Date Due

GEOLOGY OF THE EAST LAKE CREEK AREA,

EAGLE COUNTY, COLORADO

by

Jerry Herbert Clark

B.S., University of Kansas, 1954

A Thesis submitted to the Faculty of the Graduate School of the University of Colorado in partial fulfillment of the requirements for the Degree

Master of Science

Department of Geology

1960

This Thesis for the M.S. degree by

Jerry Herbert Clark

has been approved for the

department of

Geology

by

[illegible]

Theodore R. Walker

Date 31 December 1959

Clark, Jerry Herbert (M. S., Geology)

Geology of the East Lake Creek Area, Eagle County, Colorado

Thesis directed by Associate Professor John Chronic

The East Lake Creek area is in the northwest part of central Colorado, west of the Continental Divide. The area consists of about 40 square miles of Paleozoic sedimentary rocks which dip off the extreme north end of the Sawatch Range.

The medium-grained, nearly white Upper Cambrian Sawatch quartzite is about 190 feet thick, and grades into brown, sandy dolomite of the Peerless formation which is 80 to 100 feet thick. The Lower Ordovician Manitou dolomite rests unconformably on the Peerless, and is dark gray and medium to coarsely crystalline. The Manitou is absent east of East Lake Creek, but is up to 40 feet in thickness to the west. It is separated by an angular unconformity from the Middle Ordovician Harding quartzite. The Harding is a nearly white, medium-grained orthoquartzite with some grayish yellow green sandstone lenses, and is up to 20 feet in thickness.

A prominent unconformity separates the Ordovician sediments from the Upper Devonian Chaffee formation. The white, vitreous, coarse-grained Parting quartzite member is about 75 feet thick. It differs from the quartzites of the Sawatch and Harding by its coarseness and more angular grains. The upper member of the Chaffee formation is the Dyer dolomite, which is uniform, finely crystalline, light gray, and approximately 100 feet thick. The Mississippian Leadville limestone disconformably overlies the Dyer, and is a gray,

lithographic limestone, varying from 70 to 120 feet in thickness. The base of the Leadville is a grayish brown, dolomitic sandstone locally called the Gilman member.

The Belden formation of Early Pennsylvanian age disconformably overlies the Leadville. It is about 400 feet thick, and is composed of alternating beds of dark gray, aphanitic limestone and gray to black, fissile shale. It is highly fossiliferous, while the older sediments yielded no fossils. Its fauna includes abundant specimens belonging to the genera *Amphissites*, *Millerella*, *Climacammina*, *Lophophyllidium*, *Stereostylus*, *Fenestrellina*, *Rhombopora*, *Chonetes*, *Marginifera*, *Dictyoclostus*, *Spirifer*, *Composita*, *Echinocrinus*, *Stylophycus*, and several others which were not identified. Abundant *Millerella* occur in a zone 100 feet thick above the middle of the formation. The presence of the *Millerella*, and the absence of more advanced fusulinids has led to the conclusion that at least this part of the Belden is of Morrowan age.

The Belden grades into the Minturn formation which contains about 1000 feet of gray and brown, micaceous siltstones, fine to coarse gray sandstones, and thin partings of gray shale. This lower zone is overlain by several hundred feet of gray, massive beds of gypsum and anhydrite, with thin beds of dolomite, siltstone, and shale.

Two reverse faults and one anticline trend about N45E across the southern part of the area; the faults have stratigraphic throws of 1200 to 1500 feet and can be traced for about 8 miles, and the anticline can be traced for about 5 miles. The structures all appear to be the result of a local compressive force applied to the

sediments during the uplift of the Sawatch Range.

This abstract of about 250 words is approved as to form and content. I recommend its publication.

Signed ______________________________
Instructor in charge of dissertation

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

MEASURED STRATIGRAPHIC SECTIONS

INTRODUCTION

Location and Access

The East Lake Creek area is in Eagle County, Colorado, 125 miles west of Denver, and 50 miles east of Glenwood Springs, in Township 5 South, Range 82 West. It lies to the south of the Eagle River where Paleozoic sediments wrap around the north end of the Sawatch Range (Figure 1).

The area can be reached by U. S. Highway 6 from Denver or Glenwood Springs or by U. S. Highway 24 from Leadville. An improved automobile road provides access to East Lake Creek valley, and jeep trails provide access to the lower parts of Beaver Creek, McCoy Creek, and West Lake Creek valleys (Plate III).

The thesis area covers approximately 40 square miles, and is entirely mountainous. The elevations range from 7,200 feet at the southwest corner to 12,000 feet on the divides to the south.

Methods of Investigation

Mapping was done during the summer of 1959 on U. S. Geological Survey aerial photographs at a scale of 1/40,000. The geologic map was compiled from the photographs, using a U. S. Forest Service hydrology map as the planimetric base.

Stratigraphic sections of Paleozoic formations were measured with a Brunton compass and Jacob's staff. Thin-sections taken from samples of the measured sections were used to supplement field descriptions.

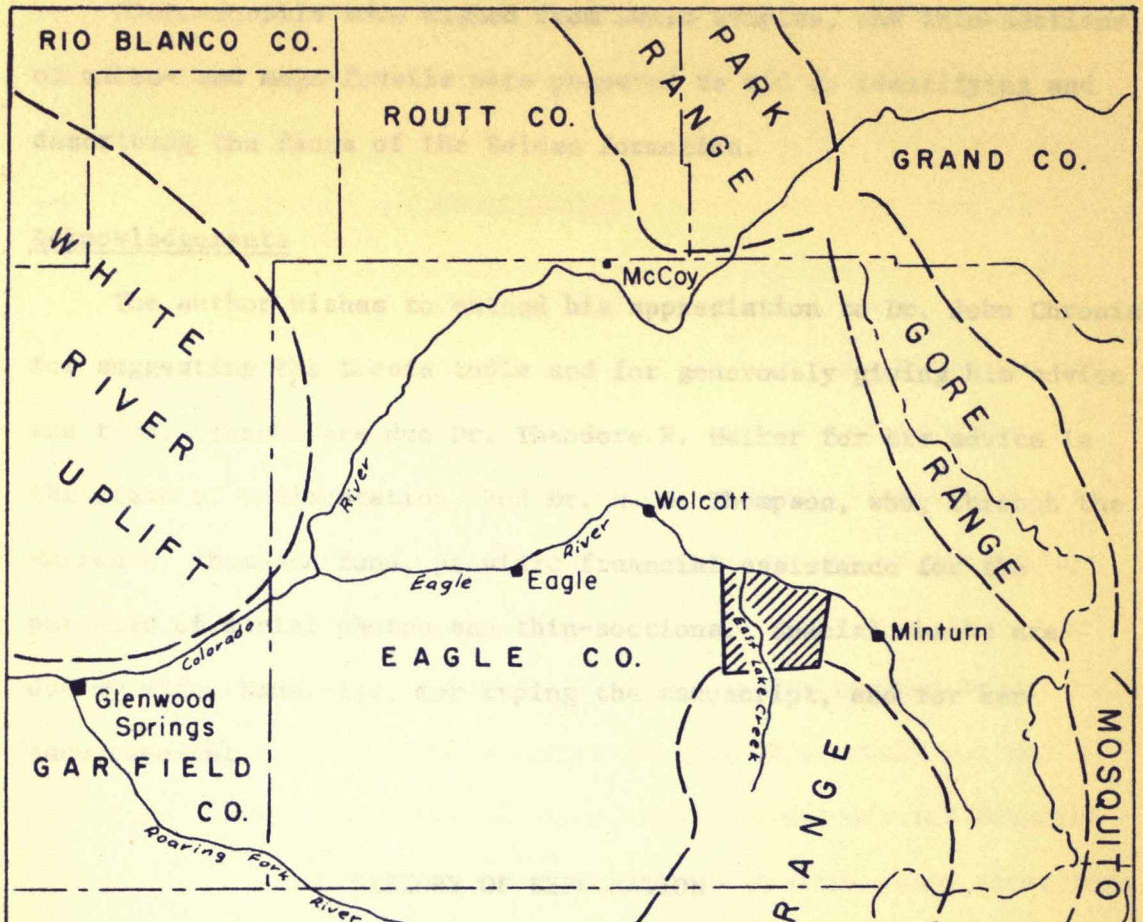


Figure 1: Index Map of northwest Colorado, showing area studied.

Micro-fossils were washed from shale samples, and thin-sections of micro- and mega-fossils were prepared to aid in identifying and describing the fauna of the Belden formation.

Acknowledgements

The author wishes to extend his appreciation to Dr. John Chronic for suggesting the thesis topic and for generously giving his advice and time. Thanks are due Dr. Theodore R. Walker for his advice in the field of sedimentation, and Dr. W. O. Thompson, who, through the Warren O. Thompson fund, provided financial assistance for the purchase of aerial photos and thin-sections. Special thanks are due my wife, Nansi-lee, for typing the manuscript, and for her encouragement.

HISTORY OF EXPLORATION

The first work of a significant geologic nature was done by Stark (1934), who discovered the reverse fault exposed in East Lake Creek valley, and by Stark and Barnes (1935), who described in a general way the geology of the Sawatch Range. Later, Johnson (1944) measured a section of lower Paleozoic rocks in East Lake Creek valley. Lovering and Tweto (1944) studied the rocks of the Minturn quadrangle a short distance east of the East Lake Creek area.

Other workers in the area or its immediate vicinity include Gableman (1949), who mapped part of the West Lake Creek area on a reconnaissance basis, Hubert (1954), who described the Mesozoic and Cenozoic deposits of the Brush Creek region immediately to the west of the East Lake Creek area, and Ridlon (1954), who measured and described a section of the Belden formation at an outcrop in the thesis area.

STRATIGRAPHY

INTRODUCTION

Paleozoic sediments in the vicinity of East Lake Creek are not well exposed, as a large part of the area consists of heavily-timbered and brush-covered dip-slopes. Quaternary glacial gravels cover the valley floors, and lateral moraines extend up the valley walls for several hundred feet.

Outcrops are generally limited to narrow divides and steep tributary walls, and formation contacts could frequently not be accurately exposed, but the author was able to measure and describe nearly complete sections of Cambrian through Mississippian formations at two locations. One excellent outcrop of the upper part of the Belden formation was measured and described. The locations of the measured sections are shown on the geologic map (Plate III). Descriptions of the locations are as follows:

<u>Section A</u>: Measured in NE¼, Sec. 33, T. 5S., R. 82W., at a series of roches moutonnees on the west side of East Lake Creek.

<u>Section B</u>: Measured on hogback 200 yards south of Barida Cabins on West Lake Creek, 7.5 miles south of bridge over East Lake Creek on U. S. Forest Service jeep trail.

<u>Section C</u>: Measured in SW¼ SW¼, Sec. 27, T. 5S., R. 82W., on southwest side of knoll, 1/2 mile east and 1,000 feet above ranch house at end of East Lake Creek automobile road.

PRECAMBRIAN

The rock most commonly underlying the Paleozoic sediments along the southern border of the thesis area is the Idaho Springs schist. This is the oldest of the Precambrian crystallines in the Sawatch Range. It is described by Lovering and Tweto (1944) as a

> Coarse-grained quartz-biotite schist, with some biotite-sillimanite schist and locally some garnetiferous schist.

On the west wall of East Lake Creek valley, the Sawatch quartzite rests on pegmatites and aplites of the Cross Creek granite which has intruded and modified the older schist. Lovering and Tweto (1944) named this rock for exposures on Cross Creek about 5 miles southeast of the thesis area in the Minturn quadrangle, and state that it probably correlates with the Boulder Creek granite of the Front Range. They described the uncontaminated part of the granite as a

> medium-coarse-grained, gray-pinkish, slightly gneissic, biotite granite.

CAMBRIAN

Nomenclature

The Sawatch formation was named by Eldridge (1894) for exposures along the flanks of the Sawatch Range. Behre (1932) subdivided the formation into the lower quartzite and upper Peerless shale members which are the equivalents of the lithologic divisions of Eldridge's type section. Later, Behre (1953) raised the shale member to formational rank.

Johnson (1944) measured a section of Sawatch quartzite at East Lake Creek, but did not recognize the Peerless formation. The author, however, identified the upper part of the Cambrian section as the Peerless formation; the lithology and the stratigraphic relations are similar to that of the type section, and are nearly identical to those of the Peerless formation in the areas adjoining the thesis area (Lovering and Johnson, 1944, and Gableman, 1949).

Sawatch quartzite

Description

Lithology: In the East Lake Creek area, the Sawatch quartzite consists of three lithologic zones: a basal zone of medium-grained, vitreous, white orthoquartzite; a middle zone of alternating beds of medium-grained, dolomitic, brown sandstone and white orthoquartzite; and an upper zone of fine-grained, vitreous, white orthoquartzite.

