BULLETIN O THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 21, NO. 6 (JUNE, 1937), PP. 715-770, 13 FIGS.

5

STRATIGRAPHY OF THE SUNDANCE FORMATION AND RELATED JURASSIC ROCKS IN WYOMING AND THEIR PETROLEUM ASPECTS[1]

JOSEPH NEELY[2]
Laramie, Wyoming

ABSTRACT

The Sundance formation of Wyoming contains a stratigraphic break which gives evidence of the result of a period of erosion during Divesian time. The lower portion of the Sundance formation is believed to be equivalent to part of the Twin Creek formation of western Wyoming and to part of the lower Ellis formation of northwestern Wyoming, as it was originally described. The upper portion of the Sundance formation is believed to be in part equivalent to the lower Beckwith of western Wyoming (the Preuss and the Stump formations of southeastern Idaho), and to the upper portion of the original Ellis formation of northwestern Wyoming. Oil production from the Sundance is found in anticlinal structures which lie in a belt slightly more than 100 miles broad trending in a northeast-southwest direction across the eastern portion of Wyoming. This belt is roughly parallel to the shore line of the Logan (Sundance) sea. Theories to account for the distribution are (1) "up-dip" migration before concentration in anticlines, (2) biochemical relationships, and (3) textural differences. Flushing appears to have played an important part in some structures.

INTRODUCTION

Many problems are presented by the marine Jurassic rocks which occur in the state of Wyoming, and the importance of these problems has been amplified in the past two years by the discovery of oil in large quantities within the Sundance formation. The problem of the age of the Jurassic rocks of Wyoming compared with the European type section has always been of scientific interest. The work of Crickmay[3] has done much toward a solution; Reeside also has made many contributions toward this end. The problem of correlation between (1) the southeastern Idaho section (the Nugget, the Twin Creek, the Preuss, and the Stump formations), (2) the northwestern Wyoming section (the Ellis formation), and (3) the marine Jurassic which is present over much of the rest of the state of Wyoming (the Sundance formation), is not completely understood. The present work was undertaken primarily in an attempt to shed some light on this problem of correlation.

[1] Manuscript received March 8, 1937. Published by permission of the Geological Survey of Wyoming.

[2] Instructor in Geology, University of Wyoming. (Now with the Magnolia Petroleum Company, Dallas, Texas.)

[3] C. H. Crickmay, "Study in the Jurassic of Wyoming," *Bull. Geol. Soc. America*, Vol. 47 (1936), pp. 541–64.

The petroleum aspect of the Sundance formation is briefly dealt with as a supplement to this paper. Included are statistics on production, limitations of known production, and the consideration of theories on the accumulation and distribution of the Sundance oil.

Acknowledgments.—The field work connected with this problem was partially financed by the Geological Survey of Wyoming, and through that agency, completion of the paper was made possible. The

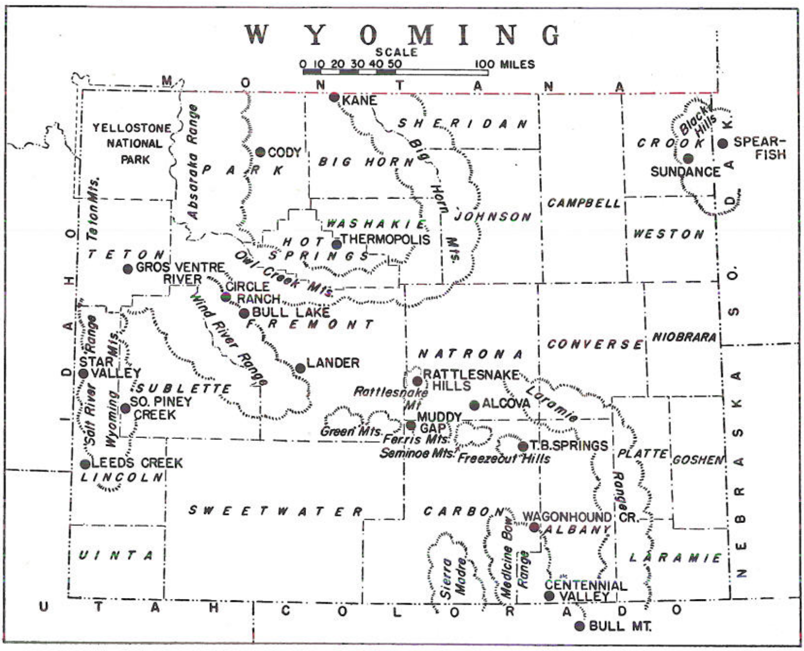

FIG. 1.—Index map.

writer is indebted to the faculty of the Geology Department at the University of Wyoming for valuable aid and suggestions. S. H. Knight made many valuable suggestions; R. H. Beckwith contributed aid and suggestions; H. D. Thomas made a critical review of the manuscript and contributed many valuable suggestions. The writer is greatly indebted to J. B. Reeside, Jr., and W. W. Rubey of the United States Geological Survey, and to G. Marshall Kay of Columbia University for a review of the manuscript and many valuable suggestions. A. M. Morgan furnished a collection of fossils from the Gros Ventre region. Pierre LaFleiche, Wyoming Mineral Supervisor, furnished much valuable information in connection with statistics of petroleum production from the Sundance formation.

Previous Investigations of Jurassic Deposits in Wyoming

Black Hills.—The presence of Jurassic rocks in the Black Hills (Fig. 1) was first ascertained by Hayden in 1857; he discovered marine Jurassic fossils which were identified and described by Meek. Hayden's descriptions were brief, and he included red beds of Triassic age in the Jurassic. In 1874, N. H. Winchell recorded some facts about the character and distribution of the Jurassic rocks in the same area. Henry Newton,[4] in 1875, made an extended survey of the Black Hills and devoted a large part of his report to the description of the marine Jurassic rocks. He described a number of exposures in some detail, but made no attempt at classification. The paleontology of the Jurassic rocks was included in Newton's report by R. P. Whitfield,[5] in which the fossils collected from marine Jurassic rocks of the area were described and illustrated.

N. H. Darton,[6] in 1899, published a report on the Jurassic formations of the Black Hills region, in which he applied the names Sundance and Unkpapa to the marine Jurassic beds. Darton gave detailed descriptions of several measured sections, and included a faunal list of all of the fossils which had been reported from the area. Darton's original description of the type section of the Sundance formation includes the following statement.

> This member of the Jurassic [the Sundance] . . . carried abundant marine fossils. . . . The formation comprises shales and sandstones, in greater part in alternating series which vary somewhat in relation in different portions of the region. The shales are mainly dark green and the sandstones pale buff in color, but there is an intermediate member of sandy shales and sandstones of reddish color, and often a local basal member of red sandstone. The shales usually include thin layers of limestone which are always highly fossiliferous. Fossils also occur in the sandstones.

In describing the Unkpapa Darton says:

> This formation is always clearly separable both from the Sundance shales below and the Beulah shales, or Lakota sandstone above. It is massive fine-grained sandstone, varying in color from white to purple or buff. . . . Contacts with the overlying buff sandstone of the Lakota formation are frequently exposed, and they are seen to be marked by considerable unconformity by erosion.

[4] Henry Newton and W. P. Jenney, "Report on the Geology and Resources of the Black Hills of Dakota," *U. S. Geog. and Geol. Survey Rocky Mountain Region* (Powell) (1880).

[5] R. P. Whitfield, "Paleontology of the Black Hills of Dakota," *U. S. Geog. and Geol. Survey Rocky Mountain Region* (1880).

[6] N. H. Darton, "Jurassic Formations of the Black Hills of South Dakota," *Bull. Geol. Soc. America*, Vol. 10 (1899), pp. 383–86.

In 1905, N. H. Darton[7] described in detail the Sundance formation of the Sundance Quadrangle. He described the very fossiliferous upper shales and included a faunal list from those beds. He also pointed out that ". . . occasional layers of fossiliferous limestone occur in the lower shales," and reported "*Pentacrinoides asteristicus*" and other commonly occurring forms. He further states:

All of these are of Upper and Middle Jurassic age. The Sundance formation is believed to be equivalent to the Ellis formation of Montana and the Yellowstone Park region.

Central and eastern Wyoming.—Hayden,[8] in 1870, referred to the Jurassic rocks of central and eastern Wyoming, briefly noting their geographical distribution and fossil content. Other early surveys[9] reported the presence of rocks of Jurassic age in this area and noted their distribution, lithologic character and fossil content.

W. C. Knight,[10] in 1900, reported on the Jurassic rocks of southeastern Wyoming. He noted the distribution and fauna and made suggestions as to the correlation of these rocks with the European type section, based on reptilian remains. In the same year, W. N. Logan[11] published a paper which dealt with the stratigraphy and invertebrate paleontology of the Freezeout Hills area, and in which a rather extensive description of the section was given.

Darton,[12] in 1908, published a paper on the Paleozoic and Mesozoic formations of part of central Wyoming, in which he briefly considered the distribution of the Jurassic rocks and believed them to be equivalent to the Sundance formation of the Black Hills.

J. B. Reeside, Jr.,[13] described and figured several ammonites collected at various localities from the Sundance over the state of

[7] N. H. Darton, "Description of the Sundance Quadrangle," *U. S. Geol. Survey Atlas Folio* (1905), p. 3.

[8] F. V. Hayden, *Geological Survey of Wyoming and Contiguous Territory* (1870).

[9] G. K. Warren, *Preliminary Report of Explorations in Nebraska Territory and Dakota* (1855–56–57); F. B. Meek and F. V. Hayden, "Paleontology of the Upper Missouri," *Smiths. Contr. Knowl. 14*, Vol. 172, Art. 5 (1865); Clarence King, "Systematic Geology," *40th Parallel Survey* (1878), pp. 286–87; F. V. Hayden, *Geological Survey of the Territories* (1867–69).

[10] W. C. Knight, "Jurassic Rocks of Southeastern Wyoming," *Bull. Geol. Soc. America*, Vol. 11 (1900), pp. 377–88.

[11] W. N. Logan, "The Stratigraphy and Invertebrate Faunas of the Jurassic Formations in the Freezeout Hills of Wyoming," *Kansas Univ. Quarterly Bull.*, Vol. 9, No. 2 (April, 1900), pp. 109–34.

[12] N. H. Darton, "Paleozoic and Mesozoic of Central Wyoming," *Bull. Geol. Soc. America*, Vol. 19 (1908), pp. 403–74.

[13] J. B. Reeside, Jr., "Some American Jurassic Ammonites of the Genera Quenstedticeras, Cardioceras, and Amoeboceras, of the Family Cardiocertidae," *U. S. Geol. Survey Prof. Paper 118* (1919), pp. 1–64.

Wyoming. From the distribution of these fossils, Reeside has drawn the conclusion that:

The Sundance formation has been considered by nearly all American authors as a single paleontologic and stratigraphic unit of lower Oxfordian age, in the sense that the term was applied by continental and particularly Russian stratigraphers. The present study bears out this interpretation.

A. E. Brainerd and I. A. Keyte,[14] in a paper published in 1927, reported the finding of a Sundance fauna below a horizon which was at that time included in the Chugwater formation, and suggested a new division of the Jurassic rocks of Wyoming. Brainerd and Keyte state:

The zone at the top of the Chugwater is widespread in the state of Wyoming. . . . It is suggested that this zone . . . be given a new name and placed in the Jurassic. It appears . . . that this would make for simpler stratigraphy than to include these red shales in the typical Sundance, inasmuch as there appears to be a definite break between the two.

The paper thus points out an erosion surface within the Sundance formation.

Willis T. Lee,[15] in correlating the Sundance formation from northwest to southeast across the state of Wyoming, believed that the thinning from northwest to southeast was due to erosion. Lee subdivided the Sundance into four members which are fairly consistent throughout the area in which he worked.

John G. Bartram,[16] in 1930, compiled many sections of Jurassic rocks in the state of Wyoming and constructed cross sections, showing his correlations. He correlated all of the Sundance, except the basal sand, which he referred to the Nugget, with the Twin Creek and lower Beckwith of western Wyoming.

C. H. Crickmay,[17] in 1931, in his noteworthy work on the Jurassic history of North America, considered the marine Jurassic of Wyoming to have been deposited as essentially a single unit and assigned it to the Argovian and the Kimmeridgian of the European type section.

In a later paper, Crickmay[18] again correlated the typical Sundance

[14] A. E. Brainerd and I. A. Keyte, "Some Problems of the Chugwater-Sundance Contact in the Big Horn District of Wyoming," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 11 (1927), pp. 747–52.

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

[16] John G. Bartram, "Triassic-Jurassic Red Beds of the Rocky Mountain Region," *Jour. Geol.*, Vol. XXXVIII, No. 4 (1930), pp. 335–45 and 667–71.

[17] C. H. Crickmay, "Jurassic History of North America; Its Bearing on the Development of Continental Structure," *Proc. American Philosophical Society*, Vol. LXX, No. 1 (1931), pp. 15–102.

[18] *Idem*, "Study in the Jurassic of Wyoming," *Bull. Geol. Soc. America*, Vol. 47 (1936), pp. 541–64.

with the Argovian and the Kimmeridgian, and considered the Sundance as a single unit. However, the basal sandstone of the sections in eastern Wyoming he thought might be equivalent to the basal Ellis sandstone of Montana, to which he gave a Callovian age.

Yellowstone National Park area.—The name Ellis was given by Arnold Hague[19] to the marine Jurassic rocks of the Yellowstone National Park, the name being derived from Fort Ellis, 50 miles north of the Park. This name is now used for the Jurassic rocks of Montana. His description includes the following statement.

> This formation [the Ellis] constitutes a series of fossiliferous beds carrying a Jurassic fauna. The formation consists of two divisions: a lower one, limestone, and an upper one, chiefly sandstone. . . .

No attempt was made to further classify the Ellis formation in the original description.

D. Dale Condit,[20] in 1918, in the correlation of the marine Jurassic rocks of Montana, made the following statement.

> It is suspected that the Ellis represents only the basal portion of the several thousand feet of Marine Jurassic beds in southeastern Idaho, but corresponds closely with the Sundance formation of Wyoming. . . .

Western Wyoming.—In western Wyoming the nomenclature is more complicated (Table I). In 1876, King[21] noted the presence of Jurassic rocks in western Wyoming, and referred to them merely as Jurassic. Powell,[22] in the same year, subdivided the Jurassic rocks in the Uinta Mountains into the Vermilion Cliff and the White Cliff, which are equivalent to the Nugget as the name is used today, and to some of the Triassic below the Nugget, and the Flaming Gorge, which is equivalent to the Preuss, the Stump, and possibly younger beds. A. C. Veatch,[23] in 1907, applied the names Nugget, Twin Creek, and Beckwith to the Jurassic rocks of southwestern Wyoming. Veatch described the Nugget as follows:

> The group of yellow, pink and red sandstones bounded below by the gray fossiliferous limestones of the Thaynes formation and above by the dark

[19] Arnold Hague, "Yellowstone National Park Sheets," *U. S. Geol. Survey Atlas Folio* (1896), p. 5.

[20] D. Dale Condit, "Relations of the Late Paleozoic and Early Mesozoic Formations of Southwestern Montana and Adjacent Parts of Wyoming," *U. S. Geol. Survey Prof. Paper 120 F* (1918), p. 114.

[21] Clarence King, *United States Geological Exploration of the Fortieth Parallel* (1876).

[22] J. W. Powell, "Report on the Geology of the Eastern Portion of the Uinta Mountains and a Region of Country Adjacent Thereto," *U. S. Geol. Survey Territories vii* (1876).

[23] A. C. Veatch, "Geography and Geology of a Portion of Southwestern Wyoming," *U. S. Geol. Prof. Paper 56* (1907), pp. 56–58.

colored fossiliferous shales and limestones of the Twin Creek formation has been named the Nugget formation. . . .

This formation Veatch named from Nugget Station on the Oregon Short Line Railroad. Veatch described the Twin Creek as follows:

The fossiliferous marine Jurassic, to which has been given the local name Twin Creek formation from the excellent exposures on that creek . . . here consists for the most part of dark, calcareous shales and thin-bedded shaly limestones, though occasionally showing lighter colored sandstone layers. These are sharply limited above by the thick red beds which mark the base of the Beckwith. . . .

Veatch states that

The Beckwith formation, which directly overlies the Twin Creek, has been so named from its occurrence and extensive development on . . . lands now forming part of the Beckwith Ranch, situated just east of the Beckwith Station . . . .

Veatch regarded the Nugget as wholly, or at least in part, Triassic, and the lower part of the Beckwith as Jurassic, on the basis of fossils collected from beds which are herein referred to the Stump formation. He stated that

The lower part of the Beckwith formation is thus clearly Jurassic and the remainder probably contains time equivalents of the Lower Cretaceous and Dakota beds, if these occur in this area.

Gale,[24] in 1910, for the area of northwestern Colorado and northeastern Utah, used the names which had been applied in southern Utah, and the names applied by Powell[25] in the Uinta Mountains, subdividing the Jurassic rocks into (1) the Vermilion Cliff and (2) the White Cliff (which are equivalent to the Nugget), and (3) the Flaming Gorge (which included the present Preuss, Stump, and Morrison formations).

