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CORRELATION OF COLORADO YULE MARBLE AND OTHER EARLY PALEOZOIC FORMATIONS ON YULE CREEK, GUNNISON COUNTY, COLORADO[1]

by

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CONTENTS.

ILLUSTRATIONS.

SUMMARY

The early Paleozoic section on Yule Creek is well developed and contains all the important units found in the Aspen and Leadville areas. For the purpose of correlation, some details of sections measured at Glenwood Springs and on Cement Creek (Crested Butte quadrangle) are given in this paper. Metamorphism of all the beds on Yule Creek obliterated some of the stratigraphic features and accentuated others. The rock known to the trade both as "Colorado Yule" and "Yule Colorado" marble is recrystallized Mississippian limestone. Because of that fact, and for other reasons, it is suggested that the term "Yule limestone" be discontinued as a name for the Ordovician rocks of central Colorado. Evidence is presented herewith to justify the application of the names Dyer and Parting to the members of the Chaffee formation (Upper Devonian) throughout central Colorado, including Yule Creek; also the application of the names Fremont, Harding, Manitou, and Sawatch to Ordovician and Cambrian rocks in the same area.

[1]Published by permission of the Director of the U. S. Geol. Survey, the Colorado Geological Survey Board, and the Colorado Metal Mining Fund.

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INTRODUCTION

The Paleozoic sequence from Cambrian to Mississippian has always been of particular interest in Colorado because of the large mineral production that has been derived from some of its members. The geologic sections have been studied and described in great detail in the mining areas, but in most districts distant from mining areas very little detailed work has been done. Yule Creek is one of the least studied areas. Eldridge[4] in 1894 named certain beds "Yule limestone" because of their supposed fine development on Yule Creek, but he goes on to say that the beds can be studied best on Cement Creek. Yule Creek is well known for the important deposit of marble, commercial known as Colorado Yule marble,[5] that has been quarried there.

Heretofore some geologists[6] assumed the Colorado Yule marble to be recrystallized "Yule limestone," but that assumption is now known to be incorrect. We, therefore, feel that a description of the geologic section on Yule Creek and its correlation to show the age of the Colorado Yule marble are of sufficient geologic and general interest to warrant this preliminary paper.

The Jurassic (Morrison) formation and Cretaceous (Mancos shale) formation, both of which are present on Yule Creek, are not discussed in this paper; their occurrence

[4]Eldridge, George H., U. S. Geol. Survey Geologic Atlas, Anthracite-Crested Butte Folio 9, p. 6, 1894.

[5]The term "Colorado Yule" marble was used by the Colorado Yule Marble Company, the first company to market the stone. This company discontinued its operations about 1916. In 1928 the Yule Colorado Marble Company came into existence and since that year has used the term "Yule Colorado" marble in preference to the older term. In as much as the term "Colorado Yule" marble became established and has been in use since about 1908 there seems to be no good reason for discarding the term for the marble from this area. In this report, therefore, the term "Colorado Yule" has been used to designate all of the limestone (Mississippian) marble in the area and the term "Yule Colorado" has been restricted to the stone quarried by the Yule Colorado Marble Company

[6]John Wellington Finch [Director, U. S. Bureau of Mines, 1934——] for many years a consulting geologist with headquarters in Denver, Colorado, and D. P. Rohlfing, mining engineer and geologist of Aspen, Colorado, were among those who early recognized that the Colorado Yule marble was Mississippian and not Ordovician in age.

a few miles east of Yule Creek has been described by Vanderwilt.[7]

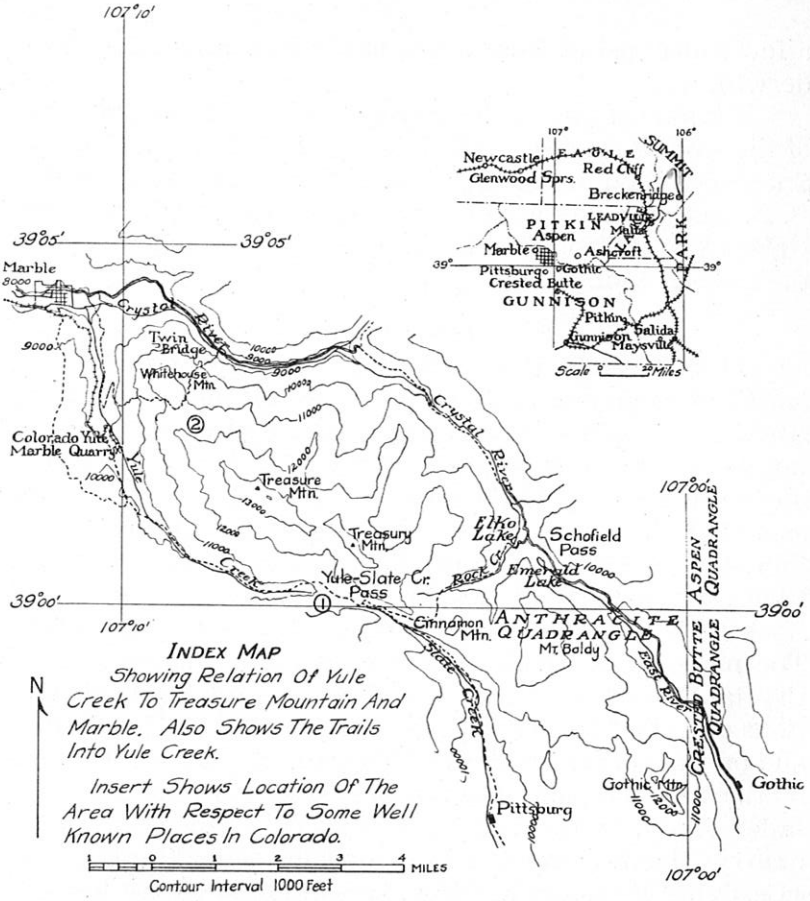
The studies on which this paper is based represent some of the work done during the seasons of 1930 and 1931 in the Snowmass Mountain area, under general supervision of Dr. B. S. Butler, as a part of the co-operative program of the United States Geological Survey, the State of Colorado, and the Colorado Metal Mining Fund.

