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CORRELATION OF GEOLOGIC FORMATIONS BETWEEN EAST-CENTRAL COLORADO, CENTRAL WYOMING AND SOUTHERN MONTANA

BY

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CONTENTS

ILLUSTRATIONS

CORRELATION OF GEOLOGIC FORMATIONS BETWEEN EAST-CENTRAL COLORADO, CENTRAL WYOMING, AND SOUTHERN MONTANA

By WILLIS T. LEE[1]

INTRODUCTION

Purpose of the paper.—The observations described in this paper were made primarily for the information of those engaged in the recovery of oil and gas in Wyoming. The paper sets forth results obtained on the correlation of the sedimentary rocks in some of the oil fields of that State.

Parts of the area here described have been examined in former years, some carefully, others hurriedly. Some parts were examined many years ago, and the formation names used then are no longer recognized; in other parts, examined more recently, modern names have been used for the formations. Much new information has been obtained since some of the older reports were published. Descriptions of isolated areas published at different times disagree on important points. Rocks of corresponding age are known under one name in some places and under a different name in other places. Certain reports, made with an explicit object in view, have not dealt adequately with problems affecting the recovery of oil. Reports of work done in some parts of this area have not been published and are not generally available. Some sedimentary rocks once supposed to be time equivalents have later proved to be different in age, and rocks which in one place or another have received different names have proved to be identical. The relationship implied by certain formation names has led to misapprehension and disappointment when the drill directed in accordance with such implications has failed to find oil. The work described in this paper was undertaken for the purpose of determining the stratigraphic and structural relations of some of the oil-bearing rocks described in the several reports, of harmonizing as far as possible these reports, and of showing how the variously named formations are related to one another.

Field work.—The work was undertaken by the oil and gas section of the United States Geological Survey under the direction of K. C. Heald. It was begun in the summer of 1921 by the writer, who was assisted in the field by Harold S. Cave. Late in the season John B. Reeside, jr., and Quentin Singewald joined the party. The writer spent two months during the summer of 1922 in the same work, and about three months in the summer of 1923.

In order to proceed from a well-known area to the one under special investigation, work was started in Colorado, and the formations that are there upturned in the foothills east of the front range were followed at the outcrop and measured at short intervals as far north as Casper, Wyo. (See fig. 1.) Most of the intervals between sections are so short and the side trips were so numerous that the formations were virtually traced. In order to compare the formations south of Casper with those in the Wind River Mountains a reconnaissance examination was made near Lander, Wyo., where considerable geologic work had been done previously. In 1922 detailed examinations were made in the Big Horn Basin, Wyo., and in 1923 observations were pushed into other parts of northern Wyoming and southern Montana.

The areas in which these sections were measured are fairly well known in a general way. The larger features in Colorado are shown on the geologic map of that State, and those in Wyoming on a similar map, which was not published until after the work described in this report was done but which was available for use in manuscript form. In a few areas of moderate extent the formations here described have been examined in detail. The first two sections of Plate 1 are taken from the Colorado Springs and Castle Rock folios. Horse Creek, in southern Wyoming, where the writer's section was measured, is situated in the area covered by the Laramie-Sherman folio. Less formal reports have been made on several areas where sections were measured by the writer.

Many thicknesses given on the chart and in the descriptions in this report do not correspond with published figures for the same or near-by localities. The discrepancies may be due either to variations in the thickness of the formations or to errors in measurement. The greatest discrepancies appear in parts of the sections representing rocks that are not well exposed. Where measurements are made across

[1] Mr. Lee died June 16, 1926, shortly before this paper was sent to the printer, and the proof has been read by some of his associates.

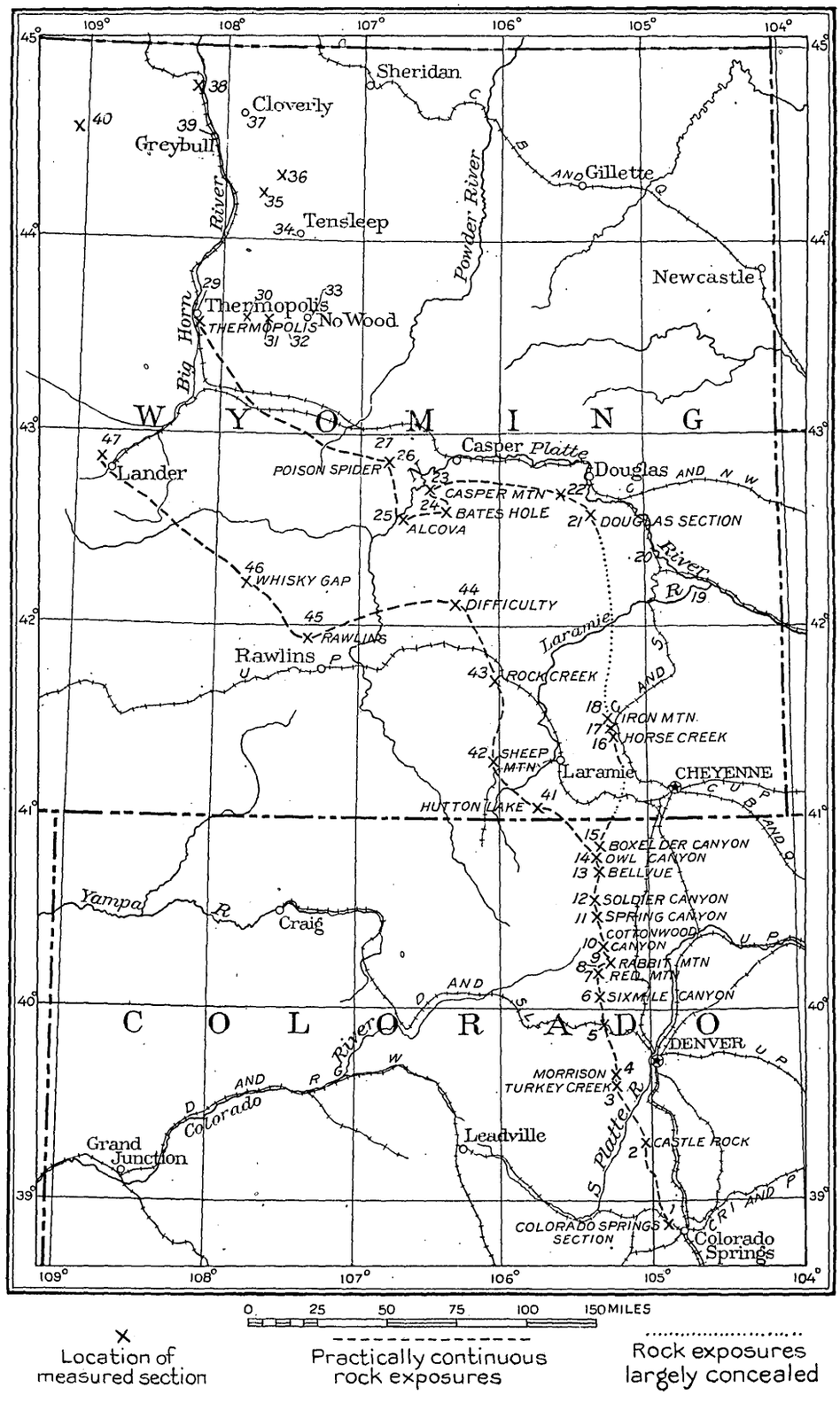

FIGURE 1.—Sketch map of parts of Colorado and Wyoming showing localities described in the text

zones in which the rocks are poorly exposed, the assumption of uniformity of dip and absence of faulting may not be justified. There is also the possibility that warped strata may have been locally thickened or thinned by the folding. It was found during the investigation that measurements made a few miles apart across the strike of gently inclined shale beds differ more than can reasonably be attributed to variations in thickness due to deposition. It is desirable from one point of view to measure

sections only where the beds are well exposed, but relatively few places were found where a sufficient number of such partial sections could be satisfactorily joined into a complete section. In the investigation here described, in which comprehensive sections were desired for direct comparison, it was deemed preferable as a rule to select the most favorable place that could be found and there measure the complete section, even though some of the beds were not exposed as plainly as at another place. Some of the comprehensive sections thus measured were supplemented by measurements at localities near by.

In order that the platted sections might be directly compared, the same methods of measurement were employed in all places. Where exposures were favorable the tape was used. On steep slopes distances were measured either by Locke level or by use of vertical-angle readings obtained with the telescopic alidade. In each section the thickness of beds was obtained by correcting the measured distances for strike and dip of beds and for surface slope and direction of traverse. When it was necessary to make observations along a winding course, the stadia and plane table were used, and thicknesses were obtained by platting strike, dip, distance, and direction.

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DESCRIPTION OF FORMATIONS

The columnar sections in Plates 1 and 2 indicate the subdivisions and age of the sedimentary rocks described in this paper, the formation and group names that have been employed in different areas, and the correlation of the formations and groups, showing their continuity from place to place, their thickness, and their structural relations. These natters are described in detail on pages 4–23.

The identification of some of the unfossiliferous beds and the determination of their continuity must depend on tracing from place to place. For a few of the formations wide covered areas prevent this tracing. For these reasons the application of the several names by which parts of the Pennsylvanian, Permian, and Triassic red beds have been known remains uncertain. The formations recognized in this report are described below.

BASAL CRYSTALLINE ROCKS

The crystalline rocks represented at the base of each section consist of the igneous and metamorphic material of the core of the Rocky Mountains (see pl. 3, *A*) frequently referred to as Archean, pre-Cambrian granite, basement complex, or ancient crystalline rocks. In several places there are layers of quartzite and argillite that aggregate thousands of feet in thickness and represent sedimentary formations probably of Algonkian age. In the walls of the canyon of Thompson River west of Loveland hard metamorphosed sediments, some thousands of feet thick where the river has cut through them, stand almost on edge. They are evenly upturned and little distorted, and in their varied lithology, metamorphic character, and nearly vertical position they are eloquent reminders of a long and varied history. (See pl. 3, *B*.) Metamorphosed sediments of a different nature were observed south of Boulder, Colo., in Eldorado Canyon, and on the Denver & Salt Lake Railroad above Eldorado Springs, at the locality shown in Plate 4, *A*. No less conclusive evidence that much of the pre-Cambrian basement originated as sedimentary rock is found in many places along the line of sections here described.

Long erosion is indicated by the unconformity between the crystalline rocks and the younger rocks of Paleozoic age. The surface of the crystalline rocks is uneven and is covered by varying quantities of débris that was once a part of the overlying formations. This débris consists of the more resistant material, especially vein quartz. In middle eastern Colorado and in central Wyoming the unconformity represents the time between Archean and Cambrian—that is, Algonkian; in northern Colorado and southern Wyoming it represents in some places the time between Algonkian and Pennsylvanian and in others all the time from Archean to Pennsylvanian.

CAMBRIAN FORMATIONS

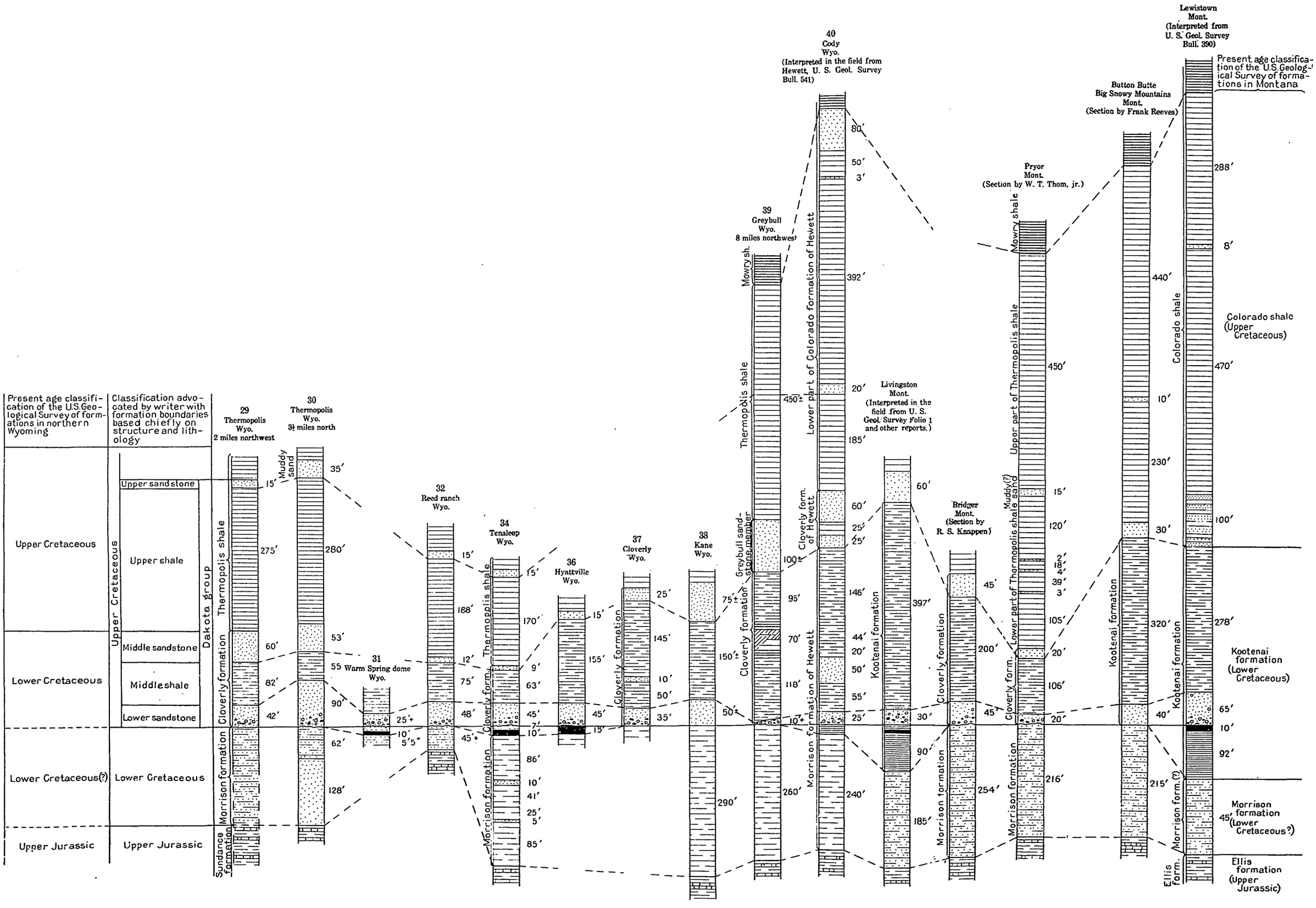
Small remnants of a Cambrian formation, the Sawatch sandstone, are found near Colorado Springs and Castle Rock, Colo., but not farther north in the foothill region of that State. In southern Wyoming rocks of Cambrian age occur in Casper Mountain (pl. 6, *B*), where they are known as the Deadwood formation, and thicken rapidly toward the west and north.

ORDOVICIAN FORMATIONS

Remnants of a limestone of Ordovician age, the Manitou limestone, are found in the Colorado Springs and Castle Rock quadrangles in Colorado, but not farther north in the eastern foothills of that State nor in southern Wyoming. Ordovician rocks reappear, however, in the Wind River and Big Horn mountains and elsewhere in northwestern Wyoming.

SILURIAN AND DEVONIAN FORMATIONS

No rocks of Silurian or of Devonian age are known in any part of the region described in detail in this paper, except in the Wind River Mountains, where



GEOLOGIC SECTIONS IN NORTHERN WYOMING AND SOUTHERN MONTANA

Showing the relation of the Cloverly formation to the rocks correlated with the Dakota group at Bellvue, Colo., and the Kootenai formation of Montana

there are 428 feet of Devonian rocks that have been described by Blackwelder under the name Darby formation.

MISSISSIPPIAN FORMATIONS

The Mississippian series of the Carboniferous system is represented in the Castle Rock quadrangle, Colo., by 85 feet of strata called the Millsap limestone. No rocks of Mississippian age are known farther north in the foothills of eastern Colorado, but the Mississippian Madison limestone occurs in many places in Wyoming. It is represented by isolated remnants of cherty limestone in the northern part of the Laramie Basin near Marshall and develops into a continuous formation farther to the north and west (see pl. 6, *B*), where it consists chiefly of cherty dolomitic limestone. In some places, however, it is made up of granular material which seems to be composed of a mixture of sand and finely crystalline calcite. In many places both the dolomitic limestone and the chert are fossiliferous. The fossils collected at the several localities were found by G. H. Girty to be of lower Mississippian age and are described on pages 47–52, 67–72.

OLDER PENNSYLVANIAN FORMATIONS

The Fountain formation, of early Pennsylvanian age, consists chiefly of arkose, red sandstone, grit, and conglomerate. It is coarse grained, crumbling, and mottled with gray and various light shades of red. The material is irregularly bedded (see pl. 7) and varies in physical character from place to place. Lenses of coarse conglomerate and breccia give place abruptly to finer material consisting of bedded sand, clay, and even impure limestone. Gravel-filled channels are common, and in many places the beds of coarse arkose, which normally are red, have a leached appearance. In brief, the formation has the characteristics of fluviatile material.

The accompanying sections indicate that the Fountain formation, which is described as more than 5,000 feet thick near Colorado Springs, Colo., thins toward the north and in southern Wyoming merges laterally into beds known under another name. This relation suggests a great cone with its apex, presumably in the mountains, in central Colorado, and its base toward the north. The suggestion of a cone is still further strengthened by the manner in which the younger formations thin and disappear on its flank. The coarse arkosic character of the material, indicating accumulation close to the place of origin, and the general structural relations strongly suggest an upland delta or alluvial cone in early Pennsylvanian time, which was gradually overlapped by later Pennsylvanian formations and finally covered completely by beds of Permian age. The original extension of this supposed cone to the west is uncertain because of recent erosion, which has removed all sedimentary rocks from the crystalline areas. To the east it is deeply buried under younger rocks. Few fossils, except those referred to below, have been found in the Fountain formation, but its apparent derivation from the mountains of post-Mississippian time and its occurrence under fossiliferous Pennsylvanian limestone harmonize with its supposed Pennsylvanian age.

Fossils of Mississippian age have been found in many places in the foothills of northeastern Colorado near the base of the Fountain formation. Some if not all of these fossils are in pebbles and boulders of chert. It is possible that during the epoch of erosion that followed the mountain uplift at the end of Mississippian time, rocks of Mississippian age escaped destruction in some places, while in other places they were broken up and the material was redeposited as parts of the succeeding formation. Several collections of these fossils have been made in northeastern Colorado and southeastern Wyoming, and little doubt remains that they were derived from an older formation and are secondary in the Fountain.

Beds about 100 feet thick at the base of the Fountain formation near Colorado Springs have been called the Glen Eyrie shale member of the Fountain formation. From fossil plants found in them David White regards this member as representing a stage in the upper Pottsville (early Pennsylvanian). About 400 feet above the base of the Fountain near Colorado Springs Finlay[1] found a few fossils supposed to belong in the Pennsylvanian fauna, and he mentions fossils of the same fauna found in northern Colorado in beds which were then supposed to represent the upper part of the Fountain but which are more likely to belong in the younger Pennsylvanian Ingleside formation.

The beds called Lyons sandstone in the Colorado Springs and Castle Rock folios are correctly correlated with the "Creamy" sandstone of the Morrison region, which in turn was formerly correlated erroneously with the Lyons sandstone of Lyons, Colo. These beds can not be the same as the Lyons sandstone of the type locality. This is indicated by the correlation lines on Plate 1. The former correlation of the upper part of the Fountain with the Lyons sandstone arose partly from the failure to discover the disappearance toward the south of beds between the Fountain and the typical Lyons, and in part to the inclusion in the Lyons formation of beds which properly belong to an older formation, as explained on page 12, under the heading of Lyons sandstone. The so-called Lyons sandstone of the Castle Rock and Colorado Springs folios and its equivalent the "Creamy" sandstone of the Morrison section contain arkose and conglomerate to the very top and differ from the underlying typical Fountain chiefly in color. They are distinctly lighter colored as a whole, thus resembling many of the arkose beds of the Fountain formation. This general absence of the deeper colors suggests

[1] Finlay, G. I., U. S. Geol. Survey Geol. Atlas, Colorado Springs folio (No. 203), 1906.

leaching of the material. At no locality north of the town of Morrison, where the Fountain is covered by the next younger formation, were the leached beds found. This suggests that the Fountain formation south of Morrison, where the Lyons sandstone is not known, was exposed at the surface much longer than it was north of Morrison, where it was protected from leaching by the covering of younger sediments.

The irregularities of the Fountain formation in constitution, hardness, and color give rise to a great variety of picturesque erosional forms where the formation is steeply upturned in the foothills. These erosional forms in the Garden of the Gods, near Colorado Springs, are widely known. Similar forms that are less widely known, though equally picturesque, occur in Perry Park and have been described and illustrated by Richardson in the Castle Rock folio. Other picturesque monuments of erosion that are still more varied are exhibited by the Fountain formation in Roxbury Park, southwest of Denver, Colo. (pl. 7, *A*); at the town of Morrison, west of Denver, in what is locally known as the Garden of the Angels; and in many places in the foothills still farther north.

There is no difficulty in recognizing the Fountain formation throughout the foothill region of northern Colorado and in southern Wyoming, as far north as Horse Creek, where the lower 132 feet of the rocks that Darton[2] called the Casper formation are assignable to the Fountain. These beds are here relatively fine grained but contain small pebbles and angular fragments of feldspar and other material of the same nature as the arkose beds farther south, where they are known as the Fountain. Farther northwest, in central Wyoming, red beds of variable character may represent the Fountain, but their correlation is uncertain. Near Iron Mountain, Wyo., the possible Fountain was examined in only one place, and somewhat hastily, but it contains arkose, pebbles, some limy layers, and thick beds of red material with much iron oxide. In the field it seemed appropriate to correlate these beds with the Fountain formation, as developed farther south. On the other hand, they are similar in color, lithology, and appearance to rocks which in some areas have been referred to as red Amsden and which in other areas have been included in a group of beds which Darton called the Casper formation. The suggestion that the red Amsden is the thin edge of the fan of the arkosic Fountain formation rests chiefly on stratigraphic position and lithologic similarity of the beds and on the relation of these beds to strata whose geologic age is established by fossil evidence. It must be confirmed or rejected by further observations.

The Fountain is separated from the overlying beds by an uneven line, which denotes erosion. (See pl. 8, *B*.) At this line the coarse beds of arkose and conglomerate cease abruptly. In a few places, where small pebbles occur near the base of the next younger beds, they are so scarce as to suggest reworked material from the underlying rocks. The appearance of this contact is strongly suggestive of an erosional unconformity.

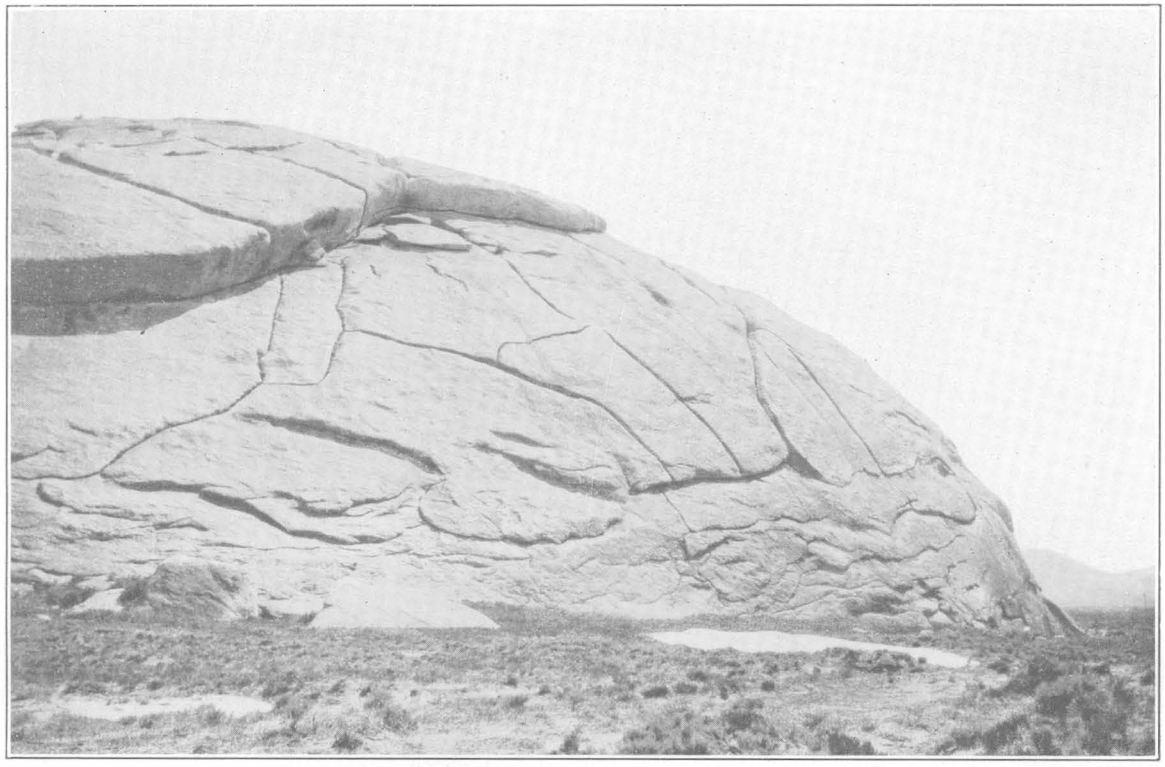
[2] Darton, N. H., and others, U. S. Geol. Survey Geol. Atlas, Laramie-Sherman folio (No. 173), 1910.

YOUNGER PENNSYLVANIAN FORMATIONS

The rocks above the Fountain formation as defined in this report differ from that formation in color, constitution, general appearance, and mode of occurrence. South of Morrison, Colo., these overlying beds, all younger than Pennsylvanian, constitute the formation called the Lykins, formerly known as "Upper Wyoming," but north of Morrison there is between the arkosic Fountain formation and the Lykins formation a group of strata which differ in many ways from either of those formations. These strata enter as a thin wedge at the south, thicken northward, and change in character in a manner best shown graphically by the sections of Plate 1. At Owl Canyon they are divisible into three members—a basal coarse-grained deep-red sandstone member 100 feet thick, a middle limestone and sandstone member 200 feet thick (see pl. 9, *A*), and an upper red sandstone member 50 feet thick. These three members constitute the Ingleside formation. The town from which the name is derived is a short distance south of Owl Canyon. The middle member thins out toward the south, and the two sandstone members merge into a series of massive ledge-making, coarsely cross-bedded red sandstones, which lie unconformably on the Fountain, as shown in Plates 8, *B*, and 9, *B*, and which in turn thin out toward the south just north of Morrison. Toward the north the lower sandstone seems to be recognizable as far as Mill Creek, Wyo. (See pl. 1.) The middle limestone and sandstone member thickens toward the north and changes in composition, merging on the east into a formation composed chiefly of limestone—the Hartville formation—and on the west into two formations consisting chiefly of sandstone—the Amsden and Tensleep of central Wyoming. The upper sandstone member is somewhat irregular in thickness and appearance, but seems to persist at least as far north as Mill Creek, and may represent the Tensleep sandstone, as suggested by Darton.[3]

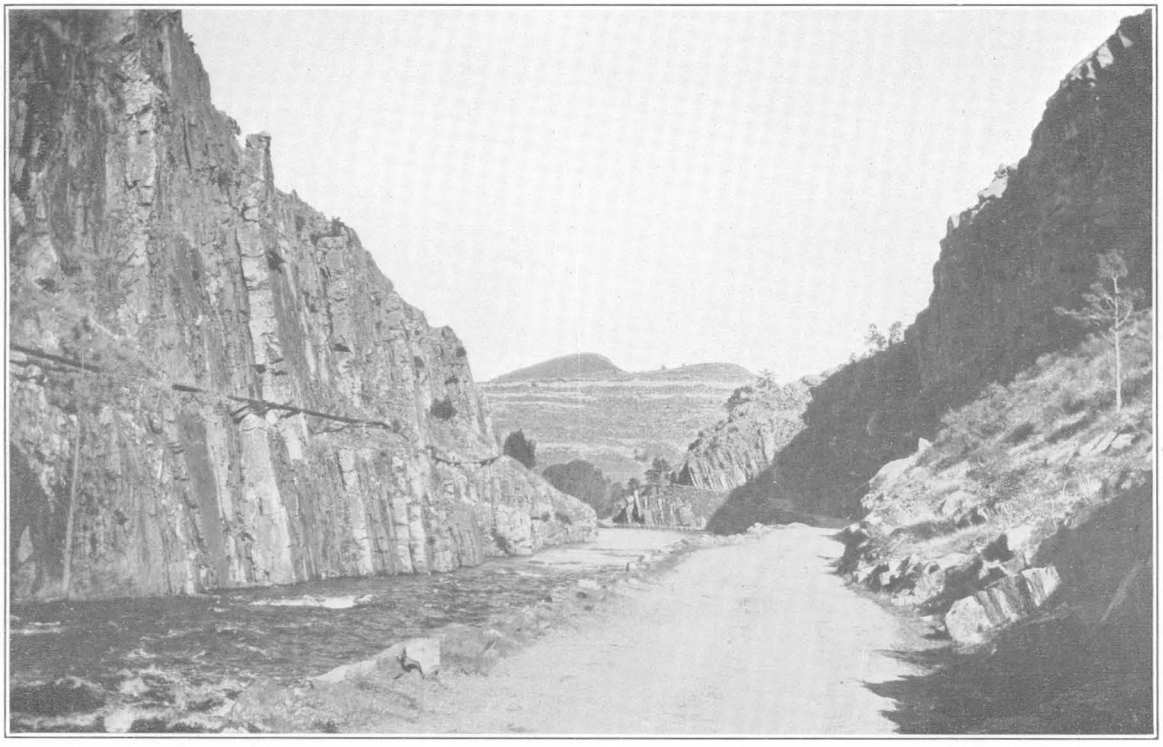
This group of younger Pennsylvanian beds has been variously treated. In the Boulder area, Colo., represented by the Eldorado section on Plate 1, where only the upper and lower sandstone members of the Ingleside formation are present, Fenneman[4] and other geologists following him have grouped these beds with the overlying light-red or pink cross-bedded sandstone to which the name Lyons sandstone is herein restricted. North of Eldorado these massive cross-bedded resist-

[3] Darton, N. H., U. S. Geol. Survey Prof. Paper 32, p. 82, 1905.
[4] Fenneman, N. M., U. S. Geol. Survey Bull. 265, p. 24, 1905.



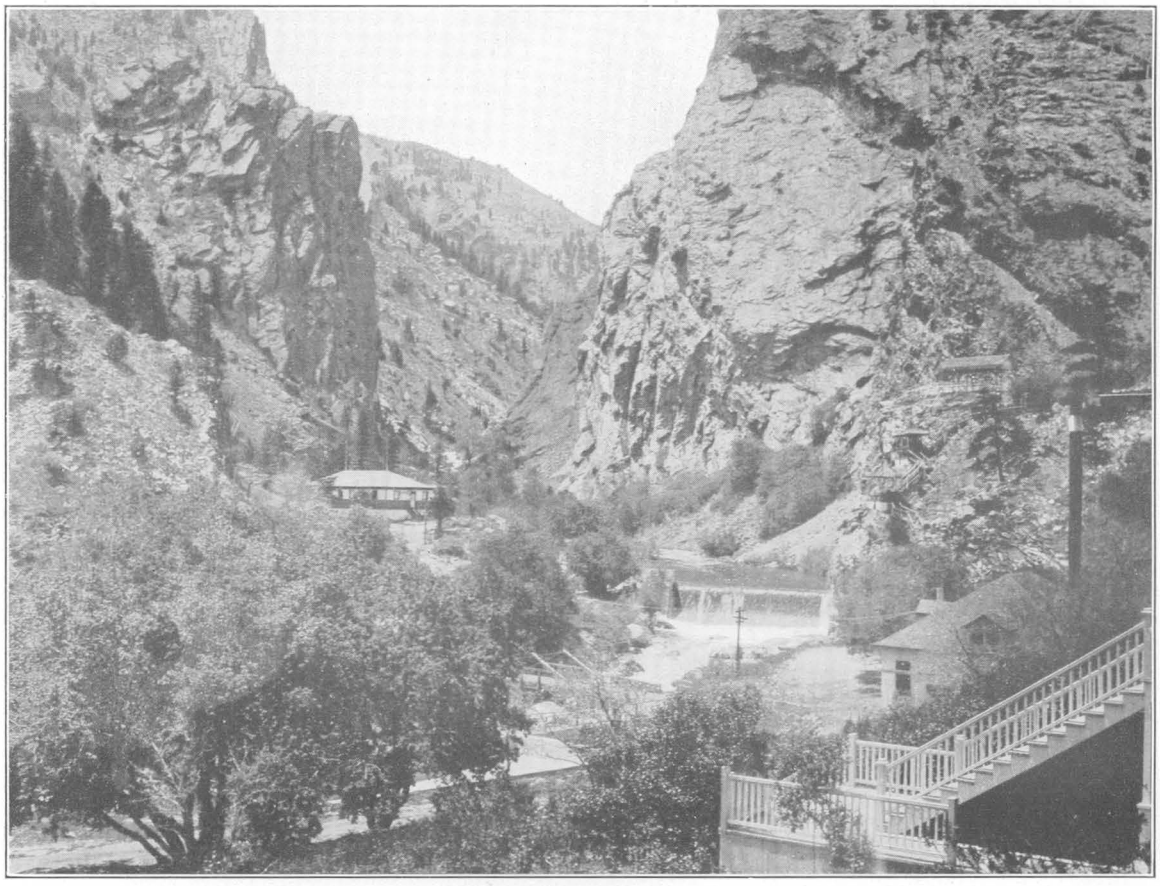
A. INDEPENDENCE ROCK ON SWEETWATER RIVER, WYO.

Showing exfoliation in massive granite



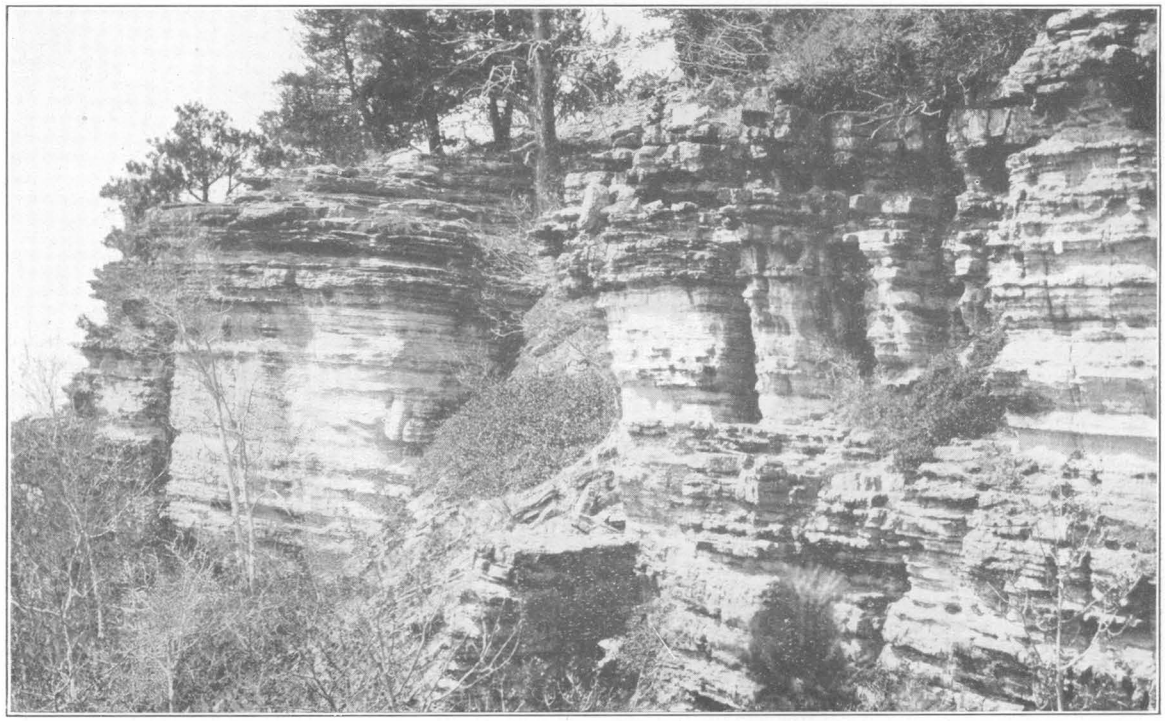
B. MOUTH OF THOMPSON CANYON WEST OF LOVELAND, COLO.

Showing metamorphosed strata of supposed pre-Cambrian age standing nearly vertical. The hogback of Fountain formation appears in the middle distance. The angular contact of these two represents all geologic time from pre-Cambrian to Pennsylvanian



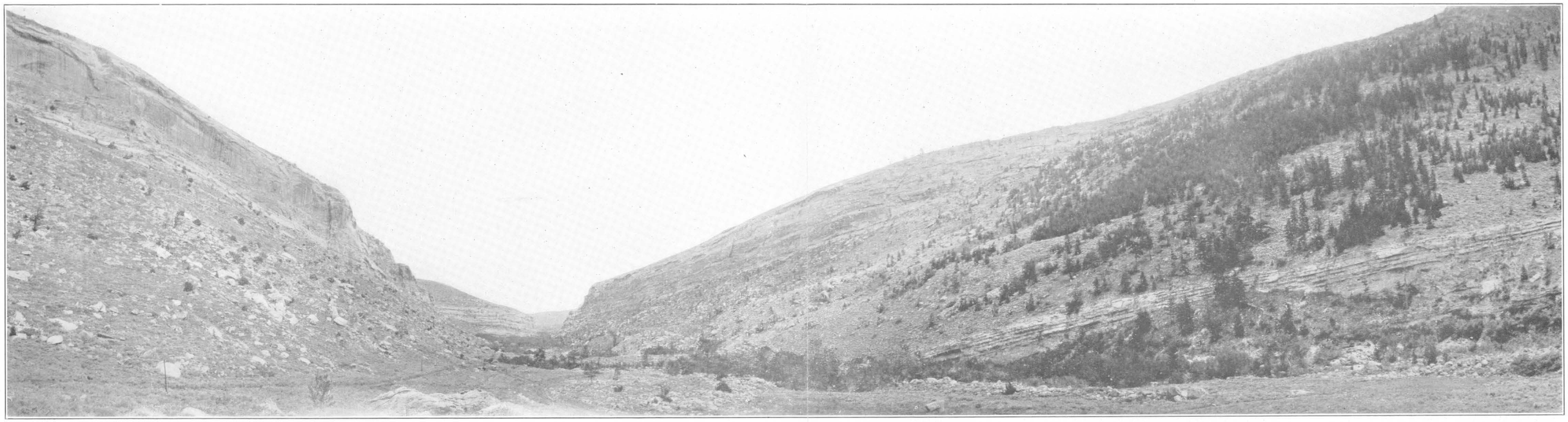
A. ELDORADO SPRINGS, COLO., LOOKING WESTWARD UP THE CANYON

Showing hills of hard massive red sandstone of the Fountain and Ingleside formations standing nearly vertical where cut by Eldorado Creek



B. DEADWOOD FORMATION ON CASPER MOUNTAIN, SOUTH OF CASPER, WYO.

In first canyon east of old asbestos mill



A. VIEW DOWN THE CANYON OF MIDDLE FORK OF POPO AGIE RIVER NEAR LANDER, WYO.

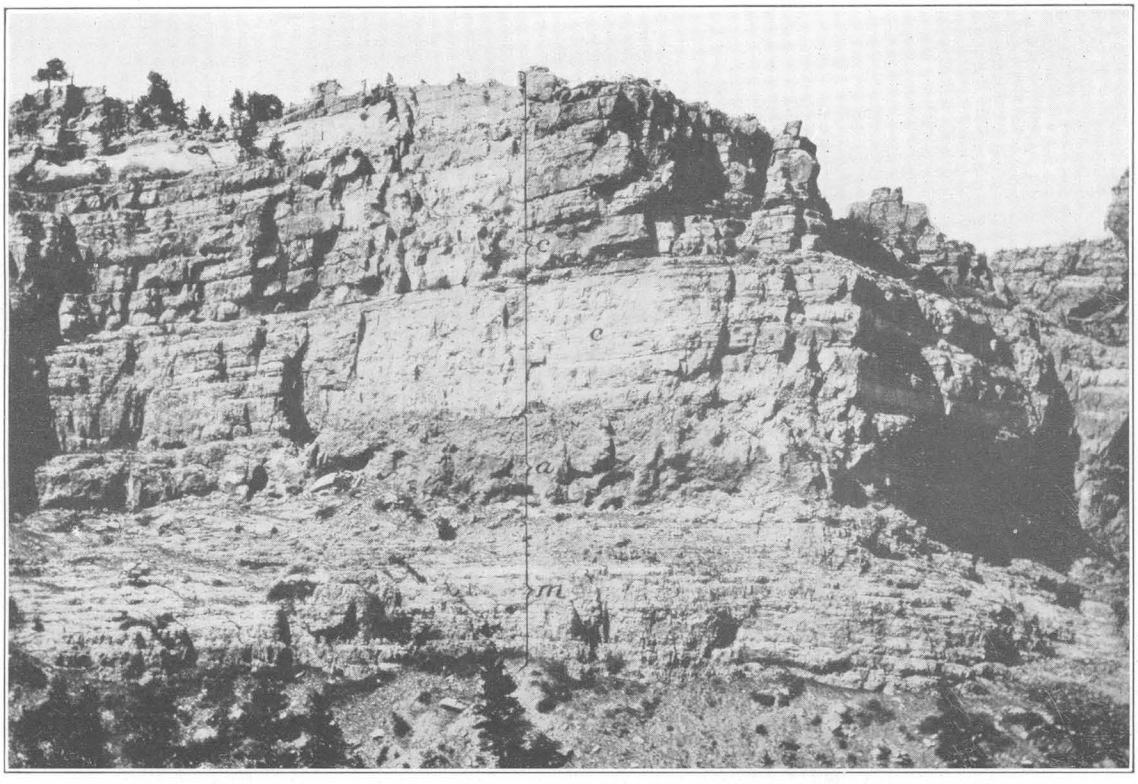
Showing walls composed of hard layers of limestone and sandstone ranging in age from Cambrian to Permian. The prominent ledge at the sky line is composed of sandstone and limestone of Pennsylvanian age

B. VIEW UP THE CANYON OF MIDDLE FORK OF POPO AGIE RIVER AT ITS JUNCTION WITH MILL CREEK, WYO.

Showing conspicuous walls and dip slopes of Pennsylvanian sandstone (Tensleep of this region) and relatively smooth slopes formed on the overlying Phosphoria beds

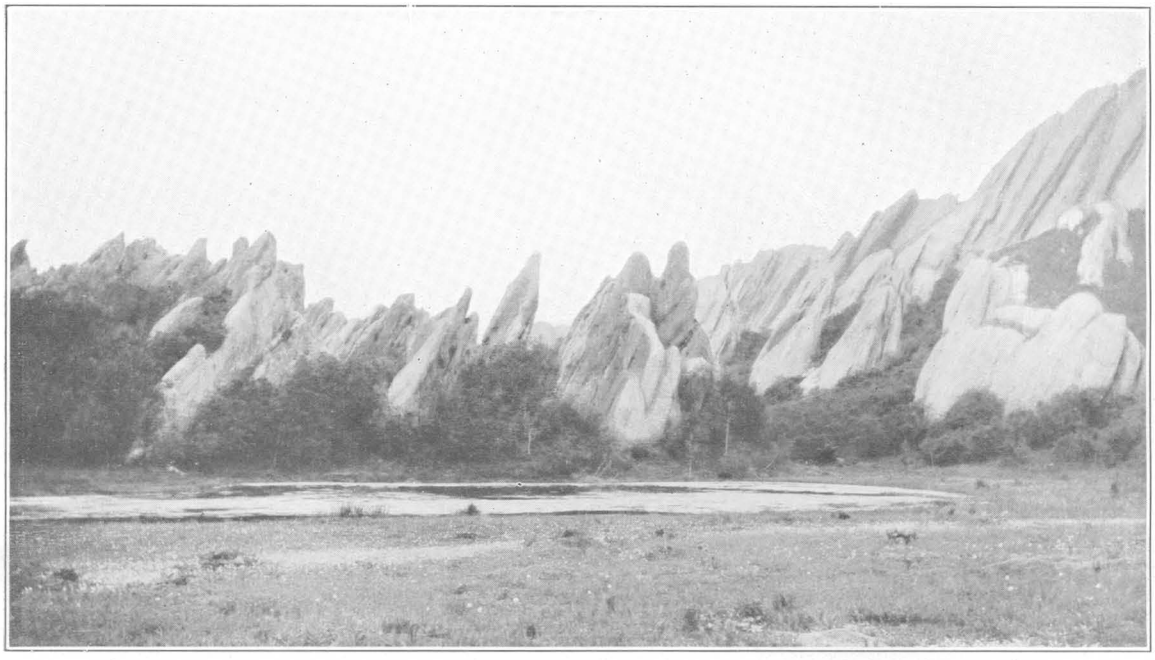
A. WHISKY GAP, WYO., LOOKING NORTH

The ridge is formed of Tensleep sandstone, Amsden sandstone and limestone, Madison limestone, and Deadwood formation



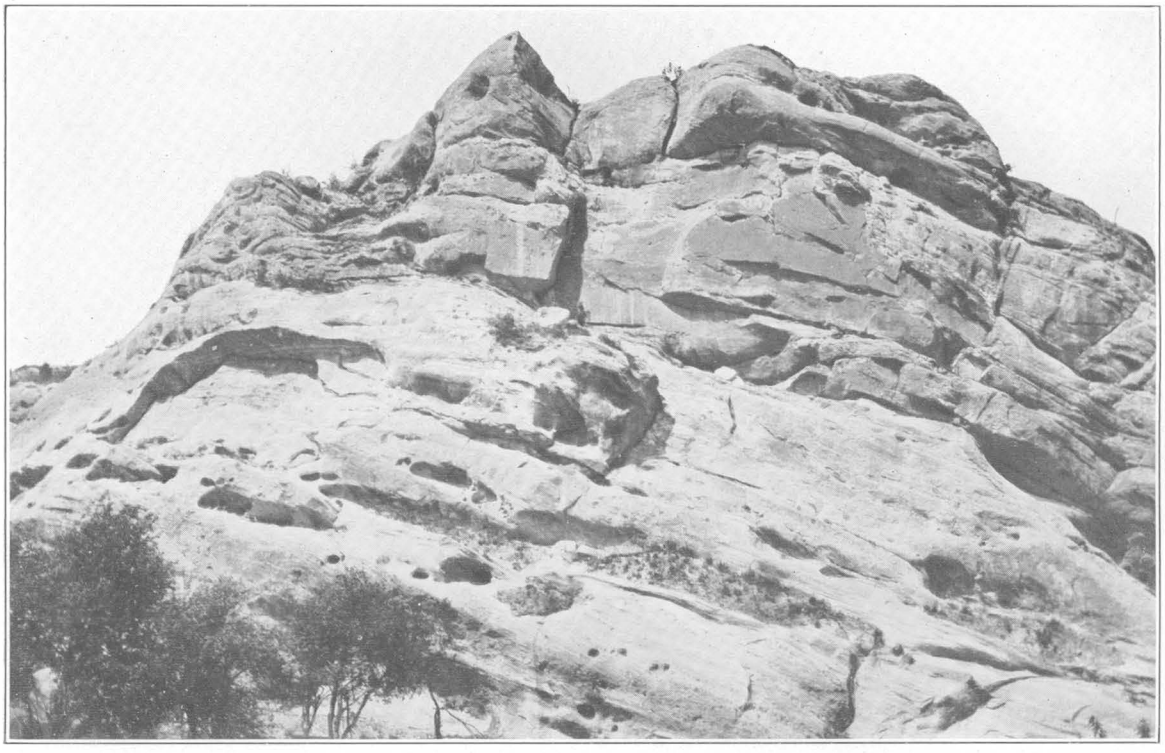
B. CANYON WALL AT EAST END OF CASPER MOUNTAIN, WYO.

Showing Madison limestone (*m*), basal part of Casper formation, equivalent to red beds of Amsden formation (*a*), and overlyin sandstone and limestone of the Casper formation (*c*)



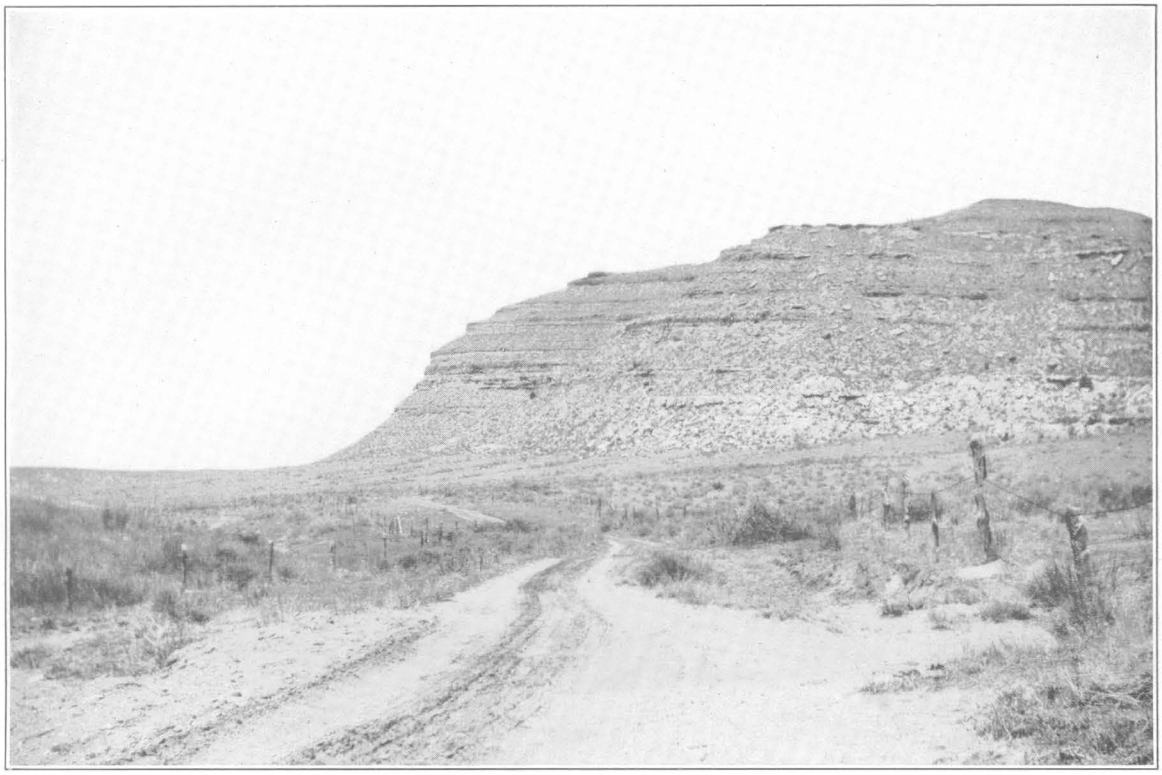
A. FOUNTAIN ARKOSE IN ROXBURY PARK, SOUTHWEST OF DENVER, COLO.

Because of irregularity in constitution and hardness the upturned beds are here eroded into a variety of picturesque monuments



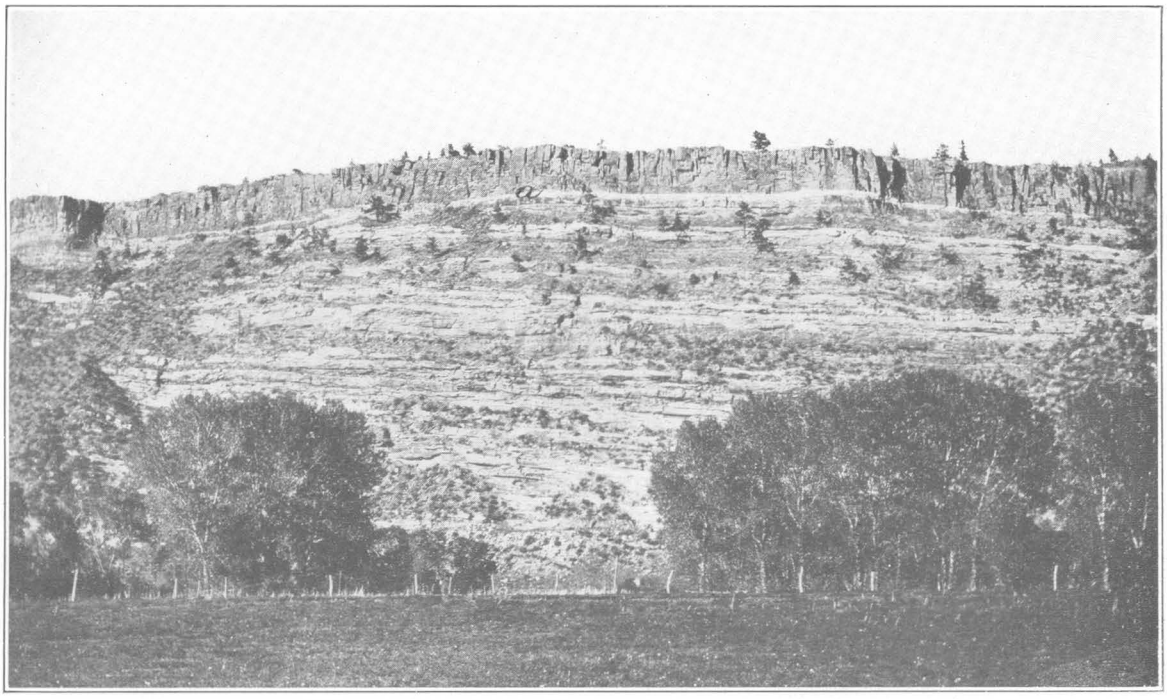
B. "CREAMY" SANDSTONE AT MORRISON, COLO.

Compare views of Lyons sandstone (pl. 17), with which the "Creamy" sandstone has been erroneously correlated



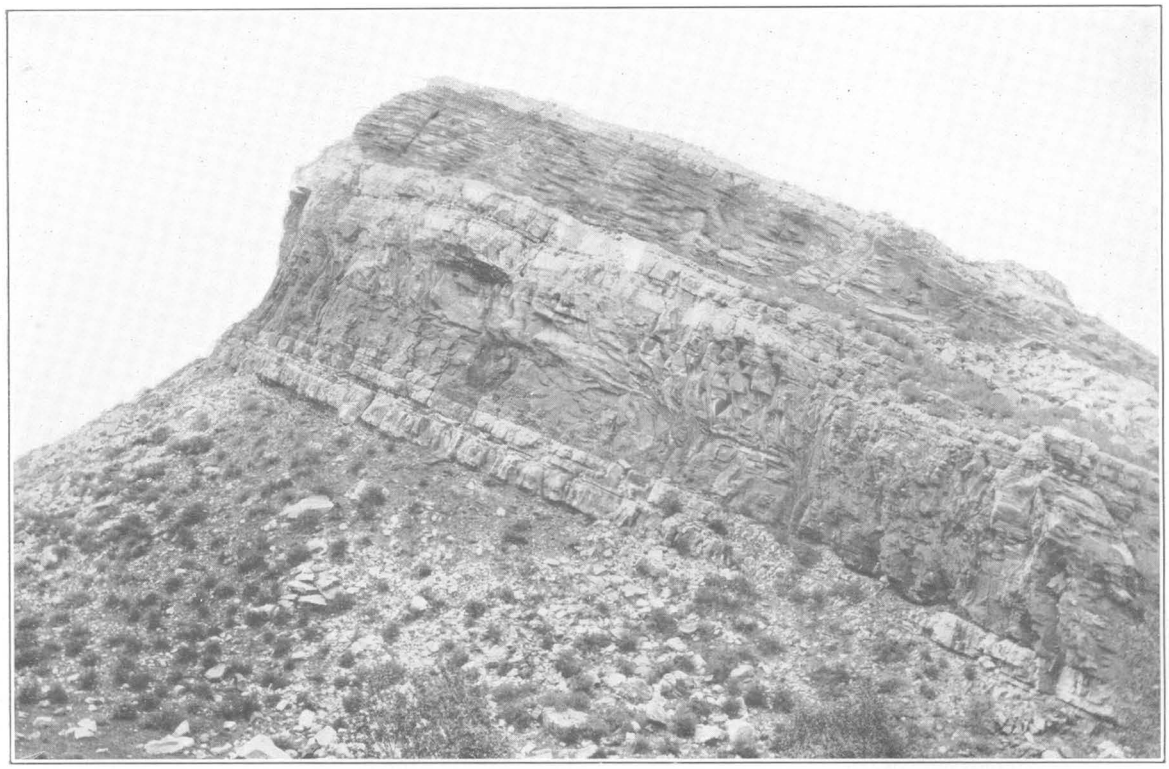
A. FOUNTAIN BEDS IN THE CASPER FORMATION NEAR STEAMBOAT ROCK, LIVERMORE QUADRANGLE, COLO.

Showing beds of sandstone, arkose, and conglomerate lying nearly horizontal



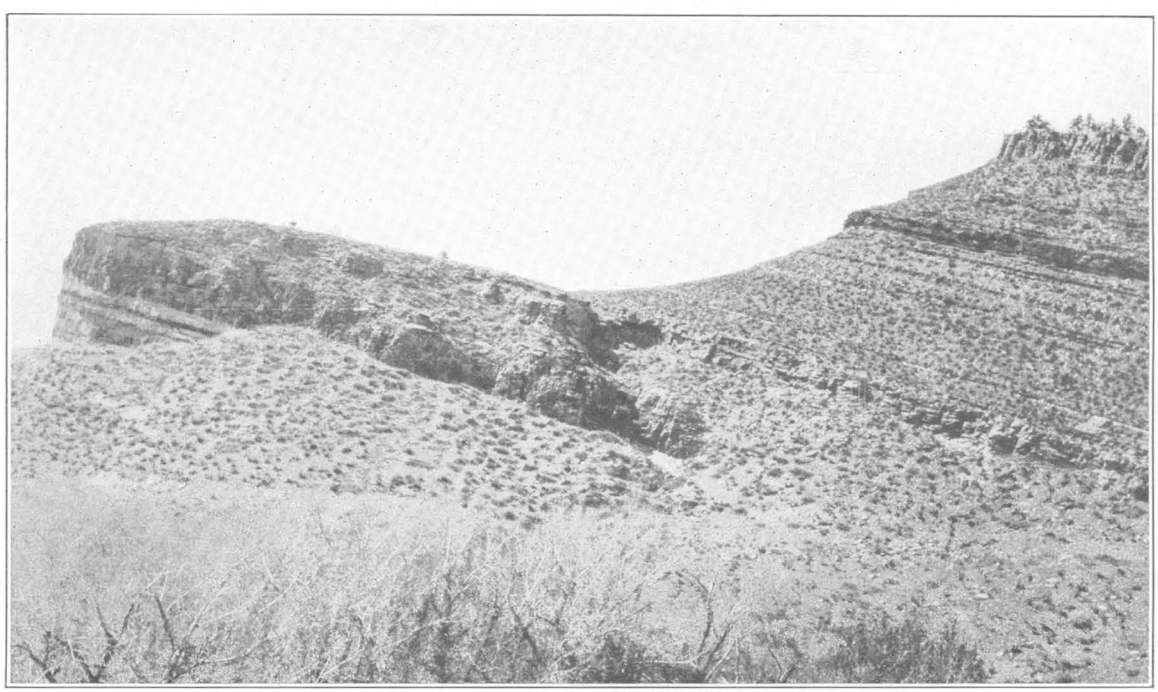
B. FOUNTAIN ARKOSE WEST OF LOVELAND, COLO.

Showing west face of hogback ridge exposing arkose below and dark-red sandstone cliff of the lower member of the Ingleside formation at the crest, separated by an unconformity (*a*)



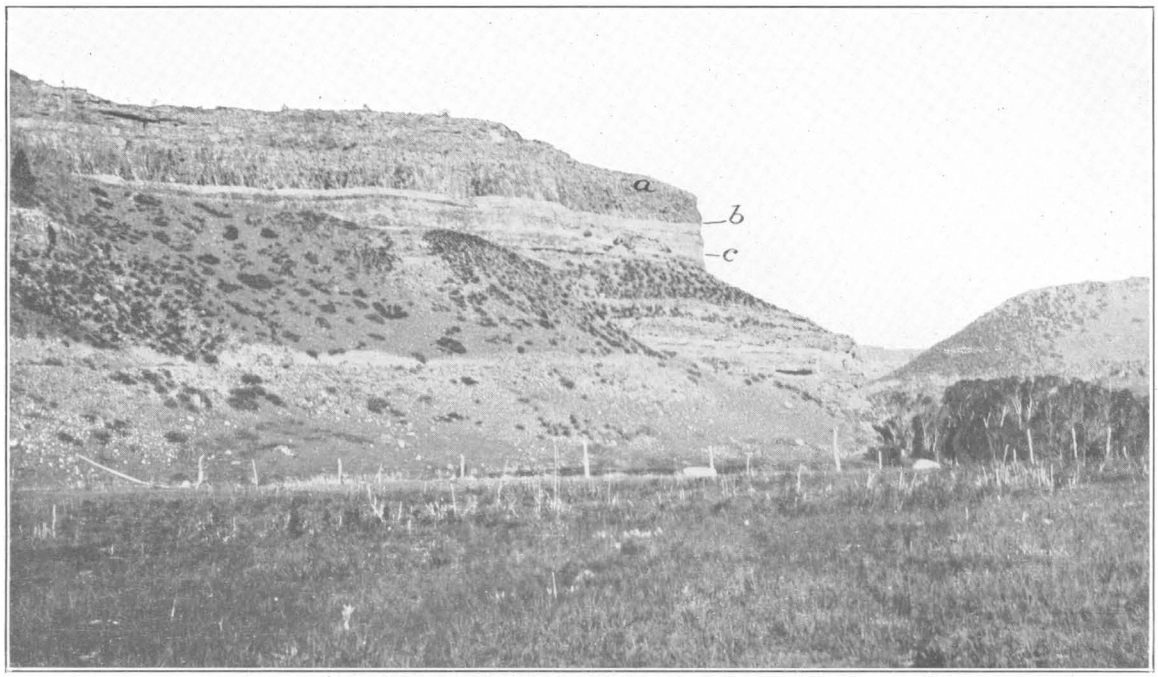
A. NORTH WALL OF GAP AT INGLESIDE, COLO.

Showing limestone and red cross-bedded sandstone in the Ingleside formation. The covered slope at the left is occupied by red sandstone of the lower member of the Ingleside formation, here shaly and soft, and the Fountain arkose



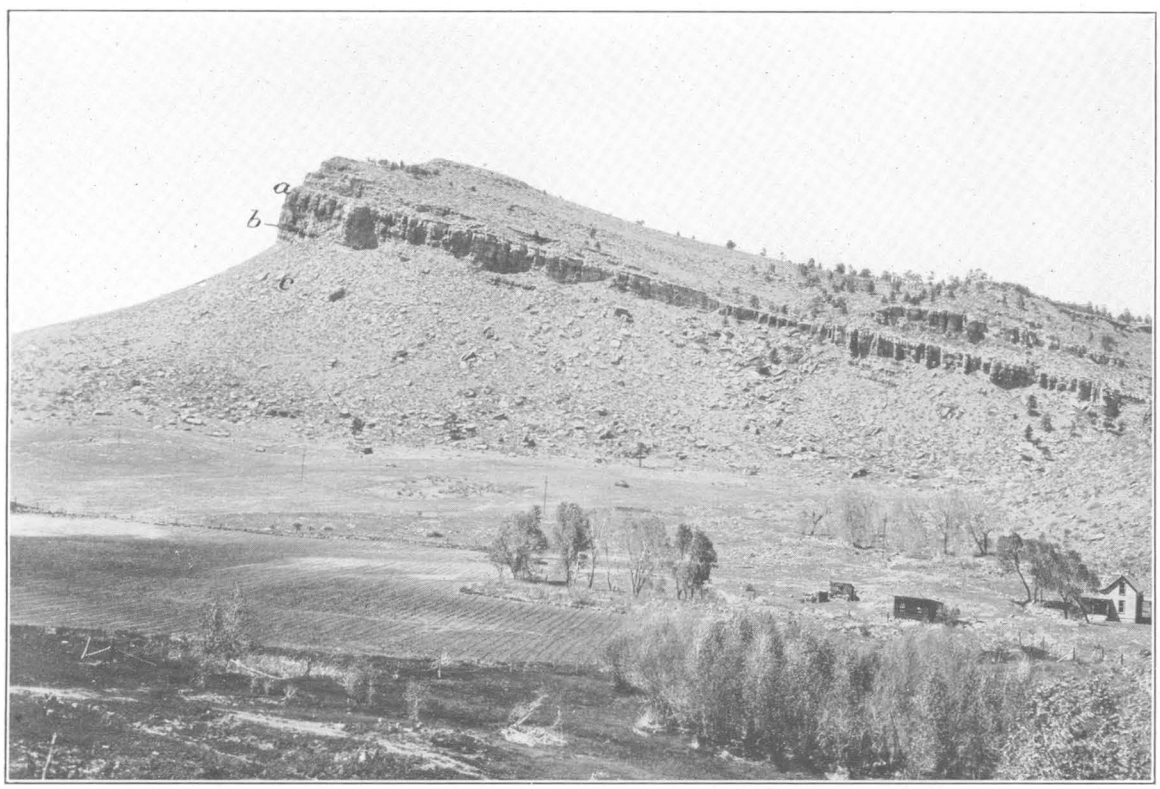
B. RED BEDS IN THE NORTH WALL OF THOMPSON CANYON WEST OF LOVELAND, COLO.

