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PHOSPHORIA AND DINWOODY TONGUES IN LOWER CHUGWATER OF CENTRAL AND SOUTHEASTERN WYOMING[1]

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ABSTRACT

Marine limestone and sandstone tongues extend southeastward from the Phosphoria and the Dinwoody formations of the Wind River Mountains and the Owl Creek Mountains, interfingering with the red shales in the base of the Chugwater formation in central and southeastern Wyoming. The intercalated marine beds and red shales constitute the red-bed "Embar" of central Wyoming. The nature of the lateral change from the Phosphoria and the Dinwoody facies to the red-bed Chugwater facies is described.

INTRODUCTION

Do the typical marine sediments of the Phosphoria and the Dinwoody formations of the Wind River Mountains grade eastward into red beds? The opposing views of various investigators led the writer to make a detailed stratigraphic study of the relations of the Phosphoria and the Dinwoody formations to the red-bed "Embar" of central Wyoming and to the red Satanka shale, the Forelle limestone, and the Chugwater red beds of the Laramie Basin.

In 1906, Darton[3] applied the name, Embar formation, to a succession of beds which occur above the Tensleep sandstone (Pennsylvanian) and below the red Chugwater shale (Triassic?) on the north flank of the Owl Creek Mountains in north-central Wyoming (Fig. 1). Blackwelder[4] subsequently gave the name, Dinwoody formation[5] (Fig. 2), to the drab sandstones and shales composing the upper part of Darton's Embar, and correlated the lower portion of the Embar with the Park City formation of Utah. Previously, Richards and

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[3] N. H. Darton, "Geology of the Bighorn Mountains," *U. S. Geol. Survey Prof. Paper 51* (1906), p. 35. "Geology of the Owl Creek Mountains," *59th Cong., First Session, Sen. Doc. 219* (1906), pp. 17–18.

[4] Eliot Blackwelder, "New Geologic Formations in Western Wyoming," *Jour. Washington Acad. Science*, Vol. 8 (1918), pp. 417–26.

[5] Type locality: Dinwoody Canyon, Wind River Mountains.

Mansfield[6] had applied the name, Phosphoria formation, to the upper two members of the Park City. Since the time of Blackwelder's work, it has been found that the portion of the Embar which he called

FIG. 1.—Index map of central and southeastern Wyoming.

Park City corresponds to only the Phosphoria portion of the Park City of the type locality. Consequently, the name, Phosphoria, is now

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<tr><td></td><td></td><td rowspan="2">EMBAR</td><td>DINWOODY</td><td>DINWOODY</td></tr>
<tr><td rowspan="2">PARK CITY</td><td>PHOSPHORIA</td><td>PARK CITY</td><td>PHOSPHORIA</td></tr>
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FIG. 2.—Evolution of nomenclature of Phosphoria and Dinwoody formations.

used for the lower portion of Darton's Embar, and the upper portion is known as the Dinwoody formation.

[6] R. W. Richards and G. R. Mansfield, "The Bannock Overthrust," *Jour. Geol.*, Vol. 20 (1912), p. 684.

The name, Chugwater formation, had been given by Darton[7] to

. . . the series of red beds extending along the foot of the Bighorn range southward through Wyoming and Colorado.

In its original definition the name included all the beds above the Tensleep sandstone and below the Sundance formation (Jurassic).

In central Wyoming a succession of alternating red shales and limestones occupies essentially the same stratigraphic position as the Embar of the type locality and was originally included by Darton[8] in the base of his Chugwater formation. These beds rest upon the Tensleep sandstone and are overlain by the main body of the red shales of the Chugwater. Even though they differ in character from the type Embar, that name was carried southward, and they also became known as "Embar." Lee[9] believed the succession to be younger than the type Embar and designated it as "The Embar of Oil Geologists." Others have indicated it as "Embar (?) formation." Controversy has arisen as to the relation of the red shales and limestones to the Phosphoria and the Dinwoody formations.

In the Laramie Basin the red Satanka shale and the Forelle limestone were named and removed from the base of Darton's original Chugwater by Darton and Siebenthal.[10] The Satanka overlies the Casper formation (Pennsylvanian) and is separated from the main body of the red shales of the Chugwater by the Forelle limestone. The Satanka and the Forelle have heretofore been recognized as bearing some indefinite relation to the red-bed "Embar" of central Wyoming.

Disregarding those writers who have stated in a casual manner that the Phosphoria and the Dinwoody do, or do not, grade into redbeds, the present status of the problem of the stratigraphic relations of the formations may be summarized as follows.

Condit[11] studied the Embar of the type locality and reached the conclusion that the beds now known as Phosphoria and Dinwoody in the Owl Creek Mountains are represented farther east in the Bighorn

[7] N. H. Darton, "Comparison of the Stratigraphy of the Black Hills, Bighorn Mountains and Rocky Mountain Front Range," *Bull. Geol. Soc. America*, Vol. 15 (1904), p. 397.

[8] *Op. cit.*, p. 397.

[9] Willis T. Lee, "Correlation of Geologic Formation between East-Central Colorado, Central Wyoming and Southern Montana," *U. S. Geol. Survey Prof. Paper 149* (1927).

[10] N. H. Darton and C. E. Siebenthal, "Geology and Mineral Resources of the Laramie Basin, Wyo.," *U. S. Geol. Survey Bull. 364* (1909).

[11] D. D. Condit, "Relations of the Embar and Chugwater Formations in Central Wyoming," *U. S. Geol. Survey Prof. Paper 98* (1916).

Mountains by a succession of red beds. Later, however, Lee[12] concluded that the Phosphoria and the Dinwoody formations are cut off farther east by an unconformity and that the red beds known in central Wyoming as "Embar," and also the Satanka shale and the Forelle limestone of the Laramie Basin, are younger than the beds originally called Embar.

More recently C. C. Branson has advanced a slightly different view. He reworked the area between the Owl Creek and the Bighorn Mountains which had been discussed by Condit, and also noted that the stratigraphic interval occupied in the Owl Creek Mountains by the Phosphoria and Dinwoody formations is occupied in the Bighorn Mountains by a red-bed series, which, in his opinion,

> . . . is continuous with and entirely similar to the overlying Chugwater.

He believes,

> that the area now occupied by the Bighorn Mountains was above the sea and was being eroded while the Phosphoria and Dinwoody formations were being deposited to the west.[13]

Three relationships, then, have been suggested up to the present. (1) Condit's belief of gradation between the Phosphoria and the Dinwoody and the red-bed "Embar,"(2) Lee's view that a post-Dinwoody unconformity separates the Phosphoria and the Dinwoody from the red beds, and (3) Branson's belief that the base of the Chugwater is homotaxial and that certain areas in Wyoming were being eroded and received no sediments during Phosphoria and Dinwoody time.

Field Work.—Condit and Branson both traced the Phosphoria and the Dinwoody from the Owl Creek Mountains into the Bighorn Mountains with a resultant conflict in their interpretations. Lee traced the red beds from the Laramie Basin northward to the Owl Creek Mountains and then made studies along the Wind River range. The writer, following a different course, traced the Phosphoria and the Dinwoody from the Owl Creek Mountains along the Wind River Mountains to the southern end of that range (Fig. 1), thence eastward to the Green Mountains, the Ferris Mountains, and the Freezeout Hills, and southward along the west flank of the Laramie Mountains to the southern end of the Laramie Basin. Studies were also made in the Rattlesnake Hills and in the region around Alcova. Field work was carried on at intervals from the summer of 1929 to 1933 and the writer is still actively engaged in the investigation of these strata.

[12] *Op. cit.*

[13] C. C. Branson, "Paleontology and Stratigraphy of the Phosphoria Formation," *Univ. of Missouri Studies*, Vol. 5, No. 2 (1930), pp. 5–6.

The study of the beds is made difficult by the fact that they can not be traced continuously, being concealed in many areas by Tertiary deposits. In addition, the red beds lie immediately above the resistant Tensleep sandstone which forms hogbacks. Consequently, the red beds, which are relatively nonresistant, are covered, in many places, by debris derived from the Tensleep.

Acknowledgments.—The writer is indebted to the following for aid in completing this paper. S. H. Knight made available the facilities of the Geological Survey of Wyoming and contributed many valuable suggestions; R. H. Beckwith aided in revising and criticising the typescript; J. B. Reeside, Jr., suggested a system of stratigraphic nomenclature; A. K. Miller studied and identified the cephalopods; C. O. Dunbar checked the identifications of some of the brachiopods; G. R. Mansfield examined specimens of brecciated chert, and H. G. Walter furnished his list of Dinwoody fossils and his conclusions regarding their age.

In addition, the writer wishes to thank the members of the faculty of the department of geology at Columbia University for their kindness in criticizing the interpretations here set forth. The suggestions of G. M. Kay, H. N. Coryell, and Ida H. Ogilvie have proved especially valuable.

SUMMARY OF CONCLUSLONS

It is the purpose of this paper to show that limestone and sandstone tongues extend east and south from the Phosphoria and the Dinwoody formations of the Wind River and the Owl Creek mountains and interfinger with the red shales in the base of Darton's original Chugwater formation of central and southeastern Wyoming. The intercalated limestones, sandstones, and red shales constitute the red-bed "Embar" of central Wyoming. Eastward the red shales become thicker and more prominent and the Phosphoria and Dinwoody tongues, thinner and less conspicuous. Each larger tongue is split into minor tongues by interfingering with tongues of different lithology. It is believed that Phosphoria and Dinwoody tongues may be traced and recognized over a much greater area than that discussed in this paper.

The Phosphoria formation of the Wind River Mountains is the time equivalent of the lower portion of the red-bed "Embar" of central Wyoming. The Phosphoria is represented in the Laramie Basin by the Satanka shale, the Forelle limestone, and a portion of the basal Chugwater. The Dinwoody formation of the type locality is equivalent to the upper portion of the red-bed "Embar" and to a portion of the lower Chugwater at localities east and south of the Wind River and the Owl Creek mountains.

The beds in the region covered by this paper show an interfingering of the Phosphoria and the Dinwoody with the lower part of the Chugwater formation similar to the interfingering described by Condit for the region between the Owl Creek and the Bighorn mountains. Lee's post-Dinwoody unconformity is believed not to be present in central and southeastern Wyoming, and his view that the red-bed "Embar" is younger than the Phosphoria and the Dinwoody formations is apparently not a tenable one. In this area no evidence was found supporting Branson's theory of local positive areas during Phosphoria and Dinwoody time, as central and southeastern Wyoming was entirely covered by sediments of Phosphoria and Dinwoody age.

STRATIGRAPHIC NOMENCLATURE

The interfingering of the Phosphoria and the Dinwoody with the Chugwater brings about troublesome problems in nomenclature. Limestones and sandstones extending eastward from the Wind River Mountains between red shales are treated as *tongues* of the Phosphoria and the Dinwoody formations. If there should be a locality at which all Phosphoria and Dinwoody tongues have thinned out, although such a section is unknown, it would there be impossible to differentiate the Phosphoria, the Dinwoody, and the Chugwater portions of the red shale series, and the entire sequence would be designated as Chugwater. Hence, all the red shales extending westward from central Wyoming into the Phosphoria and the Dinwoody formations are treated as tongues of the Chugwater formation.

In this paper, beds of Phosphoria age having the typical lithologic character of the Phosphoria formation, comprise the Phosphoria facies; those of Dinwoody age and lithologic character, the Dinwoody facies. The Chugwater facies is represented by red beds. The term *intertongued phase* is applied to sections in which the Phosphoria and the Dinwoody facies are intertongued with the Chugwater red-bed facies.

Following this system of nomenclature the Chugwater becomes a lithologic unit embracing rocks of both Permian and Triassic age, and a unit with a different age for its basal beds in different localities. Nevertheless, as J. B. Reeside, Jr.,[14] points out:

It seems . . . absurd that in the case where we have no fossils and no usable lithologic differences, we should attempt a separation into hypothetical

[14] Personal communication.

units based on tracing an invisible line from another area where the line happens to be real. That homogeneous lithologic units cover different intervals at different localities is a natural condition. It is simply a logical part of our nomenclatorial system that our names for such units have one scope at one place and another at a different place.