Location

Yule Creek is the southwest boundary of the Snowmass Mountain area, which is bounded on the south by the Anthracite quadrangle and on the east by the Aspen quadrangle as shown in figure 1. Snowmass Mountain is the northern boundary of the area and is located 7 miles northeast of Marble. Yule Creek flows west and north to its junction with Crystal River at the town of Marble. Crystal River, a tributary of Roaring Fork, was formerly called Rock Creek by local inhabitants and in geologic reports. The name Rock Creek is now used for the south fork of Crystal River east of Treasure Mountain. The geologic sections described in this paper are at the head of Yule Creek, and on the northwest slope of Treasure mountain. The formations also crop out, but not in positions favorable for detailed study, in the vicinity of the Yule Colorado marble quarry about 3 miles above Marble. The Mississippian (Leadville limestone) marble crosses Yule Creek just below the quarry, and the Cambrian quartzite crosses at a little over a mile upstream. This part of the valley is easily accessible by electric trolley line from Marble to the quarry.

The head of Yule Creek can be reached by three routes, as shown in figure 1: (1) from Marble by a trail which horses can travel in four hours or more, (2) from Pittsburg, about 5 miles south, by a poor trail up Slate Creek (see fig. 1), (3) from Gothic to Elko Lake by automobile, when roads are dry, thence by trail about 5 miles up Rock Creek

[7]Vanderwilt, John W., Preliminary Geologic notes on Galena Mountain, a part of Snowmass area, Colo.: Colo. Sci. Soc. Proc. vol. 13, pp. 3-25, 1932.



and across a saddle into Slate Creek, thence down Slate Creek on an old grade constructed for a railroad that was never built, to the junction of this trail with the second route. Slide rock has covered the trail in Slate Creek making it dangerous in places, for horses, but this trail is the least difficult of the three for a party on foot. Horses are generally available in Marble but not in Pittsburg or Elko Lake Park unless special arrangements are made. The section on Treasure Mountain can be reached from Crystal River over a trail that starts at Lower Twin bridge, about 2½ miles above Marble, and rises 2,800 feet in about a mile. Unless in good repair, this trail is dangerous for horses.

GEOLOGY

The early Paleozoic formations are exposed in several places in central Colorado in areas along the north and west flanks of the Sawatch Range; on White River Plateau; and in and around the Elk Mountains. Between this large area and the San Juan region to the southwest they have been either removed by erosion or covered by younger formations. In the Elk Mountains on and around Treasure Mountain, including the area of the Yule Creek section, both the early and late Paleozoic, the Jurassic, and the Upper Cretaceous formations are well exposed, but they have been considerably metamorphosed by an intrusion of granite and therefore differ markedly from their presentatives that have been described in other localities. The intrusion of the granite, which is believed to have taken place in Tertiary time, was accompanied by a domal uplift conveniently called the Treasure Mountain dome. Yule Creek has cut a strike valley along the south, southwest, and west flanks of this dome, and discloses a large angular unconformity at the base of the Morrison (Upper Jurassic) formation. At one place, about 2 miles below the head of Yule Creek, this unconformity has eliminated all but the lower few hundred feet of the Paleozoic section. Another important unconformity occurs between the Mississippian and Pennsylvanian; it is characterized by a conglomerate and an uneven erosion surface rather than by a marked angularity.

The late Paleozoic (Pennsylvanian and Permian formations), because of metamorphism and partial removal along the unconformity, is not suitable for stratigraphic correlation. The Mississippian and older formations, however, are completely exposed on Yule Creek and Treasure Mountain and, in spite of their metamorphism, are subject to satisfactory correlation mainly on the basis of lithology and sequence. The sections at these two places are essentially identical, and the description that follows is applicable to both.

Pre-Cambrian.—The pre-Cambrian rock is a medium-grained gray gneiss. Biotite, feldspar, and quartz are abundant. Pegmatite dikes and little pegmatitic material are sparingly present except locally where they are relatively abundant. The strike of the gneiss is very irregular but the dip is generally steep. The rock is similar in appearance to the gneiss found in the Sawatch and Mosquito Ranges.

Cambrian.—At the base of the section, and resting on the gneiss, is a thick quartzite which is well exposed in bluffs or cliffs on the steeper slopes. Overlying the quartzite and capped by a massive dolomite is a calcareous shaly zone which, although metamorphosed, with the development of silicates as well as induration of the shale, has remained a weak rock that crops out only on very steep slopes. Fossils could not be found and the two members are therefore assigned to the Cambrian Sawatch quartzite because of their stratigraphic position, sequence, and lithologic features, which correspond well with the Sawatch in other parts of the state. Measurements obtained of these beds are as follows:

	Thickness Feet
(2) Quartzite, limestone, dolomitic limestone, and shales interbedded; all gray and thin bedded. Quartzite is predominant at the head of Yule Creek, and dolomitic limestone on Treasure Mountain.	
Yule Creek 91 feet; Treasure Mt. 90 feet	90 to 91
(1) Quartzite, gray and fine grained. Well bedded, with strata 6 inches to 4 feet thick. A few calcareous zones in which the rock is a quartzite sandstone.	
Yule Creek 187 feet; Treasure Mt. 128 feet	128 to 187

The lower member (1) consists of fine-grained, light-gray to white quartzite. The bedding is well defined and the strata vary in thickness from a few inches to 4 feet. There are, as a rule, a few calcareous beds as much as 10 feet thick which do not seem to occur at any definite horizon. The calcareous zones and the thinner quartzite beds are commonly covered with debris while the more massive

beds are conspicuously exposed. Bedding planes are well developed but they are so uneven that satisfactory strikes and dips are difficult to get from small outcrops. The lower member (1) is a fine-grained quartzite in most places where it was seen, including the two sections that were measured; but basal conglomerate consisting of quartz pebbles 1 inch or less across in a fine quartz sand matrix was found due east of the summit of Treasure Mountain.

The upper shaly and calcareous member (2) in many places is thin-bedded and weathers so readily that good outcrops are uncommon and a continuous section was not found. On Treasure Mountain this member forms dip slopes covered with a rubble that consists of quartzite, sandy dolomite, calcareous shale, and impure quartzite. The fragments are tabular and less than 2 inches thick. At the head of Yule Creek the upper member of the Sawatch formation crops out in ledges; it is predominantly quartzite interbedded with layers of impure limestone and dolomite except in a few small soil-covered intervals that are probably more shaly. Some of the purer quartzites of this upper member are very similar in color and texture to the quartzite of the lower member, but the thickness of a bed or the aggregate thickness of several successive beds of purer quartzite in the upper member is rarely as much as 5 feet, whereas in many places the lower member is essentially pure quartzite throughout its entire thickness of 128 to 187 feet.