The orthoquartzite zones are medium-bedded to massive, and show some cross-bedding. The middle zone is thin-bedded, and the individual dolomitic beds are lenticular, grading into quartzite by increase in sand content.

The upper and lower zones weather light-brown or gray, due to staining, and are very resistant, forming prominent cliffs on the divides. The middle zone weathers to a dark brown, and is less resistant.

Thickness: The Sawatch quartzite is approximately 187 feet thick at East Lake Creek, and slightly more than 200 feet thick five miles west in West Lake Creek valley. The lower, middle, and upper zones are about 120, 40, and 30 feet thick, respectively.

Lovering and Tweto (1944) reported a thickness of 195 feet in

Eagle Canyon, ten miles southeast of the thesis area, and Gableman (1949) reported a similar thickness at Fulford, five miles to the southwest.

Contacts: Local exposures in the thesis area show the underlying Precambrian surface to be essentially flat and composed of fresh crystalline rocks, indicating erosion, but little weathering, just prior to deposition.

The contact between the Sawatch and the overlying Peerless formation is gradational in most areas of central Colorado. At East Lake Creek, the change in lithology between the formations is abrupt, but there is no evidence of a break in deposition.

Petrology

Petrographic Description: In thin-section, the Sawatch quartzite has a mosaic appearance due to secondary overgrowths on well-rounded quartz grains. The grains range from 0.15mm. to 0.6mm. in diameter, contain many inclusions and boehm lamellae, and sometimes show a pronounced undulose extinction. The secondary overgrowths of silica have grown in optical continuity with the original grains, filling voids and eliminating porosity. Detrital grains of feldspar, chert, and igneous rock fragments amount to three percent of the rock. Contacts between the grains are usually sutured, and feldspar grains and igneous rock fragments are occasionally crushed (Figure 2).

Diagenesis: The Sawatch quartzite was lithified by cementation with secondary silica. Pressure-solution at grain boundaries during compaction, evidenced by the sutured contacts, may have provided the secondary silica needed for cementing the rocks.

Figure 2: Photomicrograph of Sawatch quartzite (x89, crossed Nicols), showing well-rounded quartz grains with quartz overgrowths, and sutured contacts between grains. Sample from bed #3, measured section A, NE¼, Sec. 33, T. 5S., R. 82W.

Age and Paleontology

Fossils were not found in this formation in the East Lake Creek area. The age of the quartzite may be assumed to be late Cambrian, however, as Behre (1932) and Lovering and Tweto (1944) found late Cambrian brachiopods in the same stratigraphic position at other areas.

Measured Section of Sawatch quartzite

Section A: (For exact location, refer to description on page 4.)

Cambrian System

Peerless formation

Gradational contact

Sawatch quartzite	FEET
5. Quartzite, white, medium-grained, vitreous; bedding 6" to 1'; weathers white to brown; resistant.	30.0
4. Sandstone, brown, dolomitic, medium-grained; bedding thin, lenticular; weathers dark brown; semi-resistant; interbedded with and grading into quartzite, white, vitreous, medium- to fine-grained; thin-bedded; weathers gray; resistant.	37.0
3. Quartzite, white, coarse-grained, vitreous; bedding massive, cross-bedded; weathers white to gray; resistant.	36.5
2. Quartzite, white, fine-grained, vitreous; thin-bedded; weathers white to gray; resistant.	59.0
1. Quartzite, white, medium-grained, conglomeratic lenses, vitreous; bedding massive, cross-bedded; weathers white to gray; resistant.	25.0
Thickness of Sawatch quartzite	187.5

Nonconformable contact

Precambrian crystalline rocks

Peerless formation

Description

Lithology: The composition of the Peerless formation varies considerably at different localities in the East Lake Creek area. It is ordinarily a brown, sandy dolomite, with streaks and laminae of greenish-gray or dark red dolomite. It grades laterally and vertically into dolomitic sandstone by increase in sand content. At some outcrops, resistant beds similar to the Sawatch quartzite are interbedded with the dolomite. Brown or gray shale is interbedded with the dolomite in the middle parts of the formation, and becomes predominant at the top.

The dolomite beds are thin and lenticular. The sandstone beds are usually more massive, and show some cross-bedding. A dark brown or reddish-brown color on weathered surfaces is characteristic.

Thickness: The thickness of the Peerless formation varies noticeably at locations around the north end of the Sawatch Range. Tweto (1949) reported a thickness range of from 35 to 112 feet in the Pando area, 15 miles southeast of the thesis area. Lovering and Tweto (1944) reported a thickness of 65 feet at Eagle Canyon in the Minturn quadrangle. The author found a range in thickness of from 107 feet at East Lake Creek to less than 50 feet at the eastern boundary of the thesis area.

The range in thickness may be due in part to erosion prior to deposition of the overlying sediments, as the upper surface is cut locally by well-defined channels (Tweto, 1949). It is also possible that the lower boundary is not placed at the same level in all areas, due to the gradational nature of the contact.

Contacts: The nature of the lower contact in the thesis area has been described above. The upper contact between the Peerless formation and the Manitou dolomite is well exposed at Section A (for exact location, refer to page 4); it appears to be conformable and slightly wavy, and there is no angular discordance. At the upper contact 6 miles to the east, however, the Manitou dolomite is not present, and the Harding quartzite rests disconformably on the Peerless formation.

Petrology

Petrographic Description: Well-rounded, detrital quartz grains, ranging from 0.2mm. to 1.0mm. in diameter, are seen floating in a dolomite matrix. The quartz grains contain many inclusions, and are commonly etched by dolomite (Figure 3). The dolomite is crystalline, with rhombs ranging from 0.05mm. to 0.3mm. in size. Sub-rounded feldspar grains and cleavage fragments, igneous rock fragments, and chert amount to less than one percent. Secondary silica is present in small quantities as a void-filler and as secondary overgrowths on quartz grains. Porosity is less than one percent.

In parts of the rock, the quartz grains are in contact, and the contacts are often sutured.

Diagenesis: Diagenetic changes evident are: (1) the etching of quartz grains by dolomite; (2) the suturing of contacts between quartz grains; (3) the filling of voids by secondary silica.

The dolomite probably resulted from the recrystallization of an original clastic limestone, as the medium-grained clastic detrital constituents are evidence that the original carbonate fraction also

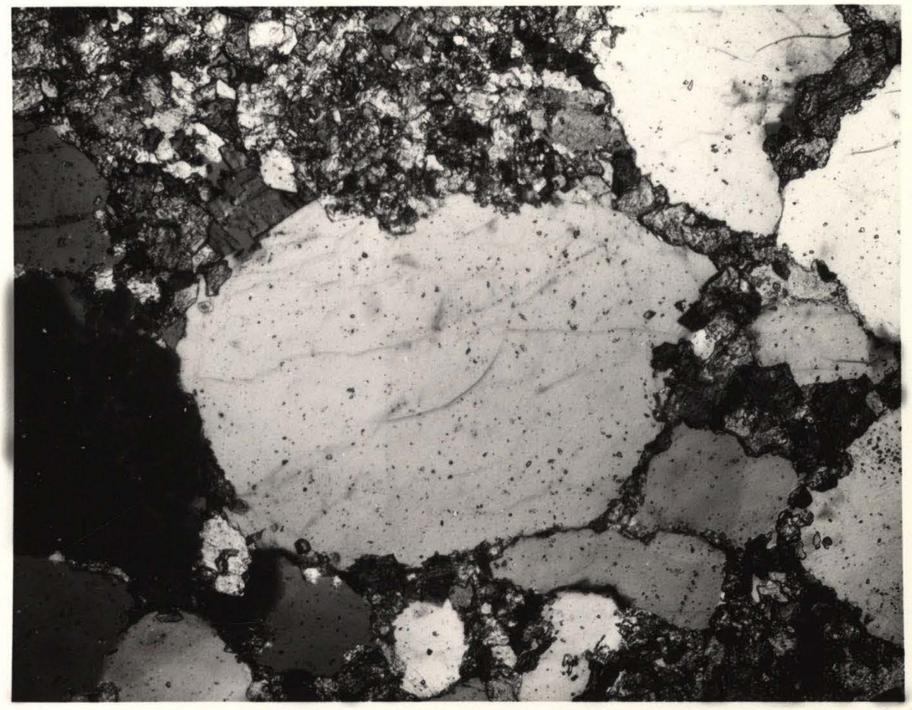


Figure 3: Photomicrograph of quartz grains in dolomite matrix (x89, crossed Nicols), Peerless formation. Note peripheral replacement of grains by dolomite. Sample from bed #4, measured section A, NE¼, Sec. 33, T. 5S., R. 82W.

was clastic. The etching of quartz grains by dolomite may have accompanied the original recrystallization, or may have taken place at a later time.

Lithification of the rock probably occurred during compaction. The secondary silica needed for filling the voids and cementing the grains could have been provided by pressure-solution at the grain boundaries during compaction, and by carbonate replacement of the grain boundaries.

Age and Paleontology

Fossils were not found in the Peerless formation in the East Lake Creek area. The stratigraphic position of the formation, however, indicates a late Cambrian or early Ordovician age. The underlying Sawatch quartzite has a late Cambrian age, and early Ordovician fossils occur in the overlying Manitou dolomite at some localities along the Sawatch Range (Johnson, 1944).

Measured Sections of the Peerless formation

Section A: (For exact location, refer to description on page 4.)

Ordovician System

Manitou dolomite

Contact covered

Cambrian System

Peerless formation		FEET
5.	Covered.	13.0
4.	Dolomite, light brown, medium crystalline, sandy; bedding 1' to 3'; interbedded with sandstone, white, fine-grained; thin-bedded; weathers dark brown to gray; resistant.	24.0

	Peerless formation (Continued)	FEET
3.	Quartzite, white, medium- to fine-grained, vitreous; bedding 6" to 1'; weathers gray; resistant.	8.5
2.	Covered.	30.0
1.	Sandstone, brown, coarse-grained, dolomitic; bedding 4" to 1', lenticular; weathers dark brown; interbedded with sandstone, white, medium-grained; bedding 1" to 2"; weathers gray; resistant.	32.0
	Thickness of Peerless formation	107.5

Gradational contact

Sawatch quartzite

Section B: (For exact location, refer to description on page 4.)

Ordovician System

Manitou dolomite

Conformable contact

Cambrian System

	Peerless formation	FEET
7.	Shale, light brown, calcareous; bedding slabby; interbedded with dolomite, gray to dark gray, fine to medium crystalline; bedding 6" to 1', lenticular; weathers dark brown; semi-resistant.	23.0
6.	Dolomite, gray, very fine crystalline; thin-bedded with shale partings; weathers light brown.	7.0
5.	Dolomite, light green, fine crystalline, glauconitic; thin-bedded with shale partings; weathers tan.	26.0
4.	Sandstone, light brown, medium-grained, dolomitic; thin-bedded; interbedded with shale; weathers dark brown; semi-resistant.	5.3
3.	Quartzite, white, fine-grained, vitreous; massive-bedded; weathers gray; resistant.	1.5

Peerless formation (Continued)	FEET
2. Dolomite, brown with green and dark red laminae, sandy; massive; weathers dark brown.	8.0
1. Dolomite, light brown, medium crystalline; bedding 6" to 1'; interbedded with dolomite, grayish-green, fine crystalline; thin-bedded; weathers light brown.	15.0
Thickness of Peerless formation	86.8

Gradational contact

Sawatch quartzite

ORDOVICIAN

Manitou dolomite

Nomenclature

Cross (1894) named the Manitou limestone from exposures near Manitou, Colorado. Kirk (1931), on the basis of stratigraphic position, lithology and fauna, showed that the formation is present in central Colorado. The term "dolomite" is used in areas where dolomite predominates over limestone (Behre, 1953).

Description

Lithology: This formation is entirely dolomite in the East Lake Creek area. The dolomite is crystalline, and fresh surfaces of the rock have a "sugary" appearance. There is an occasional trace of detrital quartz and glauconite grains. The color ranges from dark gray to reddish-brown or purple, and streaks of yellow and green give the rock a mottled appearance.

The bedding is usually thin and even, but massive-bedding and cross-bedding are also observed. The rock weathers to a dark color with reddish or brown hues.

Thickness and Contacts: The Manitou dolomite in the western half of the area is 30 to 40 feet thick. The formation is absent, however, at the eastern edge of the area and in the Minturn quadrangle (Lovering and Tweto, 1944). Gableman (1949) reported a thickness of 60 feet a few miles to the southeast.