The new names of units introduced are available as stratigraphic names, none being preoccupied. The following new stratigraphic units are defined and described within this paper: the Sybille tongue of the Phosphoria, the Ervay tongue of the Phosphoria, the Little Medicine tongue of the Dinwoody, and the Freezeout tongue of the Chugwater.

PHOSPHORIA FORMATION

General character.—Because of the occurrence of phosphate rock in the Phosphoria formation, many studies have been made of its features of economic importance. In recent years attention has been given to some of the numerous stratigraphic, paleontologic, and lithogenetic problems presented, and bibliographies on the literature of the Phosphoria have been compiled.[15]

The Phosphoria in the Wind River Mountains rests unconformably upon the Tensleep sandstone of Pennsylvanian age. This relationship is indicated by the fact that the Phosphoria rests upon an irregular surface which truncates the cross-lamination of the Tensleep, and by the presence, in places, of material in the basal bed of the Phosphoria that has undoubtedly been derived from the Tensleep sandstone.

There is great vertical lithologic variation in the formation. In the Wind River Mountains it ranges in thickness from 200–300 feet and consists of alternating beds of shales, limestones of different sorts, and unusual rock types, such as bedded cherts and phosphate rock. Limestones predominate and are characteristically cherty. They vary from pure limestones to cherty limestones and pure bedded cherts. Certain strata contain numerous calcite geodes. The shales are argillaceous, siliceous, cherty or phosphatic, and are generally gray or olive-colored. In most places there are two zones of phosphate rock. In the Owl Creek Mountains the formation retains its typical lithologic character but is considerably thinner.

The region between the southern end of the Wind River Mountains and the Green Mountains (Fig. 1) is a great area of Tertiary sediments. The Paleozoic rocks are covered nearly everywhere, but at Ice Slough Canyon the Phosphoria is partially exposed. The exposed portion is

[15] D. D. Condit, E. H. Finch, and J. T. Pardee, "Phosphate Rock in the Three Forks-Yellowstone Park Region, Montana," *U. S. Geol. Survey Bull. 695* (1928). pp. 151–66; C. C. Branson, *op. cit.*

lithologically similar to the Phosphoria of the Wind River Mountains, except for the absence of phosphate beds, and the formation apparently has about the same thickness. The mantle on the covered portion suggests that some red shale may be present.

C. C. Branson[16] and Condit[17] have described in detail the lithologic character of the formation in the Wind River and the Owl Creek mountains. Mansfield[18] has discussed the origins of the chert and phosphate beds.

Age.—The determination of the age of the Phosphoria is a paleontologic problem. At present the age remains in doubt. Girty[19] has given a history of the interpretation of the age of the Phosphoria fauna of southeastern Idaho, which is believed by him to be contemporaneous with a Permian fauna from Alaska which had been examined by Holtedahl, who gave an opinion that the Alaskan fauna was "Artinskian (basal Permian)."

The fish fauna of the lower phosphate member of the Phosphoria of the Wind River Mountains was studied by E. B. Branson.[20] He says,

> The abundance of cochliodont sharks, which have never been reported from strata younger than the Pennsylvanian, indicates an age older than the Permian.

C. C. Branson studied the fauna of the entire Phosphoria of the Wind River Mountains,[21] described new species, and arranged the biota into faunal zones. In regard to age he says:

> It seems . . . that the formation through the Lower Phosphate member is late Pennsylvanian in age, and that there is a gradation into beds of Permo-Carboniferous age somewhere between the Lower Phosphate and the Pustula member. There is no indication of a stratigraphic break in the lithology. The Pustula and Hustedia faunules are Permo-Carboniferous with Pennsylvanian holdovers, and the Aulosteges fauna is distinctly Permian. From the complete absence of ammonites, however, it must be concluded that the faunule belongs to the lowermost part of the Permian. Here, as in Kansas and Nebraska, is a gradation without a break from Pennsylvanian to Permian.

[16] *Op. cit.*

[17] D. D. Condit, "Phosphate Deposits in the Wind River Mountains, near Lander, Wyoming," *U. S. Geol. Survey Bull. 764* (1924).

[18] G. R. Mansfield, "Geography, Geology and Mineral Resources of Part of Southeastern Idaho," *U. S. Geol. Survey Prof. Paper 152* (1927), pp. 361–71; "Some Problems of the Rocky Mountain Phosphate Field," *Econ. Geol.*, Vol. 26, No. 4 (1931), pp. 353–74.

[19] G. H. Girty, in G. R. Mansfield, "Geography, Geology and Mineral Resources of Part of Southeastern Idaho," *U. S. Geol. Survey Prof. Paper 152* (1927), pp. 78–81.

[20] E. B. Branson, "The Lower Embar of Wyoming and its Fauna," *Jour. Geol.*, Vol. XXIV, No. 7 (1916), pp. 639–65.

[21] *Op. cit.*

King, in his work on the Permian brachiopods,[22] later pointed out analogies between the fauna of the Phosphoria and that of the Middle Permian Word formation of Texas, and says,

> . . . Branson's conclusion that the formation [Phosphoria] lies on the boundary between the Pennsylvanian and Permian must be considered unlikely.

Recently C. C. Branson[23] has described a fish fauna from the middle Phosphoria which in itself throws no new light on the age of the formation. The fauna consists of 11 species, 6 of which occur in the lower Phosphoria, and the remaining 5 are new species. Because of the absence of cochliodont sharks and because of the occurrence of *Punctospirifer pulchra*[24] and *Aulosteges hispidus*, he considers the fauna to be Permian.

A. K. Miller has recently found new species of ammonoids about 60 feet below the Rex chert member of the Phosphoria in western Wyoming. *Stacheoceras*, *Vidrioceras*, *Gastrioceras* and *Goniatites* are represented by species which are closely related to known Middle Permian forms. These new species, he says, are almost certainly Middle Permian in age.[25]

In the light of present knowledge, then, it is necessary to consider the problem an open one. If the lower portion of the formation is Pennsylvanian and the upper portion Middle Permian, there must be an unconformity of considerable magnitude within the formation. Bartram[26] has advanced evidence which he believes indicates the presence of such an unconformity. The writer believes that the evidence is inconclusive,[27] but admits the possibility of such a hiatus. If the entire formation proves to be Middle Permian, then early Permian time may be represented by the unconformity between the Phosphoria and the Pennsylvanian Tensleep and Casper formations.

[22] R. E. King, "Geology of the Glass Mountains, Texas," Pt. 2, *Univ. Texas Bull. 3042* (1930), pp. 30–33.

[23] C. C. Branson, "Fish Fauna of the Middle Phosphoria Formation," *Jour. Geol.*, Vol. XLI, No. 2 (1933), pp. 174–83; "Permian Sharks of Wyoming and of East Greenland," *Science*, N.S., Vol. 79, No. 2054 (1934), p. 431.

[24] *Spirifera pulchra* Meek, 1860, =*Spiriferina pulchra* (Meek), 1860, =*Punctospirifer pulchra* (Meek), 1860.

[25] Personal communication.
Since this paper was written these new species have been described. (A. K. Miller and L. M. Cline, "The Cephalopods of the Phosphoria Formation of Northwestern United States," *Jour. Paleontology*, Vol. 8, No. 3 (1934), pp. 281–302.

[26] J. C. Bartram, "Character of Producing Sandstones and Limestones of Wyoming and Montana," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 16, No. 9 (1932), pp. 870–73.

[27] Horace D. Thomas, *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 17, No. 3 (1933), pp. 268–69.

TONGUES OF PHOSPHORIA FORMATION

Sybille tongue of Phosphoria (new name).—The red Satanka shale around the Sybille anticline near Sybille, Springs (Fig. 1), in the Laramie Basin, contains a fossiliferous sandstone 21 feet thick, lying 184 feet above the base of the Satanka. To this sandstone the name *Sybille*[28] *tongue of the Phosphoria formation,* is here applied (Fig. 3). The upper portion is a massive, medium-grained, mottled, pink and buff sandstone containing a great quantity of cylindrical, gray chert nodules oriented in all directions and averaging about ½ inch in

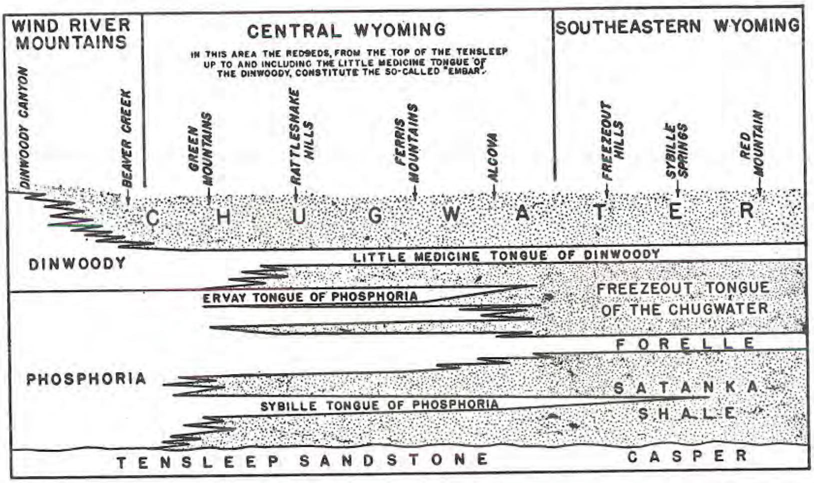

FIG. 3.—Diagram illustrating general relations of stratigraphic units discussed in text. Geographic locations of sections are shown on index map (Fig. 1).

diameter. It grades downward and becomes a thin-bedded limy sandstone containing maroon chert laminae and small, angular, gray chert masses. When freshly broken, the rock of the lower portion shows a distinctive orange-buff color with pink mottlings, but it weathers tan. Calcite geodes up to 1½ inches in diameter are abundant. Fossils are present but poorly preserved, and consist of gastropods and scaphopods, the latter represented by abundant elongate, tapering cones as much as 3 inches in length and 3/16 inch in diameter. Because of the poor preservation the surface markings are unknown, but, as the specimens are smooth, the writer provisionally refers them to the genus *Plagioglypta.*

The tongue thins southward from Sybille Springs and seems absent

[28] Spelling accepted by the U. S. Geographical Board, 1931. Pronounced Sib-beel'.

in the southern part of the Laramie Basin. Toward the north and west it becomes more limy, and the lithology varies considerably. *Plagioglypta?* occurs at many places. The geodes, however, are extremely persistent and have been noted in every locality. The writer has seen similar geodes (Fig. 4) in the lower part of the Phosphoria of the Wind River Mountains, along the Sweetwater River south of Beaver Creek and along Bull Lake Creek, and in the Owl Creek Mountains along the west fork of Sheep Creek, near Holland's ranch.

FIG. 4.—Geodes from Phosphoria formation in and near Wind River Mountains and from Sybille tongue of Phosphoria.

Condit[29] and C. C. Branson[30] also noted them in the Phosphoria. Although similar geodes occur in the upper part of the Phosphoria in certain localities, the writer believes that those in the lower part are probably characteristic of a certain horizon, and that the Sybille tongue corresponds to the geode-bearing limestone near the base of the Phosphoria formation in the Wind River and the Owl Creek ranges.

[29] D. D. Condit, "Phosphate Deposits in the Wind River Mountains, Near Lander, Wyoming," *U. S. Geol. Survey Bull. 764* (1924), p. 12.

[30] *Op. cit.*, p. 12.

Forelle limestone.—In the Laramie Basin the Forelle limestone has been taken from the base of the Chugwater and recognized as a distinct formation. It seems to be an extended tongue of the Phosphoria, and consequently may be considered as the "Forelle limestone tongue of the Phosphoria" (Fig. 3). The Forelle loses its identity north and west of the Freezeout Hills and becomes a part of a thicker succession of limestones. Additional detailed stratigraphic work must be undertaken before it can be determined which beds represent the Forelle in that area.

