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OF THE

UNITED STATES GEOLOGICAL SURVEY

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PART IV—HYDROGRAPHY

PRELIMINARY DESCRIPTION

OF THE

GEOLOGY AND WATER RESOURCES OF THE SOUTHERN HALF OF THE BLACK HILLS AND ADJOINING REGIONS IN SOUTH DAKOTA AND WYOMING

BY

NELSON HORATIO DARTON

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PRELIMINARY DESCRIPTION OF THE GEOLOGY AND WATER RESOURCES OF THE SOUTHERN HALF OF THE BLACK HILLS AND ADJOINING REGIONS IN SOUTH DAKOTA AND WYOMING.

By NELSON HORATIO DARTON.

INTRODUCTORY.

This report is the result of studies made in the field mainly in the seasons of 1898 and 1899. It relates to an area of about 5,500 square miles situated in the southwestern corner of South Dakota and the adjoining portion of Wyoming. Its location and general surroundings are shown in Pl. LVIII. It covers the southern half of the Black Hills uplift and portions of the adjacent plains. The report describes the geology of the sedimentary rocks, their structure, history, and mineral resources, including underground water, coal, gypsum, grindstone, etc. It also contains information respecting surface waters available for irrigation and stock raising, timber, climate, and the history of the topographic development of the region. The crystalline rocks of the central portion of the Black Hills area are shown on some of the maps accompanying this report, but without differentation, as it was not practicable to study their geology; neither will their mineral resources be considered here.

I was assisted in the field work by Mr. C. A. Fisher in the season of 1898 and by Mr. George B. Richardson in the season of 1899, and these gentlemen obtained a portion of the data on which this report is based.

All those who study Black Hills geology must feel impressed by the remarkably clear general conception of relations afforded by the survey made by Mr. Henry Newton nearly a quarter of a century ago.[1] In one short season, with many unfavorable conditions for travel, he determined most of the broader features and recorded many of the essential details. His partly posthumous report, edited by Mr. G. K. Gilbert, will always remain a standard work on Black Hills geology. Later studies will add greatly to our knowledge of the details of the stratigraphy and structure, and of the distribution of rocks and minerals, will throw much light on age of beds, and afford means for a more complete

[1] Geology and Resources of the Black Hills of South Dakota, by Henry Newton and W. P. Jenney: U. S. Geog. and Geol. Survey of Rocky Mountain Region, J. W. Powell, Director.

elucidation of the geologic history, particularly of the physiographic development of the Black Hills.

TOPOGRAPHY.

Extending from the Mississippi River to the Rocky Mountains is the province known as the Great Plains. It presents broad areas of treeless, plane surfaces sloping upward to the west and traversed by wide, shallow valleys of rivers flowing to the east and south. The Black Hills rise out of these plains as a small group of forest-clad mountains several thousand feet high. With their vigorous vegetation, greater rainfall, and running water these hills are an oasis in the sur-

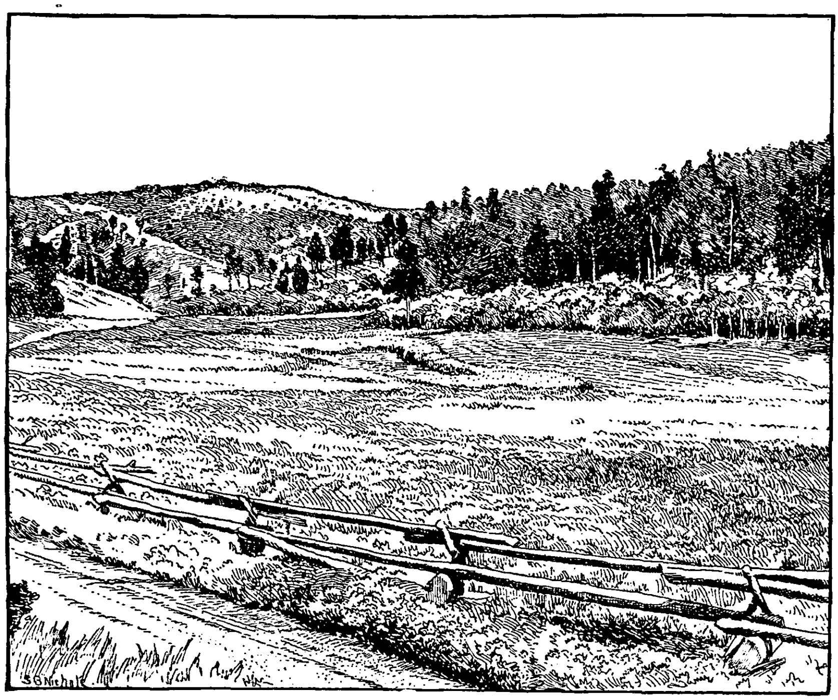


FIG. 272.—An open park north of Custer, South Dakota.

rounding semiarid plains. The length of the more elevated area is about 100 miles, and its greatest width is 50 miles. The hills rise abruptly from the plains, although the flanking ridges are of moderate elevation. The configuration of the greater part of the region is represented in Pl. LIX, and that of the southern half is shown on a larger scale in Pl. LXV. The salient features are the hogback ridges of the outer rim and the Red Valley beyond, both of which extend completely around the uplift; the limestone plateau, with its infacing escarpment; and the central area of high ridges culminating in the rough mountain crags of Harney Peak at an altitude of 7,216

PRELIMINARY GEOLOGIC MAP OF THE BLACK HILLS

WITH ADJOINING PORTIONS OF SOUTH DAKOTA, WYOMING AND NEBRASKA

BY
N. H. DARTON
1899

DATA FOR 450 SQUARE MILES ABOUT DEADWOOD BY T. A. JAGGAR JR.
DATA ABOUT RAPID BY C. C. O'HARRA.

BASE COMPILED FROM MAPS OF U.S. GEOLOGICAL SURVEY
U.S. LAND OFFICE, AND ORIGINAL SURVEYS

SCALE
5 0 5 10 15 20 MILES
CONTOUR INTERVAL 250 FEET

EXPLANATION

TERTIARY
- Arikaree formation
- White River group (Chadron, Brule and Gering formations)

CRETACEOUS
- Laramie and Fox Hills formations
- Pierre shale
- Niobrara formation
- Benton group
- Dakota sandstone (and Fuson formation)
- Lakota sandstone (and Minnewasta limestone)

JURATRIAS
- JURASSIC: Sundance formation Beulah shale and Unkpapa Sandstone
- TRIASSIC: Spearfish formation

CARBONIFEROUS
- PERMIAN: Minnekahta limestone (and Opeche formation)
- Minnelusa formation
- Pahasapa limestone (and Englewood limestone)

CAMBRIAN
- Deadwood formation

ALGONKIAN
- Schists, Granite etc.

EOCENE
- Igneous

SEIBERT COMPANY, LITHO. N.Y.

feet. All of the southern portions of the region are drained by the South Fork of Cheyenne River.

The central area.—The central area of the Black Hills comprises an elevated basin with scattered rocky ridges and groups of mountains interspersed with wide valleys or parks. These wide valleys are in the divides at the heads of canyons of greater or less size, which become deeper and steeper sided as the waters which they carry increase in volume. The region is one of crystalline schists and granite. Some typical and picturesque features of the area are shown in Pls. LX–LXII. The group of mountains culminating in Harney Peak is completely isolated by valleys, of which the highest is in the divide in a low saddle north of Custer, at an altitude of 5,800 feet. About Custer

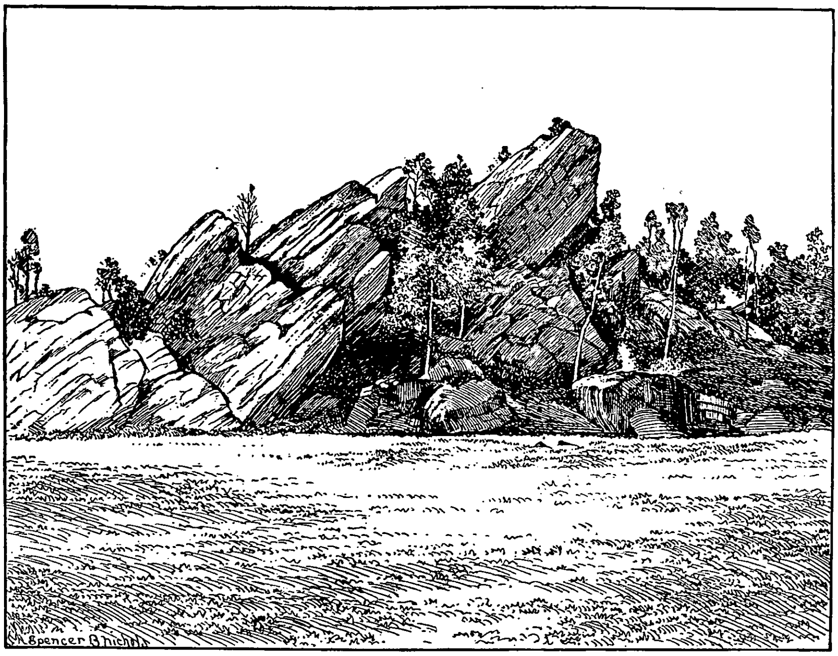


FIG. 273.—Ridge of schist rising out of a park near Custer, South Dakota.

there is a wide area of rolling park land, out of which rise steep, rocky ridges of various sizes and heights. Characteristic views of these features are given in figs. 272 and 273. Many streams head in the central basin and flow out of the hills to the northeast, east, and south. French Creek is here the dominant stream of the system.

The limestone plateau.—The limestone plateau, with its infacing escarpment, occupies a wide area of the central hills, rising high above the greater part of the nucleal area of crystalline rocks. To the west it has a very broad, flat surface, level near its inner margin, but toward its outer side sloping gently downward. On the western side of the crystalline-rock area its escarpment is a line of high cliffs presented to the east and trending nearly due north and south for many miles. It is occasionally notched more or less deeply by upper branches of streams which head on the plateau and cross the central basin. A typical view of this escarpment is shown in fig. 274. The cliffs and steep slopes which they surmount often rise 800 feet above the central basin, and the summits of the plateau attain an altitude of over 7,000 feet in Pennington County, several points being almost as high as the summit of Harney Peak. This limestone plateau is the main divide for the drainage of the Black Hills. On its western slope are head branches of affluents of Beaver Creek to the southwest and of the Belle Fourche to the northwest. Toward their heads the valleys on the plateau are

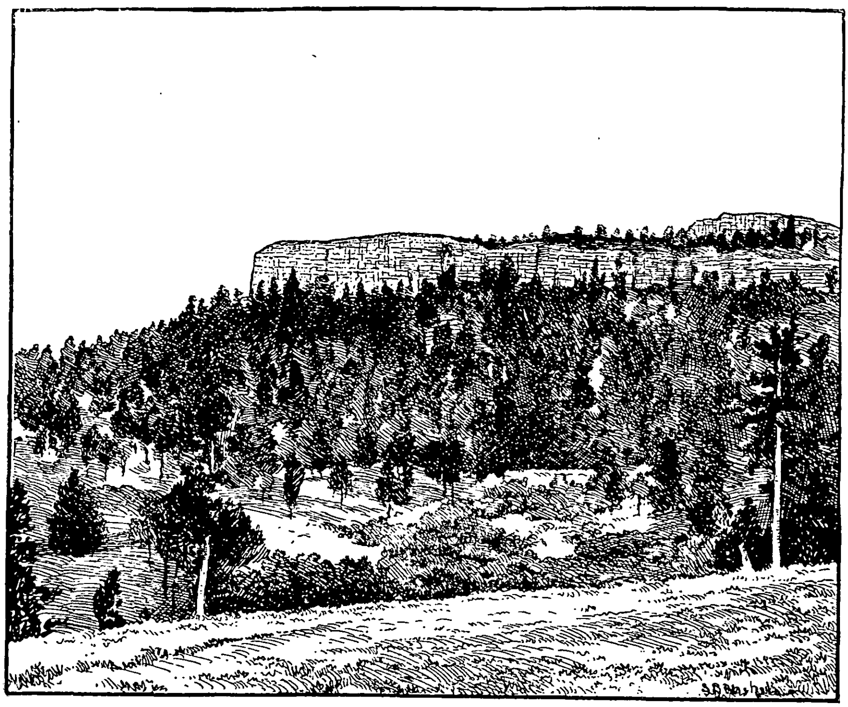
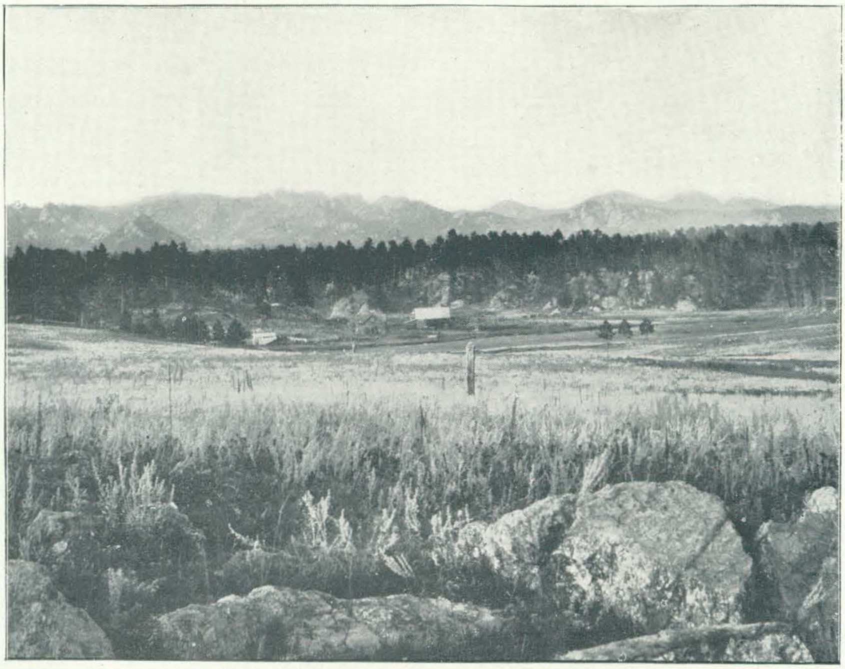


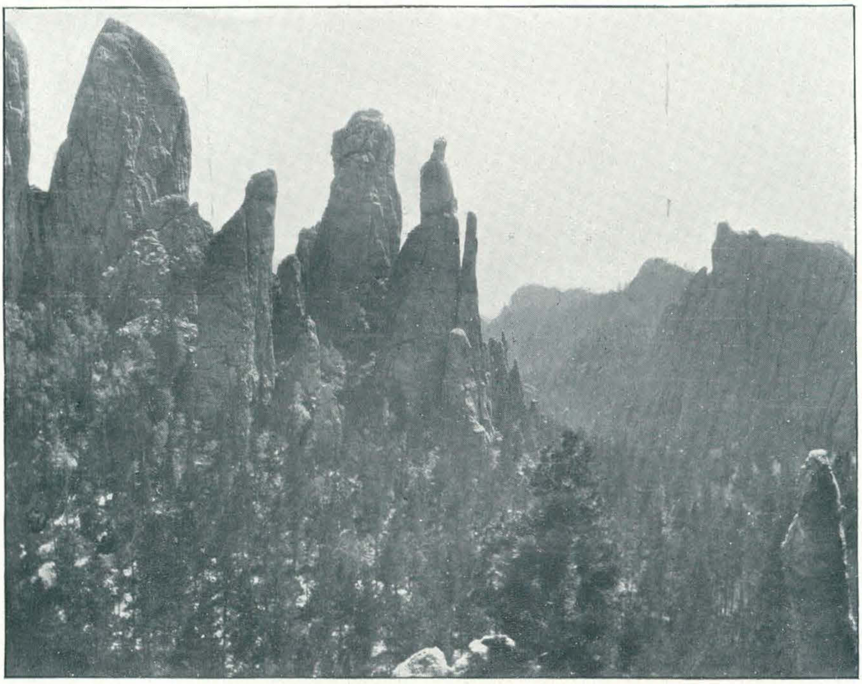
FIG. 274.—Limestone cliffs at the eastern edge of the high plateau northwest of Custer, South Dakota.

open parks, but farther down they merge into deep canyons having precipitous walls of limestone. Hell Canyon is the most notable of these, its walls being 400 feet high in places. To the south the limestone plateau and its escarpment swing around to the east side of the hills, where, owing to the steeper dip of the limestone, the plateau narrows into a sloping ridge with a west-facing escarpment which is broken by numerous cross valleys, beginning with the head branches of Red Canyon Creek. All of the larger streams in the southeastern and eastern portion of this region rise in the high limestone plateau west of the central basin, cross the region of crystalline rocks, and flow through canyons in the flanking regions of the east side of the Black Hills to reach Cheyenne River in the Plains beyond. The principal members

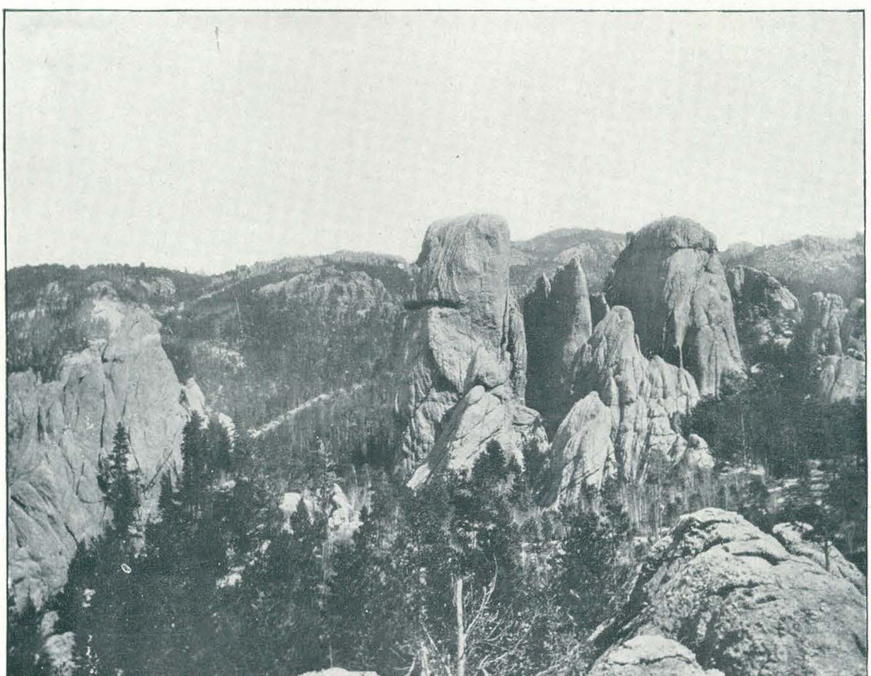


A. HARNEY PEAK RANGE FROM THE SOUTH; TYPICAL "PARK" IN MIDDLE GROUND.

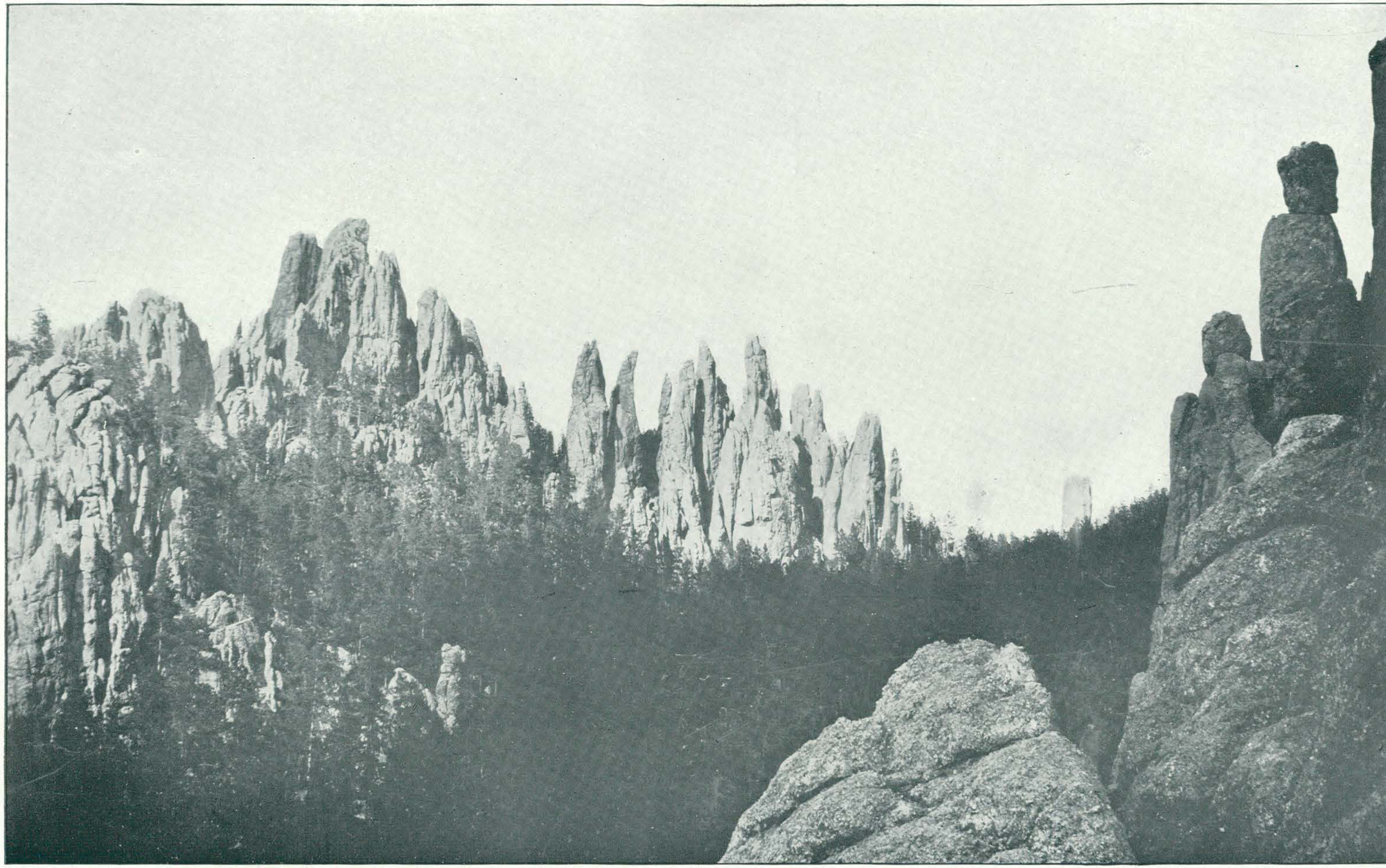
B. SYLVAN LAKE FROM THE SOUTH, SHOWING GRANITE TOPOGRAPHY NEAR HARNEY PEAK.



A. GRANITE NEEDLES SOUTH OF HARNEY PEAK.



B. HARNEY PEAK FROM THE SOUTH, SHOWING TYPICAL GRANITE TOPOGRAPHY.



GRANITE NEEDLES NEAR HARNEY PEAK.

of this drainage system are Red Canyon, Beaver, French, and Spring creeks. Battle Creek and its branches rise on the eastern slope of the Harney Peak Range. A typical canyon through the eastern limestone range is shown in Pl. LXIII.

The limestone plateau has its descending slope outward all around the hills, but this declivity always bears a low but sharp infacing escarpment of Minnekahta limestone from 40 to 50 feet high, surmounted by a bare rocky slope descending several hundred feet into the Red Valley. This minor escarpment and slope is usually sharply notched by the canyons which cross it, giving rise in each stream to a constriction, or "gate," beyond which the canyon opens widely into the Red Valley.

The Red Valley.—The Red Valley is a wide depression that extends more or less continuously around the hills, with long, high limestone slopes on the inner side and the steep hogback ridge on the outer side. It is one of the most conspicuous features of the region, owing in no small degree to the red color of its soil and the absence of trees, the main forest of the Black Hills ending at the outer margin of the Minnekahta limestone. The Red Valley often has a width of 2 miles, but in the vicinity of Cascade and in a portion of the valley of Stockade Beaver Creek it is very much less. In the region west of Fairburn and Hermosa it is extensively choked with overlapping Tertiary deposits. The larger streams coming out of the hills generally cross the Red Valley without material deflection, but the divides are usually so low as to give the valley the appearance of being continuous.

The hogback range.—The hogback range constitutes the outer rim of the hills throughout. Ordinarily it is a single-crested ridge of hard sandstone, having the form shown in Pl. LXIV, but its prominence and slope vary greatly. Along the southern margin of the Black Hills north of Edgemont and in places north of Newcastle it is spread out into a long, sloping plateau. It nearly always presents a steep face toward the Red Valley, above which its crest line rises several hundred feet. On the outer side the slopes descend to the Plains, which extend far out from the hills in every direction. The hogback range is crossed by numerous valleys or canyons cutting it into short, level-topped ridges. At the southern point of the hills Cheyenne River has cut a tortuous valley through the outer ridge for several miles.

The Plains.—In the Plains, which stretch away from the hills on all sides, the topography usually presents a vast, monotonous expanse of gently undulating prairie, with long slopes leading into wide, shallow valleys. It is a region mainly underlain by shale, rarely containing any beds of harder materials. One very persistent feature adjoining the Black Hills, which is particularly prominent in the region from near the mouth of Stockade Beaver Creek to Fairburn, is a low but characteristic escarpment due to a limestone layer in the shale series. It rises about 4 or 5 miles from the slope of the hogback range about

Edgemont, and about a mile from it near Buffalo Gap. Toward the hills it presents a steep slope or cliff 50 feet high. North of Fairburn and Hermosa it is generally buried under Tertiary deposits.

West of the Black Hills there is an east-facing escarpment of the Fox Hills sandstone which passes through central Weston and Converse counties, Wyoming. It usually presents steep slopes and cliffs rising from 100 to 250 feet above the valley to the east. From Newcastle to Argentine it lies from 12 to 15 miles from the hogback ridge of the hills, but to the south it bears off to the westward. Its surface presents features shown in fig. 278. In the region east of Fairburn and Oelrichs, and on Sage and Old Woman creeks in Converse County, Wyoming, the overlapping White River formation gives rise to bad lands of moderate extent having forms like those shown in Pl. LXXXIV, but on a much smaller scale.

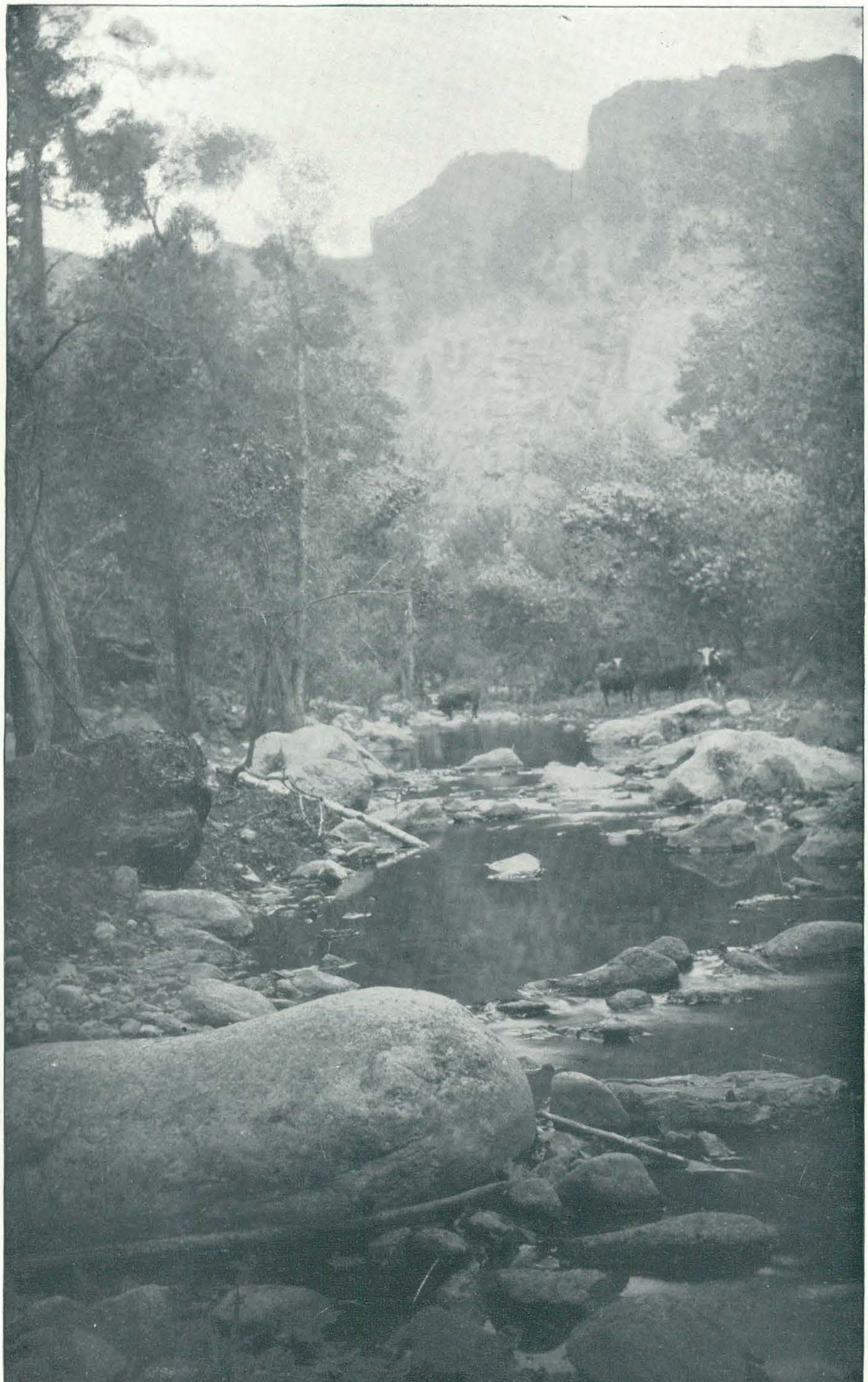
Pine Ridge.—In Pl. LIX is shown the relation of Pine Ridge to the Black Hills. It is a great escarpment marking the northern limit of the later Tertiary deposits which underlie the high plains extending far to the south through western Nebraska and Kansas. Properly speaking it is not a ridge but the eroded margin of a high plateau. It usually presents north-facing cliffs and slopes from 500 to 600 feet high.

GEOLOGY.

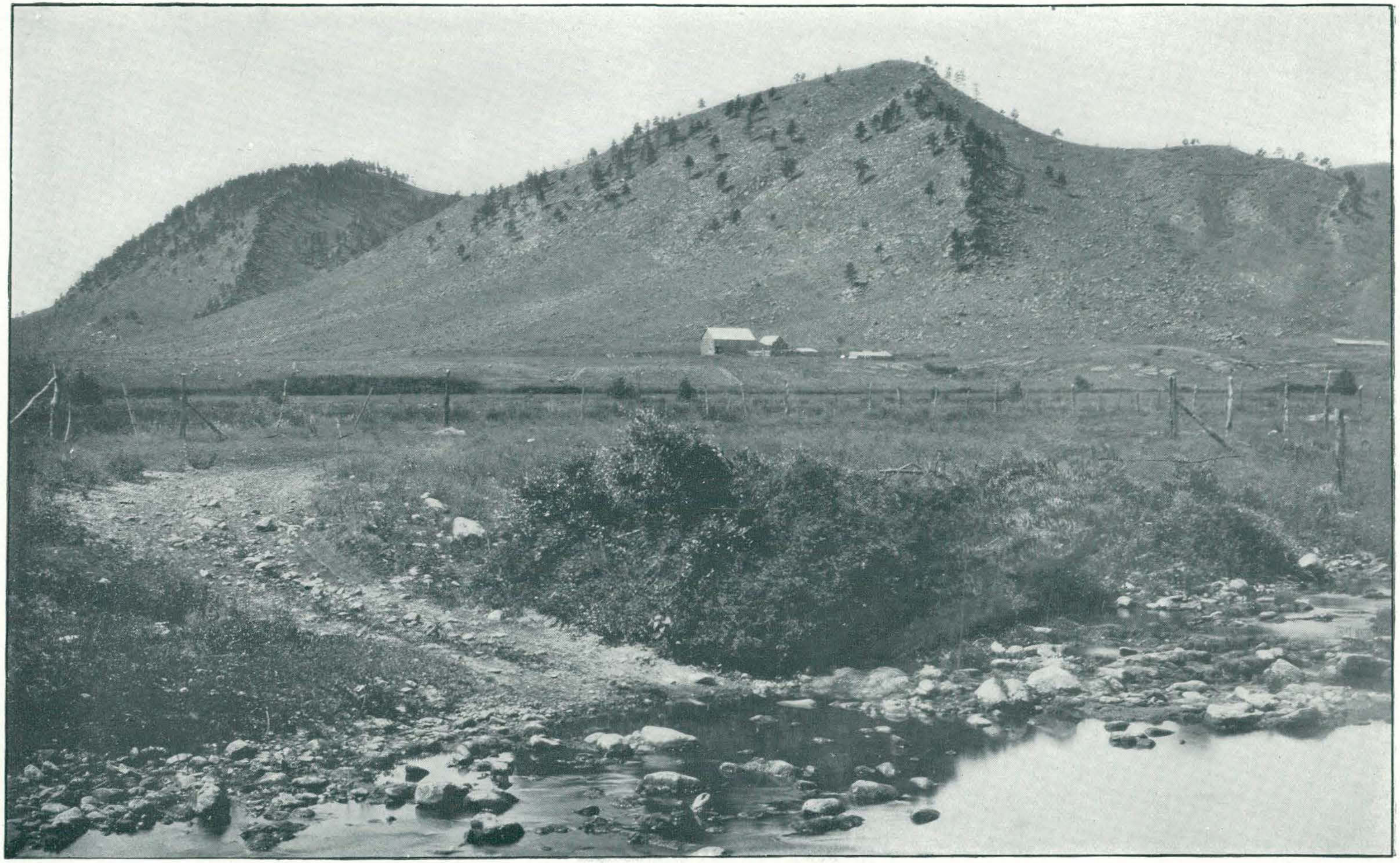
STRATIGRAPHY.

GENERAL RELATIONS.

The Black Hills uplift is an irregular dome-shaped anticline, embracing in its more obvious features an oval area 125 miles in length and 60 miles in breadth, with its larger dimension lying nearly northwest and southeast. It is situated in a wide area of almost horizontal beds underlying the great east-sloping plain that extends from the Rocky Mountains to the Mississippi River. It has brought above the general surface level an area of pre-Cambrian crystalline rocks about which there is upturned a nearly complete sequence of the Paleozoic and Mesozoic rocks from Cambrian to Laramie, all dipping away from the central nucleus. There are also extensive overlaps of the Tertiary deposits, which underlie much of the adjoining plains area. The region is one of exceptionally fine exposures, which afford rare opportunity for a study of stratigraphic relations and variations. Many of the rocks are hard, and the streams flowing out of the central mountain area have cut canyons and gorges, in the walls of which the formations are often extensively exhibited. The structure presented locally is that of a monocline dipping toward the plains. The oldest sedimentary rocks constitute the escarpment facing the crystalline rock area, and each higher stratum passes beneath a newer one in regular succession outward toward the margin of the uplift. In Pl. LXXXVIII



LIMESTONE WALLS OF FRENCH CREEK CANYON WEST OF FAIRBURN, SOUTH DAKOTA.



TYPICAL HOGBACKS OF DAKOTA SANDSTONE AT BUFFALO GAP, LOOKING SOUTHWEST.

there are given cross sections showing the general relations of the formations. In this illustration it will be seen that the sedimentary formations consist of a series of thick sheets of sandstones, limestones, and shales, all essentially conformable in structure. The overlapping areas of the Tertiary deposits extend across the edges of the older formations. The stratigraphy presents many features of similarity to the succession of rocks in the Rocky Mountains of Colorado and Wyoming, but it possesses numerous distinctive local features.

The following is a list of the formations which are exhibited in the uplift, with a generalized statement as to the thickness, characteristics, and age:

Generalized section in the Black Hills region.

Formation.	Character.	Average thickness.	Age.
		Feet.	
Laramie	Massive sandstone and shale.	2,500	Cretaceous.
Fox Hills	Sandstone and shale	250–500	Do.
Pierre shale	Dark-gray shale	1,200	Do.
Niobrara	Chalk and calcareous shale.	225	Do.
Benton group:			
Carlile formation	Gray shales with thin sandstones, limestones, and concretionary layers.	500–750	Do.
Greenhorn limestone	Impure slabby limestone	50	Do.
Graneros shale	Dark shale with lenses of massive sandstone in its lower part at some places.	900	Do.
Dakota sandstone	Massive buff sandstone.	35–150	Do.
Fuson	Very fine-grained sandstone and massive shales. White to purple color.	30–100	Do.
Minnewaste limestone.	Gray limestone	0–30	Do.
Lakota	Massive buff sandstone, with some intercalated shale.	200–350	Do.
Beulah shale	Pale grayish-green shale.	0–150	Jurassic.
Unkpapa sandstone	Massive sandstone; white, purple, red, buff.	0–250	Do.
Sundance	Dark-drab shales and buff sandstones; massive red sandstone at base.	60–400	Do.
Spearfish	Red sandy shales with gypsum bed.	350–500	Triassic.
Minnekahta limestone.	Thin-bedded gray limestone.	30–50	Permian.

Generalized section in the Black Hills region—Continued.

Formation.	Character.	Average thickness.	Age.
		Feet.	
Opeche	Red slabby sandstone and sandy shale.	90–130	Permian?
Minnelusa	Sandstones, mainly buff and red; in greater part calcareous. Some thin limestone included.	400–450	Carboniferous.
Pahasapa limestone	Massive, gray limestone.	250–500	Do.
Englewood limestone	Pink slabby limestone.	25	Do.
Deadwood	Red-brown quartzite and sandstone, locally conglomeratic, partly massive.	4–150	Cambrian.

The principal features of stratigraphic variation in the region are shown in Pl. LXVI and fig. 275, where it will be seen that certain

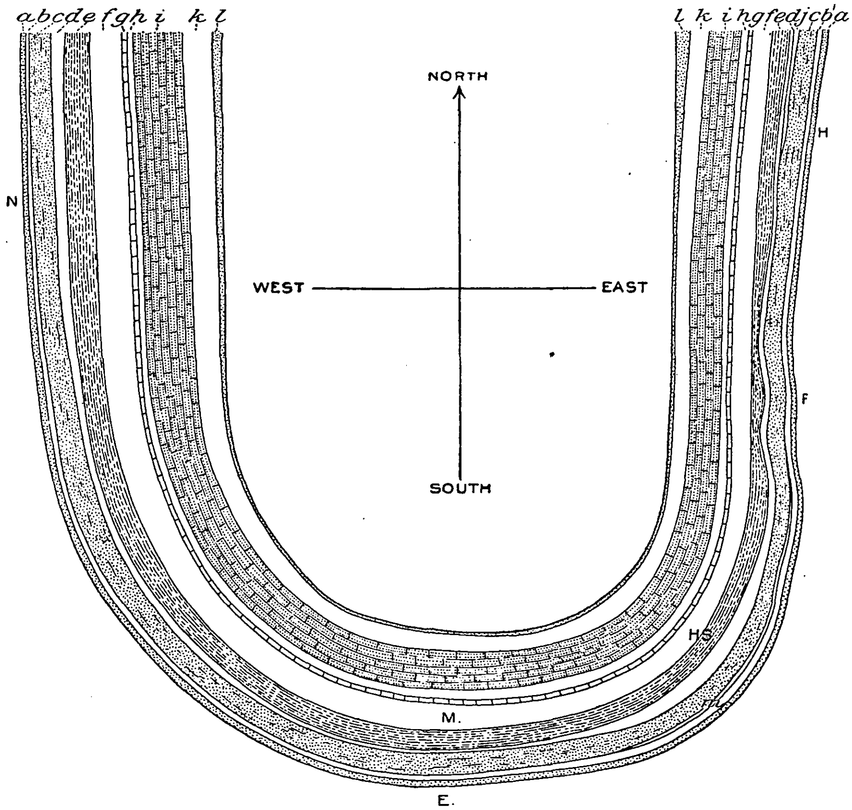
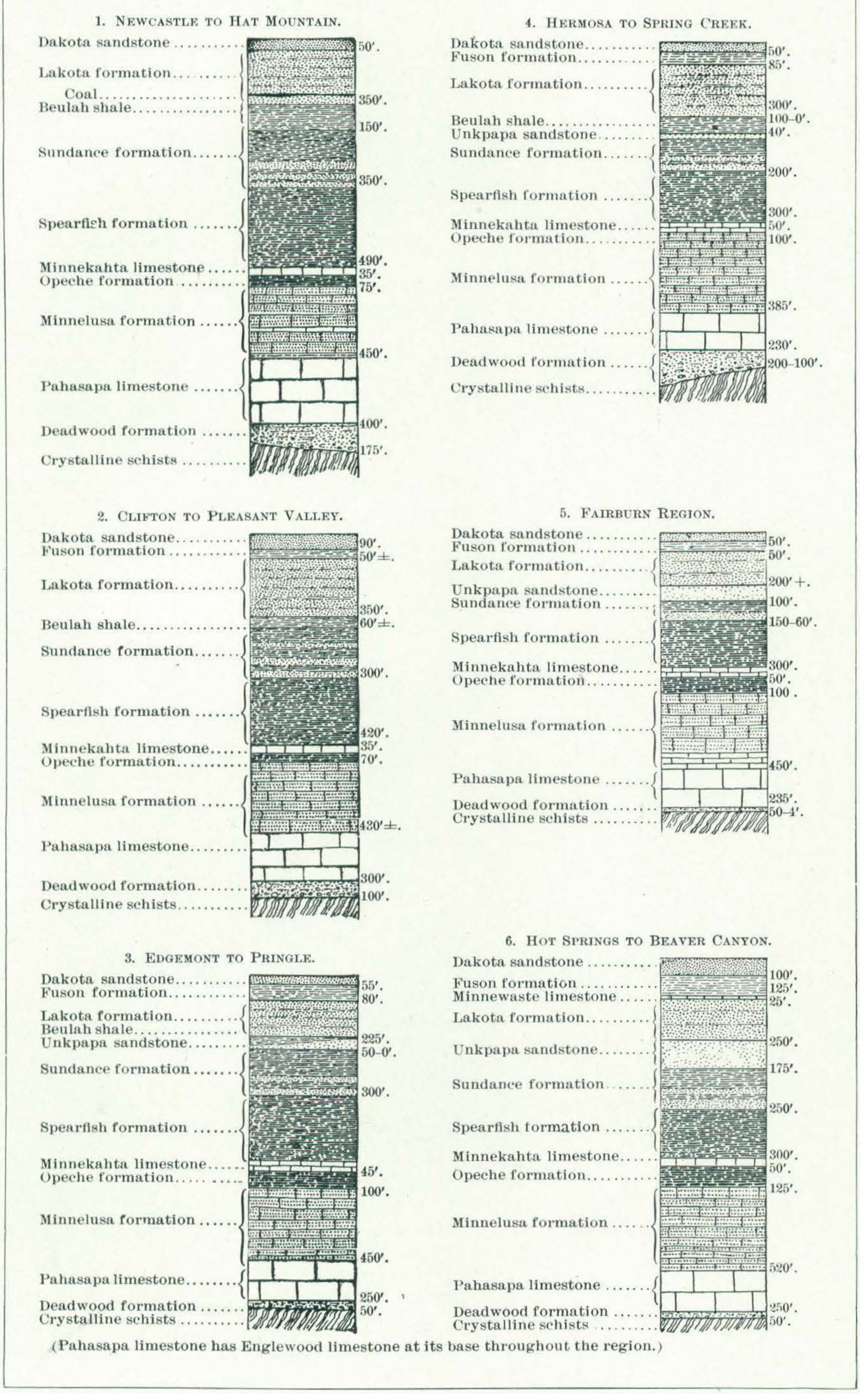


Fig. 275.—Diagram showing regional stratigraphic variations in the southern Black Hills, as exhibited along the outcrop zones. H, Hermosa; F, Fairburn; H S, Hot Springs; E, Edgemont; M, Minnekahta; N, Newcastle. *a*, Dakota sandstone; *b*, Fuson formation; *c*, Lakota formation; *d*, Beulah shale; *e*, Sundance formation; *f*, Spearfish red beds; *g*, Minnekahta limestone; *h*, Opeche red beds; *i*, Minnelusa formation; *k*, Pahasapa limestone; *l*, Deadwood sandstone; *m*, Minnewaste limestone.



COLUMNAR SECTIONS OF STRATIGRAPHIC FEATURES OF SOUTHERN BLACK HILLS.

By N. H Darton, 1899.

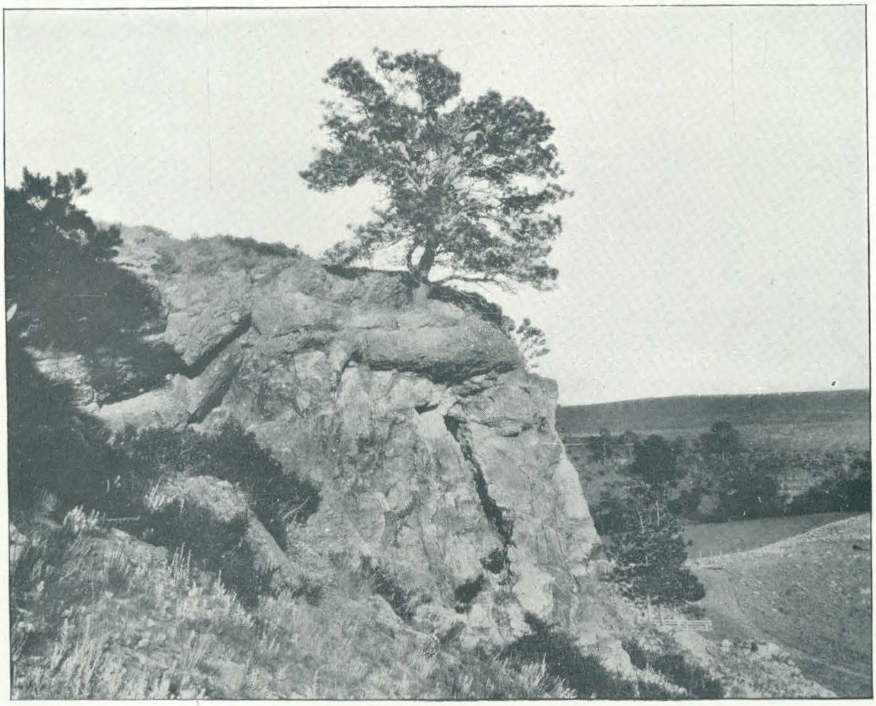
features are uniform over wide areas, with many local variations. These will be pointed out in the detailed descriptions of the individual formations. In the latter portion of this report there will also be discussed the sequence of events attending the deposition of these formations.

CAMBRIAN.

DEADWOOD FORMATION.

This representative of the Cambrian appears to entirely encircle the Black Hills, but it has been removed completely from the central area. We do not yet know whether in this region it originally covered the entire area of crystalline rocks, but it appears likely that a portion of these old rocks formed the surface during the greater part of the time, and probably furnished the material for the Cambrian sediments. The beds lie unconformably across the upturned edges of the schists and granites on a relatively smooth plain with local shallow channels. The formation is thick in the northern hills, attaining a thickness of over 300 feet in the Deadwood region, but it thins gradually to the south and especially to the southeast. In the region west of Fairburn exposures were found in which the formation is represented by only 4 feet of coarse sandstone lying on the pre-Cambrian schists. The materials of the formation are always prominently sandy, and the colors dark reddish brown or dirty buff. The basal member ordinarily is a hard, massive, reddish-brown quartzite. As the formation thickens this member is seen to be overlain by thinner bedded, softer sandstones, in some cases interbedded with more or less shale. The dark color of the rock is in striking contrast to the overlying limestones, and its nearly horizontal attitude and distinct bedding render it easily distinguishable from the underlying schists or granite. Portions of the basal beds of the Deadwood formation are conglomeratic, ranging from a sprinkling of quartz pebbles in the sandstone to a very coarse, heavy conglomerate of large, rounded masses of crystalline rocks and vein quartz in a red-brown matrix. An exposure of this sort of material on a northerly branch of Lame Johnny Creek is shown in part in Pl. LXVII, *B*. Here the crystalline schists are overlain by 8 feet of coarse conglomerate, with pebbles up to 8 inches in diameter, merging upward into coarse red sandstone, in all a thickness of about 20 feet. A few rods downstream there are exposures in which the formation is seen to consist of only 4 feet of coarse red-brown sandstone lying on the schists and overlain by Carboniferous limestones. There may be points in this vicinity where the formation thins out entirely, but it is present in all of the exposures scattered at intervals along the transverse valleys and intervening slopes.

