THE HARDING SANDSTONE OF COLORADO.*

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In a recent paper Stauffer (1930, p. 83) makes the following statements: "Some of the other western sediments, commonly referred to the Ordovician, are doubtless Devonian. This is certainly the case with the deposits at Canyon City, Colorado, where the beds of argillaceous red limestone containing fragmentary fish bones and plates have often been referred to as Ordovician. These fishes, however, are highly specialized forms belonging to the same genera as those commonly found in the Onondaga (Columbus limestone) of central Ohio and other eastern regions. The rocks in which they occur are therefore Middle Devonian† and it is evident that this portion of the system is more widely distributed over western North America than had been supposed."

As will appear, this somewhat startling statement is not novel, as Stauffer states. The same general statement was made in regard to the fish fauna at Canyon City as far back as 1897, by Frech, while the resemblance of the fish to Devonian forms was emphasized by Zittel, Jaekel, and Hall in the discussion of Walcott's original paper (1892). The resemblance of the fish fragments to Devonian types is of biological interest but of no importance in determining the age of the Harding sandstone. The indisputable occurrence of the Harding fish fauna beneath the Fremont limestone of Colorado and the Bighorn dolomite of Wyoming over an area of several thousand square miles is, however, of considerable importance.

Frech (1897, pp. 82-83) not only doubted the Ordovician age of the fish-bearing beds at Canyon City because of their similarity to Devonian types and their supposed unlikeness to what Ordovician fish should be, but also assumed tectonic structures that do not exist. This is the only place in the literature of which I know where the position of the fish-bearing beds underlying Ordovician strata is explained by overthrust, overturned folding, or what not. However, I was told by Doctor Walcott that at the time of the Inter-

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† This was first recognized by Dr. A. J. Stoyanow. Private communication.

national Geological Congress in 1891 this was the opinion of many European geologists who visited Canyon City. The section here is obvious but, as emphasized by Frech, when taken alone might not be taken as conclusive by some.

One would think that Darton's subsequent paper (1906) supplementing Walcott's section at Canyon City and demonstrating the presence of the same horizon in the Bighorn Mountains of Wyoming would have furnished the necessary additional proof. This is apparently not the case. I have therefore brought together a number of additional sections in Colorado and Wyoming, which not only substantiate the earlier work in every detail but add somewhat to our knowledge of Rocky Mountain stratigraphy. I shall at first describe sections running westward from Canyon City, which in part have either not been described or in which the Harding has been erroneously placed. I shall then give additional sections in the Bighorn and Bridger ranges of Wyoming.

Colorado.

Canyon City, Colo.—There is no need to describe the section at Canyon City. Walcott's section (1892, pp. 155-156) is quite adequate, and his discussion of the stratigraphic relations should have been conclusive. In this area some 86 to 100 feet of sandstones and shaly beds rest either on the pre-Cambrian or on Manitou limestone and are overlain by Fremont limestone. This paper is supplemented by Darton (1906, pp. 560-563), who discusses the stratigraphy of the Harding.

Salida, Colo.—About five miles southeast of Salida is an excellent section in which equivalents of the Manitou, Harding, and overlying Fremont are present. At this place the Harding equivalent has a thickness of 75 feet. It is a very dense quartzite, with occasional thin layers of softer material. The uppermost 3 feet is yellowish in color and relatively soft. In some places the top 2 or 3 inches is deeply iron-stained. The upper surface is somewhat irregular. The character of the uppermost 3 feet of the Harding is undoubtedly due to pre-Fremont weathering.

Monarch, Colo.—East of Monarch, at the crest of Monarch Hill, at an elevation of about 11,500 feet, are fair exposures of rocks of Manitou, Harding, and Fremont age. These rocks have been described by Crawford (1913, p. 56) under

the name Tomichi limestone. A sandstone which the writer correlates with the Harding sandstone is stated by Crawford to vary in thickness between 20 and 38 feet within the Monarch district. Locally this sandstone is known as the "parting quartzite," though stratigraphically it has nothing to do with the "Parting quartzite" of Leadville. I saw a few fish fragments in the "parting quartzite" at the top of Monarch Hill, but as the outcrop consisted in the main of angular blocks broken up by frost action conditions were not favorable for showing them.

