RELATIONS OF THE EMBAR AND CHUGWATER FORMATIONS IN CENTRAL WYOMING.

By D. Dale Condit.

FIELD DATA.

The information set forth in this paper was obtained in field work during the seasons of 1913 and 1915. During 1913 the writer was engaged in the detailed mapping of the phosphate beds of the Embar formation on the northeast slope of the Wind River Mountains and in the Owl Creek Mountains as far east as Bighorn River canyon. In 1915 the mapping was continued eastward as far as Holt, from which a reconnaissance examination was made east and north along both flanks of the Bighorn Range as far as the latitude of Tensleep. A visit was also made to the west end of the Rattlesnake Mountains and neighboring points in Natrona County, to the Conant Creek anticline, in the eastern part of Fremont County, and to the Sheep Mountain anticline, in the Bighorn Basin.

GENERAL CHARACTER OF THE EMBAR FORMATION.

The term Embar was introduced by Darton[1] to designate strata believed to be of "Permo-Carboniferous" age and lying between the Tensleep sandstone (Pennsylvanian) and the Chugwater formation (red beds of Triassic? age) in the Owl Creek Mountains of Wyoming. The type locality is at Embar post office, about 25 miles west of Thermopolis, where the formation is about 250 feet thick and consists largely of shaly to massive marine limestone, for the most part fossiliferous. Followed laterally eastward, the marine limestones gradually give place to red shales containing many gypsum beds. In the Bighorn Mountains, 70 miles east of the type locality, the transformation of the Embar beds is so complete that they can only with difficulty be distinguished from the overlying red beds composing the Chugwater formation.

The Embar has in recent years attracted attention on account of its yield of petroleum in the Wind River basin and also on account of its phosphate beds, which have been traced and mapped by the United States Geological Survey throughout the Wind River and Owl Creek mountains in the course of land classification. The stratigraphy of the Embar formation as found in the Wind River and Owl Creek mountains has been outlined in a reconnaissance report by Eliot Blackwelder,[2] and those areas will be only briefly reviewed in this paper, the object of which is a consideration of the formation in its eastward extensions from the Owl Creek Mountains into the Bighorn Mountains and from the Wind River range into the Rattlesnake Mountains. (See Pl. LXI.)

As found in typical development, the Embar consists of two principal parts, of which the upper is largely shaly and the lower is chiefly limestone, but includes phosphatic and calcareous shale and nodular chert. The name Park City has been adopted by the United States Geological Survey for the lower part, on the recommendation of Blackwelder, who identifies these beds with the Park City formation of Utah. He has also suggested the name Dinwoody formation for the upper shaly part, from Dinwoody Canyon, in the Wind River Mountains, where the formation, about 200 feet thick, consists of pale-green to white clay and shaly limestone weathering brown and containing obscure pelecypod shells. The Park City and Dinwoody beds as found at these localities are described by Blackwelder in a bulletin on the stratigraphy of the Wind River Mountains, submitted for publication by the United States

[1] Darton, N. H., Geology of the Bighorn Mountains: U. S. Geol. Survey Prof. Paper 51, p. 35, 1906.

[2] A reconnaissance of the phosphate deposits in western Wyoming: U. S. Geol. Survey Bull. 470, pp. 452-481, 1911.

Geological Survey. The somewhat meager evidence at hand seems to indicate that the Dinwoody beds are of Triassic age and are to be correlated with the Woodside shale and Thaynes limestone of southeastern Idaho. Toward the east the Dinwoody beds thin and change to gypseous greenish or brownish shales devoid of fossils. Outcrops of this character are found in the vicinity of Bighorn River canyon near Thermopolis. Still farther east the beds become increasingly gypseous and assume a lithology that can only with difficulty be distinguished from that of the Chugwater.

There is likewise a gradual transformation in the Park City beds as followed eastward from the Owl Creek and Wind River mountains. These changes may be summarized briefly as follows: (1) Increasing thickness; (2) lithologic changes, including thinning of limestone beds and an increasing amount of shale almost entirely of red color; (3) the appearance of beds of massive white sediment-free gypsum in all but the basal portion; (4) the gradual eastward disappearance of marine fossils except in the basal beds of the formation; (5) the increasing prevalence of calcareous conglomerates at the principal limestone horizons; (6) the disappearance of concentrated beds of phosphate rock. With these changes the equivalents of the Park City and Dinwoody units as found in the Bighorn Mountains so little resemble the typical Embar of the Owl Creek Mountains that the relation would hardly be suspected. The same is true of the Park City beds in the Rattlesnake Mountains as compared with those in the Wind River Range. The one member common to all localities is the nodular chert of the upper part of the Park City beds. It is largely through the persistence of this rock that the relations of the Embar and Chugwater beds have been determined.

The eastward thinning of the Dinwoody formation and its apparent disappearance at about the head of No Wood Creek, in the southern part of the Bighorn Mountains, may be attributed to nondeposition, although it is possible that the beds have been eroded, or, less probably, that they are present but so closely resemble the Chugwater red beds in lithology as to be unrecognizable.

