

ART. XI.—*Devonian Strata in Colorado*; by ARTHUR C. SPENCER.

Early recognition of Devonian.—The presence of Devonian strata in the San Juan region of Southwestern Colorado was announced in the report of F. M. Endlich, of the Hayden Survey, for the year 1874. The age determination, based upon a small collection of fossils, was made by F. B. Meek, the paleontologist of the Hayden Survey, and upon the evidence of this determination the geological map of Southwestern Colorado in the Hayden atlas, which appeared in 1877, had Devonian areas represented upon it. This work, however, has been either lost sight of, or discredited by recent writers upon the geology of the Rocky Mountains. In his paper upon "Orographic Movements in the Rocky Mountains," S. F. Emmons* indicates that of the areas represented upon the Hayden map as Devonian and Carboniferous, the lower part is known to be Silurian, though the facts on which this opinion was founded are not given. Again in a paper upon "Orographic and Structural Features of Rocky Mountain Geology," R. C. Hills† states, without qualification, that there are no recognizable Devonian sediments between the Silurian and Carboniferous in the San Juan region. He, however, expresses the belief that Devonian strata may yet be found in Southwestern Colorado.

Further information concerning the strata from which Endlich collected the fossils, pronounced by Meek to be Devonian, has recently been obtained by the Geological Survey party in charge of Dr. Whitman Cross, while engaged in areal mapping. The writer was a member of the party, both in 1897, when the fossiliferous limestones were found, and in 1898, when extensive collections were made. The actual localities which Endlich mentions have not been revisited as yet, but all the forms which he found, together with many others, have been obtained from beds in the Animas valley, which are evidently connected by continuous outcrop with the Devonian areas mapped by Endlich.

The fossils which Endlich collected have been preserved in the National Museum, where there are, also, other collections from beds in Central Colorado which now prove to be related to those of the San Juan region. These fossils have been made the subject of careful study by Dr. Geo. H. Girty of the U. S. Geological Survey, in connection with the determination of the more recent collections. The result of Dr. Girty's

* Bull. Geol. Soc. Am., i, p. 280.

† Proc. Sci. Soc. Colo., iii, p. 366.

investigation has been to confirm Meek's opinion of the Devonian age of the fossils which were found by Endlich, and to establish the basis for a correlation of the Devonian of the San Juan region with strata in other parts of the State which have hitherto been included in the Lower Carboniferous.

Devonian in Southwestern Colorado.—The Devonian rocks are at present the oldest formations which are well authenticated in the San Juan region of Southwestern Colorado. Silurian was represented upon the Hayden map in Endlich's area, and though the areal distribution of the lower formations, as there shown, is very incorrect and gives no basis for a conclusion, it is thought from the text* that his Silurian is the basal quartzite of our section. The quartzite is wanting or of very limited development on the east side of the Animas river, where the Devonian was first discovered by Endlich, while it is very prominent in the vicinity of Cascade creek where his Silurian is indicated. The incompleteness of the Hayden map in regard to the basal portion of the sedimentary section is to be wondered at, since at no place where it has thus far been studied by us is the Devonian limestone absent between the crystalline basement and the rocks of well-recognized Carboniferous age.

The series below the Carboniferous consists typically of three members, a sandstone or quartzite at the base, a shale series, and a massive limestone. Of these, the lowest is frequently wanting through non-deposition, and the middle member is also sometimes very thin or entirely absent. The formation name, Ouray limestone, is proposed for the only member of the section which is definitely shown by its fossils to be of Devonian age, from the prominent occurrence in the vicinity of Ouray at the junction of Cañon creek with the Uncompaghre river. No names will be proposed for the lower formations at present, since, for purposes of mapping, it may prove necessary to include them under a single name.

Above the Devonian there is apparent conformity of deposition, but the occurrence of Upper Carboniferous fossils within a few feet of the Devonian limestone, and the absence of any fauna comparable with the Lower Carboniferous fauna from the Gunnison region and from Tourtelotte park, suggests a gap in deposition which represents the whole of the Lower Carboniferous. There is, however, a possibility that there may be a few feet of unfossiliferous limestone above the true Devonian, and not differentiated from it, which is really of Lower Carboniferous age. Such a lack of lithological difference would

* Hayden Geol. and Geog. Surv. of Terr., Report of F. M. Endlich for 1874, p. 210.

be quite analogous to the relations observed between the two formations in other places.