Trout Creek, Colo.—Along the road following Trout Creek, northwest of Buena Vista, Colo., is a fairly good section showing equivalents of Manitou, Harding, and Fremont. The section is of interest in that it is the nearest locality east of Leadville at which the Harding and Fremont are represented. These formations are wanting at Leadville. In the Trout Creek section there are 21 feet of Harding, with abundant fish fragments near the top. In the upper part of the Harding are a few beds up to 1 foot in thickness of a peculiar bluish-green color, which have not been seen elsewhere.

Buxton, Colo.—Along Indian Creek near Buxton, Colo., the equivalents of Manitou and Fremont were seen, with blocks of sandstone representing the Harding carrying fish, pelecypods, *Lingula,* and gastropods on the talus below. The sandstone was not seen in the section but must be thin.

Gold Brick district, Colo.—This area is of interest in that it is geographically intermediate between Monarch and Crested Butte. Worcester (1916, p. 53 et seq.) discusses the Paleozoic rocks of the region. His section of the Yule limestone (pp. 53-54) is essentially that of Eldridge's original usage (see Crested Butte) except that he did not include Cambrian sandstone at the base. His section follows:

Section of Ordovician sediments at Fossil Ridge.

Top		Feet
	1 *Upper non-fossiliferous member*	
7	White cream, or mottled red and green, fine-grained, compact somewhat sandy, dolomitic limestone, alternating with thin beds of sandy, green shale	27
6	Mottled red, green, or chocolate, sandy shales with thin beds of light colored limestone	18
5	Brownish-gray, arenaceous shales and shaly limestone, thin bedded, somewhat ripple marked	11
4	Brown, coarse, even-grained quartzite	1
		57

Top	2 *Lower fossiliferous member*	Feet	
3	Massive blue limestone, dolomitic, sandy	35	
2	Quartzite, white or red due to iron stains; many impressions that look like pieces of wood or fish scales, but may be inorganic; 10-inch green shale parting in the center	8	
1	Thin-bedded limestone, sandy and clayey; gray or light blue with local green or red tints; very cherty at base; less cherty near top	196	
			239
	Total		296

In this section No. 1 is of Manitou age, No. 2 represents the Harding, No. 3 includes the equivalent of the Fremont with some Devonian at the top, Nos. 4-7 and part of his Leadville (pp. 59-60) are Devonian (lower Ouray). Worcester (1916, pp. 56-58) notes the presence of fish remains in his No. 3 "in a somewhat sandy phase of the limestone at the top of the horizon." As a matter of fact No. 3 represents the typical lower Fremont, a massive grayish weathering dolomite. The "sandy phase" at the top which carries the fish discussed by Worcester goes with the overlying Devonian ("Fairview" shale).

Cockerell (1915) discussed the fish from this horizon and came to the conclusion that "It must, therefore, be said of the remains now under discussion that, while they appear to be Devonian, it is by no means impossible that they are older." Henderson (1914) expressed the opinion that the fish were of Ordovician age. Cockerell's conclusions as to the affinities of these fish are quite justified, for they are unquestionably of Devonian age. As noted above, it is No. 2 of Worcester's section that represents the Harding. There are poorly preserved Ordovician fish fragments in No. 2.

Cement Creek, Crested Butte quadrangle, Colo.—This region is the farthest west the sandstone of Harding age is known. In the Crested Butte folio Eldridge (1894) combined the equivalents of a part of the upper Sawatch (Upper Cambrian), the Manitou, the Harding, the Fremont, and a part of the overlying Devonian under the name Yule limestone. As shown along lower Cement Creek the Harding equivalent has a thickness of but 13 feet. The lower 5 feet is a saccharoidal sandstone overlain by 8 feet of purplish sandy shales. Fish fragments are found in these beds. Keyes (1924, chart p. 281) has expanded Yule to "Yulean" (of late Ordovician age) with three subdivisions: Harding, 100

feet, sandstone; Fremont, 300 feet, dolomite; and Cement, 100 feet, shale. The Harding of Keyes is Upper Cambrian (Sawatch), his Fremont includes equivalents of Manitou, Harding, and Fremont, while his Cement is Devonian (lower Ouray).