The character and relations of the Embar and associated strata in the Wind River, Owl Creek, and Bighorn mountains are represented in the accompanying diagram (fig. 26). It is believed that the Embar includes strata ranging in age from Pennsylvanian to Triassic, and that its beds in the Owl Creek Mountains (see Pl. LXII, *A*) grade laterally into beds that were included in the lower part of the Chugwater formation as interpreted by Darton in the Bighorn Mountains. The beds as followed northeast approach the Chugwater more and more closely in lithologic character, and a difficulty arises in determining just how far the name Embar as a formational designation should be carried. Certainly the Embar facies is recognizable for some distance northward into the Bighorn Range, and throughout this part of the field the term Chugwater should be restricted to the overlying red beds, probably of true Triassic age, rather than to all the beds, as the term is applied in the Laramie Range and Black Hills, where strata apparently as old as Pennsylvanian are included.

FACIES OF THE EMBAR FORMATION.

ILLUSTRATIVE SECTIONS.

The lithologic character of the Embar in its typical development in the Wind River and Owl Creek mountains and in its gradual eastward gradation into gypsiferous red beds in the Bighorn Mountain region (Pl. LXII, *B*) is illustrated by the series of sections in figure 25, and also by figure 26, a diagrammatic cross section from the Wind River Range northeastward to the Bighorn Mountains. The first section in figure 25, measured in Bighorn Canyon near Thermopolis, is with slight modifications representative of the marine facies of the Wind River and Owl Creek mountains. The second section was measured near the head of No Wood Creek, T. 41 N., R. 89 W., near the southwest extremity of the Bighorn Mountains. The conditions of deposition here were evidently intermediate between the marine conditions of the west and the shallow-water or lacustrine conditions that prevailed farther east. The third section, measured at the south end of the Sheep Mountain anticline, near Greybull, illustrates conditions not greatly different from those indicated at the No Wood Creek locality. The presence of fossils at several horizons records temporary marine invasions which alternated with partial emergence or shoaling, thus favoring evaporation and concentration into beds of gypsum and possibly

Base from U. S. G. S. map of Wyoming

A. HOEN & CO. BALTIMORE, MD.

MAP OF CENTRAL AND NORTHWESTERN WYOMING

SHOWING OUTCROPS OF EMBAR FORMATION

In the Bighorn Mountains and north of Cody, where the Embar formation is thin or possibly lacking, the outcrop of the Chugwater formation is included

