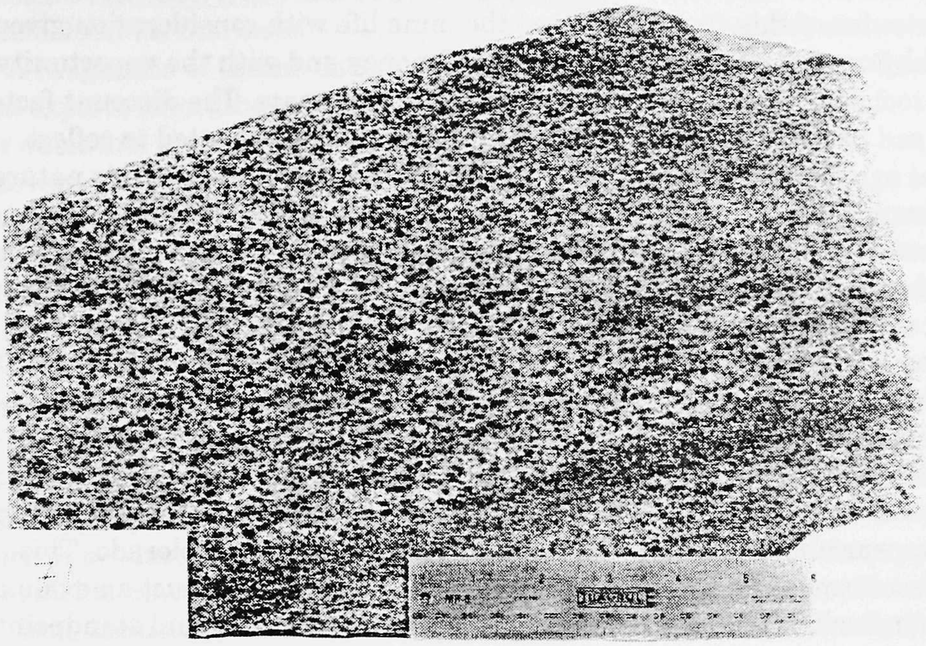


Figure 17: A polished slab of gray marble taken from an old Colorado-Highland quarry stockpile. Slab was cut and polished August, 1989 by Denver Marble Company.

White Marble (Pbwm)

White marble is extremely prevalent on the property and may exceed the gray marble in volume. The thickest outcrops are found along the southern portion of the property in two massive outcrops forming 60–80 foot vertical cliffs. The white marble is variable in color from light blue-gray to white and with another variety ranging from tan to white. Grain size varies from fine to coarse. The white marble seen on outcrop at the Conundrum Creek Properties is judged by CGS to be inferior to the Yule Marble in color and texture, and appears to have weathered to a greater extent than has the Yule Marble. These beds are 725feet in strike length, 100 feett or greater in thickness and CGS projects them 400 feet in the dip direction into the hillside. This yields a volume of

Figure 18: Gray marble found interbedded with hornfels. This marble is very quartzitic is places and is too thin to be of economic importance.

63

29 million cubic feet or 2.5 million tons of resource. CGS also believes that none of this could be economically mined by open quarry methods (Figure 7).

Banded Marble (Pbzm)

This variety outcrops stratigraphically above the dark gray marble which was previously mined and trends to the southern property line. It is a coarse grained marble with alternating bands of light to medium gray and light blue to white. These bands are approximately one inch in thickness. Another variety has a tan coloration. This tan coloration may be a surface alteration product caused by the weathering of minute pyrite grains which appear ubiquitors throughout this variety. No reserves have been assigned to this due to pyrite inclusion (see Figure 19).

CALCULATION METHODS

The evaluation procedure utilized in this study has been specified in the contract between USGS/U.S. Forest Service and CGS as a Discounted Cash Flow, Rate Of Return (DCFROR) method. This method is based on a comparison of costs to revenues taken over a period of time such as the mine life with consideration given to the cost of money and with the opportunity for competing investments. The discount factor utilized in the study was adjusted to reflect risks inherent in an investment of this nature. The value of the property is the present value factored sum of the net profit or loss after taxes and after the prudent investor has met his return goals. This evaluation does not consider the tax advantages that a mining operation might yield to other, unrelated investments, but that the proposed operation must be self supporting. The calculation employed the commercial software program $EE, Investment Evaluations Corporation, Golden, Colorado. This program allows the user to conduct an evaluation from a corporate or individual standpoint and calculates a sensitivity by up and down grading the costs and revenues by increments up to 20 percent. The $EE program was selected for use because the senior author of this report and members of the Forest Service are familiar with the program, its improvement over spread sheet DCFROR programs used in industry, and how it follows the widely accepted

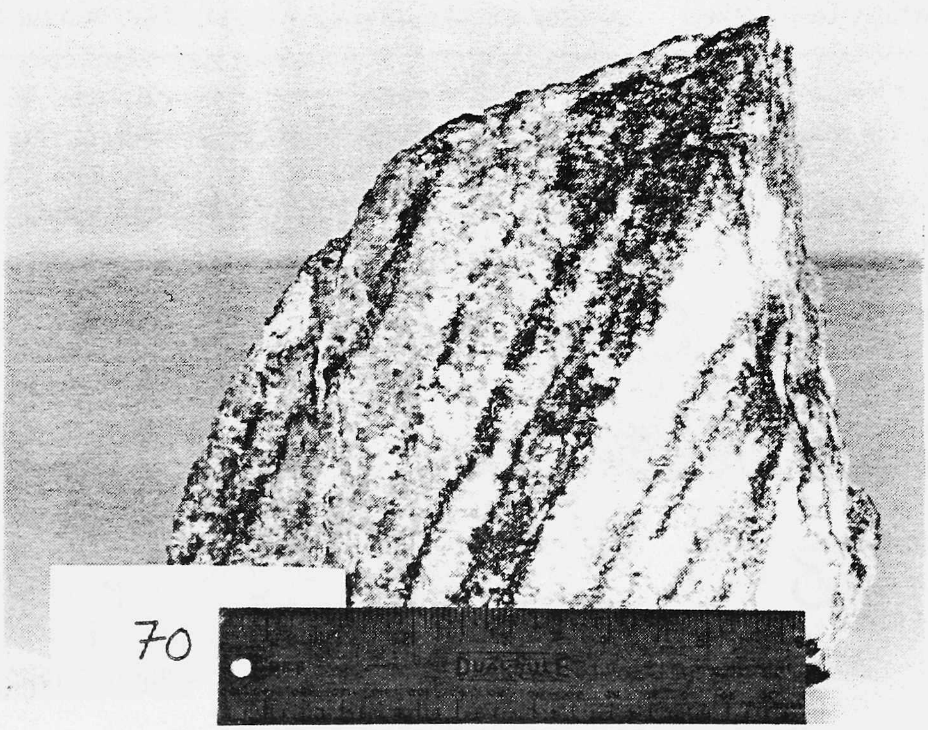


***Figure 19:* Banded marble which occurs throughout the Colorado-Highland property. The thin bedded nature and abundance of pyrite in banded (or "zebra") marble render it of no economic importance.**

Textbook, *Economic Evaluation and Investment Decision Methods, Sixth Ed.* 1987, by Franklin J. and John M. Stermole.

A rough rule of thumb used by quarry valuation experts according to Duncan Ogden is $.10 per cubic foot multiplied times the volume of recovered, fullsized mill blocks. For this project that would amount to: $.10 times 20 percent recovery times 34,820,000 cubic feet equals $696,400

Discounted Cash Flow

The Discounted Cash Flow (DCF) used in this evaluation assumes several different manifestations of production for four, five, and six months of operation. These include three iterations of production with tolling of the tiles by an outside contractor, one six minth production withthe inclusion of a tile line, and one iteration of production with the assumption that whole blocks only would be sold to fabrication contractors for final disposition. At Conundrum Creek some have significantly longer periods of temperatures above freezing allowing longer operation of water utilizing equipment.

The Discount Factor

The discount factor (DCF) utilized in this study re-flects the corporate rate of return and the individual rate of return. The corporate rate of return used by CGS is that rate which a conservative corporation must have to offset cost of money, competing investments, and risk. The corporate rate is assumed to be 18 percent. This study is extremely sensitive to the discount factor, a percentage either way makes a difference of hundreds of thousands of dollars.

Costs and Revenues

The costs and revenues used by CGS have come from the experts mentioned above and are subject to a wide range of interpretation. For this study CGS assumed that costs would fall under the following categories: Development, the building of a staging area, improving roads, and site preparation. Quarrying, which includes transportation. Fabrication, the processing of blocks into finished slabs, of broken blocks to tile planks, and sawing and guillotining waste into ashlar veneer strips.

The cost and revenues per product are summarized below. Quarrying costs are assumed at $6.00 per cubic foot of usable marble. Any block that is quarried has this cost which includes direct labor, haulage to the fabrication facility assuming that it is reasonably close, and indirect cost such as overhead. Fabrication costs for slabs of 5.5 feet by seven feet are approximately $175 per slab. This figure includes the $6.00 per cubic foot as well as overhead and direct labor.

Capital costs include quarrying equipment, fabrication equipment, and a building to house the fabrication equipment. Land for this building is assumed to be located near Basalt, Colorado, where there appears to be opportunity for an eight acre site of this nature. CGS contacted the Eagle County Assessor's Office for the cost of such a site and found it to be $5,000 per acre.

The product line for this operation includes slabs cut from large quarry blocks. These slabs are roughly 5.5 feet in width by seven feet to eight feet in length and could vary in thickness but are assumed here to be .75 inch. The large quarry blocks of these dimensions weigh between 18.5 and 20 tons and have a volume of over 200 cubic feet. The slabs which can be cut from these blocks are worth between $8.00 and $15.00 per square foot. CGS assumed $9.00 because the material would be on the low side of the market. A quote from a buyer yielded a similar number. CGS also assumed that there would be loss in slab cutting due to breakage, imperfections in color or quality, or inclusions of chert or pyrite. Production from the blocks would be 56 slabs. This 85 percent recovery is considered low by industry standards but is justified by the materials tests which place the marble in the lower spectrum of allowable strengths. The set up of the fabricating plant is directed toward producing these polished slabs which could in small part be custom fabricated into sink and counter tops but more likely will be sold to distributors These distributors expect a 100 percent markup to the contractor.

The second product expected from this operation is 12 inches square by .375 inch thick tiles. These are extremely capital intensive. CGS has assumed that these tiles will be fabricated at an existing off site facility. The Idaho Travertine Company custom cuts tiles but they require that the tile stock be in the form of marble planks which generally fall into the waste category. The blocks for calculation purposes are 100 cubic feet and comprise 10 percent of the annual quarry production. CGS assumes that 940 tiles can be recovered from these blocks at a cost of $4.10 per tile and sold for $4.50 per tile. The low margin compared to slabs is due to the shipment for custom fabrication. The calcium carbonate product is included in the calculations because quarry costs have already been incurred against it and it is a product which has a high demand. It is a low margin material and extremely sensitive to the haul. The $CaCO_3$ generally has no deleterious factors unless contaminated with hornfels or other noncarbonates and is expected to be produced at 10 percent of production from block fragments and to a limited extent from other clean quarry waste.

The ashlar strips used for exterior building facing and interior decorative walls would be also recovered from clean quarry waste. These strips are random in thickness and length but approximate the planks in size. CGS has not either seen any or heard of any gray marble ashlar veneered walls so the annual sales and margins are selected to be low. The amount of production would build eighty walls eight feet high and 50 feet long per year.

The actual calculation in the $EE program requires selection of mine life, assumed to be 30 years. The project start date is January, 1990, utilizing discrete compounding. The minimum rate of return has been selected to be 18 percent as a risk adjusted rate. The inflation rate is assumed to be four percent and the escalation rate is assumed to be six percent for capital cost. There are four products; slabs, tiles, $CaCO_3$ and ashlar as discussed previously. The tax burden has been selected as forward carry against future revenues. The federal tax rate of 34 percent and the state tax rate of 5.4 percent total 39.4 percent. Zero severance tax is used for quarry rock. The ad valorem rate is assumed to be 1.5 percent however that rate is high for this area of Pitkin County which has a very low mill levy.

The property tax is a function of assessed value given to CGS as $257,272 by Division of Property Taxation, and the buildings, and permanent equipment including underground mining equipment, non drivable or towable surface equipment and any fixture dedicated to the mine. The non-dedicated equipment is taxed also but at a different rate. Due to the complexity of this tax situation the 1.5 percent ad valorem rate was used and no other property tax treatment was programmed.

The capital costs are escalated and include land, development, buildings and equipment.

The building was assumed to have a 30 year life and equipment a five year life for depreciation purposes (See Table 2).

It is assumed that loans for all costs will be available at 16 percent except the no collateral development loan which is 18 percent.

The production is a function of the season lengths and costs are assumed to be incurred at

Table 2. Development and capital costs for the mining operation.

Cost $	Date	Item (see costs list)
175,000	June/1990	Wire saws, drills, loader, etc. minimal development work
79,500	June/1991	Development, road, staging areas site prep
212,000	June/1991	Specialized underground quarry equipment
42,400	June/1991	Land near Basalt for fabrication plant
265,000	July/1991	300 ft x 60 ft fabrication building
1,590,000	July/1991	Fabrication equipment including gang saws, polishers, fork lifts

the end of the year taken. The production is reduced when the open air quarry is exhausted.

The revenue stream is offset from the costs stream due to the wait for fabricating equipment and the necessity to expose the market place to the fabricated products at reduced prices. An alternative to this offset was to encumber the project with annual marketing and sales overhead costs which would be well over $500,000 per year. The transportation cost to the fabrication plant is in the per unit cost as shown on the cost list but with an additional $20 per slab for transportation to first point of sale. CGS assumed $10 per slab for shipment to Denver but considerably more for more distant markets.

The actual cash flow is shown in Appendix E which CGS has assumed to be a likely case. Included are the short reports for the other cases. The sensitivity analyses are included so that the reader obtains a clear understanding of the range of NPV associated with slight perturbations of assumptions. CGS believes that these assumptions are reasonable, accurate and defendable and also realizes that another evaluator picking only slightly different assumptions could arrive at an entirely different net present value (See Table 3).

QUARRY PLAN

Plan Overview

The quarry plan envisioned by CGS is phased to account for surface and underground mining, and mining in the north area of the property before mining the south property area.

The old quarry would be the site of Phase 1 mining. This area would require minor development before quarrying could begin which would include road construction and stripping of overburden. A staging area at the site of the existing boiler bench would service the Phase 1 operation. The operation itself would commence

Table 3. Costs and associated sources for the mining operation.