Showing red Fountain arkose at extreme left, unconformably below a cliff of dark-red sandstone formed by the basal member of the Ingleside formation, relatively soft shaly sandstone corresponding in position to the limestone member of the Ingleside, and a capping of Lyons sandstone at the extreme right



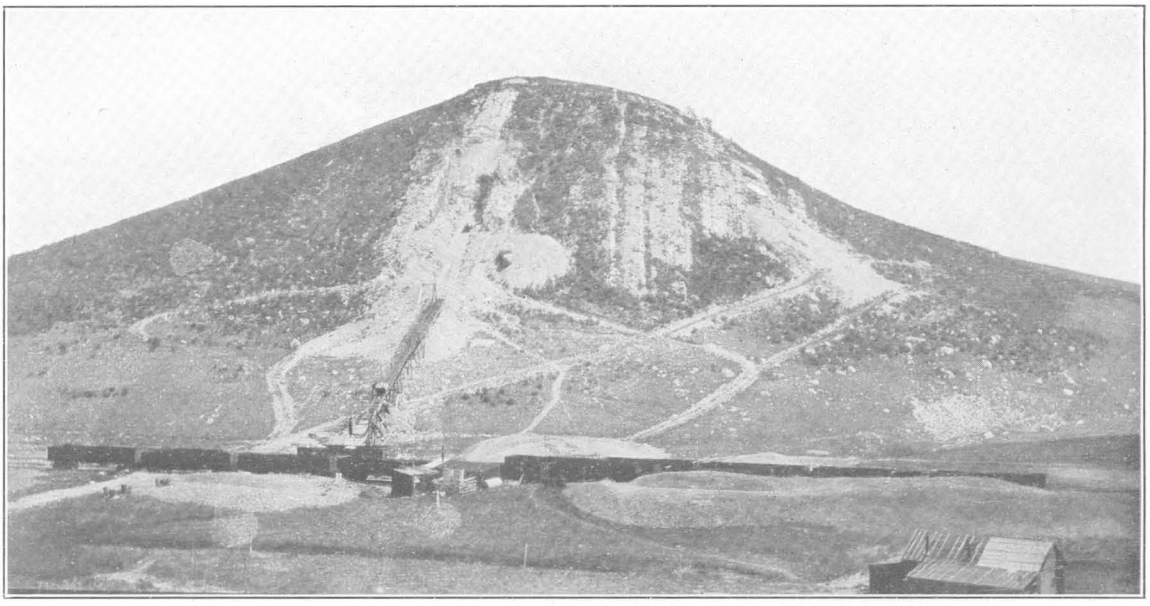
A. FOUNTAIN ARKOSE (*c*) NEAR LOVELAND, COLO.

In west face of ridge north of Thompson River; overlain unconformably at *b* by the basal red sandstone member of the Ingleside formation (*a*)



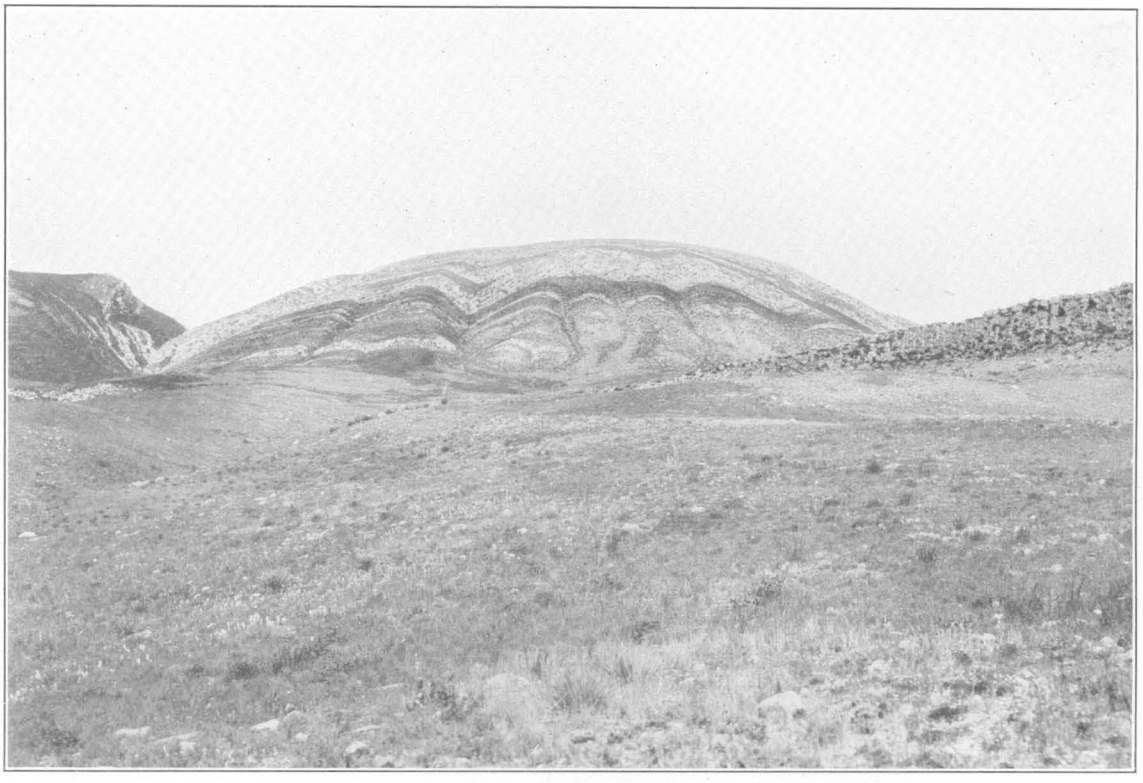
B. STEAMBOAT ROCK, LIVERMORE QUADRANGLE, COLO.

Showing the lower sandstone member of the Ingleside formation (*a*) resting unconformably at *b* on Fountain arkose (*c*), which occupies the débris-covered slope at the left



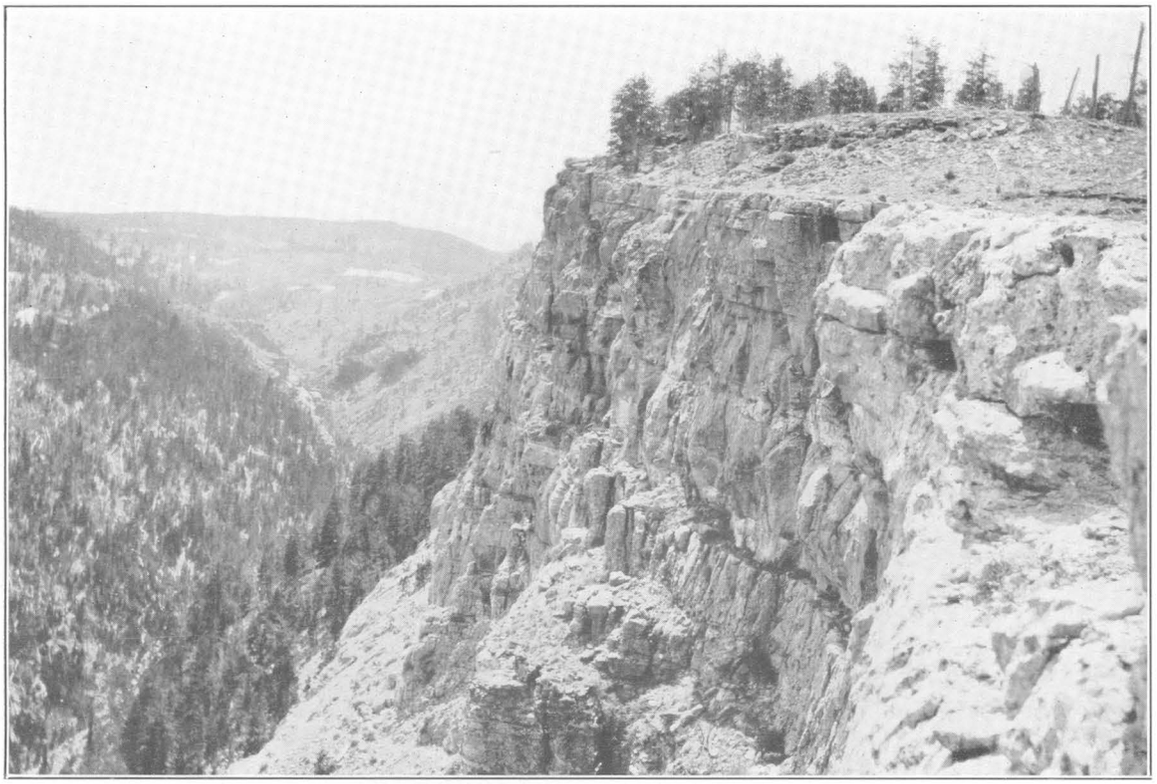
A. LIMESTONE QUARRY NEAR ALTUS, WYO.

Showing the limestone member of the Ingleside formation upturned nearly vertical. The light-colored bands indicate limestone; the dark-colored bands, brush-covered sandstone and shale. The Fountain formation lies to the right and the "Red Beds" to the left



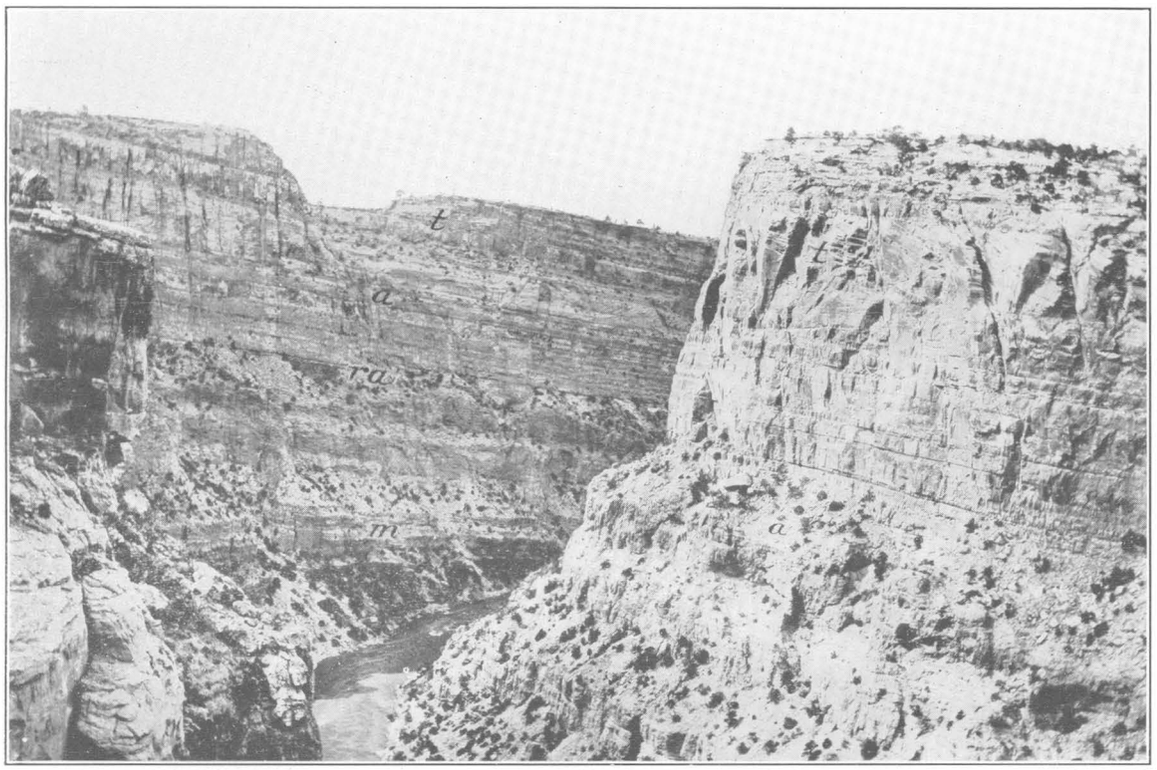
B. A SCALLOPED HOGBACK NEAR IRON MOUNTAIN, WYO.

Showing outcrops of light-colored limestone and dark-red sandstone and shale of the Casper formation. The scalloped appearance is due to erosion on the inclined layers of limestone and shale



A. SANDSTONE AND SANDY LIMESTONE AT THE TOP OF CASPER MOUNTAIN, WYO.

East of the old asbestos mill. Correspond in position to the Tensleep sandstone

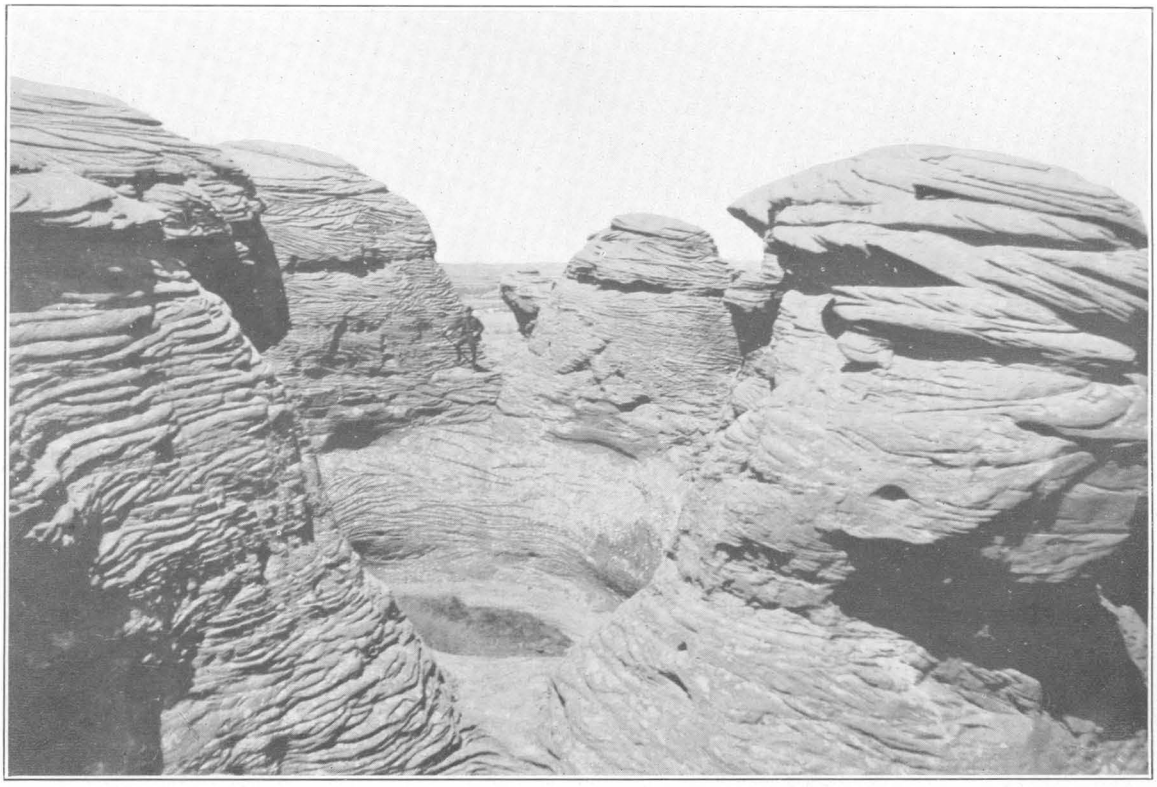


B. CANYON OF NORTH PLATTE RIVER NEAR PATHFINDER, WYO.

The Cambrian quartzite (Deadwood formation) crops out at the river level. The Madison limestone (*m*) rests unconformably on it and unconformably beneath red beds of the Amsden formation (*ra*). The well-stratified beds in the upper part of the walls are the upper part of the Amsden (*a*) and the Tensleep sandstone (*t*)

A. STEAMBOAT ROCK, LIVERMORE QUADRANGLE, COLO.

Showing the resistant cross-bedded sandstone and limestone of the Ingleside formation rising as a ledge above the slope formed on the relatively soft Fountain arkose



B. A WIND-FORMED WELL IN THE TOP OF ONE OF THE RED BUTTES NEAR LARAMIE, WYO.

The rock is cross-bedded red sandstone near the base of the Ingleside equivalent in the Casper formation

ant sandstones form prominent cliffs. Still farther north shaly beds appear near the middle with ledge-making sandstone (see pl. 9, *B*) and finally, in northern Colorado, develop into the limy beds described as the middle member of the Ingleside formation.

In northern Colorado, where the limestone of the Ingleside formation is quarried, there are three layers of limestone (see pl. 9, *A*) separated by layers of intensely cross-bedded red sandstone. The limestone consists of nearly pure calcium carbonate and is quarried for use in the beet-sugar factories. It is hard and resistant and forms a prominent ridge north of Bellvue. North of Ingleside the layers of limestone increase in number and thickness, and in Wyoming they have been included in the Casper formation. Near Horse Creek and Iron Mountain, in southeastern Wyoming, the interbedded red sandstone and shale form only thin partings between layers of massive limestone. At these places the limestones are exposed at the surface (see pl. 11, *A*) and the layers of sandstone and shale are covered with brush (appearing dark in the photograph). These younger Pennsylvanian sedimentary rocks become lighter colored toward the north. The limestones, which in Colorado are pink and sparingly fossiliferous, in Wyoming are gray and in many places rich in fossils. When viewed in cross section the alternating layers of gray limestone and red sandstone give a banded appearance to the exposure, but when viewed in the direction of dip the eroded ridges have a conspicuous and characteristic scalloped appearance, as illustrated in Plate 11, *B*.

North of Iron Mountain these beds are covered for long distances and can not be traced. However, on the evidence of fossils the thick massive limestones of the Hartville uplift are correlated with the Ingleside formation. The greater part of the Casper formation of the Laramie Basin and its equivalents of more westerly localities are practically continuous with the Ingleside and are correlated with it on lithologic and paleontologic evidence and on stratigraphic succession. The Ingleside formation may be the direct shoreward equivalent of the Hartville limestone. West of the Laramie Basin these rocks become still more sandy and merge into the cross-bedded sandstone and sandy limestone (part of the Casper formation) which near Douglas, Wyo., lie on older Casper beds that correspond to the lower red part of the Amsden. West of the mountains in the Laramie Basin the rocks corresponding to the Ingleside formation have been included in the Casper formation, and they are traceable westward and, with relatively small interruptions, northward into regions where they have been called Amsden formation and Tensleep sandstone.

Casper is a name first used in 1908 by Darton [5] for "the limestones and sandstones constituting the greater part of the sedimentary rocks in the Casper and Laramie mountains," which he stated correspond to the Tensleep, Amsden, and Madison formations, of Pennsylvanian and Mississippian age, and which he placed between pre-Cambrian crystalline rocks and the Satanka shale, now classified as Permian. The following year he stated [6] that "the name Casper is here proposed for the rocks of Carboniferous age (chiefly Pennsylvanian) capping Casper Mountain and extending along both sides of the Laramie Range." The Casper Range is capped not only by Pennsylvanian beds but in places by beds of Cambrian, Mississippian, and Permian age. (See pls. 6, *B*, and 12, *A*.) The Casper formation as the name is used in the report on the Laramie Basin and in the Laramie-Sherman folio includes in its upper part the Ingleside formation; near its base, in the southern part of Laramie Basin, arkosic beds which are now known to be Fountain; and, in the northern part of the basin, cherty limestones which belong to the Madison limestone, of Mississippian age. Because the Casper is thus a composite formation the name should, in the writer's opinion, be abandoned, the name Ingleside should be extended to apply to the younger Pennsylvanian rocks included in the Casper formation, and the name Fountain formation should be extended to apply to the older Pennsylvanian beds of the Casper.

In northern and eastern Colorado and southeastern Wyoming the Ingleside part of the Casper consists chiefly of limestone with Pennsylvanian fossils and red cross-bedded sandstone. Toward the west the Ingleside rocks become less limy (see pl. 12, *B*), the fossiliferous layers diminish in number, and the cross-bedded sandstones increase in thickness and become lighter colored. West and north of Casper, Wyo., rocks that have the same stratigraphic position as the Ingleside are known as the Amsden formation and Tensleep sandstone. The fossils on which the age determinations are based are listed in the descriptions of local sections on pages 38–52, 72.

There is not full accord among geologists as to the relation of the Fountain formation to the Ingleside formation. Some regard the Fountain as an older Pennsylvanian formation whose accumulation as a delta fan, chiefly of upland or nonmarine character, was completed before the Ingleside beds were laid down and believe that these younger marine beds represent the spread of the sea over the previously built fan. This view is opposed by S. H. Knight,[7] who has made an intensive study of a relatively small area near Laramie, Wyo. He views the nonmarine arkosic Fountain formation and the marine Ingleside beds as contemporaneous deposits interfingering where the nonmarine deposits meet those of marine origin. This view is attractive in some ways. The fossils do not assist in settling the question, for, according to G. H. Girty, they do not indicate any restricted stage within

[5] Darton, N. H., Geol. Soc. America Bull., vol. 19, pp. 407, 418, 1908.

[6] Darton, N. H., and Siebenthal, C. E., U. S. Geol. Survey Bull. 364, p. 13, 1909.

[7] Knight, S. H., Geol. Soc. America Bull., vol. 27, p. 120, 1916.

the Pennsylvanian epoch. If the deposits are contemporaneous, some place should be found where wedges of arkose extend laterally into the marine deposits. No such place has been described, but many places are known where the arkosic Fountain is separated by an unconformity from the overlying beds, as shown in the sections in Plate 1 and in the photographs reproduced in Plates 8, *B*, and 9.

This unconformity between the Fountain and the overlying Ingleside strengthens the suggestion, previously recorded, that the beds of the Amsden are the northwest extension of the Fountain, for although included in the Amsden formation, they lie in many places and perhaps everywhere unconformably beneath the beds of that formation which carry the known marine fossils of Pennsylvanian age. The details supporting this statement are given in the local descriptions.

The upper limit of the Pennsylvanian series is marked in many places, but not in all, by an obvious unconformity of erosion. South of Spring Canyon, Colo., this unconformity lies at the base of the Lyons sandstone. Still farther south the Ingleside and some of the Fountain formation were eroded away. North of Spring Canyon a red shale formation (provisionally correlated with the Satanka shale of the Laramie region) occurs between the Ingleside formation and the Lyons sandstone. Where this shale is present east of the mountains, between Soldier Canyon, Colo., and Iron Mountain, Wyo., the structural relations are obscure, and no line of separation between the Pennsylvanian and Permian series is confidently drawn. But the occurrence of the shale as a wedge which does not extend south of Soldier Canyon (see pl. 1) suggests that it may belong in the Pennsylvanian series and that the Pennsylvanian-Permian hiatus may occur between the shale and the overlying Lyons sandstone. In central Wyoming, from Douglas to Casper, and in the Rawlins and Lander sections (see pl. 1) the relation of the rocks of Pennsylvanian age to the next younger beds is one of plainly marked unconformity.

The manner in which the formations of Pennsylvanian age disappear toward the south suggests strong post-Pennsylvanian erosion, and there is evidence in many places of the removal of some of the Pennsylvanian beds. This is evidenced in some places by the overlap shown on Plate 1 and by notable changes in lithology. From the lithology as here described and the structure shown on Plate 1 it seems evident that in northern Colorado and southern Wyoming, as in many other parts of the region recently described, there is to be found a well-marked post-Pennsylvanian unconformity. It is believed that this may correspond to the Pennsylvanian-Permian unconformity recognized in Oklahoma and Texas, in many places through New Mexico, and in the Grand Canyon region in Arizona. If the identity of these unconformities is established, the Pennsylvanian-Permian unconformity assumes wide geologic importance.

PERMIAN AND LOWER TRIASSIC FORMATIONS OF WESTERN WYOMING

PHOSPHORIA FORMATION (PERMIAN)

The sedimentary rocks here described as the Phosphoria formation hold the same position in the stratigraphic column as the Phosphoria formation of Idaho and contain many of the same species of fossils. They have been variously treated in Wyoming, where some geologists have included them in a formation called Embar and others in a formation called Park City. The Embar formation of Darton, of which the Phosphoria formation constitutes the lower part, was originally defined by Darton[8] as follows:

> Throughout the Owl Creek uplift there is a prominent series of limestone and chert beds lying between the Tensleep sandstone and the Chugwater red beds. It has been designated the "Embar" formation, from Embar post office and ranch, on Owl Creek. The formation has an average thickness of between 200 and 250 feet, and it usually gives rise to long dip slopes on the flanks of the mountains. The most prominent exposure is in the great dip slope of the high range a few miles south of Thermopolis, where the formation constitutes the surface for many square miles on either side of the canyon of Big Horn River and south of Red Creek. These long slopes are due mainly to a bed of limestone about 50 feet thick, which constitutes the greater part of the upper member of the formation throughout its course. This limestone is underlain by 100 feet or more of cherty shales and overlain by yellowish sandstones and cherty beds.
>
> The formation is extensively exhibited along the mountain slopes to the west, especially on some of the ridges due to anticlines branching from the main uplift. Two of these, northwest and west of Hollands, are especially notable as exhibiting wide areas of the formation. Another appears east of Anchor, crossed by South Fork of Owl Creek in a deep gorge, and there is another extending southeast of Embar. The northwesternmost exposure is in a prominent knob near the head of Middle Fork of Owl Creek, north of which begins the overlap of the Tertiary volcanic series. It appears in the more elevated portion of the anticline which passes through Thermopolis, in a small but characteristic outcrop of limestone and cherty ridges. At a few points along the sides of the higher portion of the central uplift the formation is cut out by faults for a short distance.
>
> In the canyon walls south of Thermopolis the limestone is 50 feet thick. It is a gray rock, of moderately massive bedding and of considerable hardness. This member here lies on about 100 feet of shale, partly limy, filled with oval concretions of chert mostly from 1 to 2 inches in diameter. Next below are alternations of limestone and shale, 25 feet or more in thickness, lying on a thin deposit of sandstone breccia, which in turn lies on Tensleep sandstone. At the foot of the mountain slope the limestone is seen to pass under yellowish sandy beds containing a few thin, impure layers of limestone, in all from 50 to 60 feet thick. In the vicinity of North Fork of Muddy Creek the thickness of the formation is about 250 feet. The limestone member, here about 50 feet thick, lies nearly 100 feet below the top, and there is a thinner limestone at a higher horizon. The other material is shale, containing a large amount of nodular chert. Toward the top the beds are sandy and in

[8] Darton, N. H., 59th Cong., 1st sess., S. Doc. 219, pp. 17–18, 1906.

most places of a bright yellow color. On the south slope of the anticline, 6 miles due west of Holland's ranch, the following section of the formation was measured:

Section of Embar limestone 6 miles west of Holland's ranch

	Feet
Compact gray sandstone, weathering brown, merging downward into brownish-gray and yellowish soft sandstone	50
Light-colored massive limestone	30
Nodular dark-colored limestone, in part cherty	80
Dark-gray fossiliferous sandstone	4
Light buff-colored soft sandstone, with layers of limestone, lying on Tensleep sandstone	60

In the vicinity of Embar the limestone member is 50 feet thick. In the region near Anchor post office the top member of the formation consists of 20 feet of soft buff sandstone, which lies immediately on the massive limestone. On Dry Creek, 6 miles northeast of Black Mountain, the formation is very much thicker than observed elsewhere. At the base are nearly 200 feet of sandstones and limestones. The characteristic medial limestone is 30 feet thick and highly fossiliferous. It is overlain by over 200 feet of slabby brown sandstones, with some layers of buff soft sandstone, extending to the base of the Chugwater red beds.

As the language used in the report just quoted has been interpreted to include definitely in the Embar the beds exposed south of Thermopolis (see pl. 14, *A*) immediately above the limestone of the Phosphoria formation, and as this interpretation has been widely accepted, it seems proper that the intent should be stated by the author quoted. This is done in the following personal communication, dated February 1, 1925:

In reply to your inquiry as to the classification of the lower red beds lying on the limestone with *Spiriferina pulchra* in the gorge of Big Horn River south of Thermopolis, it was my belief that these beds were Chugwater and not part of the Embar formation.

The Embar formation at Embar post office and near Thermopolis, as described by Darton is represented in many places farther to the southwest in the Wind River Mountains (see pl. 14, *B*) where it has been described by Blackwelder,[9] Condit,[10] and others, who have divided it into the Dinwoody and Park City formations (the latter the Phosphoria of this report). The Phosphoria formation contains marine fossils that establish its Permian age and correlate it with the Phosphoria of southeastern Idaho. It lies unconformably on a sandstone that has been correlated with the Tensleep sandstone. (See pl. 5, *B*.) In the writer's opinion it thins out toward the east, although Condit maintained that it interfingers with the Chugwater red beds. It is described as only 55 feet thick in the southeastern part of the Big Horn Basin, on No Wood Creek, and is either absent farther north, near Tensleep, or so changed in character that it can not be distinguished from the "Red Beds." Also farther to the south it thins eastward. It is represented in the Rattlesnake Mountains, near Casper, where a characteristic Phosphoria fauna has been found, but it is not certainly known farther east, although certain fossils found in the Laramie Basin suggest that remnants of the Phosphoria may occur farther east. This thinning out of the formation toward the east, considered in connection with the abrupt change in lithology to the overlying beds, strongly suggests a period of erosion following Phosphoria time. The plane of unconformity that marks this period of erosion seems to be the same as the one recognized farther east in Wyoming between the upper sandstone (correlated with Tensleep sandstone) member of the Casper formation of the Casper-Douglas region and the overlying red beds; also the one in northeastern Colorado between the Ingleside formation and the Lyons sandstone, and still farther south between the Fountain and Lykins formations. (See pl. 1.)

[9] Blackwelder, Eliot, U. S. Geol. Survey Bull. 470, pp. 452–483, 1911; Washington Acad. Sci. Jour., vol. 8, pp. 417–426, 1918.

[10] Condit, D. D., U. S. Geol. Survey Prof. Paper 98, pp. 263–270, 1917.

DINWOODY FORMATION (LOWER TRIASSIC)

In many places in the Owl Creek and Wind River mountains and elsewhere in western Wyoming sandy beds, shaly beds, and limestones occur above the typical fossiliferous limestones of the Phosphoria formation, which seem more nearly like the underlying than the overlying rocks. Above these are still other beds which are more nearly like the overlying Chugwater red beds than like those of the underlying Phosphoria. All the beds in western Wyoming above the "*Spiriferina pulchra* limestone" and below the Chugwater red beds were named Dinwoody formation by Blackwelder,[11] who defined the formation as follows:

The upper part of Darton's Embar formation consists in this region (western Wyoming) of greenish-gray shales, with many thin plates of dense calcareous sandstone, or argillaceous dolomite, which weathers brown, tawny, and even black. This portion—which is to be distinguished from the lower or Park City portion of the Embar—is 250 feet thick at Dinwoody Creek, on the north slope of the Wind River Range, but thins down to less than 50 feet near Lander. In the Owl Creek Mountains it is 75 to 100 feet thick near Anchor. Eastward, near Thermopolis, the formation becomes gypseous, and more or less reddish in color. Mr. D. Dale Condit[12] has traced it into the Big Horn Range, where it merges with the lower part of the Chugwater red beds. Westward it becomes progressively thicker, more calcareous, and more fossiliferous and changes by imperceptible gradations horizontally into the Woodside and Thaynes formations of southeastern Idaho. It is about 210 feet thick on Crystal Creek in the Gros Ventre Range, 350 feet thick at the north end of the Hogback Range, and thence into Idaho it rapidly increases in volume.

The Dinwoody formation is conformable both above and below. Although some beds contain abundant Lingulas and poorly preserved pelecypods, no fossils of diagnostic value have been found in it in Wyoming. From its stratigraphic position, conformably between the Park City and Chugwater formations, and from its relation to the Woodside and Thaynes formations in Idaho, which are classified as Lower Triassic, it is inferred

[11] Blackwelder, Eliot, Washington Acad. Sci. Jour., vol. 8, p. 425, 1918.

[12] Condit, D. D., U. S. Geol. Survey Prof. Paper 98, pp. 263–270, 1916.

that the Dinwoody formation is either Permian or Lower Triassic or both. The name is derived from the canyon of Dinwoody Lakes, in the Wind River Range, where the formation is completely exposed and has been measured in detail.

In the section on page 424 of the report just quoted Blackwelder gave a detailed section of the Dinwoody, which showed it resting on the "*Spiriferina pulchra* limestone," the top member of his Park City formation (Phosphoria formation of this report). The Dinwoody formation as thus defined by Blackwelder includes some yellow gypsiferous material which the writer considers as more properly belonging in the lower part of the Chugwater formation. These yellow gypsiferous beds south of Thermopolis, Wyo. (pl. 14, *A*), are correlated by Condit[13] and Blackwelder[14] with the typical Dinwoody beds.

The writer holds to the view that the yellow gypsiferous beds in the Big Horn Basin and perhaps also some of the beds that have been included in the Dinwoody at more southerly localities rest unconformably on the Phosphoria formation. Further description of these beds will be found on pages 48–77.

PERMIAN AND TRIASSIC "RED BEDS"

GENERAL FEATURES

The "Red Beds" of this part of the Rocky Mountain region constitute a conspicuous group of sedimentary rocks lying above the formations of Pennsylvanian age and below those of Jurassic age, or still younger formations where Jurassic rocks are absent. This group includes several distinct formations, some of which contain no fossils and others are so sparingly fossiliferous that their geologic age is not fixed beyond question. Some of the several formations have been described as they occur in small areas, but their exact correlation has not been established. For these reasons it is necessary to devote more space to the "Red Beds" than is given to some of the better-known formations.

These red rocks are present at all the localities in Colorado and Wyoming described in this paper and at some of those in Montana. They thin northward and disappear in southern Montana. How much of this thinning out toward the north is due to nondeposition is not known, but the obvious erosion of their upper surface in Colorado and Wyoming indicates that much of the thinning is due to erosion prior to the deposition of the overlying beds of Jurassic age.

CHUGWATER FORMATION

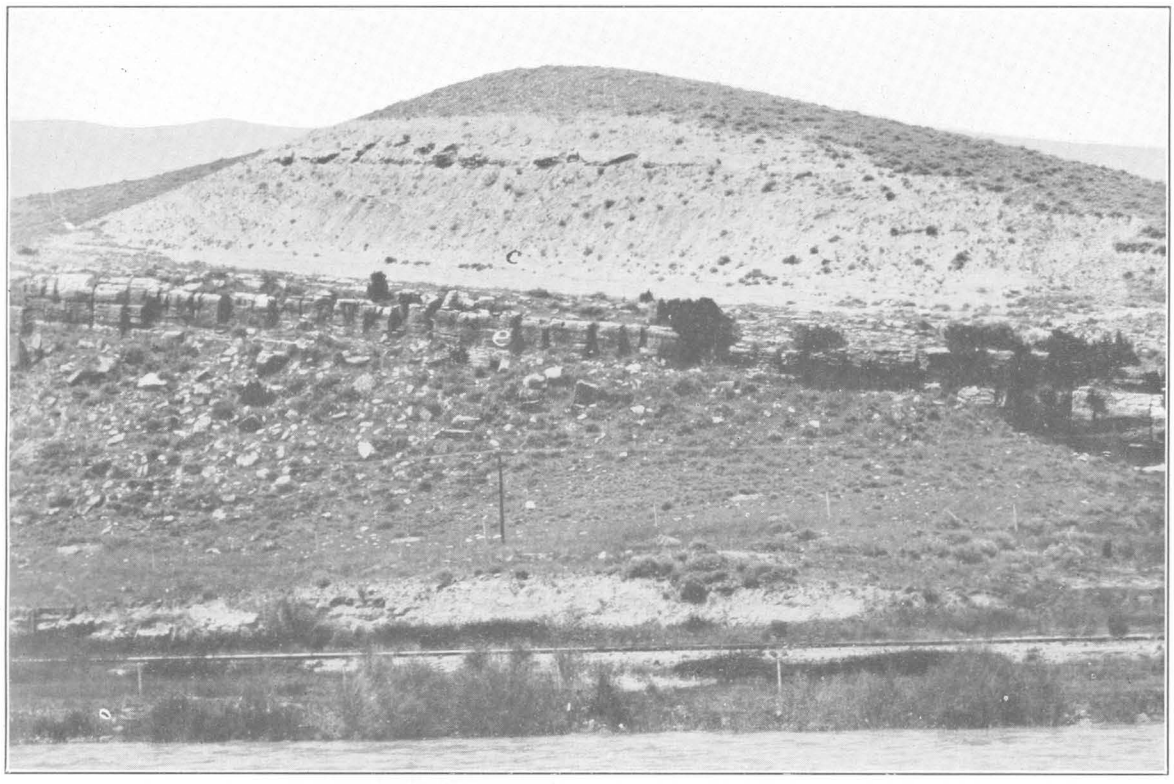
As originally defined, in 1904, by Darton,[15] the name Chugwater was "proposed for the series of red beds extending along the foot of the Big Horn Range southward through Wyoming and Colorado." The formation was named for its exposures on Chugwater Creek in southeastern Wyoming. The Chugwater formation as thus defined included all the red beds between the Tensleep sandstone (Pennsylvanian) and the Sundance formation (Jurassic). This definition of Chugwater has been generally followed, although some parts of the "Red Beds" have been described at one time or another under other names. Parts of the lower "Red Beds" have been called Opeche shale and the same beds later named Satanka shale, near Laramie; the limestone overlying the Satanka shale has been called Minnekahta limestone and later named Forelle limestone in the Laramie Basin and elsewhere; and the name Embar formation has found wide acceptance among operators in the Wyoming oil fields not only for the light-colored limy and gypsiferous beds underlying the Chugwater red beds in the Big Horn Mountains and throughout western Wyoming but also for correlated limy beds occurring in the lower part of the Chugwater red beds of southeastern Wyoming. (See pl. 1.)

Part of the upper Chugwater has been called the "Popo Agie beds" and later the Jelm, a formation of Upper Triassic age. A limestone lower in the Chugwater containing marine fossils of probable Triassic age is in this report named Alcova limestone member of the Chugwater formation.

LYKINS FORMATION

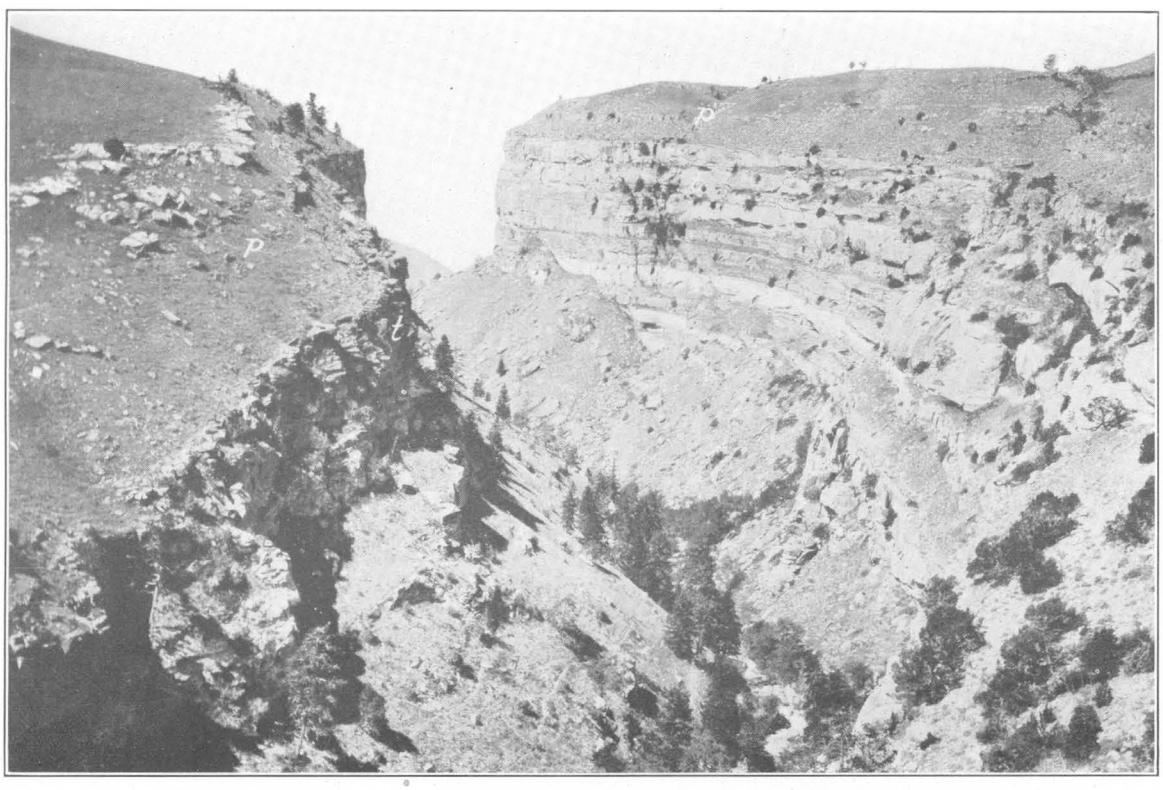
The "Red Beds" in Colorado, which are essentially equivalent to the Chugwater of southeastern Wyoming, have been named Lykins, from Lykins Gulch, in northeastern Colorado.[16] The Lykins formation differs from the Chugwater in the absence of the Alcova limestone and the gypsiferous red beds above that limestone, although the still younger Jelm formation is in places recognized in the Lykins. The lower limit of the Lykins has not been drawn at the same horizon in all places. At its type locality the formation includes the beds between the underlying Lyons sandstone and the overlying Morrison formation. Thus it is essentially the same as Eldridge's "Upper Wyoming"[17] of Denver Basin. But at more northerly localities, as in Soldier Canyon and Owl Canyon, Colo., a shale supposed to be the equivalent of the Satanka shale of the Laramie and Sherman quadrangles of Wyoming occurs beneath the Lyons sandstone, which in turn underlies the Lykins formation. As this shale in southeastern Wyoming is included in the Chugwater formation, although it is excluded from it in the Laramie Basin,[18] the Chugwater may contain beds older than the Lykins formation.

[13] Op. cit., p. 264.
[14] Op. cit. p., 425.
[15] Darton, N. H., Geol. Soc. America Bull., vol. 15, p. 397, 1904.
[16] Fenneman, N. M., U. S. Geol. Survey Bull. 265, p. 24, 1905.
[17] Eldridge, G. H., U. S. Geol. Survey Mon. 27, 1896.
[18] Darton, N. H., and others, U. S. Geol. Survey Geol. Atlas, Laramie-Sherman folio (No. 173), 1910.



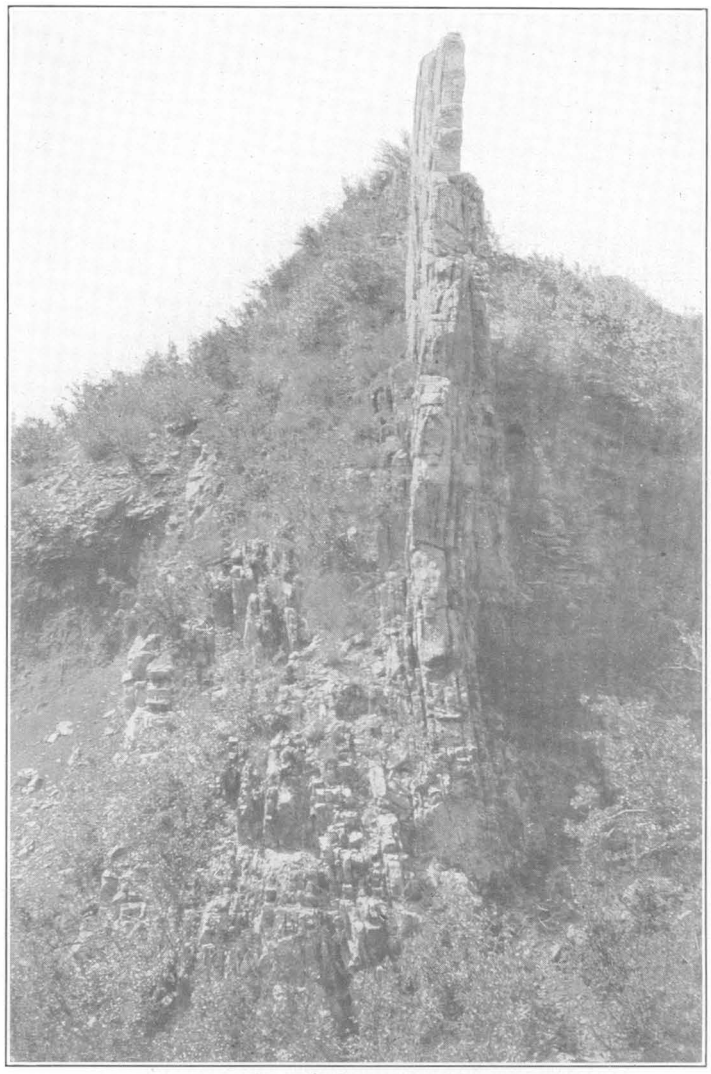
A. EXPOSURE AT THE MOUTH OF THE CANYON OF BIG HORN RIVER NEAR THERMOPOLIS, WYO.

Showing a ledge formed by the top limestone of the Phosphoria formation (*e*), overlain by pink to yellow shale (*c*) containing gypsum and thin layers of limestone. The yellow beds are lithologically distinct from the underlying massive limestone and probably younger than Dinwoody, although they have been correlated with the Dinwoody formation of the Wind River Mountains by Blackwelder and others



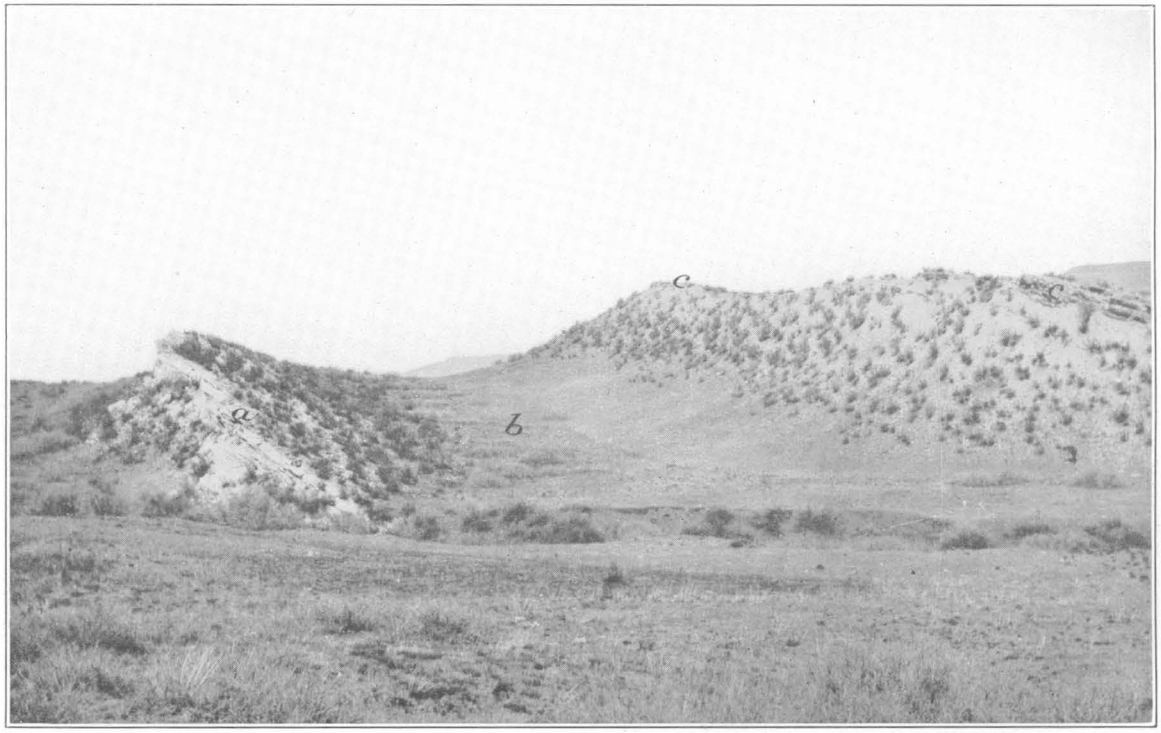
B. CANYON OF LITTLE POPO AGIE RIVER SOUTH OF LANDER, WYO.

Showing walls of Tensleep sandstone (*t*) and gentle slopes above the cliffs formed on the Phosphoria beds (*p*)



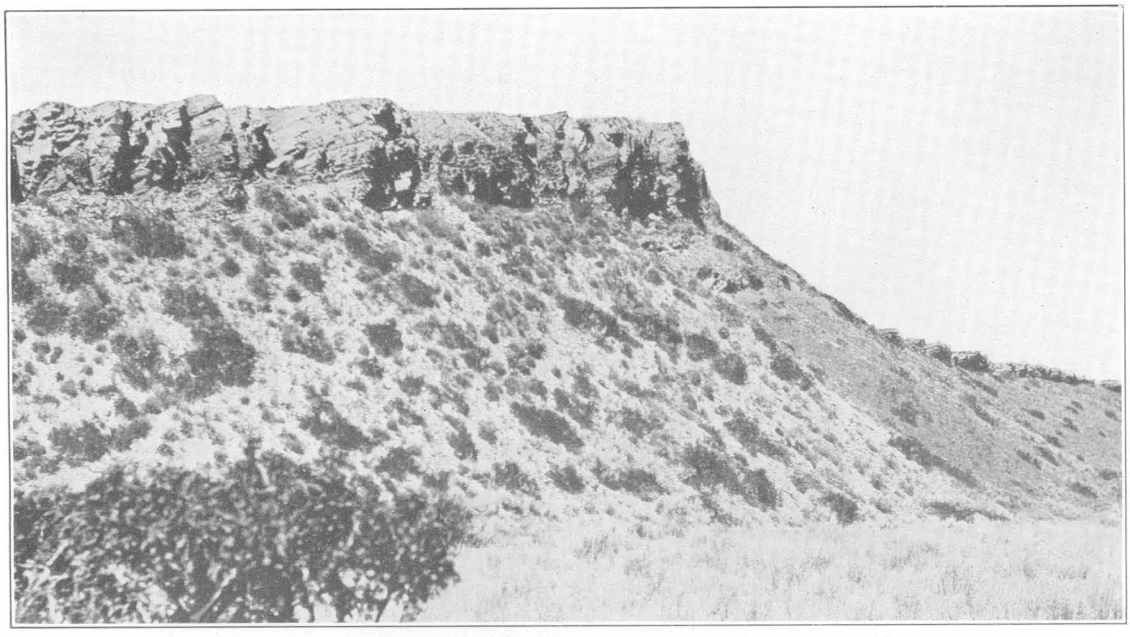
A. LIMESTONE NEAR THE BASE OF THE "RED BEDS" UPTURNED TO A NEARLY VERTICAL POSITION NEAR HORSE CREEK, WYO.

Correlated with the Forelle limestone of Laramie Basin



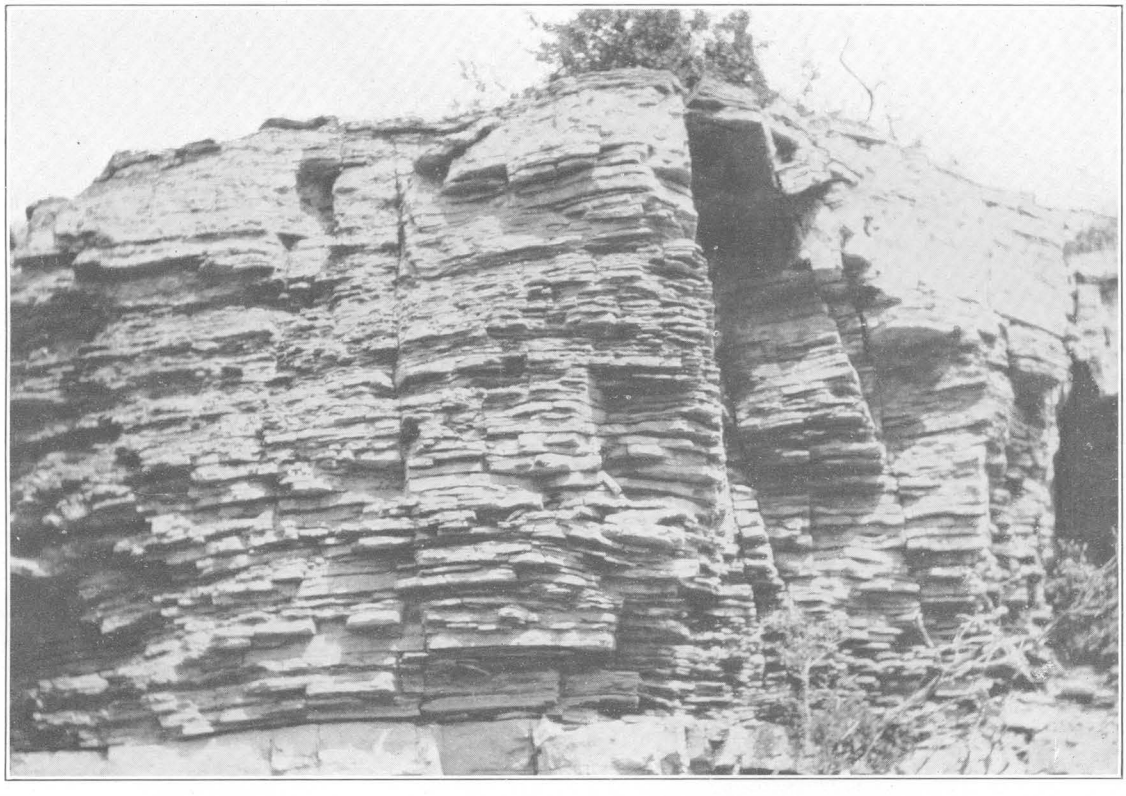
B. VIEW ABOUT 4 MILES SOUTH OF GREENACRE RANCH ON BOXELDER CREEK, COLO.

Showing Lyons sandstone (*a*), a strike valley eroded on red shale (*b*), and a ridge formed by thin layers of limestone, one of which consists of limestone breccia (*c*)

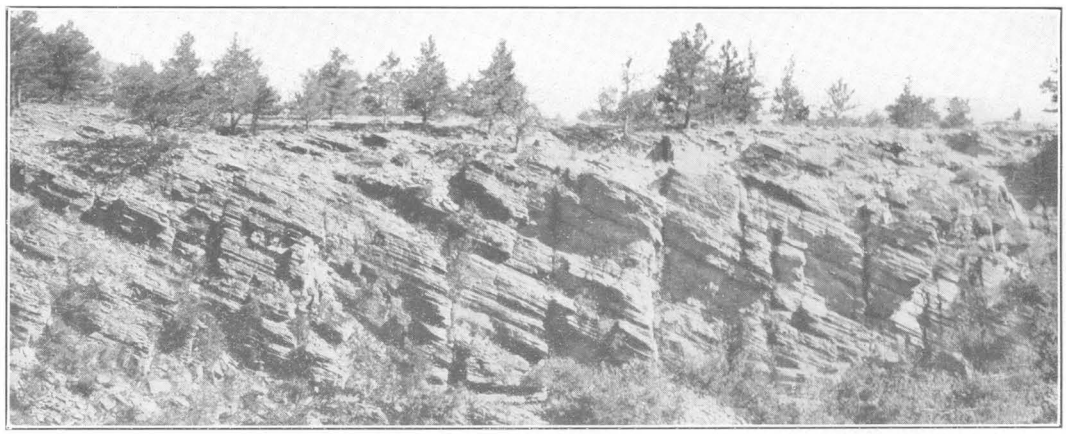


A. LIMESTONE NEAR THE BASE OF THE "RED BEDS" OVERLYING RED SHALE AT THE WEST END OF CASPER MOUNTAIN, WYO.

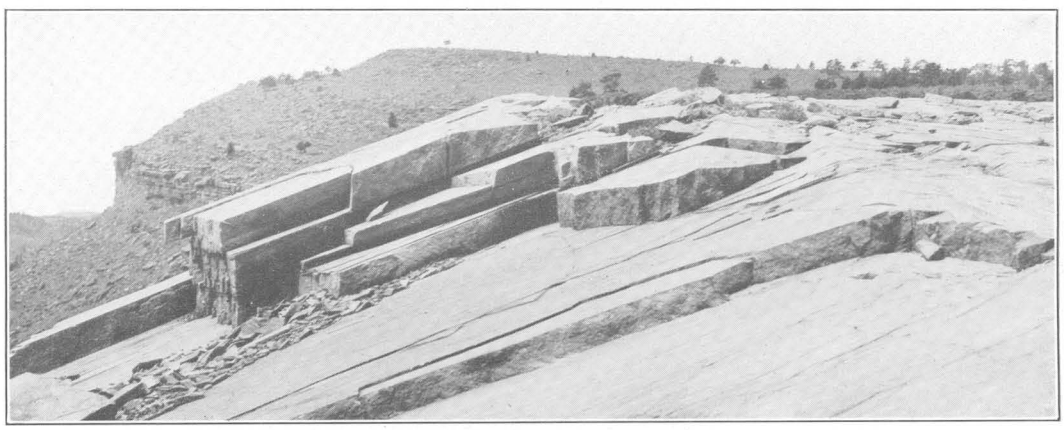
Fossils of Permian age were found here. These beds have been provisionally correlated with the Forelle limestone and Satanka shale



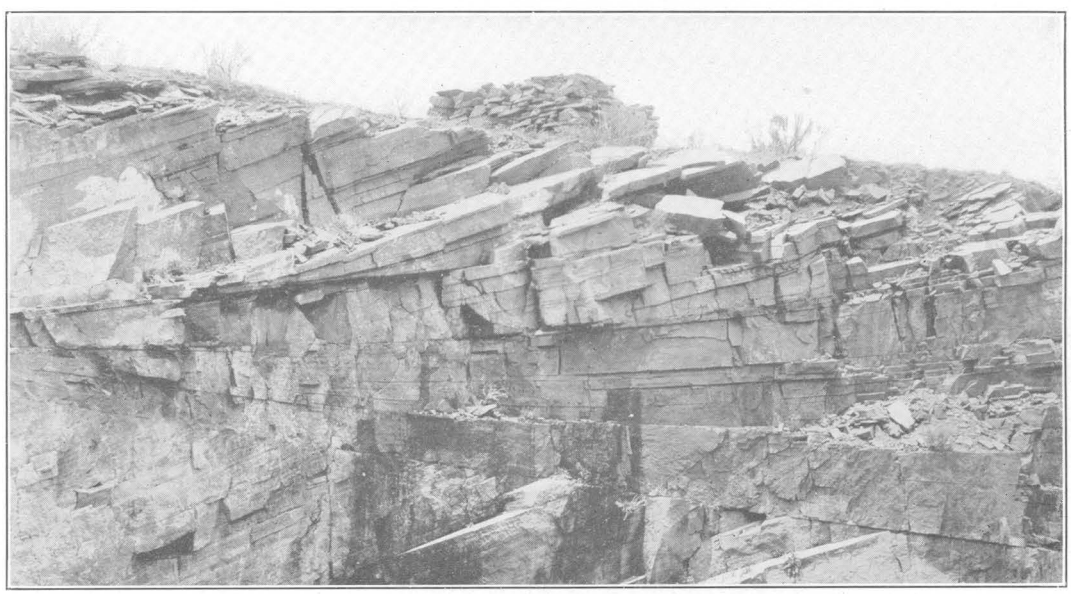
B. NEAR VIEW OF THE LIMESTONE PROVISIONALLY CORRELATED WITH THE FORELLE AT THE MOUTH OF BOXELDER CANYON, WEST OF DOUGLAS, WYO.



A



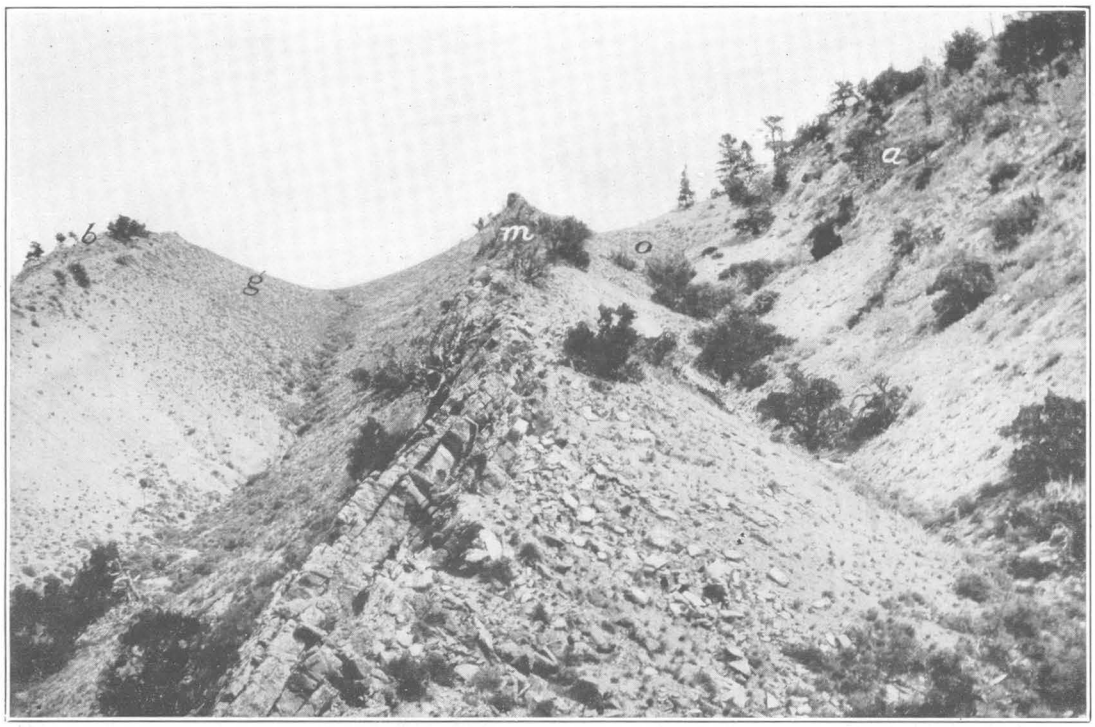
B



C

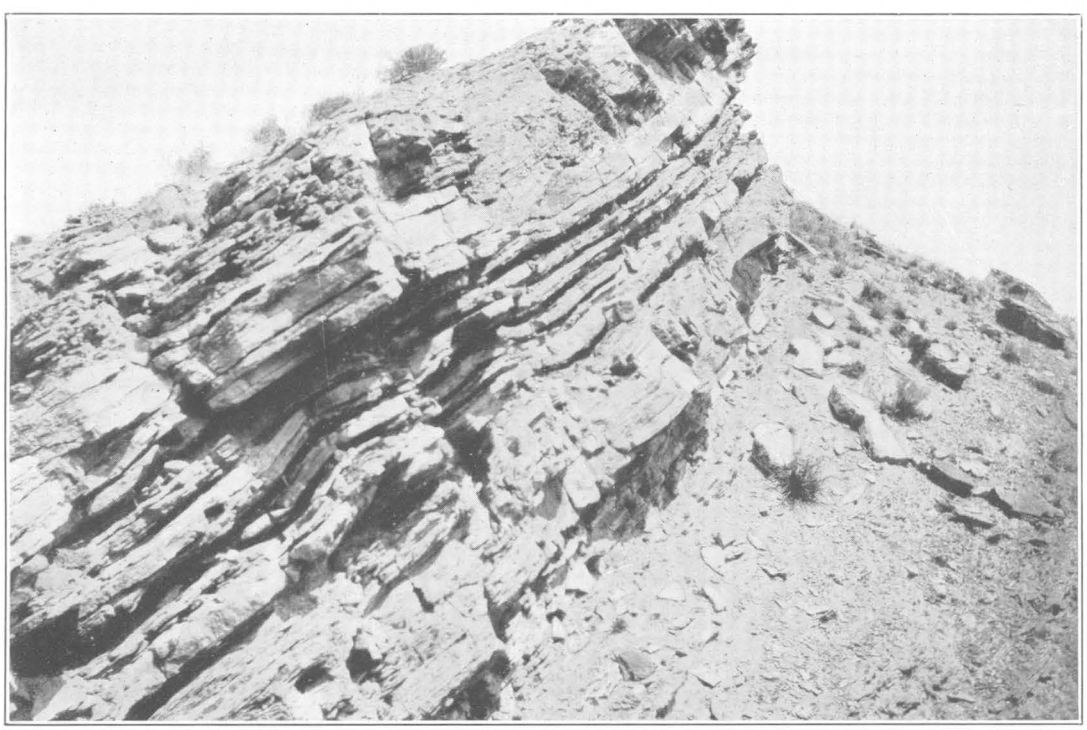
LYONS SANDSTONE AT LYONS, COLO.

In *A* the cross-bedding extends from the top nearly to the bottom of the formation, and the trees stand on the slightly eroded upper surface, or bedding plane. In *B* the eastward-sloping upper surface appears at the sky line and the westward-sloping faces of the laminae exposed in the quarry appear in the foreground. In *C* the face shows sharp boundaries between groups of the cross-bedded layers and the truncation of the older layers before the younger ones were laid down, thus forming an angular unconformity in miniature



A. VIEW A MILE WEST OF DIFFICULTY, WYO.

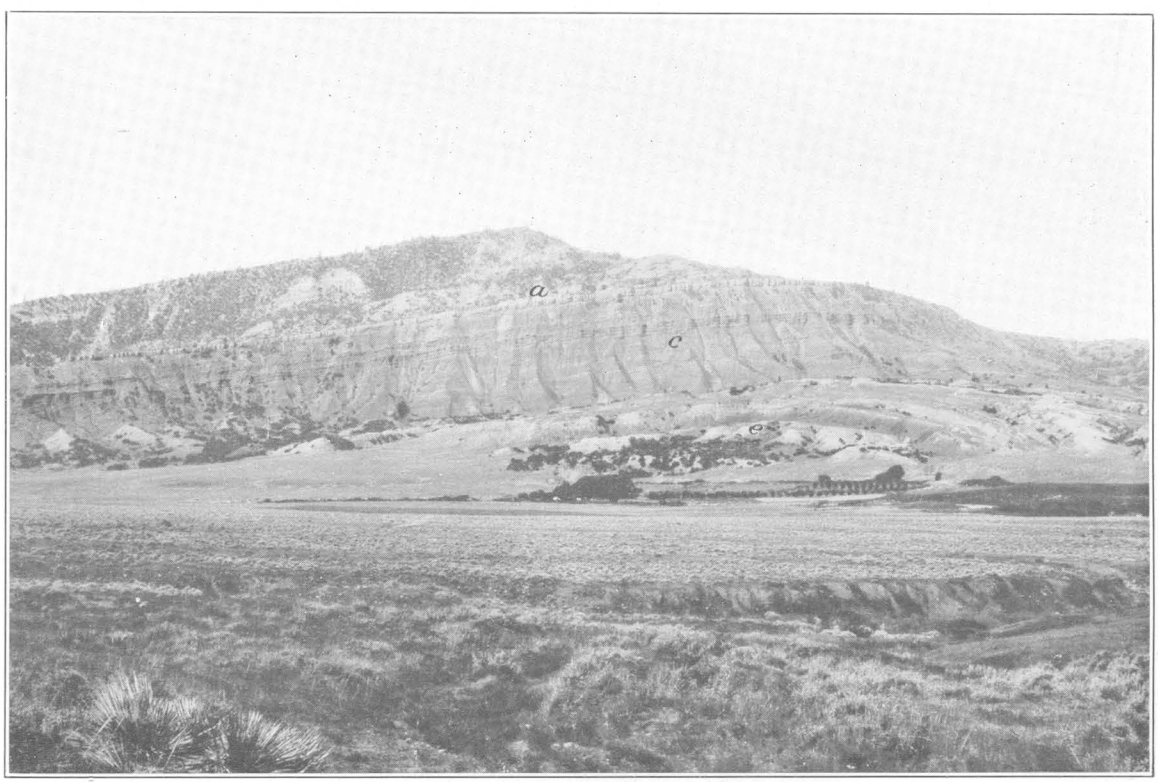
Showing a hard sandstone at the top of the Casper formation (*a*); a valley formed on red Satanka (?) shale (*o*); a sharp ridge of Forelle (?) limestone (*m*), called Minnekahta by Darton; a valley eroded in gypsiferous red shale (*g*); and a ridge formed by a limestone breccia (*b*)



B. NEAR VIEW OF THE "CRINKLED" LIMESTONE ABOUT 2 MILES WEST OF DIFFICULTY, WYO.

Forelle (?); called Minnekahta by Darton

A. LIMESTONE BRECCIA IN THE LOWER PART OF THE LYKINS FORMATION ABOUT 4 MILES SOUTH OF GREENACRE RANCH, IN BOXELDER VALLEY, COLO.