Scale $\frac{1}{1000000}$

10 0 10 20 30 40 Miles

10 0 10 20 30 40 50 Kilometers

1916

Embar formation

Embar and Chugwater formations

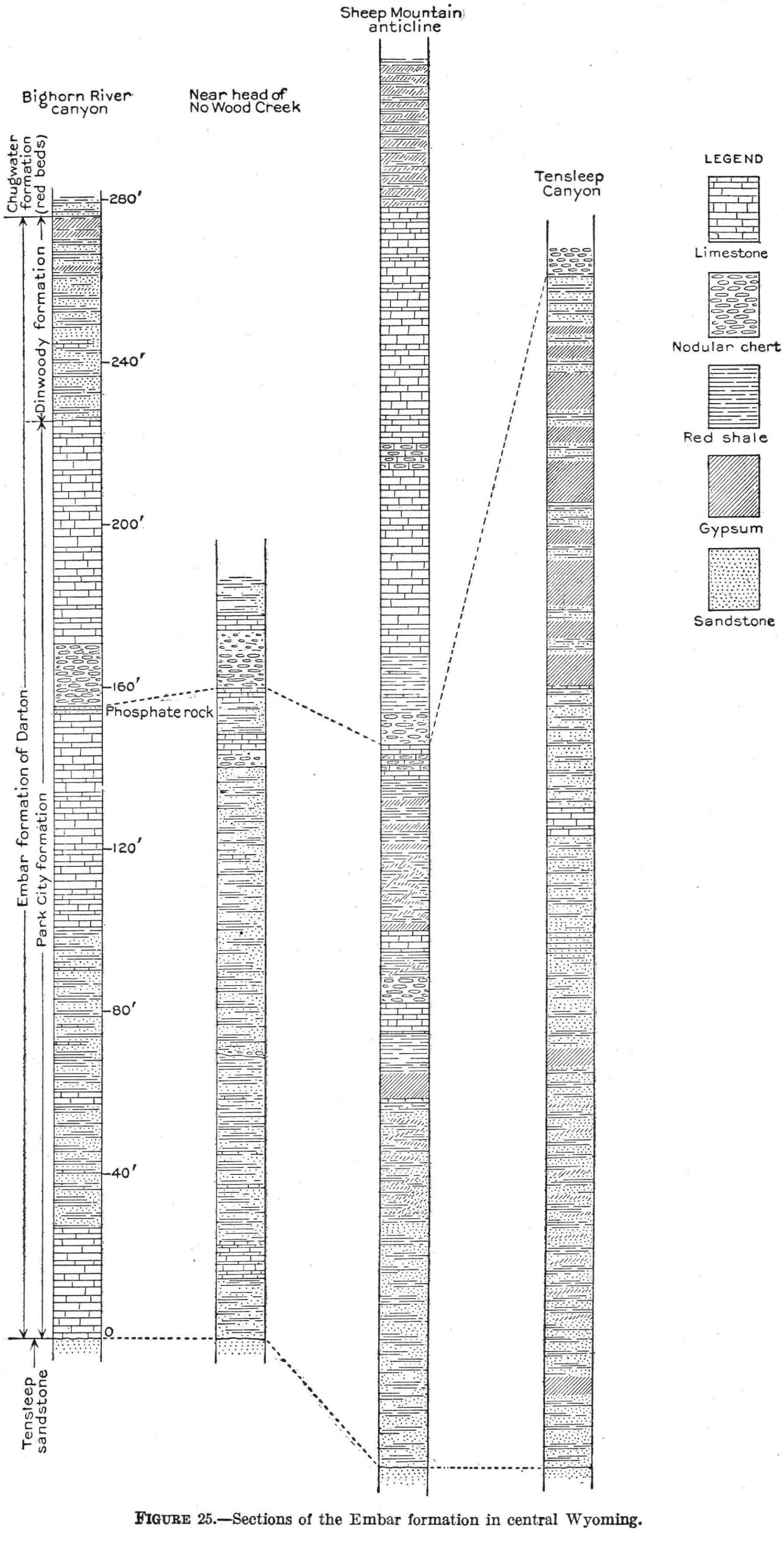


FIGURE 25.—Sections of the Embar formation in central Wyoming.

other salts. The fourth section, measured at Tensleep Canyon, is representative of the formation as found on the west slope of the Bighorn Mountains. Red shales with many thick beds of gypsum and insignificant beds of limestone make up the section. Similar conditions are recorded on the east slope of the same range. The local detailed evidence of the several facies outlined is presented below.

MARINE FACIES OF WIND RIVER AND OWL CREEK MOUNTAINS.

The Park City portion of the Embar formation in the Wind River and Owl Creek mountains consists largely of limestone with calcareous shale and nodular chert. The general sequence, in ascending order, is (1) dolomitic gray fossiliferous limestone, resting with slight unconformity on the Tensleep sandstone; (2) argillaceous shaly limestone and sandy calcareous shale of yellowish color; (3) limestone with geodes, chert masses, and many fossils, among which are *Productus nevadensis*, Leioclema, *Spiriferina pulchra*, and *Productus subhorridus;* (4) phosphatic shale of sepia-brown color, with one or more layers of granular phosphate rock and phosphatic limestone at the base; (5) nodular greenish phosphatic chert interbedded with many shale laminæ; (6) siliceous greenish limestone grading up into gray resistant limestone, with abundant fossils, including Derbya, Pseudomonotis, Leioclema, and *Spiriferina pulchra*. These and other forms mentioned in this paper were identified by G. H. Girty.

The detailed stratigraphy in the Wind River Mountains is further illustrated by a section measured on South Fork of Little Wind River in T. 1 S., R. 2 W. Wind River meridian. It will be noticed that phosphate occurs at two horizons, one in the upper part and the other near the base. The lower bed is of considerable value in the Wind River Range but is missing in the Owl Creek Mountains.