Ervay tongue of Phosphoria (new name).—The uppermost limestones of the Phosphoria extend eastward and southward from the Wind River and the Owl Creek mountains as a fairly widespread tongue. It is here proposed to designate this bed as the *Ervay tongue of the Phosphoria formation.* It crops out a few hundred feet west of Ervay, a postoffice in Natrona County, near the northern end of the Rattlesnake Hills,[31] and also at such scattered localities as the Ferris Mountains, the Green Mountains, and Alcova (Fig. 1). The tongue is not as well exposed near Ervay as on the head of Casper Creek near Garfield Peak, about 15 miles south of Ervay, where it forms the dip-slope of a prominent hogback. The type section is on Casper Creek. The details of the lithology of the tongue are given in Table I and the fossils present are listed following the table. The thickness of the tongue is fairly constant, but the lithology is quite different in various localities. The tongue includes the uppermost beds of Phosphoria age and is overlain by rocks of Dinwoody age. Consequently, at localities at which the Ervay tongue is present the top of the Phosphoria may be ascertained, and the red shales below this tongue and above the Tensleep sandstone (Fig. 3) are tongues of the Chugwater included in the Phosphoria formation. The beds between the Tensleep sandstone and the top of the Ervay tongue may be referred to as *Phosphoria, with included tongues of Chugwater.*

DINWOODY FORMATION

General character.—The Dinwoody formation in the Wind River range consists of alternating shales and sandstones resting with apparent conformity on the uppermost limestone of the Phosphoria. There is a sharp lithologic change at the boundary between the two formations. The shales of the Dinwoody are usually gray in color and alternate with dense, fine-grained calcareous sandstones, which weather

[31] The Rattlesnake Hills referred to in this paper are those in Natrona County, central Wyoming, and should not be confused with other localities in Wyoming known by the same name.

tan, brown, or black. Many of the beds contain abundant flakes of muscovite. Blackwelder[32] has pointed out that the formation becomes thicker and more calcareous westward from the Wind River Mountains. The thickness ranges from 254 feet at the type locality in Dinwoody Canyon to 37 feet at Beaver Creek near the southeastern end of the Wind River range. At Beaver Creek the formation consists of a basal, gray clay shale 10 feet thick, which contains small limonitic concretions and numerous red streaks. This bed rests upon the top cherty limestone of the Phosphoria and grades upward into 7 feet of gray limy and shaly, fine-grained sandstone. The uppermost 20 feet of the formation is harder and forms a ledge of thinly bedded, fine-grained, finely laminated, highly calcareous gray sandstone containing small flakes of muscovite. The top 3 or 4 feet is most sandy, is highly ripple marked, and some of the bedding planes are covered with fucoidal markings. This bed is overlain by red Chugwater shale.

The contact of the Dinwoody and the overlying Chugwater is, in some places, transitional. At the type locality of the Dinwoody, the upper gray shales grade upward into the red shales of the Chugwater. The two formations can be separated only by color; the buff color of the Dinwoody gives way to the red of the Chugwater along an irregular surface cutting across rocks lithologically identical. Mention has been made of Lee's belief of an unconformity at this horizon, yet in speaking of this contact in the Wind River Mountains, he says,[33]

> There is, however, a doubt in his [Lee's] mind as to the exact line of separation between the Dinwoody and the overlying beds.

Although the Dinwoody thins eastward and southward from the type locality, the writer believes that the thinning is not due to post-Dinwoody erosion, but to gradation into the red shales of the basal Chugwater, and that in the area considered in this paper there is no unconformity between the Dinwoody and the Chugwater (Fig. 3).

Age.—The age of the Dinwoody has not been definitely established. When Blackwelder[34] named the formation he correlated it with the Woodside shale of Idaho and Utah. The Woodside occupies a position between the top of the Phosphoria, which is surely Permian, and the base of the Thaynes, which is no older than middle Lower Triassic. In addition, the Woodside, in Utah, apparently rests unconformably

[32] *Op. cit.*, p. 425.

[33] Willis T. Lee, *op. cit.*, p. 76.

[34] *Op. cit.*

on the underlying Phosphoria.[35] Consequently, the Woodside seems to be early Lower Triassic in age, and is so considered by the United States Geological Survey.

Except for the sharp change in lithology between the Phosphoria and the Dinwoody, there is no evidence of an unconformity between the formations in the area studied by the writer. If the Dinwoody is Triassic in age, there is no evidence that warping or erosion took place during the interval between the withdrawal of the Permian sea and the encroachment of the Triassic sea. Throughout the area studied, the Dinwoody rests on the uppermost limestone of the Phosphoria, except where the horizon of that limestone is represented by red shale.

In speaking of the Woodside of the Wasatch Mountains of Utah, Mathews says:[36]

> A comparison of the stratigraphic sequence of the rock beds between the Phosphoria and the Pinecrest [Middle Triassic] . . . and the sequence of rocks of the same age between the Productus-limestone and the Ceratite beds of the Salt Range, India, shows a great difference in the thickness of the strata in the two areas. Waagen described the lowermost stratum containing Triassic cephalopods, the *Otoceras* bed, as only a short distance above the Productus-limestone (Carboniferous). And, according to Diener the entire Lower Triassic of the Kashmir Range, Asia, is less than 300 feet thick. It was found that the *Otoceras* bed was less than 60 feet below the *Meekoceras* fauna. Now, since the *Meekoceras* bed is above the top of the Woodside shales in the Fort Douglas area, then the lowest Triassic rocks comparable to the *Otoceras* bed in India must be about 1,000 feet above the top of the Phosphoria formation.
>
> Thus it can be seen that the age of the Woodside formation is problematical. The series probably represents the post-Permian interval but is treated . . . as Lower Triassic.

These facts may explain the anomalous nature of the Dinwoody and the Woodside faunas. Girty[37] has pointed out that the fauna of the Woodside is apparently of little value in age determination, but he considers the fauna to be Triassic. H. Glen Walters[38] has reported a Dinwoody fauna, which he believes is more closely related to the Permian faunas than to those of the Triassic, and lists the following species.[39]

[35] Asa A. L. Mathews, "Mesozoic Stratigraphy of the Central Wasatch Mountains," *Oberlin College Lab. Bull.*, New Ser., No. 1(1931), p. 6.

[36] *Ibid.*, p. 6.

[37] G. H. Girty, in G. R. Mansfield, "Geography, Geology and Mineral Resources of a Portion of Southeastern Idaho," *U. S. Geol. Survey Prof. Paper 152* (1927), pp. 84–85.

[38] H. Glen Walters, "The Dinwoody Formation of Western Wyoming," (*abst.*) *Bull. Geol. Soc. America*, Vol. 42, No. 1 (1931), p. 329.

[39] Personal communication.

Lingula carbonaria Shumard
Orbiculoidea utahensis (Meek)
Myalina congeneris Walcott
Myalina apachesi Marcou
Myalina meliniformis Meek and Worthen
Myalina perattenuata Meek and Worthen
Myalina permiana Swallow
Myalina subquadrata Shumard
Myalina sp.
Pleurophorus occidentalis Meek and Hayden
Pleurophorus sp.
Nucula sp.
Allorisma sp.
Edmondia? phosphatica Girty
Bakewellia parva Meek and Hayden
Schizodus wheeleri Swallow
Placunopsis? sp.
Aviculopecten occidentalis Shumard
Aviculopecten curtocardinalis Hall and Whitfield
Aviculopecten occidaneus Meek
Aviculopecten parvulus Hall and Whitfield
Aviculopecten 2 sp.
Bellerophon sp.

The stratigraphic relations of the Dinwoody to the overlying and underlying beds and the conflicting opinions as to whether the Dinwoody and the Woodside faunas are Permian or Triassic leave the age of the Dinwoody in doubt. Since the Dinwoody is generally assigned to the Triassic, the formation is here treated as though its Triassic age had been definitely established.

Little Medicine tongue of Dinwoody (*new name*).—The Dinwoody formation thins southeastward along the Wind River Mountains from Dinwoody Canyon to Beaver Creek by replacing overlap of the red Chugwater shale (Fig 3), but a tongue of the formation extends eastward and southward from the Wind River range as a widespread bed of variegated limy sandstone, separated from the Ervay tongue of the Phosphoria by a tongue of red Chugwater shale. It is here proposed to call the variegated limy sandstone the *Little Medicine tongue of the Dinwoody*. The type section is exposed along the north bank of Little Medicine Bow River (locally known as the "Little Medicine") in the Flat Top anticline about eight miles north of the town of Medicine Bow, on the road from Medicine Bow to Casper. The tongue is also exposed in the Rattlesnake Hills, at Alcova, in the Freezeout Hills, in the Ferris and the Seminoe Mountains and at certain localities in the Laramie Basin. The most conspicuous feature of the Little Medicine tongue, throughout its distribution, is its variegated character. Its color varies from tan to gray, olive-green, dove, lavender, maroon and purple. In general, it is a platy, finely laminated, fine-grained, highly calcareous sandstone, but at some localities it is a bed of nearly pure limestone. Invariably the tongue contains an abundance of small flakes of muscovite, and occasionally it is glauconitic. At many places the upper part is conspicuously ripple marked. The thickness is usually about 10 feet.

The contact of the Little Medicine tongue with the subjacent red shale is gradational. At most places a 2-foot bed of impure gypsum, which seems to be an integral part of the tongue, rests on the variegated portion. The gypsum is usually red or purple and in most places grades up from the underlying variegated limy sandstone. The lithologic character of the Little Medicine tongue at different localities is described in Tables I–VII. At localities at which the Ervay tongue of the Phosphoria is present, the Little Medicine tongue and the tongue of red Chugwater shale below it may be called *Dinwoody, with basal tongue of Chugwater* (Fig. 3). It is not yet known which bed in the type section of the Dinwoody represents the Little Medicine tongue.

TONGUES OF CHUGWATER FORMATION

The original scope of the term, Chugwater, has been discussed. Between Phosphoria and Dinwoody tongues occur red beds, which, in certain regions, comprise distinct stratigraphic units. Thus, in the Laramie Basin, the red shale beneath the Forelle limestone was removed from the base of the Chugwater and considered as a distinct formation—the Satanka shale. The shale is essentially the "Satanka tongue of the Chugwater." The identity of the Satanka shale is limited to the area in which the Forelle limestone can be recognized.

Freezeout tongue of Chugwater (*new name*).—From the Laramie Basin to the Freezeout Hills, red shales occur between the Forelle limestone and the Little Medicine tongue of the Dinwoody. The name *Freezeout tongue of the Chugwater* is here applied to these red shales. The tongue contains rocks of both Phosphoria and Dinwoody age, but because of the absence of the Ervay tongue, the Phosphoria and the Dinwoody portions can not be separated. The Freezeout tongue contains a few beds of limestone, breccia, and gypsum. Some of these beds may be tongues of the Phosphoria, but most of them are probably local lenticular beds. Because of lithologic variation, the Freezeout tongue can best be defined as comprising the beds between the top of the Forelle limestone and the base of the Little Medicine tongue of the Dinwoody. Such a definition limits the Freezeout tongue to localities at which the Forelle can be definitely recognized. At present, the Forelle has not been identified with certainty, except in the Laramie Basin and northward into the Freezeout Hills.

The name "Embar" is a *nomen nudum* which has been superseded by the names Phosphoria and Dinwoody. The United States Geological Survey suggests that the use of the name be avoided. If used, the name should be preceded by a dagger to indicate that it is obsolete, thus †Embar.[40] The use of the name maybe avoided by referring to the entire succession of strata from the top of the Tensleep to the top of the Little Medicine tongue of the Dinwoody as the "*intertongued phase of Phosphoria and Dinwoody age.*" There is no intent here to make a formal name. This designation may seem awkward, but until more is known of the exact correlations of the various beds, and especially until the ages of the Phosphoria and the Dinwoody formations are established, it indicates best the true relationship of the beds to which the name "Embar" has been applied.

STRATIGRAPHY OF INTERTONGUED FACIES

The intertonguing of the Phosphoria and the Dinwoody with the Chugwater was studied in the area bounded by the Green Mountains (Fig. 1) on the west, the Rattlesnake Hills on the north, the Freezeout Hills and the Laramie range on the east, and the Laramie Basin on the south. The intertongued phase, or "Embar," extends over a much larger area, however.