B. NORTH FACE OF GOOSE EGG MOUNTAIN, NEAR CASPER, WYO.

Showing the light-colored rocks (*e*) in the lower part of the "Red Beds," the Embar of the oil men; the evenly bedded overlying red beds (*c*) of the Chugwater formation in the steep slope; the ledge of Alcova limestone (*a*), which contains fossil invertebrates of probable Triassic age; and the younger formations up to early Cretaceous, which forms the crest

EMBAR FORMATION OF OIL GEOLOGISTS

The lower part of the "Red Beds"—that is, of the Lykins formation of Colorado and the Chugwater formation of Wyoming—consists of limestone, some of which is dolomitic, and soft red sandy shale, which in many places contains thick beds of gypsum. In Colorado, between Colorado Springs and Morrison, the lowest member consists of shale, less than 50 feet thick, which Darton compared with the Opeche formation of the Black Hills. Above this shale is a thin faintly purple limestone which the same writer compared with the Minnekahta limestone of the Black Hills and which he referred to as the "crinkled limestone." Others have grouped it with certain sandy beds and called it the "crinkled sandstone." It is overlain by soft red shale and thin layers of limestone, one of which, usually the highest one, is a limestone breccia.

North of Morrison the Lyons sandstone underlies this group of limy strata, and north of Spring Canyon there is a still older shale formation below it. The disappearance of the Lyons sandstone toward the north makes uncertain the correlation of individual beds of this limy group farther to the north, where they can not be traced because of the cover of younger rocks. The group as a whole persists, however, and in the Laramie Basin and in the eastern foothills of the mountains east of this basin it consists of the Satanka shale, the Forelle limestone (see pl. 15, *A*), and still younger beds, including the limestone breccia. Still farther north and west (see sections on pl. 1) the group has more nearly the aspect and constitution exhibited in northern Colorado. In brief, the Satanka shale of some localities, although now classified as Permian, may belong with the younger Pennsylvanian beds.

In the western part of the area described this group of limy beds was included by Condit[19] in the Embar formation as defined by Darton and as later described by Blackwelder[20] on the supposition that the Embar of the more westerly localities—the Park City (Phosphoria of this paper) and the overlying Dinwoody of Blackwelder—changed in character eastward and merged laterally into basal Chugwater. The exclusion of the limy gypsiferous beds from the Chugwater formation of some areas and the inclusion of correlated limy beds in the Chugwater of other areas has led to confusion.

Farther south Hares[21] observed similar beds in several places east of Lander. But they are not present near Casper, nor were they found at any place east of that city. Some have supposed that these beds change in character eastward and merge into the group "consisting mostly of red shales, with some limestone, fossiliferous red and green chert, and gypsum" at the base of the "Red Beds" east of Casper, where they have been included in the Chugwater formation of that area. Here they consist of (1) a basal red shale which Barnett[22] correlated doubtfully with the Satanka shale of the Laramie Basin; (2) a younger limestone which he correlated doubtfully with the Forelle limestone of that basin; and (3) still younger limestones and gypsum which he included in the overlying Chugwater formation. Similar subdivisions were recognized in most of the localities examined by the writer. Although the group is believed to be continuous, it is improbable that the subdivisions are exactly the same in all places. Some of the divisions of this limy group have been described under distinctive names; others equally important, in both a stratigraphic and an economic sense, have not been named. Those that have been named are the Satanka shale, the Forelle limestone, the Lyons sandstone, and the Phosphoria and Dinwoody formations. The Satanka, Forelle, and Lyons are described on the following pages. The Phosphoria and Dinwoody have been described above.

SATANKA SHALE

In an early report on the geologic formations of Wyoming Darton[23] compared a shale at the base of the "Red Beds" with the Opeche formation of the Black Hills. This usage was followed in several later reports, although the correlation was sometimes questioned. But in his report on the Laramie Basin (Bulletin 364) and in the Laramie-Sherman folio the name Satanka shale was used in place of Opeche formation.

The correlation of the Satanka shale of the Laramie Basin with the similarly situated shale of neighboring localities depends on lithologic similarity and sequence of formations. It has been supposed to be correlatable with the shale in the Douglas-Casper region (see pl. 16, *A*), which rests unconformably on the sandstone there regarded as the Tensleep, and with the thick red shale east of the Laramie Mountains shown in the Iron Mountain and Horse Creek sections above the Casper formation. This shale extends southward and appears to underlie the Lyons sandstone in Colorado. At several of the Colorado localities described in this paper the shale above the Lyons sandstone has been called Opeche (?).[24] (See pl. 15, *B*.) If the correlation of the Satanka with the lower shale is correct, the Opeche (?) of Colorado is younger than the shale that has been called Opeche at certain localities in southeastern Wyoming.

In the absence of fossils from this shale there is no direct evidence of its geologic age. The close association of the supposed equivalent of the Satanka shale

[19] Condit, D. D., op. cit.
[20] Blackwelder, Eliot, op. cit.
[21] Hares, C. J., U. S. Geol. Survey Bull. 641, p. 243, 1917.
[22] Barnett, V. H., U. S. Geol. Survey Bull. 541, pp. 49–88, 1914.
[23] Darton, N. H., Geol. Soc. America Bull., vol. 15, pl. 35, 1904.
[24] Darton, N. H., U. S. Geol. Survey Prof. Paper 32, p. 84, 1905.

with the fossiliferous Permian beds above and the unconformable relations with underlying Pennsylvanian beds indicate its probable Permian age. On the other hand, the Satanka of the Laramie and Sherman quadrangles and of correlated beds in northern Colorado seems more closely related to the underlying Pennsylvanian beds.

LYONS SANDSTONE (REDEFINED)

A hard ledge-making sandstone, 100 feet thick, characterized by conspicuous cross-bedding, occurs at Lyons, Colo., from which it takes its name. It differs in general appearance from all neighboring rocks. It is of light-red or pink color, consists almost wholly of coarse sand, contains a few small pebbles in some places near the base, and is separated by an inconspicuous erosional unconformity from the older rocks. The most conspicuous peculiarity of the sandstone is its cross-bedding. In some places the inclined layers lie at angles of 35° or less from top to bottom of the formation, as shown in Plate 17, *A*, and are so regular in thickness and so smooth faced that they afford excellent flagstones of large size (pl. 17, *B*). In other places the cross-bedding extends only part way through the formation. In still other places the bedding planes are curved and cross-bedded masses wedge out between other cross-bedded masses, as shown in Plate 17, *C*.

As originally defined[25] some of the red sedimentary rocks here referred to the Ingleside formation were included in the Lyons sandstone, for the Lyons was said to rest on the Fountain. However, the original description applies chiefly to the cross-bedded upper part (popularly called "Creamy" sandstone because of its light color), which is the Lyons of the present paper. The inclusion in the Lyons formation of sandstones here referred to the Ingleside formation and the miscorrelation of these older sandstones with beds in the upper part of the Fountain formation farther south have led to confusion, which is dispelled by following the formations at the outcrop to points where both the Lyons sandstone as here redefined and the underlying Ingleside formation wedge out toward the south.

The Lyons sandstone as here redefined is traceable by its stratigraphic position and physical peculiarity southward beyond Eldorado, where it thins out. It was not found near Golden nor at Morrison. It is practically continuous northward to Boxelder Canyon, Colo., where it seems to thin out. No definite representative of it was found north of Boxelder Creek, but at Horse Creek, Wyo., more than 35 miles still farther north, a few feet of light-colored sandstone occurs above the lowest fossiliferous limestone of the "Red Beds"—the Forelle limestone of that section. This sandstone is the only stratum found there that may possibly correspond to the Lyons, and it lies above rocks believed to be of Permian age.

No fossils have been found in the Lyons sandstone except tracks of a reptile (see pl. 33), which C. W. Gilmore regards as Permian. Mr. Gilmore,[25a] who has recently examined fossil footprints from the Coconino sandstone of the Grand Canyon in Arizona, a formation classed as Permian, says of the tracks in the Lyons sandstone:

> Through the courtesy of Prof. Junius Henderson, of the University of Colorado, I have had the loan of the slabs containing fossil footprints from the Lyons sandstone of Colorado. In his original paper in the Journal of Geology (vol. 32, 1924, p. 228), Henderson described these tracks under the name of *Limnopus? coloradoensis*. After a study and comparison of these tracks with an excellent series of fossil footprints from the Coconino sandstone of the Grand Canyon, I find that the affinities of this species fall in the genus *Laoporus*, a genus founded by Prof. R. S. Lull on specimens from the Coconino sandstone described in the American Journal of Science (vol. 48, p. 82, 1894). Furthermore, one trackway, No. 11176, United States National Museum, collected by Dr. J. C. Merriam at the Hermit trail locality in the Grand Canyon, shows hind-foot impressions which except for their slightly larger size are indistinguishable from those described by Henderson and which will now be known as *Laoporus coloradoensis* (Henderson). The dimensions of the imprints of the Colorado specimens, width of trackway, and length of stride indicate its closest affinities to be with the smaller of the two species described by Lull, *Laoporus schucherti*. More abundant specimens may eventually show that *L. coloradoensis* and *L. schucherti* are synonymous, in which event, on the ground of priority, the species of *L. coloradoensis* would have to be abandoned. From the brief review given above it becomes quite apparent that so far as the rather meager evidence of these footprints is concerned they would point to a similar age for these two widely separated sandstones.

The occurrence of the Lyons sandstone beneath fossiliferous beds in the basal part of the Lykins formation that are regarded as probably of Permian age, the possible interfingering of the sandstone with these probable Permian beds, which harmonizes with the evidence of unconformity at its base, its overlap relations toward the south, and its peculiar lithology, which is strikingly different from that of the Pennsylvanian rocks immediately under it, all indicate that it is younger than Pennsylvanian. The direction of inclination of the cross-bedded layers may be invoked to prove some notable change in ancient physiographic conditions from those of Pennsylvanian time. All things considered, the Lyons sandstone seems to be more closely related to the rocks of Permian age than to those of the Pennsylvanian series, and it is herein classified as Permian.

FORELLE LIMESTONE

The name Forelle was given by Darton[26] to a limestone 4 to 20 feet thick, lying on the Satanka shale in the Laramie and Sherman quadrangles in Wyoming. It has yielded a few fossils of marine invertebrates of

[25] Fenneman, N. M., U. S. Geol. Survey Bull. 265, p. 23, 1905.

[25a] Personal communication.

[26] Darton, N. H., U. S. Geol. Survey Bull. 364, p. 20, 1909.

Permian age. A limestone above the Opeche (?) shale of northern Colorado has yielded fossils of the same species and may be the Forelle limestone. This limestone has been included in the "crinkled sandstone" by some writers and is the "crinkled limestone" of others. It was compared with the Minnekahta limestone of the Black Hills by Darton.[27] Although the "crinkled limestone" of the several localities described seems to belong to a single continuous layer, it is possible that more than one limestone is involved, for at most of these localities there are two to five layers of limestone separated by red shale. The writer is especially doubtful concerning the equivalency of this limestone with the lowest limestone near Horse Creek, Wyo., which is supposed to be the Forelle, as it lies on the shale there correlated with Satanka. If the higher or 25-foot limestone of the Horse Creek section proves to be equivalent to the "crinkled limestone," the shale of 106 feet thick between these two limestones may be the Opeche (?) shale of northern Colorado and of the Douglas-Casper region in Wyoming. West of the Laramie Mountains the Forelle limestone and some of the older beds were eroded away in post-Forelle time, allowing a limestone slightly younger than the Forelle to be deposited on the older beds.

The uncertainty as to the correlation of beds east of the Laramie Mountains with the Forelle limestone and the Satanka shale of the Laramie Basin attaches also to the correlation of similar rocks west and north of this basin. At each locality examined one to five layers of limestone were found in the lower part of the "Red Beds" (see pl. 18, *A*), the lowest one of which appears to be persistent. Like the Forelle this limestone is sparingly fossiliferous in many places and seems to be of essentially the same age.

LIMESTONE BRECCIA

At most of the localities examined, a limestone breccia was found in the upper part of the group of limy, gypsiferous beds in the lower part of the "Red Beds." It is composed of a mixture of limy shale and angular fragments of limestone ranging from a fraction of an inch to several inches in diameter. (See pl. 19, *A*.) The brecciated character is persistent in Colorado but less so in Wyoming, although it was noted near Horse Creek and in several places farther north and west. In central Wyoming there are several thin limestones, any one of which may be the equivalent of the limestone breccia. Interbedded with these limestones are layers of gypsum, red sandstone, and shale and also one or more layers of chert nodules. The chert is abundant at Alcova and other places in central Wyoming, but it is inconspicuous or absent in southeastern Wyoming and in northeastern Colorado.

[27] Darton, N. H., Geol. Soc. America Bull., vol. 15, p. 416, 1904.

The cause of the brecciated character of the limestone is not known, nor is the stratigraphic significance of the bed understood. In most places this limestone appears to be an interformational layer, but in the Laramie Basin it lies unconformably on older beds where the Forelle limestone and possibly also the Satanka shale are absent. This occurrence was described in the Laramie-Sherman folio. On Red Mountain Darton observed a limestone which he regarded as probably the Forelle resting on sandstone where "the lower red shales" (Satanka) are absent. The writer in company with S. H. Knight found this limestone conspicuously brecciated. Furthermore, it is the only limestone in the lower part of the "Red Beds" at this place. The occurrence suggests that this is the limestone breccia of neighboring localities and that the Forelle limestone and Satanka shale were here eroded away before the breccia was formed. This suggestion leads to the further supposition that the breccia may denote slight uplift and erosion over a wide area and a corresponding break in recorded time.

The "crinkled limestone" of Colorado, the Forelle limestone of the Laramie Basin, and their supposed equivalents in central Wyoming have yielded fossils that indicate Permian age. These fossils have been used in an attempt to correlate these beds with the Phosphoria formation of the Wind River Mountains, a richly fossiliferous formation of Permian age. It is not certain, however, that the Permian beds represent continuous sedimentation, and the structure and lithology as observed from place to place suggest that the fossiliferous beds near the base of the red beds overlap the Phosphoria. A more difficult matter to explain satisfactorily is the occurrence of fossils of Phosphoria type in the limestone breccia of the Laramie Basin described in the details of sections on pages 67–69. These fossils appear to be pebbles and may prove to be of secondary nature, derived by erosion from Phosphoria beds near by, which were broken up as the breccia was formed.

MAIN BODY OF "RED BEDS"

Above the group of limy, gypsiferous layers just described (see pl. 19, *B*) lie the thick beds of red sandstone and shale which constitute the bulk of the "Upper Wyoming" of the Denver Basin. The Lykins formation in northern Colorado includes these beds, together with the lower or limy beds. Here is the main body of the well-known "Red Beds" of the Rocky Mountain region. The rocks consist chiefly of shaly sandstone, which in many places is accompanied by thick beds of gypsum. No fossils have been found except in the lower limy beds. The main body of red beds is more closely associated with the underlying Permian rocks—that is, the Forelle limestone and associated strata—than with the overlying rocks of Triassic age—that is, the Alcova limestone and the

Jelm formation. Hence the red beds are regarded as probably Permian. In most places they form prominent barren red bluffs, as illustrated in Plate 20, *B*.

ALCOVA LIMESTONE MEMBER OF CHUGWATER FORMATION

At Alcova, Wyo., an 8-foot limestone occurs 335 feet below the top of the "Red Beds." For this bed the name Alcova limestone member of the Chugwater formation is here proposed. It is a hard, resistant, purplish limestone, which forms conspicuous ledges at the outcrop. (See pl. 21.) It varies slightly in thickness from place to place but is remarkably persistent west of the Freezeout Hills in Wyoming and was noted at all the localities examined in the Big Horn Basin. It lies 420 feet below the top of the "Red Beds" at Thermopolis (pl. 20, *A*) and 345 feet below the top near Rawlins. At the west end of Casper Mountain it is only 73 feet below the base of the Sundance formation. It occurs throughout the Casper Range, but was not observed east of this range nor southeast of the Freezeout Hills. There is no indication that its disappearance toward the east is due to nondeposition. It continues eastward with full thickness and unchanged character to the last exposure. Indeed, it is more prominent in the Freezeout Hills than it is at most of the more westerly exposures.

In lithology and general appearance the Alcova limestone closely resembles the "crinkled limestone," and where only one of the two is exposed it might readily be mistaken for the other. The Alcova is made up of many thin layers of hard blue and purplish limestone, separated by red sandy shale. (See pl. 21, *B*.) It is so well developed over a wide area and so conspicuous as a horizon marker in the Red Beds, where recognizable beds are rare, that it may be desirable to give it formational rank. In several places fossil invertebrates identified as *Naiadites?* sp. and *Natica lelia* were found in this limestone, and in the same limestone in the Owl Creek Mountains Darton [28] found *Natica lelia*, *Bakewellia* sp., *Pleurophorus?* sp., and *Aviculipecten* cf. *A. curticardinalis*. Although recognized as inadequate for final determination of age, these fossils indicate that the limestone is of marine origin and probably Triassic. As the only marine Triassic rocks anywhere near central Wyoming are recognized as Lower Triassic, it is probable that the Alcova limestone also should be classed as Lower Triassic.

TRIASSIC BEDS ABOVE ALCOVA LIMESTONE

The red beds above the Alcova limestone vary in nature and in thickness from place to place. At Thermopolis, Wyo., they are 420 feet thick and contain much gypsum. In the vicinity of Lander they have about the same character and thickness as at Thermopolis. They thin out toward the east and change in character from gypsiferous shale to strata composed chiefly of sandstone. Farther south, at Whisky Gap, these beds consist of sandstone and shale. Near Rawlins (see section 45, pl. 1) they consist of hard platy sandstone and sandy shale, as illustrated in Plate 22, *A*. In the Freezeout Hills they are doubtfully represented by a few feet of shaly sandstone between the Alcova limestone and the overlying massive Jurassic sandstone. East of the Freezeout Hills, where the Alcova is not present, it would be difficult to distinguish these beds from those which normally underlie the Alcova limestone.

As these gypsiferous red beds lie between the Alcova limestone and the younger nonmarine Upper Triassic beds described below, it is probable that they belong in the Triassic system. Furthermore, they seem to belong to the Lower Triassic, or marine portion of the system, for the beds of gypsum indicate close connection with the sea, and there is no observed break in sedimentation between them and the Alcova limestone. There is, however, a distinct break in sedimentation between the gypsiferous strata and the next younger beds. Apparently a hiatus is represented here, which marks the withdrawal of the Triassic sea and an epoch of erosion that removed considerable thicknesses of the older sedimentary rocks in northeastern Colorado.

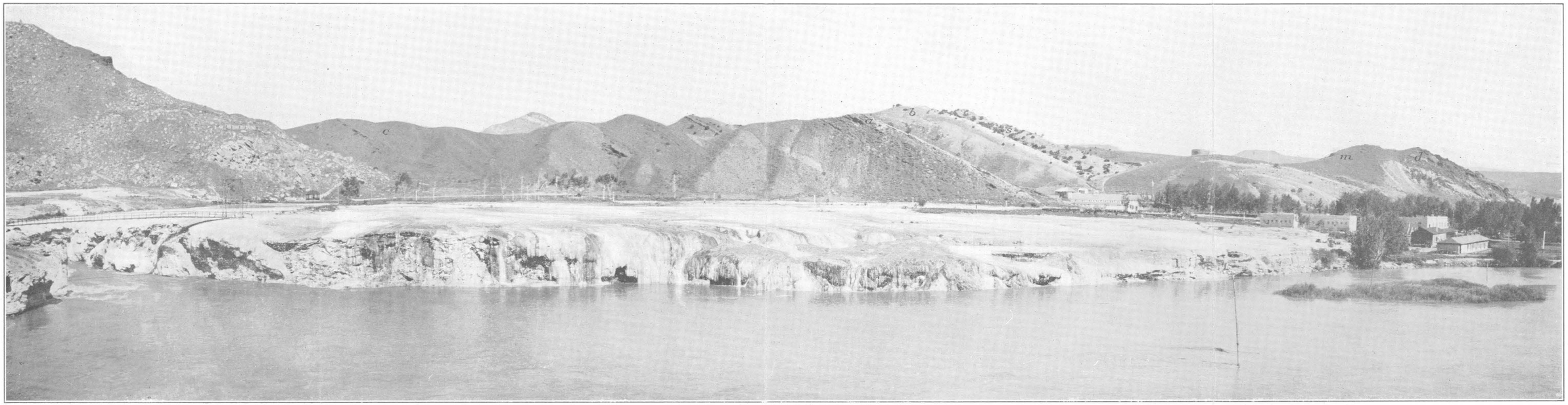
JELM FORMATION

In the Laramie Basin and neighboring localities the upper part of the "Red Beds," consisting chiefly of massive orange-colored sandstone, has been described by Knight [29] as the Jelm formation, a name taken from Jelm Mountain, in the Laramie quadrangle. This formation, which is 250 feet thick at the type locality, lies unconformably on the older red beds of supposed Permian age and contains bones of Triassic vertebrates in beds of "pebble conglomerate composed of small limestone pellets, wood fragments," etc. Similar material was noted north of Medicine Bow, where fragments of bone were found in a pellet conglomerate; also near Rawlins, at Whisky Gap, and near Lander. The beds near Lander, which contain Triassic vertebrates, were once called "Popo Agie beds." [30] North of the Granite Mountains similar beds containing lime-pellet conglomerate were noted near Alcova and are probably represented in Casper Mountain. They appear to thin out entirely toward the north and do not occur near Thermopolis. Also they thin out east of Casper, for near Douglas rocks of Jurassic age rest unconformably on the red beds that normally underlie the Alcova limestone. East of the Laramie Range in Wyoming and the Front Range in Colorado the Jelm formation is probably represented by massive cross-bedded orange-colored

[28] Darton, N. H., 59th Cong., 1st sess., S. Doc. 219, p. 19, 1906.

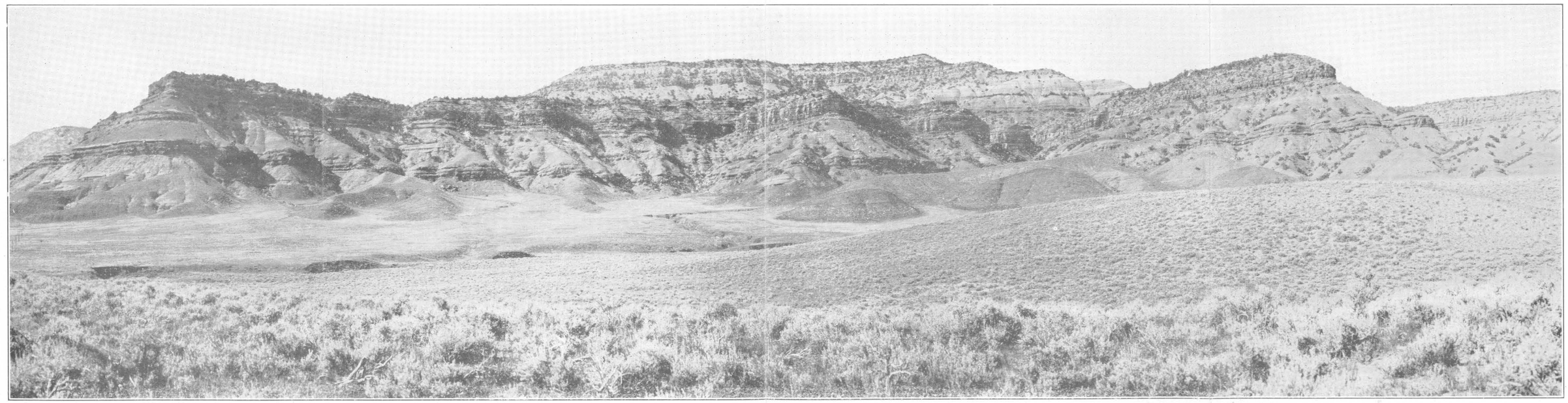
[29] Knight, S. H., Geol. Soc. America Bull., vol. 27, p. 120, 1916; vol. 28, p. 168, 1917.

[30] Williston, S. W., Jour. Geology, vol. 12, p. 688, 1904.



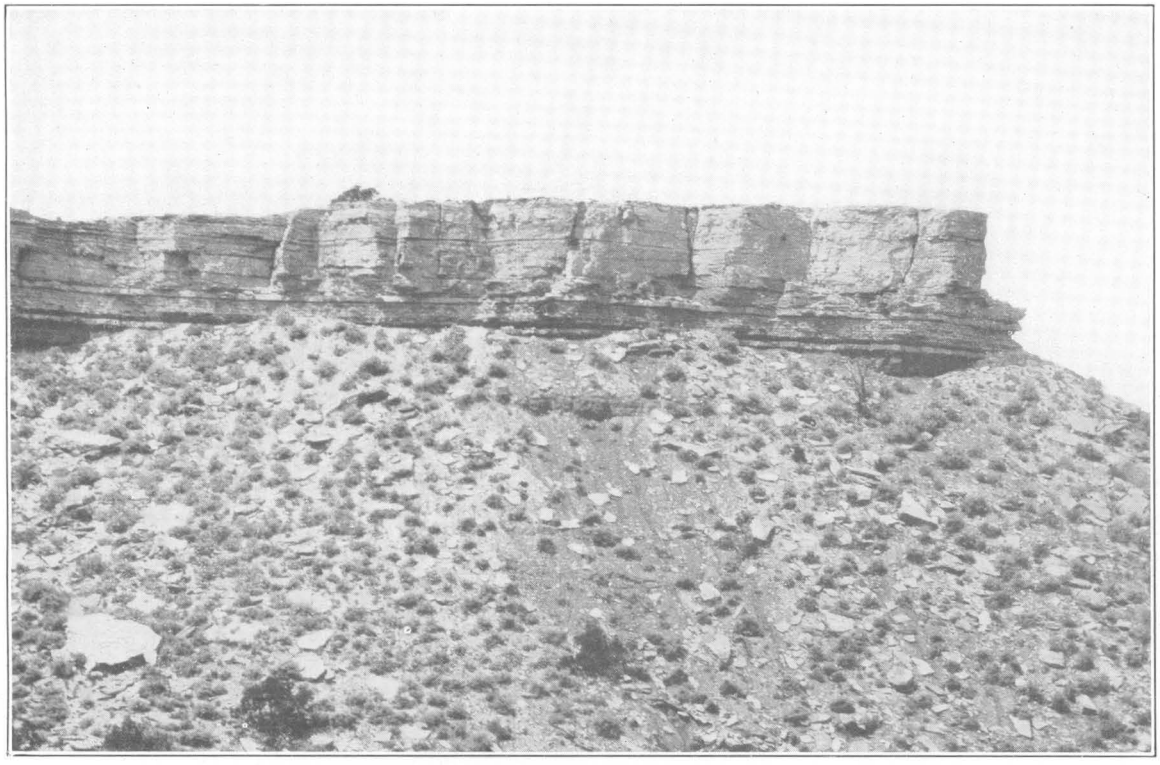
A. BIG HORN HOT SPRINGS, THERMOPOLIS, WYO.

Looking east across Big Horn River and the terrace of travertine to the "Red Beds," which are inclined southward on the flank of a sharp anticline whose apex lies to the left. From this anticline 18,600,000 gallons of sulphur water issues every 24 hours, having a temperature of 135° F. and carrying calcium carbonate and other mineral matter in solution. In the distance, in order from left to right, are the older Chugwater red beds (*c*), the Alcova marine limestone (*a*), gypsum and shale of the upper part of the Chugwater (*b*), the marine Sundance formation (*s*) (the basal sandstone is absent here), the Morrison formation (*m*), and the sandstone correlated with the lower sandstone of the Dakota group at Bellvue, Colo. (*d*)

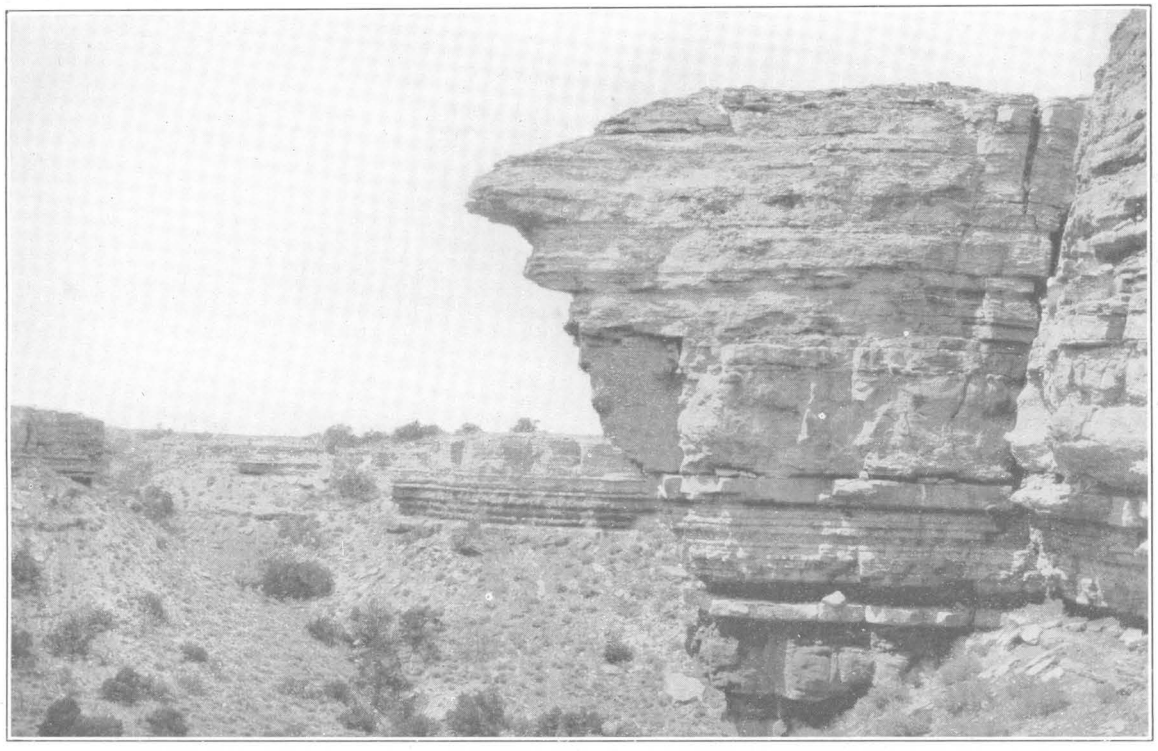


B. "RED BEDS" ABOUT 10 MILES SOUTHEAST OF THERMOPOLIS, WYO.

The sagebrush slope in the foreground is formed in the soft gypsiferous shales beneath the Chugwater red beds; halfway up the bluff at the left is a massive red sandstone with shaly beds above and below; still higher is the Alcova limestone, too thin to appear prominent at this distance, and the upper gypsiferous beds. Near the center in the distance are the Sundance and Morrison formations, capped by Cloverly sandstone, which appears at the sky line



A



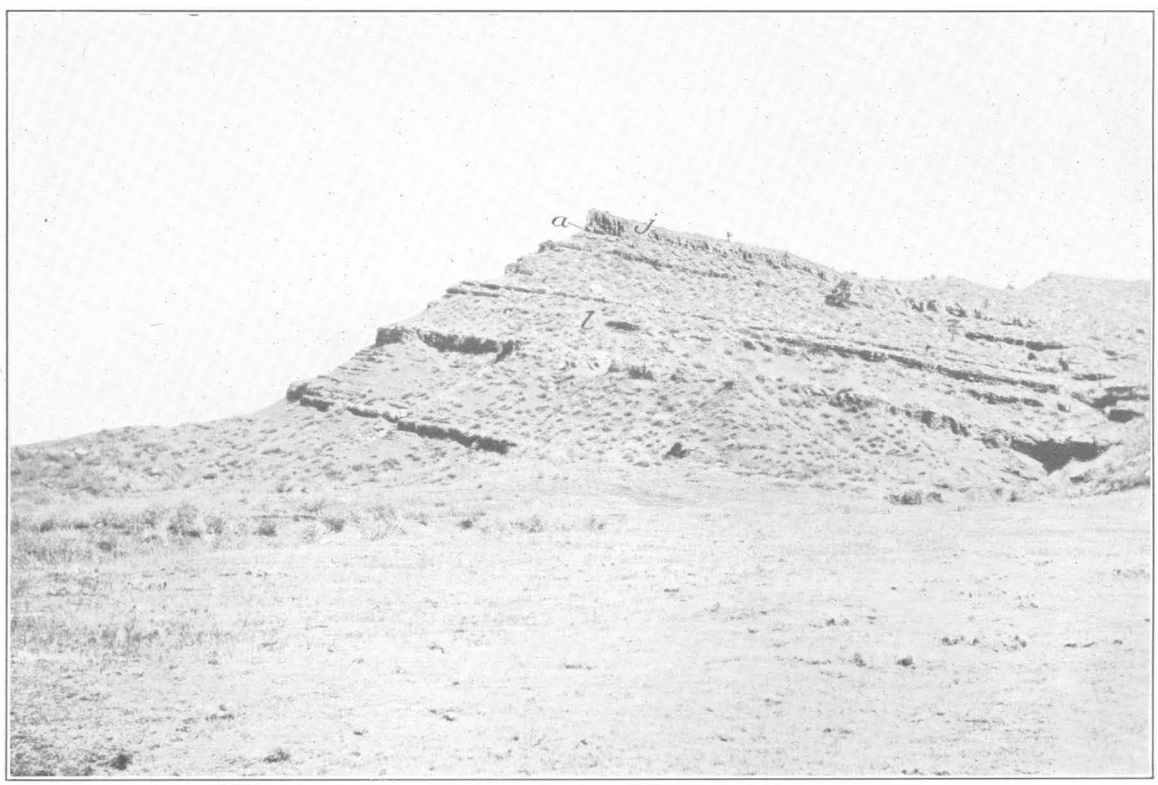
B

ALCOVA LIMESTONE SOUTH OF ALCOVA, WYO.

A shows its characteristic appearance in ledges above slopes of soft red sandstone and shale. *B* is a near view of the limestone on North Platte River, showing details of bedding, where invertebrates of probable Triassic age were found in it

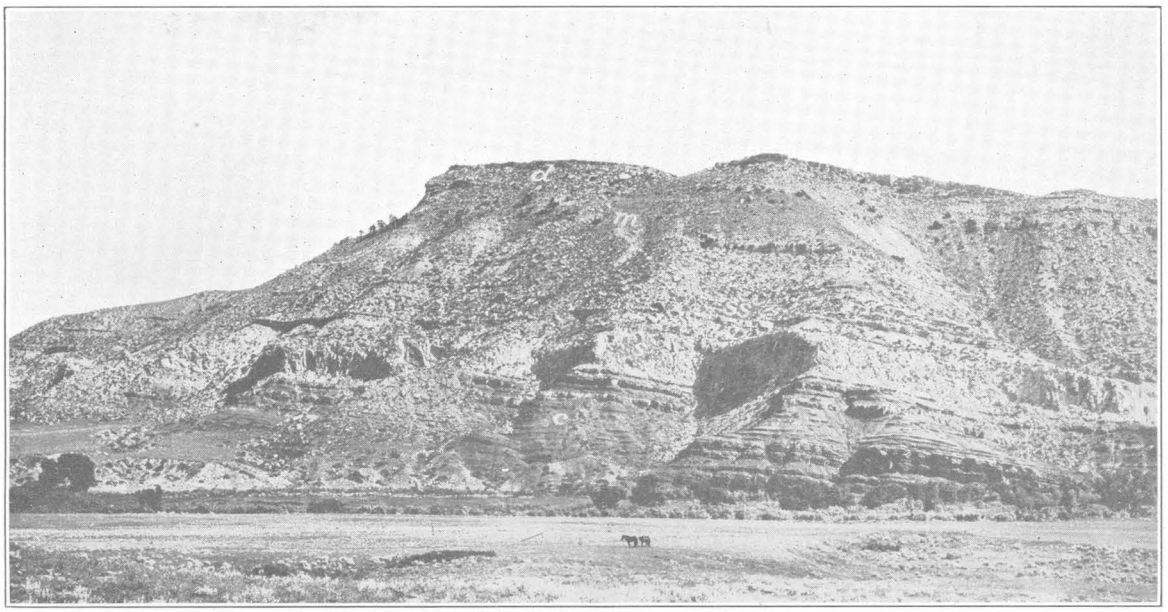
A. UPPER PART OF THE "RED BEDS" AT NORTH END OF RAWLINS HILLS, WYO.

The Alcova limestone and the Sundance sandstone do not appear in the view



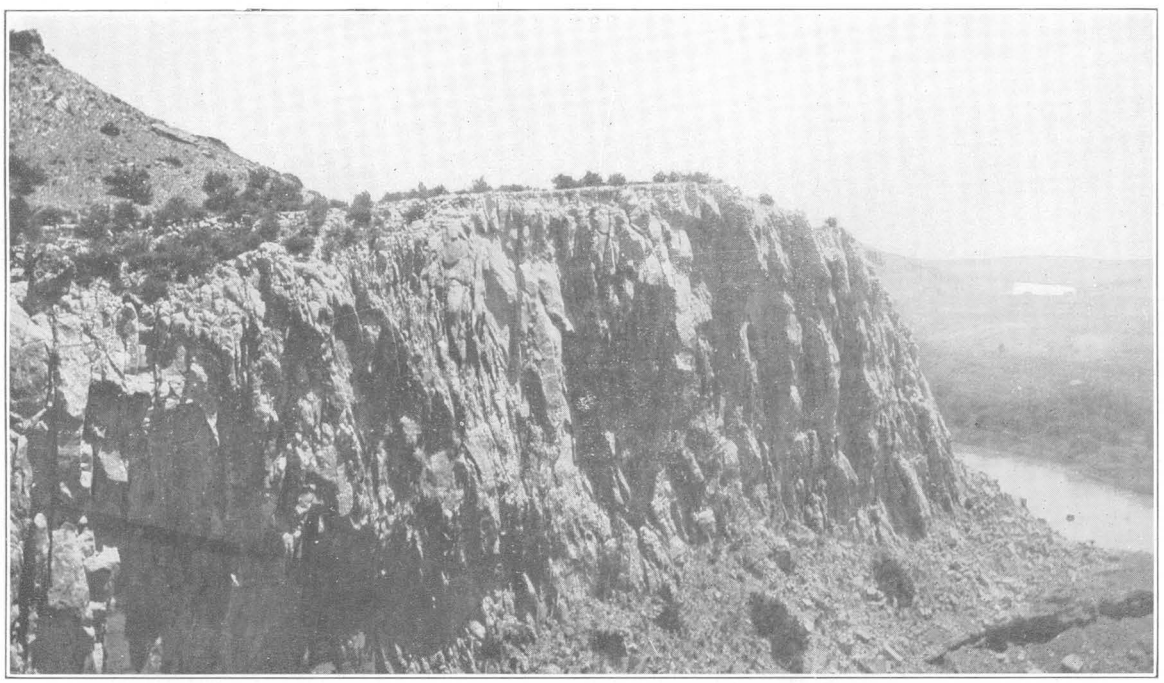
B. "RED BEDS" IN BOXELDER CANYON NORTH OF TABLE MOUNTAIN, COLO.

Showing several ledges of Lykins red sandstone (*l*) overlain unconformably at *a* by an orange-colored sandstone (*j*) which probably represents the Jelm formation



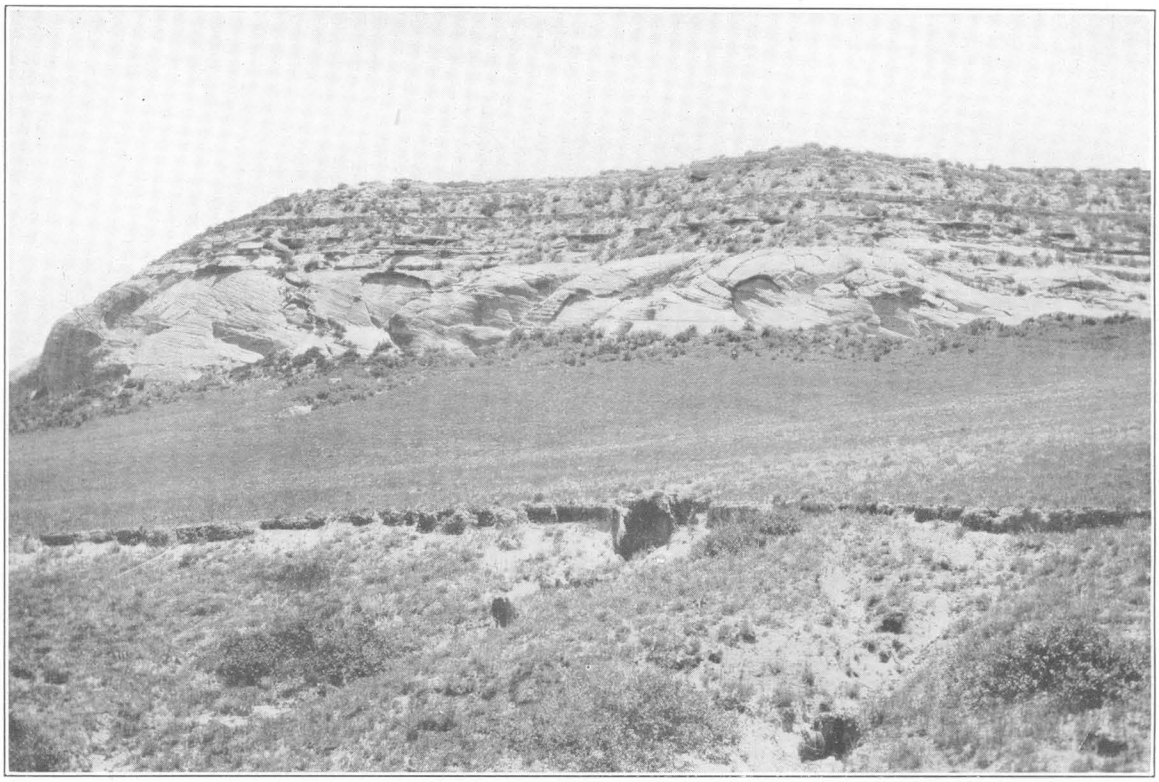
A. NORTH WALL OF NORTH PLATTE CANYON SOUTH OF DOUGLAS, WYO.

Showing evenly stratified Chugwater red beds (*c*); the light-colored basal sandstone of the Sundance formation (*s*), about 100 feet thick; the three younger members of the Sundance in a series of steplike ledges (*ss*); a smooth slope occupied by the Morrison formation (*m*); and at the top the sandstone (*d*) that is correlated with the Dakota group of the section at Bellvue, Colo.



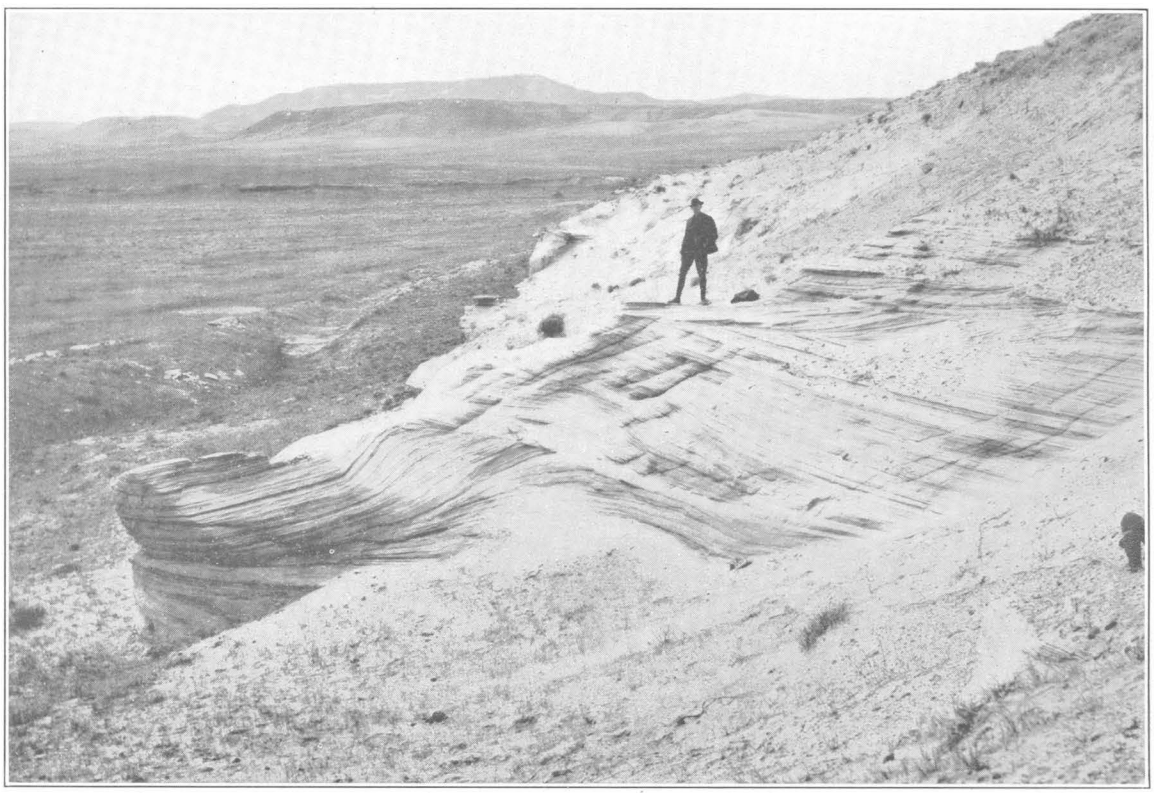
B. NEAR VIEW OF THE LOWER SANDSTONE MEMBER OF THE SUNDANCE FORMATION

At locality shown in *A*. The sandstone is massive, vertically jointed, and nearly 100 feet thick. The softer shaly beds of the marine Sundance appear at the left

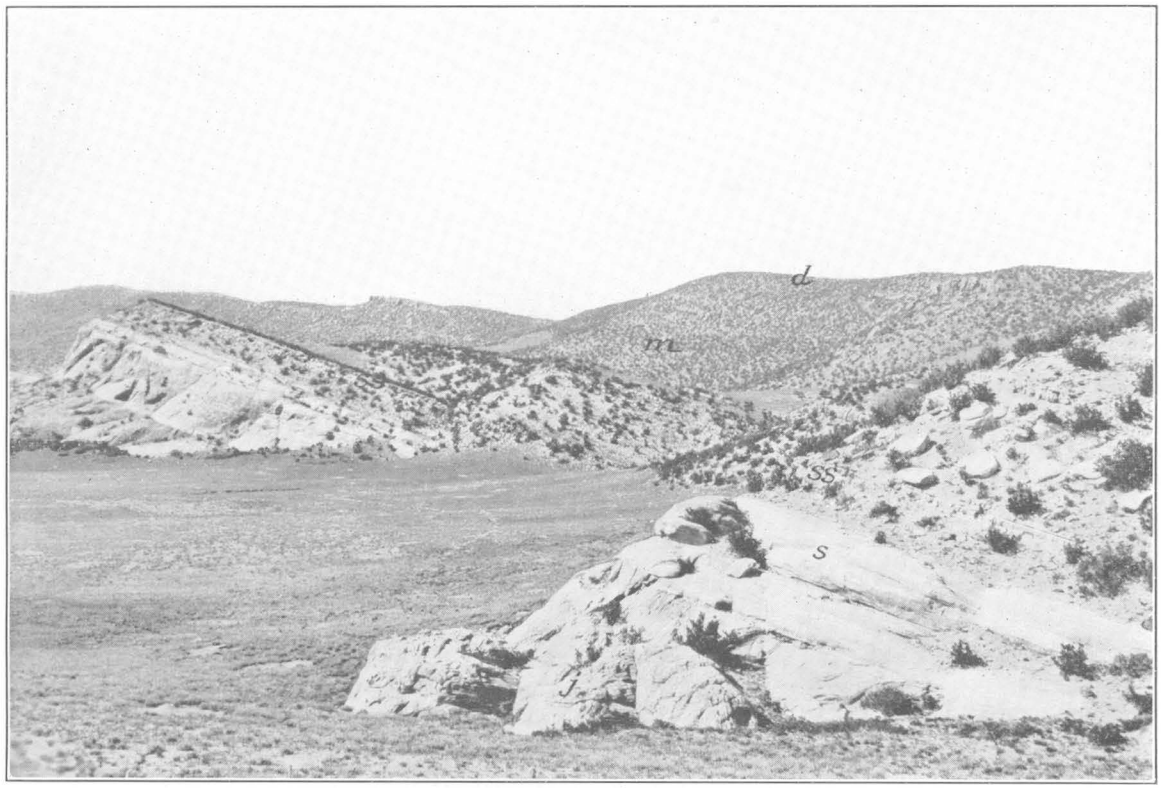


A. LOWER PART OF SUNDANCE FORMATION SOUTH OF BOXELDER CREEK, COLO.

Showing the basal cross-bedded sandstone and the overlying limestones and ripple-marked sandstones

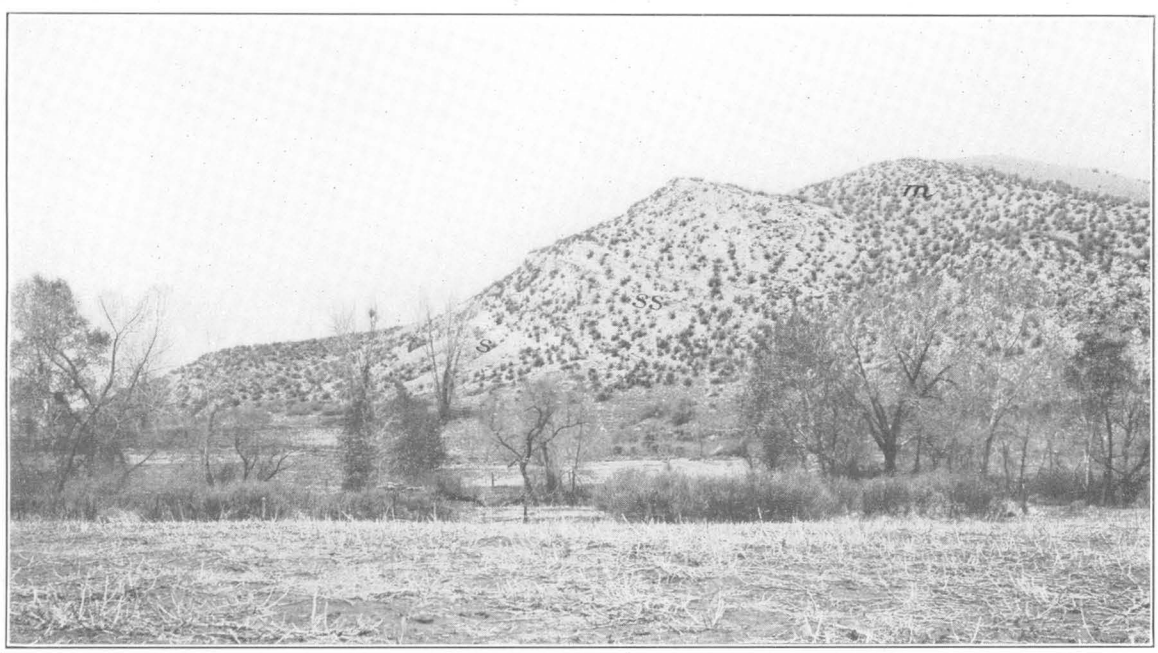


B. CROSS-BEDDED SANDSTONE IN THE LOWER PART OF THE SUNDANCE FORMATION AT "STEAMBOAT LAKE" (NOW DRAINED), LARAMIE BASIN, WYO.



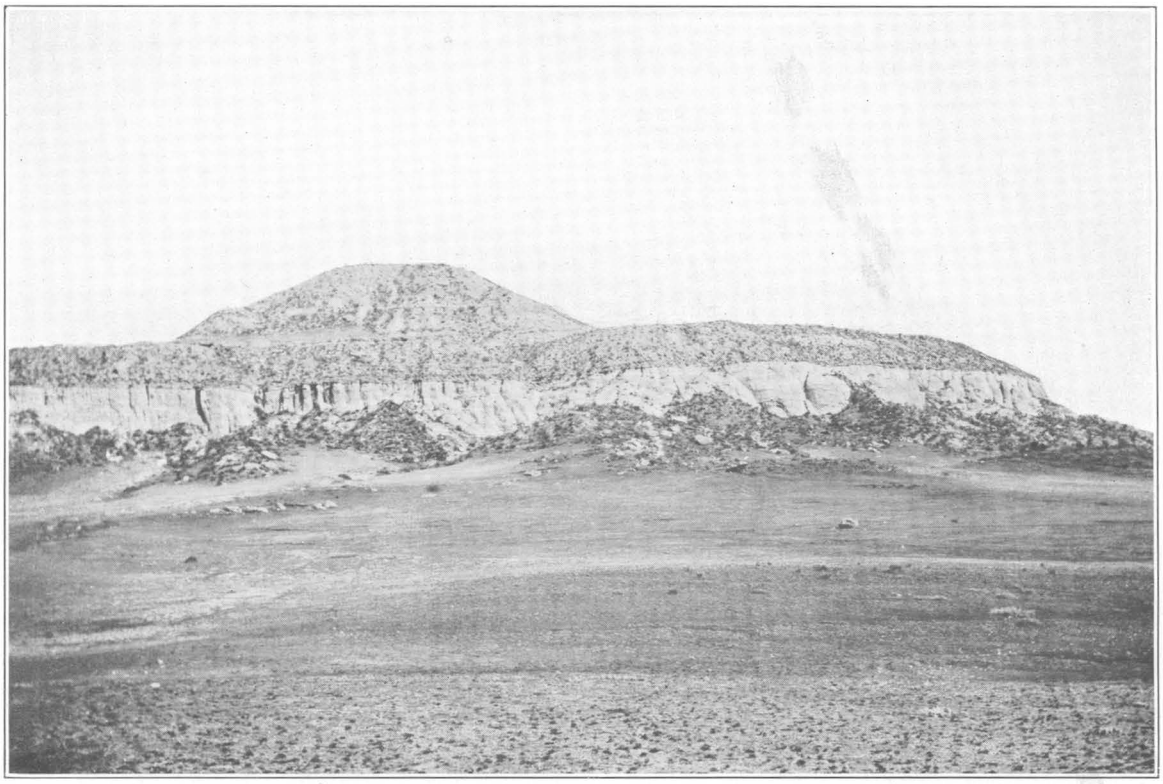
A. VIEW 2 MILES NORTH OF OWL CREEK, COLO.

Showing orange-colored sandstone (*j*) which probably corresponds to the Jelm formation; light-pink cross-bedded sandstone of the basal Sundance (*s*); thin-bedded cherty limestone, ripple-marked sandstone, and shale of the lower marine member of the Sundance (*ss*); the Morrison formation (*m*); and at the top of the ridge the beds correlated with the Dakota group at Bellvue, Colo.



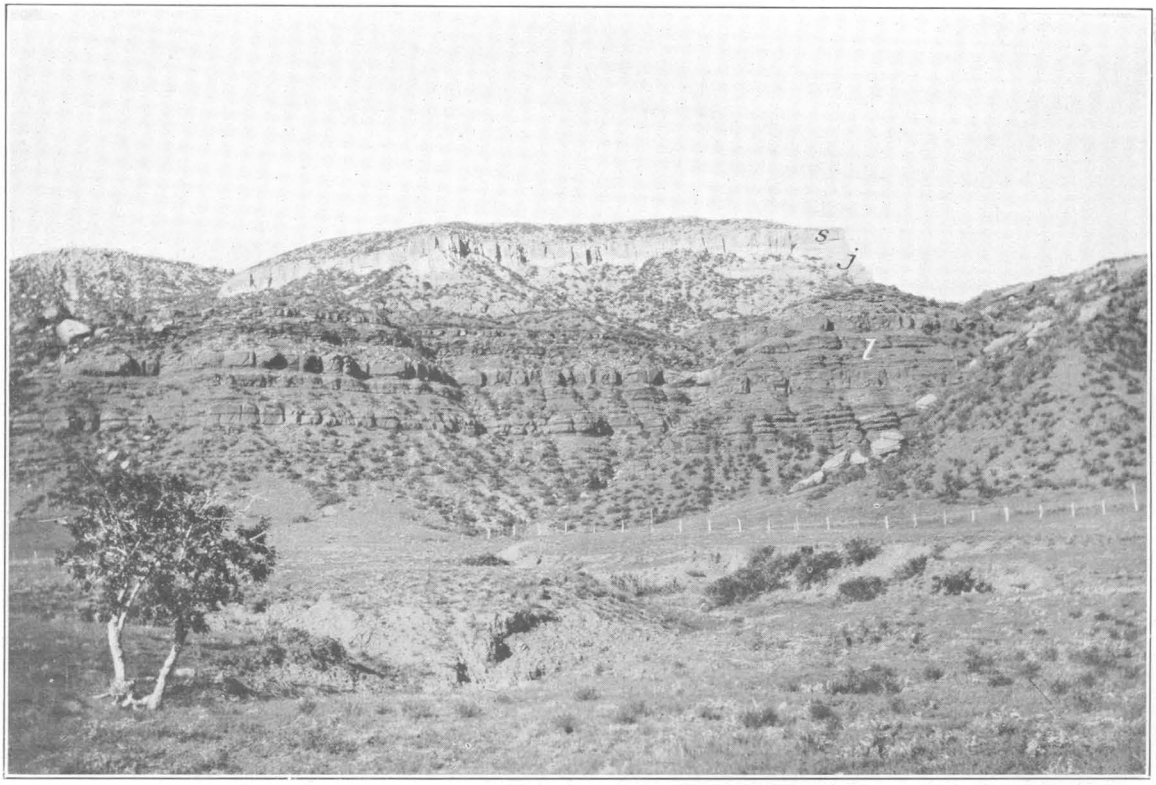
B. COTTONWOOD CANYON WEST OF LOVELAND, COLO.

Showing the pink to orange-colored cross-bedded sandstones of the lower Sundance (*s*), possibly including some of the Jelm, overlain by about 210 feet of cherty limestone with thin beds of shale (*ss*), partly or wholly of the Sundance. The Morrison formation (*m*) appears at the right above the light-colored limestone



A. THE SIDE OF A MESA ON BOXELDER CREEK, COLO.

Valley in the foreground eroded in Lykins red beds; a light-colored cliff of basal sandstone, of the Sundance; a series of thinly laminated Sundance beds above the cliff; and a steep slope of Morrison shale capped on the distant height by the sandstone that is correlated with the lower sandstone of the Dakota group at Bellvue, Colo.



B. NORTH WALL OF BOXELDER CANYON AT GREENACRE RANCH, COLO.

Showing Sundance sandstone (*s*) resting on orange-colored sandstone probably of the Jelm formation (*j*), and this on evenly stratified beds of the Lykins formation (*l*)

sandstone, reported in many of the measured sections, which lies below the beds of Jurassic age and unconformably on the older red beds, as in Plate 22, *B*. Their massive cross-bedded character, the inclusion of lenses of pellet conglomerate which may have originated as the filling of stream channels, and the bones of nonmarine reptiles indicate that the formation may be of fluviatile origin and may not be continuous from place to place. Where there are only a few feet of sandstone, it is obvious that not all of Upper Triassic time is represented.

South of Owl Creek, Colo., sandstone that may represent the Jelm formation has not been differentiated from the sandstone of the Sundance formation. It is possible that the Jelm may be represented in some places in the thin beds of massive sandstone between the Morrison formation and the underlying Lykins formation, but this sandstone is here regarded as chiefly of Sundance age.

POST-TRIASSIC EROSION

From the descriptions just given it follows that much of the region here described underwent erosion at or near the end of the Triassic period. Erosion in mid-Triassic time removed some of the marine beds of probable Lower Triassic age and formed the uneven floor on which the Jelm formation (Upper Triassic) rests. Erosion also followed the deposition of the Jelm, removing it in some places. The results accomplished during these two epochs can not now be distinguished. But during one or both of these epochs the "Red Beds" were deeply eroded, until in middle eastern Colorado nearly all of the Lykins formation was removed. This conclusion may be challenged on the ground that little is known of the lateral extent of the constituent parts of the "Red Beds." But there is a strong presumption that any Triassic beds which may have once existed in southeastern Wyoming and northeastern Colorado were eroded away before the overlying Jurassic beds were formed. In many places the upper surface of the "Red Beds" shows evidence of erosion, and there is a gradual diminution in thickness toward the south. This thinning becomes conspicuous in Perry Park and near Colorado Springs where the red sandstone and shale are of slight thickness. The southward thinning is believed to be due to erosion, as indicated in Figure 2.

No satisfactory measure of this late Triassic and post-Triassic erosion has been found in the area described in this paper. But the presence of strata of late Jurassic (Sundance) age resting on strata of late Triassic age in southern Wyoming and of probable Permian age in northern Colorado accords with the evidence gathered from other regions that the unconformity resulted from a major diastrophic movement[31] and that an extensive plain of erosion was formed, in early Jurassic or pre-Jurassic time, for which the name La Plata peneplain has been proposed.[32]

JURASSIC ROCKS

SUNDANCE FORMATION

On the eroded surface of the Triassic red beds in central Wyoming and on beds of older than any known Triassic farther east and south were deposited sand, shale, and limestone, which are referred to the Jurassic system. These beds are known as the Sundance formation, although heretofore they have in part been included in other formations. The Sundance as a whole is traceable from the northernmost localities examined southward nearly or quite to Colorado Springs, Colo. In its fullest development within the area here described—as, for example, in Wyoming between Douglas and Casper (see pl. 23)— it consists of four members. In order from base to top these are a massive basal sandstone (see pl. 23, *B*); a member composed of flaggy sandstone, sandy calcareous shale, and brittle cherty limestone containing a few marine fossils; a red gypsum-bearing member in which no fossils have been found; and an upper member consisting of sand, shale, and limestone that contain great numbers of fossils, which constitute the well-known Sundance fauna.

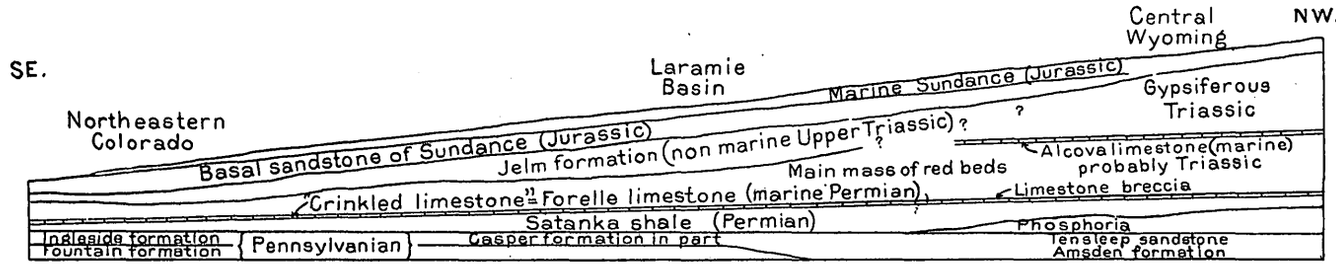


FIGURE 2.—Sketch section illustrating the structural relations of formations in northeastern Colorado and central Wyoming

At most of the localities examined in Wyoming the lower sandstone member is prominent. It is massive, light colored, cliff making, and usually cross-bedded. (See pl. 24.) Most of the cross-bedding observed is of the tangential type, consisting of curved and truncated laminae which are believed to denote wind action. It ranges in thickness from 100 feet or more down to a vanishing edge. It is continuous and conspicuous in northern Colorado as far south as Owl

[31] Lee, W. T., Smithsonian Misc. Coll., vol. 69, No. 4, p. 10, 1918.
[32] Idem, p. 25.

Creek. (See pl. 25, *A*.) Still farther south it is readily recognizable but does not stand out so prominently as it does farther north. South of Loveland (pl. 25, *B*) it is thin and variable, and in some places is absent. Near Boulder it is not present, and the Morrison formation lies on typical Lykins red beds. It is about 10 feet thick near Morrison but was not recognized farther south. It thins out also in a northwesterly direction. It was not recognized near Lander and is absent at Thermopolis, where fossiliferous limestone rests on the Triassic shale and gypsum. This sandstone has the general appearance and character of the massive Jurassic sandstones farther west and south that have been called Nugget, White Cliff, La Plata, Navajo, Exeter, etc.

The basal sandstone member is overlain by the lower marine member of the Sundance, which in some places contains great numbers of *Tancredia warrenana* Meek and Hayden. In other places it contains *Pentacrinus asteriscus* Meek and Hayden and a few indeterminate fossil forms. Throughout the part of northern Colorado here described there are thin beds of pink and yellow sandstone, colored shale, and cherty limestone above the massive cross-bedded sandstone, which probably represent this lower marine member. (See pl. 24, *A*.) Many of the thin layers of sandstone are beautifully ripple marked. The limestones contain pink chert or the so-called chalcedony that has been noted in many places in central and southern Colorado in beds there included in the Morrison formation. In Boxelder Canyon and Owl Canyon, in northern Colorado (see pl. 26, *A*), many large masses of dark chert, some of them several feet in diameter, were observed. In the field these were supposed to be petrified trunks of cycads, but F. H. Knowlton reports that the one sent to him for examination "simulates a cycad trunk, but so far as can be made out it is only a concretion."

The red gypsiferous member of the Sundance formation is well developed in Wyoming, near Douglas, Casper, and Alcova, and similar beds were noted near Lander and in the Big Horn Basin. In the southern part of the Laramie Basin and at most of the more southerly localities this member as well as the younger one was removed by post-Sundance erosion, in some such way as that illustrated in Figure 3.

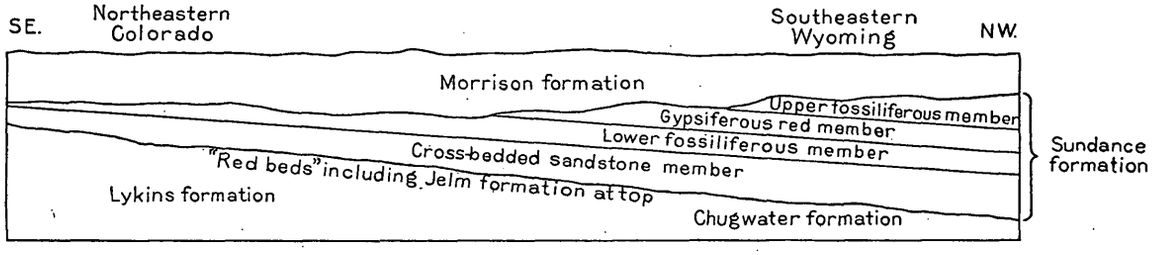


FIGURE 3.—Sketch section illustrating the structural relations of the "Red Beds" and the Sundance and Morrison formations in southeastern Wyoming and northeastern Colorado, showing the disappearance southward, probably by erosion, of the upper members of the Sundance formation

The upper marine member is the one which yields most of the Sundance fossils at all the localities examined. It consists chiefly of shale and shaly limestone but in some places includes much sandstone, usually somewhat shaly. This upper member is prominent at all the localities examined west and north of Douglas Wyo., and in the northern part of the Laramie Basin. It has not been found south of this basin nor in the eastern foothills south of Iron Mountain, Wyo. In the foothills of northeastern Colorado rocks that probably represent one of the middle Sundance members occur in several places above the basal sandstone of the formation. In Boxelder Canyon, in northern Colorado, these beds, lying immediately below dinosaur-bearing sandstone, yielded *Pentacrinus asteriscus* and other Sundance forms. Near Loveland, Colo., the rocks, chiefly limestone and shale, between the basal sandstone of the Sundance and the overlying Morrison thicken locally to 210 feet, but farther south they are absent in some places.