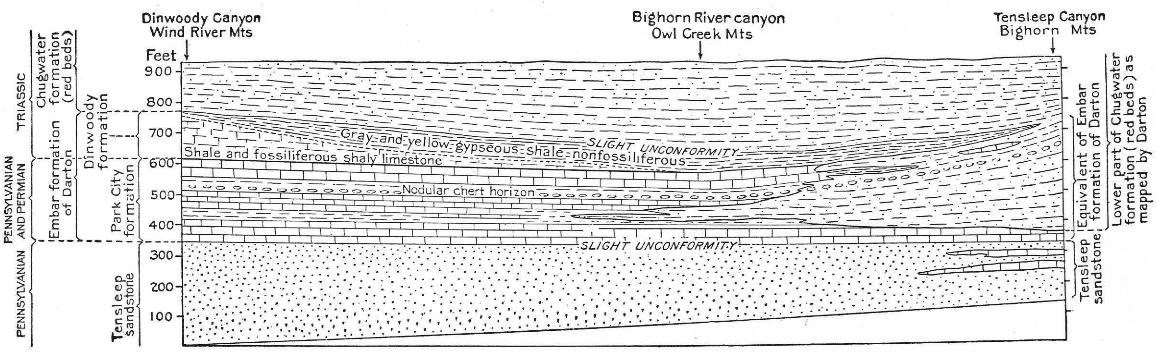
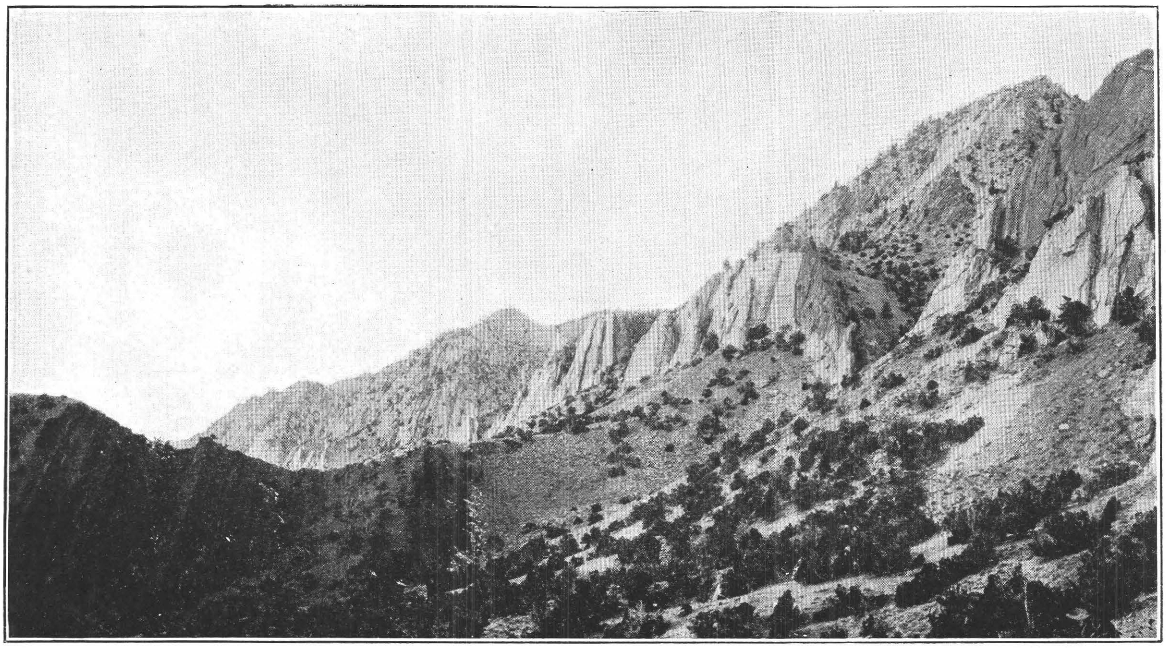


FIGURE 26.—Diagrammatic cross section from Wind River Mountains to Bighorn Mountains, Wyo.

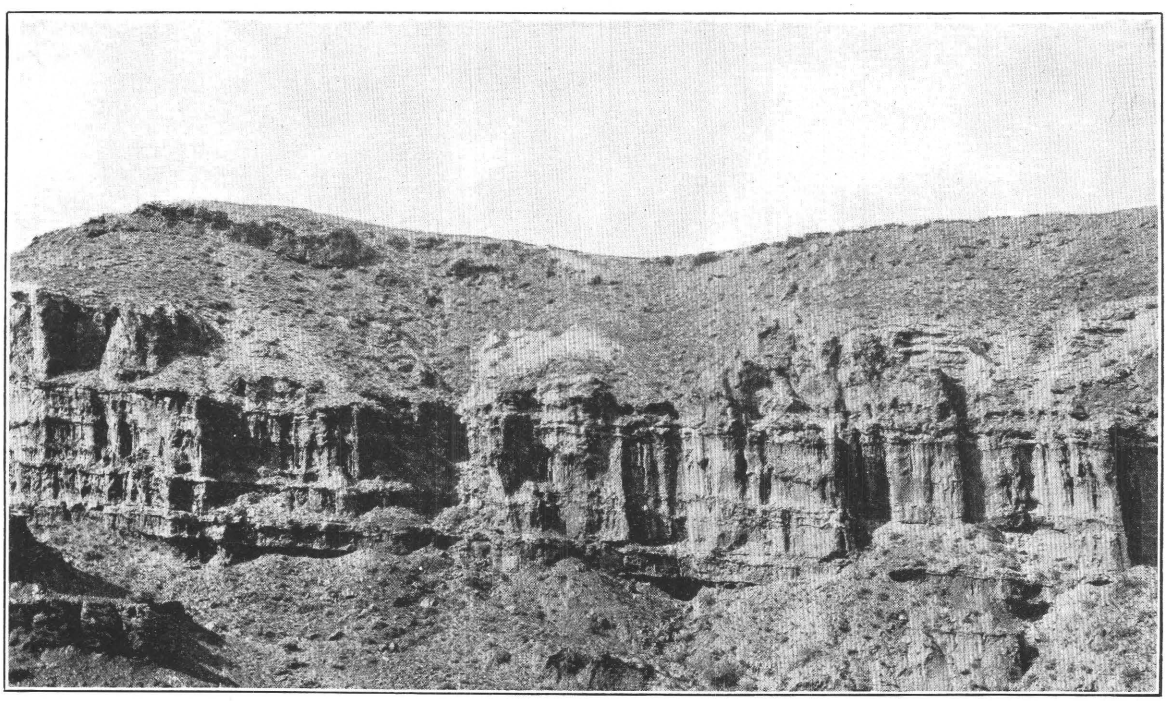
Section of Park City formation on South Fork of Little Wind River, on the northeast slope of the Wind River Mountains.

