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PALEOZOIC FORMATIONS OF THE MOSQUITO RANGE, COLORADO

BY

J. HARLAN JOHNSON

Shorter contributions to general geology, 1934–35

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PALEOZOIC FORMATIONS OF THE MOSQUITO RANGE, COLORADO

By J. HARLAN JOHNSON

ABSTRACT

The Mosquito Range is a narrow, nearly straight ridge about 80 miles long in central Colorado, separating South Park from the Arkansas River Valley. The higher peaks reach altitudes of over 14,000 feet, and very little of the region descends below 9,000 feet.

The rocks of the region range in age from pre-Cambrian to Recent but consist mainly of pre-Cambrian granite and metamorphic rocks, and Paleozoic sediments: All are cut by Tertiary intrusive rocks.

The Paleozoic sediments include deposits from every period except the Silurian. The Cambrian sediments form the Sawatch quartzite. The Ordovician includes three formations—the Manitou (†White limestone[1] of old reports), Harding, and Fremont. The Manitou consists of dolomite beds that are more or less siliceous. It is widespread and may be very thick. The Harding consists of sandstone, sandy shale, and shaly limestone, generally gray, green, or brown. The formation has not been found along the range north of Weston Pass. The Fremont formation consists of a gray fossiliferous dolomite. It is found only at the south end of the range. Pronounced unconformities occur at the top of the Manitou and at the top of the Fremont. A minor one occurs between the Harding and the Fremont.

The Devonian sediments are widespread throughout the region. They consist of the Chaffee formation, which includes the Parting quartzite member below and the Dyer dolomite member above. The Dyer represents the lower portion of the Blue limestone of Emmons. The Leadville limestone, of Mississippian age, unconformably overlies the Chaffee formation. It represents the upper portion of the Blue limestone of Emmons. Another unconformity separates the Leadville from the Pennsylvanian sediments above. The Pennsylvanian deposits grade upward into those of the Permian. Immediately over the Leadville limestone comes the Weber (?) formation. The lower portion of this formation consists mainly of black shale and sandy shale with some interbedded sandstone and grit. Higher in the section grit predominates, with some interbedded limestone, shale, and sandy shale. These beds grade upward into a series of red beds with interbedded limestone known as the Maroon formation.

At the present time no definite boundary can be drawn between the Pennsylvanian and Permian of this region. It cannot be done on the basis of lithology, for neither mineralogic composition nor grain size will serve, nor will color, for good red beds occur within definitely known Pennsylvanian. The lower beds carry abundant fossils, but fossils become progressively scarcer at higher stratigraphic levels. Evidence at hand suggests that the Permian-Pennsylvanian boundary is about 2,000 feet above the base of the Pennsylvanian.

The lithology of the Pennsylvanian sediments is discussed in detail in this paper. Grit and coarse clastic sediments form over 60 percent of the deposits. They are composed almost entirely of material eroded from the pre-Cambrian rocks.

The fossils collected from the Pennsylvanian include 92 species of invertebrates, of which 26 are new, and about 20 land plants, several of which are also new. The fossils show that the lower and middle parts of the Weber (?) formation are equivalent in age to the middle and part of the upper Pottsville of the East. The paper includes detailed sections of the Pennsylvanian sediments measured.

INTRODUCTION

From the time of the publication of the Leadville monograph [2] by the United States Geological Survey, in 1886, the general geology and stratigraphy of the Mosquito Range around the Leadville and Alma districts have been known. In the recent resurvey of the area, however, it has been found necessary to undertake much more detailed studies of most of the formations. In particular, the sediments of Pennsylvanian age and the overlying red beds have received considerable attention and thought. This study was necessary to determine the amount of displacement along some of the notable faults and the depth to older strata that had contained valuable ore deposits in the larger mining districts. In some places the outcrops appear to have been improperly correlated in the older reports. These were given additional study, and considerable revision of stratigraphic sections has been necessary.

The material on which the present report is based was collected in part by the geologists engaged in the large-scale mapping of the Alma and Leadville districts for the United States Geological Survey in cooperation with the Colorado State Geological Survey Board and the Colorado Metal Mining Fund during the seasons of 1928–31, and by Edwin Kirk, of the United States Geological Survey, who collaborated with these geologists during 1929. Special field work connecting these observations was conducted by the writer during the field seasons of 1930 and 1931. The work consisted of measuring detailed sections, tracing beds from one section to another, and searching for fossils. The field work was followed by laboratory study of the rock specimens and fossils collected, leading to the recognition of several new species.

Relatively little detailed work had been done along the Mosquito Range except in the immediate vicinity of Leadville and Alma. The area was studied in

[1] A dagger (†) preceding a geologic name indicates that the name has been abandoned or rejected for use in classification in publications of the U.S. Geological Survey. Quotation marks, which were formerly used to indicate abandoned or rejected names, are now used only in the ordinary sense.

[2] Emmons, S. F., Geology and mining industry of Leadville, Colo.: U.S.Geol. Survey Mon. 12, 1886.

reconnaissance by the old Hayden Survey,[3] and the south end of it was touched by the Wheeler Survey.[4]

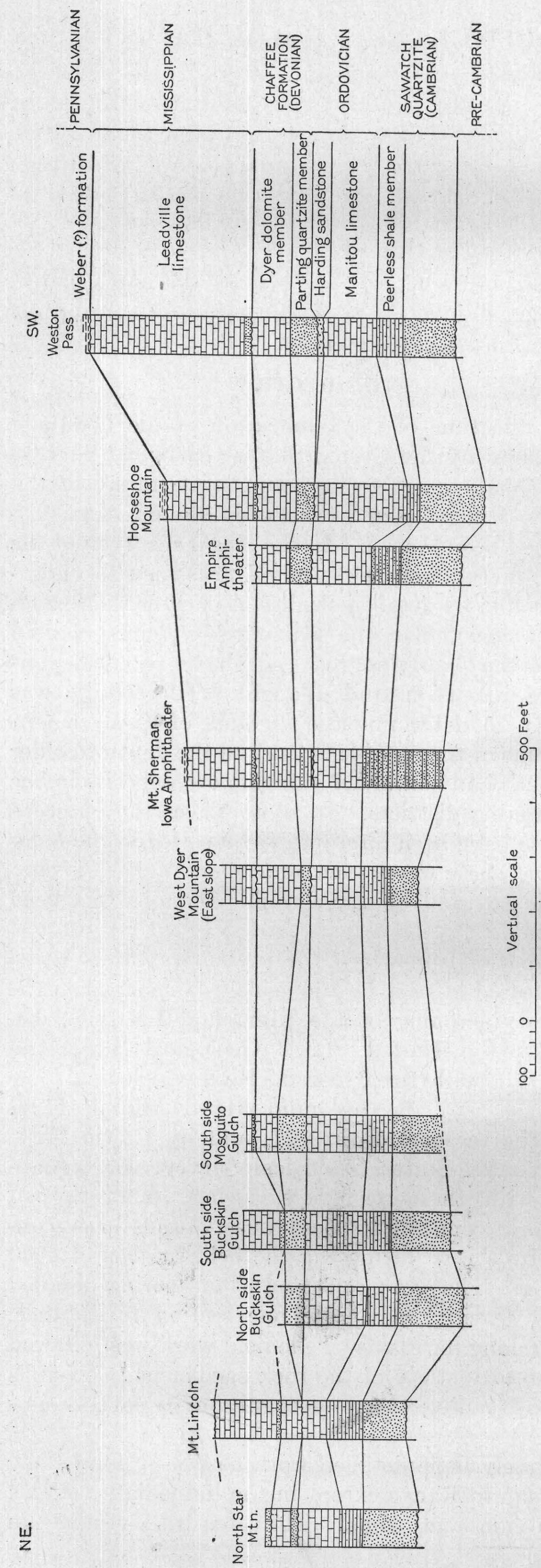


FIGURE 2.—Relations and changes in thickness of the pre-Pennsylvanian Paleozoic formations of the Mosquito Range, Colo.

Emmons,[5] in the Leadville monograph, gives a good general picture for the entire range, but his statements become more and more vague and inaccurate as the distance from Leadville increases. Irving and Loughlin,[6] in their revision of the Leadville monograph, add much information about the ore deposits but contribute little to our knowledge of the general stratigraphy of the region. The discrepancies and uncertainties in stratigraphy that confronted these authors, however, had considerable to do with initiating the critical review of the stratigraphy in the field during the last few years.

The purpose of this paper is to record the new information on stratigraphy obtained by the cooperative work together with a summary of the older material so as to present a statement of our present knowledge. The portions dealing with the pre-Pennsylvanian formations are relatively brief, whereas the discussions of the Pennsylvanian and Permian are more detailed, because they were the main subject of study.

The writer gratefully acknowledges the information supplied and the many courtesies extended to him by members of the United States Geological Survey and by other geologists. Q. D. Singewald and C. H. Behre aided greatly in the work around Alma and Leadville. T. S. Lovering aided in the area around Breckenridge. B. S. Butler and G. F. Loughlin contributed from their general knowledge of conditions in central Colorado and by many kind suggestions and encouragements throughout the period in which the work was being done. David White and G. H. Girty have given much help in connection with the study of fossils and their interpretations. Edwin Kirk supplied much of the material incorporated in the discussion of the Devonian and Ordovician deposits. C. E. Resser, of the United States National Museum, studied the Cambrian fossils and suggested their correlation. Valuable suggestions were obtained from H. A. Stewart, of the Texas Production Co.; R. Clare Coffin, of the Midwest Refining Co.; and the late H. J. Packard, of the Continental Oil Co.

Many of the photographs used as illustrations of outcrops and field views were taken by Robert E. Landon, who assisted Singewald in 1930, and photographs of specimens were taken by W. O. Hazard, of the United States Geological Survey.

LOCATION AND TOPOGRAPHY

The Mosquito Range is a narrow, nearly straight ridge about 80 miles long, trending a little west of north and extending from 38°20′ to 39°30′ north latitude and from about 105°50′ to 106°8′ west longitude. Topographically the range has a narrow crest that has been deeply incised by the action of alpine glaciers,

[3] Peale, A. C., U.S.Geol. and Geog. Survey Terr. Seventh Ann. Rept., for 1873, pp. 193–273, 1874. Endlich, F. M., idem, pp. 275–361. Peale, A. C., idem for 1874, pp. 73–180, 1875. Endlich, F. M., idem, pp. 181–240.

[4] Stevenson, J. J., U.S.Geol. and Geog. Surveys W. 100th Mer. Rept., vol. 3, pp. 303–501, 1875.

[5] Emmons, S. F., op. cit., pp. 45–88.

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

and as a result the crest in many places is surprisingly narrow, with large steep-sided cirques forming the heads of most of the gulches that cut into it. The range is bounded on the west by the valley of the Arkansas River, on the south by Trout Creek, a large tributary of the Arkansas, and on the east by South Park. Northward it passes into the Gore Range. The approximate northern boundary is generally taken to be the valley of Tenmile Creek. The highest peaks of the range attain altitudes of more than 14,000 feet, and very little of the region descends below 9,000 feet.

Most of the field work for the present report was carried on above timber line, where the intense glacial erosion has provided many splendid exposures of the formations. The geology along the lower slopes is greatly obscured by moraines and fluvioglacial deposits.

The area studied includes the Leadville and Alma mining districts and lies close to the Kokomo, Breckenridge, and Red Cliff districts.

GEOLOGY

GENERAL FEATURES

The rocks of the region range in age from pre-Cambrian to Recent but consist mainly of pre-Cambrian granite, Paleozoic sediments, and Tertiary dikes, sills, and stocklike masses. The subjoined table will give a general idea of the character of the formations.

The Buffalo Peaks form a picturesque and conspicuous pair of prominences south of Weston Pass. They represent a center of Tertiary extrusive activity which is noteworthy in the geology of South Park but not in that of the Mosquito Range.

STRUCTURE

Structurally the region consists of several asymmetric folds that have been cut by large reverse faults. In general, the regional dip is toward the east, though locally there are sharp and steep reversals, which usually indicate the proximity of important faults. These folds and faults were formed after the intrusion of most of the porphyry sills but before the intrusion of the larger Tertiary stocks and batholithic masses of monzonitic rock. Still later there was normal block faulting.

The structure is most complex at the north end of the range, in the Leadville-Alma region. According to Emmons[7] it becomes simpler to the south. The individual folds gradually merge or die out until south of the Buffalo Peaks the main range appears to consist of only one fold somewhat faulted.

STRATIGRAPHY

FORMATIONS PRESENT

The Paleozoic rocks of the Mosquito Range include deposits from every period except the Silurian. There are, however, several unconformities within the section, some of which represent long intervals of time for which deposits are lacking.

The table below shows the formations present and gives a summary of their characteristics; the two tables following it give the thickness of the pre-Pennsylvanian formations obtained in a number of measured sections. Figure 2 shows graphically the relations and changes in thickness of the pre-Pennsylvanian formations.

[7] Emmons, S. F., Introductory geological sketch of Buffalo Peaks, Mosquito Range, Colo.: U.S. Geol. Survey Bull. 1, p. 12, 1883.

General stratigraphic column of the Mosquito Range, Colo.

Age	Formation	Thickness (feet)	Lithologic character
Pleistocene.			Gravel and silt.
	—Unconformity—		
Tertiary.			Silt and volcanic rocks. Some extrusive rocks in southern part of area. Sills are common, especially at north end, and generally occur at certain stratigraphic horizons, especially at or near base of Weber (?) formation.
	—Unconformity—		
Permian and Pennsylvanian (?).	Maroon formation.	2,000±	Red sandstone and sandy shale, commonly micaceous and arkosic. A few lenticular beds of limestone and gypsum in lower portion.
Pennsylvanian.	Weber (?) formation.	1,100±	Sandstone and grit with some interbedded limestone. Material very arkosic and micaceous. Color in lower part light to dark gray. Grades upward into red beds.
		550+	Gray sandstone and grit, with interbedded limestone and shale. Becomes more and more arkosic and micaceous toward top. The beds tend to be lenticular and nonpersistent.
		50–300+	Black carbonaceous shale, commonly very sandy. Locally a thin basal sandstone or conglomerate.
	—Unconformity—		

General stratigraphic column of the Mosquito Range, Colo.—Continued

Age	Formation		Thickness (feet)	Lithologic character
Mississippian.	Leadville limestone.		50–300	Dolomite, blue to lead-gray, some beds almost black. Beds massive to thin. Contain shale in places or even sandy streaks. Chert nodules and streaks are locally abundant. Sandstone at base, a few inches to 12 feet thick, accompanied by dolomitic breccia. Is upper part of †Blue limestone of early reports.
	—Unconformity—			
Upper Devonian.	Chaffee formation.	Dyer dolomite member.	75	Gray dolomitic limestone, mainly dark gray but locally becoming lighter at the base. Tends to weather brown or tan. Locally contains sandy and shaly layers, especially toward the base. Is lower part of †Blue limestone of early reports.
		Parting quartzite member.	0–70	White or nearly white sandstone and sandy shale. Largely quartzitic in the Leadville region. Some layers of poorly rounded pebbles. Weathers pink to red-brown. Locally contains red and green shale and calcareous shale, especially at the base.
	—Unconformity—			
Upper Ordovician.	Fremont limestone.		0–75	Massive white to dark-gray dolomitic limestone.
Middle Ordovician.	Harding sandstone.		0–50	Chiefly sandstone and quartzite, with some calcareous shale and impure limestone, gray, green, and reddish brown.
Lower Ordovician.	Manitou limestone.		18–250	Thin-bedded light gray dolomitic limestone, very siliceous in places. Contains interbedded shale. The †White limestone of Leadville district.
Upper Cambrian.	Sawatch quartzite.	Peerless shale member.	40–60	Shale, thin limestone, and shaly limestone, some sandstone. Includes "transition beds." In places some of the lower †White limestone of old reports has not been separated.
			0–190	Thin to massively bedded quartzite, gray to white. Locally a basal conglomerate.
	—Unconformity—			
Pre-Cambrian.				Gneiss, schist, and granite. All cut by pegmatite and aplite dikes.

Thicknesses of pre-Pennsylvanian sediments (feet)

Alma district [a]

			Hock-Hocking mine	South side of Mosquito Gulch	Mascotte tunnel	Mascotte-Orphan Boy (composite)	South side of Buckskin Gulch (composite)	North side of Buckskin Gulch	Cliffs south of Red Amphitheater	Platte Gulch	North Star Mountain	Mount Lincoln
Leadville limestone.	†Blue limestone.	Limestone	135	----	----	----	85+					120±
		Quartzite zone	2±	5	---- 135	----	8 max.	5 max.			50±	
Chaffee formation.	Dyer dolomite member.		65	40								40±
	Parting quartzite member.		38	55	15		45	35	30	10	10	Absent
Manitou limestone († White limestone).		Upper limestone zone.	140				55±	115±		80		Absent
		Shale zone.	50	110(?)	180		24	15	110±	14	85	16
		Lower limestone zone.					20	20		15±		28

[a] Singewald, Q. D., and Butler, B. S., Preliminary geologic map of the Alma mining district, Colorado: Colorado Sci. Soc. Proc.; vol. 12, pp. 295–308, 1930; Preliminary report on the geology of Mount Lincoln and Russia mine, Park County, Colo.: Idem, pp. 389–406, 1931.

Thicknesses of pre-Pennsylvanian sediments (feet)—Continued

				Hock-Hocking mine	South side of Mosquito Gulch	Mascotte tunnel	Mascotte-Orphan Boy (composite)	South side of Buckskin Gulch (composite)	North side of Buckskin Gulch	Cliffs south of Red Amphitheater	Platte Gulch	North Star Mountain	Mount Lincoln
Sawatch quartzite.	Peerless shale member.	Limestone shale ("transition shale").	Shaly zone.	50	26	65		27	30±	30±	32±	35±	25
			Limy zone.		20			23					20
			Purple quartzite zone.		3			10	2		13	11	7
			Upper quartzite zone.		10			6	13		8	10	10
			Thin-bedded limy zone.		12		130±	12	13	90±	10	11	9
			Lower quartzite zone (including basal conglomerate).					90	92		40±	76	80±

West side of Mosquito Range [b]

		Mount Zion (composite)	West Dyer Mountain	Sherman Mountain	Head of Empire Amphitheater	West slope of Horseshoe Mountain	Weston Pass
Weber (?) formation.			Eroded.				(?)
Leadville limestone.		145. 5	60	126. 5	Top not exposed.	Top not exposed.	300
Chaffee formation	Dyer dolomite member.	95. 5	78	87. 5	76	75	70
	Parting quartzite member.	33. 5	21. 0	19	38	60	62
Manitou limestone (†White limestone).		115. 5	93	94	110	150	100
Sawatch quartzite	Peerless shale member ("transition shale").	44	49	45	55	60	50
		125. 5	63	106. 5	112	120	100
Pre-Cambrian.							

[b] Supplied by C. H. Behre.

CAMBRIAN SYSTEM

SAWATCH QUARTZITE

Subdivisions.—The Sawatch quartzite as identified in this region contains at the top about 50 feet of shale and calcareous deposits which in previous reports have been called "transition shales" and "red cast beds" but which are here designated "Peerless shale member of Sawatch quartzite." It is not known whether the Peerless member can be discriminated over wide areas or whether it is in some areas replaced by quartzite. According to Resser,[8] the few fossils that have been found in the quartzites suggest a fauna distinctly different from those found in the shales. Behre[9] suggested the use of the term "Peerless member" for the argillaceous and calcareous upper portion of the Sawatch. He subdivides the Cambrian sediments of the Leadville district thus:

Sawatch quartzite:
- Peerless shale member ("transition shale" of older reports): Alternating calcareous and shaly layers, thin-bedded. Near top "red cast beds" are numerous. (See pl. 44, *A*.)
- White, fairly pure, well-cemented quartzite, with a dark bed at the top. Base conglomeratic. Some beds near top shaly.

Singewald has subdivided the Sawatch in the Alma district as follows:

Limestone-shale member ("transition shale"):
- Upper shaly zone.
- Limy zone.

[8] Resser, C. E., personal communication, February 1931.

[9] Behre, C. H., Jr., The Weston Pass mining district, Lake and Park Counties, Colo.: Colorado Sci. Soc. Proc., vol. 13, p. 58, 1932.

Purple quartzite zone.
Upper quartzite zone.
Thin-bedded limy zone.
Lower quartzite zone (including basal conglomerate).

General features.—The Sawatch quartzite (†Lower quartzite of Emmons) lies directly upon the eroded surface of the pre-Cambrian rocks. The contact with the underlying rocks is a remarkably smooth surface and is well described by Irving and Loughlin.[10] Generally the formation consists of hard, massively bedded grayish-white quartzite. (See pl. 1, *A*, *B*.) Locally there are thin basal conglomerate beds composed of well-rounded and polished grains of bluish-gray quartz, commonly about the size of a pea, well cemented by a siliceous cement.

The Sawatch quartzite is a cliff maker and is readily recognized along the canyon and cirque walls.

Thickness.—The quartzite differs considerably in thickness in different localities. Near Trout Creek it is absent or very thin. At Weston Pass about 60 feet of it appears to be present, and in the Leadville and Alma districts a maximum of 120 to 130 feet is attained.

Age.—Only a very few fossils have been collected from the formation—none during recent years. Emmons [11] reported a few from Monte Cristo Gulch, north of Hoosier Pass. Their exact stratigraphic position could not be determined, but he believed it to be near the base of the transition shales. Such meager information as has been obtained on adjoining areas points to an Upper Cambrian age, probably middle Upper Cambrian, and the formation has for many years been classified as Upper Cambrian.