In many places in the eastern foothills thin beds of limestone that probably belong in the Sundance formation have formerly been included in the Morrison; but as no such beds as those just described occur in the Morrison in southern Wyoming, where this formation is clearly separable from the Sundance, and as the peculiar pink cherts contained in the fossiliferous limestone in Boxelder Canyon were found at practically every locality farther south in the thin limestones mentioned, it is here suggested that these limestones may belong in the Sundance formation rather than in the Morrison. On the other hand, thin limestones at about the same horizon in Perry Park contain fresh-water gastropods, and near Colorado Springs *Planorbis veternus* Meek and Hayden and *Valvata scabrida* Meek and Hayden, fossils supposed to indicate Morrison age, have been reported.[33]

The fossiliferous limestones in Perry Park and near Colorado Springs overlie a thick bed of gypsum. Because the Lykins formation farther north is gypsiferous, the gypsum at Perry Park and Colorado Springs has been included in the "Red Beds." The gypsum occurs at the horizon where evidence of the Jurassic sea is to be expected, in case this sea extended

[33] Richardson, G. B., U. S. Geol. Survey Geol. Atlas, Castle Rock folio (No. 198), 1915.

to central Colorado. The writer has suggested elsewhere [34] that this bed of gypsum may be one of an extensive series of similar beds which mark the extension of the Jurassic sea far "beyond the localities where its waters were suitable for the support of marine organisms." In brief, this gypsum may represent one of the marine Jurassic horizons of the Sundance formation.

CRETACEOUS (?) ROCKS

MORRISON FORMATION

The Morrison formation is present throughout the region examined. It consists of variegated shale, irregular masses of sandstone, and a few thin layers of brittle limestone. Dinosaur bones have been found in it in many places.

Little need be said here of this well-known formation except concerning its occurrence at two localities—at Morrison, Colo., and near Alcova, Wyo. Near Alcova the Morrison formation rests with obvious unconformity on the Sundance. Apparently after the deposition of the Sundance material valleys or broad channels were eroded in it to a maximum depth of 60 feet or more. These hollows were filled with sand (see pl. 28, *A*), which appears now in well-exposed sections, such as that a few miles southeast of Alcova, as a light-colored sandstone ranging in thickness from a feather edge to 60 feet or more. In other places near by the sandstone is not present.

At Morrison, Colo., the type locality of the Morrison formation, rocks were once assigned to this formation which do not belong there—at the base 17 feet or more of orange-colored sandstone which is now known to be unconformable with the overlying Morrison and the underlying Lykins, and at the top nearly 200 feet of beds younger than Morrison. (See pl. 1.) The reason for the revision of the type section of the Morrison formation has been discussed elsewhere,[35] but the thicknesses given in the graphic section in the present paper should replace those previously published, for the recent measurements made with stadia are considered more reliable than the earlier measurements.

The relation of the Morrison formation to the overlying rocks has been much discussed. No obvious unconformity was found at the top of beds which were formerly included in the Morrison but which now appeared to be younger. On the other hand, there appeared to be a hiatus at the base of the conglomeratic sandstone that was formerly supposed to lie within the Morrison formation but is now believed to be the base of the overlying formation. With the Morrison formation thus restricted, the geologic section at Morrison, Colo., harmonizes with those both south and north of this town. At most places where the upper part of the Morrison is exposed it is separated from the overlying conglomeratic sandstone by an irregular line of contact, which obviously denotes post-Morrison erosion. In a ditch cut about 2 miles north of Bellvue, Colo., massive hard conglomerate fills channels in the soft underlying shale. (See pl. 26, *B*.) Similar gravel-filled channels were observed near Owl Creek and Boxelder Creek and elsewhere in northern Colorado and in southeastern Wyoming. Although at many localities the contact is obscured by surface débris, the erosional unconformity was found in so many places that it is believed to represent an important break in the geologic column, although not necessarily a long time break. An erosional unconformity of this kind is to be expected between nonmarine beds and those of a transgressing sea.

No new information as to the geologic age of the Morrison was obtained during the work reported in this paper. It is regarded by some as late Jurassic and by others as early Cretaceous. It is a relatively thin formation of nonmarine beds and lies unconformably on marine beds of late Jurassic age and unconformably beneath beds regarded by some as late Lower Cretaceous and by others as Upper Cretaceous. The fact that this long period of time is represented by so thin a formation suggests that either the unconformity below the Morrison formation or the one above it—perhaps both—denote long-continued erosion.

CRETACEOUS FORMATIONS

DAKOTA SANDSTONE AND ASSOCIATED FORMATIONS

GENERAL CORRELATION

The rocks commonly known as the Dakota sandstone in northern Colorado vary in lithologic character and form a group of thin formations. Much has been written about them, and opinion concerning their correlation has differed widely. The physical character of the rocks, their differentiation into well-defined though thin formations, and their age relations demand special consideration. The name Dakota sandstone has been variously applied, and the sedimentary rocks that have been so called in Colorado do not constitute so definite a formation as the name indicates. Instead of a single formation there is a group of sandstones and shales, some of which in one place or another have been given distinctive names. In southeastern Colorado a lower sandstone and a shale overlying it that were formerly included in the Dakota formation are now called the Purgatoire formation and classed in Geological Survey publications as Lower Cretaceous, the name Dakota being limited to the upper sandstone. This usage is employed in the Castle Rock folio and other reports on central and southeastern Colorado. These two formations, however, are correlated by the writer with the Dakota group of the section at Bellvue, Colo.

[34] Lee, W. T., Smithsonian Misc. Coll., vol. 69, No. 4, p. 18, 1918.
[35] Lee, W. T., Am. Jour. Sci., 4th ser., vol. 49, pp. 183–188, 1920.

This group of rocks was followed from Castle Rock northward along the eastern foothills of the Rocky Mountains in Colorado and northwestward in Wyoming and examined at short intervals. (See fig. 4.) In northern Colorado it is divisible into a lower sandstone, a middle shale, and an upper sandstone. In southeastern Wyoming the lower portion of the correlated rocks is called the Cloverly formation, and the shale above it—the upper shale and the upper sandstone of this report—has been grouped with the still younger beds there referred to the Benton shale. In the more recent reports and especially in the usage of geologists in the employ of oil companies the sandstone that the writer correlates with the upper sandstone at Bellvue is locally known as the Muddy sand, a name derived from Muddy Creek, in northern Wyoming.

The name Dakota group applied by the writer in a recent United States Geological Survey publication [36] called middle shale in the publication just cited but which in many of the sections is the higher of two shales and is therefore designated the upper shale of this group; and (4) an upper sandstone, which is the upper Dakota of northern Colorado and the Muddy sand of many Wyoming localities and is probably equivalent to the Newcastle sandstone of eastern Wyoming.

The writer feels that the group is well defined from Colorado Springs, Colo., northward nearly to the southern boundary of Montana. According to his interpretation it includes the Cloverly formation of Wyoming and some of the rocks usually included in the Benton shale. It also includes red rocks in northern Wyoming which some geologists have included in the Morrison formation. (See Cody section, pl. 2.)

In the northern part of the Big Horn Basin, in Wyoming, the upper part of this group of rocks was

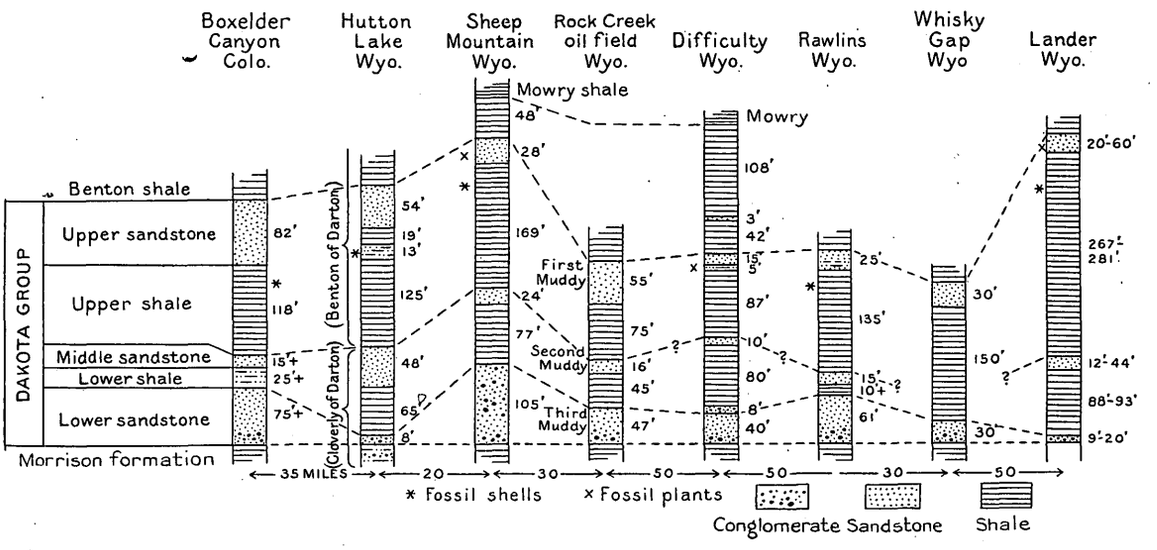


FIGURE 4.—Sections between Colorado Springs, Colo., and the Big Horn Basin, Wyo., showing rocks correlated by the writer with the Dakota group at Bellvue, Colo.

to these beds as far west as Lander and as far north as Greybull, Wyo., is accepted by the Survey only for the section at Bellvue, Colo., with the understanding that if rocks of Comanche age are proved to be present in the Dakota group of that section, they are to be excluded from the group. In accordance with the Geological Survey's adopted usage the rocks to which the writer thus applied the term Dakota group are described in this paper according to their position. In order from bottom to top the divisions are (1) a lower sandstone, which is so commonly conglomeratic throughout the area described that it might properly be called a conglomerate; (2) a variable division of sand and shale separable toward the north into a highly colored lower shale and a sandstone that becomes the middle sandstone of the group where three sandstones are present; (3) an upper shale, which was not differentiated by the writer from the other beds of Benton age. This uncertainty is indicated in the correlated sections of Plate 2.

The writer is more confident of the correlations of the lower part of the group than of the upper part. His lower and middle sandstones and the intervening colored shale are correlated with the Cloverly formation of Wyoming. The lower conglomeratic sandstone extends into southern Montana, where it has been called Dakota sandstone by some geologists, lower Cloverly by others, Dakota by others, and Kootenai by still others. Still farther north these beds seem to be correlatable with the Kootenai formation of the Great Falls coal field. These relations are best shown on Plate 2.

It may be questionable whether these beds should be called a group in the technical sense in which that term is used. They contain some beds classed as

[36] Lee, W. T., U. S. Geol. Survey Bull. 751, pp. 1–22, 1923.

Lower Cretaceous and others classed as Upper Cretaceous. The few fossils found in them do not establish the geologic age of the rocks beyond question.

In the writer's opinion structural relations are much more significant than fossils in separating the rocks into systems and series. The marine Jurassic Sundance formation, whose age is established by numerous fossils, is overlain unconformably by the nonmarine Morrison formation, whose fossil dinosaurs indicate Jurassic age to some and Lower Cretaceous age to others. This uncertainty is indicated in the United States Geological Survey classification by the interrogation mark placed after the word Cretaceous. As the Morrison formation lies unconformably on the Sundance formation, of Upper Jurassic age, and unconformably beneath rocks which the writer would include in the Upper Cretaceous series, it should in his opinion be classed as Lower Cretaceous without question.

The Morrison is followed unconformably by a conglomeratic sandstone, and this in turn by beds of variable nature. But variable as these beds above the conglomerate may be, the writer found no evidence of any unconformity that he can compare with that below the conglomerate. In his opinion this conglomerate represents the base of the series of rocks formed chiefly in the sea of Upper Cretaceous time. For this reason he has made this conglomerate the basis of correlation in Plates 1 and 2. The variations in this group of rocks are, in his opinion, best explained on the supposition that they are early expressions of the long period of sedimentation that culminated in Upper Cretaceous time in the thick masses of marine deposits. The general advance of the Cretaceous sea over the land was probably slow and was accompanied by many fluctuations and minor retreats. Nonmarine rocks may be conceived as forming on the coastal plain in advance of submergence, to be covered in time by the oncoming sea. The writer pictures this condition as resulting in the rocks which he would call the Dakota group. If this conception is true it naturally follows that the beds of this group should differ slightly in age from place to place. For this reason he regards the group as the early sedimentary expression of the great marine Cretaceous succession of the West, but he does not correlate its individual beds from place to place with great exactness. He believes that the basal conglomerate is continuous and may be correlated from place to place with much confidence. Some of the beds above this conglomerate may be correlated with considerable confidence for long distances, but the dotted lines connecting individual beds in the sections in Plates 1 and 2 are not intended to imply hard and fast correlations. Nevertheless, a significant succession is recognizable in many places. This is emphasized by the connecting lines between platted sections and in the detailed descriptions that follow.

The classification of these beds is troublesome because they are structurally parts of the Upper Cretaceous series but have been correlated with beds which many call Lower Cretaceous. On the basis of the fossils collected from the upper shale of the Dakota group at Bellvue, Colo., and neighboring localities, called "middle Dakota shale" by Reeside,[37] he correlated these rocks with the Purgatoire formation of Colorado and with beds of Washita age in Kansas. After quoting Stanton's opinion,[38] based on differences in the faunas, that these rocks at Bellvue and neighboring localities in northern Colorado are younger than the Purgatoire formation, Reeside says:[39]

> The relationship of the beds of Washita age in Kansas to the overlying Dakota formation is so intimate as to preclude any great difference in age, and the difference in interpretation of the fauna is therefore not very great. However, it seems to the writer that it is better to regard the fossils of the so-called Dakota formation as of the same age as those of the Purgatoire formation and attribute the differences between them to some now unknown difference in the conditions under which the sediments were deposited. The fauna from northern Colorado, in spite of its paucity, is more like that of the Washita group than that of the succeeding Benton shale or that of any known Dakota beds, and a correlation based on the fauna must be a correlation with the Washita rather than with the Benton. The fauna is apparently an extension of the known range of the late Comanche fauna as far north as southern Wyoming.

This opinion is in harmony with the writer's findings of several years past and with his correlations based chiefly on stratigraphic succession and continuity of formations. It is in harmony also with the opinion of several other geologists. The beds of Washita age in Kansas are placed by the writer[40] in the Upper Cretaceous series,

> on the correlation that the Washita series is Cenomanian, strata that European stratigraphers refer to the Upper Cretaceous. If the latter reference be conceded, the Purgatoire formation and "lower Dakota" of the Rocky Mountain localities will fall at the base of the Upper Cretaceous. The abrupt change from the conglomeratic "lower Dakota" to the underlying Morrison (even at the town of Morrison, if the Saurian conglomerate is "lower Dakota") is in harmony with this suggestion. This disposition would place a thin but complex group of sandstones and shales in the lower part of the redefined Upper Cretaceous series.

This opinion further is in harmony with the writer's findings described in this report, which tend to connect the fossiliferous beds, or upper shale, of the Bellvue section with the shale member of the Purgatoire formation of the Colorado Springs and Castle Rock folios, as shown in Plate 1. Whether the Purgatoire of these folios is correctly correlated with the beds of Washita age in Kansas is another question. It is, however, to be noted that these Kansas beds and the supposedly equivalent Purgatoire formation contain the rocks of which it is said:[41]

[37] Reeside, J. B., jr., U. S. Geol. Survey Prof. Paper 131, p. 199, 1923.
[38] Stanton, T. W., Geol. Soc. America Bull., vol. 33, pp. 255–272, 1922.
[39] Reeside, J. B., jr., op. cit., p. 200.
[40] Lee, W. T., Am. Jour. Sci., 4th ser., vol. 49, pp. 187–188, 1920.
[41] Wilmarth, M. G., U. S. Geol. Survey Bull. 769, pl. 1, 1925.

In publications of the U. S. Geological Survey the Comanche series has always been classified as Lower Cretaceous, as a matter of convenience, although it has long been recognized that in its upper part it includes rocks that are probably younger than any assigned to the Lower Cretaceous in Europe.

LOWER SANDSTONE

The lower sandstone is a coarse-grained, massive, conglomeratic rock ranging in thickness from a few feet to more than 100 feet, with lenses and irregularly shaped masses of pebbles usually near the base but in some places distributed through the whole thickness. It rests unconformably on the Morrison formation. (See pl. 28, *B*.) The pebble beds in some places fill channels in the shale and contain petrified trunks of coniferous trees. It is believed to be the first sedimentary expression in the region here described of the sea that invaded the interior of North America about the middle of the Cretaceous period. The sand and pebbles are regarded as coastal-plain deposits or in places as the beach deposits of the shore of the advancing sea, and as such they constitute a transgressing formation which may differ slightly in age from place to place. This sandstone corresponds to the Lytle sandstone member of the Purgatoire formation of central and southeastern Colorado, to the lower sandstone of northeastern Colorado, which has always been called Dakota, to the lower Cloverly of the Laramie and Sherman quadrangles and of other areas in southern and central Wyoming, and probably in part, at least, to the lower conglomeratic sandstone of the Cloverly formation in portions of the Big Horn Basin and to some part of the Lakota sandstone of the Black Hills. (See fig. 5.) It varies greatly in thickness and lithologic character from place to place. At some localities it is quartzose and forms the crest of the so-called Dakota hogback; at others it is soft and friable and crumbles so easily that a débris-covered slope forms at its outcrop. In such places the crest of the hogback is formed by one of the other higher sandstones or even by a hard layer of the Morrison formation.

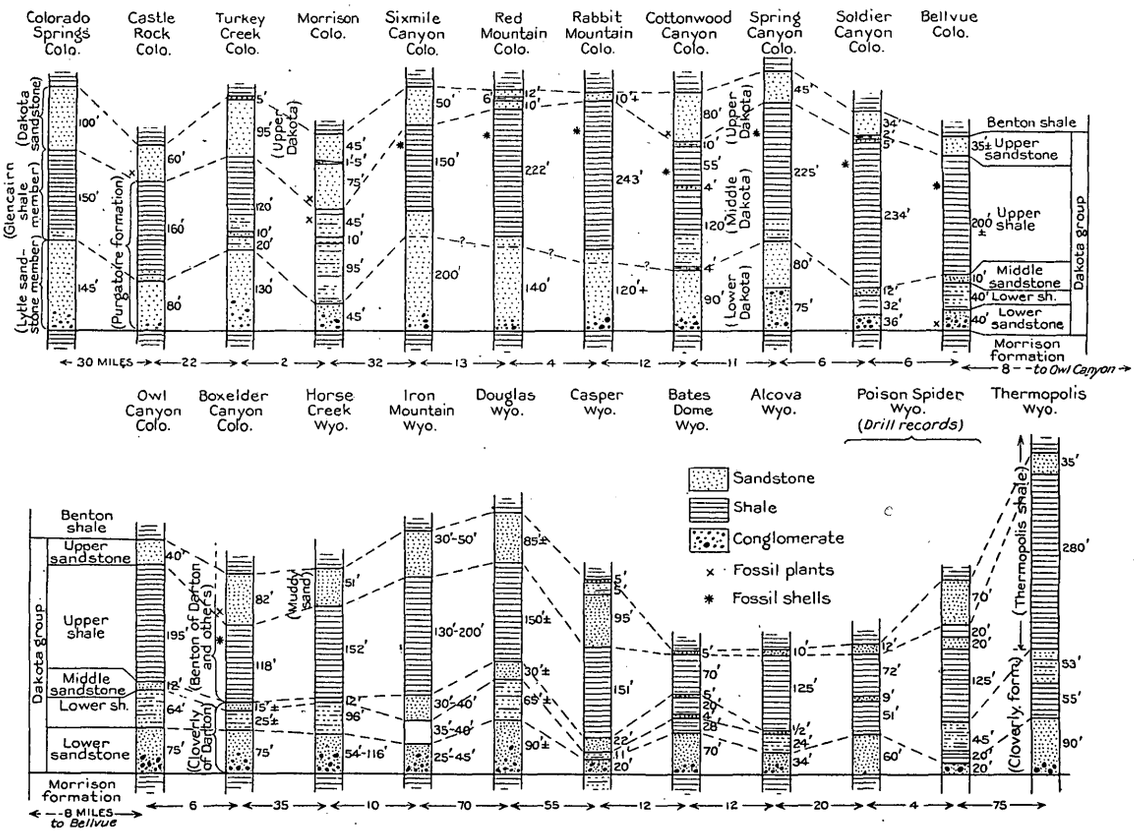
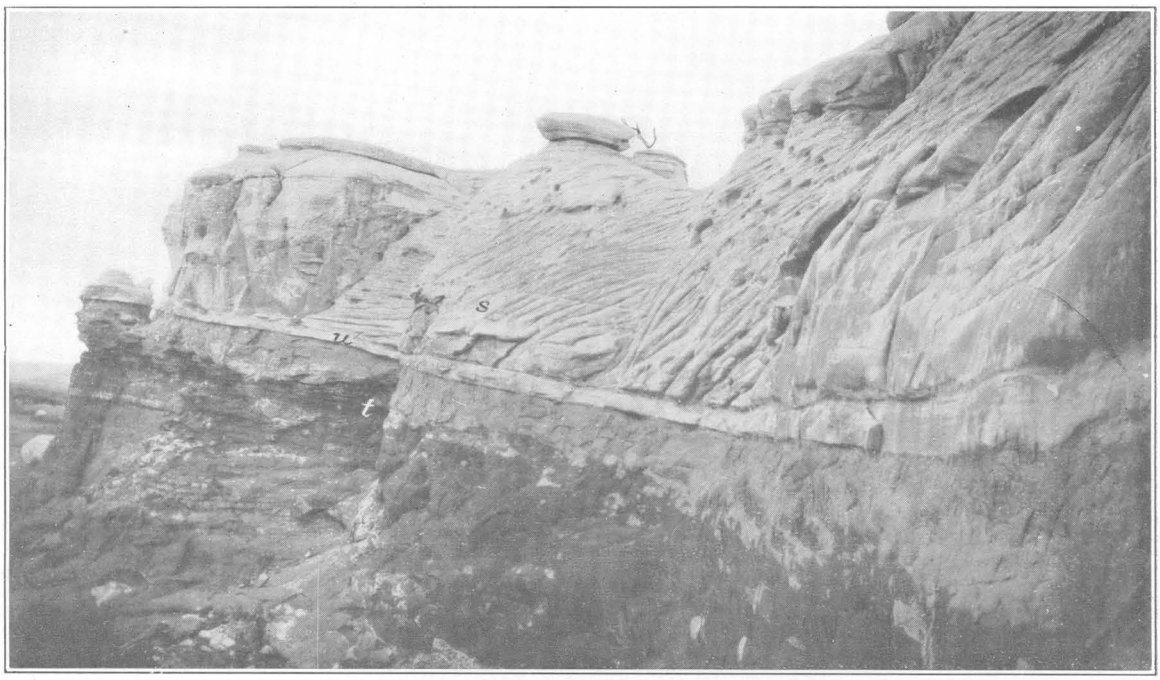


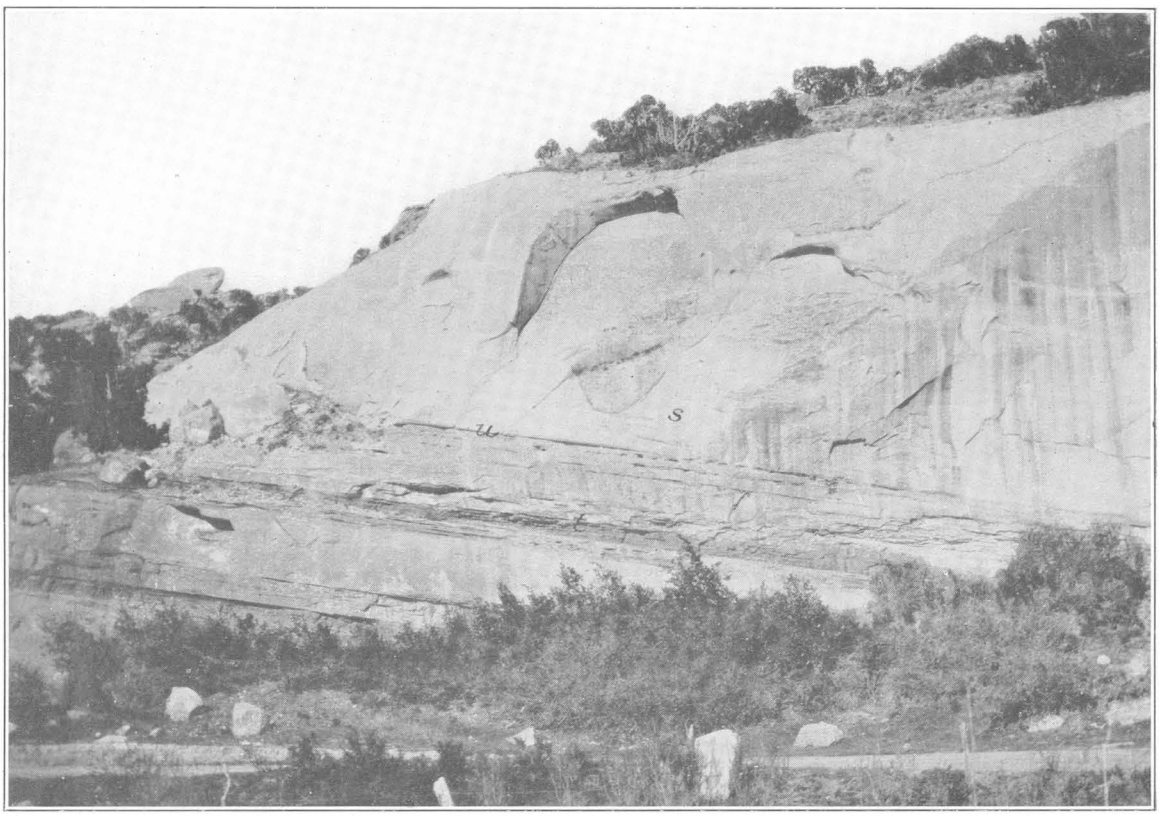
FIGURE 5.—Chart illustrating the writer's conclusions on the correlation of certain Cretaceous rocks between Colorado Springs, Colo., and Thermopolis, Wyo., with the Dakota group of the section at Bellvue, Colo.

VARIEGATED SHALE

At nearly all the localities examined in Wyoming and northeastern Colorado a formation variable in thickness, color, and constitution was found above the lower conglomerate just described. It ranges in thickness from a few feet to 75 feet and in lithology from clay shale to coarse quartzose sandstone. The shale predominates, hence the formation as a whole is soft. It lies between hard sandstones and is well exposed in only a few places. Where seen to best advantage most of the shale is colored in many shades of red, blue, and green. It was clearly recognized in northern Colorado as far south as Soldier Canyon, near Loveland. (See pl. 29, *A*.) Farther south



A. LIGHT-COLORED SUNDANCE SANDSTONE (*s*) RESTING UNCONFORMABLY (at *u*) ON CHUGWATER RED BEDS (*t*) ABOUT 1 MILE NORTHEAST OF ALCOVA, WYO.

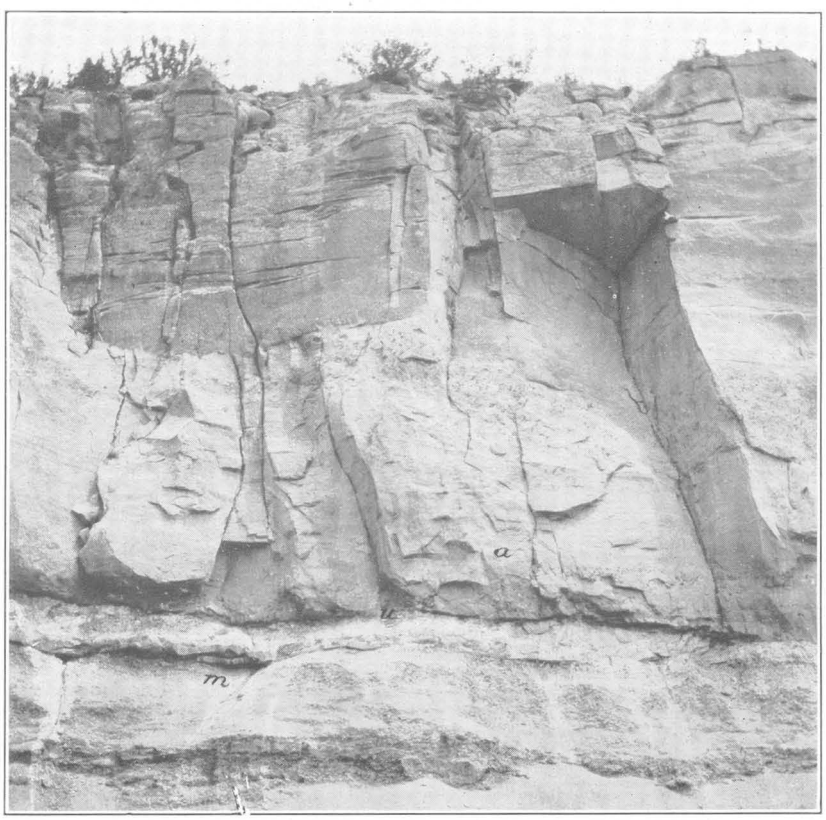


B. BLUFF AT THE WEST END OF CASPER MOUNTAIN, WYO.

Showing massive light-colored sandstone at the base of the Sundance formation (*s*) resting unconformably (at *u*) on laminated orange and salmon-colored sandstone of the Chugwater red beds (*t*). The Alcova limestone marine, probably Triassic, occurs here a few feet below the rocks shown in the view

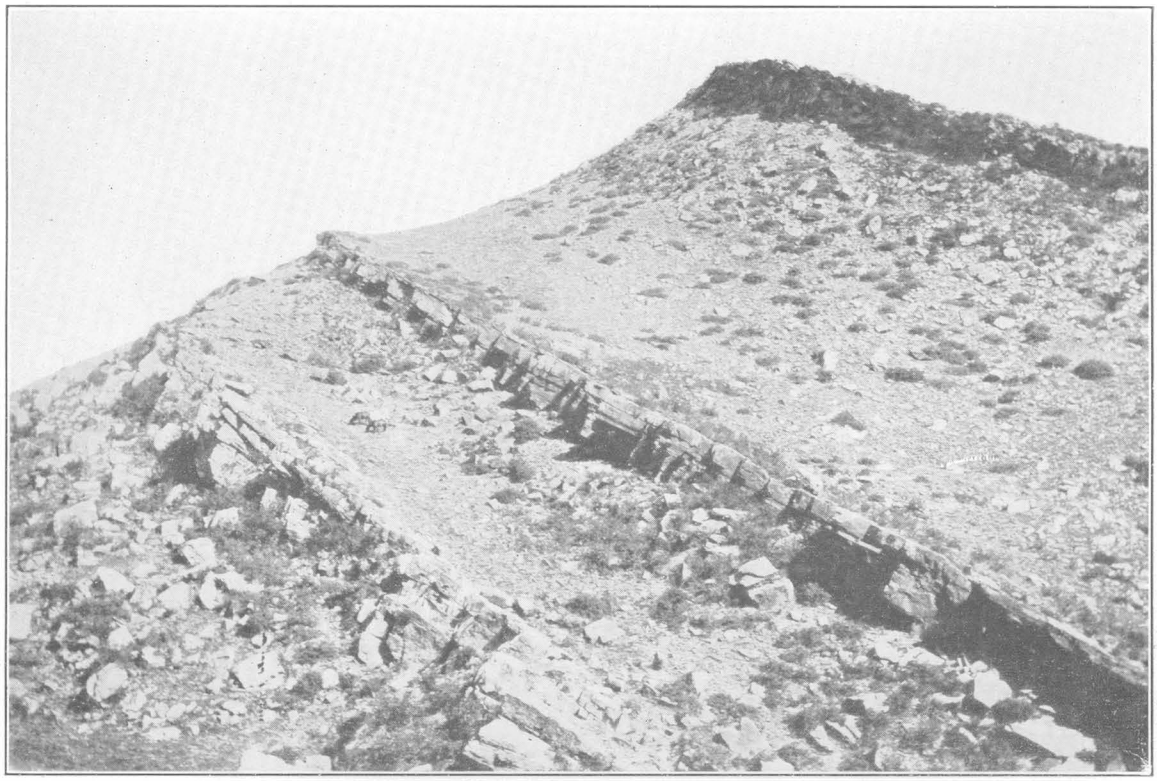
A. BASE OF MORRISON FORMATION NEAR ALCOVA, WYO.

A soft, friable gray sandstone, 60 feet thick, resting unconformably on marine Sundance beds and overlain by typical variegated shale of the Morrison formation



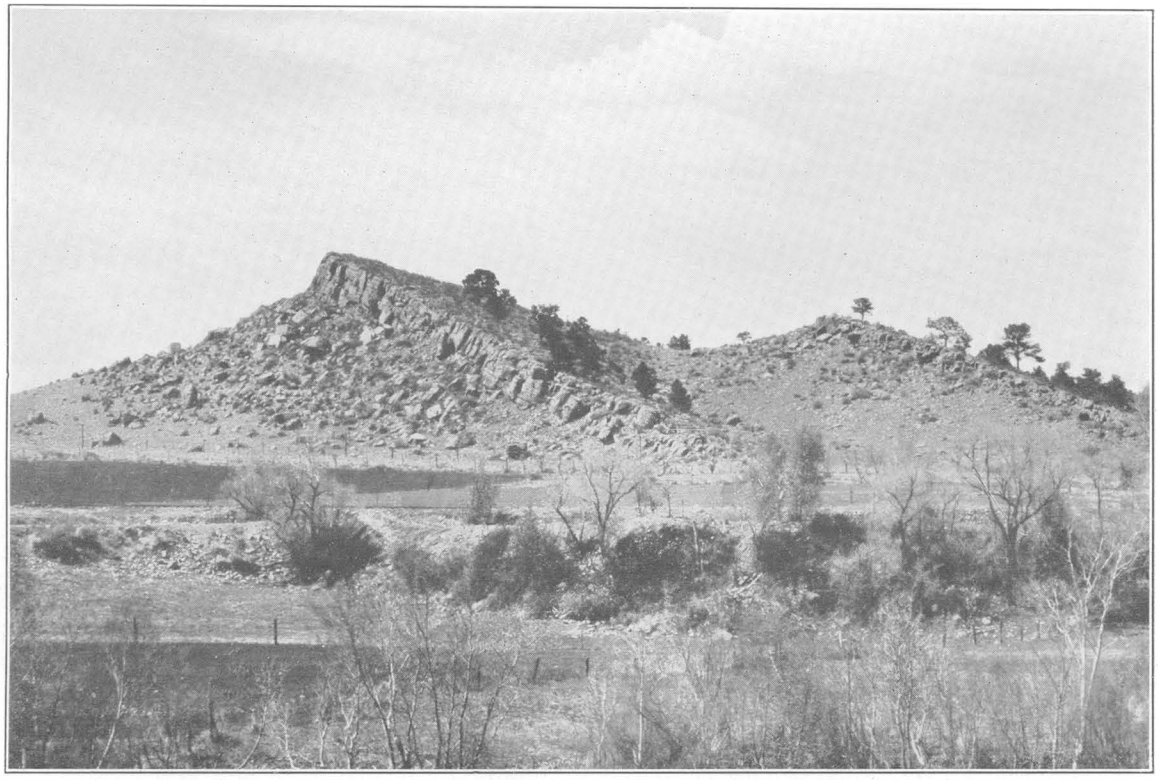
B. CONGLOMERATE OF THE LOWER SANDSTONE OF THE DAKOTA GROUP (*a*) ABOUT 2 MILES NORTH OF BELLVUE, COLO.

Resting unconformably (at *u*) on Morrison shale (*m*)



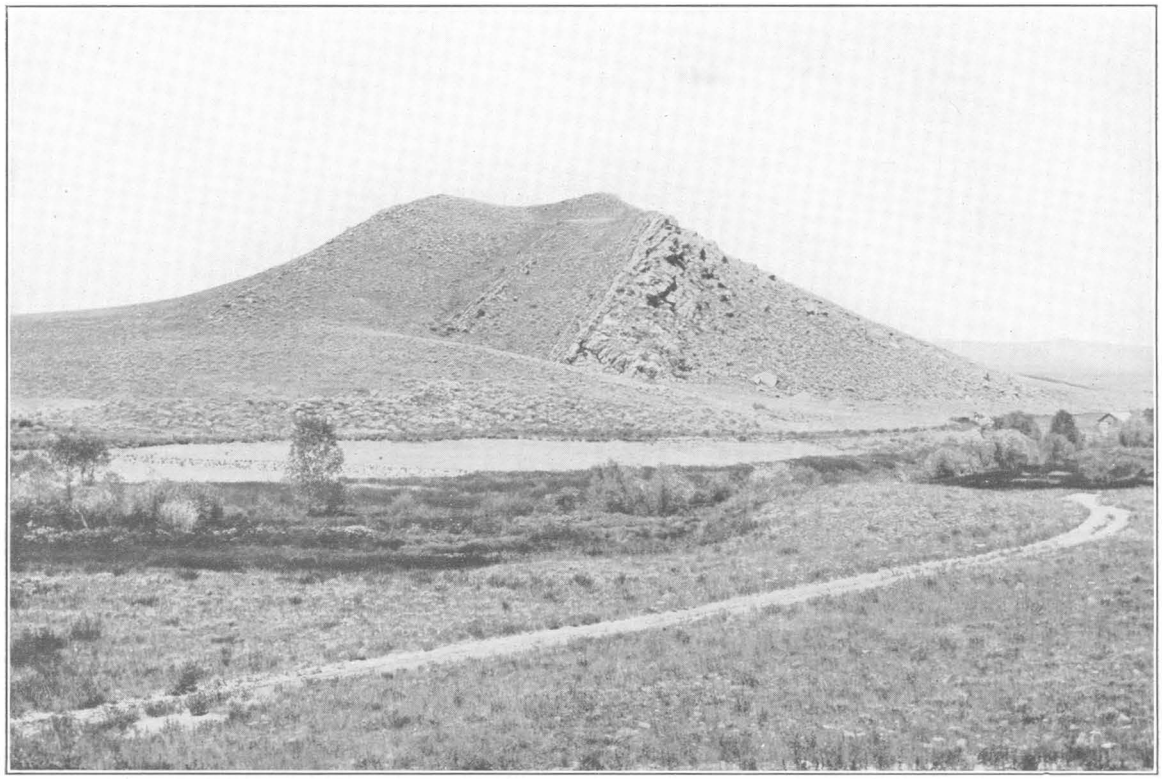
A. NORTH WALL OF SOLDIER CANYON NEAR LOVELAND, COLO.

Showing at the left the sandstone, 36 feet thick, correlated by the writer with the lower sandstone of the Dakota group at Bellvue; overlain by the lower variegated shale, 32 feet (for scale note horses on slope); the middle sandstone, 12 feet; the upper shale, 234 feet; and the upper sandstone, 41 feet, at the crest of the ridge



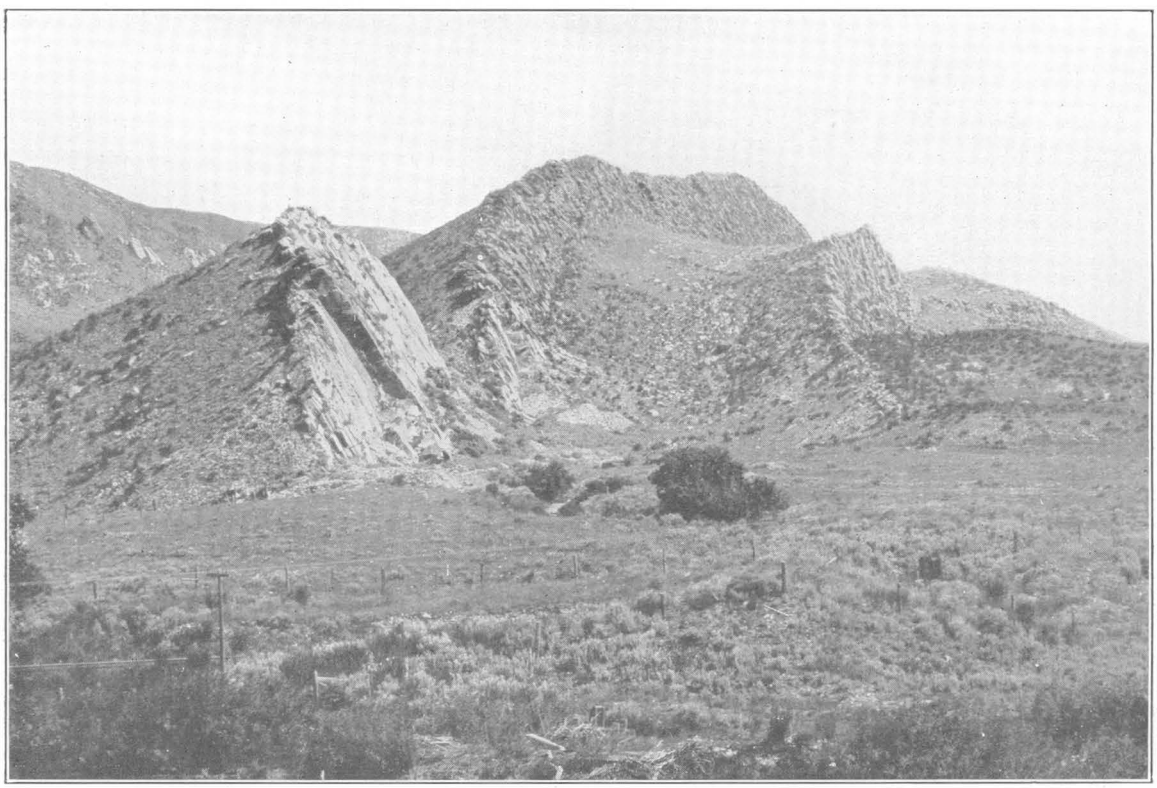
B. RIDGES IN THOMPSON CANYON WEST OF LOVELAND, COLO.

Showing rocks correlated by the writer with the Dakota group at Bellvue—the lower sandstone, at the left, above a boulder-covered slope of Morrison shale; the middle shale, between the two ridges; and the upper sandstone, at the right. The lower shale and middle sandstone are not exposed here



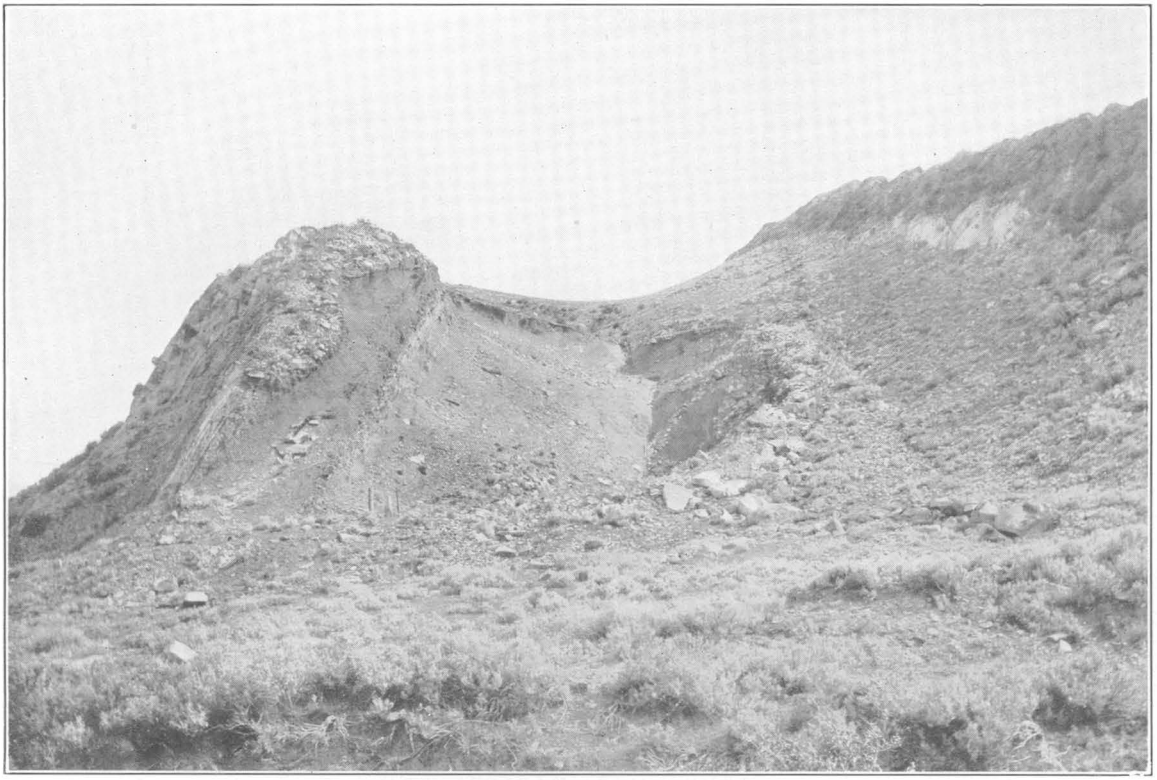
A. RIDGE NEAR POISON LAKE, SOUTH OF DOUGLAS, WYO.

At the right, massive conglomerate correlated with the lower sandstone of the Dakota group at Bellvue, Colo.; overlain by the variegated lower shale in the smooth slope to the left of the massive layer; the middle sandstone, inconspicuously exposed, forming the highest point; the middle shale still farther to the left; and the upper sandstone forming the slope to the left of that



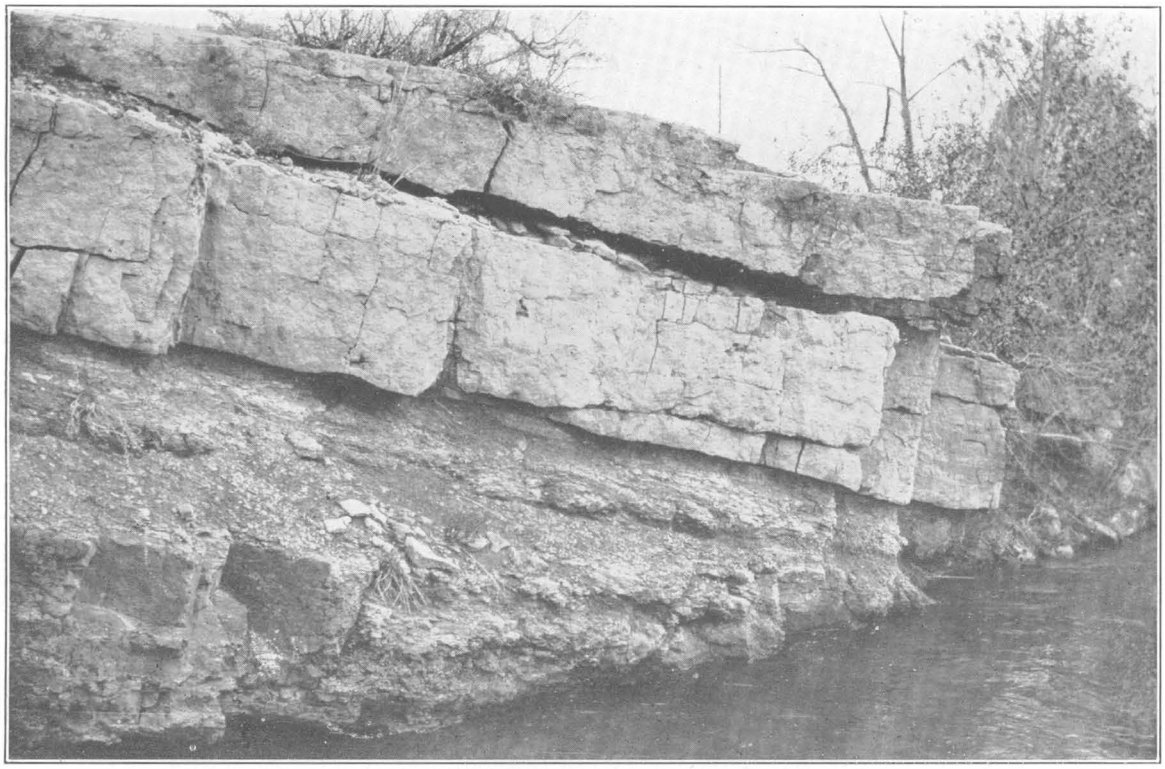
B. RIDGES NORTH OF CHUGWATER CREEK, NEAR IRON MOUNTAIN, WYO.

Formed by sandstones correlated with the Dakota group at Bellvue, Colo. The main ridge shows the platy middle sandstone, with the conglomeratic lower sandstone in the slope to the left. The upper sandstone forms the smaller ridge to the right, and the middle shale crops out between the ridges



A. RIDGE NEAR IRON MOUNTAIN, WYO.

Showing rocks correlated with the upper sandstone and fossiliferous upper shale of the Dakota group at Bellvue, Colo., where quarried south of Chugwater Creek

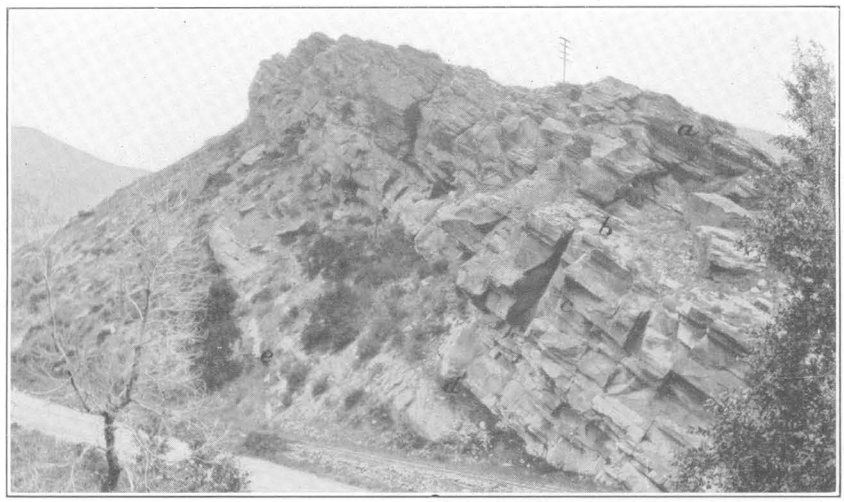


B. DETAILS OF SANDSTONE EAST OF LYONS, COLO., THAT IS CORRELATED WITH THE UPPER SANDSTONE OF THE DAKOTA GROUP AT BELLVUE

Showing a hard quartzose layer resting on carbonaceous shaly sandstone. The lower dark-colored material is full of small fragments of charcoal and impressions of twigs and a variety of plant débris

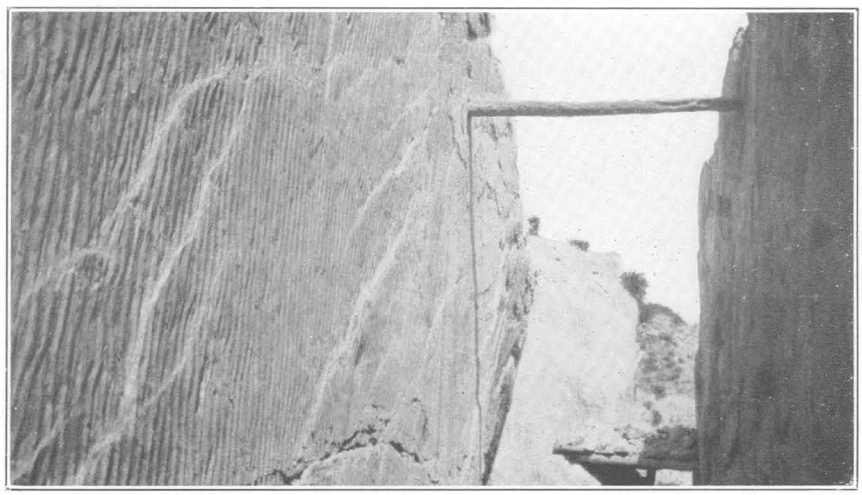
A. DAKOTA HOGBACK 3 MILES SOUTH OF GOLDEN, COLO.

Showing fire clay 8 feet thick (*b*); plant-bearing sandstone, 8 feet (*c*); fire clay, 15 feet (*d*); plant-bearing sandstone and shale (*e*). On the slope to the right are variegated beds correlated with the lower shale of the Dakota group at Bellvue, and conglomeratic sandstone which probably represents the lower sandstone of that section. The beds in the foreground are offset a few feet to the left by faulting, and at the crest of the ridge they are duplicated by faulting



B. NORTH WALL OF GAP AT MORRISON, COLO.

Showing sandstone (*a*, *c*) correlated with the upper sandstone of the Dakota group at Bellvue, separated by a lens of shale (*b*); the base of the upper sandstone (*d*); and the shaly, friable plant-bearing sandstone (*e*) of the middle shale



C. NEAR VIEW OF THE 8-FOOT SANDSTONE SHOWN IN *A*

Showing ripple-marked face exposed by the removal of the shale

FOSSIL TRACKS IN LYONS SANDSTONE

colored beds at several localities above the lower conglomerate are believed to represent this formation. These beds were studied in detail between Golden and Morrison, Colo., and the variegated beds above the conglomerate in the Morrison section, formerly included in the Morrison formation, probably represent this variegated part of the Dakota group at Bellvue. Little is known of these variegated beds farther south, but certain beds of maroon shale described in the Apishapa folio may represent it.

No fossils were found in these colored rocks, and the only means of correlation are color and stratigraphic position. In color they resemble the Fuson of the Black Hills and hold the same relation to the underlying conglomerate that the Fuson holds to the Lakota sandstone of that region, as Darton has pointed out in the Laramie-Sherman folio. But the available information is not regarded as sufficient to warrant definite correlation of the variegated shale with the Fuson formation.

MIDDLE SANDSTONE

In southern and central Wyoming and northeastern Colorado a relatively thin but persistent sandstone overlies the variegated beds just described. It ranges in thickness from a few feet to about 75 feet. It is usually evenly bedded and strongly ripple-marked. It is the upper Cloverly of most but not all of the geologic reports on southern Wyoming, and the Dakota sandstone of some localities where the names Lakota and Fuson have been used. It seems to extend continuously through northern Colorado to points south of Soldier Canyon. At the more southerly localities it has not been definitely differentiated and is included in the beds here described as middle shale.

UPPER SHALE

The dark shale here designated the upper shale (see pl. 29, *B*) is persistent throughout the region described, though somewhat variable in character. It ranges in thickness from 70 to about 245 feet, is sandy in some places, calcareous in others, and usually is dark colored and bituminous. In central eastern Colorado, represented in Plate 1 by the Castle Rock section, the 160 feet of beds assigned to it probably include equivalents of the variegated shale and the middle sandstone. In Turkey Canyon, west of Denver, it is dark and bituminous and is probably the source of the asphalt that occurs in the overlying sandstone. Near Morrison and Golden such portions of this formation as are exposed are sandy. But north of Boulder, Colo., the formation consists chiefly of dark shale containing thin layers of sandstone and platy limestone. At these localities this shale lies between two prominent sandstones and constitutes a middle shale. It was so designated in a former publication,[42] but inasmuch as farther north a lower shale occurs, this one is here called the upper shale.

The stratigraphic relations between the towns of Morrison and Boulder, Colo., are complicated by the faulting that accompanied the upturning of the formations in the foothills. This is the area long supposed to exhibit evidence of ancient transverse folds against which some of the older sedimentary formations were built but which were finally buried underneath the sediments of late Cretaceous age. This interpretation has been successfully challenged by Ziegler,[43] who shows that the absence of some of the formations is due to strike faults rather than to the presence of an ancient east-west ridge. Possibly faulting will explain the occurrence in the Eldorado section of only a few feet of shale that can be assigned to the upper shale. This section was measured where the formations are upturned to a nearly vertical position. During the upturning movement slipping would naturally take place in the soft shaly beds.

In the writer's opinion the upper shale is essentially the same as the Glencairn shale member of the Purgatoire formation of the Colorado Springs and Castle Rock folios, which holds the same stratigraphic position as a shale in the Apishapa quadrangle that contains a Kiowa fauna and which, together with the underlying sandstone, has been classed as Lower Cretaceous. The shale contains marine invertebrates at many localities between Boulder, Colo., and Iron Mountain, Wyo., but such fossils as were known prior to 1921 were interpreted as indicating that this shale was closely allied to overlying shales of unquestioned Upper Cretaceous age. In the Laramie-Sherman folio and other reports on areas in southern Wyoming this shale was included in the lower part of the shale there called Benton. Fossils from it have been known for many years, but the collections were poor and the species not well known. Henderson[44] suggested its correlation with the Comanche, but Stanton considered the fossils more closely allied to species from the overlying Benton than to the Comanche species.

In the summer of 1921 the writer found localities where the exposures were fresh and the fossils well preserved. The best collections were made in Soldier Canyon (see pl. 29, *A*) and 2 miles north of Bellvue, Colo., where fresh material was found in a ditch cut. These collections and those made in former years by Stanton and others have been examined by Reeside,[45] who describes the following species in a recent paper:

Inoceramus comancheanus Cragin.
Inoceramus bellvuensis Reeside.
Pteria salinensis White.
Ostrea larimerensis Reeside.
Ostrea noctuensis Reeside.
Anchura kiowana Cragin?.
Ammonite, undetermined.
Fish scales and bones.

[42] Lee, W. T., U. S. Geol. Survey Bull. 751, pp. 6–8, 1923.

[43] Ziegler, Victor, Wyoming Geol. Survey Bull. 14, 1917.

[44] Henderson, Junius, Colorado Geol. Survey First Rept., p. 175, 1908.

[45] Reeside, J. B., jr., U. S. Geol. Survey Prof. Paper 131, pp. 199–208, 1923.

This fauna tends to confirm Henderson's correlation of the upper shale with the Comanche—that is, with the shale member of the Purgatoire formation of southeastern Colorado and with the Kiowa shale of southern Kansas, which some geologists regard as basal Upper Cretaceous, others as Lower Cretaceous.

The structural relations in the Rocky Mountains seem to the writer so clear that even without the aid of fossils this shale and its associated formations constituting the Dakota group of the Bellvue section are naturally classed as the basal formations of the series of strata which in the main are of unquestioned Upper Cretaceous age. The rocks of this group and those correlated with it are regarded by the writer as the first deposits of the invading sea which occupied the interior of North America in Upper Cretaceous time, and they are naturally grouped with the overlying beds that were formed in this sea. There is not yet agreement on the question of correlation with rocks at distant exposures.[46]

The evidence of such fossil plants as have been collected from the sandy beds of the upper shale also tends to confirm its reference to the Upper Cretaceous series. As these do not differ from the plants in the upper sandstone they will be mentioned in the description of that formation.

UPPER SANDSTONE

At nearly all localities examined the top bed of the rocks correlated with the Dakota group at Bellvue is a sandstone. This sandstone may be a single, essentially continuous layer, or there may be many discontinuous lenses at about the same horizon. It ranges in thickness from a few feet to about 100 feet and in character from soft shaly sandstone to a massive resistant quartzite. In central Wyoming it is soft, shaly, and either inconspicuous as a ridge maker or only moderately prominent, as shown at the left in Plate 30, *A*. In northern Colorado it is quartzose and very resistant and makes a prominent ridge, which in some places forms the crest of the Dakota hogback (pl. 29, *A*) and in others a separate ridge (pl. 30, *B*). At many localities it is made up of thin layers of quartzite whose surface is covered with worm tracks and a variety of peculiar markings, the significance of which is not known. At several localities a massive layer at the top grades downward through a transitional zone of sandy shale (see pl. 31, *B*) to the underlying upper shale. In a few places, as near Golden and Morrison, the sandstone layers below the typical upper sandstone are prominent and contain fossil plants. At a number of localities a similar transitional zone was found between the upper sandstone and the overlying Benton shale, as at Eldorado. (See fig. 4.) It is possible that in some places a thin layer of sandstone may be the attenuated edge of a sandstone lens which at some locality near by is the chief ridge maker. This suggestion is strengthened by the absence of any recognizable upper sandstone in some places. Between Lyons and Fort Collins, Colo., the upper sandstone is variable in character and thickness, thinning in several places to a few feet, and at one locality it is entirely absent. South of Lyons it thickens, becomes hard, and forms the crest of the Dakota hogback. From Morrison southward beyond the canyon of South Platte River it consists of two sandstones of nearly equal thickness separated in most places by a thin layer of shale. (See pl. 32, *B*.)

The upper sandstone and the sandy portions of the underlying upper shale have yielded numerous fossil leaves and much petrified wood. In northern Colorado fossils believed to be *Halymenites major* were seen in it in several places, and near Boxelder Canyon Stanton found an ammonite which came from it. In southern and central Wyoming it is so shaly in some places that without tracing from localities where it is well developed it would be included as an inconspicuous member in the Benton shale.

The upper sandstone and the sandy shale just below it have furnished some of the plants of the Dakota flora. Many of these were collected near Morrison years ago by Lieutenant Beckwith and described by Lesquereux. In more recent years several geologists have collected plants from the upper sandstone and from the shaly sandstone at Morrison (see pl. 32, *B*), near the top of what is here called the upper shale, formerly included in the Morrison formation. The subdivisions thus made at Morrison were traced northward to Golden, where the shales and sandstones are exposed in clay pits. Unfortunately faulting has here interfered with the clear recognition of relationships. However, the lower sandstone was identified, also the overlying variegated shale. Stratigraphically above this shale, in a clay pit about 3 miles south of Golden, is a succession of shales and sandstones, as shown in Plate 32, *A*. Here fossil plants occur in great numbers, both in the shale just below the most conspicuous sandstone at the right, within this sandstone, and in the shale exposed in the excavation still farther to the right. These plants, which are listed below, are recognized by F. H. Knowlton as belonging in the Dakota flora.

Salix proteaefolia Lesquereux.
Sapindus morrisoni Lesquereux.
Liriophyllum beckwithii Lesquereux.
Ficus Lesquereux.
Ficus magnoliaefolia Lesquereux.

No fossils were found in the higher shale nor in the upper sandstone at this locality, although the upper sandstone contains fossil leaves in other places. The sandstones are massive and friable, and the middle one shown in Plate 32, *A*, is beautifully ripple-marked. The photograph reproduced in Plate 32, *C*, shows the ripple marks on the upper face of this sandstone. This photograph was taken in the clay pit shown at the

[46] Stanton, T. W., Geol. Soc. America Bull., vol. 33, pp. 255–272, 1922.

left in Plate 32, *A*, looking in the opposite direction, out of the opening.

Similar conditions were observed north of Golden, where several layers of sandstone, some of them conspicuously ripple-marked, are separated by fossiliferous shale. Farther north, at Eldorado, the rocks to the Dakota group at Bellvue consists mostly of sandstone, and no fossils were found in them. Still farther north, beyond Boulder, where the beds can be differentiated into the five formations just described, the upper sandstone is a conspicuous unit. It is the upper sandstone of the Dakota of northern Colorado, the Muddy sand of the oil men of Wyoming, the sandstone in the middle of the Thermopolis shale of the Big Horn Basin, and probably the Newcastle sandstone member of the Graneros shale of eastern Wyoming.

BENTON SHALE AND NIOBRARA LIMESTONE

At all the localities here described rocks of Benton age were observed. There is no intention of including in this paper new information relative to this shale, but as certain horizons in it are generally recognized as persistent over wide areas, they are included in the platted sections as an aid in correlation. The shale next above the upper sandstone of the rocks correlated with the Dakota group at Bellvue is a dark-colored shale, 50 to 100 feet thick, that has been generally recognized as of Graneros age throughout the area described. Above it is the Mowry shale member of the Graneros, which was found at all localities examined in Wyoming. The Mowry shale is inconspicuous at Horse Creek, the southernmost Wyoming locality examined east of the mountains, and disappears toward the south.

In some of the sections described (see secs. 5–7, pl. 1) a few thin beds of fossiliferous limestone near the top of the Benton shale represent the Greenhorn limestone, but in no place observed could these beds be differentiated on lithologic grounds as a distinct formation.

The still younger Niobrara limestone is clearly recognizable, by its lithology and fossils, as far north as Douglas, Wyo., but west of that town the lithologic criterion fails. In nearly all the sections south of Douglas a few feet of sandstone appears below the Niobrara limestone, at or near the top of the Benton shale. Near Douglas sandstone and sandy shale 75 to 100 feet thick occur lower in the sections and are believed to represent the Wall Creek sandstone. At localities farther west this sandstone, together with several older layers of sandstone separated by shale, forms the Frontier formation of southwestern Wyoming.

SUMMARY OF CORRELATIONS

The correlations made in this paper are shown graphically in Plates 1 and 2 and Figure 4.

Certain formations at the base of the generally recognized Cretaceous sedimentary succession form a well-defined group of strata, which is correlated with the Dakota group of the section at Bellvue, Colo. Throughout most of the area described these rocks consist of five divisions.

The next older formation, the Morrison, is persistent throughout the area described. It is unconformable with the overlying rocks, with the underlying Sundance formation, and with still older formations where the Sundance is absent.

The Sundance formation, of late Jurassic age, consists of a basal sandstone lithologically similar to the Nugget and other sandstones of Jurassic age; a lower, sparingly fossiliferous marine member; a middle red gypsiferous member; and an upper, abundantly fossiliferous member. These rocks were eroded in post-Sundance time and in some places entirely removed. The basal sandstone lies unconformably on the "Red Beds," which range in age from Upper Triassic to probably early Permian.

At the top of the "Red Beds" is a nonmarine sandstone—the Jelm formation—of Upper Triassic age, which lies unconformably on gypsiferous Triassic beds in central Wyoming and overlaps these and still older rocks in southeastern Wyoming and eastern Colorado. Below the Jelm, which was formerly included in the Chugwater formation, are extensive beds of red sandstone, shale, and gypsum, at the base of which is a marine limestone—the Alcova member—of probable Triassic age. This marine limestone is not known in eastern Colorado nor east of the Laramie Mountains in Wyoming. Beneath the Alcova lies the main body of the "Red Beds," which, although no fossils have been found in them, are regarded as probably Permian because they merge downward into beds containing fossils of probable Permian age. The lower parts of the "Red Beds," which may prove to be distinct from the main mass in some areas, contain Permian invertebrates. These lower beds include the Forelle limestone, the so-called "crinkled limestone," and a variety of limy, gypsiferous beds. The Satanka shale and its possible equivalent, the Opeche (?) shale, are also included in the Permian, although no fossils have been found in them. Some of the beds are only doubtfully correlated with the Satanka. All these rocks in central and eastern Wyoming are included in a general way in the Embar of the oil men. The writer's interpretation of their correlation is shown in Plate 1.