	Ft.	in.
Limestone, chalky in upper portion, dolomitic and cherty, grayish below	12	0
Limestone, brownish gray, crystalline, fossiliferous; Leioclema, Fenestella, *Spiriferina pulchra*, Derbya, and small crinoid segments plentiful	22	0
Chert, nodular, in bluish-gray shaly matrix	14	0
Shale, siliceous, bluish gray and cherty near top, drab to sepia brown, with phosphate bands, in lower part	37	8
Upper phosphate bed:		
Phosphate, dark, oolitic, sandy; Pugnax only fossil recognized (tricalcium phosphate, 41.14 per cent)	1	4
Phosphate, sandy; *Productus nevadensis* and Pugnax common (tricalcium phosphate, 43.74 per cent)	1	6
Limestone, brownish gray, thin bedded; *Productus nevadensis* and Spirifer aff. *S. cameratus* plentiful. In the lower portion are abundant specimens of Chonetes aff. *C. geinitzianus*	12	0
Limestone, massive, yellowish brown, crystalline; many fossils, Leioclema especially abundant	11	0
Limestone, dolomitic, interbedded with laminated chert and sandy shale	84	0
Limestone, gray, coarsely crystalline, massive; abundant molds of diminutive pelecypods and gastropods	31	0
Lower phosphate bed:		
Limestone, phosphatic, gray, with dark spots; *Lingulidiscina utahensis* present	1	0
Phosphate rock, calcareous, dark, granular (tricalcium phosphate, 36.51 per cent)		6
Limestone, phosphatic, dense textured, dark; a fossil, probably Composita, present		10
Phosphate rock, calcareous; green granules of glauconite (?) abundant; phosphatic shells of Lingulidiscina abound (tricalcium phosphate, 48.13 per cent)	1	0
Phosphate rock, dark, calcareous; few traces of fossils (tricalcium phosphate, 39.92 per cent)		8



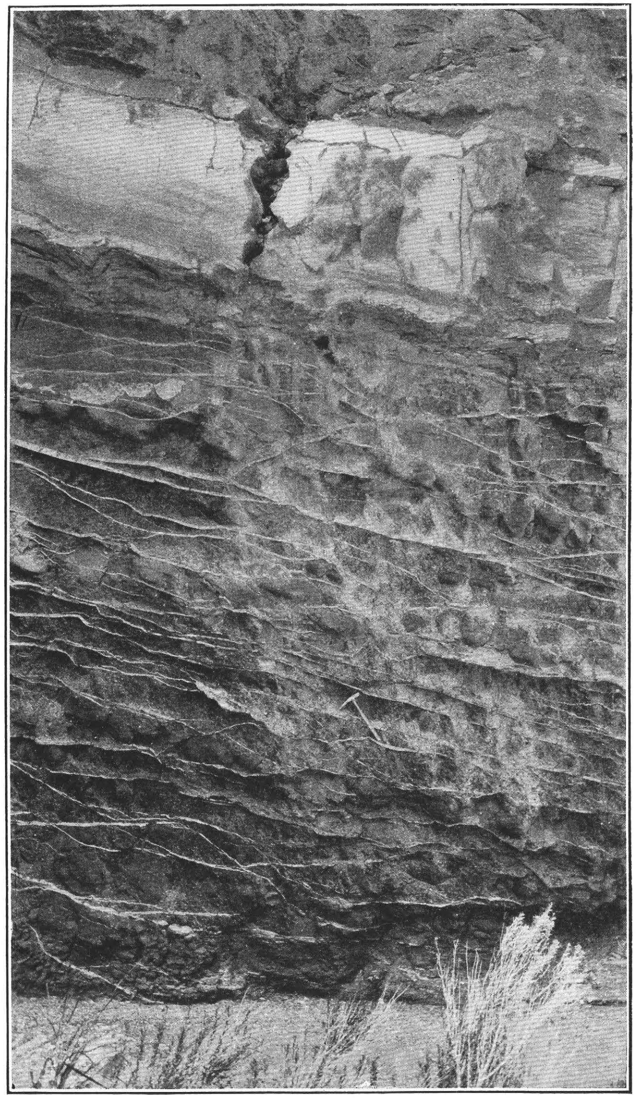
A. EMBAR AND ASSOCIATED FORMATIONS ON SOUTH FLANK OF OWL CREEK MOUNTAINS NEAR SHOT GUN CREEK, WYO., IN T. 7 N., R. 1 E.

Upturned shales of Chugwater formation at left; resistant upturned limestone of Park City formation at right, underlain by Tensleep sandstone, which forms the highest hill in the foreground at right.