Peerless shale member.—Behre [12] introduced the name "Peerless shale member", taking the Peerless mine on Sheridan Mountain, about 7 miles southeast of Leadville, as the type locality. The beds consist of thin-bedded shale, calcareous shale, and calcareous sandstone. The contact with the underlying quartzite is sharply defined in some places and gradational in others. In general it seems to be marked by the top of a black or dark-brown quartzitic layer. The contact with the overlying Manitou limestone is not well defined, as there is a gradual transition upward into the limestone series. The so-called "red cast beds" are usually considered to constitute the top of the Peerless member. These consist of a sandy limestone, nearly white where fresh, which contains numerous flat pebbles of dark red, suggesting cast of fossils on a broken or weathered surface. They are present in most of the Leadville and Alma districts but are absent at a few localities.

The colors of the Peerless sediments show considerable variety. The lower beds are usually gray or greenish gray. The upper layers may be gray, buff, brown, or even brick-red, the reddish shades being most conspicuous. All the measured sections of the Peerless member used in this report were obtained in the Leadville and Alma districts. They show thicknesses ranging from 23 to 60 feet. The beds thin to the east and south of those districts, and thicken to the west and northwest.

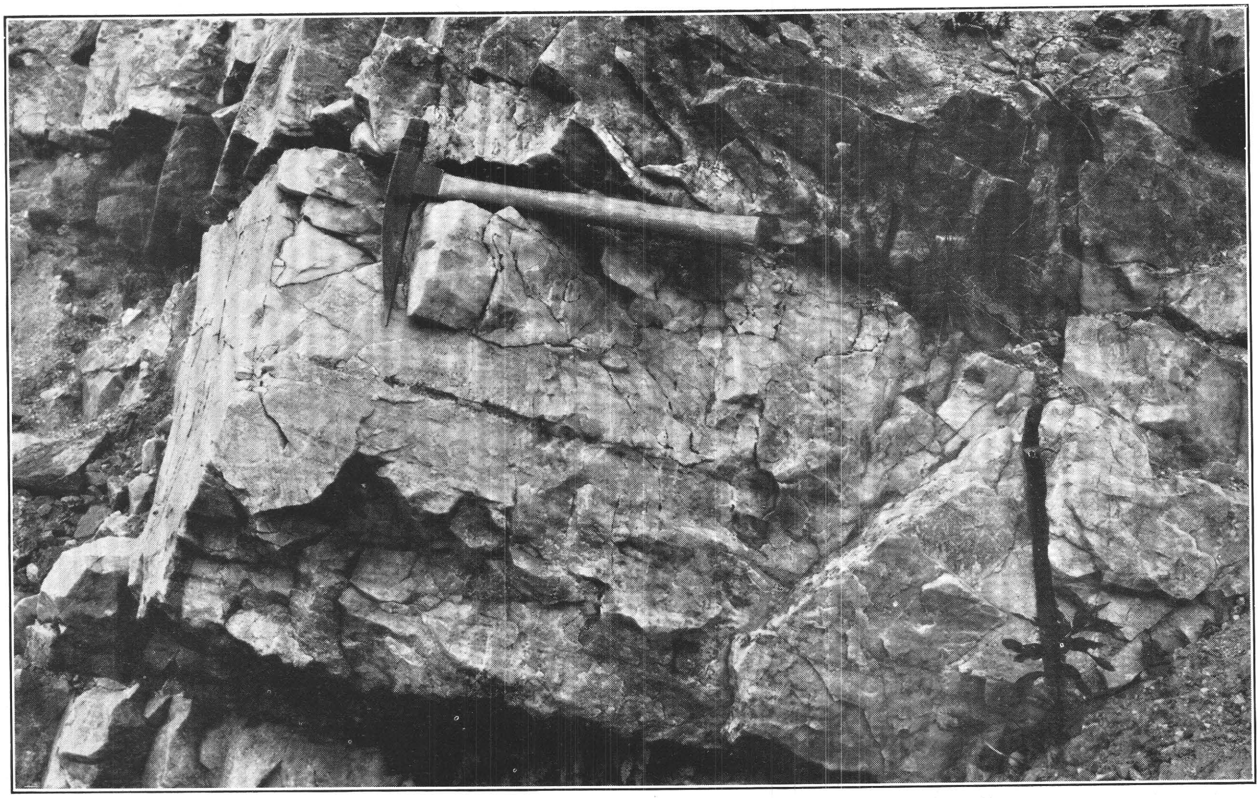
A moderate number of fossils have been collected from some of the upper layers of the Peerless member. Butler and Singewald collected from several localities in the Gilman and Alma districts, and the present writer from others. Practically all the collections represent the same stratigraphic horizon. C. E. Resser examined the fossils and reported that, with a few exceptions, they are undescribed species of trilobites and brachiopods. The trilobites belong to the genera *Tellerina*, *Saukia*, and *Briscoia* of the family Dikellocephalidae, and the brachiopods are of the *Lingulella* or *Westonia* type. *Billingsella coloradoensis* was obtained from the lower shales near Leadville. The age indicated is middle to late Upper Cambrian.

Detailed sections.—Detailed sections of the Sawatch formation, measured by C. H. Behre, Jr., are given below.

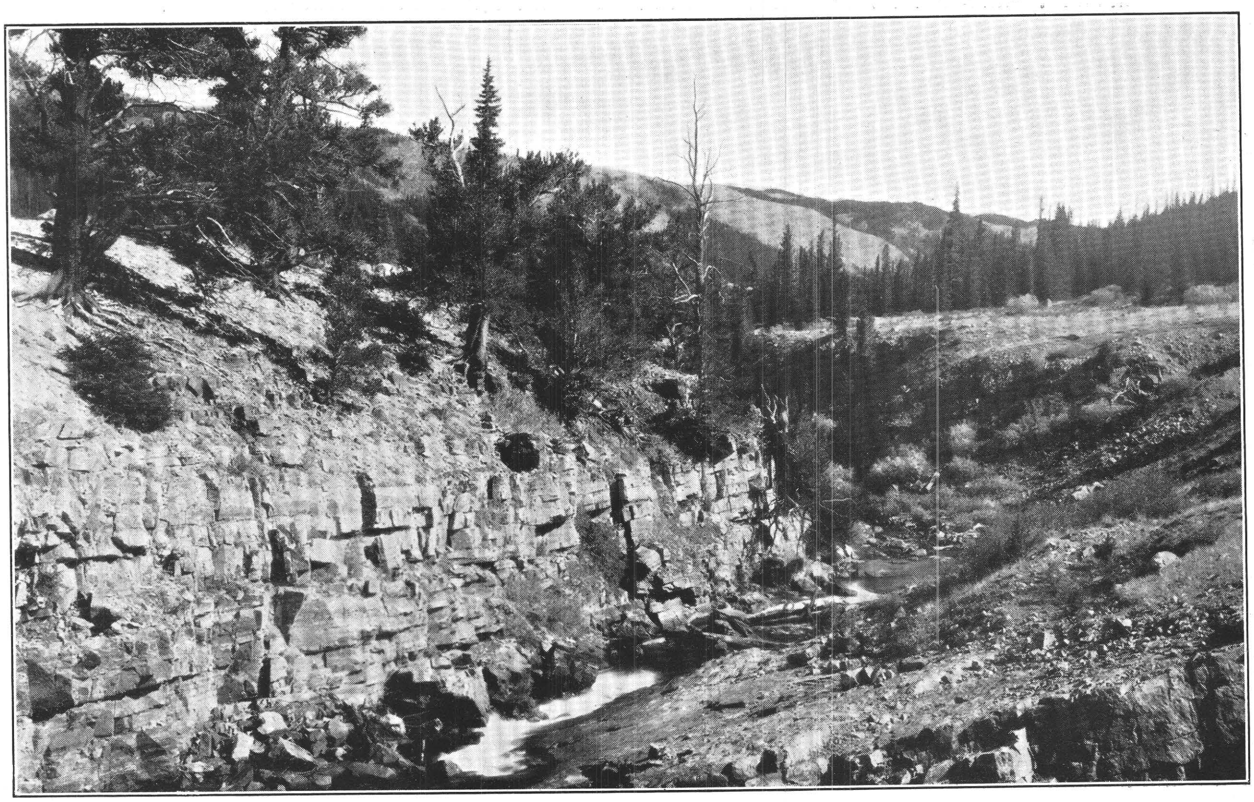
Section of Sawatch quartzite on Sherman Mountain, Iowa Amphitheater, near Leadville, Colo.

	Feet
Peerless shale member:	
Pinkish sandy limestone or calcareous sandstone, in beds 2 to 3 feet thick. Shows irregular iron-stained partings suggesting cross-bedding. General colors highly variable—brick-red to olive-gray or buff	16
Thin-bedded shaly sandstone, notably banded with iron oxide	7
Thin-bedded fissile shaly sandstone; light olive-green when fresh, weathering to deep buff or brown. A few quartzitic layers as much as 1 foot thick	22
Total thickness of Peerless member	45
Massive conglomeratic quartzite, weathering to a buff color but yellowish-gray when fresh. Subangular quartz grains, irregularly cross-bedded. Sand grains weather out on the surface	10. 5
Impure, arkosic and micaceous pinkish quartzitic sandstone, weathering gray	6
White massive quartzite, very dense; weathering pinkish. Beds 1 to 4 feet thick; a few thin, shaly layers in places	9. 5
Buff and white, streaky dense quartzite in beds as much as 6 inches thick	6. 5
Dense, very massive white quartzite	6
White quartzite	2
Massive white quartzite with local sandy-weathering brownish beds	22. 5
Massive white quartzite	10
Massive, dense quartzite, weathering white to pink, very pure	14
Massive white quartzite, weathering buff	5
White thinner-bedded quartzite, weathering gray or buff; individual beds 2 feet or less thick	14. 5
	106. 5
Total thickness of formation	151. 5

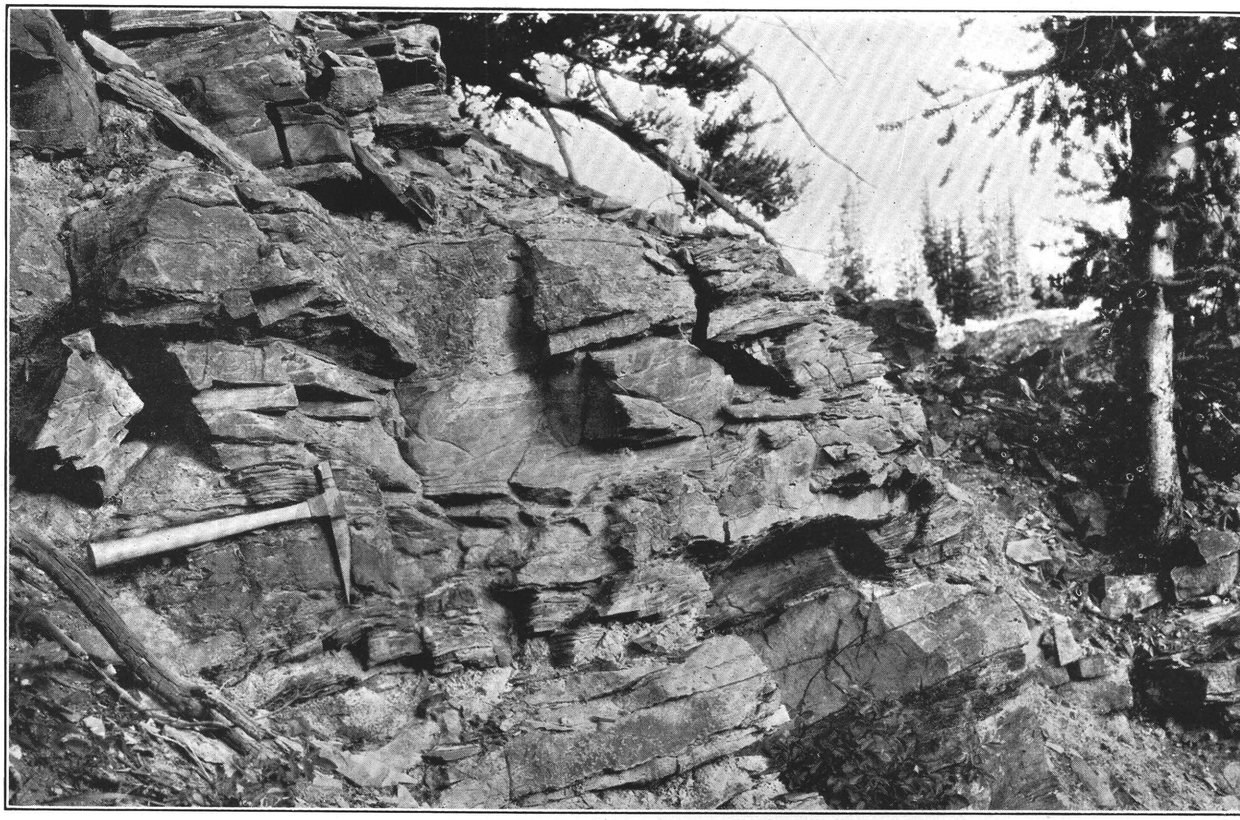
[10] Emmons, S. F., Irving, J. D., and Loughlin, G. F., U.S.Geol. Survey Prof. Paper 148, p. 25, 1927.
[11] Emmons, S. F., Geology and mining industry of Leadville, Colo.: U.S.Geol. Survey Mon. 12, p. 60, 1886.
[12] Behre, C. H., Jr., Colorado Sci. Soc. Proc., vol. 14, p. 58, 1932.



A. MASSIVE SAWATCH QUARTZITE NEAR MONTGOMERY, COLO.

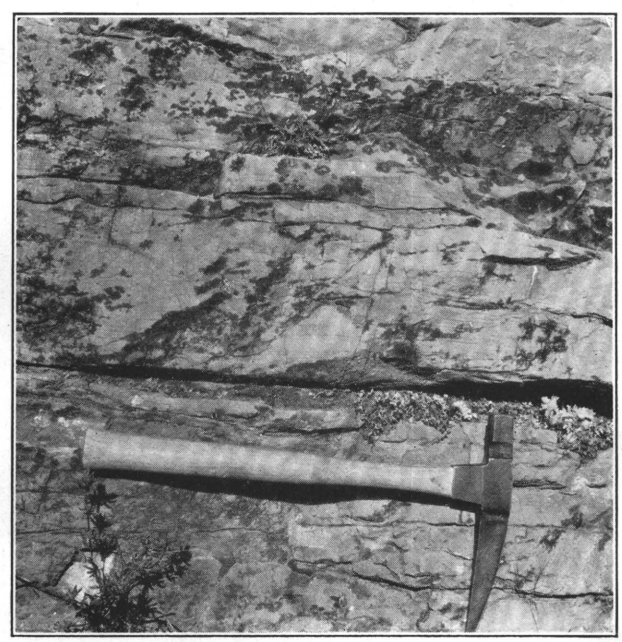


B. OUTCROP OF SAWATCH QUARTZITE BELOW MONTGOMERY.



A. SHALY "RED-CAST BEDS" AT TOP OF SAWATCH QUARTZITE NEAR MONTGOMERY, COLO.

B. THIN-BEDDED MANITOU LIMESTONE NEAR MONTGOMERY.



C. MEDIUM-BEDDED MANITOU LIMESTONE BELOW MONTGOMERY.

Section of Sawatch quartzite on east slope of West Dyer Mountain

	Feet
Peerless shale member:	
Pinkish sandy limestone in thin, shaly layers, with irregular bedding planes. Beds as much as 1 foot thick but generally only half an inch	19
Shaly, slabby impure sandstone. Some greenish and rarer brick-red shaly beds	11
Impure micaceous sandstone, weathering a rusty brown, in beds 1 foot or less thick, with shaly partings 3 inches thick; shows irregular cross-bedding	19
Total thickness of Peerless member	49
Pinkish quartzite in a single bed; weathers dark brown	2
Alternate beds of calcareous shale bearing sand and quartzitic beds, all weathering buff; beds 1 foot thick	5
White massive quartzite in beds 2 to 10 feet thick	56
	63
Total thickness of formation	112
Probable top of pre-Cambrian.	

Section of Sawatch quartzite on south slope of Mount Zion

	Feet
Peerless shale member: Covered, probably represents shale, as slope is distinctly gentler	44
White, very pure quartzite, alternating with commonly discontinuous sandy layers that lack induration and weather buff	36
White, very pure massive quartzite	24
White coarse-grained quartzite, in beds as much as 18 inches thick, with separating laminae of micaceous shaly quartzite 1 to 2 inches thick	54
White, pure quartzite, weathering with purplish blotches in grayish or buff colors. Irregularly cross-bedded	5. 5
Fine-grained conglomerate in beds as much as 6 inches thick	6
	125. 5
Total thickness of formation	169. 5

ORDOVICIAN SYSTEM

MANITOU LIMESTONE

Correlation.—In the revised Leadville report [13] the rocks designated by Emmons †"White limestone" and "Parting quartzite" were put together under the term †"Yule limestone" and were referred to as the †"White" limestone member and the "Parting" quartzite member. This treatment, for want of satisfactory data, was in accordance with the old assumption that they corresponded to the Yule limestone of the Anthracite-Crested Butte and other areas of central Colorado. Recent work by Kirk and others shows that the term †"Yule" has been applied to limestones that range in age from Upper Cambrian to Mississippian in different districts, and that the material at the type locality on Yule Creek may be of Carboniferous age. At the same time the work of Behre, Singewald, Kirk, and others in the Mosquito Range shows that the †White limestone and Parting quartzite are separated by an unconformity at their type locality. At the south end of the Mosquito Range the Harding and Fremont formations lie between them. The †White limestone is Ordovician and has been correlated with the Manitou limestone by Kirk. The term "Manitou" has long been used for the Lower Ordovician rocks of similar age and lithology in adjoining regions, so that it seems logical to apply that term to the beds in this area rather than to coin a new name. The Parting quartzite, as shown below, is Devonian, and it is therefore not advisable either to consider the Parting quartzite and †White limestone as parts of one formation or to apply the term †"Yule" to either or both. Kirk has given the name "Chaffee formation" to the Devonian rocks of central Colorado, including the Parting quartzite and the Devonian portion of the †Blue limestone of early reports.

Character.—The Manitou formation consists of thin-bedded dolomitic limestone (much of it highly siliceous), in many places with thin shaly layers. (See pl. 2, *B*, *C*.) It becomes increasingly shaly toward the top. The shales are dark green to dark gray or almost black. The amount of shale differs in different sections.

The limestones are highly crystalline and generally white or light gray. The beds are in few places over 4 or 5 inches thick and in many places are separated by partings of shale. This is almost everywhere true in the Leadville-Alma region, but at the south end of the range the formation thickens and the proportion of limestone becomes greater.

At certain horizons there are concretions and seams of white or cream-colored chert or chalcedony. (See pl. 3, *C*.) The chert remains unaltered by weathering or by mineralization or replacement of the rock. On weathered surfaces it may form conspicuous ribbing and other irregularities. Similar surface markings may be caused by the presence of irregular lenses mostly arranged parallel to the stratification, in which silica is more abundant than in the body of the rock, as noted by Patton [14] and by Loughlin.[15]

Thickness.—The thickness of the formation varies considerably even within short distances. In the Leadville area it averages about 120 feet. In the Alma district, to the east and northeast, measurements were obtained that showed a minimum of 44 feet and a maximum of 190 feet. At the south end of the range the thickness increases until at Trout Creek, in a measured section, it amounts to nearly 400 feet. Pre-Devonian erosion undoubtedly caused most of the variations in thickness.

Age.—Emmons considered the †White limestone to be Silurian, the term "Ordovician" not then being

[13] U.S.Geol. Survey Prof. Paper 148, p. 27, 1927.

[14] Patton, H. B., Geology and ore deposits of the Alma district, Park County, Colo.: Colorado Geol. Survey Bull. 3, p. 51, 1912.

[15] Emmons, S. F., Irving, J. D., and Loughlin, G. F., Geology and ore deposits of the Leadville mining district, Colo.: U.S.Geol. Survey Prof. Paper 148, p. 28, 1927.

used by the Geological Survey as a period name. For the correlation he had practically no paleontologic evidence. Later work has accumulated more information, so that Loughlin, in 1927, was able to state that the formation is unquestionably of Ordovician age. The fossils reported from it include cystid fragments, *Dalmanella melita, Orthisina* aff. *O. pepinensis, Eoorthis ochusa, Syntrophia* sp., *Piloceras* sp., *Colpoceras* sp., *Ophileta* cf. *O. trohiscus*, and fragments of trilobites and gastropods. Most of these identifications are old and may not be very accurate, but abundant fossils have been obtained from the formation in adjoining districts, so that the age can be definitely stated as Lower Ordovician.

Detailed sections.—Sections of the Manitou, measured by C. H. Behre, Jr., are given below to show its character in detail.

Section of Manitou limestone from south slope of Mount Zion

	Feet
Concealed	5. 5
Thin-bedded very light pinkish shaly limestone, weathering almost white. Texture sugary	10
Light-gray granular limestone, weathering almost white. Upper part in beds as much as 6 inches thick and banded with silica on weathered surface. Fracture distinctly platy. A few thin beds of shale interbedded in lower part, of which limy layers are like the preceding	57. 5
Blue-gray, buff-weathering limestone, granular on weathered surface. Beds 2.5 feet thick, separated by 2-inch layers of green shale; sandy layers rarely present	14. 5
Covered; probably limestone	12
Pink crystalline, slightly quartzitic limestone, in beds as much as 1 foot thick	16
	115. 5

Section of Manitou limestone in Iowa Amphitheater

	Feet
Light-colored, buff-weathering limestone of saccharoidal texture, with thin layers of white chert. In beds as much as 3 feet thick, each of which includes several cherty bands	29
Like the last but more thin-bedded; siliceous coating on exposed surfaces	65
	94

Section of Manitou limestone from east slope of Dyer Mountain, near Leadville, Colo.