Outcrops of the Deadwood formation vary greatly in prominence, but their extent in general is small. For many miles they lie in the slope below the high escarpments of the Pahasapa limestone, where the ledges are often deeply buried under talus from the cliff above. This is particularly the case on the western side of the uplift. On the eastern side, where the dip is steeper, the hard quartzitic basal member gives rise to several knobs or long, bare rocky slopes of considerable prominence. The many canyons cutting back into the western escarpment and those crossing the ridges on the eastern side of the uplift often afford excellent exposures of the formation. In the vicinity of Hat Mountain, northwest of Hill City, the formation has a thickness of 180 feet, possibly slightly less, and comprises an upper member of brown sandstone about 60 feet thick and coarse sandstone, conglomeratic in part, brownish buff above and reddish brown below, lying on the crystalline schists. Fossils occur at intervals in the beds, but mainly in the lower member. They are largely *Lingulepis* and *Obolella;* but fucoids also are found in small quantity. Hat Mountain is a small, conical outlier of the Deadwood beds, overlain by a few feet of Englewood pink limestone. Much of the sandstone in this vicinity is soft and weathers into slopes from which but few ledges protrude. The sands are composed in greater part of small, round quartz grains with occasional scales of mica. Some beds contain grains of glauconite in small proportion, a component which is abundant in the formation in the northern hills. The conglomerate which gives rise to some prominent ledges on Castle Creek, a few miles farther north, is a variable bed and becomes fine grained to the south. Its materials are mainly quartzitic crystalline rocks, similar to some of those of pre-Cambrian age in various parts of the Black Hills. The pebbles are rounded, and were doubtless the product of either a river or a shore of early Cambrian time. From Hat Mountain east is the widest portion of the Black Hills uplift, although possibly not quite the highest. The area of bared pre-Cambrian rocks is here 25 miles wide. In the escarpment west of Custer there are many scattered exposures of red sandstone in the slopes below the high cliffs of Pahasapa limestone. In this direction the formation gradually decreases somewhat in thickness, the conglomerate disappears, and sandstones are seen lying directly on the schists. In the canyons at the head of Pleasant Valley there are excellent exposures, and here, near the Eightmile ranch, *Obolella*, *Lingulepis*, and trilobite fragments are particularly abundant and well preserved. It was in this vicinity that Newton collected much of his Cambrian material. About Pringle the Deadwood sandstone is often exposed in the slopes of the escarpment and its outlying knobs, capped by the Englewood and Pahasapa limestones. It is a moderately hard, red-brown sandstone, containing numerous fossils and here dipping south on the axis of the uplift. The thickness was not ascertained precisely, owing to the lack of continuous exposures, but it is about



A. DEADWOOD CONGLOMERATE LYING ON CHANNELED SURFACE OF GRANITE AND SCHIST, ON BEAVER CREEK, 2 MILES NORTHWEST OF WIND CAVE, SOUTH DAKOTA, LOOKING EAST.

B. DEADWOOD CONGLOMERATE ON ALGONKIAN SCHIST, LAME JOHNNY CREEK, WEST-SOUTHWEST OF FAIRBURN, SOUTH DAKOTA, LOOKING NORTH. ALSO SHOWS ENGLEWOOD PINK LIMESTONE.

50 feet. On Beaver Creek, 2 miles north of Wind Cave, there are several instructive exposures. One exhibits a basal conglomerate lying on an irregular surface of crystalline rocks, shown in Pl. LXVII, *A*. The indications here suggest stream deposition, but there may have been simply a shore with low cliffs of crystalline rocks, against which the bowlder deposit was laid down. Farther down the canyon there is a cliff exposing the Deadwood formation lying between the Englewood limestone and the crystalline schists. The rock is a hard, dark-brown sandstone, massive above and conglomeratic below. Its thickness is 20 feet. Fossils occur in some of the layers. This formation is overlain by 6 feet of alternating beds of light-colored, thin sandstones, shales, and limestones which present no evidence as to their age. They are sharply separated from the underlying sandstones by abrupt change in color, texture, etc., and are overlain by the typical pink, slabby limestones of the Englewood formation.

In the gorge of Lame Johnny Creek the Deadwood formation is a coarse, brown, fossiliferous sandstone with a few intercalated pinkish, calcareous beds, having a thickness of about 40 feet altogether. On a branch of this creek 2 miles north of this place the formation thins to 4 feet, as described on page 505, and may locally thin out entirely, but this is not probable. The basal conglomerate at this place is shown in Pl. LXVII, *B*.

The deep canyon of French Creek affords a fine exposure of the contact of the Deadwood formation with the pre-Cambrian granite. The material is mainly a reddish quartzite, with streaks of quartz pebbles in its lower portion and a transition breccia for several inches. The thickness of the formation here has increased to more than 60 feet. The underlying granite is the typical pegmatite, of which there is so great a development in the Harney Peak region. At other points in the canyon different relations are exhibited, the quartzite grading into sandstones and overlapping onto schists. The upper member of the formation is thin-bedded soft sandstone. The lower quartzite is a prominent member from here northward to Hayward, rising high in knobs and ridges in the divides between the many transverse valleys. Its hardness is great and its massive dark red-brown blocks and surfaces are conspicuous features in this region.

On Squaw Creek below Otis there are extensive exposures of the Deadwood sandstones and quartzite, the latter giving rise to the fine bluff along the north side of the valley, shown in Pl. LXVIII. The series comprises a basal quartzite, which is prominent in the photograph, thin-bedded sandstone and shales, thin-bedded red sandstones, and thin-bedded gray sandstones overlain by the buff, slabby Englewood limestones. The thickness is about 75 feet.

Little Squaw Creek exposes a section showing massive red sandstones below with reddish-brown and gray, thin-bedded sandstones above and a capping of 18 inches of buff conglomerate. The pebbles in the conglomerate are small and the bed is a local one. Along the creek 2 miles below Spokane the Deadwood formation presents the following section:

Section 2 miles from Spokane, South Dakota.

	Feet.
Brown sandstone, overlain by pink, slabby limestone	5
Thin-bedded red sandstone and shale	25
Brown-red massive quartzite lying on crystalline rocks	30

In the vicinity of Battle Creek, about Hayward, the Deadwood formation is conspicuously exposed in frequent cliffs and long, rocky slopes, due mainly to the thick bed of hard quartzite at the base of the formation. This quartzite is dark reddish, moderately fine-grained, and has a thickness of about 30 feet. It is overlain by 30 feet of sandy shales and thin sandstones, varying from reddish brown to grayish brown. The top member is a bed of softer, lighter reddish-brown sandstone, averaging 10 feet in thickness. North from Hayward for several miles the formation gives rise to a narrow shelf in the slope of a west-facing ridge, capped by an escarpment of Pahasapa limestone. On Spring Creek, north of Rockerville, the formation thickens considerably, becomes glauconitic, and partially loses its quartzitic character. Its basal member is a conglomerate, at some points 20 feet thick, and a thick mass of alternating thinner and thicker bedded brown sandstones, with numerous fossils. Some of the layers are covered with impressions of large fucoids.

About Rockerville and Hayward the basal portion of the Deadwood formation has been found to be gold bearing, and many drifts have been run in on the contact.

CARBONIFEROUS.

In the Black Hills region the Carboniferous rocks comprise several formations apparently representing continuous deposition throughout the period. The many formations of Mississippian and Missourian age, which compose the Carboniferous in the central United States, are not differentiable in the Black Hills, not even in their broader features. There appear to be only five formations separable—the thin Englewood limestone at the base, the massive gray Pahasapa limestone next above, the thick mass of Minnelusa sandy beds, and the overlying series of Opeche red beds and Minnekahta limestone, the latter, at least, of Permian age. The Carboniferous lies directly on the Cambrian in the central and southern parts of the Black Hills, but to the north these are separated by a mass of buff limestone of Silurian age and some shales the age of which has not been determined.

ENGLEWOOD LIMESTONE.

In the southern Black Hills the Deadwood formation is overlain by a series of thin-bedded, pale pinkish-buff limestones. On the suggestion of Mr. Jaggar it is proposed to designate this formation the Englewood limestone, from a locality in the northern Black Hills where it is extensively exposed. It appears to extend continuously around the Black Hills, everywhere immediately underlying the Pahasapa limestone. It averages 20 to 30 feet in thickness and presents frequent outcrops in the lower slopes of the limestone escarpment and in numerous canyons. It merges rapidly into the overlying limestone, occasionally with a few feet of impure buff limestone intervening. It is usually sharply separated from the Deadwood formation, but only by a sudden change in the nature of the materials. The Englewood limestone is usually fossiliferous, containing numerous corals and occasional shells. The following forms have been reported: *Fenestella*, *Orthothetes*, *Leptæna*, *Spirifer*, *Chonetes logani*, *Reticularia peculiaris*, *Syringothyris carteri*, and crinoids. It is correlated with the Chouteau or Kinderhook of the Mississippi Valley.

PAHASAPA LIMESTONE.

This prominent member, heretofore known as the the Gray limestone, has an extensive outcrop area in the Black Hills uplift. It constitutes much of the high, wide plateau west of the central region of crystalline rocks, and is most characteristically exhibited in the great lines of cliffs in the infacing escarpment surrounding that region. Mr. Jaggar has suggested that there be applied to it the Dakota Indian name for the Black Hills, Pahasapa. The formation consists of a thick deposit of massive gray limestone, usually outcropping in precipitous cliffs with many picturesque irregularities of form, or with wide, flat surfaces. Caverns are of frequent occurrence, some of them being of large size. One having several miles of galleries is known as Wind Cave, from the strong current of air which usually issues from its mouth. It is situated 8 miles north of the Hot Springs and attracts thousands of visitors. Crystal Cave, in the northern Black Hills, is also a very interesting cavern, with many large deposits of dog-tooth spar on its walls.

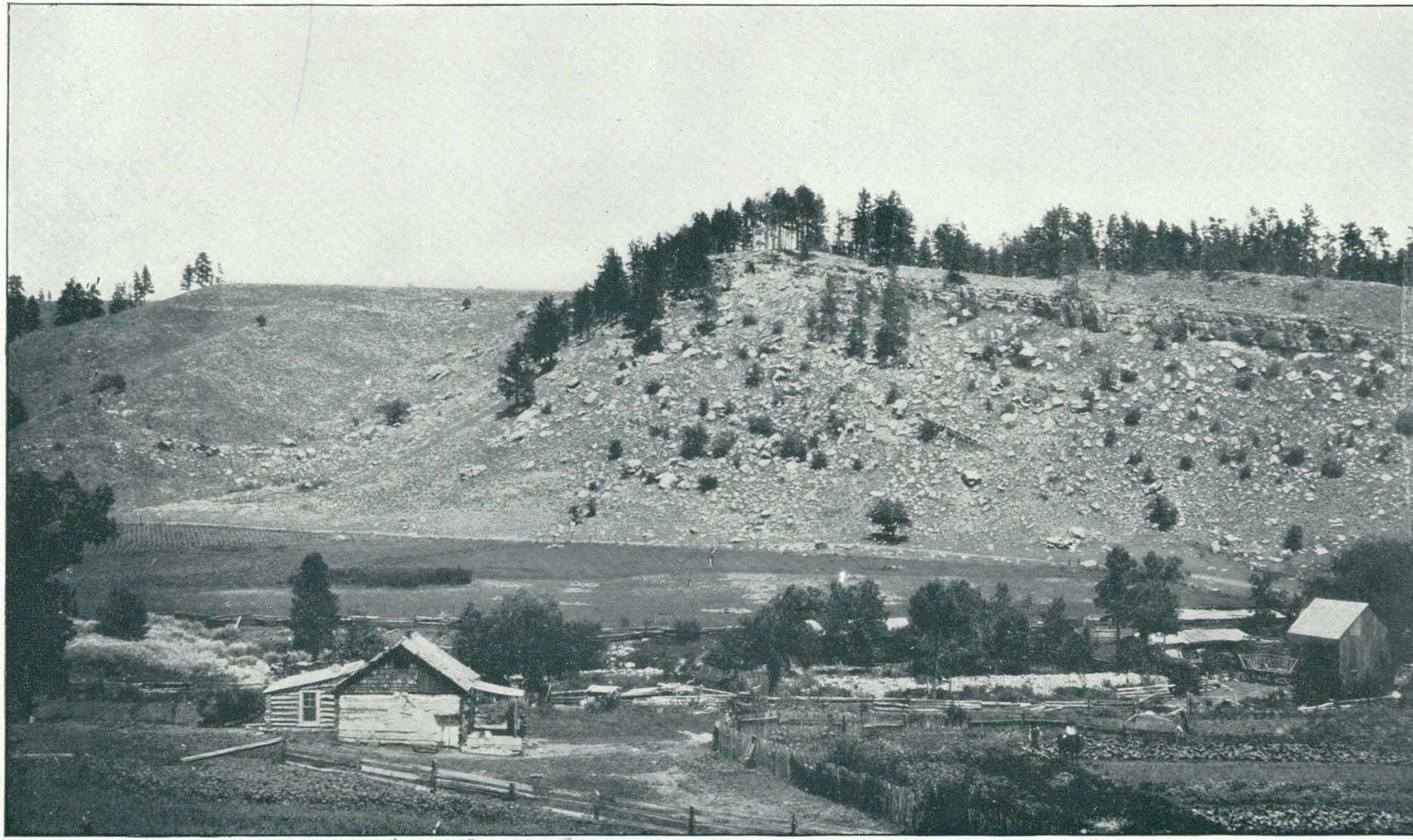
The most extensive exposures of the Pahasapa limestone are in the great plateau west of Custer. Here the formation begins in a line of high cliffs surmounting slopes of crystalline schists and the relatively thin sheets of Englewood limestone and Deadwood sandstone. A view of one of these cliffs is shown in fig. 274. In Pennington County the plateau has a width of 10 miles of continuous limestone outcrop, constituting the most elevated area in the Black Hills excepting the small summit of Harney Peak. To the west the limestone passes beneath the sandstone of the Minnelusa formation, but it is exposed again in the arch of the steep anticline near the Wyoming–South Dakota line. Hell Canyon cuts deeply into the Pahasapa limestone, as does also the wider canyon known as Pleasant Valley. East of the crystalline rock area the limestone stands out on many conspicuous knobs, or lies on the eastern slopes of ridges due to the Deadwood quartzite, but it does not attain the high altitude which it has farther west. With decreased thickness, the more rapid dip to the east soon carries the formation below the surface in that direction, but it constitutes the walls of many of the canyons of the streams from Beaver Creek northward. French Creek has extensive cliffs of the limestone, one of which is shown in Pl. LXIII, and Spring Creek has cut a long, deep canyon through it.

The thickness of the Pahasapa limestone in the central and southern Black Hills varies from about 500 feet at the northwest to 225 feet on the east and southeast. All along the eastern side of the hills it appears to have the latter thickness, with slight local variations. It does not present any noteworthy lithologic subdivisions, but its upper part is often siliceous and flinty and stained red to a greater or less extent from the overlying red beds of the Minnelusa formation. At its top there is usually a red shaly bed of slight thickness, containing oval concretions of hard silica from 6 inches to 2 feet in diameter in greater part. Fossils occur sparingly throughout the formation, including *Spirifer rockymontanus*, *Seminula dawsoni* (*Athyris subtilita*), *Productus*, and *Zaphrentis*, a fauna which indicates Lower Carboniferous age.

MINNELUSA FORMATION.

This term was applied by N. H. Winchell[1] to a portion of the bright-colored sandy members of the Carboniferous lying above the Gray or Pahasapa limestone. Minnelusa is the Dakota Indian name for Rapid Creek, and in this report will be employed to designate all the sandstones and limestones lying between the well-defined limits of the Pahasapa limestone below and the deep-red sandstones and shales of the Opeche formation above. It is next to the Pahasapa limestone in order of prominence among the Black Hills formations, extending in a broad zone all around the uplift, with conspicuous outcrops. It varies in components, but consists mainly of thick masses of buff and reddish sandstones that are striking features in the walls of the many canyons by which the formation is traversed. The sandstones are mostly fine grained, massively bedded, and in their unweathered condition contain a considerable proportion of carbonate of lime. Thin sheets of limestone occur in places, and, less frequently, sandy shales of red or gray color. Some layers are cherty. Although the formation

[1] Report of a reconnaissance of the Black Hills of Dakota made in the summer of 1874 by Capt. William Ludlow, United States Engineers, 4°, Washington, 1875, p. 65.



DEADWOOD RED SANDSTONE LYING IN ALGONKIAN SCHISTS ON SQUAW CREEK BELOW OTIS, SOUTH DAKOTA, LOOKING NORTH.

was deposited at the same time as the Coal Measures which contain extensive beds of coal in the Mississippi Valley, it is barren of coal in the Black Hills, except in the occasional occurrence of very thin beds of impure coal in gray shales. The formation is thickest on the western side, where it is fully 450 feet thick; it thins gradually to the south and east, being about 420 feet thick west of Hot Springs and less than 400 feet thick on Spring Creek. Although the Minnelusa formation has wide areas of exposure it does not give rise to very marked topographic features. It occupies elevated slopes surmounted by low hills and ridges due to its harder layers. Its inner boundary is usually not marked by an escarpment such as is seen at the inner margin of the Pahasapa limestone, and there is never any noticeable topographic break in passing from one formation to the other. On the slopes the soil becomes sandy on the Minnelusa beds. In the many canyons which are cut through the formation the Pahasapa limestone usually passes beneath it without presenting any marked change of features except in color. The fine colors exhibited by the Minnelusa formation give great beauty to some of the canyons. One of the finest exposures of this sort is on Hot Brook, the south branch of the head of Fall River. It is shown in Pl. LXIX. The upper sandstones are brilliant red-brown and orange, and contain layers presenting much bright yellow. Below these are gray sandstones containing a layer of bright purple clay. Above are the brilliant dark reds of the 100 or more feet of Opeche sandstones surmounted by a cap of the purplish-gray Minnekahta limestone. Four hundred feet of beds are exposed, with colors of most unusual brilliancy. Portions of the color on some of the beds is due to staining from the overlying strata, but several of the sandstones are colored throughout. The railroad from Minnekahta to Hot Springs passes at the foot of the cliff. The strata exposed at this place are as follows:

Section on Hot Brook, South Dakota.

Opeche red sandstone.	Feet.
Gray limestone	10
Soft red sandstone	20
Limestone breccia, red to buff matrix	15
Yellow arenaceous limestone	15
Red limestone	5
Yellow arenaceous limestone	5
Red arenaceous limestone	5
Gray limestone breccia, red matrix	15
Red sandstone	25
Greenish-gray limestone	5
Red sandstone, soft	50
Gray limestone	10
Red sandstone	10
Gray sandstone	10
Red sandstone	6

	Feet.
Red shale	30
Pale-red sandstone with thin coaly shale partings	20
Light-buff and gray sandstones	15
Breccia	3
Reddish-gray sandstone	25
Green shale	1
Gray to buff sandstone	12
Black shale	2
Light-buff, soft sandstone	15
Dark shale	2
Soft white sandstone	15
Gray calcareous sandstone with coaly shale partings	30

The section comprises about two-thirds of the formation brought up

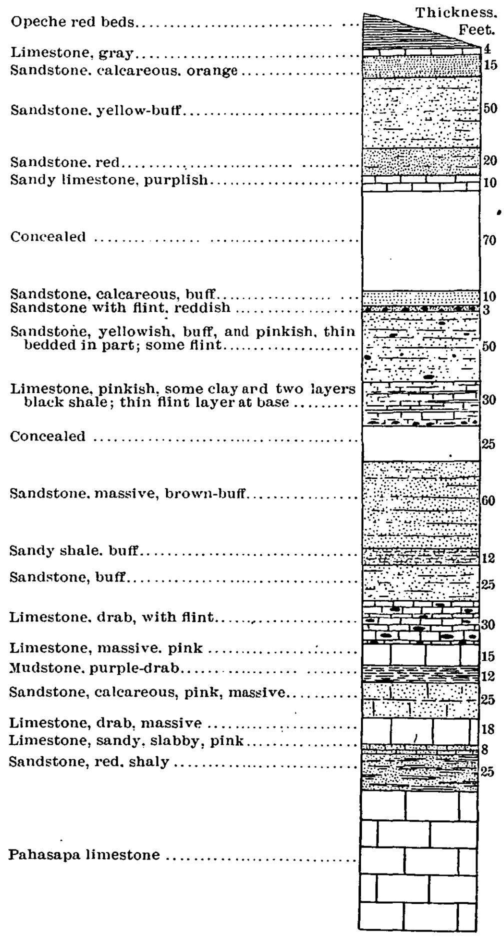
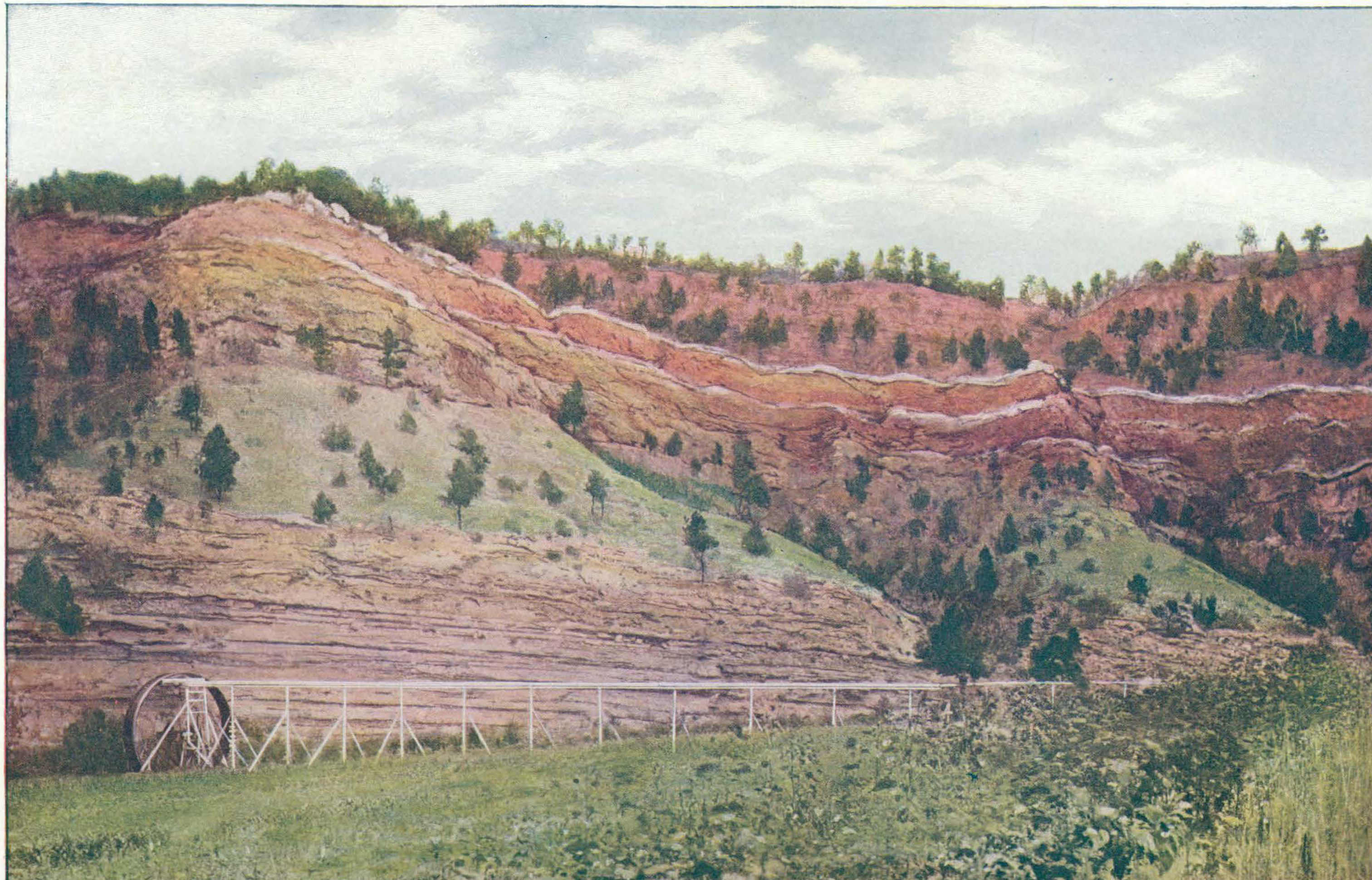


FIG. 276.—Columnar section of Minnelusa formation in Beaver Canyon, north of Hot Springs, South Dakota.

by a local anticline of considerable height. The uppermost layer is a nearly pure limestone, in which, in an adjoining canyon, were discov-



3-COLOR PROCESS FROM PHOTOGRAPH BY N. H. DARTON

UPPER PORTION OF MINNELUSA FORMATION, OVERLAIN BY OPECHE RED BEDS AND MINNEKAHTA LIMESTONE

Hot Brook, 2 miles west of Hot Springs, South Dakota. Looking north ered the typical upper Carboniferous forms *Productus semireticulatus* and *Chonetes?*, a very important occurrence, because the formation has not elsewhere yielded fossils. These remains indicate that the beds are of pre-Permian age.

In Beaver Canyon, 10 miles north, there is a complete section across the Minnelusa formation, as shown in fig. 276. This section was carefully examined by Mr. Richardson. It presents a long series of picturesque cliffs of brilliantly colored sand rocks, from under which, to the west, the Pahasapa limestone gradually rises into high, gray cliffs stained pink and reddish. The two formations are distinctly separable by a comparatively sudden change in the nature of the materials from arenaceous to more purely calcareous. The lower members of the Minnelusa formation are generally buff, slabby sandstones, often having a thickness of 100 feet. The breccias which occur in the higher beds are distinctive features seen throughout the southern Black Hills. The brecciated material is usually somewhat more calcareous than the matrix, but it is all of local origin. In the region west of Hermosa and thence northward, the Minnelusa beds consist of a thick mass of coffee-colored sandstone at the top, reddish-buff sandstone with some thin interbedded limestone layers next below, and a basal member of gray sandstone. On the western side of the Black Hills the formation consists of the members given in the record of the boring at Cambria, page 572. There are fine exposures of steep-dipping beds on the ridge east of Stockade Beaver Creek from Fanny Peak northward. These are shown in Pl. XCII. Here the formation exhibits a top series of light-colored massive sandstones, a thick medial member of bright red and buff sandstones, and a basal member of slabby, buffish-gray calcareous sandstone with reddish shale partings and considerable chert. The total thickness is about 450 feet. A chemical examination of the borings from the Cambria well shows that the materials are nearly all calcareous under ground, but in the outcrops the lime has been mostly leached out and porous sandstones remain.

OPECHE FORMATION.

This series of red beds, lying between the Minnelusa formation and the Minnekahta limestone, extends continuously around the Black Hills. Its exposures are almost always confined to the slopes below the escarpments of Minnekahta limestone. Its thickness averages slightly less than 100 feet. The material is a soft, red sandstone, mainly thin bedded, containing variable amounts of clay admixture. At the top of the formation, for the first few feet below the Minnekahta limestone, there are shales which are invariably a deep purple. The basal beds of the formation are usually red sandstones, varying in thickness from 4 to 15 inches. A few thin local beds of gypsum are sometimes observed in the formation, attaining in Gillette Canyon a thickness of several inches. On Spring Creek, Battle Creek, and

French Creek the formation averages about 100 feet in thickness. In Beaver Canyon it attains its maximum thickness of 150 feet. On Cold Brook, 4 miles northwest of Hot Springs, its thickness is 115 feet, with purple clay at the top, 50 feet of red, sandy clay below, and 60 feet of red sandstone at the bottom in beds 1 to 4 feet thick, with red clay partings. Farther down Cold Brook, at a point 1½ miles from Hot Springs, a thickness of 135 feet is exhibited. Along the southwestern side of the Black Hills the thickness averages from 90 to 100 feet. In the well at Cambria the following section was obtained:

Section at Cambria, Wyoming.

	Feet.
Purplish shales	4
Dark purple shales	4
Red clay (sandy)	62
Dark red-brown sandstone	2½
Light-red, sandy shale lying on a light pinkish sandstone at a depth of 1,096 feet, which is supposed to be the top of the Minnelusa formation	1½
Total	74

The name Opeche is applied to this heretofore nameless formation from the Indian name for Battle Creek, where the formation is typically developed, although not more so than at many other points in the region. The age of the formation has not been definitely determined, for so far it has yielded no fossils. From the facts that the overlying Minnekahta limestone is of Permian age and that there are extensive red beds in the upper part of the Permian in Kansas and eastern Nebraska, it is supposed that it may be Permian.

MINNEKAHTA LIMESTONE.

This formation, known in previous geological reports as the Purple limestone, is a prominent member of the Black Hills series. It is thin, averaging less than 50 feet in thickness, but it is hard and flexible and covers moderately extensive areas of the outer slopes of the Minnelusa formation. Southwest of Hot Springs it constitutes a prominent anticlinal ridge, which extends south to Cascade Spring. It is proposed to designate this formation the Minnekahta limestone, because a distinctive geographic name is required, and the region near the hot springs, originally known as the "Minnekahta" by the Indians, is a typical locality. The springs rise through crevices in the formation just west of the town of Hot Springs, and the exposures in the vicinity show all the characteristic features which the formation presents. The prominence of the Minnekahta limestone outcrops is due largely to the fact that the overlying formation is soft, red shale, which has been deeply eroded, leaving the underlying limestone bare on slopes up which the red shale originally extended. The underlying formation, the Opeche, also being soft, the limestone nearly everywhere presents an escarpment, and the many canyons which are cut through it have vertical walls of the limestone.

MINNEKAHTA LIMESTONE AT WILDCAT GULCH, WEST OF HERMOSA, SOUTH DAKOTA, LOOKING SOUTHWEST.

The Minnekahta limestone presents more details of structure than any other formation of the Black Hills. Normally it dips outward away from the central area at from 5° to 30°, but there are frequent variations in the amount and direction. These variations are due to the fact that the formation is a relatively hard bed of homogenous rock lying between masses of soft, red shales, so that it was free to flex wherever pressure was exerted, the plasticity of the inclosing beds favoring local flexing and warping. Its beds are sometimes traversed by small faults and minute crumplings, but considering the large amount of deformation to which the formation has been subjected the flexures are but little broken. The formation is uniform in character throughout, being a thin-bedded, light-colored limestone containing magnesia and more or less clay as an impurity. Its thin bedding is a characteristic feature, although the thin layers are so cemented together that the formation presents a massive appearance. On weathering and through the action of frost it breaks into slabs usually 2 to 3 inches in thickness. On the western side of the Black Hills, notably in the region from east of Clifton northward, its coloring is slightly darker, varying from dove color to lead gray, and some of the beds present a seminodular structure. An increased admixture of clay is also observed in some layers. The general appearance of the formation is always slightly pinkish with a tinge of purple, from which the term "Purple limestone" originated. The thickness of the formation was measured at many points; a few representative measurements are as follows:

	Feet.
Spring Creek	45
Battle Creek	40
Hot Springs	50
Stockade Beaver Creek	28–33
Cambria well	34

This relatively uniform thickness indicates very uniform conditions of deposition during the accumulation of the red bed deposits, the Opeche formation below, and the Spearfish formation above. An analysis of a typical sample of the Minnekahta limestone is as follows:

Analysis of Minnekahta limestone.

Constituent.	Per cent.
Lime	31.51
Magnesia	19.85
Alumina, iron, etc	.36
Water	1.25
Carbonic acid	44.66
Sulphuric acid (SO_3)	.07
Silica	1.12
Manganese, soda, and potash	None.

This analysis was made by Mr. George Steiger, United States Geological Survey laboratory, in March, 1900.

A characteristic feature of the Minnekahta limestone is the frequent occurrence of sink holes, a typical example of which is shown in Pl. LXXI. It is about 25 feet in diameter and 20 feet deep to débris which probably fills its bottom to a considerable amount. Other similar sink holes are to be seen on the road from Hot Springs to Cascade.

During the seasons of 1898–99 I discovered fossils in the Minnekahta limestone at several points in the area, which indicate that the age of the formation is Permian. The fossils were studied by Mr. Schuchert, who identified a small *Bakevellia* and with less certainty an *Edmondia* and a very thin-shelled *Nuculana*. The *Bakevellia* is similar to one occurring in the Permian on South Cottonwood Creek, Kansas. The most abundantly fossiliferous locality observed is in the railroad cut about 2 miles north of Minnekahta. Newton states that he made a specially extended but fruitless search for fossils in this limestone. He classified the formation provisionally as Triassic. Winchell referred it doubtfully to the Carboniferous. Hayden, who included the Purple limestone with some of the underlying formations in the "Red bed series," reported the occurrence of fossils in a bowlder which he supposed to be Purple limestone. They were distinctive Carboniferous forms, but in all probability he was mistaken as to the source of the bowlder.

JURATRIAS.

TRIASSIC.

SPEARFISH FORMATION.

The Spearfish formation is the conspicuous series of gypsiferous red beds encircling the Black Hills and usually giving rise to a wide red valley which in the northern Black Hills the Indians have designated the "race course." The formation consists of from 350 to 500 feet of red sandy clays, with intercalated beds of gypsum which sometimes are 30 feet thick. The bright red of the shales and the snowy whiteness of the gypsum are striking features of the formation. The Red Valley is treeless, and it usually presents wide areas of bare red slopes and red buttes with frequent outcrops of gypsum. If it were not for the beds of gypsum the formation would present no noticeable features of stratigraphy. The sedimentary material is almost entirely a red shale containing varying amounts of sand admixture and is generally thin bedded. The gypsum occurs in beds at various horizons, some of the larger beds extending continuously over wide areas. There is

SINK HOLE IN MINNEKAHTA LIMESTONE EAST-NORTHEAST OF CAMBRIA, WYOMING.

also throughout the formation more or less secondary deposition of gypsum in very small veins. The continuity of the outcrops of the red beds is considerably broken in the region west of Fairburn and Hermosa by overlaps of the Tertiary formations which in some places completely fill the Red Valley. The width of the outcrop of the formation varies from 1 to 3 miles, attaining its maximum in the region west of Buffalo Gap and in the broad belt extending from east of Minnekahta Station nearly to the north end of Elk Mountain. Owing to the local steep dip of the formation the outcrop is very narrow for 5 miles north from Cascade Springs and in a portion of the valley of Stockade Beaver Creek east of Newcastle. The thickness of the Spearfish formation can seldom be determined with any degree of accuracy, owing to the softness of its materials and the consequent difficulty in determining the dips of bedding planes. Along the eastern side of the Black Hills the formation appears to have a thickness of between 350 and 400 feet, so far as can be estimated from very indefinite dip observations. In this region the principal bed of gypsum occurs near the center of the formation. West of Hermosa it has a thickness of about 15 feet, but southward, in the region west of Fairburn, it thins out and may at some points be absent. West of Buffalo Gap the gypsum beds increase in thickness and attain their maximum prominence at Hot Springs, where the section shown in fig. 297 is exhibited. The exposure at this place is shown in Pl. CVI. The principal beds of gypsum have a thickness of 33½ feet, with a 10-foot parting of red shale between them. In the wide Red Valley extending south from Hot Springs to Sheps Canyon, the gypsum beds are a conspicuous feature, but they gradually diminish in thickness in that direction. At Cascade Springs, and thence north on the west side of the anticline, the dips are very steep, and the outcrop of the Spearfish formation becomes so narrow that the Red Valley is only a few rods in width from the springs north nearly to the railroad. Here a relatively accurate measurement of the beds was made from the steep slopes of Minnekahta limestone to the basal sandstone beds of the Sundance formation. At the base there are 150 feet of red beds, then a bed of gypsum in places 20 feet in thickness, overlain by 250 feet of red beds with a few thin layers of gypsum, the formation here having a total thickness of 420 feet. In the broad Red Valley extending from east of Minnekahta westward across the southern axis of the Black Hills and northward to Gillette Canyon there are red shales with intercalated gypsum beds, but the thickness could not be accurately determined. In the narrow valley of Stockade Beaver Creek east of Newcastle the upper portion of the Spearfish formation is mostly covered by alluvial materials, so that a precise measurement is difficult to obtain. Just west of Fanny Peak a measurement was made showing 450 feet, or possibly slightly more, of red beds, including two thick beds of gypsum near the middle. The lower bed of gypsum is about 150 feet above the Minnekahta limestone; then come about 40 feet of red clays, a 2-foot bed of gypsum, 15 feet of red clays with two thin gypsum beds near its top, a bed of gypsum which locally attains a thickness of 30 feet, and at the top about 200 feet of red shales and red sandy shales to the buff sandstone at the base of the Sundance formation. A short distance north of this point the dips diminish and the red beds spread out into a wider valley, followed by Stockade Beaver Creek to the northward. The contact with the Jurassic beds gradually rises on the west side of this valley and the red beds are exhibited in long slopes and picturesque red cliffs. The principal bed of gypsum continues in the center of the formation and another bed of it begins at the top of the formation, which soon attains a thickness of from 10 to 12 feet, gradually increasing in amount to the northward. This bed of gypsum is overlain by dark shales, here constituting the base of the Sundance formation. Northeast of Cambria there are exhibited 25 feet of gypsum at the top of the formation, several thick beds in its center, and a local thin bed of gypsum at its base, lying directly on the Minnekahta limestone. The top bed caps the picturesque Red Butte, shown in Pl. LXXII. In the boring at Cambria the Spearfish red beds were plainly recognized, having a thickness of 492 feet, with the following members:

Section of Spearfish formation at Cambria, Wyoming.

	Feet.
Gypsum	8
Red clay	28
Red and dark clay	28
Red clay	181
Gypsum	7
Red clay	58
Gypsum	4
Red clay and gypsum	78
Gypsum	12
Red clay lying on Minnekahta limestone	88

The name Spearfish formation has been applied to this red-bed series from the town of Spearfish, in the northern Black Hills, where there are extensive exposures. Throughout the hills the formation is distinctly separated from the underlying Minnekahta limestone and the overlying shales and red sandstone of the Jurassic Sundance formation. It is thought to be Triassic in age, because it lies unconformably beneath marine Jurassic deposits and is underlain by the Minnekahta limestone, which is known to be of Permian age. No fossils have yet been discovered in the formation except a small fragment of a fish, which was not sufficiently distinct for determination. It is pos-

3-COLOR PROCESS FROM PHOTOGRAPH BY N. H. DARTON

SPEARFISH RED BEDS, CAPPED BY 30-FOOT BED OF GYPSUM

Red Butte, northeast of Cambria, Wyoming sible that the lower portion of the formation is Permian, but there is no evidence on this point one way or the other. The red beds in Kansas are sometimes supposed to be Permian, but their age is not proved. The distance also from Kansas to the Black Hills is too great for correlation without the guidance of distinct stratigraphic characteristics or other relations besides the red color.

JURASSIC.

The existence of Jurassic beds in the Black Hills was first ascertained by Hayden, who, in 1857, discovered marine fossils which were identified and described by Meek. Hayden's descriptions of the Jurassic beds were meager, and he included in the Jurassic the red beds, and at one point a limestone with fresh-water fossils which I have recently found to be Tertiary.

N. H. Winchell visited the region in 1874, and in his report recorded a few general facts as to character and distribution of some of the Jurassic beds along his line of travel. Henry Newton made a very much more extended survey of the Black Hills in 1875, and in his report added greatly to our knowledge regarding the Jurassic deposits. He described in considerable detail a number of typical exposures, but attempted no classification of the members. His principal statements are as follows:

> The Jura of the Black Hills consists primarily of gray or ash-colored clay or marls, with occasional bands of green and red. Interbedded with these are soft sandstones, more or less argillaceous, and a few restricted bands of limestone. * * * The thickness * * * is about 200 feet, but it shows a remarkable increase toward the north and northwest, attaining in the Belle Fourche Valley a depth of nearly 600 feet. * * * On the north and west, and to a less degree to the south, the formation is well exposed and characterized by a greater or less abundance of fossils. On the southeast and east it is less plainly seen, being usually covered by a broad talus, and so far as examined it was not found to be fossiliferous. * * * It was found impossible to base a subdivision of the formation either on persistent lithological characters or on the distribution of fossil forms. The Jurassic strata * * * are always easily distinguished from the red beds. * * * Everywhere a large proportion of the formation is composed of sandstones, which are usually light in color and even sometimes of a snowy whiteness.[1]

The upper limit of the Jura is so placed by Newton in most cases as to comprise only the beds containing Jurassic molluscan remains, but in places it includes a greater or less amount of overlying sandstones.

Several years ago O. C. Marsh collected saurian remains from the shales overlying the marine Jurassic beds near Piedmont, on the east side of the hills. Near Piedmont and other places he also obtained, through a local collector, a large number of cycads from the sandstone overlying the saurian-bearing shales, which was classified as Dakota

[1] U. S. Geog. and Geol. Survey Rocky Mountain Region: Geology and Resources of the Black Hills of Dakota, pp. 152 et seq.

by Newton. The saurian remains are generally regarded as Jurassic, but Marsh has been disposed to regard the cycads also as Jurassic in age. The cycad-bearing sandstones have been examined by L. F. Ward at several points in the hills, and W. P. Jenney has collected many plants from coals associated with these sandstones in the northern hills. It is Ward's opinion that this flora is Lower Cretaceous.[1] In 1898 I discovered saurian bones at or near the cycad horizon at Buffalo Gap. Dr. Lucas is now studying this material, but is not prepared to give a decided opinion as to whether it is early Cretaceous or late Jurassic, so it is that the upper limit of the Jurassic in the Black Hills is perhaps open to question. For the present the cycad-bearing sandstone here designated the Lakota formation will be included in the Lower Cretaceous, and the underlying Beulah shales, containing saurian remains, will be regarded as the top member of the Jurassic.

The base of the Jurassic is clearly defined throughout the area of the hills by an abrupt change in the character of the sediments, more or less slight erosion, and the evidence of an entirely different history from that of the underlying Spearfish red beds. From the results of recent studies there are offered for the Black Hills Jurassic the classification and nomenclature given on page 503.[2]

SUNDANCE FORMATION.

This member of the Jurassic extends continuously around the Black Hills uplift and throughout its course presents characteristics by which it can be easily recognized. It outcrops mainly along the outer side of the Red Valley on the lower inner slopes of the hogback range. It carries abundant marine fossils, not only to the north, as stated by Newton, but in profusion also around the zone of outcrop to the south. The formation comprises shales and sandstones, in greater part in alternating series, which vary somewhat in sequence in different portions of the region. The shales are mainly dark green and the sandstones pale buff, but there is an intermediate member of sandy shales and sandstones of reddish color, and often a local basal member of massive red sandstone. The shales usually include thin layers of limestone which are always highly fossiliferous. Fossils also occur in the sandstone. Molluscan fossils predominate, together with *Pentacrinites asteriscus* and bone fragments. The following is the list of the fossils so far reported:

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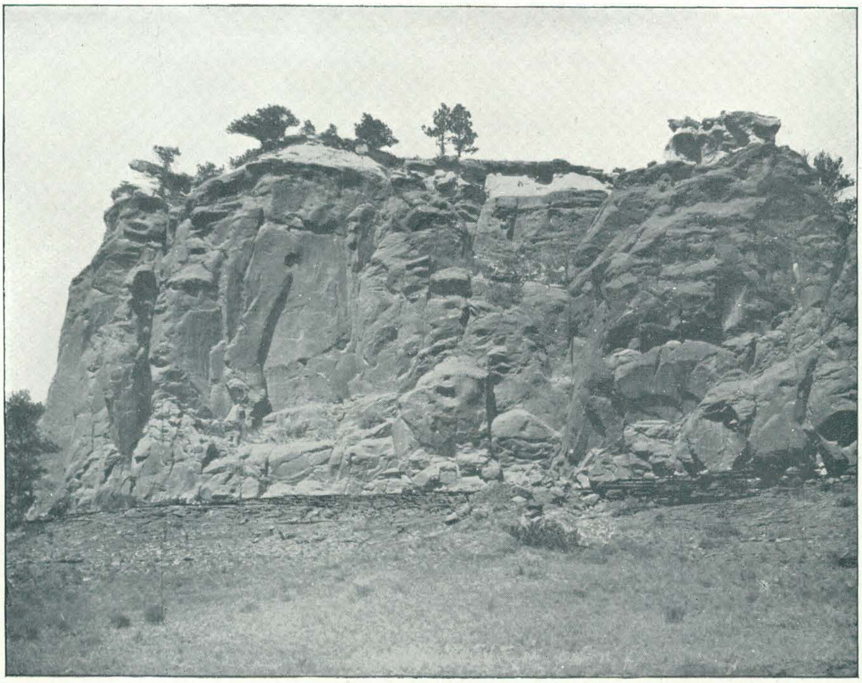
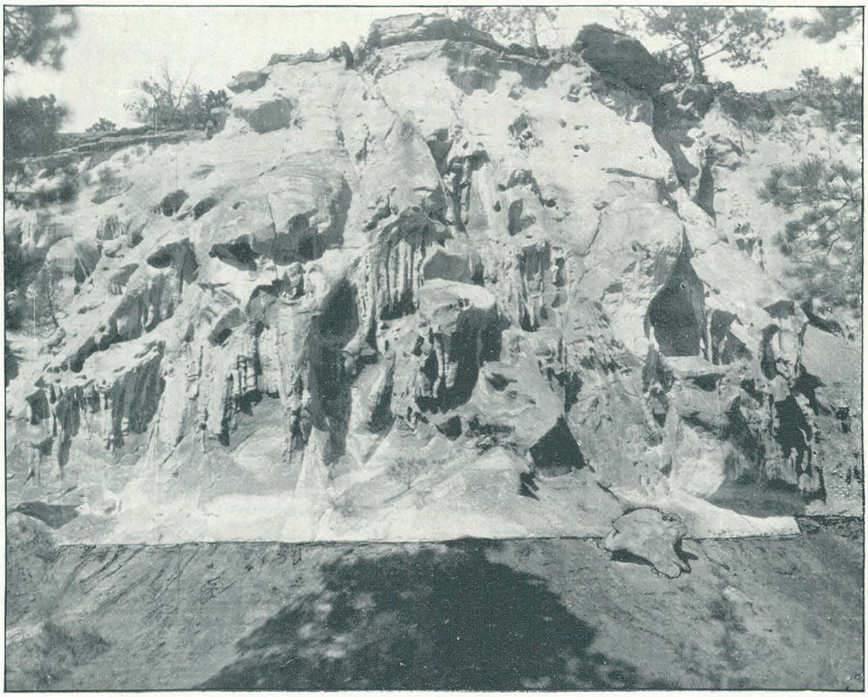
[1] Journal of Geology, Vol. II, pp. 250–266; and Nineteenth Ann. Rept. U. S. Geol. Survey, Part II, pp. 521–958.

[2] Jurassic formation of the Black Hills of South Dakota, by N. H. Darton: Bull. Geol. Soc. America, Vol. X, December, 1899, pp. 383–396.



A. SUNDANCE SANDSTONE ON SPEARFISH RED BEDS, 6 MILES WEST BY NORTH FROM MINNEKAHTA, SOUTH DAKOTA.



B. WIND-CARVED SUNDANCE BASAL SANDSTONE ON SPEARFISH RED BEDS, 7 MILES SOUTH OF HOT SPRINGS, SOUTH DAKOTA.

Fossils of the Sundance formation.