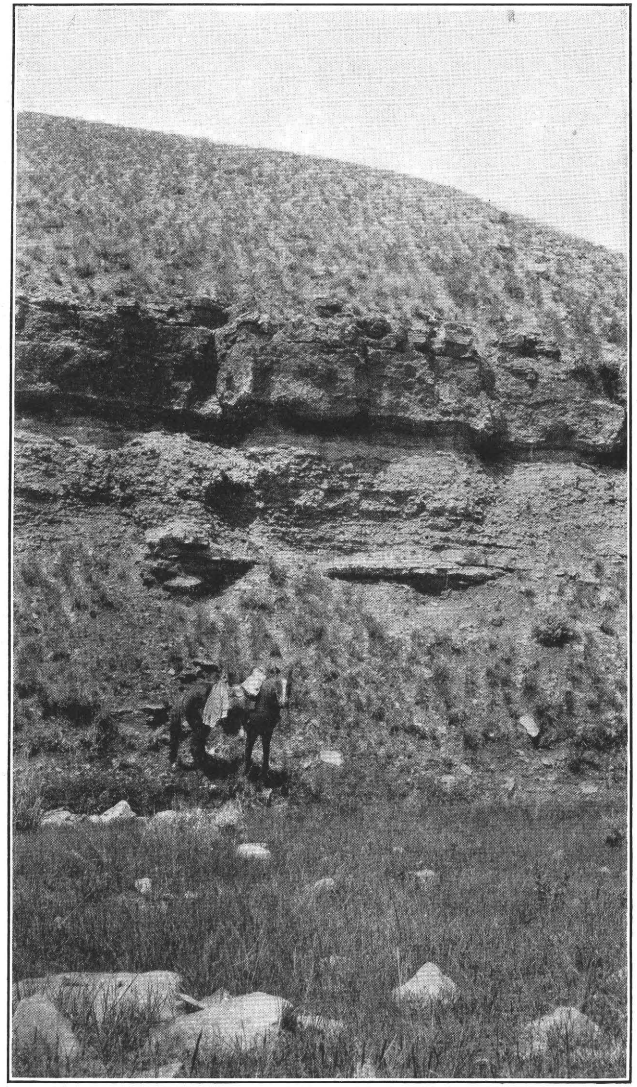
B. RED BEDS IN MIDDLE OF EMBAR FORMATION ON EAST SLOPE OF BIGHORN MOUNTAINS NEAR BARNUM, WYO., IN T. 42 N., R. 84 W.

At top of hill is calcareous conglomerate. The beds below consist of structureless friable sandy red shale with irregular laminæ of limestone, much distorted and faulted. These beds rest on even, undisturbed layers of limestone that form the basal part of the Embar formation. Thickness to top of hill is about 90 feet.



A. BED AND VEINLETS OF GYPSUM IN LOWER PART OF EMBAR FORMATION NEAR SOUTH END OF SHEEP MOUNTAIN ANTICLINE, WYOMING.

About 17 feet above the 4-foot layer of gypsum is limestone filled with marine fossils. The veinlets of gypsum are in structureless red shale.



B. NODULAR CHERTY SHALES OVERLAIN BY LIMESTONE IN UPPER PART OF EMBAR FORMATION NEAR HEAD OF NO WOOD CREEK, WYO., IN T. 41 N., R. 89 W.

At the base is phosphatic limestone in the geologic position of the principal phosphate bed found elsewhere.

	Ft.	in.
Limestone, granular, thick bedded, having small calcite vugs; granules of glauconite (?) present.	12	0
Limestone and dolomite, argillaceous, gray, with cherty layers and localized green stains........	31	0
Chert, white and gray, laminated................	7	0
Limestone, buff, dolomitic, resting on Tensleep sandstone..................................	4	0

At certain points along the Wind River Mountain front the limestone beneath the lower phosphate bed is rich in cephalopod and gastropod forms believed by Mr. Girty to indicate Pennsylvanian age. The upper phosphate bed contains the *Spiriferina pulchra* fauna, which is regarded as of Permian age.

TRANSITIONAL FACIES.

The exposures at the Sheep Mountain anticline and near the head of No Wood Creek illustrate conditions intermediate between the marine facies of the west and the shallow-water, arid conditions of the east.

In the Sheep Mountain region the fossiliferous limestones of the upper two-thirds of the formation show that deposition for the most part took place in sea water. A little below the middle, however, persistent beds of gypsum (Pl. LXIII, *A*) alternate with the fossiliferous limestones, indicating intermittent restrictions of the sea and concentration of the water, which temporarily favored precipitation. The fine-textured arenaceous even-bedded red shales of the lower part denote deposition for the most part at or a little below sea level. The general absence of coarse sandy sediments here and elsewhere at the Park City horizon indicates that the land areas supplying the sediments were reduced nearly to base-level and that the products of erosion were carried by streams of low gradient. The source of the sediment is a matter of speculation but may have been land to the east, for the beds thicken in that direction.

Evidence of depositional conditions equivalent to those recorded near Greybull and at the head of No Wood Creek is found at the west end of the Rattlesnake Range, in Natrona County. The Park City beds, where observed near the Jamison ranch, in T. 33 N., R. 88 W., are about 300 feet thick and consist largely of red shales with a few impure limestone beds and one limestone member about 25 feet thick near the base. The upper part of the formation contains much reddish-brown nodular chert (Pl. LXIII, *B*), with which are associated Derbya and other fossils characteristic of the upper part of the Park City formation. No gypsum beds were discovered here, but some have been noted by C. J. Hares at Alcova, about 35 miles to the southeast.

SHALLOW-WATER FACIES.