The wedging out of the formation to the east and south may be accounted for by erosion prior to the deposition of the Harding quartzite. Tweto (1949) states that an unstable positive area between East Lake Creek and Leadville may have existed as an extension of the highland which was present to the northwest of Minturn during the Ordovician. Uplift of this unstable area would cause tilting and erosion, accounting for the angular disconformity between the Manitou and the overlying Harding quartzite.

It is unlikely that the thinning and disappearance of the Manitou dolomite to the east is due to non-deposition, as the lithology is constant around the north end of the Sawatch Range to the eastern limit of deposition.

The conformable nature of the lower contact is discussed above.

Petrology

Petrographic description: In thin-section, the rock consists of rhombic drystals of dolomite from 0.05mm. to 0.5mm. in size. Subrounded, fine-grained quartz and glauconite fragments are present, but are minor.

Very fine-grained magnetite and hematite are abundant in thin bands through the rock, and generally appear to be detrital.

Figure 4: Photomicrograph of Manitou dolomite (x89, crossed Nicols), showing dolomite euhedra with hematite inclusions. Interstitial dark areas are filled with hematite. Sample from bed #2, measured section A, NE¼, Sec. 33, T. 5S., R. 82 W.

Hematite also occurs as inclusions within the individual dolomite crystals (Figure 4).

Diagenesis: Recrystallization of carbonate to crystalline dolomite is the most important diagenetic change evident in thin-section. The rock may have been deposited as a clastic limestone, as an agitated, shallow marine environment is indicated by the presence of detrital quartz and glauconite.

The detrital hematite appears to be present as a post-depositional oxidation product of the magnetite. The hematite may have been incorporated in the dolomite drystals during recrystallization of the carbonates.

Age and Paleontology

The Manitou dolomite in the thesis area is unfossiliferous. The age is probably early Ordovician, however, as it correlates with the Manitou formation at several localities around the Sawatch Range where it contains an Early Ordovician fauna (Johnson, 1944).

Measured Sections of the Manitou dolomite

Section A: (For exact location, refer to description on page 4.)

Ordovician System

Harding quartzite

Disconformable contact

Manitou dolomite	FEET
3. Dolomite, light brown with dark red and green laminae, medium crystalline; thin-bedded to massive; weathers brown.	22.5

Manitou dolomite (Continued)	FEET
2. Dolomite, moderate brown, medium crystalline, glauconitic; bedding 6" to 1'; cross-bedded; weathers dark gray.	12.5
1. Dolomite, dark gray, fine crystalline; bedding 1" to 6"; weathers yellow brown; semi-resistant.	3.0
Thickness of Manitou dolomite	38.0

Contact covered

Cambrian System

Peerless formation

Section B: (For exact location, refer to description on page 4.)

Devonian System

Parting quartzite

Disconformable contact

Ordovician System

Manitou dolomite	FEET
3. Dolomite, grayish-purple, medium crystalline, glauconitic; bedding 1" to 6"; weathers reddish-brown; resistant.	16.0 +
2. Dolomite, dark gray with grayish-purple streaks, medium crystalline; bedding 1" to 4"; weathers brownish-gray.	6.5
1. Dolomite, dark gray, fine crystalline; bedding massive; weathers reddish-brown; resistant.	8.0
Thickness of the Manitou dolomite	30.5 +

Conformable contact

Cambrian System

Peerless formation

Harding quartzite

Nomenclature

The Harding quartzite was named by Walcott (1892) at the Harding Quarry near Canon City, Colorado. Kirk (1930) traced the formation to central Colorado. Lovering and Tweto (1944) reported the formation in the Minturn quadrangle a short distance east of the thesis area.

Description

Lithology: In the East Lake Creek area, the upper beds of the Harding are primarily white, medium-grained, vitreous orthoquartzites which are nearly identical in appearance with the Sawatch quartzite. The beds are massive and occasionally cross-bedded. Yellowish-gray green sandstone is locally interbedded with the quartzite. Outcrops are resistant, and weathered surfaces have a gray color.

The lower few feet consist of irregular brown, dolomitic sandstone beds, with conglomeratic lenses. The beds are lenticular and cross-bedded.

Thickness: The Harding quartzite is approximately 50 feet thick at the eastern edge of the thesis area. It thins to the west and is not present at West Lake Creek. It is absent to the north-east along the Gore Range, and it thins to the southeast, pinching out several miles south of the Minturn quadrangle (Tweto, 1949).

It is possible that the Harding was deposited only locally at the north end of the Sawatch Range, but post-Harding tilting by an unstable highland to the northeast, and subsequent erosion, could have removed a large part of the formation.

Contacts: The basal contact of the Harding quartzite is represented by irregular beds of sandy dolomite breccia. The breccia appears to have been formed by erosion of the underlying Manitou dolomite. The disconformable nature of the contact has been discussed above.

The upper contact with the overlying Parting quartzite is uneven and disconformable. At East Lake Creek, the top of the Harding shows relief of from 5 to 10 feet, indicating a period of erosion prior to the deposition of the Parting.

Petrology

Petrographic description: In thin-section, the Harding quartzite is very similar to the Sawatch quartzite. The quartz grains are medium-sized, well-rounded, and have many sutured contacts and secondary overgrowths. Detrital feldspar and rock fragments constitute less than 5 percent of the rock. Secondary silica occurs as a cement.

A thin-section of a rock sample taken from the basal contact shows detrital quartz and occasional fragments of Manitou dolomite in a dolomite matrix (Figure 5). The quartz grains, which amount to nearly 50 percent of the rock, are well-rounded and range from 0.1mm. to 1.0mm. in diameter, and are etched by the dolomite matrix. The dolomite fragments are rounded, and are 0.5mm. to 3.0mm. in size. The matrix is composed of crystalline dolomite with rhombs 0.05mm. to 0.3mm. in size. Calcite fills void spaces and fractures.

Diagenesis: Compaction and lithification are the primary diagenetic changes in the Harding quartzite. The sutured contacts

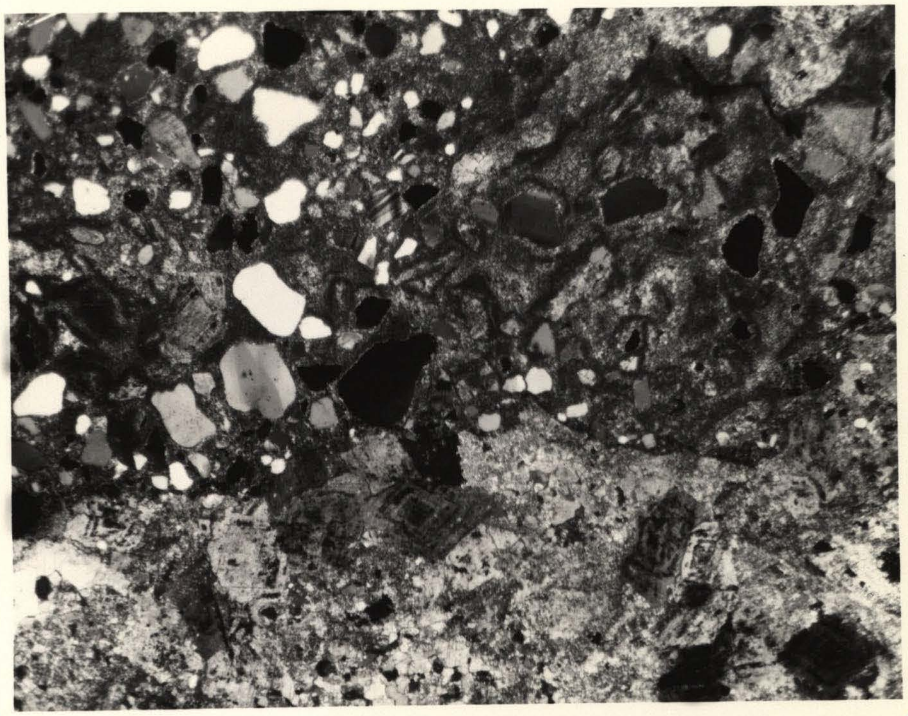


Figure 5: Photomicrograph of Harding quartzite (x29, crossed Nicols), showing detrital quartz in a dolomite matrix above, and coarse crystalline dolomite of the Manitou below. Sample from the Harding-Manitou contact, Section A, NE¼, Sec. 33, T. 5S., R. 82W.

are evidence of compaction, and lithification was provided by cementation of the grains with secondary silica. It is probable that sufficient silica was made available by pressure-solution at the grain boundaries, and by the peripheral replacement of quartz grains by dolomite.

The dolomite matrix at the base is probably secondary. The large amount of detrital material is evidence of post-depositional recrystallization of an original clastic limestone.

Age and Paleontology

The Harding quartzite is unfossiliferous in the East Lake Creek area. The formation correlates lithologically and by stratigraphic position with the Harding quartzite south of Leadville where Sweet (1954) assigned the formation a Middle Ordovician age.

Measured Section of the Harding quartzite

Section A: (For exact location, refer to description on page 4.)

Devonian System

Parting quartzite

Disconformable contact

Ordovician System

Harding quartzite	FEET
2. Quartzite, nearly white, fine-grained, vitreous; bedding massive; weathers gray; resistant.	16.0
1. Sandstone, brownish-gray to yellowish-green, coarse-grained, dolomitic, glauconitic; bedding 3" to 2', cross-bedded; weathers dark brown.	4.5
Thickness of Harding quartzite	20.5

Disconformable contact

Manitou dolomite

DEVONIAN

Chaffee formation

Nomenclature

The Chaffee formation was named by Kirk (1931) for exposures in the Mosquito Range. Included in the formation are the basal Parting quartzite member and the upper Dyer dolomite member, which were traced to the northern part of the Sawatch Range by Johnson (1944). Both members are present in the thesis area.

Parting quartzite member

Description

Lithology: The upper part of the Parting is a nearly white, medium- to coarse-grained, vitreous quartzite. It is usually massive and cross-bedded with conglomeratic lenses. Outcrops are resistant and very similar to the Sawatch quartzite, but the quartz grains are coarser and clearer, and the bedding is more massive and uneven.

The lower 5 to 10 feet consist of a non-resistant dark shale. Tweto (1949) stated that this basal zone, 15 miles southeast in the Pando area, is clayey and may represent an ancient soil developed prior to the deposition of the overlying quartzite.

Thickness: The Parting member is 75 feet thick at East Lake Creek. Gableman (1949) reported a thickness of 80 to 100 feet a few miles to the southwest, and Lovering and Tweto (1944) reported that it thins and disappears toward the Gore Range. It is apparent that the formation is wedge-shaped around the thesis area, thinning to the northeast and thickening to the southwest.

Contacts: The wedge shape of the Parting quartzite at the north end of the Sawatch Range appears to be due to deposition rather than to erosion. The upper contact with the Dyer dolomite is essentially a flat, conformable surface. Although the change in lithology between the two members is abrupt, a break in deposition is not apparent.

The lower contact is disconformable. It represents an erosional surface (discussed above) on the top of the Manitou dolomite in the west part of the thesis area, and on top of the Harding quartzite to the east.

Petrology

Petrographic description: Thin-sections of the Parting quartzite show sub-rounded to well-rounded grains of quartz, ranging from 0.1mm. to 2.0mm. in diameter (Figure 6). The grains are usually filled with inclusions and boehm lamellae, and have an undulose extinction. Contacts between the grains are frequently sutured.

Sub-angular feldspar grains of orthoclase and microcline, and of igneous rock fragments make up as much as 10 percent of the detrital constituents. Secondary silica, which is in optical continuity with the grains, fills the void spaces, giving the rock a mosaic texture.

Diagenesis: Lithification and compaction could have taken place simultaneously during the diagenesis of the rock; pressure-solution during compaction may have produced the sutured contacts, providing silica which recrystallized in optical continuity with the grains and acted as a cement.