Item	Source	Cost
988 Front Loader		$100,000 used
derrick		$100,000
Chain saw	Rex Loesby	$100,000
Land	John Sternig	$3000-5000/acre
UG equipment	Roger Baker	$500,000
12 ft diamond saw	Roger Baker	$250,000-300,000
Wire saw	Rex Loesby	$25,000
Bar drill	Claude Ledgewood	$6,000
Tile Line:	Claude Ledgewood	$2,500,000
diamond cone grinder	included in tile line	
Dryer		
Waxer, buffer		
gang saw		
polishing machine		
Quarry cost	$6/cubic foot	
Slab cost	Gene Wiston	$175/5 x 7 ft slab
Tile direct cost	Claude Ledgewood	$1.75/12 in. x 12 in. tile
Tile cost	Rex Loesby	$2.70/12 in. x 12 in. tile
Truck rates	Rex Loesby	$1.50/mile
Truck rates to TN	Bill Nelson	$10/cubic foot
In place reserves	Duncan Ogden	$.10/saved cubic foot

at or near the upper existing quarry face which is close to the upper contact of the gray marble and at its northern most outcrop. The minable reserve here is limited by the steepness of the topography and the inclusion of chert layers in the lower portions of the unit. The volume of this Phase 1 surface minable prism is 3,260,000 cubic feet. This is approximately 285,000 tons at the assumed 175 pounds per cubic foot. The Phase 2 operation here would be underground to access the remaining two million tons of gray marble. The southern area of the property is composed of white marble outcropping in rugged terrain. This area will require extensive development prior to mining and will require that all mining be underground. The development there would include site preparation of a service area, road building of 3,000 feet to the main haulage road, and stripping to an adequate area for an entry. In that area hornfels units which overlie the marble are extremely folded and would form an irregular back which would be difficult to maintain.

The quarry operation must focus on the extraction of blocks which are approximately 5.5 feet by 5.5 feet by seven to eight feet in length. These blocks are small enough to ship easily and will fit in all of the common saws used in fabrication. It is the production of these larger blocks that will represent the most economic product.

Quarrying operations generate considerable quantities of waste material which either must be disposed of or must be turned into some type of by-product which could be sold at less than the disposal cost. Such a by-product for this marble quarry is crushed aggregate for use in buffering acid mine drainage, as well as other industrial applications. The operation will generate approximately three tons of waste for each ton of large quarry block material. Part of this waste will be in the form of broken 5.5 feet blocks especially those which fail because of unseen joints. These smaller blocks represent feed for the tile fabricating facilities.

Reserves

The minable reserves are usually far less than the volume of the resource. CGS calculated the volumes based on surface mapping and on projection without drill information into the hillsides for 500 feet. The assumption is that both quality and thickness will remain constant for that distance. To support that assumption CGS mapped a marble unit at the eastern most extent of the subject property which closely resembles the gray marble of the upper falls bench. CGS believes that this marble is the exposed eastern limb of a north plunging syncline and projects some 2000 feet to the upper falls unit. The projection of the white marble is less due to the complexity of structures on the southern property boundary.

The open quarry minable reserve was calculated to be 3,260,000 cubic feet or 285,250 tons using SURFER Version 4, Golden Software. Recovery will be a function of the ratio of useable material to total material assuming a waste loss. The recovery will be 50 percent of the quarry material as follows:

Recovery of 5.5 feet by seven to eight feet blocks will be 20 percent of reserves. Recovery of tile blocks will be 10 percent of reserves, Recovery of ashlar material will be 10 percent of reserves, Recovery of useable $CaCO_3$ will be 10 percent of reserves. The remaining 50 percent will be unuseable waste.

The underground quarry will have a similar recovery ratio of waste to ore with respect to blocks but the resource will be further reduced by the placement of ground control pillars. It is assumed that pillars will have a height to width ratio of unity and that the overlying beds of white marble above the original quarry will have sufficient strength to obviate leaving a horizontal thickness of the mined gray marble. This will require 20 percent to be left for roof support allowing 80 percent of 1,421,875 tons or 1,137,500 tons to be mined.

The white marble at the south property boundary will have a lower extraction ratio because the overlying hornfels is irregular, broken, and severely folded. This will necessitate leaving a substantial thickness of white marble in the back. This is further complicated by the existence of more non-vertical joints which invariably reduce extraction ratios and increase back support costs. A 20 feet thick back support of white marble will reduce the assumed 100 feet minable thickness to 80 feet Pillar spacing will reduce the remaining minable unit to 80 percent. This will reduce the minable reserve to 18,560,000 cubic feet or 1,624,000 tons. The total minable reserve is 34,820,000 cubic feet or 3,046,750 tons. The total recoveable product will be 50 percent (waste to product ratio) of 1.42 million tons of gray and 1.62 million tons of white for 1.52 million tons of marble.

Development

The main single piece of development will be the haulage road from the surface quarry staging area to the present parking lot for the trail head. This road is currently a truck road of approximately 2.4 miles. All of this road will require at least minimal blade work and appropriate turnouts for converging traffic. The road needs major improvement for a total of 2000 feet where it encounters the steep side banks and steep grades in the Maroon Formation. One area just above Conundrum Creek will require truck and loader as well as bulldozing and retaining wall or tie back construction. The road beyond the trail head parking lot will require widening and turnouts for converging traffic. The two bridges on this section of the road will require engineering studies for load and possible reinforcement. It would take three weeks of truck and loader time to make the haulage road satisfactory for highway truck travel. The other development would involve access road building to the upper quarry area and to the south property area for the underground white marble quarry and the dozing of the two staging areas. These could be completed in a week of dozer work. Quarry development work is minimal for the Phase 1 quarry but becomes more involved for the underground quarrying. These would require adits and access drifts to set up the quarry which, although driven in potentially useable material will not be set up for optimal production. This is reflected in the reduced underground production during the start up period.

Production

Production would begin at the old Colorado Highland quarry site. It would initially require a six man crew. The expected production from this crew would be 6,000 cubic feet of material for the first month. The crew would be increased to 12 after the first month and production would be increased to 30,000 cubic feet per month. The annual production is a function of the length of the season. CGS estimates a quarry season of between four and six months for production of between 120,000 and 180,000 cubic feet per year. The quarry equipment necessary for this operation includes two wire saws, a penetrating drill, a bar drill. A derrick is standard equipment at most quarries, however, a large front end loader would suffice and is used in the cost calculation.

Production will be less per month in the underground quarry due to the nature of the working space. As the working faces advance farther underground more pressure exists on the marble. When this presure is reduced, the block adjusts in volume proportional to its bulk modulus. The resultant expansion may cause fracturing. To reduce the likelyhood of adverse strains due to this stress memory, partially cut blocks are allowed to equillibrate over an appropriate time interval before total removal. A six man crew is foreseen in the underground quarry producing 4,000 cubic feet per month until the quarry is developed sufficiently to have more working faces. The total production is between 136,000 and 204,000 cubic feet per year depending on length of season (Table 4).

Table 4. Recoverable production.

Production	Percent of Production	Amount
5.5 ft and 7 ft blocks	20	96 to 204 blocks
Tile blocks	10	96 to 204 small blocks (100 cf)
Ashlar	10	840 to 1,785 tons
$CaCO_3$	10	840 to 1,785 tons

Transportation

The transportation of all material except for tile blocks will be to a facility or storage area near Basalt. The tile blocks should be shipped to a custom tile fabrication plant ,however, should one not be available they too would be off loaded at the Basalt facility. This will involve haulage of material during the quarry season by three trucks. The trip from the quarry to the pavement is 3.8 miles and will take one hour. From this point to Basalt will take an additional hour for a total round trip distance of 50 miles. CGS assumed an hour for combined loading and unloading by quarry and fabrication personnel for a total round trip time of five hours. The total material to be shipped to this station would be 96 to 204 large blocks at one block per trip, 96 to 204 tile blocks at three per trip, 840 to 1,785 tons of palletted ashlar strips or strip material at 25 tons per trip, and 840 to 1,785 tons of $CaCO_3$ at 25 tons per trip. The blocks would require block haulers. CGS has calculated the transportation as a subcontract at $.19 per ton mile. An additional freight cost is the movement of finished slabs to a distributor or first point of sale. CGS has assumed that it would average $20 per slab.

FABRICATION PLAN AND COSTS

Overview

The fabrication of useable material for the construction industry is the most capital intensive piece of the marble industry. First, a seven acre parcel of land is necessary then a building of at least 60 times 300 feet is necessary to house the cutting and polishing equipment. The land and building would lease for $40,000 per year if one could be obtained, or purchased for $300,000. It takes six people to run a fabrication plant of the size compatible with the expected quarry production. These people should produce 2,500 square feet of slab stock in an eight hour shift which is approximately the amount contained in a large quarry block. The minimum equipment for this operation includes a gang saw and a polishing machine and various other pieces of equipment of lesser expense. The cost of this equipment is estimated at $2,500,000. The production at the fabrication plant also creates waste. The blocks which are 5.5 feet wide are fed through a gang saw which saws them into .75 inch thick slabs. The saw kerf is .25 inch in thickness. This creates a waste stream of wet fines amounting to about 60 cubic feet per block. Additionally, breakage and unacceptable colorations increase the waste to 35 percent of the original block or 79 cubic feet.

A tile line would allow all of the production to remain under one roof. However, the tile block production is insufficient to justify the high capital expense which is estimated at well over $2,000,000. For that reason the tile blocks must either be sold to a nearby tile fabricator, joint ventured with another producer, or shipped for toll fabrication. CGS used the price quote from Idaho Travertine of $2.67 per square foot in the cost consideration. The ashlar product would be trimmed at the fabrication facility by saw and quillotine. The only additional cost would be quality control for material too porous, or containing pyrite. The main use of a Lyons Sandstone ashlar is in exterior building facing. Examples of ashlar can be seen on most of the buildings on the University of Colorado campus in Boulder. CGS assumed pyrite ashlar blocks would only be used in interior construction.

Alternatives

The alternatives to in house fabrication of slab material include the sale of mill blocks to custom fabricators or the shipping of blocks to have them tolled by outside fabricators and then returned in the form of slabs for marketing and sale. The property was evaluated on the premise that mill block sale to Yule Marble Corporation was possible not to exceed 10,000 cubic feet per year at $12 per cubic foot. This yielded a NPV of $355,949.

CONCLUSION

The CGS has determined that the occurrences of marble located within the claim block have a net present value of $555,000 based on sustained production for five months per year for 30 years. The NPV ranges from $189,000 based on a four month season to $1,019,000 for a six month season. This is based on the results of the detailed mapping and sampling program and on the market study conducted by CGS personnel. The value is a function of the quality of the gray marble as judged from limited ASTM materials testing by the Indiana Geological Survey; the polishing of pieces by Denver Marble Company, Aspen Marble Company, and Wiston Marble Company, and comments from other marble and rock products producers.

The marble resource is extremely large, approaching 100 million tons, however the minable reserve on the order of 3.0 million tons is much less due to the nature and quality of the marble. Only a small portion of the deposits have sufficient thickness or are massive enough to extract.

Those which are less massive or more jointed are not economic for less capital intensive uses such as landscape rock due to mining and transportation costs. The product recovery from the 3.0 million tons will be on the order of 50 percent. This rather high recovery factor is based on marketing of the smaller broken blocks for tile fabrication, ashlar facing veneer, and a product grouped as calcium carbonate for a plethora of uses such as buffering acid mine drainage, road aggregate, chemical $CaCO_3$, feed additive, and terrazo chips. Although none of these products sell without some further processing and without transportation costs, they are considered marginally economic because mining costs have already been incurred and disposal problems and reclamation costs can be reduced.

The CGS sampled many prospect pits dug into iron oxide rich hornfels and quartzite, a sulfide rich mine dump on the south end of the claim block, and a quartz rich outcrop in hornfels which had been prospected. No economic mineral deposits were encountered. CGS also sampled many areas along Conundrum Creek by hand panning. These areas included the run previously placered by early miners and many areas which appeared geologically favorable. Visible gold was observed during this sampling but the gold was flour sized and sparse in occurrence. CGS has concluded that there are no minable reserves in close proximity to the surface which would have value.

FURTHER INVESTIGATIONS AND EVALUATIONS

The study conducted by CGS was limited to non mechanical sampling techniques which prevented investigation below outcrop. This has limited the extension of reserve estimation to a few hundred feet below cover and has prevented determination of marble quality under the weathered zone. However, it is the opinion of the CGS that this has not been detrimental to the project. The economics of this deposit are driven by the market dictating the price of the product and the quantity that can be sold. A perturbation in either of these is much more sensitive than any fine tuning of reserves, mining costs, or strength parameter refinement, which could be gained by drilling. The most indefensible part of this appraisal is the assumption that all of the production can be sold. To strengthen this, CGS recommends that the USFS undertake a more sophisticated market study which may include the extraction and toll fabricating of blocks into slabs of five feet by seven feet and tiles of 12 inches by 12 feet. The CGS has assumed that 9240 and 160,000 of these products can be produced and sold per year for $346.00 per slab and $4.50 per tile.

The CGS recommends that no further testing be done with respect to the potential for gold placer deposits or for any other potential deposits on the subject property. If the USFS believes that further evaluations are warranted utilizing heavy equipment the CGS will be available for all overseeing and supervisory work.

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APPENDIX A

Description of Rock Samples from Colorado-Highland Claim Block

By James M. Soule

First number is original field-identification number. Number in parenthesis (2) is sample number shown on Plate 2.

8-23-1 (1) Marble, (metamorphosed fine crystalline micrite-? limestone) fine crystalline with 5 YR 5/8 yellowish-red hematite stained calcite crystals tightly interlocked ranging from 0.1 to 0.5 mm across. Hand-specimen rock color most closely approximates reddish yellow 7.5 YR 7/6. Accessory minerals are fine (0.1 mm) widely spaced crystals of dark reddish brown 5 YR 3/3 hematite, similar dusky green 5 G 3/2 chlorite, and moderate green 5 G 5/6 epidote, which occurs only on the weathered surface of the sample. Some very minor weathered purple pyrite also occurs. Total percentage of accessories appears to be no more than 0.1 percent and is probably less.

8-23-2 (2) Marble (metamorphosed fine crystalline micrite limestone), with fine crystalline 0.3–0.5 mm near clear calcite crystals. Hand-specimen color is N8 very light gray. Accessory minerals are very minor (much less than 0.1 percent) 10R 3/3 dusky-red-weathered pyrite which stains to a color of 2.5 YR 5/8 red. Weathered pyrite stains adjacent calcite grains for as much as 0.5 mm. Very minor dark yellowish green 10 GY 4/4 chlorite occurs on weathered surfaces of hand specimen.

8-23-3(3) Marble, N5 medium gray in hand specimen, coarse crystalline with loosely interlocked calcite crystals 1.5 to 3.0 mm across. Very minor splotchy staining 2.5 YR 5/8 red in ca. 1 to 2 percent of the rock surface which is probably caused by weathering of included pyrite. No unweathered or partially weathered pyrite seen. Individual calcite crystals have included black clay-? or mica-? making up much less than 1 percent of the crystal typically and this is apparently the reason for a gray crystal color which closely approximates that of the overall hand specimen. Sample from proposed quarry area.

8-23-4(4) Marble, N9 white very fine crystalline with tightly interlocked calcite crystals 0.1 to 0.2 mm across. Crystals appear clear with no inclusions. One less than 0.5 mm across area of probable weathered pyrite seen.

8-23-5(5) Marble essentially identical to 8-23-3(3). Contains minor chlorite along one fracture-? surface in the small hand specimen. Sample from proposed quarry area.

8-23-6(6) Marble, N5 medium gray in hand specimen, coarse crystalline with tightly interlocked almost clear calcite crystals 2.0–5.0 mm across typically with 0.5 mm pyrite crystals in tight nearly unaltered contact with calcite. No staining caused by pyrite is apparent to the naked eye. Crystal color approximates that of hand specimen for reason indicated in 8-23-3(3). Sample from proposed quarry area.