Arid conditions, favoring concentration of brines and deposition of thick beds of gypsum and probably other salts, prevailed in the Bighorn Mountain region almost from the beginning of Embar time. The basal 20 feet or so of strata resting on the nearly even upper surface of the Tensleep sandstone consist of dolomitic cherty limestones with a few marine fossils, overlain by green and red shales containing locally a layer of impure fine-textured curly brown limestone, apparently of algal origin. Higher strata have little regularity of sequence, but there is a predominance of arenaceous red beds which are gypseous throughout and contain an increasing amount of gypsum toward the top. The thickest gypsum beds in the upper part of the formation are locally 100 feet or more thick and consist of numerous clean white layers 5 to 10 feet thick, lacking mechanical sediments and alternating with thin layers of red shale and laminæ of dolomitic limestone, generally a few inches thick. In the upper part of the formation there is a persistent layer of nodular purplish-red chert in the midst of the gypseous beds. The chert bed has been traced continuously eastward from the Owl Creek Mountains and is believed to lie at the same horizon as the greenish chert above the phosphate bed of that region.

The gypsum beds are prominent at Tensleep Canyon, at Cherry Creek near Redbank, and at numerous other points on the west slope of the Bighorn Mountains, being 50 to 100 feet or more in thickness at a number of places. Deposits even thicker than this are found on the east slope of the mountains, along the several forks of Crazy Woman Creek, and to the south, along branches of Powder River.

One of the noteworthy features concerning the gypsum beds is that they are not persistent. They grade laterally into red beds and conglomeratic limestone of vesicular, tufaceous texture. The gypsum and conglomerate beds lie approximately at the same horizon and are found in the same general vicinity, but are not as a rule associated in any one section. The gradation from one to the other not uncommonly takes place within a distance of a few hundred yards. This mode of occurrence is in large part a result of the conditions of deposition, which favored prolonged evaporation in numerous small basins, the margins of which were above water from time to time, permitting a drying and cracking of the calcareous muds and slight erosion. The fragments were rolled along and cemented by calcareous deposits of tufaceous character. The conglomerate pebbles, consisting of red shale, friable sandy material, limestone, and chert, all of local origin, occur at several horizons. A peculiar result of weathering of this rock is the removal, partly by solution and partly by wind erosion, of many of the pebbles, leaving the calcareous matrix of vesicular texture with rounded cavities as much as 4 to 6 inches in diameter.

The nonpersistence of the gypsum beds is in part attributed to solution in recent times. Evidence supporting this conclusion is seen along the east slope, where sink holes are not uncommon, and also in the absence of gypsum in exposures extending a short distance up the mountain slope. This feature is especially noticeable near No Wood and Redbank, where there is an abundance of bedded gypsum up to about the 6,700-foot contour and none at all in higher exposures. Stratigraphic measurements above and below this elevation show a corresponding difference in thickness.

The irregularity of the gypsum beds is also in part attributable to partial solution at different times in the past, when it has been favored by the ever-changing ground-water conditions. The chief evidence of this process is the greatly distorted character of the rocks in all but the basal part of the formation. The distortion is noticed even in exposures along the base of the mountains. The arenaceous red clays are structureless and loosely cemented. Thin laminæ of limestone distributed through the section are faulted and tilted in edgewise blocks. The evident disturbance of these beds and the undisturbed character of the underlying beds indicate that there has been a widespread collapse through the removal of soluble parts of the beds, perhaps at different times. Possibly the soluble parts included salt as well as gypsum. In fact, the data would seem to indicate that they did, because a certain amount of distortion is noticed even in exposures where there is much gypsum. The possibility of the former presence of saline deposits leads to the query whether those salts may not still exist down the dip far below the surface.

The evidence at hand seems to indicate that the gypsum beds were deposited under conditions somewhat different from those prevailing during the deposition of the gypsum beds found in the upper part of the Chugwater, which are described by Branson.[1] The red beds (Chugwater), which are coextensive with the Embar in Wyoming and range from about 1,000 to 1,400 feet in thickness, are believed by Branson to be for the most part of marine origin, and the presence of the gypsum in the upper part is regarded as pointing to marine origin for that part of the red beds in most of Wyoming. The reasons for his conclusions are set forth as follows:

1. Uniformity in thickness of beds over wide areas.
2. Uniformity in texture of rocks over wide areas.
3. Ripple marking on horizontal beds through most of the formation.
4. Chemical precipitation of limestone at the 800-foot level.
5. Chemical precipitate of gypsum near the top over wide areas and at various levels in many places.
6. Absence of sun cracks and fossils of land animals excepting in the Popo Agie beds.
7. Presence of undoubted subaerial evidences in the Popo Agie beds, with textures and materials like much of the rest of the red beds.