Ammonites cordiformis.	Pleuromya newtoni.
Ammonites henryi.	Protocardium shumardi.
Astarte fragilis.	Psammobia prematura.
Astarte inornata.	Pseudomonotis curta.
Asterias dubium.	Pseudomonotis orbiculata.
Avicula mucronata.	Rynchonella gnathophora.
Belemnites densus.	Rhynchonella myrina.
Camptonectes bellistriatus.	Saxicava jurassica.
Camptonectes extenuatus.	Tancredia æquilateralis.
Dosinia jurassica.	Tancredia bulbosa.
Gervillia recta.	Tancredia corbuliformis.
Grammatodon inornatus.	Tancredia inornata.
Lingula brevirostris.	Tancredia postica.
Lioplacodes veternus.	Tancredia warrenana.
Myacites nebrascenis.	Thracia arcuata.
Mytilus whitei.	Thracia sublevis.
Neæra longirostra.	Trapezium bellefourchensis.
Ostrea engelmanni.	Trapezium subequalis.
Ostrea strigilecula.	Trigonia conradi.
Pecten newberryi.	Unio nucalis.
Pentacrinus asteriscus.	Valvata scabrida.
Pholodomya humilus.	Viviparus gilli.
Planorbis veternus.	Volsella pertenuis.

The stratigraphic variations of the formation were traced with care, but the vertical distribution of the fossils has not as yet been determined. Certain members of the formation are of general occurrence, and there are others which are less persistent. The succession of a lower dark shale, a slabby, buff, ripple-marked sandstone next above, a reddish, sandy shale, and an upper green shale with fossiliferous limestone layers is continuous over a wide area. At the base of the formation there is often a massive red or buff sandstone occurring in extended lenses and frequently attaining a thickness of 25 feet. In the sandy layers at the base of the lower shales, near Hot Springs, fossil fish occur in small number. These have been described by Dr. Eastman.[1] The location is about 1 mile east-southeast from the Union railroad station, or one-half mile south of the Catholicon Springs Hotel, in a small draw which heads in the sandstone ridge lying east of the Red Valley. The succession at the fish locality is as follows:

Section near Catholicon Springs Hotel, South Dakota.

	Feet.
Unkpapa sandstones.	
Green shales with belemnites, etc	80
Red sandy shales	80
Greenish shales and thin sandstones	8
Buff, slabby, ripple-marked sandstone	15
Limestone filled with Ostrea	10
Green shales, very sandy	21
Soft, thin-bedded sandstone, fish-bearing layer	4
Buff sand	2
Spearfish red beds.	

[1] Bull. Geol. Soc. America, Vol. X, December, 1899, pp. 397–408.

The buff sand lies on a slightly eroded surface of the red beds. To the north and to the south it thickens and becomes a conspicuous bed of red to buff sandstone. A typical contact of this member with the Spearfish red beds is shown in Pl. LXXIII. The limestone with *Ostrea* is a local lens not found elsewhere. The fish appear to occur only on the surface of one of the sandstone layers, about 10 inches above the top of the buff sand. Although extensive excavations were made, only a small lot of material was found. A fairly extended scanning of the same horizon in the vicinity revealed only an occasional fish scale.

In the immediate vicinity of Hot Springs there is considerable stratigraphic variation in the Sundance formation. The general average section is as follows:

Section near Hot Springs, South Dakota.

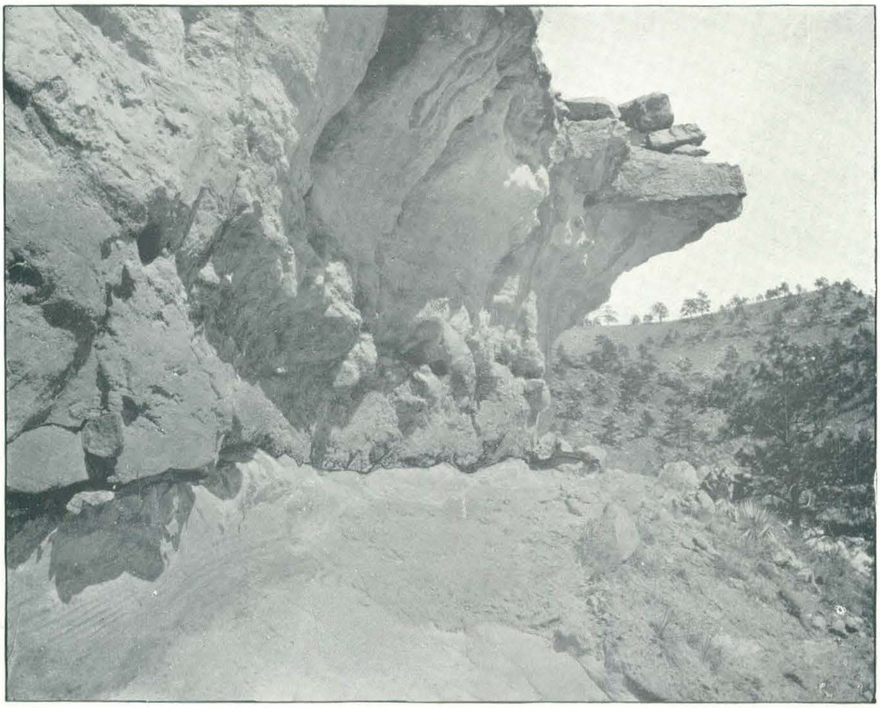
Unkpapa sandstone.	Feet.
Green shales, belemnites	90
Red sandy shales and sandstones	80
Green shales	8
Buff, slabby, ripple-marked sandstones	30
Dark shales	9
Red massive sandstone	25
Spearfish red beds.	

The fossils are very abundant both in the calcareous layers in the upper green shales and in the buff and ripple-marked sandstones. They occur in some of the other beds, but in much less number. In Buffalo Gap, where there are extensive exposures, the following beds are seen:

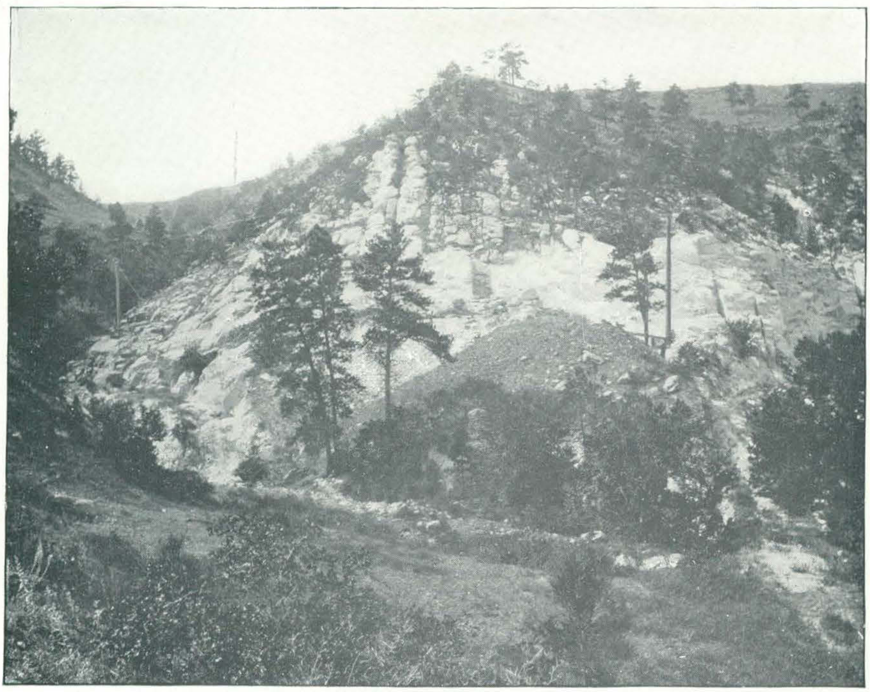
Section in Buffalo Gap, South Dakota.

Unkpapa sandstone.	Feet.
Green shales, with thin fossiliferous limestone beds	100+
Red sandy shales and soft sandstones	65
Greenish buff sandy shales and thin sandstones	15
Buff, slabby, ripple-marked sandstones	40
Pale-red, massive, soft cross-bedded sandstones	7
Purple and buff sandy clays, one-half foot of gray hard sandstone	4
Spearfish red beds.	

In the vicinity of Fuson Creek the exposures are not sufficiently continuous to afford a complete cross section. The beds outcropping are 8 feet of buff sandstone lying on the red beds and overlain by 15 feet of dark-gray shales with thin interbedded sandstones, which are succeeded by 20 feet of buff, slabby, ripple-marked sandstone. Some distance higher on the slopes there are exposed dark-green shales with abundant belemnites and other fossils in calcareous layers. The entire thickness to the base of the Unkpapa sandstone appears to be about 350 feet.



A. LAKOTA SANDSTONE LYING UNCONFORMABLY ON UNKPAPA SANDSTONE, NORTH SIDE OF SHEPS CANYON, SOUTH OF HOT SPRINGS, SOUTH DAKOTA.



B. UNKPAPA SANDSTONE NEAR HEAD OF ODELL CANYON, SOUTHEAST OF HOT SPRINGS, SOUTH DAKOTA, LOOKING WEST.

In the vicinity of Lame Johnny Creek the following section is exposed:

Section near Lame Johnny Creek, South Dakota.

	Feet.
Unkpapa sandstone.	
Buff sandstone, thin bedded below	15
Dark shales, with belemnites and other fossils	90
Buff sandstones	35
Red sandstones and sandy shales	80
Buff, slabby, ripple-marked sandstones	26+
Black shales	8
Buff sandstones	15
Dark shales	5
Red and buff massive sandstone	10
Spearfish red beds.	

In the first canyon south of French Creek, nearly due west of Fairburn, the formation is seen to be much thinner than it is elsewhere in this region, and it consists of more arenaceous materials. In the fine section on French Creek, a mile north, the formation presents more of its usual composition in the following section:

Section on French Creek, South Dakota.

	Feet.
Unkpapa sandstone.	
Red and buff soft sandstone	20
Shales, with few thin fossiliferous sandstone layers	80
Buff, soft sandstones and shales	20
Massive buff to red sandstone	30

In the canyon near the head of Dry Creek, northwest of Fairburn, the Sundance formation is represented by only 60 or 80 feet of beds, comprising green shales above and thin-bedded sandstones below, the former containing abundant fossils.

On Squaw Creek, southwest of Hermosa, the formation comprises a thin sandstone at the base, then a mass of dark shales, and a top member of buff and yellow slabby sandstone.

On Spring Creek the following features are exposed:

Section on Spring Creek, South Dakota.

	Feet.
Unkpapa sandstone.	
Buff sandstone, massive above, slabby below	25
Green shales, with three fossiliferous layers and some thin sandstones	25
Pale greenish, soft, massive argillaceous sandstone	25
Pinkish, massive soft sandstone	6
Talus	50
Buff, slabby, ripple-marked sandstone	12
Talus	20
Greenish shale	5
Buff sandstone	3
Spearfish red beds.	

The sandstone at the top of this section is a very conspicuous member for some miles on the south side of Spring Creek, and it appears to have developed out of the sandy beds which usually overlie the upper green shales to the south. It is possible, however, that it is a representative of the lower portion of the Unkpapa sandstone, which is thin in this vicinity.

Returning to the region south of Hot Springs there is found at Cascade a fairly complete section of the Sundance beds, having a thickness of 400 feet. They comprise from the top a succession of green shales with fossil-bearing layers, a considerable thickness of red sandy shales, the usual heavy bed of buff, slabby, ripple-marked sandstone, 60 feet of green shales, and a basal massive red sandstone lying on the red beds.

Along the southern margin of the uplift there are extensive exposures of the Spearfish beds, which present interesting features. The following section, made near Minnekahta Station, is typical for a wide area:

Section near Minnekahta Station, South Dakota.

Beulah shales.	Feet.
Grayish-green shales, with thin fossiliferous limestone layers	105
Red sandstone, with some red and green shales	75
Pale greenish buff thin-bedded sandstones	10
Pale grayish green shales	10
Buff, flaggy, ripple-marked sandstones	35
Gray shales	40
Red sandstone, coarse, massive, fossiliferous	25
Spearfish red beds.	

The basal red sandstone is a conspicuous member for several miles to the west, but toward Pass Creek it finally thins out and disappears. Its aspect near Red Canyon is shown in Pl. LXXIII, *A*, which shows also the contact with the red beds.

Along the western slope of the Black Hills in the vicinity of Newcastle and Cambria the Sundance formation presents the following average section:

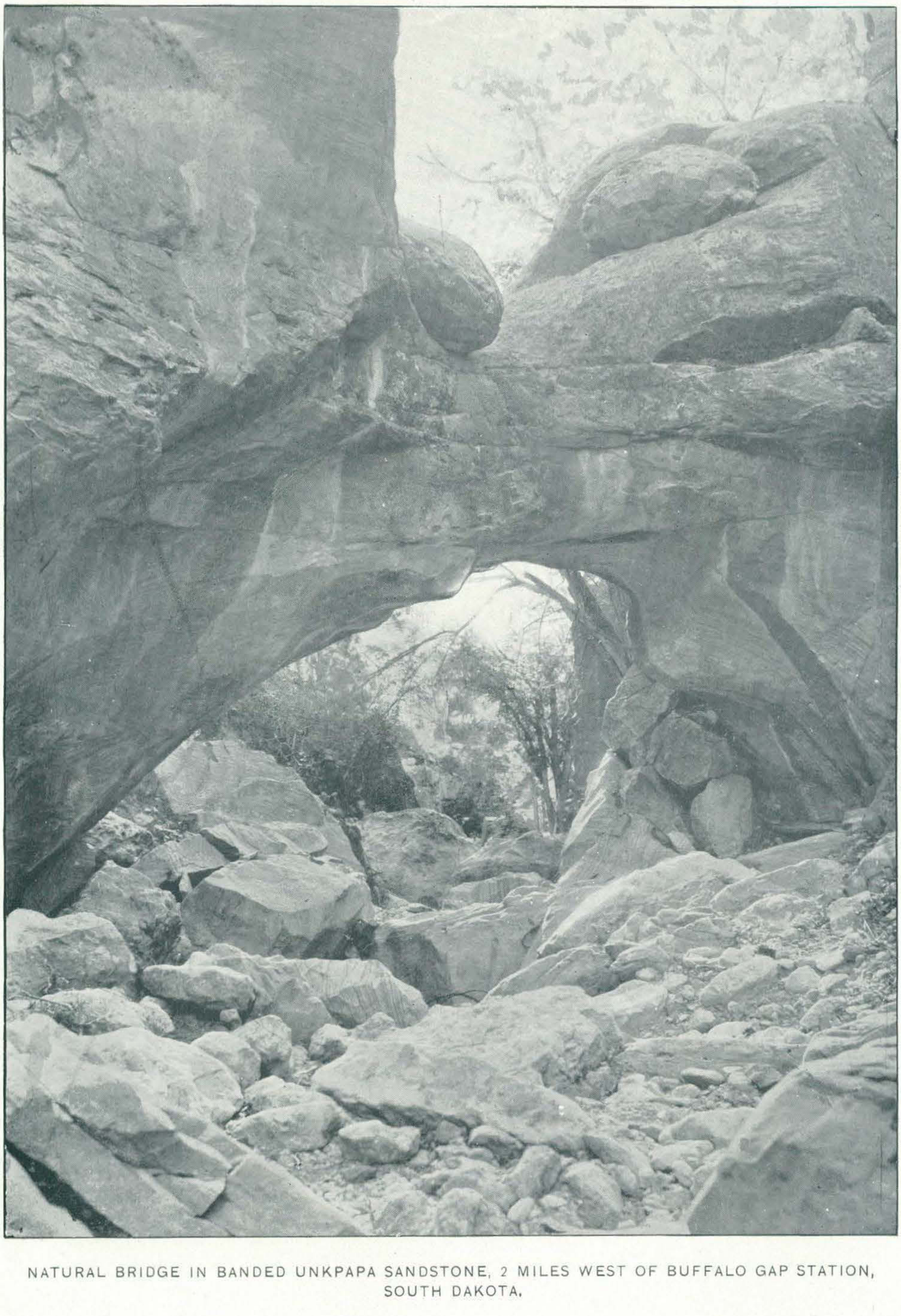
Section near Newcastle and Cambria, Wyoming.

Beulah shales.	Feet.
Greenish shales, with fossiliferous calcareous layers	120
Red, sandy shales	50
Thin sandstone and shales	25
Light-buff, slabby, ripple-marked sandstone	25
Greenish gray shales	60

These features continue far to the north, with some variations in thickness and minor changes in local included beds.

UNKPAPA SANDSTONE.

This formation is always clearly separable both from the Sundance shales below and the Beulah shales or Lakota sandstone above. It is a massive, fine-grained sandstone varying from white to purple and



NATURAL BRIDGE IN BANDED UNKPAPA SANDSTONE, 2 MILES WEST OF BUFFALO GAP STATION, SOUTH DAKOTA.

buff. Its greatest development is in the foothill ridges or hogbacks east of Hot Springs. Its first outcrops southward are observed about Cascade Springs, and it extends continuously from that region past Hot Springs, all along the eastern side of the hills, its thickness diminishing north of Buffalo Gap. Some of its exposures east of Hot Springs are very striking in their colorings of brilliant pink, purple, and pure white. The thickness is greatest in Sheps Canyon, southeast of Hot Springs, where 225 feet were measured. In three of the canyons between Fall River and Buffalo Gap it has been quarried to some extent for building stone. In Pl. LXXIV, *B*, is shown a typical outcrop of the Unkpapa sandstone, and in Pl. LXXV a natural bridge cut through the formation near Buffalo Gap. Portions of the rock are beautifully banded with various colors, in part along the stratification planes, but often diagonal to them. In the quarry west of Buffalo Gap these banded beds exhibit minute faulting in a most instructive manner, affording fine illustrations of block-fault phenomena. Pl. XCIII is from a photograph of a typical block of the faulted rock. The sandstone is characterized in general by its fine grain and very massive but uniform texture. Contacts with the overlying buff sandstones of the Lakota formation are frequently exposed, and they are seen to be marked by considerable unconformity due to erosion. One of them is shown in Pl. LXXIV, *A*. The name Unkpapa is that of one of the tribes of Dakota Indians, which was at one time located about the southeastern portion of the Black Hills.

BEULAH SHALES.

This Jurassic member has been designated the Atlantosaurus beds by Marsh and others, but recently Mr. W. P. Jenney,[1] in describing some of the overlying formations in the northern hills, has named it the Beulah shales. It is this member that has yielded the remains of a number of large saurians, collected for Professor Marsh on the north side of Piedmont Butte. The formation was regarded by Marsh as unquestionably Jurassic in age, a view which has been generally accepted. The Beulah shales first make their appearance northwest of Hermosa, lying between the Unkpapa sandstone and the Lakota formation. They thicken rapidly in their extension northward, and pass around the northern and western side of the hill as a prominent member of the series. Beyond the edge of the Unkpapa sandstone they lie conformably upon the Sundance formation, and, owing to the similarity of materials, might not be readily separated if their true relations had not been determined on the east side of the uplift. They finally thin out north of Edgemont. The formation is mainly composed of a dark shale, much more fissile and darker to the east than to

[1] Nineteenth Ann. Rept. U. S. Geol. Survey, Part II, p. 593.

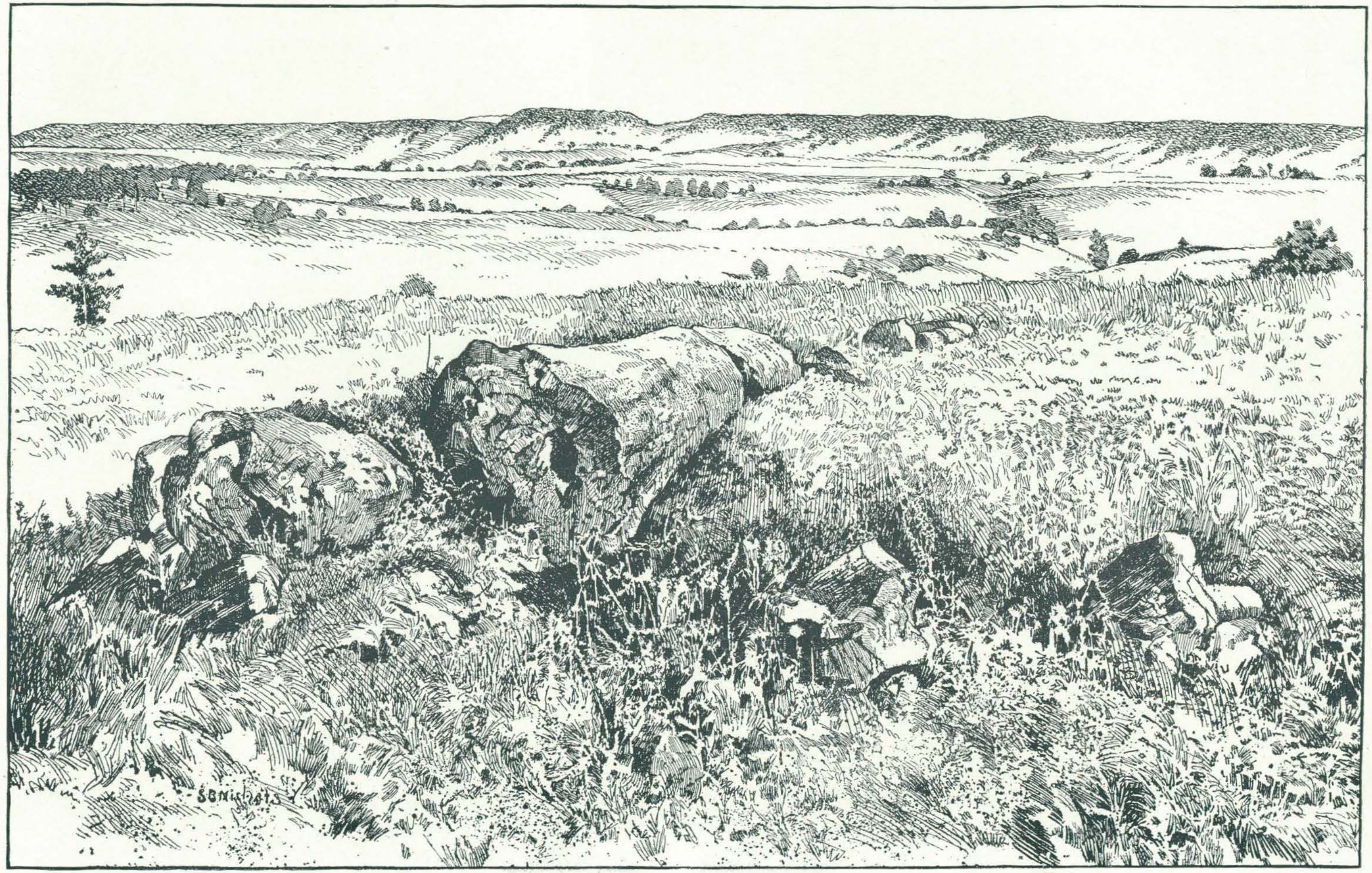
the north and west. From Sundance to Cambria and Minnekahta it is a light greenish gray, somewhat massive mixture of clay and sand, moderately hard, but crumbling more or less on weathering. In this area some of the beds exhibit purple tints. A few thin sandstone beds are included throughout.

CRETACEOUS.

All of Cretaceous time appears to be represented by the deposits in the region adjoining the Black Hills. The Lakota formation, if not of late Jurassic age, represents the earliest deposit of the Lower Cretaceous, while the uppermost members of the Laramie formation are generally regarded as extending to the end of the Cretaceous period. The deposition appears to have been essentially continuous throughout, for there are no important unconformities that are general over the entire region. The Fox Hills sandstones may possibly thin out to the northwestward, but this would not necessarily indicate either an uplift or a cessation of deposition, but probably a change from salt-water to fresh-water deposition. There are some suggestions of a possible time break at the top of the Dakota sandstone in the sudden change from sandstone to shale, and in the Lakota formation there are local unconformities probably indicating short periods of local uplift. The total thickness of the Cretaceous formations about the Black Hills is at least 5,000 feet, this estimate including a large portion of the Laramie formation. All of the formations are uplifted by the Black Hills dome, often to steep angles. The individual formations in greater part present the same features which they have over many thousand square miles in the Rocky Mountains and adjoining regions, particularly the Benton, Pierre, and Niobrara formations. The sandstone series formerly designated "the Dakota sandstone" or "Cretaceous No. 1," has in the last few years been found to comprise not only a formation carrying an Upper Cretaceous flora but an extensive series of Lower Cretaceous deposits as well. Accordingly, the term Dakota has been restricted to the upper sandstone, containing the Upper Cretaceous flora, while the much thicker lower series has been separated as Lower Cretaceous, and as it consists of several stratigraphic units these will here be differentiated as separate formations. The name Dakota will be restricted to the upper sandstones of which the upper beds have yielded plants of the well-known typical Dakota flora.

LAKOTA FORMATION.

This formation, which consists mainly of sandstone, gives rise to the crest and broader features of the hogback ranges forming the outer encircling rim of the Black Hills. It is also brought to the surface in the steep anticline on Old Woman Creek. The sandstones are hard, coarse grained, cross bedded, and massive, with partings of shale of



FOSSIL TREE TRUNK ON LAKOTA SANDSTONE, 3 MILES SOUTHWEST OF MINNEKAHTA, SOUTH DAKOTA.

no great thickness. Locally it includes beds of coal, which about Cambria and on Hay Creek are mined to some extent. Its thickness is usually from 200 to 300 feet, with certain local variations, most of which are shown in Pl. LXVI. Throughout its course it lies unconformably on the Jurassic Beulah shales to the north and west and on the Unkpapa sandstone to the east and south. The amount of unconformity is not known and the period of uplift it represents was not one of flexing of sufficient amount to give rise to any material discordance in dip. A typical exposure of the unconformity is represented in Pl. LXXIV, *A*. In this view may be seen irregularities on the surface of the Unkpapa sandstone, clearly due to channeling in the pre-Lakota interval. The name Lakota is derived from one of the tribal divisions of the Sioux Indians. It was first used in the later part of 1899 in my preliminary account of the Jurassic formations of the Black Hills.[1]

The formation has yielded a large number of cycads, notably those described by Mr. Lester F. Ward.[2] These and the associated plants are regarded by Mr. Ward as Cretaceous in age. In 1898 I discovered saurian bones in or near the cycad horizon at Buffalo Gap, but as they are of new species it is difficult to obtain from them any evidence bearing on the age of the formation. If it were not for the evidence of the flora, these bones would be regarded as late Jurassic in age. They will soon be described by Dr. F. A. Lucas, of the United States National Museum. The bone-bearing beds are in the middle of the Lakota formation, or about 90 feet above the unconformity on the Unkpapa sandstone, which is at approximately the horizon that has yielded cycads in the region between Edgemont and Minnekahta, near Blackhawk, and elsewhere about the hills.

Throughout its course the Lakota formation presents predominantly the features above described, but there are frequent local variations in the thickness of the beds and in the occurrence of intercalated fine-grained members. In the canyon of Fall River the formation has a thickness varying from 225 to 250 feet. The beds of sandstone are very massive, but they are separated by greenish-gray shales 15 to 20 feet thick at several horizons. The uppermost member, a dull yellow sandstone, is immediately overlain by the Minnewaste limestone, of which the relations are shown in Pl. LXXVIII. This view represents a fine exposure just west of Evans's quarry, near the mouth of the canyon. It exhibits the greater part of the Lakota formation, the Minnewaste limestone, with a steep slope of Fuson beds overlain by talus, and a thick capping of massive buff sandstone of the Dakota formation, which is worked near by, at Evans's quarry. In the high ridges and their numerous deep canyons east of Hot Springs the Lakota formation is the prevailing feature. Many of the surfaces of the ridges are

[1] Bull. Geol. Soc. America, Vol. X, p. 387.

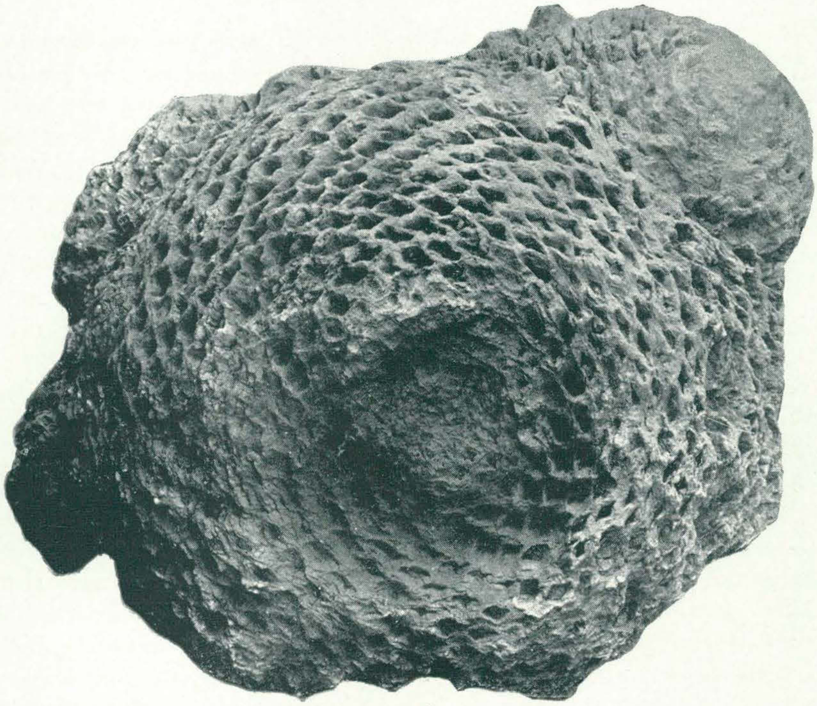
[2] Jour. Geol., Vol. II, pp. 250-266; and Nineteenth Ann. Rept. U. S. Geol. Survey, Part II, pp. 521-958.

strewn with fragments of fossil trees which have been weathered out of the sandstone. The occurrence of these trees appears to characterize a horizon high in the formation over a considerable area in the southern portion of the Black Hills. In a locality 3 miles southwest of Minnekahta, described in considerable detail by Mr. Lester F. Ward, some of these trunks are alluded to. One of the finest is shown in Pl. LXXVI. It has a diameter of nearly 3 feet at the butt, and more than 20 feet of the trunk remains. It was in the vicinity of this locality that a large number of cycads were obtained a few years ago. As these cycads are a very distinctive feature of the formation, the accompanying illustration (Pl. LXXVII) is reproduced from Ward's report. In the vicinity of Cascade Springs the Lakota and associated formations stand nearly vertical, but the exposures are not particularly good. A thickness of about 275 feet is exhibited. A short distance west, where the dips rapidly diminish, the formation spreads out into a wide table sloping to the south, with a high escarpment on the north side overlooking the wide Red Valley about Minnekahta. In this locality the formation is extensively exposed in the walls of numerous canyons which empty into Cheyenne River. This river, in cutting a gorge through the end of the anticline below Edgemont, has given an excellent exposure of the entire thickness of the formation from the underlying Beulah shales to the overlying Fuson formation. The principal members are coarse-grained, cross-bedded, massive, light-colored sandstones, here containing a number of basins of coal. That these deposits lie in shallow, eroded basins is clearly exposed in some of the cliffs of the canyon. The coal varies in thickness from a few inches to 4 feet, and occurs about 60 feet above the base of the formation. Apparently, in earlier Lakota times there was in this vicinity an uplift of the sandstone attended by some channeling of its surface, and in these channels there accumulated coal, which was buried by the subsequent deposits of sand. From here for many miles northward along the west side of the hills coal occurs at intervals, culminating in the thick deposit about Cambria. The coal basin at that place will be described on page 582. The general section there is as follows:

General section at Cambria, Wyoming.

	Feet.
Thin-bedded sandstones	20
Massive buff sandstone	40
Shale and talus	40
White sandstone with conglomerate	45
Sandstones, in part covered	65
Massive, light-gray, soft sandstone	40
Coal	7
Sandstone	10

On the wide, tabular surfaces about Cambria and northwest of Newcastle the Lakota and Dakota formations are the prevailing feature,



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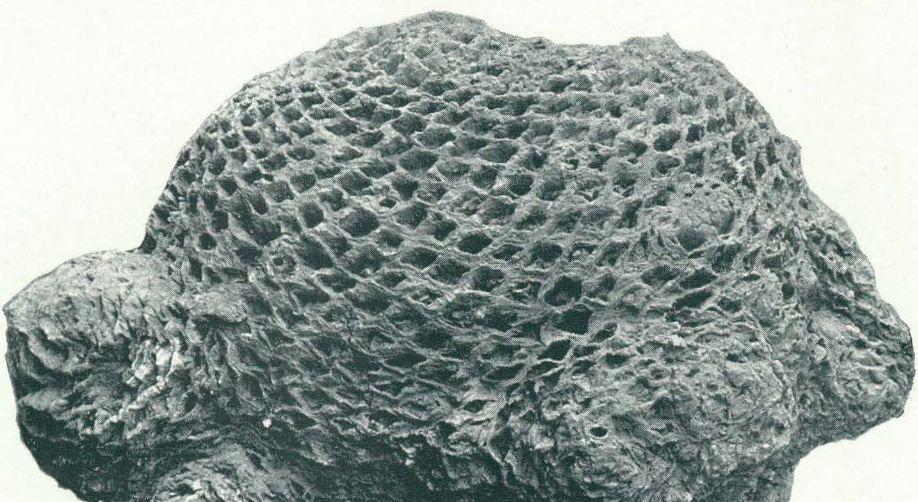

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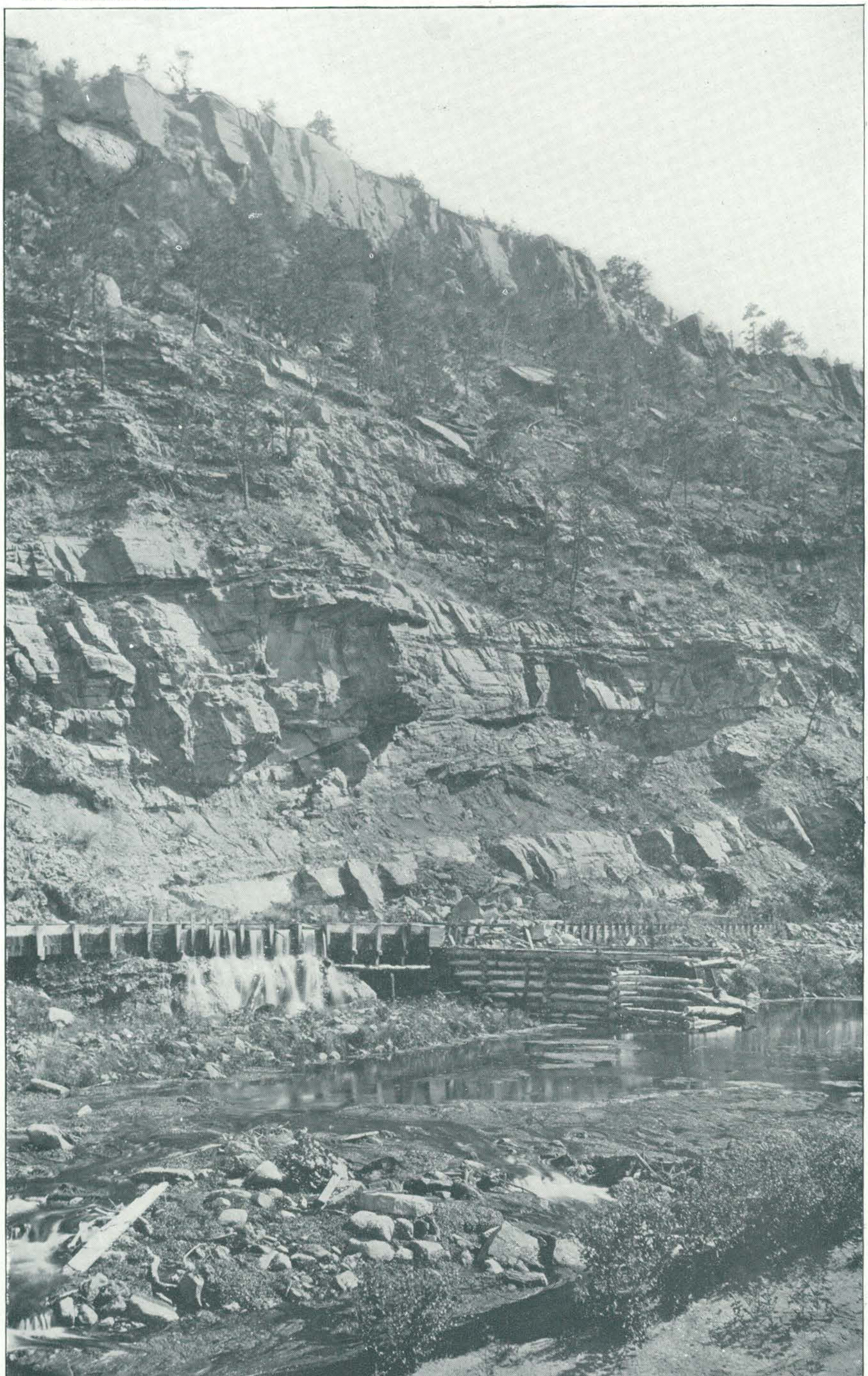
CENTIMETERS

CYCADEAN TRUNK FROM THE LAKOTA FORMATION IN THE BLACK HILLS.



DAKOTA SANDSTONE, FUSON FORMATION, MINNEWASTE LIMESTONE, AND LAKOTA FORMATION ON SOUTH SIDE OF FALL RIVER CANYON, AT EVAN'S QUARRY, 4 MILES BELOW HOT SPRINGS, SOUTH DAKOTA.

their wide extension being due to the hardness of the sandstones and the low dips. Numerous canyons traverse this plateau, cutting through the Lakota beds more or less deeply into the underlying Beulah shales. In the deep ravine behind the Mount Zion ranch the following section is exposed, beginning not far below the top of the Lakota formation:

Section near Mount Zion ranch, Wyoming.

	Feet.
Light-colored massive sandstones, with a conglomeratic layer near its base	200
Bony coal	½
Hard sandstone	3
Coal	4
Sandstone, with coaly streaks	1
Coal	2
Sandstone, with stems, etc	2
Sandstones, mainly light colored and massive	40
Beulah shales.	

In the uplift on Old Woman Creek the Lakota sandstone is clearly defined, lying between the light-colored shales of the Fuson formation above and the greenish-gray Beulah shales below. It is mainly a coarse conglomeratic sandstone, varying in thickness from 40 to 70 feet.

MINNEWASTE LIMESTONE.

This formation overlies the Lakota sandstone from the vicinity of Cascade Springs northward to Buffalo Gap. For the greater part of its course it has a thickness of only 25 feet, but it is conspicuous on the hogback ranges east of Hot Springs, extending far up the slopes on some of the higher divides. Its occurrence was not mentioned by Ward in his description of the section at Evans's quarry, where, as shown in Pl. LXXVIII, it is a conspicuous feature. It is a nearly pure light-gray limestone, presenting a uniform character throughout. An extended search has failed to detect any fossils in it, but it is supposed that it is of Lower Cretaceous age, because it lies considerably below the Dakota sandstone. The formation thins out rapidly north of Buffalo Gap, and appears to be entirely absent in the canyon of Fuson Creek. It is thin at Cascade Springs and disappears a short distance to the west, but appears again locally at the head of Bennet Canyon, east of Argentine siding. One of the most extensive exposures of the limestone is at the falls of Cheyenne River. These falls are due to this formation, the water falling over a ledge of it about 20 feet high. The name Minnewaste is the Dakota Indian name for Cheyenne River. Extensive exposures may be seen in the anticline 2 miles east of Hot Springs, where, with a steep dip to the west, it covers a wide area of the western slope of the anticlinal ridge. In the anticline on the east side of Old Woman Creek there is exposed at one point a thin layer of limestone which appears to be an extension of the Minnewaste. It lies immediately above the Lakota sandstone and is overlain in regular order by mudstones of the Fuson formation.

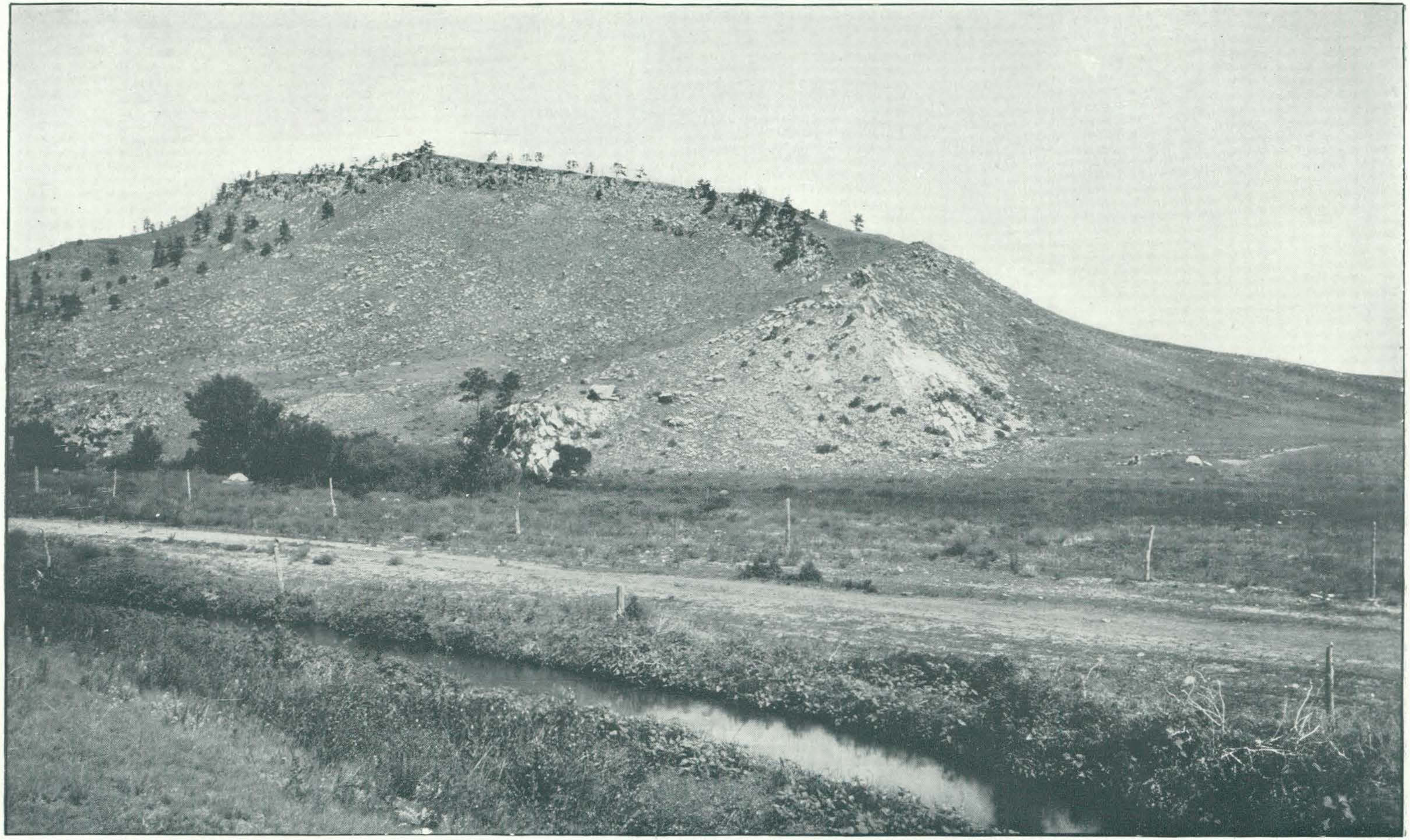
FUSON FORMATION.

This is a series of fine-grained deposits lying between the Dakota sandstone and the Lakota sandstone and nearly encircling the Black Hills. Its thickness averages about 100 feet. The material consists of a mixture of fine sand and clay, usually massively bedded and weathering out in small cylindrical blocks like dry starch. Some beds of coarser sandrock are locally included and other portions are nearly pure shale. The predominant color is white or gray, but buff, purple, and maroon tints are often conspicuous. As the formation is relatively soft as compared with the adjoining sandstones, it usually gives rise to a depression between a low crest of Dakota sandstone on the one hand and the higher summits of the Lakota sandstones on the other. No fossils have been found in the formation, so that we have no evidence as to its precise age. One of the most extensive exposures is at the falls of Cheyenne River, shown in the bluff to the left on Pl. LXXX. The section at this interesting locality is as follows:

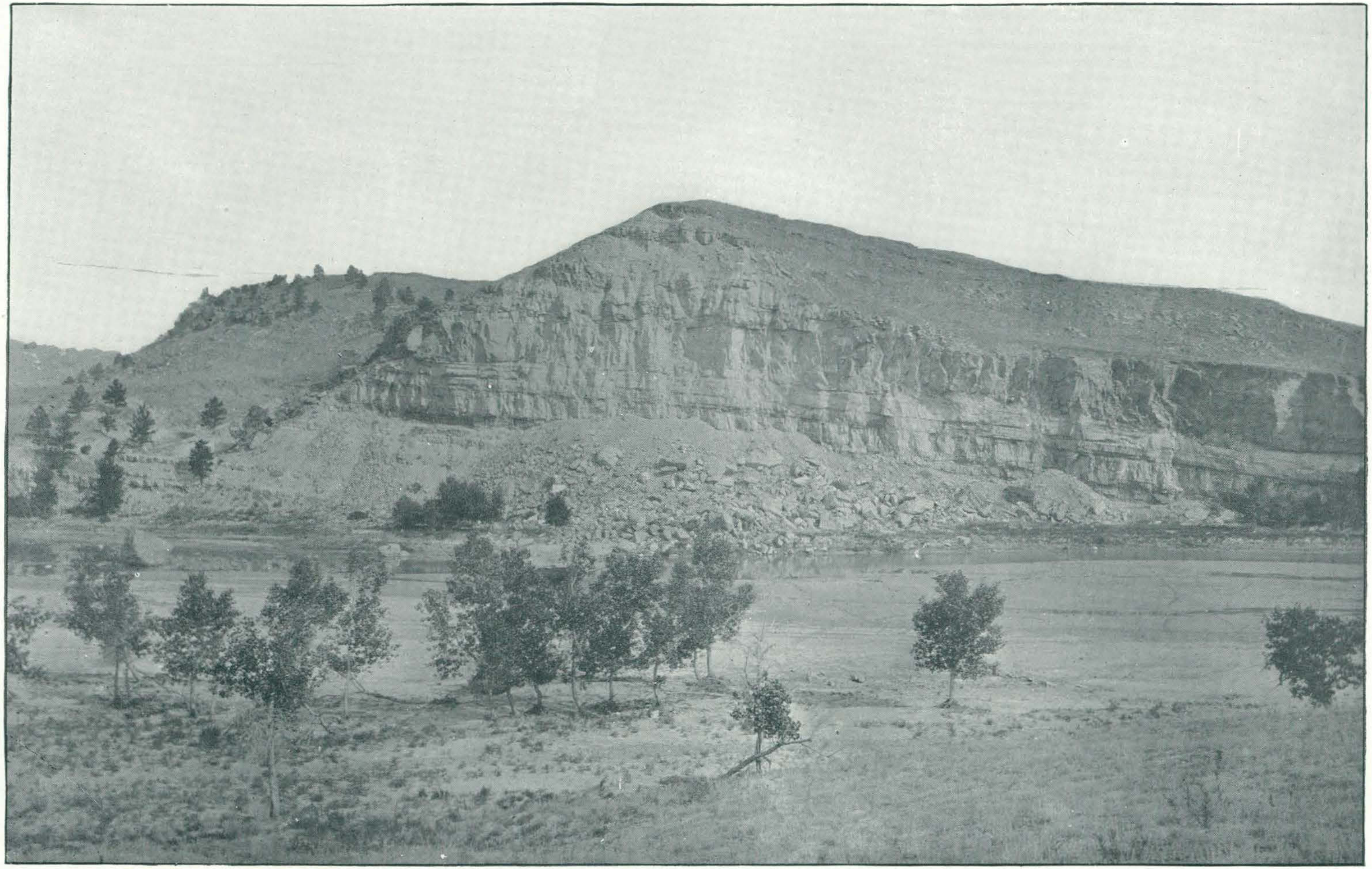
Section at falls of Cheyenne River, South Dakota.