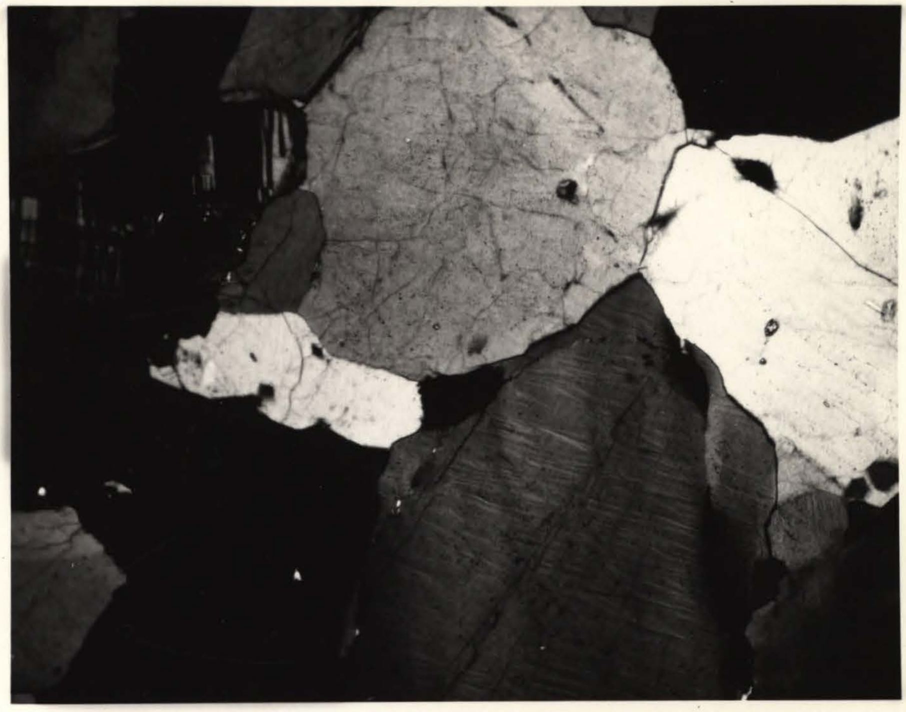


Figure 6: Photomicrograph of Parting quartzite (x89, crossed Nicols), showing sub-rounded quartz grains with secondary overgrowths and sutured contacts, and a sub-angular feldspar grain. Sample from Bed #2, measured section A, NE¼, Sec. 33, T. 5S., R. 82W.

Age and Paleontology

The Parting quartzite member is unfossiliferous. The age is probably Late Devonian, however, as fish scales of this age have been found in the Elbert formation which underlies the Parting in the Mosquito Range (Thompson, 1956), and a Late Devonian marine fauna has also been identified in the Chaffee formation about 40 miles south (Johnson, 1944).

Measured Section of the Parting quartzite

Section A: (For exact location, refer to description on page 4.)

Devonian System

Dyer dolomite

Conformable contact

Parting quartzite	FEET
5. Quartzite, yellowish gray, medium- to coarse-grained with conglomeratic lenses, vitreous; bedding massive, cross-bedded; weathers white to gray; resistant.	43.0
4. Covered.	15.0
3. Quartzite, nearly white, medium-grained, vitreous; bedding 6" to 2'; weathers white; resistant.	6.0
2. Sandstone, very light gray, coarse-grained with conglomeratic lenses; bedding massive, cross-bedded; weathers gray or brown; resistant.	7.5
1. Shale, dark reddish-brown and dark gray; non-resistant; mostly covered.	5.0
Thickness of the Parting quartzite	76.5

Disconformable contact

Ordovician System

Harding quartzite

Dyer dolomite member

Description

Lithology: The Dyer member is a uniformly thin-bedded, very finely crystalline, gray dolomite in the East Lake Creek area. Weathered surfaces are light brown or light gray.

Thickness: The Dyer is approximately 100 feet thick, and varies only a few feet in the thesis area. It thins a few miles to the east where Lovering and Tweto (1944) reported 75 to 80 feet, and it thickens to the southwest where Gableman (1949) reported up to 150 feet.

Contacts: The disconformable upper contact is well exposed at the Barida Cabins. It is a wavy erosion surface marked by a dolomite pebble conglomerate of the lower beds of the Gilman sandstone. At East Lake Creek, the contact is marked by a thin dolomite pebble conglomerate separating the Dyer from the overlying Leadville limestone.

The conformable nature of the lower contact is discussed above.

Petrology

Petrographic description: Microscopically, the Dyer dolomite is very uniform. It consists of dolomite rhombs ranging from 0.05mm. to 0.2mm. in size (Figure 7). Very fine angular quartz grains scattered through the dolomite constitute less than one percent of the rock.

Diagenesis: The only diagenetic change evident in the Dyer is some recrystallization of the dolomite.

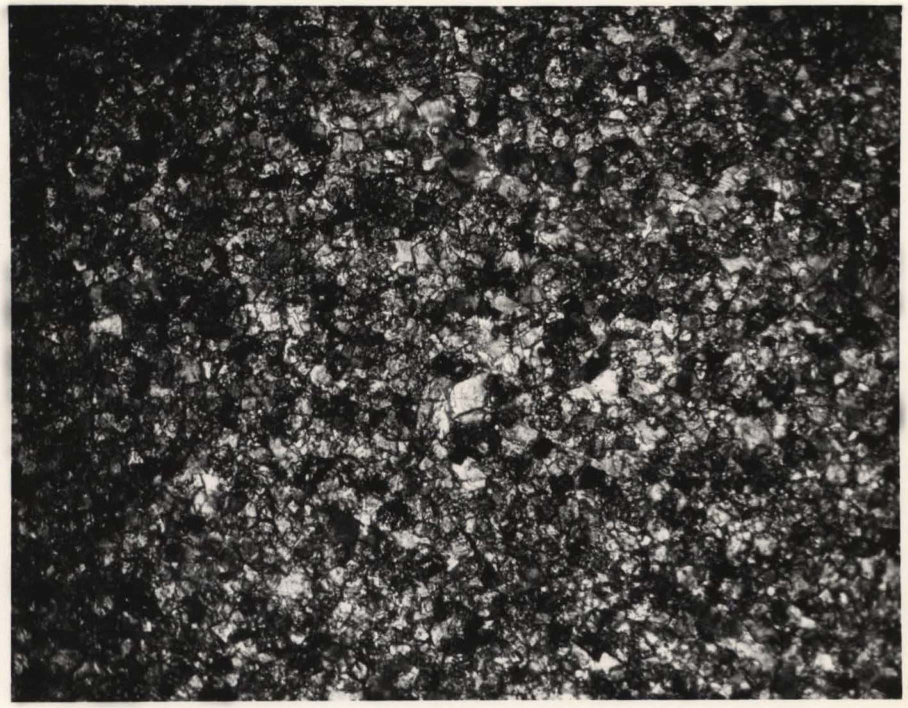


Figure 7: Photomicrograph of the Dyer dolomite (x89, crossed Nicols), showing finely crystalline dolomite. Note uniformity of composition and texture. Sample from top of bed #4, measured section A, NE¼, Sec. 33, T. 5S., R. 82W.

Age and Paleontology

No fossils are present in the Dyer dolomite in the thesis area, but Johnson (1944) reported the age to be Late Devonian, based on vertebrate and invertebrate fossils found in the Chaffee about 40 miles south.

Measured Sections of the Dyer dolomite

Section A: (For exact location, refer to description on page 4.)

Mississippian System

Leadville limestone

Disconformable contact

Devonian System

Dyer dolomite

		FEET
4.	Dolomite, light gray, fine crystalline; even 1' to 2' beds; weathers light olive gray.	69.5
3.	Dolomite, medium light gray, fine crystalline, brecciated; even 1' to 2' beds; weathers dark brown.	5.0
2.	Dolomite, medium light gray, fine crystalline; even 6" to 1' beds; weathers reddish-brown.	21.0
1.	Covered.	10.0
	Thickness of the Dyer dolomite	105.5

Conformable contact

Parting quartzite

Section B: (For exact location, refer to description on page 4.)

Mississippian System

Gilman sandstone

Disconformable contact

Devonian System

Dyer dolomite

		FEET
4.	Dolomite, light brownish gray, fine crystalline; even 1' to 3' beds; weathers gray; resistant.	59.0
3.	Dolomite, dark gray, fine crystalline, brecciated; bedding massive, some cross-beds; weathers yellowish brown.	2.8
2.	Dolomite, light brownish gray, fine crystalline; even 1' to 2' beds; weathers light brown; resistant.	23.5
1.	Dolomite, medium dark gray, fine crystalline; even 6" to 1' beds; weathers light olive gray; semi-resistant.	17.0
	Thickness of Dyer dolomite	102.3

Conformable contact

Parting quartzite

MISSISSIPPIAN

Leadville formation

Nomenclature

Eldridge (1894) named the Leadville limestone for a unit of carbonate rocks exposed near Leadville, Colorado. His unit included Devonian rocks, however, and Kirk (1931) restricted the name to Mississippian rocks. Tweto (1949) divided the formation into the basal Gilman sandstone member, which he named for exposures at Eagle Canyon in the Minturn quadrangle, and the upper limestone member. Both members are present in the thesis area.

Gilman sandstone member

Description

Lithology: The Gilman member is composed of thin and uneven beds of grayish-brown, medium-grained, calcareous sandstone. Outcrops are less resistant than the adjacent formations, and weathered surfaces are yellowish-brown. The lower few feet consist of a light gray, sandy, dolomite breccia which fills depressions in the underlying Dyer dolomite.

Thickness: The Gilman is 15 feet thick at the west edge of the thesis area, but is not present at East Lake Creek. It is not exposed in the eastern part of the area, but is again present in the Minturn quadrangle where Lovering and Tweto (1944) reported thicknesses of from 10 to 50 feet. This variation is probably due to the uneven surface at the top of the Dyer dolomite.

Contacts: The Gilman member grades into the Leadville member by a decrease in sand content. The disconformable lower contact has been previously discussed.

Petrology

Petrographic description: In thin-section, the Gilman consists of detrital quartz grains and limestone fragments floating in a dolomite matrix. The quartz grains range from 0.1mm. to 0.6mm. in diameter, and constitute slightly more than 50 percent of the rock, except at the base, where they are scattered in a dolomite matrix. The grains are well-rounded and are etched by the dolomite (Figure 8). The detrital limestone fragments are rounded and are about 0.5mm. in size. The dolomite matrix is crystalline, with rhombs ranging from

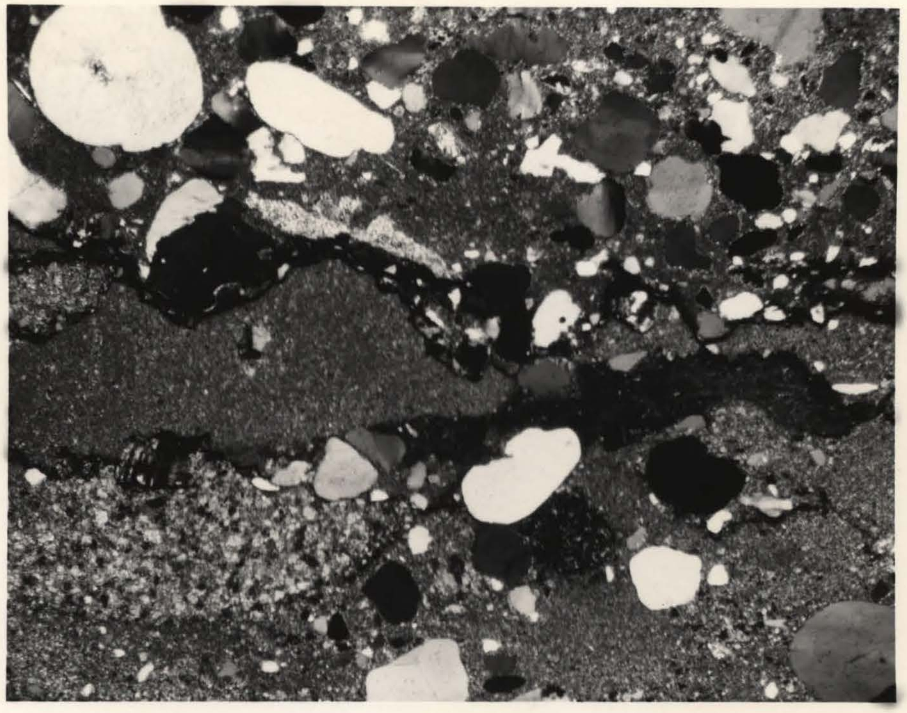


Figure 8: Photomicrograph of Gilman sandstone (x29, crossed Nicols), showing a finely crystalline carbonate matrix with detrital quartz grains and dolomite fragments which have been modified by pressure solution at the boundaries. Sample from the base of bed #1, measured section B, Barida Cabins (for exact location, refer to measured section B, page 4).

0.03mm. to 0.15mm. in size. Voids are filled with sparry calcite.

A thin-section of a rock sample taken from the lower breccia beds shows well-rounded quartz and feldspar grains and rounded fragments of dolomite and limestone floating in a fine crystalline dolomite matrix (Figure 8). The dolomite fragments have the same appearance as the underlying Dyer dolomite.

Diagenesis: The matrix of the rock has probably recrystallized from a finely crystalline clastic limestone, as an original clastic rock is indicated by the amount of detrital material present. The etching of quartz grains by the dolomite is also strong evidence of post-depositional recrystallization.

Age and Paleontology

The age of the Gilman sandstone is in doubt. It is unfossiliferous and could be either Late Devonian or Early Mississippian. It seems more likely, however, that it is closer to the age of the overlying Leadville limestone (Early Mississippian), as an erosional surface separates the member from the underlying Devonian beds.