The succession rests unconformably upon the Tensleep sandstone, or upon the Casper formation (Fig. 3), and is characterized by striking lithologic changes both vertically and laterally. The strata are mostly unfossiliferous, but many beds contain fragmentary remains which are rarely well enough preserved to be recognizable. The thickness of the succession ordinarily ranges from 350–400 feet.

The intertongued phase is characterized by several distinctive types of rocks. Breccias are quite abundant and form thin beds, usually less than 5 feet thick, most of which are composed of red shale fragments in a gray lime matrix. Others consist of limestone fragments in a red shale matrix or of red sandstone fragments in a red sandstone matrix. The size of the fragments rarely exceeds 3 inches. The writer has gained the impression that the breccias do not indicate disconformities as some have supposed.[41] The disruption of previously deposited beds by storm waves might produce a rock of this sort. The limited areal extent of the breccias is indicated by exposures around the Flat Top anticline; on its south flank are seven breccia beds within the Freezeout tongue, whereas they are absent on the north flank, 6 miles away.

[40] Joint Committee on Stratigraphic Nomenclature, "Classification and Nomenclature of Rock Units," *Bull. Geol. Soc. America*, Vol. 44 (1933), p. 434.

[41] Willis T. Lee, *op. cit.*, p. 13.

Many of the limestones are of the "ribbon" variety. These are light-colored, extremely fine-grained, finely laminated limestones. They may be clastic lime muds or chemical precipitates deposited on a portion of the sea floor where there were no mud digesting organisms and where there was not enough agitation of the water to destroy the perfect lamination. Commonly the ribbon limestones have undergone a change that produced "crinkly" limestones in which the lamination planes were warped into small domes and basins from several inches to several feet apart. The amplitude of the folds varies from a fraction of an inch to as much as 6 inches. On outcrops cut nearly at right angles to the bedding the laminae show as wavy lines. The origin of the crinkly structure has been briefly discussed by S. H. Knight,[42] who believes that the volume of the rock was increased by the addition of magnesium carbonate, for the higher the magnesium content, the greater is the amplitude of the crinkling.

Many of the carbonate beds are dolomites or dolomitic limestones. Numerous writers have pointed out the difficulties of sight identification of dolomites, and Suffel[43] has recently called attention to this in his work on the Permian dolomites of Oklahoma. Due to the fact that no microscopic or chemical examinations of the samples collected have been made, the term "limestone" is used here in a broad sense to include calcitic limestones, dolomitic limestones, and dolomites.

The variability of the beds from place to place makes it impossible to generalize the lithology, and for that reason it is necessary to treat each area individually.

LOCALITIES BETWEEN OWL CREEK MOUNTAINS AND FREEZEOUT HILLS

Rattlesnake Hills.—Few geologists have visited the Rattlesnake Hills (Fig. 1), and the little that has been published concerning the stratigraphy of the beds equivalent to the Phosphoria and the Dinwoody in this area has been misleading. Speaking of the Rattlesnake Hills, Darton[44] says,

> . . . the Tensleep sandstone is separated from the Chugwater red beds by buff shale and thin layers of pure limestone which probably represent the Embar formation.

[42] S H. Knight, "Origin of the Crinkly Structure of the Forelle Limestone," (*abst.*) *Jour. Colo.-Wyo. Acad. Sci.*, Vol. 1, No. 4 (1932), p. 32.

[43] G. G. Suffel, "Dolomites of Western Oklahoma," *Okla. Geol. Survey Bull. 49* (1930), p. 11.

[44] N. H. Darton, "Paleozoic and Mesozoic of Central Wyoming," *Bull. Geol. Soc. America*, Vol. 19 (1908), p. 418.

Fossils collected by C. J. Hares in the Rattlesnake Hills were identified by Girty as Phosphoria species.[45] Information on their exact stratigraphic position, however, has not yet been published.

The impression has been given that the Phosphoria is here lithologically similar to the formation in the Wind River Mountains. However, the Phosphoria and the Dinwoody are represented by about 350 feet of strata of which about 250 feet, about three-quarters, are red shales, which are included tongues of Chugwater. Condit[46] mentioned that in this locality red shales occur below limestones containing typical Phosphoria fossils, but the significance of this fact seems to have been overlooked by later writers. Table I shows a section of the intertongued phase measured at the head of Casper Creek, just south of Garfield Peak (Figs. 1 and 5).

TABLE I

SECTION MEASURED ALONG CASPER CREEK, RATTLESNAKE HILLS, NATRONA COUNTY

Column A: thickness of individual beds in feet *Column B: feet from top of Tensleep sandstone to top of bed*	*A*	*B*
CHUGWATER: red shale, not measured		
DINWOODY, WITH BASAL TONGUE OF CHUGWATER		
Little Medicine tongue of Dinwoody		
Impure gypsum	10	377
Fine-grained, finely laminated, ripple-marked, calcareous sandstone; mostly light greenish gray in color but varies to maroon and purple; weathers into plates and grades into subjacent bed	10	367
Thin-bedded, red shaly sandstone with fucoidal markings, similar to those in Dinwoody at Beaver Creek, grading downward into fine-grained, red clay shale	58	357
PHOSPHORIA, WITH INCLUDED TONGUES OF CHUGWATER		
Ervay tongue of Phosphoria		
Fine-grained, pink to gray, sandy limestone which contains great amount of laminated blue and gray chert; caps prominent hogback	4	299
Lavender, shaly limestone, which contains nodules and laminae of maroon and greenish gray chert and occasional calcite geodes; grades downward into massive, fine-grained, gray limestone with irregular maroon chert nodules. This bed contains great numbers of silicified fossils which are discussed below	8	295
Extremely fine-grained, very hard, sublithographic limestone of porcellaneous appearance; no chert present	4	287
Purple shale	12	283
Fine-grained, finely laminated, gray limestone	1.5	271
Red shale	3	269.5

[45] Willis T. Lee, *op. cit.*, p. 54.

[46] D. D. Condit, "Relations of the Embar and Chugwater Formations in Centra Wyoming," *U. S. Geol. Survey Prof. Paper 98* (1916), p. 267.

TABLE I (*Cont.*)

Column A: thickness of individual beds in feet *Column B: feet from top of Tensleep sandstone to top of bed*	*A*	*B*
Laminated, gray chert	0.5	266.5
Red clay shale	13	266
Maroon and greenish gray chert, which grades downward into very fine-grained, finely laminated, gray limestone	12	253
Red clay shale	9	241
Laminated, bluish gray chert	5	232
Massive, gray limestone, which contains gray chert laminae	4	227
Purple shale, which contains laminae of maroon chert	10	223
Breccia composed of angular, gray limestone fragments in matrix of red sandstone	2	213
Red shale	15.5	211
Finely laminated, light gray limestone	2	195.5
Red shale	49	193.5
Beds of fine-grained, finely laminated, slightly crinkly limestone, which alternate with four 6-inch beds of gray paper shale	4	144.5
Ochre shale, 3 feet thick, which grades downward into dense, thin-bedded, finely laminated, grayish white limestone	8	140.5
Red, flaky shale	60	132.5
Sybille tongue of Phosphoria		
Dense, white limestone with numerous black specks of dendrite	5	72.5
Purple, limy sandstone, which grades downward into purple and white sandstone containing numerous small cavities, occasional calcite geodes and *Plagioglypta?* sp.	7.5	67.5
Covered portion; soil derived mainly from red shale	40	60
Conglomerate composed of rounded cobbles up to 6 inches in diameter; mainly covered, and contact with the Tensleep is obscured	20±	20±
TENSLEEP SANDSTONE: cross-laminated sandstone; not measured		
TOTAL	377±	

The conglomerate composed of cobbles of chert, sandstone, and quartzite at the base of the section is deserving of further study. Where seen it was not well exposed and its relations to the overlying beds and to the underlying Tensleep could not be ascertained. However, it is a rock type foreign to the Tensleep and may be considered as the basal conglomerate of the Phosphoria. A basal conglomerate occurs farther south at Alcova. It differs from the conglomerate at Casper Creek in that it is not a true conglomerate, but consists of sporadic blocks of Tensleep sandstone in a sandstone bed. At Ervay, about 10 miles northwest of the Casper Creek locality, there is no evidence of such a conglomerate, the basal member of the Phosphoria being a 60-foot bed of limestone. At present the relations of these basal beds to each other are not understood.

The Sybille tongue, as usual, carries calcite geodes and *Plagioglypta?* sp. The bed of breccia is similar to the breccias so common in the red-bed facies farther south.

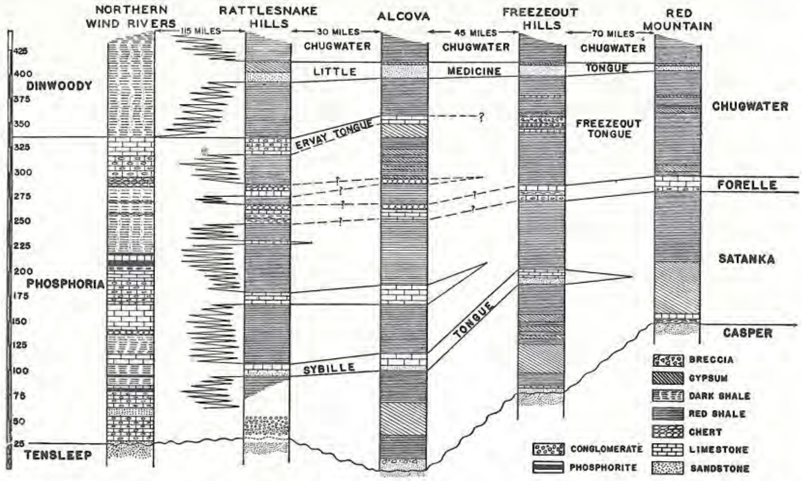

FIG. 5.—Correlation chart of sections between northern end of Wind River Mountains and southern end of Laramie Basin.

The following fossils were collected from the Ervay tongue at the head of Casper Creek and along Poison Spider Creek, south of Garfield Peak.

Bryozoans (many species)	c*
Punctospirifer pulchra (Meek)	c
Punctospirifer aff. *P. kentuckyensis* (Shumard)	s
Composita cf. *C. mexicana* (Hall)	c
Derbya aff. *D. plicatella* Waagen	a
Tentaculites sp.	r
Plagioglypta? sp. (small)	r
Myalina sp. (large)	c
Myalina aff. *M. perattenuata* Meek and Hayden	c
Pleurophorus pricei Branson	r
Pleurophorus (four species)	s
Leda obesa (White)	s
Cyrtorostra? sp.	r
Aviculopecten sp.	r
Deltopecten vanvleeti (Beede)	r
Parallelodon aff. *P. tenuistriatus* (Meek and Worthen)	r
Edmondia? sp.	r
Schizodus cf. *S. wheeleri* (Swallow)	c
Schizodus? sp. (large)	c
Schizodus sp. (small)	c
Pinna peracuta Shumard	a
Euphemus subpapillosus (White)	c
Bellerophon sp.	c
Gastropod (high-spired form)	r
Coelogasteroceras thomasi Miller and Cline	r
Coloceras? sp.	r
Denticles, probably from the spine of an elasmobranch	r

* In the faunal lists relative abundance of specimens is indicated as follows. a, abundant; c, common s, scarce; r, rare.

This faunule, which serves as a basis for the correlation of the Ervay tongue with the top limestone of the Phosphoria, contains many species which are common in, or confined to, the upper limestone member of the Phosphoria of the Wind River Mountains. This limestone has been referred to by several geologists as the "Upper Bryozoan limestone," and its fauna has been called the "*Spiriferina pulchra* fauna," because of the abundance of bryozoans and of *Punctospirifer pulchra*. These fossils occur in the Ervay tongue in considerable abundance. *Pleurophorus pricei*, *Euphemus subpapillosus* and *Deltopecten vanvleeti* are confined to the top limestone of the Phosphoria in the Wind River Mountains. Many other species found in the Ervay tongue are confined to the upper portion of the Phosphoria.