Dakota sandstone.	Feet.
Dark sandy shale	4
Soft, gray, slabby sandstone; plants	6
Compact white mudstone	8
Dark-green clay	1
Dark-gray compact mudstone	25
Very compact white mudstone	2½
Gray mudstone	6
Harder white mudstone	9
Purplish shale	1
White fine-grained sandstone	5 to 12
Purple shale	6 to 8
Light-buff massive sandstone	25
Dark-buff coarser sandstone, much honeycombed by weathering	25
Minnewaste limestone.	

Outcrops of the formation are considerably obscured by talus along the canyon of Fall River, but there are extensive exposures in the sides of the canyons in this vicinity, notably in the canyon on the steep side of the anticline 2 miles due east of Hot Springs, where much of the material is bright purple and strongly resembles a shale which has been subjected to alteration by the presence of igneous matter. Fuson Canyon affords some striking exposures of a portion of the Fuson formation in cliffs capped by the Dakota sandstone. The uppermost bed is a moderately hard sandstone underlain by 10 feet of purplish-gray shale, then 10 feet of white mudstone and 20 feet of bright purple shale. The name of the formation is derived from that of this canyon. On Dry Creek the formation is represented by 50 feet of white mudstone. On Squaw Creek the Dakota sandstone is overlain by about 50 feet of buff and purple mudstones, grading upward to the Dakota sandstone through several feet of shale and thin sand-



DAKOTA SANDSTONE ON NORTH SIDE OF BUFFALO GAP; IRRIGATION DITCH IN FOREGROUND.



DAKOTA SANDSTONE AND FUSON FORMATION AT FALLS OF CHEYENNE RIVER, LOOKING NORTHEAST.

stone. Northwest of Hermosa mudstones of bright color prevail, much of the material being purple. One section exhibits the following components:

Section northwest of Hermosa, South Dakota.

	Feet.
White and dark mudstones	20
Buff massive sandstone	0–10
Gray clay	3
Light-buff thin sandstone	3
Sandy light-gray shale	18
Soft white sandstone	0–20
Mottled purple mudstone	30

The Fuson formation extends around the southern and western side of the hills, but north of Elk Mountain it becomes thinner and often so sandy as to be difficult to distinguish from the Dakota sandstone. In a section on Cheyenne River northeast of Edgemont the following measurements were made by Mr. Richardson:

Section of Fuson formation on Cheyenne River northeast of Edgemont, South Dakota.

	Feet.
Purplish mudstone	3
Greenish mudstone	4
Drab mudstone	3
Calcareous mudstone	1½
Dark mudstone	3½
Purple mudstone	1
Dark shale	1
White cherty limestone	1½

The Fuson mudstones are brought to the surface by the anticline on the east side of Old Woman Creek, where the material is mainly gray and has a thickness of about 60 feet.

DAKOTA FORMATION.

This formation is the uppermost member of the series formerly designated, in the Black Hills region, the Dakota sandstone. It is thin, being rarely over 100 feet thick, and constitutes only a small part of the mass of the hogback range. It is, however, a conspicuous formation, because the foothills to which it usually gives rise slope steeply out of the adjoining valley or level plain underlain by the Graneros shales. It generally consists of a brown sandstone, hard and massive below but thinner bedded above. It appears to extend continuously around the hills. The fossil plants which have been obtained from it are impressions of dicotyledonous leaves occurring in the upper portion of the formation. Prof. L. F. Ward has described their occurrence at Evans's quarry, east of Hot Springs, South Dakota. Some aspects of the Dakota sandstone are shown in Pls. LXIV, LXXVIII–LXXX. The more massive variety of the rock is shown in Pl. LXXVIII, at the top of the cliff. Here the dip is steep and soon carries the formation down to the floor of the canyon, where it gives rise to a series of cascades in the bed of Fall River. This is the ledge that is worked extensively for building stone at the quarries adjoining the cascades, and furnishes the grindstones at Edgemont.

GRANEROS SHALE.

This shale is the lowest member of the Benton group, and it is believed to be the precise equivalent of the Graneros shale of southeastern Colorado, for it lies between the Dakota sandstone and a very characteristic limestone layer which in both regions is filled with impressions of the same *Inoceramus*. It extends entirely around the Black Hills uplift, with a course usually marked by lowlands and valleys all the way. In some areas it contains, near its base, a thin layer of hard sandstone which often rises in a ridge of considerable prominence. This sandstone is a noticeable feature in the vicinity of Newcastle, where it contains petroleum and has been explored as an oil sand. It there attains a thickness of 30 feet and lies 275 feet above the Dakota sandstone. To the north, in the vicinity of Pedro, it thins to less than a foot in thickness, and in the vicinity of Edgemont it disappears. In the Newcastle region it is overlain by 600 feet of black shales, constituting the remainder of the formation which here, consequently, has a total thickness of 900 feet. The formation thins slightly toward Edgemont, but to the northeast its thickness is about 900 feet, and, so far as could be ascertained from numerous cross-section measurements, with rather uncertain dip determinations, this amount continues uniform for many miles. These measurements may be in error a hundred feet either way. West of Hermosa the sandstone again comes in about 200 feet above the base of the formation and attains a thickness of about 15 feet, being traceable for about 4 or 5 miles and then thins out again. At a point 2 miles north of Hermosa the sandstone contains abundant impressions of fossil leaves.

At several localities the Graneros shale is traversed by sandstone dikes. The first of these is at the southern end of the anticline east of Maitland, where dikes from the underlying Dakota sandstone extend for some distance through the lower beds of the shale. The largest of the dikes at this locality is 20 feet wide. The dikes have a linear arrangement occurring in a narrow zone about a mile in length having a north-northeast-south-southwest direction. Several small dikes are observed in the shale on the north bank of Cheyenne River a little more than a mile southeast of Evans's quarry. Another group of them may be seen north of Lame Johnny Creek, 7 miles north of Buffalo Gap.

GREENHORN LIMESTONE.

One of the most prominent features in the plains immediately adjoining the Black Hills is a low but distinct escarpment due to a hard limestone bed in the middle of the Benton group. It usually lies from a mile to 4 miles distant from the hogback ridge of the Dakota sandstone and presents its face toward the hills. The limestone is thin but persistent and is characterized by large numbers of impressions of *Inoceramus labiatus*, which is of infrequent occurrence in the adjoining formations. As this limestone occurs at apparently the same horizon about the Black Hills as in southeastern Colorado, I have applied to it the name Greenhorn, by which it has been designated by Mr. Gilbert in the Pueblo region.

The Greenhorn limestone contains a considerable amount of clay and fine sand. It appears to gain hardness on weathering, breaking out into hard, thin, pale-buff slabs covered with impressions of the distinctive fossil. (See Pl. XCVIII.) Its thickness averages about 50 feet. At its base it is usually distinctly separated from the dark shales of the Graneros formation. The upper portion of the limestone appears to grade into shales of the Carlile formation through 6 or 8 feet of passage beds. The most extensive exposures of the Greenhorn limestone are in the prominent escarpments west and northwest of Edgemont, where they rise high above the slopes extending up from the west side of Cheyenne River. Owing to the low dip in this vicinity the limestone is spread out in plateaus extending back for some distances from the edge of the escarpment. In Weston County, Wyoming, where the dip soon increases in amount, the escarpment ceases, giving place to a small but very persistent ridge of nearly vertical beds, which continues for many miles to the north. In the ridge south of Newcastle there is a local diminution of dip in which the formation again spreads out into a narrow sloping plateau for a few miles. In the region about Fairburn the formation is traversed by a syncline which spreads it out into a bifurcated ridge south of the town. On the adjoining divides, notably in those between French Creek and Battle Creek and Battle Creek and Spring Creek, the formation is buried beneath the overlapping White River deposits. It is well exposed in the banks of Battle Creek 1½ miles below Hermosa, where in its but slightly weathered condition in the fresh stream cut it is seen to be a hard, calcareous, light-gray shale filled with inocerami.

CARLILE FORMATION.

The series of shales, with thin sandstone and impure limestone layers, lying between the Greenhorn limestone and the Niobrara chalk is so similar in character and relations to the deposits occupying the same position in southeastern Colorado that it is here designated by the term which was applied to it by Mr. Gilbert in the Pueblo region. The formation consists mainly of shales, with two thin hard beds of sandstone, the upper one calcareous, and at the top several layers with oval concretions. The thickness varies from 500 to slightly over 700 feet, the larger amount being in the region about Newcastle. Some typical sections are as follows:

Section of Carlile formation near Buffalo Gap, South Dakota.

	Feet.
Niobrara chalk.	
Shales, with large buff concretions	150
Hard, slabby sandstone	2
Gray shale	130
Thin, coarse sandstone	4
Gray shale	75
Concretions in gray shale	2
Gray shale	40
Calcareous beds, with Ostrea, etc	4
Shale and talus	180
Greenhorn limestone.	

Section of Carlile formation 1½ miles southeast of the falls of Cheyenne River, South Dakota.

	Feet.
Niobrara chalk.	
Gray shale, with large buff concretions	50
Gray shale	70
Light-gray sandstone	4
Dark-gray shale, with thin sandy layers	160
Sandstone	2
Gray shales	150
Greenhorn limestone.	

Section of Carlile formation 3 miles west of Newcastle, Wyoming.

	Feet.
Niobrara chalk.	
Dark shales, with light-colored concretions	130
Dark shales	200
Calcareous concretions	3
Sandy shales, with thin sandstones	170
Brown sandstone	4
Dark shales	200
Greenhorn limestone.	

Section of Carlile formation north of Pedro, Wyoming.

	Feet.
Niobrara chalk.	
Drab shales, with numerous concretions near top	550
Thin-bedded sandstone	5
Shale	30
Sandstone, drab below, reddish above	30
Dark shale	50
Thin-bedded, light-brown sandstone	35
Gray shales	90
Greenhorn limestone.	

The thickening of the sandstones in this section is due mainly to intercalations of sandy shales.

The stratigraphy of the Carlile formation in the uplift on Old Woman Creek presents the usual features above described. They are set forth in detail in fig. 283.

NIOBRARA FORMATION.

The calcareous deposits of the Niobrara formation completely encircle the Black Hills, presenting their distinctive features throughout the region to which this report relates. The material is a soft, shaly limestone or chalk, containing greater or less admixture of clay and fine sand. Its weathered outcrops have a bright-yellow color which usually renders them conspicuous, although, owing to the softness of the materials, they rarely give rise to noticeable ridges. The thickness of the formation is about 225 feet. In unweathered exposures the material is usually light gray. Thin beds of hard limestone are often included, consisting of an aggregation of shells of *Ostrea congesta*, a fossil very distinctive of the formation when it occurs in this manner. (See Pl. XCVIII.)

PIERRE SHALE.

Many thousand square miles of the country adjoining the Black Hills are occupied by the Pierre shale. It is a thick mass of dark-colored shale, weathering light brown, and relatively uniform in composition throughout. It gives rise to a dreary monotony of low, rounded hills, sparsely covered with grass and not very useful for agriculture. The formation is about 1,200 feet thick, so far as can be ascertained, but it is only rarely that its thickness can be measured. Where it dips gently away from the hills it is almost impossible to measure the rate of dip of the shale. Fortunately it has been found that the formation includes, at a horizon about 1,000 feet above its base, scattered lenses of limestone usually containing numerous shells of *Lucina occidentalis*. The greater number of these lenses occur at the definite horizon just mentioned, and as in some places they occupy the surface over a wide area, they throw light on the structure of the formation. It is from evidence of this sort that we have made some of the determinations of structure which afford an important part of the data for Pls. XCVI and XCVII. The limestone lenses with *Lucina* vary in size from 2 or 3 cubic feet to masses 20 feet in diameter and 6 or 8 feet thick, usually of irregular lens shape. A typical occurrence of one of these lenses in a bank of shale is shown in Pl. LXXXI, *B*. Owing to their hardness these lenses when they are uncovered by erosion give rise to low conical buttes resembling in form a very squat tepee. Accordingly they have been designated tepee buttes, a term used by G. K. Gilbert for similar occurrences in the Pierre shale of southeastern Colorado.[1] They occur in large numbers in the vicinity of Oelrichs, varying in height from 10 to 150 feet above the surrounding slopes. The lenses occur at irregular intervals horizontally, so that the Tepee buttes are scattered very irregularly and are sometimes separated by many miles. They occur in considerable number west and southwest of Newcastle. Some are shown in Pl. LXXXI, *A*. The occurrence of these tepees in some of the steeply tilted sections of the Pierre and underlying formations in Converse and Weston counties, particularly

[1] Tepee buttes, by G. K. Gilbert and F. P. Gulliver: Bull. Geol. Soc. America, Vol. VI, pp. 333-342, Pl. XVII.

near Old Woman Creek, has afforded opportunity for determining the distance of the horizon above the base of Pierre shales. Numerous concretions occur in the Pierre shales at various horizons and usually contain large numbers of very distinctive fossils, of which the more abundant are of the following species: *Baculites compressus*, *Inoceramus sagensis*, *Nautilus dekayi*, *Placenticeras placenta*, *Heteroceras nebrascense*, and an occasional *Lucina occidentalis*. The most fossiliferous horizon is in the upper part of the formation. The concretions are generally of small size, of a siliceous nature, and break into small pyramidal fragments which are more or less scattered over all the Pierre surfaces. At the base of the formation, overlying the Niobrara chalk, there is always a very distinctive series of black, splintery, fissile shales containing three beds of concretions, which I have included in the Pierre shales, although they have not yet been found to contain distinctive fossils. The series is about 150 feet thick, and it gives rise to a steep slope that often rises conspicuously above lowlands eroded in the Niobrara chalk. The concretions exhibit a curious sequence. The lower ones are biscuit shaped, hard, and siliceous. Those in the layers next above are similar in shape and composition but are traversed in every direction by deep cracks filled with calcite and sometimes scattered crystals of barite. Next above are two or three layers of large, lens-shaped, highly calcareous concretions of a light straw color, with beautifully developed cone-in-cone structure.

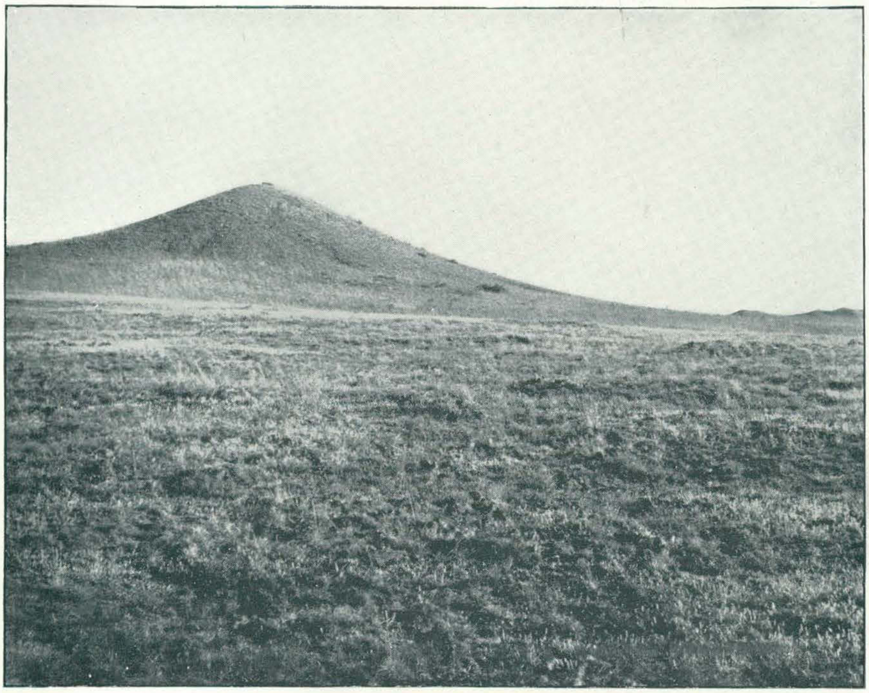
FOX HILLS AND LARAMIE FORMATIONS.

These formations occupy a vast area of the plains adjoining the Black Hills in all directions except to the east and southeast. They approach nearest to the hills in the eastern portion of Weston and Converse counties, Wyoming, where they occupy several hundred square miles of the area to which this report relates. It is from the Laramie formation in this district that Hatcher and Marsh obtained the large collection of remains of Ceratopsidæ in deposits which have been designated locally[1] the Ceratops beds. These Ceratops beds extend northward from Buck and Lance creeks into Weston County. They have been described by Hatcher,[2] and by Stanton and Knowlton,[3] who have shown conclusively, from faunal, floral, and stratigraphic evidence, that they are of Laramie age. The underlying Fox Hills formation is fully characterized by its distinctive marine fauna, and the overlying beds are found by Knowlton to contain a typical Fort Union flora. The precise boundary between the Ceratops beds, or

[1] The skull of the gigantic Ceratopsidæ, by O. C. Marsh: Am. Jour. Science, 3d series, Vol. XXXVIII, pp. 501-606, Pl. XII, 1889.

[2] The Ceratops beds of Converse County, Wyoming, by J. B. Hatcher: Am. Jour. Science, 3d series, Vol. XLV, pp. 135-144, 1893. Some localities for Laramie mammals and horned dinosaurs, by J. B. Hatcher: Am. Naturalist, Vol. XXX, pp. 112-120 and map, 1896.

[3] Stratigraphy and paleontology of the Laramie and related formations in Wyoming, by T. W. Stanton and F. H. Knowlton: Bull. Geol. Soc. America, Vol. VIII, pp. 127-156, 1897.



A. TYPICAL TEPEE BUTTES, DUE TO LIMESTONE LENS, WITH LUCINA OCCIDENTALIS, IN PIERRE SHALE, VALLEY OF BEAVER CREEK, WEST NEWCASTLE, WYOMING.

B. LENS OF LIMESTONE, WITH LUCINA OCCIDENTALIS, IN PIERRE SHALE, NEAR CHEYENNE RIVER, 5 MILES SOUTHEAST OF BUFFALO GAP, SOUTH DAKOTA.

Laramie formation, and the Fox Hills has not yet been ascertained, but on the map (Pl. LXV) the approximate line has been represented at the top of the deposits which have yielded a marine fauna. In the Laramie formation this includes a series of sandstones and shales of no great thickness, in which no fossils have been discovered, but which appear more closely allied to the well-defined Ceratops beds above than to the Fox Hills below.

The Fox Hills formation in Converse and Weston counties, Wyoming, presents an alternation of slabby sandstones and sandy shales, apparently in conformable succession to the Pierre shale. The sandstones give rise to an escarpment which faces eastward, overlooking the lower lands of the Pierre, Niobrara, and Benton formations. It is about 15 miles distant from the foothills of the Black Hills at Newcastle and through Weston County, but lies much farther west in Converse County, as the hogback range bears to the southeast.

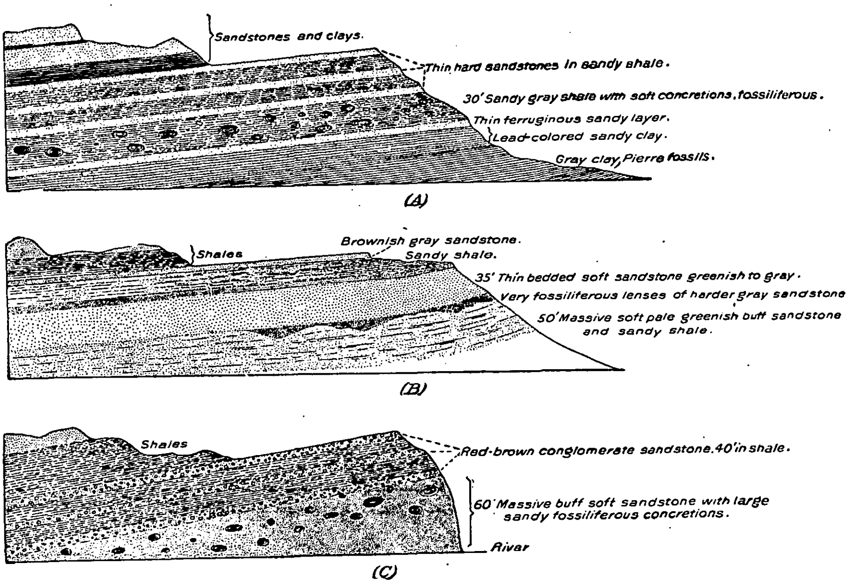


FIG. 277.—Sections of Fox Hills escarpment in Weston and Converse counties, Wyoming. A, southwest of Newcastle; B, west of Clifton; C, on Cheyenne River.

The escarpment has a height of from 150 to 200 feet in greater part, comprising lower slopes of Pierre shale, a gray sandstone or sandy shale series in the middle slopes, and a capping of three thin but hard beds of slabby sandstone intercalated in sandy shales. The sandstones or sandy shales next above the Pierre shales usually contain large, faintly defined concretions, due to local increase of lithification, and they carry abundant fossils, mainly *Veniella*. The thickness is from 250 to 500 feet.

The sections given in fig. 277 illustrate the principal features of the formation in southern Weston and northern Converse counties.

The members as shown in A thin somewhat to the north, but they retain their thickness southward. The sandy shales under the series containing the thin sandstone layers become thicker and more sandy to the south, where they are finally represented by the lower member exhibited on Cheyenne River (C). Here also the upper thin sandstones become bright red-brown and in part conglomeratic with small quartz pebbles. These two members are finely exposed in the north bank of Cheyenne River just below the mouth of Lance Creek, where the massive sandstone outcrops in high cliffs capped by the red conglomeratic beds, all profusely fossiliferous. A portion of these cliffs is shown in Pl. LXXXII. The dip is to the west at a moderate angle. Across the river the amount of dip increases and the red sandstone outcrops as a monoclinal ridge of some prominence, which continues far to the south, crossing Old Woman Creek 5 miles above its mouth and extending along the west side of the Old Woman Valley for 10 miles. In this region the dip changes abruptly to a pitch to the northwest, causing the ridge to trend off to the west, and giving rise to an escarpment on the divide between Buck and Old Woman creeks, and to the "narrows" in Buck Creek Valley.

Next above the sandstones of the Fox Hills escarpment and ridge

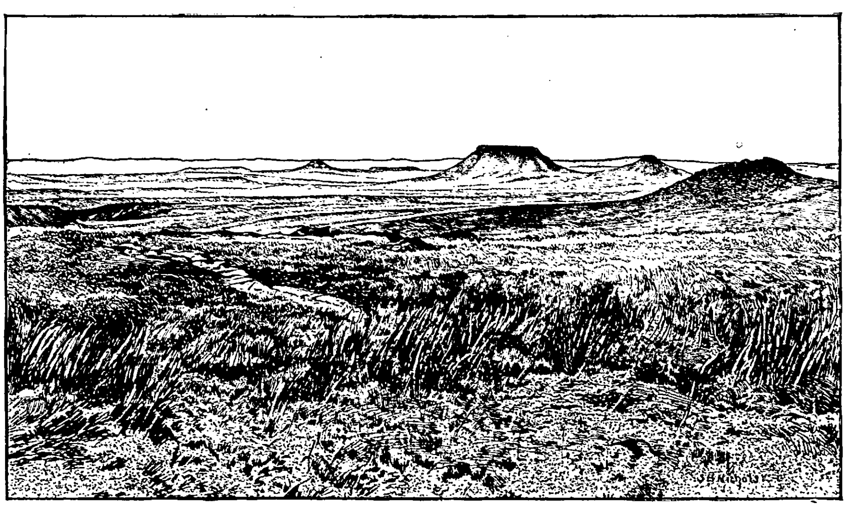
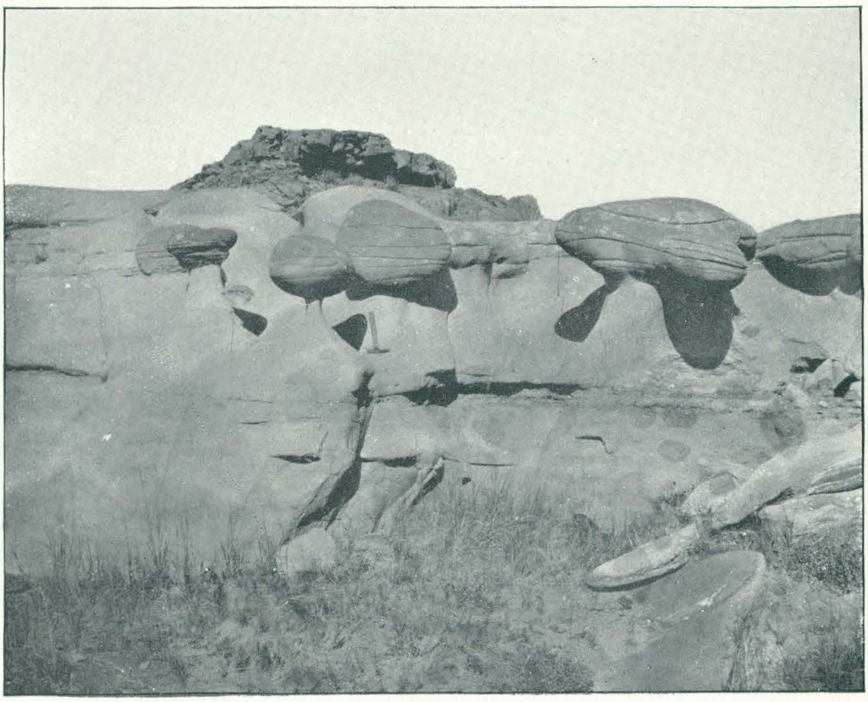


FIG. 278.—Alkali Butte, Weston County, Wyoming, from the southeast.

are slopes of sandy shales surmounted by high hills of the succession of sandstones and shales constituting the Ceratops beds. These deposits alternate through a series several thousand feet thick, the component beds varying greatly in thickness and extent. No stratigraphic order of beds has yet been detected, and none of the strata are continuous for any great distance. Sandstones predominate, consisting mainly of fine-grained, loosely cemented beds of light-buff color, often

A. FOX HILLS SANDSTONE ON NORTH SIDE OF CHEYENNE RIVER, JUST BELOW MOUTH OF LANCE CREEK, CONVERSE COUNTY, WYOMING.



B. CONCRETIONS IN SOFT LARAMIE SANDSTONE, 20 MILES SOUTHWEST OF NEWCASTLE, WYOMING.

having a thickness of 40 feet. They contain very characteristic concretions of gray color and great variety of shapes. The material is simply the sand of the soft sandstone, locally lithified to increased hardness and slightly darkened. The sizes vary from a few inches to many feet. The forms are usually elongated, with rounded outlines, but spherical and lens-shaped concretions abound. In Pl. LXXXII, *B*, some representative forms are shown. Shales occur interbedded among the sandstones of the Laramie formation and are often 30 to 50 feet thick. They are usually of dark-gray color and in places lignitic. Coal was not observed in the area to which this report relates, but it is found extensively to the north and west.

Alkali Butte is one of the most prominent features in the Laramie area of Weston County. Its aspect is shown in fig. 278. It is a landmark for many miles to the east, but it is found to be only 200 feet high above the adjoining rolling hills. It exposes the following section:

Section at Alkali Butte, Weston County, Wyoming.

	Feet.
Light-brown sandstone, hard	20
Light-buff, massive sandstone, coarse but soft	50±
Brownish buff, massive sandstone, with a few large, irregular concretions	20
Dark, sandy, and lignitic clays, with thin sandstone partings	60±
Hard, brown sandstone	3
Soft, massive sandstone	25±
Hard, brown sandstone	2
Light-gray sandstone, with dark-gray, hard sandstone layers and concretions	40±

Mr. Hatcher described the sections of Fox Hills and Ceratops beds on Buck Creek as follows:

Along the southeastern border, especially between Lance and Buck creeks, are many fine exposures of the Ceratops beds and the underlying Fox Hills. Perhaps the best exposure is that made by a small tributary emptying into Buck Creek about 4 miles east of Lance Creek and one-half mile northwest of the Buck Creek pens used by the cattlemen for round-up purposes. This water course has here cut its way in a southerly direction, at right angles to the strike, down through the lower half of the Ceratops beds, through the underlying Fox Hills sandstones and into the Fort Pierre shales. At this place the bed of Buck Creek and the rounded hills of that region at the head of this stream, embraced between the border of the Ceratops beds and Fox Hills sandstones on the north and the bluffs of Miocene clays and conglomerates on the south, are composed of Fort Pierre shales. All the strata of this entire section dip to the northwest at an angle of 16°. The exposure is a continuous one and, commencing from below, the section is as follows:

At the base are the Fort Pierre shales, of unknown thickness, several hundred feet of which are exposed. They consist of argillaceous, finely laminated, dark shales, quite soft and easily eroded. They contain many limestone concretions and numerous invertebrates. Among others are *Baculites ovatus*, *B. compressus*, *Scaphites nodosus*, *Placenticeras placenta*, *Nautilus dekayi*, etc.

Overlying the Fort Pierre deposits is an alternating series of sandstones and shales with an estimated thickness of 500 feet. In the lower portion of this series the shales predominate, but toward the middle the sandstones are in excess, and in the upper 50 feet they entirely replace the shales. The sandstones are of a yellowish-brown color, very fine grained, firm, and well stratified below, but softer and quite massive at the top, where they contain numerous large concretions and a rich marine invertebrate fauna. Representatives of this fauna have been sent to Mr. T. W. Stanton, of the United States National Museum, and were pronounced by him to be characteristic of the uppermost Fox Hills, in direct conformity with their stratigraphical position.

The Ceratops beds.—Next come the Ceratops beds, with an estimated thickness of 3,000 feet, resting directly upon the Fox Hills series. Immediately above the Fox Hills is a very thin but persistent layer of hard sandstone, well stratified, and easily cleavable along the lines of stratification. This stratum of sandstone is about 6 inches thick, and is regarded as the dividing line between the marine and fresh-water beds. It is overlain by about 150 feet of yellowish-brown, well-stratified sandstones, apparently nonfossiliferous. These are in turn overlain by about 250 feet of almost white, fine-grained, massive sandstones with numerous concretions, but no fossils were found in them. Next comes the fossiliferous portion of the Ceratops beds, consisting, as before stated, of alternating sandstones, shales, and lignites.

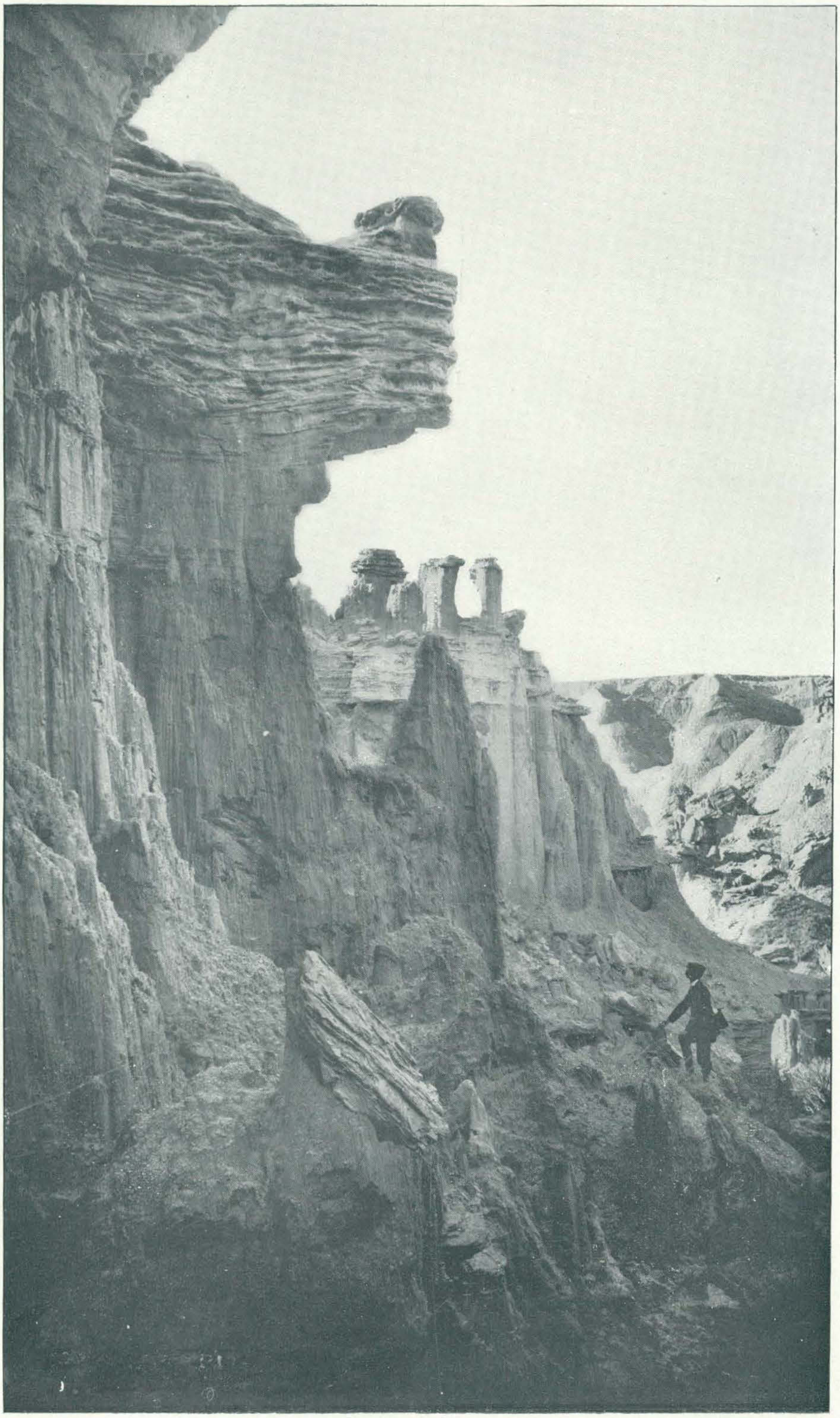
All the beds of the entire section are conformable and bear evidence of a continuous deposition from Fort Pierre shales up through the Fox Hills sandstones and the overlying fresh-water Ceratops beds. The Fort Pierre shales are not suddenly replaced by the Fox Hills sandstones, but the transition is a gradual one, and it is impossible to say just where the one ends and the other commences. The same is true of the beds overlying the Fox Hills. The thin seams of hard sandstone, just referred to as separating the fossil-bearing Fox Hills sandstones below from the very similar nonfossiliferous sandstones above, is here regarded as the dividing line between the Fox Hills and the Ceratops beds. But this decision, it must be admitted, is quite arbitrary, and the evidence in its favor is negative rather than positive. The only reason for placing the overlying 400 feet of nonfossiliferous sandstones in the fresh-water series is the absence of fossils in them, which may perhaps be accounted for by the destruction of the marine forms brought about by the change from salt to fresh waters. The overlying nonfossiliferous beds may have been deposited in the fresh waters before fresh-water forms had distributed themselves over this region. The sandstones of the entire series are very similar, and since there is entire conformity throughout, it is absolutely impossible to determine just where the marine beds end and the fresh-water beds commence. The Ceratops beds of this region are a natural sequence of the Fox Hills. The materials composing both were evidently derived from a common source. The only safe criteria for distinguishing one from the other are their fossils.

A short distance farther down Buck Creek there is the following section, as given by Stanton and Knowlton:[1]

Section on Buck Creek, Wyoming.

	Feet.
Sandstone	10
Clay	25
Sandstone with bands of clay	20
Clays with lignitic seams	15
Clays with concretions containing *Ostrea glabra*, *Corbula subtrigonalis*, *Anomia*, and *Corbula cytheriformis* (Laramie brackish-water fossils)	20
Massive, nearly white, sandstones with brown concretions	40
Shaly sandstone	5
Lignite and clay	15

[1] Stratigraphy and paleontology of the Laramie and related formations in Wyoming, by T. W. Stanton and F. H. Knowlton: Bull. Geol. Soc. America, Vol. VIII, pp. 129–130.



IN THE BAD LANDS EAST OF HERMOSA, NEAR HEAD OF COTTONWOOD DRAW, WASHINGTON COUNTY, SOUTH DAKOTA. PROTOCERAS SANDSTONE OF WHITE RIVER GROUP.

Massive, light-colored sandstone	60
Clay	8
Sandstone	10
Clay	5
Massive, light-colored sandstone	100
Brownish and gray sandstone in alternating bands, massive and thin bedded	130
Gray thin-bedded sandstone	20
Brown micaceous sandstone	20
Yellowish gray argillaceous sandstone with large concretions containing *Veniella humilis*, *Sphæriola*, and other Fox Hills fossils; dip northwest	30
Sandy clay shales with occasional bands of brown sandstone; thickness unknown, as base is not opened.	

All the Laramie beds in this region appear to be of fresh-water origin, although farther west in Wyoming they have been found to include some marine beds, with recurrence of many of the Fox Hills fossils. The fresh-water fossils reported in the Converse County area by Hatcher and by Stanton are as follows:

Fossils from Converse County, Wyoming.

Unio danæ, M. and H.
Unio brachyopisthus, White.
Unio couesi, White.
Unio holmesianus, White.
Unio proavitus, White.
Unio endlichi, White.
Unio cryptorhynchus, White.
Unio (about eight undescribed species).
Anodonta parallela, White.
Anodonta propatoris, White (?).
Sphærium planum, M. and H.
Sphærium sp.
Viviparus trochiformis, M. and H.
Tulotoma thompsoni, White.
Campeloma producta, White.
Campeloma multilineata, M. and H.
Goniobasis tenuicarinata, M. and H.
Thaumastus limnæiformis, M. and H.
Physa copei, var. canadensis, Whiteaves.
Helix vetusta, M. and H.
Limnæa sp.

TERTIARY.

The earliest deposits of Tertiary age—those of the Eocene period—are not found in the region adjoining the Black Hills, and there are many reasons for believing the principal epoch of uplift in the Black Hills region was in early Tertiary time. Early Eocene deposits may have been laid down and removed by erosion in consequence of uplift in later Eocene time, but it is much more probable that the entire area was above water throughout the portion of Eocene time prior to the Oligocene. During the Oligocene epoch there was widespread inundation in the West, and adjoining the Black Hills there was deposited a thick mantle of the sands and clays which will be described below. The Arikaree[1] formation, of Miocene age, which caps Pine Ridge, has not been found on the Black Hills, and nothing is known as to its former extension in their direction. According to Prof. J. E. Todd, a representative of the formation occurs north of the hills in

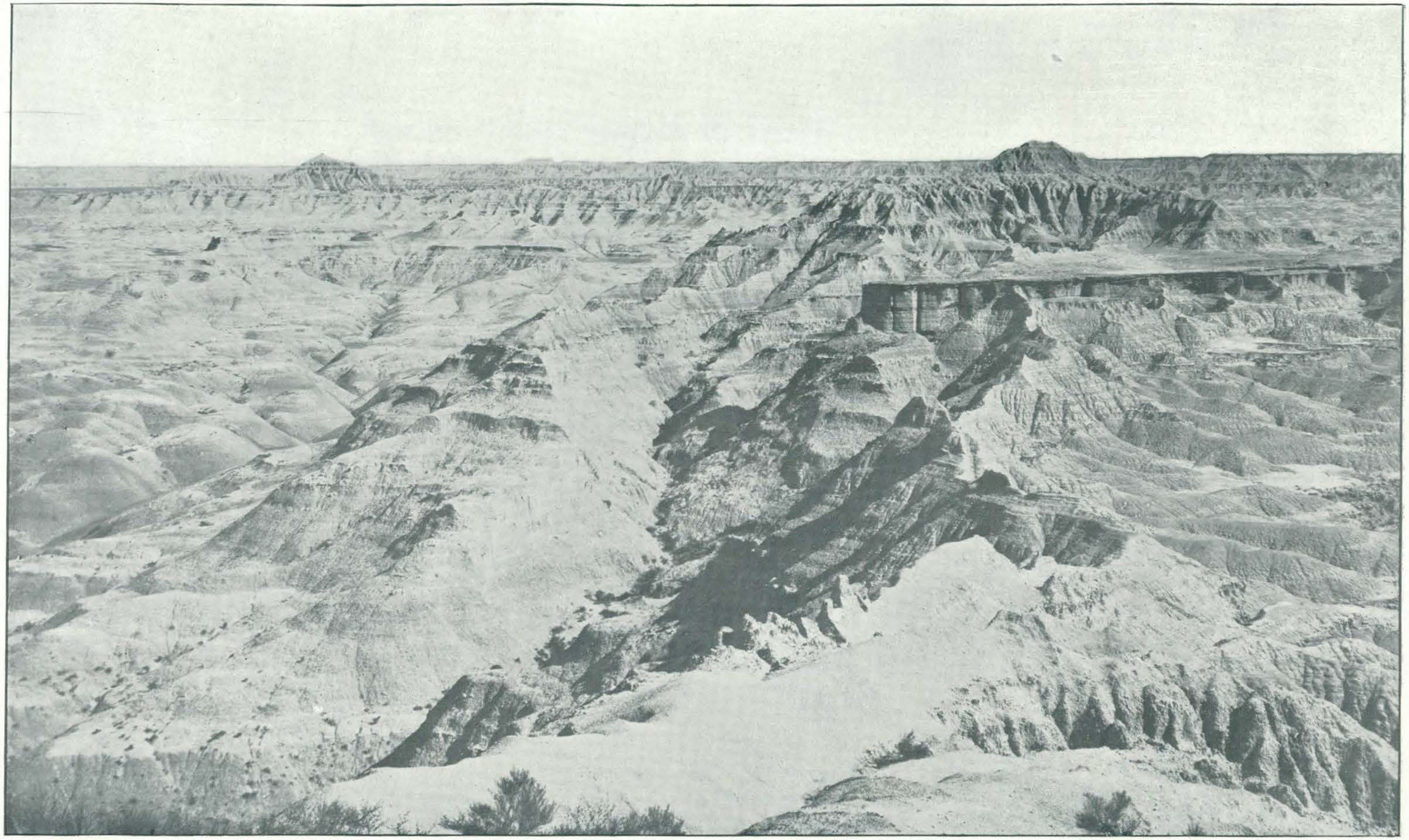
[1] Report on Nebraska west of the one hundred and third meridian, by N. H. Darton: Nineteenth Ann. Rept. U. S. Geol. Survey, 1897-98, Part IV, p. 735.

the high buttes beyond the Belle Fourche River, in the northwestern corner of South Dakota.

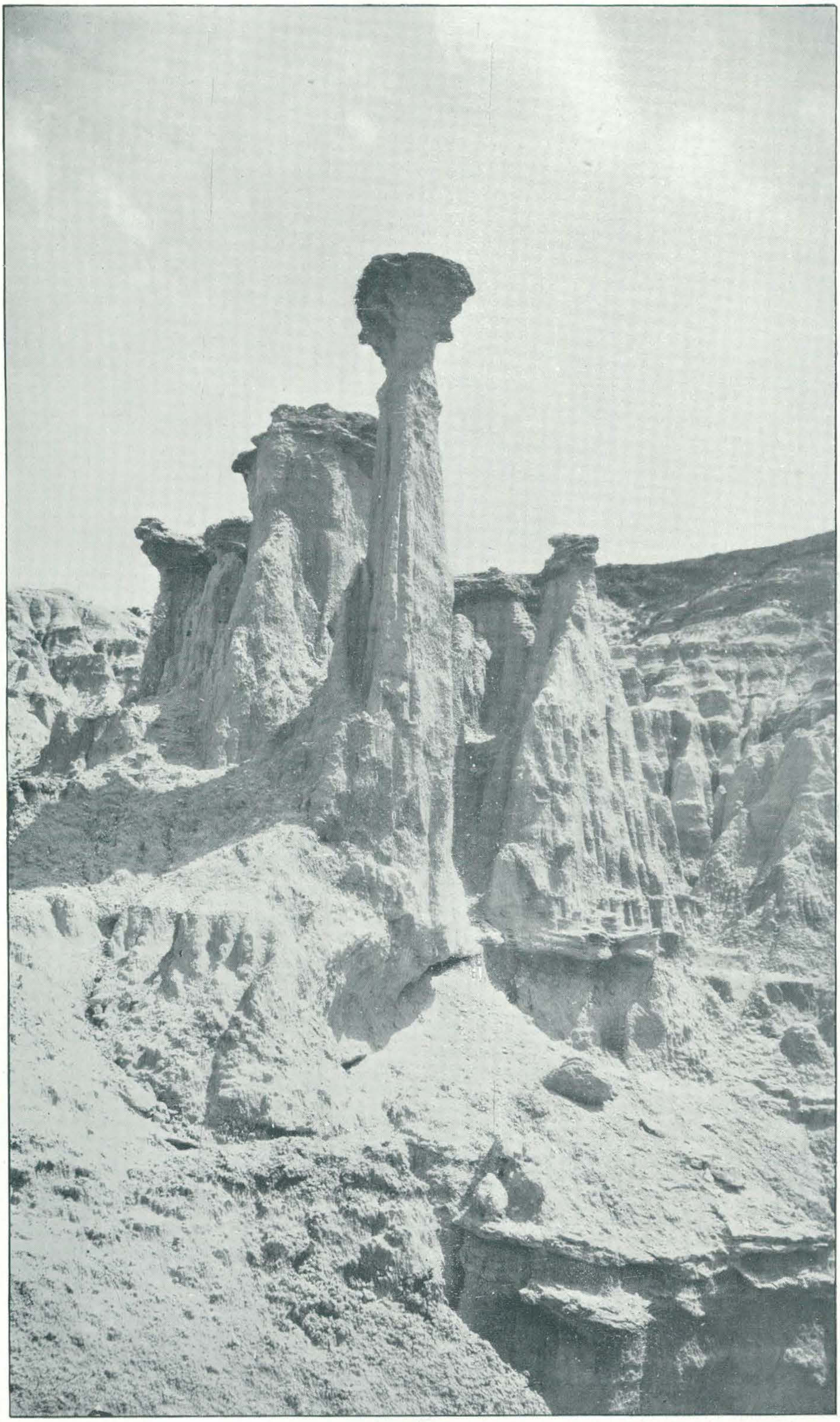
WHITE RIVER GROUP.

The well-known formations of the bad lands lying between the Cheyenne and White rivers in western South Dakota and underlying Pine Ridge have been found to extend to the Black Hills and high up onto their flanks in a portion of the region. About Fairburn and Hermosa wide areas of the highlands are occupied by the White River formations, which often give rise to miniature bad lands of considerable extent. The deposits comprise fine-grained materials, apparently laid down in a large body of water that had its shores far up the slopes of the Black Hills, and coarser materials marking the courses of some of the streams of the period. There are large areas of fullers' earth, sand, limestone, calcareous grit, and channels filled with conglomerate, in some places silicified and in others cemented by carbonate of lime. The principal areas now remaining are on the high divides between Lame Johnny and Rapid creeks, but there are also extensive masses in the broad Red Valley behind the hogback range, and there are narrow valleys filled with the deposits which extend several miles back over the Carboniferous sandstones onto the Algonkian crystalline rocks. Some of the details of their distribution are shown on the geologic map (Pl. LXV). To the southwest there are scattered areas at a number of points between Edgemont and Pringle, notably on the Minnelusa formation west of Argyle, in the Red Valley north and west of Minnekahta, and on the Dakota sandstone not far north of Edgemont. South of Oelrichs there is a narrow basin which has been preserved in a syncline extending toward the bad lands. In Converse County, Wyoming, the formation extends from the foot of Pine Ridge over portions of the anticline rising along the east side of Old Woman Creek.

The deposits of the White River group exhibit considerable diversity of composition. The principal material is a porous, crumbling clay of pale flesh color when dry, but a light-brown color when damp. Some portions of it are pale green when dry or olive when wet. It is a hydrosilicate of alumina with some admixture of sand and clay, being in reality fullers' earth, and differing from ordinary clay in being much less plastic. In the lower beds of the group it merges into sand on the one hand and into clay on the other. It is often associated with or gives place to coarse materials occupying channels or broad sheets. In the vicinity of Hermosa the principal material is coarse sandstone and conglomerate, mainly of dark, brown color, which mantles extensive plateaus. On the high level ridge north of Spring Creek there are coarse conglomerates which extend entirely across the hogback range. About Fairburn, and to the westward, there



CHADRON AND BRULE FORMATIONS OF WHITE RIVER GROUP, BAD LANDS NEAR HEAD OF BATTLE DRAW, WASHINGTON COUNTY, SOUTH DAKOTA, NORTHEAST OF FAIRBURN.