8-23-7(7) Marble, N5 medium gray in hand specimen, coarse crystalline with tightly interlocked calcite crystals 1.5 to 3.0 mm across. Minor splotchy staining on weathered surfaces is caused by oxidation of pyrite crystals which are 0.3 mm or less across and are uniformly and relatively widely dispersed through out the specimen. Calcite crystals are 2.0-3.0 mm across, approximate the color of the hand specimen, and contain similar amounts of impurities first described in 8-23-3, and then subsequently.

8-23-8(8) Marble, N4 medium dark gray in hand specimen, medium crystalline with very tightly interlocked calcite crystals 0.5 to 1.0 mm across. Specimen provided contains essentially no pyrite (One 0.2 mm oxidized crystal seen.). Digestion of Calcite in cold HCL demonstrated a considerably higher percentage of organic matter and clay than the coarser grained specimens above. This is probably the reason for the darker color than earlier specimens. Crystal color approximates that of the hand specimen.

8-23-9(9) Marble, medium light gray N6 to white N9. Specimen is banded (gradual transition) between gray and white. Rock is fine crystalline with individual crystals 0.1 to 0.3 mm across. Individual crystals upon digestion in HCL yield very minor (ca. 1 percent) impurities consisting predominantly of clay. Rock has less than 0.1 percent pyrite in octahedrons and cubes less than 0.1 mm across which in a few cases in less than 5 percent of the rock form 2.5 YR 5/4 reddish brown staining halos as much as 1 mm across in otherwise a nearly pure crystalline marble. Sample shows dissolution effects of surface weathering.

8-23-10(10) Limestone, impure medium gray N5 dolomitic, sandy (Quartz grains make up about 1/10 of total volume of rock.). Calcite is partially recrystallized and is in a matrix of angular to subangular quartz grains with subordinate 2.5 YR 5/8 red limonite. Quartz grains are mostly equant and rarely exceed 0.3 mm in size.

8-23-11(11) Marble, medium light-gray N6. Rock is essentially all fine crystalline dolomite with no accessory minerals observed.

8-23-12(12) Limestone, medium gray N5, fine crystalline. Sample provided has one medium crystalline white calcite vein about two mm wide which passes through the sample. Calcite crystals in limestone are much less than 0.1 mm across and were not measured. Digestion of limestone in cold HCL demonstrates that gray color is due to presence of small amount (less than 1 percent) of clay in limestone.

8-24-1(13) Marble, dark gray N3 fine crystalline, dolomitic. Sample provided has about five percent of its surface area 2.5 YR 2.5/4 dark reddish brown limonite and hematite-? (after pyrite) and limonite staining of calcite. Crystals are not closely interlocked apparently as rock disaggregates easily and shows effects of weathering. Both individual calcite crystals and the overall rock specimen are approximately the same color which is attributable to gray to black clay and organic matter impurities in the crystals.

8-24-2(14) Marble, medium light gray N6 coarse crystalline with calcite crystals typically one to two mm across. Crystal color and overall hand specimen color are approximately the same and are attributable to a small amount of black clay and organic matter in crystals. Sample is weathered and the rock disaggregates easily despite good interlocking of crystals. Less than 0.1 percent of rock is cubic pyrite crystals ca. 0.2 mm across or less.

8-24-3(15) Marble, medium gray N5 coarse crystalline with calcite crystals 1 to 3 mm across. Crystals are closely interlocked but disaggregate easily which is probably attributable to weathering. Individual crystals and hand-specimen color are approximately the same which is attributable to impurities in the crystals consisting of less than 1.0 percent gray to black clay. Pyrite crystals (cubic) ca. 0.2 mm are found within and between calcite crystals in the calcite. On weathered surfaces they form staining halos about 1.0 mm wide. Pyrite forms less than 0.1 percent of the rock.

8-24-4(16) Marble, nearly pure white N9+ coarse crystalline with calcite crystals 2-4 mm across. Rock is essentially pure calcite except for much less than 1 percent of ca. 0.1 mm pyrite in equant cubes and pyritohedrons. In this sample pyrite is only slightly altered to hematite.

8-24-5(17) Marble, nearly pure white N9+ coarse crystalline with calcite crystals 2-4 mm across. Rock is essentially pure calcite except for 1 percent of ca. 0.1 mm pyrite in pyritohedrons. In sample nearly all pyrite surfaces are slightly to greatly altered to hematite. (N.B. Rock is essentially the same as 8-24-4(16).)

8-24-6(18) Marble, medium gray N5, medium grained with calcite crystals 0.3 to 1.0 mm across. Crystals are tightly interlocked and rock offers excellent resistance to disaggregation. Less than 0.1 percent of rock consists of weathered (altered) pyrite crystals to 2.5 YR 4/4 reddish brown hematite which produces only a minor staining halo in calcite. Calcite crystals are the same color as the hand specimen. Subsidiary secondary crystalline quartz forms less than 1 percent of specimen. Calcite contains inclusions of dark gray clay which are yielded upon digestion of the calcite in cold HCL.

8-24-7(19) Dolomite, medium light gray N6, fine crystalline with tight interlocking of individual dolomite crystals. Rock contains ca. 5 percent of angular fine-sand-size quartz grains with dark inclusions of clay(?) that are apparently responsible for the rock color. Rock contains a very small amount of 0.1percent weathered pyrite (to limonite).

8-24-8(20) Marble, medium light gray N6, coarsely crystalline with calcite crystals ranging from 2 to 4 mm across. Individual crystals have included black silt which gives them an overall color the same as the hand specimen. Rock contains very minor less than 0.1 percent magnetite and pyrite.

8-24-8(21) "White" Marble, nearly pure white N9, medium grained with most calcite crystals 0.3 to 0.8 across. Crystals are tightly interlocked and the overall rock appearance uniform and granular on fresh facture. Accessory minerals are less than 0.1 percent slightly oxidized magnetite and pyrite.

8-24-9(22) Marble, medium light gray N6, medium crystalline with tightly interlocked calcite crystals 0.4 to 1.0 mm across. Crystal color is same as hand specimen color. Calcite contains small amount of black clay which gives rock its color. Rock contains very small amounts of pyrite which weathers to a red hematite 2.5 YR 4/8. Also contains very minor magnetite and quartz.

8-24-10(23) Marble, very light gray N8. Sample contains one larger 10 mm partially oxidized pyrite crystal and two others that are essentially completely oxidized to 2.5 YR 3/8 limonite. In HCL the calcite reacts to form essentially no residue of impurities.

8-24-10(24) "Gray" marble essentially identical to 8-24-11(25) below.

8-24-11(25) Marble, medium light gray N6, fine grained dolomite with tightly interlocked crystals with minor quartz. Minor amount of black clay in crystals less than 0.1 percent. Small amount chlorite seen on one fracture.

8-24-12(26) Marble, dark gray N3, medium grained with calcite crystals 1 to 2 mm across. Crystals are tightly interlocked but disaggregate easily due to weathering and contamination by 2.5 YR 4/8 red limonite from decomposed oxidized pyrite which makes up about 0.5 percent of the rock. Crystal color is the same as the hand specimen and the darker color than the other gray marble samples is attributable to a higher content of both clay and organic impurities in the crystals. Virtually all pyrite in the sample is oxidized to limonite and digestion of calcite in HCL released no unaltered pyrite.

8-24-13(27) Quartzitic-gray marble medium dark gray N4 (on fresh fracture only). Smaller piece of sample has a light gray N7 quartz zone approximately 5 mm across whose protolith probably was a nearly pure quartz pebble. Quartz grains in the original sedimentary rock ranged from 0.5 to 2 mm across and were subangular to well rounded. Rock color is attributable to organic-? and clay impurities entrained in the quartz grains which otherwise have a gross appearance similar to the gray calcite seen in other samples. (Sample not digested.)

8-24-14(28) Quartzite (orthoquartzitic conglomerate). Protolith conglomerate consisted of 4 to 15 mm subrounded to rounded 5 Y 8/4 grayish yellow to 10 Y 8/2 pale greenish yellow clasts of essentially pure quartz set in a matrix of fine quartz sand tightly cemented by silica. Rock is contaminated by organic material and possibly clay. Matrix color is N4 medium dark gray attributable to the impurities indicated. Rock is stained on weathered surfaces and, in zones adjacent to quartz clasts, by 2.5 YR 2.5/6 dark red hematite. One oxidized pyrite crystal was noted. (Sample was not digested.)

8-24-15(29) "Fine" marble, medium gray N5, fine crystalline with tightly interlocked crystals 0.3 to 0.8 mm across. Rock shows excellent resistance to disaggregation. Very minor 0.1 percent pyrite noted and only seen in digested sample. Impurities in calcite crystals are clay and organic matter-? and give both them and the hand specimen the same color. Digested sample yielded 5 percent quartz in stubby crystals contaminated with apparently the same impurities as the calcite.

8-24-15(30) "Coarse" marble, medium gray N5, coarse crystalline with tightly interlocked crystals 2 to 4 mm across. Sample is essentially identical in composition 8-24-15(29) except for crystal size.

AI (31) Marble, white (except for staining as noted) medium crystalline with crystals 0.5 to 1.0 mm across. Most crystals, although nearly pure calcite internally, are stained by hematite resulting from oxidation of magnetite and pyrite whose crystal pseudomorphs make up ca. 0.5 percent of the rock. Thus the rock has a hand specimen color of mottled 5 YR 7/6 reddish yellow whereas the altered hematite and magnatite is 2.5 YR 4/6 red. The sample is weathered and disaggregates easily on weathered surfaces. It appears as if the limonite stain weakens the adherence between the otherwise closely interlocked crystals of calcite and the result is a friable rock. The sample was taken at the surface and less weathered material would have better structural coherence. Sample taken from proposed underground, white marble quarry area.

AI-1(32) Sample is missing.

AI-2 (33) This sample has essentially the same characteristics as AI except that it is slightly more mottled in overall color. Sample taken from proposed quarry area.

AI-3 (34) AI-3 has, essentially the same characteristics as AI (on fresh fracture) except that the sample is surrounded by weathering surfaces. Digestion yielded one crystal of epidote. Sample taken from proposed quarry area.

AI-4 (35) Marble 10 Y 8/2 pale greenish yellow, medium grained crystalline with well developed calcite crystals. The sample is highly weathered and disaggregates readily. Individual crystals are nearly pure calcite and are nearly pure white. The overall rock color is due to oxidation of very minor 0.1 percent pyrite and the presence of minor chlorite which forms a band across one side of the specimen. Oxidation of iron minerals produces a red 2.5 YR 5/8 limonite which occurs in minor amounts. Sample is poor.

AII (36) Marble, white N9 to light greenish gray 5G 8/1, where chlorite occurs between calcite crystals, coarse crystalline marble with calcite crystals ranging in size from 1.0 to 3.0 mm. Rock has very minor oxidized magnetite and pyrite less than 0.1 percent stain calcite with red 2.5 YR 5/8 limonite for less than 1.0 percent of the rock. Calcite crystals are tightly interlocked but the rock disaggregates easily owing to weathering.

AII-1 (37) Marble as AII except sample is very poor.

AII-2 (38) Marble, very light gray N8, medium crystalline with tightly interlocked calcite crystals 0.3 to 1.0 mm across. Finely disseminated magnetite or hematite after magnetite occurs throughout the rock, but makes up less than 1 percent of the sample. Most magnetite cannot be seen by the naked eye and it imparts no perceptable change to the color of the rock. Rock appears uniformly very light gray. Rock disaggregates easily owing to weathering.

AIII (39) Marble, white N9, coarse crystalline with tightly interlocked calcite crystals ranging in size from 0.8 to 3.5 mm across. Rock contains less than 1.0 percent oxidized pyrite and magnetite oxidized to hematite—and limonite which stains the rock to a reddish yellow 5 YR 7/6 in hand specimen. The sample is weathered and disaggregates easily.

AIII-1 (40) Dolomitic marble, very light gray N8, fine crystalline with 5 YR 5/4 reddish brown staining caused by hematite after very minor 0.1 percent pyrite and magnetite. On fresh fracture, staining halos around these nearly completely oxidized iron minerals are found in about one third of the rock.

AIII-2 (41) Marble light gray N7, coarse crystalline with calcite crystals 0.8 to 3.0 mm across with 2.5 YR 4/8 red staining caused by near complete oxidation to limonite of less than 0.1 percent pyrite and magnetite. Slight grayish color is caused by very minor entrained impurities in the calcite, probably organic matter and clay.

AIII-3 (42) Quartzite Hornfels, light gray N7. Relict quartz grains are subangular and range from 0.8 to 1.5 mm across. Rock contains a very small amount less than 0.1 percent epi dote, is tightly cemented by silica, and is very slightly calcareous. (Sample not digested.)

AIII-4 (43) Hornfelsic quartz sandstone (quartzite) splotchy grayish orange 10 YR 7/4 to dark reddish brown 2.5 YR 3/6 where stained by hematite. Rock is very fine grained and shows no relict sedimentary structure nor is it calcareous. (Sample not digested.)

AIII-5 (44) Hornfelsic quartz sandstone (quartzite) as AIII-4 (43).

AIV (45) Marble, medium dark gray N4, medium grained with medium dark gray N4 calcite crystals 0.5 to 1.0 mm across. Crystals are tightly interlocked but rock disaggregates easily because of weathering. Impurities in calcite crystals give them their color and are probably clay and organic matter. Less than 0.5 percent of the rock is accessory pyrite which is oxidized and stains the rock with staining halos. There is some minor accessory quartz also.

AIV-1 (46) Marble, medium light gray N6, medium grained with medium light gray closely interlocked calcite crystals 0.5 to 1.0 mm across. Rock has accessories of 0.1 percent oxidized pyrite and magnetite which do not have staining halos around individual crystals. Rock is somewhat weathered but does not disaggregate readily.

AIV-2 (47) Marble as AIV except sample is more weathered.

AIV-3 (48) Marble, medium light gray N6, medium grained with medium light gray closely interlocked calcite crystals 0.5 mm to 1.0 mm across. Rock has accessories of pyrite, magnetite, and limonite after pyrite and magnetite in less than 0.1 percent of the rock. Slight staining in a few places is in evidence in the hand specimen. Rock does not disaggregate readily.

AIV-4 (49) Marble, very light gray N8 to light greenish gray 5 GY 8/1, medium grained with calcite crystals ranging from 0.5 to 1.0 mm across. Calcite crystals are tightly interlocked and show excellent resistance to disaggregation. Rock contains less than 0.1 percent pyrite and magnetite and there is slight pinpoint staining in the vicinity of these crystals where oxidized. Less than 0.1 percent of rock is white muscovite mica. The slightly greenish color of the hand specimen is caused by indistinct zones of finely disseminated chlorite. Staining on weathered surface is caused by oxidation of iron minerals

AIV-5 (50) Hornfels (low grade contact metamorphosed rock). Rock consists predominantly of gypsum crystals elongate to as much as 10 mm stained by hematite to 5 YR 5/8 yellowish red which make up ca. 80 percent of the rock. Similarly stained quartz (10 percent), 5 percent of 2.5 YR 3/6 dark red hematite and specular hematite, and probably other unidentified accessory minerals including pyrite, magnetite, moscovite-phlogopite, and possibly barite make up the remainder of the sample. (Sample not digested.)

AIV-6 (51) Quartzite Hornfels, medium light gray N6 on fresh fracture and stained to a mottled darker gray and red 2.5 YR 5/8 where (apparently) stained by limonite. Some impurities (undetermined) are present in the very fine grained quartz. Sample not digested.