The Phosphoria formation, which is the equivalent of the lower part of the type Embar, lies conformably beneath the Dinwoody formation, which is in turn overlain, with probable unconformity, by Chugwater red beds in western and northern Wyoming. The Phosphoria and Dinwoody are both believed by the writer to thin out toward the east and south, probably because of erosion, but Condit believes that they merge into the Chugwater. The Phosphoria was not found east of Casper. The writer believes that a

hiatus occurs within the rocks here classed as Permian and that the Dinwoody formation was eroded away in some places prior to the deposition of the overlying red beds, including the Forelle limestone and Satanka shale.

Below the Permian Phosphoria formation in western Wyoming and below the Permian Forelle limestone and Satanka shale in eastern Wyoming lie rocks of Pennsylvanian age, which differ in character and appearance from place to place. They have been described under several names. They include the Tensleep, Amsden, Casper, and Hartville formations in Wyoming and the Ingleside formation (younger Pennsylvanian) and Fountain formation (older Pennsylvanian) in northeastern Colorado. South of Soldier Canyon, Colo., the Ingleside formation has been variously treated in former reports. In some it has been included in the overlying Lyons sandstone; in others in the underlying Fountain. The writer's views regarding its correlation are expressed graphically in Plate 1.

The older Pennsylvanian beds of this region lie unconformably under the younger Pennsylvanian beds. The older Pennsylvanian beds of Colorado (the Fountain formation) are said to be 5,000 feet or more in thickness at the southernmost locality described, and they thin northward to about 170 feet at Mill Creek, in southeastern Wyoming. Still farther north and west rocks lithologically similar to those of the Fountain lie unconformably on the older rocks and have been included in the overlying formations, although in some of the places examined, if not in all, they are unconformable with the next younger rocks—that is, the Amsden formation. The Fountain is a fanlike accumulation of coarse fluviatile material, thick in central eastern Colorado and thinning out toward the north, perhaps also in other directions, underneath the marine rocks of later Pennsylvanian age. It may be represented in central Wyoming by the red rocks locally called red Amsden, here included in the Amsden formation but possibly separated by an unconformity from the fossiliferous Amsden above.

The Mississippian series is represented in eastern Colorado by the Millsap limestone and in Wyoming by the Madison limestone, a marine formation which is unconformable with both overlying and underlying rocks. In nearly all places where the Madison was observed it is underlain by the Deadwood, a formation of Cambrian age. But east of Casper Mountain and in the northern part of the Laramie Basin it may overlap the Deadwood onto the pre-Cambrian granite. Certain conglomeratic sandstones under the Madison limestone at these two localities differ in general appearance from the typical Deadwood but still may belong to that formation.

The sedimentary formations of the area described were laid down during epochs widely distributed through geologic time. The area is in a continental region which was only occasionally submerged for short periods. The marine formations are relatively thin. The nonmarine deposits, although more voluminous, are variable in thickness and character, owing in part to depositional conditions, in part to erosion. It is probable that the breaks in the continuity of the deposits represent more time in the aggregate than that recorded by the deposits themselves. The periods of unrecorded time are shown below in relation to the periods of deposition represented by sedimentary rocks.

Sedimentary rocks and periods of erosion in Colorado and Wyoming

Dakota group at Bellvue, Colo., and rocks correlated with this group (Cretaceous).
Cretaceous erosion.
Morrison formation (Cretaceous?).
Late Jurassic erosion.
Sundance formation (late Jurassic).
Early Jurassic erosion.
Jelm formation (late Triassic).
Middle Triassic erosion.
Alcova limestone and overlying gypsiferous beds (marine transgression, probably early Triassic).
Post-Permian (?) erosion.
Main body of "Red Beds" (Permian?).
Limestone breccia (Permian?).
Permian (?) erosion.
Forelle and Minnekahta (?) limestones, Satanka and Opeche (?) shales (Permian).
Permian erosion (?).
Phosphoria formation (Permian).
Permian-Pennsylvanian erosion.
Younger Pennsylvanian beds, including Tensleep sandstone, Ingleside formation, and Amsden and Casper formations in part.
Mid-Pennsylvanian erosion.
Older Pennsylvanian beds, including Fountain formation and lower (red) part of Amsden formation.
Post-Mississippian erosion.
Madison limestone (early Mississippian).
Cambrian to Mississippian erosion.
Deadwood formation (Upper Cambrian).
Early Cambrian erosion.
Algonkian and Archean.

LOCAL DETAILS

SCOPE OF DESCRIPTIONS

The details on which the foregoing statements are based are recorded in the following descriptions, which include all personal observations and impressions and such previously published facts as seem especially significant. All publications dealing with geologic relations at or near the localities described have been consulted, but only the more pertinent ones are included in the list of papers cited on pages 3–4. The localities are described in order from south to north and are numbered in that order on the key map (fig. 1). The photographic illustrations are grouped according to geologic age from older to younger, the order followed in the preceding discussion.

An explanation of the reasons for undertaking the work described in this paper and of the manner in

which the work was done may help in understanding the details that follow.

Many reports on parts of the region here considered have been published, chiefly on relatively small areas. These reports were made by geologists working independently and at widely separated times. They brought to their study the accepted beliefs of their day. In so far as the present writer disagrees with their conclusions he has tried to express that disagreement without objectionable criticism. During the long period covered by these reports progress has been made, knowledge has increased, and some beliefs have been modified. The writer is confident that if these geologists could review in the office and in the field all the information now available they would reach the same conclusions that he has reached.

When the field work was undertaken in 1921 it was understood that differences of opinion would arise, that some of the new interpretations would be at variance with the old, and that many difficulties would be found. After consultation with the chief of the section of geology of oil and gas fields, at whose request the work was done, the geologist in charge of areal geology, and several other officials of the United States Geological Survey, a definite plan was adopted. It was agreed that sections should be measured wherever practicable, with tape or with stadia, and that only these sections, supplemented by such previously measured sections as were verified, should be used in correlation. In brief, the study was to be an independent one, uninfluenced so far as this was possible by previous reports.

It was found difficult to carry out this plan, and many modifications were made. But in accordance with the purpose of the original plan many reported sections are omitted, not because they are believed to be incorrect but because the writer has no first-hand information regarding them.

A part of this paper was published in 1923 under the title "Continuity of some oil-bearing sands of Colorado and Wyoming," [47] in which certain rocks above the Morrison formation at many localities between Colorado Springs, Colo., and Thermopolis, Wyo., and between Boxelder Canyon, Colo., and Lander, Wyo., were described as the Dakota group. The name Dakota group, however, is accepted by the United States Geological Survey only for the section at Bellvue, Colo., and the responsibility for the correlation of other sections with that at Bellvue is assumed by the writer. He believes that these rocks form a group, as that term is used both popularly and technically. But they include some rocks which are classed by the Geological Survey as Upper Cretaceous and others which are classed as Lower Cretaceous. As entire agreement on the age of the beds has not been reached (see pp. 17–23), it is deemed preferable to use a noncommittal term and to correlate the beds at other localities with the Bellvue section.

The correlation implied by the names used in the written and platted sections should not be interpreted too exactly. It is the writer's opinion that the lowest sandstone of this assemblage of rocks—that is, the conglomeratic sandstone that lies unconformably on the Morrison shale—is essentially the same in all the sections. The rocks above this sandstone, however, are variable in thickness and character and consist of broad thin lenses. For example, the upper sandstone followed along the strike is found to be variable in thickness and at a few localities is not present, although within a short distance from a locality where it is absent sandstone reappears at the same or nearly the same horizon.

From an inspection of the sections it appears probable that all the beds thicken and thin in a similar manner, but the thickness of the group as a whole is so small that there is little probability of great difference in age unless some unconformity thus far unsuspected can be found.

The following summary published in 1923 expresses the writer's present conviction:

> There is no single, definite, persistent, and easily recognized sandstone such as was formerly supposed to exist and was termed the Dakota sandstone. In its place there is a group of intimately related beds, probably even more complicated than the correlation lines of Figure 2 [fig. 4 of the present paper] indicate. Doubtless there are many overlapping lenses that differ slightly in age. The group as a whole is interpreted as the result of accumulation of sediments near the strand line of the advancing Cretaceous sea, and as such it differs in age from place to place by the length of time consumed by the advance of the strand line across the intervening distance.

In the following description the numbers 1 to 47 given in some of the locality headings correspond to the locality numbers on the key map (fig. 1) and to the section numbers of Figure 2 and Plate 1.

The continuity of the formations between the localities described may be traced on the geologic map of Colorado, published by the Colorado Geological Survey in 1913, and the geologic map of Wyoming, published by the United States Geological Survey in 1925.

LOCALITIES IN THE FOOTHILLS OF COLORADO

COLORADO SPRINGS (1)

The Colorado Springs section (No. 1, pl. 1) is taken from the Colorado Springs folio of the Geologic Atlas. In this folio certain rocks called Lyons sandstone were correlated with the upper part of the "Lower Wyoming" division of the Denver Basin (section 3, pl. 1), which is shown in this paper to be older than the typical Lyons sandstone at Lyons, Colo. In the lower part of the overlying red beds, or Lykins formation, is a series of beds which correspond to the Embar formation of some of the oil men of Wyoming. The

[47] Lee, W. T., U. S. Geol. Survey Bull. 751, pp. 1–22, 1923.

red beds are thin and are overlain by gypsum, which has been included in the Lykins formation, although it occupies a position appropriate for the Sundance, a marine formation of late Jurassic age.

The sandstone (Lytle) above the Morrison formation and the overlying shale (Glencairn), which constitute the Purgatoire formation and which are classed as Lower Cretaceous, correspond to the lower sandstone, lower shale, middle sandstone, and upper shale of the Dakota group of the section at Bellvue, Colo., the Dakota sandstone of the Colorado Springs folio being the upper sandstone of that group as described in this report.

CASTLE ROCK QUADRANGLE (2)

In the geologic folio covering the Castle Rock quadrangle, which adjoins the Colorado Springs quadrangle on the north, the same formations are described by Richardson. The thin beds of sandstone and limestone of Cambrian and Ordovician age found near Colorado Springs occur also in the Castle Rock area, and a small remnant of younger rocks, the Millsap limestone, of Mississippian age, was found in Perry Park, which is in this quadrangle. The Fountain formation, about 2,000 feet thick, lies unconformably on the Millsap limestone. It is correlated with the Fountain of the type locality, which is described by Cross in the Pikes Peak folio as "red sandstone, grits, and conglomerates." Cross added that the Fountain consists chiefly of "coarse-grained, crumbling arkose sandstone, locally conglomeratic, and mottled with gray and various light shades of red." The upper 600 feet of the Fountain is lighter colored than the lower beds, possibly because of leaching near the surface before the overlying beds were deposited on it. These light-colored beds were correlated with the Lyons sandstone, but as they are lithologically the same as the underlying rocks, especially in containing arkose and conglomerates to the very top, the writer regards them as the upper part of the Fountain formation and much older than the typical Lyons sandstone, as indicated in Plate 1. The light-colored upper part of the Fountain is correctly correlated with the upper part of Eldridge's "Lower Wyoming" (the "Creamy" sandstone), which, like the equivalent beds in Perry Park, contains conglomerates and beds of arkose up to the contact with the overlying Lykins red beds. The Fountain formation of the Castle Rock quadrangle yielded *Stigmaria verrucosa*, which David White regards as probable evidence of Pennsylvanian age.

The Lykins formation ("Red Beds"), 225 feet thick in the Castle Rock region, overlies the Fountain formation. It is described as apparently conformable on the light-colored beds just described. However, an irregular line of contact and an abrupt change in lithology suggest the unconformity which is indicated farther north by change in structure and the time break which is indicated by differences in fossils. Beds of limestone and gypsum occur in the lower part of the Lykins and are correlated with the Embar formation of the oil geologists of Wyoming. The layers of limestone are persistent and usually form ridges along the foothills. These ridge makers are the chief means by which the beds are distinguished from the overlying red beds. The lower red shale member, which is here 20 to 30 feet thick, is the persistent shale which Darton [48] has described as extending from Colorado Springs, Colo., where it is 55 feet thick, to the Black Hills in South Dakota, where he has called it the Opeche formation.

Above this shale are sandy limestone, gypsum, and red shale, not sharply separable from the overlying red beds but traceable into central Wyoming, where they are known to oil men as the Embar formation. (See discussion on p. 11.) The lower sandy limestone in the Castle Rock quadrangle is the "crinkled sandstone" of the Colorado Geological Survey, [49] so called because it consists of numerous thin crinkly layers of sandstone and limestone. The upper ridge here and in many other localities in Colorado and Wyoming is formed by a limestone breccia. Beds of gypsum occur in many places with the sandy limestones. The thin bed of limestone near the base of the "crinkled sandstone" yielded the fossils *Myalina wyomingensis, M. perattenuata, Alula squamulifera, A. gilberti?*, and *Pleurophorus* sp., regarded by G. H. Girty as probably Permian. This limestone has been reported by Darton in many places in the foothills and correlated by him with the Minnekahta limestone of the Black Hills. The layer of limestone breccia is nearly as persistent but has not been given a distinctive name.

In the Castle Rock quadrangle the Lykins formation, including the limestone and shale of probable Permian age, is slightly thicker than at Colorado Springs but includes at the top a thick bed of gypsum similar to that of the Colorado Springs section. The Sundance formation, of Upper Jurassic age, may be represented in both sections by the gypsum and associated beds. Although this thick gypsum has been regarded generally as a member of the Lykins formation, its occurrence in the Castle Rock quadrangle above a greater thickness of red beds than in the Colorado Springs quadrangle suggests that the gypsum may lie unconformably on the Lykins, as the beds of Sundance age do at localities farther north.

The next younger formation, the Morrison, here 200 feet thick, is overlain by two thick sandstones separated by shale in which are thin sandstones and sandy shale.[50] These sandstones and the intervening shales are correlated with the Dakota group of the Bellvue section, as shown in Plate 1. In some places both of the sandstones are ridge makers; in others

[48] Darton, N. H., U. S. Geol. Survey Prof. Paper 32, p. 90, 1905.
[49] Butters, R. M., Colorado Geol. Survey Bull. 5, p. 82, 1913.
[50] Darton, N. H., U. S. Geol. Survey Prof. Paper 32, pl. 34, *B*, 1905.

the higher one forms the chief ridge, the lower beds cropping out in the slope. In the Castle Rock folio the lower sandstone and the shale, together 240 feet thick, are correlated with the Purgatoire formation and assigned to the Lower Cretaceous series, and the upper sandstone, 60 feet thick, is called Dakota sandstone and assigned to the Upper Cretaceous.

Above the main mass of the lower sandstone is a stratum of friable shaly sandstone a few feet thick, which has the physical character and color of the lower shale of the Bellvue section and which in Wyoming develops into a well-defined and persistent formation. This shaly sandstone is overlain by a few feet of hard, quartzose sandstone which has the general appearance of the sandstone that farther north overlies the variegated lower shale and assumes prominence as a distinct continuous sandstone in northern Colorado, where, in the Bellvue section, it is called the middle sandstone of the Dakota group. These two thin strata are not here separated from the lower sandstone.

The succeeding shale is soft and usually crops out in a covered slope on the west face of the hogback or occupies a valley between the two sandstone ridges. It is the Glencairn shale of the Colorado Springs folio. The highest sandstone is the chief ridge maker in the Castle Rock quadrangle and underlies typical Benton shale. It is about 60 feet thick, is fine grained and quartzose, and holds the position of the sandstone called Muddy sand by oil men in northern Colorado and throughout Wyoming. In Perry Park it has yielded fossil wood and impressions of two species of plants of the Dakota flora, *Salix proteaefolia* Lesquereux and *Sapindus morrisoni* Lesquereux.

ROXBURY PARK

About 10 miles north of Perry Park, in Roxbury Park, the rocks are sufficiently well exposed to indicate that the units noted in Perry Park are represented, but no complete section was measured. The Fountain formation, 1,500 to 2,000 feet thick, is carved by erosion into many curious forms, which rival in interest those of the Garden of the Gods. The upper 75 feet or more is made up of light-colored or leached material, such as constitutes the "Creamy" sandstone of the Morrison section.

The Lykins formation contains the limy gypsiferous beds near the base which are here correlated with the limy beds in the lower part of the red beds of Wyoming that the oil men call Embar. The lower shale, about 30 feet thick, is overlain by 3 to 5 feet of "crinkled sandstone," 12 to 14 feet of red shale, and 8 to 10 feet of brecciated limestone.

3619—27——3

The rocks between the lower limy part of the Lykins and the top of the Morrison are not well exposed here, but the Morrison was easily recognized and is overlain by a conglomerate with an abruptness that suggests unconformity. The conglomerate and associated sandstone are white, friable, and relatively soft and form an inconspicuous ridge on the west face of the Dakota hogback. These rocks and the overlying shale occupy a slope generally covered with brush and rock waste from the upper sandstone, which forms the crest of the hogback. In normal order above the upper sandstone are good exposures of Benton shale and Niobrara limestone.

DEER CREEK

Between Roxbury Park and Turkey Creek, a distance of about 12 miles, the foothill formations are continuously exposed and exhibit no notable change in character from place to place. The Dakota hogback is prominent and is formed by two main sandstones separated by a thick shale and thin layers of sandstone and shale. The higher sandstone forms the crest of the ridge. The middle shale is more sandy than it is farther south.

In Deer Creek Canyon, 5 miles south of Turkey Creek, the Fountain formation has a light-colored ridge-making layer at the top, which has been erroneously correlated with the Lyons sandstone. It is the "Creamy" sandstone of the Morrison section. All members of the limy beds at the base of the Lykins were recognized here. The "crinkled sandstone" member consists of two layers and is separated from the overlying limestone breccia by 12 to 14 feet of shale.

TURKEY CREEK (3)

In the canyon of Turkey Creek the Fountain formation has the usual leached zone at the top (heretofore erroneously called Lyons in this region), and all four members of the limy beds in the lower part of the Lykins are represented. The "crinkled sandstone" member is about 3 feet thick, the upper shale member 12 to 15 feet, and the limestone breccia 8 to 10 feet. Above the red beds is a yellow sandstone which may represent either the Jelm formation, of late Triassic age, or the lower sandstone of the Sundance formation, of late Jurassic age.

About an eighth of a mile south of Turkey Canyon the upper of the sandstones here correlated with the Dakota group at Bellvue contains asphalt, probably a residuum from oil derived from the bituminous shale below. The formations exposed in Turkey Canyon are as follows:

Section on Turkey Creek, Jefferson County, Colo.

[Measured with stadia. The portion inclosed by the brace at the left is correlated by the writer with the Dakota group of Bellvue, Colo., and the names in quotation marks indicate the corresponding parts of that group]

	Feet
Niobrara limestone.	
Benton shale: Shale including thin layers of fossiliferous limestone of Greenhorn age	530
"Upper sandstone":	
Sandstone, friable, chalky white	5
Shale	1
Sandstone, hard, quartzose, massive, in two layers separated by a thin layer of shale	95
"Upper shale":	
Shale, bituminous in upper part and containing many thin layers of sandstone in lower part	120
Sandstone—ridge making (probably same as middle sandstone of Bellvue section)	10
Shale, sandy (probably same as lower shale of Dakota group of Bellvue section)	20
"Lower sandstone": Sandstone, massive, lower half conglomeratic, upper half cross-bedded, friable, easily eroded	130
Morrison formation.	

MORRISON

In Bear Creek Canyon, about 2 miles north of Turkey Creek, the formations of the foothills are fairly well exposed. The sandstone that is correlated with the upper sandstone of the Dakota group at Bellvue as observed in Turkey Canyon is perfectly exposed through the intervening 2 miles, where it forms the crest of the hogback and is the upper sandstone of the Morrison section. It is the sandstone which has long been known in the Denver region as Dakota and which has yielded many of the fossil plants of the Dakota flora.

The extensive use that has been made of the section in Bear Canyon at the town of Morrison calls for careful consideration in connection with the other sections here described. Some time ago the writer offered reasons for believing that the Morrison section should be revised.[51] But such measurements of thickness as he had at that time did not correspond well with generally accepted estimates or with measurements at neighboring localities. Good exposures near the town of Morrison are so distributed over a slope cut in a direction diagonal to the strike of steeply dipping strata that it is difficult to include them in a single measured section. For this reason the thickness of the Morrison and overlying beds was measured with stadia and plane table in 1921, and the results should replace those previously published.

There is no reason for questioning the description in the Denver monograph[52] of the beds older than Morrison. Hence the lower part of the following section is adapted from that report. The Morrison and younger rocks were measured by the writer.

[51] Lee, W. T., Am. Jour. Sci., 4th ser., vol. 49, pp. 183–188, 1920.
[52] Emmons, S. F., and others, U. S. Geol. Survey Mon. 27, 1896.

Section at Morrison, Colo.

[The portion inclosed by the brace at the left is correlated by the writer with the Dakota group of Bellvue, Colo., and the names in quotation marks indicate the corresponding parts of that group]

	Feet
Niobrara limestone.	
Benton shale: Shale, including Greenhorn limestone	580
"Upper sandstone":	
Sandstone, massive, quartzose (the "Upper Dakota" of many geologists)	45
Shale, sandy, dark colored, lenticular ("Dakota fire clay"); contains fossil plants	1–5
Sandstone, massive, quartzose ("Lower Dakota" of some geologists); contains fossil plants in lower part	75
"Upper shale":	
Sandstone, shaly, dark colored, easily eroded; fossil plants in upper part	45
Sandstone, ledge making	10
Shale and sandstone, poorly exposed (upper part of Morrison formation of some geologists); colored sandy shale in lower part resembling the variegated beds of the Morrison formation may represent the lower shale of the Dakota group of the Bellvue section	95
"Lower sandstone": Sandstone, massive, conglomeratic	10–40
Morrison formation:	
Shale and sandstone	110
Shale, variegated, and sandstone, with a dinosaur-bearing sandstone at the base having pebbles half an inch in diameter	215
Sundance or Jelm formation: Sandstone, massive, pink to yellow; absent in some places (included in Lykins by former writers)	0–17
Lykins formation ("Upper Wyoming" of Eldridge):	
Clay, bright colored; gypsiferous and calcareous especially 40 feet below top	125–175
Clay, more arenaceous than above	150–200
Sandstone and shale	110
Shale, sandy and argillaceous, brick-red, carrying narrow bands (3 to 5 feet) of white crystalline limestone included in the Embar of the oil men in southeastern Wyoming	75
Fountain formation ("Lower Wyoming" of Eldridge):	
"Creamy" sandstone; quartzose, conglomeratic at base [also conglomeratic and arkosic at top]	200–400
Red beds; conglomerate, sandstone, and shale	270–2,000
Archean (crystalline rock).	

The lowest subdivision of this section is clearly the arkosic formation of the sections just described south of Morrison. The "Creamy" sandstone is the Lyons sandstone of some writers, but that it is properly included in the Fountain formation is indicated by conglomerate and arkosic material throughout. Arkose and large pebbles occur in it at Morrison, close to its contact with the overlying Lykins formation. The light color of this material may be due to leaching during the time of exposure represented by the unconformity shown on Plate 1.

The red sandy shale and limestone 75 feet thick at the base of the "Upper Wyoming" (Lykins formation)

are correlated with rocks in Wyoming called Embar by the oil men. The lower red shale member of this formation, the Opeche (?) of Darton [53] is 30 to 40 feet thick; the sandy "crinkled limestone" member (Minnekahta (?) limestone of Darton) yielded indistinct fossils which appear to be *Bakewellia*.

The upper part of the Lykins formation consists of soft red sandstone and sandy shale, which crop out in a valley that lies parallel to the strike of the strata. Eldridge's section shows its thickness to be 385 to 485 feet; Butters,[54] of the Colorado Geological Survey, states that it is 150 to 200 feet. Its upper sandstone, from a featheredge to 17 feet thick (15 to 25 feet according to some observers) may represent the basal sandstone of the Sundance formation, which is well developed farther north, or it may represent the Jelm formation, which has not been clearly separated from the basal Sundance in northern Colorado.

MORRISON TO GOLDEN

The two sandstones of the upper part of the rocks correlated with the Dakota group at Bellvue are well exposed where Bear Creek cuts them and are separated by 1 to 5 feet of sandy shale. (See pl. 32, *A*.) These beds, according to the late Prof. George L. Cannon, of Denver, who claimed to have first-hand information gained by association on the ground with Eldridge and other early observers in the Denver region, are the two sandstones and the fire clay of the Dakota as originally interpreted for this locality. The shale was followed at the outcrop north of Morrison and was found to thin out within a short distance, no continuous bed being found that might correspond to it. The sandstone below the shale (c) of Plate 32, *B*, is hard and quartzose, but the writer failed to find any conglomerate in it. He did, however, find numerous impressions of leaves near the base.

A layer 2 inches thick at the base of this sandstone is full of small fragments of carbonized wood. This layer was pointed out on the ground by Cannon as being the base of the Dakota of Eldridge and other early observers. From blocks of the overlying sandstone fallen from the cliffs Lieutenant Beckwith collected most, if not all, of the so-called Dakota plants of this region which are now in the United States National Museum. In some places this sandstone rests on shale and its under surface is covered with wormlike bodies such as have been seen in the upper sandstone in many other places.

The upper part of the Morrison as first delimited, which in this paper is correlated with parts of the Dakota group of the Bellvue section, consists of soft, friable sandstone and sandy shale. The lower part of these beds is similar in color to the Morrison. As nothing was known at that time of colored material in beds then called Dakota, these colored beds were naturally included in the Morrison. The upper part of these beds yielded the fossil plants which Knowlton [55] has described as belonging in the Dakota flora.

All the formations of the Morrison section, except the shale in the upper sandstone, are traceable northward about 5 miles to a point nearly 3 miles south of Golden, where the fossiliferous shaly sandstone contains the two beds of fire clay shown in Plate 32, *A*. The sandstones below and between the two clay beds contain great numbers of fossil plants which Knowlton identifies as Dakota. (See p. 22.) The lower sandstone is resistant and forms the crest of the hogback where the prominent quartzose crest maker at Morrison is subordinate and crops out in the eastern face of the ridge. This lower sandstone is the one which at Golden has been called "Lower Dakota," although a still older sandstone, the conglomeratic basal sandstone of this paper, crops out inconspicuously in the west slope of the ridge. North of this point for a distance of about 11 miles the rocks are so much faulted and otherwise disturbed that it is difficult to trace individual beds or to recognize the normal succession. No satisfactory section was measured in this interval, but the area was described at length by Eldridge in the Denver monograph as the site of a transverse fold against which the several formations were built and which was finally buried by these formations. This interpretation has been successfully challenged by Ziegler,[56] who discusses the structural relations found near Golden and explains them as due to faulting.

The conglomeratic sandstone at the base of the assemblage of rocks correlated with the Dakota group of Bellvue, Colo., the variegated beds above it, and the variegated beds of the Morrison below it were traced northward nearly to Golden, where they crop out stratigraphically below the plant-bearing beds at the clay pits shown in Plate 32, *A*. These beds do not crop out at Golden, but less than 2 miles north of this town they reappear and form the usual Dakota hogback. In spite of much faulting and warping, the general succession is recognizable in many places where the fire clay has been mined and corresponds to the succession south of Golden.

Some of the facts relative to the formations of this area, which are of prime importance in comparing the section at Morrison with others, are as follows:

[53] Darton, N. H., U. S. Geol. Survey Prof. Paper 32, p. 87, 1905.
[54] Butters, R. M., Colorado Geol. Survey Bull. 5, p. 81, 1913.
[55] Knowlton, F. H., Am. Jour. Sci., 4th ser., vol. 49, pp. 189–199, 1920.
[56] Ziegler, Victor, Jour. Geology, vol. 25, pp. 715–740, 1917.

1. Rocks between those of the typical Morrison formation and typical red beds as originally described are lithologically unlike either of these formations. They are separated from the overlying dinosaur-bearing rocks by an unconformity which seems to represent more than local erosion. They are unconformable also on the red beds and represent either the Sundance formation or the still older Jelm formation.

2. The variegated beds containing dinosaur bones are similar in thickness and character to the Morrison formation elsewhere, and the conglomeratic sandstone above them is lithologically similar to the lower sandstone of the Dakota group of the Bellvue section and also to the correlated beds of other localities both north and south of Morrison. These facts strengthen the suggestion made by Eldridge of an unconformity at the top of the Morrison formation, but this unconformity is now regarded by the writer as situated at the base of the above-mentioned sandstone, which is probably the same as what was formerly called the "Saurian sandstone" and included in the Morrison formation.

3. The sandy shale above the conglomerate is variegated in color and lithologically similar to the dinosaur-bearing rocks below. Probably for this reason it was included in the Morrison formation. It is lithologically similar to the lower shale of the Dakota group of the Bellvue section. The dinosaur bones of the "Saurian sandstone" and overlying rocks seem never to have been distinguished from those below this sandstone. If the base of the conglomerate marks an unconformity, the beds above it should contain a different fauna from those below.

4. Shaly sandstone in the upper part of the Morrison formation as originally described (the part which in this paper is interpreted as equivalent to the upper shale of the Bellvue section) contains impressions of net-veined leaves of types indicating Upper Cretaceous age. These beds are traceable along the outcrop to localities near Golden where the plant-bearing rocks occur still lower down in the section.

VAN BIBBER CANYON

In Van Bibber Canyon, 3 miles north of Golden, no "Creamy" sandstone was found at the top of the Fountain formation, which there is overlain by a few feet of cross-bedded pink sandstone, of wholly different character, that forms a small but well-defined ridge. This pink sandstone seems to represent either the Lyons sandstone of the more northerly localities or the still older sandstone which in some places is not readily separable from the Lyons and which in this report is included in the Ingleside formation. Neither of these sandstones was recognized south of Golden. It is significant that neither here nor at localities farther north, where these sandstones are present, is there any conspicuous leaching of the upper part of the Fountain formation, and there is no "Creamy" sandstone.

The limy beds near the base of the Lykins formation appear in normal development here, but no measurement of them was made. The Morrison formation is poorly exposed, but the overlying lower sandstone, upper shale, middle plant-bearing sandstone, and upper sandstone are all well exposed. In several places between this canyon and Eldorado Springs the observed stratigraphic relations are such that no change in the stratigraphy is suspected.

RALSTON CANYON

In Ralston Canyon, 2 miles north of Van Bibber, the Fountain formation is very thick, coarse, and so much altered that it is said to resemble granite. No "Creamy" sandstone was found here. The Fountain is overlain by about 50 feet of red sandstone, which probably represents the lower member of the Ingleside formation. This is followed, in ascending order, by the prominent cross-bedded, ridge-making Lyons sandstone and the limy beds in the lower part of the Lykins formation. The Lyons and possibly also the underlying sandstone of the Ingleside seem to be what Darton [57] regarded as probably equivalent to the Tensleep sandstone. He quotes Marvine as stating that this sandstone is 125 feet thick, overlain by 100 feet of red sandy shale and 25 feet of cherty limestone, which Darton assigns to the Opeche (?) and Minnekahta (?), respectively. The latter is the "crinkled sandstone" of the Colorado Geological Survey and consists of red shale, yellow sandstone, and bluish-gray brittle limestone that has been used here for the manufacture of lime.

ELDORADO CANYON (5)

At Eldorado Springs, Boulder County, 8 miles north of Ralston Canyon and about 5 miles south of Boulder, most of the beds correlated with the Dakota group at Bellvue are perfectly exposed in a road cut, where the following section was measured. The formations between the Niobrara limestone and Lyons sandstone were measured with stadia; the still older ones by pacing across the strike.

Section measured near Eldorado Springs, in Eldorado Canyon, Colo.

[The portion inclosed by the brace at the left is correlated by the writer with the Dakota group of Bellvue, Colo.]

	Feet
Niobrara limestone.	
Benton shale: Shale, not well exposed; sandy layers in lower part which may belong in the group below..	530

[57] Darton, N. H., U. S. Geol. Survey Prof. Paper 32, p. 84, 1905.

	Feet
Shale and sandstone, light colored, in several layers, including three sandstones 4 to 10 feet thick	105
Sandstone, light colored, hard, massive in thick layers; makes main crest of the hogback ridge	70
Shale	1
Sandstone and carbonaceous shale, a mudstone	5
Sandstone in irregular but well-defined layers several inches to several feet in thickness, separated by thin layers of shale	55
Shale, dark, carbonaceous, with many irregular layers of sandstone	15
Clay shale, yellow, sandy, with lenses of sandstone	22
Sandstone, upper part massive and cross-bedded, lower part conglomeratic (rests on soft Morrison shale)	113
Morrison and Lykins formations:	
Shale, variegated; lower part not well exposed	200+
Red beds covered in valley, lower part limy	700
Lyons sandstone: Sandstone, pink to yellow, cross-bedded	30
Ingleside formation: Sandstone, red, massive	115
Fountain formation: Sandstone, red, coarse grained, arkosic, and coarsely conglomeratic in many places, pebbles as much as 6 inches in diameter	1,500
Conspicuous angular unconformity.	
Pre-Cambrian: Quartzite, chiefly light colored.	

The stratified rocks near Eldorado Springs have been upturned to a vertical position (see pl. 4, *A*), and it is possible that some of the softer layers have been squeezed out or sheared during the process of upturning. The sandstones that are here correlated with the upper and lower sandstones of the Dakota group of the Bellvue section are normal in appearance, although thicker than these sandstones are in other places, but the intervening rocks are too thin and too sandy to be normal representatives of the middle formations of that group. The suggestion that squeeze and shear have diminished the thickness of some of the beds finds support in the proximity of this locality to Golden, Colo., where faulting and shearing have occurred to a notable extent. The relations observed between Eldorado and Morrison might be interpreted as indicating a significant change in depositional conditions during the time represented by this group of rocks, were it not that both north and south of this area of disturbed strata the formations of this interval are similar and their succession the same.

BOULDER (6)

In Bear Canyon, 2½ miles north of Eldorado Springs, Darton [58] found 800 feet of Fountain beds overlain by 300 feet of beds that seem to indicate the Lyons sandstone and Ingleside formation of this paper. Above the Lyons sandstone is 200 feet of red shaly sandstone (Opeche (?) of Darton), 25 feet of limestone (Minnekahta (?) of Darton), 400 feet of still younger red beds, and 30 feet of "soft white massive sandstone" that probably represents the lower part of the Sundance formation.

[58] Darton, N. H., U. S. Geol. Survey Prof. Paper 32, p. 84, 1905.

In this canyon Butters [59] noted 100 feet of heavy-bedded sandstone between the top of the Fountain formation and the top of the Lyons sandstone. He also reports that the red shale (Opeche?) is 30 feet thick, as compared with the 200 feet reported by Darton, and that his "crinkled sandstone" (probably the Minnekahta (?) limestone of Darton) is 12 to 15 feet thick.

The Morrison and overlying formations are not well exposed near Boulder, but about 2 miles north of the town Prof. R. D. George pointed out to the writer an exposure in which the basal sandstone of the Morrison formation, here containing a few small pebbles of chert, rests unconformably on typical Lykins red beds, with no Sundance or other sandstone between. The rocks above the Morrison formation are best exposed near Boulder, in Sixmile Canyon, and at other places north of the town and have been described by Fenneman [60] and others.

RED MOUNTAIN (7)

A section of the lower part of the Cretaceous rocks was measured with stadia near Lyons, about 1 mile southeast of Red Mountain. The results are as follows:

Section measured southeast of Lyons, Colo.

[The portion inclosed by the brace at the left is correlated by the writer with the Dakota group of Bellvue, Colo., and the names in quotation marks indicate the corresponding parts of that group]

	Feet
Pierre shale.	
Niobrara limestone:	
Shale	95
Limestone, shaly	10
Shale	120
Limestone, shaly	20
Shale	125
Limestone, with *Inoceramus deformis* and other fossils	15
Benton shale:	
Shale	20
Sandstone	1
Shale	5
Sandstone	2
Shale	48
Shale, with four 6-inch layers of limestone containing *Inoceramus labiatus* and other fossils (horizon of Greenhorn limestone)	30
Shale	370
"Upper sandstone":	
Sandstone, quartzose, in thin layers	12
Shale, black, and thin layers of sandstone, leaf bearing	6
Sandstone, quartzose, in layers	10
"Upper shale": Shale with thin layers of sandstone	222
"Lower sandstone," probably including the "middle sandstone" and "lower shale": Sandstone, strongly conglomeratic in lower part	140

[59] Butters, R. M., Colorado Geol. Survey Bull. 5, p. 80, 1913.

[60] Fenneman, N. M., U. S. Geol. Survey Bull. 265, 1905.

LYONS (8)

The older formations of the foothills are well exposed near Lyons, and a section of them was measured with stadia in the canyon of the St. Vrain near this town. This and the foregoing Red Mountain section are combined to form section 5 of Plate 1.

Section at Lyons, Colo.

[Younger rocks reported in foregoing section]

	Feet
Ridge-making, massive, cross-bedded sandstone, conglomeratic in lower part, correlated by the writer with the lower sandstone of the Dakota group at Bellvue, Colo	120
Morrison formation:	
Shale, variegated, and thin sandstone	195
Sandstone, massive	10
Shale, variegated	45
Limestone and thin layers of shale (may belong to Sundance)	5
Sundance formation:	
Sandstone, yellow	5
Sandstone, orange, cross-bedded (may represent Jelm formation)	30
Abrupt change in lithology.	
Lykins formation:	
Sandstone and shale, red	620
Limestone, sandy, and shale (Darton's Minnekahta (?) limestone, containing *Natica* or *Naticopsis*[61]	20+
Shale, sandy, red (Opeche (?) of Darton)	40
Lyons sandstone: Sandstone, yellowish pink, strongly cross-bedded; small pebbles near the base in a few places	100
Abrupt change in lithology and irregular line of contact.	
Ingleside formation: Sandstone, massive, cliff-making in lower part; beds of shaly and limy sand of variable thickness in upper part; included in Lyons sandstone by some writers and in Fountain by others	200
Unconformity by erosion.	
Fountain formation: Sandstone, arkose, and conglomerate, red and yellow, mottled with gray, purple, etc.; rests with irregular contact on ancient crystalline rocks	1,190
Pre-Cambrian granite.	

The Fountain formation near Lyons differs in no essential from that at localities farther south above described. It is conspicuously exposed in Steamboat Rock (see pl. 10, *A*), where the unconformity between it and the overlying sandstone is readily found.

The reference of the cliff-making red sandstones between the Fountain and the Lyons sandstone to the Ingleside formation rests on tracing these red sandstones northward into the group of limestones and sandstones of the Ingleside formation of northeastern Colorado and the Casper formation of southeastern Wyoming. These sandstones have been included in the Fountain formation by some writers and in the overlying Lyons by others. The writer's observations indicate that they are unconformable with both.

At Lyons, Colo., the type locality of the Lyons sandstone, the Lyons formation as described by Fenneman[62] includes not only the Lyons as used in the present report but also the rocks at that locality that are now correlated with the Ingleside formation.

The Lyons sandstone is overlain by red beds for which Fenneman[63] in 1905 proposed the name Lykins formation. In the preceding year Darton[64] had described the same beds under the name Chugwater. The lower limy part of these red beds (correlated by the writer with the rocks which the Wyoming oil men call Embar) includes Darton's Opeche (?) shale and his Minnekahta (?) limestone. The beds of Sundance age and possibly a representative of the Jelm formation, of late Triassic age, were also included, for the Lykins of most former writers is overlain by the Morrison.

The upper part of the succeeding post-Morrison sandstone and the overlying shale are poorly exposed near Lyons and were not measured, but Darton's unpublished notes give this interval as 160 feet. Beds of gray friable shaly sandstone above the massive part of this lower sandstone suggest the lower shale of the Bellvue section. The upper sandstone of this section is exposed north of the river, where it was cut during the construction of a ditch. (See pl. 31, *A*.) Here the ledge-making sandstone rests on soft sandy shale, which is full of fragments of charcoal and impressions of twigs and roots.

RABBIT MOUNTAIN (9)

At the south end of Rabbit Mountain, about 3 miles northeast of Lyons, Stanton[65] found "a small exposure of shale and fossiliferous shaly sandstone beneath a quartzitic ridge-making sandstone which has always been called the top of the Dakota." It overlies a quartzitic sandstone with much conglomerate, which forms the top of Rabbit Mountain and which is here correlated with the lower sandstone of the Dakota group at Bellvue. The fossils collected between the two sandstones are a small simple *Ostrea* and *Inoceramus* sp. related to *I. labiatus* Schlotheim, later identified by Reeside as *I. comancheanus* Cragin.

The section given below was measured a few miles north of this locality. An especially noteworthy feature is the diminution in thickness of the sandstone that is correlated with the upper sandstone at Bellvue. Although this sandstone forms the main hogback ridge farther south and continues prominent northward to the town of Lyons, it disappears entirely in some places

[61] Darton, N. H., U. S. Geol. Survey Prof. Paper 32, p. 84, 1905.

[62] Fenneman, N. M., U. S. Geol. Survey Bull. 265, pp. 23–24, 1905.

[63] Idem, p. 24.

[64] Darton, N. H., Geol. Soc. America Bull., vol. 15, p. 397, 1904.

[65] Stanton, T. W., personal communication.

east of Rabbit Mountain. Where the following section was measured it is only a few feet thick, and the ridge made by it is barely distinguishable on the plain. Half a mile south of this locality, where the rocks are perfectly exposed, this sandstone was not found. For convenience this section is added to that measured at Lyons in the platted section (No. 5, pl. 1).

Section measured with stadia east of Rabbit Mountain, Colo., in sec. 13, T. 3 N., R. 70 W.

[The portion inclosed by the brace at the left is correlated by the writer with the Dakota group of Bellvue, Colo., and the names in quotation marks indicate the corresponding parts of that group]

	Feet
Niobrara limestone (possibly including at top some Pierre shale):	
Limestone, yellow, fissile	1
Shale, dark	80
Limestone, yellow, fissile	1
Shale, dark	20
Limestone, yellow, fissile; many large fish scales	18
Niobrara limestone:	
Shale, limy	10
Limestone, gray, fissile, shaly	68
Limestone, platy, in thin layers	70
Limestone, massive	7
Shale	103
Limestone, massive, containing *Inoceramus deformis*, *Ostrea congesta* Conrad, and other fossil shells	31
Benton shale:	
Shale	20
Sandstone, separated by 2 feet of shale	4
Limestone, sandy, with worm trails	1
Shale	82
Shale, with three 1-foot layers of limestone of Greenhorn type, containing *Inoceramus labiatus*	20
Shale	358
"Upper sandstone," thin, quartzose, with carbonaceous layers; not present a quarter of a mile farther south	10
"Upper shale," mostly covered	243
"Lower sandstone," conglomeratic in lower part; (probably includes middle sandstone and lower shale of Dakota group of Bellvue)	174

The sandstone immediately underlying the Benton shale continues thin and inconspicuous for nearly 8 miles north of Lyons, but west of Loveland it thickens and again forms a prominent ridge. In this 8-mile interval the other formations of the foothills appear normal except the Sundance formation and the limy beds which are supposed to be near the base of the Morrison formation but which can not now be definitely separated from the Sundance. These beds thicken northward to a maximum in Cottonwood Canyon. Butters[66] states that the Fountain formation near Carter Lake, west of Loveland, is overlain by younger cross-bedded sandstone (probably the lower sandstone of the Ingleside formation of this paper), succeeded by what he called cross-bedded Lykins (Lyons sandstone of this report), by 30 to 40 feet of red shale (Opeche (?) of Darton), and by "crinkled sandstone" with two or three thin layers of limestone.

[66] Butters, R. M., Colorado Geol. Survey Bull. 5, p. 79, 1913.

COTTONWOOD CANYON (10)

The younger rocks in Cottonwood Canyon (Dry Creek) west of Loveland are well exposed, and those of the following section from Niobrara limestone to Lyons sandstone were measured by stadia. The older rocks are somewhat disturbed by the faulting and warping of the en échelon fold near Thompson Canyon and their thickness was estimated. Dry Creek is a tributary of Thompson River, and comments on the formations are given under the next heading.

Section measured in Cottonwood Canyon (Dry Creek) west of Loveland, Colo.

[The portion inclosed by the brace at the left is correlated by the writer with the Dakota group of Bellvue, Colo., and the names in quotation marks indicate the corresponding parts of that group]

	Feet
Niobrara limestone: Limestone and shale, massive, with large *Inoceramus deformis* at base	240
Benton shale:	
Shale, light colored	10
Sandstone, cross-bedded	1
Shale, dark colored	25
Limestone (included in Greenhorn), with *Inoceramus labiatus* Schlotheim, *Inoceramus labiatus* var., *Helicoceras corrugatum* Stanton, *Acanthoceras coloradoense* Henderson, *Acanthoceras* sp	1
Shale	10
Limestone	4
Shale	260
"Upper sandstone": Upper layer of hard, quartzose sandstone, and a lower layer of softer, friable carbonaceous sandstone	80
"Upper shale" and "middle sandstone":	
Sandstone, shaly, with *Inoceramus* sp. undet	10
Shale	55
Sandstone, hard, ridge making	4
Shale, with limestone in thin irregular layers near the top, containing *Ostrea* n. sp., *Inoceramus* sp., fish scales, and bones. In the lower part are three sandstones, each about 5 feet thick, and two layers of shale, each about 10 feet thick, which may represent the middle sandstone	120
"Lower shale": Clay shale, pink, red, and gray	4
Abrupt change.	
"Lower sandstone": Sandstone, massive, conglomerate in lower part; makes prominent ridge	90
Abrupt change to red clay shale.	
Morrison formation:	
Shale, variegated	210
Limestone, blue, dense; light-colored sandstone at the base (similar to the limestone below and may belong in Sundance)	95
Sundance formation:	
Limestone, blue, brittle; gray sandstone and thin layers of dark shale; small concretions of pink chalcedony in the lower layers of limestone	115
Sandstone, yellow, evenly bedded, probably basal sandstone of Sundance formation	15
Erosional unconformity.	
Jelm (?) formation: Sandstone, orange-colored, massive, grading down to underlying Lykins formation; possibly belongs in Lykins or may be the Upper Triassic Jelm formation of Wyoming	25

	Feet
Lykins formation:	
Sandstone and shale, red; upper third massive, cross-bedded; lower two-thirds soft, deep red, shaly	495
Limestone, gypsum, and red sandy shale	135±
Lyons sandstone: Pink cross-bedded sandstone	30+
Ingleside formation: Sandstone, pink to red, cross-bedded, with a thin limestone at the top; base not seen	60+
Unconformity seen at near-by localities.	
Fountain formation (estimated)	1,000
Contact uneven.	
Granite.	

THOMPSON CANYON

Thompson River has cut gorges through the several ridges formed in the fold or plunging anticline by which the outcrops are here offset to the east. Although the exposures are not continuous, all the formations are clearly shown in one place or another. The Fountain formation rests on an uneven surface of coarse-grained granite, is 1,000 feet or more in thickness, and terminates above at a sharp line of unconformity (see pls. 9, *A*, and 8, *B*), which separates it from the cliff-making lower sandstone member of the overlying Ingleside formation. The photograph taken in the gorge south of Arkins (pl. 8, *A*) shows this sandstone separated by somewhat softer red beds from younger massive sandstone and all capped at the right by the Lyons sandstone, which lies on them with uneven contact.

The lower part of the Lykins formation here contains much limestone and thick beds of gypsum, which is manufactured into plaster. The lower red shale of this formation is not well exposed, but the limestone and gypsum beds have been opened at the plaster mill. Three limestones have been uncovered here, the middle one 20 to 40 feet thick; also three thick beds of gypsum, one below the lowest limestone and two between the limestone layers. Some of the gypsum beds are lenticular. One that has been worked ranges in thickness from 3 feet at one side of the opening to about 30 feet at the other side, with an unknown thickness not yet uncovered. Near this quarry the gypsum and limestone beds are exposed in a pitching anticline, on one side of which they stand nearly vertical, and have been crosscut at several horizons to a depth of 80 feet below the surface. Several caverns have been encountered in the gypsum, some open, others filled with detritus and fossil bones.

Stratigraphically above the gypsum beds are the thick red shaly sandstones of the Lykins formation, the orange-colored and yellow sandstones representing the lower Sundance, and possibly the Jelm formation, and limestone with much red chalcedony believed to be of Sundance age. Mr. J. B. Bryan, superintendent of the plaster mill, states that he has found fossil shells in these limestones, but although he guided the writer to the limestone of supposed Sundance age, no fossils were found. The limestone of this section, 210 feet thick where measured in Cottonwood Canyon, is a local development of the limestone and dark shale found in many places in northeastern Colorado below typical Morrison beds. It is similar to the limestone in northern Colorado which contains fossils of the Sundance fauna (see pp. 16, 39–40), and similar also to the limestone farther south, near Colorado Springs, which contains fresh-water shells and is included in the Morrison formation.

A sandstone of variable thickness lies unconformably on these limestones of the plaster mill, filling broad channel-like hollows in which the limestone is nearly all cut out. This sandstone has only local development and is overlain by typical Morrison shale. Similar sandstones occurring farther north are described elsewhere in this paper (pp. 50–51) as the filling of old channels formed in pre-Morrison time. If a similar explanation applies here, the underlying limestone should all be included in the Sundance. The sandstone that is correlated by the writer with the lower sandstone of the Dakota group at Bellvue is here the most prominent representative of that group, although the upper sandstone in some places makes a ridge of nearly equal prominence. (See pl. 19, *A*.) However, a few miles to the north this upper sandstone thins again and makes a ridge so inconspicuous that it easily escapes notice.

Near Arkins, a few miles north of Thompson River, the Lyons sandstone has been quarried in many places. It is here 30 to 40 feet thick, is strongly cross-bedded, and rests with seeming unconformity on the red sandstones of the Ingleside formation. At the top it gives place abruptly to the red shale of the lower member of the Lykins formation (Opeche (?) of Darton), 30 feet or more in thickness. The limestone member of these lower beds, the Minnekahta (?) of Darton, is represented here by 2 to 8 feet of limestone.[67]

Near Masonville, about 4 miles north of Arkins, a massive cross-bedded ledge-making sandstone more than 75 feet thick lies unconformably on the Fountain formation. North of that town it was observed filling channel-like hollows several feet deep in the arkose.

SPRING CANYON (11)

The upturned formations lying between the ancient granite and the Cretaceous are well exposed in Spring Canyon, about 6 miles southwest of Fort Collins, and those from the base of the Benton to the Hygiene sandstone member of the Pierre shale appear about 3 miles south of this canyon. The measurements at these two localities, made with stadia, are combined in the following section:

[67] Butters, R. M., Colorado Geol. Survey Bull. 5, p. 78, 1913.

Section measured in Spring Canyon, Larimer County, Colo., and 3 miles to the south

[The portion inclosed by the brace at the left is correlated by the writer with the Dakota group of Bellvue, Colo., and the names in quotation marks indicate the corresponding parts of that group]

	Feet
Pierre shale:	
Hygiene sandstone member, containing *Serpula markmani* Henderson, *Membranipora* n. sp., *Pinna?* sp. undet., *Inoceramus barabini* Morton, *Inoceramus sagensis* Owen, *Ostrea* sp. undet., *Exogyra costata* Say, *Anomia raetiformis* Meek, *Cardium speciosum* Meek and Hayden, *Anchura haydeni* White, *Mactra?* sp. undet., *Baculites nodosus* Owen, *Placenticeras* sp. undet.	
Shale (measured across covered plain where possible faulting and warping could not be detected)	4, 100
Niobrara limestone:	
Limestone, yellow, fissile, large fish scales	25
Shale, upper third yellow, flaky; lower two-thirds dark colored	78
Limestone, fissile	32
Oyster bed	1
Shale, dark colored, flaky	125
Limestone, shaly	78
Shale, fissile	63
Shale, with four 1-foot layers of limestone	24
Limestone, with large *Inoceramus deformis*	25
Benton shale:	
Shale	10
Sandstone	3
Shale (estimated)	20
Limestone (included in Greenhorn)	1
Shale	10
Limestone, in several layers, *Inoceramus labiatus* zone (included in Greenhorn)	5
Shale	380
"Upper sandstone": Sandstone, hard, quartzose, massive; makes prominent hogback	45
Contact irregular and lithologic change abrupt.	
"Upper shale": Shale, sandy, and thin sandstone and limestone; dark carbonaceous shale and streaks of coal near the top. Fossiliferous in the upper third, where Stanton found *Ostrea* sp. and *Inoceramus* sp. Near the bottom is a hard, quartzose ripple-marked cross-bedded sandstone 10 feet thick, with worm trails and other markings. Below it are beds of faintly colored granular sands softer than the sandstone above or below	225
"Lower sandstone" (possibly including "middle sandstone" and "lower shale"):	
Sandstone, chiefly massive, relatively soft	80
Sandstone, conglomeratic	75
Morrison and Lykins formations:	
Covered (estimated) (Butters[68] states that the Lykins here is 600 feet thick)	900
Limestone, sandstone, and gypsum, including the "crinkled sandstone," limestone, the limestone breccia, and intervening red shale. *Myalina wyomingensis* and *M. perattenuata* were collected from the "crinkled" limestone	60
Shale, red	40
Lyons sandstone: Sandstone, cross-bedded	50
Ingleside formation: Sandstone and shale, red. A persistent band of red shale at the top forms a strike valley. Below the shale are two massive red sandstones separated by softer red shaly sandstone, in the middle of which is a thin bed of crystalline limestone	100
Fountain formation; not measured.	

[68] Butters, R. M., Colorado Geol. Survey Bull. 5, p. 90, 1913.

SOLDIER CANYON (12)

The relations just described continue north of Spring Canyon. In Dixon Canyon, 2 miles to the north, the rocks correlated with the Dakota group of Bellvue are well exposed. There is a prominent sandstone between the massive lower sandstone and the fossiliferous upper shale of this group. (See pl. 29, *A*.) Were it not for the still higher (upper) sandstone, which is inconspicuous here, these lower layers would doubtless be interpreted as the two sandstones commonly called "Upper Dakota" and "Lower Dakota". These sandstones and the intervening shale, in the writer's opinion, constitute the Cloverly formation of more northerly localities.

Section measured in Soldier Canyon, Larimer County, west of Fort Collins, Colo.

[The portion inclosed by the brace at the left is correlated by the writer with the Dakota group of Bellvue, Colo., and the names in quotation marks indicate the corresponding parts of that group]

	Feet
"Upper sandstone": Sandstone, massive, yellow, quartzose, chief ridge maker of this locality	34
"Upper shale":	
Shale, dark; carbonaceous mudstone at top, full of charcoal and fragments of wood	2
Sandstone, yellow, with fragments of charcoal	5
Shale, with thin layers of sandstone and limestone with *Inoceramus* n. sp., *Ostrea* n. sp., *Anchura?* sp., about 75 feet from top	234
"Middle sandstone": Sandstone, hard, quartzose, massive, ridge making (see pl. 29, *A*)	12
"Lower shale": Covered interval, probably shaly sand	32
"Lower sandstone": Sandstone, hard, massive, cross-bedded, conglomeratic in lower part	36
Morrison to Lykins formations:	
Exposed in some places	870
Shale, red, crinkled sandy limestone, brecciated limestone, and gypsum. (Correlated with rocks in Wyoming which the oil men call Embar)	110
Abrupt change in lithology.	
Lyons sandstone: Sandstone, yellowish-pink, cross-bedded, ridge-making	43
Abrupt change in lithology; probable unconformity.	
Satanka (?) shale:	
Sandstone, soft, yellow	1
Shale and thin resistant, ridge-making deep-red sandstones; absent or not conspicuous at localities farther south	180
Ingleside formation: Sandstone, red, in thick, massive, cross-bedded layers, and thin beds of shale. The lower part is conspicuously massive and characterized by cross-bedding of the curved or eolian type. The calcareous layers occur near the middle, but half a mile farther south 4 feet of white limestone in the form of a lens several hundred feet across occurs in the middle of these red beds	238
Unconformity by erosion.	
Fountain formation; base not exposed	180+

Half a mile north of Soldier Canyon, on Ernest Andrew's ranch, a layer of limestone 4 feet thick, which probably represents one of the limestone members of the Ingleside formation, overlies a red sandstone which is probably the lowest member of the

Ingleside. This limestone thins out laterally along the outcrop in both directions within a few hundred feet. The rocks of this middle zone are represented by shaly beds farther south and by the interbedded limestones and red sandstones of the Ingleside formation of the Colorado Geological Survey[69] farther north. Soldier Canyon is practically the southern limit of the limestones that are characteristic of the Ingleside formation. It is also near the southern limit of a red shale formation, here 181 feet thick, which lies between the Ingleside and Lykins formations. This shale appears as a new element in the sections as viewed from the south, but it persists northward. Its relations are in doubt. Lithologically it is more nearly like the underlying than the overlying beds. It is at or near the horizon of the Satanka shale of the Laramie Basin and is provisionally correlated with that shale.

The Lyons sandstone and the overlying limy beds in the lower part of the Lykins formation are normal in appearance here, the latter containing beds of gypsum.

BELLVUE (13)

The foothill formations near Bellvue, Colo., were thrown into a dome and later eroded by Cache la Poudre River, in the bluffs of which some of them are strikingly exposed. No measurements were made here of the Fountain formation or of the lower sandstone of the Ingleside. The beds above this lower sandstone consist of red cross-bedded sandstone and shaly sandy limestone, most of which is too impure to be useful in the manufacture of lime. The Lyons sandstone is thin, but the limy gypsiferous beds in the lower part of the Lykins formation, which may represent the Forelle limestone and associated beds, increase in thickness and prominence toward the north. The orange-colored and yellow sandstones of the Jelm(?) formation and the basal lower member of the Sundance formation appear in an inconspicuous band along the hillsides, and a considerable thickness of chalcedony-bearing limestone occurs above them. The Morrison formation south of the river contains fossil bones, and the lower sandstone of the Dakota group consists of thick beds of conglomerate and contains petrified logs.

North of the river, near Laporte, the Lyons sandstone, 15 to 20 feet thick, forms a low ridge, and the basal Lykins beds contain "crinkled sandstone," red shale, and beds of gypsum. Darton[70] says of this locality:

> The supposed representative of the Tensleep horizon is prominent (here interpreted as the upper sandstone member of the Ingleside formation), overlain by about 150 feet of soft red shales, on which there is a series of limestones 30 feet thick. This series consists of a bed of massive limestone at the base, thin red limestones and shales alternating, and at the top a 10-foot bed of limestone almost precisely similar in aspect and relations to the Minnekahta limestone of the Black Hills.

He makes no mention of the gypsum or of the sandstone here called Lyons sandstone. However, in recent years a gypsum bed has been opened near Laporte, and the Lyons sandstone is recognizable in one of the excavations. About 2 miles north of Bellvue the Dakota group is well exposed where the ridge formed by the sandstones of this group was cut for an irrigation ditch. A section measured here with Locke level and tape is as follows:

Section of Dakota group measured 2 miles north of Bellvue, Colo.

	Feet
Benton shale.	
Dakota group:[71]	
Upper sandstone	35±
Upper shale: Shale, dark-colored, with layers and concretions of fossiliferous limestone (see list below)	200±
Middle sandstone:	
Sandstone, hard flaggy layers, with worm trails	10
Lower shale:	
Shale, buff colored, with thin layers of limestone	7
Shale, dark	2
Sandstone	4
Shale	1
Sandstone	2
Shale	1
Sandstone	1
Shale, red and blue	2
Sandstone, irregular, and shale in many shades of green, blue, and yellow	20
Lower sandstone: Sandstone, massive, coarsely conglomeratic at base, contains fossil logs	40
Erosional unconformity.	
Morrison formation (variegated shale).	

The upper sandstone of this section is quartzitic and contains near the base a clay-ball conglomerate with streaks containing charcoal and many impressions of stems of plants. This sandstone rests with uneven base on buff-colored shale. The sandy shale below this upper sandstone contains many large masses of cone-in-cone limestone and thin layers of sandy limestone full of fossil shells. These fossils, collected in a ditch in sec. 12, north of Bellvue, were identified by Reeside[72] as follows:

Inoceramus comancheanus Cragin.
Inoceramus bellvuensis Reeside.
Pteria salinensis White.
Ostrea larimerensis Reeside.
Ostrea noctuensis Reeside.
Anchura kiowana Cragin?
Fish scales (probably undescribed).

Below the dark-colored shale is a 10-foot sandstone, the middle sandstone, and a series of alternating thin sandstones and beds of colored shale, which represents the lower shale.

[69] Butters, R. M., Colorado Geol. Survey Bull. 5, p. 67, 1913.
[70] Darton, N. H., U. S. Geol. Survey Prof. Paper 32, p. 82, 1905.
[71] The Geological Survey accepts the term Dakota group for this section only, with the understanding that if any rocks of Comanche age are found to be included in this group they are to be excluded from it. The writer assumes entire responsibility for the correlation of other sections with it, as shown in the chart.
[72] Reeside, J. B., jr., U. S. Geol. Survey Prof. Paper 131, p. 201, 1923.

The unconformity at the base of the lower sandstone of the Dakota group is marked by channel-like hollows in the variegated Morrison shale filled with the pebble beds of the overlying conglomerate. (See pl. 28, *B*.)

INGLESIDE

Northward from Bellvue the limestones of the Ingleside formation increase in number and thickness, become so resistant as to form a prominent ridge, and are composed of nearly pure calcium carbonate. They are quarried extensively for use in the manufacture of beet sugar. Streams have cut sharp notches through the ridge in several places, making good exposures of the limestones and cross-bedded sandstones. (See pl. 9, *A*.) In the gorge at Ingleside a section was measured with stadia as follows:

Section at Ingleside, Colo.

[For the Cretaceous rocks to upper part of Lykins formation, see Owl Creek section, below]

	Feet
Lykins formation (basal part):	
"Crinkled sandstone," brecciated limestone, gypsum and red shale—thickness estimated	75
Shale, red, soft	175
Lyons sandstone: Sandstone, yellowish pink, cross-bedded, ridge making	25
Satanka (?) shale (possibly belongs with underlying formation): Red shale, poorly exposed with thin layers of ridge-making sandstone	375
Ingleside formation:	
Sandstone, ledge making, red to yellowish pink (Tensleep sandstone of Darton [78])	65
Limestone, pink to gray, with many solution cavities and masses of calcite	25
Sandstone, red, intensely cross-bedded	25
Limestone, gray, brittle, impure, in places variable	22
Sandstone, red, massive, cross-bedded	40
Sandstone, limy, gray, quartzose	6
Shale, soft, red	1
Sandstone, red, ledge making (thickness estimated)	100
Fountain formation, not well exposed.	

OWL CANYON (14)

In Owl Canyon, 3 miles north of Ingleside, the limestone and the red sandstones of the Ingleside formation are perfectly exposed where the stream has cut through the ridge. The overlying "Red Beds" (Lykins formation) crop out in a broad strike valley lying between the limestone ridge and the Dakota hogback, and the formations between the "Red Beds" and the marine Cretaceous rocks are exposed in this hogback. All these beds were measured with stadia on Owl Creek with results as follows:

[78] Darton, N. H., U. S. Geol. Survey Prof. Paper 32, p. 82, 1905.

Section measured on Owl Creek, Larimer County, Colo.

[The portion inclosed by the brace at the left is correlated by the writer with the Dakota group of Bellvue, Colo., and the names in quotation marks indicate the corresponding parts of that group]

	Feet
Pierre shale.	
Niobrara limestone: Limestone, in three thick layers, separated by shale	260
Benton shale:	
Sandstone, ridge making	4+
Shale, dark, sandy in upper 15 feet, continuously exposed	675
"Upper sandstone": Sandstone, massive, quartzose near top, friable below, many worm trails and other markings	40
"Upper shale": Shale, dark, fossiliferous, with thin layers of limestone in upper part	195
"Middle sandstone": Sandstone, hard, flaggy in some places, cross-bedded in others	12
"Lower shale":	
Covered interval	22
Sandstone	6
Covered interval	14
Sandstone, soft, friable	10
Shaly sandstone, friable, colored	12
"Lower sandstone": Sandstone, massive, cross-bedded, strongly conglomeratic at base; less strongly conglomeratic in middle and upper part. Rests unconformably on soft Morrison shale	75+
Morrison formation: Shale, variegated, with dinosaur bones near the top	195
Sundance formation:	
Limestone, blue, brittle	15
Sandstone, gray	8
Shale, light colored	18
Limestone	1
Shale, pink	2
Sandstone, strongly ripple marked	4
Shale, with thin ripple-marked sandy layers in lower part	11
Sandstone, massive, buff to yellow; bedding relatively even	80
Jelm (?) formation: Sandstone, massive, orange-colored, conspicuously cross-bedded	60+
Lykins formation ("Red beds"):	
Shale and sandstone, with several buff-colored layers. Two thin strata of impure limestone, one 50 feet and the other 25 feet above the base. (The thickness obtained from measurements across a grassy valley is 855 feet. As this is more than the thickness of these beds where they are better exposed, a lower figure is here used)	650+
Limestone breccia	2
Shale, red	10
Limestone, sandy, crinkled	12
Sandstone, shaly, thin bedded, buff	18
Shale, red, partly covered	77
Gypsum, with layers of red shale	108
Lyons sandstone: Sandstone, pink, cross-bedded, ridge making	25

	Feet
Satanka (?) shale:	
Shale, red, sandy	25
Sandstone, shaly, buff-colored	10
Shale, red, sandy	50
Sandstone and shale, buff-colored	12
Shale, sandy, red	75
Ingleside formation:	
Sandstone, massive, yellowish red (Tensleep of Darton) [74]	50
Limestone	2
Sandstone, red, limy	6
Sandstone, yellowish red	32
Limestone, in two layers, variable because of solution and caving	40±
Sandstone, red	20
Limestone, impure in lower part; upper part contains *Composita subtilita?*, *Myalina wyomingensis*, *Pseudomonotis?* sp., *Bellerophon crassus?*, *Strophostylus remex*	35
Sandstone, red	35
Limestone, sandy	30
Abrupt change in lithology suggesting unconformity.	
Sandstone, red, massive, ledge making. Rounded pebbles and angular fragments near the base of material like that in the upper part of the underlying Fountain formation suggest reworked material	100
Unconformity by erosion.	
Fountain formation: Sandstone, red, arkosic; conglomeratic in some places, shaly in other places, with layers of impure limestone	575±
Granite.	

The Fountain formation is here much thinner than it is farther south, but its character is the same. The figure given may not adequately represent the thickness, for it was measured across a covered space where possible faulting and warping might escape notice.