SANDY LAYERS IN WHITE RIVER GROUP ON EAST SIDE OF CEDAR DRAW, WASHINGTON COUNTY, SOUTH DAKOTA, NORTHEAST OF FAIRBURN.

are long channels filled with conglomerate consisting of limestone pebbles and a calcareous matrix. These extend up several of the depressions through the hogback range, either displacing the fullers' earth deposits, or being intercalated among them. The limestone pebbles appear to have been derived from Tertiary limestones, for they do not represent any of the Mesozoic or Paleozoic rocks of the hills. On the higher lands in the Red Valley, between Hermosa and Rockerville, there is an extensive deposit of nearly pure limestone giving rise to a high plateau of considerable extent. The total thickness of the beds is nearly 30 feet at some places, the limestone being underlain by fullers' earth. Limestones of various degrees of purity are abundantly intercalated in the fullers' earth deposits in the region west and southwest of Fairburn, lying in depressions on the older rocks. These limestones usually contain fresh-water fossils, mainly gasteropods, often in great abundance. The most southerly occurrence of the limestone is on the ridge a short distance northwest of the western entrance of Fuson Canyon, and on the high divide just north of Lame Johnny Creek and a short distance west of the Fremont, Elkhorn and Missouri Valley Railroad. There are extensive exposures of coarse materials of White River age in the railroad cuts through this divide south of Fairburn, where the materials are mainly cross-bedded coarse sands with a large proportion of gravel largely derived from the crystalline rocks of the hills. The thickness of the White River deposits on the flanks of the Black Hills varies from a thin remnant to 200 feet or more. In the divide just south of Lame Johnny Creek, in the Red Valley, at a point 10 miles southwest of Fairburn, over 200 feet were measured, consisting mainly of pale flesh-colored sandy clay and fullers' earth. East of the hills the White River group is usually divisible into two formations—the Titanotherium beds or Chadron formation below, and the Oreodon beds or Brule clay above. The Chadron formation consists of fullers' earth of light-gray, drab, pale-green, or pinkish tints, traversed by channels filled with gray sandstone. At the base there is usually a bed of coarse gravel composed of rocks derived from the Black Hills. The Brule clay is a thickly laminated sandy clay of pale-flesh and drab colors. These formations are most extensively exhibited in the large area of bad lands lying southeast of Cheyenne River. Some typical features in these bad lands are illustrated in Pls. LXXXIII–LXXXV.

All of the White River beds have yielded fossil bones of various kinds which are typical of the White River group. The following bones, determined by Prof. F. A. Lucas, were obtained in beds high up on the flanks of the Black Hills west of Fairburn: *Oreodon culbertsoni*, *Poebrotherium wilsoni*, *Stylemys nebrascensis*, and *Hyracodon nebrascensis*.

The White River deposits southwest of Argyle consist mainly of fullers' earth. A few turtle bones were found in them, but no extensive search was made for fossils. North and west of Minnekahta the material is a mixture of fine sand and clay. The outlier northwest of Edgemont caps an area of Graneros shale high on the slope of the Dakota sandstone. It consists mainly of gray conglomeratic sandstone.

During White River time in the Black Hills and adjoining regions there was deposition of considerable volume of volcanic ash. It appears to have been a period of volcanic activity in the region west, and the ashes were borne on the winds and dropped into the waters so as to be deposited over a wide area of country adjoining the Black Hills. There is more or less volcanic ash throughout the White River deposits as an admixture with the clay and sand. Accumulations of the pure material are often found at various horizons from the lower Chadron beds to the highest formation in Pine Ridge. In the Chadron formation the ash occurs in local lenses and general admixture. The most notable occurrence is in the fullers' earth deposit southwest of Argyle, where there is a bed of relatively pure ash having a thickness of 3 feet. Its composition is given in the following analysis, made by Mr. George Steiger in the laboratory of the United States Geological Survey:

Analysis of ash from near Argyle, South Dakota.

Constituent.	Per cent.
Silica	64.47
Alumina	14.74
Iron (Fe_2O_3)	2.73
Iron protoxide	0.78
Magnesia	0.29
Lime	4.00
Soda	2.55
Potash	3.31
BaO	0.13
TiO_2	0.76
P_2O_5	0.29
H_2O	5.71
Total	99.76

Its local extent could not be determined, owing to lack of exposures. The material consists of fine shreds of volcanic glass or pumice, mainly of pure white color and translucent, mixed with occasional flakes of dark-colored glassy materials. It represents a rock of rhyolitic character. A thinner deposit occurs in the Chadron formation, near its base, 6 miles southeast of Oelrichs, probably at about the same horizon as the one above described. Its thickness is only 10 inches and its extent small.

PLEISTOCENE.

EARLIER PLEISTOCENE DEPOSITS.

A mantle of bowlders, gravel, and sand is found occupying extensive areas on many of the divides along the lower slopes of the Black Hills and portions of the adjoining plains, and also extending up the older valleys far into the central area. This deposit is presumably of early Pleistocene age, laid down at the period which followed the deposition and uplift of the White River deposits. The streams from which it was derived had courses somewhat different from the present drainage, and much of the original area of the deposits has been removed by subsequent uplift and erosion. Portions of these gravel and sand deposits may readily be recognized as old stream courses, although they lie high above the newer valleys of the present time. One notable example of this is on the divide between French Creek and the drainage basin next south, southeast of Fairburn, where at an altitude of 400 feet above the valley of French Creek there is a broad valley carved mainly in the soft deposits of the White River group and floored by a thick mantle of sand and gravel with many bowlders. It is a valley with sloping and terraced sides descending gently into a central trough now occupied for several miles by a small stream which is dry the greater part of the year. Due south of Fairburn this elevated valley is cut away for some distance by branches of French Creek. Standing on its western edge and looking toward the Black Hills one may see how it originally extended out of narrow valleys among the schist ridges, now elevated far above the present drainage; a predecessor of the present French Creek, having in general the same drainage basin, but with many differences in course and branches (see Pl. XCV). These old high valleys are usually found to be floored with gravel, sand, and bowlders, but in the higher hills they have been extensively bared and cut down by erosion, especially where they coincide with the course of the present valleys. In the Red Valley southwest of Fairburn there are extensive flat surfaces mantled by these earlier Pleistocene deposits, as shown in Pl. LXXXVI and figs. 279 and 280. Both these figures also show old stream channels extending out of the Black Hills through gorges cut in the Algonkian schists, Cambrian sandstone, and Pahasapa limestone.

They also show the old shore line at this earlier Pleistocene period of deposition carved mainly on the limestone slopes. To the eastward, this earlier Pleistocene plain abuts against the slopes of the Lakota sandstone of the hogback ridge, excepting where it extends out to the plains through wide, high gaps not now occupied by water courses.

These earlier high-level Pleistocene valleys extend far back among the ridges of crystalline rocks, their course being now defined by many low, gravel-floored saddles. One of these saddles is shown in Pl. LXXXVI, *A*. It was formerly the bed of French Creek, which now

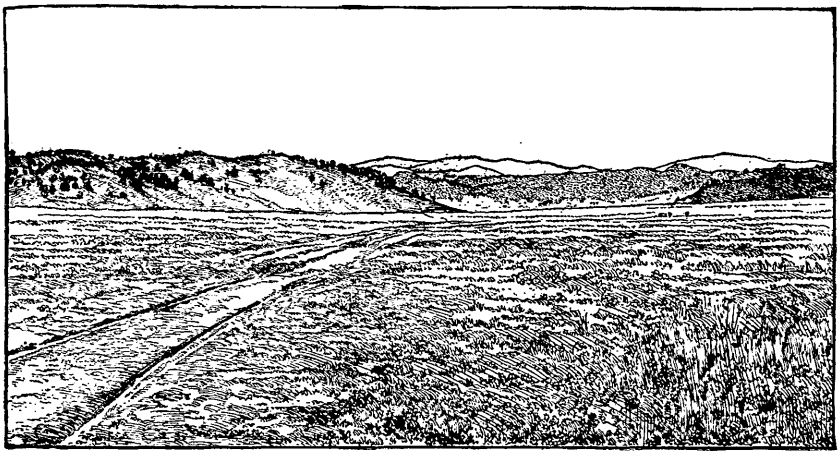


FIG. 279.—Earlier Pleistocene plain and valley 10 miles northwest of Buffalo Gap, South Dakota, looking west through gap in ridge of Pahasapa limestone to high ridges of crystalline rocks.

has a course more to the northeast and occupies a canyon 200 feet below the saddle. To the east of the Black Hills in Custer and Pennington counties, South Dakota, nearly all of the higher divides are

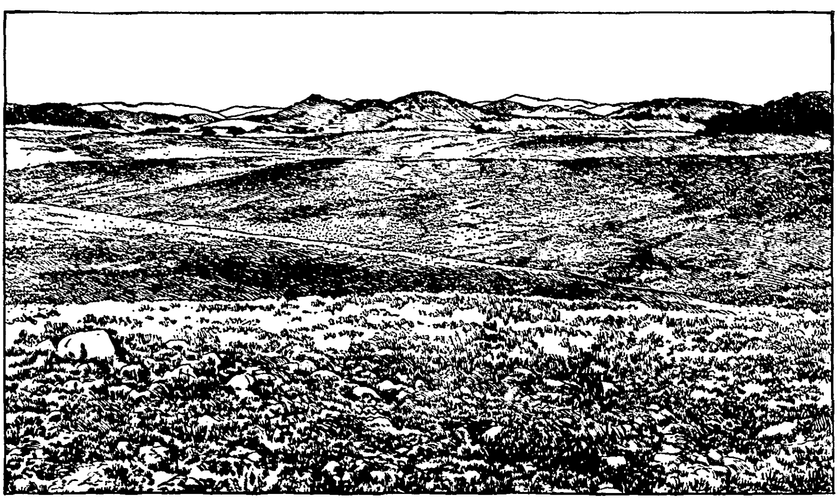


FIG. 280.—Earlier Pleistocene plain with old valley heading in region of crystalline rocks north of Wind Cave, South Dakota.

mantled by these earlier Pleistocene deposits lying on the White River sediments. Probably they were originally a continuous covering over this region, but the present streams have cut wide valleys through them. They appear not to have extended far into Fall River County, where the

A. EARLIER PLEISTOCENE VALLEY (OLD CHANNEL OF FRENCH CREEK) SOUTH OF FRENCH CREEK, 10 MILES WEST BY NORTH OF FAIRBURN, SOUTH DAKOTA, LOOKING NORTHWEST.

Hill of deadwood sandstone on right. Ridges of crystalline rocks in the distance.

B. EARLIER PLEISTOCENE (?) PLAIN, 9 MILES WEST OF FAIRBURN, SOUTH DAKOTA, LOOKING SOUTHWEST.

divides are bare, excepting occasional small gravel sprinklings on the hilltops which are remnants of the former capping of the Chadron formation at the base of the White River group. East of Custer County the earlier Pleistocene deposits extend across the divide between Cheyenne and White rivers, for they occur as cappings on remnants of the original plateau surface now remaining in the big Bad Lands. South and west of the Black Hills there are high-level gravel deposits on the slopes adjoining Cheyenne River and Beaver Creek valleys, and a wide area of tabular surface representing an old valley is found in the extended area of the Sundance formation beginning 8 miles west of Minnekahta. Pleasant Valley is also occupied by high terraces indicating deposition by a large stream in an early period of the development of the stream which now empties through Red Canyon.

At several points about the Black Hills some of the valleys contain gravel and sand which are not as ancient as the high-level deposits above described, but are much older than the alluvial deposits of the last few centuries. One of the most remarkable instances of this sort is the filling in an old valley of Fall River, extending across the Red Valley at Hot Springs. It gives rise to a plain at about the level of the adjoining slopes of the Red Valley to the north and south, and Fall River has cut a narrow canyon through it to a depth of about 80 feet. The material is largely cemented into a hard conglomerate which outcrops in picturesque ledges at the town of Hot Springs. In Pl. LXXXVII, *A*, is shown the old wide valley filled with this Pleistocene deposit to a relatively low floor, the new canyon now occupied by the river, and the canyon walls of massive conglomerate. In *B* of the same plate is shown an exposure of conglomerate in the river bank, in the center of the town. The materials are mainly bowlders of sandstones and fragments of Minnekahta limestone from the hills west, cemented by a matrix of sand and carbonate of lime. The lithification is only local, for in the lower part of the town the conglomerate may be seen merging into loose gravel and sand. The deposit lies on a very irregular surface with a maximum thickness of about 55 feet. To the east it is seen lying on and abutting against the lower portion of the Sundance formation. In the center of the town of Hot Springs it lies on red beds and gypsum of the Spearfish formation, and in the extreme upper portion of the town, near the warm springs, it overlaps and abuts against the east-sloping Minnekahta limestone. It extends but a short distance north and south of Fall River, where it abuts against slopes of the older and wider Fall River Valley as originally excavated in the soft red beds. The calcareous cementing material of the conglomerate was probably supplied by the warm water which issues from the great springs just west of the town and which contains much lime. Another deposit of this conglomerate, of which some small masses still remain, appears to have extended through Buffalo Gap.

LATER PLEISTOCENE DEPOSITS.

All of the wider valleys in the Black Hills and adjoining plains are more or less extensively floored by alluvial deposits of relatively recent origin. The chief of these are along Cheyenne River, in the wide valleys in the Pierre and Graneros shales, where the deposits are often 3 miles in width on each side of the stream, rising in gentle

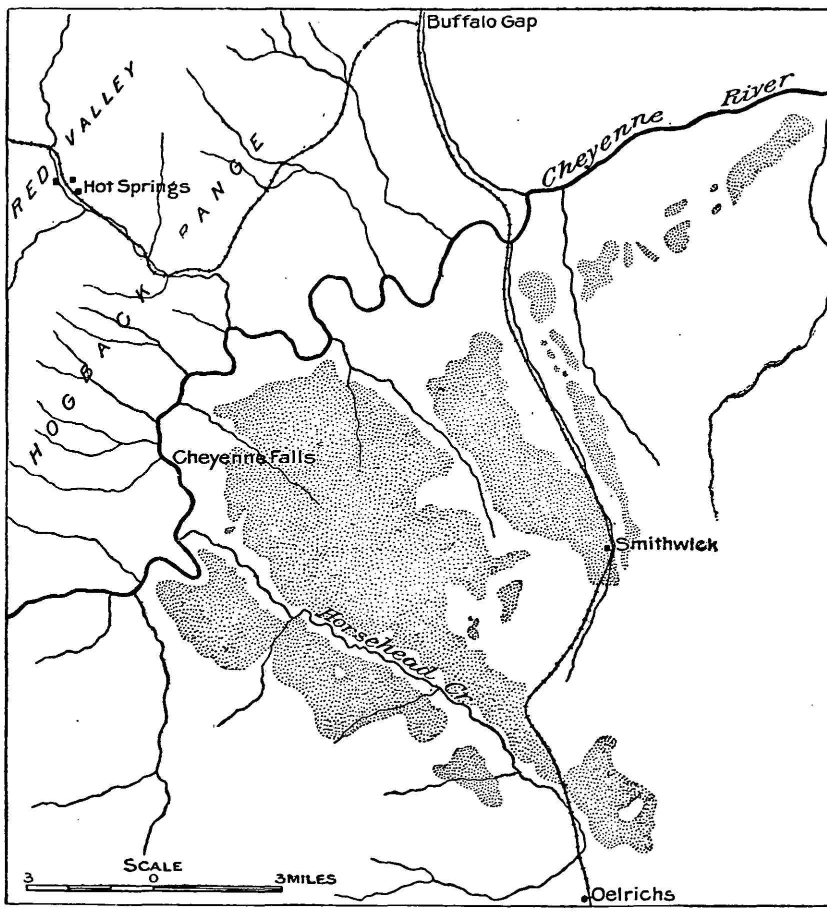
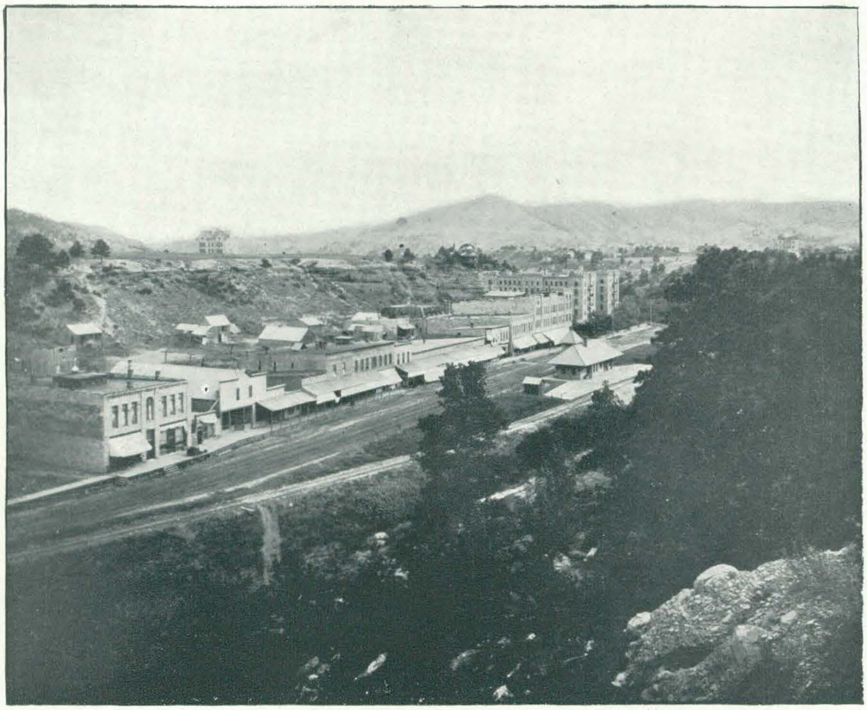


FIG. 281.—Map of region north of Oelrichs, South Dakota, showing distribution of dune sands.

slopes from low banks. Hat, Beaver, Lance, Lame Johnny, French, Battle, and Spring creeks all are widely bordered by alluvial deposits where they traverse the softer formation. These deposits consist mainly of sands and loams, with scattered pebbles and bowlders. The materials were derived from various sources along the streams and naturally vary somewhat in composition, according to the rocks which the streams traverse.



A. HOT SPRINGS, SOUTH DAKOTA, SHOWING NEW CANYON OF FALL RIVER CUT IN WIDE OLD VALLEY FILLED WITH PLEISTOCENE DEPOSITS, MAINLY CONGLOMERATIC, LOOKING SOUTHEAST.

B. PLEISTOCENE CONGLOMERATE LEDGES ON BANKS OF FALL RIVER AT HOT SPRINGS, SOUTH DAKOTA.

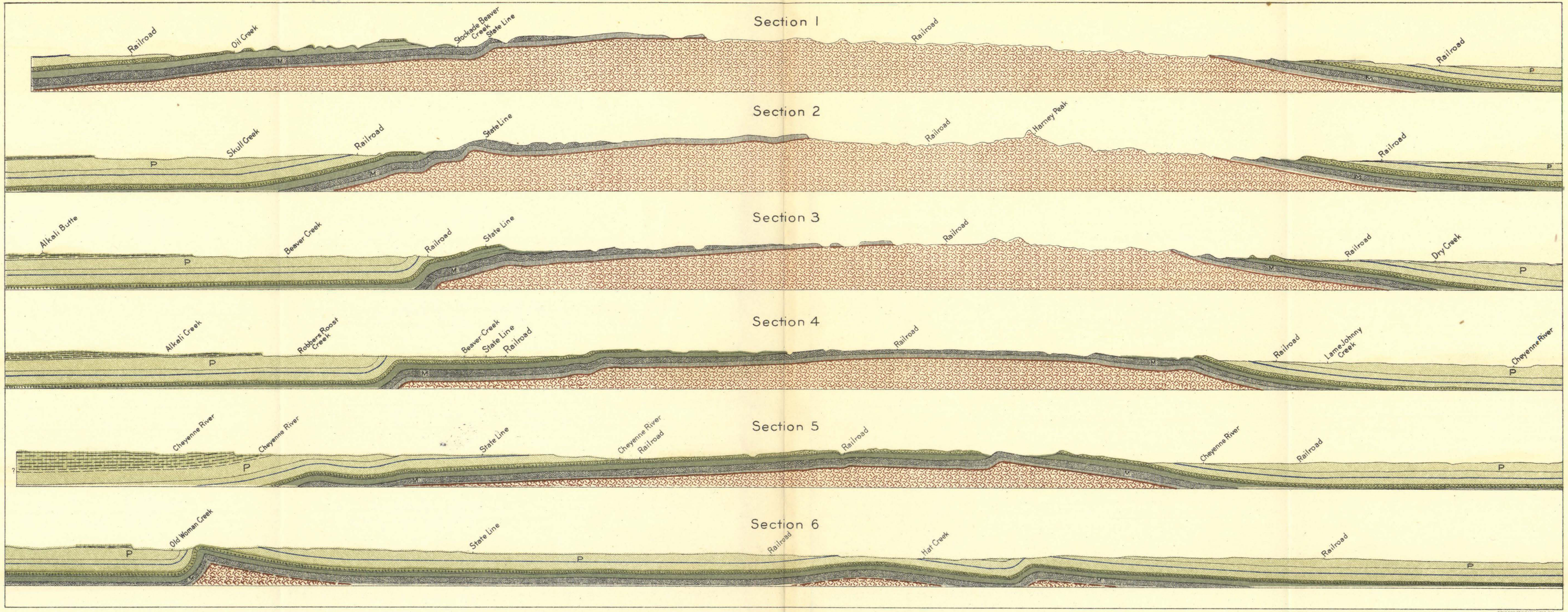
One of the latest geological formations in the region is represented by the sand dunes which have been accumulating in the region north and west of Oelrichs. The sand is principally derived from the alluvial flats bordering Cheyenne River where it flows out of the hogback range southeast of Hot Springs. It has been carried to the southeast by the strong northwesterly winds, and accumulated in extensive dunes, which now extend in long fingers to and beyond the railroad. Portions of these dunes are grassed over, but in much of the area the sand is loose and advances along its course with every wind that blows. The accumulations are not thick, but as they cover a wide area their bulk is considerable. On the wide terraces north of Edgemont and along the bottom lands of Cheyenne River at various places some low sand dunes are accumulating, but they are of very restricted occurrence.

Fall River and Cascade Creek, and other streams to a less degree, deposit calcareous sinter in large amount, giving rise to great masses of spongy rock, usually filled with impressions of various kinds of vegetation.

STRUCTURE.

The Black Hills uplift is a dome rising high on the irregular zone of uplift extending from the Laramie Range of the Rocky Mountains. It is elongated to the south and northwest and bears a number of subordinate flexures or crenulations. In its greatest elevation north of Harney Peak the uplift amounts to about 9,000 feet vertical displacement. In Pl. LXXXIX there is shown the configuration of the greater part of the Black Hills uplift, including also its connection to the southwest with the high, sharp anticline of Old Woman Creek, a northern extension of the range of uplifts which extends more or less continuously southwestward into the Laramie Range. In Pl. XC the principal features are shown in cross section. These plates represent the present attitude of the Minnekahta limestone at the surface and in its extension under ground, together with its hypothetical contour over the area from which it has been removed by erosion. Data for the underground relations of this limestone are definite, for we have numerous determinations of the thickness and structure of the overlying formations within moderate limits of error. For the eroded area now occupied by outcrops of the underlying Carboniferous formations the approximation is well within reasonable limits, since it is based on many measurements of the thickness of these formations as they pass beneath the Minnekahta limestone, and the structure is clearly exhibited. In the relatively small area of the bared pre-Cambrian crystalline rocks, however, there is less definite guidance, excepting the probability that the slopes of the dome continued upward with symmetrical form, and that the base of the sedimentary series was somewhat above such summits as are now represented by Harney Peak and Sheep Mountain. The facts for the center of the northern portion of the area were obtained from manuscript maps of the geology of the Spearfish and Sturgis quadrangles by Dr. T. A. Jaggar, jr. For the extreme northern and western portion of the uplift no data are available, and for the region southeast of Sundance we have at present only some general information, shown by the dotted lines.

In the southern portion of the Black Hills region it will be seen that the dome is steeply compressed on the sides but broadly extended in the center, where it slopes off gently to the south-southwest. Adjoining the central area there are gentle dips on the west side giving rise to the wide sloping plateau of "the limestone," and steeper dips on the east side carrying the formations from Cambrian to Niobrara rapidly beneath the surface. One of the most striking structural features is the steep compression of beds along the middle of the western slope of the dome in the eastern part of Weston County, Wyoming, where from Spencer southward there are nearly vertical dips in the Greenhorn limestone and associated formations in a belt about a mile wide. The relations in that vicinity are shown in sections 3 and 4, Pl. LXXXVIII. East of Newcastle these steep dips pass into lower beds and soon involve the Minnekahta limestone, the Minnelusa sandstone, etc., along the valley of Stockade Beaver Creek. Some features of the structure in this locality are shown in Pl. XCII, in which the sudden steepening of the dips is beautifully exhibited. A branch of this steep-dipping limb passes south of Newcastle, extending southwest of a broad, gently sloping monocline which spreads out the Lakota sandstone in a wide plateau about Cambria, affording most favorable conditions for working the coal. From the S. and G. ranch, where there is a faint cross flexure, to beyond Edgemont the formations all dip gently to the southwestward, with frequent local variations in the amount of dip. To the southwest of Edgemont the dips are very low, and there is a shallow basin which extends across to the flank of the anticline of Old Woman Creek and contains a moderate thickness of Pierre shale, as shown in section 6, Pl. LXXXVIII. Under the axis of this syncline the crystalline rocks are just about at sea level, over 5,000 feet below their elevation in the ridge at Lusk, as shown in Pl. LIX, and over 7,000 feet below the summit of Harney Peak. A short distance east of Edgemont there is the southern prolongation of the main north-south axis of the Black Hills uplift. This is broad and flat in greater part, but for several miles opposite Edgemont presents steep dips along its western side. Next east is the syncline, the axis of which passes near Maitland and extends north up the valley of Cascade Creek. On its east side is a prominent anticline, which may be regarded as a bifurcation of the southern extension of the central axis of the Black Hills dome. It begins a short distance north of Hot Springs and extends southward into the plains. Its first



SECTIONS ACROSS THE SOUTHERN BLACK HILLS

BY

N. H. DARTON

1899

HORIZONTAL SCALE

5 0 5 10 MILES

VERTICAL SCALE

5000 0 5000 10000 15000 20000 FEET

EXPLANATION

- Tertiary
- Laramie and Fox Hills formations
- Pierre Niobrara and Benton formations (P: Pierre shale. "Inoceramus bed")
- Dakota, Fuson and Lakota formations
- Juratrias (Beulah, Sundance, Unkpapa and Spearfish formations)
- Minnekahta limestone and Opeche formation
- Minnelusa formation (M)
- Pahasapa limestone
- Deadwood formation
- ALGONKIAN: Crystalline rocks

feature is a prominent ridge exhibiting an anticline of Minnekahta limestone deeply trenched by the canyon of Hot Brook, tributary to Fall River, and pitching beneath the surface at Cascade Springs. Next west of this anticlinal ridge of Minnekahta limestone there is a narrow valley of Spearfish red beds and a high, narrow ridge of Unkpapa and Lakota sandstones, all dipping from 75° to 85° to the west. To the southward these beds pass over the anticline in regular succession, and on the eastern side are spread out widely by relatively gentle dips, as shown in section 5, Pl. LXXXVIII. The prolongation of the anticline to the southward in the Benton and Niobrara formations is shown in section 6 of Pl. LXXXVIII. East of Hot Springs the east-dipping limb of this anticline bears a subordinate anticline which extends for several miles with the contour shown in Pl. LXXXVIII and fig. 290. It is exhibited mainly in the Minnewaste limestone north of Fall River Canyon, and dies out a short distance to the south in the Dakota sandstone. The dips on its western side are very steep for about 2 miles, but on the eastern side they are low. The northern extension of this flexure is clearly shown in the western end of Buffalo Gap, by a low arch of Minnekahta limestone, from which the red beds have been eroded over a small area, and again a short distance north of Fuson Creek Gap, where two small exposures of the limestone are seen. Just west of the town of Buffalo Gap the eastern slope of the Black Hills dome is locally steepened, giving increased prominence and steepness to the hogback range of Dakota sandstone, as shown in Pl. LXIV. It is in this vicinity that is found the local area of faulting in the Unkpapa sandstone which has yielded most instructive specimens illustrating small block faults traversing the bright-colored layers of the rock. Some of the features of these faults are shown in Pl. XCIII. The faults are all of very small amount and do not traverse the entire thickness of the formation. They make their first appearance in Elm Creek quarry, 2 miles southwest of Buffalo Gap, but attain their greatest development in the old sandstone quarries in the first small gap south of the main Buffalo Gap, where a large amount of the material is exposed. Faults are rarely observed in the Black Hills, so that these dislocations near Buffalo Gap are especially interesting. They appear to be due to movement that is entirely taken up within the Unkpapa formation in part by cross faulting and in part by diago-

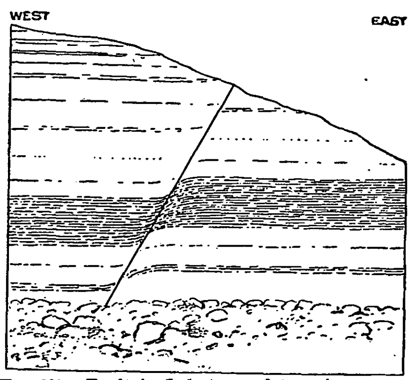


FIG. 282.—Fault in Lakota sandstone in canyon of Dry Creek, northwest of Fairburn, South Dakota.

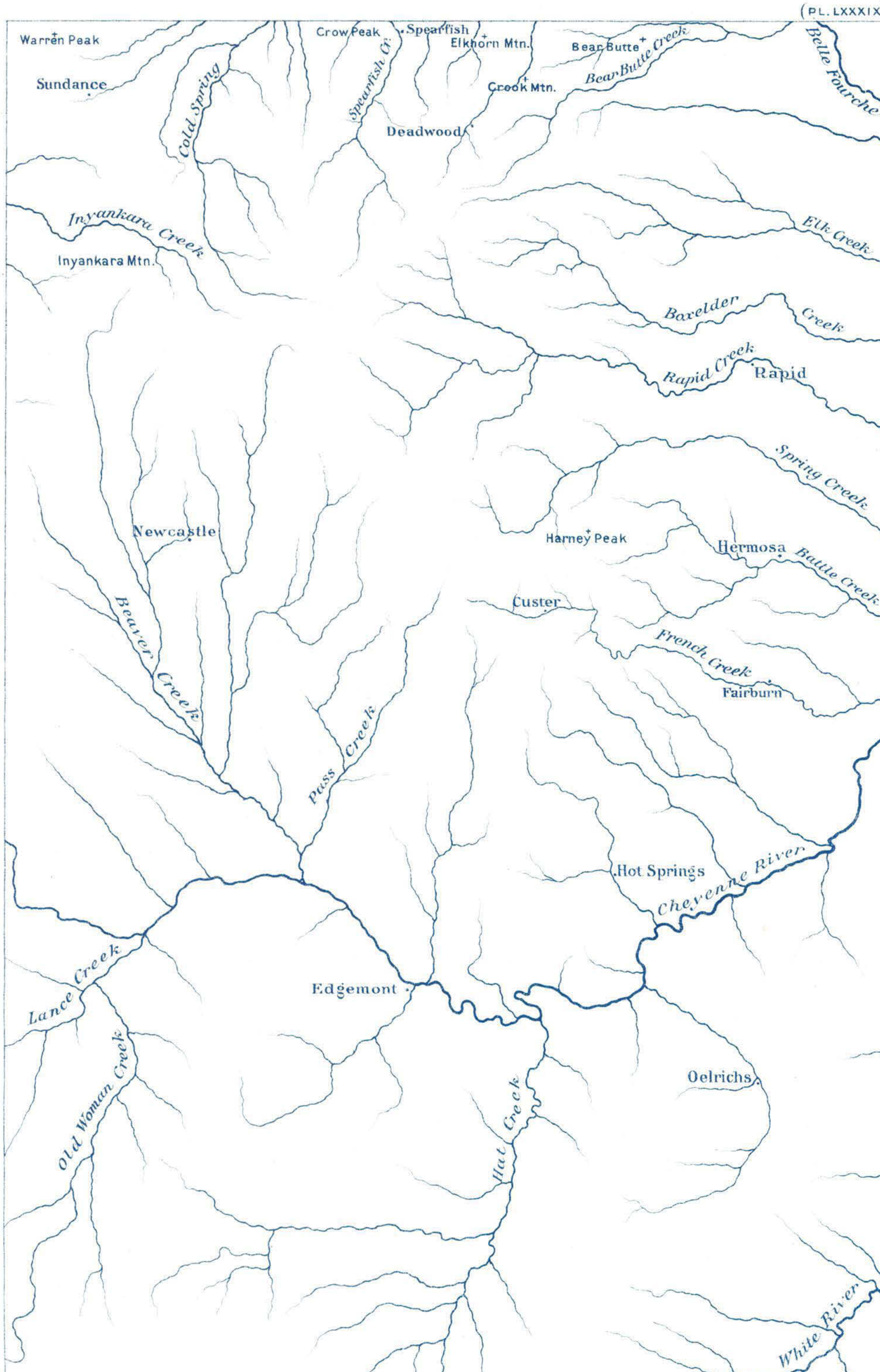
nal shearing. In the gap of Dry Creek, north of Buffalo Gap, there is exposed a small fault in the Lakota sandstone, of which the principal features are shown in fig. 282.

At Fairburn the general east-sloping limb on the eastern side of the Black Hills dome bears a small local anticline and syncline, giving rise to a double ridge of Greenhorn limestone just south of the town. Another slight irregularity is a small dome-like anticline on Dry Creek, 7 miles northwest of Fairburn, in the Minnekahta limestone.

In Pls. LXXXIX and XC the contour of the Minnekahta limestone surface is only carried down to sea level, below which it soon flattens out on both sides of the dome. Some features of this flattening are shown by the contour of the upper surface of the Dakota sandstone about Oelrichs, as represented in fig. 290 and by cross section 6, Pl. LXXXVIII.

ANTICLINAL AREA ON OLD WOMAN CREEK.

This uplift, which has not heretofore been noted, lies south of the Black Hills, on the eastern side of the valley of Old Woman Creek, in Converse County, Wyoming. It is a single anticline, with gentle dips on the east and nearly vertical beds on the west, which brings to the surface an extensive series of Upper and Lower Cretaceous beds and the upper members of the Jurassic, the Beulah shales, and the Sundance formation. The Dakota and Lakota sandstones here give rise to a ridge 7 or 8 miles long, of which the higher summits are elevated about 500 feet above Old Woman Creek. To the north the anticline extends across Cheyenne River, where it upturns Fox Hills and Laramie beds, and dies out a short distance north of Alkali Creek. To the south the uplifted beds pass beneath nearly horizontal White River deposits, which hide the relations in that direction. Doubtless the anticline is an extension of the uplift which brings to the surface the crystalline rocks in the vicinity of Lusk and in the high mountain known as Rawhide Butte, a spur of the Laramie Range rising in the midst of the wide Tertiary plain south of Lusk. As shown in Pls. LXXXVIII and LXXXIX, the anticline is separated from that of the the Black Hills by a low saddle west of Edgemont, but it is to be regarded as a link in the chain which connects the Black Hills with the Rocky Mountains. In Pl. XCI are shown the relations and distribution of the formations brought to the surface by this anticline. The area is one in which the exposures are extensive and the steep dips on the west side of the flexure afford an excellent opportunity to obtain measurements of all of the Cretaceous formations from Lakota to Fox Hills. It was in this area that the Pierre shale was ascertained to be 1,200 feet thick, with the tepee zone 1,000 feet above its base. The Fox Hills beds are upturned by this flexure so that cross-section measurements can be made at numerous localities. To



MAP SHOWING THE PRINCIPAL DRAINAGE OF THE BLACK HILLS.

the west, in the lower part of Buck Creek, the dips gradually diminish, and apparently the flexure dies out in the Ceratops beds or the Laramie formation. On the east side of Old Woman Creek the formations from the Niobrara to Lakota present dips from 70° to 80° for several miles. The results of cross-section measurements in this vicinity are given in fig. 283.

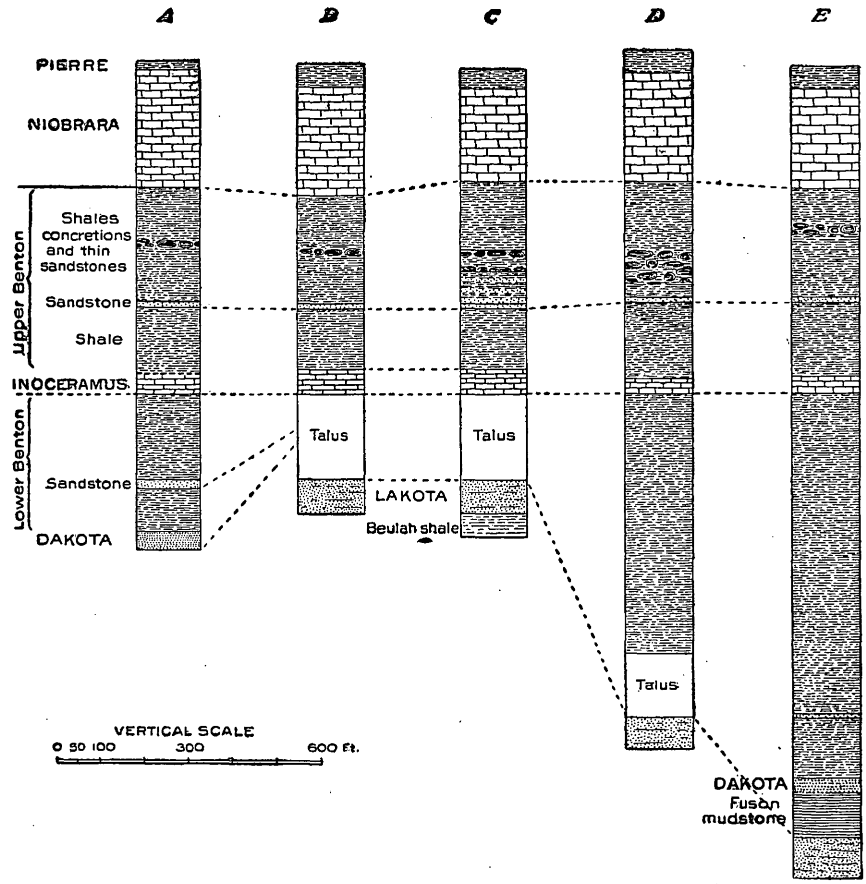
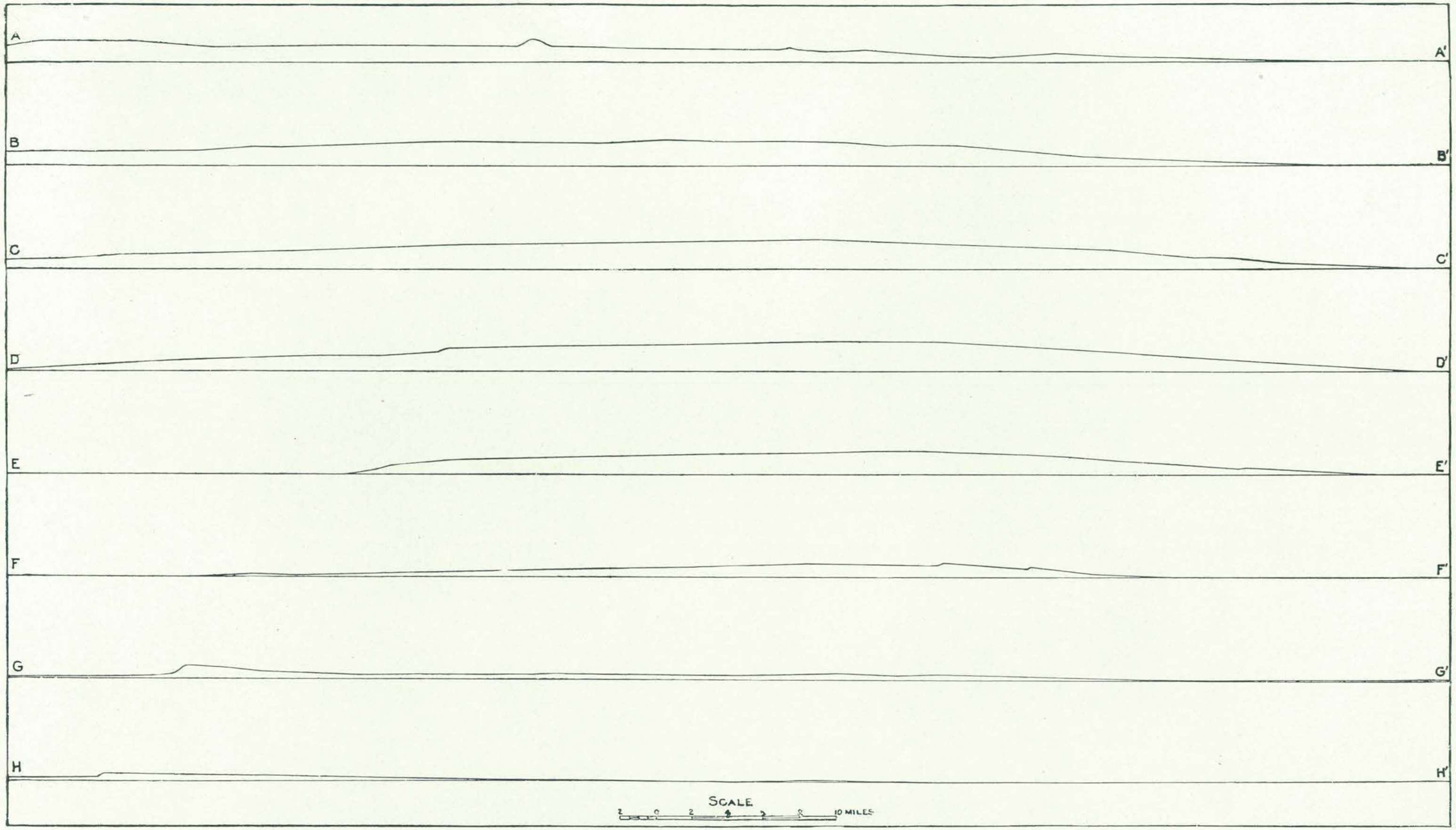


FIG. 283.—Columnar sections of Cretaceous formations in the anticline on east side of Old Woman Creek, Converse County, Wyoming.

These measurements are very satisfactory and consistent, except for the Graneros shale, which varies so greatly in apparent thickness in the different sections as to lead to the belief that it is traversed by a fault along a portion of one side of the anticline. The Dakota sandstone, the Niobrara chalk, the Pierre shale, and the formations of the Benton group present their usual characteristics in this area, even to the occurrence of a local lens of hard sandstone in the lower portion of the Graneros shale. The Fuson formation is well characterized, and it is probable that a thin layer of impure limestone underlying this formation near the southern end of this uplift represents the Minnewaste limestone. The Lakota sandstone is much thinner here than in the hogback ranges of the Black Hills, averaging less than 100 feet. The Beulah shales are well characterized, and the upper portion of the Sundance formation exposed in a small area in a canyon in the central part of the range presents the usual succession of thin-bedded buff sandstones and drab shales with typical marine Jurassic fossils.

GEOLOGIC HISTORY.

In the rocks uplifted in the Black Hills there is recorded an interesting geologic history extending from Cambrian to the present time. There has been considerable diversity of conditions, but an extensive stratigraphic record is presented. Some of the chapters of the history appear plain, but for others much additional study is required before we can know the complete sequence of events. It is probable that throughout Cambrian time there were extensive exposures of crystalline rocks about the present location of the Black Hills, but the relations of these to other pre-Cambrian land areas is not known. The Cambrian sands were deposited mainly on sea beaches and in the shallow waters offshore, and in their earlier stages, at least, also in estuaries bounded by shores of the crystalline rocks. Very little can be suggested regarding the extent of the land surface or the precise configuration of its shores. That shores were present is clearly shown by numerous exposures of the conglomerates and sandstones abutting against irregular surfaces of the crystalline rocks, and by the presence of a large amount of local material in the deposits. In the southern portion of the present hills deposition did not proceed sufficiently for the accumulation of a large body of sediments, or if they were laid down they were subsequently removed by erosion. To the northward, where the deposits attain a thickness of several hundred feet, it is possible that the crystalline rock area was eventually buried as the land subsided, an idea further borne out by the presence of widespread sheets of fine-grained materials which the Deadwood formation contains in the northern hills. For the time extending from the close of the Cambrian to the early Carboniferous the Black Hills area presents a scanty record. In the southern hills, where Silurian and Devonian are absent, there may have been long-continued but slight submergence with no near land and no currents to bring deposits, or there may have been alternations of deposition and erosion, which left nothing of the scanty Silurian and Devonian deposits and yet did not remove much of the Cambrian. Possibly this latter hypothesis would best account for the relative thinness of the Cambrian now remaining in the southern part of the Black Hills, and the supposition that there was less uplift and erosion to the north would explain the thicker Cambrian and the remaining Silurian in that region. Probably more



CROSS SECTIONS OF THE BLACK HILLS AT THE SURFACE OF THE MINNEKAHTA LIMESTONE.

[The letters refer to lines of cross section shown on Pl. LXXXIX.]