Measured Section of the Gilman sandstone

Section B: (For exact location, refer to description on page 4.)

Mississippian System

Leadville limestone

Gradational contact

Gilman sandstone	FEET
2. Sandstone, grayish-brown, medium- to coarse-grained, calcareous; thin-bedded, cross-bedded; weathers yellowish-brown; non-resistant.	11.5

Gilman sandstone (Continued)	FEET
1. Dolomite, light gray, fine crystalline; lenticular beds; weathers grayish-brown; non-resistant.	3.5
Thickness of the Gilman sandstone	15.0

Disconformable contact

Devonian System

Dyer dolomite

Leadville limestone member

Description

Lithology: The Leadville limestone is a uniform, dark gray, lithographic limestone in most of the thesis area. It is evenly massive-bedded, except for the lower beds which are thin and contain limestone pebbles. Weathered surfaces have a distinctive bluish-gray color.

Chert is present in this formation at many localities in the Sawatch Range, but it is not seen at exposures in the thesis area.

The Leadville is a highly fractured, silicified, altered dolomite near East Lake Creek. In this locality, it appears to be similar to the Leadville dolomite near Gilman, Colorado, 10 miles to the southeast, which Tweto (1949) believes has been altered from an original limestone by hydrothermal solutions. The Leadville is not altered at other localities in the thesis area.

Thickness: The best exposure of the Leadville limestone in the thesis area is at the Barida Cabins section where it is at least 120 feet thick. A thickness of 75 feet was measured at East Lake

Creek, but only a few feet are exposed at other locations.

Contacts: The lower gradational contact has been discussed above. The upper contact is not exposed, but the variation in thickness is probably due to erosion prior to the deposition of the overlying Belden formation. Scott (1954) stated that the upper surface is quite uneven in west-central Colorado, with at least 100 feet of relief locally.

Petrology

Microscopically, the Leadville appears to be primarily a homogenous, microcrystalline limestone, with a few cavities and fractures filled with sparry calcite.

A thin-section of a sample from the basal beds shows scattered rhombs of dolomite and a few fine, angular grains of quartz (Figure 9).

The lithographic character of the rock is undoubtedly primary, and diagenetic changes are not evident.

Age and Paleontology

The Leadville in the thesis area is not fossiliferous. However, the unit is probably equivalent to the basal, unfossiliferous part of the Leadville limestone in west-central Colorado which Scott (1954) concluded is

> probably correlative with the Madison limestone of Utah, Montana, and Wyoming, and is probably Kinderhookian and Osagian.

Figure 9: Photomicrograph of Leadville limestone (x89, crossed Nicols), showing lithographic texture. Note scattered, fine-grained quartz, and cavities and fracture filled with sparry calcite. Sample from 25 feet below the top of the formation, measured section B, Barida Cabins (for exact location, refer to measured section B, page 4).

Measured Section of the Leadville limestone

Section B: (For exact location, refer to description on page 4.)

Pennsylvanian System

Belden formation

Contact covered

Mississippian System

Leadville Limestone	FEET
3. Limestone, dark gray, lithographic; massive-bedded; weathers bluish-gray.	114.0 -
2. Limestone, gray, lithographic; bedding uneven, edgewise conglomerate; weathers gray.	4.0
1. Limestone, light gray, fine crystalline; bedding 1" to 2"; weathers light gray.	2.0
Thickness of the Leadville limestone	120.0 -

PENNSYLVANIAN

Belden formation

Nomenclature

The Belden formation was named by Brill (1944) for exposures in Eagle Canyon, about 15 miles southeast of East Lake Creek. The formation had previously been called the Weber shale in west central Colorado.

Description

Lithology: The Belden formation in the thesis area is composed primarily of alternating beds of dark gray or black, aphanitic limestone and gray or black, fissile shale, with shale predominating. Many of the limestones and shales are highly fossiliferous.

Sandstone is restricted to two massive, conglomeratic, arkosic beds near the middle of the section, and a few thin beds of micaceous siltstone are present near the top.

Thickness: A thickness of approximately 400 feet was measured at East Lake Creek (Plate III, Section A), but only 36 feet of the section near the top was visible. Ridlon (1954) reported a thickness of 426 feet at East Lake Creek (near the author's Section C, Plate III). These thicknesses agree approximately with Brill's (1944) isopach map of the Belden, and it is apparent that the thesis area lies about 20 miles southeast of the northeastern limit of the Belden depositional basin.

Contacts: In the thesis area, the basal beds of the Belden formation are covered. However, the basal contact at other locations in west central Colorado has been described by Ridlon (1954) as unconformable, with the Belden resting

> on a karst topography developed on the surface of the Mississippian Leadville formation.

The upper contact is gradational, and was arbitrarily placed where micaceous brown sandstones and siltstones become the precominant lithology.

Petrology

Petrographic description: In thin-section, the limestones are primarily lithographic, with occasional beds composed almost entirely of fossiliferous material.

Thin-sections of sandstones show that angular grains of quartz and chert amount to 80 - 85 percent of the detrital constituents. The quartz grains are inclusion-filled, have secondary quartz overgrowths, and some sutured contacts (Figure 10). Feldspar grains and fragments of igneous and sedimentary rocks amount to about 12 percent of the detrital constituents. Porosity ranges from 10 to 15 percent, with most of the pore spaces filled with clay and limonite.

Diagenesis: The limestones are unaltered, and do not show any recognizable diagenetic effects. In the sandstones, evidence of compaction is seen in the sutured contacts between grains, and lithification appears to have been produced by the cementing of grains by secondary silica.

Paleontology

Introduction: The Belden formation at East Lake Creek contains an abundant, highly varied fauna, indicating a shallow, warm, normally saline, marine environment with calcareous mud bottoms. Well-preserved megafossils weather out of the shales. Ostracods and foraminifera were obtained from the shales by washing. The limestones are usually hard and dense, requiring sectioning for identification of contained faunas, but many fossils were collected from the weathered upper surfaces of the beds. Crushing of one limestone produced many complete specimens of the genus Millerella.

Figure 10: Photomicrograph of sandstone in the Belden formation (x89, crossed Nicols), showing angular grains of quartz with many inclusions and with quartz overgrowths. Note rock fragments and interstitial clay. Sample from bed #2, measured section C (for exact location, refer to measured section C, page 4).

The author collected many species which Ridlon (1954) had previously described from the thesis area, and which include:

Chonetes granulifer Owen
Marginifera muricatina Dunbar and Condra
Dictyoclostus inflatus var. coloradoensis (Girty)
Spirifer rockymontanus Marcou
Fenestrellina mimica (Ulrich) var. raymondi Elias
Rhombopora lepidodendroides Meek
Echinocrinus halliana (Geintz)
Amphissites rugosus Girty

Several species which have not been reported from the East Lake Creek area were collected by the author, and are described below.

Systematic Descriptions:

Phylum Protozoa

Class Sarcodina

Order Foraminifera

Family Textulariidae

Genus Climacammina Brady 1873

Climacammina cylindrica Cushman and Waters 1928

Plate I, Figure 1

Climacammina cylindrica Cushman and Waters, 1928, Jour. Paleont., vol. 2, p. 128, pl. 17, figs. 4, 9-13, pl. 20, figs. la-g.

Description: Test free, elongate, subcylindrical, periphery broadly rounded, about 2 to 3 times as long as wide, averaging 1.90mm. in length, and 0.71mm. in width. Early 12 to 15 chambers biserial, and one or two uniserial chambers in adult stage. Aperature single in early biserial stage, becoming irregular and multiple in uniserial stage.

C. cylindrica has been reported from the Graham formation of Texas, from the Lower Pennsylvanian Glen Eyrie formation of Colorado, and from the Belden formation of west central Colorado.

Occurrence: Bed 10, abundant.

Family Fusulinidae

Genus Millerella Thompson, 1942

Millerella marblensis Thompson

Plate I, Figures 3, 4, 6

Millerella marblensis Thompson, 1942, Am. Jour. Sci., vol. 240, pp. 405-407, pl. 1, figs. 3-14.

Description: Shell minute, discoidal, umbilicate in axial region; very short axis of coiling, rounded periphery, slightly convex to strongly convex lateral slopes. Average form ratios of third to fifth volution of 4 specimens 1:0.51, 1:0.41, and 1:0.32, respectively. Proloculus minute, outside diameter 23-30 microns, averaging 26 microns for 6 specimens. First volution evolute, next 2 or 3 volutions involute, fourth and fifth volutions evolute, with fifth volution extending over about one-third of preceding volution. Average heights of first to fifth volution of 6 specimens 18, 28, 37, 62, and 100 microns, respectively. Spirotheca thin, averaging about 13 microns. Tunnel angles about 16 degrees throughout shell. Chomata massive, extending nearly to polar regions. Measurements of thin-sections of M. marblensis given in Table 1. Diagram of measurements of specimens shown in Figure 11.

Remarks: Specimens from the East Lake Creek area are nearly identical with the type specimens described by Thompson (1942) from west Texas.

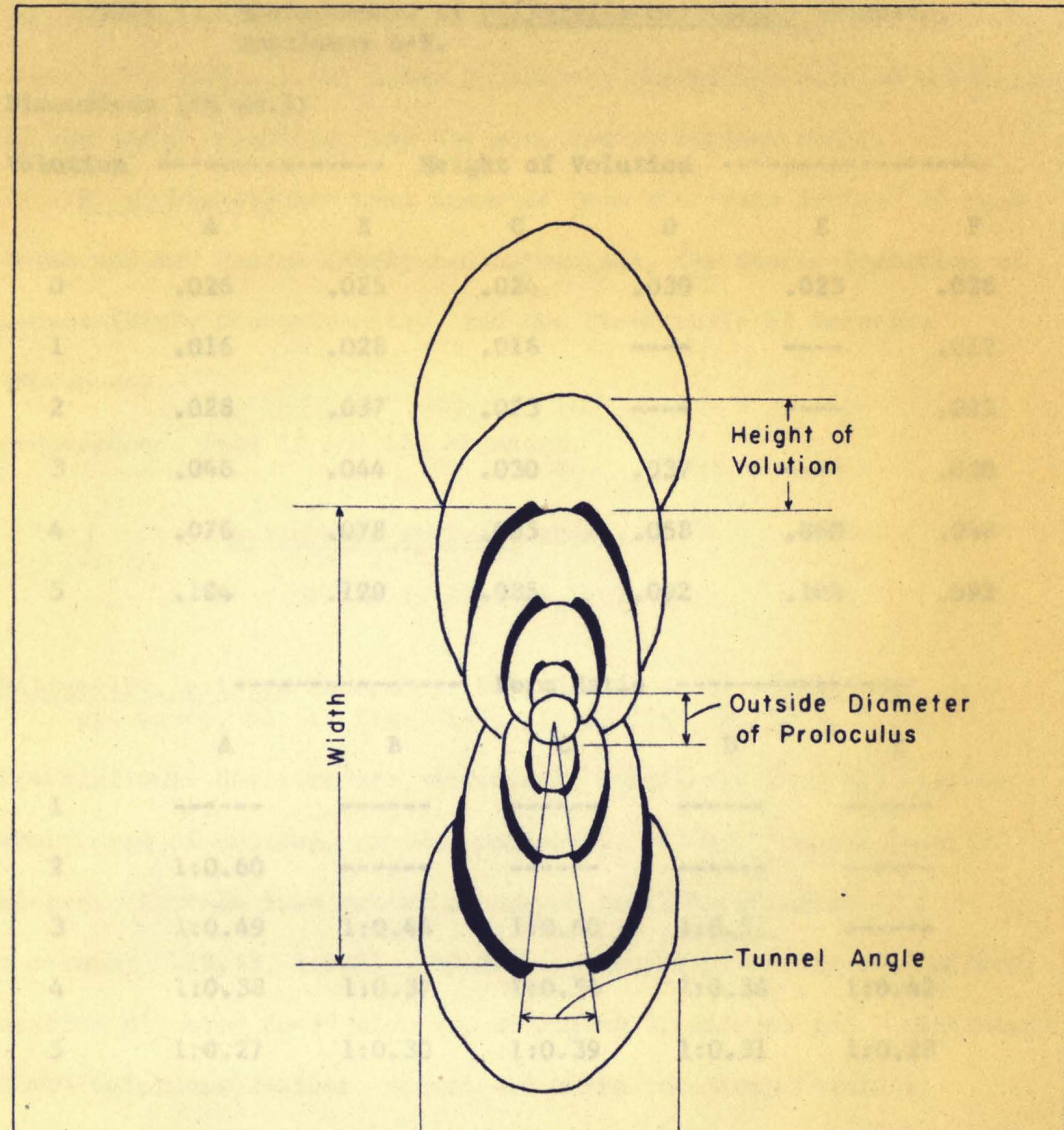


Figure 11: Diagram showing locations of measurements taken on specimens of Millerella Thompson.