AIV-7 (52) Quartzite Hornfels, as AIV-7 (51) except it is darker medium dark gray N4 on fresh fracture. Sample shows some alteration and solution(?) voids.

AIV-8 (53) Quartzite Hornfels as A-IV-7 (52).

AIV-9 (54) Quartzite Hornfels, mottled red 2.5 YR 5/8 resulting from oxidation to limonite of magnetite-?. Crystalline quartz is vitreous and shows no relict sedimentary structure. Where limonite staining is not apparent the rock is a fine crystalline quartzite light gray N7. (Sample not digested.)

AIV-10 (55) Quartzite Hornfels, as AIV-7 (52).

R-1 (56) Quartzitic marble, medium light gray N6, fine grained. Rock consists of a tight fine grained "matrix" of crystalline quartz with intergrain crystals of calcite and dolomite. Finely disseminated pyrite and magnetite and found throughout the sample and make up ca. 5 percent of the rock. Estimated percentages of other minerals are 50 percent calcite 40 percent quartz and 5 percent dolomite. Color of rock is caused by relatively high percentage of dark minerals.

R2 (57) Quartzitic marble breccia, very light gray N8 on fresh fracture of angular breccia clasts. Overall specimen color is mottled pale yellowish brown 10 YR 6/2 caused by clay impurities on the surface of the specimen, probably of surficial origin. Marble clasts are ca. 70 percent calcite and ca 30% quartz in a tightly interlocked matrix. Less than 0.1 percent of the rock is magnetite, oxidized magnetite, and chlorite. Breccia fragments are angular to subangular and range upwards to 15 mm across.

R3 (58) Marble, medium gray N5 coarse crystalline with minor limonite staining presumably caused by oxidation of iron minerals (not seen). Calcite crystals are same color as hand specimen and contain less than 1 percent organic impurities and clay. Calcite crystals are tightly interlocked and have good resistance to disaggregation.

9-20-1 (59) Quartzite Hornfels, very light gray N8 on fresh fracture, very fine grained. Weathered surface of hand specimen is grayish brown 5 YR 3/2 with one weathered surface splotched grayish orange. Rock appears to be essentially pure silica with slight impurities undetermined. (Sample not digested.)

9-20-2 (60) Quartzite as 9-20-1 (59) except rock has very slight pinpoint staining by limonite -? red 2.5 yr 4/6. Weathered surface of specimen does not exhibit staining.

9-20-3 (61) Quartzite, medium dark gray N4, fine grained. Vitreous dark gray quartz probably owes its color to entrained impurities (not determined). Very slight staining 2.5 yr 4/6 by limonite in less than 1.0 percent of rock.

"Upper bed" (62) Marble, dark gray N3 medium grained with tightly unterlocked calcite crystals 0.7 to 1.5 mm across. Crystals are same color as hand specimen and owe their color to less than 1 percent organic material and minor clay contained within them. Rock exhibits excellent resistance to disaggregation and digestion of sample revealed no accessory minerals whatsoever.

9-22-1 (63) Quartzitic marble, medium light gray N6, fine grained. Rock consists of a tight fine-grained "matrix" of crystalline quartz with intergrained crystals of calcite and possibly very minor dolomite. Finely disseminated pyrite and very minor magnetite are found throughout the sample and make up ca. 5 percent of the rock. Other mineral percentages are estimated to be 60 percent calcite and 55 percent quartz. Color of rock is caused by the relatively high percentage of dark minerals. Sample is, except as noted, identical to R-1 (56).

9-22-2 (64) Quartzitic marble, white N9 to medium light gray N6 (Specimen is banded.) Rock consists of ca. 60 percent calcite, 35 percent quartz, and ca. 5 percent dolomite in a tightly interlocked fine grained crystalline structure, where near pure white. Where medium light gray N6, the rock is ca. 50 percent calcite, 35 percent quartz, 10 percent dolomite, and ca. 5 percent magnetite, pyrite and, on fractured surface on one side of hand specimen, reddish yellow 5 yr 6/8 limonite. Sample is similar to 9-221 (63) and R-1 (56) except for banding in hand specimen and oxidation of iron minerals to limonite.

9-22-3 (65) Shale, grayish black; slightly metamorphosed to a low grade slate. Specimen does not exhibit a slaty cleavage. The rock is calcareous and contains a high percentage of organic material and apparently unmetamorphased clay as evidenced by the near lack of sericite. It is very difficult to estimate percentages of constituents visually owing to the specimen's fine grain and color but they most certainly consist of clay, sericite mica, organic material, calcite, quartz, and hematite/limonite (probably after pyrite). (Sample not digested.)

(66) Marble, medium dark gray N4, medium grained with closely interlocked calcite crystals ranging from 0.5 to 1.5 mm across. Crystals are same color as hand specimen. Color is attributable to organic material and a very small amount of clay contained within the crystals. Rock on fresh fracture shows pinpoint staining by red limonite 2.5 yr 4/8 or possibly hematite after magnetite and pyrite in less than 1.0 percent of the rock. Digestion of sample in cold HCL indicates 0.1 to 0.5 percent of rock is oxidized pyrite and magnetite. Rock disaggregates easily despite its interlocked crystalline structure.

(67) Quartzite, dark greenish gray 5 G 4/1, fine grained with stringers of light greenish gray 5 G 8/1 fine crystalline quartz. Rock is apparently nearly pure quartz and possibly owes it greenish color to minor finely disseminated chlorite; chlorite crystals were not seen. Limonite stains are present on one edge of sample. (Sample not digested.)

(68) Marble, dark gray N3, fine crystalline with tightly interlocked calcite crystals from 0.1 to 0.5 mm across. Crystals are same color as hand specimen owing to presence of ca. 1-2 percent organic impurities and very minor less than 0.1 percent magnetite contained within the crystals. Rock shows excellent resistance to disaggregation and on weathered surface shows little staining.

(69) Marble, medium gray N5 with bands ranging up to very light gray N8, coarse crystalline with crystals ranging from 1.0-4.0 mm across. Calcite crystals are tightly interlocked. Lighter bands contain 1 to 2 percent slightly oxidized magnetite and very minor less than 0.1 percent pyrite. Darker N5 areas contain very minor ca. 0.1 percent iron minerals. Crystal color is same as hand specimen owing to less than 1 percent organic impurities contained within crystals. Rock shows good resistance to disaggregation on fresh surfaces and poor resistance where weathered.

(70) Marble as (69) except larger crystals range upwards to 6 mm across and the magnetite is oxidized to hematite/limonite resulting on a 2.5 YR 4/8 red splotchy staining in the otherwise near white bands.

71) Marble, medium gray N5 coarse crystalline with calcite crystals from 1.0 to 2.0 mm across with calcite crystals tightly interlocked. Calcite crystals are the same color as hand specimen owing to organic impurities and clay making up less than 1.0 percent of them. Very minor less than 0.1 percent magnetite and pyrite. An unidentified dark yellowish orange 10 YR 6/6 mineral, possibly sphene, forms less than 0.1 percent of the rock. Stubby, prismatic crystals 0.2-0.5 mm across do not disaggregate or oxidize to stain or deteriorate adjacent calcite crystals. Rock exhibits good resistance to disaggregation except on weathered surface(s).

(72) Metaquartzite, hydrothermal iron-sulfide mineralized. Protolith of rock probably is a quartz sandstone with a small amount of clay or a quartz porphyry intrusive. Rock consists of veinlets of finely disseminated crystalline pyrite and minor magnetite? in a matrix y N9 near white five grained crystalline quartz. Biotite and phlogopite ? are distributed in small 0.5 mm masses throughout the rock. Estimated percentages of minerals are quartz 75 percent pyrite 15 percent, biotite/phlogopite ? 9+ percent, other undetermined constituents 1 percent. Note: There is a very small amount 0.1 percent of a soft jade-green mineral that was not determined.

APPENDIX B

ASTM Test Procedures and Results for Colorado Highland Marble

ASTM Test Procedures intentionally omitted from this report

INDIANA DEPARTMENT OF NATURAL RESOURCES

PATRICK R. RALSTON, DIRECTOR

Geological Survey Division
611 North Walnut Grove
Bloomington, Indiana 47405
812-855-2687

September 27, 1989

Mr. John W. Rold
Colorado Geological Survey
1313 Sherman Street, Room 715
Denver, CO 80203

Dear John:

Further to our telephone conversation about physical testing and the results I subsequently sent you, I am sending you a copy of Occasional Paper 38, a Xeroxed sheet of ASTM C503-85, Standard Specification for Marble Building Stone (Exterior), and a bill for our services.

The section on "Choice of Building Stone for Various Applications" in Occasional Paper 38 (p. 28-29) gives our philosophy on physical testing. Our testing would seem to bear out that the marble specimens meet the requirements for ASTM C503-85. The results for compressive strength (ASTM C170) would seem to be slightly below the requirement, but if the high and low values are discarded, a common laboratory practice, the specimens average 7,600 psi, which is above the minimum required.

I mentioned on the phone that our retesting of absorption, bulk specific gravity, and abrasion resistance showed considerable improvement in these results. I attribute these later results to our selection of test pieces from the interior of the large specimen. I feel that the long period of weathering, which affected the outer part of the specimen, may have contributed to increased values of absorption and decreased values of abrasion resistance. I also feel that weathering may attribute to the wide range of results for compressive strength; hence we can justify discarding extreme values.

I mentioned on the phone the controversy among architects and engineers on deterioration of stone due to weathering. One example frequently mentioned is the failure of Carrara marble panels on the Amoco building, completed in 1973 in Chicago. About 30 percent of the panels have bowed more than half an inch, causing concern that they may fall from the building. A decision was made this year to replace all of the marble panels with granite from North Carolina at a cost of about $80 million. There is no unanimity of opinion as to what is causing the problem, but 15 years of weathering has caused a change in the stone's physical condition.

A similar problem developed on the Indiana National Bank Tower in Indianapolis. Here Carrara marble has been replaced with Danby Marble from Vermont. The replacement took place only a few years ago, so not enough time has elapsed to evaluate the new stone.

Please let me know of ways that I could be of further help.

Sincerely,

Don

Donald D. Carr, Branch Head
Mineral Resources & Data Management

Enclosures

INDIANA DEPARTMENT OF NATURAL RESOURCES

PATRICK R. RALSTON, DIRECTOR

Geological Survey Division
611 North Walnut Grove
Bloomington, Indiana 47405
812-855-2687

RECEIVED
OCT 10 1989
COLO. GEOL. SURVEY

October 5, 1989

Mr. John W. Rold
Colorado Geological Survey
1313 Sherman Street, Room 715
Denver, CO 80203

Dear John:

We did further compressive strength tests on material that we could identify as coming from the interior of the large marble specimen. Presumably these samples would not be weathered. The results follow:

Sample no.	Size (inches)	Compressive strength (lb/in^2)	Mean
2a	2x2	8,100	
2b	2x2	8,500	
2c	2x2	8,200	8,270

We were able to determine that samples 1c and 1a from previous testing of compressive strength came from near the exterior of the specimen, which suggests that the low values may be the result of weathering. I feel that the results above are more typical of unweathered material and should be used for your evaluation.

Sincerely,

Donald D. Carr, Branch Head
Mineral Resources & Data Management

DDC:md

cc: Randall K. Streufert

"EQUAL OPPORTUNITY EMPLOYER"

APPENDIX C

Report Forms for Geochemical Testing: Colorado-Highland Claim Block and Conundrum Valley

SKYLINE LABS, INC.
SPECIALISTS IN EXPLORATION GEOCHEMISTRY
12090 WEST 50TH PLACE • WHEAT RIDGE, COLORADO 80033 • TEL.: (303) 424-7718

REPORT OF ANALYSIS

JOB NO. DFP 023
September 6, 1989

Colorado Geological Survey
Attn: Randall Streufert
1313 Sherman Street
Denver, Colorado 80203

Analysis of 10 Rock Chips, 8 Pan Concentrates & 3 Rock Samples

ITEM	SAMPLE NO.	Au (ppm)	Ag (ppm)	Cu (ppm)	Pb (ppm)	Zn (ppm)	Mo (ppm)
1	MD-01	<.05	.4	60.	<5.	70.	6.
2	MD-02	<.05	.6	25.	<5.	10.	6.
3	MD-03	.05	1.0	155.	<5.	15.	20.
4	MD-04	<.05	1.2	335.	<5.	45.	4.
5	MD-05	<.05	.4	10.	<5.	<5.	<2.
6	MD-06	<.05	.2	30.	<5.	25.	<2.
7	MD-07	<.05	.2	15.	<5.	30.	4.
8	MD-25	<.05	4.2	15.	175.	10.	90.
9	PL-01	4.50	40.0	170.	65.	180.	6.
10	PL-02	4.40	22.0	235.	50.	115.	6.
11	PL-03	1.50	7.2	145.	60.	70.	22.
12	PL-04	6.00	8.8	135.	30.	95.	6.
13	PL-05	1.10	4.9	145.	30.	80.	4.
14	PL-06	1.50	2.4	100.	25.	65.	<2.
15	MD-26	.60	4.1	85.	15.	80.	6.
16	RS-1	I/S	4.7	115.	50.	110.	<2.

ITEM	SAMPLE NO.	FIRE ASSAY Au (oz/T)	FIRE ASSAY Ag (oz/T)
19	FA-01	<.005	<.01
20	FA-02	<.005	<.01
21	FA-03	.006	<.01

ITEM	SAMPLE NO.	W (ppm)
9	PL-01	95.
10	PL-02	195.
11	PL-03	135.
12	PL-04	200.
13	PL-05	110.
14	PL-06	180.
15	MD-26	90.
16	RS-1	135.

ITEM	SAMPLE NO.	U308 (%)
17	MD-23	<.0002
18	MD-24	<.0002

Gordon H. VanSickle
Manager

NOTE: I/S = Insufficient sample for analysis

SKYLINE LABS, INC.
SPECIALISTS IN EXPLORATION GEOCHEMISTRY

SKYLINE LABS, INC.
SPECIALISTS IN EXPLORATION GEOCHEMISTRY
12090 WEST 50TH PLACE • WHEAT RIDGE, COLORADO 80033 • TEL.: (303) 424-7718

REPORT OF ANALYSIS

JOB NO. DFP 024
September 12, 1989

Colorado Geological Survey
1313 Sherman Street
Denver, Colorado 80203

Analysis of 2 Marble, 1 Rock, & 1 Concentrate Sample

ITEM	SAMPLE NO.	SiO_2 (%)	$MgCO_3$ (%)	$CaCO_3$ (%)
1	CG-1	.47	.54	97.5
2	CG-2	.90	.64	98.3

ITEM	SAMPLE NO.	FIRE ASSAY Au (oz/T)	FIRE ASSAY Ag (oz/T)	Au (ppm)	Ag (ppm)
3	FA-4	<.005	<.01	N/R	N/R
4	AB-1	N/R	N/R	.31	2.6

ITEM	SAMPLE NO.	Cu (ppm)	Pb (ppm)	Zn (ppm)	Mo (ppm)	W (ppm)	Hg (ppm)
4	AB-1	85.	30.	135.	<2.	285.	.02

Gordon H. VanSickle
Manager

NOTE: N/R = Analysis not requested.