The most important areas of Devonian lie in the region south and west of the pre-Paleozoic core of the Needle Mountains. (Quartzite Mountains of the Hayden map.) The Ouray limestone has been noted as far east as Los Pinos river, and may be traced across the Florida river, and still westward to the Animas, where it was first observed by the writer. Detailed studies have not been made throughout this region, but the two lower members of the section are known to be locally absent. All of them are present along the west side of the Animas river for about twenty-five miles, from their southernmost outcrop about thirteen miles north of Durango, at Pinkerton Springs, to where they are covered by volcanic rocks of Tertiary age, just south of Silverton. In the vicinity of Ouray this formation rests upon the Algonkian rocks, the lower beds being absent. Southeast of Silverton, in Deer Park, and along the Bare creek trail, the quartzite is locally missing, while the shaly series is always present underneath the limestone. Still farther east and more to the north, upon the headwaters of the Lake Fork of the Gunnison river, none of the Devonian formations are found in place, but several huge blocks of quartzite and limestone like those of the Devonian were observed in the lower part of the great complex of effusive rocks which covers that region. Apparently these were wrenched off during some eruption and floated up by the fluid or viscous rhyolite lava, to be subsequently covered by streams of andesite and similar rhyolite. The Ouray limestone has also been identified in the marbled limestones which appear near the center of the remarkable structural dome at Rico, some fifteen miles west of the Animas valley, opposite the Needle mountains. The known occurrences of the Devonian thus indicate its distribution over an area of approximately six hundred square miles in the San Juan region, with every reason for supposing an actual extent very much in excess of this.

The relations of the formations indicate an overlap, and, therefore, an advancing sea during the period of their deposition; however, the vertical element of the overlap was, at the most, not more than 200 feet. Thus, the relations of the sediments to their basement is indicative of a surface of very low relief in the pre-Devonian topography.

The quartzite which forms the basal member of the series here considered varies in thickness from zero to perhaps 100 feet. It is typically a massive white or reddish quartzite in which a well marked jointing is usually developed. It is composed almost entirely of quartz and its grain is rather fine and

uniform. Local variations are observed where the sandstone is flaggy, and conglomerates of medium coarseness are not rare in the lower part. Near the southernmost exposures in the vicinity of Rockwood, the contact with the basement rock, which at that place is granite, is marked by a basal conglomerate some six feet in thickness. The bowlders in this conglomerate, which have a diameter of six inches or more, are confined to the slight depressions in the floor. Above the conglomerate, and running over the tops of the knolls, there comes a fine-grained sandstone or quartzite. At the top of the quartzite there is an alteration of red or gray earthy limestone with reddish shales for a thickness of a few feet. The lowest of the earthy limestones is luted onto the topmost layer of the quartzite. The materials of this basal formation are remarkable in that they contain no fragments of feldspar though they rest directly upon a coarse granite, and that the bowlders were not derived from the rocks which immediately underlie the conglomerate. Such a formation is not the result of a rapidly advancing coast-line, but is rather the effect of activities which must have been long continued.

The occurrence of fish scales in the sandstone of the basal formation was reported by Endlich, and a single slab exhibiting fish remains was found by us in a talus pile at the base of a quartzite cliff near Rockwood, on the Silverton branch of the Denver and Rio Grande Railroad. The only other fossils from the quartzite are very imperfect impressions, which Mr. Walcott is inclined to refer to *Cruziana* or *Rusophycus*, supposed plants which are respectively of Silurian and Cambrian types.