	Feet
Prominent buff-weathering beds of coarse-grained dolomite	6
Blocky, locally siliceous light-gray limestone; weathers buff	68
Pinkish, sandy limestone, weathering to massive buff beds	19
	93

HARDING SANDSTONE

At the south end of the range two formations, the Harding and the Fremont, occur between the Manitou limestone and the Parting quartzite, which immediately overlies the Manitou in the Leadville area.

General features.—The Harding formation, as developed along Trout Creek, consists of a series of alternating beds of shale and calcareous sandstone with a few beds of impure limestone and quartzitic sandstone. The individual beds are generally rather thin. The color ranges from light greenish gray to dark reddish brown. Fragments of fish plates such as characterize the Harding at its type locality, near Canon City, Colo., were found in considerable numbers at the locality on Trout Creek. No definite outcrops of this formation were observed north of the Buffalo Peaks, although the presence of a small amount of it is suggested at Weston pass by the occurrence of some greenish shale and mottled sandstone containing fragments of fish plates, which, however, may belong to the basal Parting. The following section shows the character of the Harding formation at Trout Creek. (See pl. 7, *A*.)

Section of Harding sandstone along Trout Creek

[Measured on north side of creek near the old railroad water tank at the abandoned station of Newett, in Tps. 13–14 S., R. 77 W.]

	Feet
Contact with Fremont limestone appears regular.	
Harding sandstone:	
Sandstone. Rich green where fresh but weathering to a dark reddish brown. Suggests glauconite, but a microscopic examination does not confirm this suggestion. Contains abundant worm borings or small fucoid casts	2. 2
Sandstone, white, fine-grained. A thin layer 8 feet above base contains abundant worm borings and fucoid casts. Also fish plates	9. 3
Sandy limestone, gray; becomes greenish gray at top. Massively bedded at base; platy at top	2. 0
Hard gray sandstone, fine-grained. Suggestions of shale on the bedding planes	3. 5
Sandy limestone, light greenish gray	. 7
Quartzitic sandstone, gray	1. 0
Sandy limestone, light greenish gray	. 7
Quartzitic sandstone, gray-brown	1. 2
Sandy limestone, light greenish gray	2. 8
Quartzite, white, thin-bedded	10. 5
Quartzite, light gray, almost white, massively bedded	19. 0
Contact with Manitou limestone regular.	

Thickness.—At Trout Creek about 50 feet of the Harding was observed. It thickens southward, about 75 feet being found on the Arkansas River below Salida. North of Trout Creek it thins rapidly and is absent north of Weston Pass. This northward thinning was caused, at least in part, by erosion before the deposition of the Parting quartzite and possibly before the deposition of the Fremont. Kirk[16] in a recent publication discusses the distribution and characteristics of this formation in areas beyond that here considered.

Age and correlation.—The only definitely recognizable fossils obtained in this area are fish plates of the types described by Walcott as *Dictyorhabis priscus*,

[16] Kirk, Edwin, The Harding sandstone of Colorado: Am. Jour. Sci., 5th ser., vol. 20, pp. 456–466, 1930.

Astraspis desiderata, *Eriptychius americanus*, and several others. Kirk [17] summarizes the information on the subject and states that the formation is undoubtedly Ordovician, of about late Black River or early Trenton age, both of which are Middle Ordovician.

FREMONT LIMESTONE

General features.—Overlying the Harding sandstone along Trout Creek is a thick, massively bedded dolomitic limestone identified as the Fremont limestone. The color is light gray or light brown, but on weathered surfaces it becomes gray to dark gray. Usually the material is highly dolomitized. The formation is a cliff maker and as such can often be recognized topographically.

Distribution and thickness.—The formation rapidly thins out to the north of Trout Creek and was not observed at Weston Pass. To the west, south and southeast, however, it is well developed, good outcrops being found near Salida, around Monarch, and in the Canon City quadrangle. It is about 75 feet thick at Trout Creek.

Age and correlation.—The Fremont is rich in fossils, though they are hard to collect on account of the character of the rock. Corals are especially common, but brachiopods are not rare. The following forms are known from this district: *Receptaculites* sp., *Streptelasma* sp., *Paleophyllum thomi*, *Calapoecia* sp., *Paleofavosites* sp., *Halysites gracilis*, *Rhynchotrema capax*, and *Dinorthis subquadrata*. The forms not named specifically are mostly undescribed species.

According to Kirk,[18] the Fremont is approximately equivalent to the Montoya limestone of Texas and New Mexico and the Bighorn dolomite of Wyoming, both of Upper Ordovician age.

DEVONIAN SYSTEM

CHAFFEE FORMATION

One result of the recent work has been to demonstrate the existence and widespread distribution of Devonian rocks in central Colorado. Girty [19] suggested their probable existence in 1903. Field work by Behre,[20] Kirk, [21] and the writer has supplied detailed evidence as to their presence and character. Kirk in his paper gives a summary of the Devonian of Colorado and supplies the term "Chaffee formation" for the sediments of Devonian age found in the Mosquito Range and adjoining areas. The formation has two members, the Parting quartzite member below and the Dyer dolomite member above. The Parting quartzite member corresponds to the Parting quartzite of Emmons. The Dyer dolomite member is the lower part of the †Blue limestone of Emmons and others.

[17] Kirk, Edwin, op. cit., pp. 463–465.

[18] Kirk, Edwin, personal communication.

[19] Girty, G. H., The Carboniferous formations and faunas of Colorado: U.S.Geol. Survey Prof. Paper 16, p. 162, 1903.

[20] Behre, C. H., Jr., Revision of structure and stratigraphy in the Mosquito Range and the Leadville district, Colo.: Colorado Sci. Soc. Proc., vol. 12, pp. 37–57, 1929.

[21] Kirk, Edwin, The Devonian of Colorado: Am. Jour. Sci., 5th ser., vol. 22, pp. 222–240, 1931.

PARTING QUARTZITE MEMBER

Occurrence.—In the Leadville district a comparatively thin quartzite occurs above the Manitou (†White) limestone and below the †Blue limestone. Emmons called it the "Parting quartzite" because it separated the two limestones. Its persistence around Leadville has made it a valuable horizon marker, especially for determining the amount of displacement along faults, and it is well known to the mining fraternity. Its name has therefore recently been given a geographic significance, [22] by applying the name "Parting Spur" to the spur that extends from Dyer Mountain northwestward toward West Dyer Mountain. This spur is now considered the type locality of the Parting quartzite.

General features.—The Parting normally occurs as a rather thick bedded quartzite, which, however, contains shale partings or layers. Locally considerable shale occurs in it. In places there are alternations of thin beds of quartzite, limestone, and shale, particularly near the top or base of the member. At Trout Creek the total thickness of shale equals that of quartzite. The basal shale beds are commonly red.

A basal conglomerate was noted in several localities, and some streaks of poorly rounded pebbles were observed, both within the Leadville district and near Trout Creek. In the Leadville-Alma region the original sandstone beds have been altered to quartzite, but farther south some beds of soft and friable sandstone occur.

Loughlin [23] gives the following petrographic description of the material as studied in the Leadville district:

> The quartzite layers consist of grains of bluish-white quartz which range from 0.25 to 5 millimeters in diameter and average about 0.5 millimeter. In places large pebbles of quartz are present. Component quartz particles are seen under the microscope to consist of more or less well-rounded grains enlarged by the addition of interstitial silica. It is usually very difficult to detect the boundary between the newly added quartz and the original grain, but the addition of cementing material has imparted to the grains an interlocking character. In the less pure beds the matrix consists partly or wholly of carbonates and aluminum silicates. The original quartz grains are filled with a great profusion of indeterminable minute inclusions and are presumably derived from the pre-Cambrian granite and related rocks that consituted the land surface from which the material was derived. Inclusions of muscovite and minute rutile needles are present locally in the quartz grains.

Thickness.—The Parting quartzite member shows a considerable range of thickness, even within short distances. Loughlin [24] shows thicknesses ranging from 10 to 70 feet around Leadville. In the Alma district

[22] Kirk, Edwin, Am. Jour. Sci., 5th ser., vol. 22, p. 228, 1931.

[23] Emmons. S. F., Irving, J. D., and Loughlin, G. F., op. cit., pp. 30–31.

[24] Idem, p. 30, diagram on p. 31, and pl. 29.

Singewald obtained thicknesses as much as 55 feet, though the member is completely absent in at least one locality. A little over 60 feet of beds were found in the Trout Creek section.

Age and correlation.—Emmons put the Parting quartzite into the Silurian. Loughlin [25] reviewed the evidence available in 1926 bearing on the age and tentatively classified it as Ordovician.

Kirk [26] presents considerable evidence to show that the Parting quartzite is of Devonian age. He does this partly on the basis of close lithologic agreement with known Devonian beds found short distances east, west, and south of the Mosquito Range and partly from the general stratigraphic succession in central Colorado.

The field work connected with the present report demonstrated the existence of an unconformity at the base of the Parting. The fact that at Leadville the Parting rests upon the Manitou (†White) limestone, whereas at Trout Creek the Fremont and Harding formations occur between them, is in itself evidence of such an unconformity. In any case it seems more logical now to group the Parting with the lower part of the conformably overlying †Blue limestone, as a member of the Chaffee formation, rather than with the unconformably underlying Manitou (†White) limestone. Field work on the west side of the Holy Cross and Sawatch uplifts disclosed sections where transitional gradations from Parting type of sediment to †Blue type occurs. For these reasons the present writer believes that the Parting should be considered Devonian rather than Ordovician.

Well-preserved fish plates of Devonian type were found by the writer during the field season of 1934 near the base of the Chaffee formation about 16 miles northeast of Salida.

Detailed sections.—The following sections, measured by C. H. Behre, Jr., will give an idea of the character of the Parting member:

Section of Parting quartzite member of the Chaffee formation on south slope of Mount Zion

	Feet
Pink, slightly conglomeratic quartzite	7
Cross-bedded pink quartzite	1. 5
Massive white quartzite	1. 5
Conglomeratic very light pink quartzite. Grains are subangular and clear and composed of quartz only. Some irregular cross-bedding at base	7
White very pure quartzite	10
Finely conglomeratic layer, with subangular clear quartz grains	2. 5
Greenish shale, very distinct	1
Poorly consolidated brown coarse sandstone	3
	33. 5

Section of Parting quartzite member in the Iowa Amphitheater

	Feet
Pinkish, "rotten"-weathering conglomeratic quartzite; irregularly cross-bedded; conglomerate layers lenticular	8. 5
Shaly, blocky limestone, in beds 3 inches thick	2. 5
Pink massive quartzite	8
	19

Section of Parting quartzite member on east slope of West Dyer Mountain near Leadville

	Feet
Pinkish-weathering conglomeratic quartzite in beds as much as 2 feet thick; cross-bedded, especially at base	21

DYER DOLOMITE MEMBER

General features.—Overlying the Parting quartzite is the †Blue limestone of Emmons. In the Leadville-Alma region this division is about 200 feet thick. In the report of Emmons, Irving, and Loughlin [27] the upper portion of the Leadville was considered as being of Mississippian age, on the basis of paleontologic determinations by Girty. The lower portion was referred tentatively to the Devonian on the basis of probable correlations with known Devonian limestones in nearby areas, as suggested by Girty [28] in 1903, no fossils being known from it around Leadville. Behre [29] and Kirk [30] have presented detailed evidence supporting these conclusions.

The term "Leadville limestone" is used in this paper to include only that portion of the †Blue limestone of Emmons which is of Mississippian age. In accordance with Kirk's suggestion, the term "Dyer" is used for the Devonian portion of the †Blue limestone.

The Dyer dolomite member consists of dense dolomitic limestone. The color is gray to bluish gray on fresh surfaces. The upper beds generally weather to a brownish tint, which may vary from a yellowish tan to a deep brown. The lower beds locally show alternations of light and dark materials. Thin shale partings occur along the surfaces of bedding planes. The beds become somewhat shaly or sandy toward the base. Locally they contain thin beds of shale or sandstone.

Thickness.—The thickness of the Dyer member shows considerable variation. In a few places it is more than 80 feet thick; in other places it is absent. In the vicinity of Leadville it averages about 75 feet and reaches a maximum of 95 feet, but around Alma it is thinner. This variation in thickness is probably more the result of pre-Leadville erosion than of great original differences in deposition. As Kirk [31] states:

25 Emmons, S. F., Irving, J. D., and Loughlin, G. F., op. cit., pp. 31-32.

26 Kirk, Edwin, The Devonian of Colorado: Am. Jour. Sci., 5th ser., vol. 22., pp. 231-239, 1931.

27 Emmons, S. F., Irving, J. D., Loughlin, G. F., op. cit., p. 37.

28 Girty, G. H., The Carboniferous formations and faunas of Colorado: U. S. Geol. Survey Prof. Paper 16, p. 162, 1903.

29 Behre, C. H., Jr., Revision of structure and stratigraphy in the Mosquito Range and the Leadville district, Colo.: Colorado Sci. Soc. Proc., vol. 12, pp. 37-57, 1929.

30 Kirk, Edwin, The Devonian of Colorado: Am. Jour. Sci., 5th ser., vol. 22, pp. 231-239, 1931.

31 Idem, pp. 226-227.

It must be borne in mind that the important erosional unconformity affecting the Leadville is the one within it, that is below the sandstone approximately 75 feet above the base of the limestone at Leadville and at the base of the Mississippian. The assumed unconformity of earlier geologists between the composite Leadville and Parting quartzite probably does not exist in fact and represents no more than an abrupt change in lithology. It is to be expected that if not at Leadville itself at least within a short distance to the north sections will be found where the Mississippian cuts through the Devonian limestone and rests on the Parting quartzite. An interesting section on Mount Zion (east) studied by Behre is suggestive of this condition. According to him (personal communication) the yellowish-weathering Devonian limestone is wholly or mostly absent.

The variable thickness and general relations are shown in the table of formational thicknesses in the Alma district (p. 18).

Age and correlation.—Few fossils have been found in the Dyer in the Mosquito Range. Kirk [32] states:

> Paleontological evidence as to the age of the lower part of the Leadville at Leadville is poor. On West Dyer Mountain we collected several specimens of *Syringopora* sp. [which, by itself, is not conclusive. However,] apparently identical *Syringopora* was collected at Gilman, 20 miles away, below the *Spirifer animasensis* zone.

The writer, in 1930, found similar *Syringopora* on the lower (northeast) end of Pennsylvania Mountain and again near Trout Creek. The Dyer member is considered the equivalent of at least the lower portion of the Ouray limestone of southwestern Colorado.

DEVONIAN-MISSISSIPPIAN BOUNDARY

On canyon walls and cliffs the Devonian-Mississippian boundary can be clearly drawn in many places on the basis of color, as some beds near the top of the Devonian portion almost invariably assume a tan, "buckskin," or brownish coloration on weathering, whereas the Mississippian beds retain a dark gray or gray-blue color. Similarly it has been frequently noted that on old weathered surfaces the Mississippian beds tend to develop shallow caverns and solution features which were not observed on surfaces of the Devonian.

Behre [33] has shown that in the Leadville district a siliceous bed marks the base of the Mississippian. This bed occurs about 75 feet above the base of the †Blue limestone. It ranges from 2 to 12 feet in thickness and averages about 8 feet. The sandy bed was noted locally in the Leadville district,[34] but nothing definite could be stated regarding its continuity. It is now known to be of widespread occurrence, as it is not only persistent in the Iowa Gulch district but is present on Zion Mountain, 4 miles north of Leadville, and at Gilman, 20 miles farther north. At these places it is 70 to 80 feet above the Parting quartzite. The typical sandstone is white, with a sugary texture and medium to coarse grain, but nowhere resembles a conglomerate. Its grains are held in a calcareous and siliceous matrix. In some places it approaches quartzite in character, and in others it is little more than a limestone with numerous quartz grains. In parts of the Leadville district it seems to be represented by shaly instead of sandy layers, a fact which may account for its previous inadequate recognition. Immediately above this sandstone there is generally a conspicuous limestone breccia from 2 to 5 feet thick, composed of various colored fragments of limestone set in a sandy calcareous matrix. Gibson [35] found the same sandstone and breccia in the Red Cliff district.

The widespread occurrence of this sandstone has also been confirmed by the detailed observations of E. P. Chapman, of Leadville. It seems to represent the beginning of Mississippian sedimentation and is included in the Leadville formation in this paper.

The sections given below illustrate the character of the Leadville and Chaffee formations in the Leadville district.

Composite section on south slope of Mount Zion, near Leadville

[Supplied by C. H. Behre, Jr.

	Feet
White porphyry sill.	
Leadville limestone:	
Altered, coarsely crystalline Blue limestone. Light blue-gray; local black chert lenses. Weathers to "checkered" color pattern that brings out dark splotches	20
Similar to above, but beds not coarsely crystalline	40
Similar to second above but free from chert	23
Dense cherty dark blue-gray layers (secondarily silicified?)	5½
Blue-gray limestone, much like the last but locally recrystallized into "zebra" rock	14
Blue limestone, with black chert lenses and spheres and local shaly layers	37½
Conglomerate of limestone boulders and pebbles in a lime matrix. Individual boulders not well rounded. Some black chert pebbles also. In middle 1 foot of coarse yellowish-weathering arkosic sandstone, cemented with lime	5
Total thickness of Leadville formation	145
Dyer dolomite member of Chaffee formation:	
Limestone in beds generally as much as 3 feet thick but bedding not well marked. Banding locally visible, the banding due to alternations of light and dark gray colors	24½
Similar to above but beds thinner—few more than 1 foot thick. Many are shaly, with distinctly granular weathering. Largely individual lime beds are separated by layers 1 to 4 inches thick of brick-red or greenish shale	10
Yellow thin-bedded, very shaly limestone, with irregular cross-bedding	8

[32] Kirk, Edwin, op. cit., p. 226.

[33] Behre, C. H., Jr., op. cit., pp. 38-39.

[34] U.S. Geol. Survey Prof. Paper 148, p. 34, 1927.

[35] Gibson, Russell, in Crawford, R. D., Geology and ore deposits of the Red Cliff district, Colo.: Colorado Geol. Survey Bull. 30, pp. 36, 38, 1925.

Composite section on south slope of Mount Zion, near Leadville—Continued

	Feet
Dyer dolomite member of Chaffee formation—Contd.	
Shattered, irregularly bedded, slightly sandy layer	1½
Pinkish limestone, in beds 6 inches thick	8
Shattered concretionary layer; conspicuously brownish	2
Light-gray, uniformly white-weathering limestone; beds blocky, 1 foot thick	41½
Total thickness of Dyer dolomite member	95½

Detailed section on Sherman Mountain, Iowa Amphitheater, near Leadville

[Supplied by C. H. Behre, Jr.]

	Feet
Leadville limestone:	
Blue-gray, granular, shattered limestone	16½
Alternate blue-gray and buff-weathering limestone, in beds 1 to 2 feet thick	10½
Dark blue-gray limestone, with some rusty-weathering cherty bands	87½
Limestone breccia	6
Buff-weathering sandy beds	6
Total thickness of Leadville limestone	126½
Dyer dolomite member of Chaffee formation:	
Light-gray, pinkish-weathering quartzite and thin limy beds, alternating	5½
Alternate light and dark banded shaly limestone, the banding 6 inches thick	28½
Same as above but weathering brownish to buff	4
Dark blue-gray limestone, weathering bright buff	10½
Blue-gray streaked limestone, in beds 1 to 2 feet thick, with some siliceous banding. Beds lower down become massive, as much as 3 feet thick, and weather rusty	39
Total thickness of Dyer dolomite member	87½

Detailed section on West Dyer Mountain, near Leadville

	Feet
Leadville limestone:	
"Pepper and salt" dark-gray beds of coarsely crystalline limestone, partly "zebra"-marked	20±
Dense, highly recrystallized blue-gray limestone, weathering to dull dark gray. Fracture brittle	2
"Pepper and salt" dark-gray beds of coarsely crystalline limestone, partly "zebra"-marked	11
Dense, closely fracturing sandy limestone, with closely banded fetid beds near the middle. Color deep slate-gray where fresh; weathers buff; the bands are accentuated by weathering	33
Dull blue-gray limestone; weathers buff. Delicate recrystallization outlines fossil traces in white. Rare chert lenses as much as 2 inches thick, locally in definite beds. Some darker blotching	20±
Typical "zebra" rock, dull dark gray, almost black limestone, locally spotted or blotched with darker color. Areas of recrystallization and "zebra" effects common	13±
Dense slate-colored (blue-gray) limestone. Shows faint banding on the weathered surface, which is dark gray, slightly lighter than when the rock is fresh. Suggestions of wormholelike markings, elongated parallel to the beds. Lower part contains rare bands of iron-stained chert	22

Detailed section on West Dyer Mountain, near Leadville—Contd.

	Feet
Leadville limestone—Continued.	
Light-colored, moderately fine textured limestone, with traces of limestone breccia locally near base	14±
Slightly sandy, very brittle light-gray limestone, weathering a slightly darker shade	8±
Limestone breccia; subangular fragments of limestone, from very light slate-gray to almost coal-black, set in sandy buff limestone as matrix	8
Very sandy limestone, with quartz grains weathering out of exposed surface; light buff	3
Total thickness of Leadville limestone	154
Chaffee formation:	
Dyer dolomite member:	
Dense, blue-gray limestone in massive beds. Color slaty blue-gray, weathering to light buff-gray. Faint suggestion of banding	14
Brownish spotted gray limestone, densely granular, thin-bedded; weathers so as to show distinct bands 1 to 2 inches thick	8
Like the beds above, but less distinctly banded	29±
Light blue-gray limestone with pronounced platy fracture; weathers to an ocher color, very conspicuous	4
Massive light blue-gray, faintly buff-weathering limestone. Massive beds; becomes whiter near base	30±
Very sandy, medium fine to locally coarsely crystalline limestone of light-buff color	14±
Total thickness of Dyer dolomite member	99
Parting quartzite member: Pinkish, coarsely granular quartzite, locally conglomeratic.	
Total thickness measured	253

Section on east slope of West Dyer Mountain near Leadville

[Supplied by C. H. Behre, Jr.]