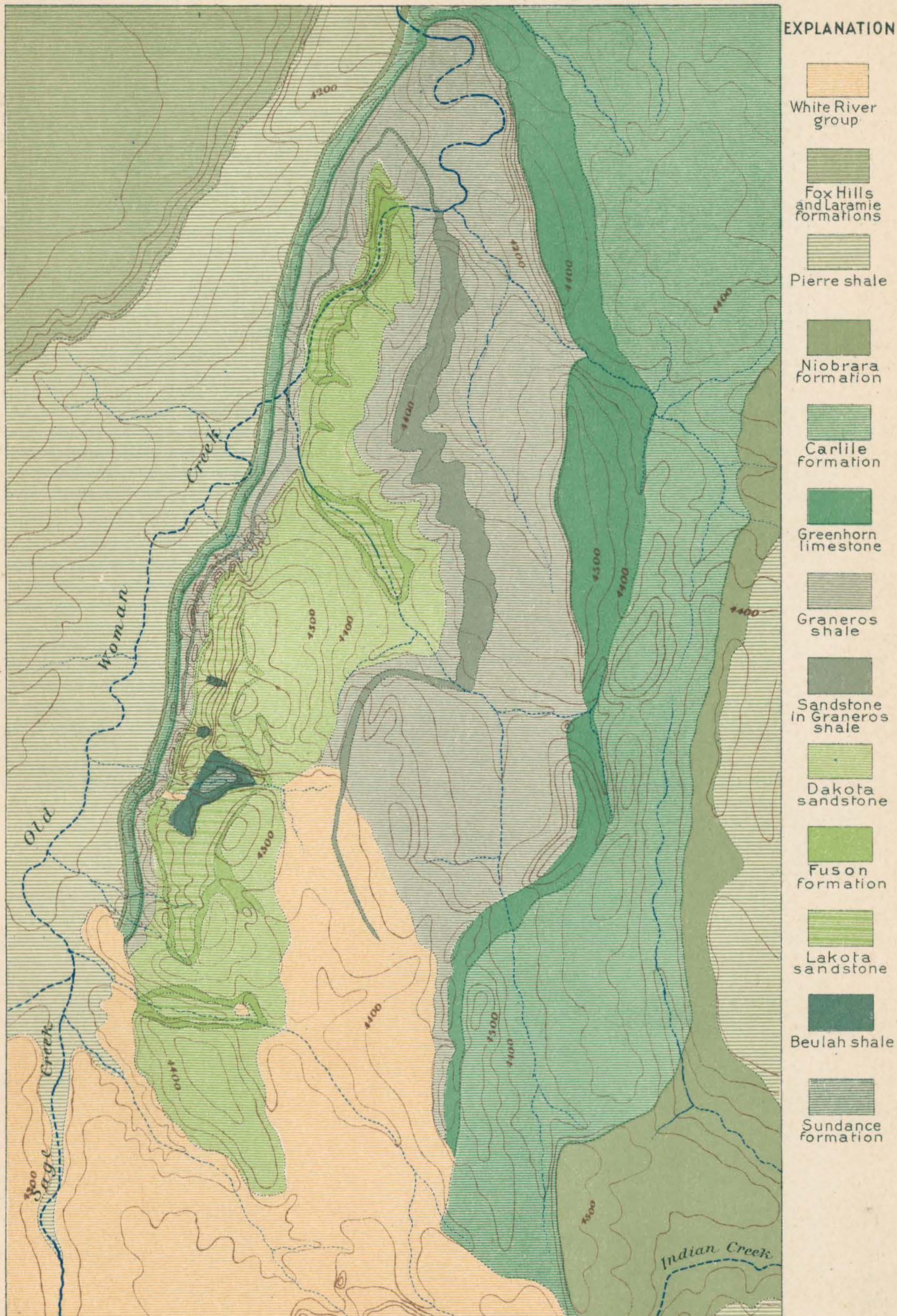
extended study of the Carboniferous-Cambrian contact will give additional evidence, but at present no definite theory can be proposed. The Carboniferous period began with relatively deep-water and marine conditions under which was laid down a great mass of calcareous sediments now represented by several hundred feet of nearly pure limestones. As no coarse deposits occur in the Pahasapa limestones, it is probable that no crystalline rocks were exposed above water in this region in the early Carboniferous, although it is possible that the limestone was deposited immediately upon them in some places.[1] In the latter part of the Carboniferous there was a change of condition that brought into the region a large amount of fine sand which was deposited in thick but regular beds, apparently with a large mixture of calcareous precipitates. More or less ferruginous material was also deposited at the same time, as is indicated by the color of much of the Minnelusa formation, the color apparently being due to the presence of iron in the original deposits. Minnelusa deposition was followed by the accumulation of materials of the Opeche formation, with its bright red sandstones and sandy shales. Next came the Minnekahta limestone, which was laid down in thin layers, but only to a thickness now represented by from 30 to 50 feet of the limestone. It was deposited from sea water, and from its fossils we know with fair degree of certainty that it is a representative of Permian time. The very great uniformity of this formation over the entire Black Hills area is an impressive feature, probably indicative of increased submergence with a cessation of those currents which brought the coarser materials of the two preceding formations. A great change of condition began suddenly at the close of the period represented by the Minnekahta limestone, for without apparent unconformity or time interval there began the deposition of the great mass of red shales constituting the Spearfish red beds. Vast lakes of saline waters were inclosed probably by a general uplift of a wide area of the West, and the red mud was laid down in thin layers to a thickness of from 350 to 500 feet, as now represented by the formation. That the red color is indigenous seems certain, for it is impossible to believe that it could have been subsequently segregated from exterior sources over so wide an area. The deep-red color is not due to later or surface oxidation, for, as shown by deep borings, it extends throughout the formation. Either the original sediments were red or they were colored by precipitation of iron oxide in the waters which deposited the sediments. At various times, which were not synchronous throughout the region, the clay sedimentation was interrupted by chemical precipitation of gypsum in beds ranging in thickness from a few inches to 30 feet.

[1] Recent observations in the uplifts in the Hartville region and northern end of the Laramie Mountains farther south in Wyoming show extensive areas of crystalline rocks which were bare through the greater part of Carboniferous time, so it appears probable that from these were derived more or less of the sandy sediments of the Minnelusa formation in the Black Hills.

It is believed that these beds are the products of evaporation due to increased aridity of climate, which at the same time temporarily suspended erosion and the general influx of the red-clay sediment; otherwise it is difficult to understand their nearly general chemical purity or freedom from admixture with red clay. Although there is no direct evidence, it is believed that the red beds above the Minnekahta limestone represent a whole or a part of Triassic time. It appears to have been everywhere followed by uplift without local structural deformation, but with general planation and local channeling, which represents a period of time of unknown duration. Then followed the deposition of the great series of deposits of the Jurassic.

The geologic history of the Jurassic deposits in the Black Hills region can be outlined in a general way. They represent conditions of deposition intermediate between those under which the red beds were laid down and those which gave rise to the Lakota and Dakota sandstones. It was mainly a time of submergence, in which sands and clays were deposited, but apparently in waters without strong currents. The isolated masses of coarse basal sandstones indicate shore conditions which varied locally and were a transient feature in the early part of the submergence. The ripple-marked sandstones following the lower shales were evidently laid down in shallow waters, probably marking a time of more rapid sedimentation than submergence, if not an arrest in the submergence. The extensive marine fauna and limestone layers in the later shales are indicative of deeper water conditions. At this stage sedimentation commenced to gain on submergence, the deposits became sandy, and there soon began the accumulation of sands now represented by the Unkpapa sandstone, which, as above described, has in places a thickness of 225 feet. Apparently the area of deposition at this time was to the east and southeast, for there is no evidence of degradation of Unkpapa beds where that formation thins out to the west and north. The Unkpapa sands were deposited in relatively quiet water, for the material is uniformly fine grained and rarely shows current bedding. Next came the deeper waters, in which were deposited a widespread mantle of sandy clay, now represented by the Beulah shales. Although these shales are absent in the southeastern portion of the hills, yet it is probable that they were originally deposited there to a greater or less thickness and then removed by erosion. This erosion resulted from the uplift which constituted the next stage. The extent of this degradation is not known, but it has given rise to a general erosional unconformity at the base of the Lakota sandstone, the next succeeding deposit. In fig. 284 an attempt has been made to represent the principal stages in the cycle of events in Jurassic times, as above described. The diagram has little or no quantitative status, but it shows the general nature and sequence of events.

In Cretaceous time the region of the present Black Hills received a great succession of deposits of various kinds, but in greater part uni-



GEOLOGIC MAP OF THE ANTICLINAL AREA ON OLD WOMAN CREEK, CONVERSE COUNTY, WYOMING

BY

N. H. DARTON

Contours based entirely on barometric observations

SCALE

1 0 1 2 MILES

CONTOUR INTERVAL 50 FEET

1899

SEIBERT COMPANY, LITHO. N.Y.

form over a wide area. The variety of materials indicates considerable diversity of conditions, but in general there was a cycle beginning and ending with sands, with a long period of clay deposition in the middle. The first formation, the Lakota, consisted mainly of coarse sands, in greater part deposited by strong currents in beds 30 to 40 feet thick, with short intervening periods of deeper water or slackened currents in which several partings of clay were laid down. Probably the submergence at the time was slight, and there were periods of emergence, with slight planation in some regions and local accumulations of coal in others. At the end of the Lakota there accumulated a thin layer of calcareous deposit, now represented by the Minnewaste limestone, which may not have extended far beyond its present limits. Then followed deposition of the light-colored fire clays of the Fuson formation, which were much intermixed with sand to the northwestward. In the time of Dakota deposition the conditions were similar to those of Lakota time, but the accumulation of sand was not so long continued. There was everywhere in the region a rapid change from

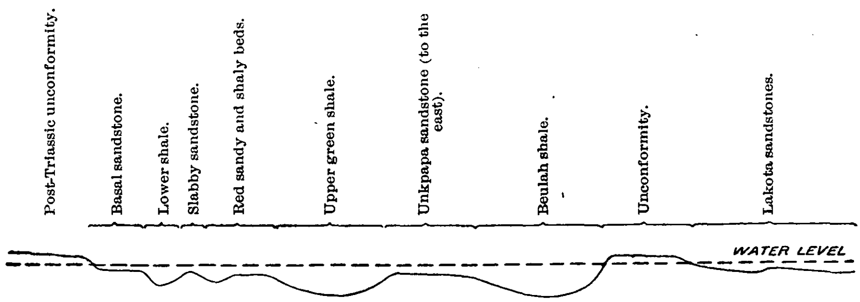


FIG. 284.—Outline of history of Jurassic deposition in the Black Hills region.

sand to clay deposition at the beginning of the Benton, doubtless due to sudden increased submergence.

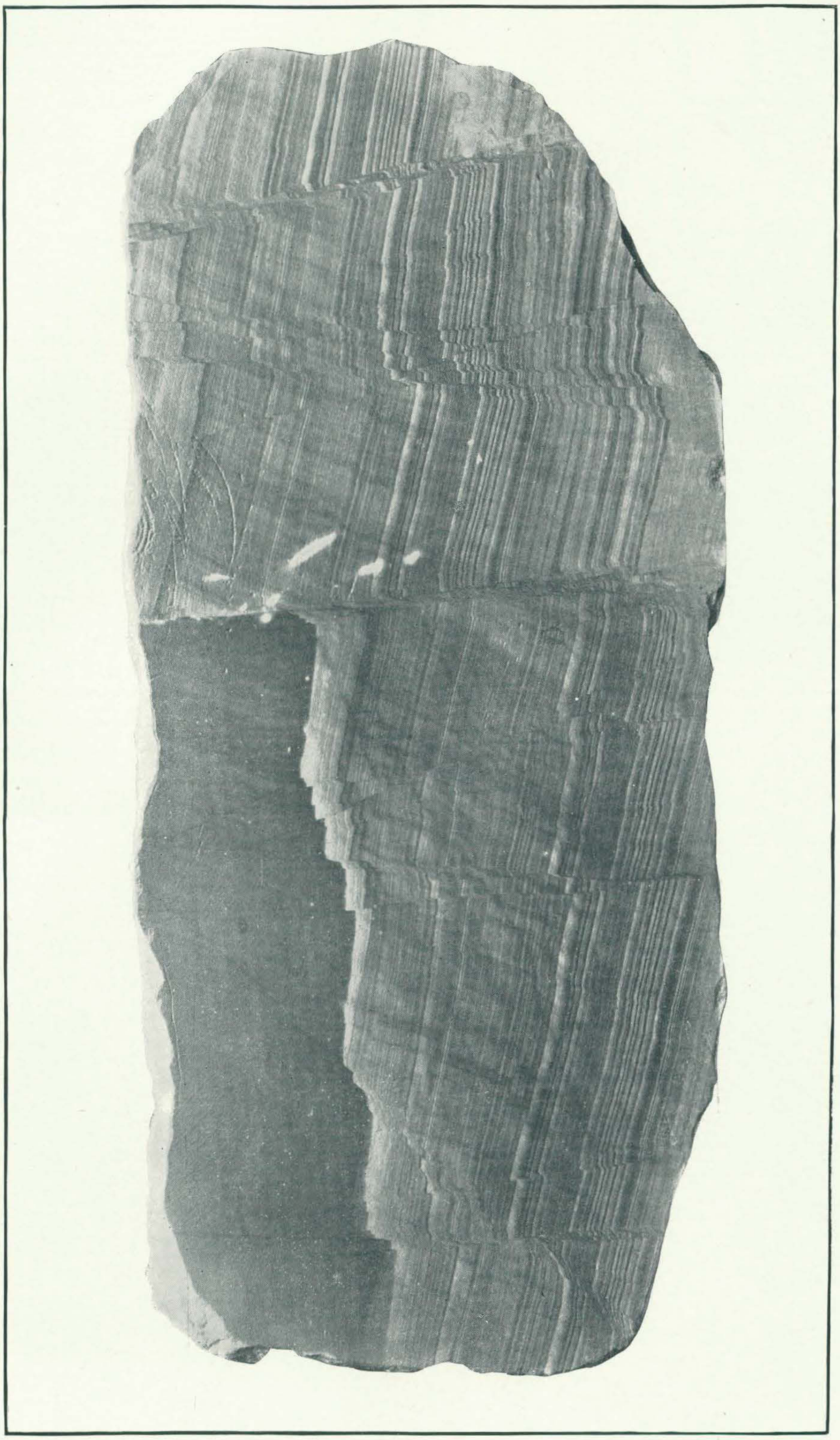
In Benton, Niobrara, and Pierre times there was a long-continued, deep submergence, with the accumulation of several thousand feet of clay. In Benton time there were occasional interruptions by sand depositions, two of them in the later part of the epoch that were general over the greater part of the Black Hills region, and one in the earlier part that was local, giving rise to the lenses of sandstone which are now found in the vicinity of Newcastle and northwest of Hermosa. Another marked date was a relatively transient but general deposition of the calcareous bed of the Greenhorn limestone in the middle of the Benton sedimentation. The shale deposition of the Benton was followed by the accumulation of several hundred feet of impure chalk, now constituting the Niobrara formation. This was succeeded by the very uniform conditions attending the deposition of the great mass of clay now represented by over a thousand feet of Pierre shale. In Fox Hills time there was a gradual change to conditions which produced alternations of clays and coarse sand of marine origin. This period gave place gradually, doubtless through uplift, to deposition in a wide fresh-water basin of the alternations of thick masses of sands and clays of the Laramie formation. Whether these formations were deposited over the area now occupied by the Black Hills dome is not definitely known, but it is probable that they were, as they extend around two sides of the uplift and are upturned by it. The Black Hills dome was uplifted in early Tertiary time, and the larger topographic outlines of the region were developed before the Oligocene. The dome was truncated and its larger valleys excavated in part to their present depths, as is indicated by the occurrence in them of White River deposits, even in some of their deeper portions. Where the great mass of eroded material was carried is not known, for in the lower lands to the east and south we have no Eocene deposits nearer than those on the Gulf coast and the Mississippi embayment. The great lake which deposited the White River sediments of the Oligocene had its early shores on the Black Hills, and the higher portions of these hills were probably an island throughout that period. Arms of the lake extended part way up the larger valleys, receiving from various streams products of erosion from the Black Hills rocks, which now are prominent among the constituents of the early White River sediments. Some conditions at an early period in this Oligocene deposition are shown in Pl. XCIV (oversheet), which has been constructed largely from observed deposits and shore lines. Some of the drainage of the period is also shown on the oversheet, but with much less certainty, as it has not always been practicable to differentiate between the Oligocene and earlier Pleistocene drainage in the higher portions of the hills, where the White River deposits are absent. It is probable that the maximum submergence was much greater than is shown in the plate above referred to, for there are evidences in the relations of the drainage that many of the valleys and lower divides of the central portions of the hills were completely filled with White River deposits. They are found up to high altitudes—in the vicinity of Lead at an elevation over 5,200 feet and on the north end of the Bear Lodge Mountains, a thousand feet higher—and they are believed to have caused a superimposition of drainage at various points in the central and southern hills which can not be accounted for in any other way. It would not be safe at present to draw a map suggesting the maximum submergence of Oligocene times, but possibly later studies will afford means for doing so. Post-Oligocene erosion has removed most of the more elevated areas of White River deposits and probably the maximum submergence was so transient that no conspicuous shore lines were cut. No one who has observed extensive exposures of the finer-grained White River sediments would regard them as other than lake deposits. It has been suggested that their materials were carried by the wind, and also that they were

3-COLOR PROCESS

FROM PHOTOGRAPH BY N. H DARTON

FLEXURES IN MINNEKAHTA LIMESTONE AND MINNELUSA SANDSTONE

West side of Black Hills uplift, east of the valley of Stockade Beaver Creek, 5 miles east of Newcastle, Wyoming



BLOCK OF FAULTED UNKPAPA SANDSTONE FROM WEST OF BUFFALO GAP, SOUTH DAKOTA.

deposited by running water on broad slopes by a network of streams; but the formations present features which are entirely at variance with these hypotheses. They consist mainly of very fine-grained materials, usually spread out in thin beds with perfectly even stratification, in which precisely the same sequence of beds may be traced for miles. This is an impressive feature in the big Bad Lands, where in widespread exposures the very even and uniform bedding of the Oreodon or Brule clays is everywhere to be observed. In the lowest member, the Chadron formation, the extensive deposits of fullers' earth are almost certainly of chemical origin and afford no suggestion of stream deposition. At the base of this formation there are extensive areas of very coarse materials, the products of streams which immediately preceded the general submergence by the advancing lake waters. There are also in that formation certain stream deposits which meander across the fine-grained materials, occupying channels which often are traceable to and through the pre-Oligocene gaps in the hogback range of the Black Hills. These stream deposits, however, are generally completely inclosed by the fine-grained sediments, and they represent episodes in some stages of the deposition when the subsidence was slightly retarded and surface streams or strong currents extended out over the lake-laid deposits for a short time. It is in these channels of coarser material that the greater number of titanotherium bones are found. These remains are of animals that died on the shores or in the waters of the early Oligocene streams in the Black Hills, and while their bodies were inflated by the gases of decomposition were carried out into the lake a greater or less distance or deposited along the courses of the streams. This condition of deposition is one that is to be seen at the present day, and I think fully accounts for the conditions under which the remains are found in the White River formations. In the Oreodon beds, or Brule clays, where the products of currents are in evidence only locally, at two widely separated horizons, it is easy to understand that the bodies floated part way across the lake before they dropped to its bottom, eventually to be buried by the sediments. The eastern margin of this lake has not been traced for any distance, but there is no great difficulty in seeing that it consisted of low hills of Pierre shale and Fox Hills beds against which the Tertiary formations now abut to the east. The region adjoining the Black Hills and Laramie Range was uplifted several thousand feet at a period subsequent to the deposition of the White River and overlying Miocene formations, an uplift which amounts to as much as the present upslope of the plains now partly underlain by Tertiary formations in Nebraska and Dakota. The deposition extended far to the north of the Black Hills, as shown by Professor Todd in his discovery of extensive areas of White River beds in the extreme northwestern part of South Dakota. To the southwest I have traced them along the foot of Pine Ridge to Douglas, in central Wyoming, where they abut against hills of Laramie sand-

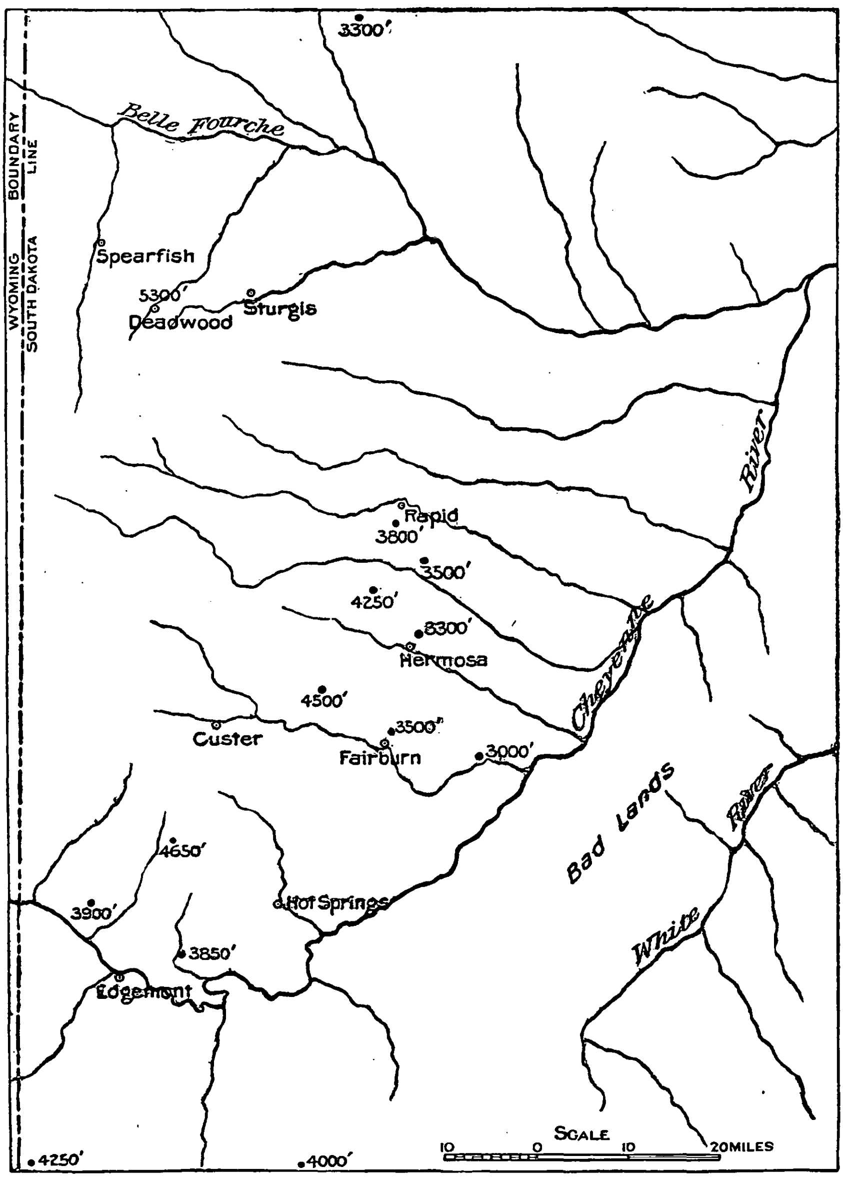


FIG. 285.—Map of the Black Hills and adjoining regions, giving altitudes of White River deposits at various points in order to show the amount and distribution of post-Oligocene uplift.

stone. They have not yet been discovered directly west of the Black Hills, unless, possibly, there is a small, thin remnant on top of the

(PL. XCIV)

APPROXIMATE AREA OF DEPOSITION OF LOWER BEDS OF WHITE RIVER GROUP IN THE SOUTHEASTERN PORTION OF THE BLACK HILLS

ALSO THE COURSE OF THE PRINCIPAL DRAINAGE

Laramie sandstone capping the summits of Pumpkin Buttes, at the head of Belle Fourche River. I have recently (1900) found them on the high ridges extending north from Warren Peak, in Bear Lodge Mountain, at an altitude of over 6,000 feet.

Following the deposition of the White River formations there were several hundred feet of uplift, with erosion and probable complete draining of the lake. No representatives of the Loup Fork group—the Arikaree and Ogallala formations—have been discovered in the immediate vicinity of the Black Hills, but they are extensively developed in Pine Ridge on the south and remain in portions of the area of the high buttes to the north in the northwestern corner of the State of South Dakota. There was probably slow but continuous uplift during the Loup Fork period, and the Black Hills contributed materials from its higher slopes at that time, but whether they ever were deposited in the immediate vicinity of the hills is not ascertained. The present altitude of the base of the White River deposits in the Black Hills and adjoining regions is shown in fig. 285, which indicates the amount of uplift, mainly of late Tertiary date. During the early portion of the Pleistocene period there was widespread planation of the Tertiary deposits, and many of the old valleys were revived. There was at this time, however, considerable rearrangement of the drainage, probably caused on the eastern side of the hills by increased tilting to the northeast during the late Tertiary uplift. Some of the streams superimposed upon the White River deposits cut across old divides, and in some cases connected valleys with their next neighbor to the north. This history is clearly indicated by the offsetting of pre-Oligocene valleys to the northward through canyons of post-Oligocene age, leaving numerous elevated saddles to mark the original course of the valleys to the southeastward. Some of the offsetting in the present drainage has been largely increased by early Pleistocene erosion and recent stream robbing. The early Pleistocene streams had in greater part the course shown in the oversheet of Pl. XCV. The erosion of the White River deposits in the higher valleys was easily effected, owing to their softness, so that the upper portions of most of the old valleys were completely cleaned out. In the lower lands to the east of the hills there was wide planation, but apparently it was not sufficiently long continued to cut en-

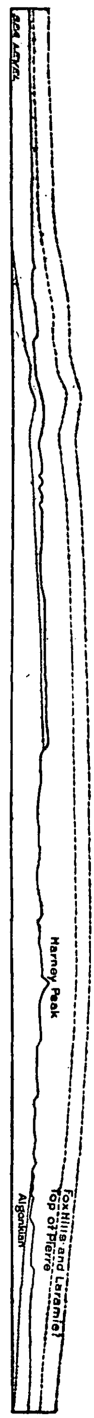


Fig. 286.—Section across center of Black Hills uplift to show extent of degradation.

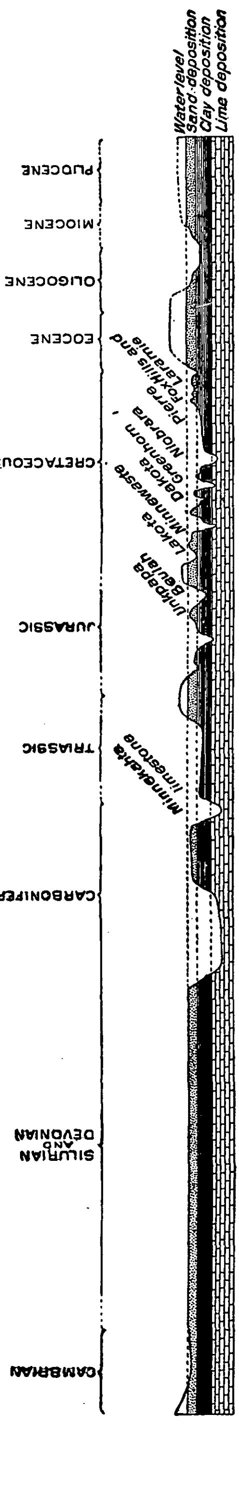
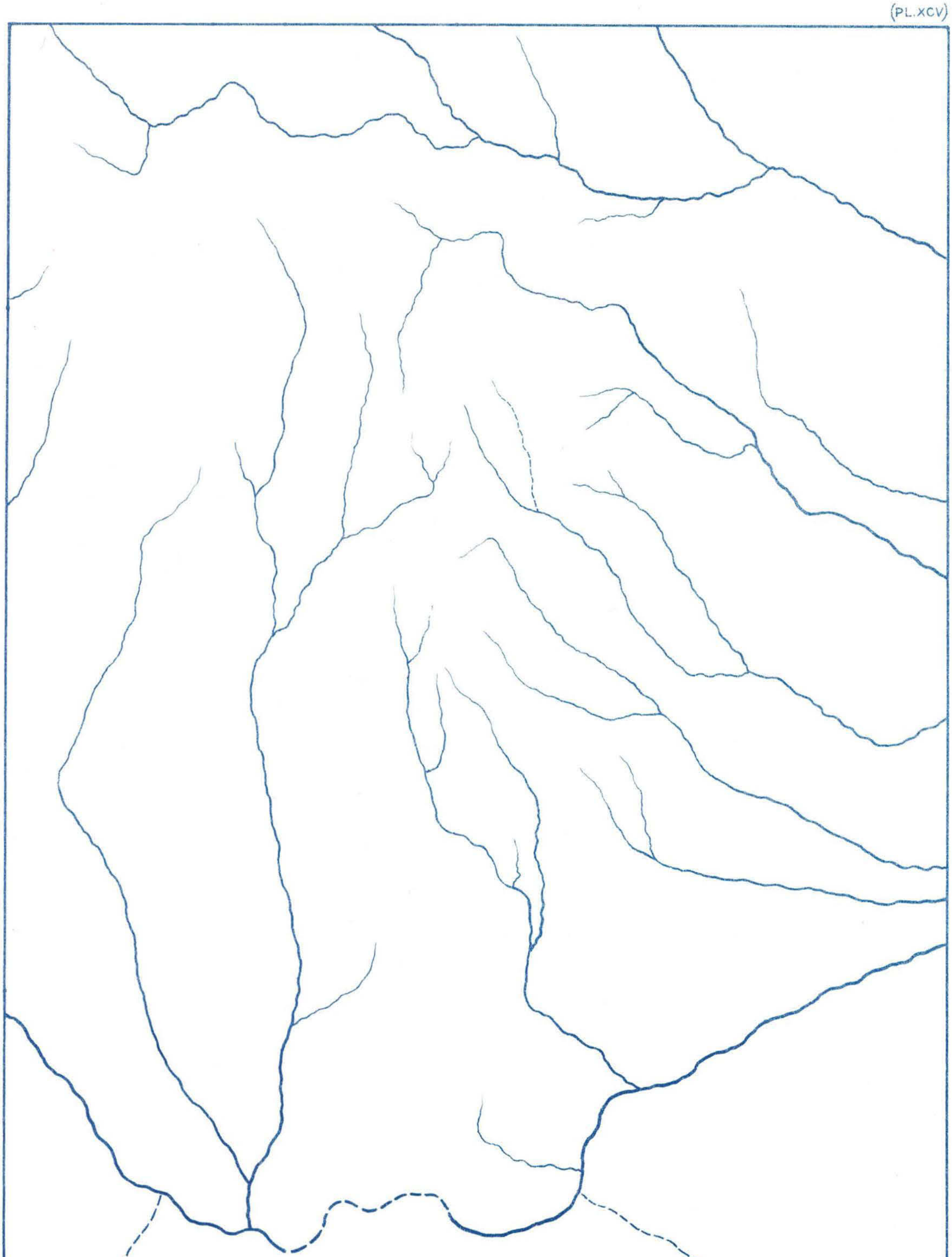


Fig. 287.—Diagram of the principal events in the geologic history of the southern Black Hills region.

tirely through the White River formations. The Pleistocene streams were in narrow valleys in the hills, but they spread out widely in the Red valley, then mostly filled with White River sediments, and east of the hogback range excavated wide valleys, probably shifting more or less laterally, which extended far east to beyond the present valley of White River. There appears to have been further uplift in late Pleistocene time, for the present valleys below the level of the earlier Pleistocene high-level deposits seem to be cut deeper than would result simply from the natural progression of a lower plain of base leveling up the Missouri and Cheyenne rivers. The result has been the cutting of wide, shallow valleys in the soft deposits and canyons of moderate extent and depth in the harder rocks. The erosion has progressed with regularity in the main, but in some cases, with the shifting of channels, there have been accumulations of local deposits on small terraces at various levels. The more notable of these are the terraces along Cheyenne River, the deposit of conglomerate, etc., at Hot Springs, and the gravel accumulations on the "high bars" at different points in the higher canyons. Stream robbing has been constantly in progress in the eastern portion of the hills, nearly always to the northeast, the more northerly streams here often having the advantage of increased declivity over their neighbors on the south.

In fig. 287 a diagram is given to show the geologic history of the Black Hills mainly as represented by the nature of the sediments. The principal periods of uplift are also indicated. The diagram has no quantitative scale, either horizontal or vertical, for we do not know the relative lengths of geologic periods, and the nature of the materials does not always indicate the depth of water in which they were deposited.

(PL. XCV)



APPROXIMATE COURSE OF EARLY PLEISTOCENE DRAINAGE IN THE SOUTHEASTERN BLACK HILLS

BY

N. H. DARTON

1899

WATER RESOURCES.

UNDERGROUND WATERS.

GENERAL RELATIONS.

The underground water problem in the region to which this report relates is mainly in the plains adjoining the Black Hills. There extend

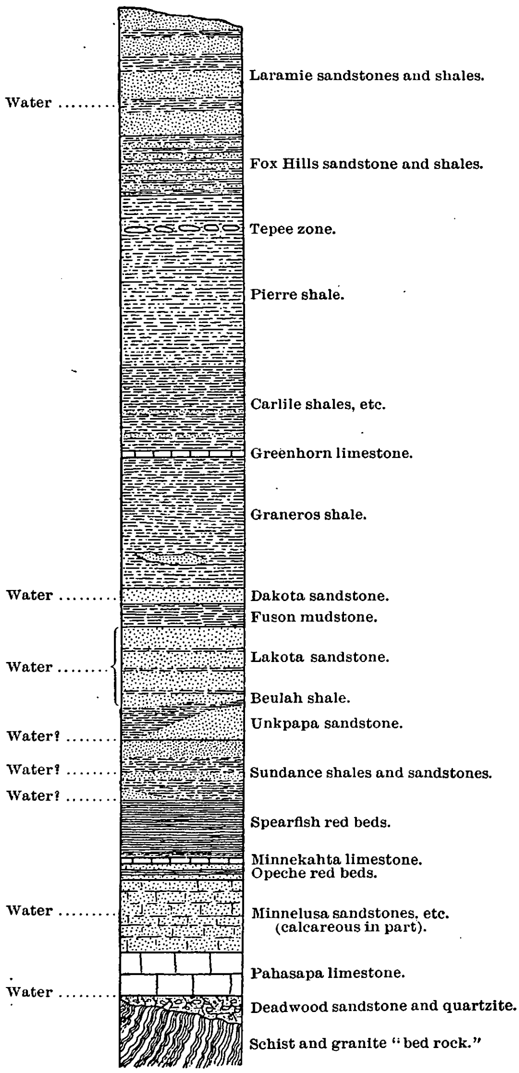


FIG. 288.—Columnar section of sedimentary formations in Black Hills region, showing the water-bearing beds.

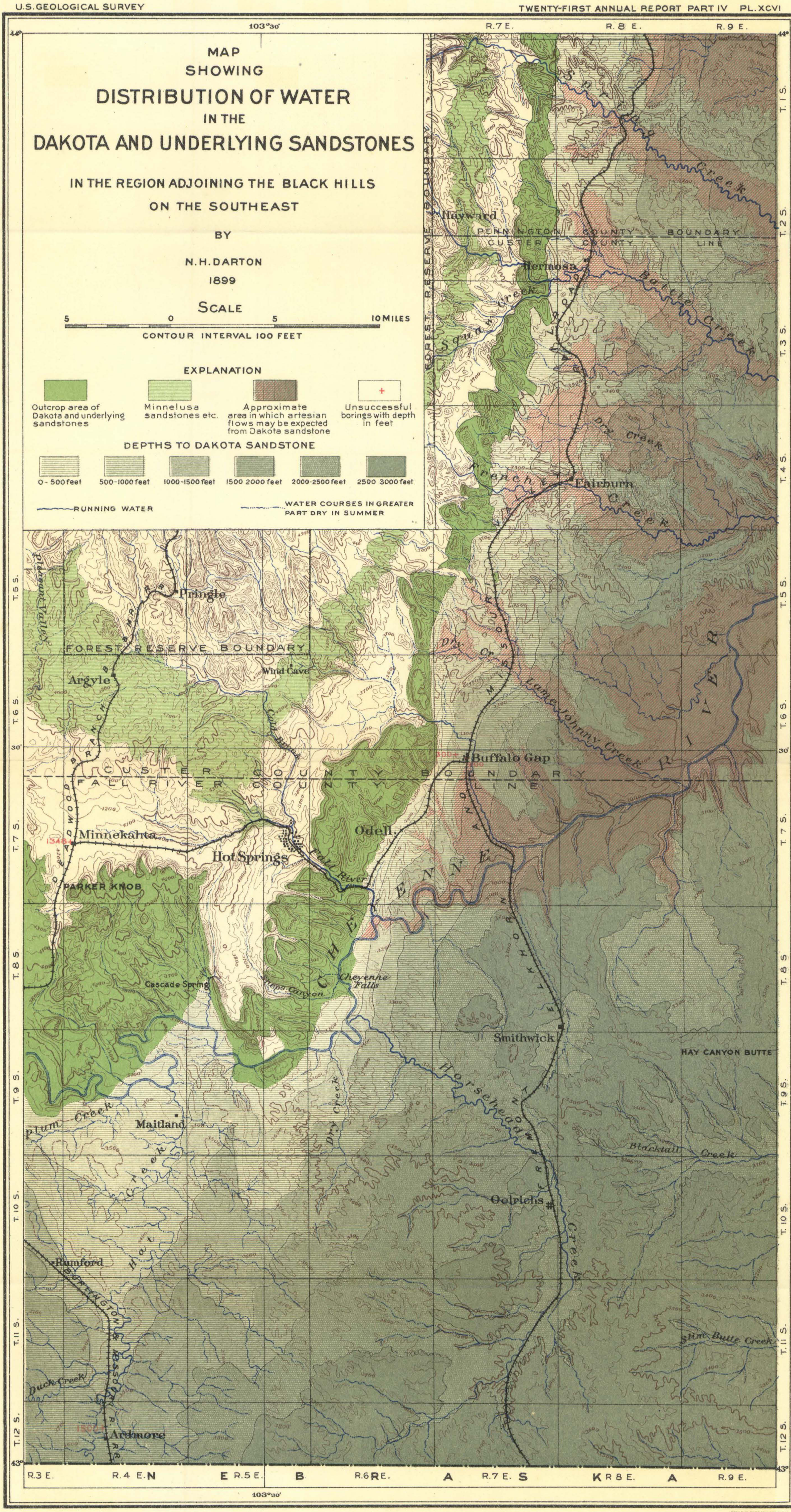
under these plains several thick sheets of water-bearing sandstones, which receive water supplies at the surface in the high lands of the

Black Hills. These sandstones are carried under ground on the general outward dip on the flanks of the hills, and owing to the relative steepness of this dip a considerable depth is soon attained. In most parts of the area the inclination of the strata diminishes away from the hills, and there is a wide area of the surrounding country under which the water-bearing beds lie at a depth that is within reach of the well-borer. As the region is semiarid, with surface waters often containing much "alkali," there is great need at most places for the underground waters. In fig. 288 are shown the principal water-bearing horizons in the Black Hills and their vicinity. These formations are all uplifted above the surface on the slopes of the Black Hills in regular succession, as described in the geologic portion of this report. They outcrop in wide zones encircling the hills, and receive a large amount of water not only from the rainfall on their surface, but from the streams which at many points sink in whole or in part in crossing the outcrops of the more permeable beds. The sinking of streams in this manner is to be observed in almost every valley leading out of the crystalline-rock area. Few of the streams carry more than a small proportion of the total original run-off of their watersheds into Cheyenne River, as much of it sinks under ground in crossing the sandstones, particularly those of the Minnelusa, Lakota, and Dakota formations. These waters pass far beneath the surface as the water-bearing beds descend on the slopes of the Black Hills uplift.

DAKOTA-LAKOTA HORIZON.

Under the plains to the east of the hills the waters lie in some places as deep as 3,000 feet, and in the case of the Dakota-Lakota horizon the water-bearing beds continue all the way under the States of South Dakota and Nebraska, outcropping on Missouri River below the mouth of Big Sioux River, where for many miles the waters escape in copious springs. Artesian wells have been sunk by the hundreds in eastern South Dakota to depths of from 400 to 1,000 feet in greater part, and yield a vast volume of waters for domestic use and even for extensive irrigation. A view of a typical well from this horizon in eastern South Dakota is given in Pl. XCIX, and the extension of the water-bearing beds from the Black Hills uplift is shown in fig. 289.

Various wells have been bored in the vicinity of the Black Hills which in most cases have yielded satisfactory supplies of water. The most notable of these are on the Burlington and Missouri River Railroad at Argentine, near Clifton, and at Jerome Siding. There are also flowing wells at Newcastle and at Belle Fourche, on the northern edge of the Black Hills, and deep wells at Edgemont, which contain water, but without sufficient pressure to flow at the surface. All of these wells and the numerous artesian wells that yield so large a volume of water in the eastern part of South Dakota obtain their sup-


MAP
SHOWING
DISTRIBUTION OF WATER
IN THE
DAKOTA AND UNDERLYING SANDSTONES
IN THE REGION ADJOINING THE BLACK HILLS
ON THE SOUTHEAST
BY
N. H. DARTON
1899
SCALE
5 0 5 10 MILES
CONTOUR INTERVAL 100 FEET
EXPLANATION
Outcrop area of Dakota and underlying sandstones
Minnelusa sandstones etc.
Approximate area in which artesian flows may be expected from Dakota sandstone
Unsuccessful borings with depth in feet
DEPTHS TO DAKOTA SANDSTONE
0-500 feet
500-1000 feet
1000-1500 feet
1500-2000 feet
2000-2500 feet
2500-3000 feet
RUNNING WATER
WATER COURSES IN GREATER PART DRY IN SUMMER
103°30'
R. 7 E.
R. 8 E.
R. 9 E.
44°
43°
T. 1 S.
T. 2 S.
T. 3 S.
T. 4 S.
T. 5 S.
T. 6 S.
T. 7 S.
T. 8 S.
T. 9 S.
T. 10 S.
T. 11 S.
T. 12 S.
30'
Hayward
PENNINGTON COUNTY BOUNDARY LINE
CUSTER COUNTY
Hermosa
Battle Creek
Squaw Creek
Spring Creek
Dry Creek
French Creek
Fairburn
FOREST RESERVE BOUNDARY
Pringle
Pleasant Valley
Argyle
Wind Cave
Beaver Creek
Lame Johnny Creek
Buffalo Gap
CUSTER COUNTY BOUNDARY
FALL RIVER COUNTY LINE
Minnekahta
Hot Springs
Fall River
Odell
PARKER KNOB
CHEYENNE RIVER
Cascade Spring
Cheyenne Falls
Smithwick
HAY CANYON BUTTE
Plum Creek
Maitland
Dry Creek
Horsehead Creek
Blacktail Creek
Hat Creek
Oelrichs
Rumford
BURLINGTON & MISSOURI RIVER R. R.
ELKHORN R. R.
Slim Butte Creek
Duck Creek
Ardmore
R. 3 E.
R. 4 E.
R. 5 E.
R. 6 E.
R. 7 E.
R. 8 E.
R. 9 E.
NEBRASKA
SOUTH DAKOTA

plies from the Dakota-Lakota horizon. This horizon is the one nearest the surface in the region adjoining the Black Hills, although, owing to the steep dip of the beds, it lies deep beneath the overlying Cretaceous shales under most localities. These shales are barren of water and in all cases have to be penetrated to reach the Dakota sandstone. In Pls. XCVI and XCVII are shown the depth to this sandstone over the entire area to which this report relates. In these plates there is also represented the area in which artesian flows may be expected, the outcrop areas of the water-bearing formations, and the location of all deep borings that have been reported. The depth to the Dakota sandstone has been ascertained by careful measurements of the thickness of the overlying formations and the determination of the structure in the region adjoining the hills. The principal guide to the structure in the wide area about Oelrichs was the occurrence of the horizon of limestone lenses in the Pierre shales, giving rise to tepee buttes.

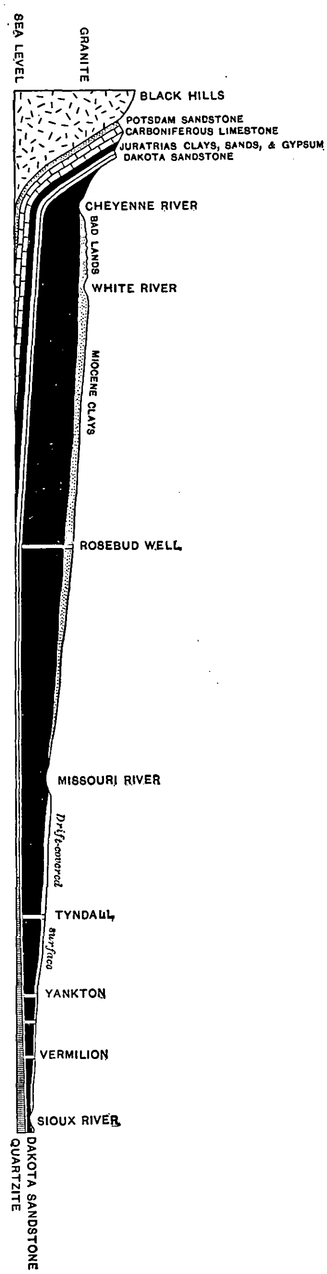


Fig. 289.—Section across South Dakota from the Black Hills to Sioux River to show the artesian conditions.

It should be stated that the depths shown in Pls. XCVI and XCVII are to the top of the Dakota sandstone, and ordinarily it would be necessary to bore some distance farther in this sandstone before any large volume of water could be expected. The principal supplies usually occur in the upper part of the Lakota formation, which often lies 200 feet below the top of the Dakota beds. It will be noticed on the maps that the zone in which water may be obtained at depths less than 500 feet is a very narrow one for the greater part of its course and lies along the base of the hogback foothills. The belt in which the waters lie between 500 and 1,000 feet below the surface is somewhat broader and passes outside of many of the small settlements that are scattered along the railroad just outside of the hills. In the area under which the water lies more than 2,500 feet below the surface it would probably not be desirable to sink a well, for it is very difficult to bore to this depth through the great mass of overlying shale. In the wide area of central Weston and Converse counties, Wyoming, the Dakota-Lakota horizon lies at great depth under the great mass

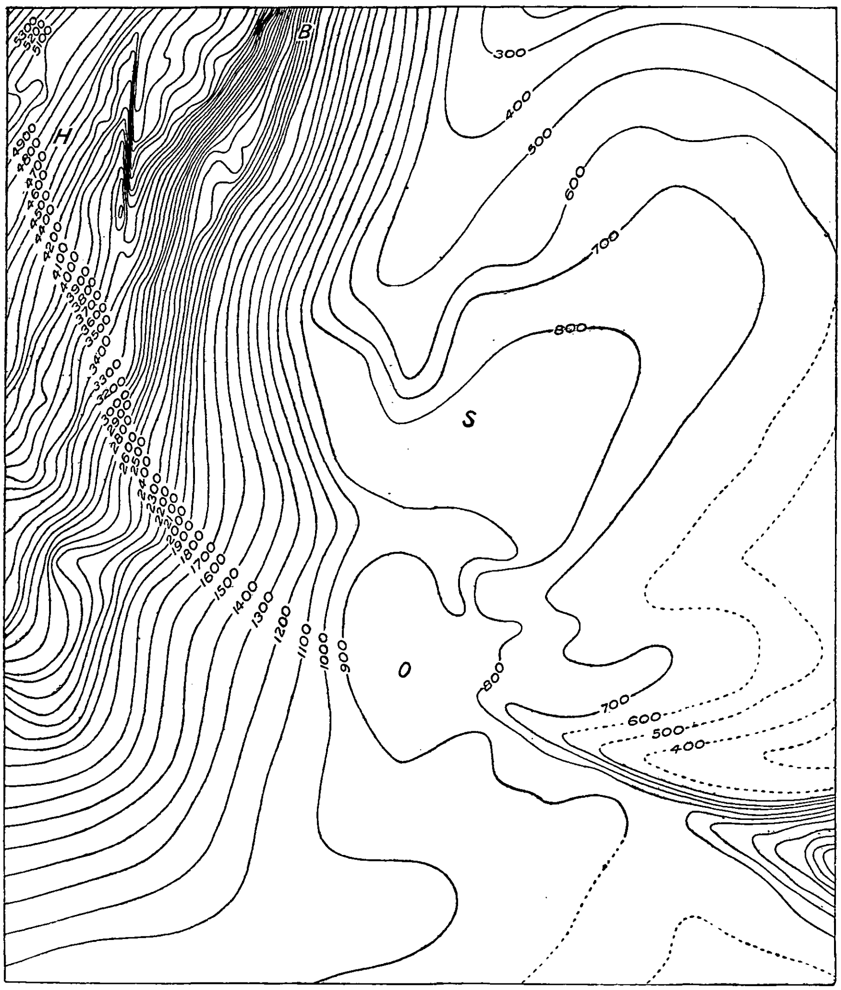
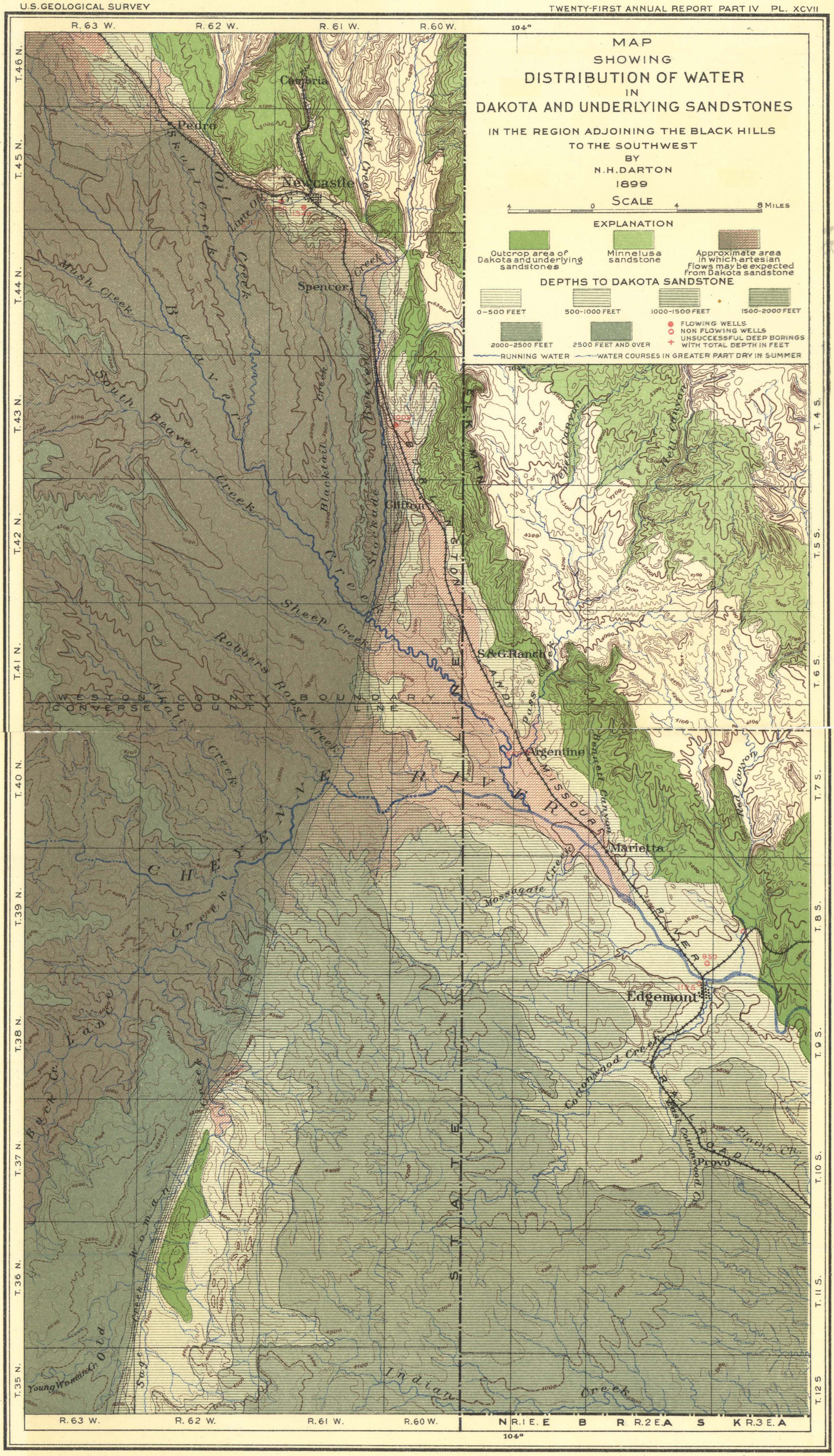


FIG. 290.—Diagram of contour of top of Dakota sandstone about Oelrichs and Hot Springs, South Dakota. O, Oelrichs; S, Smithwick; B, Buffalo Gap; H, Hot Springs.

of Laramie deposits. In that region, however, there are prospects for finding waters in the Fox Hills and the Laramie sandstone, but these would not yield surface flows in the area described in this report.