The middle or shaly member varies in thickness from 25 to perhaps 100 feet in the Animas region. As already stated, it is missing in the Uncompahgre region. The shale series is very imperfectly exposed upon the west side of the Animas river, but upon the east side it may be studied at several places. It is especially well exposed in the high basins at the head of Deer Park, southeast of Silverton. It consists of calcareous marls and flaggy shales containing an occasional band of white sandstone. In color it has a somewhat variegated appearance, due to alternating bands of red, green and gray color. Wherever it is exposed, or wherever talus derived from it is found, it may be readily recognized from its general appearance. One of the most characteristic features is the appearance of slabs of sandy shale, which contain the curious markings that are known to represent crystals of halite, showing hopper-shaped crystals preserved as pseudomorphs in the substance of the rock.

The Ouray limestone is a massive limestone varying in thickness from 100 to 300 feet. In places the limestone is in one massive layer, while elsewhere it is in two or three heavy bands separated by greenish crumbling marls. The limestone is usually white, but is sometimes stained red or pink. Certain strata are somewhat coarsely crystalline, but as a rule the limestone is fine-grained. The chemical composition is variable, as is shown by the careful selection of certain portions for use in the smelter at Durango. The discarded portion is said to be too siliceous for metallurgical use.

The total thickness of the Devonian in the Animas region varies from 200 to nearly 500 feet, the former figure representing the usual development. At Ouray the thickness is not far from 200 feet.

The fossils which have enabled a determination of the age of this series are found in the limestone a short distance below the top. Neither the extreme upper or lower layers have thus far yielded organic remains. In the zone in which the shells occur there are several thin layers which are more coarsely crystalline than the mass of the limestone, and these are very frequently fossiliferous. The fossils are never prominent to casual observation, but when their horizon is once located and patiently searched, it usually proves to be quite productive. In some places, however, where many fossils are present, collecting proves unsatisfactory because of minute jointing which makes it impossible to secure perfect specimens. A list of the forms which have been recognized is here given :

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| <i>Streptelasma</i> sp. | <i>Mytilarca</i> ? sp. |
| <i>Schizophoria striatula</i> . | <i>Paracyclas</i> sp. |
| <i>Orthothetes chemungensis</i> var. | <i>Modiomorpha</i> sp. |
| <i>Productella semiglobosa</i> . | <i>Allorisma</i> sp. |
| <i>Productella subalata</i> ? | <i>Euomphalus clymenioides</i> . |
| <i>Spirifer disjunctus</i> var. <i>Ani-</i> | <i>Euomphalus Decewyi</i> . |
| <i>masensis</i> . | <i>Pleurotomaria</i> sp. |
| <i>Spirifer coniculus</i> . | <i>Naticopsis</i> ? <i>humilis</i> . |
| <i>Athyris coloradaensis</i> . | <i>Naticopsis gigantea</i> . |
| <i>Athyris vittata</i> var. | <i>Bellerophon</i> sp. |
| <i>Camarotoechia (Rhynconella)</i> | <i>Orthoceras</i> sp. a. |
| Endlichi. | <i>Orthoceras</i> sp. b. |
| <i>Camarotoechia contracta</i> ? | <i>Orthoceras</i> sp. c. |

Devonian Strata in Central Colorado.—In the course of the geological studies which have been made from time to time in Central Colorado, under the direction of Mr. S. F. Emmons of the U. S. Geological Survey, the determination of the presence or absence of Devonian rocks was a problem most difficult of satisfactory solution. Only the recent work at

Aspen has given any evidence of a positive nature, but a re-examination by Dr. Girty of the fossils collected at various localities in the central portion of the State has resulted in establishing the occurrence of Devonian strata in this region. It seems desirable to bring together in this place all the available information concerning the strata of Central Colorado which are now known to be of Devonian age. Some of the data have not been published hitherto.

At Leadville Emmons* was not able to find strata which could be referred with certainty to the Devonian. A meagre Silurian fauna was found in the lower part of the sedimentary series, while higher in the section, Carboniferous fossils were also found, but between these there was a considerable thickness of strata from which no organic remains were obtained. In the absence of adequate fossils, and in view of the opinion expressed by R. P. Whitfield,† that the characters of *Rhynconella Endlichi* were Carboniferous rather than Devonian, it was concluded that Devonian strata had not yet been found in Colorado, and it was thought advisable to apportion the lower part of the Paleozoic section between the Silurian and the Carboniferous. Between the white limestone of the Silurian and the blue limestone, which was classified as Lower Carboniferous because of the fossils which were found in its upper part, there is a quartzite which is typically about forty feet in thickness. This siliceous band was called the "Parting Quartzite" and it was given position as the uppermost member of the Silurian. Between it and the fossiliferous horizons of the blue limestone there are nearly 200 feet of limestone which are entirely unfossiliferous. It is this portion of the limestone immediately above the "Parting Quartzite" that probably corresponds with the Devonian of the Gunnison and Salida sections, described in what follows.