	Feet
Leadville limestone (partly eroded at top):	
Dark blue-gray limestone, with beds prominently weathering to rusty brown; cherty, especially in lower part, the chert in black lenses	23
Alternating very dark and very light blue-gray limestone, with black chert nodules	27
Buff sandy limestone	2
Light-gray matrix studded with dark and light gray poorly rounded blocks of limestone—limestone conglomerate	8
Total thickness of Leadville limestone	60
Dyer dolomite member of Chaffee formation:	
Banded dark blue-gray and light blue-gray limestone	10
Buff-weathering, light-gray massive limestone	27
Gray limestone, slightly bluish, in irregular massive beds 2 feet or less thick; black chert lenses near the top	21
Blue-gray limestone; weathers to dull, dark-gray	10
Buff-weathering massive beds of limestone, with limestone conglomerate at base	10
Total thickness of Dyer dolomite member	78

CARBONIFEROUS SYSTEM

LEADVILLE LIMESTONE (MISSISSIPPIAN)

General features.—The Leadville or upper part of the †Blue limestone overlies the Dyer dolomite member of the Chaffee formation and is the formation in which the largest ore bodies in the region have been mined. As shown in the sections, it consists of dense blue to blue-gray dolomite, some layers of which contain numerous lenses, concretions, and streaks of black chert. Locally metamorphism has given rise to banded patches of white recrystallized dolomite to which the miners have applied the name "zebra rock." In the northern part of the range contact metamorphism has caused considerable local alterations of the formation, which change its appearance and give it different characteristics of weathering. The features by which it may be distinguished from the underlying Dyer member of the Chaffee have been treated in the discussion of that formation.

West and southwest of the area of the Mosquito Range the Leadville formation gradually loses its dolomitic character, becoming a pure limestone. This is very noticeable as it is followed south from the Eagle River to the Aspen mining district.

Thickness.—The thicknesses measured range from less than 50 feet to 160 feet. The thickness changes markedly within short distances, and the differences appear to have resulted more from erosion preceding the deposition of the Pennsylvanian sediments than from original differences in deposition.[35a]

Age and correlation.—Fossils are rare in the Leadville formation. None were found by the writer during his field work in this area. In fact, practically all the known fossils from the formation in the Mosquito Range area were obtained in the early days by Emmons and his assistants. The fossils reported are *Zaphrentis* sp., *Orthotetes inaequalis*, *Spirifer* sp. *a* Girty, *Spirifer* sp. *b* Girty, *Seminula subquadrata*, *Eumetria woosteri*, *Myalina arkansana?*, *Conocardium* sp.?, and *Straparollus* cf. *S. spergenensis*. Girty[36] expresses the opinion that the fauna is equivalent to the Kinderhook and possibly lower Burlington of the Mississippi Valley. He also considered it to be more closely related to the Millsap limestone of the Front Range than to the Mississippian limestones of Aspen and Crested Butte. However, all form a general equivalent of the Madison limestone, so widely deposited over the Northern Rocky Mountain province.

MISSISSIPPIAN-PENNSYLVANIAN BOUNDARY

Though there is no apparent discordance in dip between the Mississippian and Pennsylvanian in the regions here studied there is an unconformity between them which represents a time interval of great length—equal, in fact, to about half of the Mississippian and part of the early Pennsylvanian. This is evident from the faunas. The lithologic change from limestone to shale is abrupt, with a slight suggestion of sand or gravel at the contact in a few places. Signs of weathering and solution were noted in the upper layers of the limestone in several localities. A short distance northwest of the area here discussed, in the Red Cliff and Gilman districts, signs of weathering and erosion, with solution of the upper Leadville before deposition of the overlying Weber (?) formation, are evident. In fact, in the mines at Gilman the contact is uneven, and the funnel-shaped masses of the younger formation penetrate into the limestone, suggesting fillings of old sink holes and solution cavities.[37] The surface outcrops in the same vicinity show that the younger formation rests on an irregularly eroded surface of limestone. Similar occurrences of Pennsylvanian shale resting on irregularly eroded limestone surfaces were also observed during 1931 at several localities in the Aspen district and along the west side of the Holy Cross uplift.

PENNSYLVANIAN AND PERMIAN SEDIMENTS

GENERAL FEATURES

Above the Leadville limestone rises a series of shale, sandy shale, limestone, sandstone, and grits, which ranges upward without stratigraphic break into red beds of great thickness. Emmons in the Leadville monograph applied the terms †"Weber shales" and †"Weber grits" to the lower part of the series, on the supposition that it was equivalent to the Weber quartzite of northern Utah. For the upper portion of the series, which consisted mainly of red beds, he used the term †"Upper Coal Measures" and later[38] the term "Maroon formation", considering them to be equivalent to the formation that constitutes Maroon Peak southwest of Aspen. In the Tenmile district he found still higher beds, to which he applied the term †"Wyoming formation," a term first used for deposits to the east of the Front Range.

Lacking paleontologic evidence and without distinctive lithologic features to aid him, he arbitrarily separated the formations at certain limestone beds that were well developed in the Tenmile district. Thus the base of the Maroon was considered to be the base of a limestone to which he applied the name "Robinson," and the top member of the formation was his Jacque Mountain limestone. There seems to be no need or justification for separating the sediments above the Jacque Mountain limestone from those below, so in this report the term "Maroon formation" is used to include both. The term †"Wyoming" has been abandoned.

Very little of the Maroon formation is left in the Leadville district, and in general it is not well exposed

[35a] Lovering, T. S., and Johnson, J. H., Am. Assoc. Petroleum Geologists Bull., vol. 17, pp. 366–367, 1933.

[36] Girty, G. H., The Carboniferous formations and faunas of Colorado: U.S.Geol. Survey Prof. Paper 16, pp. 217, 229, 1903.

[37] Barcherdt, W. O., Eng. and Min. Jour., vol. 132, p. 100, 1931.

[38] U.S.Geol. Survey Geol. Atlas, Tenmile district special folio (no. 48), 1898.

in the Mosquito Range. It is, however, well developed in the region north and northwest of Leadville, and most of the information used in this discussion was obtained in that area.

WEBER (?) FORMATION (PENNSYLVANIAN)

Subdivisions.—Three general zones can be roughly recognized in the Pennsylvanian sediments of the Mosquito Range—a lower shale zone, a limestone zone, and the upper zone of grit. These zones grade into one another and are not everywhere well defined.

The lower zone averages about 300 feet in thickness and consists mainly of dark shale, though locally thin sand and even shaly limestone may occur. In the Leadville district the individual layers are usually less than a sixteenth of an inch thick. They contain much carbonaceous material, locally even thin beds of impure coal. At two localities well-preserved land plants were obtained, but traces of vegetable matter were noted at this horizon in all the sections studied. Along Trout Creek numerous pieces of silicified wood, some of them large, were obtained. In some sections part of the shale is calcareous. Suggestions of a sandy or slightly conglomeratic basal layer were noted at a few localities, but generally very fine shale was deposited immeditely upon the surface of the Leadville limestone. Throughout the series interbedded layers of coarse micaceous sandstone occur. These are more abundant and thicker at the north end of the Mosquito Range than at the south end. The contact between the upper and middle zones may be well defined in a few sections, but more commonly there is a gradual transition. This zone corresponds to the †Weber shales of Emmons.

The middle zone, which is 700 to 1,000 feet thick, consists of grit, sandstone, sandy shale, shale, and limestone, named in the order of their abundance. The limestone is dolomitic and contains some iron carbonate. Many of the limestone beds carry marine fossils. The limestone beds constitute only 3 to 8 percent of the deposits, yet from their resistance to weathering and from their coloration they form the conspicuous outcrops. Nearly all the thicker limestone beds of the local Pennsylvanian occur in this zone. The shale of this zone is not so carbonaceous as that in the lower zone. Many of the beds are calcareous. Locally they may be micaceous. The sandstone is white to light gray. The beds are commonly micaceous, the number and size of the mica flakes increasing progressively at higher stratigraphic levels. This zone is approximately equivalent to the †Weber grits of Emmons.

The upper zone consists mainly of coarse-grained sandstone and grit, which locally become coarse conglomerates. In general the texture becomes coarser toward the top of this section. Thick, irregular beds of coarse grit and conglomerate are characteristic of this zone, although it contains local beds of sandy shale and a few lenticular beds of limestone. Its thickness differs greatly from place to place but reaches 1,200 to 1,600 feet at the north end of the area and in the Tenmile district. Much of the material is arkose. Feldspar fragments may be so abundant as to aid in coloring the rock. Mica is surprisingly abundant in many of the beds. In some beds it is scattered through the rock; in others it occurs mainly on and near the bedding planes. The coarser conglomerates contain fragments of pre-Cambrian granite and schist. In general the deposits are such as one would expect to result from rapid deposition as wash, alluvial fans, and deltas around areas of pre-Cambrian rock. Most of this zone belongs with the Maroon of Emmons. No lithologic boundary can be drawn between the "Weber" and Maroon.

Age.—The typical material of the so-called "Weber" in the region where it was originally studied (the Leadville district) is unquestionably of Pennsylvanian age, as can be demonstrated from the abundant fossils collected at a large number of localities. Full faunal lists and a statement regarding their interpretation are given on pages 31–33.

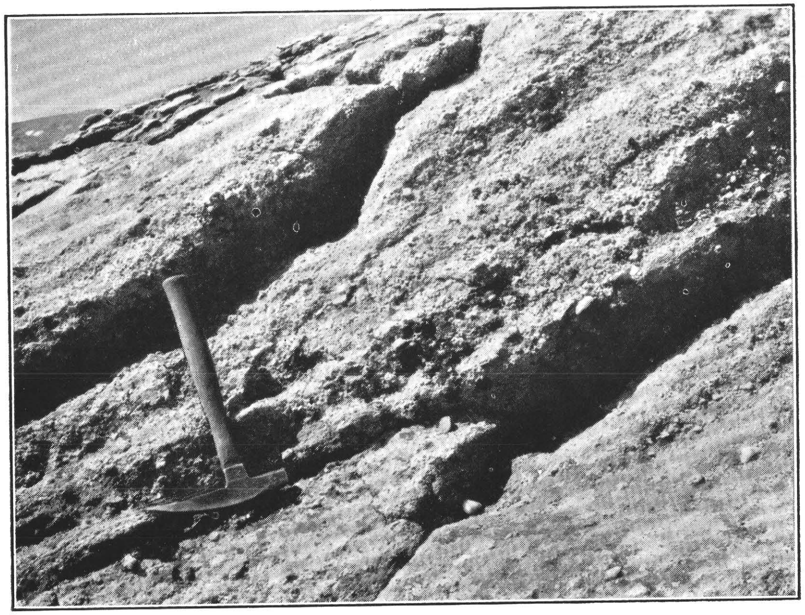
Relation to ore-bearing beds.—The so-called "Weber" formation has been of interest to the mining men because experience has shown that it is stratigraphically above the top of most of the ore beds of the Leadville and Alma districts. Numerous efforts have been made to locate ore within this formation, but it has been productive only in the Robinson and Kokomo districts. The lower shale member appears to have served as an impervious blanket that stopped the upward migration of ore-bearing solutions and thereby caused an increased concentration in the underlying Mississippian limestone in a number of places.

Lithology.—The Pennsylvanian sediments include such a variety of types that it seems desirable to give them special study.

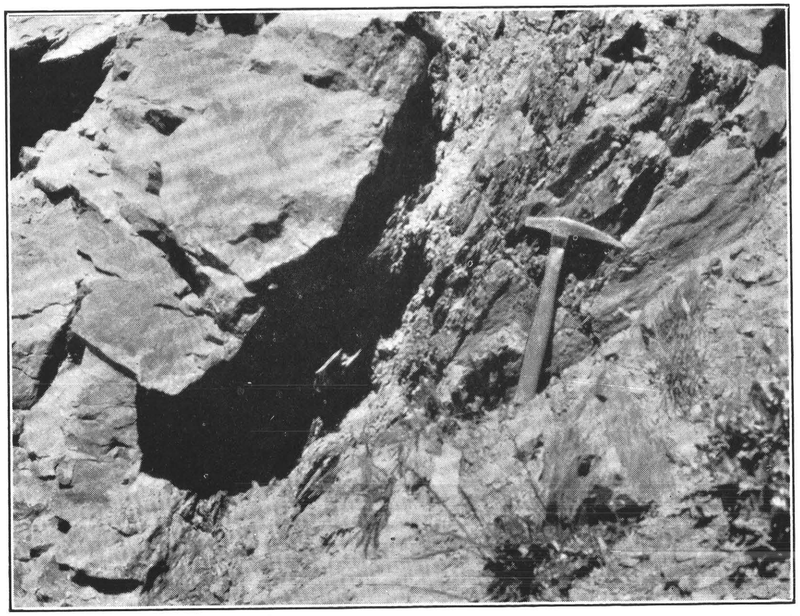
The shale beds include purely argillaceous material, calcareous shale, bituminous shale, and sandy shale. They are best developed at and near the base of the formation. Over 85 percent of the shale observed was contained in the lower 450 feet of the Pennsylvanian. (See pl. 3, *B.*)

Generally the shales are black or dark gray, but they may be light gray, tan, brown, or red. The basal shales are universally black; the red and red-brown colors occur highest in the section.

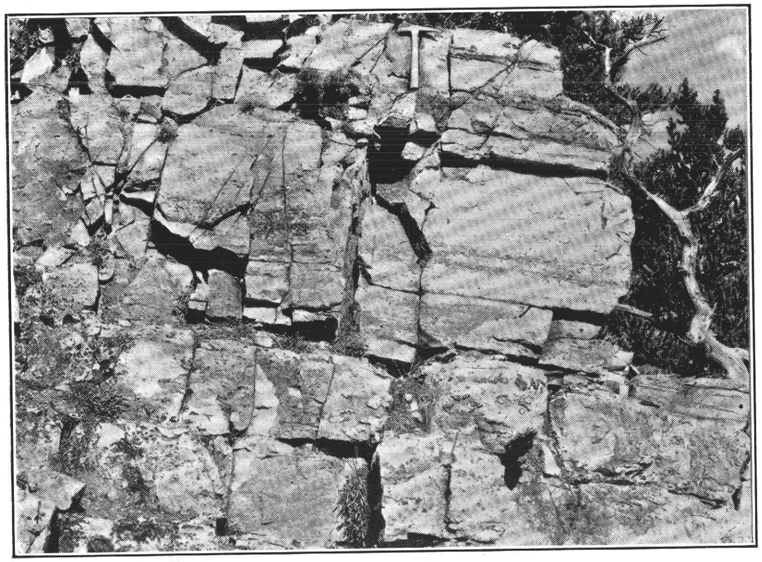
Bituminous shale is common at the base of the formation. Around Leadville there is 50 to 70 feet of it. Usually it is purer and of finer texture near the base. The carbonaceous matter is largely if not entirely of vegetable origin. Plant fragments, root impressions, carbonized wood, coaly material, and even streaks of impure coal occur. At two localities well-preserved fossil ferns and related land plants were obtained. In the Trout Creek section well-preserved silicified wood



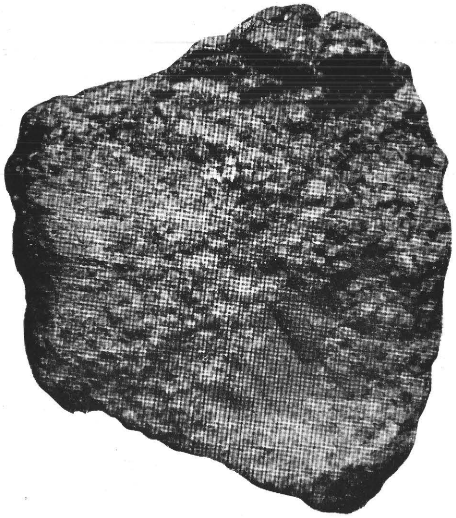
A. †WEBER GRITS ON SOUTH MOSQUITO CREEK.



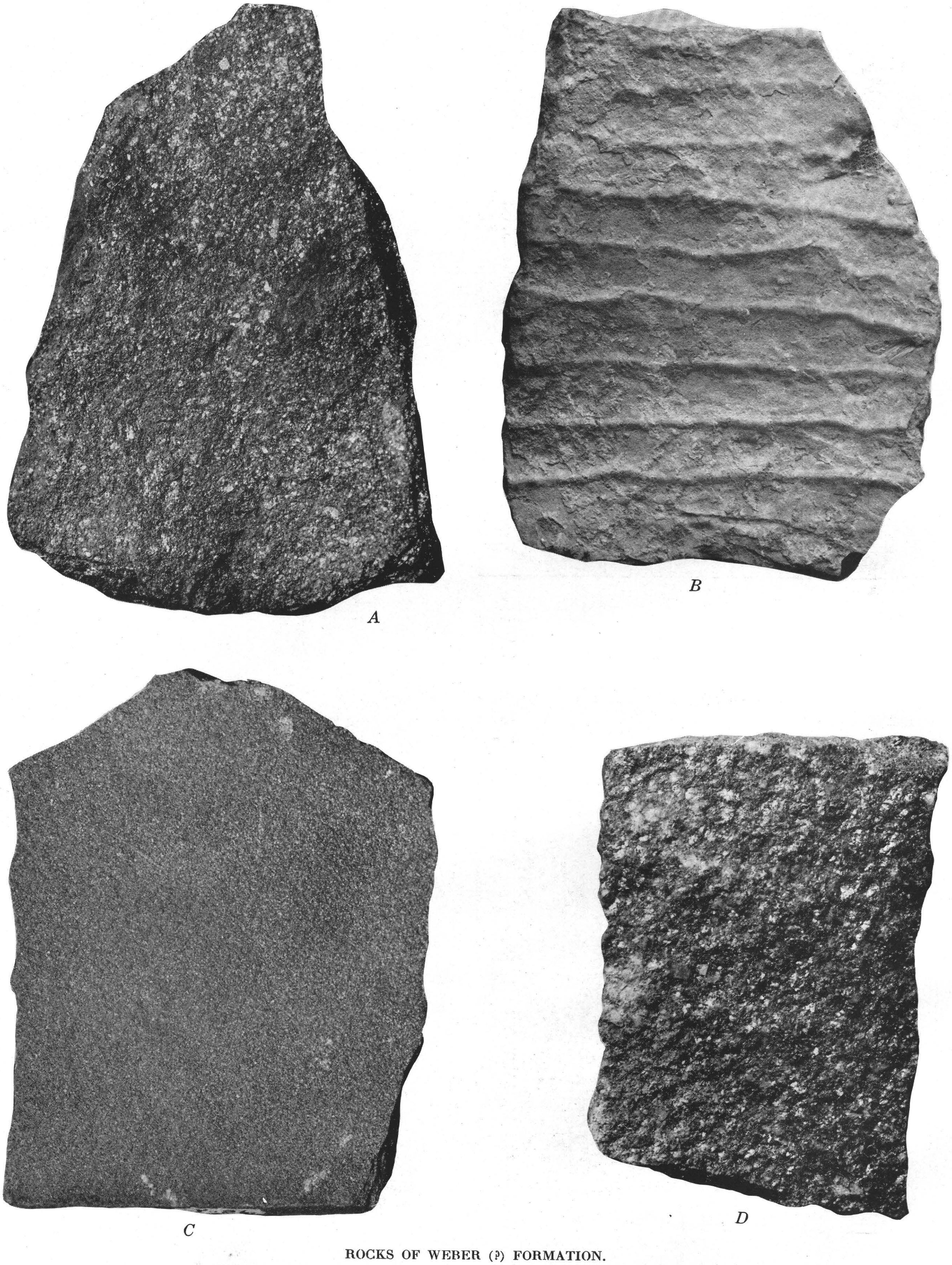
B. †WEBER SHALES ON LONDON MOUNTAIN.