Table 1: Measurements of Millerella marblensis Thompson, Specimens A-F.

Dimensions (in mm.):

Volution	Height of Volution					
	A	B	C	D	E	F
0	.026	.025	.024	.030	.023	.026
1	.016	.028	.016	----	----	.012
2	.028	.037	.023	----	----	.023
3	.046	.044	.030	.037	----	.030
4	.076	.078	.055	.058	.060	.048
5	.104	.120	.085	.092	.104	.092

	Form Ratio				
	A	B	C	D	E
1	------	------	------	------	------
2	1:0.60	------	------	------	------
3	1:0.49	1:0.44	1:0.60	1:0.51	------
4	1:0.38	1:0.37	1:0.54	1:0.36	1:0.42
5	1:0.27	1:0.30	1:0.39	1:0.31	1:0.28

	Thickness of Spirotheca			Septal Count	Tunnel Angle (degrees)		
	A	E	F	F	A	B	D
1	----	----	----	--	--	--	--
2	----	----	.010	11	--	--	--
3	.012	----	.012	13	--	17	--
4	.014	.014	.014	16	15	--	15
5	----	----	.014	20	--	--	--

The features which distinguish this species from M. inflecta are the lower form ratio of the outer volutions, the higher rate of expansion of the outer volutions, and the more highly evolute shell.

M. marblensis has been reported from the "Bend Series" of west Texas and New Mexico (Early Pennsylvanian), the Kearny formation of Kansas (Early Pennsylvanian), and the Bloyd shale of Arkansas (Morrowan).

Occurrence: Beds 12 and 13, abundant.

Millerella inflecta Thompson

Plate I, Figures 5, 7, 8

Millerella inflecta Thompson, 1945, Kansas Geol. Survey Bull. 60, pp. 44-46, pl. 1, figs. 1-7; pl. 5, figs. 2, 3.

Description: Shell minute, discoidal, umbilicate in axial region; short axis of coiling, rounded periphery, strongly convex lateral slopes. Average form ratios of second to fifth volution of 5 specimens, 1:0.52, 1:0.51, 1:0.37, respectively. Proloculus minute, outside diameter 28-39 microns, averaging 32 microns for 7 specimens. First volutions evolute, second and third volutions involute, fourth and fifth volutions somewhat evolute. Average heights of first to fifth volution of 7 specimens 17, 26, 38, 61, and 75 microns, respectively. Apirotheca thin, averaging about 10 microns. Tunnel angle about 16 degrees throughout shell. Chomata massive, extending to polar regions in early volutions. Measurements of thin-sections of M. inflecta given in Table 2.

Remarks: Specimens from the East Lake Creek area are similar to the type specimens described by Thompson (1945) from northwest Colorado,

Table 2: Measurements of Millerella inflecta Thompson, Specimens A-G.

Dimensions (in mm.):

Volution	A	B	C	D	E	F	G
	Height of Volution						
0	.036	.034	.029	.028	.030	.030	.039
1	.016	.014	.021	----	.023	.014	.016
2	.023	.021	.025	.037	.034	.023	.021
3	.035	.032	.037	.041	.047	.034	.037
4	.058	.055	.078	.060	.064	.051	.062
5	.081	.069	.074	.083	----	.064	.076

	Form Ratio				
	A	B	C	D	E
1	1:0.65	------	------	------	1:0.50
2	1:0.63	1:0.43	1:0.46	1:0.56	1:0.52
3	1:0.69	1:0.40	1:0.52	1:0.47	1:0.45
4	1:0.45	1:0.36	1:0.45	1:0.36	1:0.41
5	------	1:0.33	1:0.38	1:0.36	------

	Thickness of Spirotheca			Septal Count		Tunnel Angle (degrees)		
	B	C	F	F	G	B	C	D
1	----	.007	.007	8	10	--	--	--
2	.008	.009	.008	12	13	15	16	--
3	.009	.010	.013	15	15	18	16	17
4	.008	.010	----	20	17	18	17	19
5	----	----	----	--	20	--	--	--

except for a slightly lower form ratio of the fifth volution (1:0.49 to 1:0.37). A maximum of 5 volutions was seen in mature specimens, whereas Thompson reported specimens with 6 volutions.

M. inflecta has been reported from the Belden formation, northwestern Colorado and eastern Utah.

Occurrence: Beds 12 and 13, abundant.

Millerella sp. A Thompson

Plate I, Figure 2

Millerella sp. A Thompson, 1945, Kansas Geol. Survey Bull. 60, p. 48, pl. 1, figs. 12-14.

Description: Shell minute, discoidal, slightly umbilicate, with short axis of coiling, sharply angular periphery, straight lateral slopes. Average form ratios of second to fifth volution of 3 specimens 1:0.52, 1:0.56, 1:0.55, and 1:0.42, respectively. Proloculus minute, averaging 28 microns for 3 specimens. First volution evolute, outer volutions involute, except for fifth volution which is slightly evolute. Average heights of first to fifth volution of 3 specimens 15, 20, 31, 51, and 78, respectively. Spirotheca thin, averaging about 10 microns. Tunnel angle about 16 degrees throughout shell. Chomata massive, extending nearly to polar regions.

Remarks: Only 3 well-preserved specimens of this species were obtained, but the flat lateral slopes and sharply angular periphery are features that are identical with the type specimens described by Thompson (1945).

This species has been reported from the Belden formation, about 50 miles west of the thesis area.

Occurrence: Bed 13, rare.

Phylum Coelenterata

Class Anthozoa

Subclass Zoantharia

Order Rugosa

Family Lophophyllidiidae

Genus Lophophyllidium Grabau, 1928

Lophophyllidium beldenensis Ridlon

Plate II, Figures 1a,b, 3, 4

Lophophyllidium beldenensis Ridlon, 1954, Univ. Colorado, M. S. thesis, pp. 85-87, pl. 2, fig. 19-24; pl. 3, figs. 1-3b.

Description: Basal part of corallite conical, becoming conico-cylindrical; slightly curved. Theca thick with sharp septal grooves and broadly flattened ridges, broadly wrinkled. Transverse sections show 26 to 28 septa, cardinal septum short, counter septum connected to column to the mature stages.

Remarks: Specimens from East Lake Creek are identical with the type specimens described by Ridlon (1954).

L. beldenensis has been reported from the Belden formation, about 10 miles southwest of the thesis area.

Occurrence: Beds 5, 7, and 13, abundant.

Genus Stereostylus Jeffords, 1947

Stereostylus cf. S. mccoyensis Stevens

Plate II, Figures 2, 5, 6

Stereostylus cf. S. mccoyensis Stevens, 1958, Univ. Colorado, M. S. thesis, pp. 66-68, pl. 2, figs. 2a-c, 20-23.

Description: Corallite broadly conical, strongly curved near apex. Theca thick with fine septal grooves and broad interseptal ridges, broadly wrinkled. Transverse sections show 32-36 septa with the following arrangement: counter septum, 9 metasepta, alar septum, 6 metasepta, cardinal septum, 6 metasepta, alar septum, 9 metasepta. Cardinal septum very short, counter septum long. Height about 37mm., width about 20mm.

Remarks: The specimens collected in the thesis area are similar to the type specimens described by Stevens (1958), and the species are probably the same. The corallites are slightly larger, however, and there are usually two more septa at maturity.

S. mccoyensis has been reported from the Minturn formation (Desmoinesian), 25 miles northwest of the thesis area.

Occurrence: Beds 6 and 15, common.

Phylum Brachiopoda

Class Articulata

Order Spiriferida

Family Spiriferidae

Subfamily Spiriferinae

Genus Spirifer Sowerby, 1818

Spirifer opimus Hall

Plate II, Figures 8a,b

Spirifer opimus Hall, 1858, Geol. of Iowa, vol. 1, pt. 2, p. 711, pl. 28, figs. 1a-b.

Spirifer opimus, Dunbar and Condra, 1932, Nebr. Geol. Survey Bull. 5, 2nd ser., p. 320, pl. 41, figs. 10-11c.

Description: Shell rotund, the length slightly less than the width, and the hingeline equal to maximum width: length 19mm., width 25mm. Brachial valve convex with four or five plications on the fold. Pedicle valve convex with 3 or 4 plications on fold, with beak elevated and curved over hingeline.

S. opimus has been reported from Early and Middle Pennsylvanian formations of Colorado, Missouri, Kentucky, Oklahoma, and Wyoming.

Occurrence: Bed 5, rare.

Family Athyridae

Subfamily Athyrinae

Genus Composita Brown, 1849

Composita subtilita (Hall) 1852

Plate II, Figures 7a,b

Terebratula subtilita Hall, 1852, Stansbury's Expl. and Surv. Great Salt Lake, p. 409, pl. 4, figs. 1a-2c.

Composita subtilita Dunbar and Condra, 1932, Nebr. Geol. Surv. Bull., 5, 2nd ser., p. 363, pl. 43, figs. 7-13.

Description: Shell small, suboval in outline, greatest width 1/3 to 3/5 the distance from beak to anterior margin. Pedicle valve with broad, rounded sinus developed anteriorly, and with large, incurved beak. Brachial valve convexly curved at beak, and less convex anteriorly, with a low, broad fold developed anteriorly. Four specimens range from 15mm. to 17mm. long, 15mm. to 16mm. wide, and 11mm. to 13mm. thick.

Remarks: This species can be distinguished from other Composita species by its shape, more pronounced fold and sulcus, and by relative dimensions. The species is widespread in the United States and ranges throughout the Pennsylvanian and Permian.

Occurrence: Bed 13, abundant.

Phylum Thallophyta

Genus Stylophycus Johnson 1940

Stylophycus radiatus Johnson 1940

Plate II, Figure 9

Stylophycus radiatus Johnson, 1940, Geol. Soc. Am. Bull., vol. 51, p. 589, pl. 5, fig. 2.

Description: Colony roughly circular in outline, surface strongly arched. Basal part composed of concentric light and dark layers, about 25mm. to 30mm. to a centimeter. In upper part of colony, layers developed into finger-like projections 3mm. to 4mm. wide, and about 1 cm. high.

Remarks: Only one specimen was collected; it is similar to, but smaller than the form described by Thompson (1940). S. radiatus has been reported from the Belden formation, near Thomasville, Colorado.

Occurrence: Bed 6, rare.

Geologic Age

Previous reports on the age of the Belden formation are conflicting. Brill (1942), who described the type section 15 miles southeast of the thesis area, concluded that the age was probably Desmoinesian. Thompson (1945) identified several species of the genus Millerella and concluded that the Belden formation near Glenwood Springs (50 miles west of the thesis area) is Morrowan in age, and correlates with Morrowan rocks in west Texas, Kansas and Arkansas. A comprehensive faunal study was made by Ridlon (1954), who reported both Desmoinesian and Morrowan species occurring together.

Ridlon concluded that the age may vary in different areas, and stated that the

> Lack of typical, highly developed Desmoinesian fusulinids, as found in the McCoy formation about 30 miles to the north, indicates that Desmoinesian time either is not represented in Belden deposition, or is only partly represented.

Representatives of the primitive fusulinid genus Millerella, or more advanced forms, have not previously been reported in the Belden formation east of Glenwood Springs. The presence of abundant specimens of Millerella in a zone 100 feet thick just above the middle of the formation, and the absence of more advanced forms, strongly indicates that this part of the formation is correlative with the "zone of Millerella" as described by Thompson (1945). The fact that Atokan fusulinid faunas in Colorado, New Mexico, Texas, Kansas, and Arkansas contain more advanced forms along with the genus Millerella appears to restrict the lower 300 feet of the Belden in the thesis area to Morrowan age.

Measured Section of the Belden formation

Section C: (For exact location, refer to description on page 4.)