With the knowledge gained in the Leadville work, Mr. Emmons was able to establish the general correspondence of the Paleozoic rocks at several places adjacent, and his general results have been found correct by those who have made more detailed examinations under his direction.

During the field seasons of 1885-86, Mr. George H. Eldridge was engaged in the study of the stratified rocks of the Gunnison region. At this time, he also made careful sections and collections in the vicinity of Salida. At both places, Mr. Eldridge was able to recognize the "Parting Quartzite," and in the limestone strata which immediately overlie it, fossils

* Geology and Mining Industry of Leadville. Monograph U. S. Geol. Surv., xii, p. 56.

† Idem.

were found which had a Devonian aspect, but, in the absence of any stratigraphic criterion, the data were not considered to be sufficient to warrant the mapping or the description of the Devonian in the Anthracite-Crested Butte Folio, published in 1894. Part of the fossils which were collected in this region are in the National Museum and have been examined by Dr. Girty, who finds among them forms identical with those from the Devonian limestone from the San Juan region. The Devonian fauna is succeeded by a characteristic assemblage of Lower Carboniferous forms.

In the summer of 1889, at the instance of Mr. Emmons, a careful search for fossils was made by T. W. Stanton, in the lower Paleozoic strata near Glenwood Springs. *Rhynconella Endlichi* was one of the few forms collected, the rest being either Lower Carboniferous or pre-Devonian. At the time, this was taken as negative evidence in favor of the absence of Devonian, but since *Rhynconella Endlichi* is now known to be of that age, it seems probable that the Devonian limestones are present at this place. The "Parting Quartzite" is also probably present, though its true relations are obscured by the faulting which has taken place.*

At Aspen, Spurr† has described the same stratigraphic elements as those recognized at Leadville: the white limestone, the "Parting Quartzite," and the blue limestone are all present. Fish remains of a Devonian type, which were found in the "Parting Quartzite," furnish the basis for correlating this series with the Devonian of the Kanab valley in Southern Utah and Northern Arizona, as described by Walcott.‡ The stratigraphic position and lithology of the siliceous series in both regions are similar and have been considered by Spurr a sufficient basis of correlation.

The fossils occurring at Salida have been determined as follows:

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| <i>Monotrypella</i> sps. a, b, and c. | <i>Spirifer disjunctus</i> var. <i>Ani-</i> |
| <i>Schizophoria striatula</i> . | <i>masensis</i> . |
| <i>Orthotheses Chemungensis</i> . | <i>Athyris Coloradensis</i> . |
| <i>Orthotheses Chemungensis</i> var. | <i>Camarotoechia (Rhynconella)</i> |
| <i>Productella subalata</i> ? | <i>Endlichi</i> . |
| <i>Productella subalata</i> var. | <i>Camarotoechia contracta</i> ? |
| <i>Productella semiglobosa</i> . | <i>Euomphalus clymenioides</i> . |
| | <i>Orthoceras</i> sp. a. |

* Opinion of Mr. Emmons in conversation.

† Monographs of U. S. Geol. Survey, xxxi, pp. 9-30.

‡ This Journal, xx, p. 224.