In different localities different species occur in varying degrees of abundance. On Casper Creek *Derbya* aff. *D. plicatella* occurs in extreme abundance, but on the north, at Ervay, and on the south along Poison Spider Creek, the species is quite rare. *Punctospirifer* aff. *P. kentuckyensis* is the most abundant species along Poison Spider Creek, is rare along Casper Creek, and is absent at Ervay. At Ervay, *Myalina* and *Bellerophon* are the most abundant fossils. *Euphemus subpapillosus* is relatively common at all three localities.

The species of *Derbya* is comparable to *Derbya plicatella* Waagen in that both are characterized by radial plications. The Rattlesnake Hills specimens have the precise internal structure of *Derbya*, i.e., a rather high ventral septum and dental lamellae which are almost obsolescent, but differ from typical members of the genus in the presence of rounded plications upon which are superimposed finer striations. Similar plicated specimens of *Derbya* are found in the upper part of the Phosphoria formation in the Wind River Mountains.

The productids are perhaps the most abundant brachiopods, both in number of species and in number of specimens, in the Phosphoria fauna of western Wyoming, but are represented in the top limestone by only one species, *Aulosteges hispidus*. No productids are present in the Ervay tongue faunule. The occurrence of *Tentaculites* is unusual, for this genus apparently has not heretofore been reported in North America from rocks younger than the Devonian.

Another section, which differs little from that on Casper Creek, was measured at Ervay. The total thickness of the Phosphoria and the Dinwoody with included tongues of Chugwater is 388 feet. The basal member, previously mentioned, is a fine-grained, thin-bedded, white, sandy limestone containing scattered calcite geodes. Near the top it becomes dense and brittle and contains a few layers of brown chert. The middle portion of the section consists mainly of red shale, but is largely covered. The main dip slope is formed by a chert member, 25 feet stratigraphically below the Ervay tongue. The chert member consists of 57 feet of gray and lavender, cherty limestones and beds of pure chert. In the middle portion of the member were found *Punctospirifer pulchra* and *Orbiculoidea* cf. *O. utahensis*. The Ervay tongue is here much less fossiliferous than at Casper Creek. It was only after an extended search that the following fossils were collected.

Derbya aff. *D. plicatella* Waagen	r
Leda obesa (White)?	s
Myalina sp. (large)	c
Myalina sp. (small)	c
Pelecypod, indeterminable	r
Euphemus subpapillosus (White)	c
Bellerophon sp.	c

Alcova.—In speaking of the region around Alcova, Lee[47] made the following statement.

> The writer . . . believes that such beds of Phosphoria and Dinwoody age as may have existed here were eroded away before the deposition of the red beds, and that the geologic time denoted by these formations is here represented by the unconformity that separates the Chugwater red beds from the underlying Casper formation.

A section (Table II) measured by the writer northeast of Alcova Cut (Fig. 5) shows representatives of the Phosphoria and the Dinwoody.

TABLE II

SECTION MEASURED NEAR ALCOVA, NATRONA COUNTY

Column A: thickness of individual beds in feet *Column B: feet from top of Tensleep sandstone to top of bed*	*A*	*B*
CHUGWATER: red shale, not measured.		
DINWOODY, WITH BASAL TONGUE OF CHUGWATER		
Little Medicine tongue of Dinwoody		
Laminated red gypsum	2.5	450.3
Finely laminated, thin-bedded, ripple-marked purplish to greenish gray, calcareous sandstone weathering brown in upper portion; grades downward into red shaly sandstone	14	447.8
Fine-grained, thin-bedded, platy, red sandstone grading downward into red sandy shale	37.5	433.8
PHOSPHORIA, WITH INCLUDED TONGUES OF CHUGWATER		
Ervay tongue of Phosphoria		
Extremely fine-grained, massive, conspicuously mottled gray and lavender limestone containing a few unrecognizable fossils	8	396.3

[47] *Op. cit.*, p 50.

TABLE II (*Cont.*)

Column A: thickness of individual beds in feet *Column B: feet from top of Tensleep sandstone to top of bed*	*A*	*B*
Alternating beds of red shale and gypsum	55	388.3
Chert member; fine-grained, finely laminated dark gray limestones interbedded with brittle, siliceous black paper shale containing laminae and nodules of light blue chalcedony	5	333.3
Interbedded gypsum and gray flaky shales	19.5	328.3
Chert member; limy, dark gray paper shale with laminae of bluish gray chalcedony	5	308.8
Limestone and gypsum occurring in different proportions in different localities; usually some breccias present, which are composed of angular clay fragments in gray lime matrix	9	303.8
Ten feet of purple sandstone grading downward into brick-red sandy shale containing numerous circular white spots	90	294.8
Finely laminated, gray limestones, some of crinkled variety and others partially replaced by gypsum, interbedded with thin gray shales; some brown chert present. In limestone near middle are found many poorly preserved specimens of following fossils: *Myalina permiana* Swallow, *Pinna* cf. *P. peracuta* Shumard, *Pleurophorus* sp., high-spired gastropods, several species	22.2	204.8
Flaky red shale with numerous small oval cream-colored spots	54.7	182.6
Sybille tongue of Phosphoria		
Alternating gray sandstones and gray limestones, upper part of which contains abundant calcite or quartz geodes and poorly preserved specimens of *Plagioglypta?* sp.	17.7	127.9
Fine-grained, flaky, brick-red shale	35	110.2
Gypsum	37	75.2
Red shale with several thin, porous, gypsiferous limestones	25	38.2
Massive, medium-grained, tan sandstone with red streaks. In upper portion are sporadic angular blocks of Tensleep sandstone as large as 3 feet. The bed abruptly truncates cross-lamination of underlying Tensleep	13.2	13.2
TENSLEEP SANDSTONE: not measured.		
TOTAL	447.8	

The blocks of Tensleep sandstone in the upper part of the basal bed provide additional evidence of the unconformity which separates the Tensleep from the Phosphoria. It has been pointed out that with an advancing shore line, there may be deposited

> . . . a thin layer of sediments derived from the residual soil, and these will be succeeded by coarser sediments . . . derived from erosion of bed rock.[48]

It appears that the Phosphoria sea advanced over a surface composed of weathered Tensleep sandstone, and that wave erosion on bed rock dislocated the large, angular blocks of Tensleep which were incorporated in the basal bed of the Phosphoria.

The beds representing the Phosphoria at Alcova differ from those in the Rattlesnake Hills mainly in the smaller amount of chert, in the occurrence of thick gypsum beds near the base, and in the presence of more abundant breccias and gypsiferous limestones.

[48] W. H. Twenhofel, *Treatise on Sedimentation* (1932), p. 144.

The writer believes, because of stratigraphic sequence and lithologic similarity, that the 10-foot bed of mottled limestone represents the Ervay tongue of the Rattlesnake Hills, which in turn represents the top of the Phosphoria of the Wind River range. The bed here is apparently unfossiliferous, but this is of little significance, for in the Rattlesnake Hills the Ervay tongue is extremely fossiliferous in some localities, and in others, a few miles away, contains few fossils.

The Little Medicine tongue and the subjacent, red, sandy shale, which represent the Dinwoody, are here lithologically typical and have their usual thickness.

Freezeout Hills and Flat Top anticline.—The Freezeout Hills are located at the junction of a line of measured sections extending northwest from the southern end of the Laramie Basin to the Rattlesnake Hills (Fig. 1) and another line extending westward from the Freezeout Hills to the southern end of the Wind River Mountains. Consequently, sections in the Freezeout Hills occupy a key position for correlation. Lee[49] has said:

> There are no rocks in this region that can be confidently correlated with the Embar formation of the Wind River Mountains and Owl Creek Mountains —that is, with the Phosphoria and Dinwoody formations. However, the beds which Condit regarded as the eastern representatives of the Embar, and which oil operators in Wyoming call Embar, are typically developed in the lower part of the "Red Beds" near Difficulty.

A section measured by the writer at the Ellis Ranch on Difficulty Creek is shown in Table III in considerable detail.

A section measured at Flat Top anticline, about 12 miles southeast of Difficulty, differs only a little from the Difficulty section. In neither of these localities is the Ervay tongue present, and therefore it is impossible to separate the Phosphoria from the Dinwoody. Here, however, the Forelle limestone may be differentiated, and strata of both Phosphoria and Dinwoody age occurring above the Forelle and below the Little Medicine tongue are placed together to form the Freezeout tongue of the Chugwater formation. The beds below the Forelle represent the Satanka shale of the Laramie Basin.

The basal bed of the section appears to consist of reworked sandy material derived from the Tensleep sandstone. The limy beds below the 70 feet of red shale in the upper part of the Satanka constitute the Sybille tongue. The gypsum beds below the tongue are known to be lenticular and probably do not represent Phosphoria tongues, although they are of that age.

The Forelle may be traced almost continuously from here into the

[49] *Op. cit.*, p. 71.

TABLE III

SECTION MEASURED NEAR DIFFICULTY POST OFFICE, FREEZEOUT HILLS, CARBON COUNTY

Column A: thickness of individual beds in feet *Column B: feet from top of Tensleep sandstone to top of bed*	*A*	*B*
CHUGWATER: red shale, not measured		
RED-BED FACIES OF THE PHOSPHORIA AND DINWOODY FORMATIONS		
Little Medicine tongue of Dinwoody		
Variegated sandy and shaly limestone, predominantly lavender in color but varying to purple, dove, olive and gray; not entirely exposed. In the Flat Top uplift is capped by 2 feet of porous, gypsiferous limestone and breccia	10	327.2±
Freezeout tongue of Chugwater		
Covered portion, probably mostly red shale; in Flat Top uplift this portion consists of red shales and thin breccias. Exact thickness not measurable	20±	317.2±
Porous, impure, massive gray limestone	2	297.2
Variegated, red and olive, gypsiferous shale	16.5	295.2
Gypsum	3	278.7
Breccia; angular masses of gray limestone in red shale matrix	6	275.7
Breccia; angular fragments of red shale and crinkled limestone in gray lime matrix	4	269.7
Red shale	2	265.7
Breccia; angular fragments of crinkled limestone and red shale in gray lime matrix grading downward into crinkly limestone	2	263.7
Gray shale	1	261.7
Breccia; red, sandy shale fragments in matrix of same character	2	260.7
Breccia; red shale fragments in lime matrix	0.2	258.7
Fine-grained, finely laminated, slightly crinkled white limestone	1.5	258.5
Red sandy shale with numerous circular gray spots	50	257
Forelle limestone		
Cream-colored, porous, gypsiferous crinkly limestone	2	207
Shale, upper 2 feet gray, lower foot red	3	205
Finely laminated, dark gray, siliceous shale	5	202
Gray, crinkly limestone containing dark gray and black chert	4	197
Satanka shale		
Red sandy shale containing numerous gray spots. Very sandy in middle. Ten feet of leached, olive shale at base	70	193
Sybille tongue of Phosphoria		
Sugary, coarse-grained limestone. Upper portion contains numerous gray, irregularly shaped chert nodules	8	123
Gray shaly sandstone	2.5	115
Gray sandstone containing numerous small calcite geodes	2	112.5
Gray sandstone grading downward into gray sandy shale	5	110.5
Flaky red shale with numerous gray spots	30	105.5
Gypsum	8	75.5
Red shale with thin gypsum beds	21	67.5
Gypsum	30	46.5
Olive sandy shale	12	16.5
Finely laminated pink and white limestone	1.5	4.5
Soft, saccharoidal sandstone and very fine-grained, sandy material. Strikingly different from subjacent Tensleep sandstone	3	3
TENSLEEP SANDSTONE: not measured.		
TOTAL	327.2±	

Laramie Basin. It is not truly typical in the Difficulty section, but in the Flat Top anticline is lithologically identical with the Forelle at the type locality in the Laramie Basin.

The Freezeout tongue consists of interbedded red shale, numerous breccias and crinkly limestone, and a little gypsum. Some of the limestone, gypsum and breccia beds are lenticular; possibly none represent Phosphoria tongues, although one of them may be an edge of the Ervay tongue. The Little Medicine tongue is readily recognized in both localities.