Mansfield and Roundy,[26] in 1916, split the Jurassic rocks of Idaho from the lower part of the Beckwith and gave two new formational names. They applied the name, Preuss, from Preuss Creek, in the southeastern part of the Montpelier Quadrangle in Idaho, to the red sandstones and shales at the base of the Beckwith, and the name, Stump, taken from Stump Creek, in the same general area, to the marine sandstone which overlies the Preuss and contains Jurassic fossils.

[24] H. S. Gale, "Coal Fields of Northwestern Colorado and Northeastern Utah," *U. S. Geol. Survey Bull. 415* (1910), pp. 56–59.

[25] *Op. cit.*

[26] G. R. Mansfield and P. V. Roundy, "Revision of the Beckwith and Bear River Formations of Southeastern Idaho," *U. S. Geol. Survey Prof. Paper 98 G* (1916), pp. 75–84.

Schultz,[27] in 1918, used the name Ankareh for the basal Triassic portion of the Nugget as originally named by Veatch. The name Ankareh had previously been used for equivalent beds by Boutwell[28] in the Park City Mining District, Utah. For the Jurassic portion of the Nugget formation of Veatch, Schultz retained the name Nugget. For the remainder of the Jurassic rocks, he used the terms as originally applied by Veatch. In a later paper, 1920, which was a regional report on the area around Rock Springs, Wyoming, Schultz[29] employed essentially the same nomenclature.

TABLE I*

EVOLUTION OF NOMENCLATURE FOR JURASSIC ROCKS IN WESTERN WYOMING

<table>
<tr><th>Standard</th><th>Clarence King (1876)</th><th colspan="2">Powell (1876)</th><th colspan="2">Veatch (1907)</th><th>Gale (1910)</th><th>Schultz (1920)</th><th>Mansfield (1927)</th></tr>
<tr><td rowspan="2">Cretaceous?</td><td rowspan="5">Dakota</td><td colspan="2" rowspan="2">Henry's Fork Group</td><td colspan="2">Bear River</td><td>Dakota</td><td rowspan="2">Absent</td><td rowspan="2">Gannet Group</td></tr>
<tr><td colspan="2" rowspan="4">Beckwith</td><td rowspan="2">Flaming Gorge</td></tr>
<tr><td rowspan="6">Jurassic</td><td rowspan="4">Flaming Gorge</td><td rowspan="3"></td><td rowspan="3">Beckwith</td><td rowspan="2">Stump</td></tr>
<tr><td rowspan="4">White Cliff</td></tr>
<tr><td>Preuss</td></tr>
<tr><td rowspan="3">Jurassic</td><td>White Cliff</td><td colspan="2">Twin Creek</td><td>Twin Creek</td><td>Twin Creek</td></tr>
<tr><td colspan="2">White Cliff</td><td rowspan="2">White</td><td rowspan="3">Nugget</td><td rowspan="2">Nugget</td><td rowspan="2">Nugget</td></tr>
<tr><td colspan="2">Vermilion Cliff</td><td>Vermilion Cliff</td></tr>
<tr><td rowspan="2">Triassic?</td><td rowspan="2">Triassic</td><td colspan="2" rowspan="2">Shinarump</td><td>Red</td><td rowspan="2">Shinarump</td><td rowspan="2">Ankareh</td><td rowspan="2">Wood</td></tr>
<tr><td colspan="2"></td></tr>
</table>

* The nomenclature used in this paper for southwestern Wyoming is that used by Mansfield for southeastern Idaho, *U. S. Geol. Survey Prof. Paper 152* (1927).

In 1927, Mansfield[30] discussed the Nugget, the Twin Creek, the Preuss and the Stump formations of southeastern Idaho and included detailed descriptions and a list of the fossils which had been collected from them. He also stated that there is evidence of unconformable relationships between the Nugget and the Twin Creek, and between

[27] A. R. Schultz, "A Geological Reconnaissance for Phosphate and Coal in Southeastern Idaho and Western Wyoming," *U. S. Geol. Survey Bull. 680* (1918), pp. 25-26.

[28] J. M. Boutwell, "Park City District, Utah," *U. S. Geol. Survey Prof. Paper 77* (1912).

[29] A. R. Schultz, "Oil Possibilities in and around Baxter Basin, Wyoming," *U. S. Geol. Survey Bull. 702* (1920), p. 24.

[30] G. R. Mansfield, "Geography, Geology and Mineral Resources of Part of Southeastern Idaho," *U. S. Geol. Survey Prof. Paper 152* (1927), pp. 96–101.

the Twin Creek and the Preuss formations, and that the Preuss grades upward into the Stump sandstone.

Baker, Dane, and Reeside,[31] in 1936, correlated the formations of southeastern Idaho and southwestern Wyoming with those of southern Utah. They correlated the Nugget with the Navajo, the Twin Creek with the Carmel, the Preuss with the Entrada, and the Stump with the Curtis.

General Discussion of Formations

NUGGET FORMATION

GENERAL CHARACTER

The Nugget formation was named by A. C. Veatch[32] in 1907 from the locality of Nugget Station on the Oregon Short Line Railroad between the towns of Fossil and Sage, Lincoln County, southwestern Wyoming. There are many good exposures of Nugget sandstone in western Wyoming and they are usually expressed topographically as high rounded hills flanked by steep talus slopes. The talus is typically composed of large angular sandstone blocks many of which are pinkish or light buff in color and weather to dark green or brown. The formation is composed of a sequence of resistant reddish to light buff sandstones and a few interbedded shales. The sand grains are partially rounded, generally small and uniform-sized quartz fragments, bound by a siliceous cement. Bedding planes are prominent and cross bedding is a very common structure.

DISTRIBUTION

The Nugget sandstone is present over much of the western margin of the state of Wyoming and retains a fairly constant lithologic character throughout. In Star Valley (Fig. 1), along the Idaho-Wyoming border, the formation is at least 1,200 feet thick. It thins to the east, and on the South Piney Creek, 20 miles east of Star Valley, measures approximately 1,000 feet. The Nugget is not represented along the northwestern flank of the Wind River Mountains, and it thins out completely at some point between these mountains and the Wyoming Range. At Kelly Slide, on the Gros Ventre River, which is almost due north of the South Piney section, approximately 300 feet of Nugget is present, and at no other sections studied, with exception of those in central Wyoming in the Freezeout Hills area (Fig. 1), is this sandstone

[31] A. A. Baker, C. H. Dane, and J. B. Reeside, Jr., "Correlation of the Jurassic formations of Parts of Utah, Arizona, New Mexico and Colorado," *U. S. Geol. Survey Prof. Paper 183* (1936).

[32] *Op. cit.*, p. 56.

present. In the Freezeout Hills, a sandstone 125 feet thick occurs at the base of the Sundance formation. This sandstone is tentatively correlated with the Nugget because of its lithologic similarity and seeming unconformable relationship to the overlying portion of the Sundance.

AGE AND STRATIGRAPHIC RELATIONS

The relationship of the Nugget formation to older rocks is probably an unconformable one, although no definite evidence of this can be cited at the present time. Mansfield[33] suggests that the relations in some areas indicate an unconformity at the base of this sandstone series. The contact of the formation with younger rocks is unconformable, and this relationship is made evident by an irregular surface in several exposures. It is particularly well demonstrated by the contact on South Piney Creek.

A Jurassic age has been assigned to the Nugget by Mansfield[34] on the basis of the stratigraphic breaks which occur between it and the fossiliferous beds of the Triassic Thaynes group.

Baker, Dane, and Reeside[35] consider the Nugget equivalent to the Navajo sandstone of southern Utah, to which they give a questionable Jurassic age.

TWIN CREEK FORMATION

GENERAL CHARACTER

A. C. Veatch[36] applied the name Twin Creek to this formation, in 1907, from exposures along Twin Creek, between Sage and Fossil, on the Oregon Short Line Railroad. Typical exposures of Twin Creek limestone in western Wyoming form rounded gray hills with steep talus slopes composed of fine chips of gray, shaly limestone. The formation is composed, for the most part, of thin-bedded, fine-grained, black shaly limestone which weathers gray. Massive limestones and sandy limestones are scattered through the entire thickness, and where these are exposed they form ledges. In some localities, a thick shaly sand is present in the upper part, and, locally, lenticular red beds occur near the base. Fossils are far from abundant, but *Pentacrinus* and *Camptonectes* occur commonly in some localities and seem to be distributed throughout most of the formation. In other localities, pelecypods and some very poorly preserved ammonites were collected. The Twin Creek is 2,800 feet thick along the western border of the state.

[33] *Op. cit.*, pp. 96–97.

[34] *Ibid.*

[35] *Op. cit.*, p. 44.

[36] *Op. cit.*, pp. 56–57.

DISTRIBUTION

The distribution of the Twin Creek limestone is much the same as that of the Nugget sandstone. The thickest sections are present along the Wyoming-Idaho and Wyoming-Utah state lines, and the formation thins rapidly toward the east.

TABLE II

STRATIGRAPHIC SECTION OF TWIN CREEK LIMESTONE MEASURED IN SWIFT CREEK CANYON, 1½ MILES EAST OF AFTON, WYOMING

	Feet	Inches
Preuss red beds		
Twin Creek formation		
Shaly black limestone, mostly covered	435	0
Massive sandstone	98	6
Very poorly exposed. Thin-bedded shaly black limestone forming rounded hills	458	0
Thin-bedded black shaly limestone. *Gryphaea* sp. was collected from the base	69	6
Thin-bedded black shaly limestone	441	6
Thin-bedded black shaly limestone weathering gray and forming rounded hills and poor exposures. *Dosinia jurassica* was collected from the top	342	0
Massive to thin-bedded black shaly limestone with a dense massive oölitic limestone at the base 4 feet thick	150	0
Covered interval. Talus slope of blocks of limestone weathered from the Twin Creek	80	0
Thin-bedded black shaly limestone containing a few massive beds 1–3 feet thick	86	0
Thin-bedded black shaly limestone which weathers gray and contains, in the middle, a massive bed about 4 feet thick	54	10
Massive and thin-bedded black shaly limestones at the top of which *Pleuromya subcompressa* was collected	28	3
Massive beds, averaging about 1 foot in thickness, of black shaly limestone. Large joints and minor faults are prevalent	44	0
Alternating massive and thin-bedded black shaly limestones weathering grayish to brownish. Ammonite ind., *Astarte packardi*, *Pinna* sp., *Pleuromya* sp. were collected	40	6
Exposures of thin-bedded black shaly limestone in part covered by a talus slope of small flakes of the same material	95	0
Massive black calcareous sandstone which weathers grayish brown	26	0
Fine-grained thin-bedded flaky black shaly limestone which weathers gray and forms splintery talus slopes	3	3
Massive black bed of limestone which weathers gray	2	7
Thin-bedded flaky black shaly limestone which weathers gray and forms flaky talus slopes	13	8
Massive hard resistant bed of black crystalline limestone	5	0
Extremely thin-bedded flaky black shaly limestone	12	0
Hard massive black limestone containing *Tancredia* sp., *Pleuromya* sp., and *Camptonectes* sp	0	10
Soft thin-bedded calcareous shaly sandstone	3	5
Massive black nodular to even-bedded shaly unfossiliferous limestone	26	7
Thin-bedded nodular black shaly limestone bed containing poorly preserved fossils. *Pleuromya* sp. was collected	0	6
Massive hard black shaly and sandy limestone which weathers yellowish and forms a prominent hogback. The rock contains many calcite seams and in places appears to be cherty. Distinct joints and small fractures are prominent. No fossils were found	23	0
Total	2,539	11
Nugget sandstone		

Star Valley.—In Star Valley, along the Wyoming-Idaho state line (Fig. 1), the Twin Creek formation is 2,539 feet thick. It is composed for the most part of thin-bedded, fine-grained shaly limestones which characteristically form rounded hills covered with splintery talus. Fossils from this locality are scarce, and when found are poorly preserved. Table II shows a section of the Twin Creek formation measured in Swift Creek Canyon, adjacent to Star Valley.

Leeds Creek.—The section at Leeds Creek (Fig. 1), 15 miles southeast of Cokeville, Wyoming, is about 400 feet thinner than it is in Star Valley. Lithologically, these two sections are very similar, although the faunal content seems to be different in some respects. The presence of *Pentacrinus* in abundance in the Twin Creek limestone on Leeds Creek is in contrast to the Star Valley section. Table III shows a section of the Twin Creek limestone measured on Leeds Creek (Fig. 1).

TABLE III

STATIGRAPHIC SECTION OF TWIN CREEK LIMESTONE MEASURED ON LEEDS CREEK, 15 MILES SOUTHEAST OF COKEVILLE, WYOMING IN T. 23 N., R. 118 AND 119 W.

	Feet	Inches
Preuss red beds		
Twin Creek limestone		
Thin-bedded shaly and sandy limestone	78	0
Thin-bedded black shaly limestone which weathers gray with *Pentacrinus* beds at the top in a ledge-forming, thin-bedded limestone	190	0
Thin-bedded black shaly limestone mostly covered with steep gray flaky talus	699	2
Thin-bedded black shaly limestone, poorly exposed and forming a depression. A 6-inch bed of limestone containing *Camptonectes* sp. is present at the top	41	0
Thin-bedded black shaly limestone which weathers gray	119	0
Thin-bedded black shaly limestone containing *Pentacrinus asteriscus* and *Camptonectes* sp.	173	0
Massive and thin-bedded yellowish calcareous ripple-marked sandstone containing some beds of thin-bedded limestone	88	0
Thin-bedded black shaly limestone carrying fragments of poorly preserved pelecypods. *Ostrea* sp., and *Camptonectes* sp., were collected at the top. The upper beds are more massive and black	204	0
Poorly exposed thin-bedded shaly limestone	10	6
Poorly exposed thin-bedded black shaly limestone weathering gray and forming rounded hills	68	0
Red beds. Poorly exposed	44	0
Black thin-bedded to massive sandy and shaly limestones weathering gray to brown and forming a ledge	88	0
Red sandstones and red shales	110	0
Basal resistant shaly limestone containing ripple marks	224	0
Total	2,136	8
Nugget sandstone		

South Piney Creek.—On South Piney Creek (Fig. 1), which is approximately 20 miles east of Star Valley, the Twin Creek limestone is only 928 feet thick. At this locality the Twin Creek is characterized by some massive fossiliferous limestones near the middle of the section, and, in general, the beds are much more fossiliferous than in the exposures which occur farther west. Table IV shows a section of the Nugget, the Twin Creek, the Preuss, and the Stump formations measured on South Piney Creek.

TABLE IV

STATIGRAPHIC SECTION OF NUGGET, TWIN CREEK, PREUSS, AND STUMP FORMATIONS MEASURED IN T. 34 N., R. 114 W., ON SOUTH PINEY CREEK, 24 MILES WEST OF BIG PINEY, WYOMING, AND 2 MILES EAST OF SNYDER BASIN RANGER STATION

	Feet	Inches
Stump sandstone		
The Stump in this locality is not well exposed. It is composed of white to buff to reddish even-grained sandstone. Red beds lie directly above and the Preuss directly below it. The sandstone is cross-laminated in places	150	0
Preuss red beds		
These beds were not measured, but they appear to be less than 500 feet thick, and form a depression where they are exposed. They are composed, for the most part, of unfossiliferous red shales and sandstones	500±	0
Twin Creek limestone		
Massive greenish black to gray fine-grained arenaceous limestones containing clay galls	94	0
Gentle slope covered with talus, probably thin-bedded shale or sandy limestone. *Pentacrinus asteriscus* was collected from the talus	48	0
Massive black limestone weathering gray and forming ledges	8	0
Gentle slopes covered with talus. A few thin-bedded shaly limestone beds are exposed containing poorly preserved fragments of fossils	52	0
Massive black limestone forming a prominent ledge. The bed contains numerous calcite seams	5	0
Thin-bedded gray shaly and sandy limestone bed containing *Pentacrinus asteriscus*	40	0
Massive black ripple-marked limestone beds forming ledges	2	0
Mostly covered. Thin-bedded shaly and sandy limestone containing *Camptonectes* sp., *Ostrea* sp., and *Pentacrinus asteriscus*	62	0
Light-colored soft sandy shale forming a depression. Near the top is a fossiliferous limestone containing *Gryphaea* sp., *Ostrea* sp., *Camptonectes* sp., and *Lima occidentalis*	26	0
Massive bed of limestone composed almost entirely of fossils. This bed contains *Pentacrinus asteriscus*, *Lima occidentalis*, *Parapecten* sp., *Camptonectes* sp., and *Ostrea* sp.	2	0
Covered interval. The cover contains *Camptonectes* sp. There are two limestone beds 1 foot thick exposed near the middle	142	0
Covered interval. A 6-inch bed of very fossiliferous limestone containing *Ostrea* sp. occurs near the top	52	0
Massive black limestone at the top 2 feet thick containing poorly preserved *Camptonectes* sp. Thin-bedded calcareous shale is present in the middle, and massive black limestone at the bottom. The sequence forms a ledge	13	6
Black shaly limestone with a massive sandy ledge-forming limestone near the base	15	0
Calcareous and arenaceous soft thin-bedded gray shale containing fragments of fossils. *Pentacrinus asteriscus* is present in abundance	9	0
Massive black sandy ledge-forming limestone full of minute fragments of fossils. *Camptonectes stygius* and *Pentacrinus asteriscus* are nu-		

TABLE IV (*Continued*)

	Feet	Inches
merous	8	0
Dark gray calcareous shales weathering buff to brown. Forms a gentle slope	6	0
Alternating massive black fossiliferous limestones and thin-bedded calcareous shales. The limestone is oölitic in some places and contains *Camptonectes* sp.	12	0
Soft thin-bedded black shales with yellow sandy shales at the base. Forms a gentle slope	8	0
Thin-bedded black limestone containing a massive limestone 1½ feet thick at the base	12	0
Alternating thin-bedded calcareous shales and massive black limestones. The beds are sandy	13	0
Covered interval. Forms a depression in which the soil shows a reddish tinge, probably from lower beds. Contains an 8-inch massive limestone at the base	25	0
Mostly covered, with occasional thin-bedded black shaly limestone exposures. Forms a typical splintery, gray talus slope	98	0
Mostly covered, with yellowish talus at the base. Here and there thin-bedded limestones are exposed	75	0
Red beds. Soft red shale forming a depression	61	0
Massive gray knotty and gnarled limestone weathering yellowish and forming a ledge. This bed is very uneven, fragmented, and full of clay galls and mottled shales. It rests on an even-bedded, even-grained, ripple-marked sandstone containing beds of shale at the top of the Nugget. The contact appears to be unconformable	39	0
Total	927	6
Nugget sandstone		
The Nugget sandstone is not well exposed because of structural complications. However, it appears to be thick—probably more than 1,000 feet	1000±	

Gros Ventre River.—On the Gros Ventre River (Fig. 1), the Twin Creek is represented by 212 feet of limestones and shales which are extremely fossiliferous. However, the preservation of the fossils is poor. These beds are equivalent to the beds referred to the Ellis formation by Crickmay,[37] and to those designated as the lower series of the Ellis formation as originally described.[38] The evidence of this relationship is discussed later in the paper. Table V shows a section of the Twin Creek formation measured on the Gros Ventre River, near Kelly Slide (Fig. 1).