C. MANITOU LIMESTONE WITH CHERT.



D. SAMPLE OF †WEBER GRITS.



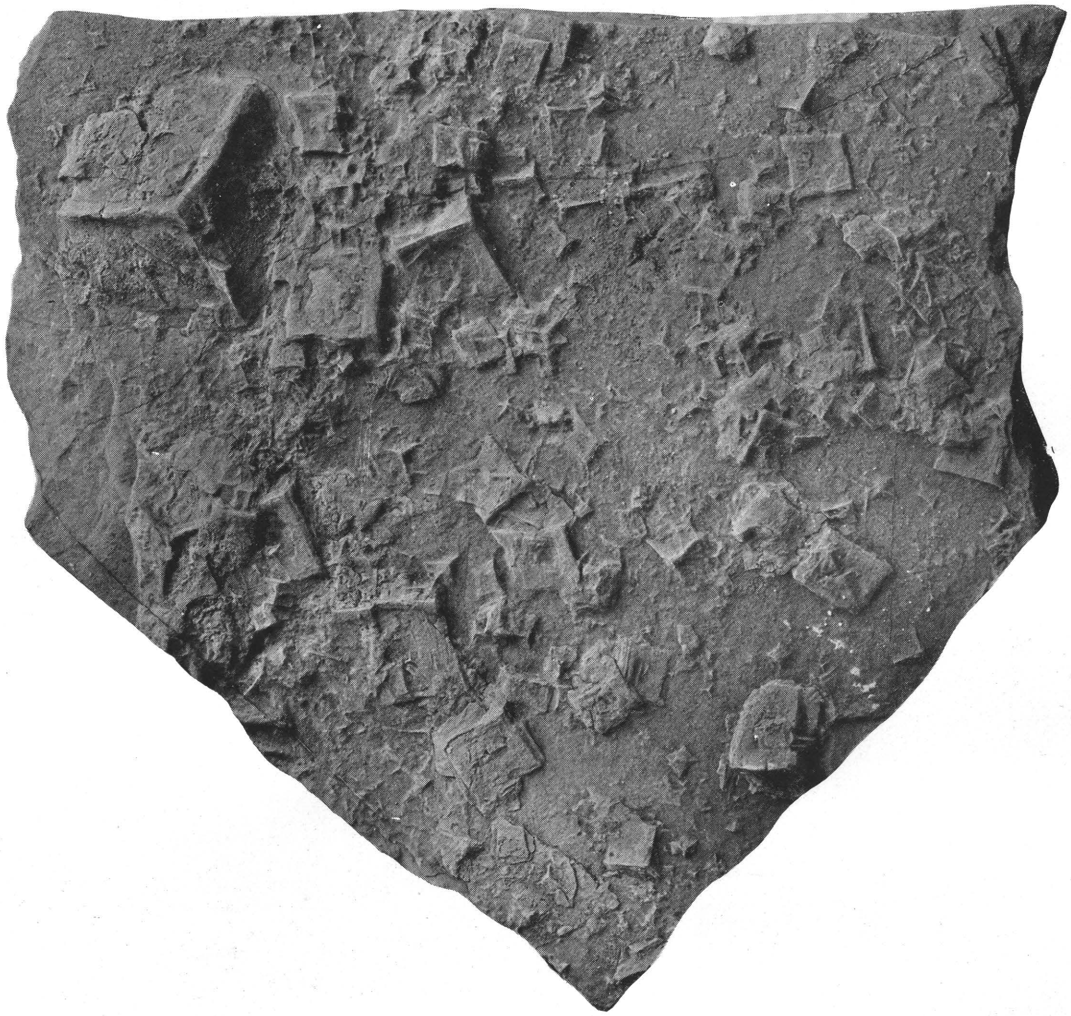
ROCKS OF WEBER (?) FORMATION.

A, Micaceous sandstone. *B*, Ripple-marked sandstone. *C*, Micaceous sandy shale. *D*, Micaceous arkose.

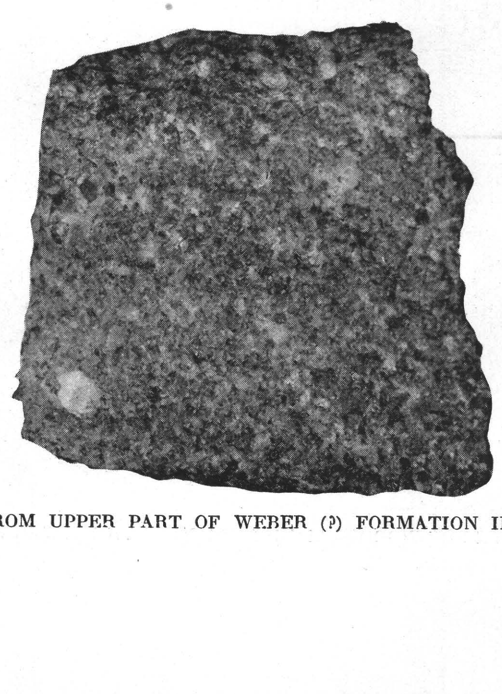
A

B

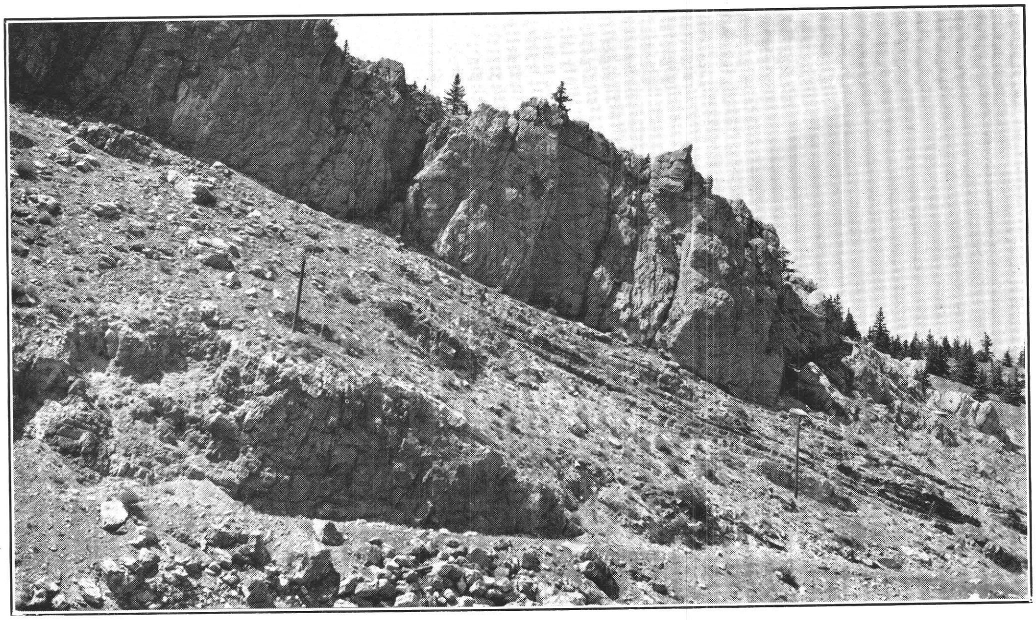
TOP AND SIDE VIEWS OF A THIN LAYER OF FIBROUS LIMESTONE FROM THE LOWER PART OF THE MIDDLE WEBER (?) BEDS.



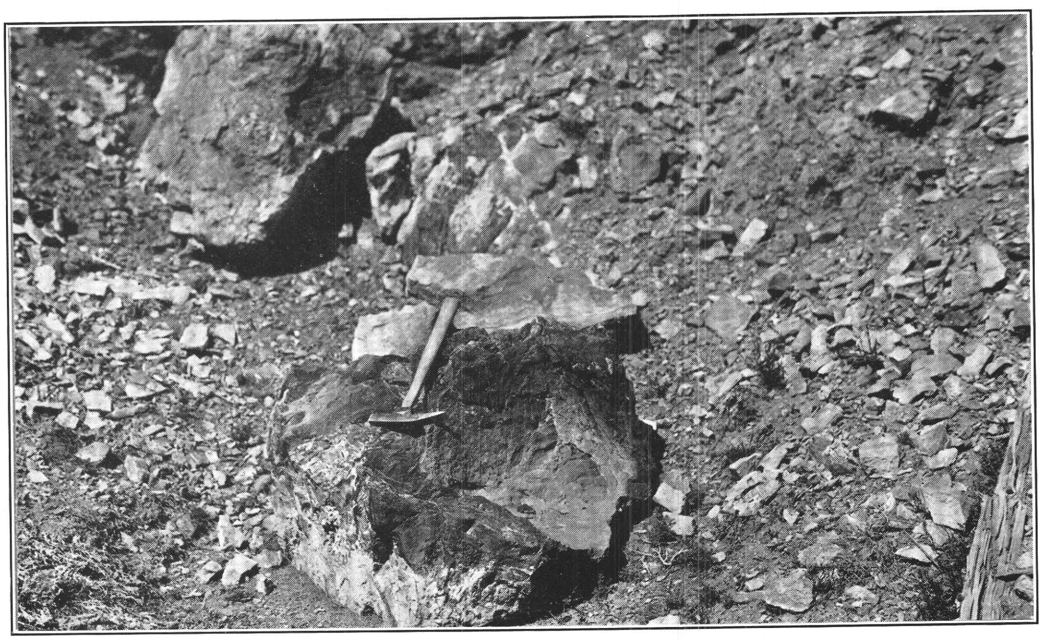
A. CASTS OF SALT CRYSTALS ON SURFACE OF SHALY LIMESTONE FROM LOWER PART OF WEBER (?) FORMATION NEAR TROUT CREEK.



B. ARKOSIC GRIT FROM UPPER PART OF WEBER (?) FORMATION IN ALMA DISTRICT.



A. OUTCROP OF FREMONT, HARDING, AND PART OF MANITOU ALONG TROUT CREEK NEAR OLD NEWETT STATION.



B. LOG OF SILICIFIED WOOD FROM THE LOWER PENNSYLVANIAN NEAR TROUT CREEK.

was abundant in the upper part of a thick shale bed. Some shale beds are so carbonaceous that they have been prospected for coal, but as yet no commercial coal has been found.

Beds of dark-gray to black calcareous shale were noted in the lower zone of the Weber (?) formation, usually above the highly bituminous shale, and in the middle zone associated with the limestone. Most of those noted were not fossiliferous, but in a few localities—for example, on the south side of Empire Hill and on the hill northeast of Levick—many marine invertebrates were obtained. In the Trout Creek sections both brackish-water and marine invertebrates were found in some of the shales.

Sandy shale is most common in the upper part of the lower zone and in the middle zone of the formation. The beds are black, dark gray, light gray, tan, brown, red-brown, and red. In character they range from nearly pure shale to sandstone. The texture is usually finest in the lower beds and becomes coarser higher in the section, but this is not universal, as there are many and locally abrupt changes in lithology. Many of the sandy shale beds are micaceous, especially in the middle zone, the mica flakes being generally small but locally surprisingly abundant. (See pl. 4, *C*.) Certain beds of black sandy shale near Alma are so micaceous that in hand specimens of fresh material they might easily be mistaken for mica schist.

Limestone may occur throughout the formation (see pls. 5, *A*, *B*; 6, *A*, *B*), but it is most common in the middle zone. The thickness of the beds ranges from less than 1 inch to 50 feet, but most beds are less than 10 feet thick. Where fresh the color is dark gray to black, but many beds on weathering take on a brownish tint, becoming a rich chocolate-brown. Usually the limestone is rather massively bedded and has a distinctly crystalline texture. Analyses show it to be dolomitic and commonly somewhat ferruginous.

Most of the limestone beds contain fragments of marine organisms. In a few beds good fossils are abundant, but the crystallization of the limestone has spoiled many of the fossils and made them difficult to obtain from unweathered rock.

Though some beds of limestone were traced for miles along the outcrop, the individual beds tend to be lenticular and discontinuous. Calcareous deposition was widespread at some horizons, however, for limestone and calcareous shale occur at about the same stratigraphic levels, though the individual beds do not carry through.

In the sections actually measured the limestone beds form 3 to 8 percent of the total thickness of the sediments.

Sandstone is the most common rock of the Pennsylvanian deposits. (See pl. 4, *B*.) Together with the grit and conglomerate it makes up 83 percent of the sediments in the sections measured. The color is usually a light gray, but white, dark gray, black, pink, tan, brown, and red were also noted. Many of the beds in the lower part of the section are intensely black, owing to some carbonaceous, apparently bituminous substance in the cementing material. Certain specimens are composed largely of coarse grains of white quartz in a black cement that has the color and luster of liquid shoe polish. Emmons [39] remarks concerning these black sandstones:

> The sandstones often contain so large a quantity of carbonaceous material as to become quite black. This carbonaceous material, which is insoluble in ether, alcohol, or sulphide of carbon, is probably either graphite or anthracite.

The belief that the gray and black coloration is due to carbonaceous material is further strengthened by the fact that in the contact areas around the larger intrusions the sandstone beds are commonly white, whereas the same beds where not affected by the intrusions are dark. This change can be well seen in the amphitheater above the London mine, northwest of Pennsylvania Mountain. Here fine-grained sandstone beds in the lower part of the Weber (?) formation have been altered to white quartzite.

In most of the sections studied the sandstone beds become coarser in texture at progressively higher stratigraphic levels. They also tend to become progressively more arkosic, and the upper part contains many thick layers of arkosic grit or conglomerate. This grit is composed of pieces of quartz, feldspar, some mica, and more rarely gneiss, schist, or granite (pls. 3, *A*, *D*; 6, *B*). Fragments of sandstone, shale, and limestone were noted in a few specimens. The constituent fragments may be well rounded and smooth, but in many specimens the rounding is not complete. Feldspar may be present in such amounts as to give a pink tint to the rock. Mica is noticeable in most of the beds of sandstone and grits and is surprisingly abundant in some of them (pl. 4, *A*, *D*)—in fact, so abundant that Emmons [40] doubted that it could have been derived from the older rocks. Observations of the pre-Cambrian rocks of the district, however, show that they could easily have supplied the mica, for many of the larger pieces contain inclusions of hematite identical with those observed in the mica of the pre-Cambrian granite, and a microscopic study of the mica in the sandstone and shale shows that it was deposited as a part of the original sediment. The mica flakes are torn, frayed, scratched, crinkled, and show other evidences of wear.

The individual beds of grit may locally attain thicknesses of 40 or 50 feet but are decidedly lenticular. In many places they have well-developed cross-bedding.

The following descriptions of the samples collected from the Windy Ridge section is given to show in

[39] Emmons, S. F., Geology and mining industry of Leadville, Colo.: U.S.Geol. Survey Mon. 12, p. 68, 1886.

[40] Emmons, S. F., U.S.Geol. Survey Geol. Atlas, Tenmile district special folio (no. 48), p. 1, 1898.

detail the character of the sandstone and associated rocks. This is a typical section of the upper zone of the Weber (?) strata.

Samples collected from the upper part of the Weber (?) formation on Windy Ridge, north of Alma

[See Windy Ridge section, p. 37]

Black conglomeratic quartzite; grains chiefly quartz and feldspar, well rounded, 0.8 to 11 mm; quartz grains mostly gray with pronounced greasy luster, few white or transparent, colorless; feldspar grains white to creamy white with good cleavage and slight alteration to kaolin; a small amount of muscovite in flakes 0.8 mm across.

J–23. Dark-gray shaly micaceous quartzite; resembles quartz-mica schist; quartz grains angular and subround, 9.30 mm maximum; muscovite relatively abundant, in decidedly crinkled plates 20 mm across; a little biotite.

J–24. Gray micaceous sandstone. Quartzitic. Distinctly laminated. Sand grains angular, 9.15 mm. Muscovite abundant. Biotite present in small amounts. The rock has metamorphic characteristics, with the appearance of a phyllite. Mica grains are 0.40 mm in diameter. The specimen is greenish when wet.

J–25. Gray quartzitic conglomerate. Large grains well rounded. Grains variable in size, 20.0 mm maximum diameter. Largest grain consists of shaly sand or quartzite similar to J–30 and J–49–S. A few of the grains are of attached quartz and feldspar, probably granite pebbles. Muscovite present in small amounts.

J–25–40. Micaceous quartzite sandstone. Dull, dark-lavender color. Quartz grains angular to subround, 0.30 mm maximum diameter. Muscovite very abundant. Some flakes 5.0 mm across. The flakes are decidedly crinkled and contain hematite inclusions.

J–26. Micaceous quartzite sandstone. Looks like quartz-mica schist or phyllite. Variable grain size, 0.30 mm maximum, angular to subround.

J–28. This specimen is similar to J–31 except that some of quartz grains are as much as 2.0 mm in diameter.

J–29. Gray dolomite. Massive, fine-textured, even-grained. Diameter of grain on cleavage faces averages 0.29 mm. Irregularly fractured. Thin layers of calcite along fractures.

J–30. Gray shaly micaceous quartzite. Quartz grains angular and subround, 0.30 mm maximum. Muscovite relatively abundant. Material poorly laminated. The shale layers are fine-textured and crinkled. Muscovite flakes are also crinkled. Somewhat green when wet. Looks like mica schist.

J–31. Dark-gray micaceous sandstone. Massive, nearly quartzite. Fine, uniform grains. The quartz grains are angular to subround, 0.30 mm average diameter but range from 0.11 to 0.60 mm. The muscovite flakes are as much as 12 mm in diameter, and many show hematite inclusions. The largest flakes occur along the indistinct bedding planes and along fractures. The specimen has the appearance of a mica schist.

J–32. Gray micaceous shaly sandstone. Very quartzitic, distinctly laminated. Sand grains angular, 0.15 mm average diameter. Muscovite abundant. Biotite present in small amounts. The mica grains are 0.40 mm in diameter. Color greenish when wet. The rock has the appearance of a phyllite.

J–34. Gray sandy shale. Alternating light and dark-gray bands. Light bands are sandy, but sand grains are very fine, 0.06 mm average diameter. The rock is well laminated and breaks along the least sandy streaks. Light streaks slightly calcareous. The rock has been altered and appears like a schist.

J–35. Gray quartzite. Massive. Grains of variable size, angular to round, 2.0 mm maximum diameter. Minerals are essentially quartz, feldspar, and muscovite. The quartz is gray and has a very greasy luster. The feldspar shows some alteration.

The Pennsylvanian sediments have all been definitely consolidated and lithified since they were deposited. The shale is well compacted, the limestone is crystalline, and the sandstone and grit are thoroughly cemented. In fact, where encountered in fresh outcrops and in mine workings the limestone, sandstone, and grit are decidedly hard rocks.

In the vicinity of Tertiary intrusive rocks metamorphism has aided in altering and hardening the sediments. The shale has become slate and the sandstone quartzite. Color changes have also resulted.

Sandstone, grit, shale, and limestone in measured sections of Pennsylvanian sediments

[None of the sections measured reach to the top of the formation]

	Horseshoe		London Mountain		Pennsylvania Mountain		Empire Hill		Board of Trade		Evans Peak		Trout Creek (Upper)		Windy Ridge	
	Feet	Percent	Feet	Percent	Feet	Percent	Feet	Percent	Feet	Percent	Feet	Percent	Feet	Percent	Feet	Percent
Sandstone	1, 173	64	488	51	578	36	341	38	260	30	121	34	205	11	49	15
Shale	143	8	147	16	231	15	361	41	99	11	103	30	1, 513	81	6	1
Conglomerate and grits	416	23	277	29	693	45	41	5	490	56	98	28	0	0	258	78
Limestone	84	5	38	4	58	4	143	16	23	3	30	8	147	8	18	5
	1, 816	100	950	100	1, 560	100	886	100	872	100	352	100	1, 865	100	331	99

Paleontology.—The fossils obtained from the Weber (?) formation include plants and animals. The plant fossils are algae and land plants. The algae are considered to be brackish-water and fresh-water forms, and the commonest type makes small glassy rods and tubes. The land plants collected were examined by Read, who has described the species.[41] The species found at the several localities are as follows:

[41] Read, C. B., A flora of Pottsville age from the Mosquito Range, Colo.: U.S. Geol. Survey Prof. Paper 185–D, 1934.

8050 (J–36 of Mr. Johnson's Pennsylvania Mountain section):

- Stigmaria verrucosa.
- Neuropteris dluhoschi.
- Sphenopteris asplenioides.
- Cordaites sp.

This collection must be regarded as representing a middle Pottsville flora, as indicated by the *Neuropteris*.

8049 and 8083 (J–42 and J–43 of Mr. Johnson's Evans Peak section):

- Lepidostrobus weberensis.
- Stigmaria verrucosa.
- Calamites sp.
- Asterophyllites longifolius?
- Neuropteris dluhoschi.
- Neuropteris heterophylla.
- Neuropteris cf. N. gigantea.
- Sphenopteris cf. S. microcarpa.
- Sphenopteris cheathami.
- Diplotmema patentissima.
- Adiantites rockymontanus.
- Cordaites sp.
- Cordaianthus sp.
- Cordaicarpon sp.
- Trichopitys whitei.
- Dactylophyllum johnsoni.

The plants here listed were collected at a horizon somewhat higher than that of the plants in the first list. The development of *Neuropteris* and *Sphenopteris* suggests a middle Pottsville age.

Besides the forms identified, a large amount of well-preserved silicified wood was obtained along Trout Creek. (See pl. 7, *B*.)

The animal fossils are listed in the table below. These include only forms collected during the present work. A few other forms have been reported by earlier geologists but are not included, as there is some doubt as to the locality, horizon, or identification. The fossils listed in the table were identified by the writer and checked by George H. Girty, of the United States Geological Survey. Only crinoid stems, *Chonetes geinitzianus*, *Marginifera ingrata*, *Productus cora*, and *Productus coloradoensis* were common. Of the other species 26 are new.