Colorado Springs quadrangle, Colo.—North of Canyon City along the Rocky Mountain front the farthest north the Harding sandstone has been recorded is in the southwest portion of the Colorado Springs quadrangle north of Table Mountain. Finlay (1916, p. 6) notes the presence here of a few feet of sandstones that he correlates with the Harding. It overlies the Manitou and is overlain by Carboniferous rocks. Without the confirmatory evidence of fossils or the presence of Fremont above it the assignment of this sandstone is doubtful.

Manitou, Colo.—Tomlinson (1917, Pt. I, p. 117) notes a section "on the ridges from one to two miles northwest of Manitou, Colorado," measured by him. In the correlation chart, page 118, and again on page 127 he notes the presence of a "very arkosic, and in part deeply stained (red and green)" sandstone that he correlates with the Harding. In the correlation chart it is given a thickness of 58 feet, and in the "standard list of members" (p. 127) he describes it as 47 feet thick. According to his correlation chart the sandstone is followed by 201 feet of lower Bighorn. This sandstone could be only Sawatch (Cambrian) and the overlying rocks must be Manitou rather than Bighorn.

WYOMING.

Ordovician fish remains were first found in Wyoming and described by Darton (1906). The occurrence of the fish-bed as described by Darton was in the south-central portion of the Bighorn Mountains, extending from the head of the main (south) fork of Red Fork of Powder River southward for some 7 miles. Darton considered the entire thickness of sandstone lying between the Cambrian and Bighorn dolomite to represent a horizon equivalent to the Harding. As described by him the sandstone had a thickness of from 6 to 8 feet.

There are in the Bighorn and Bridger ranges two Ordovician sandstones that may be confused and were combined by Darton. The lower is the true Harding equivalent and usually

carries fish fragments in fair abundance. The overlying sandstone, the basal sandstone of the Bighorn, also carries an occasional fish fragment. In this sandstone the bones as seen were small rolled pieces that may well have been derived from the underlying horizon. Extensive collecting in this sandstone in the Wind River and Teton ranges to the west did not yield a single piece of bone. The two sandstones differ lithologically and may readily be distinguished. The upper sandstone usually carries a characteristic and sometimes abundant invertebrate fauna consisting of cephalopods, gastropods, and *Receptaculites.*

According to Darton (1906, p. 546) the sandstone at the base of the Bighorn disappears some 22 miles southeast of Bigtrails, the most southerly exposure being on the West Fork of Powder River. As a matter of fact the basal sandstone of the Bighorn was traced in this region westward along the Bridger Range to the Wind River (Bighorn) Canyon south of Thermopolis and is extensively developed in the Wind River and Teton ranges. The Harding equivalent does not extend as far west as the Bighorn Canyon. On the west side of the canyon at what is arbitrarily taken as the eastern limit of the Owl Creek Range near Boysen a 1.5-foot bed of sandy dolomite lies at the base of the Bighorn in contact with flat-pebble conglomerates that are probably of Cambrian age. To the east of the canyon along the Bridger Range exposures of the basal Bighorn are poor, usually being covered with talus. From Ditch Creek eastward, however, sandstones between the Cambrian and Bighorn are apparently everywhere present, as evidenced by float in the talus. On Kirby Creek a 5-foot bed of sandstone (basal Bighorn) carrying large cephalopods was seen. Whether the Harding equivalent is present or not was not determined. From the east side of West Bridger Creek eastward and then northward on the Bighorn uplift both the basal sandstone of the Bighorn and the Harding equivalent are present in all sections, except where the Mississippian (or possibly Devonian) rests directly on the Cambrian.