AGE AND STRATIGRAPHIC RELATIONS

The Twin Creek limestone is separated from the underlying Nugget formation by an irregular surface which is believed to represent an unconformity, and also bears an unconformable relationship to the overlying Preuss formation as evidenced by a sharp and distinctive change in lithology. Mansfield[39] assigns an Upper Jurassic age

[37] *Op. cit.*, pp. 541–64.

[38] Arnold Hague, *op. cit.*, p. 5.

[39] *Op. cit.*, pp. 97–98.

TABLE V

STRATIGRAPHIC SECTION OF SUNDANCE AND TWIN CREEK FORMATIONS MEASURED ON GROS VENTRE RIVER, 2 MILES EAST OF KELLY SLIDE, TETON COUNTY, WYOMING

	Feet	Inches
Morrison? formation		
Sundance formation		
Sandstones and shales of the typical Sundance lithology	423	0
Greenish gray shales, sandy in the upper 200 feet. *Gryphaea calceola* var. *nebrascensis* occurs in the lower 150 feet. These beds also contain brachiopods and *Ostrea* sp.	302	0
Total	725	0
Twin Creek formation		
Dark gray fossiliferous limestones from which were collected two specimens of poorly preserved ammonites, *Trigonia quadrangularis*, *Trigonia americana*, *Trigonia montanaensis*, *Pleuromya autolycus*, *Pleuromya subcompressa*, *Astarte packardi*, *Gervillia* cf. *G. montanaensis*, *Trigonia* sp., *Ostrea* sp., and several small specimens of gastropods	18	0
Greenish gray and red shales	65	0
Dark shale with bands of limestone; fossiliferous limestone in the base from which the following fossils were collected: *Camptonectes platessiformis*, *Ostrea strigilecula*, *Ostrea* sp., *Pleuromya subcompressa*, *Pleuromya* sp., *Gryphaea* sp., *Astarte?* sp., *Pleuromya* cf. *P. subcompressa*, *Trigonia* cf. *T. quadrangularis*	67	0
Dark gray and buff limestones from which were collected the following fossils: *Gervillia montanaensis*, *Trigonia americana*, *Camptonectes* cf. *C. extenuatus*, *Dosinia jurassica*, *Pholadomya kingii*, *Astarte packardi*, *Trigonia montanaensis*, *Pleuromya subcompressa*, *Ostrea* sp., *Trigonia* sp., *Gryphaea planoconvexa*, *Camptonectes* cf. *C. platessifirmis*, several specimens of small gastropods and 6 specimens of poorly preserved ammonites	62	0
Total	212	0
Nugget formation	300±	

to the upper part of the formation and states that the lower part possibly includes Middle Jurassic rocks. Baker, Dane, and Reeside[40] consider the Twin Creek equivalent to the Carmel formation of southern Utah. Reeside[41] places the Carmel formation in the early Late Jurassic (Callovian) and is of the opinion that the Twin Creek is of the same age.

PREUSS FORMATION

GENERAL CHARACTER

The name Preuss was applied to the red sandstones and shales in the base of the Beckwith by Mansfield and Roundy[42] in 1916, and the type locality was designated as Preuss Creek, in the southeastern part of the Montpelier Quadrangle, Idaho. The Preuss is composed of unfossiliferous, fine-grained red sands and shales. The topographic

[40] *Op. cit.*, p. 45.

[41] J. B. Reeside, Jr., personal communication (1937).

[42] *Op. cit.* p. 81.

expression of exposure is usually a depression covered with dull red soil, and good exposures are rare. The thickness varies from approximately 1,000 feet along the Idaho-Wyoming state line to 0 feet 50 or 75 miles farther east.

DISTRIBUTION

The Preuss formation is present in a limited area in the west-central and southwestern parts of Wyoming. The thickness is greatest in Star Valley (Fig. 1) and along the southern half of the western border of the state. The Preuss formation thins very rapidly toward the east, and is present only in the sections measured on Leeds Creek, in Star Valley, and on South Piney Creek (Fig. 1). The formation is entirely missing on the Gros Ventre River. In Star Valley, the Preuss has a thickness of over 1,000 feet. It thins to less than 500 feet on South Piney Creek (Table IV), and is not present in any of the exposures which occur east of that locality.

AGE AND STRATIGRAPHIC RELATIONS

The Preuss formation lies between two fossiliferous formations which contain Upper Jurassic fossils, and for that reason has been assigned an Upper Jurassic age by Mansfield.[43] The lower contact of the Preuss is marked by an unconformity where it rests on the Twin Creek as indicated by a sharp change in lithology with unfossiliferous red beds lying directly on fossiliferous marine limestones. The Preuss grades into the overlying Stump sandstone. Baker, Dane, and Reeside[44] consider the Preuss equivalent, in part at least, to the Entrada formation of southern Utah.

STUMP FORMATION

GENERAL CHARACTER

The name Stump was applied by Mansfield and Roundy[45] in 1916. The name was taken from Stump Peak at the head of Stump Creek, in the Freedom Quadrangle, Idaho, where this sandstone forms the most prominent topographic point. The formation consists mainly of thin-bedded, fine-grained gray sandstones which weather greenish and form prominent ridges where exposed. Near the base is a fossiliferous calcareous sandstone from which Mansfield[46] reports fossils which occur commonly in the Sundance formation of central and eastern Wyoming. The thickness of the Stump in the western part

[43] *Op. cit.*, pp. 98–99.

[44] *Op. cit.*, p. 46.

[45] *Op. cit.*, pp. 81–82.

[46] *Op. cit.*, pp. 99–101.

of Wyoming varies from 250 to 400 feet and it does not appear to deviate greatly from this wherever the formation can be recognized.

DISTRIBUTION

The Stump formation can be recognized as such only in exposures where the Preuss red beds are present. The Stump is about 400 feet thick in Star Valley, and thins to 150 feet on South Piney Creek (Table IV). The Stump is present on Leeds Creek but could not be recognized on the Gros Ventre River.

AGE AND STRATIGRAPHIC RELATIONS

The Stump grades downward into the underlying Preuss red beds and is overlain unconformably by the Gannet group as indicated by massive conglomerates in the base of the Gannet. Mansfield[47] assigns an Upper Jurassic age to the Stump on the basis of the fauna. Baker, Dane, and Reeside[48] state that the Stump is equivalent to the Curtis of southern Utah and believe that the Stump is also equivalent to the Sundance formation of central and eastern Wyoming.

ELLIS FORMATION

GENERAL CHARACTER

The name Ellis was applied to the marine Jurassic rocks of the Yellowstone National Park region by Arnold Hague[49] in 1896, and has since been carried north into Montana. The name was derived from the old military post, Fort Ellis, near Bozeman, in the Gallatin Valley, Montana. The formation as originally described is composed of two divisions, the upper one being sandstones and sandy shales, and the lower one, shales and limestones. The formation contains Upper Jurassic fossils. The thickness of the Ellis varies from 200 to 400 feet or more in the area of the type section.

DISTRIBUTION

The name Ellis is applicable to the marine Jurassic rocks of the Yellowstone National Park area, and northward and westward into the state of Montana. The formation thickens toward the northwest and thins toward the east and southeast.

AGE AND STRATIGRAPHIC RELATIONS

There is an unconformity both at the base and the top of the Ellis formation. The unconformity at the base of the Ellis is necessary to

[47] *Ibid.*

[48] *Op. cit.*, p. 8 and pp. 46–47.

[49] *Op. cit.*, p. 5.

account for Lower and Middle Jurassic and the unconformity at the top is made evident only by a change from marine to continental sediments. Condit[50] states that the Ellis probably represents only the basal portion of the several thousand feet of marine Jurassic rocks in southeastern Idaho, but corresponds closely with the Sundance formation of Wyoming. However, Reeside[51] states that all of the Ellis fossils known to him are earlier late Jurassic and certainly most of them do not occur in the Sundance. In dealing with the Ellis of the Yellowstone National Park Region, Crickmay[52] has referred the upper sandy portion, as it was originally defined, to the Sundance, and carried the name Sundance into this area. He assigns these beds to the Argovian and Kimmeridgian of the Upper Jurassic of the European type. For the lower portion of the Jurassic rocks, or the limestone and shale sequence, he retains the name Ellis, and assigns this to the Callovian of the European Upper Jurassic. These divisions and correlations were made on the basis of paleontological evidence.

SUNDANCE FORMATION

GENERAL CHARACTER

Darton[53] applied the name Sundance to the fossiliferous marine Jurassic rocks of the Black Hills region in 1899. In general, the Sundance formation is composed of a basal sandstone which contains fossils in a few localities, a series of red shales and sands which are lenticular and generally unfossiliferous, a series of fossiliferous dark marine shales containing some beds of limestone, and an upper sandy series. Many fossils have been collected and described from the dark shales and upper sands. The thickness varies from 0 feet in the southeastern corner of the state to more than 500 feet in the northwestern portion of the state. The average thickness is about 300 feet. In some localities the red beds are not present, and the sandstones vary greatly in thickness and character from place to place. For convenience, in this paper, the Sundance has been divided into an upper and a lower part, the reasons for which are given on pages 758–759, based on evidence of an unconformity.

DISTRIBUTION

The Sundance formation, as recognized in this paper, is present everywhere in the state of Wyoming with the exception of the extreme

[50] *Op. cit.*, p. 114.

[51] John B. Reeside, Jr., personal communication (1937).

[52] *Op. cit.*, pp. 541–64.

[53] N. H. Darton, "Jurassic Formations of the Black Hills of South Dakota," *Bull. Geol. Soc. America*, Vol. 10 (1899), pp. 383–86.

TABLE VI

STRATIGRAPHIC SECTION OF SUNDANCE FORMATION MEASURED BELOW THE FORKS OF WIND RIVER ON THE NORTH SIDE OF THE RIVER IN SEC. 3, T. 5 N., R. 5 W., OF THE WIND RIVER MERIDIAN, WYOMING, 12 MILES EAST OF DUBOIS, NEAR CIRCLE RANCH

Morrison variegated shales		
Sundance formation	*Feet*	*Inches*
Upper Sundance		
Thin-bedded and cross-laminated friable fine-grained green sandstone containing ripple marks, extremely cross-laminated in places. The beds weather to a pinkish cast and form ledges in this outcrop.....	16	0
Alternating resistant gray sandstones 1 inch thick with greenish black shale bands about 1 foot thick containing carbonaceous matter. Typical soft greenish flaky shale. *Belemnites densus** (sparse) and *Ostrea* sp. were collected in talus from this shale; and *Kallirhyncia myrina* collected from the base..........	15	6
A bed of alternating fairly resistant gray to greenish friable sand containing clay galls and dark to greenish shales. The bed contains a 4-inch band of calcareous fossiliferous sandstone 5 feet 6 inches above the base..........	26	6
Very fossiliferous resistant sandstone bed about 6 inches thick at the top of this measurement which contains *Kallirhyncia myrina, Trapezium* sp., *Camptonectes* sp., *C. extenuatus* and *Gervillia recta* in abundance. Below this is a green friable sandstone from which *Belemnites* was collected. A 6-inch bed of fossiliferous limestone is present at the base and contains *Belemnites densus, Gervillia recta, Mytilus whitei? Kallirhyncia myrina, "Myacites" subellipticus?* and *Camptonectes extenuatus?*..........	17	8
Covered interval, talus containing *Belemnites densus*..........	33	0
Fossiliferous chert conglomerate containing *Belemnites densus* and *Camptonectes* sp..........	1	0
Covered interval, talus containing *Belemnites densus, Camptonectes* sp., and an occasional small *Gryphaea* sp..........	30	0
White to buff fine-grained thin-bedded sandstone containing ripple marks in the upper part and grading into a shale in the lower part. Contains an occasional *Gryphaea* sp..........	8	0
Soft green shales forming a talus slope with abundant *Gryphaea calceola* var. *nebrascensis*..........	68	0
Covered interval, some *Gryphaea* and *Belemnites* found in the talus. A limestone bed is present about 5 feet above the base..........	76	0
	291	8
Erosion surface indicated by a sharp change in lithology.		
Lower Sundance		
Hard pinkish to gray massive cherty unfossiliferous limestone 3 feet thick is present at the top. The lower portion is composed of soft gray shale..........	19	0
Massive gray limestone containing *Camptonectes* sp..........	5	6
Fossiliferous white to light gray shaly limestone containing *Dosinia jurassica, Trigonia quadrangularis, Tancredia inornata*, and *Tancredia* sp..........	6	0
Covered interval. Red beds and possibly other beds..........	37	0
Covered slope..........	27	0
Mottled rocks composed of shales and marls..........	11	6
	106	0
Total..........	397	8
Red Triassic? beds		

* The name *Belemnites* is used in this paper to refer to the same fossil which Crickmay has referred to *Pachyteuthis*. (C. H. Crickmay, "Study in the Jurassic of Wyoming," *Bull. Geol. Soc. America*, Vol. 47 (1936), p. 555.)

TABLE VII

STRATIGRAPHIC SECTION OF SUNDANCE FORMATION MEASURED ON THE WEST SIDE OF BULL LAKE, IN THE WIND RIVER MOUNTAINS, IN SEC. 31, T. 3 N., R. 3 W., OF THE WIND RIVER MERIDIAN

	Feet	Inches
Morrison variegated shales		
Sundance formation		
Upper Sundance		
Soft friable thin-bedded yellow sandstone. Fossils were collected from the talus made up of this rock	3	0
Very fossiliferous yellow to buff resistant beds forming a ledge near the top of the section. This bed contains *Camptonectes* sp., *Pleuromya* sp., *Trapezium* sp., and *Kallirhyncia myrina*	5	0
Soft yellow friable sandy shale containing clay galls and many gypsum-filled cracks, alternating with beds of unfossiliferous resistant sandstone	20	0
Two thin fossiliferous beds containing *Camptonectes* sp., *Killirhyncia myrina*, and *Ostrea* sp.	1	0
Hard massive brown chert conglomerate forming a ledge and contain-taining *Ostrea* sp.	2	0
Soft unfossiliferous sandy gray shale grading into a dark shaly limestone near the base	24	0
Clay and shale beds containing *Camptonectes* sp. in abundance, and *Kallirhyncia myrina, Belemnites densus, Pleuromya newtoni, Volsella* sp., and *Ostrea* sp.	1	0
Unfossiliferous sandstone	1	0
Very thin clay beds containing *Camptonectes bellistriatus* in abundance and some *Belemnites densus*	0	3
Soft sandy gray shale	5	3
Soft sandy shale containing *Belemnites densus*, *Camptonectes* sp. and *Ostrea* sp.	22	0
Talus slope. One-foot bed of fossiliferous brown chert conglomerate at the base containing *Belemnites densus* and *Pleuromya* sp.	19	0
Interval covered by talus. Unfossiliferous soft gray sand at the base. *Pleuromya newtoni*, *Pleuromya* sp., and *Camptonectes* sp. were collected from the talus	24	0
Partially covered. Soft fine-grained white sandstone containing ripple marks is present at the base	26	0
Soft shale, mostly covered	40	0
Unfossiliferous shale	2	0
Soft gray shale containing an abundance of *Gryphaea calceola* var. *nebrascensis* and some gypsum	36	0
	231	6
Erosion surface evidenced by sharp change in lithology		
Lower Sundance		
Massive pink cherty sandy limestone forming a ledge 3 feet thick, underlain by softer gray sandstone	31	0
Gray limestone at the top. Massive ledges formed by middle beds of friable gray sandstone. Massive gray sandstone containing scattered pebbles is present at the base	20	0
Six-foot bed of hard white sandstone at the top of soft red sandy shale	15	0
Thin-bedded hard resistant shaly limestone which forms a ledge and contains crinkled laminations. The contact at the base appears to be irregular	9	0
	75	0
Total	306	6
Chugwater formation		

southeast corner and the area in which the Nugget, the Twin Creek, the Preuss, and the Stump occur. The formation thins toward the southeast and thickens toward the northwest over the state. Extremely good exposures are present along the northeast flank of the Wind River Mountains and in certain localities in the Big Horn Basin area. Also, good exposures are present in central Wyoming, southeastern Wyoming, and the northeastern part of the state.