Ordovician.—The Ordovician rocks are also correlated on the basis of their stratigraphic position and the sequence from bottom to top of dolomite, quartzite, and limestone recognized in the Ordovician in neighboring areas. Fossils were not found, and it is doubtful that a further search will uncover any because both dolomite and limestone are completely recrystallized and any fossils that may have been present probably have been destroyed. The measurements obtained are as follows:

Ordovician:

	Thickness
Fremont limestone:	
(5) Limestone marble, white, medium grained, and massive. 6 to 10 feet of dark gray marble at base. Yule Creek 63 feet; Treasure Mountain 60 feet	60 to 63
Harding quartzite:	
(4) Quartzite, gray and fine grained. Dolomitic and shaly in places. Yule Creek 4 feet; Treasure Mountain 5 feet	4 to 5
Manitou dolomite:	
(3) Dolomite marble, gray to buff. Bedding well developed and generally less than 12 inches thick. In places chert is found in upper ten feet. Much serpentine is present and develops a characteristic banding or ribbing on exposures across bedding. Yule Creek 81 feet; Treasure Mountain 151 feet	81 to 151

The gray to buff dolomite marble (3) that overlies the Cambrian is characterized by very abundant green and black serpentine as well as by diopside developed in irregular stringers parallel to the bedding. Weathered surfaces perpendicular to the bedding show a very characteristic grooved and ribbed pattern. The grooves average about 3 mm. in width and 5 to 20 mm. in length. They are 2 to 3 mm. deep and although they are wavy they are oriented nearly parallel to the bedding. On Treasure Mountain serpentine is abundant only in the lower beds, and diopside predominates in the upper beds although it is inconspicuous due to its white color. At the head of Yule Creek serpentine is abundant throughout the formation.

The dolomite marble is uniformly well bedded with strata 12 inches or less thick. It is not certain, of course, that the bedding planes now seen account for all of those originally present; minor bedding planes may have been obliterated by recrystallization of the rock. In places the lower 15 to 20 feet is sandy, and even contains a few sandstone layers 1 to 2 inches thick. The upper part of the dolomite contains no sandy members; but in places near the top, chert nodules, irregular in form and distribution, are developed along the bedding.

Above the dolomite is a persistent bed of quartzite (4), 4 to 5 feet thick, which is shaly (argillite) in places. The upper part of the Ordovician (5) is a massive limestone or calcite marble about 60 feet thick. The lower 6 to 10 feet is gray in places but the remainder is uniformly white and medium grained, very much like the Colorado Yule marble, which it resembles also in forming white ledges that stand out in contrast to the darker beds that lie immediately above and below it.

Devonian:

Chaffee formation:

	Thickness Feet
Dyer dolomite member:	
(11) Dolomite marble, light gray weathering to pale buff, fine grained and well bedded strata from a few inches up to 5 feet thick. Lower 20 feet appear to be more calcareous than dolomite. Yule Creek 97 feet; Treasure Mountain 72 feet	72 to 97
Parting member:	
(10) Quartzite, gray and fine grained. Pyrite along joints	5
(9) Limestone marble, white, fine grained and massive. 10-inch shale band near middle	12
(8) Shale, dolomitic, black and dense grain. In places shows a peculiar green coat on weathered surfaces	2
(7) Dolomitic limestone marble, light gray to white and fine grained. Beds 1 to 4 feet thick with a persistent sandy shale near middle	18
(6) Shale and limestone interbedded, gray. The shale is altered to brown, green, and gray and outcrops are poor	17
Total	54

The interval identified as the Parting member of the Chaffee formation (6-10) is the only horizon above the Cambrian and below the Pennsylvanian that contains relatively important shales. In this horizon, which averages 55 feet in thickness, there are about 36 feet of limestone and dolomite, 14 feet of shale, and 5 feet of quartzite. The quartzite occurs as a single bed at the top. Although individual beds

vary along the strike the Parting member as a whole is uniform throughout the area.

The dolomite marble (11) above the Parting members forms conspicuous brown to buff cliffs. It is a little more massive than the dolomite marble (3) of the Ordovician. In places the beds are thin but they average 2 to 5 feet in thickness. The dolomite marble appears quite uniform from top to bottom but the beds near the bottom effervesce more readily with acid than do the beds in the upper part. The higher calcium carbonate content which is thus indicated may have developed as a result of dedolomitization due to the formation of magnesium silicates, chiefly diopside, which are present although noticeably less abundant than in the marble below the Parting member.

Mississippian:

Leadville limestone:

(14) Limestone (calcite) marble, white, medium grained and massive. Irregular thin bands and nodules of chert in places and especially common near top. Locally dolomite beds 1 foot thick were observed.

(13) Dolomite and dolomitic limestone marble, gray to buff, fine grained, and massive.
Yule Creek 68 feet; Treasure Mountain 22 feet ..... 22 to 68

(12) Limestone (calcite) marble, gray and white bands, medium grained, and massive. Some dolomite.
Yule Creek 30 feet; Treasurer Mountain 21 feet ..... 21 to 30

The Mississippian is mostly white calcite marble 170 to 274 feet thick. Where present it invariably forms conspicuous white cliffs or ledges. The lower 20 to 30 feet (12) is characterized by lenticular banding of gray and white color parallel to the bedding. The bands are well-crystallized marble and appear identical except for color. They are irregularly spaced, 4 to 6 feet apart, and are about 3 to 8 feet thick by 100 to 1000 feet in length. Relationships suggest that the white marble is bleached gray marble. Above the banded zone, the upper limits of which are not sharp, is massive dolomite marble (13) which has a less dense grain than the dolomite marble in the Devonian and Or-

dovician and yet it is appreciably finer grained than any of the calcite marble. The upper 127 to 176 feet (14) is a single massive bed of medium-grained white marble from the upper part of which the Colorado Yule marble is quarried. Gray chert in thin lenses or discontinuous stringers, and in beds up to 2 feet thick, is present in places in the Colorado Yule marble zone as well as locally throughout the formation. In the quarry there is a fine-grained gray rock (called "lime" by the quarryman) which grades from a fine-grained dolomite marble with some calcite to calcite marble containing disseminated grains of dolomite. This dolomitic marble occurs in very irregular patches along certain zones that are approximately parallel to the bedding planes, but it seems to occur only locally. However, it is very inconspicuous on weathered surfaces and can easily escape notice. The chert and dolomitic marble are common in the quarry where they constitute an important problem in quarrying. Within 10 to 15 feet of the top of the marble there are irregular nodules of black flint; some of these contain fragments of small cup corals, the only fossils found in the entire section. Along the upper contact at the head of Yule Creek, brown garnet, andradite, in places 30 feet thick, has replaced the Colorado Yule marble and overlying beds. On the east end of Treasure Mountain, on the Yule Creek side, irregular patches of garnet replace the entire thickness of the marble, but nowhere are silicates disseminated through the rock; diopside and serpentine, common in the older formations, are lacking.