From the east side of West Bridger Creek to the neighborhood of Depass (or D Ranch) both sandstones are exposed in several sections. In this area the Harding equivalent is approximately 5 feet in thickness and is a dense fine-grained quartzite at times nearly resembling a novaculite. Above this is a 1-foot bed of coarse saccharoidal sandstone, carrying characteristic Bighorn fossils. The Harding equivalent

carries abundant fish fragments and an occasional *Lingula.* The upper surface of the Harding equivalent is irregular and evidently represents an erosion surface. On the main fork of Beaver Creek the base of the Bighorn is sandy dolomite, some 8 inches thick, rather than a true sandstone. The underlying Harding equivalent carries abundant fish fragments and is notable as to the irregularity of its upper surface, depressions 6 inches or more in depth being present. On the west side of the Bighorns the Harding equivalent is present on Lee Creek as shown by large numbers of fish fragments. The basal sandstone of the Bighorn was not seen. On Tensleep Creek there is a sandstone at the base of the Bighorn, but which one it is was not determined.

On the east side of the Bighorns, on Billy Creek, in the southern part of the Fort McKinney quadrangle and about 3 miles south of Crazy Woman Hill, is a very interesting section of the Harding equivalent and the thickest seen by me. From the top downward the section is as follows:

	Massive Bighorn dolomite.
3′	Basal sandstone of the Bighorn. Dense iron-stained medium-grainel sandstone with *Receptaculites* and gastropods.
	Unconformity.
5′	Fairly coarse sandstone, reddish-brown in color. Carries fish fragments.
6″	Shaly seam like 10′ bed below.
2′	Mottled sandstone.
10′	Soft mottled shaly sandstone. Dirty bluish-gray in color with reddish mottling. Slope, no fresh exposure.
5′	Dense fine-grained sandstone, capping low cliff.
20′	Thin-bedded (average 6″) fine dense sandstone almost a novaculite. Light-grayish color when fresh.
	Base not exposed.
42′ 6″	of Harding equivalent as exposed.

North of this locality I examined only two sections, in neither of which were the basal Ordovician beds exposed. Darton, however (1906, p. 546), states that the basal sandstone "is most extensively developed in the northern central portion of the uplift, where its thickness usually is from 25 to 30 feet." It is probable that the greater portion of this thickness represents the Harding, but it is also probable that the basal sandstone of the Bighorn is also present.

From the foregoing summary of sections in which the Harding horizon is clearly shown in its proper stratigraphic

position it may be seen that over an area aggregating several thousand square miles a sandstone carrying fish underlies beds of unquestioned Ordovician age. It is undoubtedly true that at times Devonian and Ordovician horizons have been confused, but this has no bearing on the age of the Harding and its contained fish fauna.

The exact age of the Harding sandstone can not be determined with certainty. The rich invertebrate fauna of the Harding in the Canyon City area associated with the fish remains is unlike any other known. It consists in the main of pelecypods, gastropods, and cephalopods. Trilobites, eurypterids, and brachiopods also are found. Although abundant the preservation of the fossils leaves much to be desired, as in the case of most sandstone faunas. It has every appearance of being a Middle Ordovician fauna, however. The placement of the Harding therefore depends to a great extent on age determinations of the overlying beds.

Immediately above the Harding at Canyon City is a thin layer of shale, about 1-foot in thickness as I saw it and given a thickness of 2 to 4 feet by Walcott. This layer is deeply stained with iron, and there are hematite replacements of rolled fossils. At the base of the shale are rolled fragments of fish bone. This bed I consider the weathered and reworked top of the Harding. At and near Canyon City the next higher horizon is a deeply iron-stained crystalline limestone which ranges in thickness from 3 to 10 feet within a short distance, as seen. In the basal portion of this horizon *Echinosphaera* sp. is abundant, either as dissociated plates or entire individuals. The upper surface of this horizon is very irregular and gives evidence of considerable erosion prior to the deposition of the main mass of the Fremont. This *Echinosphaera* horizon is not present elsewhere in the Rocky Mountain region so far as known. It is to be correlated with beds in the upper part of the Kimmswick limestone of the Mississippi Valley or in a possible unnamed formation lying above the Kimmswick. Considering the stratigraphic position of the widely distributed *Echinosphaera* this horizon can not be considered as other than of approximately Black River or Trenton age. The associated fossils also bear out this age assignment.