SKYLINE LABS, INC.
SPECIALISTS IN EXPLORATION GEOCHEMISTRY
12090 WEST 50TH PLACE • WHEAT RIDGE, COLORADO 80033 • TEL.: (303) 424-7718

REPORT OF ANALYSIS

JOB NO. DFP 025
October 16, 1989

Colorado Geological Survey
Attn: Randy Streufert
1313 Sherman Street
Denver, Colorado 80203

Analysis of 5 Rock Samples

ITEM	SAMPLE NO.	SiO_2 (%)	$CaCO_3$ (%)	$MgCO_3$ (%)
1	CG-3	1.10	97.3	.33
2	CG-4	.11	97.3	.53
3	CG-5	.81	95.1	.96
4	CG-6	1.20	95.0	.46
5	CG-7	.59	95.0	.69

Gordon H. VanSickle
Manager

ALLIED ENVIRONMENTAL SERVICES, INC.
16203 I-10 EAST, SUITE #9, CHANNELVIEW, TX 77530 (713) 452-5897

TO: Coloradc Geological Survey

SAMPLE ID	LAB ID	DESC	ANALYST	RESULTS
MD-21 GREY	6321.011	HOM	EB	Asbestos N.D. 90% CACO, 10% NCB
MD-22 GREY	6321.012	HOM	EB	Asbestos N.D. 90% CACO, 10% NCB

APPROVED: Subbarayudu V. Gogineni
DATE: 8/25/89

APPENDIX D

Industry Contact Documentation

Stevator and Czaja, Architects, Brian Czaja
Commercia—Residential

Use of marble is becoming more popular for interiors and exteriors. Brian says maintenance or life span is not a major consideration and he would use marble in design if budget permitted, but it is usually too expensive a luxury. Synthetics are used because of weight and budget considerations.

R.M. Klimet and Francis Halsband Architects, 255 West 26th Street, New York, NY 10001, (212) 243-7400, Jennifer Greene, April 18, 1989

This firm never uses either black or dark gray marble.

Hellmuth, Obata and Kassabaum Architects, 1270 Avenue of the Americas, New York, NY 10020, (212) 741-1200, Daniel Dolen, April 18, 1989

Dan said that there would be a market for dark gray or black marble. Because of the problems with foreign imports and predictability he would like to see a more accessible supply.

Market 65%	NY
30%	Other USA
5%	Innternational

Chevron USA, Land Department, Andy Balch, (415) 894-2591, November 9, 1989

Contacted Chevron to establish a discount factor with risk. Chevron uses a high risk, low, and expected for rate of return. A no risk rate of return is cost of capital plus two percent and that would be used for a pipeline type of investment. A land acquisition for "strategic reasons" would be up to 15 percent but usually is 14 percent, a high risk purchase is between 20 percent and 25 percent.

Breton of the Americas, (305) 564-2708, Gianni Moscandini, November 9, 1989

I called to confirm equipment costs. He included items which are listed below:

To get 30,000 cubic feet of production gross not net. requires two wire saws at $25,000 each, two drills at $18,000 each, pneumatic hammers, quarry bar and 300 cfm compressor for $50,000, derreck or used 988 front loader, either is $100,000, diesel generator. He told me that the weather is a drawback. No quarry people work when it is raining or snowing and must consider the length of season.

(718) 784-4646, Alex Gere, and Steve Gulias, April 7, 1989

These consultants evaluate quarries for production capabilities. Gere said that Black Marble has a good market and dark gray does not necessarily have a good market. He said he would have to have a sample and that he would then tell me if there is a market.

Christian Marble Company, (919) 828-8001, Derek Hardy, April 13, 1989

He is a fabricator, said three cubic feet is too small—needs a minimum of 4 ft by 5 ft by 8 ft. Most important aspect is how well it polishes especially if black marble which doesn't often polish very well. He does use marble chips in his terrazzo business which utilizes cement or resinous binder but still must take a good polish. Transportation would make Colorado production more expensive.

Emser International, 8431 Santa Monica Blvd., Los Angeles, CA 90069, (213) 650-2000, Unknown, April 7, 1989

They deal with 12in. by 12in. by .375 in. tiles of Ebony and Negro Marquina and special tiles of 18 in. by 18 in. by .375 in.. They are used some in floors but are usually not hard enough to maintain shine. These people have no interest in the product from Colorado. The Ebony and Negro Marquina sell very well.

Designers Tile and Marble, 1928 East Glenwood Place, Santa Ana, CA 92705, (714) 258-1202, Adam Scholze, April 7, 1989

Scholze advised that it would be difficult to break into a share of Negro Marquina marble because it has been in the pipeline for a long time and it is widely known. Because it is foreign the labor costs are lower than those expected in the United States. He knows of no use for black marble fines.

Marble Institute of America, 33505 State Street, Farmington MI 48024, (313) 476-5558, Bob Hurd, April 7, 1989

There is a U.S. Marble Imperial Black from Knoxville, TN in seams of dolomitic limestone but none is being quarried in the U.S. He suggested that the dark gray marble could be used as a filler. There are currently seven deposits of white marble being mined in North America including British firm just mining crushed marble. He thought that slate would be a competition problem for dark gray marble partly because it would be more durable.

Grani-Decor, Canada, (819) 652-200, Serge, April 12, 1989

Bought out Georgia Granite and have been conducting a tremendous marketing push. Are building a road in Oklahoma and have a black and green granite in Virginia too close to a small town to quarry. He suggested that I get a block and saw it up for testing for structural soundness and distribute samples to architects everywhere.

New England Stone Industries, Rhode Island, (401) 232-2040, John Soyes, April 12, 1989

They import from four counties

Spain - Negro Marquina

Portugal

France

Greece - black with white blotches and not in demand

John said that they only deal with slabs and veneers not tiles.

David Allen Company Inc., P.O. Box 27705, Raleigh, NC 27611, (919) 821-7100, Robert Robertson, April 6, 1989

I was specifically seeking information on the Carolina Ash which I saw at Denver Marble to learn if it had a market in the east. Robertson was not familiar with it but said that imported Negro Marquina was very popular.

International Granite, (703) 573-5643, Lillian Perlatte, April 6, 1989

She says there is definitely a market for dark gray marble as I described, she sells a dark gray from Portugal for $4 to $6 per tile 12 in. by 12 in. by .375 in.. They are used primarily in lobbies alternately matched with white.

Carnevale and Lohr Inc., 6521 Clara Street, Bell Gardens, CA 90201, (213) 927-8311, Tony Reta, April 6, 1989

Black Granite is priced at $20 per ft and black marble at $15 to 20 per ft, but it must be consistent. Black marbles are usually soft although Negro Marquina is used in floors.

Bruner Pacific Marble and Granite Inc., 11180 Penrose Street, Sun Valley, CA 91352, (818) 768-8930, Marko Salvini, April 6, 1989

This company works with Belgium Black and people are always looking for black marble which are often specked out for counter tops and pavers. He evaluated a sample of Yule Marble which was sent by the new quarry operators for appraisal and for marketing. Blue-gray marble from Taiwan is selling for $.50 per square foot.

Battaglia Inc., 25022 S. Vermont Avenue, Harbor City, CA 90710, (213) 534-0110, Unknown, April 6, 1989

There is no market for black or dark gray marble. They have discontinued all of their black and dark gray marbles.

Valley Marble and Slate Corporation, 463 Danbury Road, New Milford, CT 06776, (203) 354-3955, Gene Wiston, April 12, 1989

Wiston is seeking another source for dark gray marble. the quarry of Charcoal Gray and Champagne Black currently being used is being exhausted. Gene wanted me to ship him a five ton block as a minimum so that he could test the center away from weathering effects. They are currently getting stone from Idaho, Tennessee, Vermont, and Europe and would be very interested in the Conundum Creek occurrence. Gene says the quality would be better at depth but coring would only tell engineering properties and not how well it takes a shine. They will do all of the testing and evaluation for free and conduct the marketing. Stone must have no brown, or soft spots in it. He says slab costs are $175.

Trade International Inc., P.O. Box 888-568, Dinwoody, GA 30356, (404) 391-0395, Jeffrey Mathews, April 6, 1989

A market consultant especially for international markets, conducted a market study for a Chinese Black Marble (very black). Black marbles are in demand but must run tests and have samples to determine the market. He says tests are most important, modules of rupture, density, tensile strength, flexural strength, abrasion, running approximately $800 for the testing. Must know mine production capability also to tell user. Must have contacts on a world-wide basis for marketing the material.

Atlas Marble and Granite Inc., 9184 San Fernando Road, Sun Valley, CA 91352, (818) 767-4220, Lady (Name Unknown), April 6, 1989

I told her about the dark gray marble, she said black granite real hot, no one can keep supplies in stock. Said Mexican black marble sells for $14 per tile, $7-8 to contractors, sells 30,000 sq ft/yr of black. Dark gray would have much more competition but could still sell 10,000 to 20,000square foot per year but would be a much harder market to break into. Quarries have 100's of distributors. 3 ft by 3 ft by 3 ft would be ok for tiles but no good for the slabs she sells. She buys from European fabricators because U.S. black marble not available and labor costs too high.

The cheapest is travertine as natural rock say $4 per tile but agglomerate $3 per tile. Aggregate is not poured but the mixture of pieces cemented together, cut and polished.

Idaho Quartzite Corporation, 671 River Park Lane, Suite 210, Boise, ID 83706, (208) 343-2580, 1-(800)-852-3214, Donald Seehusen, April 27, 1989

They do not toll saw other quarry's blocks but are thinking about another product line to complement their quartzite. Black marble now is in extremely high demand and Don would be delighted to send their quarry expert Dr. Hollenbaugh, Boise State College, to Conundrum Creek to examine the deposit at no charge. He wanted a softball sized piece to examine. He stated that cannot use wire saws in winter months.

Idaho Travertine, (208) 529-4207, Ted Orchard, October 27, 1989

Idaho travertine custom saws tile for $2.65 per asquare foot and is now working on some Tennessee marble which costs $2500 per block to ship. Approximately 14 tiles can be obtained from a cubic foot. They deal in planks which are 4.5 in. by 13 in. by 3-5 ft to minimize waste. They can handle up to 10,000 tiles/month with their two large diamond gang saws. One 9 ft dia radial saw, three monolama single blade saws, and splitting saws with two sets of five blades in tile splitting saws. Will do custom slabs for $5.00 per swuare foot 7/8 in. thick or larger. This is $192/slab.

Colorado Yule Marble Company, Denver, Colorado, Rex Luesby, October 24, 1989

Supplied me with tax information and generalized other costs, plans, and suggested that there might be an opportunity to toll fabricate or buy whole, sound, blocks for $10-12 per cubic foot.

Luck Stone Company, (804) 784-3335, Bill Nelson, October 27, 1989

Just purchased Tennesee Pink, employs Claude Ledgewood. Is travelling to Italy to buy equipment for a tile line did not commit to wanting feed stock.

U.S. Bureau of Mines, Washington, D.C., (202) 634-1185, Val Teportei, October 27, 1989

Called to get price quotes on limestone and any uses for the waste stream from a black marble quarry. He said that tonnage was too low and distance to market too far to justify any use for the waste material.

U.S. Bureau of Mines, Washington, D.C., (202) 634-1177, Michael Miller, October 27, 1989

Mr. Miller stated that the lime price at $48.03 per ton was for CaO, which is a product derived from calcining limestone. The feed stock limestone is worth one-tenth of the final product cost and the calcining plant containing rotary or vertical kilns is a capital intensive operation involving large tonnages of throughput for amortization.

U.S. BOM, (202) 634-1180, Harold Taylor Jr., August 17, 1989

To get cost information on equipment contact Park Industry, St. Cloud, MN or Elizebeth Granite. The only producers of marble in the U.S. are Georgia Marble and Vermont Marble and half a dozen "mom and pop" operations in Idaho, New Mexico, and Montana. A small producer would not need the heavy front-end capital investment that big companies need. He could also find a company to buy his mill blocks. The size should be at least 2 x 3 x 6 preferably 3 x 3 x 6 for minimum. This is the size of blocks mined in China. Take a block to the Verona show in Italy to generate interest.

Georgia Marble Company, (404) 421-6500, Dr. W. Bob Power, August 17, 1989

Mr. Power said that it is extremely difficult for a small "mom and pop" dimension stone quarry to be profitable. It is extremely labor intensive to cut the blocks by hand or with jack-hammers. Premium Monument grade marble in mill block form is worth $18.00 per cubic foot. He speculated that $10.00 per cubic foot is a realistic number for a 4 x 4 x 8 block. The waste from a quarry runs between 75 percent and 90 percent leaving only 10–25 percent as salable product. An underground mine, however, can get as much as 40 percent recovery with very selective mining. It is very difficult to break into the market with a small operation because buyers will want assurance that the company will be in operation in five years for a match job/repairs.

Vermont Marble, 61 Main Street, Proctor, VT 05765, 1-800-451-4468, Dan Burns, April 13, 1989

Is it producable? Test quarrying core, call Duncan, Ogden, on the 20th he is a geologist and will know in detail because it was probably evaluated by Vermont Marble Company.

Westchester Marble & Granite, (914) 472-5666, Jonathan Zanger, April 19, 1989

Negro Marquina most inexpensive, and black marble from Mexico, tiles $4–6 per square foot must be super high quality to compete. Must prepare some samples and get into presentation sizes and market all over the world.

The Imperial Black Marble Company, 8013 Chesterfield Drive, Knoxville, TN, (615) 690-4269, Barkdale Jones, April 19, 1989

The only black marble quarry in the U.S. they produce both tile and slab. Finished, polished ready for placement.

Cold Spring Granite Company, 202 South Third Avenue, Cold Springs, MN 56320, 1-800-328-7038, Dan Lovaas, April 21, 1989

He acknowledged that he gave the marketing talk at "StonExpo '89" and suggested that I call marble producers such as Georgia Marble and Vermont Marble and also call some end users such as large architectural firms. He suggested that I be prepared to send samples to prospective users with test data to be evaluated. Cold Springs Granite Company is strictly granite. Black granite extremely popular and so he suspects would be black marble but only in non-flooring uses such as furniture. Marble scratches easily and cracks show up very obviously in black marble.

Vermont Marble Company, 61 Main Street, Proctor, VT 05765, 1-800-451-4468-185, Duncan Ogden, April 21, 1989

He said that he had never visited the quarry but might have a file on it from the Highland Marble Company which he would send. He thought the marble was "Blue" and might have a chance at the market but very risky with competing third-world companies "giving away" their product. Vermont Marble would have no interest in the Conundrum Creek deposit due to their experience at Yule Creek. It is just too remote and access so limited, transportation costs too high to run risk. He suggested that I contact Stacy Dunn, President of Yule Marble Company to see if they would want to complement their product line with black marble. They would be the most probable to establish an infrastructure. Ogden said he would gladly visit the Conundrum Creek site on his October visit.

Vermont Marble Company, Duncan Ogden, November 3, 1989

When calculating the value of marble which is potential quarry material, a very rough guideline is to use $.10 per cubic foot of the saved blocks not applied to scrap pieces or any smaller or broken blocks.

Breton of The Americas, Roger Baker, November 3, 1989

To open a quarry would require a minimum of $100,000 for drills and wire saws. Underground quarries require 10 ft to 12 ft Diamond chain saws costing $250,000 to $300,000. With other accessories expect to spend 500,000 on underground more specialized equipment.