Pennsylvanian.—A characteristic conglomerate deposited on an uneven surface of the Mississippian formation indicates an erosional unconformity and is the base of a series of Pennsylvanian beds. The conglomerate consists of angular to subrounded fragments of chert and fragments that look like fine-grained quartzite in a dense black matrix which was originally shale and may have been red in color. The chert and quartzite fragments average less than 3 inches across but may be as large as 12 inches. They are rarely closely packed and generally occur scattered or even

as isolated blocks in the dense matrix. The thickness ranges from a few feet to 20 feet or more not including a certain thickness added locally where depressions occur in the top surface of the underlying marble. The depressions as exposed in bluffs are 10 to 20 feet across and equally as deep with their third dimension not evident. The amount of erosion or angularity of the unconformity between Mississippian and Pennsylvanian could not be determined because of the limited extent of this contact and the massive character of the marble.

The overlying Pennsylvanian beds consist of interbedded limestone, sandstone, and shale at least 1,000 and possibly 1,800 feet thick. The lower part is predominantly limestone with interbedded shales and sandstones some of which are fossiliferous. The amounts of sandstone and shale increase upward and the middle and upper parts contain more than 400 feet of sandstone and shaly sandstone.

The series as a whole resembles the Pennsylvanian section described by Burbank[8] in the San Juan Mountains area. Representatives of the "Weber shales" that occur in areas to the east and southeast or of the gypsum that is common over large areas to the north are not present. Fossils were found in siliceous shales and in thin limestones, but they were poorly preserved. The following is a composite list of the species collected in both the shaly and calcareous beds. The identifications are by George H. Girty.

Triplophyllum ? sp.
Spirorbis sp.
Composita subtilita
Solenomya radiata
Solenomya anodontoides
Clinopistha radiata var. laevis
Cardiomorpha missouriensis
Aviculipecten rectilaterarius
Pseudorthoceras knoxense

[8]Burbank, W. S., Revision of geologic structure and stratigraphy in the Ouray district of Colo.: Col. Sci. Soc. Proc., vol. 12, no. 6, pp. 161-166, 1930.

Concerning this fauna Mr. Girty[9] wrote:

"The fauna of the siliceous shale is of a character most disadvantageous for age determination for the fossils are none too well preserved and represent only pelecypod types, many of which can be identified even generically only upon characters that are not very trustworthy. This is more true of the fauna under consideration than of most pelecypod faunas for it has been necessary to identify these fossils with types that are relatively little known. In spite of this fact I can hardly doubt that the age of this fauna is Pennsylvanian (possibly Pottsville). This interpretation is to some extent corroborated by the specimens from the calcareous beds, especially by the collection which contains so many shells of Spirorbis, if it belongs to the same horizon for although we find Spirorbis in marine faunas these minute worm tubes are especially abundant in rocks of non-marine origin where they are associated with plant remains indicating an environmental condition that is rare if not wholly unknown in our Mississippian rocks."

The Pennsylvanian on Treasure Mountain and to the north is overlain by Permian(?) beds. On the south side of Treasure Mountain and in Yule Creek the Pennsylvanian is unconformably overlain and in places cut out by the Upper Jurassic which also overlies the bevelled edges of all of the Paleozoic formations down to the Cambrian.

CORRELATION

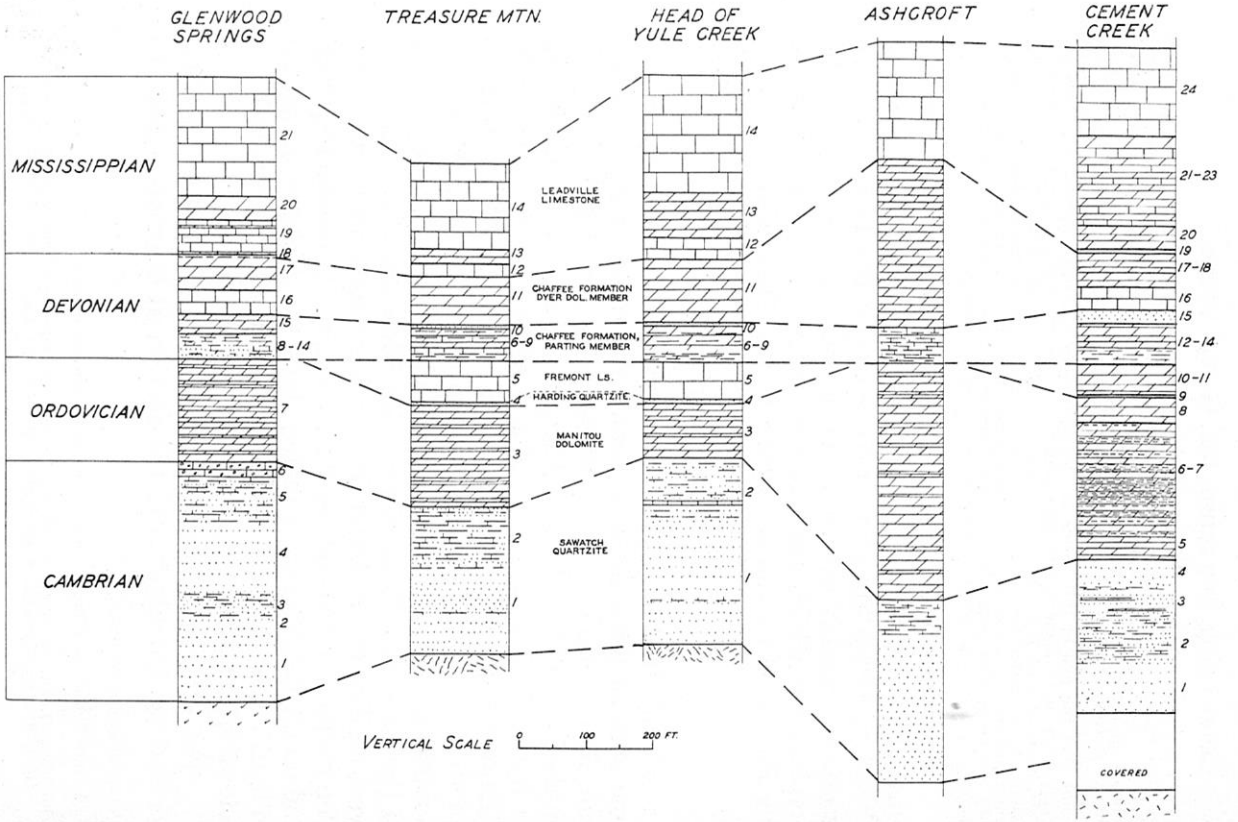
Fossils that may have been present in the early Paleozoic beds in the area have been obliterated by metamorphism. The sections can be satisfactorily correlated, however, on the basis of lithology and sequence, as graphically shown in figure 2, with sections of the same age near Ashcroft, Glenwood Springs, and in Cement Creek, Crested Butte quadrangle. Data for the section at Ashcroft were kindly furnished by J. H. Johnson,[10] who has been making a study of the Paleozoic formations of the Mosquito Range and the west side of the Sawatch Range from Redcliff to Ashcroft. The major subdivisions of the sections at Glenwood Springs and on Cement Creek (Crested Butte quadrangle) as shown in figure 2, were made to conform as far as possible with the established boundaries.