The basal sandstone of the Ingleside formation lies unconformably on the arkosic Fountain formation, and, although red like the underlying rocks, it is neither conglomeratic nor arkosic. The overlying limestones contain fossils of Pennsylvanian age, and there are many solution cavities and masses of calcite partly or wholly filling old cavities. In some places where the roof of a cave had collapsed the limestone is thin. Hence measurements differ considerably from place to place. Some of the limestones are red and crystalline; others consist of white, brittle, noncrystalline calcium carbonate. The sandstones are red and conspicuously cross-bedded. The highest cross-bedded layer is somewhat lighter colored than the others and was correlated by Darton [74] with the Tensleep sandstone. The shale above this sandstone holds the position of the Satanka shale of the Laramie Basin, but it seems here to be closely related to the older rocks.

The Lyons sandstone on Owl Creek is much thinner and less conspicuously cross-bedded than it is farther south, but it is clearly recognizable in a small ridge. Above it are the gypsiferous shales and limestones of the lower part of the Lykins formation, including the "crinkled" limestone. The upturned bed of limestone above the gypsum forms a ridge. Darton compared this limestone with the Minnekahta limestone of the Black Hills. The main body of the red beds of the Lykins crops out in a broad valley. At their top is a massive orange-colored cross-bedded sandstone (see pl. 25, *A*) that resembles the sandstone called Jelm formation [75] in the Laramie Basin, where it lies unconformably on the typical red beds and contains vertebrate fossils of Upper Triassic age. Darton and others included this sandstone in the Chugwater formation, but the discovery of Upper Triassic fossils in it in the Laramie Basin and of the unconformity below it indicates that these orange-colored beds of Owl Canyon will probably prove to be distinct from the older red beds.

Above the orange-colored sandstone and not readily separable from it is a similar buff to yellow ledge-making sandstone. In general this higher sandstone, which is here referred to the Sundance, is more conspicuously cross-bedded than the lower one, and in some places the two are clearly unconformable. The higher sandstone is overlain conformably by yellow beds and cherty limestone such as that which yielded fossils near the Greenacre ranch. (See pp. 39–40.) The upper part of the Sundance formation is not represented here, and the Morrison shale, which rests on the limestone, contains dinosaur bones.

Hard conglomeratic sandstone immediately above the Morrison shale rests with uneven contact on this shale. The sandstone forms a prominent ridge, at the eastern slope of which are exposed the soft colored sandy beds correlated with the lower shale and the middle sandstone of the Dakota group at Bellvue. The upper shale of this group crops out in a broad strike valley between the hogbacks formed by the upper and lower sandstones of the group. In this shale were found the same species of marine invertebrates that were found in corresponding shale in many places between Boulder, Colo., and Iron Mountain, Wyo. The younger formations measured here are indicated in the foregoing section.

BOXELDER VALLEY (15)

The geology of the region between Owl Creek and the Colorado-Wyoming boundary is significant in that the sedimentary rocks flatten and the older formations occupy a broad embayment in the ancient crystalline rocks, where they are separated from outcrops of the same formations in the Laramie Basin, west of the mountains, by a distance of only a few miles. They obviously extended uninterruptedly across this space before their removal subsequent to the mountain uplift.

The road was traversed from Owl Canyon past the Spring Hill ranch to the Greenacre ranch, which is on

[74] Darton, N. H., U. S. Geol. Survey Prof. Paper 32, p. 82, 1905.

[75] Knight, S. H., Geol. Soc. America Bull., vol. 27, p. 120, 1916.

Boxelder Creek, 8 miles northwest of Owl Canyon. Along this route the Fountain formation is not conspicuous because of the overlying hard limestones of the Ingleside formation, which dominate the topography. (See pl. 13, *A*.) The Lyons sandstone was recognized, by its color and cross-bedding, in an inconspicuous ridge south of the Greenacre ranch (see pl. 15, *B*), but it seems to be absent farther northwest. It was not recognized north of Table Mountain.

The older formations are well exposed between Table Mountain and the State line, where they were examined years ago by Darton and later by Butters.[77] Near the base of the Fountain formation, here 500 feet thick, Butters found Mississippian fossils in chert boulders, which he thinks [78] were formed in place but which others think were derived by erosion from some older formation.

The "Red Beds" are exposed in the north face of Table Mountain, where a sharp fold brings the limestone of the Ingleside formation to the surface. The beds above the Ingleside differ in no essential respect from those in Owl Canyon, described above, except that they contain thin layers of limestone in the lower part, which yielded the Permian invertebrates *Myalina wyomingensis, Myalina perattenuata, Alula squamulifera,* and *Murchisonia buttersi,*[79] and thick beds of gypsum at higher horizons. Here, as elsewhere in the foothills, the main body (Lykins formation) of the "Red Beds" occurs above the fossiliferous limestones, and according to Butters [80] is 790 feet thick. This thickness, however, includes the orange-colored sandstone, which probably belongs to the Jelm formation. Where these red beds were examined north of Table Mountain the cross-bedded massive sandstone, the supposed Jelm, is more than 100 feet thick and lies on typical Lykins material (see pl. 22, *B*) with an uneven contact suggesting unconformity.

The uneven contact obviously represents a period of erosion and strengthens the opinion expressed by Henderson,[81] of the Colorado Geological Survey, that a period of unrecorded time is represented between these lower red beds and the overlying orange-colored sandstone. At that time the orange-colored sandstone had not been recognized as separable from the overlying buff sandstone and was probably included in the Sundance formation.

Lying on the orange-colored sandstone is the lighter colored and more conspicuously cross-bedded lower sandstone of the Sundance. Where these two sandstones are well exposed, as they are near the Greenacre ranch (see pl. 26, *B*), they not only appear lithologically distinct but are separated by an irregular line suggesting an erosion interval.

[77] Buttors, R. M., Colorado Geol. Survey Bull. 5, p. 73, 1913.
[78] Idem, p. 72.
[79] Idem, p. 77.
[80] Idem, p. 90.
[81] Idem, p. 71.

GREENACRE RANCH, BOXELDER CREEK (15)

The upper part of the Lykins red beds and the younger formations were measured with Locke level about a mile north of the Greenacre ranch. The orange-colored sandstone (Jelm?), here 122 feet thick, is massive and cross-bedded, forms a nearly vertical cliff (see pl. 26, *B*), and lies with uneven base on typical Lykins material. It is overlain by the still more intensely cross-bedded buff sandstone at the base of the Sundance formation, which here varies in thickness from 20 to 100 feet. Above the buff sandstone are beds of soft yellow sandstone, hard ripple-marked sandstone, and cherty limestone containing the marine invertebrates of the Sundance fauna named in the following section (see pl. 24, *A*), and Morrison shale with dinosaur bones near the base.

The formations correlated with the Dakota group of the Bellvue section are better exposed near the mouth of the canyon. The following section is a composite one. The upper part was measured near the schoolhouse about 2 miles east of the Greenacre ranch, and the part from the top of the Morrison to the middle of the Lykins about a mile north of the ranch. The lower part is adapted from Butters's section.[82]

Section near Greenacre ranch, on Boxelder Creek

[The portion inclosed by the brace at the left is correlated by the writer with the Dakota group of Bellvue, Colo., and the names in quotation marks indicate the corresponding parts of that group]

	Feet
"Upper sandstone": Sandstone, quartzose, ridge making, with layers of thin shaly sandstone; many worm trails and other markings	82
"Upper shale": Shale, dark colored, with thin beds of warped sandy limestone, containing *Inoceramus* n. sp., *Ostrea,* and fish remains	118
"Middle sandstone": Sandstone, quartzose, ridge making, variable in character and thickness	15±
"Lower shale": Shale, sandy, red, yellow, blue, green, etc.; variable in character and thickness	25±
"Lower sandstone": Sandstone and conglomerate, resistant, ridge making; contains petrified logs; rests on soft shale	75±
Unconformity by erosion.	
Morrison formation:	
Shale, variegated, with sandy concretions in upper part and layers of sandstone in lower part	200±
Sandstone, gray, soft, thin bedded; contains small pebbles and dinosaur bones	5
Unconformity by erosion; upper part of Sundance absent.	
Sundance formation (lower fossiliferous zone with *Pentacrinus* sp., probably *P. asteriscus* Meek and Hayden, undetermined pelecypods, and *Pleuromya* sp. undet.):	
Shale, with several layers of shaly sandstone	24
Limestone, gray, soft	3
Shale, pink to gray, sandy to limy	20
Limestone, gray, sandy	4

[82] Idem, p. 90.

Sundance formation—Continued.	Feet
Sandstone, blue, brittle limestone, and shale, with fossils	40
Sandstone, lemon-yellow, evenly bedded, ripple marked	5
Shale, pink to gray	7
Sandstone, pink	2
Shale, red	3
Sandstone, yellowish pink, ripple marked	5
Sandstone, massive, ledge making, lemon-yellow	16
Local erosional unconformity.	
Sandstone, buff, massive, cliff making, variable in thickness, with cross-bedding of eolian type	20–100
Jelm (?) formation: Sandstone, massive, cross-bedded, generally orange-colored to red but gray in some places near the top	122
Erosional unconformity.	
Lykins formation, underlain by Satanka (?) shale: Sandstone, red and purple sandy shale in many layers (270 feet); lower part in valley not measured; thickness estimated	700
Ingleside formation: Limestone and cross-bedded sandstone; thickness estimated	350
Fountain formation (thickness given by Colorado Geological Survey)	500

LOCALITIES IN EASTERN FOOTHILLS OF WYOMING

BOXELDER CREEK, COLO., TO HORSE CREEK, WYO.

About 7 miles northeast of the Greenacre ranch most of the older formations of the foothills disappear under a cover of Tertiary deposits. Recent erosion has removed these Tertiary beds in a few places, exposing the harder rocks, such as the sandstones correlated with those of the Dakota group at Bellvue, Colo., and the limestones of the Ingleside (upper part of Casper) formation. The exposures are not continuous, and the rocks have been steeply upturned, faulted, and generally disturbed. They have been mapped and described by Darton and others in the Laramie-Sherman folio. These authors do not recognize the arkosic Fountain formation in the Laramie and Sherman quadrangles but include it in the Casper formation. The beds of arkose and conglomerate between the granite and the limestones of Darton's Casper formation have, however, been traced southward into unquestioned Fountain. These arkosic beds thin toward the north and have not been recognized north of these quadrangles.

All the formations recognized in Colorado, except the Lyons sandstone, were recognized west of Islay, Wyo., and examined by the writer. At the horizon where the Lyons sandstone might be expected the rocks are well exposed and a red shale was noted which probably represents the Satanka. Above this red shale two limestone layers, the "crinkled" limestone and the limestone breccia, each several feet thick, were found. At the top of the Chugwater is the cross-bedded orange-colored sandstone, probably the Jelm formation; a buff sandstone 10 to 15 feet thick at the base of the Sundance; a yellow sandstone above it, here shaly, 30 to 40 feet thick; and the blue brittle cherty fossiliferous limestone, of lower Sundance age. The upper, strongly fossiliferous member of the Sundance is not present. The Morrison is not well exposed here, but the conglomeratic sandstone immediately above it forms a ridge. A higher sandstone (probably the middle sandstone at Bellvue), about 15 feet thick, is hard, flaggy, and ripple marked and contains worm borings. The upper shale of the Bellvue Dakota section was recognized, and a few poorly preserved fossils were found in it. The upper sandstone, 75 feet thick, is hard and ripple marked and contains worm tubes and small masses of fine conglomerate near the top.

In the area east of the Laramie Mountains the Chugwater formation is said to rest on the limestones and sandstones of the Casper formation. This statement implies that the thick red shale at the base of the red beds is the Satanka shale, and the overlying "crinkly" limestone is the Forelle. At the line between Colorado and Wyoming the Chugwater is said to be 900 feet thick and to have a lower member of red sandstone and shale 385 feet thick, a middle member of gypsiferous red beds and thin limestones, and an upper red beds member 450 to 500 feet thick. This description corresponds to the Satanka shale, Forelle limestone, and the main body of the "Red Beds" in the Laramie Basin, where the Chugwater is restricted to the red beds above the Forelle limestone.

HORSE CREEK (16) AND MILL CREEK (17)

On Horse Creek, in the northern part of the Sherman quadrangle, the several formations described are well exposed in quarries, and the following section of them was measured with tape and stadia. The names used in this section are those of the Laramie-Sherman folio, except that the sandstone above the Cloverly formation and the intervening shale near the base of the Benton shale of the folio section are here grouped with the Cloverly and correlated with the Dakota group of the section at Bellvue, Colo.

Section measured at the limestone quarries 2 miles northwest of Horse Creek station, Wyo.

[The portion inclosed by the brace at the left is correlated by the writer with the Dakota group of Bellvue, Colo., and the names in quotation marks indicate the corresponding parts of that group]

	Feet
Niobrara limestone (possibly including some Pierre shale): Limestone and shale, not well exposed	430
Benton shale:	
Sandstone, shaly, with a 2-foot limestone in middle	10±
Shale, dark	215
Limestone, brittle, in thin irregular layers separated by shale; contains *Inoceramus dimidius* White, *I. fragilis* Hall and Meek, *Gryphaea* sp. undet., *Mortoniceras* aff. *M. shoshonense* Meek, *Helicoceras corrugatum* Stanton, *Ptychodus* sp. undet., fish scales	5

Benton shale—Continued.	Feet
Shale, dark colored, with black lime concretions in lower part	118
Shale, dark colored, including 15 feet of Mowry shale in lower part and "rotten" yellow lime concretions in upper part	190
"Upper sandstone": Sandstone, quartzose, massive, coarse grained, a prominent ridge maker	51
"Upper shale": Shale, dark colored, with thin layers of limestone; cone-in-cone limestone and fossiliferous limy sandstone in upper part	152
Cloverly formation: Sandstone, conglomeratic in lower part, covered above (considered by writer to correspond to the lower shale and middle and lower sandstones of the Dakota group of the Bellevue section)	116
Morrison formation (not well exposed)	200
Sundance formation: Sandstone, shale, and cherty limestone	45±
Chugwater formation:	
Shale and sandstone, red, partly exposed in broad valley	770
Limestone breccia	5
Shale and sandstone, red	95
Limestone, "crinkled"	25
Shale, red, and thin layers of red sandstones	80
Limestone, hard, sandy	1
Shale, red	25
Sandstone, white, friable	4
Limestone (Forelle?), gray to purple, hard, platy; forms conspicuous vertical wall, fossiliferous (Darton's 20-foot dolomitic limestone)	13
Red sandstone and shale in many alternating layers (Satanka (?) shale and possibly the sandstone which elsewhere occurs at the top of the Ingleside formation)	573
Casper formation:	
Limestone, sandstone, and pink shale, not continuously exposed, many solution cavities partly filled with calcite and much chert in the limestones (corresponds to some of the upper part of the Ingleside formation of Colorado)	113
Sandstone, shaly, red	85
Covered	61
Sandstone and limestone, red	50
Limestone	16
Sandstone	14
Limestone, exposed in old quarry, variable because of much solution	40+
Sandstone and limestone, poorly exposed	80
Limestone, impure	8
Limestone and shale, not continuously exposed	45
Shale, red	6
Sandstone, red	6
Limestone, exposed in quarry	13
Limestone, cherty, fossiliferous	6
Covered	7
Limestone	6
Sandstone, red	10
Limestone, gray, exposed in quarry	26
Sandstone, red, evenly bedded	13
Limestone, gray	7
Sandstone, dark red, variable	2
Limestone, gray	6
Sandstone, red, quartzose, limy in some places	39
Sandstone, red, limy	10
Limestone, gray	8
Covered interval; 5 feet of red shale at top (meager exposures suggest basal sandstone of the Ingleside formation of Colorado)	50
Casper formation—Continued.	Feet
Sandstone, arkose, and conglomerate, red, mottled with buff and gray, with pebbles 4 inches or more in maximum diameter (corresponds to Fountain formation of Colorado)	132
Limestone, cherty, and red sandstone (possibly a remnant of the Madison limestone, which is prominent farther to the northwest)	22
Granite.	

Section on Mill Creek, Wyo. (17), 1½ miles north of Horse Creek

[The portion inclosed by the brace at the left is correlated by the writer with the Dakota group of Bellvue, Colo., and the names in quotation marks indicate the corresponding parts of that group]

Niobrara limestone:	Feet
Limestone, white, shaly	25+
Shale, dark, poorly exposed	215
Limestone, massive, white	20
Benton shale:	
Sandstone, limy, containing *Inoceramus fragilis* Hall and Meek, *Inoceramus dimidius* White, *Exogyra?* sp. undet., *Crassatellites* aff. *C. excavata* Stanton, *Scaphites warreni* Meek and Hayden, *Prionocyclus wyomingensis* Meek, *Prionotropis woolgari* Mantell	4
Shale, poorly exposed in soil-covered plain	810
"Upper sandstone": Sandstone, quartzose, ridge maker	18
"Upper shale": Shale, dark, not well exposed	145
Cloverly formation:	
"Middle sandstone": Sandstone, hard, granular, containing much ironstone	12
"Lower shale": Shale and friable sandstone, colored in many shades of green, pink, blue, etc.; variable in thickness and character	96
"Lower sandstone": Sandstone, hard, massive, ridge making	54
Morrison formation: Shale, exposed in few places	230
Sundance formation:	
Limestone, yellow	2
Sandstone and shale, pink to yellow	45
Shale, blue	8
Sandstone, soft, orange-colored	19
Sandstone, soft, white, friable	12
Chugwater formation:	
Sandstone and shale, red	588
Limestone breccia	6±
Shale, red	26
Limestone, pink, "crinkled"	9
Shale, red, not well exposed	42
Limestone, sandy, hard, prominent ridge maker (Forelle (?) limestone)	13
Sandstone and shale, red (Satanka (?) shale)	360
Casper formation:	
Sandstone and shale, red; contains three layers of limestone	350
Limestone in thick layers, with five beds of red sandstone 1 to 6 feet thick	285
Shale, red	2
Limestone, hard, resistant, gray to pink	3
Sandstone and shale, red, poorly exposed	44
Limestone, sandy, hard, gray to pink	5
Limestone, shaly, thin bedded, gray; contains *Chonetes mesolobus* var. *decipiens*, *Productus cora*, *Pustula nebraskensis*, *Spirifer triplicatus*, *Squamularia perplexa*	2
Sandstone, massive, gray to pink	5
Sandstone, limy, thin bedded, gray to pink	7

Casper formation—Continued.	Feet
Sandstone, red, soft	21
Sandstone, coarse grained, red, with arkose and conglomerate; lower part covered (correlated by writer with the Fountain formation of Colorado)	170+
Granite.	

The rocks of the Casper formation above the basal 170 feet of sandstone are correlated by the writer with the Ingleside formation of north-central Colorado.

Several features in these two sections call for comment. Although but a mile and a half apart, only one of the two shows sedimentary rocks older than the Fountain formation. The arkosic beds are thin but exhibit the unmistakable characteristics of the Fountain formation. The massive red sandstone found generally between the arkose and the overlying limestone and the sandstone above the limestones that Darton correlated with the Tensleep were recognized. Above the higher sandstone of the Casper formation are the thick red beds of the Chugwater formation, including the Satanka (?) shale below and a possible representative of the Jelm formation above. The lower shale of the Chugwater in Darton's section measured 1½ miles northwest of Horse Creek station[83] is 261 feet thick. This thickness and its position suggest that it is the Satanka shale, which at the type locality at Satanka siding, on the west slope of Laramie Mountains, is 232 feet thick. Possibly in the sharp upturning of the beds near Horse Creek (see pl. 15, *A*) the thickness of this soft shale has been increased. If it represents the Satanka shale, the lower fossiliferous limestone is correlated naturally with the Forelle west of the range, as Darton suggested, and with the similar limestone elsewhere called Minnekahta. But where there are three or more limestones in the lower part of the "Red Beds," as there are near Horse Creek, it is not certain which one should be correlated with the Forelle. The younger formations appear in normal sequence as shown in the platted sections, except the Jelm formation, which was not recognized here, possibly because of poor exposures where this formation should crop out.

ALTUS

Near Altus, about 5 miles northwest of the Horse Creek quarries, the limestones that correspond to those of the Ingleside formation are upturned to a nearly vertical position (see pl. 9, *A*) and have been stripped of surface débris for quarrying. The lowest bed of limestone contains Pennsylvanian fossils identified by George H. Girty as *Cyclotrypa barberi, Derbya crassa, Chonetes granulifer* var., *Productus cora, Productus pertenuis, Pustula nebraskensis, Marginifera splendens, Dielasma bovidens, Spirifer triplicatus, Ambocoelia planiconvexa, Composita subtilita,* and *Allerisma terminale.* The youngest limestone contains crinoid segments, *Derbya?* sp., *Pustula semipunctata, Pustula nebraskensis?, Composita subtilita,* and *Bellerophon crassus.*

[83] Darton, N. H., U. S. Geol. Survey Prof. Paper 32, p. 71, 1925.

IRON MOUNTAIN (18)

North of Altus Tertiary deposits cover the older sedimentary rocks for a few miles, but the older rocks reappear in many places near Iron Mountain, about 10 miles north of Horse Creek, where they are much warped and faulted. In the small canyon called Threemile Canyon, near the Jordan ranch, the exposures of formations from granite to Cretaceous are favorable for measuring total thickness but are not adequate for detailed examination. Arkosic material and conglomerate above the granite probably represent the Fountain formation, although they differ somewhat from typical Fountain beds. They are intensely red in some places, being almost an iron ore. Possibly the proximity of Iron Mountain, a great mass of titaniferous iron ore of pre-Cambrian age, is sufficient reason for this difference.

The limestone and cross-bedded sandstone, 710 feet thick, and possibly also some of the overlying red beds, represent the Ingleside formation of Colorado. The contact between these beds and the overlying Chugwater formation was not found here. The top of the 525-foot shaly bed of the section (No. 14, pl. 1) is marked by a ridge formed by the thin hard limestone that may be the Forelle. The main part of the Chugwater formation crops out in a strike valley and is poorly exposed, but the limestones of the Sundance formation form a ridge. The sandstones correlated with the Dakota group at Bellvue, Colo., also make prominent ridges. The Benton shale, fossiliferous in some places, crops out in the grassy plain.

The lower part of the Niobrara is massive limestone, full of the large fossil *Inoceramus deformis.* Above this limestone are red and orange-colored shale and thin layers of limestone. Still higher in the section is another ridge-making light-yellow to orange-colored limestone. These beds are similar to the yellow fish-scale limestones found at many of the localities examined in northern Colorado and southeastern Wyoming, in the upper part of the Niobrara formation. Where Chugwater Creek crosses Jordan ranch these limestones crop out in a dome and contain great numbers of *Inoceramus deformis* Meek and *Ostrea congesta* Conrad.

This locality is not far north of the Sherman quadrangle, and the names used in the Laramie-Sherman folio are here adopted, except that some of the rocks in the lower part of the Benton are here correlated with the Dakota group of Bellvue, Colo.

Section measured with tape in Threemile Canyon at Jordan ranch, near Iron Mountain, Laramie County, Wyo.

[The portion inclosed by the brace at the left is correlated by the writer with the Dakota group of Bellvue, Colo., and the names in quotation marks indicate the corresponding parts of that group]

	Feet
Niobrara limestone:	
Limestone, orange-colored to yellow	15
Shale, mostly covered, orange-colored in some places	290
Limestone, gray	20
Benton shale:	
Shale, dark colored, containing near the middle *Inoceramus fragilis* Hall and Meek, *Ostrea* sp., *Exogyra columbella* Meek, *Prionotropis* sp. undet., *Ptychodus* sp. undet., *Isurus* sp. undet., *Galeocerdo* sp. undet.	850
Shale, light colored (Mowry)	75
Shale, dark colored, with thin layers of fossiliferous limestone	100
"Upper sandstone": Sandstone, hard, massive, ridge making	72
"Upper shale" (covered)	155
Cloverly formation:	
"Middle sandstone" and "lower shale": Sandstone and shale	105
"Lower sandstone": Sandstone, hard, ridge making	50
Morrison formation (covered)	230
Chugwater formation:	
Red beds, including sandstone and limestone above (Sundance and possibly Jelm) and some limy beds below	710
Red beds, including a limestone which may be Forelle and a shale which may be Satanka	525
Casper formation:	
Limestone in massive layers and shaly sandstone in thin beds; correlated with Ingleside formation of Colorado	710
Sandstone, shale, arkose, and conglomerate, deep red	215
Limestone, cherty, arkose, and quartzose sandstone	20
Granite.	

Short sections showing details of some of the formations were obtained at neighboring localities. The rocks correlated with the Dakota group of the section at Bellvue, Colo., and the Sundance formation were observed in the gap where Chugwater Creek cuts through the Dakota hogback (see pl. 31, *A*) and in a gulch one-eighth of a mile north of this gap. Much quarrying has been done here, exposing the shale correlated with the upper shale of the Dakota group at Bellvue. The measurements below indicate considerable variation in the thickness of the rocks at these two localities.

Section measured with tape in gap on Chugwater Creek, Wyo.

[The portion inclosed by the brace at the left is correlated by the writer with the Dakota group of Bellvue, Colo., and the names in quotation marks indicate the corresponding parts of that group]

	Feet
Benton shale (see pl. 30, *B*):	
"Upper sandstone": Sandstone, massive, hard	30–50
"Upper shale": Shale, dark colored, with thin layers of "warped" limestone near the top, containing *Inoceramus* n. sp., *Pteria* n. sp., *Ostrea* n. sp., ammonite, possibly *Metoicoceras* sp., *Leucichthyops vagans* Cockerell	130–200
Cloverly formation:	
"Middle sandstone": Sandstone, hard, ripple marked	30–40
"Lower shale" (covered)	35–40
"Lower sandstone": Sandstone, coarse grained, dark gray, conglomeratic near base	25–45
Morrison formation: Shale, variegated	220
Sundance formation:	
Limestone and shale	10
Shale, mostly covered	15
Limestone	1
Shale, mostly covered	15
Sandstone, gray to yellow	75
Chugwater formation:	
Sandstone, orange colored, cross-bedded. (Possibly represents the Jelm formation (Triassic), which to the south overlies the Chugwater, as now restricted)	36
Red beds. (Darton[84] gives a thickness of 700 to 800 feet for Chugwater at this locality, but his Chugwater includes the cross-bedded orange-colored sandstone (Jelm?) above and the beds below that are probably to be correlated with the Forelle limestone and Satanka shale.)	

Section measured with Locke level south of Chugwater Creek, about 4 miles west of Iron Mountain station

	Feet
Cloverly formation: Conglomerate, forms crest of ridge; correlated by writer with lower sandstone of Dakota group of section at Bellvue, Colo.	
Morrison formation (covered interval; some Sundance shale may be included)	200
Sundance formation:	
Limestone, hard, gray, cherty	14
Shale, blue to gray, with thin layers of cherty limestone	9
Shale, mostly covered	11
Sandstone, shaly, soft, red to buff	26
Sandstone, soft gray to buff	19

[84] Darton N. H., U. S. Geol. Survey Prof. Paper 32, p. 70, 1905.

Sundance formation—Continued.	Feet
Sandstone, hard, yellow	1
Sandstone, soft, yellowish green	2
Sandstone, soft, red	9
Sandstone of prominent cliff, buff to gray, strongly cross-bedded, particularly near the base	49
Chugwater formation:	
Sandstone and sandy shale, soft, light yellow. (Possibly represents Jelm formation to south, which is now excluded from Chugwater formation)	16
Red beds (typical Chugwater).	

Near the locality mentioned above a "crinkled" limestone, which probably represents the Forelle limestone, and a higher thin limestone breccia were recognized near the base of the red beds. Still farther west, about half a mile southwest of the Talbot ranch, about 25 feet of soft shaly sand was found above the cherty limestone of the Sundance formation. A 3-inch layer near the middle of this bed is composed almost exclusively of oyster shells and *Belemnites densus* Meek and Hayden.

IRON MOUNTAIN TO CASSA (19)

Several miles north of Iron Mountain the older sedimentary rocks disappear beneath beds of Tertiary age. They reappear in the Hartville uplift, where they were observed near Cassa, about 60 miles north of Iron Mountain, in the canyon of the North Platte. The rocks, consisting chiefly of limestone, were measured by the writer's assistant, H. S. Cave, as follows:

Section of part of the Hartville formation measured with Locke level, in Platte Canyon, about 3 miles southeast of Cassa, Wyo.

	Ft.	in
Limestone, cherty, light gray	125+	
Sandstone, thin bedded, pink to yellow	4	
Limestone, gray, massive	11	
Sandstone, pink to gray, slightly cross-bedded	6	
Limestone, gray	5	
Chert, gray		2
Chert, red		4
Sandstone, pink, thin bedded	2	
Limestone, gray, massive, cherty	22	
Sandstone, hard, cross-bedded, cream colored	6	
Uneven contact, suggesting local unconformity.		
Limestone, with large chert nodules; contains *Meekella striaticostata?, Chonetes verneuilianus, Productus cora, Marginifera splendens, Spirifer triplicatus*	11	
Sandstone, mostly covered	16	
Limestone	4	
Sandstone, thin bedded	7	
Limestone, massive, gray, with chert nodules, layers of purple and black shale; contains *Productus hermosanus*	64	
Limestone, chalky white	13	
Sandstone, gray, fine grained	10	
Sandstone, red, fine grained	9	
Sandstone, gray, limy	11	
Shale, soft red sandstone, and limestone (poorly exposed on slope)	134	
Limestone and soft shale	29	
Covered	21	
Limestone, pink (base irregular, suggesting local unconformity)	4	
Sandstone, red, cross-bedded, cliff making	27	
Sandstone and shale, red (similar to red shale of Amsden formation of more westerly localities)	21	
Limestone, pink (bottom of canyon)	30+	

According to Darton [85] the rocks of Algonkian age in this uplift are overlain by the Guernsey formation (Mississippian), Hartville formation (Pennsylvanian and Mississippian), Opeche formation (Permian?), Minnekahta limestone (Permian?), and Spearfish formation. The part of the Hartville formation examined in the canyon of the Platte east of Cassa probably corresponds to the Ingleside formation of Colorado. The alternation of red sandstone and shale with limestone that contains Pennsylvanian fossils is the same except that the limestone predominates in Platte Canyon and the red sandstone predominates at more westerly localities. Red clastic material near the base of the canyon walls seems to correspond to similar beds below the limestones at more northerly localities that are correlated with the Ingleside formation—that is, the red shaly beds forming a part of the Amsden formation.

GLENDO (20)

The upper part of the Hartville formation exposed on the railroad about 4 miles north of Glendo yielded fossils identified by G. H. Girty as follows:

Meekella striaticostata?.
Chonetes granulifer.
Productus cora.
Productus hermosanus.
Pustula nebraskensis.
Marginifera wabashensis.
Pugnax osagensis var. percostata.
Spirifer triplicatus.
Spiriferina kentuckyensis.
Ambocoelia planiconvexa.
Composita subtilita.

Stratigraphically above this limestone are red shales, beds of gypsum, and impure limestone. Darton [86] mentions the occurrence of Minnekahta limestone and Opeche shale and sandstone, the latter 60 feet thick and resting unconformably on massive white sandstone at the top of the Hartville formation, 15 miles northwest of Guernsey—that is, about 10 miles southwest of Glendo. It appears, therefore, that in the Hartville uplift the stratigraphic relations are not unlike those of the mountain region farther west. However, it may be noted that the beds of the Hartville formation that represent the Ingleside formation consist largely of limestone, whereas farther west the beds correlated with the Ingleside consist chiefly of sandstone.

[85] Darton, N. H., U. S. Geol. Survey Prof. Paper 32, p. 63, 1905.
[86] Idem, p. 65.

LOCALITIES NORTH OF THE LARAMIE MOUNTAINS, WYO.

DOUGLAS (21)

The next locality to the northwest at which a section was measured is south of Douglas, about 70 miles north of Iron Mountain. The sedimentary rocks of Paleozoic and Mesozoic age south of this town crop out in several sharp folds. All the formations, from pre-Cambrian to middle Upper Cretaceous, are exposed in one place or another. The following section is a composite one, but the parts were measured only a few miles apart and are joined by means of easily recognized key rocks. The older Paleozoic formations were examined in two places, one on the Laramie road about 10 miles southwest of Douglas, the other about 7 miles nearly due south of Douglas. At both these localities thicknesses were obtained by pacing across the strike of the rocks and correcting for dip and surface slope. The Permian and Triassic "Red Beds" were measured with stadia 6 miles south of Douglas. The formations above the "Red Beds" were examined in the north wall of the canyon of the Platte where the river turns sharply to the east. (See pl. 23, *A*.) The thicknesses here were obtained by correcting Locke level measurements for dip of beds and slope of hillside. Some of the details of the rocks correlated by the writer with the Dakota group of the section at Bellvue, Colo., were obtained at this locality; others from several neighboring localities. The rocks of Benton and Niobrara age are exposed about 12 miles south of Douglas, where the dip is low and the outcrops obscure. Measurements of these rocks were made with stadia.

Nearly all the formation names used in this section are those that were used by Barnett[87] for the rocks exposed several miles to the west and are in common use throughout southeastern Wyoming by practically all geologists familiar with this region. However, several differences in usage may be noted. The writer correlates some of the rocks commonly included in the Benton with the upper part of the Dakota group at Bellvue, Colo. Also he recognizes four members of the Sundance formation. The Embar of many of the oil men of Wyoming probably includes the limestones near the base of the Chugwater formation and the Forelle (?) limestone. The Casper formation of Barnett[88] includes rocks of Mississippian age. At the locality where the writer's section was measured the lower Mississippian beds now recognized as Madison limestone were not recognized but may possibly be represented.

[87] Barnett, V. H., U. S. Geol. Survey Bull. 541, pp. 49–88, 1914.
[88] Idem, p. 54.

Section near Douglas, Wyo.

[The portion inclosed by the brace at the left is correlated by the writer with the Dakota group of Bellvue, Colo., and the names in quotation marks indicate the corresponding parts of that group]

	Feet
Niobrara limestone:	
Limestone and shale in thin layers, orange-colored; upper limit uncertain	50±
Limestone, gray, in layers about 1 foot thick, contains *Inoceramus deformis* Meek, *Ostrea congesta* Conrad, and undetermined fish remains	25
Benton shale:	
Shale, dark, mostly covered; contains *Inoceramus fragilis* Hall and Meek and other invertebrates	375
Sandstone (Wall Creek?) shaly, variable—hard, massive, cross-bedded, and cliff making to soft and friable; gray weathering to brown	75–100
Shale, dark, sandy above; many septaria concretions below	150
Shale, dark, mainly covered; contains *Syncyclonema* n. sp., *Nucula?* sp., and *Lucina?* sp., near top, thin sandstones near middle, and 50 to 150 feet of Mowry shale in lower part	955
"Upper sandstone": Sandstone, massive, coarse grained, quartzose, variable in thickness; forms the main hogback in some places and an inconspicuous ridge in others	85±
"Upper shale": Shale, black, with thin layers of sandstone and limestone	150±
"Cloverly" formation:	
"Middle sandstone": Sandstone, in some places in well-defined ripple-marked layers, shaly at base, with 1 foot of impure coal; in other places a hard ridge making sandstone	30±
"Lower shale": Shale and soft sandstone, of many colors, pink, yellow, brown, etc	65±
"Lower sandstone": Sandstone, hard, coarse grained, massive, conglomeratic in some places; ranges from less than 30 feet to more than 150 feet	90±
Morrison formation:	
Shale, variegated	118
Limestone, blue	3
Shale, variegated	18
Sandstone, ledge making	16
Sundance formation:	
Upper marine member:	
Sandstone and shale; fossil bones in upper part and *Belemnites densus* Meek and Hayden and other fossil invertebrates below	43
Shale, gray, sandy	58
Layer composed almost wholly of oysters and *Belemnites densus* Meek and Hayden	0–3
Shale, dark	1
Sandstone, pink, ripple marked	1
Shale and sandstone, gray	16
Sandstone, limy, with small bivalves (*Tancredia inornata* Whitfield)	2
Middle colored member:	
Shale, dark colored	20
Sandstone, ledge making, gray	8

	Feet
Sundance formation—Continued.	
Middle colored member—Continued.	
Sandstone, pink, friable	30
Sandstone, yellow, ledge making	12
Lower marine member:	
Sandstone, soft, shaly, yellow, with *Tancredia extensa*? White, *Tellinomya protensa* Hall, *Astarte*? sp. undet	11
Sandstone, gray, massive, friable above, thin bedded, ripple marked, with small bivalves (*Tancredia warrenana* Meek and Hayden)	19
Shale, sandy, with small bivalves	38
Basal sandstone member: Sandstone, gray, weathering to light buff, massive, cross-bedded; forms prominent ledge	80
Unconformity by erosion. (No orange-colored sandstone was found that can represent Jelm formation.)	
Chugwater formation:	
Sandstone and shale, red beds (depositional thickness doubtful because of faulting and warping)	585±
Shale, sandy, with 10 beds of gypsum and many "stringers" of gypsum in the shale; no gypsum found at this horizon at neighboring localities	320
The following section was covered where the overlying beds were measured, and the details were obtained 1 mile farther east:	
Limestone breccia	5
Shale, red	10
Limestone breccia	5
Shale, red	8
Limestone breccia and "crinkled" limestone	10
Shale, red	30
Gypsum and red shale	100±
Forelle (?) limestone:	
Limestone, sandy, red, in thin layers	10
Limestone, hard, gray, brittle	4
Limestone, hard, purple, in many irregular layers; makes a prominent mountain-facing scarp (Minnekahta limestone of Darton)	20
Satanka (?) shale: Shale, sandy, deep red (Opeche shale of Darton)	75
Unconformity and change from soft red shale above to dark quartzite below.	
Casper formation (probably equivalent in part to Amsden and Tensleep of Big Horn Mountains; all but the basal 101 feet and the upper 220 feet of this section of the Casper formation is correlated by the writer with the Ingleside formation of Colorado; the upper quartzitic breccia is different from anything seen elsewhere in the Tensleep sandstone):	
Quartzite (tentatively correlated with Tensleep sandstone), dark gray, weathering to brown, with about 40 feet of conglomerate in upper part, with angular blocks several inches in diameter; variable in thickness and character	220
Sandstone, gray massive, cross-bedded (lithologically similar to Tensleep sandstone of other localities)	60
Covered	100
Limestone and red cross-bedded sandstone	15
Sandstone and cherty limestone	15
Covered; much red material on slopes	140
Casper formation—Continued.	Feet
Sandstone, gray	165
Limestone, sandstone, and shale, variable color	180
Quartzite, white	10
Sandstone and shale, pink to red	100
Granitic débris	1
Granite, coarse-grained, red.	

The 101 feet of pink to red sandstone and shale and granitic débris above the granite hold the position of the Fountain formation of Colorado and southern Wyoming and may represent its northward extension.

No rocks of Cambrian age were observed south of Douglas, but Darton[89] states that they occur at neighboring localities. Some of the lower beds of the section may belong to the Madison limestone, but no evidence of Mississippian age was found here. The higher beds constitute the unnamed formation 200+ feet thick of Darton's section for the north end of the Laramie Range,[90] which he regarded as equivalent to the Amsden formation of the Big Horn Mountains and which, together with the overlying sandstone, correlated with the Tensleep, he later called Casper formation.[91] The upper sandstone 220 feet thick includes locally in its upper part a coarse breccia conglomerate, the pebbles and angular fragments of which are cemented together with silica. Although it corresponds in stratigraphic position with the Tensleep, it differs materially in lithologic character from the Tensleep sandstone of more westerly localities.

The correlation of the older beds of this section is a problem of considerable importance in the stratigraphic study of Wyoming localities and one for which more detailed information is desired. Some of the basal rocks may represent the Madison limestone, which occurs a few miles farther west, and still higher red strata correspond in position to certain red rocks that locally lie below the fossiliferous limestones of Pennsylvanian age and are called Amsden formation by some and red Amsden by others. The rocks above these red strata correspond in general character, appearance, and position to the limestones and sandstones of the Iron Mountain section and the similar rocks of the Hartville uplift. However, the proportion of sandstone is greater, the color a much lighter red, the cross-bedding of the sandstones conspicuously more pronounced, and the limestone thinner and more sandy. In brief, the rocks correlated with the Ingleside formation of Colorado, which consists chiefly of limestone to the east, change in constitution toward the west and become chiefly sandstone.

The correlation of the brown quartzitic sandstone and conglomerate above the limy beds with the typical Tensleep sandstone also needs further consideration. These rocks are lithologically dissimilar to the typical Tensleep rocks. It is possible that the name Tensleep has been used for more than one sandstone.

[89] Darton, N. H., U. S. Geol. Survey Prof. Paper 32, p. 56, 1905.
[90] Idem, p. 55.
[91] Darton, N. H., and Siebenthal, C. E., U. S. Geol. Survey Bull. 364, p. 11, 1909.

The rocks that are called Embar formation by the oil men correspond to the Forelle limestone of the Laramie Basin and slightly younger beds of limestone and gypsum, ending above with the limestone breccia, which were included in the lower part of Barnett's Chugwater formation. They possibly include the shale described by Barnett [92] as Satanka (?) and a 34-foot limestone which he called Forelle (?). Most of the Chugwater red beds above the breccia, which are classed as Triassic and Permian, are without fossils. The Alcova limestone member of the Chugwater formation, which occurs farther west, was not found here, nor was the Jelm formation found near Douglas.

Several significant features of the Sundance formation were noted near Douglas. The basal sandstone, regarded by the writer as the representative, at least in part, of the Navajo and Wingate sandstones, forms a conspicuous light-colored cliff and lies unconformably on the Chugwater red beds. (See pl. 23, *B*.) The beds above this sandstone show three subdivisions—a lower fossiliferous member, a red member, gypsiferous in some places, and an upper fossiliferous member.

The Morrison formation has the same character here as elsewhere, except that at its base is a sandstone that may be of the same nature as the white sandstone near Alcova described below, which obviously originated as the filling of old stream channels. For this reason the sandstone is regarded as basal Morrison rather than as a part of the Sundance formation.

The three lower divisions of the overlying Cretaceous rocks of the section as platted (No. 15, pl. 1) constitute the Cloverly formation, as generally defined in central Wyoming, and are the formations compared by Darton [93] with the Dakota sandstone, Fuson formation, and Lakota sandstone of the Black Hills. The overlying shale, 150 feet thick, is the basal Benton of most reports dealing with the stratigraphy of southeastern Wyoming but is correlated by the writer with the upper shale of the Dakota group of the section at Bellvue, Colo. The next higher sandstone, or Muddy sand, is correlated by the writer with the upper sandstone of this group, also with the unnamed sandstone included in the Graneros shale in the Laramie-Sherman folio, and probably with the Newcastle sandstone member of the Graneros shale of eastern Wyoming.

The stratigraphic relations observed in several places between Douglas and Casper harmonize with the relations shown in sections 14 and 15 of Plate 1. About 3 miles east of La Prele Creek coarse sandstone, 31 feet thick according to Barnett,[94] resting on granite, may represent the Deadwood formation, of Cambrian age. Above it is the massive cherty dolomitic limestone of the Madison formation, the 150-foot dolomite of Barnett, containing *Spirifer centronatus* in masses of chert near the base.

[92] Barnett, V. H., U. S. Geol. Survey Bull. 541, p. 57, 1914.
[93] Darton, N. H., U. S. Geol. Survey Prof. Paper 32, p. 55, 1905.
[94] Barnett, V. H., U. S. Geol. Survey Bull. 541, p. 56, 1914.

The Madison is overlain by red beds of variable character and thickness, 81 feet thick according to Barnett, which are correlated with the red beds of the Amsden, and these in turn by limestone and pink sandstone several hundred feet thick. Fossils of Pennsylvanian age—*Meekella striaticostata*, *Composita subtilita*, and *Aviculipecten* sp.—were found near the base of these rocks. The upper layer, Barnett's 40-foot sandstone, is hard and in some places consists of a quartzite breccia similar to that south of Douglas but much thinner. Above it are the soft red Satanka (?) shale and gypsum and the Forelle (?) limestone, which has been correlated in some reports with the Minnekahta limestone of the Black Hills.

The section on La Prele Creek is still better exposed, but faulting and warping of the strata leave the exact thickness of some of the rocks in doubt. Conglomeratic sandstone, probably Deadwood, here rests on granite and is overlain by the Madison limestone; the red beds, about 100 feet thick, locally called Amsden; and the fossiliferous limestones and cross-bedded sandstones (of the Casper formation) which are characteristic of the Ingleside formation of Colorado and are correlated with that formation. A partial section of these beds was measured in the west wall of La Prele Canyon at the reservoir as follows. Unfortunately the top of the limestone series was obscured by faulting, and the thickness of the lower rocks was estimated.

Partial section of beds of Casper formation that are correlated with the Ingleside formation at the reservoir in La Prele Canyon, Wyo. (22)

[Upper part measured with Locke level by the writer's assistant, H. S. Cave]

Top uncertain because of faulting and erosion.	Feet
Sandstone, pink, cherty	3+
Limestone, cherty, nodular, pink to yellow, base uneven	21
Shale, limy, yellow	2
Limestone, thin bedded	5
Sandstone, cherty	1
Limestone, cherty	15
Sandstone, cross-bedded, red to yellow	66
Limestone, nodular, pink to yellow	13
Sandstone, cross-bedded, massive, ledge making	96
Limestone, pink, base uneven	31
Sandstone, massive, cross-bedded in thick layers, light red to yellow, calcareous in some places	228
Sandstone, conglomeratic, soft, red	5
Sandstone, quartzitic, massive	36
Base of Locke leveled section. Thicknesses of beds below are estimated.	
Sandstone, quartzitic, and limestone; may duplicate in part some of the higher beds	275±
Shale, sandy, red (lower part of Amsden)	200±
Limestone, cherty, and sandstone; 10 feet of conglomerate at base	65+
Sandstone, limy, pink to white	10
Sandstone, soft, coarse grained, dark colored, conglomeratic	150
Granite, coarse grained, red.	

The relations of the beds above those represented in this section are not certain because of faulting and

warping. There are several thick, massive cross-bedded sandstones. The uppermost of these is the Tensleep sandstone of Darton,[95] which forms Ayers Natural Bridge at the mouth of this canyon.

Still farther west, on Boxelder Creek, the Deadwood formation was observed, and the cherty fossiliferous Madison limestone[96] forms a prominent cliff. Above this is an unusual thickness of red material that belongs to the Amsden and a thick series of limestone and cross-bedded sandstone. The first limestone above these red beds yielded *Fusulina secalica, Productus semireticulatus, Productus cora, Composita subtilita, Aviculipecten* sp., and *Meekospina peracuta?*.

The still higher beds consist chiefly of sandstone, but no quartzitic layer comparable to that south of Douglas and east of La Prele Creek was found. Here, however, as elsewhere in southern Wyoming, these rocks of Pennsylvanian age are overlain by beds of very different character, which are called Embar by the oil men. The lower shale of this group is soft, lies unconformably on the Pennsylvanian beds, and is overlain by "crinkled" limestone (see pl. 16, *B*), which forms a persistent ridge.

The same formations were observed farther west in the Casper Range. At the east end of this range the Deadwood formation was found at the bottom of a canyon, but it is better exposed in the north face of the range. Near the old asbestos mill south of Casper it is 130 feet thick (pl. 4, *B*). Above it lies the Madison limestone, consisting of cherty dolomitic limestone and shale. From a cherty layer near the top of this formation at the east end of the mountains, shown in Plate 6, *B*, were collected *Schuchertella* aff. *S. chemungensis, Spirifer centronatus*, and *S. centronatus* var. Similar beds south of Casper in the first canyon east of the old asbestos mill yielded *Syringopora surcularia, Spirifer centronatus*, and *Composita humilis*.

The red material that represents the lower part of the Amsden formation was recognized in several places in the Casper Range between the Madison and the overlying limestones and cross-bedded sandstones that represent the upper part of the Amsden and are correlated by the writer with the Ingleside formation of Colorado. The highest layer correlated with the Ingleside formation near the old asbestos mill contains the Pennsylvanian forms *Girtyina ventricosa, Derbya crassa?*, and *Chonetes granulifer*. The upper part of the group of Pennsylvanian strata in the Casper Range (see pl. 12, *A*) consists chiefly of massive cross-bedded ledge-making sandstone, but there is no layer here that can be directly correlated with the quartzitic breccia south and west of Douglas.

The limy, gypsiferous beds of the lower part of the Chugwater formation are characteristically developed in these mountains, and the relatively soft red beds above form a broad valley. Stratigraphically above these red beds is a conspicuous ledge formed by the thin Alcova limestone member of the Chugwater formation. Between this limestone and the overlying Sundance formation are red beds that differ in physical character and general appearance from those below the Alcova.

The Sundance, Morrison, and Cloverly formations were all recognized at the east end of the mountains. The conglomeratic lower Cloverly (in this paper correlated with the lower sandstone of the Dakota group of the section at Bellvue, Colo.) is 17 to 100 feet thick and crops out in a prominent ridge. The colored lower shale and the middle sandstone of this group were noted but not measured. The upper sandstone of the group (Muddy sand) is probably represented by a small ridge between the main hogback and the outcrop of the Mowry shale.

CASPER (23)

Most of the formations just described are well exposed at the west end of the Casper Range, and all except the older ones were measured. The rocks of Mississippian age were examined in the north face of the mountains and the younger formations along North Platte River. Although the rocks in these mountains are faulted and folded in many places, the several formations are exposed in one place or another in such manner that satisfactory measurements of the strata above the Casper formation were obtained by J. B. Reeside, jr., with tape and stadia. The thicknesses of the lower part of the Pennsylvanian beds and the still older strata were estimated.

Most of the formation names used in this section are those used by practically all geologists familiar with this part of Wyoming. However, the rocks immediately above the Morrison formation, including the Cloverly formation and overlying beds, are correlated by the writer with those of the Dakota group of the section at Bellvue, Colo. Certain modifications relative to the still older rocks are explained beyond.

Section measured with tape and stadia near west end of Casper Range, Wyo.

The portion inclosed by the brace at the left is correlated by the writer with the Dakota group of Bellvue, Colo., and the names in quotation marks indicate the corresponding parts of that group]

	Feet
Benton shale:	
Shale, poorly exposed, not measured.	
Sandstone, buff, argillaceous, thin bedded	15
Shale, dark gray	95
Sandstone, buff, platy	5
Shale, dark gray	45
Sandstone, buff, not well exposed but making a bench	2
Shale, dark gray	48
Sandstone, massive, buff, with many large chocolate-brown concretions (probably Wall Creek sandstone of current usage)	20
Shale, dark gray	60
Sandstone, massive, medium grained, buff, with many chocolate-brown concretions (the "Lower Wall Creek" sand of current usage)	20

[95] Darton, N. H., U. S. Geol. Survey Prof. Paper 32, p. 80, 1905.
[96] Barnett, V. H., U. S. Geol. Survey Bull. 541, p. 57, 1914.

Benton shale—Continued.	Feet
Interval forming a valley with few exposures but apparently all a very dark shale	390
Mowry shale, the usual bluish-gray fissile fish-scale shale; forms prominent pine-covered ridge	225
Shale, dark, bluish gray	90
"Upper sandstone":	
Sandstone, thin bedded, gray to rusty brown	5
Shale, dark bluish gray, and thin sandstone	25
Sandstone, coarse, gray to rusty brown, fairly massive but shows bedding on weathered surface	95
"Upper shale": Shale, bluish black, with thin worm-tracked limy sandstones and black sandy concretions	151
Cloverly (?) sandstone:	
"Middle sandstone": Sandstone, massive, cross-bedded, gray to rusty brown, coarse grained; contains many lenses of fine conglomerate	22
"Lower shale":	
Shale, bluish black, sandy	11
Sandstone, massive, gray to rusty brown, coarse grained	18
"Lower sandstone": Conglomerate, massive, composed of siliceous pebbles ½ to 1½ inches in diameter; cross-bedded; matrix rusty brown, but whole mass has a dark-brown to dark-green tone because of the dark chert pebbles	20
Unconformity by erosion.	
Morrison formation:	
Shale, variegated	130
Sandstone, massive, white, medium grained; ranges from a featheredge to 40 feet; occurs as filling of channels	10±
Unconformity by erosion.	
Sundance formation:	
Shale, pink to red, and soft white sandstone, irregularly intermingled	86
Sandstone, greenish white, massive, coarse grained	8
Interval not well exposed but apparently all a gray-green shale, with many round septarian limestone concretions	97
Limestone, brown, sandy; contains *Eumicrotis curta* (Hall), *Ostrea strigilecula* White, *Ostrea englemanni* Meek, *Camptonectes bellistriatus* Meek, *Modiola formosa* Meek and Hayden, *Pleuromya subcompressa* (Meek), *Tancredia inornata* Whitfield, *Tancredia corbuliformis?* Whitfield, *Dosinia jurassica* Whitfield, *Belemnites densus* Meek	3
Limestone, drab, sandy; contains *Belemnites densus* Meek	38
Sandstone, soft, white, fine grained	15
Sandstone, soft, pink, fine grained, massive	54
Sandstone, platy, hard, gray	1
Sandstone, soft, pink, fine grained, massive	27
Shale, dark gray, with some platy sandstone	4
Sharp erosional contact, suggesting unconformity.	
Sandstone, massive, yellow, friable, fine grained, calcareous	10
Shale, dove colored, with many thin layers of hard gray sandstone near the top	92
Limestone, dense, buff, platy	3
Sandstone, massive, white, cross-bedded, coarse grained; forms a prominent ledge. (Another measurement made a mile farther south shows a thickness of 45 feet)	27
Unconformity.	

"Red Beds":	Feet
Sandstone, orange-colored, cross-bedded, medium grained, massive; contains some thin beds of red shale (possibly equivalent to the Jelm formation, of late Triassic age, which is now excluded from the Chugwater formation). (Another measurement made a mile farther south shows a thickness of 88 feet)	73
Limestone (Alcova limestone member, marine, of probable Triassic age), purple, banded, with crinkly layers. Upper 3 feet sandy, practically a sandstone. (A mile farther south 16 feet of red beds occur between this limestone and the overlying orange-colored sandstone. Elsewhere still greater thicknesses are found)	20
Sandstone, indurated, mottled brick-red, gray, and purple	8
Red beds; main body of Chugwater formation	630
Limestone, greenish white to purple, fine grained, ripple marked	10
Sandstone, pistachio-green, platy, ripple marked, fine grained	8
Shale, red, sandy, with an indurated platy red sandstone near top	38
Limestone, platy, purple to gray	5
Limestone, gray-white, hackly on surface, full of solution cavities	1
Gypsum, with a little red shale	86
Red shale and sandstone grading upward into gypsum and limestone breccia	35
Limestone, with rough, irregular surface, gray, with small chert nodules	1
Shale, red	5
Limestone, gray, platy, ripple marked; has some purplish layers of the "crinkled" limestone type	6
Shale and sandstone, brick-red	58
Limestone, gray (Minnekahta of Darton and possibly Forelle of Laramie-Sherman folio); lower part reddish, platy; upper 4 feet a solid bed that breaks into angular fragments, with hackly surface; contains *Pinna peracuta, Schizodus ferrieri, Pteria?* sp., *Plagioglypta canna*	10
Shale and sandstone, brick-red (Opeche shale of Darton and possibly Satanka shale of Laramie-Sherman folio; base of Embar of oil men)	70
Casper formation (all except basal 85 feet is correlated by writer with Ingleside formation of Colorado):	
Sandstone, white to brown, massive, intensely cross-bedded; includes sandstone supposed to be Tensleep	215
Sandstone, quartzitic, brown	100
Concealed interval	67
Limestone, white, massive; weathers hackly	8
Shale, red, sandy	35
Limestone, white, massive; weathers hackly	10
Shale, deep claret-red, sandy; contains layers of a coarsely crystalline, heavy mineral (correlated by writer with lower red beds of the Amsden formation; may possibly represent the Fountain formation of Colorado)	85
Madison limestone (thickness estimated); contains *Spirifer centronatus, Spirifer centronatus* var., *Spiriferina solidirostris, Composita humilis?, Cliothyridina crassicardinalis?, Euomphalus* sp	200
Deadwood formation (estimated)	200
Pre-Cambrian crystalline rocks.	

The 85 feet of shale immediately above the Madison limestone is compared by the writer with the Fountain formation of Colorado, although it is included with the overlying rocks of Pennsylvanian age that are correlated with the Ingleside formation of Colorado. However, the upper part of the latter group of rocks may not be of the same age in all places. An unconformity separates them from the overlying red shale. Erosion represented by this unconformity may have removed more of these Pennsylvanian rocks in one place than in another, and a query arises as to the identity of the Tensleep sandstone. Without knowledge to the contrary, any one of the sandstones in the upper part of the Casper formation which in the process of erosion happened to be left at the top might readily be interpreted as Tensleep.

The red beds commonly known as the Chugwater formation, except where the Satanka shale and Forelle limestone are recognized as distinct from the Chugwater, lie unconformably on the Casper formation. The lower or limy and gypsiferous part of these red beds is thicker here than farther east. They are correlated in a general way with beds called Embar by many of the oil men in central and southeastern Wyoming. They include the limestone which Darton compared with the Minnekahta limestone of the Black Hills and the Forelle limestone of the Laramie Basin and a shale which he compared with the Opeche shale and the Satanka shale. These beds may be the same as the Forelle limestone and the Satanka shale of the Laramie-Sherman folio, but the presence of several limestones, any one of which may or may not represent the Forelle limestone and the occurrence of the unconformity below the lower shale render the correlation of this shale with the Satanka shale of the Laramie-Sherman folio open to question and make doubtful any close correlation between the limestones.

These lower red beds have been called Embar in the belief that they are equivalent to the beds in the Owl Creek Mountains to which Darton applied the name Embar formation. The writer found no beds near Casper which he can confidently correlate with those of Darton's Embar. The lower part of that formation, now known as the Phosphoria formation, is clearly absent, and the upper part, if present at all, is so changed as not to be clearly recognizable. Some geologists have thought that the limy, gypsiferous beds correspond with the upper part of Darton's Embar, which is now known as the Dinwoody formation and which Condit[97] describes as occurring between the Phosphoria formation and the overlying Chugwater red beds.

After satisfying himself that the red beds near Casper lie unconformably on those of Pennsylvanian age and that no beds are present here that can be correlated with the Phosphoria formation, the writer visited the Owl Creek Mountains, the type locality of the Embar formation, and the Wind River Mountains, the type locality of the Dinwoody formation. He verified the subdivisions made at these localities and noted in the lower part of the Chugwater red beds, at both places, rocks which he would, on grounds of stratigraphic position and lithology, compare with the limy, gypsiferous beds in the lower part of the Chugwater red beds near Casper.

The writer found near Casper no rocks which he can confidently correlate with the Dinwoody formation. He believes that such beds of Phosphoria and Dinwoody age as may have existed here were eroded away before the deposition of the red beds, and that the geologic time denoted by these formations is here represented by the unconformity that separates the Chugwater red beds from the underlying Casper formation.

A still further complication arises relative to the upper part of the red beds. The main body of the red beds above the lower, limy, gypsiferous part is clearly the same as the main body of the Chugwater formation farther east. But it is overlain by a limestone that contains fossils of probable Triassic age and still younger beds that may be of Jurassic age, in a manner which indicates probable overlap, as explained on page 15. Although the limestone, the Alcova, is classed as a member of the Chugwater formation, it and the beds above it are, in the writer's opinion, inappropriately assigned to a formation that includes the beds below it. For these reasons the noncommittal term "Red Beds" is used in the section in place of Chugwater formation.

The Alcova limestone marks a conspicuous change from the rocks on which it rests. It is a persistent layer of compact limestone, of marine origin, and although not obviously unconformable with the underlying strata it must represent a wide transgression of the sea or spreading of marine waters over the land in what the writer believes to be Triassic time. The sedimentary rocks above it, of orange, buff, and salmon colors, are quite different in general aspect from those below, and they in turn give place abruptly to the cliff-making basal sandstone of the Sundance formation, which rests unconformably on the post-Alcova red beds where this limestone is present and on the pre-Alcova red beds where this limestone and the overlying red beds are absent.

Here, as near Douglas, the Sundance formation has four members—a massive basal sandstone (see pl. 27, *B*), which resembles the Nugget sandstone of western Colorado and eastern Utah; a lower sparingly fossiliferous marine member; a red gypsum-bearing member; and an upper richly fossiliferous member.

The Morrison beds differ little from those of localities already described, except that the lowest bed here included in this formation is a sandstone of uneven thickness, which seems to represent the filling of stream

[97] Condit, D. D., U. S. Geol. Survey Bull. 764, pp. 10–11, 1924.

channels. Above the Morrison, at the west end of Casper Mountain and along its south flank, were recognized the five divisions which the writer correlates with the Dakota group of the section at Bellvue, Colo. The lower sandstone is here thin and the upper one unusually thick. Otherwise the divisions are about the same as at other localities described.

BATES HOLE (24)

All the formations herein described above the Casper formation were observed on the south slope of Casper Mountain and have been penetrated by the drill in Bates Hole, in the Bodie anticline, and on Bolton Creek. The Embar formation of the oil men is limy and gypsiferous and yields oil on Bolton Creek. The Chugwater red beds where penetrated by the drill are 600 feet thick. The Alcova limestone is not mentioned in the drill records, but it is conspicuously exposed on the south slope of Casper Mountain a few miles north and east of the Bodie anticline. A thick sandstone above the red beds is probably basal Sundance. The youngest members of the Sundance and the Morrison formation were recognized in the drill records. The rocks correlated with the Dakota group of the section at Bellvue, Colo., are 202 feet thick and consist of layers of sandstone and shale in the usual order. The lower sandstone, 70 feet thick, is conglomeratic. The upper sandstone is variable in thickness in this part of Wyoming and in some places is so thin that it might readily escape notice.

ALCOVA (25)

The sedimentary rocks near Alcova, which is about 25 miles southwest of the west end of Casper Mountain, are thrown into sharp folds where the section next described was measured. North Platte River has cut across these folds, making excellent exposures. The Cambrian (Deadwood), Madison, Amsden, and Tensleep formations were measured with Locke level in the upper canyon north of Pathfinder, near the locality illustrated in Plate 12, *B*, and the younger formations were measured near Alcova, where the distances were obtained by tape and stadia, and the thicknesses of the formations by correcting the measurements for dip, slope, and direction of traverse.

Aside from the exceptions noted beyond the geologic names employed in the following section are those used by Hares [98] and other geologists familiar with the geology of central Wyoming. For reasons explained under the foregoing section, the name "Red Beds" is used in place of Chugwater formation. The combined section is as follows:

[98] Hares, C. J., U. S. Geol. Survey Bull. 641, pp. 233–279, 1917.

Section measured near Alcova, Wyo.

[The portion inclosed by the brace at the left is correlated by the writer with the Dakota group of Bellvue, Colo., and the names in quotation marks indicate the corresponding parts of that group]

	Feet
Carlile, Frontier, Mowry, and Thermopolis formations (all of Benton age):	
Shale, dark.	
Sandstone and shale (Frontier)	185
Shale, light, including Mowry, and much white bentonite	760
"Upper sandstone": Sandstone, shaly, brown (Muddy sand)	10±
"Upper shale" (Lower Cretaceous shale of Hares and others): Shale, dark colored, with layers of thin sandy limestone	125+
"Middle sandstone" (Lower Cretaceous conglomerate of Hares and others): Sandstone, conglomeratic, with worm trails	½
"Lower shale": Shale and friable sandstone, varicolored	24±
"Lower sandstone": Sandstone, coarse grained, brown to yellow, conglomeratic, with pebbles 1½ inches in maximum diameter	34
Unconformity by erosion.	
Morrison formation:	
Shale, dark, variable; thins out in some places	15±
Sandstone, coarse grained, brown	5
Shale, variegated	48
Sandstone, brown, with quartz pebbles and fossil bones of dinosaurs	3
Shale, gray to yellow	20
Shale, variegated	54
Sandstone, gray	9
Shale, variegated	23
Sandstone, gray	3
Uneven contact suggesting erosion.	
Sundance formation:	
Upper marine member:	
Shale, light, sandy, with *Camptonectes* and *Belemnites*	17
Limestone, with *Ostrea strigilecula* White, *Gryphaea calceola* var. *nebraskensis* Meek and Hayden, *Camptonectes bellistriatus* Meek and Hayden, *Plicatula* sp. undescribed, *Pleuromya subcompressa* (Meek), *Tancredia inornata* Whitfield, *Dosinia jurassica* Whitfield, *Belemnites densus* Meek and Hayden	5
Shale, light, sandy	92
Red gypsiferous member:	
Sandstone, pink, gypsiferous	78
Gypsum	3
Sandstone, massive, gray	4
Lower marine member:	
Sandstone, thin bedded, ripple marked	13
Shale, sandy, with *Tancredia warrenana* Meek and Hayden	97
Basal sandstone member:	
Sandstone, gray, massive, with eolian cross-bedding; thickness variable (5 to 40 feet)	14±
Sandstone, gray to yellow, with pink "mud balls"	5
Unconformity.	
"Red Beds" (Chugwater formation of Hares and others):	
Sandstone and shale, red, with bands of gray; a bed of limestone pellets several feet thick near the top.	