Looking at the water problem of the Northwest in a broader way, and taking the data which has been secured in the course of the last few years in the Dakotas, Nebraska, and the adjoining States, Pl. C


MAP
SHOWING
DISTRIBUTION OF WATER
IN
DAKOTA AND UNDERLYING SANDSTONES
IN THE REGION ADJOINING THE BLACK HILLS
TO THE SOUTHWEST
BY
N.H. DARTON
1899
SCALE
4 0 4 8 MILES
EXPLANATION
Outcrop area of Dakota and underlying sandstones
Minnelusa sandstone
Approximate area in which artesian flows may be expected from Dakota sandstone
DEPTHS TO DAKOTA SANDSTONE
0-500 FEET
500-1000 FEET
1000-1500 FEET
1500-2000 FEET
2000-2500 FEET
2500 FEET AND OVER
FLOWING WELLS
NON FLOWING WELLS
UNSUCCESSFUL DEEP BORINGS WITH TOTAL DEPTH IN FEET
RUNNING WATER
WATER COURSES IN GREATER PART DRY IN SUMMER
R. 63 W.
R. 62 W.
R. 61 W.
R. 60 W.
104°
T. 46 N.
T. 45 N.
T. 44 N.
T. 43 N.
T. 42 N.
T. 41 N.
T. 40 N.
T. 39 N.
T. 38 N.
T. 37 N.
T. 36 N.
T. 35 N.
T. 4 S.
T. 5 S.
T. 6 S.
T. 7 S.
T. 8 S.
T. 9 S.
T. 10 S.
T. 11 S.
T. 12 S.
N R. 1 E. E B R R. 2 E. A S K R. 3 E. A
Cambria
Pedro
Newcastle
Spencer
Clifton
S.&G. Ranch
Argentine
Marietta
Edgemont
Provo
Salt Creek
Oil Creek
Skull Creek
Mush Creek
South Beaver Creek
Beaver Creek
Blacktail Creek
Stockade
Sheep Creek
Robbers Roost Creek
Mill Creek
Cheyenne River
Crown Creek
Lance Creek
Buck Cr.
Young Woman Cr.
Old Woman Creek
Sage Creek
Indian Creek
Mossagate Creek
Cottonwood Creek
Plains Cr.
Hell Canyon
Red Canyon
Pass Creek
WESTON COUNTY BOUNDARY
CONVERSE COUNTY LINE
STATE LINE
BURLINGTON AND MISSOURI RIVER RAILROAD

is offered to illustrate the factors bearing on the prospects for obtaining artesian waters from the Dakota-Lakota horizon over the entire area of the northern Great Plains region.

MINNELUSA SANDSTONE.

The Minnelusa formation is of so sandy a nature that we may expect it to contain water in sufficient volume to furnish supplies to wells in portions of the Red Valley. As it lies 1,000 feet or more below the Dakota sandstone and is several hundred feet thick itself, its waters lie too deeply buried to be available in the plains adjoining the Black Hills. The Red Valley contains but little surface water, and there are many places where a water supply from deep wells would be very serviceable. There are several large springs about the hills which appear to flow from the Minnelusa formation either directly or through crevices in the Opeche formation and the Minnekahta limestone. The most notable of these are the thermal springs at Hot Springs and Cascade, where very large volumes of water are undoubtedly derived from the Minnelusa beds, although they emerge from crevices in the Minnekahta limestone. Their temperatures indicate that they come from a considerable depth. At the Soldiers' Home at Hot Springs a well has been sunk into Minnelusa sandstone which furnishes a water supply. At Minnekahta Station a deep boring was made, apparently through the Minnekahta formation, that yielded no water. At Cambria a boring is now in progress which has penetrated through the formation without finding more than a very moderate supply of water. For part of the area at least the Minnelusa formation, although a porous sandstone at the surface, is much less permeable under ground. This is due to its being cemented into a very compact rock by carbonate of lime, which appears to so fill up its interstices that it could not contain much water. How general this condition may be under ground is not yet known.

DEADWOOD SANDSTONE.

The Pahasapa limestone is traversed by numerous open joints and caves of vast extent, but they do not appear to contain much water. It is probable that the water in the limestone is not great in volume at most, and is free to sink into the underlying Deadwood sandstone. This sandstone contains much water that would be available for wells, but in the southern Black Hills the area is very restricted in which these waters could be obtained within a reasonable limit of depth. In the sections (Pl. LXXXVIII) are shown the underground relations of the Carboniferous and Cambrian formations in the southern Black Hills. These it is thought will afford all necessary information to persons contemplating sinking wells to these lower horizons.

BORINGS.

Several wells have been bored in the region to which this report relates, some have been successful and others have failed to yield water. In most cases the unsuccessful borings were made at points where their failure might have been predicted by the geologist, but for others an explanation is difficult. As it is desirable to place on record all of the data which have been obtained regarding the borings they will be given on the following pages.

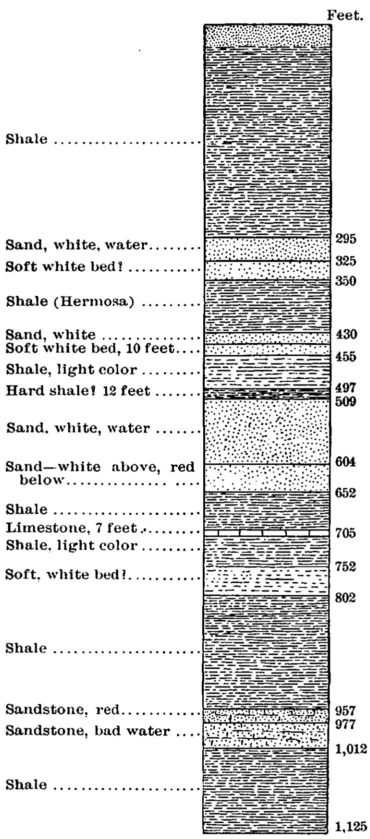


FIG. 291.—Log of deep well at Edgemont, South Dakota.

Edgemont.—In this city and its vicinity a number of wells were sunk several years ago for water from the Dakota sandstone. They nearly all obtained supplies for pumping, but owing to the low level of the outcrops of the Dakota sandstone in the vicinity the water did not have sufficient head to flow. The water did not prove satisfactory for use in locomotives, and all but the deeper well at the railroad roundhouse have been abandoned. The records of the two wells are given in figs. 291 and 293, and their location is shown in fig. 292. One of the wells at the roundhouse, of which the log is given in fig. 291, has a depth of 1,125 feet, but is now filled to the depth of 700 feet. Water of bad quality was found in the white sand at 295 feet and in the sandstone at 977 feet. Fairly good water is now obtained from the sandstone which begins at a depth of 509 feet. It rises to within 60 feet of the surface. It contains 239 grains of solid matter per gallon, of which 9.33 grains are lime. The log appears to be a fairly reliable one, indicating the Dakota sandstone from 295 to 350 feet; the Fuson formation from 350 to 430 feet; the Lakota formation from 430 to about 635 feet; possibly the Unkpapa sandstone between 635 and 652 feet; and the Sundance shales and sandstones thence to 1,125 feet, which is probably not far above the top of the red beds of the Spearfish formation. The Beulah shales may be represented between 652 and 700 feet, lying above the limestone between 705 and 712 feet, which usually occurs near the top of the Sundance formation. The well at the north end of the Y across the river from Edgemont has a depth of 960 feet, and probably ends in Sundance shales. Some water was found in the white sand at 230 feet, and in sandstones at 290 and 430 feet. At 578 feet a sandstone begins which yields a good supply of water, rising to within 30 feet of the surface. A thin sand-rock at 703 feet also yields water, but its volume is small.

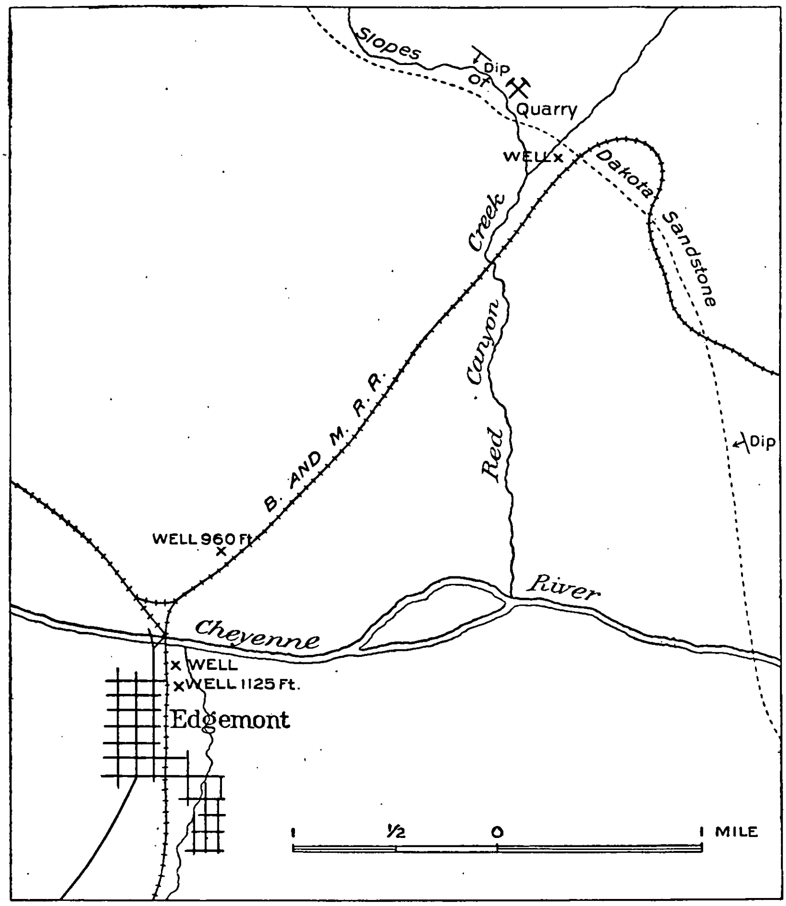


FIG. 292.—Map of Edgemont and vicinity to show the location of the deep borings.

Ardmore.—At Ardmore, on the Burlington and Missouri River Railroad, 26 miles south of Edgemont, the railroad company has made a boring to a depth of 1,500 feet without obtaining water. The hole is entirely in shale, excepting about 40 feet of white sand containing thin partings of black shale. This boring begins just about the surface of the Niobrara formation, and apparently penetrates very nearly to the Dakota sandstone, the sandstone bed reported probably being in the Graneros shales. As Ardmore is at the altitude of 3,557 feet, and the water-bearing Dakota sandstone outcrops about Edgemont are at an altitude of 3,400 feet, there is no possibility of a flow at the former place, but probably a supply of water for pumping could be obtained by deepening the boring into the Dakota sandstone. The estimated altitude to which the water would rise in such a well is about 3,450 feet.

Argentine.—This station is a water-tank siding on the Burlington and Missouri River Railroad, 17 miles northwest of Edgemont. The well is on the south side of Pass Creek, a short distance west. It is a flowing well 550 feet deep, yielding a fairly large volume of water, but of a quality not satisfactory for locomotives, as the following analysis will show:

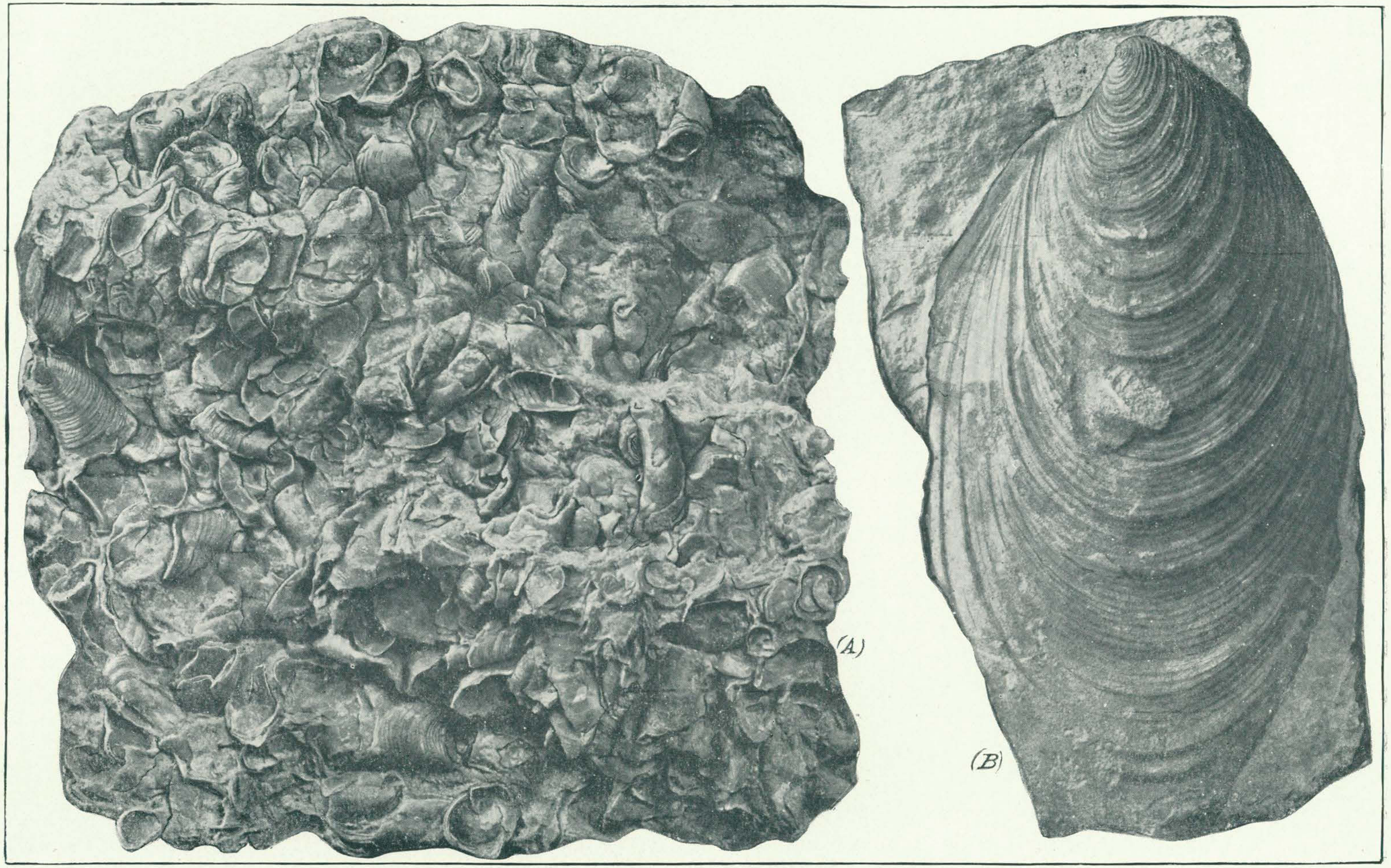
Analysis of artesian water at Argentine, South Dakota.

Constituent.	Grains per gallon.
Sodium sulphate	39.90
Potassium sulphate	0.90
Lime sulphate	4.20
Lime carbonate	6.00
Magnesia carbonate	4.00
Alumina and iron oxide	0.05
Silica	0.19
Total solids	56.60
Organic matter	0.55

This analysis was kindly furnished by the railroad company. The log of the boring was not obtainable. The well begins in Graneros shales and undoubtedly obtains its water supply from the Lakota sandstone, which outcrops in the high ridge to the east.

Clifton.—There is a flowing well 4 miles north of Clifton Siding on the Burlington and Missouri River Railroad. The log furnished by the railroad company is given in fig. 294. Flows of water are reported at 72, 210, 490, and 925 feet. The upper sandstone appears to be in the lower part of the Graneros shale, the 20-foot bed from 62 to 82 feet being the one in the small ridge just east. The Dakota sandstone probably comprises the beds lying between 200 and 290 feet. The Lakota formation is represented by heavy beds of sandstone extending down to at least 682 feet. Then come Beulah and Sundance beds, of which the limits are not recognized from the log as it is given. The 120 feet of red beds probably include the usual red member of the upper part of the Sundance formation, but as here reported doubtless include some of the adjoining beds which are not red. The water is unsatisfactory in quality and the well is abandoned.

There is another flowing well by the side of the railroad a mile and a half farther north, which yields a supply of very saline, ferruginous water. Its depth was not ascertained. At Clifton a supply of water for locomotives is pumped from a 300-foot well sunk into the Lakota sandstone, a few rods west of the Dakota sandstone ledges.



CHARACTERISTIC FOSSILS OF GREENHORN LIMESTONE AND NIOBRARA CHALK; IMPORTANT GUIDES IN WELL BORING.

(*A*) Ostrea congesta. (*B*) Inoceramus labiatus.

Newcastle.—No attempts have been made to obtain underground waters at Newcastle, but several of the oil wells have yielded promising flows of water. As these wells are described quite fully on pages 586 and 587 in connection with the oil, it is not necessary to repeat the statements.

Jerome.—There is a flowing well at this siding on the Burlington and Missouri River Railroad a few miles north of Osage Siding. Although it is just outside of the region to which the report relates, it indicates a continuation of the artesian conditions north from Newcastle in the

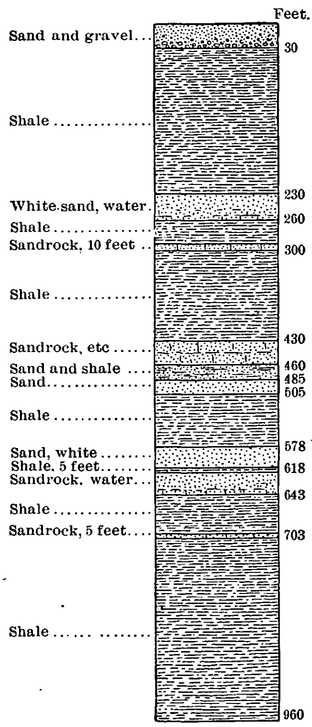


FIG. 293.—Log of deep boring at the Y near Edgemont, South Dakota.

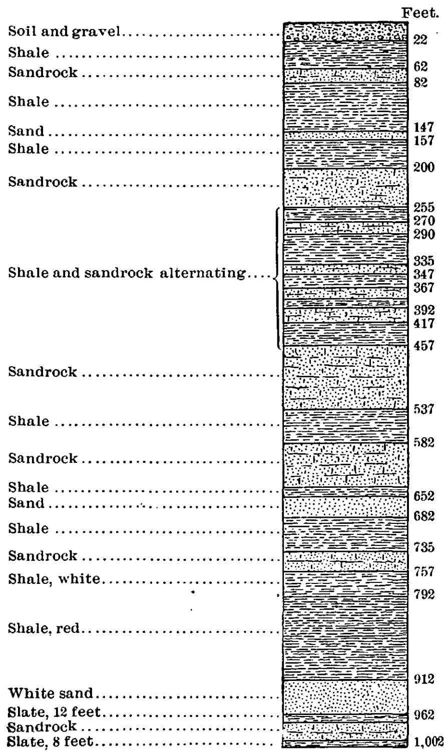


FIG. 294.—Log of artesian well at Whoopup, near Clifton Siding, Wyoming.

lowlands bordering the western slopes of the Black Hills. The depth of the Jerome well is 520 feet. It begins in Graneros shales and extends into Lakota sandstone. The railroad company has kindly furnished the following analysis:

Analysis of artesian water from Jerome, Wyoming.

Constituent.	Grains per gallon.
Sodium chloride	0.7
Sodium sulphate	29.8
Magnesia sulphate	7.0
Lime sulphate	2.3
Magnesia carbonate	0.5

Cambria.—A deep boring is now in progress at Cambria to furnish a local water supply for the town. It reached a depth 1,810 feet in the Pahasapa limestone in the early part of 1900. So far no large volume of water has been found, but there are prospects of finding a supply in the coarse Deadwood sandstone below. The experiment is an extremely important and interesting one, for it will throw light on the

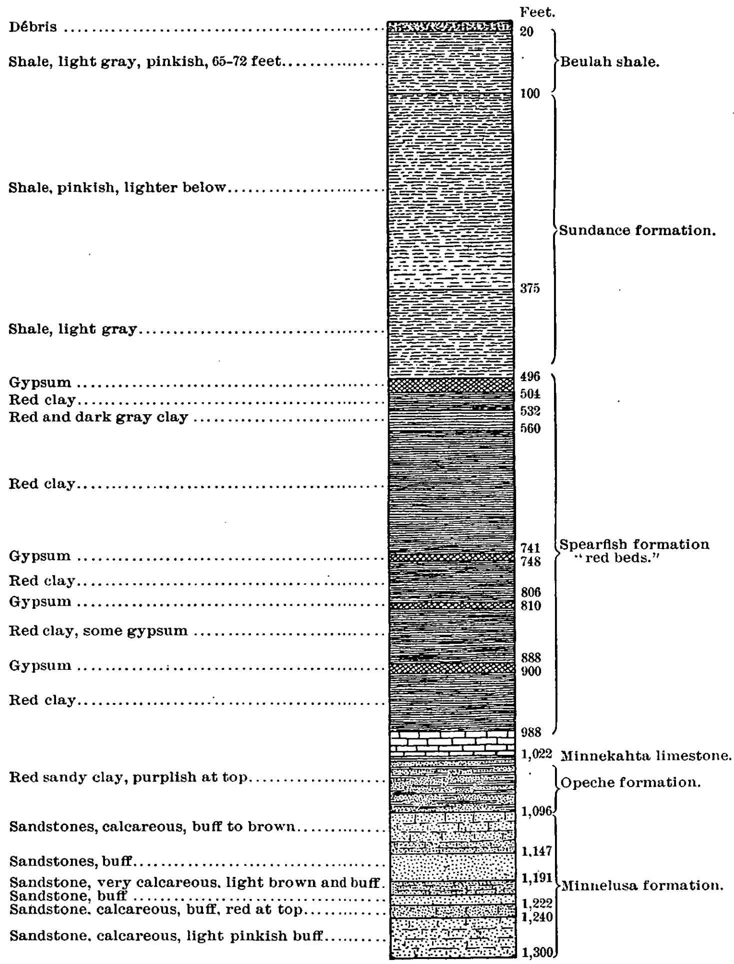


FIG. 295.—Log of deep boring at Cambria, Wyoming.

underground water conditions in all the older formations on the west slope of the Black Hills. A partial log of the boring is given in fig. 295, compiled from the set of borings admirably preserved in glass tubes by Mr. Mouck, the superintendent of the Cambria mines. The general relations are shown in section 2, Pl. CIV, which passes through Cambria. The different formations are readily recognized in the log of the Cambria boring. It begins in the Beulah shales at an altitude

ARTESIAN WELL AT WOONSOCKET, SOUTH DAKOTA.

of 5,075 feet, or about 50 feet below the coal bed. It passes through the Sundance formation and enters the Spearfish red beds at 496 feet, the first member being a bed of gypsum 8 feet thick, which caps the red beds in the exposures east of Cambria. The Minnekahta limestone occurs at a depth of 988 feet, having a thickness of 34 feet, as in the outcrops in the valley of Stockade Beaver Creek. Then come the red sandy clays of the Opeche formation, 74 feet thick, with the purplish beds at their top, and then the great mass of Minnelusa beds. They consist of sandstone with a greater or less admixture of carbonate of lime, all so fine-grained and compact as not to yield much water. The underlying Pahasapa limestone is very compact and has yielded no water.

Minnekahta.—Several years ago the Burlington and Missouri River Railroad Company made a deep boring at Minnekahta Station to obtain a water supply for locomotives. A depth of 1,348 feet is said to have been attained, but no promising amount of water was reported. The log, which is given in fig. 296, is clearly an unreliable one and very unsatisfactory for the identification of the geologic formations. No clew is given as to the location of the Minnekahta formation, which should be expected to begin at about 300 feet below the surface at Minnekahta Station. The red sands, from 743 to 908 feet, are doubtless in the Minnelusa formation. At a depth of 1,348 feet the boring should be near the granite or schist bed rock, for the thickness of the formations from the lower half of the Spearfish through the Deadwood is not much more than this in the surface exposures in the region to the north. The references to gypsum at various depths in the boring are mistakes as to the identity of the material, excepting those near the top. It is to be deeply regretted that the log is not more accurate, for it could have thrown important light on the stratigraphy.

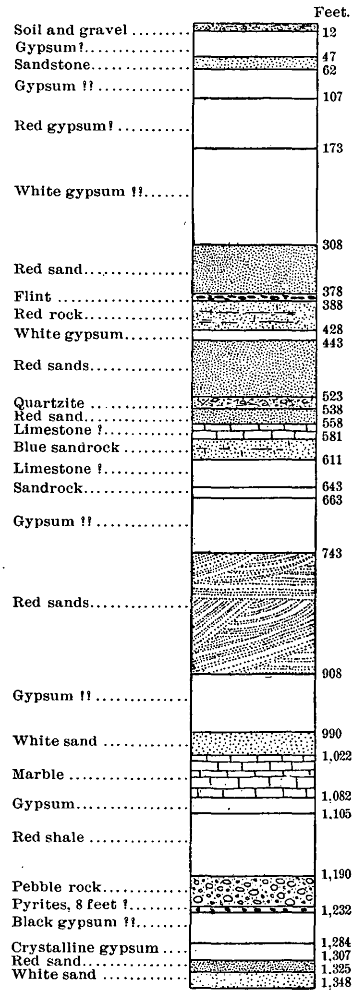


FIG. 296.—Log of deep boring at Minnekahta, South Dakota.

Buffalo Gap.—Two borings were made at this place several years ago to obtain a water supply, but they were not sunk to a depth sufficient to reach the Dakota sandstone. One was on a hill just west of the town and the other was on the principal street. The latter had a depth of 800 feet, entirely in dark shale. The boring began in the shales above the Greenhorn limestone of the Benton group and passed far down into the Graneros shales. Probably the Dakota sandstone would have been entered at a depth of about 1,100 feet.

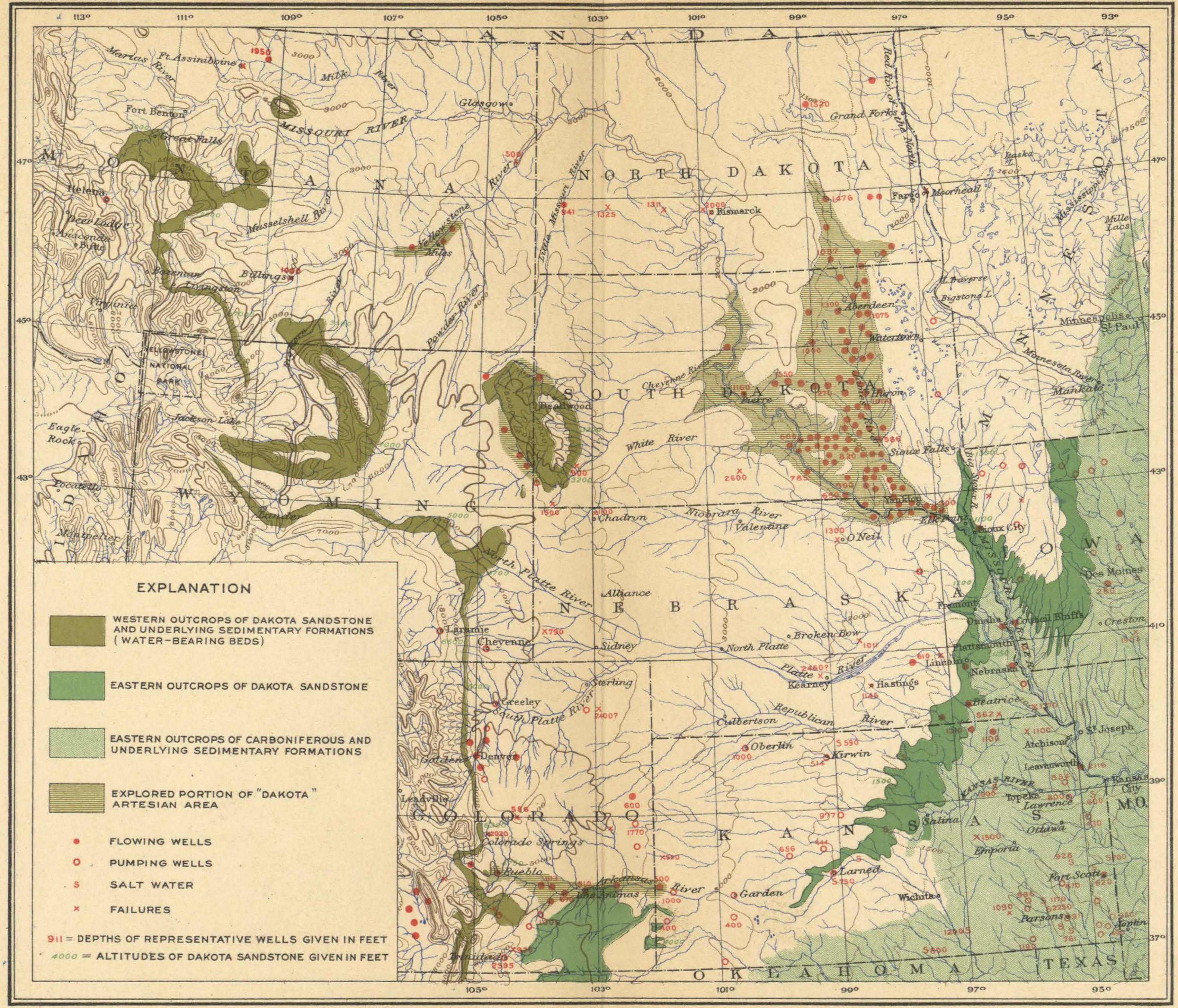
Hot Springs.—At the Soldiers' Home, a short distance west of the town, a well was sunk some time ago to a depth of 223 feet. It began just above the top of the Minnekahta limestone, and obtains a moderate water supply from the sandstones in the Minnelusa formation.

SURFACE WATERS[1] AND IRRIGATION.

On the plains adjoining the Black Hills there are usually long periods of drought during summer, so that irrigation is necessary for raising crops. In many of the valleys there are wide areas of fertile soils suitable for agriculture, and to portions of them it is practicable to carry waters for irrigation. These waters are obtainable from such of the rivers and creeks as continue to flow in midsummer. In many localities it would be practicable to pond a large part of the water from the spring rains by means of dams of greater or less size. Water could also be obtained from deep wells, and in some cases for smaller supply from shallow wells. At present the principal purposes of agriculture in the region are to raise hay, etc., for winter feed for stock, vegetables for local use, and garden truck for the small local markets. The latter is raised at several places with good profits, notably near Hot Springs, where the waters of Fall River are diverted into ditches and employed for irrigation. There is water available for a considerable extension of this industry at many points through the hills, but local markets provide for only a small consumption, and the profit is too small to pay for long-distance shipment.

Cheyenne River.—This stream enters South Dakota with a fair supply of water in midsummer, which averages from 10 to 15 second-feet at Edgemont. Along most of its course its freshet waters could be extensively impounded if they were needed, but long and very substantial dams would be required to withstand the sudden heavy flows which follow the rains. The river flows through a broad valley, usually containing low flats of good land from a quarter to a half mile wide, often in long strips well suited for agriculture. Portions of the soil are sandy, but this is the exception. The channels of the river do not change position rapidly, and the average flat is seldom widely or long overflowed during freshets. The banks vary mostly from 5 to 8 feet above the low-water level of the river. The conditions for ditch construction are usually favorable, but freshets are liable to tear out the headgates unless they are carefully constructed. A large system of irrigation from Cheyenne River was laid out above Edgemont some

[1] Gagings of the principal streams of the southern Black Hills are given on page 599.



MAP OF THE NORTHERN GREAT PLAINS REGION
SHOWING FACTORS BEARING ON PROSPECTS FOR DEEP UNDERGROUND WATERS

BY

N. H. DARTON,

SCALE

100 0 100 200 MILES

CONTOUR INTERVAL 1000 FEET (ABOVE 2000 FEET)

1899.

years ago, but it was not operated extensively. It was intended to make available the wide, fertile alluvial flats extending down the south side of the river from the mouth of Stockade Beaver Creek to Edgemont. The location and course of the main channel is shown in Pl. CII, *B*.

The principal volume of water in the river at Edgemont is derived from Beaver and Stockade Beaver creeks for the greater part of the year. Above the mouth of Beaver Creek the river rarely contains running water, except for a few days during freshets. More or less water remains in pools all summer, and there is undoubtedly a moderate volume of underflow. Very little surface water is received from Lance Creek, as all of the streams in that district have water only in pools and underflow. Pass Creek, Bennett Canyon, Red Canyon, and Mossagate Creek bring no surface waters to the river except for a few days after rains. Cottonwood Creek usually flows in small volume. There appears to be considerable seepage into the river from springs in the gorge below Edgemont, for its volume steadily increases in this portion of its course. It receives water from Hat Creek, Cascade Creek, and Fall River, but a large part of the water appears to sink in the Lakota and Dakota formations about Cheyenne Falls. All along the river below Edgemont there are flats of greater or less width, which could be irrigated by water from the river with very little difficulty. A few attempts have been made to utilize the water, but they were local, transient efforts.

Fall River.—This vigorous stream is the product of springs of warm water in the gorge a short distance above Hot Springs. The principal flow is from orifices in the western part of the town, which have in all an average, nearly uniform flow of 25 second-feet. Above these springs there is a stream of small volume known as Hot Brook, fed from springs rising in the axis of the anticline 3 miles west of Hot Springs. Cold Brook, a branch of Fall River from the north, joins Fall River just above Hot Springs, but usually does not carry water at its mouth. It contains running water at various points for some miles below its head in the high hills south of Pringle. Fall River as it flows through Hot Springs is a good-sized stream of beautifully clear, tepid water, which continues down the gorge to Cheyenne River. Owing to sinkage in the porous sandstones, it diminishes somewhat in volume in passing over the Lakota formation. All running water in the vicinity of Hot Springs—Cold Brook, Hot Brook, and Fall River—is utilized to a considerable extent for irrigation. It is diverted into ditches partly supplied by water wheels. Garden truck and fruit are raised in considerable abundance and find a ready market at Hot Springs. Water power is also obtained from Fall River to supply electric light for Hot Springs. One power plant is in the town and another is at the cascades over the Dakota sandstone near Evans's quarry, 5 miles southeast of the town. The ditch at this place carries the greater bulk of the water, leaving a small amount to descend over the ledges of sandstone.

Beaver Creek.—The stream on the eastern side of the hills known as Beaver Creek rises in the schist area north of Pringle and flows through Buffalo Gap, reaching Cheyenne River 5 miles southeast of the gap. For many miles from its head, in its passage across the crystalline rock area and down a canyon in the Cambrian and Carboniferous rocks, it is a small run nearly everywhere containing a moderate amount of water. It appears to sink in the Minnelusa sandstone, but water again comes to the surface in the anticline which exposes the Minnekahta limestone at the western entrance of Buffalo Gap. From this place it flows in moderate volume continuously to the river. It is used to some extent for irrigation about Buffalo Gap, where there are several lines of ditches supplying water to large fields of alfalfa and other products.

Lame Johnny Creek.—Lame Johnny Creek heads in the higher ridges southeast of Custer, where its numerous branches are rivulets of running water. In crossing the Minnelusa formation the creek loses this water, and thence to Cheyenne River usually has water only in scattered pools. There is possibly more or less underflow.

French Creek.—This stream contains more or less water throughout its course. It is fed by springs at the foot of the limestone escarpment west of Custer, and in its passage across the crystalline rock area receives many small tributaries, some carrying small flows of water. In this region it is often bordered by narrow flats where a small amount of irrigation is practicable. It loses considerable water in passing over the sedimentary beds on the east side of the hills, and does not receive any running affluents in this part of its course. Below Fairburn it meanders through a wide valley in the bottom of which it has cut a narrow, winding trench often 15 feet in depth. In this region it has not yet been utilized for irrigation, and its volume is not sufficiently great to permit of extensive use for that purpose. The appearance of the stream at the mouth of Dry Creek is shown in Pl. CI. The appearance of the creek in the canyon in the Pahasapa limestone 10 miles west of Fairburn is shown in Pl. LXIII. Dry Creek, one of the principal branches of French Creek, often contains extensive pools of water, but rarely flows.

Battle Creek.—Battle Creek drains a portion of the elevated country about the eastern slopes of Harney Peak, receiving several large branches, of which the more important are Little Squaw, Big Squaw, Iron, and Spokane creeks. These streams all contain a moderate volume of water throughout their course, but they flow mainly in narrow channels, with the adjoining flat too small and often too rocky for agriculture. The wider portion of the valley of Squaw Creek on the Spearfish red beds contains alluvial flats of some extent in which the creek water is used for irrigation, mainly for alfalfa. In the upper portion of its course the water of Battle Creek is used for hydraulic

FRENCH CREEK NEAR ITS MOUTH, SOUTHEAST OF FAIRBURN, SOUTH DAKOTA.

mining. In crossing the sedimentary formations from Carboniferous to Dakota, Battle Creek and its branches lose considerable water. About Hermosa the valley widens, and thence toward Cheyenne River its width averages 2 miles, with fertile flats admirably suited to agriculture. The water is utilized for irrigation to some extent, but its volume is inadequate for present demands.

Spring Creek.—Spring Creek crosses the crystalline rock area and for the greater part of its course contains a moderate volume of water. There is considerable loss by underground seepage in crossing the Lakota sandstone, east of which for some distance the flow is feeble. The valley is wide east of the Black Hills, and it is utilized to some extent for dry farming. Considerable irrigation would be practicable.

Hat Creek.—The headwaters of Hat Creek rise in canyons in the north face of Pine Ridge, and are fed by numerous springs issuing from the Arikaree formation. The creek flows north for 35 miles across the shales of the Pierre and Benton formations to empty into Cheyenne River near Maitland. In this portion of its course it receives no water from the numerous side valleys, and in summer loses much by evaporation. It traverses a valley usually bordered by wide flats, which could be irrigated.

Cascade Creek.—This vigorous stream is the product of the springs at Cascade, where a large volume of water issues from the Minnekahta limestone. In Pl. CIII are shown the two largest springs at this place. The water is slightly warm, and contains a large amount of mineral matter, as is shown in the following analysis kindly furnished by the Burlington and Missouri River Railroad Company:

Analysis of water from Cascade Creek, South Dakota.

Constituent.	Grains per U. S. gallon.
Chloride of sodium	3.97
Sulphate of soda	0.29
Sulphate of lime	119.84
Carbonate of lime	34.75
Carbonate of magnesia	15.68

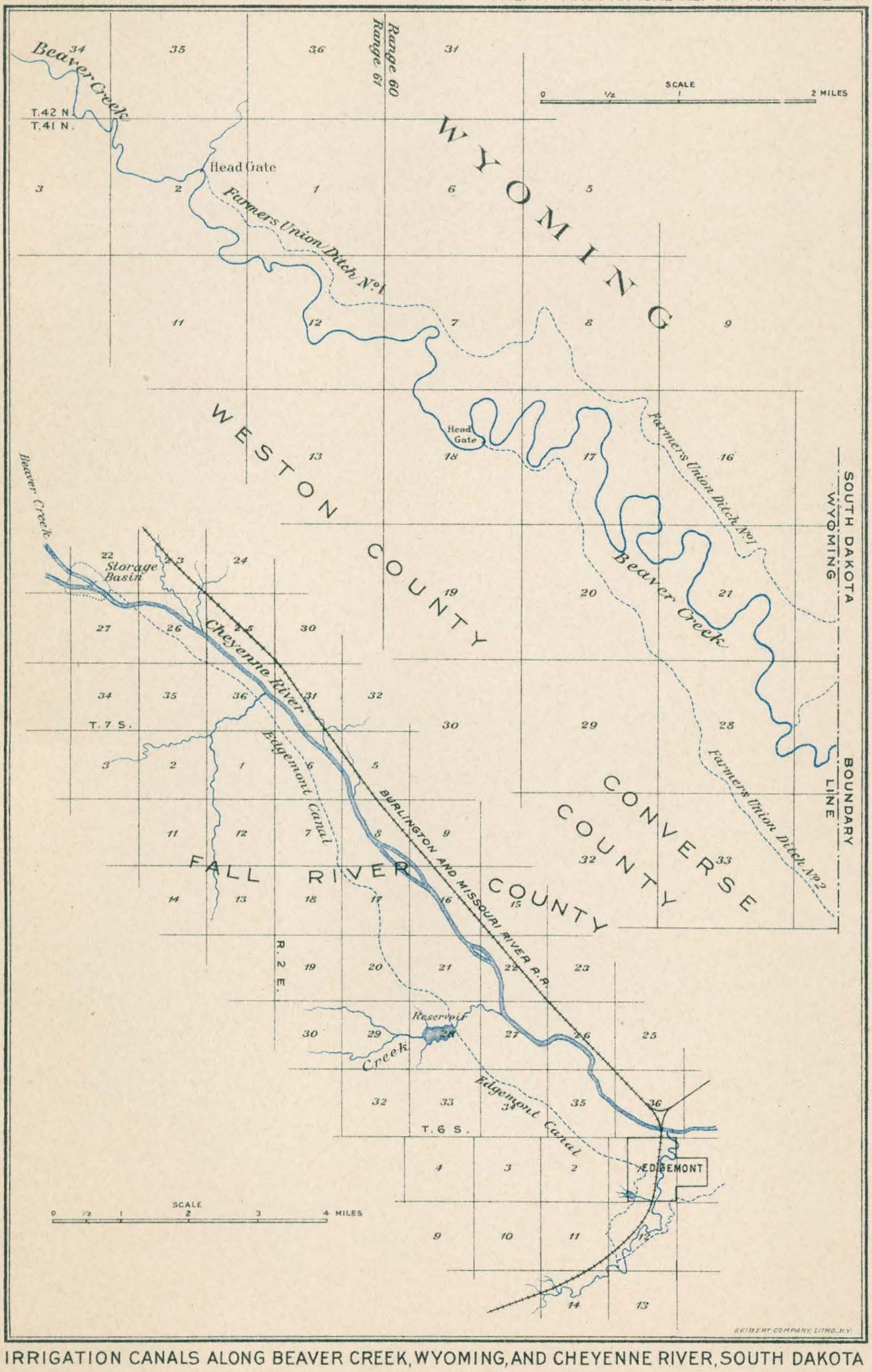
It appears not to lose any of its volume in traversing the Lakota and adjoining formations. In the flat which it crosses to reach Cheyenne River some of the water has been employed for irrigation with most gratifying results, but only a portion of its volume is utilized. The volume of the creek at its mouth was 25 second-feet on May 18, 1900.

Stockade Beaver Creek.—This fine stream rises in the ravines heading in the Minnelusa sandstone and Pahasapa limestone in the northeastern corner of Weston County, Wyoming, and carries a large volume of water to the main Beaver Creek, into which it empties in the southeastern corner of the county. It receives water from a number of springs in the Minnekahta limestone east of Newcastle, one of the most prominent of which lies a short distance west of the foot of Fanny Peak. Another source of water is Salt Creek, which brings a small volume of saline waters from the springs northeast of Cambria. Portions of the valley contain flats suitable for moderately extensive agriculture by irrigation, and several small ditches are now in operation east of Newcastle, notably one for the extensive alfalfa fields of the L A K ranch. Stockade Beaver Creek receives the drainage of the western slope of Elk Mountain and of a wide area of the western portion of the limestone plateau and slopes in the northwestern corner of Custer County and the southwestern corner of Pennington County. Two of the most extensive drainage basins empty through Redbird and Gillette canyons, but the waters of these rarely reach the main creek. Redbird Canyon has at its two head branches Antelope Spring and Preacher Spring, which yield small flows of water that sink in a short distance. This also is the case with Buck Spring and some minor seeps in the adjoining limestone area. Nearly all the springs of this series and others at the head of Stockade Beaver Creek are at the contact of the Minnelusa and Pahasapa limestone, where there are porous, water-bearing beds.

Beaver Creek.—This stream occupies the valley lying between the western slope of the Black Hills and the escarpment of Fox Hills sandstone in the southeastern portion of Weston County, Wyoming. The origin of its water is difficult to determine, but west of Newcastle it has considerable volume, which flows more or less continuously to its junction with Stockade Beaver Creek. The combined waters of the two streams flow into Cheyenne River in the northwestern corner of Fall River County, constituting the principal volume of water to Edgemont. The main Beaver Creek receives several branches that probably carry more or less water as underflow. Those heading in the Fox Hills and Laramie County to the west are dry at the surface. Oil Creek and its two branches, Skull Creek and Little Oil Creek, contain running water in the canyons north and northwest of Newcastle, but in dry weather their waters do not flow to the main Beaver Creek. The waters of Oil Creek are used for irrigation just north of the railroad, west of Newcastle. The valley of Beaver Creek is wide and contains some land that could be irrigated, but no attempts have yet been made to utilize it.

SOILS.