Wind River Mountains-Circle Ranch.—At Circle Ranch (Fig. 1), one of the northernmost exposures along the northeastern flank of the Wind River Mountains, 401 feet of Sundance are present. Table VI shows a section measured at that locality.

Wind River Mountains-Bull Lake.—At Bull Lake (Fig. 1), which is about 25 miles southeast of the Circle Ranch section, the Sundance is 94 feet thinner than at Circle Ranch. Table VII shows a section measured on the west side of Bull Lake in the Wind River Mountains.

Wind River Mountains-Lander.—The section of Sundance measured near the town of Lander (Fig. 1) contains 255 feet of sandstones and shales, having thinned about 50 feet in the 40 miles between this locality and Bull Lake. Table VIII shows a section measured near the town of Lander.

TABLE VIII

STRATIGRAPHIC SECTION OF SUNDANCE FORMATION MEASURED $8\frac{1}{2}$ MILES SOUTHEAST OF LANDER, WYOMING, IN SEC. 14, T. 32 N., R. 99 W.

	Feet	Inches
Morrison formation		
Sundance formation		
Upper Sundance		
White cross-laminated friable sandstone forming a ridge	30	0
Soft gray sandy shales forming a depression	20	0
Resistant sandstone bed containing an abundance of *Camptonectes* sp.	8	0
Soft gray shales forming a depression. The upper half of the shale series contains *Belemnites densus* in abundance. No fossils were observed in the lower half	150	0
	208	0
Erosion surface evidenced by sharp change in lithology.		
Lower Sundance		
Hard massive buff to white sandy and cherty bed	12	0
Alternating red beds, white to purple marls, and marly thin limes	35	0
	47	0
Total	255	0
Red Triassic? beds		

Correlation between the Circle Ranch, Bull Lake, and Lander sections.—Fossiliferous beds in the upper part of the section measured at Circle Ranch (Figs. 1 and 2) are missing in the Bull Lake and Lander sections. These beds contain *Ostrea*, *Belemnites* and *Kalli-*

rhyncia. Another group of fossiliferous beds which are here designated the *Trapezium beds* (Fig. 2), because they are characterized by the fossil *Trapezium*, are present 60 feet below the top of the section at Circle Ranch, a few feet below the top of the Bull Lake section, and are not represented in the Lander section. A series of fossiliferous shales below this, which is here designated the *Belemnites zone*[54] because of the very abundant occurrence of *Belemnites densus*, is continuous throughout this entire area, being present at all three of the localities. There is evidence of disconformity below the *Belemnites zone*, as indicated by the presence of conglomerates composed of well rounded chert pebbles, reworked belemnites, and in other sections at the same horizon, the presence of well rounded, worn fragments of *Cardioceras* sp. The chert pebbles, when examined in thin-section, have a very distinctive internal structure which is peculiar to the type of secondary chert which occurs as seams in the Sundance east of these localities. A sand is present below the *Belemnites zone* at Circle Ranch and Bull Lake, and this sandstone contains ripple marks, which indicate shallow-water conditions. The fossil zone which is characterized by an abundance of *Gryphaea calceola* var. *nebrascensis*, and is here referred to as the *Gryphaea zone*, wedges out toward the southeast. It is present in the Circle Ranch and Bull Lake sections and absent in the Lander section. This thinning may be partially due to the overlap of the sea in which the upper Sundance was deposited (the Logan sea), and it may be due in part to erosion. It is believed, however, that the erosion which took place above this zone was of a submarine character, and that it does not represent a complete withdrawal of the sea from this area, but merely shallow-water conditions.

There is a sharp break at the base of the dark fossiliferous marine shales in all three of the sections, and this break is present also in other localities within the state, where dark marine shales rest on red sandstones, red shales, and red marls. This break represents an erosional period of some magnitude, and a complete retreat of the sea. Near the base of the section at Circle Ranch, in the top of the red beds, fossiliferous sandstones are present from which were collected *Trigonia quadrangularis* and other fossils, and to these sandstones the name *Trigonia beds* has been applied (Fig. 2). The *Trigonia beds* are not present at Bull Lake or Lander, but wedge out toward the southeast, probably due to overlap.

[54] The name *Belemnites* is used in this paper to refer to the same fossil which has been referred to *Pachyteuthis* by Crickmay. (C. H. Crickmay, "Study in the Jurassic of Wyoming," *Bull. Geol. Soc. America*, Vol. 47 (1936), p. 555.)

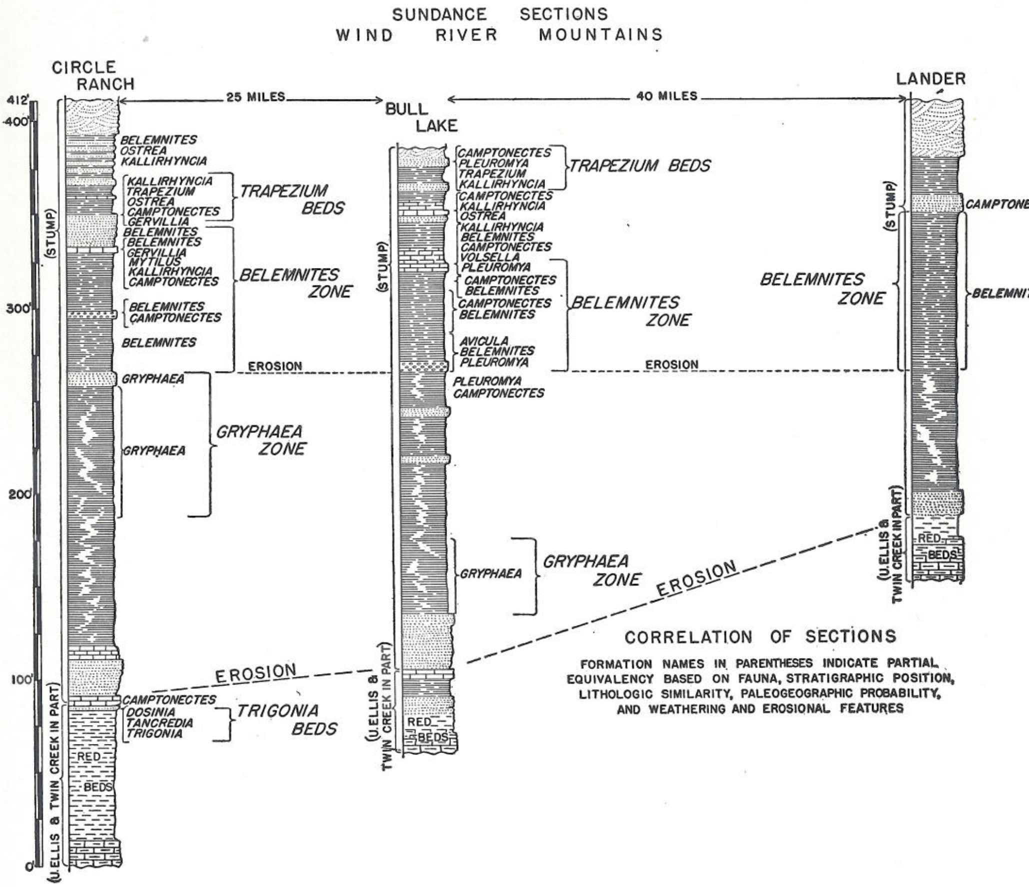

FIG. 2.—Correlation of the Circle Ranch, Bull Lake and Lander sections.

Big Horn Basin-Cody.—A section of the Sundance formation measured near the town of Cody (Fig. 1) is 472 feet thick. The formation at this locality contains a series of red beds and gypsum near the base of the section. Below the red beds and gypsum are sandstones and shales which contain *Camptonectes* sp., and *Ostrea* sp. The section measured near the town of Cody is shown in Table IX.

TABLE IX

STRATIGRAPHIC SECTION OF SUNDANCE FORMATION MEASURED BELOW THE CANYON OF THE SHOSHONE RIVER, ABOUT 2 MILES WEST OF CODY, WYOMING, IN SEC. 36, T. 53 N., R. 102 W.

	Feet	Inches
Morrison formation		
Sundance formation		
Upper Sundance		
Soft thin shaly sandstone beds alternating with gray shales	19	0
Massive sandstone bed containing very poorly preserved pelecypods in the upper portion. Cross-laminated and ripple-marked in places	18	0
Very soft shales and sandstones	12	0
Very fossiliferous resistant sandstone containing thin shales in places. It is cross-laminated and ripple-marked near the base and contains poorly preserved large pelecypods 2 inches in diameter	14	0
Cross-laminated and ripple-marked gray sandstone with some thin fossiliferous beds containing *Kallirhyncia myrina*, *Ostrea* sp., and *Camptonectes* sp. Becomes much more massive and less fossiliferous near the base	65	0
Dark shales with limonitic sandstone band at top containing a very fossiliferous bed from which was collected *Belemnites densus*, *Camptonectes* sp., and *Pentacrinus asteriscus*	10	0
Dark gray shales containing small sandstone fragments at the top and many belemnites. Becomes more sandy near the base	52	0
Black to gray fine-bedded shales containing some yellow limonitic beds and an abundance of *Belemnites densus*. They also contain well polished and highly rounded chert pebbles. A fragment of a worn ammonite (*Cardioceras* sp.) was collected from this bed	18	0
Thin-bedded platy black to gray calcareous shale containing *Gryphaea calceola* var. *nebrascensis* in abundance	115	0
Gray to black soft shales containing *Gryphaea calceola* var. *nebrascensis* in abundance. A 4-inch sand is present at the base from which was collected *Dosinia jurassica*, *Pleuromya newtoni*?, many gastropods, and a large ammonite	16	0
Tan to white marls alternating with gray shales and containing numerous fossils	9	0
	348	0
Erosion surface indicated by a sharp lithologic change.		
Lower Sundance		
Red sandy shales containing many gypsum seams and nodules	85	0
Alternating buff to yellow sandy beds and gray to black shales. A lenticular bed of gypsum 6 inches thick is present locally at the top. *Camptonectes* sp., *Ostrea* sp., and other genera are present. The basal contact appears to be irregular	39	0
	124	0
Total	472	0
Chugwater formation		

Big Horn Basin-Kane.—A section of the Sundance formation, measured on the south flank of the Big Horn Mountains, near the point where the Big Horn River cuts through the mountains, and not far from the town of Kane (Fig. 1), comprises 336 feet of sandstones, shales, limestones, and red beds. This locality is approximately 50 miles northeast of the Cody section, and the beds have thinned more than 100 feet in that distance (Table X).

TABLE X

STRATIGRAPHIC SECTION OF SUNDANCE FORMATION MEASURED IN BIG HORN COUNTY, WYOMING, ON THE WEST FLANK OF BIG HORN MOUNTAINS, NEAR THE HEAD OF BIG HORN CANYON, IN SEC. 12, T. 57 N., R. 95 W.

	Feet	Inches
Morrison? sandstone		
Sundance formation		
Upper Sundance		
Resistant cross-bedded sandstone forming a ledge	25	0
Very fossiliferous sandstone containing *Ostrea* sp., and *Pleuromya?* sp. Cross bedding and ripple marks are present in thin beds which are not fossiliferous	10	0
Soft gray to buff and black shales containing *Belemnites densus* in abundance near the base. Land-slide conditions did not permit detailed measurement. *Ostrea* sp. and *Kallirhyncia?* sp. were also collected from these beds	123	0
White thin-bedded shale	10	0
Extremely thin-bedded platy sandy and calcareous shale	15	0
Soft gray shale containing *Gryphaea calceola* var. *nebrascensis* in abundance	40	0
	223	0
Erosion surface indicated by a sharp lithologic change.		
Lower Sundance		
Alternating sandy, shaly, and calcareous beds containing *Pentacrinus asteriscus*, *Trigonia quadrangularis*, *Dosinia jurassica*, *Ostrea* sp., *Volsella?* sp., *Mytilus?* sp., and small gastropods	18	0
Red beds containing gypsum	75	0
Alternating massive and thin-bedded black limestones which weather white. Pinkish to red marly shales, sands, and gypsum beds	30	0
	123	0
Total	346	0
Chugwater? red beds		

Big Horn Basin—Thermopolis.—The Sundance formation is 280 feet thick on the north flank of the Thermopolis anticline, 4 miles north of the town of Thermopolis (Fig. 1). This locality is about 90 miles south of the section which was measured near Kane.

Correlation between the Cody, Kane, and Thermopolis sections.—The correlation of these three sections is very similar to that along the northeast flank of the Wind River Mountains. Fossiliferous beds in the upper part of the section at Cody are absent from the sections at Kane and Thermopolis (Fig. 3). The *Belemnites zone* in present in all three sections and can be correlated. Below the *Belemnites zone*, as in the sections measured along the northeast flank of the Wind River Mountains, there is evidence of erosion. Well rounded chert pebbles and sandy beds occur in the section at Cody, and sandy beds are present immediately below the *Belemnites zone* in the sections measured at Kane and Thermopolis. The *Gryphaea zone* is present at Cody and Kane, but is absent at Thermopolis.

TABLE XI

STRATIGRAPHIC SECTION OF SUNDANCE FORMATION MEASURED ON THE NORTH FLANK OF THERMOPOLIS ANTICLINE, 4 MILES NORTH OF THERMOPOLIS, WYOMING, IN SEC. 35, T. 43 N., R. 95 W.

	Feet	Inches
Morrison? sandstone		
Sundance formation		
Upper Sundance		
Massive to thin-bedded cross-laminated conglomeratic sandstone	50	0
Dark gray and greenish shales	35	0
Massive white friable sandstone	35	0
Thin-bedded sandstone	25	0
Soft gray shales with thin beds of very fossiliferous limestone containing an abundance of *Camptonectes* sp. *Belemnites densus* was collected from the shales. The absence of *Gryphaea calceola* var. *nebrascensis* is very noteworthy	100	0
Cross-laminated thin-bedded ripple-marked sandstone grading downward into a fine-grained conglomerate	10	0
	255	0
Erosion surface evidenced by the presence of a conglomerate and a sharp lithologic change.		
Lower Sundance		
Pink to red and white shales, sandy and marly at the base.* Contains *Trigonia quadrangularis* and a gastropod	25	0
Total	280	0
Chugwater? red beds		

* In regard to this section, Reeside[55] made the following statement: "There is a conspicuous zone of red beds, under which lies a fossiliferous marine limestone several feet thick. It is decidedly not Alcova, faunally or lithologically, and must be part of the Jurassic."

Red beds occur below the *Gryphaea zone* at Cody and Kane, and below the *Belemnites zone* at Thermopolis. Here again, as in the Wind River Mountains, there is a sharp break between the fossiliferous dark marine shales and the red sandstone, red shale, and gypsum, and it is believed that this represents a period of erosion during which time the sea had retreated from this area. At the top of the red beds at Cody there is a fossiliferous marl from which *Trigonia*, *Dosinia*, and numerous gastropods were collected. Below the red beds, 30 feet of sandstones and shales are present from which were collected *Ostrea*,

[55] John B. Reeside, Jr., personal communication (1937).

Camptonectes, *Volsella*, and *Mytilus*. No fossils were found within or below the red series at Kane, although *Trigonia quadrangularis* and small gastropods have been collected from the red beds at Thermopolis.

Shirley Mountain-Muddy Gap.—A section measured at Muddy Gap, in the Shirley Mountains (Fig. 1), contains 275 feet of Sundance. The upper sandy series is present at this locality and below the sandy series the *Belemnites zone* occurs. Below the *Belemnites zone* are unfossiliferous shales, red beds, and sandstones. The exposure at this locality is not good enough to portray further details of the section.