LOCALITIES BETWEEN SOUTHERN END OF WIND RIVER MOUNTAINS AND FREEZEOUT HILLS

A series of sections was measured in the region between the southern end of the Wind River Mountains and the Freezeout Hills. Mention has previously been made of the occurrence of typical Phosphoria at Ice Slough (p. 1661).

Green Mountains.—The next exposed section eastward from Ice Slough is located in the Green Mountains. Here the beds are highly deformed and, where the section was measured, are upside down and dip 50°. Such deformation has undoubtedly affected the thicknesses of the less competent members, but the measurements obtained do not seem to be greatly different from those that might be expected (Table IV).

TABLE IV

SECTION MEASURED ON WEST FORK OF COTTONWOOD CREEK, GREEN MOUNTAINS, FREMONT COUNTY

Column A : thickness of individual beds in feet *Column B : feet from top of Tensleep sandstone to top of bed*	*A*	*B*
CHUGWATER: red shale, not measured.		
DINWOODY		
Thin-bedded, oil-saturated sandstone, which weathers brown. Upper part is ripple marked and contains fucoidal markings.	41	336.7
Soft tan shale	13	295.7
Red, pink, and ochre shale	10	282.7
PHOSPHORIA, WITH INCLUDED TONGUES OF CHUGWATER		
Ervay tongue of Phosphoria		
Brown sandstone containing much chert and poorly preserved fossils; *Derbya* aff. *D. plicatella* Waagen, *Hustedia* sp., *Punctospirifer pulchra* (Meek), *Polypora?* sp.	9	272.7
Tan sandy shale	6	263.7
Gray, fossiliferous limestone with fragmentary unrecognizable fossils	2	257.7
Tan shaly sandstone	5	255.7
Lavender shaly limestone	1.6	250.7
Light gray siliceous shale	0.5	249.1

TABLE IV (*Cont.*)

Tan cherty sandstone	2.2	248.6
Brown chert in beds 2–6 inches thick	3.6	246.4
Tan sandstone containing chert nodules	3	242.8
Red sandstone	0.5	239.8
Pink shaly limestone with irregular, gray chert nodules	3.5	239.3
Pure gray chert; weathers into angular fragments because of its brecciated condition	25	235.8
Red sandy shale with ramifying, harder, red sandy aggregates	127	210.8
Sybille tongue of Phosphoria		
Hard, dense, siliceous, gray limestone with small, angular, gray chert masses	0.6	83.8
Thick-bedded, lavender limestone with individual beds ranging from 9 inches to 20 inches in thickness, some slightly shaly, contains numerous calcite geodes; weathers brown	6.7	83.2
Lavender and maroon shaly sandstone; not well exposed	7	76.5
Dense, lavender limestone	1.2	69.5
Hard, dense, white limestone with a few calcite geodes	3.3	68.3
Red sandy shale with ramifying aggregates of red sandstone	35	65
Very dense, very hard, siliceous, gray limestone with occasional lamina or nodule of gray chert	25	30
Red shale with unconsolidated, fine sand resting directly on Tensleep sandstone and truncating its cross-lamination	5	5
TENSLEEP SANDSTONE: not measured.		
TOTAL	336.7	

The Sybille tongue carries the usual geodes, but no fossils were found in the bed at this locality. The upper part of the Phosphoria is very cherty and is similar to the upper part of the formation in the Rattlesnake Hills. The uppermost 9-foot bed of sandstone is probably

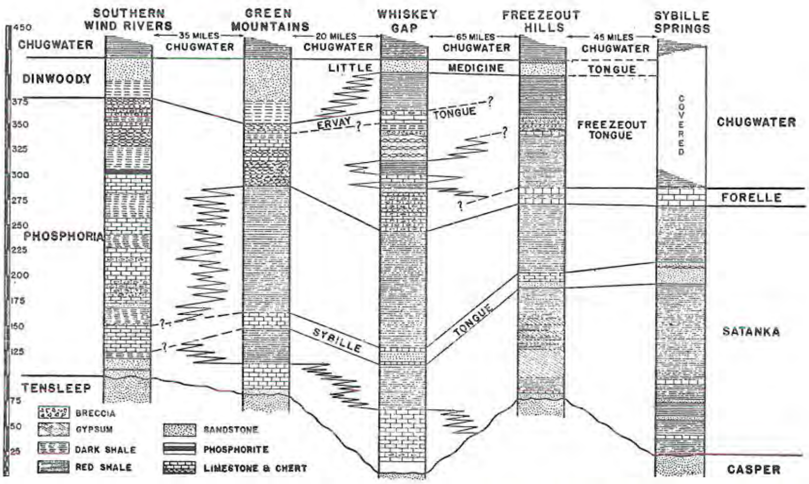

FIG. 6.—Correlation chart of sections between southern end of Wind River Mountains and northern end of Laramie Basin.

the Ervay tongue, for it occupies the correct stratigraphic position and carries a similar fauna.

The chert beds here are all highly brecciated and consist of angular fragments of chert in a siliceous matrix. The brecciation is undoubtedly the result of proximity to a large thrust fault along which these beds have been overturned. G. R. Mansfield has examined a specimen of the chert and believes that the brecciation is similar to that produced in the Rex chert member of the Phosphoria formation along the Bannock overthrust in Idaho.[50] This sort of breccia should not be confused with the calcareous breccias so prevalent in the red beds, for the two have distinctly different origins.

The upper sandy portion of the Dinwoody is similar in lithology to the Dinwoody along the southern end of the Wind River range, but the lower shaly portion contains red beds in its base. East of the Green Mountains the upper sandstone forms the Little Medicine tongue of the Dinwoody. The subjacent shales grade into the red sandy shale between the Little Medicine tongue and the Ervay tongue of the Phosphoria.

Numerous changes take place in the intertongued phase of the Phosphoria between the Green Mountains and Whiskey Gap. The intervening area is covered with Tertiary beds, however, and no intermediate sections can be measured.

Whiskey Gap.—The strata that have been called "Embar" by oil geologists are conspicuously exposed in the vicinity of Whiskey Gap. The beds here stand vertically, or are overturned, and because the resistant Tensleep sandstone forms a high ridge, the softer Phosphoria and Dinwoody representatives are partly covered with detritus. However, a nearly complete section can be compiled between Whiskey Gap and Muddy Gap, several miles farther west. Because of the rapid alternation of beds lithologically different it is impracticable to reproduce the section here in all its detail (Table V).

The section bears a strong resemblance to the section at Ervay in the Rattlesnake Hills in the abundance of chert in the upper portion and in the presence of a thick basal limestone.

It is believed that the irregular surface below the breccia near the top of the Phosphoria does not represent an unconformity. Although the bed contains fragments of the underlying beds in its base, these fragments have not been moved far (Fig. 7), and the feature can perhaps be attributed to contemporaneous erosion brought about by shifting marine currents. A considerable break may be indicated, how-

[50] Personal communication.

TABLE V

SECTION MEASURED BETWEEN WHISKEY GAP AND MUDDY GAP, CARBON COUNTY

Column A: thickness of individual beds in feet *Column B: feet from top of Tensleep sandstone to top of bed*	*A*	*B*
CHUGWATER: red shale, not measured.		
DINWOODY, WITH BASAL TONGUE OF CHUGWATER		
Little Medicine tongue of Dinwoody		
Finely laminated red limestones and red shales	8	426
Red shale	30	418
Flaky, gray shale	5	388
PHOSPHORIA, WITH INCLUDED TONGUES OF CHUGWATER		
Ervay tongue of Phosphoria		
Gray limestones, cherty in upper portion	14	383
Flaky gray and tan shale	6	369
Breccia composed of angular fragments of chert, limestone and sandstone; rests on irregular surface and contains fragments of underlying bed in its basal part (Fig. 7)	3	363
Thick-bedded gray sandstone; contains much chert	25	360
Red shale	14	335
Gray limestone with nodules and laminae of gray and red chert.	7	321
Red shale	6	314
Breccia composed of angular fragments of chert and lavender ribbon limestone in gray lime matrix	3	308
Dense, light gray limestone with abundance of chert occurring as nodules and laminae; upper part sandy	28	305
Finely laminated, fine-grained, lavender sandy limestone containing chert nodules	12	277
Brick-red sandy shale	115	265
Sybille tongue of Phosphoria		
Dense, white limestone	2	150
Purple shaly sandstone seamed with occasional chalcedony veins along bedding. Contains poorly preserved specimens of *Euphemus carbonarius* (Cox), *Bucanopsis* cf. *B. meekiana* (Swallow) *Bellerophon?* sp., *Nucula?* sp., and numerous fragments of unrecognizable fossils	10	148
White limestone with small black specks of dendrite	2	138
Red shales, thin sandstones, and thin limestones	52	136
Thick-bedded gray limestone; portions seem to be made up of macerated fragments of fossils and other portions are composed of algae (?); small amount of laminated chert near base	64	84
Covered portion	20	20
TENSLEEP SANDSTONE: not measured.		
TOTAL	426	

ever, but until further knowledge is available it is impossible to judge the time value of this erosion surface.

The upper 14-foot bed of cherty limestone probably represents the Ervay tongue of the Phosphoria. Although it is unfossiliferous, it lies in the same stratigraphic position as the Ervay tongue in the Rattlesnake Hills, i.e., below the basal red shale of the Dinwoody and above the main chert member of the Phosphoria. The Little Medicine tongue of the Dinwoody is present, as in all other sections, but is completely red in color.

Black Canyon.—The section on the east side of Black Canyon, where the North Platte River cuts through the Seminoe Mountains, is not well exposed, and consequently a detailed section could not be measured. From Whiskey Gap eastward toward Black Canyon the most outstanding change in the Phosphoria is the disappearance of the thick chert beds and the cherty limestones. A bed of lavender

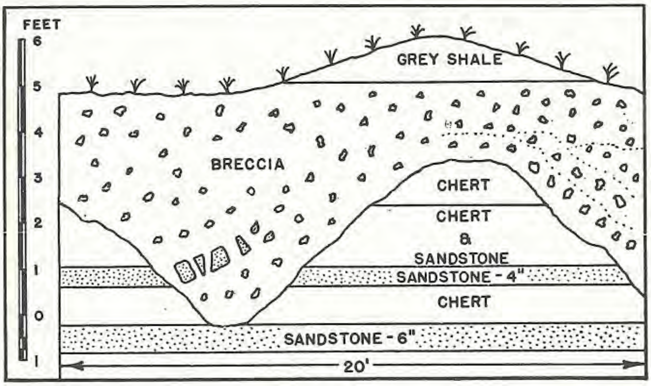

FIG. 7.—Sketch of erosion surface within beds of Phosphoria age at Whiskey Gap.

limestone 20 feet thick near the top of the Black Canyon section probably does not represent the Ervay tongue, although it occupies the same stratigraphic position. It is lithologically more like the lavender limestones below the Ervay tongue at Whiskey Gap and at Ervay. Furthermore, its thickness seems too great, for here the Ervay tongue should be thinner than it is at localities on the west and north of Black Canyon. It is believed that the Ervay tongue thins out between Whiskey Gap and Black Canyon and between Alcova and Black Canyon, and that the lavender limestone at Black Canyon represents beds below the Ervay tongue at Whiskey Gap. If this be true, the basal portion of the red shale above the lavender limestone and below the Little Medicine tongue is of Phosphoria age. Beds representing the Forelle limestone have not been recognized at Black Canyon, but eastward toward the Freezeout Hills, beds lithologically typical of the Forelle appear. The Little Medicine tongue of the Dinwoody is readily recognizable at Black Canyon and continues eastward into the Freezeout Hills with almost no change in lithology or in thickness.