Pennsylvanian System

Minturn formation

Gradational contact

Belden formation	FEET
19. Shale, gray, silty; fissile.	5.0
18. Shale, gray to black, calcareous; fissile; interbedded with limestone, dark gray, aphanitic, silty; bedding 2" to 1'; weathers yellowish-brown.	35.0

Belden formation (Continued)	FEET
17. Shale, brownish-gray; slabby; interbedded with siltstone, yellowish-gray, micaceous; 1" beds.	4.0
16. Limestone, dark gray, aphanitic; massive-bedded; weathers olive gray; resistant.	5.0
15. Shale, gray, silty, micaceous; fissile; fossiliferous; with some 1" beds of limestone, dark gray, aphanitic.	28.0
<u>Stereostylus</u> cf. <u>S. mccoyensis</u> Stevens	
14. Limestone, dark gray to black, aphanitic; massive-bedded; weathers brown; resistant.	2.0
13. Shale, black, carbonaceous; fissile; fossiliferous; interbedded with limestone, dark gray to black, aphanitic; bedding 2" to 6"; fossiliferous.	28.0
<u>Composita subtilita</u> (Hall) <u>Lophophyllidium beldenensis</u> Ridlon <u>Millerella marblensis</u> Thompson <u>Millerella inflecta</u> Thompson <u>Millerella</u> sp. A Thompson	
12. Limestone, light gray, aphanitic; thin-bedded with shale partings; weathers brown; very fossiliferous.	3.0
<u>Millerella marblensis</u> Thompson <u>Millerella inflecta</u> Thompson <u>Millerella</u> sp.	
11. Shale, gray, silty, micaceous; fissile.	7.0
10. Limestone, gray, aphanitic; massive; weathers light gray; fossiliferous.	2.5
<u>Climacammina cylindrica</u> Cushman and Waters <u>Millerella</u> sp.	
9. Shale, gray to black, carbonaceous; fissile; interbedded with limestone, gray, aphanitic; 6" to 1' beds.	16.0
8. Limestone, gray, aphanitic; massive; weathers yellowish brown; resistant.	3.0
7. Siltstone, light gray, calcareous, micaceous; slabby; interbedded with shale, gray; fissile; fossiliferous.	32.0
<u>Spirifer opimus</u> Hall <u>Lophophyllidium beldenensis</u> Ridlon <u>Millerella</u> sp.	

Belden formation (Continued)	FEET
6. Limestone, dark gray, aphanitic; bedding 6" to 1', with shale partings; weathers yellowish-brown; resistant; fossiliferous. *Stylophycus radiatus* Johnson	5.0
5. Shale, black, carbonaceous; fissile; fossiliferous; interbedded with siltstone, light gray, calcareous; very thin-bedded. *Spirifer opimus* Hall *Lophophyllidium beldensis* Ridlon	20.0
4. Sandstone, yellowish gray, coarse-grained, conglomeratic; massive; weathers light brown; resistant.	8.0
3. Siltstone, gray, calcareous, micaceous; slabby.	3.5
2. Sandstone, gray, medium- to coarse-grained; conglomeratic; massive; weathers greenish-gray; resistant.	9.5
1. Shale, black, carbonaceous; fissile; mostly covered.	15.0 +
Thickness of the Belden formation	231.5 +

Base covered

Mississippian System

Leadville limestone

Minturn formation

Nomenclature

The Minturn formation was named and described by Tweto (1949) from prominent outcrops near Minturn, Colorado, about 10 miles east of East Lake Creek. The unit had previously been included with the Maroon formation which contained Pennsylvanian, Permian, and Triassic (?) sediments overlying the Belden formation. Tweto placed the upper limit of the Minturn about the top of the Jacque

Mountain limestone which is approximately 5,900 feet above the Belden formation.

In the thesis area, only the lower part of the formation is present. For convenience in describing, it has been divided into two zones: the lower gray zone, and the Eagle evaporite member. Gableman (1949) and Hubert (1954) have previously used these divisions in localities a few miles west of the thesis area.

Lower gray zone

Description

Lithology: The basal part of the Minturn formation consists of alternating beds of sandstone, siltstone, and shale, with the siltstones predominating.

The sandstones are composed of fine to coarse grains of quartz and feldspar. They are massive, cross-bedded, and are the most resistant beds of the lower zone. Weathered surfaces are light brown, while fresh surfaces are usually gray with occasional white or pink streaks.

The siltstones are dark gray or brown, highly micaceous, and very thin-bedded or platy.

Outcrops of shale are very rare, and are usually exposed as partings in or just below resistant sandstone outcrops. The shales are usually dark gray, micaceous, and fissile. Several shales in the lower part of the gray zone are calcareous, and grade vertically into very thin beds of muddy limestone.

Thickness: The lower gray zone could not be measured accurately in the thesis area, due to the large amount of cover and reverse faulting in the beds. However, the author measured approximately 1200 feet along the west boundary, and approximately 1000 feet along the crest of the divide east of East Lake Creek.

Contacts: The gradational nature of the lower contact has been discussed above. The upper contact is not exposed in the thesis area, but is probably gradational with the overlying gypsum. Significant interruptions in the deposition of the Minturn formation have not been reported in west central Colorado.

Age and Paleontology

Fossils were not collected from this zone in the thesis area. Due to its stratigraphic position below the Eagle evaporite member and above the Belden formation, it could be no older than Morrowan, and no younger than Desmoinesian. Tweto (1949) reported that the basal Minturn beds are probably Desmoinesian.

Eagle evaporite member

Introduction

Murray (1950) proposed the name "Eagle evaporite member" of the McCoy formation (Minturn formation of this report) for the evaporite deposits in the basin that existed in northwest Colorado during Pennsylvanian time. The thesis area is located at the east edge of this basin. The gypsum interfingers with and grades laterally into the sandstones of the Minturn formation a few miles east of the thesis area (Lovering and Tweto, 1949).

Description

Lithology: In the East Lake Creek area, the evaporites consist primarily of gray, massive beds of gypsum. The gypsum beds are distorted, and locally grade into "patches" of anhydrite. The attitude of the beds is difficult to determine, due to the contorted nature of the outcrops.

Thin zones of interbedded siltstone, dolomite, and shale are seen in the evaporites near the northern boundary of the thesis area. The siltstones are brown, dolomitic, micaceous, and thin-bedded; the dolomites are dark gray and occur as beds up to one foot thick, and the shales are black, carbonaceous, and occur as thin partings in the siltstone and dolomite.

Thickness: The author was unable to measure the thickness of the evaporites in the thesis area. However, the general areal extent and attitude of the zone indicates that the thickness is at least 800 feet. The maximum thickness reported for the member is 1100 feet, near Eagle, Colorado (Katich, 1958).

Age and Paleontology

Although fossils were not collected from the evaporite member, it correlates stratigraphically with the Desmoinesian Minturn a few miles to the east (Lovering and Tweto, 1944). Brill (1944) reported *Marginifera muricatina* of Desmoinesian age from carbonates interbedded with the evaporites at the northern border of the area.

STRUCTURAL GEOLOGY

Introduction

The sediments in the East Lake Creek area generally dip to the north, away from the extreme north end of the Sawatch Range. The major structural features are reverse faults and drag folds. Minor structures are undoubtedly present, but are obscured by the large amount of cover.

The faults and associated folds all appear to be the result of a local compressive force which acted in a northwest-southeast direction. Stark (1934) concluded that reverse faults in the Sawatch Range are the result of tangential compression during the Laramide orogeny. In the thesis area, however, it appears that the force could have been the result of local warping of the sediments during vertical uplift; this is evidenced by the fact that the faulting is more intense where the sediments have the greatest amount of dip.

Reverse Faults

The faults are expressed on the surface by drag in the upthrown sides, by fracturing in the adjacent beds, and commonly by a topographic depression. Gouge and breccia are not seen, due to the large amount of cover.

East Lake Creek Fault: A reverse fault is exposed about one mile south of Section 33, T. 5S., R. 82W. in East Lake Creek valley (Figure 12). It strikes N45E across the thesis area for about 6 miles, dipping to the northwest. Near East Lake Creek, the fault is in Precambrian rocks and dips 60° to 70°; to the northeast, it enters

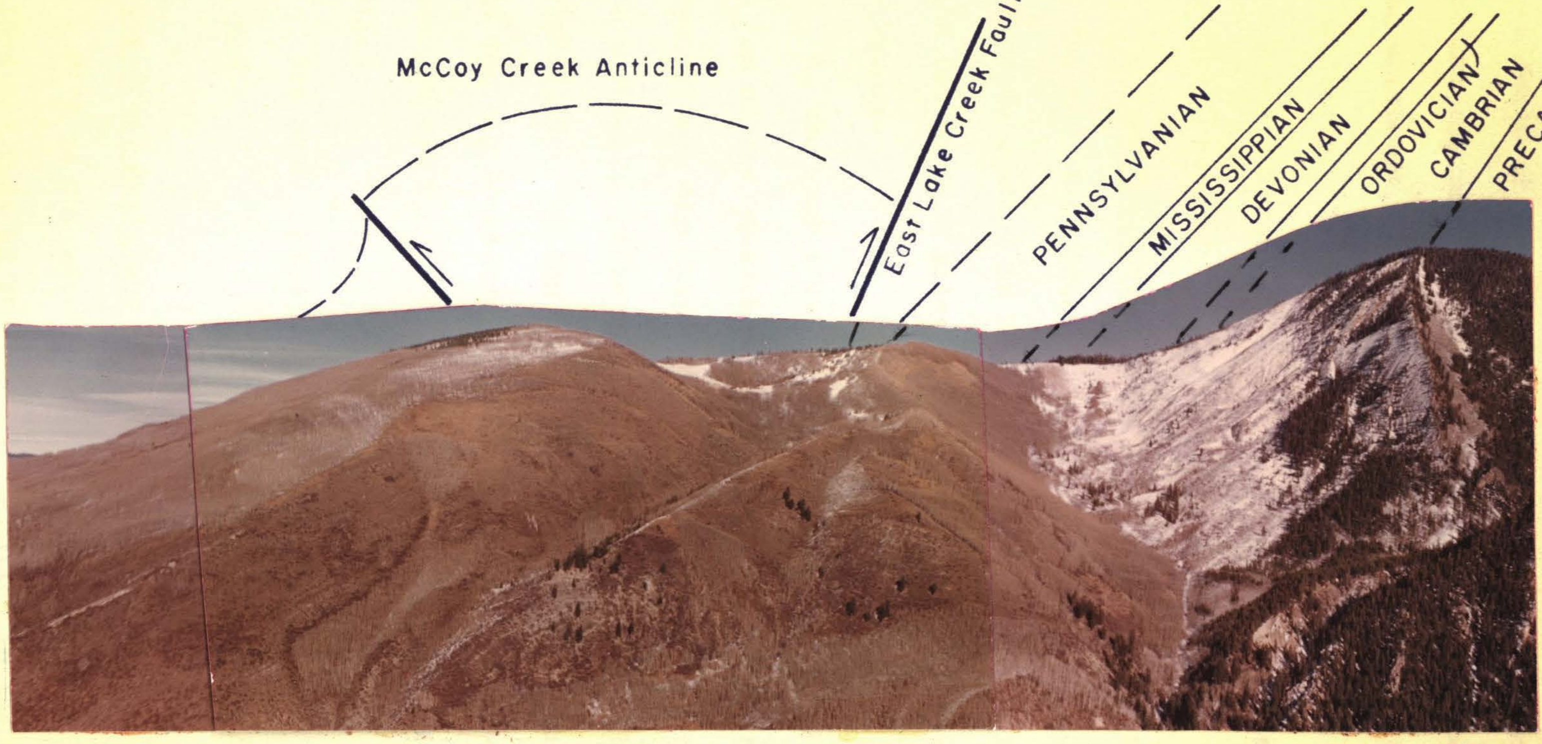


Figure 12: View of east side of East Lake Creek valley, looking northeast.

the sediments and the dip decreases to less than 30^o.

South of Section 33, Precambrian crystalline and Paleozoic sedimentary rocks have been thrust over the Sawatch quartzite from the northwest, offsetting the Sawatch at least 1,500 feet stratigraphically. To the northeast, the fault is in the basal part of the Minturn formation for several miles until it disappears in the overlying evaporites.

Beaver Creek Fault: A reverse fault with the same orientation as the East Lake Creek fault can be seen near the Precambrian-Paleozoic contact in Beaver Creek valley. It strikes approximately N45E for about 5 miles across the thesis area, and dips to the northwest.

On the west side of Beaver Creek valley, the fault is located on top of the Sawatch quartzite, and dips more than 60^o. Precambrian crystallines and Paleozoic sediments have been thrust upward from the northwest, offsetting the Sawatch at least 1,300 feet stratigraphically. To the northeast, it enters the Minturn formation, and the dip decreases to about 30^o. Drag in the upthrown side has reversed the dip of the sediments on the west wall of Stone Creek valley.

The fault could not be traced farther than Section 20, T. 5S., R. 81W.

McCoy Creek Anticline

Drag on the upthrown side of the East Lake Creek fault has folded the beds of the Minturn formation in the McCoy Creek area. A cross section of this structure is exposed on the east side of

East Lake Creek valley (Figure 12). The southeast limb strikes N40E, dips about 40° southeast, and is truncated by the East Lake Creek fault. The northwest limb strikes N50E, is nearly vertical, and is offset by a reverse fault which dips toward the axial plane.