Denver Marble Company, South Platte Valley Drive, Bernie Polack, March 24, 1989

Denver Marble Company, 100 years old, is an impressive plant which retails stone from around the world. We toured the plant and were shown some of the most beautiful stone; granites, gabbros, monzonites, as well as many different types of marble. One marble display was of Carolina Ash, strikingly similar to the Conundrum Creek Marble in texture and color. This Carolina Ash is not in demand . Another "off-black" was Regal Blue from the same area as the Carolina Ash. This was a very beautiful marble but was not selling. Belgian Noire, the most notable black marble in the world was also not selling.

Bernie said that the Yule Quarry which he has been watching would take one tothree million to start up which is extremely high risk considering the very soft nature of white marble sales. He carries Yule because of its sporadic demand as maintenance rock on existing structures. Most demand now is for the more durable granites, the domestic producer is at a tremendous disadvantage because there are no pooled supply areas. If Idaho Travertine is wanted it is obtained from Idaho. furthermore, foreign suppliers are aggressively pursuing U.S. markets. The closest gang saws are in New Mexico and in Idaho with only 72 in the entire U.S.

Marble testers include; Testwell Craig, World Trade Center NY, phone 914-762-9000. Contact Roger Baker, Breton of the Americas, 305-564-2708.

An important aspect of marketing is the absorption potential of the material. Marbles with high absorption characteristics weather rapidly and demand costly maintenance in areas of high humidity. Another aspect is guaranteed supply. Users want material fast and when their contracts are ready for it. The supplier must be capable of delivery.

APPENDIX E

Title: Four months production
Project ID: 1
Run Date: 4/11/1990
Evaluation Date : 01/90
Project Start: 01/90
Evaluator: M. Davis

(All Values in Thousands)

	Escalated Dollar	Constant Dollar
Net Present Value	$189	$189
Discounted Cash Flow ROR	19.02%	14.44%
Growth Rate of Return	18.26%	13.71%
Present Worth Cost Modified ROR	19.02%	14.44%
Present Value Ratio	0.0680	0.0680
Benefit Cost Ratio	1.0680	1.0680
Payback From Project Start (Years)	8.3494	8.9647

Compounding: Discrete, Annual.
Escalated $ Minimum Rate of Return: 18.00%
Inflation Rate: 4.00%
Constant $ Minimum Rate of Return: 13.46%

Title: Four months production with TL
Project ID: 1
Run Date: 4/16/1990
Evaluation Date: 01/90
Project Start: 01/90
Evaluator: M. Davis

(All Values in Thousands)

Sensitivity Analysis

Percent Revenue	Percent Op. Cost	Percent Cap. Costs	NPV at 18.000	DCFROR
80.00	120.00	100.00	-$4,370	-2.383
84.00	116.00	100.00	-$3,413	1.575
88.00	112.00	100.00	-$2,456	6.076
92.00	108.00	100.00	-$1,520	10.493
96.00	104.00	100.00	-$627	14.795
100.00	100.00	100.00	$189	19.016
104.00	96.00	100.00	$966	23.470
108.00	92.00	100.00	$1,709	28.189
112.00	88.00	100.00	$2,422	33.196
116.00	84.00	100.00	$3,111	38.525
120.00	80.00	100.00	$3,787	44.257

Title: Five month poorboy
Project ID: 1
Run Date: 4/12/1990
Evaluation Date: 01/90
Project Start: 01/90
Evaluator: M. Davis

	Escalated Dollar	Constant Dollar
Net Present Value	$355,949	$355,949
Discounted Cash Flow ROR [Out of Range]	500.00%	500.00%
Growth Rate of Return	205.00%	205.00%
Present Worth Cost Modified ROR	500.00%	500.00%
Present Value Ratio	0.0000	0.0000
Benefit Cost Ratio	1.0000	1.0000
Payback From Project Start (Years)	0.0000	0.0000

Compounding: Discrete,annual.
Escalated $ Minimum Rate of Return: 14.00%
Inflation Rate: 4.00%
Constant $ Minimum Rate of Return: 9.62%

Title: Five months production
Project ID: 1
Run Date: 4/16/1990
Evaluation Date: 01/90
Project Start: 01/90
Evaluator: M. Davis

(All Values in Thousands)

	Escalated Dollar	Constant Dollar
Net Present Value	$555	$555
Discounted Cash Flow ROR	20.57%	15.94%
Growth Rate of Return	18.59%	14.03%
Present Worth Cost Modified ROR	20.57%	15.94%
Present Value Ratio	0.1627	0.1627
Benefit Cost Ratio	1.1627	1.1627
Payback From Project Start (Years)	7.7995	8.3231

Compounding: Discrete, annual.
Escalated $ Minimum Rate of Return: 18.00%
Inflation Rate: 4.00%
Constant $ Minimum Rate of Return: 13.46%

Title: Five month production with TL
Project ID: 1
Run Date: 4/16/1990
Evaluation Date: 01/90
Project Star: 01/90
Evaluator: M. Davis

(All Values in Thousands)

Sensitivity Analysis

Percent Revenue	Percent Op. Cost	Percent Cap. Costs	NPV at 18.000	DCFROR
80.00	120.00	100.00	-$5,068	2.361
84.00	116.00	100.00	-$3,880	1.703
88.00	112.00	100.00	-$2,692	6.621
92.00	108.00	100.00	-$1,539	11.401
96.00	104.00	100.00	-$445	16.028
100.00	100.00	100.00	$555	20.574
104.00	96.00	100.00	$1,502	25.310
108.00	92.00	100.00	$2,401	30.248
112.00	88.00	100.00	$3,264	35.458
116.00	84.00	100.00	$4,103	40.954
120.00	80.00	100.00	$4,928	46.795

Title: five months production
Project ID: 1
Run Date: 4/11/1990
Evaluation Date: 01/90
Project Start: 01/90
Evaluator: M. Davis

(All Values in Thousands)

Period Ending	**12/90**	**12/91**	**12/92**	**12/93**	**12/94**	**12/95**
Revenue	0	66	1,068	4,129	4,210	4,210
-Smelting Cost	-12	-144	-175	-190	-190	-190
Net Smelt Return	-12	-78	893	3,939	4,019	4,019
-Operation Costs	-153	-1,874	-2,280	-2,481	-2,481	-2,481
-Severence, Ad-Val	0	1	-13	-59	-60	-60
-Development	0	-56	0	0	0	0
-Depreciation	-35	-425	-627	-382	-243	-232
-Amortization	0	-3	-5	-5	-5	-5
-Interest	-5	-87	-376	-327	-270	-205
Before Depletion	-204	-2,521	-2,409	685	960	1,037
-50% Limit	0	0	0	-342	-480	-519
-Percent Depletion	0	0	125	551	563	563
-Cost Depletion	0	0	0	0	0	0
-Loss Forward	0	-204	-2,725	-5,134	-4,792	-4,312
Taxable	-204	-2,725	-5,134	-4,792	-4,312	-3,793
-Tax at 39%	0	0	0	0	0	0
Net Income	-204	-2,725	-5,134	-4,792	-4,312	-3,793
+Depreciation	35	425	627	382	243	232
+Depletion	0	0	0	342	480	519
+Amortization	0	3	5	5	5	5
-Principal	0	-25	-303	-352	-409	-474
+Loss Forward	0	204	2,725	5,134	4,792	4,312
-Capital Costs	-175	-2,133	0	0	0	0
+Borrowed	175	2,189	0	0	0	0
Cash Flow	-169	-2,062	-2,080	720	799	799

Title: Five months production
Project ID: 1
Run Date: 4/11/1990
Evaluation Date: 01/90
Project Start: 01/90
Evaluator: M. Davis

All Values in Thousands)

Period Ending	12/96	12/97	12/98	12/99	12/00	12/01
Revenue	4,210	4,210	4,210	4,210	4,210	4,210
-Smelting Cost	-190	-190	-190	-190	-190	-190
Net Smelt Return	4,019	4,019	4,019	4,019	4,019	4,019
-Operation Costs	-2,481	-2,481	-2,481	-2,481	-2,481	-2,481
-Severence, Ad-Val	-60	-60	-60	-60	-60	-60
-Development	0	0	0	0	0	0
-Depreciation	-117	-12	-11	-11	-10	-9
-Amortization	-2	0	0	0	0	0
-Interest	-128	-48	-48	-48	-48	-47
Before Depletion	1,231	1,417	1,418	1,419	1,420	1,421
-50% Limit	615	709	709	710	710	711
-Percent Depletion	-563	-563	-563	-563	-563	-563
-Cost Depltion	0	0	0	0	0	0
-Loss Forward	-3,793	-3,125	-2,270	-1,414	-557	0
Taxable	-3,125	-2,270	-1,414	-557	300	859
-Tax at 39%	0	0	0	0	-118	-338
Net Income	-3,125	-2,270	-1,414	-557	182	520
+Depreciation	117	12	11	11	10	9
+Depletion	563	563	563	563	563	563
+Amortization	2	0	0	0	0	0
-Principal	-497	-1	-1	-2	-2	-2
+Loss Forward	3,793	3,125	2,270	1,414	557	0
-Capital Costs	0	0	0	0	0	0
+Borrowed	0	0	0	0	0	0
Cash Flow	852	1,428	1,428	1,428	1,310	1,090

Title: Five months production
Project ID: 1
Run Date: 4/11/1990
Evaluation Date: 01/90
Project Start: 01/90
Evaluator: M. Davis

All Values in Thousands)

Period Ending	12/02	12/03	12/04	12/05	12/06	12/07
Revenue	4,210	4,210	4,210	4,210	4,210	4,210
-Smelting Cost	-190	-190	-190	-190	-190	-190
Net Smelt Return	4,019	4,019	4,019	4,019	4,019	4,019
-Operation Costs	-2,481	-2,481	-2,481	-2,481	-2,481	-2,481
-Severence, Ad-Val	-60	-60	-60	-60	-60	-60
-Development	0	0	0	0	0	0
-Depreciation	-9	-8	-7	-7	-7	-6
-Amortization	0	0	0	0	0	0
-Interest	-47	-47	-46	-46	-45	-44
Before	Depltn	1,422	1,423	1,424	1,425	1,426
1,427						
-50% Limit	711	712	712	713	713	714
-Percent Depletion	-563	-563	-563	-563	-563	-563
-Cost Depletion	0	0	0	0	0	0
-Loss Forward	0	0	0	0	0	0
Taxable	860	861	862	863	864	865
-Tax at 39%	-339	-339	-339	-340	-340	-341
Net Income	521	522	522	523	523	524
+Depreciation	9	8	7	7	7	6
+Depletion	563	563	563	563	563	563
+Amortization	0	0	0	0	0	0
-Principal	-3	-3	-3	-4	-5	-5
+Loss Forward	0	0	0	0	0	0
-Capital Costs	0	0	0	0	0	0
+Borrowed	0	0	0	0	0	0
Cash Flow	1,090	1,089	1,089	1,088	1,088	1,088

(Title: Five months production
Project ID: 1
Run Date: 4/11/1990
Evaluation Date: 01/90
Project Start: 01/90
Evaluator: M. Davis

All Values in Thousands)

Period Ending	**12/08**	**12/09**	**12/10**	**12/11**	**12/12**	**12/13**
Revenue	4,210	4,210	4,210	4,210	4,032	2,074
-Smelting Cost	-190	-190	-190	-190	-182	-93
Net Smelt Return	4,019	4,019	4,019	4,019	3,849	1,980
-Operation Costs	-2,481	-2,481	-2,481	-2,481	-2,376	-1,225
-Severence, Ad-Val	-60	-60	-60	-60	-58	-30
-Development	0	0	0	0	0	0
-Depreciation	-6	-6	-6	-6	-6	-6
-Amortization	0	0	0	0	0	0
-Interest	-43	-42	-41	-40	-38	-37
Before Depletion	1,428	1,429	1,430	1,432	1,371	683
-50% Limit	714	715	715	716	685	341
-Percent Depletion	-563	-563	-563	-563	-539	-277
-Cost Depletion	0	0	0	0	0	0
-Loss Forward	0	0	0	0	0	0
Taxable	866	867	868	869	832	406
-Tax at 39%	-341	-341	-342	-342	-328	-160
Net Income	525	525	526	527	504	246
+Depreciation	6	6	6	6	6	6
+Depletion	563	563	563	563	539	277
+Amortization	0	0	0	0	0	0
-Principal	-6	-7	-8	-10	-11	-13
+Loss Forward	0	0	0	0	0	0
-Capital Costs	0	0	0	0	0	0
+Borrowed	0	0	0	0	0	0
Cash Flow	1,087	1,087	1,086	1,086	1,038	516

Title: Five months production
Project ID: 1
Run Date: 4/11/1990
Evaluation Date: 01/90
Project Start: 01/90
Evaluator: M. Davis

All Values in Thousands)

Period Ending	**12/14**	**12/15**	**12/16**	**12/17**	**12/18**	**12/19**
Revenue	2,074	2,074	2,074	2,074	2,074	2,074
-Smelting Cost	-93	-93	-93	-93	-93	-93
Net Smelt Return	1,980	1,980	1,980	1,980	1,980	1,980
-Oper Costs	-1,225	-1,225	-1,225	-1,225	-1,225	-1,225
-Severence, Ad-Val	-30	-30	-30	-30	-30	-30
-Development	0	0	0	0	0	0
-Depreciation	-6	-6	-6	-6	-6	-6
-Amortization	0	0	0	0	0	0
-Interest	-35	-32	-29	-26	-22	-18
Before Depletion	685	687	690	694	697	702
-50% Limit	343	344	345	347	349	351
-Percent Depletion	-277	-277	-277	-277	-277	-277
-Cost Depletion	0	0	0	0	0	0
-Loss Forward	0	0	0	0	0	0
Taxable	408	410	413	416	420	424
-Tax at 39%	-161	-162	-163	-164	-166	-167
Ne tIncome	247	249	250	252	255	257
+Depreciation	6	6	6	6	6	6
+Depletion	277	277	277	277	277	277
+Amortization	0	0	0	0	0	0
-Principal	-15	-18	-20	-24	-27	-32
+Loss Forward	0	0	0	0	0	0
-Capital Costs	0	0	0	0	0	0
+Borrowed	0	0	0	0	0	0
Cash Flow	515	515	513	512	511	509

Title: Five months production
Project ID: 1
Run Date: 4/11/1990
Evaluation Date: 01/90
Project Start: 01/90
Evaluator: M. Davis

(All Values in Thousands)

Period Ending	12/20	Salvage
Revenue	2,074	0
-Smelting Cost	-93	0
Net Smelt Return	1,980	0
-Operation Costs	-1,225	0
-Severence, Ad-Val	-30	0
-Development	0	0
-Depreciation	-6	-3
-Amortization	0	0
-Interest	-15	0
Before Depletion	704	-3
-50% Limit	352	0
-Percent Depletion	-277	0
-Cost Depletion	0	0
-Loss Forward	0	0
Taxable	427	-3
-Tax at 39%	-168	1
Net Income	259	-2
+Depreciation	6	3
+Depletion	277	0
+Amortization	0	0
-Principal	-80	0
+Loss Forward	0	0
-Capital Costs	0	0
+Borrowed	0	0
Cash Flow	463	1

Title: Six monthe production with TL
Project ID: 1
Run Date: 4/11/1990
Evaluation Date: 01/90
Project Start: 01/90
Evaluaton: M. Davis

(All Values in Thousands)