LOCALITIES IN LARAMIE BASIN

The Satanka shale, the Forelle limestone, the Freezeout tongue of the Chugwater, and the Little Medicine tongue of the Dinwoody are probably everywhere present in the Laramie Basin, but there is no place between the Flat Top anticline and Red Mountain where all are exposed in the same section. The soft shales of the Satanka and the Chugwater are poorly exposed along the west flank of the Laramie Mountains, and it is impossible to measure detailed sections of the Satanka or to find the Little Medicine tongue. The Forelle is fairly well exposed in most places. Therefore, in the Laramie Basin, it is most convenient to apply the name, Chugwater, to all the red beds between the Forelle and the Jelm formation (Upper Triassic). The name, thus applied, includes the Freezeout and the Little Medicine tongues (Figs. 5 and 6).

Along the west flank of the Laramie Mountains the Casper formation consists of a cyclical sequence of cross-laminated sandstones grading upward into fossiliferous limestones. Each limestone was subjected to erosion before the deposition of each overlying sandstone.[51] It is not possible at present to locate the pre-Satanka erosion surface because of confusion with the intra-Casper erosion surfaces. For this reason some beds now included in the Casper may properly belong in the Satanka. The writer has placed the base of the Satanka at the horizon above which red shales predominate and above which no festoon[52] cross-laminated sandstones are found.

In the Centennial Valley, along the east side of the Medicine Bow Mountains, the Casper contains festoon cross-laminated sandstones similar to the Tensleep sandstones. The contact of the red shale of the Satanka and the upper cream-colored sandstone of the Casper is an undulating surface with 5 or 6 feet of relief. The exact relation of the Casper to the Tensleep is, however, still an open problem. The writer believes that the unconformity between the Casper and the Satanka is the same as the one separating the Tensleep from the intertongued phase of the Phosphoria in central Wyoming and the Tensleep from the Phosphoria farther west.

The Satanka consists almost wholly of red shale, but a few thin beds of other sorts are intercalated throughout. Gypsum is present near the base of the formation, especially in the southern part of the Laramie Basin. The thickness of the Satanka varies considerably, but averages about 250 feet. The Forelle is almost everywhere divisible

[51] S. H. Knight, "The Fountain and Casper Formations of the Laramie Basin," *Univ. of Wyoming Pub. in Science*, Geology, Vol. 1, No. 1 (1929), p. 53.

[52] *Ibid.*

into (1) a basal gray limestone, which is usually crinkly and is dolomitic or gypsiferous at various localities; (2) a middle lavender, platy limestone, generally fine-grained, and finely laminated, and (3) an upper gray limestone, usually crinkly and dolomitic or gypsiferous. The Forelle has been reported to be fossiliferous by Darton and Siebenthal,[53] but the writer has not found fossils that are identifiable. Fragments of fossils abound, but complete specimens have been obliterated by changes which produced the crinkly structure, by dolomitization, or by gypsum replacement. The average thickness of the Forelle is about 18 feet.

The ages of the Satanka and the Forelle have never been definitely determined. W. C. Knight[54] believed that the beds which now comprise the Satanka and the Forelle were of Permian age. Darton and Siebenthal,[55] however, treated the formations as Pennsylvanian. Lee[56] made no definite statements regarding the age of the Satanka and the Forelle, but in his graphic sections placed the Phosphoria, the Satanka and the Forelle in the Permian. He classed the Dinwoody as Triassic and said he believed it "to thin out toward the east and lie unconformably beneath Satanka shale." He thus placed the Triassic rocks below the Permian rocks, yet he correlated the Satanka and the Forelle with the "Embar," which he placed above the Dinwoody. It is difficult to decide whether Lee considered the Satanka and the Forelle as Permian or Triassic.

The formations, however, were undoubtedly deposited during Phosphoria time, and the determination of their age necessarily rests upon the determination of the correct age of the Phosphoria. If the Phosphoria is considered wholly Middle Permian, the age of the Satanka and the Forelle must also be Middle Permian. The fauna of the Satanka is of little value for age determination.

In order to demonstrate that all the beds present in the "Embar" of central Wyoming are represented in the Laramie Basin by the Satanka, the Forelle, and the lower part of the Chugwater, the few localities in the Laramie Basin where the rocks are well exposed are discussed below.

Como Bluff.—North of Como Bluff, along Rock Creek, the Little Medicine tongue and a portion of the subjacent Freezeout tongue are exposed. The Little Medicine tongue has the same lithologic character

[53] *Op. cit.*

[54] W. C. Knight, "The Laramie Plains Red Beds and Their Age," *Jour. Geol.*. Vol. 10, No. 4 (1902).

[55] *Op. cit.*

[56] *Op. cit.*

and thickness as in the Flat Top anticline. The red shales of the exposed portion of the Freezeout tongue contain several beds of gypsum.

Boswell Springs.—In the vicinity of Boswell Springs the Satanka and the Forelle are present, although the Satanka is completely covered. A short distance farther southeast the Little Medicine tongue is exposed above the red shales and gypsum of the Freezeout tongue, but it is impossible to measure the stratigraphic interval between the Little Medicine tongue and the Forelle.

Sybille Springs anticline.—The Satanka is poorly exposed, but a nearly complete section can be compiled. The Forelle is exposed in several places, but all the beds above it are covered. The formations are shown in Table VI.

TABLE VI

SECTION MEASURED AT SYBILLE SPRINGS ANTICLINE, ALBANY COUNTY

Column A: thickness of individual beds in feet *Column B: feet from top of Tensleep sandstone to top of bed*	*A*	*B*
CHUGWATER (*including Little Medicine and Freezeout tongues*): covered.		
FORELLE		
Crinkly ribbon limestone	4	278
Red shale	5	274
Crinkly ribbon limestone	2	269
Purple shale	4	267
Crinkly ribbon limestone	3	263
SATANKA		
Red shale, not well exposed	55	260
Sybille tongue of Phosphoria		
Buff limy sandstone mottled with pink and containing calcite geodes and chert	21	205
Red shale, with a few thin beds of buff sandstone, gray porous limestone, and pink and gray ribbon limestone	184	184
CASPER: not measured.		
TOTAL	278	

The lithologic character of the Sybille tongue has been discussed in its definition (p. 1664). Its fauna consists of the following incompletely silicified specimens.

Aviculopecten sp. undescribed	r
Small pelecypod	r
Plagioglypta? sp.	c
Euphemus carbonarius (Cox)	r
Bellerophon? sp.	r
Strophostylus? sp.	r

Fragments of other species exist, and further collecting will undoubtedly add to this fauna.

The Forelle is typical in lithologic character. The exposures of the

Satanka and the Forelle from this point southward are poor, and the next available complete section is on the southern edge of the Laramie Basin, at Red Mountain.

Forelle Siding.—The Forelle is poorly exposed at its type locality south of Laramie. The lower limestone is made up principally of small fragments of fossils. Overlying it is a platy, purple limestone, above which is a porous gypsiferous limestone. It is impossible to discover whether this is the top of the Forelle.

Satanka Siding.—At the type section of the Satanka the exposures are such that one can determine only that the formation consists predominantly of red shale.

Red Mountain.—Misstatements as to the stratigraphy of the Satanka, the Forelle, and the lower part of the Chugwater at Red Mountain have become almost hoplessly entangled in the geologic literature. A fossiliferous limestone, which in places is a breccia, was mistaken by Darton and Siebenthal[57] for the Forelle. Since the limestone occurs only three feet above the top of the Casper, they assumed that the Satanka was absent at Red Mountain. Lee had noted a conspicuous breccia which occurs above the Forelle at various localities and, because of the similarity between this breccia and the one in the base of the Satanka at Red Mountain, he decided that the two were the same, and says:[58]

> If the fossiliferous breccia at Red Mountain proves to be the equivalent of the similar limestone breccia of neighboring localities, the unconformity beneath it must represent Forelle, Satanka and Phosphoria time . . . No purple shale that can be called Satanka was found, nor any limestone which the writer would call Forelle.

It has been pointed out that a number of different beds of breccia occur in different localities and that these beds do not represent a single horizon. The section at Red Mountain is interpreted by the writer as shown in Table VII.

The red shale of the Satanka is typical in lithologic character, but the gypsum in the base is absent at the type locality. Gypsum, however, is common in the basal portion of the intertongued phase of the Phosphoria at localities north of the Laramie Basin. The Sybille tongue is not present at Red Mountain.

The basal fossiliferous limestone of the Satanka is a variable bed. In some places it is a breccia and in others it has been replaced to various degrees by gypsum. Changes taking place within a few tens of feet considerably alter the lithologic sequence of the basal beds. A

[57] *Op. cit.*

[58] Willis T. Lee, *op. cit.*, p. 69.

TABLE VII

SECTION MEASURED ON NORTHWEST FACE OF RED MOUNTAIN

Column A: thickness of individual beds in feet *Column B: feet from top of Tensleep sandstone to top of bed*	*A*	*B*
CHUGWATER		
Red shale and sandstone, not measured		
Little Medicine tongue of Dinwoody		
Purple, finely laminated gypsum, grading downward into sub-jacent bed	2	261.8
Very fine-grained, limy sandstone, mostly red, but with greenish laminae; finely laminated throughout; gypsiferous patches present; grades into subjacent bed	4.2	259.8
Freezeout tongue of Chugwater		
Red shale	24.3	255.6
Gypsum	2	231.3
Red shale	13	229.3
Gypsum	5	216.3
Red shale	52.8	211.3
Gypsum grading downward into 6 inches of porous gray limestone	7.3	158.5
Red shale	2.7	151.2
FORELLE LIMESTONE		
Finely laminated, crinkly gypsum	7.5	148.5
Finely laminated, dense, purple limestone	3	141
Dense, crinkly, gray limestone with a few angular chert masses of small size. Caps mesa known as Gypsum Butte	5	138
SATANKA SHALE		
Red sandy shale	72	133
Gypsum with a few thin beds of red shale, one of which contains numerous masses of aragonite which are pseudomorphs after hanksite*	53	61
Pinkish shaly limestone, mostly unfossiliferous but with 2-foot bed of fossil coquina in center; brecciated in places	5	8
Olive-colored flaky shale	3	3
CASPER FORMATION: not measured.		
TOTAL	261.8	

* N. H. Darton and C. E. Siebenthal, *U. S. Geol Survey Bull. 364*, p. 24.

fauna collected by W. C. Knight and identified by G. H. Girty has erroneously been reported as occurring in the Forelle. The following species have been collected by the writer; those previously listed by Darton and Siebenthal[59] as from the Forelle are marked by asterisks.

Allorisma capax Newberry	c
**Deltopecten* cf. *D. coreyanus* (White)	c
**Deltopecten manzanicus*	c
**Myalina perattenuata* Meek and Hayden	c
Myalina cf. *M. aviculoides* Meek and Hayden	r
Myalina cf. *M. permiana* Swallow	c
**Plagioglypta canna* (White)	c
**Pleurophorus* aff. *P. taffi* Girty	c

[59] N. H. Darton and C. E. Siebenthal, *op. cit.;* Willis T. Lee, *op. cit.;* C. C. Branson, *Univ. Missouri Studies*, Vol. 5, No. 2 (1930).

**Schizodus compressus* Beede	c
**Schizodus meekanus* Girty	c
Bellerophon crassus Meek and Worthen	c
Coelogasteroceras cf. *C. mexicanum* (Girty)	r

In addition, Darton and Siebenthal listed "*Allorisma terminale*, *Solenomya* sp. and *Orthonema?* sp." which the writer has not identified.

This fauna has been cited by C. C. Branson[60] as bearing affinities to the fauna of the top limestone of the Phosphoria of the Wind River Mountains. The fossils, however, occur far below the Forelle, and the fauna can not be contemporaneous with that of the top limestone of the Phosphoria.

PALEOGEOGRAPHY AND LITHOGENESIS

The best discussion of the paleogeography of Phosphoria time has been given by Mansfield.[61] He points out, however, that large gaps exist in the knowledge regarding the facts on which such a discussion is based. Much more detailed information is necessary before a true reconstruction can be formulated of the conditions under which the rocks of Phosphoria time and of Dinwoody time were deposited. Of prime importance is the establishment of the definite ages of the formations. With this in mind, the writer ventures to add to the existing knowledge the information gained through the study of the relatively small area embraced by this paper.