The Cement Creek section was first studied and described by Eldridge[11] and the section at Glenwood Springs

[9]Personal communication.

[10]Colorado School of Mines, Golden. Personal communication.

[11]Eldridge, G. H., In Emmons, S. F., Cross, Whitman and Eldridge, G .H.: U. S. Geol. Survey Geologic Atlas Anthracite-Crested Butte folio (No. 9), 1894.



Figue 2. Correlation of columnar section of Yule Creek and Treasure Mountain with those at Glenwood Springs, Ashcroft, and on Cement Creek (Crested Butte quadrangle).

by Kindle.[12] These sections are reviewed and discussed by Kirk[13] in two papers on the Harding sandstone and Devonian of Colorado. As detailed measurements of these two sections have not been published, the measurements made by us are given below.

Section of the early Paleozoic on Cement Creek, Crested Butte quadrangle.

The lower part of the section, from pre-Cambrian up to and including the fossil horizon above the Parting member, described below, was measured on the north side of the stream at a locality 2.7 miles up Cement Creek road and 0.5 mile east of Cement Creek Ranger station. [Cement Creek road branches to the east from the Crested Butte-Gunnison highway at a point 7.4 miles south of Crested Butte.] The upper part of the section was measured at a locality 0.2 mile farther east and is separated from the lower part by a small gully. The fossil horizon crops out continuously between the two places.

Pennsylvanian:

"Weber shales" ?, slopes covered with soil.

Mississippian:

		Thickness Feet
Leadville limestone:		
(24)	Limestone, gray, medium grained, massive, partly recrystallized	131
(23)	Dolomite, gray to buff; and limestone, gray, fine grained, interbedded. The beds are massive and there is more dolomite than limestone	32
(22)	Dolomite, gray to buff, fine grained; and limestone, gray, fine grained, interbedded. Thin bedded, with more dolomite than limestone	71
(21)	Limestone, gray, fine grained; and dolomite, gray to buff, fine grained, interbedded. Thin bedded, limestone beds 2 to 4 feet and dolomite beds 1 to 2 feet or less in thickness. Limestone predominates	32

[12]Kindle, E. M., The Devonian fauna of the Ouray limestone: U. S. Geol. Survey Bull. 391, p. 9, 1909.

[13]Kirk, Edwin, The Harding sandstone in Colorado: Am. Jrn. Sci., vol. 2, p. 459, 1930. The Devonian of Colorado: Am. Jrn. Sci., vol. 22, pp. 220, 229, 231, 233, 1931.

(20) Dolomite, gray to buff, dense, thin bedded 34
(19) Sandstone, white, fine grained 5

Devonian:

Chaffee formation:
Dyer dolomite member:
(18) Limestone, gray, dense 2
(17) Dolomite, gray, dense grain, thin bedded 49
(16) Dolomitic limestone, gray, medium grained, massive. Devonian fossils poorly preserved. *Fenestella* sp., *Camarotoechia endlichi* (Meek), and *Athyris coloradoensis* Girty were collected. (Identified by Edwin Kirk) 36
Parting member:
(15) Sandstone, gray, fine grained, thin bedded. The bed is calcareous but the upper part less so than the lower. Low angle cross bedding is conspicuous 20
(14) Dolomite, white to light gray. Brecciated along bedding 6
(13) Dolomite, white to light gray, fine grained 30
(12) Shale and dolomite interbedded. The shale is gray with parts conspicuously green, red and maroon approaching variegated shale. The dolomite is thin bedded, fine grained, and gray 24

Ordovician:

Fremont dolomite:
(11) Dolomite, gray, fine grained, massive bed 27
(10) Dolomite, light gray, dense, massive. Pink cast on weathered surfaces. No chert. Shows a few crinoid stems 18
Harding quartzite:
(9) Quartzite, gray, fine grained. Has a streak of pinkish ⅛-to ¼-inch chert fragments 2
Manitou dolomite:
(8) Dolomite, massive, dense, light gray. Pink cast on weathered surfaces. No chert 40
(7) Dolomite, cherty, gray to buff with a reddish cast, fine grained, thin bedded. Red cast on weathered surfaces. In lower part there are a few 3-to 4-foot beds free from chert. Upward the beds without chert increase in number. Upward the percentage of chert also decreases in the cherty beds. At top there is probably not over 5 per cent of chert 81
(6) Dolomite, cherty, gray to buff with a reddish cast, fine grained, thin bedded. Red cast on weathered surfaces. Near base there are only a few 1-inch or thinner streaks of chert a few feet long. Upward they increase in number but not much in size. At top chert bands are spaced 3 to 6 inches apart. Between the chert bands in

the dolomite are seams of chert or sandy material which produce a ribbed surface on weathering. Chert at top estimated as 20 per cent of rock. A few thin sandy beds at top 89

(5) Dolomite, thin bedded, fine grained, white to gray with reddish cast 34

Cambrian:

Sawatch quartzite:

(4) Sandstone, quartzitic, slightly calcareous and fine grained. Bedding 1 to 4 feet thick with some cross bedding. Color is predominantly gray but has a pronounced brown to red cast 40

(3) Sandstone, calcareous, well bedded, fine grained. Some 1-inch beds of limestone are present. Color is gray with brown to red cast on weathered surfaces 41

(2) Sandstone, gray, fine grained, thin bedded. Micaceous, shaly, calcareous, and some bright-green glauconitic beds are present. Some cross bedding. Outcrops have a reddish cast 73

(1) Sandstone, gray to reddish-gray color, medium to fine grained, bedding 1 to 4 feet 76

Covered interval 115

Pre-Cambrian granite, coarse, pink, biotitic.