	Escalated Dollar	Constant Dollar
Net Present Value	$729	$729
Discounted Cash Flow ROR	20.36%	15.73%
Growth Rate of Return	18.50%	13.94%
Present Worth Cost Modified ROR	20.36%	15.73%
Present Value Ratio	0.1336	0.1336
Benefit Cost Ratio	1.1336	1.1336
Payback From Project Start (Years)	7.5470	8.0464

Compounding: Discrete, Annual.
Escalated $ Minimum Rate of Return: 18.00%
Inflation Rate: 4.00%
Constant $ Minimum Rate of Return: 13.46%

Title: Six months production with TL
Project ID: 1
Run Date: 4/16/1990
Evaluation Date: 01/90
Project Start: 01/90
Evaluator: M. Davis

(All Values in Thousands)

Sensitivity Analysis

Percent Revenue	Percent Op. Cost	Percent Cap. Costs	NPV at 18.000	DCFROR
80.00	120.00	100.00	-$5,308	3.121
84.00	116.00	100.00	-$3,959	6.775
88.00	112.00	100.00	-$2,674	10.226
92.00	108.00	100.00	-$1,486	13.526
96.00	104.00	100.00	-$363	16.867
100.00	100.00	100.00	$724	20.343
104.00	96.00	100.00	$1,768	23.932
108.00	92.00	100.00	$2,781	27.680
112.00	88.00	100.00	$3,781	31.664
116.00	84.00	100.00	$4,759	35.854
120.00	80.00	100.00	$5,708	40.239

APPENDIX F

Calculations

Minable Reserves

1. Open Quarry: 3,260,000 cf = 285,250 tons

2. Underground extention of open quarry gray
Lower falls unit.
Extraction ratio R- 1- [(F)(S)1/(cp)]
F = safety factor say 5;
S = applied stress = 200 ft x 62.4 x 2.6 x 1/144 = 225 psi
C = compressive stength 82 1/0 psi
R = 1- [(5)(225)(1/8240)] = 86%, say 80%

   Minable reserve = .80 x 500 ft x 500 ft x 65 ft x 13,000,000 cf
   13,000,000 x 175 x 1/2000 = 1,137,500 tons

3. Underground at south property white marble leave a layer of white marble below hornfels: L – [(2t2 x Oe)/W)].5
Where L = length of span, say 50 ft
t = thickness of beam in the back
Oe = allowable working stress, modulus of rupture divided by safety factor
W = uniform load

   Modulus of rupture/ SF = Oe = 1200/2 = 600 psi

   Uniform load = 200 psf/lin ft

   Say span = 50 ft $50^2 = 2t^2 \times 600 \times 1/200$
   t = 20 ft thickness of layer

   Reserve is 100 ft thick - 20 ft = 80 ft remaining
   pillars at W/H = 1, 20% required

   Minable reserve = 80 ft x 725 ft x 400 ft x .80 = 18,560,000
   18,560,000 cf x 175 x 1/2000 =1,624,000

   Total minable reserve = 34,820,000 cf or 3,046,750 tons

Production Calculations

Cubic Feet

Assume 6,000 cf from open quarry 1st month; 30,000 cf all additional months
Underground quarry develped during 1990, production starts in 1991 at 1000 cf/mo, 4000 cf/mo in 1992

	1990	1991	1992 and after
4 months			
Open	96,000	120,000	120,000
UG	0	4,000	16,000
Total	96,000	124,000	136,000
5 months			
Open	126,000	150,000	150,000
UG	0	5,000	20,000
Total	126,000	155,000	170,000
6 months			
Open	156,000	180,000	180,000
UG	0	6,000	24,000
Total	156,000	186,000	204,000

Tiles

Assume: 1) send to custom fabricator who demands pre-cut "planks" 4.5 in. x 13 in. x 3–4 ft, 2) come from broken blocks of 100 cf

Block sawed into 4 planks deep

13 + 13 + 13 + 13 = 52 in.
by 13 planks wide
4.5 in. + .25 in." (kerf) x 13 = 61.75 in.
4 x 13 = 52, -10% break or imperfect = 47
7 tiles wide .375 in. + .25 in.) x 7 = 4.375 in.
by average 3.5 tiles long = 24 tiles
24 tiles x 47 planks = 1128 tiles/block
assume 17% waste tiles = 940 tiles/block

Months of Production	1990	1991	1992+
4 months	90,240	116,560	127,840
5 months	118,440	145,700	159,800
6 months	146,640	174,840	191,760

$CaCO_3$ Products

Assume: 1) $CaCO_3$ is 10% of monthly production

Example: 10% x 96,000 cf x 175 lbs/cf x 1/2000 = 840 tons

Months of Production	1990	1991	1992+
4 months	840	1,085	1,190
5 months	1,103	1,356	1,488
6 months	1,365	1,628	1,785

Ashlar

Assume: 1) generated from broken blocks,
2) get 30 veneers per ton the rest is waste,
3) from 10% of monthly production

Example: 10% x 96,000 x 175 x 1/2000 x 30 = 25,200

Months of Production	1990	1991	1992+
4 months	25,200	32,550	35,700
5 months	33,075	*40,688	44,625
6 months	40,950	48,825	53,555

*NOTE: 44,625 veneers at 4 in. x 4 in. x 30 in. aveerage
= 149,000 sf = 372 8 ft high by 50 ft long walls

Slabs

5.5 ft x 7 ft + .75 in. = 38.5 sf
Assume maximum height of block for saw is 5.5 ft, can be less
slab + kert = .75 in.+ .25 in.= 1 in. 66 or fewer slabs per block max

Assume 15% slab breakage or unusable = 56

Months of Production	1990	1991	1992 and after
4 months	5,376	6,944	7,616
5 months	7,056	8,680	9,520
6 months	8,736	10,416	11,424

Tile Blocks

Assume: 1) from broken 5.5 ft x 5.5 ft x 7 ft blocks,
2) represent 10% of monthly production,
3) 100 cf/block

Example: 10% x 96,000 x 1/1000 cf =

Months of Production	1990	1991	1992 and after
4 months	96	124	136
5 months	126	155	170
6 months	156	186	204

Products

Blocks: 5.5 ft x 5.5 ft x 7 ft at 20% of monthly cf production

4 months	.20 x 96,000 cf (1990)	200 cf/work = 96 blocks
	.20 x 124,000 cf (1991)	200 cf/work = 124 blocks
	.20 x 136,000 cf (1992+)	200 cf/work = 136 blocks
5 months	.20 x 126,000 cf (1990)	200 cf/work = 126
	.20 x 155,000 cf (1991)	200 cf/work = 155
	.20 x 170,000 cf (1992+)	200 cf/work = 170
6 months	.20 x 156,000 cf (1990)	200 cf/work = 156
	.20 x 186,000 cf (1991)	200 cf/work = 186
	.20 x 204,000 cf (1992+)	200 cf/work = 204

APPENDIX G

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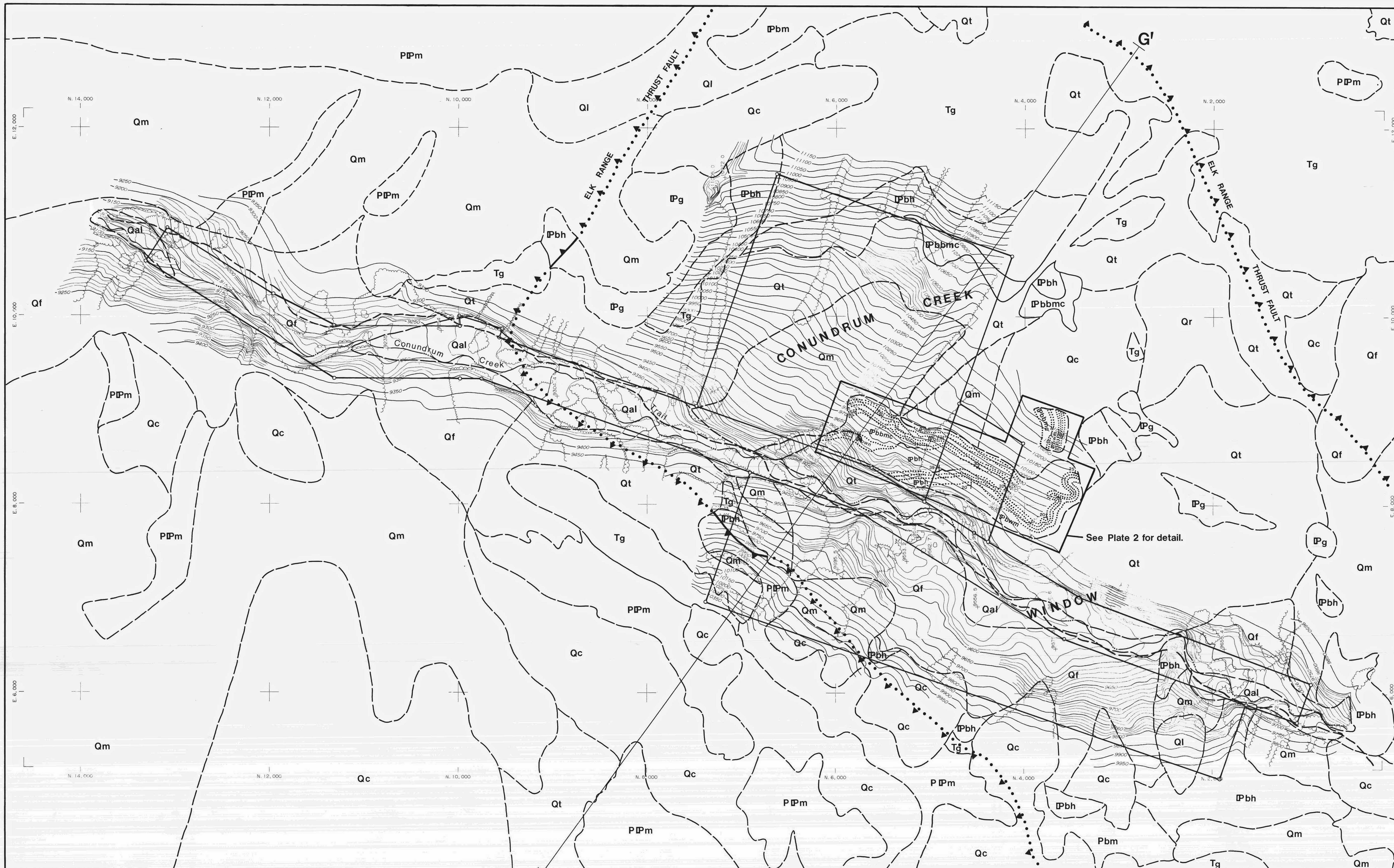
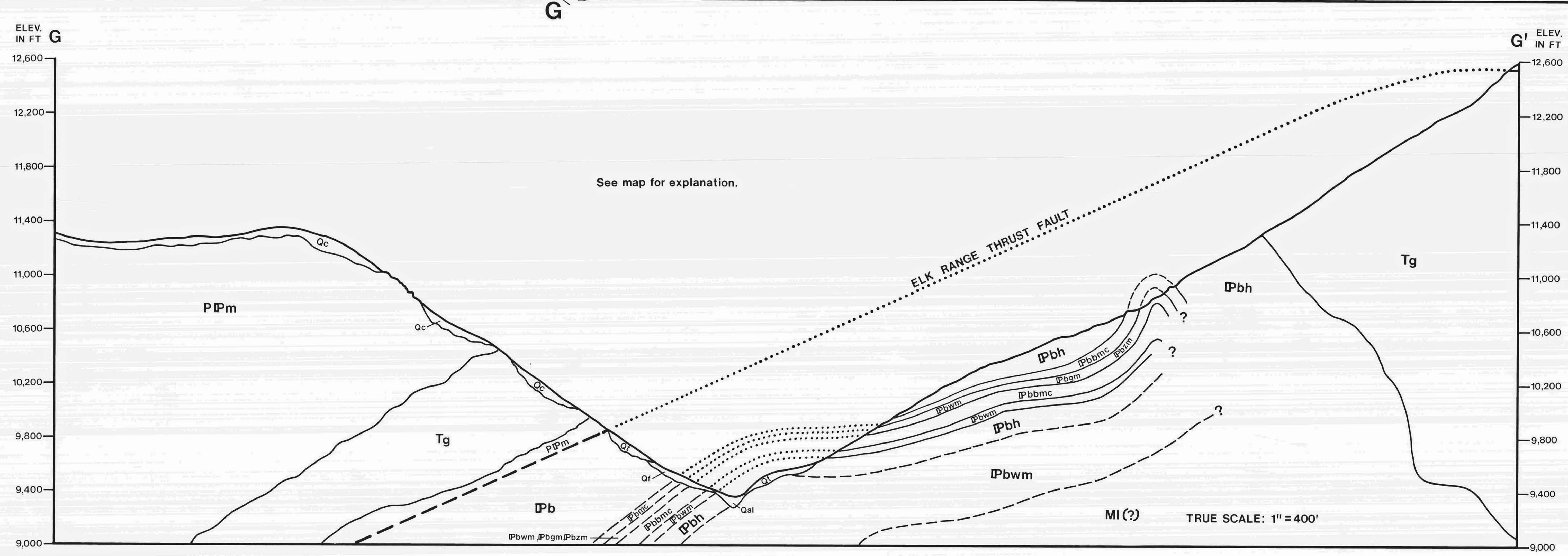
Colorado Geological Survey
Department of Natural Resources
John W. Rold, Director

Regional Geologic Map and Cross–Section of the Colorado Highland Marble Quarry Area, Conundrum Creek, Pitkin County, Colorado

By
Colorado Geological Survey

OF 90-2
Plate 1
1989





EXPLANATION

SYMBOLS

Contact, dashed where approximate, dotted where inferred

Thrust fault, sawteeth on upper plate, dotted where inferred, encompasses the Conundrum Creek window

34 Strike and dip of bedding

Claim boundary, circles are corners

G——G' Cross-section line

Adit

GEOLOGIC UNITS

Quaternary

Recent

Qal — Alluvium: silt, sand, and gravel in valley bottom

Qf — Alluvial fan deposits: generally poorly sorted material ranging from silt to boulders; may grade to talus, alluvium, or colluvium

Qt — Talus: angular pieces of rock ranging from 1/2 in. to several feet in diameter; locally well sorted.

Qc — Colluvium: poorly sorted material ranging from silt to boulders; finer grained fractions mostly predominate; deposit supports vegetation

Qr — Rock glacier: glacier like deposits of angular pebbles to boulders; generally lacking fine grained material on the upper surface; grades to talus on upper margins.

Pleistocene to Recent

Qm — Morainal deposits: poorly sorted deposits ranging from silt to boulders. Commonly contains rounded boulders derived from valley head. In many places has typical hummocky or ridgy topography. May be indisguishable from landslides containing morainal material.

Tertiary

Tertiary

Tg — Granodiorite: white to light-gray and greenish-gray granodiorite, 0.5—3 mm in grain size, containing various portions of augite, hornblende, and biotite. Locally contains phenocrysts of potassic feldspar. Occurs as plutons, dikes, and sills.

Unconformity
Upper Paleozoic

Permian-Pennsylvanian

PIPm — Maroon Formation: light to dark-maroon, brick red, and gray generally calcareous and micaceous interbedded sandstone, siltstone, mudstone, conglomerate, and limestone, Sandstones reach 10 feet in thickness. Limestones can be up to 3 feet in thickness. Limestones more abundant in lower portions of formation. Bedding ranges from 3 feet to 1/2 inch normally. Cross bedding is abundant and widespread. Where metamorphosed, is conerted to white quartzite, green calc-silicate hornfels, and, rarely, gray biotite hornfels.