The axis of the fold bears N45E and plunges to the northeast at an angle of $5-10^{\circ}$, disappearing in the gypsum beds northeast of Section 23, T. 5S., R. 82W.

EXPLANATION OF PLATE I

Figure		Page
	Climacammina cylindrica Cushman and Waters	42
1.	Transverse section parallel to plane of biserial arrangement, X55.	
	Millerella sp. A Thompson	48
2.	Axial section, X138.	
	Millerella marblensis Thompson	43
3-4.	Axial sections, X138.	
6.	Sagittal section, X138.	
	Millerella inflecta Thompson	46
5,8.	Axial sections, X138.	
7.	Sagittal section, X138.	

PLATE I

FORAMINIFERA

EXPLANATION OF PLATE II

Figure		Page
	Lophophyllidium beldenensis Ridlon	49
1a,b.	Transverse sections near midpoint and near base of calyx, X2.	
3.	Longitudinal sections showing column and tabulae, X2.	
4.	Typical corallite, X1.	
	Stereostylus cf. S. mccoyensis Stevens	50
2.	Transverse sections near base of calyx, oriented with cardinal septum at top, X2.	
6.	Transverse section near midpoint, oriented with cardinal septum at top, X2.	
5.	Corallite, X1.	
	Composita subtilita (Hall)	52
7a,b.	Brachial valve, lateral view, X1.	
	Spirifer opimus Hall	51
8a,b.	Brachial valve, lateral view, X1.	
	Stylophycus radiatus Johnson	53
9.	Polished and etched section of colony, X1.	

PLATE II

COELENTERATA, BRACHIOPODA, AND ALGAE

BIBLIOGRAPHY

BIBLIOGRAPHY

Bass, N. W. and Northrop, S. A., 1955, Lower Paleozoic rocks of the White River Uplift, Colorado: Guidebook to the Geology of Northwest Colorado, pp. 3-9.

Behre, C. H., Jr., 1932, The Weston Pass Mining District, Lake and Park Counties, Colorado: Colo. Sci. Soc. Proc., vol. 13, no. 3, pp. 53-75.

________, 1953, Geology and ore deposits of the west slope of the Mosquito Range: U. S. Geol. Survey Prof. Paper 235, 170 pages.

Brill, K. G., Jr., 1942, Late Paleozoic stratigraphy of the Gore area, Colorado: Am. Assoc. Petrol. Geol. Bull., vol. 26, pp. 1375-1397.

________, 1944, Late Paleozoic Stratigraphy, west-central and northwestern Colorado: Geol. Soc. Am. Bull., vol. 55, pp. 621-656.

________, 1952, Stratigraphy in the Permo-Pennsylvanian zeugogeosyncline of Colorado and northern New Mexico: Geol. Soc. Am. Bull., vol. 63, no. 8, pp. 809-880.

Cross, Whitman, 1894, Pikes Peak Folio: U. S. Geol. Survey Folio 7.

Eldridge, G. H., 1894, Anthracite-Crested Butte Folio: U. S. Geol. Survey Folio 9.

Ellis, C. H., 1958, Geology and Pennsylvanian Paleontology of Perry Park, Colorado: Univ. Colorado, M. S. Thesis.

Gableman, J. W., 1949, Geology and Ore Deposits of the Fulford Mining District, Eagle County, Colorado: Colorado Sch. Mines, D. Sc. Thesis.

Girty, G. H., 1903, The Carboniferous formations and fauna of Colorado: U. S. Geol. Survey Prof. Paper 16.

Hanshaw, B. B., 1958, Structural Geology of the West Side of the Gore Range, Eagle County, Colorado: Univ. Colorado, M. S. Thesis.

Hubert, J. F., 1954, Structure and Stratigraphy of an Area East of Brush Creek, Eagle County, Colorado: Univ. Colorado, M. S. Thesis.

Jeffords, R. M., 1947, Pennsylvanian lophophyllidid corals: Univ. of Kansas Paleo. Contr. 1, Coelenterata, Art. 1, pp. 1-84.

Johnson, J. H., 1934, Paleozoic formations of the Mosquito Range, Colorado: U. S. Geol. Survey Prof. Paper 185-B, pp. 1-27.

________, 1940, Lime-secreting algae and algal limestones from the Pennsylvanian of central Colorado: Geol. Soc. Am. Bull., vol. 51, no. 4, pp. 571-596.

________, 1944, Paleozoic stratigraphy of the Sawatch Range, Colorado: Geol. Soc. Am. Bull., vol. 55, no. 3, pp. 303-378.

________, 1945, A resume of Paleozoic stratigraphy of Colorado: Colo. Sch. Mines Quart., vol. 40, no. 3, 109 pages.

Katich, P. J., Jr., 1958, Stratigraphy of the Eagle Evaporites: Guidebook to the Geology of Northwest Colorado, pp. 106-110.

Kirk, Edwin, 1930, The Harding sandstone of Colorado: Am. Jour. Sci., 5th Ser., vol. 20, pp. 456-467.

________, 1931, The Devonian of Colorado: Am. Jour. Sci., 5th Ser., vol. 22, pp. 222-240.

Lovering, T. S. and Johnson, J. H., 1933, Meaning of unconformities in the stratigraphy of central Colorado: Am. Assoc. Petrol. Geol., vol. 17, no. 4, pp. 353-374.

Lovering, T. S. and Tweto, O. L., 1944, Preliminary report on geology and ore deposits of the Minturn quadrangle, Colorado: U. S. Geol. Survey Open File Report.

Murray, H. F., 1950, Stratigraphic Study of Pennsylvanian of McCoy Area, Colorado: Univ. Colorado, M. S. Thesis.

Ridlon, J. B., 1954, Stratigraphy and Paleontology of the Belden Formation in Part of West Central Colorado: Univ. Colorado, M. S. Thesis.

Scott, K. E., 1954, Fauna and Age of Leadville Limestone (Mississippian) in Part of West-Central Colorado: Univ. Colorado, M. S. Thesis.

Stark, J. T., 1934, Reverse faulting in the Sawatch Range: Geol. Soc. Am. Bull., vol. 45, pp. 1001-1016.

Stark, J. T. and Barnes, F. F., 1932, The structure of the Sawatch Range: Am. Jour. Sci., vol. 24, pp. 471-480.

________, 1935, Geology of the Sawatch Range, Colorado: Colo. Sci. Soc. Proc., vol. 13, no. 8, pp. 467-479.

Stevens, C. H., 1958, Stratigraphy and Paleontology of the McCoy, Colorado Area: Univ. Colorado, M. A. Thesis.

Sweet, W. C., 1954, Harding and Fremont formations, Colorado: Am. Assoc. Petrol. Geol. Bull., vol. 38, no. 2, pp. 284-305.

Thompson, M. L., 1942, New genera of Pennsylvanian fusulinids: Am. Jour. Sci., vol. 240, pp. 403-420.

________, 1944, Pennsylvanian Morrowan rocks and fusulinids of Kansas: Kansas Geol. Survey Bull. 52, pp. 409-431.

________, 1945, Pennsylvanian rocks and fusulinids of East Utah and Northwest Colorado correlated with Kansas section: Kansas Geol. Survey Bull. 60, pp. 17-84.

Tweto, O. L., 1949, Stratigraphy of the Pando Area, Eagle County, Colorado: Colo. Sci. Soc. Proc., vol. 15, no. 4, pp. 149-235.

Walcott, C. D., 1892, Preliminary notes on the discovery of a vertebrate fauna in Silurian (Ordovician) strata: Geol. Soc. Am. Bull., vol. 3, pp. 153-172.

Rockmont Clasp
10x13
ROCKMONT ENVELOPE CO.
DENVER

GEOLOGIC MAP AND CROSS SECTIONS

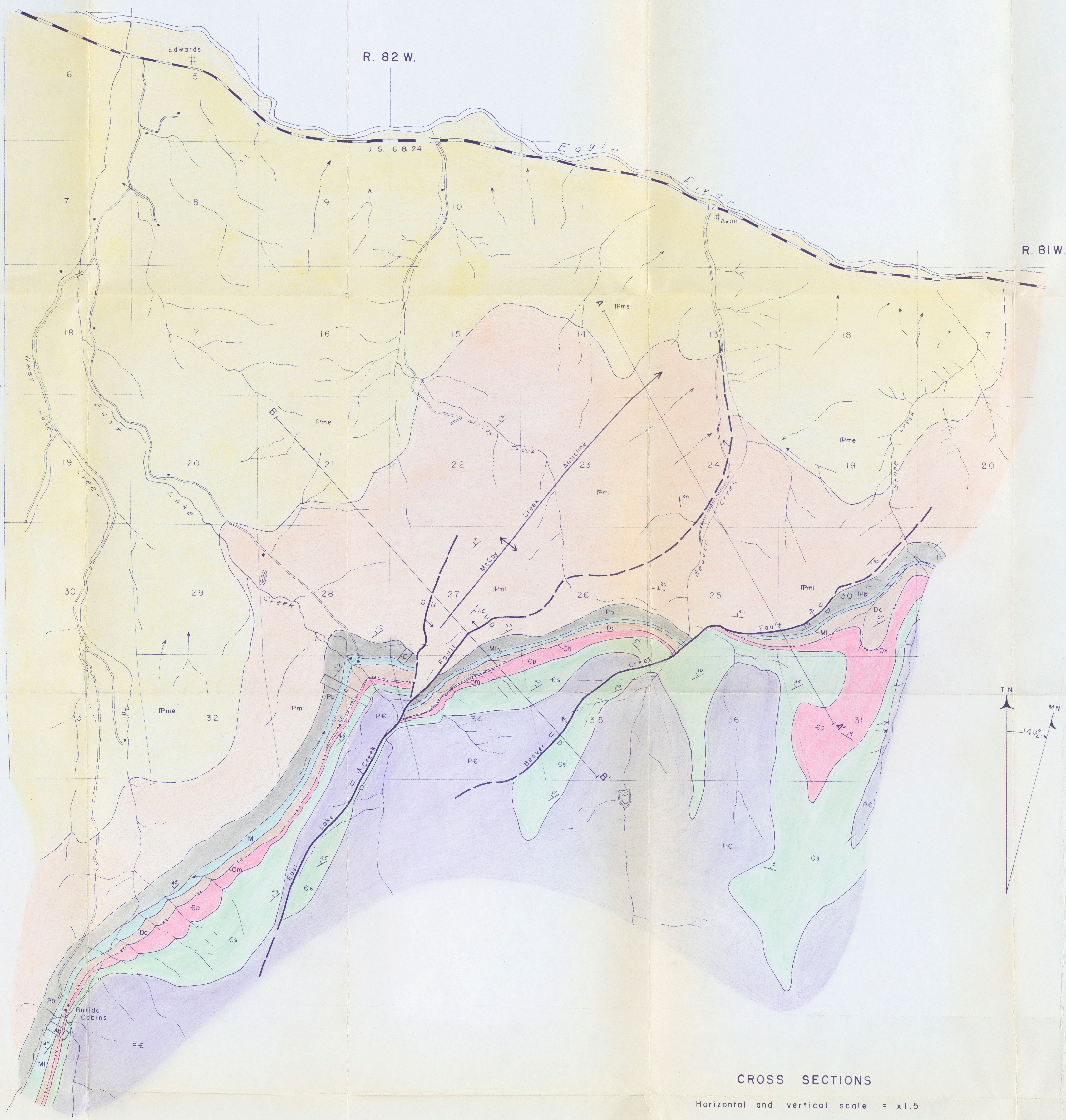
OF THE

EAST LAKE CREEK AREA

EAGLE COUNTY, COLORADO

JERRY H. CLARK

1960



SCALE

1 / 25,300

1/2 0 1

IN MILES

LEGEND

PENNSYLVANIAN

Minturn Formation

- ℙme — Eagle evaporite member
- ℙml — Lower gray zone
- ℙb — Belden formation

MISSISSIPPIAN

- Ml — Leadville limestone undivided

DEVONIAN

- Dc — Chaffee formation undivided

ORDOVICIAN

- Oh — Harding quartzite
- Om — Manitou dolomite

CAMBRIAN

- €p — Peerless formation
- €s — Sawatch quartzite

PRECAMBRIAN

- P€ — Crystalline rocks undivided

- Contact (dashed where inferred)
- Strike and dip of beds
- Fault - showing direction of dip and relative movement (dashed where inferred)
- Anticlinal axis showing direction of plunge
- Location of measured section
- Location of cross section
- Permanent stream
- Intermittent stream
- Highway
- Improved road
- Jeep trail
- Buildings

CROSS SECTIONS

Horizontal and vertical scale = x1.5