Section of early Paleozoic at Glenwood Springs.

Section measured on south side of Colorado River Canyon about one-half mile upstream from station where D. & R. G. W. R. R. tunnel cuts through Cambrian quartzite.

Pennsylvanian:

"Weber" (?) formation:

Limestone, gray, fine grained, thin bedded, with interbedded shale.

	Thickness Feet
Mississippian:	
Leadville limestone:	
(21) Limestone, gray, medium grained, massive, partly recrystallized	180
(20) Dolomite, gray, fine grained. Sandy and cherty bands up to 2 inches thick in upper part	33
(19) Dolomitic limestone, gray, fine grainer, thin bedded. Upper 10 feet is sandy	54

Devonian:

Chaffee formation:

Dyer dolomite member:

(18) Shale and shaly dolomite 5

(17) Dolomite, gray to buff, fine grained 48
(16) Slightly dolomitic limestone, gray, partially recrystallized, massive. Upper 4 feet shows bedding and contains Devonian fossils. *Fenestella* sp., *Schizophoria striatula* var., *australis* Kindle, *Productella depressa* Kindle, *Camarotoechia endlichi* (Meek), and *Spirifer animasensis* Girty were collected. (Identified by Edwin Kirk) 37
(15) Dolomite, gray, sandy, fine grained 26
Parting member:
(14) Shale ?, covered 6
(13) Dolomite, gray, fine grained 5
(12) Dolomite, gray, fine grained. Contains fine-grained sandy streaks with quartz pebbles up to ¼-inch across 5
(11) Shale, gray, sandy, micaceous 12
(10) Limestone, gray, sandy 5
(9) Shale, gray, sandy, micaceous 4
(8) Quartzite, gray, fine grained 3

Ordovician:

Manitou (?) dolomite:
(7) Dolomite, gray weathering to buff, fine grained and thin bedded. Has shale partings especially near base. Partly recrystallized in places 154

Cambrian:

Sawatch quartzite:
(6) Limestone, predominantly gray, fine grained. Conglomerate-like with angular limestone fragments some of which are red. May be "red-cast beds" 24
(5) Quartzitic sandstone, shale, and limestone, all interbedded. All limestone is sandy and sandstone limy. The beds make poor outcrops 67
(4) Quartzite, gray, fine grained, well bedded 109
(3) Shale, fossiliferous 6
(2) Quartzite, with interbedded shale and calcareous shale 60
(1) Quartzite, gray, fine grained, bedding 2 inches to 2 feet thick 93

Pre-Devonian Rocks

Sawatch quartzite (Cambrian), resting on pre-Cambrian gneiss and overlain by Ordovician dolomite, constitutes a very satisfactory unit for correlation. The Cambrian-Ordovician contact is at a sharp lithologic change and therefore is easily established. The Harding and Fremont formations of the Ordovician, present in Cement Creek, are readily recognized on Yule Creek and on Treasure Moun-

tain, although they are absent at Glenwood Springs and at Ashcroft. The change from the Fremont dolomite to the overlying shaly member of the Devonian is marked on Cement Creek by a change of slope, and the contact is therefore conspicuous; but the opposite is true on Treasure Mountain, and on Yule Creek, where the shales are indurated and exposed in cliffs.

Devonian Rocks

Chaffee Formation

The two members of the Chaffee formation are well developed on Yule Creek and can be readily correlated with similar horizons on Cement Creek, at Glenwood Springs, and at Ashcroft. They have been recognized for many years throughout central Colorado, including the Leadville-Aspen area, but in the past there has been some confusion in their correlation, first from inability to definitely establish the age of the Parting quartzite, whether Devonian or Ordovician, and second because the upper boundary of the Devonian was only tentatively fixed and therefore the dolomite was included in the Leadville limestone. It is, therefore, advisable at this point to present the evidence which justifies the correlation of the Dyer[14] and Parting members of the Chaffee (Devonian) of Leadville and Aspen areas with the corresponding horizons in this more western area as well as in all of central Colorado.

We feel that the evidence presented below shows that the Chaffee formation is naturally divisible into two very characteristic members, which, although not everywhere necessarily equivalent in time, represent the same stratigraphic horizons. Since these members are called Parting and Dyer in the Leadville district, it is recommended that these terms be used for the respective members throughout central Colorado.

[14]Proposed by Behre, C. H., Jr., The Weston Pass mining district, Lake and Park counties, Colorado: Col. Sci. Soc. Proc., vol. 13, No. 3, p. 60, 1932.

Parting member.—The two members of the Chaffee formation are found, so far as we could determine, in every described occurrence of the Devonian in central Colorado. Kirk[15] has recently discussed the Devonian of this area and reviews several representative sections all of which, with

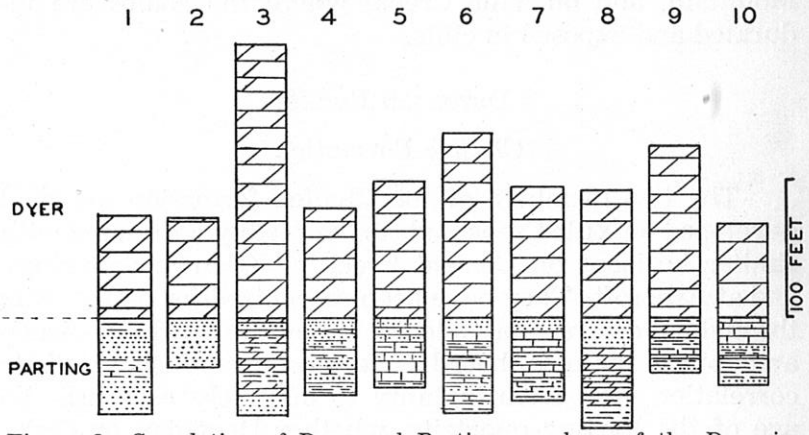


Figure 3. Correlation of Dyer and Parting members of the Devonian (Chaffee formation) in central Colorado.
1, Leadville; 2, Redcliff-Gilman; 3, Aspen; 4, Salida; 5, Monarch; 6, Gold Brick; 7, Yule Creek; 8, Cement Creek in Crested Butte quadrangle; 9, Glenwood Springs; 10, Ouray.
Note: Nos. 1 to 6 are sections redescribed by Kirk; Nos. 7 to 9 are sections as measured by us; and No. 10 is the section measured by Burbank.

the section on Yule Creek, are plotted in figure 3. The Dyer is uniformly dolomite, or dolomite with some interbedded limestone. Sections of the Parting, however, even in the same locality rarely match, so variable is the member along the strike. The sections represented in figure 3 have been described by geologists (names in parentheses and source in footnotes) as follows:

1, Leadville (Loughlin[16]), "quartzite predominates, but shale, calcareous shale, and limestone are important in places."