Pennsylvanian-Carboniferous

IPg — Gothic Formation: gray calcareous arkose and siltstone and dark-gray shale and limestone containing marine fossils.

IPbm:

IPbh — Belden Formation hornfels: dark-gray to light-gray, pyrite bearing carbonaceous hornfels. Mostly fine grained and massive. Interbedded with gray marble beds up to 1-2 inches in thickness. Weathering of pyrite give unit a characteristic reddish-brown to yellow stain in outcrop.

IPbbmc — Belden gray marble, coarse grained: light to dark gray to black coarse grained, calcitic marble. Frequently pyritic. Beds range from 80 to 10 ft or less in thickness.

IPbwm — Belden white marble: generally coarse grained, white to grayish-white calcitic marble. Somewhat less pyritic than gray marble. Bedded to unknown thickness in Conundrum Creek window. Sometimes brecciated.

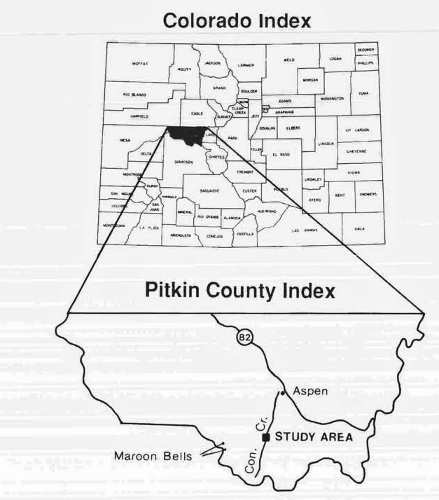
IPbgm — Belden gray marble: fine grained, light to dark gray calcitic marble, thin bedded.

IPbzm — Belden "zebra" marble: interbedded gray and white marble. Bands range in thickness from 1 to 1.5 ft.

SOURCES OF GEOLOGIC DATA

Detailed mapping by CGS staff. More regional 1:24,000 scale geology from: Bryant, U.S.G.S. GQ-788 and 863; verified by CGS where relevant to marble question.

Colorado Index



SCALE
0 400 800 1200
FEET
Contour interval = 10 feet

Colorado Geological Survey
Department of Natural Resources
John W. Rold, Director

Detailed Geologic Map and Longitudinal Section of the Belden Formation Marble Occurrence in the Vicinity of the Highland Marble Quarry Area, Condundrum Creek, Pitkin County, Colorado

By
Colorado Geological Survey

OF 90-2
Plate 2
1989

EXPLANATION

GEOLOGIC UNITS

Unconformity
Upper Paleozoic

ℙbh Belden Formation hornfels: dark-gray to light-gray pyrite bearing carbonaceous hornfels. Mostly fine grained and massive. Interbedded with gray marble beds up to 1-2 inches in thickness. Weathering of pyrite give unit a characteristic reddish-brown to yellow stain in outcrop.

ℙbbmc Belden gray marble, coarse grained: light to dark gray to black coarse grained, calcitic marble. Frequently pyritic. Beds range from 80 to 10 ft or less in thickness.

ℙbwm Belden white marble: generally coarse grained, white to grayish-white calcitic marble. Somewhat less pyritic than gray marble. Bedded to unknown thickness in Conundrum Creek window. Sometimes brecciated.

ℙbgm Belden gray marble: fine grained, light to dark gray calcitic marble, thin bedded.

ℙbzm Belden "zebra" marble: interbedded gray and white marble. Bands range in thickness from 1 to 1.5 ft.

SYMBOLS

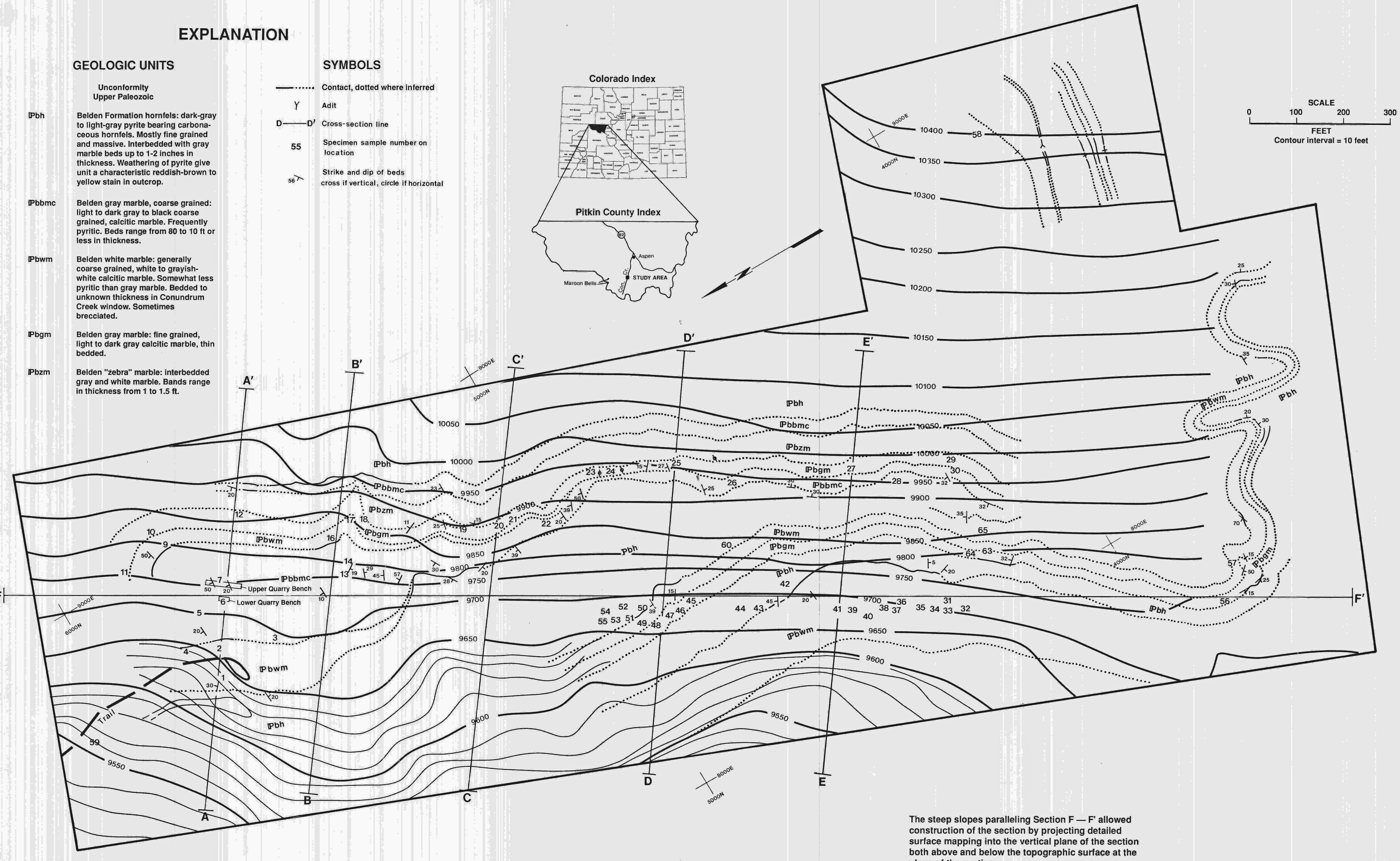
Contact, dotted where inferred

Adit

D—D′ Cross-section line

55 Specimen sample number on location

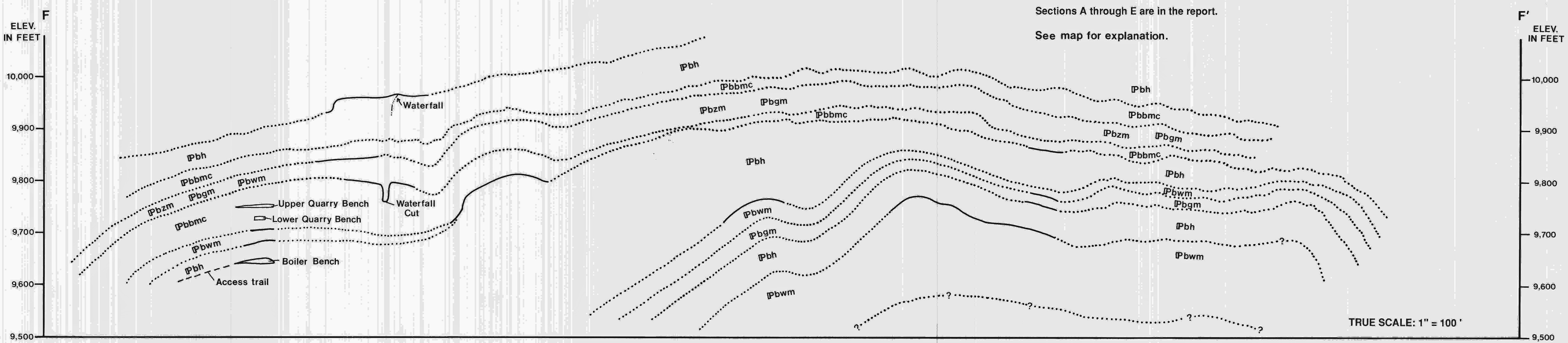
56 Strike and dip of beds cross if vertical, circle if horizontal



The steep slopes paralleling Section F — F′ allowed construction of the section by projecting detailed surface mapping into the vertical plane of the section both above and below the topographic surface at the plane of the section.

Sections A through E are in the report.

See map for explanation.



Colorado Geological Survey
Department of Natural Resources
John W. Rold, Director

Sample Location and Property Boundary Map of the Colorado Highland Marble Quarry Area, Conundrum Creek, Pitkin County, Colorado

By
Colorado Geological Survey

OF 90-2
Plate 3
1989

EXPLANATION

SAMPLING

- PL-5 — Placer/pan concentrate—multi element suite and sample number
- MD-4 — Whole rock—multi element suite and sample number
- CG-7 — Marble sample—geochemistry and sample number
- FA-2 — Fire assay and sample number

See Table 1 to reference number and results.

CLAIM CORNERS

- Claim corner location and number
- Recovered claim corner
- EDITH M — Claim name

GEOLOGIC UNITS

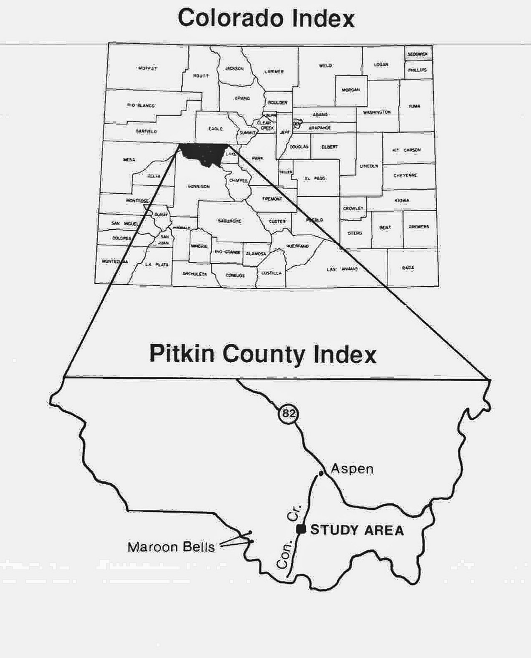
Upper Paleozoic

Pennsylvanian—Carboniferous

IPbh — Belden Formation hornfels: dark-gray to light-gray pyrite bearing carbonaceous hornfels. Mostly fine grained and massive. Interbedded with gray marble beds up to 1-2 inches in thickness. Weathering of pyrite give unit a characteristic reddish-brown to yellow stain in outcrop.

IPbm — Belden Formation marble undifferentiated: marble, small to large grained, gray, white, buff, and white and gray banded marble. Frequently pyritized.

Colorado Index



SCALE
0 400 800 1200
FEET
Contour interval = 10 feet

Table 1
Sampling: Geochemistry—Multi Element Results

Sample Type & No.	Element							
Whole Rock	Au (ppm)	Ag (ppm)	Cu ppm)	Pb (ppm)	Zn (ppm)	Mo (ppm)	W ppm)	Hg (ppm)
MD–1	<0.05	0.4	60.0	<5.0	70.0	6.0	N/T	N/T
MD–2	<0.05	0.6	25.0	<5.0	10.0	6.0	N/T	N/T
MD–3	0.05	1.0	155.0	<5.0	15.0	20.0	N/T	N/T
MD–4	<0.05	1.2	355.0	<5.0	45.0	4.0	N/T	N/T
MD–5	<0.05	0.4	10.0	<5.0	<5.0	<2.0	N/T	N/T
MD–6	<0.05	0.2	30.0	<5.0	25.0	<2.0	N/T	N/T
MD–7	<0.05	0.2	15.0	175.0	10.0	90.0	N/T	N/T
MD–25	<0.05	4.2	15.0	175.0	10.0	90.0	N/T	N/T
Stream Sediment Concentrates								
PL–1	4.50	40.0	170.0	65.0	180.0	6.0	95.0	N/T
PL–2	4.40	22.0	235.0	50.0	115.0	6.0	195.0	N/T
PL–3	1.50	7.2	145.0	60.0	70.0	22.0	135.0	N/T
PL–4	6.00	8.8	135.0	30.0	95.0	6.0	200.0	N/T
PL–5	1.10	4.9	145.0	30.0	80.0	4.0	110.0	N/T
PL–6	1.50	2.4	100.0	25.0	65.0	<2.0	180.0	N/T
MD–26	0.60	4.1	85.0	15.0	80.0	6.0	90.0	N/T
RS–1	I/S	4.7	115.0	50.0	110.0	<2.0	135.0	N/T
AB–1	0.31	2.6	85.0	30.0	135.0	<2.0	285.0	0.02

I/S—insufficient sample
N/T—not tested

Sample No.	Comment
PL–7	No visible gold in panned concentrates
PL–8	No visible gold in panned concentrates
PL–9	No visible gold in panned concentrates
PL–10	No visible gold in panned concentrates
PL–11	No visible gold in panned concentrates
PL–12	No visible gold in panned concentrates
PL–13	No visible gold in panned concentrates
PL–14	2 small flecks of flour gold in panned concentrates
PL–15	No gold observed in panned concentrates
PL–16	3 small flecks of flour gold in panned concentrates

Fire Assay	Element	
Whole Rock	Au (oz/ton)	Ag (oz/ton)
FA–1	<0.005	<0.01
FA–2	<0.005	<0.01
FA–3	0.006	<0.01
FA–4	<0.005	<0.01

Marble	Element			
Whole Rock	U_3O_8 (wt. %)	$CaCO_3$ (wt. %)	$MgCO_3$ (wt. %)	SiO_2 (wt. %)
CG–1	N/T	97.5	0.54	0.47
CG–2	N/T	98.3	0.64	0.90
CG–3	N/T	97.3	0.33	1.10
CG–4	N/T	97.3	0.53	0.11
CG–5	N/T	95.1	0.96	0.81
CG–6	N/T	95.0	0.46	1.20
CG–7	N/T	95.0	0.69	0.59
MD–23	<0.0002	N/T	N/T	N/T
MD–24	<0.0002	N/T	N/T	N/T