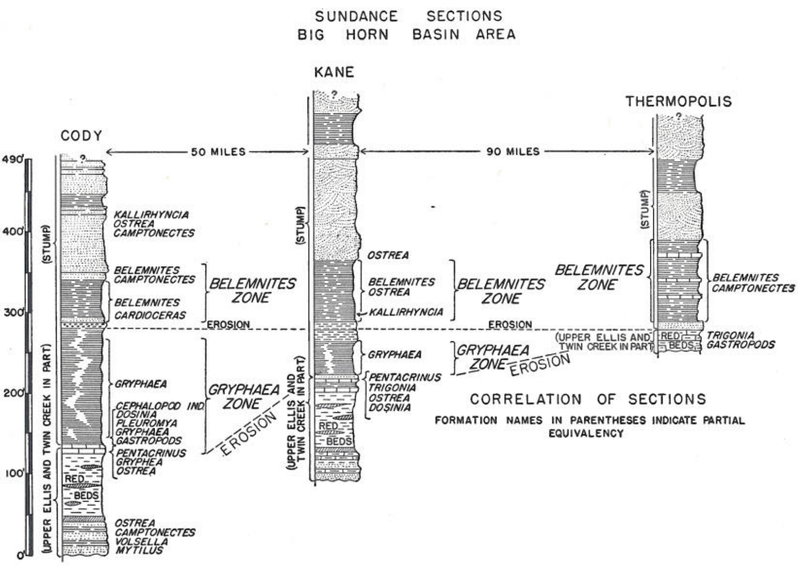

FIG. 3.—Correlation of the Cody, Kane, and Thermopolis sections.

Rattlesnake Hills.—The Sundance section at Rattlesnake Hills (Fig. 1) is very similar to that at Muddy Gap. The *Belemnites zone* is present and the general lithologic relations appear to be the same.

Alcova.—The Sundance formation at Alcova (Fig. 1) comprises 264 feet of sandstones, shales, and red beds. The *Belemnites zone* persists throughout this area. Table XII shows a section of the Sundance formation measured at Alcova.

Freezeout Hills-Trabing Brothers Spring (T. B. Spring).—There are excellent exposures of the Sundance formation near Trabing Brothers Spring, in the Freezeout Hills (Fig. 1). The following section was measured at that locality.

TABLE XII

STRATIGRAPHIC SECTION OF SUNDANCE FORMATION MEASURED 4 MILES SOUTH OF THE TOWN OF ALCOVA, NATRONA COUNTY, WYOMING

	Feet	Inches
Morrison? sandstone		
Sundance formation		
Upper Sundance		
Fine-grained calcareous massive to thin-bedded unfossiliferous soft sandstone containing limonite concretions. This bed forms a ledge in places and has a pinkish coating from the overlying shales. Fresh fractures are yellow. It appears to be cemented with a calcareous cement	25	0
Thin-bedded black platy shale bed which has a more or less irregular and lenticular form. No fossils were found	0	10
Fine-grained sandstone, much the same as above	2	0
Unfossiliferous irregular thin-bedded platy black shale	0	8
Fine-grained thin-bedded white to yellowish sandstone containing a few limonite concretions. Cross-laminated on a very small scale	4	6
Alternating beds of white thin-bedded shaly sandstones and unfossiliferous black shales. The sandstone contains fucoids	4	0
Platy unfossiliferous dark red to maroon shale	1	0
Soft platy unfossiliferous black shale	3	0
Blocky thin-bedded crinkly gray limestone	1	0
Very fine-bedded platy unfossiliferous dark gray to black shale	5	0
Ripple and fucoid-marked platy thin-bedded fine to medium-grained sandstone containing fragments of pelecypod shells	9	0
Alternating sandy and calcareous beds with dark platy shale in which *Camptonectes* sp. is abundant. A few specimens of *Belemnites densus* were also found	17	0
Very fossiliferous marly clay containing an abundance of *Camptonectes* sp., *Ostrea* sp., *Ostrea strigilecula*, and a few specimens of *Gryphaea?* sp.	1	0
Soft green to dark gray shales with a 2-foot bed of fine-grained thin-bedded sandstone at the base	4	6
Soft black shales with *Belemnites densus* in abundance	65	0
	143	6
Erosion surface indicated by a sharp lithologic change		
Lower Sundance*		
Very fine-grained white shaly sandstone, darker on fresh surfaces	4	0
Deep red soft sandy shale	2	0
Gray shale	1	0
Pink fine-grained resistant shaly sandstone	5	0
Soft red sands with occasional thin white sandy beds	20	0
White gypsum bed	8	0
Fine-grained white sand	1	0
Dark red to pink fine-grained shaly sand	25	0
Fine-grained platy sand with shale partings	6	0
Fine-grained thin-bedded brown sandstone containing ripple marks	4	0
Soft green platy unfossiliferous shales. The basal four feet is of a maroon color	25	0
White to gray fine-grained thin-bedded to massive basal sand with irregular basal contact	20	0
	121	0
Total	264	6
Jelm formation		

* Reeside[55] reports a thin bed containing *Tellina*-like pelecypods, having no chronologic meaning but suggesting marine origin, from somewhere in the lower part of the Alcova section.

TABLE XIII

STRATIGRAPHIC SECTION OF SUNDANCE FORMATION MEASURED NEAR TRABING BROTHERS SPRING, IN FREEZEOUT HILLS, T. 24 W., R. 78 N., CARBON COUNTY, WYOMING

	Feet	Inches
Morrison formation		
Sundance formation		
Upper Sundance		
Thin-bedded shaly cross-laminated buff to light gray sandstone, topographically prominent	11	0
Soft black flaky shales which weather gray. A bed of sandstone occurs near the top from which was collected *Ostrea* sp	12	0
Very thin-bedded cross-laminated sandstone	3	0
Black flaky shales which weather gray and form a depression. They contain *Cardioceras* sp. and *Ostrea strigilecula*	27	6
Soft gray flaky shales containing *Belemnites densus*	19	6
Sandstone bed	0	6
Soft gray shales containing *Belemnites densus* in abundance	33	0
	106	6
Erosion surface indicated by sharp lithologic change		
Lower Sundance		
White to buff to pinkish fine-grained sandstone. This bed is cross-laminated on a minute scale and is prominent topographically	4	6
Flaky black shale which weathers light gray. Contains a sandstone in the middle 4 feet thick	6	0
Soft red sandy shale forming a depression	24	0
Buff to gray resistant cross-laminated sand	3	0
Soft sandy shale. Mottled red and white at the top and red through most of the bed	5	6
Thin-bedded fine-grained white sandstone topographically prominent.	3	6
Red sandy shale forming a depression	5	6
Very soft friable white sandstone forming a depression	25	0
Resistant cross-laminated buff sandstone	8	0
Soft gray to buff shaly sandstone forming a depression	5	0
	90	0
Unconformity?		
(*Nugget?*)		
White to buff, weathering steel gray, cross-laminated friable sandstone forming a cliff. The basal portion is coarse-grained. The cross bedding is on a large scale and very pronounced	128	0
	128	0
Total	324	6
Jelm formation		

Medicine Bow Mountains-Wagonhound Creek.—A section measured at the locality where Wagonhound Creek cuts through the Sundance formation, on the north end of the Medicine Bow Mountains (Fig. 1), comprises approximately 75 feet of shales and sandstones. The shales predominate and the *Belemnites zone* is present. There are no red beds present at this exposure, and the sandstones are very thin.

Centennial Valley.—The Sundance formation is represented by 45 feet of shales and some thin sandstones at an exposure near the town

TABLE XIV

STRATIGRAPHIC SECTION OF THE SUNDANCE FORMATION MEASURED IN CENTENNIAL VALLEY, NEAR THE TOWN OF CENTENNIAL, ALBANY COUNTY, WYOMING, IN SEC. 3, T. 15 N., R. 78 W.

	Feet	Inches
Morrison formation		
Sundance formation		
Upper Sundance		
Thin-bedded fine-grained platy white sandstones	2	0
Soft unfossiliferous light gray shales forming a depression	9	0
Medium-grained friable white to yellow sandstone	5	0
Soft gray shales forming a depression. Contains *Belemnites densus* in abundance	14	0
Coarse-grained cross-bedded friable gray sandstone containing *Belemnites densus* and fragments of other fossils. Calcite seams and secondary chert are present in this sandstone	1	0
Soft yellow thin-bedded sandy shale. This bed contains *Belemnites densus* in abundance in the upper part. The exposure forms a depression	11	0
Fine-grained yellowish friable sandstone forming a slight ridge where exposed. It ranges from massive to thin-bedded and contains fucoid markings and slickensides. Beneath the sand and above the red beds are yellow and black shales which grade into the sand above. The lower contact seems to be slightly irregular	3	6
	45	6
Jelm formation		

TABLE XV

STRATIGRAPHIC SECTION OF SUNDANCE FORMATION MEASURED ON THE SOUTH FACE OF BULL MOUNTAIN, COLORADO, SOUTH OF THE WYOMING-COLORADO STATE LINE, IN SEC. 30, T. 11 N., R. 76 W.

	Feet	Inches
Morrison formation		
Sundance formation		
Upper Sundance		
Yellowish gray fine-grained thin and even-bedded unfossiliferous shaly sandstone. The sand is friable and forms a gentle slope	6	0
Massive friable medium to fine-grained unfossiliferous sandstone forming a slight topographic expression	2	6
Alternating black and yellowish bands of soft flaky shale	2	0
Resistant yellow to brown quartzitic sandstone	0	3
Soft unfossiliferous dark gray flaky shale	0	10
Very resistant brown quartzitic bed	0	4
Unfossiliferous gray flaky shales with thin beds of brown sandstone	3	0
Soft yellow sandy shale, thin and even-bedded	5	0
Massive to thin-bedded alternating medium to fine-grained friable yellow shaly sandstone. Becomes orange-colored near the base and contains a thin flaky green shale near the middle	6	0
Massive cross-bedded resistant yellowish to orange to pink mottled sandstone of medium to fine-grained texture. The cross bedding is not pronounced	18	0
Massive uniformly medium-grained resistant gray sandstone with no pronounced cross bedding. At the base of this bed there is an irregular erosion surface	10	0
Extremely cross-bedded, predominantly yellow, but also orange and pink, coarse to fine-grained resistant sandstone forming a ridge. The cross bedding is of a large magnitude with high-angle discordances cut off sharply both above and below by extremely flat even surfaces	24	0
Total	77	11
Jelm formation		

TABLE XVI

STRATIGRAPHIC SECTION OF SUNDANCE FORMATION MEASURED ON THE HILL ½ MILE NORTHEAST OF THE TOWN OF SPEARFISH, SOUTH DAKOTA, IN THE BLACK HILLS

	Feet	Inches
Morrison shales		
Sundance formation		
Upper Sundance		
Yellow limonitic sandstone, resistant and unfossiliferous. Breaks up into blocks and forms yellow soil	3	0
Soft black shales which weather gray and contain lime concretions. No fossils were observed	16	0
Hard, resistant yellow sandstone which weathers brown and contains many fragments of pelecypod shells and large worm borings. This bed is ripple-marked in places and from it were collected *Ostrea strigilecula*, *Camptonectes bellistriatus*, and large *Ostrea* sp. It also contains many lime concretions and grades downward into platy thin-bedded shaly sand	3	0
Shaly sand, grading downward into soft gray shales which form gentle slopes. Occasional lime concretions are present and contain fossils	45	0
Thin limestone beds containing *Eumicrotis curta* and *Pleuromya* sp. in abundance	0	6
Soft black shale which weathers gray and contains *Belemnites densus* in abundance. Forms a gentle slope and contains occasional limestone beds which are extremely fossiliferous	41	0
Light-colored soft sandy shale which grades downward into soft shaly sandstone. There are occasional limonite concretions. No fossils were observed. The basal member of this sand is somewhat cross-bedded and lies with an irregular wavy contact on red sandy shale	20	0
	128	6
Erosion surface indicated by an irregular surface and a sharp lithologic change.		
Lower Sundance		
Soft red unfossiliferous sandy shales containing small gypsum spheres and gypsum seams	45	0
Greenish yellow shaly sandstone. Very soft, friable, and poorly cemented. No fossils were observed	24	0
Soft pinkish sandy shale	4	0
Gray to yellow thin-bedded sand and alternating pinkish shale	5	0
A succession of resistant fine to medium-grained sandstones, some massive and some thin-bedded, slightly cross-bedded, from dark brown to pinkish to buff in color and containing some shaly members. Large ripple marks are present at several horizons and all seem to trend north-south	20	0
Soft thin-bedded greenish shales forming gentle slopes. No fossils were observed	30	0
Dark gray to buff sandy shales. No fossils were observed	13	0
	141	0
Total	269	6
Spearfish formation		
The top of the Spearfish is a thick gypsum bed and the nature of the contact is obscured.		

of Centennial, in Centennial Valley (Fig. 1). The *Belemnites zone* is present at this locality and *Belemnites densus* is the most characteristic and abundant fossil in the entire section (Table XIV).

Colorado-Bull Mountain.—The Sundance formation on the south face of Bull Mountain, Colorado (Fig. 1), is represented by 78 feet of unfossiliferous sandstone containing a few black shale partings. No fossils were observed in the formation at this locality (Table XV).

Black Hills-Sundance.—The Sundance at the type locality, near the town of Sundance, in the Black Hills (Fig. 1), is approximately 400 feet thick. The exposures near this locality are very good in places, but it is difficult to find a continuous section exposed from the base to the top, and for this reason the thickness specified is probably not accurate. A much better exposed section was measured on the hill northeast of the town of Spearfish, South Dakota (Fig. 1), which is 30 miles northeast of Sundance.

South Dakota-Spearfish.—The Sundance formation at Spearfish, South Dakota, is 269 feet thick. The *Belemnites zone* is present in this section. Table XVI shows a section of the Sundance measured at this locality.

AGE AND STRATIGRAPHIC RELATIONS

The Sundance formation rests unconformably on Triassic rocks and is overlain unconformably by the Morrison formation. The unconformity at the top of the Sundance formation is made evident in most places only by the change from marine to continental sediments, which in many places appears to be gradational from Sundance to Morrison. As far as can be determined, there is no angular discordance, and the time interval separating the two formations might be almost negligible. However, there must almost certainly have been some erosion taking place with the removal of the marine environment and deposition of stream sediments. The unconformity at the base of the Sundance is not well evidenced by physical relations, although in some places an irregular contact can be seen. There is certainly an unconformity of long time value at the base of the Sundance to account for all of Lower and Middle Jurassic, none of which seems to be represented in the Sundance formation in most exposures, the Freezeout Hills section being a possible exception. Crickmay[56] assigns the Sundance to an Argovian-Kimmeridgian age with respect to the European section, with the questionable reference of the basal sandstone to the basal Ellis of the Yellowstone National Park region which he considers to be of Callovian age. Baker, Dane, and Reeside[57] refer to the Curtis formation of Utah as being partially equivalent to the Sundance.

[56] *Op. cit.*, pp. 541–64.

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

Correlation of Formations

NUGGET SANDSTONE

The Nugget sandstone has been tentatively correlated with the basal sandstone member of the Sundance formation in the limited area of Freezeout Hills in southeastern Wyoming (Figs. 1, 5, and 6). This correlation has been based solely on lithologic similarity, stratigraphic position, and the evidence of an unconformable relationship at the top of the sandstone. Bartram[58] has correlated the basal Sundance sand with the Nugget formation and believed that this can be traced from western Wyoming to the Black Hills. However, the presence of a marine fauna not found in the Nugget, in the basal Sundance sandstone at certain localities, and the absence of any evidence of an erosion surface at the top of the basal sandstone, tends to disprove this correlation for all of the localities except that in the vicinity of Freezeout Hills.

The Nugget formation is apparently of continental origin, and, although one fossil has been reported from it in the Wasatch Mountains, in all other localities it seems to be unfossiliferous. To the south, in southern Utah, it is said to have an eolian origin and is thought to be equivalent to the Navajo sandstone.[59]

TWIN CREEK FORMATION

The Twin Creek formation is here correlated, in part at least, with the lower portion of the Sundance formation, or that portion of the Sundance which is below the major erosion surface, and with the Ellis formation as defined by Crickmay,[60] the limestone and shale series of the Ellis formation as it was originally described by Hague[61] (Figs. 5 and 6). This correlation has been based on the following considerations. 1. Evidence of an erosion surface at the top of the Twin Creek limestone, at the top of the Ellis formation as defined by Crickmay,[62] and within the Sundance formation. 2. Faunal relations between the Twin Creek limestone, the Ellis formation, and that portion of the Sundance formation below the major erosion surface. 3. The presence of red sandstones, red shales, and gypsum beds beneath the major erosion surface within the Sundance formation. 4. The presence, in certain isolated eastern localities, of remnants of

[58] John G. Bartram, *op. cit.*, pp. 335–45.

[59] A. A. Baker, C. H. Dane, and J. B. Reeside, Jr., *op. cit.*, p. 6.

[60] *Op. cit.*, p. 552.

[61] *Op. cit.*, p. 5.

[62] *Op. cit.*, p. 552.

limestone in the lower shales, below the red beds, which contain *Pentacrinus asteriscus*, a fossil which is extremely common and abundant in the Twin Creek formation and which is rare in the upper Sundance.