The succession of events is summarized as follows:

1. The red beds began under marine conditions, and the sea gradually became more and more charged with calcium carbonate and magnesium carbonate until a dolomitic limestone was precipitated.
2. Above the limestone the sea gradually filled with sand until the sediments were exposed, and the Popo Agie beds were formed under subaerial conditions.
3. The sea in upper Triassic time readvanced and some 200 feet of sandstone and shales filled the western margin.
4. Subaerial deposition, mainly of wind-blown sand, succeeded and lasted while beds varying from a few feet to 60 feet in thickness were deposited.
5. The sea readvanced, but concentration of calcium sulphate had been in progress for a long time and soon resulted in widespread deposits of gypsum.
6. Usually some sandstone and some thin layers of limestone were deposited above the gypsum before the withdrawal of the sea at the close of the period.

[1] Branson, E. B., Origin of the Red Beds of western Wyoming; Origin of thick gypsum and salt deposits: Geol. Soc. America Bull., vol. 26, No. 2, pp. 217-242, 1915.

Darton's conception of the history of Chugwater red-bed deposition is as follows:[1]

In the latter part of Carboniferous [Pennsylvanian] time, and probably during the Permian also, there was a widespread emergence, resulting in shallow basins with very wide mud flats which occupied a large portion of the Rocky Mountain province. In these regions were laid down the last deposits of the Pennsylvanian division and the great mass of red clay and sands constituting the Chugwater formation. These beds probably were deposited by saline water under arid-climate conditions and accumulated in a thickness of 1,000 feet or more. The waters were shallow much of the time, and there were wide, bare wash slopes and mud flats, as is indicated by the frequent mud cracks, ripple marks, and impressions of various kinds on many of the layers throughout the formation.

In contrasting the Embar of the Bighorn Mountains with the overlying Chugwater beds the following features are noted:

1. Limestone is much more plentiful in the Embar, but, aside from that which occurs in the basal portion, it is in small patches laterally alternating with thick beds of gypsum.

2. There is ample evidence of frequent emergence and slight erosion during late Embar time, a feature not observed in the Chugwater. This is especially true of exposures on the east slope of the Bighorn Range. The conglomerates are, in part, composed of travel-rounded pebbles, denoting contemporaneous erosion. There are, however, other conglomeratic beds regarded as breccias. These consist of angular pebbles of various materials bound together by a spongy calcareous, travertine-like cement. The brecciated portion may be in part of secondary origin, produced by the solution of gypsum and possibly salt beds and the resultant collapse of the strata. Breccias and conglomerates such as these have not been observed in any part of the Chugwater formation.

3. Although the evidence of contemporaneous erosion in the Embar denotes temporary emergence, it is believed that the materials were for the most part laid down beneath the surface of the sea. The persistence of the nodular chert and the similarity of certain other beds over nearly all the area indicate that throughout Embar time the sea waters frequently extended from the west over the entire region. Reductions of the sea were the rule during the later part of the epoch, and aridity favored prolonged evaporation of the inclosed salt-water basins.

[1] Darton, N. H., Paleozoic and Mesozoic of central Wyoming: Geol. Soc. America, Bull., vol. 19, pp. 465–466, 1908.

SOURCE OF MATERIALS.

The source of the materials of the Tensleep, Embar, and Chugwater formations is largely a matter of speculation. That the Tensleep sandstone was at least in part deposited in the sea is indicated by its beds of arenaceous dolomite, some of which contain fossils. The following collection was obtained from beds a little above the middle of the formation on the east slope of the Bighorn Range in T. 44 N., R. 84 W.:

Crinoid stems.
Nucula levatiformis var. obliqua.
Deltopecten sp.
Astartella subquadrata?
Schizodus ovatus.
Plagioglypta canna?
Lævidentalium? sp.
Bellerophon aff. B. sublevis.
Euphemus? sp.
Bucanopsis? sp.
Phanerotrema aff. P. grayvillense.

Mr. Girty reports that the fauna is too small to warrant positive statement as to its relations. It shows a new and very indefinite combination of specimens, which may be late Pennsylvanian or, less probably, Permian. Elsewhere reedlike, columnar plant remains have been observed in the Tensleep sandstone.

It has been found that over the greater part of central Wyoming there is a general southward direction of inclination of the lines of deposition, suggesting a possible derivation of the sands from the north; but this view is not supported by the data as to thickness, for the formation at the north end of the Bighorn Range is 30 to 40 feet thick and increases southward to 200 or 300 feet in the Owl Creek Range and to more than 500 feet in the Wind River Range.

The slight thickening of the Embar formation eastward from Bighorn River canyon into the Bighorn Mountains has been mentioned. There is likewise a gradual increase to the southwest, where the beds become more and more calcareous. The change is not considerable westward along the Wind River Mountain front, and, in fact, the formation thins from about 430 feet at Dinwoody Canyon to a little more than 200 feet about 50 miles farther northwest, across the divide, on Buffalo Fork of Snake River at a locality measured by Blackwelder.

ABSTRACT OF PAPER.

The Embar formation of central Wyoming, which lies between the Tensleep sandstone and the Chugwater formation, comprises several distinct facies, each of which is considered in detail, and some of the formational boundaries in the Bighorn Mountain region are redefined. In connection with the description of the gypsum and associated strata it is suggested that conditions were possibly also favorable for accumulation of salt beds. The chance of finding such deposits down the dip below the surface is believed to be sufficient to merit further investigation.