Overlying this Kimmswick equivalent at Canyon City is a series of limestones and dolomites of Ordovician age that may readily be subdivided into two or possibly three strati-

graphic units with characteristic faunal aggregates. The unit immediately above the Kimmswick equivalent correlates with the lower part of the Bighorn dolomite of Wyoming, the lower part of the Montoya limestone of Texas and New Mexico, and possibly the lower part of the Fish Haven dolomite of Utah. This horizon in the main seems to be wanting in the Great Basin region but to be present in isolated areas. It is not present at Gold Hill, Utah, and Pioche, Nev., where I have seen the sections. It probably is not present in the White Pine and Eureka districts, Nev., though in the latter area it may be present as a thin, sparingly fossiliferous dolomite immediately overlying the Eureka quartzite.

In Wyoming the Harding equivalent as noted above is overlain by a fossiliferous sandstone that I consider the initial deposit of the lower Bighorn. The lower massive Bighorn extends westward from its type area with practically its normal thickness and similar lithology as far west as the western side of the Teton mountains, near the Wyoming-Idaho line. It probably extends further westward into Idaho but has not been determined with certainty. In the Black Hills of South Dakota the lower Bighorn horizon is present and has been named the Whitewood limestone. To the north in Manitoba the same stratigraphic horizon is represented in the Red River formation. There is no equivalent to the lower Bighorn in the British Columbia sections that I have seen. The Beaverfoot formation is a higher horizon and in its lower part is the equivalent of the widespread dolomite that generally marks the base of the Upper Ordovician of the Great Basin region. As noted above the lower Bighorn is represented in Texas and New Mexico by the lower Montoya, but to the east, in the Marathon Basin region of Texas, it is wanting. Here, however, rolled silicified corals of this age are present in the basal conglomerate of a limestone series of Upper Ordovician age. It seems probable that rocks of lower Bighorn age were deposited widely over western North America, and their absence in sections to-day may quite as well be explained by erosion as non-deposition.

The exact age of the lower Bighorn is in doubt. It has been variously correlated with the Galena and Trenton and the Richmondian. Equivalent beds in Manitoba and the far north have been correlated by Foerste (1929, a and b) with the Richmond. Several years ago (1925) I suggested that this horizon was probably of Cincinnatian age (used in the

sense of being pre-Richmond, post-Trenton), and this I believe to be the case. A considerable amount of corroborative evidence has since come to hand. One of the striking pieces of evidence has been the finding of *Cryptolithus* sp. in abundance in the Eureka district, Nev., and the Marathon Basin, Texas. In the former area the *Cryptolithus* zone overlies an horizon either of lower Bighorn age or younger. In the Marathon Basin it occurs in a series of limestones carrying a fauna of post-lower Bighorn age, and at the base of this series is a conglomerate carrying fossils of lower Bighorn age. This line of evidence alone strongly suggests that the lower Bighorn fauna is of pre-Maysville age. It does not dispose, however, of the possible correlation of the horizon with the Trenton.

Foerste's objections to the assignment of this horizon to the Trenton as given in the papers cited above and elsewhere appear valid to me. I do not see the necessity of skipping the lower Cincinnatian, however, as he does, and correlating with the Richmond. It may well be that the lower Bighorn finds its equivalent in some part of the Galena of the upper Mississippi Valley. In this connection it is very interesting to note that in a recent correlation chart published by Ulrich (1930, p. 73) the Galena is cited as "age?" and tentatively placed in line with the Eden and Maysville. It is possible that the lower Bighorn is not an exact time equivalent of any known Cincinnatian but represents a stratigraphic unit to be interpolated in the time scale. I feel, however, that it can be interpreted as lower Cincinnatian of a different faunal facies. At any rate it were better considered as post-Trenton.

From the foregoing account it may be seen that over a very large area sandstones carrying indubitable fish remains are normally overlain by sediments ranging in age from Middle to Upper Ordovician. This fixes the age of the Harding horizon as Ordovician beyond question, and the presumptive evidence is that the horizon is of Middle Ordovician age, probably about late Black River or early Trenton.

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