EVIDENCE OF AN EROSION SURFACE

The contact between the Twin Creek limestone and the Preuss formation has been generally considered an unconformable one,[63] and from the evidence seen in the field, the writer believes this to be the fact. The presence of a hiatus between the Ellis and the Sundance formation in the Yellowstone National Park region has been pointed out by Crickmay[64] as shown by a faunal break. Evidence of an erosion surface within the Sundance formation in the regions of the Wind River Mountains and the Big Horn Basin has been referred to in the preceding pages of this paper (Figs. 2 and 3). The distinct and sharp change in the lithology within the Sundance formation, between the red gypsiferous sandstones and red shales and the overlying dark fossiliferous marine shales, is considered as evidence of an erosional break within the formation. At Spearfish, South Dakota (Table XVI), there is an irregular contact between the red beds and the overlying fossiliferous shales, and at Thermopolis (Table XI), a conglomerate is associated with the change in lithology.

Brainerd and Keyte,[65] in speaking of the red beds in the lower part of the Sundance formation, make the following statement:

> It is suggested that this zone should, when thoroughly outlined, be given a new name and placed in the Jurassic. It appears to the writers that this would make for simpler stratigraphy than to include these red shales in the typical Sundance, inasmuch as there appears to be a definite break between the two.

The red beds within the Sundance formation in northwestern Wyoming, the region to which Brainerd and Keyte referred, has apparently been mapped as Chugwater (Triassic), although there are red beds in the Sundance type section which are probably equivalent to them.

For convenience, in this paper, the portion of the Sundance below this major erosion surface will be referred to as lower Sundance, and the portion above the break, as upper Sundance.

[63] George Rogers Mansfield, *op. cit.*, p. 99; and G. R. Mansfield and P. V. Roundy, *op. cit.*, p. 81.

[64] *Op. cit.*, p. 553.

[65] *Op. cit.*, p. 752.

FAUNAL RELATIONS

The faunas which have been collected and reported from the Twin Creek, the lower Sundance, and the Ellis formation as defined by Crickmay, are similar, but hardly conclusive as to exact correlation. Twin Creek fossils are typically widely scattered and poorly preserved, and identification of the more diagnostic ammonites has been impossible. Fossils from the Ellis formation are common, especially the pelecypods, and many have been reported by various authors. In the lower Sundance, fossils are scarce and are chiefly pelecypods. However, the absence of very common and abundant fossils which characterize the upper Sundance seems to indicate almost conclusively that the Twin Creek, Ellis and lower Sundance are in no part equivalent to the upper Sundance. The two most common upper Sundance fossils are *Belemnites densus* and *Gryphaea calceola* var. *nebrascensis*, and the writer has never collected these from the Twin Creek or the lower Sundance, and they have not been reported from the Ellis of Crickmay.

The following fossils have been collected from the Twin Creek limestone.[66]

Gryphaea planoconvexa Whitfield
Dosinia jurassica Whitfield
Pleuromya subcompressa Meek
Pleuromya autolycus Crickmay
Pleuromya sp.
Astarte packardi White
Ostrea strigilecula White
Ostrea sp.
Camptonectes stygius White
Camptonectes platessiformis White
Camptonectes sp.
Trigonia quadrangularis Hall and Whitfield
Trigonia montanaensis Meek
Trigonia americana Meek
Trigonia sp.
Gervillia montanaensis Meek
Gervillia cf. *G. montanaensis* Meek
Pholadomya kingii Meek
Pentacrinus asteriscus Meek and Hayden
Lima occidentalis Hall and Whitfield
Pinna sp.
Tancredia sp.
Parapecten sp.
Eight specimens of ammonites
Several specimens of brachiopods

Fossils have been reported from the Twin Creek by Mansfield,[67] and those which the writer has not collected include the following.

[66] For localities and horizons from which these fossils were collected see Tables II, III, IV, and V.

[67] *Op. cit.*, p. 98, Pl. 31.

Serpula sp.
Pecten sp.
Camptonectes pertenuistriatus Hall and Whitfield?
Gryphaea calceola var. *nebrascensis* Meek and Hayden
Perisphinctes sp.

The listing of *Gryphaea calceola* var. *nebrascensis* is rather puzzling. This fossil is very common in the upper Sundance, but the writer was unable to find one in the Twin Creek at any of the localities visited which was a true *Gryphaea calceola* var. *nebrascensis*.

The following fossils have been reported from the Ellis as defined by Crickmay.[68]

Trigonia americana Meek
Camptonectes distans Stanton
Camptonectes platessiformis White
Gervillia montanaensis Meek
Gervillia cf. *sparsilirata* Whitfield
Gervillia dolabrata Crickmay
Astarte meeki Stanton
Astarte morion Crickmay
Pinna kingii Meek
Ostrea strigilecula White
Pleuromya subcompressa Meek
"*Dosinia*" sp.
Pentacrinus sp.
Grammatodon sp.
Lima aff. *cinnabarensis* Stanton
Tancredia sp.
Mytilus sp.

The following fossils were reported and described from the Ellis formation by C. A. White.[69] These fossils were collected at random, and while most of them probably came from the lower Ellis, or the Ellis as defined by Crickmay, some of them may have been collected from the overlying upper Ellis beds.

Camptonectes platessiformis Meek
Gervillia montanaensis Meek
Volsella subimbricata Meek
Trigonia montanaensis Meek
Trigonia americana Meek
Astarte packardi White
Pholadomya kingii Meek
Goniomya montanaensis Meek
Pleuromya subcompressa Meek

The following fossils were collected from the lower Sundance.[70]

Trigonia quadrangularis Hall and Whitfield
Trigonia sp.

[68] *Op. cit.*, pp. 546–51.

[69] C. A. White, "Jurassic Fossils from the Western Territories," *U. S. Geol. and Geog. Survey Territories of Wyoming and Idaho* (1878), pp. 143–53.

[70] For the localities and horizons from which these fossils were collected see Tables V, VI, IX, X, and XI.

Dosinia jurassica Whitfield
Pentacrinus asteriscus Meek and Hayden
Tancredia inornata? Meek and Hayden
Tancredia sp.
Camptonectes sp.
Volsella sp.
Mytilus sp.
Ostrea sp.
Several specimens of gastropods.

Brainerd and Keyte[71] reported the following fossils from red beds in the lower Sundance in the Pryor Mountains of northwestern Wyoming. The collection was made from beds which had been mapped as Chugwater (Triassic).

Stylina sp.
Ostrea strigilecula White
Lima occidentalis Hall and Whitfield
Modiolus subimbricatus Meek?
Trigonia quadrangularis Hall and Whitfield
Astarte? sp.
Pleuromya subelliptica Meek and Hayden
Nerinea sp.
Quenstedticeras? sp.

Of the fossils previously listed, the following are common to the Ellis of Crickmay, the Twin Creek, and the lower Sundance (Table XVII).

TABLE XVII

FOSSILS COMMON TO THE ELLIS, TWIN CREEK, AND LOWER SUNDANCE FORMATIONS

Fossil	*Ellis*	*Twin Creek*	*Lower Sundance*
Camptonectes platessiformis	×	×	
Gervillia montanaensis	×	×	
Gryphaea planoconvexa	×	×	
Pleuromya subcompressa	×	×	
Pentacrinus asteriscus	×	×	×
Pholadomya kingii	×	×	
Trigonia quadrangularis		×	×
Trigonia americana	×	×	×
Trigonia montanaensis	×	×	
Ostrea strigilecula	×	×	×
Astarte packardi	×	×	×
Mytilus sp.	×		×
Dosinia sp.	×	×	×
Lima occidentalis		×	×
Tancredia sp.	×	×	×
Camptonectes sp.	×	×	×

The faunal similarity between the Twin Creek, the Ellis of Crickmay, and the lower Sundance, and the absence of the very commonly occurring fossils of the upper Sundance, upper Ellis (Sundance of Crickmay in the Yellowstone National Park region), and the Stump,

[71] *Op. cit.*, pp. 747–52.

such as *Belemnites densus* and *Gryphaea calceola* var. *nebrascensis*, point toward this correlation.

LOWER SUNDANCE RED BEDS

Most of the sections of the Sundance formation which were observed are characterized by the presence of red sandstone, red shale, and gypsum beds which occur beneath the fossiliferous dark shales. The red beds are lenticular, and in some localities, such as at Alcova (Fig. 1), contain considerable gypsum. The typical red beds are not fossiliferous. The fossils of the lower Sundance have been collected from sandstones and marls below, within, or at the top of the red beds. These sediments were probably deposited in inland lakes, and by evaporation from undrained depressions, although some portions of them are undoubtedly marine and probably represent the shore facies sediments deposited in the marginal lagoons and bays of the retreating Twin Creek sea. In the writer's opinion, this is strong evidence of the retreat of the sea and a period of erosion. The erosion surface at the top of the red beds corresponds in position in the formation to the position of the erosion surface at the top of beds of Twin Creek age in the western part of the state, and tends to strengthen the belief that a general period of erosion took place before the deposition of the typical fossiliferous upper Sundance.

FOSSILIFEROUS LIMESTONE REMNANTS IN THE LOWER SUNDANCE SHALES

Remnants of limestone containing *Pentacrinus* sp. have been reported from the lower Sundance shales in the Black Hills and also in southeastern Wyoming.[72] This fossil is extremely abundant in the Twin Creek limestone and comparatively rare in the upper Sundance. This appears to be another fragment of evidence which tends to substantiate the belief that there was a period of erosion, and that these limestones are merely erosional remnants which were not removed.

PREUSS FORMATION

The unfossiliferous Preuss formation is apparently a delta deposit, partly of continental and partly of marine origin. As far as the writer has been able to determine, the lower part of the Stump formation is probably of the same age as a portion of the Preuss, the contact between the two being one of gradation between delta red beds and marine sandstones. The lower part of the upper Sun-

[72] Willis T. Lee, *op. cit.*, p. 39; N. H. Darton, "Description of the Sundance Quadrangle," *U. S. Geol. Survey Atlas Folio* (1905), p. 3; S. H. Knight, oral communication (1936).

dance was probably deposited at the same time. The Preuss formation is thought to be equivalent to the Entrada sandstone of southern Utah by Baker, Dane, and Reeside,[73] the Entrada being correlated with the lower part of the Beckwith formation of southeastern Wyoming.

STUMP FORMATION

The Stump formation is believed to be partly equivalent to the upper Sundance of central and eastern Wyoming and is probably also equivalent in its lower part to the upper portion of the Preuss red

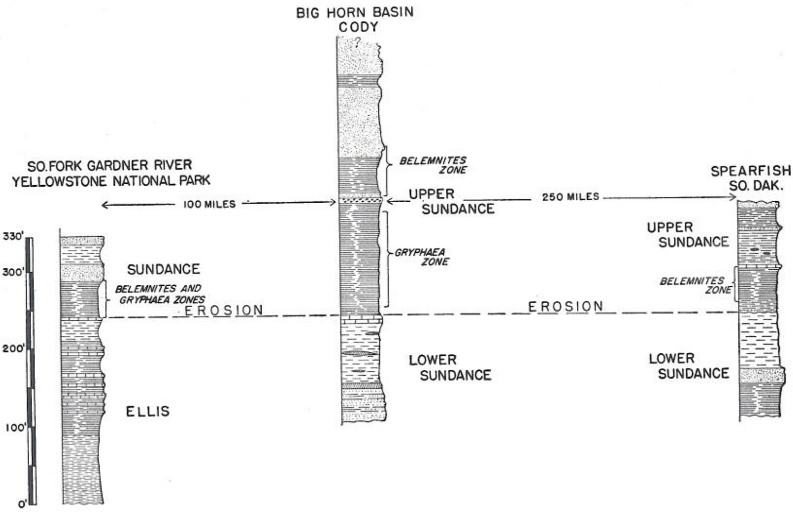

FIG. 4.—Correlation of sections from Yellowstone National Park to Spearfish, South Dakota.

beds. *Belemnites densus* occurs in abundance in the Stump formation in certain localities, and has also been reported from beds above the Stump.[74] Among other fossils which occur commonly in the Stump are *Camptonectes bellistriatus* and *Gryphaea calceola* var. *nebrascensis*. These fossils are extremely abundant in the upper Sundance of central and eastern Wyoming, and do not occur in the Twin Creek, the Ellis of Crickmay, or in the lower Sundance. It appears, from these faunal relations, that the Stump, the Sundance of Crickmay, and the upper Sundance of central and eastern Wyoming, are quite definitely correlatives.

[73] *Op. cit.*, p. 7.

[74] W. W. Rubey, oral communication (1936).

SUNDANCE FORMATION

From the foregoing evidence, the lower Sundance is thought to be equivalent in part to the Ellis formation of northwestern Wyoming and Montana, as the Ellis has been defined by Crickmay (Fig. 4), and to the Twin Creek limestone of southeastern Idaho and western Wyoming. The upper Sundance is thought to be equivalent to part of the Stump and the Preuss formations of southeastern Idaho and western Wyoming, and the Sundance formation as it has been defined by Crickmay, or the upper Ellis as it was originally defined, in northwestern Wyoming (Fig. 4). Bartram,[75] in 1930, suggested a correlation between the western and eastern Wyoming sections which is quite similar to the one presented by the writer. In referring to this correlation, Bartram says:

> . . . Twin Creek of western Wyoming is correlated with the Sundance formation by everyone, but it is not known yet how the various units of the Sundance carry through into the very different section of the Twin Creek. . . . Additional work can well be done between the western Wyoming area and the Wind River Mountains, perhaps in the Gros Ventre Mountains, to determine the exact relation of the Twin Creek to the various units of the Sundance. It is suggested here that the Twin Creek of western Wyoming may be largely equivalent to the lower and middle parts of the Sundance and with perhaps some of the upper part, and that the lower part of the Beckwith formation may be equivalent to at least some of the upper part of the Sundance.

Age of the Formations

GENERAL STATEMENT

The age of the Wyoming Jurassic rocks compared to the European type section is beyond the scope of this paper. However, age assignments have been made by Crickmay for the Yellowstone National Park region, by Baker, Dane, and Reeside for the Utah Jurassic, and to some extent by Mansfield for the southeastern Idaho section. Moreover, personal communication with Reeside has thrown much controversial light on the subject. With the correlations which have been postulated by the writer in this paper, and the age assignments which have been made by authors for other regions, it is possible to approach the matter of dating the Wyoming Jurassic. This dating must necessarily depend upon two factors: first, the correctness of the correlations which have been presented in this paper, and second, the correctness of the age assignments which have been made by authors for the various regions surrounding the area in question. The evidence has been presented in this paper for the first consideration,

[75] *Op. cit.*, pp. 342–43.

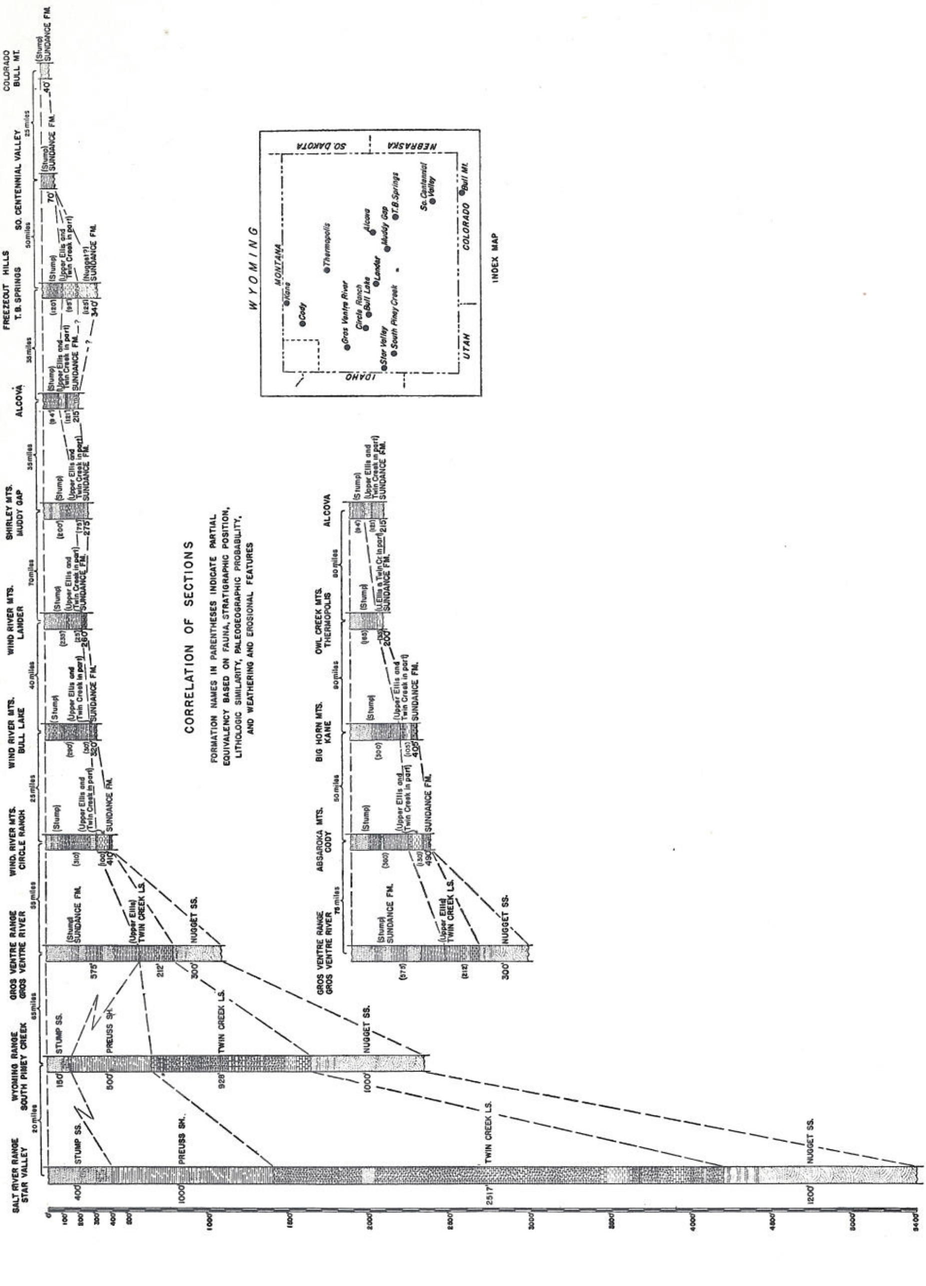

FIG. 5.—Correlation of sections from western Wyoming to north-central Colorado.