Distribution by locality of fossils obtained from the Weber (?) formation

	6851c	6851e	6852	6852a	6853	6854	6855	6855a	6856	6857	6858	6860	6860b	6860c	6860d	6860e	6860f
CORALS																	
Amplexus zaphrentiformis						×											
Lophophyllum profundum								×									
Lophophyllum profundum var. sauridens			×								×						
Lophophyllum sp.?						×											
ECHINODERMS																	
Archaeocidaris sp.?				×			×			×							
Archaeocidaris cratis				×													
Crinoid stems			×	×	×	×	×	×		×			×	×			
Echinocrinus sp.?					×												
BRYOZOANS																	
Fenestella sp.?				×													
Fistulipora sp.?							×										
Polypora sp.?					×											×	
Rhombopora lepidodendroides				×										×			
Septopora sp.?				×													
Stenopora sp.?				×													
BRACHIOPODS																	
Chonetes geinitzianus?			×	×				×	×								
Chonetes aff. C. geinitzianus							×										
Chonetes sp.?					×												
Cleiothyridina pecosi			×														
Cleiothyridina pecosi?								×									
Cleiothyridina pecosi var									×								
Composita subtilita				×	×		×	×	×								
Composita sp.?									×	×							
Derbya crassa							×										
Lingula carbonaria												×					
Lingula sp.?															×		
Marginifera ingrata			×					×									
Marginifera ingrata var			×														
Marginifera muricata											×						
Marginifera sp.?		×															
Orbiculoidea missouriensis		×															
Orbiculoidea sp.?			×				×										
Productus coloradoensis			×	×			×		×				×				
Productus cora			×	×			×	×		×			×	×		×	
Productus cora var. nodosus			×				×	×									
Productus aff. P. pertenuis								×									
Productus n. sp. aff. P. semistriatus							×										
Productus sp.?					×				×	×							
Pustula nebraskensis				×									×				
Pustula nebraskensis var							×										
Pustula n. sp								×									

Distribution by locality of fossils obtained from the Weber (?) formation—Continued

	6851c	6851e	6852	6852a	6853	6854	6855	6855a	6856	6857	6858	6860	6860b	6860c	6860d	6860e	6860f
BRACHIOPODS—continued																	
Spirifer opimus									×								
Spirifer opimus var. occidentalis													×			×	
Spirifer opimus var							×										
Spirifer rockymontanus			×	×													
Spirifer sp					×												
Squamularia perplexa?					×												
Squamularia sp										×							
Strophalosia spondyliformis								×									
PELECYPODS																	
Aviculipecten scalaris																×	
Deltopecten occidentalis				×													
Deltopecten aff. D. scalaris							×										
Deltopecten sp														×			
Edmondia sp.?													×				
Leda n. sp														×			
Leda sp.?													×				
Lima sp.?			×		×												
Myalina perniformis				×									×				
Nucula sp.?					×												
Pleurophorus subcostatus?									×								
Schizodus sp.?									×					×			
Yoldia glabra									×								
GASTROPODS																	
Aclisina (4 n. sp.)					×												
Bellerophon crassus					×												
Bellerophon n. sp														×			
Bellerophon sp.?					×					×							
Bucanopsis sp.?													×				
Bulimorpha sp.?														×			
Bulimorpha n. sp					×												
Cyclonema n. sp					×												
Enchostoma sp.?							×										
Euomphalus 4 n. sp					×												
Euphemus carbonarius								×									
Euphemus nodicarinatus?													×				
Gastropod fragments	×																×
Goniospira sp.?					×												
Meekospira sp.?			×		×												
Microdoma 2 n. sp					×												
Naticopsis 5 n. sp					×												
Orthonema? sp.?					×												
Patellostium n. sp														×			
Patellostium sp.?										×							
Phanerotrema grayvillense			×														
Pharkidonotus percarinatus														×			
Placunopsis sp														×			
Plagioglypta sp.?														×			
Pleurotomaria 2 n. sp					×												
Pleurotomaria sp.?					×												
Schizostoma catilloides					×								×				
Sphaerodoma primigenia														×			
Sphaerodoma sp.?			×		×												
Trachydomia 2 n. sp					×												
Zygopleura sp.?					×									×			
Conularia crustula			×														
Dentalium sp.?														×			
CEPHALOPODS																	
Goniatites sp.?			×														
Orthoceras sp.?									×								×
Protocycloceras sp.?			×														
CRUSTACEANS																	
Estheria aff. E. ortoni												×					
Phillipsia sp.?				×			×										
Trilobite fragment			×														
VERTEBRATES																	
Coprolites														×			×
Fish tooth					×												

6851=J–6. Horseshoe section (bed 8), hill north and northeast of old town of Leavick.

6851a=J–7. Horseshoe section (bed 13), hill north and northeast of old town of Leavick.

6851b=J–8. Horseshoe section (bed 25), hill north and northeast of old town of Leavick.

6851c=J–9. Horseshoe section (bed 28), hill north and northeast of old town of Leavick.

6851d=J–10. Horseshoe section (bed 30), hill north and northeast of old town of Leavick.

6851e=J–11. Horseshoe section (bed 45), hill north and northeast of old town of Leavick.

6852=J–12. Ridge south of the Horseshoe cirques, near top about 150 feet above porphyry. (Same bed as J–7.)

6852a=J–18. Same as J–12 but stratigraphically about 50 feet higher. (Same bed as J–8.)

6853=J–19. Hoosier Ridge, about 2 miles north of Hoosier Pass. Represents a horizon just about at the boundary between the Weber (?) and Maroon formations. (Gastropod fauna mostly new.)

6854=J–37. Pennsylvania Mountain section (bed 50), on sharp crest on west end. (Alma district.)

6855=J–41. Empire section (bed 12), south side of Empire Hill. (Leadville district, south end, about 200 feet above fault.)

6856=J–45. Evans Peak section (bed 46), at top of Evans Peak, shoulder below monument.

6855a=J–50. Empire section (bed 14), locality same as J–41 but about 70 feet higher stratigraphically.

6857=J–51a and J–52a. Jacque Mountain, about 3 miles west-northwest of Kokomo; from the Jacque Mountain limestone (top bed of Emmons' Maroon formation). Probably Permian.

6858=J–53. Ridge south of Jacque Mountain and west of Kokomo (Tenmile quadrangle). Horizon uncertain, supposed to be in the Maroon formation.

6859=J–60. Cliffs north of the Eagle River about three-fourths of a mile below Minturn, Eagle County, Colo. Somewhere in the Maroon formation.

6860=J–74. Trout Creek section (bed 32, center). Along Trout Creek about 1½ miles from old Colorado Fuel & Iron Co.'s quarries, in valley bottom west of road.

6860a=J–75. Trout Creek section (bed 32, top).

6860b=J–77. Trout Creek section (bed 43). Same locality as J–74–75 but 124 feet higher stratigraphically.

6860c=J–78. Trout Creek section (bed 48). Same locality as J–77 but about 70 feet higher stratigraphically.

6860d=J–84. Trout Creek section (bed 89).

6860e=J–85. Trout Creek section (bed 90).

6860f=J–86. Trout Creek section (bed 91).

Correlation.—The fossils obtained indicate that the lower and middle zones of the Weber (?) formation are of Pennsylvanian age and equivalent to the middle Pottsville and part of the upper Pottsville of the East. No equivalent of the lower part of the Pottsville was observed.

In Colorado the Weber (?) formation is the equivalent of the Lower Sangre de Cristo of the Sangre de Cristo region, a portion of the Hermosa formation of southwestern Colorado, and at least some of the lowest part of the Fountain formation of the Colorado Springs region. It is also equivalent to part of the Magdalena formation of northern New Mexico.

Detailed sections.—Except where otherwise noted the sections given below were measured by the writer and his assistant, Mr. C. D. Hier. The exact method used differed somewhat in different sections. Wherever possible the work was done with a tape on steep slopes and cliffs. Where the slopes were gentle or there were large covered areas transit and stadia were used. On the longer sections the tape results were checked by surveying methods.

Section on London Mountain

[Section in lower part of the Weber (?) formation on London Mountain, commencing at saddle west of North London mine. Includes the lower zone and about half of the middle zone. Section measured up the crest to the southeast along London Mountain to the London fault]

		Feet
	Pre-Cambrian. Fault contact.	
93.	Quartzite, badly shattered	55. 0
92.	Shaly sandstone	5. 0
91.	Brownish-gray limestone	6. 0
90.	Coarse light-gray grit	35. 0
89.	Porphyritic quartz monzonite dike	20. 0
88.	Quartzite and grit	65. 0
87.	Conglomeratic sandstone	35. 0
86.	Sandy shale	8. 0
85.	Light-gray conglomeratic grit	75. 0
84.	Red shaly sandstone	5. 0
83.	Conglomeratic sandstone	85. 0
82.	Thin limestone. Weathered into small brown pieces. Contains abundant fragments of crinoid stems, a few bryozoans, pieces of brachiopod shells and an orbiculoidea (J–17)	6. 0
81.	Black papery shale	6. 4
80.	Gray conglomeratic grit with numerous small quartz pebbles	30. 2
79.	Dark reddish brown, sandy, micaceous shale. Small fault about 6 feet displacement	26. 0
78.	Conglomeratic grit, light gray, almost white. Abundant quartz pebbles	11. 0
77.	Gray sandstone with interbedded red sandy shale	8. 1
76.	Red sandy shale, slightly micaceous	5. 1
75.	Gray grit. Numerous quartz pebbles up to 1 inch long. Poorly cross-bedded. Just below top pebbles increase in size to about 2½ inches	34. 0
74.	Gray sandy shale, slightly micaceous	3. 0
73.	Coarse light-gray grit with small quartz pebbles	5. 0
72.	Badly shattered material. Fault with iron-stained fine material along its trace	40. 0
71.	Gray sandstone	12. 0
70.	Gray shale, with limy concretions	6. 2
69.	Gray quartzite	3. 5
68.	Black papery shale, slightly micaceous	1. 0
67.	Gray quartzite	5. 1
66.	Gray sandy shale; weathers light brown	6. 4
65.	Hard gray sandstone	10. 1
64.	Dark-gray sandy limestone; weathers brown	3. 0
63.	Light brown-gray shale containing abundant rounded pieces of brown limestone	9. 2
62.	Gray fine-grained quartzite	8. 0
61.	Black, impure limestone, nodular; contains carbonaceous particles	5. 5
60.	Yellowish-gray friable sandstone nodular toward top	6. 5
59.	Dark-gray quartzite	4. 6
58.	Sandy, slightly micaceous shale	1. 7
57.	Limy shale grading upward into a nodular limestone; weathers brown	4. 7
56.	Dark-gray quartzite, weathering brown	4. 5
55.	Dark-gray thin-bedded sandstone with shaly bedding planes	5. 0
54.	Dark-gray to black sandy shale. A little fine-grained mica	2. 1

Section on London Mountain—Continued

	Feet
53. White conglomeratic quartzite. Abundant quartz pebbles as much as 1½ inches across	8. 5
52. Irregularly bedded dark-gray sandstones and brownish-gray shale	15. 0
51. Light-gray to white conglomeratic grit. Contains abundant quartz pebbles as much as 2½ inches across. Cross-bedded	13. 0
50. Shaly sandstone like that below fault	4. 5
49. Gray to brown shaly sandstone	1. 2
48. Dark-gray quartzite and fine-grained shaly sandstone	7. 5
Porphyry (quartz monzonite); irregular sill	45+
47. Sandy shale like that under sill. Igneous rock apparently has wedged into the shale	2. 3
Greenish-white porphyry; about	3. 6
46. Olive-brown altered shale, alternating with thin sandstone and some brownish shale	6. 5
45. Black quartzite	3. 5
Porophyry (quartz monzonite) sill; about	10
44. Alternating quartzite and sandy shale	3
43. Dark-gray calcareous sandstone, very calcareous at base. Weathers into peculiar pitted nodular brown pieces	2. 5
42. Gray sandstone	2
41. Gray sandy shale, micaceous	2. 8
40. Gray quartzite	1. 6
39. Gray impure limestone; weathers brown; contains small angular particles of white quartz; becomes very sandy at top	3. 6
38. Black sandy shale	2. 7
37. Coarse sandstone with sandy shale breaks. These beds are irregular and pinch and swell. Streaks of pebbles at base of some of the sandstone	4. 7
36. Gray shale, slightly micaceous, sandy	1. 6
35. Dark-gray quartzite	4. 5
34. Light-gray sandy shale	1. 1
33. Coarse gray sandstone, with small quartz pebbles scattered through it. Rather massively bedded. Thin breaks of light-gray sandy shale between some beds	17. 3
Porphyry sill; about	25
32. Coarse sandstone, almost white; contains scattered quartz pebbles as much as 1½ inches in diameter	13. 1
Several small faults. Similar sequences of beds in the several blocks and on far side. Section continued beyond.	
31. Yellowish-brown sandy shale	7. 0
30. Black quartzitic sandstone, massively bedded	12. 9
29. Light-gray, limy, sandy shale; weathers tan	4
28. Dark-gray quartzite, shaly, coarsely ripple-marked bedding planes	1. 5
27. Light-brown to black sandy shale; contains some vegetable material	3. 3
26. Greenish-gray quartzite	5
25. Coarse white grit, with conglomerate streaks	12
24. Conglomerate. White quartz pebbles; some shaly pieces with an inky-black cement (pebbles 1 inch or less, shale pieces larger)	. 8
23. Black shale; contains abundant poorly preserved plant stems (J–15)	1. 5
22. Sandstone, 6 inches to 2 feet thick	1. 0
Suggestions of a slight unconformity, as the limestone has an irregular upper surface; the sandstone is of variable thickness.	
21. Black impure limestone; weathers rich brown	3. 2
20. Yellowish-gray calcareous sandstone, slightly micaceous; weathers into nodular fragments. Crosses a fault	6. 1
19. Black shaly sandstone	1. 7
18. Dark-gray quartzite. Coarse ripple marks on top of layers. Massively bedded	5. 5
17. Alternating gray quartzite and sandy shale	1. 4
16. Black sandy shale; contains a little fine mica	5. 1
15. Black quartzite	7. 1
14. Brownish-black, sandy limestone, alternating with light-gray sandy shale. Limestone is probably somewhat dolomitic. Dark gray when fresh, but most of the material is brown. Top layer contains large irregular "ironstone" concretions	11. 7
13. Dark-gray to black gritty quartzite, hard, massively bedded. Along stratification planes are streaks of white quartz pebbles as much as five-eighths of an inch across and in a few places black micaceous shale streaks. Some shale fragments are included in grits (J–13)	8. 7
12. Light-gray shaly sandstone, slightly micaceous, soft	4. 3
11. Light-gray, almost white quartzite, massively bedded	7. 0
10. Light-tan sandy micaceous shale, fine-grained; contains nodules of siliceous material that weathers dark	2. 5
9. Light-gray coarse-grained sandstone; weathers brown. Beds 6 inches to 2½ feet thick	12. 0
8. White to light-gray quartzite; contains two streaks of black micaceous shale	3. 6
Porphyry	25. 5
7. Dark-gray quartzite, medium-grained, and hard grit, light brownish gray	1. 1
6. Black sandy shale, carbonaceous, slightly micaceous	. 5
5. Dark-gray fine-grained quartzite	1. 3
4. Black sandy shale, slightly micaceous; contains a few suggestions of plant fragments	1. 0
3. Gray quartzite, massively bedded, medium fine-grained. Some white quartz pebbles, half an inch or less in size, along bases of some layers	18. 5
Porphyry sill. Monzonite, light gray. A small fault may occur, but there appears to be only slipping caused by a wedge-shaped sill.	
2. Gray quartzite, alternating with a black, highly carbonaceous sandy shale that has been baked until it has almost an anthracite luster. Some shale surfaces show pyrite in iridescent coatings. A few undeterminable plant fragments in shales	27. 3
1. Dark-gray quartzite, hard, massively bedded, probably somewhat silicified by the underlying sill	7. 4
Porphyry sill.	

The base of the formation is concealed, but outcrops in adjoining canyons indicate that there are about 60 feet of beds between the base of the section measured and the top of the Leadville.

Section of lower part of Weber (?) formation at Evans Peak

[About 3 miles east of Leadville, Colo., south of Mosquito Pass. All of the section is in the lower zone. Present erosion surface on top of the peak]

	Feet
51, 50. White pebbly grit, some layers slightly micaceous. Pronounced cross-bedding	17. 0
49. Dark-gray grit; contains pebbly streaks	28. 3
48. Dark-gray limestone; weathers brownish	11. 0

Section of lower part of Weber (?) formation at Evans Peak—Continued

	Feet
47. Dark-gray sandstone, somewhat gritty	12. 3
46. Dark-gray limestone; weathers brown; thin-bedded, contains the following marine fossils (locality 6856): *Cleiothyridina pecosi* var., *Composita subtilita*, *Composita* sp., *Chonetes geinitzianus?*, *Productus coloradoensis*, *Productus* sp.?, *Spirifer opimus*, *Pleurophorus subcostatus?*, *Schizodus* sp.?, *Yoldia glabra*	8. 3
45. Dark-gray shale	9. 6
44. Massive light-gray grit	31. 0
43. Massive light-gray sandstone, with thin streaks of interbedded dark-gray shale. Both sandstone and shale slightly micaceous	28. 1
42. Sandstone, thin-bedded, slightly micaceous	2. 0
41. Black sandy shale	1. 3
40. Dark-gray impure limestone; weathers gray-brown	5. 2
39. Dark-gray alternating sandstone and shale	12. 4
38. Light-gray grit with scattered quartz pebbles 1½ inches in size	15
37. Alternating sandstone and shale	21. 0
36. Dark-gray shale	4. 1
35. Dark-gray sandstone; porphyry sill	2. 8
34. Alternating black sandstone and shale; porphyry sill (thin)	15. 0
33. Alternating gray sandstone and black shale	6. 1
32. Dark-gray calcareous grit	2. 3
31. Dark-gray sandy shale. Poor plant fragments	. 8
30. Light-gray fine-grained sandstone	2. 5
29. Dark-gray sandy shale	. 4
28. Light-gray, almost white fine-grained sandstone, massively bedded	2. 8
27. Alternating thin limestone and black sandy, slightly micaceous shale	8. 8
26. Coarse gray sandstone. Scattered quartz pebbles, three-quarters of an inch in diameter	3. 4
25. Black flaky shale	. 8
24. Massive light-gray sandstone	3. 2
23. Black, slightly sandy shale	1. 0
22. Massive dark-gray sandstone	2. 5
21. Alternating black, slightly micaceous shale and thin dark-gray sandstone	2. 0
20. White to light-gray grit; contains numerous quartz pebbles, 1 inch in diameter	4. 1
19. Dark-gray, slightly micaceous shale	1. 1
18. Gray sandstone	1. 8
17. Dark-gray shale. Contains some beautifully preserved plants, especially ferns. The forms collected from this layer and from the black "slate" mentioned below (localities 8049 and 8083) were identified by C. B. Read. (See p. 31.)	. 4
16. Light-gray sandstone, fine-grained	5. 5
15. Light-gray shale	. 4
14. Light-gray sandstone, fine-grained	2. 5
13. Dark-gray sandy shale. Very friable at base	8. 8
12. Fine-grained white sandstone. Massively bedded	6. 4
11. Black "slate" with a few interbedded sandstones; carries a few well-preserved plants listed on p. 31 (J–43)	3. 9
10. Shaly sandstone, somewhat coaly	2. 8
9. Dark-gray sandstone; carries abundant poorly preserved plant stems	3. 1
8. Black carbonaceous shale, somewhat sandy	2. 6
7. White sandstone, massively bedded	12. 0
6. Black carbonaceous shale; contains much vegetable material	1. 5
5. Dark-gray limestone, fine-grained; weathers brown	2. 0

Section of lower part of Weber (?) formation at Evans Peak—Continued

	Feet
4. Black slaty shale; contains numerous plant impressions. A few ferns obtained from this bed. About 1 foot of coaly shale at top	4. 7
3. Dark-gray shaly sandstone	2. 6
Mainly black shale, somewhat slaty. Sill several hundred feet thick	25+
2. Some shale and sandy shales between sills	50+
Sills	
1. Largely covered; appears to be mainly or entirely black shale	35±
Unconformity.	
Leadville limestone	

Section of part of Pennsylvanian beds (Weber ? formation) along Trout Creek

[Section commences at mouth of second gulch north of Colorado Fuel & Iron Co.'s old kilns, extends northeast for several hundred feet to a conspicuous limestone, follows it along the strike for nearly a mile southward, then extends perpendicular to the strike across the valley to a fault, occasionally offsetting along the strike until better outcrops of overlying beds could be obtained. The section starts at the base of the formation and includes nearly all of it. It would appear that the last beds obtained in the section are close to the base of the red beds, to judge by outcrops farther up the valley. Some red beds appear among the gray farther up the valley but beyond some faults]

	Feet
Faults.	
124. Crumpled and brecciated material	85±
123. Thin sandstone and shaly sandstone; some calcareous streaks. Some layers show very small ripple marks. Material fine-grained	60. 0
122. Yellowish-gray sandstone, slightly arkosic, mainly thin-bedded	41. 0
121. Sandy shale	22. 8
120. Thin impure dark-gray limestone (J–96)	4. 6
119. Gray to greenish-gray sandy shale with a few thin sandstones. One sandstone contains black-shale pebbles	34. 5
118. Gray calcareous sandstone, weathered brown	1. 6
117. Green-gray shaly sandstone	6. 0
116. Gray impure limestone with numerous enclosed pieces of black shale as much as 3 inches across. Resembles a caliche conglomerate	2. 8
115. Gray calcareous shale with streaks of limestone and black shale	14. 0
114. Slabby gray limestone	. 8
113. Black shale	5. 0
112. Slabby impure limestone; contains a few fine mica flakes	1. 3
111. Sandy shale with interbedded slabby sandstone, 8 inches or less thick	30. 0
110. Gray, slightly micaceous sandstone and shaly sandstone. A few streaks of shale. Sandstone medium to fine grained	34. 0
109. Gray slabby ripple-marked sandstone. Toward top becomes gritty and even contains streaks of conglomerate. The coarse material is arkosic with feldspar pieces as much as three-quarters of an inch across and only slightly rounded	14. 0
108. Gray shale	3. 3
107. Gray sandstone, slabby, surfaces ripple marked; contains a few poor impressions of land plants	2. 3
106. Gray to black shale with streaks of interbedded brownish limestone 4 inches or less thick	68. 3
105. Sandstone, thin-bedded, surfaces ripple marked	8. 2
104. Gray to black shale, with thin streaks of brown limestone	63. 3
103. Gray limestone; weathers tan	1. 3
102. Gray shale	5. 5

Section of part of Pennsylvanian beds (Weber? formation) along Trout Creek—Continued