[15]Kirk, Edwin, The Devonian of Colorado: Am. Jrn. Sci., vol. 22, pp. 222-240, 1931.

[16]Emmons, S. F., Irving, J. D., Loughlin, G. F., Geology and ore deposits of the Leadville mining district: U. S. Geol. Survey Prof. Paper 148, p. 30, 1927.

2, Gilman-Redcliff (Kirk[17]), " . . . cross-bedded grayish-white sandstone which grades upward into sandy and occasionally finely conglomeratic dolomite."

3, Aspen (Spurr[18]), "The series may be summed up as broadly characterized by an impure feldspathic quartzite at the base and a heavier and purer quartzite at the top, with an intermediate series of massive lithographic dolomites and shaly dolomites."

4, Salida (Kirk[19]), "calcareous sandstone, sandstone, lenticular limestone, thin-bedded limestone, shales."

5, Monarch (Crawford[20]), "a predominantly limestone and dolomitic limestone series of which he says, "The basal part of the formation, [reference to Devonion-Mississippian series] for about 80 feet is more or less argillaceous or arenaceous. Most of it weathers to red or chocolate brown, making it a good horizon marker in unmetamorphosed areas."

6, Gold Brick (Worcester[21]), "limestone, sandy dolomitic limestone, sandy shale, shaly limestone, shale, quartzite."

7, Yule Creek (see p. 447), quartzite, limestone, dolomitic shale, shale, dolomitic limestone."

8, Cement Creek in Crested Butte quadrangle (see p. 454), "calcareous sandstone, dolomite, shale."

9, Glenwood Springs (see p. 455-6), "shale, dolomite, sandy dolomite, limestone, quartzite."

10, Ouray (Burbank[22]), the Elbert includes sandy limestone, siliceous shale, calcareous quartzite and sandstone, of which he says, "the sections of the Elbert formation are very different at different localities."

The term "Parting quartzite" has been regarded with disfavor by some geologists for other than local use; first, because the Parting quartzite member at Leadville is lithologically very unlike the same horizon in adjoining areas to the west and south, where it contains important amounts of shale and limestone as well as sandstone, and second, because quartzite was found at other horizons, which naturally made it necessary to be cautious in any attempts of extended correlation. These objections would probably

[17]Kirk, Edwin, loc. cit. p. 235.

[18]Spurr, J. E., Geology of the Aspen mining district, Colo.: U. S. Geol. Survey Mon. 31, pp. 13-22, 1898.

[19]Kirk, Edwin, loc. cit. p. 231.

[20]Crawford, R. D., Geology and ore deposits of the Monarch and Tomichi districts, Colo.: Colo. Geol. Survey Bull. 4, pp. 61-66, 1913.

[21]Crawford, R. D., and Worcester, P. G. Geology and ore deposits of the Gold Brick district, Colo.: Colo. Geol. Survey Bull. 10, pp. 55-56, 1916.

[22]Burbank, W. S., Revision of geologic structure and stratigraphy in the Ouray district of Colo.: Colo. Sci. Soc., vol. 12, No. 6, pp. 157-159, 1930.

never have been raised if the true character of the Parting quartzite at Leadville had always been fully appreciated. Loughlin,[23] in his revision of the geology of the Leadville district, says of the Parting quartzite member:

> "Locally there are successive alternations of thin beds of quartzite, limestone, and shale of different kinds. These shaly beds between limestone and quartzite have customarily escaped the observation of those interested in mining. In nearly all records of drill holes and shafts they are included without further comment in the limestones or are set down as porphyry. Besides marking the transition of quartzite into the adjacent limestones they occur in variable thickness and at irregular intervals through the quartzite itself. In some places the 'Parting' quartzite is divided into as many as five different layers of quartzite and shale, the shale layers equaling those of quartzite in thickness."

The columnar sections further show shale above and below quartzite. Northeast of Leadville, on the east side of the Mosquito Range, in the Alma district, according to Singewald and Butler,[24] the Parting contains "* * * variable amounts of calcareous conglomerate, limestone, and shale." From these descriptions it is evident that shales and limestones are common in the Leadville district, and that the characteristic feature of the Parting member, namely its rapid variation of lithology, is as striking there as in other areas. It is well known that south and west of the Leadville area, as at Aspen, the equivalent of the Parting quartzite is a series of shales, thin-bedded dolomites and sandstone, but it is not sufficiently emphasized that this change is very evident in the Leadville area itself.

In the San Juan Mountains the Elbert, the lower formation of the Devonian, has a lithology very similar to the Parting member, and it is probably equivalent to it. Kindle[25] used the term in the Glenwood Springs section, and this correlation has not been questioned. We feel that the term Parting is preferable to Elbert, since the areas referred to above are much closer to the Leadville-Aspen districts than to the San Juan Mountains.

[23]Emmons, S. F., Irving, J. D., and Loughlin, G. F., Geology and ore deposits of the Leadville mining district, Colo.: U. S. Geol. Survey, p. 148, pp. 30, 31, 1927.

[24]Singewald, Quentin D., and Butler, B. S., Preliminary geologic map of the Alma mining district, Colo.: Colo. Sci. Soc., Proc., vol. 12, No. 9, p. 299, 1930.

[25]Kindle, E. M., The Devonian fauna of the Ouray limestone: U. S. Geol. Survey Bull. 391, p. 9, 1909.

Dyer dolomite member.—The upper member of the Chaffee formation is clearly a continuous horizon in central Colorado and consists of dolomite, or dolomite with limestone, and is lithologically uniform although varying somewhat in thickness. The type locality of the Dyer member is in the Leadville district where it overlies the Parting quartzite, as it does at Yule Creek.