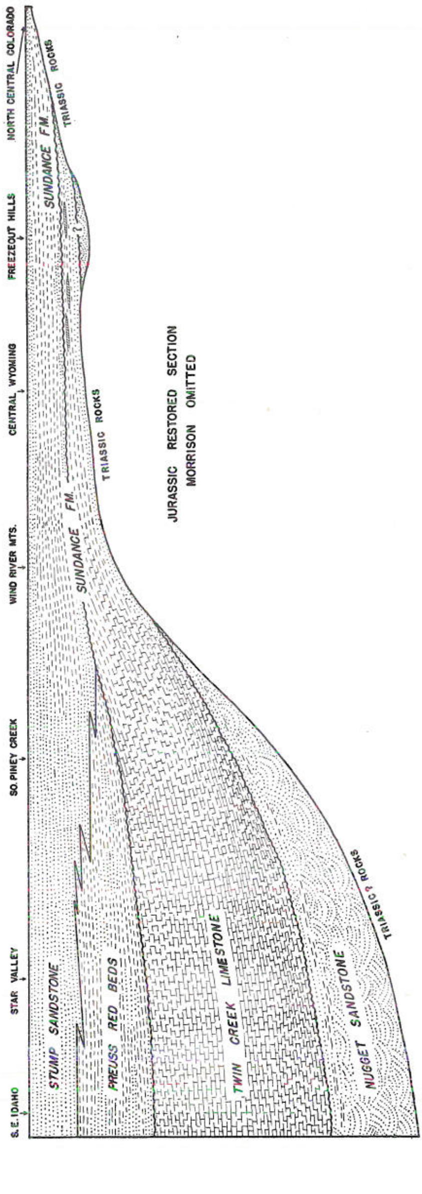

FIG. 6.—Jurassic restored section (Morrison omitted).

but it is of course impossible to present the evidence upon which various authorities have made their European assignments. Although Crickmay's assignments are seriously questioned by some, the writer has no new evidence to contradict or verify them, and because they have been made on the basis of work done chiefly in the Yellowstone National Park region, similarity of these rocks to those investigated by the writer makes the use of Crickmay's European correlation advantageous. Therefore, the correlations set forth by Crickmay[76] have, with some small changes, been used for the assignment of the Wyoming Jurassic rocks to the European type section until such time as new evidence is given which will change these correlations.

NUGGET SANDSTONE

Mansfield[77] has assigned a Jurassic age to the Nugget sandstone. He states:

> Two unconformities, one of which is probably extensive, occur, . . . in rocks that lie between the Nugget and the fossiliferous rocks of the Thaynes group. For these reasons the Nugget sandstone is referred to the Jurassic.

The other reason to which Mansfield referred had to do with the Jurassic fossils collected from the Vermilion Cliff sandstone, but these have been found to be definitely younger than Nugget. No more definite age assignment can be given to the Nugget formation, in view of the present knowledge, other than that of probable Middle or Lower Jurassic age (Table XVIII).

TWIN CREEK LIMESTONE

If the writer's correlation of the Twin Creek with the Ellis formation is correct, the Twin Creek can be assigned to the Callovian of the European type section (Table XVIII). This assignment is made on the basis of the correlation of the Ellis formation with the Callovian by Crickmay.[78] Crickmay's correlation was based on a comparison of the faunas.

PREUSS AND STUMP FORMATIONS

An Argovian and Lower Kimmeridgian age can be assigned to the Preuss and Stump formations, because they are thought to be equivalent to the Sundance formation of northwestern Wyoming as defined by Crickmay,[79] to which he has given this dating.

[76] *Op. cit.*, p. 552.

[77] *Op. cit.*, p. 97.

[78] *Op. cit.*, p. 552.

[79] *Ibid.*

ELLIS FORMATION AND LOWER SUNDANCE

The Ellis formation has been assigned to the Callovian of the European type section by Crickmay,[80] and for this reason, the equivalent lower Sundance can also be assigned to the Callovian (Table XVIII).

THE UPPER SUNDANCE OF EASTERN WYOMING AND THE SUNDANCE FORMATION OF NORTHWESTERN WYOMING AS DEFINED BY CRICKMAY

Crickmay[81] assigned his Sundance of northwestern Wyoming to the Argovian and Kimmeridgian of the European type section, and the upper Sundance of eastern Wyoming, if the writer's correlation is correct, is of the same age.

TABLE XVIII

CORRELATION CHART

Germany	*Utah*†	*Southeastern Idaho and West-Central Wyoming*	*Southwestern Montana and Northwestern Wyoming**	*Central Wyoming*	*Eastern Wyoming*
Kimmeridgian	Summerville ——?—— Curtis	——?—— Stump	——?——	——?——	——?——
Argovian	Entrada	Preuss	Sundance	U. Sundance	U. Sundance
Divesian	------- ? ------- ------- ? -------	------- ? ------- ------- ? -------	------- ? ------- ------- ? -------	------- ? ------- ------- ? -------	------- ? ------- ------- ? -------
Callovian	Carmel	Twin Creek	U. Ellis L. Ellis	L. Sundance	L. Sundance
Middle or Lower Jurassic	Navajo Kayenta Wingate	Nugget	Basal Ellis in part?	Basal Ellis in part?	

* In the northwestern Wyoming section, the nomenclature of Crickmay has been used, dividing the section into the Ellis and Sundance formations. C. H. Crickmay, "Study in the Jurassic of Wyoming," *Bull. Geol. Soc. America*, Vol. 47 (1936), pp. 541–64.

† A. A. Baker, C. H. Dane, and J. B. Reeside, Jr., *op. cit.*, pp. 4–9.

NOMENCLATURAL PROBLEMS

The problem of nomenclature involved within the Sundance formation is troublesome. If the writer's correlations are correct, and if Crickmay is correct in his interpretation of the age of the Yellowstone National Park section, the Sundance formation contains a

[80] *Ibid.*

[81] *Ibid.*

hiatus which includes all of Divesian time of the European type section. The lower part of the Sundance is of Callovian age and the upper part of Argovian and Kimmeridgian age. Then also, the lower portion of the Sundance is equivalent in part to the Twin Creek and the lower Ellis as originally described,[82] or to the Ellis of Crickmay,[83] and the upper portion of the Sundance is equivalent to the lower Beckwith, or the Preuss and the Stump formations, of western Wyoming, and to the upper Ellis as originally described (Sundance of Crickmay), in the northwestern portion of Wyoming. This brings up the question as to whether or not the name "Sundance" should be applied to the beds originally described as Sundance, and include the hiatus, or whether it should be split into two formations. Inasmuch as this break is within the Sundance formation as it was originally described, it is the writer's opinion that no attempt should be made at the present time to subdivide the Sundance into two formations. It is suggested, however, that until such time as it seems wise to subdivide the Sundance, the term "lower Sundance" be applied to those beds which are in part equivalent to the Twin Creek, and "upper Sundance" include all of the Sundance above this major erosion surface.

Paleogeography and Lithogenesis

Six blocks have been constructed to illustrate the outstanding paleogeographic features of the state of Wyoming and the immediately surrounding territory during the time of deposition of the marine Jurassic rocks (Figs. 7, 8, 9, 10, 11, and 12). Much of the apparently rapid thinning in the Jurassic rocks, particularly along the western border of the state of Wyoming, is due to the fact that the rocks have been folded and faulted since deposition, and consequently the distances between measured sections have been shortened. Therefore an attempt has been made to stretch the area out to its original form to more nearly portray the distances and conditions as they actually existed at the time of deposition. The areas which contain no state boundaries are the areas which have been stretched out (Fig. 7). The folded and faulted regions within the state correspond, in general, to these areas.

Deposition of the Nugget

Figure 8 shows the distribution of the Nugget sandstone as it is believed to have been at the time of the deposition. The formation was deposited by the filling of an inland basin by clastic material,

[82] Arnold Hague, *op. cit.*

[83] *Op. cit.*, p. 552.

predominantly quartz sand, by fluvial and eolian agents. Much of the red material within the Nugget is probably due to the erosion and re-deposition of the underlying Triassic red beds. The region

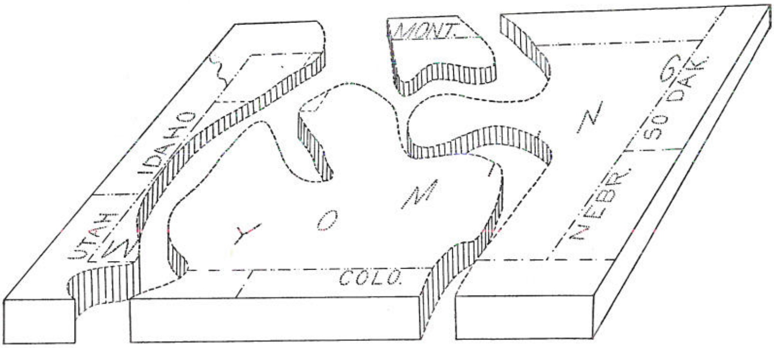

FIG. 7.—Diagrammatic illustration of the manner in which the state of Wyoming was stretched out to more closely resemble its total area during the deposition of the Jurassic rocks.

corresponding to the state of Wyoming was probably very low, and little material was supplied from an eastern direction. The main source of supply was probably a high area on the southwest, called Jurosonoria by Crickmay.[84]

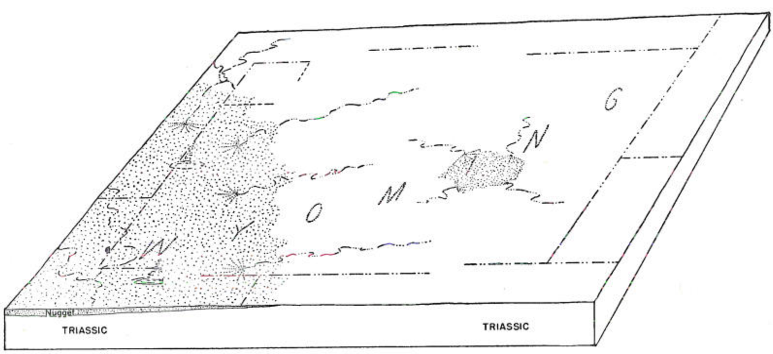

FIG. 8.—Paleogeographic map of Wyoming during Nugget deposition.

The climatic conditions which persisted at this time were probably semi-arid or arid. Plant and animal life in this region was probably very scarce.

[84] C. H. Crickmay, "Jurassic History of North America: Its Bearing on the Development of Continental Structure," *Proc. Amer. Philos. Soc.*, Vol. LXX, No. 1 (1931), p. 80.

WIDEST EXTENT OF THE TWIN CREEK SEA

Figure 9 shows the widest extent of the Twin Creek sea over the area of the state of Wyoming, in which was deposited the Twin Creek, the Ellis, and the lower Sundance. This diagram represents the region during the late Callovian or early Divesian time. Extensive shaly limestone deposition was taking place along the western margin of the state, and the source of the shaly material was undoubtedly farther west. The occurrence of lenticular red beds in the base of the Twin Creek formation is probably the result of some accumulation of clastic material from the red Triassic rocks forming the margins of the advancing sea during early Callovian time, and some of the red beds in the base of the lower Sundance formation were

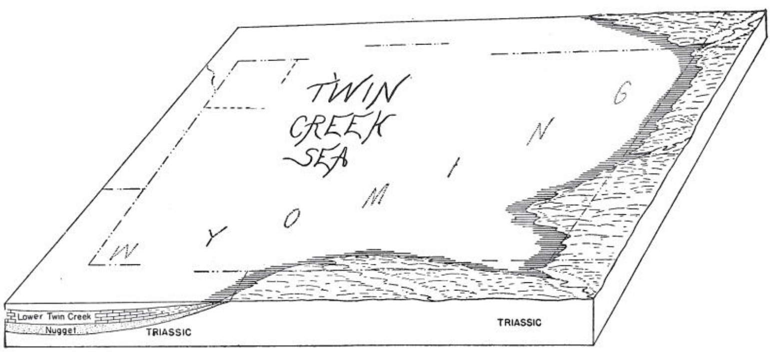

Fig. 9.—Paleogeographic map of Wyoming showing the widest extent of the Twin Creek sea.

probably derived from this same source at a later time. Some of the red beds might also have been embayment and shore facies deposits during the advance of the Twin Creek sea. The land mass on the east was very low and could not have supplied much clastic material.

A steady subsidence must have been taking place in the Cordilleran geosyncline to accommodate the great thickness of Twin Creek deposits.

Marine invertebrate life was abundant in the Twin Creek sea, and marine reptiles were also undoubtedly present, although no reptilian finds have been reported as yet, to the writer's knowledge. The climate which prevailed at this time was probably warm and humid.

The general advance of the Twin Creek sea was from the north, but its advance over the state of Wyoming was from the west or northwest.

WITHDRAWAL OF THE TWIN CREEK SEA

Figure 10 is an attempt to represent the region during the period of erosion which took place during the withdrawal of the Twin Creek sea toward the west and north. The time represented by this erosion period is some part of the early Divesian of the European type section and it is probable that at some time during the Divesian the sea was completely removed from this region. The regional drainage was probably toward the northwest, following the Twin Creek sea in its retreat. With the removal of the sea, red beds and gypsum were deposited in marginal lagoons and bays, and some interior lakes and undrained depressions were left in the central part of Wyoming. Into these depressions material was deposited. Evaporation taking place

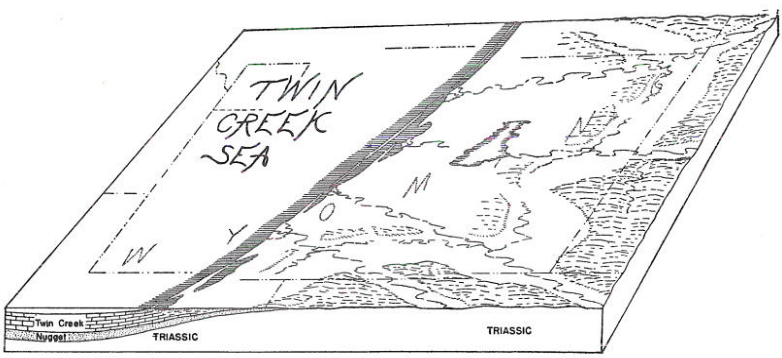

FIG. 10.—Paleogeographic map of Wyoming during the withdrawal of the Twin Creek sea.

within the inland lakes resulted in the accumulation of gypsum in the red beds. This period of erosion was not vigorous because the land was still very low. However, some of the sediment deposited from the Twin Creek sea was undoubtedly removed to the north and west by streams.

The climate during this time was probably arid, and the plant and animal life scarce.

ADVANCE OF THE LOGAN SEA

A sea again advanced from the North, following the seaway previously occupied by the Twin Creek sea, and encroached upon the area of the state of Wyoming from the west. This is known as the Logan sea. Early during the advance of the Logan sea, the Preuss formation was being deposited in the form of a great delta built out from a relatively high land mass which formed the western margin of the sea and to which the name Jurozephyria[85] has been given. At the same time, sandstones were being deposited in the Logan sea the material being derived from streams entering the sea from the north, east and south, and also from material being re-worked by the advance of the marine waters. This sandstone has been consolidated to form the Stump formation and some of the lower sandstones in the upper Ellis or Sundance of the Yellowstone National Park region. The land mass on the east was still very low, and only a limited amount of material was derived from this direction.

The climate was probably growing more humid at this time and invertebrate and reptilian life was apparently quite plentiful in the Logan sea.

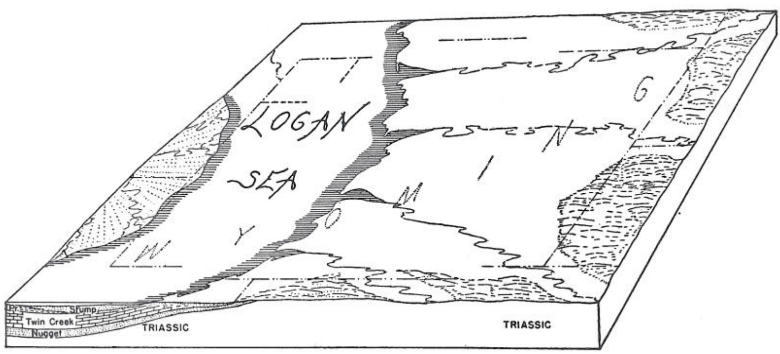

FIG. 11.—Paleogeographic map of Wyoming early during the advance of the Logan sea.