	Feet
101. Fine-grained gray-brown sandstone	0. 8
100. Black shale with small calcareous masses and some streaks of shaly limestone	42. 0
99. Gray limestone; weathers light brown; contains small fossils, probably algal tubes	4. 1
98. Gray calcareous shale	4. 0
97. Black limestone	2. 1
96. Black shale	6. 0
95. Gray nodular limestone; contains abundant tubular masses with concentric structure	. 8
94. Gray sandy mudstone; contains some calcareous concretions	2. 6
93. Black shale	19. 3
92. Gray nodular limestone; contains tubular masses with a concentric structure that suggest algae or replaced plant stems	. 7
91. Black shale. Lower portion contains calcified objects suggesting coprolites, also fragments of gastropods and *Orthoceras* (locality 6860f)	11. 0
90. Yellowish chalky limestone; carries marine fossils: *Polypora* sp.?, *Productus cora, Spirifer opimus* var. *occidentalis, Aviculopecten scalaris* (locality 6860e)	2. 6
89. Black shaly limestone; carries small fossils—Lingulas and possible ostracodes (locality 6860d)	1. 3
88. Black shale; suggestions of small fossils	58. 6
87. Greenish-gray shaly limestone	. 8
86. Black papery shale	14. 6
85. Thin fibrous calcite bands half an inch to 3 inches thick, containing algae; two such bands 3 inches apart	1. 0
84. Brown sandy shale, soft	40. 0
83. Gray calcareous shale	4. 7
82. Dark-gray limestone	1. 3
81. Gray limy shale	4. 2
80. Sill, dark-green coarse-grained rock, about 20 feet thick.	
79. Calcareous shale	1. 3
78. Black, slightly sandy shale	9. 2
77. Black limestone	1. 4
76. Black papery shale	5. 8
75. Thin limestone and interbedded calcareous shale. Contains a few fossils—*Lingula carbonaria* and *Estheria* aff. *E. ortheni* (locality 6860)	4. 6
74. Dark-gray limestone, coarsely rippled surface	1. 9
73. Black papery shale with interbedded limestone. Limestone beds average about 0.3 foot thick and are spaced about 2½ feet apart	20. 1
72. Dark-gray limestone; weathers brown. Contains numerous algal tubes	1. 0
71. Black papery shale	6. 6
70. Dark-gray limestone	. 6
69. Black shale	2. 1
68. Dark-gray nodular limestone; weathers brown	1. 6
67. Black shale with thin beds of gray calcareous shale here and there	10. 0
66. Dark-gray limestone; weathers brown	1. 8
65. Black shale	5. 2
64. Gray sandstone	2. 1
63. Gray shaly sandstone	11. 4
62. Brownish-gray medium to fine-grained sandstone. Slabby. Shows small cross-bedding. Contains fragments of land plants (calamite, etc.) in poor state of preservation, also small pieces of mica as much as an eighth of an inch across	7. 5

Section of part of Pennsylvanian beds (Weber? formation) along Trout Creek—Continued

	Feet
61. Sandy shale, soft, brown	40. 0
60. Gray calcareous shale (J–80)	4. 7
59. Dark-gray limestone	1. 3
58. Gray calcareous shale	4. 2
Sill; dark green coarse-grained rock about 20 feet thick.	
57. Gray calcareous shale	1. 3
56. Black shale, slightly sandy	9. 2
55. Black limestone	1. 4
54. Black papery shale	5. 8
53. Thin limestone with interbedded calcareous shale	4. 6
52. Dark-gray limestone, surface coarsely rippled	1. 9
51. Shale, partly covered	4. 5
50. Dark-gray limestone	. 9
49. Black shale with thin limestone streaks	11. 0
48. Thin limestone (beds average 2 inches) with interbedded shale. One very fossiliferous shale yielded crinoid stems, *Rhombopora lepidodendroides, Productus cora, Deltopecten* sp.?, *Placunopsis* sp.?, *Leda*, n. sp., *Schizodus* sp., *Bellerophon* n. sp., *Patellostium* n. sp., *Plagioglypta* sp.?, *Bulimorpha* sp., *Pharkidonotus percarinatus, Sphaerodoma primigenia, Zygopleura* sp.?, *Dentalium* sp.?, *Aclisina* sp., and coprolites (locality 6880c)	12. 0
47. Black carbonaceous shale	14. 0
46. Gray limestone, thin-bedded	1. 4
45. Black papery shale	24. 0
44. Calcareous shale with thin limestone	29. 1
43. Gray limestone; weathers platy. Fossiliferous, yielding crinoid stems, *Septopora, Productus cora, Productus coloradoensis?, Pustula nebraskensis, Spirifera opimus* var. *occidentalis, Edmondia* sp.?, *Leda* sp.?, *Mylina perniformis, Bucanopsis* sp.?, *Euphemus nodicarinatus?, Schizostoma catilloides* (locality 6860b)	1. 8
42. Black carbonaceous shale	11. 3
41. Gray limestone	. 8
40. Dark-gray shale with numerous thin streaks of brownish-gray limestone	65. 5
39. Black limestone	1. 6
38. Gray shale	3. 0
37. Brown limestone; contains shale flakes	. 8
36. Dark-gray sandy limestone; contains a few very fine mica flakes	2. 1
35. Gray shale, becoming jet-black toward top	28. 6
34. Black limestone, thin-bedded, slightly fossiliferous; contains a few marine fossils	1. 3
33. Dark-gray, somewhat calcareous shale	4. 1
32. Brown shaly limestone, very thin-bedded. One layer near middle largely of algal origin. Carries fossils in center. Top layer is chocolate-brown; contains small pelecypods	5. 0
31. Black shale	58. 1
30. Black limestone; weathers nodular	3. 9
29. Dark-gray shale	65. 6
28. Slabby greenish-gray limestone with clay pebbles and shell fragments	2. 6
27. Light-gray shale	3. 0
26. Nodular limestone	. 8
25. Covered, probably gray shale	15. 1
24. Gray laminated limestone	2. 0
23. Gray shale	7. 2
22. Gray limestone, very thin-bedded, almost slaty	3. 7
21. Covered (appears to be shale)	125. 4

Section of part of Pennsylvanian beds (Weber? formation) along Trout Creek—Continued

		Feet
20.	Gray limestone; contains fragments of marine fossils	4. 6±
19.	Covered; apparently shale with a few thin beds of limestone. No suggestion of sand in soil or float	223. 7
18.	Gray limestone; contains a few small angular quartz pebbles	1. 3
17.	Covered	43. 1
16.	Dark-gray limestone	1. 0
15.	Covered	28. 0
14.	Limestone; some interbedded shale. One thin limestone bed has structure and markings suggestive of algae in roselike beads a quarter of an inch or less across. Other layers have small rodlike forms	12. 8
13.	Covered (probably shale)	18. 6
12.	Black limestone, massively bedded	5. 4
11.	Basic sill	4. 0
10.	Shale with thin streaks of limy shale and a few thin beds of fine-grained sandstone. Sandstone surfaces show ripple marks that suggest shallow water	75. 0
9.	Black limestone, massively bedded	1. 6
8.	Black shale; contains fragments of lepidodendrons and silicified masses of what appear to be large logs poorly preserved, showing several coats of bark. Logs at a definite horizon about 14 feet above base	21. 0
	Porphyry, about 35 feet thick.	
7.	Covered, probably shale or sandy shale	98. 2
6.	Gray limestone, thin-bedded; somewhat shaly; contains numerous fragments of Pennsylvanian fossils	1. 8
5.	Covered	14. 0
4.	Gray sandstone, fine-grained	6. 2
3.	Covered	11. 4
2.	Friable sandstone, gray but locally ferruginous and dark gray to red	2. 4
1.	Covered	6. 0
	Top of †Blue limestone; upper layers considerably impregnated with limonite.	

Section of part of Weber (?) formation on Windy Ridge

[Outcrop on east side of Windy Ridge about halfway between end and Dolly Varden mill, north of Alma, Colo. Taken only to show character of material. Thicknesses given are only approximate. Section starts about the middle of the formation]

		Feet
	Porphyritic quartz monzonite.	
16.	Grit	45
15.	Fine-grained micaceous black sandstone (J–23)	17
14.	Light-gray coarse arkosic conglomerate grit	38
13.	Dark-gray fine-grained micaceous sandstone (J–24)	6
12.	Grit, black at top, becoming light gray at base. Conglomeratic pebbles (averaging 1 to 1½ inches) of quartz, feldspar, and schist and some pieces of black shale (J–25)	45
11.	Light-gray slaty micaceous sandstone (J–26)	4
10.	Grit, greenish gray when fresh; becomes light reddish brown on weathering. Is highly arkosic. General run of grains three-sixteenths of an inch or less, but pebbles as much as 4 inches in diameter occur singly or in streaks through it. For an arkose these materials are unusually well cemented (J–27)	70
9.	Dark-gray to black sandstone, very micaceous on and parallel to bedding planes (J–28)	12

Section of part of Weber (?) formation on Windy Ridge—Contd.

		Feet
8.	Dark-gray limestone; weathers brownish. Hard and fine-grained. No fossils observed (J–29)	3. 5
7.	Gray micaceous sandy shale (J–30)	2
6.	Red micaceous sandstone, blending downward into a greenish-gray quartzose sandstone (J–31)	10
5.	Gray micaceous sandy shale (J–32)	1. 0
4.	Gray to black arkosic conglomeratic girt. Well-rounded pebbles as much as 3 inches in diameter scattered through it (J–33)	28
3.	Dark-gray sandy shale; slightly micaceous	2. 5
2.	Black limestone; weathers brown. Highly siliceous. Streaks of white chert in upper layers. Lower layers contain streaks of black shaly material, and a few layers contain what appear to be altered crinoid stems (J–34)	15
1.	Dark-gray slightly arkosic grit. Some layers moderately micaceous (J–35)	32

Below this horizon all is covered by float and dense aspen thickets and other vegetation.

Section of part of Weber (?) formation at Horseshoe Mountain

[Uphill northward from old town of Leavick, following around hill and through first cirque. Section starts at base of the formation and includes all of the first two zones and part of the upper zone]

		Feet
	Covered with grass to big fault (about three-fourths of a mile). Only two outcrops in that interval. Each has a different dip and strike.	
95.	Light-gray grits	142
94.	Dark-gray limestone; weathers brown	6
93.	Covered, mainly grass; a little sandstone float	167
92.	Black shaly, very micaceous sandstone	42
91.	Massive gray grit	18
90.	Dark sandy micaceous shale (soft)	33. 5
89.	Covered. Judging from talus it is largely coarse light-gray grit that weathers brownish. Much of it is micaceous	172. 5
88.	Sandstone	7. 4
87.	Shale	2
86.	Sandstone	6
85.	Shale	2
84.	Sandstone	6. 6
83.	Shale	3
82.	Gray sandstone, lenticular	4
81.	Shale	2
80.	Gray sandstone, lenticular	1
79.	Brown-gray papery shale	1. 2
78.	Brown shaly sandstone; looks calcareous	2
77.	Coarse gray grit	3. 5
76.	Black papery shale, slightly micaceous	2. 4
75.	Light-gray, almost white coarse granular sandstone; contains a little silvery mica	19
74.	Dark-gray micaceous shale	1. 3
73.	Light-gray coarse micaceous sandstone	7. 7
72.	Black sandy micaceous shale	1. 5
71.	Coarse gray micaceous sandstone; near the base contains large fragments of black shale. The surfaces of some of the strata show coarse ripple marks, 7 to 8 inches across	33
70.	Black sandy shale, carbonaceous	7
69.	Soft shaly micaceous sandstone, partly covered	48
68.	Gray to white hard coarse sandstone, slightly to moderately micaceous; partly covered	67
67.	Covered. To judge from the float, it is all gray sandstone and grit. There is considerable slickenside but appreciable faulting, as all slickenside is on bedding planes, and beds above and below seem to be continuous	202. 5

Section of part of Weber (?) formation at Horseshoe Mountain—Continued

		Feet
66a.	Black grit, mainly quartz with black cementing material	12
66.	Black limestone, weathering brown; dolomitic. No trace of fossils	4. 1
65.	Black grit, mainly white quartz, some mica; cementing material inky black	29
64.	Grayish-brown sandstone, hard and coarse; considerable mica along bedding planes	22
63.	Black to light-gray micaceous shale. Locally contains plant fragments, including small calamite stems	1. 5
62.	Gray sandstone, coarse, slightly micaceous	5. 5
61.	Gray-brown sandy micaceous shale	1
60.	Gray sandstone, hard, quartzitic	1. 5
59.	Dark-gray sandstone, calcareous and slightly micaceous, soft	5. 2
58.	Dark-gray limestone, impure and very nodular. Many of the nodules are of pyrite that is weathering to limonite. Weathers brown	6. 4
57.	Light-brown to tan calcareous shale, very fine grained	1. 5
56.	Reddish-brown shaly sandstone, moderately micaceous	2. 5
55.	Light-gray coarse sandstone or fine grit; weathers brownish, moderately micaceous	45
54.	Gray, very sandy micaceous shale; weathers reddish brown	5
53.	Light-gray sandstone; some almost white. Fine to medium grained, slightly micaceous, rather thin bedded; shows poor cross-bedding	27. 0
52.	Light-gray shaly micaceous sandstone	8. 1
51.	White sugary sandstone, slabby at base and massive toward top. Shows good cross-bedding	26
50.	White shaly sandstone	1. 6
49.	Light-brown sandstone, massive and hard	1. 3
48.	Light-brown sandy shale, slightly micaceous	1. 8
47.	Light-gray quartzitic sandstone, medium texture; weathers brownish	1. 9
46.	Cream-colored, flaky, limy shale, slightly micaceous	. 5
45.	Black limestone (does not weather brown), hard and massive. Weathers into small irregular, angular pieces. At this locality it contains many small limonite stains that represent oxidized pyrite present in fresh material as small cubes. Contains numerous poorly preserved marine fossils, including crinoid stems, *Marginifera* aff. *M. ingrata*, and *Orbiculoidea missouriensis* (locality 6851c). Near the top the limestone becomes slightly nodular and weathers more massively and brownish. Farther up the strike the pyrite and the slight metamorphism disappear	21. 7
	A small sill wedges in at this horizon a short distance down the strike from the place where the section was measured.	
44.	Light-gray coarse sandstone; weathers brownish. Lower portion massively bedded; upper portion somewhat slabby. A massive 5-foot bed on top	
43.	Black limestone, thin-bedded to slabby; weathers brown. Upper foot becomes sandy and in places almost conglomeratic. The limestone contains poorly preserved marine fossils	12
42.	White grit, coarse, mainly quartz, massively bedded	10. 5
41.	Light-gray massive sandstone	1. 4
40.	Light-tan sandy shale	. 8
39.	Slaty sandstone	1
38.	Light-tan limy shale, hard	1. 4

Section of part of Weber (?) formation at Horseshoe Mountain—Continued

		Feet
37.	Light brownish-gray sandstone, massively bedded, of medium texture	12. 5
36.	White limy shale, hard but almost papery	1. 5
35.	Sandstone, fine quartzitic, thin-bedded. Several streaks of white limy shale between sand beds	4. 7
34.	Black sandy limestone; weathers brown	1. 2
33.	White limy shale	. 5
32.	Sandstone, massive, light brown (one bed), hard	7. 3
31.	Limestone, almost white, very fine grained, slaty	1. 5
30.	Very limy shale. Splits like slate. Fossiliferous; yielded *Septopora* sp.?, *Productus cora*, *Deltopecten occidentalis?*, *Leda* sp.?, gastropod fragments (collection 6851d)	9. 5
29.	Light-gray sandstone, hard and massive; contains considerable calcium-carbonate cement	2. 6
28.	Dark-gray to black limestone, thin-bedded; weathers brown; contains fragments of fossils. One layer about the middle shows numerous cross sections of small gastropods (collection 6851c)	2. 5
27.	Black limy shale; becomes less calcareous at top	6. 3
26.	Light-brownish sandstone, rather coarse grained and granular, massively bedded	8. 5
25.	Shaly limestone, very fine grained, almost white. Contains abundant *Chonetes* and some other fossils including Bryozoa, *Orbiculoidea* sp.?, *Chonetes geinitzianus?*, *Productus coloradoensis*, *Productus cora*, *Composita* sp.?, *Myalina perniformis*, *Yoldia* n. sp.?, *Leda* n. sp., *Parallelodon* sp.?, *Parallelodon carbonarius*, *Edmondia* sp.? (collection 6851b). In spite of its thinness this bed is a good horizon marker	4. 2
24.	Cream-colored massive sandstone	2
23.	Cream-colored thin-bedded sandstone	4. 0
22.	Black, slightly calcareous shale, very slightly fossiliferous	8. 6
21.	Sandstone, almost white, coarse-grained	26. 4
20.	Cream-colored shale, sandy and micaceous	. 8
19.	Gray sandstone, massive, hard	. 9
18.	Very light gray shale, limy, slightly micaceous	. 5
17.	Dark-gray to black limestone	1.
16.	Light-gray grit	1. 5
15.	Nodular light-gray limestone, with some light chert	1. 2
14.	Lighter-gray shale, very calcareous; contains a few scattered fossils. Limy concretions (average 4 inches long) abundant. At the top lies several inches of limestone	5. 0
13.	Black shale, slightly calcareous and very fossiliferous (*Marginifera* especially). The following fossils were obtained: Crinoid stems, bryozoans (*Fenestella* sp., *Polypora* sp., *Rhombopora* sp.), *Composita* sp.?, *Derbya* sp., *Productus cora*, *Productus coloradoensis*, *Productus coloradoensis* var., *Productus* sp., *Pustula nebraskensis*, *Pustula nebraskensis?*, *Marginifera ingrata*, *Marginifera muricata?*, *Orbiculoides* cf. *O. missouriensis*, *Spirifer rockymontanus*, *Acanthopecten* cf. *A. carboniferus*, *Deltopecten arkansanus*, *Leda bellastriata*, *Nucula?* sp., *Yoldia* sp., fish tooth (collection 6851a)	13
12.	Largely covered. Apparently light-gray sandstone and fine grit. Some layers have white quartz pebbles as much as 2 inches across	47
11.	Sandstone, massively bedded, medium-coarse	106
10.	Largely covered, probably sandstone	58
9.	Light, gray sandstone, fine to medium texture, slightly micaceous, massively bedded	18. 5

Section of part of Weber (?) formation at Horseshoe Mountain—Continued

Feet

8. Dark-gray fine-grained limestone, thin-bedded, slightly fossiliferous. Yielded *Archaeocidaris*, spines and plates (2 species), bryozoans, *Productus cora*, *Productus* sp.?, (*semireticularis* type), *Schizophoria texana?*, *Spirifer rockymontanus*, *Deltopecten occidentalis*, *Pteria* aff. *P. ohioensis*, pelecypod fragments (collection 6851) — 11
7. Limy shale, blending upward into limestone — 8
6. Coarse gray sandstone — 8
5. Gray shaly sandstone and shale, mostly fine-grained and slightly micaceous — 21
4. Very light gray to dark sandstone and grit, rather thin-bedded, slightly micaceous. Some beds arkosic — 27
3. White quartzitic sandstone — 22
2. Shale, sandstone, and grit (not very coarse), some sandy shale, light to dark gray, slightly micaceous. Partly covered — 57
1. Yellowish-tan limy shale — 6

Unconformity.

Leadville limestone.

Section of part of Weber (?)f ormation at west end of Pennsylvania Mountain

[Section starts at top of porphyry in saddle at southwest corner of ampitheater. Follows along crest of ridge to London fault. Section starts almost at base of the formation and includes about two-thirds of it]

Feet

Fault.

133. Covered up to fault and badly fractured and displaced. There appear to be about 180 feet of strata, mainly sandstone and shale. Some coarse pebbly grit at top — 180
132. Light-gray grit — 35. 8
131. Gray sandy shale — 12. 1
130. Gray limestone; weathers brown — 9. 0
129. Black grit — 15
128. Black arkosic grit, pebbles as much as 5 inches across. Coarse feldspar fragments among the pebbles — 5. 6
127. Brown sandy shale — 4. 9
126. Gray-black sandy shale — 5. 0
125. Gray limestone; weathers brown — . 8
124. Gray limy shale; weathers brown — 2. 7
123. Light-gray shale — 1. 1
122. Limestone — . 7
121. Gray sandy micaceous shale — 1. 3
120. Limestone grading upward into sandstone — 1. 4
119. Limestone — . 8
118. Light-gray shale — 1. 4
117. Dark-gray grit — 4. 0
116. Dark-gray sandstone and shale — 2. 5
115. Dark-gray sandy limestone, thin-bedded; weathers brown — 3. 0
114. Dark-gray sandstone — 1. 8
113. Light-gray sandy shale — 3. 0
112. Dark-gray grit — 104. 0
111. Sandy micaceous shale, with a few thin sandstone layers near top — 8. 3
110. Dark-gray sandy grit — 3. 7

A small fault cuts through at this place, but the same bed was picked up on the other side and the section continued.

109. Gray to brown sandy shale — 4. 3
108. Gray-brown fine-grained sandstone — 2. 4
107. Gray to black shale, some slighly micaceous — 4. 6

Section of part of Weber (?) formation at west end of Pennsylvania Mountain—Continued

Feet

106. Gray limestone; weathers brown — 1. 8
105. Light-gray grit — 6. 2
104. Micaceous sandstone, fine-grained, thin-bedded — 3. 1
103. Dark-gray grit, highly cross-bedded (short-length cross-bedding) — 15. 5
102. Light-gray, almost white grit, highly cross-bedded; pebble streaks near top — 31. 8
101. Black micaceous shale — 1. 1
100. Gray micaceous sandstone — 4. 2
99. Light-gray shaly sandstone with streaks of tan shale — 4. 2
98. Light-gray pebbly sandstone. Pebbles small but abundant. Numerous flakes of mica — 4. 1
97. Light-gray shale with thin interbedded sandstone. Both contain considerable mica. Mica scattered through the shale but concentrated mainly on bedding planes of the sandstone — 3. 4

Tan-gray shaly sandstone. Thin-bedded.