"Red Beds"—Continued.	Feet
The beds of limy pellets resemble the bone-bearing beds of the Jelm formation in the Laramie Basin. Those between the pellets beds and the Alcova limestone, although included by some geologists in the Chugwater, are now known to be younger than the Chugwater of Chugwater Creek, to be of probable Triassic age, and to overlap the older red beds (see fig. 2)	355
Limestone, gray to purple, sandy, hard, in many thin layers, "crinkled" in some places; contains *Natica lelia* and *Naiadites?* sp. (Alcova limestone member; marine; probably Triassic)	8
Probable overlap.	
Sandstone, brown, coarse grained, massive	10
Red beds, gypsiferous in places; a persistent 4-foot layer of light-colored sand 300 feet from top	800
Embar formation of Hares and others (regarded by the writer as younger than typical Embar):	
Limestone, shaly, with *Nucula?* sp. and fish remains	6
Gypsum	3
Sandstone, red shale, gypsum, and nodular chalcedony	126
Limestone, sandy, gray, gypsiferous	6
Gypsum	10
Sandstone and shale, red, gypsiferous (corresponds to Minnekahta limestone of Darton and perhaps to Forelle limestone), gray to purple, platy; contains *Pinna peracuta?*, *Schizodus* aff. *S. compressus*, *Schizodus* aff. *S. meekanus*, *Pleurophorus?* sp., *Bellerophon* aff. *B. crassus*, *Nautilus* sp., fish remains	15
Shale, sandy, red, gypsum near middle (corresponds to Opeche shale of Darton and perhaps Satanka shale)	66
Unconformity.	
Tensleep sandstone and Amsden formation (correlated by the writer with the Ingleside formation of Colorado):	
Sandstone, ledge making, intensely cross-bedded, weathering brown (Tensleep sandstone of local geologists; relation to typical Tensleep unknown)	97
Sandstone, massive	25
Sandstone, platy, calcareous	3
Sandstone, massive, buff, intensely cross-bedded	166
Limestone, sandy, cream-colored; contains *Allorisma terminale*, *Pteria longa?*, *Deltopecten aviculatum*, *Parallelodon?* sp., *Schizodus?* sp., *Pleurophorus?* sp., *Bellerophon* n. sp., *Euphemus carbonarius?*, *Naticopsis* aff. *N. nana*	11
Sandstone, quartzitic, pink to yellow	3
Sandstone, massive, cross-bedded	42
Limestone, sandy, pink to yellow; many solution cavities; contains *Productus cora*, *Productus hermosanus*, *Composita subtilita*, *Parallelodon?* sp., *Deltopecten?* sp., *Pteria* sp., *Plagioglypta?* sp., *Bellerophon crassus?*	12
Sandstone, coarse grained, massive, yellow	12
Limestone, sandy, cream-colored; many solution cavities	8
Sandstone and limestone, cream-colored	22
Limestone, cream-colored	2
Irregular contact suggesting erosion.	
Sandstone, yellow	2
Limestone, cream-colored; solution cavities	12
Limestone, gray to pink, massive	12
Tensleep sandstone and Amsden formation—Contd.	Feet
Sandstone, red, purple, gray, and yellow, with thin layers of cherty limestone and conglomerates with chert pebbles; variable in thickness and character; fills hollows in underlying limestone (the red Amsden of local geologists; holds the stratigraphic position of the Fountain formation of Colorado and is compared with this formation by the writer)	40±
Unconformity.	
Madison limestone:	
Limestone, gray, cherty, massive, contains *Productus parviformis*, *Spirifer centronatus*, *Spiriferina solidirostris*, *Cliothyridina crassicardinalis*	73
Uneven contact as if by erosion.	
Limestone, yellow, hard	2
Limestone, cherty, massive, yellowish gray	98
Sandstone, limy, massive, yellowish gray	2±
Covered	7
Limestone, sandy in some places, massive, cherty; contains *Camarotoechia* aff. *C. sappho*, *Camarotoechia* sp., *Spirifer* aff. *S. keokuk*, *Spiriferina solidirostris?*, *Cliothyridina crassicardinalis*	40
Covered	12
Sandstone, limy, cherty	25
Cambrian formation (Deadwood):	
Shale, gray to dark red	3
Sandstone, dark red, quartzitic, evenly bedded above, massive, and conglomeratic below; rests on an uneven surface of crystalline rock	197
Granite and dark-colored intrusive rocks.	

The basal granite is the rock in which the Pathfinder Dam is built and is obviously much older than the Deadwood formation. Thick dikes of dark-colored rock, intrusive in the granite, end abruptly at the contact of the Deadwood formation.

The change from the Deadwood to the overlying limestones is abrupt, but there is less visible evidence of unrecorded time here than at several horizons within the younger rocks. However, the lowest fossiliferous beds contain invertebrates of Mississippian age, and therefore, until positive evidence to the contrary is found, it may be assumed that the Ordovician, Silurian, and Devonian periods are not represented near Alcova.

The upper surface of the Madison limestone is conspicuously uneven. As viewed from a distance in the nearly vertical walls of the canyon of the North Platte (see pl. 12, *B*) the Madison appears to have been deeply eroded, and the red material of the next younger formation, included perhaps erroneously in the Amsden, to have been deposited in the hollows. This red material is locally known as the red Amsden.

The Amsden rocks above the red-bed member just mentioned rest with uneven contact on the red material and consist chiefly of thick cross-bedded gray to light-pink sandstone, with a few thin limestones containing fossils of Pennsylvanian age. These beds constitute the main body of the Casper formation as that term is locally used. The cross-bedded sandstones are most conspicuous near the top. The youngest one, 97 feet thick, is more coarsely cross-bedded

than the underlying layers, on which it rests with irregular base, and may be the typical Tensleep sandstone, but no convincing evidence was found for separating it from the older beds, which have heretofore been included in the Tensleep sandstone, although their fossils are of Amsden type.

Most of the beds of the Tensleep sandstone and Amsden formation of this section are correlated by the writer in a general way with the Ingleside formation of Colorado, but the lower red part of the Amsden may be the time equivalent of the Fountain formation of Colorado. The top of this group of rocks was eroded before the deposition of the next younger beds. Hence the exact age equivalents of individual beds are doubtful.

The overlying red gypsiferous shale, 66 feet thick, lies with uneven contact on the cross-bedded sandstone and is overlain by purple fossiliferous crinkly limestone. This is followed by the gypsiferous beds that contain the chert nodules on which Condit[99] based the correlation of these beds with the lower (Phosphoria) part of the Embar formation of more westerly localities. These beds are not sharply separable from the overlying red beds. Here, as elsewhere in eastern Wyoming, the upper limit of the Embar formation, as the name is used in the Alcova section, is the highest limestone of the group of limy, gypsiferous rocks in the lower part of the "Red Beds." But it is not certain that the highest limestone of this group is the same in all places. As explained in the description of the section at Casper, Wyo., the writer believes that any equivalents of the Phosphoria and Dinwoody formations which may have existed here were eroded away prior to the deposition of the beds here called Embar.

The Alcova limestone member of the Chugwater formation, which takes its name from this locality, forms a sharp ridge where the upturned beds are eroded and prominent ledges where the beds lie more nearly horizontal. (See pl. 21.) It varies slightly in thickness in the several exposures near Alcova from a minimum of about 5 feet to more than 20 feet. It is a marine limestone of probable Triassic age, as shown by the fossils contained in it. No evidence of geologic age has been found in the thick red rocks between the Alcova limestone and those which are here called Embar formation and which contain fossils believed to be of Permian age.

The red beds above the Alcova limestone member differ in color, character, and general aspect from those below this limestone. Where examined in detail, about 4 miles southeast of Alcova, they contain limy beds and hard layers of ledge-making sandstone of orange and salmon colors. A layer near the top consists of small pellets of impure limestone suggesting balls of limy mud formed in shallow, gently moving water. These beds resemble the bone-bearing material of the Jelm formation, of Upper Triassic age, in the Laramie Basin. They are terminated above at an unconformity by the light-colored massive cross-bedded sandstone of the basal member of the Sundance formation, of late Jurassic age. (See pl. 27, *A*.)

The Sundance formation above the basal sandstone member consists of a lower sparingly fossiliferous marine member, a red gypsiferous member, and an upper strongly fossiliferous marine member. In this fourfold nature the formation corresponds to the Sundance near Casper and Douglas and at many localities farther to the west and north.

In some places near Alcova where unfossiliferous beds occur above rocks of undoubted Sundance age the top of the formation is in doubt, but 4 miles southeast of the town the fossiliferous Sundance gives place abruptly to a massive, friable light-colored sandstone (see pl. 28, *A*) ranging in thickness from a featheredge to 60 feet, which seems to have originated as the filling of stream channels. The evidence of erosion at the base of this sandstone seems sufficient reason for regarding it as a basal member of the Morrison formation; also for believing that a considerable period of unrecorded time is represented by the unconformity at the base of the Morrison. The Morrison formation here contains many dinosaur bones. Hundreds of fragments were found scattered over the surface about 2 miles northeast of Alcova.

The overlying Cretaceous rocks occur here in normal succession. The sandstone that is correlated with the lower sandstone of the Dakota group at Bellvue, Colo., is variable in thickness, is abnormally conglomeratic, and rests on the Morrison with uneven base, suggestive of erosion. In some places it consists chiefly of siliceous pebbles unevenly cemented. The more firmly cemented parts break down into huge boulders of resistant conglomerate; the less resistant parts into scattered gravel. The overlying shale is inconspicuous in most places and is generally obscured by surface débris, but the succeeding sandstone is relatively thin. Where the section was measured the latter sandstone is represented by only 6 inches of sand and pebbles. At near-by localities it is many feet thick.

The sandstone (Muddy sand) that the writer correlates with the upper sandstone of the Dakota group at Bellvue, Colo., is shaly and is separated from the overlying Mowry shale by black shale and beds of white bentonite. The Mowry is thick, contains much bentonite, and forms a conspicuous succession of low, rounded pine-covered hills.

POISON SPIDER CREEK (26)

Southwest of Casper the Mesozoic and some of the Paleozoic rocks have been penetrated by the drill in many places and observed at the surface in many other places. The following record of a well on Poison Spider Creek, 20 miles west of Casper, is representative. The names used in this record and the section on

[99] Condit, D. D., U. S. Geol. Survey Prof. Paper 98, p. 264, 1916.

the Poison Spider dome are the same, with minor exceptions, as those of Hares[1] and other geologists familiar with central Wyoming.

Section on Poison Spider Creek, 20 miles west of Casper, Wyo., in the SE. ¼ SE. ¼ sec. 18, T. 33 N., R. 82 W.

[Interpreted by the writer from driller's record. The portion inclosed by the brace at the left is correlated by the writer with the Dakota group of Bellvue, Colo., and the names in quotation marks indicate the corresponding parts of that group]

	Feet
Colorado group: Shale (of Benton age)	641
"Upper sandstone" (Muddy sand; Dakota sandstone of Hares): Sandstone, containing some oil	12
"Upper shale" (Lower Cretaceous shale of Hares and others)	72
"Middle sandstone": Sandstone (?) (not clearly recognized in well record)	9
"Lower shale": Shale (?), colored (not clearly delimited in well record)	51
"Lower sandstone" (Lower Cretaceous conglomerate of Hares and others)	60
Morrison and Sundance formations:	
Shale, sandstone, and limestone, variegated	605
Sandstone, water bearing (probably basal Sundance)	20
Chugwater formation:	
Sandstone and shale, red	1,072
Limestone, red shale, and gypsum (Embar formation of oil men)	298
Tensleep sandstone (of local usage): Sandstone, with strong flow of water	15

Another record of a well about 4 miles farther to the northwest is interpreted as follows:

Section adapted from record of a well near Poison Spider Creek, Wyo., in sec. 34, T. 34 N., R. 83 W. (27)

[Interpreted by the writer. The portion inclosed by the brace at the left is correlated by the writer with the Dakota group of Bellvue, Colo., and the names in quotation marks indicate the corresponding parts of that group]

	Feet
Colorado group: Shale (of Benton age)	750
"Upper sandstone": Sandstone (Muddy sand; Dakota sandstone of Hares and others)	70
"Upper shale": Shale, with a 20-foot sandstone 20 feet from top (probably Lower Cretaceous shale of Hares and others)	165
"Middle sandstone" and "lower shale": "Red rock" and shale	65
"Lower sandstone": Sandstone (Lower Cretaceous conglomerate of Hares and others)	20
Morrison and Sundance formations:	
Shale	150
"Red rock"	63
Shale	71
Sandstone	21
Sandstone, red shale, and limestone	187
Chugwater formation: Red beds	691
Embar formation (of Hares):	
Limestone	13
Shale	18
Limestone, gray and pink	62
Shale	8
Limestone	10
Shale	44
Limestone	15
Shale	75
Limestone	15
Shale	116
Tensleep sandstone: Sandstone, oil bearing; supposed to be Tensleep sandstone but possibly is in overlying Phosphoria formation	51

The presence of oil in sandstone at the bottom of this well suggests the presence here of the oil-bearing Phosphoria formation, which overlies the Tensleep sandstone of more westerly localities but which has not been identified east of the Poison Spider dome.

RATTLESNAKE MOUNTAINS

The Rattlesnake Mountains lie 20 to 40 miles west of the Poison Spider localities. Darton[2] visited these mountains before 1908, and Hares[3] later included them in his studies of the anticlines in central Wyoming. The following generalized section compiled from Darton's description is given for comparison with neighboring sections:

Generalized section of formations exposed in north slope of Rattlesnake Mountains, Wyo.

	Feet
Cloverly sandstone	60–80
[Morrison formation	(?)]
Sundance formation	300
Chugwater red beds	1,200
Embar formation probably	Not given.
Tensleep sandstone	150
Amsden formation	250
Madison limestone	250–400
Deadwood formation	800
Granite.	

The Deadwood formation consists of gray to red shale, buff, brown, and gray sandstone, impure limestone, and glauconite. The Big Horn limestone seems not to be represented here, as the Madison limestone rests on the Deadwood formation. The Madison is a cherty fossiliferous limestone of lower Carboniferous (Mississippian) age. The Amsden formation of the section consists of 60 feet of red shale overlain by poorly exposed slabby sandstone and cherty limestone, above which lies a massive sandstone supposed to be the Tensleep. Above this Tensleep sandstone are beds of buff shale and thin layers of limestone which Darton[4] states "probably represent the Embar formation." Hares collected at a locality 2½ miles west of Oil City, in this group of mountains, the following Permian fossils, which Girty includes in the Phosphoria fauna (lower part of Embar), but their exact stratigraphic position is not given:

Phyllopora? sp.
Leioclema n. sp.
Lingulidiscina convexa?
Derbya n. sp.
Dielasma? sp.
Spiriferina pulchra.
Composita mexicana.
Pinna peracuta.
Leda obesa?

[1] Hares, C. J., U. S. Geol. Survey Bull. 641, pp. 233–279, 1917.

[2] Darton, N. H., Geol. Soc. America Bull., vol. 19, pp. 403–470, 1908.

[3] Hares, C. J., U. S. Geol. Survey Bull. 641, pp. 233–279, 1917.

[4] Darton, N. H., op. cit., p. 418.

Pseudomonotis sublevis?
Pseudomonotis aff. P. hawni.
Myalina deltoidea.
Myalina n. sp. aff. M. perattenuata.
Chaenomya? sp.
Schizodus n. sp. aff. S. compressus.
Pleurophorus sp.
Bellerophon sp.
Euphemus n. sp. aff. E. subpapillosus.

The Chugwater red beds in the Rattlesnake Mountains are said to contain thin limestones near the base and an 8-foot limestone 200 feet from the top. The 8-foot bed is probably the Alcova limestone of this report.

SOUTH END OF BIG HORN MOUNTAINS

The older rocks are covered with Tertiary deposits in many places north of the Rattlesnake Mountains but reappear at the surface in the Big Horn Mountains. Those near the south end of these mountains, in the Powder River and Salt Creek oil fields, have been described by Wegemann.[5] His Dakota (?) sandstone, 56 feet thick, seems to correspond to the lower sandstone of the Dakota group of the section at Bellvue, Colo., but the colored shales that occur in most places above that sandstone are not mentioned as present here but are said to occur 25 miles farther north. A significant feature in the Powder River oil field is a coal bed lying unconformably[6] beneath the conglomeratic Dakota (?) sandstone. This coal may correspond with the coal and carbonaceous shale noted in several places in the Big Horn Basin below the main conglomerate of the beds correlated with the Dakota group of Bellvue, Colo. The lower part of Wegemann's Benton shale corresponds in thickness and stratigraphic position to the upper part of the Dakota group of the Bellvue section and the shale between that group and the overlying Mowry shale.

Wegemann's section includes only the younger formations described in this paper—Sundance to Mowry shale—but its correspondence with other sections indicates that the same stratigraphic relations exist at the south end of the Big Horn Mountains as were found by the writer at neighboring localities.

LOCALITIES IN BIG HORN BASIN, WYOMING AND SOUTHERN MONTANA

Some of the formations considered in this report were described years ago from observations made in the Big Horn and Owl Creek mountains, and several papers giving local details of parts of the Big Horn Basin have recently appeared. In order to compare the results reported in these papers with those obtained in southeastern Wyoming and northeastern Colorado, a short time was spent in 1921 in the study of critical localities in this basin. The rock formations were found comparable to those examined farther to the south and east, and two years later, in 1923, when work on the problems here discussed was resumed, observations were pushed northward into Montana.

The main object of the later work was to trace northward the rocks which the writer had described as the Dakota group.[7] These rocks were followed as closely as discontinuous exposures allowed, and sections were measured at short intervals. The nature of the rocks and their correlations are indicated on Plate 2, and most of the written sections are omitted. In only a few places were observations made on the Cretaceous beds younger than the Muddy sand, or on the rocks older than Jurassic. Such observations are embodied in the following descriptions.

It was the original intention of the writer to make the Montana line the northern limit of his observations. He found, however, that it was desirable to examine sections in Montana described by several geologists in order to compare his results with theirs. For this reason he examined the Pryor Mountain section measured by W. T. Thom, jr., and the Bridger section measured by R. S. Knappen, in southern Montana; also the Button Butte section of Frank Reeves and the Lewistown section of W. R. Calvert, farther to the north. He visited several of the localities in the Great Falls coal field described by C. A. Fisher, the Livingston section, north of Yellowstone Park, and the section of Hewett[8] at Cody, Wyo., in the western part of the Big Horn Basin.

The following subdivisions of the sedimentary rocks described by Darton[9] may serve as the basis of comparison:

Geologic section applicable to Big Horn Mountains

	Thickness (feet)	Age
Colorado formation	1, 050–1, 700	Upper Cretaceous.
Cloverly formation	100–250	Upper and Lower Cretaceous.
Morrison formation	140–300	Cretaceous (?).
Sundance formation	250–450	Jurassic.
Chugwater formation	700–1, 300	Triassic (?) and Permian.
Embar formation	0–250	Carboniferous (Pennsylvanian). (Now known to be Permian.)
Tensleep sandstone	30–300	Carboniferous (Pennsylvanian).
Amsden formation	100-350	Carboniferous (Pennsylvanian and Mississippian).
Madison limestone	250–1, 000	Carboniferous (Mississippian).
Bighorn limestone	0–300	Ordovician.
Deadwood formation	900–1, 150	Middle Cambrian. (Fossils now classified as Upper Cambrian.)
Granite		Archean or Algonkian.

[5] Wegemann, C. H., U. S. Geol. Survey Bull. 452, pp. 37-87, 1911; Bull. 471, pp. 50-75, 1912.
[6] Wegemann, C. H., op. cit. (Bull. 471), p. 62.
[7] Lee, W. T., U. S. Geol. Survey Bull. 751, pp. 1–22, 1923.
[8] Hewett, D. F., U. S. Geol. Survey Bull. 541, pp. 89–113, 1914.
[9] Darton, N. H., U. S. Geol. Survey Prof. Paper 51, 1906; 59th Cong., 1st sess., S. Doc. 219, 1906.

The Deadwood and Morrison formations of the Big Horn Basin call for little comment in this paper, except that the Bighorn limestone, which separates them here, has not been found in southeastern Wyoming. Some of the younger formations were examined near Embar post office, the type locality of the Embar formation; near Thermopolis, where nearly all the formations are plainly exposed; near Tensleep, the type locality of the Tensleep sandstone; and near Greybull, where the Cloverly formation is typically exposed between this town and Cloverly, the type locality of the Cloverly formation. The localities where the other formations were examined in detail are indicated in the following descriptions.

EMBAR POST OFFICE (28)

The name Embar formation was introduced by Darton [10] for certain strata lying on the Tensleep sandstone and overlain by the Chugwater red beds near Embar post office and elsewhere in the Owl Creek Mountains. As the name has been extensively used in other areas to designate strata that are doubtfully equivalent to the type Embar, it seemed desirable to examine the rocks near Embar post office in order to compare them critically with the rocks at a distance to which the name has been applied.

Darton described the Embar on Owl Creek as 200 to 250 feet thick and as consisting of sandstone, shale, chert, and limestone. The formation makes the long dip slope of the north face of the Owl Creek Mountains, which is "due mainly to a bed of limestone about 50 feet thick, which constitutes the greater part of the upper member of the formation throughout its course." However, he shows that 6 miles west of Holland's ranch this limestone is overlain by 50 feet of brownish-gray and yellowish sandstone, on the North Fork of Muddy Creek by 100 feet of yellow beds of sandy shale with thin limestones, and near Anchor post office by 20 feet of soft buff sandstone, and that on Dry Creek these upper beds between the limestones and the Chugwater red beds are 200 feet thick. All these overlying yellowish sandy beds were included in the Embar formation as thus defined.

The writer examined these beds in the canyon of the South Fork of Owl Creek about 2 miles east of Anchor, where the Tensleep sandstone forms nearly vertical walls, and later at several other localities west of Thermopolis. Just above the hard brown cross-bedded Tensleep sandstone 2 miles east of Anchor is soft, friable yellowish conglomeratic sandstone, 10 to 20 feet thick, which is notably unlike the sandstone below. Above this conglomeratic sandstone the beds are soft and shaly and not continuously exposed, but sandstone and cherty limestone crop out in several places. The upper part of these shaly beds contains phosphate, fossiliferous limestone, and thick irregular masses of chert. The following fossils identified by George H. Girty were collected from the cherty layers:

Stenopora aff. S. carbonaria.
Leioclema n. sp.
Leioclema n. sp.
Phyllopora sp.
Derbya multistriata?.
Spiriferina pulchra.
Deltopecten aff. D. coreyanus.
Pseudomonotis? sp.
Schizodus sp.
Plagioglypta canna.

The 50-foot massive limestone that forms the dip slope lies on the cherty beds. It is fossiliferous but so resistant that collecting from it is difficult. On this limestone rest the soft buff sandy shale and thin beds of limestone beneath the red beds that constitute the Chugwater formation of Darton in this area. In the lower part of the Chugwater are pink and yellow shales, thin beds of limestone, and beds of gypsum similar to those found generally near the base of the Chugwater red beds. The thick red strata form conspicuous buffs similar to those shown in Plate 20, *B*. The Alcova limestone was recognized here, and the red gypsiferous Triassic beds above it are of different aspect from those below.

A difference of opinion has arisen as to the extension eastward of Darton's Embar formation. His lower Embar, now called the Phosphoria, extends eastward to the Big Horn Mountains, where it seems to thin out. The upper part of his Embar, ranging from 30 to 200 feet in thickness, as just indicated, is the Dinwoody formation of the Wind River Mountains [11] and lies between the Phosphoria formation and the gypsiferous beds in the lower part of the Chugwater formation. In the writer's opinion these beds do not extend eastward to Thermopolis, although the language used by Darton [12] seems to have led some observers to interpret him as correlating certain beds south of Thermopolis, which overlie the Phosphoria formation, with the upper part of the Embar—that is, with the Dinwoody formation. This subject is more properly discussed under the next heading.

THERMOPOLIS (29)

Observations were made in several places near Thermopolis, and a section from the Alcova limestone to the top of the Morrison formation was measured with tape across the steeply upturned strata east of Big Horn Hot Springs. (See pl. 20, *A*.) One section of the overlying rocks was measured in the same manner about 2 miles northwest of Thermopolis, and another about 3½ miles north of the town, where they are all exposed in and near a railroad cut. The lower part of the platted section (No. 22, pl. 1) is adapted from Collier's generalized section [13] in order to carry corre-

[10] Darton, N. H., 59th Cong., 1st sess., S. Doc. 219, pp. 17–18, 1906.

[11] Condit, D. D., U. S. Geol. Survey Bull. 764, p. 13, 1924.

[12] Darton, N. H., op. cit. (S. Doc. 219), p. 17.

[13] Collier, A. J., U. S. Geol. Survey Bull. 711, p. 65, 1920.

lations across the chart. Collier's measurements for the beds between his Tensleep sandstone and the Alcova limestone are accepted and added to the writer's section; but as Collier's section below the Phosphoria formation (which he calls Park City formation) was not measured by him, these formations are omitted from the following section, which is thus brought into conformity with the others, in which only new measurements are given.

Section measured near Thermopolis, Wyo.

[The portion inclosed by the brace at the left is correlated by the writer with the Dakota group of Bellvue, Colo., and the names in quotation marks indicate the corresponding parts of that group]

	Feet
Mowry shale, light colored.	
Thermopolis shale, dark colored:	
"Upper sandstone" (Muddy sand), shaly, variable	35
"Upper shale": Shale, dark colored, flaky at top, yellow sandy layers ("rusty beds") in lower part	280
Cloverly formation:	
"Middle sandstone": Sandstone in thin layers, separated by variegated shale; possibly included by some geologists in the "rusty beds," all of which are now referred to the Cloverly formation	53
"Lower shale": Shale, sandy, chiefly red but bluish near top	55
"Lower sandstone": Sandstone, massive, coarsely conglomeratic in some places; includes at the bottom beds of dark-colored conglomeratic and black carbonaceous shale which may be older than Dakota group at Bellvue (see sections of pl. 2)	90
Morrison formation, upper part variegated shale, lower part massive light-colored sandstone	275
Sundance formation:	
Limestone and shale	55
Shale, with thin layers of limestone containing *Camptonectes bellistriatus* (Meek and Hayden), *Ostrea strigilecula* White, and other Sundance forms	160
Limestone and cross-bedded ridge-making sandstone	15
Shale, red, with thin layers of light-colored limestone	80
Sandstone, calcareous	3
Limestone with *Neritina?* sp. undet. and gastropods, undetermined high spiral form	6
Basal sandstone of Sundance formation absent. Abrupt changes in lithology and probable unconformity.	
Chugwater formation:	
Shale, sandy, and gypsum	420
Limestone (Alcova, marine, containing *Natica lelia* and *Bakewellia?* n. sp.)	5
Sandstone and shale, red, limy, and gypsiferous in lower part (measured by Collier) [14]	854
Gypsum, impure, yellowish, and buff shale, with beds of impure gray limestone. (Called Dinwoody formation by Collier but believed by writer to be a part of the Chugwater formation and younger than Dinwoody)	60±
Phosphoria formation (Park City formation of Collier):	
Limestone, shale, phosphate rock, etc	302±

No observations were made near Thermopolis on the formation below the Tensleep sandstone, but the writer satisfied himself that the fossiliferous part of the Embar formation near Thermopolis, as described by Darton, is the same as the fossiliferous part of the type Embar at Embar post office. In the canyon of Big Horn River the following fossils of Permian age were collected from the massive limestone of the Embar (now included in the Phosphoria formation) and identified by George H. Girty:

Stenopora n. sp.
Phyllopora sp.
Derbya aff. D. multistriata.
Spiriferina pulchra.
Solenomya? n. sp.
Chaenomya? n. sp.
Deltopecten aff. D. vanvleeti.
Pseudomonotis aff. P. sublevis.
Pseudomonotis aff. P. hawni.
Oxytoma?? n. sp.
Myalina wyomingensis?.
Myalina sp.
Schizodus aff. S. deparcus.
Schizodus aff. S. subcircularis.
Schizodus ferrieri?.
Pleurophorus n. sp.
Plagioglypta canna.
Bellerophon aff. B. crassus.
Euphemus? sp.
Naticopsis? sp.
Omphalotrochus? sp.

This limestone (see pl. 14, *A*) forms the great dip slope of the north face of the Owl Creek Mountains. On it lie the pink and yellow shale, gypsum, and thin beds of limestone which have caused much discussion, as previously described (pp. 8–10). Condit,[15] Blackwelder,[16] and many other geologists have accepted these beds as equivalent to the upper part of Darton's Embar, the part now called Dinwoody formation, possibly in the belief that all the formations represented near Embar post office are present south of Thermopolis. The writer found no beds south of Thermopolis that are lithologically identical with those of the Dinwoody formation. He believes that in that area Dinwoody time is represented by a hiatus and that the beds in question (see pl. 14, *A*) properly belong in the Chugwater formation and are essentially the same as the shale at the base of the Chugwater red beds at more easterly localities. Nevertheless they are included by Collier[17] and many other geologists in the Embar.

The main body of the "Red Beds" is illustrated in Plate 20, *B*. These beds have practically the same appearance and thickness here that they have at most of the other localities described, but with the Alcova limestone, which at Thermopolis and elsewhere contains marine fossils regarded by Girty as probably Triassic, a change in the "Red Beds" begins. The strata above the Alcova, here and in many other places in the southern part of the Big Horn Basin, consist of red shale and sandstone with thick beds of gypsum.

[14] Idem, p. 66.

[15] Condit, D. D., U. S. Geol. Survey Prof. Paper 98, pp. 263–270, 1916.
[16] Blackwelder, Eliot, Washington Acad. Sci. Jour., vol. 8, pp. 417–426, 1918.
[17] Collier, A. J., U. S. Geol. Survey Bull. 711, p. 65, 1920.

These give place abruptly at the top to limestone containing Jurassic fossils of the Sundance fauna. There is no massive orange-colored sandstone to represent the Jelm formation. Unless some of the gypsiferous beds represent the Jelm, this formation is absent at Thermopolis.

The Sundance formation here consists of a lower fossiliferous marine member of shale and limestone, which rests directly on the gypsiferous red beds; a red sandy member; and an upper strongly fossiliferous marine member. The Morrison formation differs locally from the Morrison of neighboring localities. North of Thermopolis a thick, massive, light-colored sandstone occurs above the fossiliferous beds of the Sundance formation. Some observers have regarded this as a member of the Sundance, leaving but little space above it for the Morrison. But east of Thermopolis this sandstone is somewhat thinner and is separated from the underlying Sundance by variegated beds. Typical Morrison shale occurs above this sandstone.

Because some of the rocks of the Morrison and younger formations are variable in character and thickness near Thermopolis, they were examined with care from a point about 2 miles northwest of the town eastward to the Warm Springs dome. Although the formations in the Big Horn Basin above the Morrison have been described by many geologists, there still remains uncertainty as to interformational boundaries and correlation with formations at localities outside the basin. The beds above the Morrison have been called Cloverly, Thermopolis, Mowry, etc. The Cloverly corresponds in position and lithologic character to the lower and middle sandstones and the intervening colored shale of the Dakota group of the section at Bellvue, Colo. The lower part of the Thermopolis shale corresponds to the shale of the Dakota group of Bellvue, and the Muddy sand, which occurs about midway of the Thermopolis, corresponds to the upper sandstone of the Bellvue section. The lower sandstone, however, includes a carbonaceous shale and a dark-brown conglomerate which may be older than any part of the Dakota group at Bellvue. The main, coarsely conglomeratic mass of this sandstone is overlain by deep-red shale, which is the middle Cloverly of many writers, and this in turn is followed by a sandstone (upper part of the Cloverly), which is the Greybull sandstone of some writers and the Dakota sandstone of others. The lower part of the Thermopolis shale includes near the base brown sandy material that constitutes the so-called "rusty beds," which are included by the writer in the group correlated by him with the Dakota group at Bellvue.

The upper sandstone (Muddy sand) is as variable in thickness and character here as it was found to be in many other places examined. It forms a prominent ledge where it was measured north of Thermopolis, but in some other places it is so thin and shaly that no ledge or ridge is formed by it.

The occurrence of carbonaceous shale below the main conglomerate of the lower Cloverly recalls Fisher's description [18] of a coal bed on No Wood Creek "beneath the lowest prominent sandstone" of the Cloverly, where he found fossil plants of the Kootenai flora. The similar occurrence in the Powder River oil field, east of the Big Horn Mountains, has been noted. Fisher also described a section near Frannie, Wyo., in the northern part of the Big Horn Basin, in which 50 feet of leaf-bearing sandstone occurs beneath the lower conglomeratic sandstone of his Cloverly formation. Many similar occurrences noted in northern Wyoming and southern Montana suggest that the isolated remnants of coal-bearing strata may represent the lower or coal-bearing part of the Kootenai formation, and that this part of the Kootenai thins out toward the south and east. This suggestion can be substantiated only by further observation.

At the locality examined 2 miles northwest of Thermopolis, where the rocks dip about 50° in a general southerly direction, the variegated shale of the Morrison formation is overlain by the rocks correlated with the Dakota group of the section at Bellvue, Colo. The lowest bed is a conglomeratic sandstone 42 feet thick. Stratigraphically above it are the colored sandy shale of the middle part of the Cloverly formation and the ripple-marked rusty-brown sandstone and thin layers of dark shale which some have called the "rusty beds." Above these "rusty beds" is a thick mass of dark shale—the Thermopolis shale—in the midst of which is a coarse-grained brown sandstone called the Muddy sand. The Thermopolis shale is overlain by the Mowry shale and still younger rocks.

The same formations were examined west of Big Horn River, about 3½ miles north of Thermopolis. This section was used in an earlier paper [19] and is repeated in Plate 2. Some geologists have regarded the red sediments, or the lower shale of the Dakota and associated formations of this section, and the underlying conglomerate as parts of the Morrison formation, pointing out that there is little variegated shale below the conglomerate, such as is found in the Morrison formation in most places. Because of this opinion the writer reexamined this section in 1923.

The beds below the Morrison formation—that is, the Chugwater red beds and the Sundance formation—are exposed here. The Sundance consists chiefly of brown sandy shale and impure limestone with great numbers of fossils. Lying on these brown fossiliferous beds is a soft, friable massive cross-bedded sandstone 128 feet thick, gray below but yellowish brown in some places near the top. It is similar in character, color, and general aspect to the sandstone found locally in

[18] Fisher, C. A., Econ. Geology, vol. 3, p. 85, 1908.
[19] Lee, W. T., U. S. Geol. Survey Bull. 751, p. 15, 1923.

several places in central Wyoming between typical Sundance and typical Morrison. This rock is interpreted as a channel sandstone at the base of the Morrison formation.

Above this sandstone is a bed of variegated shale 62 feet thick, on which rests the 90-foot conglomeratic sandstone at the base of the group of rocks correlated with the Dakota group of Bellvue, Colo. The contact of this conglomerate with the variegated shale is uneven, suggesting unconformity. There are in this locality no carbonaceous shale or brown conglomerate such as lie between the lower Dakota and the Morrison formation just east of the river and at many other localities still farther to the east and north. The occurrence and correlation of the younger formations is indicated on Plate 2.

East of Big Horn River, about a mile from the locality just described, all the formations represented west of the river were recognized and in addition certain beds between the Morrison formation and the overlying conglomerate that appear to be highly significant because they seem to constitute an erosional remnant of a once continuous formation. This remnant consists of a 25-foot conglomerate, composed chiefly of pebbles of brown and black chert, resting with irregular contact on Morrison shale and overlain by carbonaceous shale 28 feet thick, with irregular masses of brown lignite. It probably represents the coal-bearing rocks of the Kootenai formation, typically developed in central Montana. Because of its significance the measured section is given below.

Section measured east of Big Horn River, northeast of Thermopolis, Wyo.

	Feet
Sandstone, conglomeratic (lower sandstone of group of rocks correlated by the writer with Dakota group of Bellvue, Colo.)	75+
Sandstone, white, shaly, local in occurrence	4±
Shale, carbonaceous, with thin seams of black coal and irregular masses of brown lignite at the top, composed chiefly of reeds pressed together. The lower part of the shale contains pebbles of dark chert half an inch or more in diameter	20
Not exposed	4
Conglomerate, brown, composed chiefly of pebbles of brown and black chert, an inch or less in diameter	25
Shale, variegated (Morrison formation).	

WARM SPRINGS DOME (31)

East of Thermopolis the formations just described are almost continuously exposed and were observed at short intervals as far as the Warm Springs dome, about 10 miles east of Big Horn River. The Chugwater red beds and the Sundance and Morrison formations crop out in this dome in the side of a ridge whose crest is formed by the conglomeratic sandstone. Here, as at the locality northeast of Thermopolis above described, coal and carbonaceous shale were found between the Morrison shale and the overlying conglomerate. An entry driven in on a coal bed for about 100 feet reveals coal nearly 3 feet thick. The following measurements of the beds between the Morrison formation and the conglomerate at the base of the rocks correlated with the Dakota group of Bellvue, Colo., were made at the mouth of this entry:

Section measured about 10 miles east of Thermopolis, Wyo.

	Ft.	in.
Sandstone, conglomeratic	25	
Sandstone, fine grained, white, in thin layers alternating with layers of light-colored clay shale	10	
Clay, light, with fragments of charcoal and impressions of reeds	1	4
Coal, impure		5
Shale, carbonaceous, and thin seams of coal		11
Coal, impure	2	9
Shale, dark		(?)
Shale, variegated (top of Morrison formation).		

The lower part of the carbonaceous beds is not exposed, but variegated shale of the Morrison formation appears a few feet below the prospect entry. The brown conglomerate that occurs below the carbonaceous shale near Thermopolis was not found. It may be absent, or it may occur in the covered interval between the coal bed and the underlying Morrison shale.

REED RANCH (32)

Southeast of the Warm Springs dome the formations described are continuously exposed for about 15 miles. About 12 miles southeast of this dome, near the Reed ranch, in sec. 11, T. 41 S., R. 92 E., the formations above the Chugwater red beds were examined and a section was measured, as shown in Plate 2. In comparing this section with those previously described it may be noted that the Morrison formation is usually thin and that the sandstone found near Thermopolis below the variegated shale and the coal-bearing rocks between this shale and the overlying conglomerate are absent. Possibly these rocks and the upper part of the Morrison formation were eroded away before the overlying conglomerate was formed. The colored beds farther south described as the lower shale of the Dakota group at Bellvue, Colo., and as the middle part of the Cloverly formation of Wyoming localities are conspicuously represented here. Many of the so-called gastroliths or supposed gizzard stones of dinosaurs were found, and many small masses of chalcedony of botryoidal form and rough surface, together with trunks of petrified coniferous trees with conspicuous annular rings. No bones were found here, but in other places dinosaur bones were found in the colored beds, with the polished pebbles and the petrified wood.

NO WOOD (33)

For several miles east of the Reed ranch the older sedimentary rocks are covered with Tertiary beds, but they reappear on the west slope of the Big Horn Mountains, where many exposures were observed in the val-

ley of No Wood Creek. Special attention was given to the No Wood locality because of its importance in interpreting the relations of the Tensleep sandstone to the overlying red beds, and because of the possible presence here of rocks of the Embar formation. The writer verified Darton's description [20] of the rocks near No Wood, as follows:

In the southern part of the Big Horn uplift between the red beds and Tensleep sandstone is a limestone with some associated shaly and cherty beds, which, with gradual increase in thickness, is continued westward in the Bridger Range and Owl Creek Mountains. Apparently it is neither a development of the basal portion of the Red Beds nor of the calcareous sandstone which sometimes occurs at the top of the Tensleep sandstone in the region north. The occurrence of this formation is here reported for the first time, and the name "Embar" is applied, from the name of the post office on Owl Creek, a short distance south of which the formation is extensively developed. On the east side of the Big Horn Mountains the formation first appears near the West Fork of Powder River, and on the west side in the slopes south of Redbank. It finally attains a thickness of about 200 feet on the ridge south of Thermopolis, where it constitutes an extensive dip slope several miles wide, extending along the north slope of the Bridger Range. Prominent exposures appear in the upper canyon of the Big Horn River, which cuts deeply into this slope. Here the formation consists of 50 feet of massive limestone, underlain by calcareous shale filled with nodules and lenses of chert, a member which merges down into sandy shales and impure limestones. At the base there is a thin mass of sandstone breccia lying on the massive Tensleep sandstone. Owing to extensive faulting the formation appears only at one point on the south side of the Bridger Range, but it outcrops prominently at the southwestern termination of the Big Horn uplift, 3 miles east of Deranch. Here the limestone constitutes a line of low hogback ridges, at the base of which appear sandy and cherty shales of buff color lying on the Tensleep sandstone. A thick mass of the limestone appears in the 7,000-foot knob 6 miles northeast of Deranch, which at first sight might be mistaken for Madison limestone. Two miles south of No Wood. at the northern end of a short deep gorge of No Wood Creek, a partial section is exposed in which the Embar limestone is seen to be 10 feet thick, somewhat cherty, and lying on 10 feet of cherty shales, which extend to the top of the Tensleep sandstone. The limestone is overlain by a yellowish sandy bed, which may constitute the base of the Red Beds. At the head of West Kirby Creek the limestone is underlain by gray and reddish sands, in all about 30 feet thick. A short distance north of No Wood post office the following section is presented:

Section on No Wood Creek 1 mile northeast of No Wood, Wyo.

	Feet
Red beds, with 10-foot bed of limestone 100 feet from base (Chugwater).	
Limestone, light yellow; weathers in thin beds; has a layer of flint near the center and occasional flinty concretions	10
Shale, light yellow	25
Limestone, massive, of light-gray color, with chert concretions and layers of black chert between bedding planes	20
Buff shale	0–2
Soft white sandstone (Tensleep).	

A mile north of this locality there is a similar section, but the basal limestone is thinner, not over 10 feet thick, is yellowish in color in its lower portion, and lies directly on the Tensleep sandstone. At the western entrance of the deep canyon, 4 miles north of No Wood, the top limestone underlying the Red Beds is 12 feet thick, massive, cherty, impure, and of yellow color. Next below are 40 feet of shales and soft sandstones, partly pale red but yellowish near the top. They contain a few layers of limestone and lie on the Tensleep sandstone. On the east slope of Big Horn Mountains the formation appears at intervals in the valley of Buffalo Creek, near the Hole in the Wall. The limestone is 20 feet thick, with a 2-foot massive layer at the top and with thinner-bedded slabby limestones of greenish-gray color and green shale below, lying on the Tensleep sandstone. The formation is traceable continuously northward to the Red Fork of Powder River, but gradually thins in that direction. On the anticline in Red Fork Valley, 5 miles northeast of Barnum, the Tensleep sandstone is overlain by a thin mass of limestone breccia, merging up into 6 feet of buff sands and greenish shale, which probably represent the northeasternmost extension of the Embar formation.

No fossils were found here in the rocks supposed to represent the Embar formation, but the writer gained the impression, as Darton did, that these rocks probably represent the attenuated edge of the Embar formation, and that the Chugwater red beds lie unconformably on them, or on the underlying Tensleep sandstone in places where no rocks are found that can be correlated with the Embar.

On a tributary of this creek about 10 miles by road northwest of No Wood post office, probably about 6 miles in a straight line, all the formations between the Chugwater red beds and the Mowry shale were recognized. The Morrison formation is here overlain unconformably by a conglomeratic sandstone at the base of the Cloverly formation (pl. 33, *A*). No coal or carbonaceous shale was found between these two formations. Above the conglomerate are the colored shale of the middle part of the Cloverly formation, containing numerous polished pebbles; a thin sandstone, which probably represents the Greybull or upper sandstone of the Cloverly formation; a thick dark shale, the lower part of the Thermopolis shale; the Muddy sand; a dark shale that represents the upper part of the Thermopolis shale; and the Mowry shale. Near this locality, in sec. 15, T. 43 N., R. 89 W., a well reported by Lupton [21] shows 200 feet of Mowry shale and more than 500 feet of Thermopolis shale with a sandstone, probably the Muddy sand, about 250 feet above the base.

It was near this locality on No Wood Creek that Fisher [22] found fossil plants, which Knowlton identified as Kootenai species, in shale above a bed of coal. As the only coal near this horizon on No Wood Creek is that between the Morrison shale and the conglomeratic sandstone at the base of the Cloverly, it is obvious that the fossil plants came from the beds here described as lying between the Morrison formation and the conglomerate that the writer correlates with the lower sandstone of the Dakota group of Bellvue, Colo.

The several formations here described are continuously exposed between No Wood and Tensleep—a

[20] Darton, N. H., U. S. Geol. Survey Prof. Paper 51, pp. 35–36, 1906.

[21] Hewett, D. F., and Lupton, C. T., U. S. Geol. Survey Bull. 656, p. 121, 1917.

[22] Fisher, C. A., Econ. Geology, vol. 3, p. 85, 1908.

distance of about 30 miles—and were examined at several localities in this interval.

TENSLEEP (34)

The section in Tensleep Canyon was examined in 1921 chiefly for the purpose of comparing the Tensleep sandstone and overlying rocks with rocks at other localities that have been correlated with them. The Tensleep sandstone takes its name from this canyon and has been generally accepted as the youngest formation of Pennsylvanian age in this region. According to Darton[23] this sandstone ranges in thickness from 30 to 300 feet. This variation suggests the possibility of erosion prior to the deposition of the next younger formation and harmonizes with the evidence of erosion found at several localities east of Casper, between rocks correlated with the Tensleep sandstone and overlying beds.

The Tensleep sandstone is typically exposed in Tensleep Canyon. Sandstones in many other places have been correlated with it because of similarity in physical character and stratigraphic position. There is no convincing evidence that the Tensleep of the several localities in southeastern Wyoming described is not its exact equivalent, but the type Tensleep is much more massive and friable and more conspicuously cross-bedded than the supposedly equivalent sandstone farther southeast. The sandstones of the underlying Amsden formation resemble the sandstones in the upper part of the Ingleside formation more closely than do those of the typical Tensleep sandstone.

No rocks resembling those of the Phosphoria formation of the Owl Creek Mountains were found in Tensleep Canyon. The 300 feet of soft pink to yellow limy gypsiferous beds at the base of the Chugwater red beds of Darton in this area rest on the Tensleep sandstone with uneven contact suggestive of unconformity. One limestone 7 feet thick, about 75 feet above the base, is made up of thin crinkled layers like the limestone in southeastern Wyoming which Darton called Minnekahta (?). The pink to yellow limy, gypsiferous beds are, in the writer's opinion, equivalent to the pink and yellow gypsiferous, limy beds above the Embar formation near Embar post office and to those near Thermopolis which Blackwelder[24] and Condit[25] correlated with the Dinwoody or upper part of the Embar of the Wind River Mountains. These are the beds which Condit calls "equivalent of Embar formation of Darton" in his section at Tensleep Canyon[26], and which the writer regards as the basal part of the Chugwater formation, which overlies the Dinwoody. In other words, the writer believes that Embar time is represented here by the unconformity between the Tensleep sandstone and the overlying red beds.

The Alcova limestone was recognized near Tensleep above the main body of Chugwater red beds, where it forms a well-defined shelf because of its superior resistance to erosion. The still younger red beds are exposed in an anticline west of No Wood Creek on the road between the towns of Tensleep and Worland, where the following section of some of the younger beds was measured. On the flanks of this anticline the rocks correlated by the writer with the Dakota group of Bellvue, Colo., are steeply inclined and well exposed. The measurements with tape across the strike were corrected for dip and used in platting the Tensleep section in Plate 2. In the following section the formation names correspond with those of most United States Geological Survey publications.

Section near Tensleep, Wyo.

[The portion inclosed by the brace at the left is correlated by the writer with the Dakota group of Bellvue, Colo., and the names in quotation marks indicate the corresponding parts of that group]

	Feet
Mowry shale.	
Thermopolis shale:	
Shale	100+
"Upper sandstone": Sandstone, shaly, yellow (Muddy sand)	10
"Upper shale": Shale, poorly exposed	100
Cloverly formation:	
"Middle sandstone": Sandstone, ripple marked; forms red boulders on weathering	10±
"Lower shale": Shale, sandy, pink, red, blue, etc	30
"Lower sandstone": Sandstone, conglomeratic, massive, chalky, white	70
Sandstone, conglomeratic, yellow to brown; believed by the writer to represent the coal-bearing part of the Kootenai formation and not to belong to the Cloverly formation	7
Morrison formation: Shale, variegated, and sandstone, with dinosaur bones and fresh-water shells, 50 feet from the top	262
Sundance formation: Fossiliferous shale and limestone above; pink sandstone and shale in lower part; and conglomerate with siliceous pebbles, fossils, and limy cement at base; lies unconformably on gypsiferous red beds	400±

The Morrison here contains dinosaur bones and fresh-water shells identified by John B. Reeside, jr., as *Unio* n. sp. cf. *U. stewardii* White and *Neritina nebrascensis* Meek and Hayden. It is overlain by carbonaceous shale, which represents the coal-bearing horizon of this region; conglomeratic sandstone, which is correlated by the writer with the lower sandstone of the Dakota group of Bellvue, Colo., red material characteristic of the Cloverly formation, which, in the writer's opinion, represents the lower shale of the Dakota group of Bellvue; the Greybull sandstone; the Thermopolis shale, containing the Muddy sand; and the Mowry shale. The relation of these sections to those at neighboring localities is shown in Plate 2.

At an exposure a few miles northwest of this locality, in sec. 14, T. 47 N., R. 89 W., Lupton found fossil

[23] Darton, N. H., U. S. Geol. Survey Prof. Paper 51, p. 34, 1906.
[24] Blackwelder, Eliot, Washington Acad. Sci. Jour., vol. 8, p. 425, 1918.
[25] Condit, D. D., U. S. Geol. Survey Prof. Paper 98, pp. 263–270, 1916.
[26] Idem, pp. 265–266.

plants which Knowlton [27] identified as *Nilsonia nigracollensis* Wieland, a species from the Lakota sandstone of the Black Hills, and *Zamites arcticus* Goeppert, a species abundant in the Kootenai formation. Lupton's description [28] of the plant-bearing beds "just beneath a prominent 50-foot bed of white ledge-making sandstone containing a little conglomerate at its base" indicates that they lie between the Morrison and Cloverly formations.

BONANZA (35)

Through a distance of about 20 miles northwest from Tensleep the rocks correlated by the writer with the Dakota group of Bellvue, Colo., were observed in several places, and also the black carbonaceous shale between typical Morrison beds and the overlying conglomerate believed to represent the Kootenai coal-bearing beds. This representative of the Kootenai formation is 50 feet or more in thickness at some of these localities.

North of the Bonanza dome the several formations here described were all observed but not measured. The variegated shale of the Morrison formation is here overlain by brown conglomerate like that near Thermopolis. This conglomerate ranges from 1 to 10 feet in thickness and seems to represent the filling of channels. Above it is a carbonaceous shale 10 feet thick, with many impressions of reeds. The shale is overlain by the basal conglomeratic sandstone of the group here correlated with the Dakota group of Bellvue, Colo. This sandstone is the lower member of the Cloverly formation of this region and is estimated as more than 100 feet thick. Stratigraphically above it are red sandy shale about 200 feet thick, containing many polished pebbles or "stomach stones," and a sandstone 5 to 15 feet thick, which has the position and lithologic character of the Greybull or upper sandstone member of the Cloverly. Above the Greybull sandstone is a thick dark shale, the Thermopolis, and the light-colored Mowry shale. A sandy zone in the Thermopolis probably represents the Muddy sand.

HYATTVILLE (36)

The next locality at which a section was measured is near Hyattville, about 7 miles northeast of Bonanza. This section, platted in Plate 2 was measured with tape about a mile south of the town. The formations below the coal bed were not measured here but were observed in several places near Hyattville, where the thick Sundance formation rests on gypsiferous red beds of the upper part of the Chugwater formation and are overlain by the Morrison formation, which appears normal in thickness and lithologic character. No brown conglomerate was found here below the carbonaceous shale that holds the position of the Kootenai coal. This shale is overlain by 15 feet of conglomeratic sandstone (pl. 33, *C*) which the writer correlates with the lowest member of the Dakota group at Bellvue, Colo. Above it is the red shaly material of the middle Cloverly, which he correlates with the lower shale of the Dakota group of the Bellvue section. It is overlain by a sandstone called Greybull by some geologists and upper Cloverly by others. Beds representing the upper part of the Dakota group of the Bellvue section were not differentiated here. The Muddy sand has been recognized in this part of the Big Horn Basin, but the writer was not able to identify it to his satisfaction, although the dark-colored Thermopolis shale and the overlying light-colored Mowry shale were recognized.

About 6 miles northwest of Hyattville the Cloverly formation is exposed in a small dome not shown on the map. The dips are low, and most of the exposures are poor. But one place was found where the Morrison and Cloverly formations and the beds between them are well exposed. Here a brown conglomerate consisting chiefly of pebbles of chert and ranging in thickness from 1 to 25 feet rests on variegated shale of the dinosaur-bearing Morrison formation. Above the brown conglomerate is a brown to black shale 5 to 20 feet thick containing carbonized plant remains and thin seams of brown lignite. The variation in thickness seems to be due to erosion, for the overlying conglomeratic sandstone rests on the shale with sharp irregular contact. Between this higher conglomerate and the brown lignite are beds of a yellow powder which Frank L. Hess, of the United States Geological Survey, identified as iron sulphate. The higher conglomeratic sandstone is gray, massive, and cross-bedded and is 50 feet or more in thickness. It is the lower part of the Cloverly of northern Wyoming and is the lower conglomeratic sandstone of the group of rocks which the writer correlates with the Dakota group of Bellvue, Colo.

CLOVERLY (37)

The next localities to the north at which detailed observations were made are near Shell, Wyo., about 20 miles northwest of the locality near Hyattville. All the formations between the Chugwater red beds and the Thermopolis shale were observed in many places between Shell and Cloverly, a distance of about 10 miles.

The Cloverly locality, from which the Cloverly formation takes its name, has special significance in this connection, and care was taken to find a clean exposure where the entire formation could be examined and measured with tape. Such a place was found about 2 miles west of Cloverly post office, where the strata from the Greybull sandstone to the Morrison shale are exposed in the side of a small mesa. Here the measurements used in the Cloverly section in Plate 2 were made.

[27] Knowlton, F. H., Washington Acad. Sci. Jour., vol. 6, pp. 181–182, 1916.
[28] Idem, p. 180.

At several localities near this mesa the formations both below and above the Cloverly were observed. The gypsiferous red beds of the Chugwater formation are overlain by the Sundance formation, which is here richly fossiliferous and has a fossiliferous conglomerate at the base. The Morrison formation was observed but not measured. No brown conglomerate was found here above the Morrison formation, but there is a dark-colored shale which may represent the coal-bearing part of the Kootenai formation. Above the dark shale is a light-colored sandstone 35 feet thick, which contains pebbles in some places and which is believed to represent the lower sandstone of the Dakota group of Bellvue, Colo. Above this sandstone are colored sandy shales and sandstones, with many polished pebbles or so-called gizzard stones. The color is variable, but the reds predominate. These red rocks are overlain by the Greybull sandstone, 25 feet thick. The locality where the section was measured is close to that where Darton measured the Cloverly section, which has been quoted frequently. The writer's section differs from Darton's only in the thickness of the beds.

KANE (38)

The Cloverly and associated formations were not observed by the writer between Cloverly and the junction of Shoshone and Big Horn rivers, a distance of about 22 miles, but they have been mapped by others, who met with the difficulty experienced by the writer in recognizing certain beds. The Thermopolis shale and Muddy sand are not differentiated.

An exposure about 4 miles north of Kane was examined. Here the fossiliferous Sundance formation is more than 320 feet thick and the Morrison formation 290 feet. Bones identified by C. W. Gilmore as probably dinosaurian were found 75 feet above the base of the Morrison. The coarse-grained massive cross-bedded sandstone of the basal Cloverly, about 50 feet thick, rests with uneven base on the variegated shale. It is overlain by red sandy shale of middle Cloverly type and by upper Cloverly or Greybull sandstone, and this is succeeded by dark-colored Thermopolis shale.

West of Kane the formations at the north end of a great anticline plunge steeply beneath the surface. On the eastern slope of the anticline the writer recognized Chugwater red beds, Sundance and Morrison formations, conglomeratic lower Cloverly sandstone, the red shale of the middle Cloverly, rusty beds or Greybull sandstone, a thick dark shale, the Thermopolis, near the top of which is a thin ridge-making sandstone that may represent the Muddy sand, and the Mowry shale. Above the Mowry, in order upward, were noted black shale, sandstone with pebbles of black chert, another dark shale, and another sandstone with brown concretions and pebbles of black chert. In brief, the succession here is the same as that farther south, near the town of Greybull.

Fisher [29] describes a section on Gypsum Creek, about 12 miles northwest of Kane and 15 miles east of Frannie, in which he found 192 feet of colored material below a "rust-colored" sandstone. Still lower in the section are white sandstone and red shale, 25 feet thick, containing beds of gypsum. These gypsiferous rocks probably correspond in position to a bed of gypsum near Greybull described below. Beneath the gypsum is a conglomeratic sandstone 40 feet thick and a 50-foot leaf-bearing sandstone, both of which Fisher includes in his "Cloverly (Kootenai) formation."

GREYBULL (39)

The rocks are well exposed in many places in the uplift north of Greybull. They were examined northeast of this town, near Sheldon's ranch, and near the south end of the uplift, about 25 miles southeast of Kane and 15 miles southwest of Cloverly.

A well reported by Washburne,[30] 1½ miles southeast of Greybull, penetrated the Mowry shale, 430 feet of shaly beds of the upper part of the Thermopolis shale, 40 to 50 feet of white sandy clay supposed to represent the Muddy sand, 150 feet of shale in the lower part of the Thermopolis, and 20 feet of Greybull sandstone, then entered red shale. In another well near the refinery, reported by Lupton,[31] the Greybull sandstone was found, 20 feet thick, and a sandstone 332 feet above it is supposed to represent the Muddy sand.

The locality from which Darton [32] named the Cloverly formation is only 15 miles from Greybull. His description leaves no room for doubt that the same beds are exposed near Greybull. They were observed in the anticline north of Sheldon's ranch and near the south end of Sheep Mountain, a few miles northeast of Greybull. At both localities the rocks are relatively soft and friable and are colored like those of the Morrison formation. Because of this color some geologists have included the lower sandstone and the overlying shale of the Cloverly formation of this area in the Morrison formation. It is therefore not certain that the subdivisions of different observers are the same.

On the eastern slope of Sheep Mountain, about 5 miles northeast of Greybull, the Mowry shale and the dark shale of the upper part of the Thermopolis beneath it were recognized. The Muddy sand forms a low ridge, and the shale of the lower part of the Thermopolis forms a broad valley-like depression. The Cloverly formation is much thicker here than it is at more southerly localities and consists of two sandstones and a thick varicolored shale. The increase in thickness is chiefly in the middle shale. The lower sandstone, about 20 feet thick, is cross-bedded and

[29] Fisher, C. A., Econ. Geology, vol. 3, p. 85, 1908.
[30] Washburne, C. W., U. S. Geol. Survey Bull. 340, p. 352, 1908.
[31] Hewett, D. F., and Lupton, C. T., U. S. Geol. Survey Bull. 656, p. 62, 1914.
[32] Darton, N. H., U. S. Geol. Survey Prof. Paper 51, p. 52. 1906.

conglomeratic. The Morrison formation, consisting of variegated shale, is about 140 feet thick. The Sundance formation comprises fossiliferous limestone and buff shale underlain by red shale and gypsum, below which is a mass of siliceous pebbles and fossil shells, chiefly *Gryphaea calceola* var. *nebrascensis* Meek and Hayden and *Ostrea strigilecula* White, cemented with lime carbonate into a limestone conglomerate. No observations were made on the older rocks at this locality.

A section was measured with tape across the strike about 8 miles northwest of Greybull, and corrections were made for dip. These measurements are used in the Greybull section in Plate 2. The formations are described below in order from above downward.

Two conglomeratic sandstones, separated by 240 feet of shale, hold the same position as the similar sandstones observed near Kane, which are included in the Frontier formation. The Mowry shale here contains great numbers of fish scales and includes some beds of hard limy material several inches thick and one layer which resembles quartzite. The thickness of 450± feet shown for the Thermopolis shale in the Greybull section is not wholly reliable because of variation in dip. This shale is black and contains thick beds of bentonite, but the Muddy sand was not found at this locality. The Greybull sandstone consists of many layers of rusty-brown sandstone and shale, which grade upward into the Thermopolis shale without sharp demarkation. The beds below the rusty sandstone consist of highly colored material characteristic of middle Cloverly, except that near the middle are gypsiferous beds 70 feet thick. These may correspond to the gypsum beds of Fisher's section on Gypsum Creek, just referred to, although at that locality the gypsum seems to be at the base instead of in the middle of the red shale. On the other hand, no conglomeratic sandstone was found northwest of Greybull, where the section was measured, although it is present in other places near Greybull. In its place are irregular masses of nodular chert ranging from 1 to 20 feet in thickness. This chert rests on the variegated shale of the Morrison formation. The marine Jurassic rocks are unusually thick here and contain great numbers of fossils. The upper part contains *Belemnites* and the other fossils usually found in the Sundance formation. Below the *Belemnites* zone is a layer consisting largely of *Gryphaea* shells, underlain in turn by colored shale and limestone which contain fossils identified by Reeside as *Gervillia montanaensis* Meek, *Camptonectes bellistriatus* Meek, *Thracia weedi* Stanton, and *Cyprina? cinnabarensis* Stanton. These species, according to Reeside, indicate the "Ellis rather than the Sundance formation." Two of these fossiliferous limestones were found separated by gypsum. They lie on gypsiferous red beds which probably represent the Upper Triassic part of the Chugwater formation.

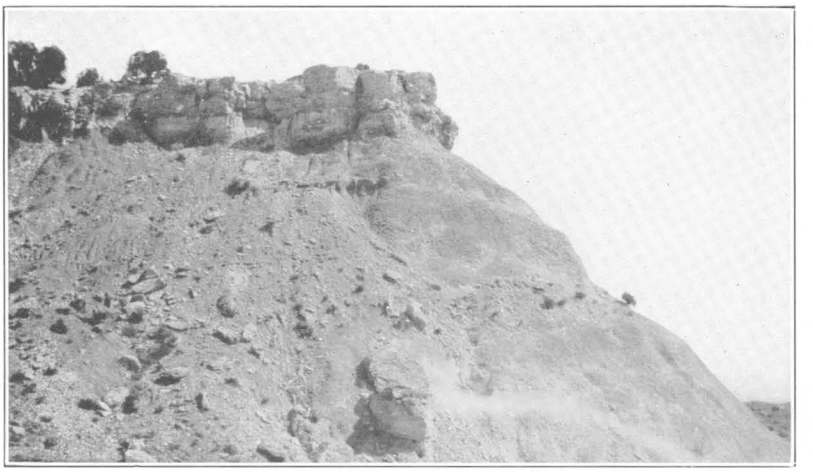
CODY (40)

The rocks correlated by the writer with the Dakota group of Bellvue, Colo., are well exposed in the western part of the Big Horn Basin. Their occurrence on Shoshone River about 50 miles west of Greybull has been described by Hewett.[33] The writer examined this section in 1923 in order to compare it with those examined in the eastern part of the basin. The measurements used in the Cody section in Plate 2 are those given by Hewett. The responsibility for the subdivision into formations and for the correlation shown in this plate is assumed by the writer. The variegated beds above the marine Jurassic have typical Morrison characteristics. The writer would restrict the Morrison to the lower 240 feet, whereas Hewett included in this formation the higher beds of maroon color, thus making his Morrison 582 feet thick. He discusses the reasons for his subdivisions as follows:[34]

> As no fossils other than saurian bones from the middle portion have been found in either this formation or the overlying "Cloverly," the upper limit is taken to be the base of the sandstone overlying the uppermost maroon clay. In describing the character of the overlying "Cloverly" formation in the vicinity of the Big Horn Mountains Darton states that the base is usually marked by a conglomeratic sandstone and considers that this member limits the underlying Morrison. On this criterion several beds of maroon clay are included in the "Cloverly" formation, though beds of similar character occur throughout the Morrison. In the absence of a conglomerate at this horizon on Shoshone River it seems reasonable to consider that the uppermost red clay marks the limit of Morrison sedimentation.
>
> There is striking resemblance between the middle portion of the formation along Shoshone River and that in the region north of Thermopolis described by Darton. Evidence of an unconformity between the Morrison and "Cloverly," noted by Fisher in places, has not been found on Shoshone River.
>
> Besides the variegated color and alternations of several diverse types of material, a characteristic feature of the formation is the presence of gastroliths, or "stomach stones," which are found in intimate association with large saurian bones. In an area 20 feet in diameter on the cut bank where the beds are exposed on the north side of the river no less than 60 pounds of large bone fragments and 15 pounds of gastroliths were found. The gastroliths range from 2 to 15 inches in diameter and are faceted but highly polished. Most of them are chert, showing crinoid stems and Bryozoa, and one large pebble is hornstone, containing a few pyrite crystals, a rock not known to exist in place within 150 miles of this locality.

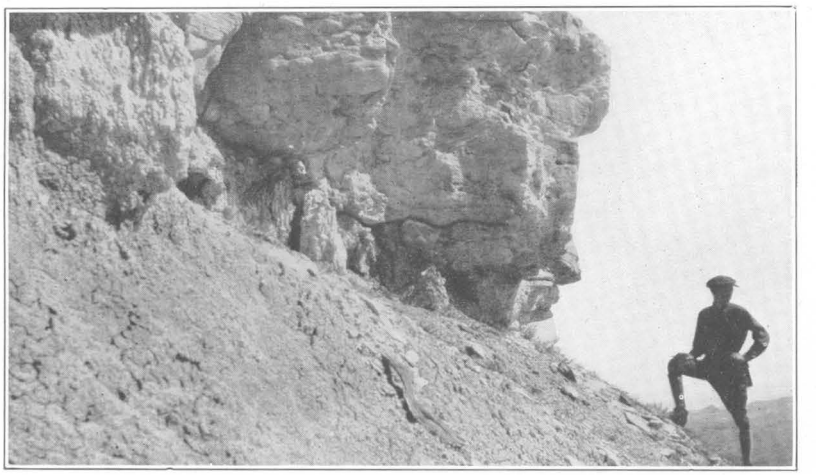
Above the variegated beds in some places are dark-colored shales which may represent the coal-bearing part of the Kootenai formation of more northerly localities. (See pl. 34, *B*.) Lying on the dark-colored shale, or on the variegated shale where no dark shale occurs, is a light-colored sandstone which is massive, cross-bedded, and locally conglomeratic. It has the appearance and physical characteristics of the lower sandstone of the Cloverly formation of more easterly localities and, although included in the Morrison by

[33] Hewett, D. F., U. S. Geol. Survey Bull. 541, pp. 89–113, 1914.
[34] Idem, p. 94.



A. BLUFF NEAR NO WOOD, WYO.

Showing conglomeratic sandstone of lower part of Cloverly formation resting on Morrison shale

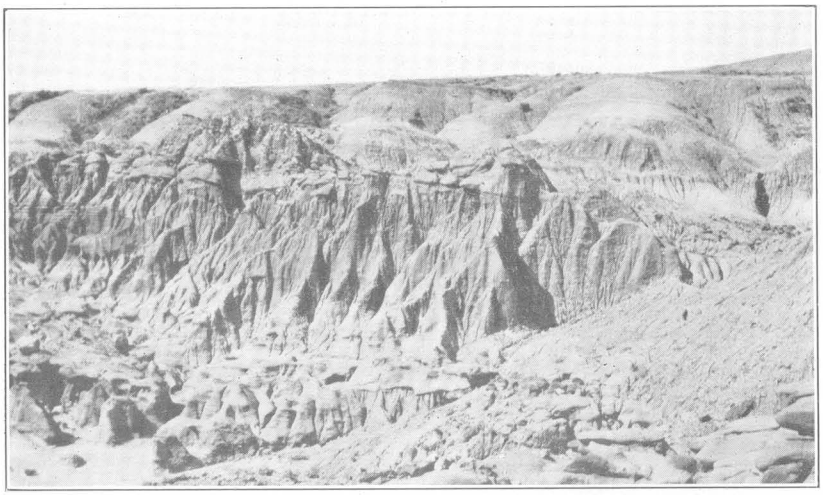


B. NEAR VIEW OF BLUFF NEAR NO WOOD, WYO.

Showing irregular plane of contact between Morrison and Cloverly formations

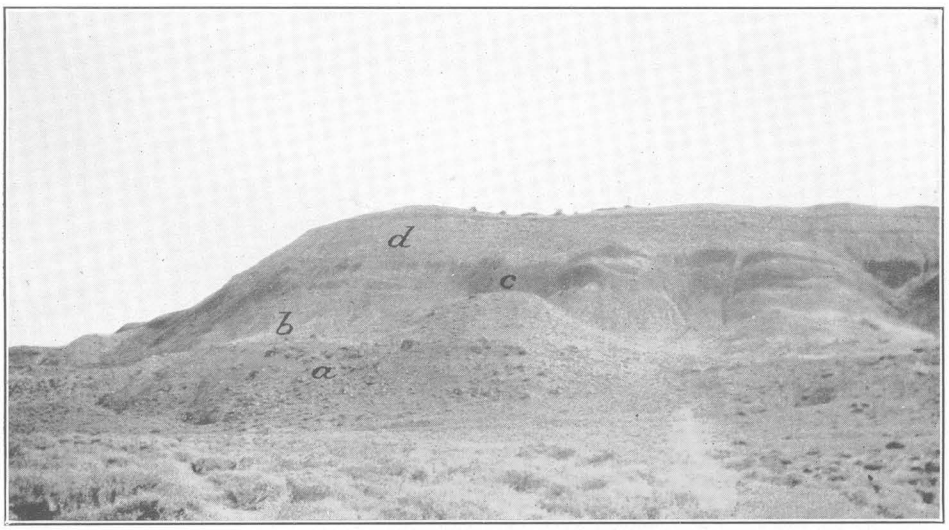
C. CONGLOMERATIC SANDSTONE REGARDED BY THE WRITER AS THE BASE OF THE CLOVERLY FORMATION SOUTH OF HYATTVILLE, WYO.