The time represented by this diagram is early Argovian of the European type section (Fig. 11).

WIDEST EXTENT OF THE LOGAN SEA

Figure 12 shows the shore line of the Logan sea at its most widespread extent over this region. The time represented by this diagram is late Argovian of the European time scale. In this sea, the Stump, the upper Ellis or Sundance of the northwestern portion of the state, and the upper Sundance of central and eastern Wyoming were deposited. The chief source of material was at the west, and probably most of it was derived from Jurozephyria, the high land which furnished the material for the formation of the Preuss delta. Some of the material was also derived from the eastern and northern shore lines, but these areas were very low-lying, and consequently most of the

[85] C. H. Crickmay, *op. cit.*, p. 84.

clastic material in the eastern portion of Wyoming is fine-grained shale.

The climate during this time was probably humid and warm. There was an abundance of marine invertebrate life in the Logan sea, and reptiles were apparently also fairly abundant.

Petroleum Aspects

STATISTICS

The state of Wyoming has 99 producing oil fields, and of these, 17 have production in the Sundance formation. In 38 fields the Sundance has been drilled, but has not proved productive. The Sundance is exposed at the surface in 8 fields; and in 36 fields has not been tested.

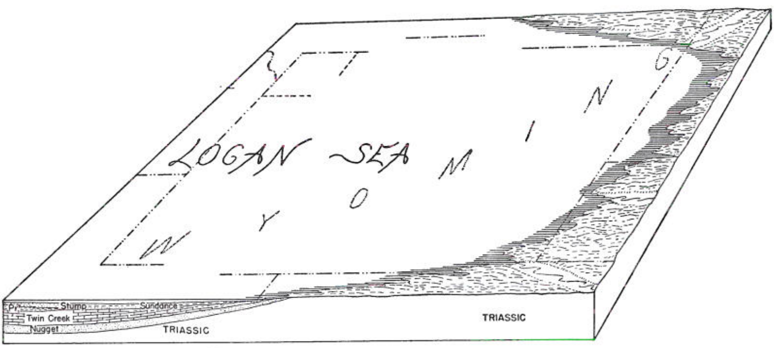

FIG. 12.—Paleogeographic map of Wyoming showing the widest extent of the Logan sea.

The information compiled for Table XIX was assembled from various sources including driller's logs and original records by Pierre LaFleiche, State Mineral Supervisor of Wyoming. Due to the difficulty in interpreting driller's logs and the difficulty of correlating the Sundance from well to well in certain fields, this information is not always accurate as to depth and thickness. Some records were lost or not available, and in those cases, the information is, of course, lacking.

LIMITATION OF KNOWN SUNDANCE PRODUCTION

Fields in which there is production of present large economic importance are limited to five counties: Sweetwater, Carbon, Albany, Natrona, and Niobrara (Table XIX). These fields all lie roughly in a belt, something more than 100 miles wide, which trends in a northeast-southwest direction across the southeastern portion of the state

TABLE XIX

DATA ON SUNDANCE IN WYOMING OIL FIELDS

County	*Field*	*Statistics*
Albany	Quealy	Sundance from 3,678 to 3,728 feet. Initial production 155 barrels of 32°? gravity oil. One well. (Record not complete.)
Big Horn	Byron	Sundance from 4,000 to 4,302 feet. Oil from 4,204 to 4,245 feet. Initial production 50 barrels of 32° gravity oil. One well.
Carbon	Allen Lake	Sundance from 2,010 to 2,558 feet. Gas from 2,010 to 2,090 feet. Average initial production 33,000,000 cubic feet. Three wells.
	East Allen Lake	Sundance from 1,865 to 2,084 feet. Gas from 2,044 to 2,084 feet. Initial production 11,000,000 cubic feet. One well.
	Big Medicine Bow	Sundance from 5,151 to 5,400 feet. Oil and gas from 5,151 to 5,222 feet and from 5,299 to 5,400 feet. Initial production 6,000 barrels of oil and 81,000,000 cubic feet of gas. Gravity of the oil from the first sand, 70.6 (distillate), from the second sand, 63.1° A.P.I.
	Ferris	Sundance from 2,528 to 2,960 feet. Oil from 2,615 to 2,705 feet. Initial production 30 barrels of 32° gravity oil. Two wells.
	Ferris (West)	Gas in the Sundance from 2,292 to 2,296 feet. Four wells.
	Mahoney	Sundance from 2,410 to 3,136 feet. Gas from 2,525 to 2,925 feet. Initial production 25,000,000 cubic feet. Twenty-one wells.
	Rock River	Sundance from 3,128? to 3,360 feet. Oil from 3,150 to 3,210 feet. Initial production from 200 to 1,000 barrels of 36.4° gravity oil. Ten wells.
Fremont	Alkali Butte	Sundance from 4,670 to 5,240 feet. Salt water from 4,290 to 4,930 feet. A showing of oil and gas at 4,925 feet.
Natrona	Bolton Creek	Sundance from 1,090 to 1,335 feet. Oil from 1,090 to 1,110 feet. Initial production 150 barrels of 26.9° gravity oil. Six wells.
	Poison Spider	Sundance from 1,160 to 1,415 feet. Oil and gas from 1,350 to 1,415 feet. Initial production 13,000,000 cubic feet of gas and 45 barrels of 21° gravity black asphalt oil. Eighteen wells.
	Salt Creek	Sundance from 2,425 to 2,860 feet. First sand from 2,425 to 2,525 feet, water. Second sand from 2,630 to 2,730 feet, oil (all producing wells are now in this sand). Third sand from 2,822 to 2,860 feet, oil. Initial production from 250 to 6,000 barrels of 35.7° gravity oil. There were 47 wells; now 42, of which 9 are abandoned.
	South Casper Creek	Depth unknown. Gas from 1,400 to 1,500 feet. Initial production 18,000,000 cubic feet. Four wells producing.

TABLE XIX (*Continued*)

County	Field	Statistics
Niobrara	Lance Creek	Sundance from 3,615 to 3,887 feet. Gas and black oil of 36–38° gravity from 3,645 to 3,654 feet and from 3,690 to 3,704 feet. Three wells. Green oil of 49° gravity from 3,794 to 3,819 feet and from 3,844 to 3,887 feet. Thirty-nine wells. Average initial production of green oil 2,000 barrels, black oil 500 barrels, and gas 3,000,000 cubic feet.
Park	Oregon Basin	Sundance from 1,810 to 2,320 feet. Gas from 2,020 to 2,100 feet.
Sweetwater	Lost Soldier	Sundance from 1,831? to 2,526 feet. Oil from 1,831? to 1,848 feet. Average initial production from 147 to 1,500 barrels of 28.2° gravity oil. Six wells.
	North Baxter Basin	Depth unknown. Gas from 3,466 to 3,473 feet. Initial production 3,500,000 cubic feet. Two wells.

of Wyoming (Fig. 13). Sundance production farther south, in Colorado, also falls within this belt. The majority of the wells drilled in the Big Horn Basin region, northwestern Wyoming, have tested the Sundance formation, and produce from horizons below the Sundance. With the exception of one well, in the Byron field, Big Horn county, no well in the Big Horn region has yielded commercial quantities of oil or gas from the Sundance. The Byron well is small, with an initial production of 50 barrels. From Fremont county, only one field has reported a showing of oil and gas in the Sundance, and the Sundance gas production in Baxter Basin, Sweetwater County, is limited to two wells which are located on a fault block. Other Sundance tests in the Baxter Basin field have shown no production.

THEORIES ON ACCUMULATION AND DISTRIBUTION

Three theories can be cited as applicable to the method of accumulation of oil in the Sundance formation to account for the distribution of production. They are (1) the existence of certain zonal paleo-biochemical conditions during the deposition of Sundance sediments, (2) migration of oil up the initial dip of the Sundance sediments before post-Cretaceous folding, and (3) near-shore facies textural control of the reservoir qualities of the Sundance sands.

Paleo-biochemical conditions.—Trask[86] has demonstrated that the source of petroleum is controlled by the presence or absence of marine

[86] Parker D. Trask, "Origin and Environment of Source Sediments of Petroleum," *American Petroleum Institute* (1932).

organisms, and that the distribution of marine organisms depends on their physical and chemical environments. Trask also points out that the organic content of marine sediments is highest near shore and in shallow water, and, from the coast seaward, the organic content remains more or less constant for 100 miles. From 100 to 500 miles off shore the organic content diminishes rapidly, and at the 500-mile point it is present in an insignificant quantity.

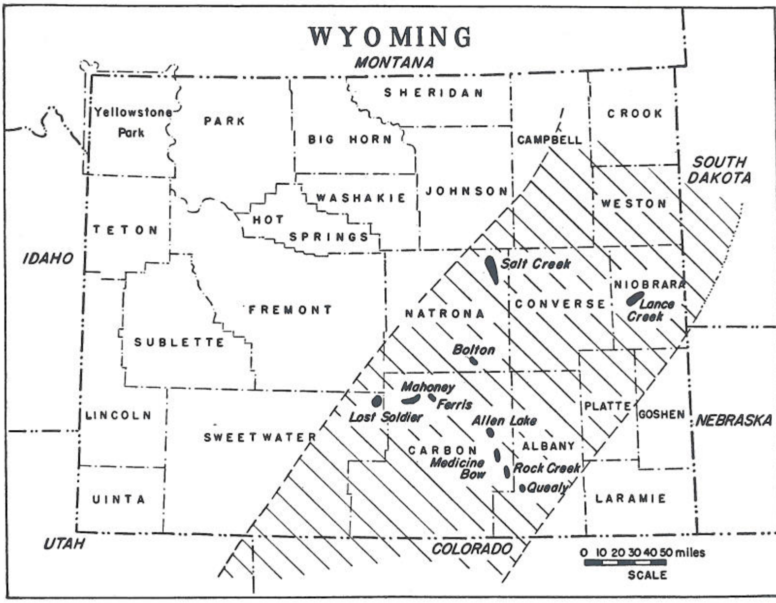

FIG. 13.—Sundance "belt of production."

The major producing Sundance fields consist of anticlinal structures lying in a belt slightly more than 100 miles broad. This belt trends along, and is parallel to, the ancient shore lines of the Twin Creek and Logan (Sundance) seas (see Figs. 9, 12, and 13). The easternmost margin of the "belt of production" lies a few miles west of the easternmost occurrence of marine Sundance. However, no favorable structure has yet been tested which involves the apex of the wedge of marine Jurassic sediments, and if such a structure were found and proved productive, the "belt of production" would extend to the shore line. The Twin Creek and Logan seas were probably shallow, and no doubt the shore line fluctuated during the deposition of

Sundance sediments, so that the zone of high concentration of organic matter was probably of unusual width. This zone necessarily advanced and retreated across the state with the transgression and regression of the seas, and fluctuated with the changing shore line. It seems logical to believe that conditions controlling the organic content of Jurassic sediments were comparable to those which control the organic content of modern sediments. If zonal bio-chemical conditions existed near shore during the deposition of Jurassic sediments, and if those conditions are responsible for the general distribution of petroleum in the Sundance formation today, the shore line during most of the time of deposition probably remained in close proximity to the shore line at the time of the most widespread inundation.

Up-dip migration.—Levorsen[87] has been a strong advocate of stratigraphic accumulation of petroleum, and has demonstrated that many of the major fields in the United States exist because of stratigraphic rather than structural traps. This theory of accumulation is applicable, with reserve, to the distribution of petroleum within the Sundance sediments. The "belt of production" trends along the "wedge edge" of the Sundance. However, as far as exploration has progressed to date, local structures within this belt have been essential for production. The Wyoming Sundance sediments, upon deposition, must have had an initial dip from the shore line on the west, and, as far as can be determined, no marked folding took place in Wyoming until late Cretaceous time. To those who advocate long-distance migration, it might seem plausible to account for the distribution of oil in the "belt of production," and the lack of Sundance oil in the northwestern part of the state, by migration up the initial dip of the sediments. It might also be pointed out that there is strong evidence of an unconformity between the lower and upper Sundance sediments, as discussed in the preceding pages of this paper, and also that the basal sand of the Sundance is one of the major producing horizons. Although there is no evidence of angular discordance between the lower and the upper Sundance, petroleum may have been formed and trapped beneath that unconformity. Strictly speaking, the distribution of petroleum within the Sundance formation requires many conditions which are not required in the "up-dip wedge-edge porosity" theory of Levorsen and others; namely, extremely long-distance migration and general concentration in a broad zone rather than in actual small stratigraphic traps. Stratigraphic traps of that type no doubt exist within the Sundance formation, and they may well con-

[87] A. I. Levorsen, "Stratigraphic Versus Structural Accumulation," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 20 (1936), pp. 521–30; and others.

tain oil in commercial quantities, but none have been discovered up to the present time.

Near-shore facies textural control.—Extensive sand analyses have not yet been completed for the Sundance sands. However, some progress is now being made by the Geological Survey of Wyoming toward that end. Due to the nature of the succession of Sundance rocks, that is, alternating carbonaceous shales and porous sandstones, and because the sands are probably coarser and more porous in the near-shore deposits, the sands of near-shore facies probably make better reservoirs for the accumulation of oil generated in, and derived from, the carbonaceous shales. If the shore line fluctuated, which seems logical, the coarser near-shore sediments would extend over a more widespread area than would be the case with a nearly stationary shore line. It is possible, therefore, that the creation of more porous reservoir rocks along the fluctuating shore line of the Twin Creek and Logan seas might exercise some control over the distribution of oil.

Flushing.—Southeastern Wyoming is, in general, an area of high hydrostatic pressures, and water flushing has probably played no small part in local accumulations of oil and in the absence of oil in certain well-defined structures. It may be that steep-sided structures are essential to hold oil in the Sundance sands, which are apparently more pervious than sands in some of the other producing formations. The Big Muddy field, Converse County, lies in the middle of the "belt of production" and is almost completely surrounded by commercial Sundance fields, yet a test to the Sundance at Big Muddy proved unproductive. The flanks of the Big Muddy structure have relatively low dips, and the hydrostatic pressure is high. The absence of Sundance oil can logically be explained as being due to flushing.

Probability of theories of accumulation.—It is probable that no one of the previously listed theories descriptive of the method of accumulation and distribution of petroleum in the Sundance formation, nor any other single method, could account for the distribution of Sundance oil. There were no doubt many unknown factors which controlled the accumulation of oil in commercial amounts. The three theories listed may have played some part. It is not the intention of the writer to advocate any theory pertaining to distribution of Sundance oil, but merely to point out the nature of the distribution and list some of the theories which seem to be suggestive. Of the three listed, the first, that of a "paleo-biochemical" control seems to the writer to be most suggestive of the cause of the type of accumulation which has been found in the Sundance.

Summary

In the preparation of this paper, it has been the writer's purpose to make additional contributions toward a clearer understanding of the marine Jurassic rocks which occur within the state of Wyoming. It is the writer's belief that evidence has been shown which tends to substantiate the following correlations: 1, that the Nugget formation may be equivalent to the thick basal sandstone within the Sundance formation in the vicinity of the Freezeout Hills, southeastern Wyoming; 2, that the Twin Creek formation is in part equivalent to the Ellis formation of northwestern Wyoming, and to the lower portion of the Sundance formation in central and eastern Wyoming; 3, that there is an erosional interval within the Sundance formation, and that this erosion period corresponds with the time of withdrawal of the Twin Creek sea; 4, that the upper portion of the Sundance formation is equivalent to the Preuss and the Stump formations of western Wyoming and southeastern Idaho and to the upper portion of the Ellis formation of northwestern Wyoming, or the Sundance formation as it has been re-defined by Crickmay. In this paper, the writer has also attempted an explanation of the occurrence of red beds and gypsum within the Sundance formation. It is believed that these red beds were deposited, in part at least, in inland lakes and undrained depressions immediately after the retreat of the Twin Creek sea and during the erosion period which followed, and in part in the marginal lagoons and bays of the retreating sea. An attempt has also been made to clarify the paleogeography of this region during the time of deposition of the marine Jurassic rocks.

The economic portion of this paper is intended to point out the areas, depth, initial production, and quality of the oil from the Sundance formation. The distribution of Sundance fields is striking. The important Sundance fields lie in a broad belt which parallels the shore line of the Twin Creek and Logan (Sundance) seas. Theories which appear to be in part applicable to such an accumulation are (1) the existence of paleo-biochemical conditions associated with the shallow-water near-shore deposits which controlled the abundance of petroleum-forming organisms, (2) migration of petroleum up the initial dip of the Sundance sediments before the folding during late Cretaceous time, and (3) porosity control by the coarser-textured sandstones deposited near the shore. It is not advocated that any one, or all, of these theoretical concepts accounts for the distribution of Sundance oil; however, they may have been in some part responsible for the distribution.