96. Dark-gray sandy shale — 7. 3
95. Dark-gray grit — 5. 2
94. Black sandy micaceous shale — . 8
93. Dark-gray sandstone — 1. 3
92. Black sandy micaceous shale — 2. 8
91. Gray sandstone, slightly pebbly. Surfaces of some beds marked with 4-inch ripples — 31. 5
90. Dark-gray shaly sandstone — 4. 2
89. Dark-gray grit, hard — 12. 3
88. Black shale ("slate"); contains a number of markings suggestive of roots of land plants — 1. 2

Porphyry about 40 feet thick, but thickness differs along the strike.

87. Dark-gray pebbly grit; contains a few thin streaks of black micaceous shale near base — 12. 0
86. Light-gray coarse grit; contains mica in noticeable amounts, some pieces three-eighths of an inch across. Some layers slightly pebbly — 6. 3
85. Light-gray sandy shale — 1. 2
84. Dark-gray quartzite — 1. 6
83. Light tan-gray sandy shale, slightly micaceous — . 8
82. Dark-gray quartzite — 2. 0
81. Light-gray pebbly grits, slightly cross-bedded. Pebbles almost all of white quartz — 14. 0
80. Papery black shale — 4. 2
79. Dark-gray pebbly sandstone — 2. 1
78. Coarse gray grit, some layers near base almost a fine conglomerate; coarsely cross-bedded — 11. 2
77. Yellowish-gray sandy shale; contains a noticeable amount of very fine mica — 8. 5
76. Dark-gray, almost black, cross-bedded; contains streaks of pebbles, also streaks of fine sand — 68. 4
75. Light-gray sandy shale, slightly micaceous — 3. 6
74. Yellowish-gray micaceous grit — 1. 8
73. Gray sandy shale — 4. 6
72. Yellow-gray grit, slightly micaceous — 3. 1
71. Red sandy shale, slightly micaceous — 7
70. Light-gray grit, cross-bedded; contains a few scattered quartz pebbles — 8
69. Light-gray micaceous sandstone — 4. 2
68. Yellow-gray soft sandstone, slightly shaly; contains a little mica — 2. 8
67. White grit, massively bedded — 11
66. Light-gray quartzite, almost white. Beds about 10 inches thick. Surfaces coarsely ripple marked — 5
65. Yellow sandstone — 2
64. Red sandy shale — 3. 8

Section of part of Weber (?) formation at west end of Pennsylvania Mountain—Continued

	Feet
63. Brownish-gray coarse grit	2. 6
62. Red and gray sandy micaceous shale	2. 4
61. Coarse white grit, massively bedded	3. 5
60. Yellow sandstone	2. 1
59. Red sandy shale	1. 5
58. Dark-gray sandstone beds, about a foot thick. Surface of layers marked with ripples about 5 inches across	11. 0
57. Brownish-gray shaly sandstone, slightly micaceous	3. 6
56. Red shaly sandstone	1. 8
55. Yellowish-brown sandstone	2. 0
54. Dark-gray pebbly grits with some interbedded gray quartzite	13. 1
53. Light-gray pebbly grit; shows good cross-bedding	44. 4
52. Soft yellow sandstone	4. 1
51. Green-gray quartzite	2. 4
50. Calcareous shales grading upward into impure limestone. Weathers into small angular and concretionary pieces. Fossiliferous; contains crinoid stems and horn corals, *Amplexus saphrentiformis*, and *Lophophyllum* sp.? (station 6854)	5
49. Black papery shales	7. 2
48. White pebbly grit, highly cross-bedded	52. 2
47. Reddish-brown sandstone	11. 8
46. Dark-gray quartzite	6. 1
45. Gray sandstone marked with ripples about 3 inches across	8. 0
44. Red sandy shale, slightly micaceous	2. 4
43. Coarse grit, almost white	18. 1
42. Light-gray conglomerate	3. 2
41. Gray coarse pebbly grit	14. 1
40. Largely covered. All outcrops and talus of light-gray to white pebbly grit. Some brown and gray quartzite	212. 0
39. Sandy limestone, almost black; becomes rich brown on weathering	4. 6
38. White sugary sandstone; shows well-developed crossbedding	27. 0
37. Covered; appears to consist largely of light-gray grit	41. 0
36. Dark-gray limestone; weathers brownish; contains coarse grains of white quartz. No fossils observed	3. 6
35. Light grayish-brown sandstone	20. 0
34. Dark-gray quartzite	8. 0
33. Light-gray grit, rather pebbly; pebbles in streaks, cross-bedded	25. 0
32. Black grit, soft; contains numerous fragments of black shale and carbonaceous matter	6. 0
31. White to light-gray pebbly grit; contains abundant small quartz pebbles. Pronounced cross-bedding	31. 5
30. Dark-gray limestone; weathers brownish gray. Thin-bedded. No fossils observed	23.0
29. Shales, covered	3. 1
28. Coarse gray grit	6. 0
27. Grayish-brown shaly sandstone, partly covered	6. 1
26. White cross-bedded coarse sandstone	24. 5
25. Dark-gray limestone; weathers brownish, granular appearance, no fossils visible	4. 3
24. Black sandy shale, slightly micaceous	1. 4
23. Covered	14. 3
22. Coarse gray sandstone	25. 5
21. Covered, probably sandstone	9. 5
20. Porphyry	66
19. Dark-gray sandy shale	6
18. Gray sandstone, slightly pebbly	17
17. Covered	12. 5
16. White coarse quartzitic grit, somewhat pebbly at top	12. 5
15. Dark-gray limestone; weathers brownish	2. 4
14. Gray sandy shale	12. 0
13, 12. Coarse gray gritty sandstone	25. 2
11. Dark-gray sandy shale	4. 6
10. Gray quartzitic sandstone	6. 3
9. Light-gray granular sandstone	15. 6
8. White quartzite, fine-grained, very hard	17. 2
7. Covered, probably sandy shale	4. 6
6. Calcareous sandy shale, greenish gray when fresh; weathers light yellowish brown	5. 5
5. Black shale. Bed differs in thickness from place to place. Contains abundant impressions of land plants, identified by C. B. Read as *Stigmaria verrucosa*, *Neuropteris dluhoschi*, *Sphenopteris asplenioides*, *Cordaites* sp. (locality 8050)	2. 8
4. Light-gray quartzite, rather thin-bedded	15. 5
3. Black sandy shale, slightly micaceous; contains poor plant fragments and impressions of stems	1. 1
2. Light-gray quartzite, fine-grained, hard	7. 5
1. Quartzite, originally probably gray; now highly silicified and light gray to white. Hard	6. 5
Porphyry; large, thick, almost domelike intrusion.	

A study of the outcrops at the base of Evans Peak, west of Pennsylvania Mountain, suggests that there is about 65 feet of Weber (?) beds below the porphyry.

Section of part of Weber (?) formation along south side of Empire Hill

[Taken from east to west. Section commences at top of porphyry marking the second (western) fault mapped by Behre. Includes only about the lower third of the formation]

	Feet
Section crosses axis of a syncline and a repetition of beds commences.	
60. Black shale; contains a few poor impressions of plants	54
59. Fine-grained gray sandstone	28. 6
58. Dark-gray to black slabby micaceous sandstone; contains a few beds of arkosic grit	61. 3
57. Greenish-gray fine-grained micaceous sandstone, slightly arkosic	5. 0
56. Light-gray arkosic sandstone	11. 5
55. Light-gray sandstone with a few thin interbedded layers of dark-gray shale. Sandstone slightly arkosic; shale micaceous	20. 1
54. Black papery shale	18. 0
53. Gray sandstone, thin-bedded, slightly micaceous. Surfaces marked with 2-inch ripples	4. 7
52. Dark-gray sandy, slightly micaceous shale	6. 5
51. Black papery shale	4. 7
50. Dark-gray shaly sandstone	5. 0
49. Dark-gray arkosic grit	6. 0
48. Dark-gray shaly sandstone, very micaceous	20. 0
47. Light-gray arkosic sandstone; contains a few pebbles 1½ inches or less in diameter	13. 7
46. Dark-gray sandstone alternating with black micaceous sandy shale	14. 0
45. Dark-gray shale (J–48–S)	1. 8
44. Gray arkosic sandstone, rather fine grained	14. 8
43. Dark-gray sandy micaceous shale	5. 1
42. Gray arkosic sandstone with a few pebbly and gritty streaks	52. 6

Section of part of Weber (?) formation along south side of Empire Hill—Continued

	Feet
41. Dark-gray fine-grained micaceous arkose; weathers rusty brown	2. 3
40. Light-gray arkosic grit	10. 0
39. Dark-gray micaceous shale that becomes black at top	15. 2
38. Light-gray arkosic sandstone	7. 0
37. Black micaceous shale. A few streaks appear to be slightly calcareous	5. 1
36. Alternating sandstone and sandy micaceous shale. Sandstone light gray; shale darker	49. 0
35. Dark-gray, slightly micaceous sandstone, hard	2. 5
34. Dark-gray shaly micaceous sandstone	6. 5
33. Light-gray arkosic sandstone; weathers rusty brown; contains mica flakes as much as three-eighths of an inch across	2. 7
32. Dark-gray sandy shale with interbedded sandstone	12. 5
31. Dark-gray sandstone	3. 0
30. Dark-gray sandy shale, micaceous	3. 3
29. Gray arkosic grit; contains a little mica. Poorly bedded, easily eroded. Contains some fragments of shale (J–47–S)	10. 2
28. Dark-gray sandy shale and soft sandstone; contains abundant fine white mica	13. 0
27. Coarse light-gray sandstone	7. 1
26. Impure shaly limestone	2. 0
25. Black sandy shale and soft sandstone, micaceous	4. 8
24. Gray sandstone, rather fine grained; surfaces show coarse ripple marks	4. 1
23. Dark-gray micaceous sandy shale; fine mica flakes abundant	. 4
22. Black slaty shale with thin streaks of limestone interbedded. (Limestone averages 1½ inches thick)	21. 8
21. Coarse gray grit	3. 0
20. Dark-gray sandy micaceous shale, with a few thin layers of sandy limestone and sandstone interbedded. The limestone contains fragments of shale, large plates of mica, and angular pieces of quartz and feldspar (J–46)	7. 5
19. Dark-gray sandstone	1. 9
18. Gray sandy shale	2. 5
17. Dark-gray sandstone, almost black	3. 5
16. Gray sandy shale, slightly micaceous	17. 5
15. Dark-gray sandstone	2. 1
14. Black shale with numerous thin beds of dark-gray limestone. Abundant Marginiferas in a few layers near center. Fossils include crinoid stems. *Lophophyllum profundum*, *Cleiothyridina pecosi?*, *Composita subtilita*, *Chonetes geinitzianus?*, *Marginifera ingrata*, *Productus cora*, *Productus cora* var. *nodosus*, *Productus* aff. *P. pertenuis*, *Pustula* n. sp., *Strophalosia spondyliformis*, *Euphemus carbonarius* (locality 6855a)	65. 3
13. Black papery shale	3. 8
12. Alternating limestone and shale. Limestone dark gray; weathers light gray. Contains particles of shale. Some layers at top are fossiliferous and yielded crinoid stems, *Archaeocidaris* sp.?, *Fistulipora* sp.?, *Orbiculoidea* sp.? (2 species), *Chonetes* aff. *C. geinitzianus*, *Composita subtilita*, *Derbya crassa?*, *Productus cora*, *Productus cora* var. *nodosus*, *Productus coloradoensis*, *Productus* n. sp. aff. *P. semistriatus*, *Pustula nebraskensis* var., *Deltopecten* aff. *D. scalaris*, *Enchostoma* sp.?, *Phillipsia* sp.?	102. 1
11. Gray calcareous sandstone; weathers brown; thin-bedded; contains a few fine mica flakes; at top (10) is about 2 feet of material which suggests altered gypsum (J–40)	10. 2
9. Dark-gray limestone with some interbedded limy shale; weathers light; contains some suggestions of fossils but nothing recognizable	56. 5
8. Largely covered. Part if not all is black papery shale	11. 0
7. Dark-gray limestone; weathers light; contains small crinoid stems and small fragments of shells	12. 5
6. Arkosic grit	10. 0
5. Gray sandstone and grit; weathers yellowish	17. 2
4. Dark-gray shale and thin shaly limestone, the limestone weathers light gray	10. 1
3. Dark-gray limestone; weathers light gray. Weathered surfaces show some small quartz particles and what appear to be numerous small pieces of black shale	1. 3
2. Black papery shale	12. 2
1. Altered and shattered impure limestone, stained yellow to brown	10
Fault.	
Porphyry.	

Section of part of Weber (?) formation in Board of Trade Cirque

[About 2 miles east of Leadville, Colo. This section was measured for Mr. Behre's report on the Mosquito Range region. It does not show either the top or bottom of the formation but covers the largest and best outcrop of the Weber (?) in the vicinity of Leadville. According to Behre, this section starts over halfway up in the Weber (?). He thinks it represents material in the upper third of the formation but below the top. It begins roughly N. 30° E. from the Ibex mine and S. 30° W. from Dyer Peak]

	Feet
Base of thick sill of Lincoln porphyry; the same porphyry that is exposed on Little Ellen Hill.	
51. Light-gray grit, very slightly micaceous. Partly covered. Appears to contain some interbedded sandy shale	114. 4
50. Black micaceous shale	1. 5
49. Largely covered; appears to be gray grit. Some is highly conglomeratic, with quartz pebbles as much as 4 inches across	148. 9
48. Porphyry sill, 63.3 feet thick.	
47. Rather fine grit, moderately arkosic; shows coarse cross-bedding	12. 6
46. Covered, heavy sod	10. 1
45. Coarse pebbly arkosic grit	4. 0
44. Covered, sod	22. 0
43. Dark-gray to tan shale, partly limy, partly micaceous. Most of it sandy and slightly micaceous. One layer about a foot thick, very fine grained and calcareous	6+
42. Covered, sod	10. 5
41. Gray grit; contains a few quartz pebbles, an inch or less across, and a few small pieces of feldspar	11. 2
40. Dark-gray limy, shaly sandstone, slabby weathering	2. 0
39. Covered but appears to be gray sandy shale	13. 0
38. Light-gray grit, rather fine grained but contains a few scattered quartz pebbles 1½ inches in size. Some beds near top slightly arkosic	10. 3
37. Brownish-gray shaly sandstone, slightly micaceous. Beds appear to be lenticular. Thickness appears to be about half the interval	4. 0
36. Light-gray arkosic sandstone, massive	8. 8

Section of part of Weber (?) formation in Board of Trade Cirque—Continued

	Feet
35. Light-gray sandy shale, slightly micaceous. Represents about half the interval	7.4
34. Dark-gray calcareous sandstone, with a few fine mica flakes	2.6
33. Light-gray arkosic sandstone	.7
32. Black limy shale	3.8
31. Gray arkosic sandstone	7.9
30. Sandy calcareous shale	2.0
29. Light-gray, slightly arkosic sandstone that tends to weather brown, slightly limy. Grades downward into coarse pebbly arkosic grit showing cross-bedding to the south	43.0
28. Gray sandy shale, partly covered	4.6
27. Light-gray, almost white sandstone, grading downward into arkosic grit, slightly pebbly near base. Poorly cross-bedded	25.7
26. Dark-gray arkosic sandstone, slightly micaceous, particularly along bedding planes; contains a few streaks of quartz and feldspar pebbles 1½ inches in size	18.7
25. Black sandy shale, fine-grained at the top, becoming sandy and lighter in color toward the bottom	11.3
24. Coarse grit, dark gray when fresh	7.0
23. Coarse gray sandy shale	7.3
22. Dark-gray sandstone	3.0
21. Dark-gray sandy calcareous shale	4.5
20. Dark-gray arkosic sandstone, grading downward into a coarse light-gray grit, with streaks of pebbles	21.6
19. Covered, probably shaly sandstone	29.2
18. Coarse gray grit	35.4
17. Covered, probably gray grit	11.8
16. Sandstone	8.3
15. Impure shaly limestone	6.0
14. Gray grit	18.1
13. Dark-gray fine-grained sandstone	4.2
12. Gray shale	1.5
11. Impure shaly limestone with considerable white mica on bedding planes; weathers olive-green	8.4
10. Dark-gray arkosic sandstone	5.7
9. Dark-gray impure shaly limestone; weathers white	5.8
8. Dark-gray to brown arkosic grit; contains some streaks of 2-inch pebbles of quartz and feldspar, the latter remarkably fresh looking	6.8
7. Dark-gray calcareous sandstone, rather fine grained	5.7
6. Light-gray coarse arkosic sandstone	17.4
5. Black slaty shale; shows some poor impressions of plant stems and fibers. Some layers sandy and slightly micaceous	11.0
4. Black shaly sandstone	16.5
3. Dark greenish-gray shaly limestone	3+
2. Covered; probably gritty sandstone; some beds slightly conglomeratic	35.5
1. Gray to dark-gray alternating sandstone, grit, and shaly sandstone	49.3
Covered (end of section measured).	

PENNSYLVANIAN-PERMIAN BOUNDARY

At the present time a definite boundary cannot be drawn between the Pennsylvanian and the Permian of this region. Emmons[42] in the Tenmile district arbitrarily used the top of his Jacque Mountain limestone for the base of his †Wyoming formation and stated:

> If the Permian is represented in Colorado * * * it would be included in these beds, which have evidently been deposited in direct and unbroken succession over the upper Carboniferous.

There is no stratigraphic break and no particular lithologic change, and sufficient paleontologic data to permit a distinction have not yet been obtained. In general it appears to have been the practice of most geologists to call the deposits Maroon wherever they consist largely or entirely of red beds. This is not good practice, for it can be easily demonstrated that the deposition of red beds did not start at the same time in all parts of the Mosquito Range. In adjoining areas there is an even greater difference in the horizon at which red sediments first appear—in fact, a lateral gradation from the Weber (?) sediments into red beds was observed in several localities, and beds of red material appear in the gray beds far below the horizon where red sediments predominated. In the Red Cliff and Minturn areas, northwest of the Mosquito Range, thick red beds occur below limestone and shale carrying definite Pennsylvanian fossils, and still farther northwest, around McCoy, almost the entire Pennsylvanian section has a brilliant red color.

Fossils become progressively scarcer in the sequence of beds upward in the series. A careful search has shown, however, that the redbeds are by no means devoid of organic remains. A surprising number of limestone beds are sandwiched between the sandstones and grits. Many of these beds carry marine fossils. Land plants have been found in several localities. Future work in the areas west and northwest of the Mosquito Range will probably supply sufficient material to permit a definite determination of age and will permit the recognition and correlation of zones within the red beds. It will probably also supply a basis on which a definite boundary may be drawn within the actual area of the Mosquito Range.

Emmons stated that his Maroon of the Tenmile district carried a †Coal Measures fauna, and though it is now known that the Pennsylvanian does not run as high as his Jacque Mountain limestone, there is no doubt that at least a considerable portion of the lower red beds are of Pennsylvanian age.

Abundant fossils have been found in the lower part of the Weber (?) formation, all of which give it a definite lower Pennsylvanian age. Fossils obtained in the Jacque Mountain limestone and adjoining beds are of a definite Permian type. David White obtained Permian plants at a much lower stratigraphic level near Red Cliff and in the vicinity of Minturn. However, the sediments appear to form an unbroken suc-

[42] Emmons, S. F., U.S.Geol. Survey Geol. Atlas, Tenmile district special folio (no. 48), p. 2, 1898.

cession between the beds that carry the Pottsville fossils and those, thousands of feet higher, that carry Permian forms, so it seems only reasonable to suppose that some of the sediments must represent middle and upper Pennsylvanian time.

During the summer of 1931 the writer spent some time studying the red beds west of the Gore Range. In that region there is a maximum of about 5,700 feet of sediments between the Jacque Mountain limestone and the horizon of the Leadville limestone. The paleontologic material obtained suggests that about the lower 2,000 feet is of Pennsylvanian age, whereas the beds above are Permian. It seems probable that in the Leadville and Alma districts the same would be approximately true.

MAROON FORMATION (PENNSYLVANIAN? AND PERMIAN)

The sediments typical of the Weber (?) formation of this area pass upward and in several places laterally into a series of red beds, mainly sandstone and sandy shale but locally containing lenticular conglomerate and limestone. These deposits in the Breckenridge and Tenmile districts have been called the Maroon formation.

At first glance the sediments appear to be all red and to consist mainly of coarse clastic deposits. Closer inspection, however, reveals a surprising amount of limestone and many gray, greenish-gray, and brown beds.

Erosion has removed the Maroon from the upper portions of the Mosquito Range, especially in the Leadville and Alma districts. The Maroon is, however, well developed along the eastern slopes of the range and in South Park, where it covers large areas. It is also present over considerable areas to the northeast in the Breckenridge district and to the northwest in the Red Cliff and Gilman districts. To the north, in the Kokomo and Robinson districts, it attains a great thickness and covers large areas.

In South Park the sediments are mainly rather fine grained sandstone and sandy shale, locally with thin beds of limestone, mainly of algal origin. In a few places streaks or thin beds of gypsum have developed. Ripple marks and sun cracks are not uncommon on the surface of the beds.

The deposits tend to be coarser in character in the other districts mentioned, containing a larger proportion of conglomerate, grit, and sandstone. Some shale occurs and limestone is common, some of the beds being rather thick.

At least the greater part of the Maroon is of Permian age.

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