Resting on the carbonaceous shale which separates it from the Morrison



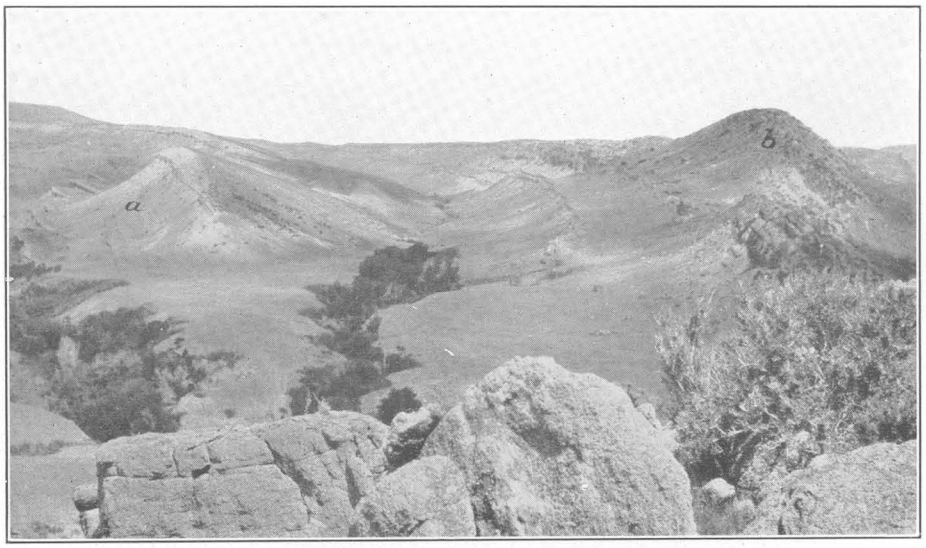
A. RED ROCKS OF THE MIDDLE PART OF THE CLOVERLY FORMATION NEAR SHELDON RANCH, NORTHEAST OF GREYBULL, WYO.

Showing the "badland" forms of erosion characteristic of this formation



B. BLUFF SOUTHWEST OF CODY, WYO.

Showing dark shale (*c*) between Morrison formation (*b*) and Cloverly formation (*d*). *a*, Sundance formation



C. VIEW ON GRAPEVINE CREEK ,MONT., NEAR MOUTH OF BIG HORN CANYON

Showing at the right the ridge formed by the conglomerate (*b*) at the base of the Cloverly formation and in the middle the valley in which the Morrison and Sundance formations crop out. The boulders in the foreground show the conglomeratic nature of the basal member of the Cloverly

Hewett, is believed by the writer to correspond to the lower sandstone of the Dakota group at Bellvue, Colo. Above this conglomeratic sandstone is colored material 263 feet thick, which Hewett included in the Morrison formation but which corresponds in position and lithologic character to the middle part of the Cloverly formation. Where examined by the writer, about 2 miles south of Cody, it is prevailingly maroon and contains dinosaur bones, polished pebbles or "stomach stones," and petrified logs of coniferous wood. In brief, it is the same as the beds a few miles farther north, described by Hewett in the quotation just given, as being a part of his Morrison. Above the colored material are layers of rusty-brown ripple-marked sandstone and thin beds of shale, the whole 110 feet thick in Hewett's section and somewhat thicker 2 miles southwest of Cody. This sandstone corresponds in position and character to the so-called "rusty beds" and the Greybull sandstone. The relations of the still younger sandstone and shaly beds are shown in Plate 2. Bentonite was found at several horizons above the "rusty beds," and 185 feet above the top of these beds Hewett found a sandstone containing plant remains, crocodile teeth, a fossil turtle, and bones of a dinosaur. This sandstone holds the general position of the Muddy sand.

COWLEY (41)

On the east side of Big Horn Basin the formations here described were observed about 5 miles north of Cowley, on the southern flank of the Pryor Mountains. Here the Mowry shale, about 150 feet thick, was recognized; also the overlying shale and conglomeratic sandstone noted near Greybull. Below the Mowry are 500 feet or more of dark shale and bentonite and about 200 feet of rusty-brown sandstone and shale. Below the rusty beds the red material here interpreted as middle Cloverly was observed but not examined closely. The exposures are too poor for exact measurements.

SOUTHWESTERN MONTANA

The formations here described have been observed still farther to the northwest. Fisher [35] found them east of the Absaroka Mountains, and Calvert and other geologists have described their occurrence west of these mountains in Montana. Calvert's section near Gardiner, Mont.,[36] was reexamined for comparison with the other sections here described. At this locality marine Jurassic rocks of the Ellis formation are overlain by variegated shale and brown sandstone of the Morrison formation 185 feet thick. Above the Morrison are beds containing coal near the top, referred by Calvert to the Kootenai formation. These beds correspond in character and position to the coal-bearing part of the Kootenai formation of central Montana. Above the coal is a 30-foot conglomerate included by some geologists in the Dakota but by Calvert in the Kootenai formation. The writer interprets this to be the lowest member of the group of rocks which he correlates in a general way with the Dakota group of Bellvue, Colo. Above the conglomerate is colored material which the writer regards as middle Cloverly, 34 feet of buff to orange-colored limy beds, and 108 feet of shale and quartzite in the position of the Greybull sandstone. This sandstone is the upper part of Calvert's Cloverly and is correlated by the writer in a general way with the upper part of the Cloverly formation and with the middle sandstone of the Dakota group of Bellvue, Colo. It is overlain by dark shale which corresponds to the Thermopolis shale.

About 20 miles north of the locality just described, or 4 miles south of Livingston, the same formations were observed on Yellowstone River. Here the conglomerate above the Morrison forms a prominent hogback. It has been included in the Upper Cretaceous by some geologists and in the Kootenai formation, of Lower Cretaceous age, by Calvert [37] and others. This conglomerate is overlain by colored beds which correspond in character and position to the middle Cloverly and by a quartzite 60 feet thick which, in the writer's opinion, corresponds to the upper Cloverly or Greybull sandstone.

RED DOME, MONT.

No good exposures of the formations here described were found west of the Pryor Mountains for about 30 miles northwest of Cowley. But they are exposed in the Red dome, near Bridger, Mont., where they were observed in detail. This dome has been studied for the Geological Survey by R. S. Knappen, whose conclusions as to correlation correspond with those of the writer. Mr. Knappen has kindly furnished the data for the Bridger section platted in Plate 2.

The Chugwater red beds exposed in the Red dome are overlain by more than 600 feet of marine Jurassic rocks and 254 feet of Morrison beds. A hard conglomerate 10 to 45 feet thick, consisting chiefly of pebbles of black chert, lies unconformably on the Morrison formation. This conglomerate holds the position of the basal Cloverly. It is overlain by about 200 feet of the highly colored shaly beds of the red part of the Kootenai formation of Montana. These colored beds correspond in position and lithologic character to the middle Cloverly of more southerly localities. They are overlain by a sandstone 12 to 45 feet thick, which the writer compares with the Greybull sandstone. The Thermopolis and Mowry shales were recognized, and the still younger dark shale above the Mowry, with two conglomeratic sandstones in the same position as those found near Greybull, Wyo.

[35] Fisher, C. A., U. S. Geol. Survey Prof. Paper 53, p. 27, 1906.

[36] Calvert, W. R., U. S. Geol. Survey Bull. 471, p. 413, 1912.

[37] Calvert, W. R., U. S. Geol. Survey Bull. 390, p. 24, 1909.

PRYOR, MONT.

The rocks here described are exposed in many places in the Pryor Mountains, where they were examined in several places. The Pryor section platted in Plate 2 was measured by W. T. Thom, jr., about 18 miles northeast of the Red dome. Formations in this part of Montana have been correlated with the formations of northern Wyoming by some geologists, and provisionally with those of the Black Hills by others. The conglomerate is regarded by the writer as equivalent to the lower part of the Cloverly formation (pl. 34, *C*). The colored shaly beds above the conglomerate hold the position of the middle part of the Cloverly formation and the red part of the Kootenai formation. The higher sand is compared by the writer with the Greybull sandstone of more southerly localities. It is the sandstone said to lie at the base of the Colorado farther north and may correspond to the Dakota sandstone of the Black Hills. The shale that corresponds in position to the Thermopolis is thicker than it is farther south. It contains three thin sandstones in the lower part and one nearly 300 feet from the bottom, which may be the Muddy sand. The writer is doubtful about the correlation of beds above the Greybull sandstone.

With this section may be compared one measured about 10 miles farther west, in T. 5 S., Rs. 23 and 24 E., by Gail F. Moulton for the United States Geological Survey. He found the conglomeratic base of the Cloverly 50 feet thick, the overlying colored shale 117 feet thick, and the Greybull sandstone about 30 feet thick. Between the Greybull sandstone and the shale supposed to be Mowry is 1,026 feet of shale, with sandstone at three horizons. A sandstone 30 feet thick, 256 feet above the base of this unit, may represent the Muddy sand, but until this sandstone has been traced through northern Wyoming and southern Montana the writer prefers to question its identity.

LOCALITIES IN CENTRAL MONTANA

After having followed the outcrop of the formations of the group which the writer correlates with the Dakota group of Bellvue, Colo., as shown in Plates 1 and 2, northward through Wyoming, he wished to learn how this group of rocks is related to the Kootenai formation of central Montana. Fisher has shown in the paper already cited that the Kootenai beds of the Great Falls coal field in Montana include the Cloverly of the Big Horn Basin in Wyoming. During the summer of 1923 the writer made a somewhat hasty examination from the Pryor Mountains northward through Billings and Roundup to Lewistown, thence westward to Belt, where one of the best exposures in the Great Falls coal field is found. The rocks examined along this route are represented in the columnar sections in Plate 2. The section at Button Butte was kindly furnished by Frank Reeves, of the United States Geological Survey, who agrees with the writer in the correlations as shown.

The Lewistown section is a composite one made up from sections of the several formations described by Calvert.[38] The marine Jurassic beds are here known as the Ellis formation, and the coal-bearing rocks above the Morrison are included in the Kootenai formation. Calvert's Kootenai includes the pebbly sandstone 65 feet thick[39] that holds the position of the basal Cloverly and the overlying colored material 278 feet thick, which is pebbly in some places. The question arises whether the pebbles mentioned indicate the presence of ordinary conglomerate or are the polished pebbles, or "stomach stones," found generally in the colored shale of the Cloverly formation in southern Montana and northern Wyoming, at the localities described in this paper.

The rocks above the Kootenai, described by Calvert as Colorado shale, contain at the base rusty-brown sandy beds 25 to 100 feet thick,[40] which hold the general position of the Greybull sandstone of more southerly localities and the Second Cat Creek sand of central Montana. Between this sandstone and the Mowry shale is a dark shale 766 feet thick which holds the position and has some of the characteristics of the Thermopolis shale. It includes an 8-foot sandstone, which is believed by some to represent the Muddy sand, although it is so high in the section that this correlation seems questionable.

The workable coal of the Lewistown region occurs beneath the pebbly sandstone, here regarded as essentially the same as the basal Cloverly. This sandstone was observed to be conglomeratic westward nearly to Lewistown. Farther west, between Lewistown and Belt, no conglomerate was noted below the red rocks, although a cliff-making sandstone that seems to represent this conglomerate is generally present. Dark shale and beds of coal were observed below this sandstone in many places. The statements of Calvert and Fisher to the effect that the coal occurs in areas of small extent were verified. One place, at which the relations seemed particularly significant, was found a few miles west of Rainsford, where variegated shale characteristic of the Morrison formation is separated from the overlying ledge-making sandstone by about 5 feet of dark shale. This shale was observed almost continuously between Rainsford and Belt in the canyon occupied by the railroad. Near Belt it is 60 feet or more in thickness and contains the thick beds of coal mined in that region.

The overlying sandstone, 100 feet or more in thickness near Belt, lies between the coal-bearing rocks and the red material of the Kootenai formation—that is, it holds the position of the conglomeratic basal sandstone of the Cloverly formation. How-

[38] Calvert, W. R., U. S. Geol. Survey Bull. 390, 1909.
[39] Idem, p. 27.
[40] Idem, p. 30.

ever, pockets or lenses of conglomerate were observed in several places within the red material above the ledge-making sandstone, but in none of these were polished pebbles found like those of the middle Cloverly shale in northern Wyoming. Fisher[41] found impressions of leaves in this sandstone, which were identified as the same as those from the underlying coal-bearing rocks. These plants and the absence, so far as known, of well-defined masses of conglomerate in the cliff-making sandstone throw doubt on its correlation with the lower or conglomeratic sandstone farther east and south. On the other hand, the irregularity in thickness of the coal-bearing rocks and the absence in some places of coal beds suggest erosion, which removed some of the coal-bearing rocks prior to the deposition of the overlying beds. This suggestion of erosion is in harmony with the evidence of erosion that removed the coal-bearing rocks from many of the localities in the Big Horn Basin here described before the deposition of the conglomeratic sandstone of the lower part of the Cloverly formation.

LOCALITIES BETWEEN EASTERN COLORADO AND THE WIND RIVER MOUNTAINS OF WYOMING

In northeastern Colorado the sedimentary formations described in this paper occupy a reentrant extending westward into the mountains, where they are separated from those of the Laramie Basin by a low ridge of the older crystalline rocks, a few miles wide, from which the sedimentary rocks have become eroded. The Owl Canyon and Boxelder sections are comparable with those west of the mountains. A few miles west of Boxelder Canyon the Fountain formation and the overlying limestones and sandstones of the Ingleside formation form conspicuous bluffs, the most prominent of which is known as Steamboat Rock. (See pl. 13, *A*.) Here the Fountain beds lie in a nearly horizontal position and are more evenly stratified than at more southern localities. (See pl. 8, *A*.) Above the Fountain are the fossiliferous limestones and cross-bedded sandstones of the Ingleside formation, which Darton and others include in the Casper formation. These beds crop out in nearly vertical walls (pl. 13, *A*) and are distinctly different from the Fountain, on which they rest unconformably. Comparison of these beds with those of the Owl Creek section indicates that the cross-bedded sandstone increases in thickness westward toward the mountains and the limestone decreases.

LARAMIE BASIN (41)

The several formations west of the Laramie Mountains have been described by Darton and others in the Laramie-Sherman folio and have recently been reexamined by S. H. Knight. For these reasons the writer's examination of this basin was chiefly in the nature of an inspection, in order to compare the Laramie Basin section with the sections of neighboring regions. Knight's results have not yet been published, except in abstract, but he has kindly permitted the use of data essential to the correlation of the formations. The section used in Plate 1 is that of the folio, slightly modified in accordance with recently acquired information given in the following pages.

Madison limestone.—The sedimentary rocks older than Pennsylvanian were found in the southern part of the Laramie Basin. In the northern part, north of Marshall, small remnants of cherty limestone resting on granite yielded fossils of Mississippian age identified by Girty as follows:

Camarotoechia mutata?
Spirifer centronatus.
Spirifer sp. b.
Composita sp.
Cliothyridina aff. C. sublamellosa.
Eumetria vera.
Myalina arkansana?
Ostracoda, several species.

Apparently these rocks are remnants of erosion of the Madison limestone, which were buried by younger deposits and still later uncovered by erosion. The surface about them is thickly strewn with boulders of chert, some of which contain fossils. The boulders are similar to those found in many places in the lower part of the next younger or Fountain formation, and the occurrence indicates that the cherts bearing Mississippian fossils were derived from the older formation, most of which was eroded away before the Fountain was laid down.

Casper formation.—The Casper formation of Darton and others consists chiefly of limestone and red cross-bedded sandstone in varying proportions. It includes equivalents of the Ingleside formation of the Colorado Geological Survey and of this paper and of the underlying arkosic conglomerates, which are now known to be the northward extension of the Fountain formation. It includes also supposed equivalents of beds which in northern Wyoming have long been known as the Tensleep sandstone and the Amsden formation. Rocks of essentially the same age in eastern Wyoming are known as the Hartville formation. In brief, the Casper formation is a group of rocks that includes equivalents of strata known in one place or another under other names. Except for the arkosic beds at the base of the Casper formation, which are now known to correspond to the Fountain formation, and the cherty beds now proved to be Madison, the Casper formation of this basin corresponds to the Ingleside formation of Colorado.

The arkosic and conglomeratic red beds in the lower part of the Casper formation, which correspond to the Fountain formation so prominent farther to the southeast, thin out in the Laramie Basin. Siebenthal[42] found in the southern part of the basin 155 feet

[41] Fisher, C. A., U. S. Geol. Survey Bull. 356, p. 34, 1909.

[42] Darton, N. H., and Siebenthal, C. E., U. S. Geol. Survey Bull. 364, 1909.

of beds in the Casper formation which probably belong to the Fountain, and Knight has measured a thickness of 400 feet of similar beds on Red Mountain. They rest on pre-Cambrian crystalline rocks in many places in the southern part of the basin but toward the northwest either thin out or merge into beds that are not now clearly recognized as belonging to the Fountain formation. Near the base these arkosic beds contain the chert nodules supposed to be derived by erosion from an older formation. From nodules found in these beds about 10 miles northeast of Laramie the following invertebrates of Mississippian age were collected by Knight and identified by Girty:

Schuchertella aff. S. chemungensis.
Productus aff. P. setiger.
Spirifer centronatus.
Euomphalus sp.

From the several published sections of the strata in the Laramie Basin it is evident that the Ingleside part of the Casper formation changes in lithologic character within short distances. The limestones thicken toward the east and the sandstones toward the west. The sandstones are conspicuously cross-bedded and form prominent monuments (see pl. 13, *B*), which have suggested the name "Monument sandstone" for one of them. The cross-bedding becomes more prominent as the sandstones thicken westward, and a corresponding change in color is noticeable. The rocks are deep red near Laramie, lighter red in the vicinity of Medicine Bow, and pink to gray still farther west. Possibly the highest sandstone is the Tensleep, but this can not be asserted with confidence.

Satanka shale.—In the Laramie Basin, as elsewhere in the region here described, the lower part of the "Red Beds" consists of soft red sandy shale, limestone of a peculiar nature, and beds of gypsum. The basal member of these "Red Beds" is the Satanka shale of Darton,[43] a soft sandy pink to purplish-red shale that rests unconformably on the Ingleside part of the Casper formation and has been correlated somewhat doubtfully with the shale called Opeche (?) in some places, which likewise rests unconformably on the older rocks. East of the Laramie Mountains this shale is included in the lower part of the rocks which are there classed as the Chugwater formation.[43] °At most of the localities examined there is an abrupt change from coarse cross-bedded sandstone below to the soft purple shale above and an irregular contact which suggests a time break. In some places the Satanka shale is absent and beds younger than Satanka rest unconformably on the cross-bedded sandstone of the Casper formation. A conspicuous example is described below under the heading "Red Mountain."

Forelle limestone.—Above the Satanka shale is the Forelle limestone of Darton,[43] which contains the few invertebrates that led to its assignment to the Permian series. It is correlated tentatively with the limestone which in many places has been called Minnekahta (?). East of the Laramie Mountains a limestone supposed to be the Forelle has been included in the rocks there classed as Chugwater.[43]

In some places one to three beds of limestone occur above the Forelle, separated by gypsiferous shale. Locally the highest of these beds is a breccia consisting of angular fragments of limestone cemented together with lime carbonate. It has the general appearance of a mass made up of angular fragments of limestone dropped into a bed of limy ooze.

Because of the questions raised in this paper relative to the relation of the Forelle limestone to the Phosphoria formation, special attention is called to the relations that have been noted in the Laramie quadrangle. Darton[44] states that the Forelle limestone contains *Myalina perattenuata.* He found in the Red Mountain-Ring Mountain region, where the underlying shales (Satanka) are absent, a limestone which

lies directly on sandstone. Apparently it is the Forelle limestone that immediately underlies the 67-foot bed of gypsum in Red Mountain and that yielded the numerous fossils discovered by W. C. Knight. * * * The supposed Forelle limestone just below the gypsum bed 2 miles south of Ring Mountain afforded great numbers of *Aviculipecten occidentalis, Myalina perattenuata, Allorisma terminalis,* and *Schizodus compressus.* The limestone believed to represent the Forelle formation in the Red Mountain section consists mostly of casts and impressions of fossils, specimens of which were collected by W. C. Knight in 1902. According to Doctor Girty they comprise *Solenomya* n. sp., *Deltopecten manzanicus, D. coreyanus?, Schizodus meekanus, Pleurophorus* aff. *P. taffi, Dentalium canna, Orthonema?* sp., and *Myalina perattenuata.*

It is further pointed out in the folio that "the Minnekahta limestone which occurs south of Douglas on the east side of the Laramie Mountains and in the Black Hills contains a different fauna from that of the Forelle."

The so-called Minnekahta limestone near Douglas may be the equivalent of the Forelle limestone of some parts of the Laramie Basin, but probably not of the breccia in this basin, which also is called Forelle. Little has been said of the limestones above the so-called Minnekahta, and little significance has heretofore been attached to the brecciated nature of the higher one. If this breccia marks a period of erosion, it may be that its fossils were derived by erosion from older beds.

Red Mountain locality (42).—In company with S. H. Knight, the writer visited the Red Mountain locality, where the elder Knight collected the Permian fossils named in the above quotation. Here only one bed of limestone occurs beneath the thick bed of gypsum. This bed is the one which Darton "believed to represent the Forelle." It is a breccia of similar nature to the limestone breccia found near the base of the "Red Beds" at many of the localities described in this report, and it rests unconformably on Casper rocks believed

[43] Darton, N. H., U. S. Geol. Survey Geol. Atlas, Laramie-Sherman folio (No. 173), 1910.
[44] Idem, p. 7.

to belong to the Ingleside formation. The fossils belong to the Permian fauna and are believed to indicate essentially the same age as the Phosphoria formation. Yet no rocks have been found in the Laramie Basin that could have furnished these fossils, and the breccia is lithologically similar to breccias found in many places stratigraphically above the Forelle limestone. If the fossiliferous breccia proves to be equivalent to the similar limestone breccia of neighboring localities, the unconformity beneath it must represent Forelle, Satanka, and Phosphoria time.

This seeming conflict in evidence induced the writer to visit the Red Mountain locality. He found the fossiliferous breccia resting unconformably on the upper sandstone of the Casper formation—that is, the sandstone which corresponds in stratigraphic position with the Tensleep sandstone. No purple shale that can be called Satanka was found, nor any limestone which the writer would call Forelle. The breccia, although similar in some respects to the breccia of many localities described in this report as lying above the "crinkled limestone," differs from this breccia in its association with gypsum. Some of the fossils are contained in masses of magnesian limestone; others consisting of casts of the same limy material are embedded in massive gypsum. Some of the fossils occur in pockets, and some are irregularly distributed. Many of the scattered fossils were found in solid gypsum. In one bed of gypsum nearly 6 feet thick the limestone fossils occur at several horizons and have the appearance of pebbles in a conglomerate. As the fossils are of Permian species and are composed of material quite different from the rock in which they are embedded, they may be pebbles derived by erosion from some older formation. As the unconformity below the breccia clearly denotes erosion, it seems probable that this breccia is to be correlated with the breccia which lies above the Forelle limestone at neighboring localities and that the fossils in the gypsum are pebbles eroded from Permian rocks which existed in this basin before the breccia was formed.

Chugwater formation.—The main mass of the "Red Beds" (about 1,000 feet thick in the Laramie Basin) to which the name Chugwater formation has been restricted in this basin consists of soft red sandstone and sandy shale with beds of gypsum in the lower part. No fossils have been found in these beds. The Alcova limestone, which is prominent in the Freeze-out Hills, was not found farther to the east and south, but the massive cross-bedded orange-colored sandstone and associated strata that lie stratigraphically above the marine (Alcova) beds are prominently developed. On Jelm Mountain these beds are 250 feet thick, and S. H. Knight[45] has named them the Jelm formation and on the basis of fossil vertebrates has correlated them with the Dolores, a nonmarine formation of Upper Triassic age in southwestern Colorado. Knight pointed out to the writer an exposure on Red Mountain where the orange-colored sandstone lies with well-marked erosional unconformity on the typical Chugwater red beds. In the absence here of the marine Alcova limestone (Triassic?) this unconformity probably represents a long period of erosion. The pebble beds of the Jelm formation are peculiar in that the pebbles consist of impure limestone and may have originated as mud pellets rather than from erosion of consolidated rocks. This pellet conglomerate has been found in several places, notably near Jelm Mountain and Sheep Mountain, where Williston[46] and later Knight found bones denoting Upper Triassic age, and north of Medicine Bow, where the writer found fragments of bone. A similar conglomerate was observed 4 miles southeast of Alcova, but no fossils were found in it. Because of the nonmarine nature of the Jelm formation, its unconformable relations with the underlying Triassic rocks, the absence in some places of the marine Alcova limestone and overlying gypsiferous shale, and the fossil bones of the Jelm formation, which indicate Upper Triassic age, as pointed out by Williston, it is probable that the Jelm represents the widely distributed Upper Triassic Chinle formation of the Southwest, and the formations (now classified as Triassic?) in southwestern Wyoming and southeastern Idaho, including the Ankareh of Schultz[47] and the Higham grit, Deadman limestone, and Wood shale of Mansfield.[48]

Sundance formation.—The strata of known Jurassic age in the Laramie Basin constitute the Sundance formation, but recent observations indicate that although their total thickness is only 20 to 179 feet,[49] the beds constitute a somewhat complicated unit. At the base is a sandstone ranging from a few feet to nearly 100 feet in thickness, buff or dark gray to pink, and conspicuously cross-bedded. (See pl. 24, *B*.) It lies with uneven contact on the Jelm formation, suggesting erosion before Sundance time. Immediately above this basal sandstone are shale in thin beds, hard ripple-marked sandstone, and cherty limestone, which is sparingly fossiliferous in some places. On the Medicine Bow road a few miles south of Marshall these beds yielded *Eumicrotis curta* (Hall), *Ostrea strigilecula* White, *Pleuromya subcompressa* (Meek)?, *Tancredia warrenana* Meek and Hayden?, and *Gryphaea calceola* var. *nebrascensis* Meek and Hayden. The younger beds are locally absent, having been eroded away, according to Knight (as quoted by Schuchert[49]). Above this variable group of strata to the north, but absent to the south, are the strongly fossiliferous beds which have yielded an abundant Jurassic fauna and which constitute the upper member

[45] Knight, S. H., Geol. Soc. America Bull., vol. 27, p. 122, 1916; vol. 28, p. 168, 1917?

[46] Williston, S. W., Jour. Geology, vol. 12, pp. 688–697, 1904.

[47] Schultz, A. R., U. S. Geol. Survey Bull. 702, p. 24, 1920.

[48] Mansfield, G. R., Am. Jour. Sci., 4th ser., vol. 50, pp. 53–64, 1920.

[49] Schuchert, Charles, Geol. Soc. America Bull., vol. 29, p. 256, 1918.

of the Sundance formation of this paper. In the northern part of the Laramie Basin these beds are regular in character and occurrence, but toward the south they thin and are locally absent, because of the post-Sundance erosion. They are not known to extend southward into Colorado.

Morrison formation.—Little new information relative to the Morrison formation was obtained in the Laramie Basin, except additional proof that the Morrison lies unconformably on the Sundance. It overlaps the upper, strongly fossiliferous member of the Sundance with a contact suggestive of erosion and in some places lies directly on the cross-bedded basal sandstone of this formation. Also in the Laramie Basin, as in other areas described in this paper, there are localities where coarse-grained sandstone occurs between typical Sundance beds and typical Morrison shale. This sandstone seems to have originated as the filling of stream channels which had been eroded into the Sundance beds, and for this reason it is regarded as basal Morrison. In brief, the observations near Laramie harmonize with the views of Knight as quoted by Schuchert [49] that there is a distinct break in sedimentation and a time of erosion represented between the Sundance and Morrison formations.

Rocks in Laramie Basin correlated by the writer with the Dakota group of Bellvue, Colo. (43).—The rocks correlated by the writer with the Dakota group of northeastern Colorado are relatively uniform in thickness and character over wide areas, including the Laramie Basin. They comprise the Cloverly formation, as that formation has been defined by Darton and others [50] in southeastern Wyoming, and the lower part of the beds described in the Laramie-Sherman folio as the Benton shale. These rocks have been observed in many places in the Laramie Basin, but as they are relatively uniform in character and thickness only a few sections need be used to illustrate the correlations. (See fig. 5.)

A section of the Cloverly formation was measured years ago near Hutton Lake, in the southeastern part of the basin, and described in the Laramie-Sherman folio.[51] According to this section the Cloverly is here 236½ feet thick, although this formation is said to average about 120 feet.

This formation was later measured by S. H. Knight south of Hutton Lake, where the beds were cut in digging an irrigation ditch. Knight's measurements were used in platting the second section in Figure 5. The thicknesses do not correspond very closely to those formerly published, but as Knight had the advantage of rocks perfectly exposed in the cut, his measurements are used in Figure 5 and in Plate 1. His Cloverly consists of two sandstones separated by colored shale and is about 188 feet thick. Knight assigns only 8 feet to the lower sandstone, whereas Darton assigns 75 feet to it. The writer, in company with Knight, observed here below the 8-foot layer a considerable thickness of conglomeratic sandstone which, because of highly colored interbedded shale, might be included in the underlying Morrison formation but which, because of the conglomerate, is here included in the Cloverly. Doubtless in weathered exposures the conglomeratic beds would seem to belong together, and if in spite of the interbedding of colored material they are included in the lower Cloverly, the thickness would approach the 75 feet formerly assigned to this member. The overlying shale is variegated, and the succeeding sandstone sparingly fossiliferous.

Another section of the rocks correlated with the Dakota group of the Bellvue section was measured by Knight on the west slope of Sheep Mountain, 20 miles northwest of Hutton Lake. Here the basal conglomerate is unusually thick and rests with sharply marked contact on soft Morrison shale. The succeeding shale or middle Cloverly is highly colored—pink, orange, red, and black. The overlying sandstone—the middle sandstone of the rocks correlated with the Dakota group—is brown, flaggy, and ridge making. The succeeding shale or upper shale of the group is dark colored, with ironstone concretions near the base that give it a rusty aspect. Near the top of this shale are thin warped layers of fossiliferous sandy limestone which yielded *Pteria salinensis* White and *Inoceramus comancheanus* Cragin—the same fossils that were found in many other places in this upper shale. Above the brown cross-bedded upper sandstone is black to greenish-gray shale, 48 feet thick, with beds of bentonite, and above this shale in turn lies the Mowry shale.

In the Rock Creek oil field, about 30 miles north of Sheep Mountain, many wells have penetrated these early Cretaceous rocks. Some of these wells are on the side of the Rock Creek oil dome and penetrate diagonally through the beds. However, several are so near the top of the dome that the drillers' records of thicknesses are reasonably trustworthy. In six of these wells the three sandstones correlated with those of the Dakota group at Bellvue, Colo. (here called First Muddy, Second Muddy, and Third Muddy), seem clearly recognizable, and the figures used in the platted section for this field (the fourth section of fig. 5) indicate average thicknesses as shown by the six well logs.

HANNA BASIN AND HILLS TO THE NORTH (44)

The beds of Mississippian age, like those found in the isolated exposures near Marshall, apparently increase in thickness westward, and near Shirley, Wyo., where they are recognized as Madison limestone, they are 75 to 110 feet thick.[52] Still farther south, near

[49] Schuchert, Charles, Geol. Soc. America Bull., vol. 29, p. 256, 1918.

[50] Darton, N. H., and others, U. S. Geol. Survey Geol. Atlas, Laramie-Sherman folio (No. 173), p. 9, 1910.

[51] Idem, p. 9.

[52] Darton, N. H., Geol. Soc. America Bull., vol. 19, p. 413, 1908.

Difficulty, they are 400 feet thick. Conglomeratic sandstone about 30 feet thick[53] below the Madison limestone may represent the Deadwood formation, as suggested by Darton. No beds that can be confidently correlated with the Fountain formation were found near Difficulty. However, the red shaly material, 25 to 100 feet thick, above the Madison limestone, which has been referred to as the Amsden red shale,[54] may represent the Fountain. This red shale is overlain by the cross-bedded massive sandstones and thin layers of limestone which constitute the main body of the Ingleside formation of Colorado and probably the Amsden formation of more northerly localities. The cross-bedded sandstones here are lighter colored than the correlated sandstones in the Laramie Basin. There seems to be a progressive change in color from deep red east of the Laramie Mountains through light red and pink near Difficulty to gray tinged lightly with pink still farther west. The highest sandstone, the one which Darton regarded as possibly equivalent to the Tensleep sandstone, is hard and resistant. Where the sedimentary beds are upturned near Difficulty, it forms the face of a mountain. (See pl. 18, *A*.)

There are no rocks in this part of Wyoming that can be confidently correlated with the Embar formation of the Wind River Mountains and Owl Creek Mountains—that is, with the Phosphoria and Dinwoody formations. However, the beds which Condit[55] regarded as the eastern representatives of the Embar, and which the oil operators of Wyoming call Embar, are typically developed in the lower part of the "Red Beds" near Difficulty. The lower shale is soft and rests unconformably on a sandstone that is correlated with the highest sandstone of the Ingleside and Casper formations. (See pl. 18, *A*.) Above this shale is the hard ridge-making "crinkly" limestone (see pl. 18, *B*), above which are gypsiferous shale and limestone breccia. Stratigraphically above the breccia is the main mass of the "Red Beds," here so soft that a broad strike valley has been formed on them. The marine Alcova limestone, 8 feet thick, forms a sharp ridge with serrate crest. This limestone is conspicuous near Shirley, where it contains *Natica lelia* and *Bakewellia?* n. sp., and it extends throughout the Freezeout Hills, where the same species of marine fossils (regarded as probably Triassic) were collected from it; but it was not found near Medicine Bow nor at any locality east of that town.

The Jelm, Sundance, and Morrison formations were recognized in the hills north of the Hanna Basin, but no new information was obtained concerning them. However, east of Medicine Bow, at the well-known locality on Como Ridge where dinosaur bones were found many years ago, a collection was made of Jurassic ammonites and other species of the Sundance fauna, identified by Reeside as follows:

Pentacrinus asteriscus Meek and Hayden.
Eumicrotis curta (Hall).
Ostrea strigilecula White.
Pleuromya newtoni (Whitfield)?
Thracia? sublaevis Meek.
Tancredia bulbosa Whitfield?
Dosinia jurassica Whitfield.
Astarte packardi White.
Belemnites densus Meek and Hayden.
Cardioceras wyomingense Reeside.
Cardioceras cordiforme (Meek and Hayden).
Cardioceras plattense Reeside.
Cardioceras cf. C. stantoni Reeside.

The rocks correlated with the Dakota group of the section at Bellvue, Colo., are well exposed in the hills north of the Hanna Basin, where the strata are steeply upturned. In a report on the geology of this basin, which is about 30 miles northwest of Rock River, Bowen[56] assigns 231 feet of strata to the Cloverly formation, which he describes as consisting of an upper sandstone, a middle shale, and a lower conglomeratic sandstone. This statement of thickness leads to the suspicion that his upper sandstone may be the Muddy sand of this report rather than the upper part of the Cloverly. It also raises a question as to Bowen's Thermopolis shale, which lies between his Cloverly and the Mowry shale. If the Thermopolis of the Hanna Basin is equivalent to the Thermopolis of the Big Horn Basin, the Muddy sand should be within it rather than below it. The Thermopolis of the Hanna Basin may be the dark shale that has been observed generally in Wyoming above the sandstone that the writer correlates with the upper sandstone of the Dakota group at Bellvue, Colo., and below the Mowry shale.

S. H. Knight measured a section on Difficulty Creek on the north rim of this basin, in sec. 21, T. 24 N., R. 80 W., which is platted in Figure 5. He found here no colored shale above the basal conglomerate. The beds between the conglomerate and the sandstone assigned to the "upper sandstone" in this report are all dark-colored shales "of Benton type." Hence it is not certain that the 10-foot sandstone near the middle is properly correlated with the middle sandstone at Bellvue, Colo. The uppermost sandstone of the group contains fossil plants, and between it and the Mowry shale is black shale which is here interpreted as the upper part of the Thermopolis shale.

RAWLINS (45)

A section of the sedimentary formations was measured in the hills northwest of Rawlins, about 75 miles northwest of Laramie. The oldest sedimentary rocks of the region, those of the Deadwood formation, of late

[53] Darton, N. H., Geol. Soc. America Bull., vol. 19, p. 408, 1908.
[54] Idem, p. 414.
[55] Condit, D. D., U. S. Geol. Survey Prof. Paper 98, pp. 263–270, 1916.
[56] Bowen, C. F., U. S. Geol. Survey Prof. Paper 108, p. 229, 1918.

Cambrian age, are exposed near the town, and the Madison limestone and the overlying beds of Pennsylvanian age farther to the north. The still younger rocks are perfectly exposed near the north end of the Rawlins uplift, about 12 miles northwest of the town. The Deadwood and Madison formations of the following section were measured by the writer with Locke level about 4 miles north of Rawlins, and the lower part of the Amsden formation was measured by pacing across the strike about 8 miles north of the town. The Amsden of this locality includes the red Amsden beds, which may represent the Fountain formation, and the Ingleside equivalent. The dip of the rocks here is low, and the complete thickness of the Amsden was not ascertained. The upper part is covered.

Near the north end of the hills the formations from the highest sandstone (possibly Tensleep) of the Pennsylvanian beds to the Cretaceous were measured with tape across the strike, and corrections were made for direction of dip and surface slope. In the composite section that follows the geologic names except for modifications explained beyond are those used by Bowen[57] and many other geologists familiar with central Wyoming.

Composite section measured by the writer north of Rawlins, Wyo.[58]

[The portion inclosed by the brace at the left is correlated by the writer with the Dakota group of Bellvue, Colo., and the names in quotation marks indicate the corresponding parts of that group]

	Feet
Mowry shale.	
Thermopolis shale of Bowen: Shale, dark-colored (upper part of Thermopolis shale of some geologists)	50±
Cloverly formation of Bowen:	
"Upper sandstone" (Muddy sand): Sandstone, dark brown, shaly; forms small ridge	25
"Upper shale" (lower part of Thermopolis shale of some geologists): Shale, dark colored; upper part contains thin layers of "warped" sandy limestone covered with worm tracks	135
"Middle sandstone": Sandstone, hard, quartzitic, with sparkling grains, variable	15±
"Lower shale": Shale, sandy, soft, poorly exposed, white in some places, pink and blue in others, variable	10+
"Lower sandstone": Sandstone, coarse grained, massive, conglomeratic, quartzitic in some places	61
Erosional unconformity; hard pebble beds rest with uneven contact on soft shale.	
Morrison formation: Shale, variegated, with thin beds of fine-grained sandstone	234
Sundance formation:	
Limestone, dark gray, fossiliferous	5
Sandstone, green, soft	6
Limestone, gray, dense, and very fossiliferous	1
Sandstone, green, soft	5
Shale, green and gray	80
Sandstone, grayish cream, soft and gray shale	35
Sandstone, light yellow or cream colored, very soft	80
Sandstone, gray, soft, and greenish sandy shale	12
Sandstone, gray, hard	4
Sandy shale, green, and several thin beds of fine-grained grayish sandstone	19
Sandstone, reddish, green, and gray, cross-bedded, mud cracked, with some intercalated sandy shale	78
Sandstone, greenish gray, jointed, well bedded	15
Sandy shale, green	3
Sandstone, gray, quartzitic	11
Sandy shale, red	12
Sandstone, light gray, ripple marked	62
Shale, red, and soft fine-grained shaly sandstone	221
Sandstone, grayish white, soft	62
"Red Beds" (Chugwater formation of Dobbin):	
Sandstone, red, and red shale	74
Limestone (Alcova, marine, probably Triassic), dark bluish gray, contains *Natica lelia?* and *Naiadites?* sp	12
Sandstone, red, and red shale	899
Limestone, gray to purple	25
Shale, light red, with thin beds of limestone, chert nodules, and gypsum	108
Limestone (possibly Forelle), light blue, and thin "crinkly" layers	12
Shale (possibly Satanka) sandy, pink to purple	60
Limestone, shale, and some thin layers of sandstone	80
Abrupt change suggesting unconformity.	
Tensleep (?) Sandstone: Sandstone, massive, in thick cross-bedded layers, separated by limy sandstone. The upper 12 feet contains cherty limestone. (Base not seen where section was measured. Unmeasured beds lie between this sandstone and limestone below)	360+
Below is the part of the section examined about 5 miles northwest of Rawlins.	
Amsden formation (in part ?):	
Limestone, containing *Derbya crassa?*, *Chonetes granulifera* var., *Productus cora*, *Productus hermosanus*, *Pustula semipunctata*, *Marginifera splendens*, *Spirifer rockymontanus*, *Squamularia perplexa*, *Composita subtilita*	42+
Covered	70+
Limestone, gray	12
Limestone, pink, cherty; lower 10 feet consisting chiefly of red chert	46
Sandstone and shale, red, with irregular masses of red quartzite at the base which weather out as boulders	40
Unconformity by erosion.	
Madison limestone: Limestone, with layers of quartzitic sandstone. The following invertebrates indicating Mississippian age were found in the highest bed: *Productus parviformis?*, *Rhynchopora* aff. *R. beecheri*, *Spirifer centronatus*, *Brachythyris?* sp., *Cliothyridina crassicardinalis*	100±
Abrupt change from brittle limestone above to quartzite below.	
Deadwood formation: Quartzite, conglomeratic, with ripple-marked layers, worm trails, and markings of unknown origin	395
Granitic rock.	

[57] Bowen, C. F., U. S. Geol. Survey Prof. Paper 108, pp. 227–241, 1918.

[58] The part of the section including the Morrison, Sundance, and "Red Beds" is contributed for this paper by C. E. Dobbin, H. W. Hoots, and C. H. Dane.

The Deadwood and Madison formations are essentially the same as at other localities in central and northern Wyoming described in this paper. The red material above the Madison limestone is the red-bed member of the Amsden formation, known locally as red Amsden, which has been noted generally at this horizon and which corresponds in stratigraphic position to the Fountain formation of Colorado. (See

pl. 1.) This red material is overlain north of Rawlins by fossiliferous limestones of Pennsylvanian age similar to those of the Amsden formation farther north and to those of the Ingleside formation of Colorado. Above the Pennsylvanian limestones is a thick gray cross-bedded sandstone, which seems to represent the upper part of the Ingleside formation and which may be the Tensleep sandstone of more northerly localities.

The overlying beds here consist of shale, gypsum, and limestone, which are correlated by some geologists with the upper or Dinwoody part of the Embar of the Lander section, to the west, but which the writer regards as probably younger than Dinwoody. A soft shale at the base has the general characteristics and position of the Satanka shale of neighboring localities. The overlying limestone seems to be the same as the Forelle limestone and the limestone which in many other places Darton called Minnekahta limestone. Above this are gypsum beds, chert nodules, and other limestones. As a whole these post-Tensleep beds, here 205 feet thick, have all the characteristics of the group of rocks which many of the oil men of Wyoming call Embar.

The next younger beds, nearly 600 feet thick, have the characteristics of the typical Chugwater, but the upper part of the "Red Beds" is of different character. The Alcova limestone is hard and regular in thickness and occurrence. It forms a prominent shelf where the strata lie nearly flat and a sharp ridge where they are upturned. The red rocks above this limestone are thicker and more varied than the upper part of the "Red Beds" in other places examined. Some of them may represent the orange-colored sandstone (Jelm) of more easterly localities, although they are lithologically different from the Jelm formation. No pellet conglomerate like that of the bone beds in the Jelm of the Laramie Basin was found. The upper sandy beds illustrated in Plate 22, *A*, are underlain by shale that may prove to represent the gypsiferous beds, although no thick beds of gypsum were noted. The threefold division of the red beds above the Alcova limestone—that is, the lowest member, consisting chiefly of sandstone; the middle member, consisting chiefly of soft red shale; and the upper member, consisting chiefly of relatively thin beds of hard sandstone, some of which are quartzose—was not noted in other sections. The upper part of this section is worthy of more careful study than it has yet received.

Near Rawlins, as elsewhere, the Sundance formation consists of a massive cross-bedded gray to buff sandstone at the base and softer fossiliferous beds above. It is not well exposed where the section was measured and may be considerably thicker than the section shows.

The Morrison formation maintains its usual character and consists chiefly of soft variegated shale. An excellent opportunity is offered here for observing the relation of the Morrison to the overlying conglomeratic sandstone. The soft shale at the top of the Morrison shows old depressions a few feet deep filled with the pebbles of the overlying formation in a manner that clearly indicates erosion before the sandstone was laid down.

The rocks that are correlated with the Dakota group of Bellvue, Colo., are well exposed except the lower shale. The thick, resistant conglomerate at the base forms the crest of a ridge, and the overlying shale crops out in places on the dip slope. Several isolated exposures of the colored material characteristic of the lower shale at Bellvue were observed, but no accurate measurement of its thickness was obtained. The middle sandstone and upper shale of the Bellvue section were recognized, the shale with thin layers of "warped" limestone near the top and a few fossil shells too fragmentary for recognition. The upper sandstone is shaly but is resistant enough to form a small ridge and is separated from the overlying light-colored Mowry shale by about 50 feet of dark shale, which is probably equivalent in a general way to the upper part of the Thermopolis shale.

WHISKY GAP (46)

For a distance of about 25 miles north of the Rawlins uplift the surface is occupied by beds of Upper Cretaceous age, but the older rocks crop out again in the Ferris and Seminoe mountains. They were observed in Whisky Gap, near the west end of these mountains. Here the pre-Cambrian granite is overlain in succession by the Deadwood formation, the Madison limestone, the red shaly beds of the lower part of the Amsden, and the limestones and cross-bedded sandstones correlated with the Ingleside formation of Colorado. These formations are steeply upturned (see pl. 6, *A*) and in some places are faulted and crushed. South of the sharp ridge formed by these hard rocks is a broad strike valley eroded in the softer red beds. The lower part of these red beds is limy and gypsiferous and constitutes the Embar of the oil men of Wyoming. Fath [59] reports its thickness here as 403 feet. The main mass of the Chugwater formation crops out in the valley, and stratigraphically above it is a small ridge formed by the Alcova limestone, from which the fossils *Natica lelia* and *Naiadites?* sp. were collected about a mile east of the gap. The red beds above this limestone are similar in some respects to those in the Rawlins uplift; but the shaly portions are covered with soil, and only the hard sandstones are well exposed.

The Sundance formation lies unconformably on the Chugwater and consists here, as elsewhere, of four members—a gray cross-bedded sandstone at the base, relatively thin where examined but 60 feet thick where measured by Fath; a buff shale containing thin layers

[59] Fath, A. E., and Moulton, G. F., U. S. Geol. Survey Bull. 656, p. 15, 1924.

of hard limestone carrying small fossils of the species *Eumicrotis curta* (Hall), which belongs in the Sundance fauna; an unfossiliferous member consisting of red shale and sandstone; and an upper shale and limestone member in which *Belemnites*, *Camptonectes*, and other characteristic Sundance fossils are numerous.

The Morrison formation is not well exposed, but the sandstone immediately above it is conglomeratic and resistant and forms a prominent ridge. The next higher sandstone is less prominent, and the intervening (lower) shale crops out in a soil-covered depression. The upper shale of the Bellvue section was recognized by its position beneath the light-colored Mowry, which forms a ridge, but the writer failed to find the upper sandstone of the Bellvue section where he examined these rocks. Probably in this as in many other places the upper sandstone is variable and locally absent. Fath, who examined the Lost Soldier and Ferris oil fields, found the upper sandstone 30 feet thick but makes no mention of the middle sandstone, probably because at the time of his examination little attention was given to the lower beds of this group. Fath follows Bowen [60] in placing the sandstone which the writer regards as the Muddy sand at the top of his Cloverly formation, thus restricting the Thermopolis to the higher shale. Fath's section interpreted by the writer is platted as the Whisky Gap section in Figure 5.

Whisky Gap is about 50 miles southwest of Alcova and on the opposite side of the granite area that represents the western extension of the Laramie Mountains. The sections measured near this gap and at Alcova serve to connect the series of sections measured west of the mountains with those east and north of them and to indicate that the formations on opposite sides of this mountain range are so similar that it seems obvious that they originally extended without interruption across the area occupied by the mountains.

WIND RIVER MOUNTAINS (47)

Between the Lost Soldier oil field and the south end of the Wind River Mountains, to the west, a distance of about 40 miles, the surface is occupied generally by Tertiary rocks, and there is little opportunity of observing the older formations. But in these mountains all the formations examined at more easterly localities and four not found farther east are continuously and conspicuously exposed for many miles. The four additional formations that enter the section in this interval of 40 miles are the Bighorn limestone, of Ordovician age; the Darby formation of Blackwelder,[61] of Upper and Middle Devonian age; the Phosphoria formation, of Permian age; and the Dinwoody formation, of Lower Triassic age. The Phosphoria and Dinwoody formations constitute the Embar of Darton, and the Dinwoody has been correlated by many geologists with the lower part of the "Red Beds" farther east called Embar by the oil men of Wyoming. The writer believes that the Dinwoody is older than these "Red Beds" and that its time is represented by the unconformity that was found farther east between the rocks of Pennsylvanian age and the overlying "Red Beds."

Several geologists have described parts of the Wind River Range. In order to compare the formations described by them directly with those examined at more easterly localities, the canyons of North, Middle, and South forks of Popo Agie River near Lander, Wyo., and the Dinwoody and neighboring canyons were visited by the writer. The older formations exposed in these mountains have been described by Blackwelder,[62] Condit,[63] and others, and the younger ones by Woodruff.[64] The following section is compiled from publications by these writers:

Geologic section in Wind River Mountains, Wyo.

[Mancos to Sundance, inclusive, after Woodruff; Chugwater to granite after Condit and Blackwelder. The correlations are by the writer of this report. The portion inclosed by the brace at the left is correlated by the writer with the Dakota group of Bellvue, Colo., and the names in quotation marks indicate the corresponding parts of that group]

	Ft.	in.
Mancos shale, including Mowry shale member near base.		
Dakota sandstone: "Upper sandstone," gray massive; weathers rusty	20–56	
Lower Cretaceous (?):		
"Upper shale," soft, sandy, tan in lower part, drab in upper part	267–281	
"Middle sandstone," slightly shaly, rusty	12–44	
"Lower shale," soft, sandy, brick-red and gray	88–93	
"Lower sandstone," massive, gray; locally a conglomerate	9–20	
Morrison formation	236–242	
Sundance formation	347–350	
Chugwater formation: Red shale and sandstone, with thin beds of limestone, gypsum, and orange-colored sandstone in upper part. (Includes Alcova limestone member (marine) and Jelm formation (nonmarine Upper Triassic) of this report)	1,200–1,450	
Embar formation of Darton: [65]		
Dinwoody formation (interpreted from Blackwelder and Condit):		
Pale-green to white clay, with local sandy and calcareous beds, overlain conformably by bright-red sandy shale of the Chugwater formation	130	
Gray shaly limestone, weathering brown	28	

[60] Bowen, C. F., U. S. Geol. Survey Prof. Paper 108, pp. 227–235, 1918.

[61] Blackwelder, Eliot, Washington Acad. Sci. Jour., vol. 8, p. 425, 1918.

[62] Blackwelder, Eliot, U. S. Geol. Survey Bull. 470, pp. 452–483, 1911; Washington Acad. Sci. Jour., vol. 8, pp. 417–426, 1918.

[63] Condit, D. D., U. S. Geol. Survey Prof. Paper 98, pp. 263–270, 1916; U. S. Geol. Survey Bull. 764, 1924.

[64] Woodruff, E. G., U. S. Geol. Survey Bull. 452, pp. 1–36, 1911.

[65] See Blackwelder, Eliot, U. S. Geol. Survey Bull. 470, p. 476, 1911; Washington Acad. Sci. Jour., vol. 8, pp. 417–426, 1918; Condit, D. D., U. S. Geol. Survey Prof. Paper 98, pp. 263–270, 1916.

	Ft.	in.
Embar formation of Darton—Continued.		
Dinwoody formation—Continued.		
Alternate calcareous and sandy shale and argillaceous sandstone in thin beds	12	
Dark argillaceous limestone with shale partings containing many obscure pelecypod shells	10	
Grayish sandy shale, shaly limestone, and shaly sandstone in alternate beds	75	
Park City formation (Phosphoria of this report):		
Massive gray crystalline limestone with fossil bryozoans and brachiopods	16	6
Nodular greenish-gray clay, greenish limestone, and chert; *Spiriferina pulchra, Hustedia meekana, Derbya* sp., crinoids, and bryozoans in abundance	6	
Alternating sepia phosphatic and calcareous shale and shaly limestone with thin beds of chert near the top; abundant *Productus nevadensis?* near the base	35	6
Brown shale and soft nodular black and gray phosphate rock interlaminated	1	8
Dark greenish-gray oolitic and argillaceous phosphate rock	1	
Gray to sepia-brown shale, full of oval nodules, somewhat more calcareous; abundant *Spirifer, Productus*, etc	12	5
Hard greenish-brown phosphatic limestone, with glauconite grains	7	
Brown argillaceous limestone and calcareous shale, nodular as above; abundant *Productus nevadensis, P. cora, P. subhorridus, Spiriferina pulchra, Pugnax utah*, bryozoans, etc	6	
Dark-drab or brown fetid limestone in massive beds; upper layers crowded with bryozoans	21	
Green clay shale with thin beds of chert and platy gray limestone	43	
Gray speckled phosphatic sandstone	1	
Earthy-white sandstone	2	
Greenish-gray speckled phosphatic sandstone containing *Lingulidiscina utahensis*, etc	2	2½
Light-gray earthy limestone	1	9½
Dark-green shale	1	3½
Pale-green smoky dolomite, with seams of black chert and pores full of black bitumen	25	
White calcareous sandstone and conglomerate of chert pebbles. (This lies with obscure unconformity upon the Tensleep sandstone)	1	7
Tensleep sandstone (Pennsylvanian): Cross-bedded white to buff sandstone with some limy layers	300–450	
Amsden formation: Sandstone, shale, and dolomitic limestone; red below, lighter colored above	80–275	
Madison limestone (Mississippian), dolomitic, cherty; 800 feet thick at north end of Wind River Mountains, 500 feet near Lander, thinner toward the south	500–800	
Devonian: Darby formation: Dolomite and shale in alternating beds	428	
Ordovician: Bighorn dolomite (including Leigh dolomite member at top); 300 feet thick at north end of Wind River Mountains; 127 feet in Dinwoody Canyon; 163 feet near Lander	100–300	
Cambrian:		
Gallatin limestone (Upper and Middle Cambrian): Limestone, dolomitic, shale, sandstone, and "edgewise conglomerate"	250	
Gros Ventre formation (Middle Cambrian): Shale, limy, and "edgewise conglomerate"	600±	
Flathead sandstone (Middle Cambrian): Sandstone, shale, quartzite, and conglomerate	300	
Pre-Cambrian: Granitic and intrusive rocks.		

As the Wind River Mountain section is used in this report only for general comparison with sections farther east that were examined in detail, little need be said of the older formations. The rocks of the Amsden formation and Tensleep sandstone (see pl. 5) differ but little from those of the equivalent formations of Casper Mountain and localities farther to the east and south, except that the sandstones have lost their red color and the limestones have almost disappeared. The Tensleep sandstone is more obviously separable from the underlying limy beds than the sandstone of more easterly localities that has been called Tensleep. On the other hand, it is probable that the Tensleep of the foregoing section, 300 to 450 feet thick, includes representatives of beds which farther east are included in the Amsden or Casper, according to locality, and which are correlated in a general way with the Ingleside formation of Colorado. The Amsden of this section may be the red-bed member of the Amsden of these more easterly localities. The Amsden of this section seems to correspond to beds containing many Pennsylvanian fossils which Blackwelder [66] found in the Gros Ventre Range.

The Phosphoria formation lies unconformably on the Tensleep sandstone. This unconformity is marked by an abrupt change in lithology from hard cross-bedded sandstone below to relatively soft friable sandstone, conglomeratic in some places, overlain by beds of phosphate and soft shale, from which, on Little Popo Agie River, *Lingulidiscina utahensis, Leda bellistriata?, Pleurophorus* sp., *Plagioglypta canna?*, and *Nautilus* sp. were collected. The Phosphoria beds are more easily eroded than the Tensleep sandstone,

[66] Blackwelder, Eliot, Am. Jour. Sci., 4th ser., vol. 36, p. 174, 1913.

and their outcrop is marked by a distinct recession of the upper part of the canyon walls. (See pl. 5, *B.*)

The upper part of the Phosphoria formation characteristically contains persistent layers of chert, beds of phosphate, and a thick resistant limestone in which there are great numbers of fossils. In some places the limestone is made up largely of the coral-like bryozoans *Stenopora* and *Leioclema*. Above the chert is the fossiliferous cherty limestone containing *Spiriferina pulchra*, which is the most conspicuous member of the Phosphoria formation and which appears to be persistent over a wide region. It is very resistant, is 25 to 50 feet or more in thickness, and forms vertical scarps facing the canyons and long dip slopes on the sides of the mountains. It contains great numbers of brachiopods, but they are difficult to collect because of their tenacious adherence to the matrix in which they are embedded. From this limestone on the Middle Fork of Popo Agie River were collected *Derbya?* aff. *D. multistriata*, *Spiriferina pulchra*, *Myalina* sp., *Mytilus?* n. sp., *Myophoria lineata?*, *Schizodus?* sp., *Pleurophorus* aff. *P. occidentalis*, and *Pleurotomaria?* aff. *P. carbonaria*, and from the uppermost layer of this limestone on the North Fork of the Popo Agie *Derbya* n. sp., *Pustula nevadensis*, *Spiriferina pulchra?*, *Leda obesa?*, *Plagioglypta canna*, and *Euphemus* sp. Blackwelder[67] states that the Dinwoody formation is 250 feet thick at Dinwoody Creek but thins down to less than 50 feet near Lander. His description in the quoted section states that the light-colored beds below the base of the Chugwater red beds and above the "*Spiriferina pulchra* limestone" constitute his Dinwoody formation.

In a recently published report Condit[68] says:

> Typically the Dinwoody formation consists of greenish-gray shale alternating with thin slabs of dense calcareous sandstone or sandy limestone of greenish-gray color that weathers to a deep brown. Near the top the beds are more argillaceous and locally contain more or less gypsum. The thickness is 150 to 200 feet in the northwestern part of the Wind River Mountains (250 feet, according to Blackwelder, on Dinwoody Creek) and gradually diminishes eastward, being 70 feet at Bea Ogwa Canyon and 30 feet at Sheep Mountain south of Lander.

Because of the bearing of the Wind River Mountain sections on the problems of correlation discussed in this paper, the writer spent some time studying them. He recognized the beds described as Embar by Darton and later separated into the Phosphoria formation below and the Dinwoody formation above. He noted as former observers did, that the Dinwoody formation thins eastward and almost disappears south of Lander.

He found the Dinwoody as described by Condit lithologically different from the underlying Phosphoria and from the overlying red beds. There is, however, a doubt in his mind as to the exact line of separation between the Dinwoody and the overlying red beds. In some places the gypsiferous red beds lie with sharp contact on the greenish-gray beds that are clearly included in the Dinwoody formation. In other places the contact is not clear, and possibly some of the beds which the writer would place in the Chugwater have been included by others in the Dinwoody.

At several of the localities examined by the writer he recognized limy and gypsiferous beds, which he would include in the Chugwater formation, above the greenish-gray and brown beds that are characteristic of the Dinwoody formation. These gypsiferous beds he would correlate with the beds farther east which many of the oil men call Embar and which are described in this report as Satanka shale, Opeche (?) shale, Forelle limestone, Minnekahta (?) limestone, etc. In brief, the writer is convinced that these beds, which occur in the lower part of the red beds farther east, are represented in the Wind River Mountains by beds younger than those of the unquestioned Dinwoody. He found no gypsum in the beds which he would interpret as Dinwoody, although Condit[69] states that the Dinwoody "contains more or less gypsum." This statement has led the writer to the suspicion that some of the gypsiferous beds of the overlying Chugwater formation were included in some places in the Dinwoody.

The Dinwoody formation is classed as Triassic[70] on the basis of a "few satisfactory fossils." The writer collected fossils in 1923 in Red Canyon, about 3 miles northwest of Dinwoody Canyon, from the greenish-gray limy beds of the Dinwoody formation that lie between the "*Spiriferina pulchra* limestone" below and the Chugwater red beds above. These fossils were identified by Girty as *Aviculipecten* sp., *Aviculipecten?* sp., *Pleurophorus?* several species, and *Myophoria?* sp. Girty regards these fossils as "probably Triassic." He says further:

> I am not certain as to this assignment, partly because the Triassic faunas are in large measure undescribed and partly because the fauna shown by this collection is small and very ill preserved. On the other hand, this fauna contains not a single brachiopod, nor is any one of the pelecypods recognizable as a type found in our Carboniferous faunas. It is true that I can not definitely identify any of the pelecypods with Triassic species, partly for the reason given above, but in general character the forms are much more like those of the Lower Triassic than those of the Carboniferous.

In the Wind River Mountains, as in many other places throughout Wyoming, the Chugwater formation is made up chiefly of red sandstone and shale. Here, as elsewhere, the lowest beds of the formation are lighter colored than those above and contain limy layers and gypsiferous shales, which some observers may have included in the underlying Dinwoody formation. The writer believes that these varicolored beds in the lower part of the Chugwater formation correspond to the similarly situated beds farther east

[67] Blackwelder, Eliot, Washington Acad. Sci. Jour., vol. 8, p. 425, 1918.
[68] Condit, D. D., U. S. Geol. Survey Bull. 764, p. 13, 1924.
[69] Idem, p. 3.
[70] Idem, p. 13.

which constitute the Embar formation of many of the oil men of Wyoming.

The erosional unconformity separating these basal red beds from the underlying Tensleep sandstone at localities farther east, where no rocks of the Phosphoria formation were found, led to the suspicion that an unconformity should be found beneath the similar beds in the Wind River Mountains. There is a change in lithology at the line that the writer would draw between Dinwoody and Chugwater, which suggests a hiatus. The great variation in thickness (20 to 250 feet) of the Dinwoody formation as described strengthens this suggestion. But no erosional unconformity was found in the Wind River Mountains so clearly marked as that at the more easterly localities here described.

The main body of "Red Beds" in the Wind River Mountains has essentially the same characteristics as those observed near Rawlins and at other places described in this paper. Near the base are thin limestones in which a few poorly preserved fossils have been found. South of Lander, where the Dinwoody is said to be 20 to 50 feet thick, the writer found, in a layer of "crinkly" limestone, several fossils which Girty refers provisionally to *Pleurophorus*, although "none of them are identical with the *Pleurophorus*" of the underlying Phosphoria formation. This "crinkly" limestone is similar to that farther east which is described as occurring in the lower part of the "Red Beds" and which contains fossils supposed to be Permian.

The lower two-thirds of the Chugwater formation consists of soft red rocks, and the upper third of the Alcova limestone of gypsiferous shale and red sandstone, including beds that have yielded the same vertebrates [71] as those found in the Jelm formation of the Laramie Basin, which is now excluded from the Chugwater formation.

The Sundance formation lies on the "Red Beds" in a manner which suggests unconformity. No massive gray sandstone was observed at the base of the Sundance, and buff or tan-colored shale lies directly on the red beds. The red median member and the upper strongly fossiliferous member were both recognized. The Morrison formation here differs from that at more easterly localities in being locally conglomeratic near the base. Where the conglomerate is absent, as on Twin Creek,[72] the lowest member is described as a massive cliff-forming gray sandstone.

The five subdivisions of the Dakota group at Bellvue, Colo., were recognized near Lander. The upper sandstone is the plant-bearing Dakota sandstone of Woodruff,[73] and the lower four divisions constitute his Lower Cretaceous (?) rocks. He describes a massive gray coarse-grained cross-bedded conglomeratic sandstone, 9 feet thick on Twin Creek south of Lander and 20 feet thick on Sage Creek northwest of Lander, as resting on Morrison shale. This sandstone obviously corresponds to the lower sandstone of the Dakota group at Bellvue. Above it are soft sandy shales of varied color, 88 feet thick on Twin Creek and 93 feet thick on Sage Creek, which correspond to the lower shale of the Dakota group at Bellvue and to the middle Cloverly of other geologists. The upper sandstone of the Cloverly (equivalent to the middle sandstone of the Dakota group at Bellvue) is 12 to 44 feet thick and contains fresh-water shells and fossil plants. Above this sandstone is shale 267 to 281 feet thick, containing layers of rusty sandstone, black carbonaceous shale, and near the top limy layers with undetermined marine shells.[73] The upper sandstone, 20 to 60 feet thick according to Woodruff, has yielded fossil plants of the Dakota flora.[74] The writer has little hesitancy in correlating this sandstone in a general way with the upper sandstones of the Dakota group at Bellvue, Colo., and with the Muddy sand of more easterly localities in Wyoming. It has the same stratigraphic position—that is, it lies between dark rusty fossiliferous shale below and dark shale (upper part of Thermopolis) overlain by light Mowry shale above—and, like the Muddy sand in many other places, this upper sandstone is locally absent near Lander. At two localities southeast of Lander where the Mowry shale and 300 feet of dark shale below the Mowry are plainly exposed, no sandstone was found that could represent the upper or Muddy sand. Apparently here, as in several other places noted, this sandstone is discontinuous.

[71] Williston, S. W., Jour. Geology, vol. 12, pp. 688–697, 1904.

[72] Woodruff, E. G., U. S. Geol. Survey Bull. 452, p. 17, 1911.

[73] Idem, p. 19.

[74] Idem, p. 20.

INDEX