The Devonian-Mississippian contact is not marked by a sharp lithologic change, and although exposures were good the writers found the contact rather indefinite. Gibson[26] was the first tentatively to fix the top of the Devonian at the base of a quartzite bed which contained breccia fragments of limestone, chert, and quartzite. Later Behre[27] used a similar quartzite-breccia bed as the base of the Mississippian in the Mosquito Range. J. H. Johnson, in 1931, traced this horizon from Redcliff to Ashcroft, where he found it well developed. At Glenwood Springs a 5-foot shaly bed 85 feet above the Parting, and on Cement Creek a 5-foot sandstone bed 87 feet above the Parting, may represent this same horizon even though a breccia was not found. In both places the horizons are in dolomite and appreciably distant below the Leadville limestone. Subsequent work has shown this horizon to be present at Aspen.[28] On Yule Creek neither shale nor quartzite were observed, and the Devonian-Mississippian contact is tentatively placed at a noticeable though not sharp change from fine-grained, thin-bedded dolomite marble below to medium-grained, more massive, interbedded limestone and dolomite marble above. The exclusion of limestone beds from the upper part of the Chaffee (Devonian) formation is obviously open to serious question, because limestones are known to occur in this formation.

[26]Crawford, R. D., and Gibson, R., Geology and ore deposits of the Redcliff district, Colo.: Colo. Geol. Survey Bull. 30, pp. 37-38, 1925.

[27]Behre, C. H. Jr., Revision of structure and stratigraphy in the Mosquito Range and the Leadville district, Colo.: Colo. Sci. Soc. Proc., vol. 12, No. 3, p. 41, 1929.

[28]Vanderwilt, John W., Revision of structure and stratigraphy of the Aspen district, Colorado, and its bearing on the ore deposits: Ec. Geol., vol. 30, pp. 226-228, 1935.

Mississippian Rocks

Leadville limestone.—The Mississippian beds are chiefly limestone. The upper part, or zone, from which the Colorado Yule marble is obtained, is an exceptionally pure calcite rock; but in its lower part some interbedded dolomite is found. Dolomite is also found both on Cement Creek and at Glenwood Springs at the base of the massive Leadville limestone. In each locality the presence of Pennsylvanian beds overlying the Leadville limestone helps to verify the correlation.

Rock alteration on Yule Creek

Metamorphism, caused by the granite intrusion which arched up Treasure Mountain dome, has profoundly changed the rocks. A full description of the alteration will be included in the final report on the Snowmass Mountain area and only enough is given here to explain several references made to metamorphism in this paper.

The changes that have taken place are typical contact effects but are not confined to the actual contact and are not noticeably more intense there than elsewhere. Metamorphism is relatively uniform over an area of several square miles in which the distance from the igneous contact, perpendicular to the bedding, ranges from a few inches to at least 3,000 feet.

The sandstones are changed to dense quartzites and, of all the rocks involved, their appearance is least changed. Shale is altered to a dense chert-like argillite or hornfels which, as in the Morrison (Jurassic formation), is a cliff-making formation, but where carbonates are present in the shale, as in the Upper Cambrian Sawatch quartzite, the altered rock readily weathers to a rubble of angular fragments that completely obscures outcrops. Shaly, siliceous, and impure dolomite and limestone commonly show much epidote and a variety of silicates as garnet, diopside, hornblende, tremolite, and a small amount of wollastonite. Lime-

stone and dolomite have been changed to marbles, of which the Colorado Yule marble is economically important.

All of the limestone beds from the thick massive Leadville limestone to local and thin beds at different horizons have been changed to white marble without any uniform development of silicates, although locally, particularly along the upper contact, the Leadville limestone has been replaced by massive garnet. The Fremont limestone marble contains no silicates, although serpentine or diopside are everywhere abundant in the Parting, immediately above, as well as in the Manitou, a few feet below the marble. All of the dolomites are also changed to marble which, however, is gray to buff in color and finer grained than the white or limestone marble. The dolomite marbles, other than those of the Mississippian, generally contain either serpentine or diopside, uniformly distributed and abundant, although the two are not commonly found together. The development of silicates in the dolomite appears to have formed calcite so that the hydrochloric acid test for distinguishing between dolomite and limestone is not always reliable.

The combined effects of metamorphism completely obliterated much of the primary lithology and developed in their stead a series of equally characteristic features which, if once recognized, can be readily used to identify the different important horizons.

Conclusion

1. This study has shown that the lower Paleozoic section on Yule Creek is very similar to those found in neighboring areas to the north, east, and south. The formations on Yule Creek, although well developed, are not suitable for a type locality chiefly because of their alteration. The "Yule limestone" of Eldridge on Yule Creek is predominantly dolomite, and, as he defined it, probably did not include the Colorado Yule marble which is recrystallized Mississippian (Leadville) limestone and much younger than the "Yule limestone" of Eldridge.

2. "Yule limestone"[29] is not suitable as a stratigraphic term for the following reasons:

a. The term "Yule limestone" as defined by Eldridge contains Cambrian, Ordovician, and Devonian beds, for which the formation names are available.

b. Continued use of Yule as a stratigraphic term would imply that these beds were first studied or are particularly well developed for study on Yule Creek. The "Yule limestone" was so named "because of its fine development in Yule Creek" according to Eldridge, but Eldridge does not describe, and apparently did not study, the beds on Yule Creek in detail. He states specifically that the best locality for studying them is on Cement Creek. Moreover, the Paleozoic beds on Yule Creek, because of intense metamorphism, are not suitable as a type section for stratigraphic study. The geographic term "Yule" is restricted to a small and local area without any special significance except that in recent years it has been closely associated with production of Colorado Yule marble.

c. The term Colorado Yule marble is well established in the marble industry, and its use as a commercial term will probably continue indefinitely. To use the same name in a stratigraphic sense for Ordovician beds, when the marble quarried is Mississippian in age, is certain to cause confusion for laymen as well as for geologists.

3. The Devonian-Chaffee formation throughout central Colorado consists of two members which can be identified, by lithology and sequence, as the Parting and Dyer members of the Chaffee formation in the Leadville area, and it is recommended that these names be adopted for these members, at least as far south as Salida and as far west as the Elk Mountains, including the section exposed on Cement Creek and in the vicinity of Glenwood Springs.

[29]The Geologic Names Committee of the U. S. Geol. Survey has already voted to discontinue the use of "Yule": Personal communication from Edwin Kirk.