In the Gunnison region the following forms were found :

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|--------------------------------------|---|
| <i>Streptelasma</i> sp. | <i>Spirifer disjunctus</i> var. <i>Ani-</i> |
| <i>Chaetetes</i> sp. | <i>masensis</i> . |
| <i>Monotrypella</i> sp. b. | <i>Athyris Coloradænsis</i> . |
| <i>Schizophoria striatula</i> . | <i>Camarotoæchia (Rhynconella)</i> |
| <i>Orthis</i> sp. | <i>Endlichi</i> . |
| <i>Orthothetes Chemungensis</i> var. | <i>Camarotoæchia contracta?</i> |
| <i>Chonetes</i> sp. | <i>Naticopsis? humilis</i> . |
| <i>Productella semiglobosa</i> . | |

Other localities which are represented in the collections of the U. S. National Museum have yielded some of the forms listed above. The labels are not definite, but show the occurrence of the fauna over a wider area than that in which the section has been studied in detail. They are as follows: Massive limestone of White river, Colorado; Cañon of Cement creek, Colorado; Northwestern Colorado; Southwestern Colorado.

After a comparison of the fossils from the various localities, Dr. Girty says: "The strata from which these forms have been collected are without doubt of Devonian age. As they have essentially the same fauna, I refer them to the same horizon, which I take to be well up in the Devonian. In my opinion, it probably belongs below the Chemung, at about the base of the Upper or near the top of the Lower Devonian. While this fauna is clearly related to other fossil assemblages of our western Devonian, it cannot be said to be strictly identical with any one of them, for its common forms, *Spirifer disjunctus* var. *Animasensis*, *Athyris Coloradænsis*, and *Camarotoæchia Endlichi*, which, so far as I am aware, have not been found elsewhere, give it considerable individuality. Of the faunas with which I am familiar, it most closely resembles that described by Whiteaves from Hay river, Canada, and from other parts of the Mackenzie region."

Correlation.—The combined evidence furnished by paleontology and stratigraphy, as set forth in the preceding paragraphs, is thought to be sufficient to establish the practical equivalency of formations of Devonian age occurring in widely separated localities of Colorado, Utah and Arizona. The "Parting Quartzite" has been a datum of reference in all the geological investigations in the Central region of Colorado. With the discovery of its age as Devonian its equivalence with strata of that age in the Grand Cañon district was established, and now it is found to be represented in the San Juan region of Colorado. The evidence upon which this correlation rests, is the occurrence of fish remains of similar types in the three regions, and the corresponding position which the siliceous

series occupies below the Devonian limestone, in the San Juan region, and in certain localities in Central Colorado.

Fossils from the limestone immediately above the "Parting Quartzite" in the Gunnison region and at Salida are found to represent a fauna which is identical with that obtained from the Devonian limestone occurring above the siliceous series in the San Juan region. The correlation is thus firmly established, both as regards the limestone and the siliceous beds beneath it. It must be borne in mind, however, that in the San Juan region the lowest strata may be older than Devonian. There is a suggestion of this in the poorly preserved plants from the lower part of the quartzite, but the unity of the quartzite member as a whole is distinctly against this view.*

Following up the correlation brought out by Spurr between the "Parting Quartzite" of Central Colorado and the Devonian of the Grand Cañon region, it is of interest to note that the lower part of the Red Wall limestone of the Grand Cañon, below the part which contains the well recognized Lower Carboniferous forms, is unfossiliferous. It was suggested by Gilbert† that the base of the Red Wall Carboniferous limestone had possibly been placed so low that it might include the Devonian and even part of the Silurian. Devonian rocks have since been found below it,‡ and if the sequence is parallel in Colorado and the Grand Cañon district, it is very probable that the lower part of the Red Wall limestone is equivalent in age as well as in position to the Devonian limestone of Colorado.

If the correlations here suggested are correct, it appears that Devonian and associated strata were originally deposited over an extensive area in the Southern Rocky Mountain region, the boundaries of which are as yet entirely unknown.

U. S. Geological Survey, June, 1899.

* While there is, in the mind of the writer, no reason for doubting the equivalence of the siliceous formations which he correlates with the "Parting Quartzite," he does not accept as conclusive the evidence concerning their age. The fish remains have been pronounced of Devonian types, but in no case have they been specifically determinable, and it is to be remembered that the fishes from the Lower Silurian near Cañon City are of types not previously known to occur below the Devonian.

† U. S. Geol. Surv. W. of 100th Mer., iii, p. 178.

‡ C. D. Walcott, loc. cit.