PHOSPHORIA TIME

Paleogeography.—The area covered by the Phosphoria sea on Mansfield's paleogeographic map[62] must be extended eastward. During portions of Phosphoria time the sea entirely covered central and southeastern Wyoming. At present it is not known how much farther eastward the sea extended.

The locations of positive areas which supplied land-derived material during Phosphoria time are not definitely known. Their character, however, was apparently quite different from that of the land masses which supplied material for the Pennsylvanian sediments of central and southeastern Wyoming, for the Permian land masses did not furnish such coarse clastic material as those of the Pennsylvanian.

A land mass in north-central Colorado, which undoubtedly furnished sediments during Pennsylvanian time, was overlapped and buried by sediments of Phosphoria age. In North Park, Colorado

[60] *Op. cit.*, p. 21.

[61] G. R. Mansfield, "Geography, Geology and Mineral Resources of Part of Southeastern Idaho," *U. S. Geol. Survey Prof. Paper 152* (1927), pp. 184–88.

[62] *Ibid.*, Fig. 22, p. 185.

(Fig. 1), the pre-Cambrian granite is overlain by about 100 feet of alternating red shales and limestones probably of Phosphoria age. Limestones comprise 35 feet of the total thickness.[63] The small percentage of land-derived material in this section compared with sections in central Wyoming, and the comparative thinness, suggest that the terrigenous material present in central Wyoming did not come directly from the south. It may be said, however, that insufficient evidence is at hand to indicate the importance of Colorado land masses in contributing to the Phosphoria sediments.

The increase in the amount of clastic material in the sediments of Phosphoria age from west to east across Wyoming seems to indicate that some of the material came from east of Wyoming. Regarding the distribution of the Permian seas, P. B. King[64] says:

> During Permian time an embayment from the Gulf of Mexico extended inland through Mexico into western Texas, where it divided into two branches, one of which reached northeast into the mid-continent region beyond Nebraska and the other penetrated the Cordilleran region of New Mexico, Arizona and Utah.

Inasmuch as the Phosphoria sea was a part of the Cordilleran invasion, the region lying east of Wyoming, between these two embayments, seems to be a logical source of supply for some of the terrigenous material of the sediments of Phosphoria age in southeastern Wyoming, although the source does not seem adequate. Possibly, some of the material was distributed northward from the east side of the Paleo-Rockies in central Colorado.

Sedimentary environments.—If residual red soils were being produced by weathering of rocks in the positive areas, it is possible that such soil would be transported and deposited along the margin of the Phosphoria sea as red material. Certain facts lead the writer to believe that most of the red shale tongues were deposited in a specialized marine environment. Individual beds of red shale show slight variation in thickness or in texture over wide areas. Mud cracks or raindrop impressions have never been noted in the red shales. These red beds lack the lithologic features characteristic of the Fountain formation (Pennsylvanian) and the Jelm formation (Upper Triassic). Both are red beds of unquestionable continental origin, characterized by lenticularity of beds, rapid changes in texture within short distances, channeling and cross-lamination. Poorly preserved marine fossils have been found in a thin limy red bed in the Satanka in the Laramie Basin, and over most of the region thin beds of red shale are inter-

[63] S. H. Knight, personal communication.

[64] P. B. King, "The Geology of the Glass Mountains," Pt. 1, *Univ. Texas Bull 3038* (1930), p. 89.

bedded with limestones or sandstones of undoubted marine origin. Mansfield[65] has shown that the beds of chert within the Phosphoria are chemically precipitated marine deposits. Just below the Ervay tongue in the Rattlesnake Hills are thin beds of laminated chert intercalated with beds of red shale. This suggests that the conditions under which the chert was deposited were not markedly different from the conditions under which the red shale was deposited. The thick gypsum beds in the red shales indicate some relationship to a marine environment. The absence of fossils in the red beds has no bearing on their origin; both continental and marine beds are frequently found to be unfossiliferous. However, if the unfossiliferous nature of the red beds of Phosphoria age be interpreted as the result of the absence of organisms in a specialized marine environment, the red material could have been deposited without the reduction of its ferric iron and with the retention of its original color.

Western Wyoming, then, was occupied during Phosphoria time by a sea in which the typical facies of the formation was deposited. At the same time, a marginal portion of the sea covered southeastern Wyoming. Here were deposited red sediments which intertongued with the typical facies of the Phosphoria. It is not known whether this relationship was brought about by oscillatory movements of the sea or whether it was the result of intermittent cessation of uplift in the land masses which supplied the red clastic material. Both would allow the clear water zone favorable to the deposition of limestone to move eastward. It seems best, however, to think of the red beds as a marginal deposit built out westward in an oscillatory sea. During the time of deposition of any limestone tongue, the sea would be most widespread and the red-bed marginal facies would migrate eastward. With regression of the sea the red-bed facies would move back toward the west. The transgressions were rapid and probably of short duration, for some of the limestone tongues, although thin, cover hundreds of square miles. That the rate of sedimentation was not markedly slower during times of limestone deposition is indicated by the fact that the thickness of the typical facies of the Phosphoria is not much less than the thickness of the formation where it is split by tongues of red shale. The lack of terrigenous material in the limestone tongues indicates, however, that any particular locality was separated from the source of supply of the red sediments by a greater extent of water during limestone deposition than during red shale deposition. It is believed that the clastic material of the Sybille tongue had a different source from that of the red shales. This may be accounted

[65] *Op. cit.*, pp. 367–72.

for by the fact that the Phosphoria sea, as shown by Mansfield, was a more or less enclosed body of water.

The limestones in the red-bed facies are diverse in origin. Many of them are due to the accumulation of calcareous organic material. Only a few of these beds yield recognizable fossils because of the broken condition of the shells. The extremely fine-grained, finely laminated limestones may be the result of deposition of chemically precipitated lime. It is apparent that they were deposited in water which was not agitated enough to obliterate fine lamination. The sedimentary environment in which these limestones were deposited is in contrast with that of the breccia beds, whose origin has been attributed to contemporaneous erosion in highly agitated water.

The mode of origin of the gypsum beds is not well understood. It is believed that many of the thinner ones are replaced limestones; most of the thicker ones are undoubtedly chemical precipitates.

In interpreting the origin of the chert in the Phosphoria formation, Mansfield was influenced by Lee's belief that the Phosphoria was older than the red-bed "Embar" and that the two were separated by an unconformity.[66] Hence, Mansfield believed that a low peneplane cut on the Tensleep sandstone formed the land surface east of the Phosphoria sea,[67] which he thought was confined to western Wyoming. He pointed out that such conditions have been postulated by W. A. Tarr as being conducive to the deposition of chemically precipitated chert beds, and he used Tarr's theory in explaining the origin of the Phosphoria chert.

The paleogeography postulated by Mansfield must be revised, however, for the sea was more widespread and instead of being bordered by peneplaned sandstone was adjacent to land which supplied clastic red sediments. Furthermore, by the time that chert deposition became prominent in the Phosphoria, the peneplaned Tensleep sandstone of central Wyoming, which was considered as the probable source of the silica in the cherts, had long been buried by red beds.

DINWOODY TIME

The same land masses which supplied the red sediments of Phosphoria age continued to produce similar material which was carried over southeastern and central Wyoming during Dinwoody time. However, the red shales, instead of interfingering toward the west with limestones and chert as during Phosphoria time, graded into

[66] G. R. Mansfield, *op. cit.*, p. 373.

[67] *Ibid.*, p. 372.

clastic shales and limy sandstones. This means, perhaps, that a positive area on the western border of the Dinwoody sea began to function and to give rise to the land-derived material in the typical Dinwoody, or that the Dinwoody is a seaward facies of the red shales which was deposited under reducing conditions, resulting in the loss of the red color of the sediments. A maximum advance of the sea during the time of deposition of the Little Medicine tongue was followed by a retreat throughout the remainder of Dinwoody time, and caused the red-bed facies to migrate westward with its base rising in the column (Fig. 3).

BOUNDARY BETWEEN PALEOZOIC AND MESOZOIC

The effects of the almost world-wide crustal unrest during the interval between the Paleozoic and the Mesozoic eras are conspicuously absent in central or southeastern Wyoming. If the age of the Phosphoria is Middle Permian and that of the Dinwoody is Lower Triassic, there must be, between the formations, an unconformity which represents an interval of non-deposition of considerable duration. If such a break is present it is not conspicuous. The areal extent of the red-bed and normal marine environments during Phosphoria time was almost indentical with the areal extent of similar environments during Dinwoody time, indicating that no marked changes in the crustal configuration took place between the times of deposition of the two formations. There is no measurable angular discordance between the Phosphoria and the Dinwoody to indicate diastrophism between Phosphoria time and Dinwoody time.

Even though the Dinwoody should be found to be Permian, or be found to represent the interval between the Permian and the Triassic, there is still no well defined break between Paleozoic and Mesozoic rocks. In southeastern Wyoming sedimentation was apparently continuous from the Forelle portion of Phosphoria time, through Dinwoody time, until the close of Chugwater time. However, between Chugwater time and Upper Triassic (Jelm) time the region was gently warped and the strata beveled by erosion, so that the younger members of the Chugwater progressively disappear from north to south.

CLIMATE

The evidence bearing on the climate of Phosphoria time and Dinwoody time is meager. The production of residual soils indicates a source in which oxidation dominated over reduction. The presence of locally abundant gypsum suggests high evaporation with a relatively small inflow of fresh water, such as would characterize a warm, arid climate. The Phosphoria sea, during times other than those of phosphate deposition, swarmed with organisms which are similar to those which inhabited the warm Pennsylvanian seas. Mansfield,[68] however, believes that the phosphate beds in the Phosphoria are a reflection of a cool climate.

DIFFICULTIES IN PALEONTOLOGIC CORRELATION

Most of the organisms which lived in the portion of the Phosphoria sea which is now occupied by the Wind River Mountains were markedly different from the organisms which are now found farther east and south as fossils in limestones and sandstones intercalated in red beds. Most of the faunules of the Phosphoria of the Wind River Mountains consist principally of brachiopods and bryozoans, a feature which contrasts strongly with the molluscan character of the faunules of the calcerous facies in the intertongued phase. The differences in the two types of faunules indicate strongly that they lived in distinctly different environments. There were, however, certain genera or species living during Phosphoria time which were not sufficiently specialized to be confined to one set of environmental conditions. The genus *Myalina*, for example, is found in the Phosphoria of both the Wind River Mountains and the intertongued phase, but certain species of the genus are confined to the former and others to the latter. *Plagioglypta canna* seems to have been able to exist in equal abundance in both environments.

Between the two areas providing the two distinct types of environment there was undoubtedly a zone of environmental gradation in which certain genera or species found in one type of faunule could exist and intermingle with certain genera and species found in the other type. The faunule of the Ervay tongue in the Rattlesnake Hills furnishes a good example of this environmental gradation and consequent faunal intermingling. The organisms of the molluscan type of faunule in the intertongued phase are here represented by *Schizodus*, *Myalina*, *Pleurophorus* and *Pinna*, and the organisms of the Phosphoria of the Wind River Mountains by *Composita*, *Derbya*, *Punctospirifer*, *Euphemus*, and numerous bryozoans.

The writer believes that the erroneous paleontologic correlation of beds in the intertongued phase with certain horizons in the Phosphoria and Dinwoody of the Wind River Mountains has resulted from relying too strongly on general faunal similarity and on the presence of species which are found in both areas. General faunal similarity and common species are not always reliable criteria for correlating beds

[68] *Op. cit.*, p. 366.

which occur in different sedimentary facies. Most of the fossils in the intertongued phase of the Phosphoria are long-ranging species. Similarities in faunas of markedly different age may result from these long-ranging species appearing at one locality under certain environmental conditions and appearing much later at another locality upon the initiation there of a suitable environment.

SUMMARY

Marine limestone and sandstone tongues extend southeastward from the Phosphoria and the Dinwoody formations of the Wind River and the Owl Creek mountains, intertonguing with the red shales in the base of the Chugwater formation in central and southeastern Wyoming. The nature of the intertonguing has been demonstrated through lithologic and faunal correlation of sections. Significant stratigraphic units have been defined and named.