The soils in the southern Black Hills and adjoining regions are closely related to the underlying rocks. Excepting deposits in the larger valleys, some sand dunes, and a few local gravel areas, the soils are residuary products of the decay and disintegration of the rocks on which they lie. The larger valleys are floored by alluvial deposits of various materials washed from the higher lands and brought down by streams during freshets. All of the rocks in the region are changed more or less rapidly by surface waters, the rapidity depending on the



IRRIGATION CANALS ALONG BEAVER CREEK, WYOMING, AND CHEYENNE RIVER, SOUTH DAKOTA character of the cement which holds their particles together. Siliceous cement dissolves most slowly, and rocks in which it is present, such as quartzite and sandstones, are extremely durable and produce but a scanty soil. Calcareous cement, on the other hand, is more readily dissolved by water containing carbonic acid, and the particles which it holds together as rock crumble and form a deep soil.

Classification.—If the calcareous cement makes up but a small part of the rock, it is often leached out far below the surface, the rock retaining its form, but becoming soft and porous, as in the case of the Minnelusa sandstone. If, as on the limestone plateaus, the calcareous material forms a greater part of the rock, the insoluble portions collect on the surface as a mantle of soil, varying in thickness with the character of the limestone, being quite thin where the latter is pure, but often very thick where the rock contains much insoluble matter. Of course all soil accumulation is dependent upon erosion, for where there are slopes the erosion is often sufficient to remove the soil as rapidly as it forms, leaving bare rock surfaces. Crystalline schists and granitic rocks decompose mostly by the solution of a portion of the contained feldspar. The result is usually a mixture of clay, quartz grains, mica, and other minerals. Shales decompose less than most other formations, but readily give rise to soils by softening and washing down slopes. If they are sandy, sandy soils result, and if they are composed of relatively pure clay a very clayey soil is the product. When derived in this way from the disintegration of the underlying rock, soils are called sedentary. The character of the soils thus derived from the various geologic formations being known, their distribution may be approximately determined from the map showing the areal geology, which thus serves also as a soil map. It must be borne in mind that some of the geologic formations present alternations of beds of various materials, such, for instance, as shales and sandstones alternating with limestone. These give abrupt transitions in the character of their disintegration products with soils differing widely in composition and agricultural capabilities occurring side by side. This, however, is a less marked feature in the Black Hills region than in some other districts, for here all the formations are thick and relatively homogeneous in composition throughout. The only areas in which the boundaries between different varieties of soil do not coincide with the boundaries of the rock formations are in the river bottoms, in the sand dunes, in the areas of high level gravels described on page 545, and upon steep slopes, where soils derived from rocks higher up the slope have washed down and mingled with or covered the soils derived from the rocks below. Soils of this class are known as overplaced, and a special map of large scale would be required to show their distribution.

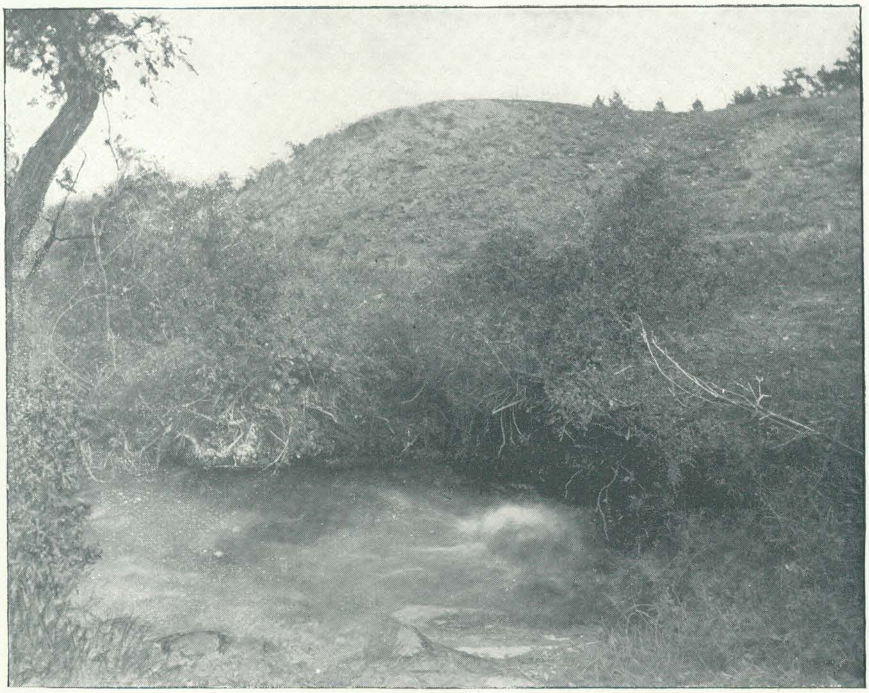
Interior region.—In the region of the schists and granites in the interior of the Black Hills there are numerous valleys between the rough, rocky ridges. These valleys are mainly parks or open glades in the forest, where the soil is deep and rich. Areas of this sort occur along the headwaters of the numerous branches of the streams which flow eastward out of the hills. Surface waters accumulate in these parks and cause deep decay of the schists, but the volume of water is not sufficiently great to carve a deep valley and carry away the soil. As the water increases in volume down the valleys, the open parks give way to deep, rocky canyons, such as those of Spring Creek, French Creek, Beaver Creek, and some of their branches. A view of a typical glade or park in the schist area is given in fig. 272. There are extensive areas of this sort about Custer, but only a relatively small proportion of the land is under cultivation. Oats and hay are the principal products, but many other crops could be raised, particularly by the aid of irrigation. Portions of the timbered area are valuable for agriculture when cleared, but such fields would be much encumbered by loose rocks and often intersected by rocky ledges.

The limestone.—On the broad limestone plateau on the western side of the hills there are extensive tracts with good soil, usually rather clayey, but containing a large proportion of plant food. There are many open parks along the heads of the small streams, and portions of the timbered area yield good farming lands when they are cleared. The sandy loams resulting from the disintegration of the Minnelusa formation are particularly favorable for agriculture. Owing to the high altitude of this plateau the seasons are short, so that only the hardier crops can be raised. Water also is so scarce that irrigation is seldom practicable. On the eastern side of the hills the high ridges of Pahasapa limestone and Minnelusa sandstones are mainly too rugged for farming, and bare, rocky ledges prevail. The Minnekahta limestone usually presents rocky slopes with very little soil.

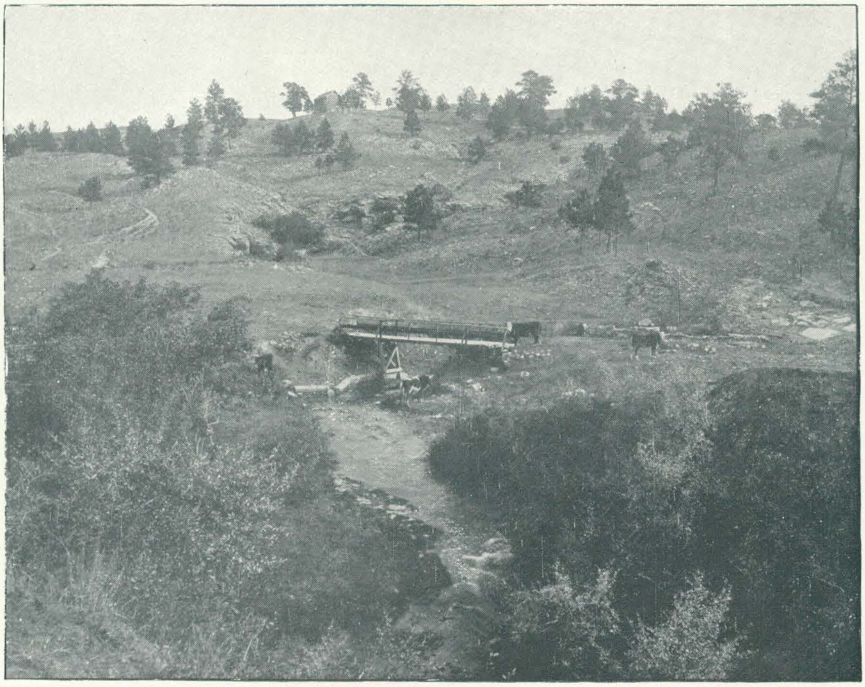
The Red Valley.—The sandy clays of the Spearfish formation give rise to a relatively barren soil, which, together with the usual absence of water in the Red Valley, has excluded farming almost altogether. Portions of the region underlain by the formation present gentle slopes and wide, level areas supporting a fair growth of grass, so that the region is one of considerable value for grazing.

The hogbacks.—The sandstone of the hogback ridges surrounding the Black Hills uplift disintegrates into a thin, sandy soil, but as the beds nearly everywhere have a steep dip down the outer slope of the ridge much of the soil washes away, and bare, rocky ledges remain. North of Newcastle, where the formations of the hogback spread out in broad, gently sloping plateaus, there are some areas which present farming capabilities. One of these is that occupied by the Mount Zion ranch, where there are several large fields under cultivation.

The Benton Valley.—The wide valley which surrounds the Black Hills is underlain by the lower shales of the Benton group. These



A. SPRING AT CASCADE SPRINGS, SOUTH DAKOTA, EMERGING FROM CREVICES IN MINNEKAHTA LIMESTONE.



B. SPRING AT CASCADE SPRINGS, SOUTH DAKOTA, EMERGING FROM CREVICES IN MINNEKAHTA LIMESTONE.

shales yield a barren soil, but they give rise to valleys which are often occupied for many miles by large streams which had deposited widely extended sheets of alluvial sands and loams, often of considerable fertility. The lower part of Beaver Creek follows a valley of this character, which extends through the southeastern corner of Weston County, Wyoming, to the vicinity of Edgemont, where it is occupied by Cheyenne River. The broad alluvial flats along this wide valley have fertile soils, and under proper irrigation would produce large crops. Hat Creek flows in a valley on the lower Benton shale, which contains some land of considerable fertility from the mouth of Plains Creek to Cheyenne River. This area has a wide extent for several miles north of the river up the valley of Cascade Creek.

The Plains.—Much of the Plains region adjoining the Black Hills is underlain by Pierre shale. This formation consists mainly of clay, and its disintegration gives rise to a stiff gumbo, which is not only very barren in itself but is acid from decomposing pyrites and too sticky for suitable working. Its area is shown on the geologic maps (Pls. LIX and LXV). It is covered with grass, which originally afforded excellent pasturage, but in some areas it has been grazed down by excessive herding. As the soil is not rich the grass grows slowly, and some time will be required for it to regain its former growth. Some areas of the Pierre shale are traversed by wide valleys with overplaced soils of considerable fertility. This is notably the case along Spring Creek, Battle Creek, French Creek, Cheyenne River south and east of Buffalo Gap, and on Beaver Creek and Stockade Beaver Creek in the lower portions of their courses. The most barren areas are on the upper portion of Beaver Creek, the slopes west of Beaver Creek, the high lands between the valleys of Old Woman Creek, Indian Creek, and Hat Creek, and the extensive areas east of Ardmore and about Oelrichs and Smithwick.

The region occupied by the Fox Hills and Laramie formations in Weston and Converse counties, Wyoming, is in greater part sandy, barren, and dry. There are some narrow strips of loamy soils derived from the sandy shales in the Laramie formation, but they are mainly on the higher land and entirely too dry for agriculture. Along the larger valleys in this region there are occasional flats of considerable width which yield an excellent growth of hay. Probably by irrigation some of these flats could be made to produce other crops if there were markets for them. The Laramie formation usually supports an excellent growth of grass for grazing, and there are wide areas of good grazing grounds remaining.

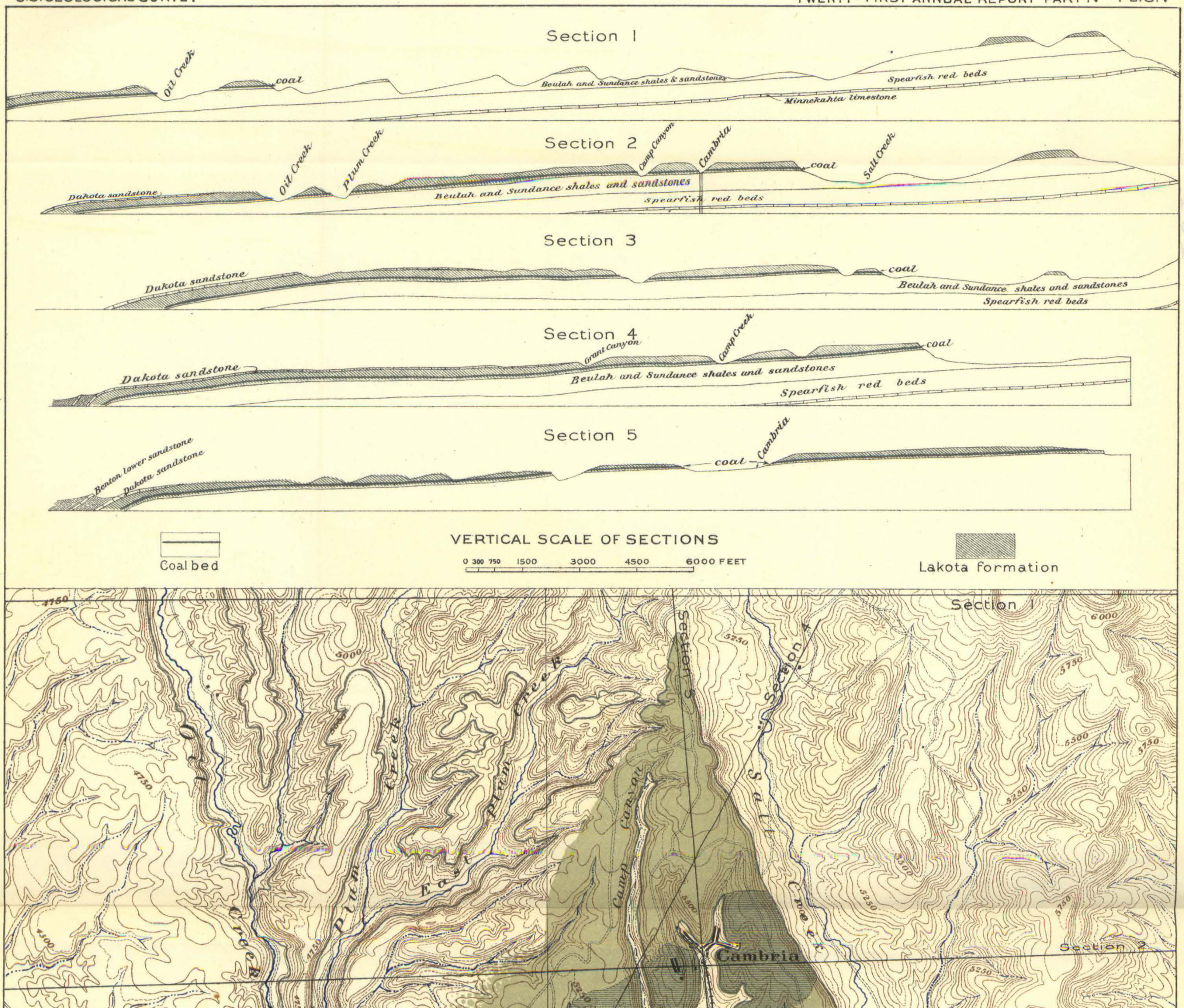
The Tertiary formations present bare slopes more or less broken into bad lands, with intervening plateau ridges of greater or less width that often have fertile soil and invariably support a rich growth of grass. The Tertiary area about Fairburn and north of Hermosa presents many small areas of fertile soils, particularly on the portions where there remain the gravel caps of the earlier Pleistocene deposition, which spread its mantle of alluvial materials over the surface of the Tertiary formations. In the regions about Hermosa and Fairburn the principal farms are either along the streams on alluvial deposits or on the tabular surfaces of the earlier Pleistocene gravel and loam. Owing to the dry climate, however, there has been difficulty in obtaining water on these higher lands, and many of the farms which were located upon them have been abandoned.

MINERAL RESOURCES.

COAL.

Coal is the principal mineral resource in the sedimentary formations of the Black Hills. Its occurrence is confined mainly to the Lakota formation, where it is characteristic of one horizon over a considerable area. The Carboniferous formations which are the coal measures in the Mississippi Valley and eastward do not contain beds of coal in the Black Hills region. Along the eastern side of the Black Hills the Lakota formation shows no trace of coal. The first deposits begin near Edgemont, and continue at intervals along the western side of the hills and around the northern foothills to the Hay Creek coal field. In much of the area the beds are too thin or impure to be of economic value, but in the vicinity of Cambria, north of Newcastle, they attain a thickness of 7 feet or more and furnish coal of excellent quality. Coal has been mined at Cambria for the last decade, and during this time nearly 4,000,000 tons have been produced, with an average shipping value of about $1.50 per ton. The product in 1889 was over a half million tons, valued at over $800,000. A portion of the product is converted into coke, which is shipped to smelting works in the northern Black Hills.

The mines are at Cambria, 6½ miles north of Newcastle, where a settlement of about 500 inhabitants owes its existence and sustenance to the mining and coking operations. It is connected with Newcastle by a branch line from the Burlington and Missouri River Railroad. The distribution of coal and the structural relations of this region are shown by the map and sections (Pl. CIV). It will be seen that the coal underlies all of the plateau on the west side of Salt Creek, but the horizon has been cut through by Little Oil Creek, Oil Creek, Plum Creek, and their branches. To the south and west it dips beneath the surface, and passes deeply beneath a thick mass of overlying sandstone and shale. The structure is shown in the cross sections. The coal in this area varies greatly in thickness and purity, but as shown on the map (Pl. CIV) there is a large area in which the thickness is 5 feet or more, attaining in places over 7 feet. In the adjoining areas the thickness rapidly diminishes and the coal becomes extremely impure,



TOPOGRAPHY BY W. H. HERRON

MAP AND SECTIONS OF THE CAMBRIA COAL FIELD NEAR NEWCASTLE, WYOMING

BY
N. H. DARTON
1899

HORIZONTAL SCALE
0 2 MILES

Contour interval 50 feet

EXPLANATION

Coal outcrop

Approximate area of coal known to be over 5 feet thick

Area of workings to end of 1899

Area in which coal horizon is more than 400 feet below the surface in greater part giving place to dark carbonaceous shales. The course of the principal basin of purer, thicker coal trends northeast and southwest, with its center passing through Cambria. To the northeast it has been entirely eroded away by the valley of Salt Creek, and, although some Lakota sandstone remains on the high ridges east of that valley, it is the bed lying beneath the coal horizon. To the southwest the coal slopes gently downward, lying from 250 to 325 feet below the surface of the table, to the Mount Zion ranch, beyond which the sudden increase in dip carries it rapidly below the surface, as shown in section 4 of Pl. CIV. In the canyon a few rods southwest of Mount Zion ranch, the following section was measured:

Section near Mount Zion ranch, Wyoming.

	Feet.
Bony coal	½
Hard sandstone	3
Good coal	4
Sandstone with coaly streaks	½–1½
Coal	2

This section is 150 feet below the top of the table. The overlying formation is sandstone and conglomerate. Underneath there are 40 feet of very light-colored massive sandstones, in part cross bedded, lying on Beulah shales. A mile northeast of this locality two shafts were sunk in which the coal was found at depths of 312 and 324 feet, exhibiting a thickness of from 5½ to 6½ feet. A mile farther northeast are the mines of which the present workings occupy the area indicated on the map. In the mines the thickness of the coal averages from 6 to 7 feet over a wide area. In Camp Canyon, northwest of Cambria, a trial pit exhibited the following section:

Section in Camp Canyon, Wyoming.

	Feet.
Coal	2½–3
Shale and bone	1½
Coal	6

There are three mines, known as Jumbo, lying east of Cambria; Antelope No. 1, between Cambria and Camp Canyon; and Antelope No. 2, between Camp Canyon and Grant Canyon. The two Antelope mines are connected by a continuous main shaft leading out to a breaker on the west side of the valley at Cambria, while the Jumbo mine is worked from the main drift opening on the east side of that valley. The dip is gentle to the southwestward, so that the drainage of the mines is easily effected, the workings being 50 to 60 feet above the valleys which here cut across the coal horizon.

A coal bed averaging 6 feet in thickness contains about 3,000,000 tons of coal per square mile, but of course there is considerable loss in working. There are now in the Cambria coal field about 10 square miles underlain by coal that would average 5 feet or more in thickness, lying above the general country level. On this estimate the field has a productive capacity of 30,000,000 tons. How far under ground the coal bed may extend to the southwest of the Dakota sandstone ridge is not known, but owing to the steep pitch of the beds it lies too deep for profitable working. North of Cambria the coal appears at intervals, apparently in detached basins. The most promising developments are on Skull Creek, near its forks, where 6 or 7 feet of coal are exposed in recent drifts. In Elk Mountain the Lakota formation exhibits the coal horizon at many points, but the contained coal bed is thin and impure. So far as observed here the deposit usually consists of carbonaceous shale with occasional thin coaly lenses. South of Pass Creek the coal beds are thicker, and there are several deposits which promise to have some little value. In the canyon 4 miles north-northeast of Marietta Station there has been considerable prospecting for coal, but the material exposed is mainly a sandstone with thin coaly layers and black shale intercalations. In the gorge of Cheyenne River below Edgemont the coal beds have been opened at various points. On the south bank of the river 3 miles below the town a drift has been run in on a thin bed of coal in the basal portion of the Dakota sandstone 50 feet below the top ledges of the formation, in which a thickness of 3 feet of coal of fairly good quality is exposed. Beginning at the second bend of the river, 5 miles southeast of Edgemont, where the stream is flowing nearly due south, there are a number of coal openings in the bluffs on the east bank. From 1 to 3 feet of variable coal is exhibited in the first series of prospect pits. In the bend where the river turns east-northeast again there is a mine which has been worked to a small extent, exhibiting 4 feet of coal lying in a basin which is seen thinning out to the east. There are two tunnels about 75 to 100 feet in length along which the coal varies in thickness from 4 to 5 feet. It lies between massive, light-colored, fine-grained sandstones about 40 feet above the base of the Lakota formation. The bed dips very gently to the southeast. Small showings of coal occur in the deep canyons northeast of this locality, but the beds are very thin and impure. Apparently this is at the southeastern margin of the area in which the conditions were favorable for coal accumulations at the time of the deposition of the Lakota formation.

GYPSUM.

The Spearfish red beds carry deposits of gypsum—a hydrous sulphate of lime—throughout their extent, and often the mineral occurs in very thick beds. These are relatively pure, and if nearer to good markets the deposits would be of great value. The only commercial operations so far have been at Hot Springs, but they are discontinued for the present owing to the expense of taking the product to market. A view of the works is shown in Pl. CVI, *B*. The gypsum is calcined

COAL MINE OPENING AT MOUNT ZION RANCH, NORTHWEST OF NEWCASTLE, WYOMING.

at a red heat, to drive off the chemically combined water, and is then ground and packed in barrels. The product is plaster of paris.

The gypsum deposits attain great thickness in the vicinity of Hot Springs. In the valley of Cold Brook, three-quarters of a mile northwest of the station and a short distance north of the works above mentioned, is an exposure shown in Pl. CVI, *A*. The section there exhibited is shown in detail in the following figure:

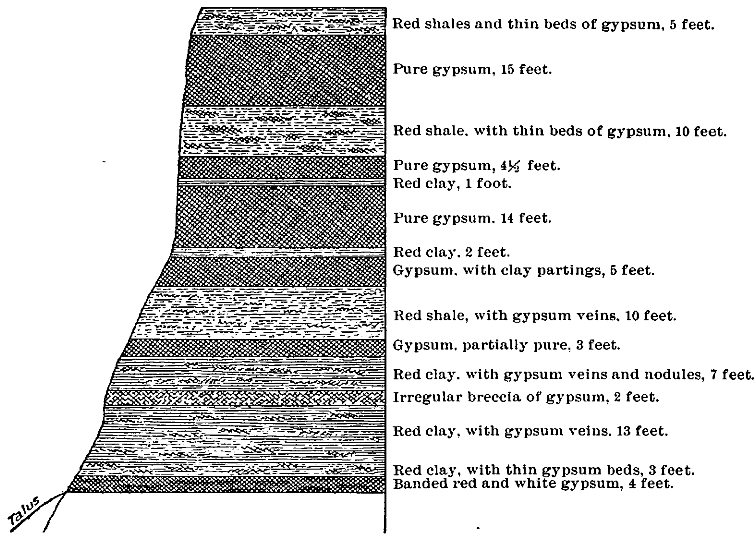


FIG. 297.—Section of Spearfish red beds containing gypsum deposits, on Cold Brook, three-fourths of a mile northwest of Hot Springs, South Dakota.

This deposit is an unusually extensive one, but nearly everywhere throughout the outcrop area of the red beds there are workable beds of gypsum from 5 to 15 feet thick. Further details of their distribution are given on pages 517 and 518.

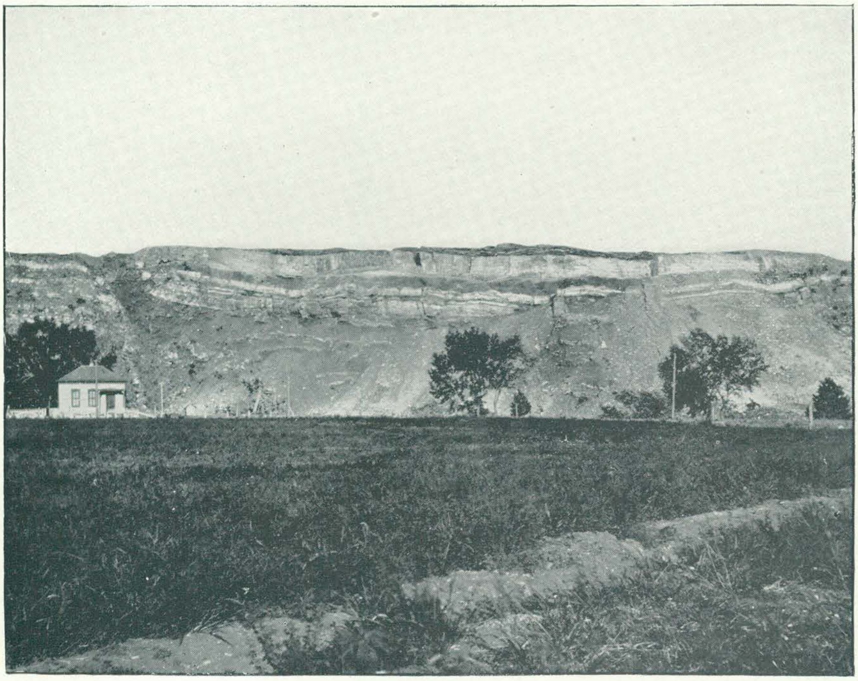
The following is an analysis of a typical gypsum from south of Hot Springs. It was made by Mr. Steiger in the laboratory of the United States Geological Survey.

Analysis of gypsum from south of Hot Springs, South Dakota.

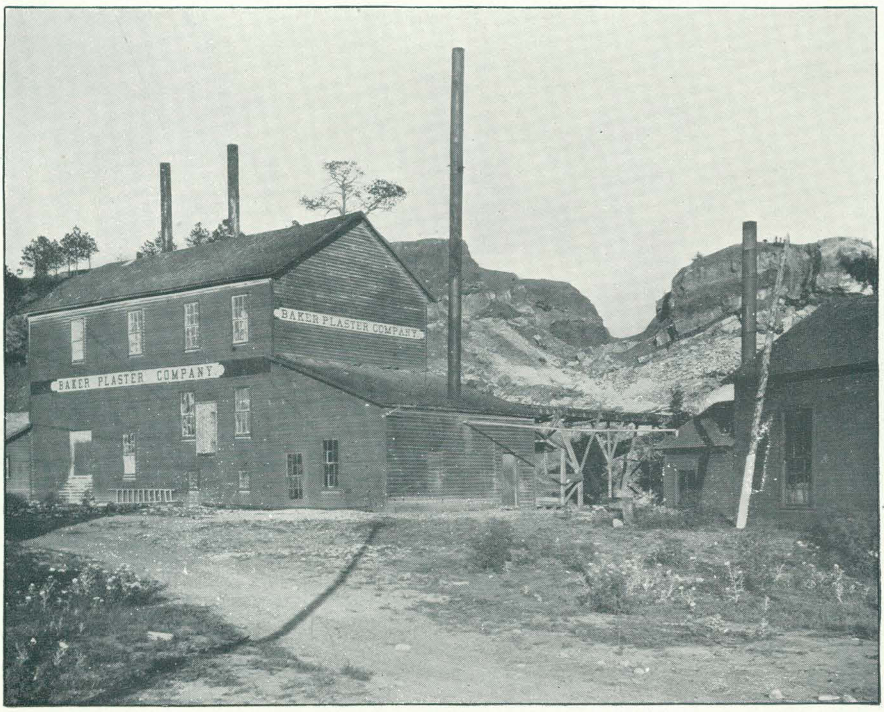
Constituent.	Per cent.
Lime	32.44
Magnesia	0.33
Alumina	0.12
Silica	0.10
SO_3	45.45
CO_2	0.85
Water	20.80
Total	100.09

PETROLEUM.

In the vicinity of the town of Newcastle explorations to develop an oil field have been in progress for several years. Small supplies of excellent petroleum have been obtained from borings and from two oil springs. The oil is very heavy, and even in its crude state is a high-grade lubricant. The oil occurs in a sandstone in the lower portion of the Graneros formation, which is extensively developed in the vicinity of Newcastle. It lies between 250 and 275 feet above the Dakota sandstone, from which it is separated by the basal black shales of the formation. The Graneros sandstone here varies in thickness from 10 to 30 feet in greater part, and its surface outcrops give rise to ridges of considerable prominence. The first line of ridges lying west-northwest of Newcastle owe their prominence to the locally increased thickness and hardness of this sandstone. Where the rock has been exposed to the weather it is hard, moderately fine-grained, light-gray sandstone in massive beds. As it passes below the surface it is softer in texture, buff or brown in color, and usually strongly charged with petroleum. At two localities the oil oozes out of the sandstone and collects in springs, which for many years have yielded a small supply of oil for local use. One of these springs is 2¼ miles due west of Newcastle, just north of the railroad, and the other is 2 miles farther northwest and slightly farther north of the railroad. At these points the oil-bearing sandstone passes beneath the surface in small draws, and the escaping oil accumulates in the loose materials adjacent. Cisterns have been constructed in such manner as to catch the oil, and a few gallons per week are obtained which find ready sale as a lubricant. Several attempts have been made to develop the oil sand in its extension under ground by means of wells in the region west and southwest of Newcastle, but so far these operations have not yielded a large supply of oil. In most cases the oil horizon has been passed through and the boring uselessly extended far into the underlying shales and sandstones. As the sandstone appears to contain considerable oil in the vicinity of the oil springs, and as it underlies a wide area about Newcastle, it is difficult to understand why the wells have not given more encouraging results. From the statements made by the promoters of the enterprise, it seems probable that the oil sand was not always recognized in the boring operations, and at any rate was not adequately tested. The oil is very viscid and should hardly be expected to flow from wells at any point in the area, but possibly by dynamiting and pumping a supply can be obtained. In Pl. CVII are shown the relations of the oil-bearing sandstone and associated formations and the location of wells which have been bored. In the sections may be seen the conditions under which the oil sand passes under ground and the thickness and nature of the overlying materials. These formations are



A. GYPSUM LAYERS ON SPEARFISH RED BEDS ALONG COLD BROOK, 1 MILE ABOVE HOT SPRINGS, SOUTH DAKOTA.



B. GYPSUM WORKS NEAR HOT SPRINGS, SOUTH DAKOTA.

relatively uniform in thickness and invariably lie in regular sequence. In surface exposures they are all distinctive in appearance, particularly the bed of Greenhorn limestone and the thin sandstone layer 300 feet above. The distinctive fossils of the Greenhorn limestone and of the Niobrara chalk, which lies 700 feet above, are shown in Pl. XCVIII. In sections 1 and 2 may be seen the manner in which the formations dip steeply beneath the surface in the vicinity of the railroad, so that to the southeastward the oil sand soon lies under 2,500 feet or more of shales. Approaching Newcastle, as shown in sections 3 and 4, the dips diminish rapidly and there is a basin of considerable size in which the formations are spread out widely. The deepest boring in the region, the one shown in section 3, has a depth of 1,950 feet. It passed through the oil sand at a depth of about 100 feet and then penetrated the shales, Dakota and Lakota sandstones, and underlying shales and red beds. From the Lakota sandstone it obtained a flow of water which is still running over the mouth of the well. Only a small amount of oil was observed. The well a half mile southwest of Newcastle, with a depth of 1,340 feet, penetrated the oil sand at a somewhat greater depth than the first well, and oil brought up by water from the underlying sandstones is still flowing out of the casing. The 420-foot well, a short distance northwest of the 1,340-foot well, is said to have just reached the top of the oil sand, where a promising showing of oil was observed. The 720-foot well, 3½ miles southwest of Newcastle, as shown in section 2, was entirely in shale and failed to reach the oil-bearing sandstone by about 2,000 feet. It is greatly to be regretted that this boring was not continued sufficiently deep to test the contents of the oil sand where it is deeply buried and so far from surface outcrop as to permit the accumulation of considerable head if there is any oil present. In the vicinity of section 1 two deep borings have been made and another one is now in progress in the steep-dipping beds near the outcrop of the sandstone. The results so far obtained have not been successful, although the borings are midway between the two oil springs described on a preceding page. It can not be claimed that the Newcastle oil field presents promise of being a bonanza, but it is believed that the capabilities of the oil-bearing sand have not been adequately tested and the prospects are sufficiently good to warrant further exploration. The oil sand horizon extends southward nearly to Clifton and is over 30 feet thick near the L A K ranch. To the north it thins out near Skull Creek. Whether it contains oil away from the immediate vicinity of Newcastle remains to be ascertained by borings.

GRINDSTONE.

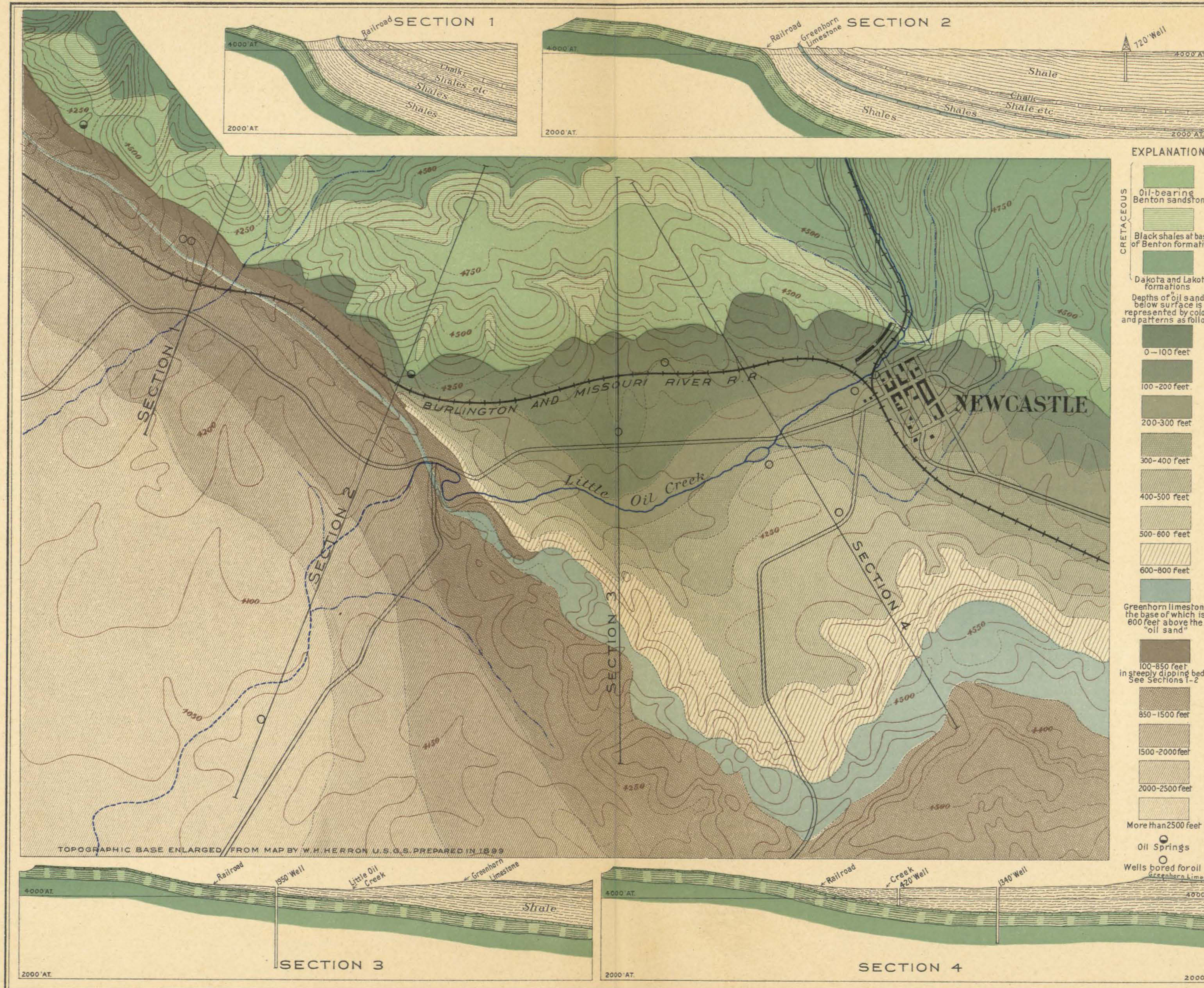
Three and a half miles north-northeast of Edgemont the Dakota sandstone has been quarried to some extent for grindstones. The product has not been large so far, and at present the quarry is not in operation, but the stone is claimed to be obtainable in large supply and to be of excellent quality. The conditions for working are most favorable, as the beds are in a high bank on the north side of Red Canyon, with plenty of room for the disposal of waste, perfect drainage, and no great amount of stripping. The dip is to the southwest at a low angle.

HONESTONE.

Portions of the Dakota sandstone at the Edgemont quarry are of fine, uniform grain, suitable for giving the finest edge to tools. Shipments have been made, and the materials have been received with greatest favor by tool finishers and cutters. It is said to be entirely satisfactory for sharpening razors.

FULLERS' EARTH.

A large portion of the Chadron formation—the basal member of the White River group—consists of fullers' earth, using the term more in a mineralogic than in an economic sense. The deposit consists of hydrous silicate of alumina with a small variable admixture of other components. It is amorphous and spongy in texture. Much of it has the property of decolorizing oils, etc., and when this property is highly developed the material is economically a fullers' earth and of considerable value. It differs from ordinary clay in its texture, which is spongy rather than plastic, and the water in its composition appears to be combined in a relatively definite ratio. Its economic value depends entirely upon its physical constitution, and can only be determined by practical tests. It is a material greatly in demand for clarifying oils, lard, etc. At present the greater part of the supply used in this country is imported from England, but there are mines of considerable extent in Florida. In the Chadron formation adjoining the Black Hills there are thousands of square miles of deposits having the chemical and physical properties of fullers' earth, but it is not known what proportion of the material is available for commercial use. Mining operations were begun at a point 3 miles southwest of Argyle and on the east side of the hills 3 miles south of Fairburn, but the first shipment failed to yield satisfactory results in the factory tests. It is claimed by owners of the Argyle property that their trial shipment was not selected with sufficient care to exclude extensive admixture with the more sandy associated beds, and the failure at Fairburn appears to be due to a similar hasty shipment without careful selection of the best material. As tests of the small samples were satisfactory, the miners supposed that the earth was all serviceable and did not discriminate in making a bulk shipment. It is desirable that further trial should be made of these earths on a larger scale and that the shippers should be guided by careful sampling and testing, so as to be able to select only the very best material obtainable.



MAP AND SECTIONS SHOWING RELATIONS OF "OIL SAND" IN THE VICINITY OF NEWCASTLE, WYOMING

BY

N. H. DARTON

HORIZONTAL AND VERTICAL SCALE

1000 500 0 ½ 1 MILE

FEET

CONTOUR INTERVAL 50 FEET

1899

Proper powdering and drying are also to be considered. The fullers' earth deposits extend from the high slopes of the hills west of Fairburn and Hermosa far eastward into the Bad Lands, as shown on the geologic maps (Pls. LIX and LXV) and explained in the description of the geology of the Chadron formation on page 543. The deposit southwest of Argyle covers an area of at least 1,000 acres. The tests made of small samples of these earths from Argyle and from the beds a mile northeast of Fairburn have given excellent results with cottonseed oil, and, as they present all the characteristics of genuine commercial fullers' earth, they deserve to be carefully developed.

The following are analyses of some of the fullers' earth deposits, taken from a paper by Heinrich Ries:[1]

Analyses of fullers' earth from South Dakota.

Constituent.	I.	II.	III.
	Per cent.	*Per cent.*	*Per cent.*
Silica	68.23	60.16	56.18
Alumina	14.93	10.38	23.23
Ferrous oxide	3.15	14.87	*a* 1.26
Lime	2.93	4.96	5.88
Magnesia	0.87	1.71	3.29
Loss on ignition	6.20	7.20	*b* 11.45
Total	96.31	99.28	101.29

	IV.	V.	VI.
	Per cent.	*Per cent.*	*Per cent.*
Silica	55.45	57.00	58.72
Alumina	18.58	17.37	16.90
Ferrous oxide	3.82	2.63	4.00
Lime	3.40	3.00	4.06
Magnesia	3.50	3.03	2.56
Loss on ignition	8.80	9.50	8.10
Volatile	5.35	5.85	....
Alkali	....	....	2.11
Moisture	....	....	2.30
Total	98.90	98.38	98.45

a Fe_2O_3. *b* H_2O.

Analyses I to V were made by Professor Flinterman, of the South Dakota School of Mines, at Rapid, and VI by Mr. E. J. Riederer. No. I is from William Bodemer's pit north of Fairburn; II and III are from M. Palmiter, Fairburn; IV and V from D. Henault, Custer (from the Argyle mines), and VI from southeast of Fairburn.

[1] The fullers' earth of South Dakota: Trans. Am. Inst. Min. Eng., 1897.

BUILDING STONE.

Several of the sedimentary formations in the Black Hills region would afford large supplies of building stones, but so far they have had but little more than local use. The red and banded sandstones of the Unkpapa formation have been worked to some extent in the canyons in the hog-back range between Buffalo Gap and Hot Springs and furnish a stone of beautiful color, even texture, and a fair degree of durability. It is soft, but when properly selected does not crumble on exposure. Buildings in Hot Springs, Buffalo Gap, and other places have been erected of the stone, but it has not yet found an extensive market. The massive sandstone of the Dakota formation has been quarried for several years at Evans's quarry on Fall River, 5 miles east of Hot Springs. The stone varies from gray and buff to a very attractive pinkish tint. It is easy to work, but is much harder than Unkpapa sandstone. Several of the hotels and other buildings at Hot Springs have been built of this rock. The quarrying operations are on a small scale, but they are still in progress and recently work has been begun on the same ledge at the mouth of Odell Canyon, 3 miles to the north. A small amount of limestone was quarried at Limestone Butte, near Oelrichs, for building in the vicinity. Much of the Lakota sandstone could be employed for construction and there are numerous beds of limestone in the Pahasapa formation which would furnish desirable building stone. The local demand for stone in the Black Hills is not large and it is generally claimed that the expense of shipment is too great at present to enable any but the most attractive materials to compete with the present supplies in distant markets.

LIMESTONE.

Under this heading it may be desirable to call attention to the vast quantities of limestone in the Black Hills which are available as flux in metallurgical processes. The Pahasapa limestone is well suited to this use throughout its extent, as are also the Minnekahta, Minnewaste, and White River limestones. An analysis of a typical sample of Minnekahta limestone from near Cascade Springs is given on page 515.

LITHOGRAPHIC STONE.

West of Custer, on the limestone plateau, there are beds in the Pahasapa limestone which present promise of being suitable for lithographic stone. The texture appears to be right, and it is stated that a slab of moderate size has proved satisfactory in practical tests. Large stones can be obtained, but until they are produced and tested the availability of the deposits for this purpose must remain uncertain.

VOLCANIC ASH.

The volcanic-ash deposits in the White River formations have economic value as polishing powder. It is the material that is used in some of the abrasive soaps and in its raw state as a polishing powder. The deposits in this region so far have not been worked. The thick bed at the fullers' earth mines southwest of Argyle would furnish a large amount of ash of excellent quality. The grains are small, uniform in size, and have sharp, cutting edges. The deposit is 3 feet thick and probably retains approximately this thickness for a few acres at least. The deposit southeast of Oelrichs is too small in extent to be worked for shipment, but it is a particularly sharp-edged ash, and consequently very powerful as an abrasive.

SALT.

The salt springs at the head of Salt Creek issue in large volume from the red beds of the Spearfish formation, giving rise to a creek that flows for many miles and finally empties into Stockade Beaver Creek. For a number of years the waters have been evaporated for the purpose of obtaining salt for local use. It is possible, however, that the output could be increased and a moderate amount of salt of good quality obtained for shipment. An analysis of the brine, made in the laboratory of the Geological Survey by Mr. Steiger, gave the following results in parts per hundred:

Analysis of brine from salt from Salt Creek, Wyoming.

Constituent.	Per cent.
Lime	0.20
Magnesia	0.04
Soda	2.73
SO_3	0.36
Chlorine	3.15
Bromine	None.
Iodine	None.
	6.48
Less O=Cl	0.71
	5.77

This is equal to a little more than 5 per cent of sodium chloride or common salt. The flow from the spring is about a gallon per second, which is equivalent to a production of about 35,000 pounds of salt every twenty-four hours.

CLIMATE.

The Black Hills have a climate much more attractive than that of the adjoining plains. The extremes of temperature are less, both diurnally and annually, and there is a more abundant precipitation. The weather is dry and hot in summer, moderately moist in late spring, and cold, with moderate snowfall, in winter. The climatic features vary

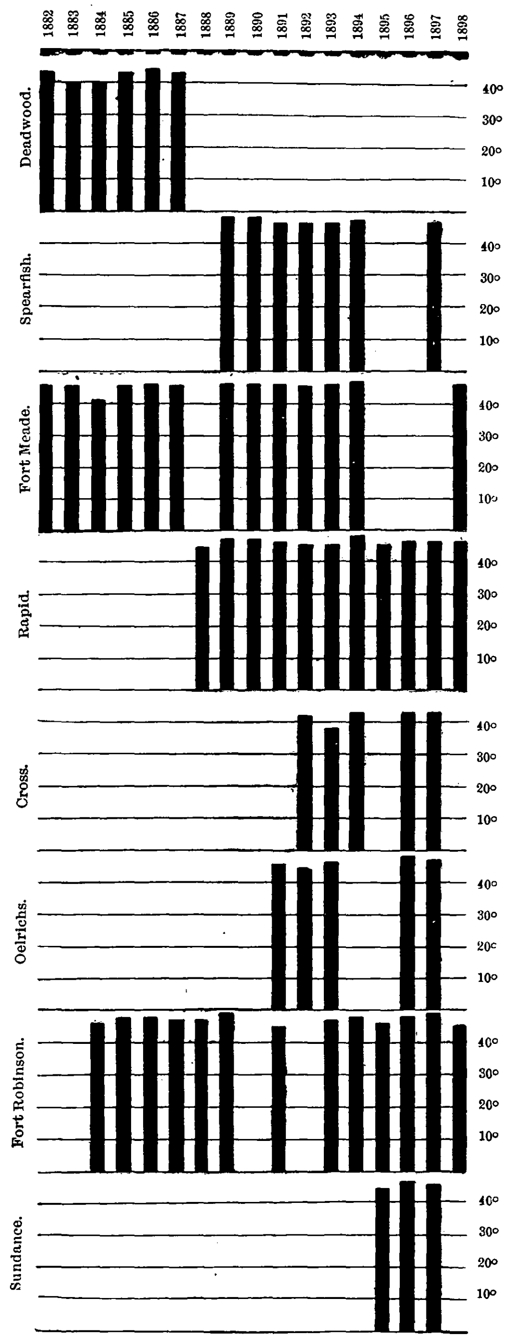


FIG. 298.—Diagram of mean annual temperature in the Black Hills and adjoining regions.

from year to year, and show much local variation from point to point,

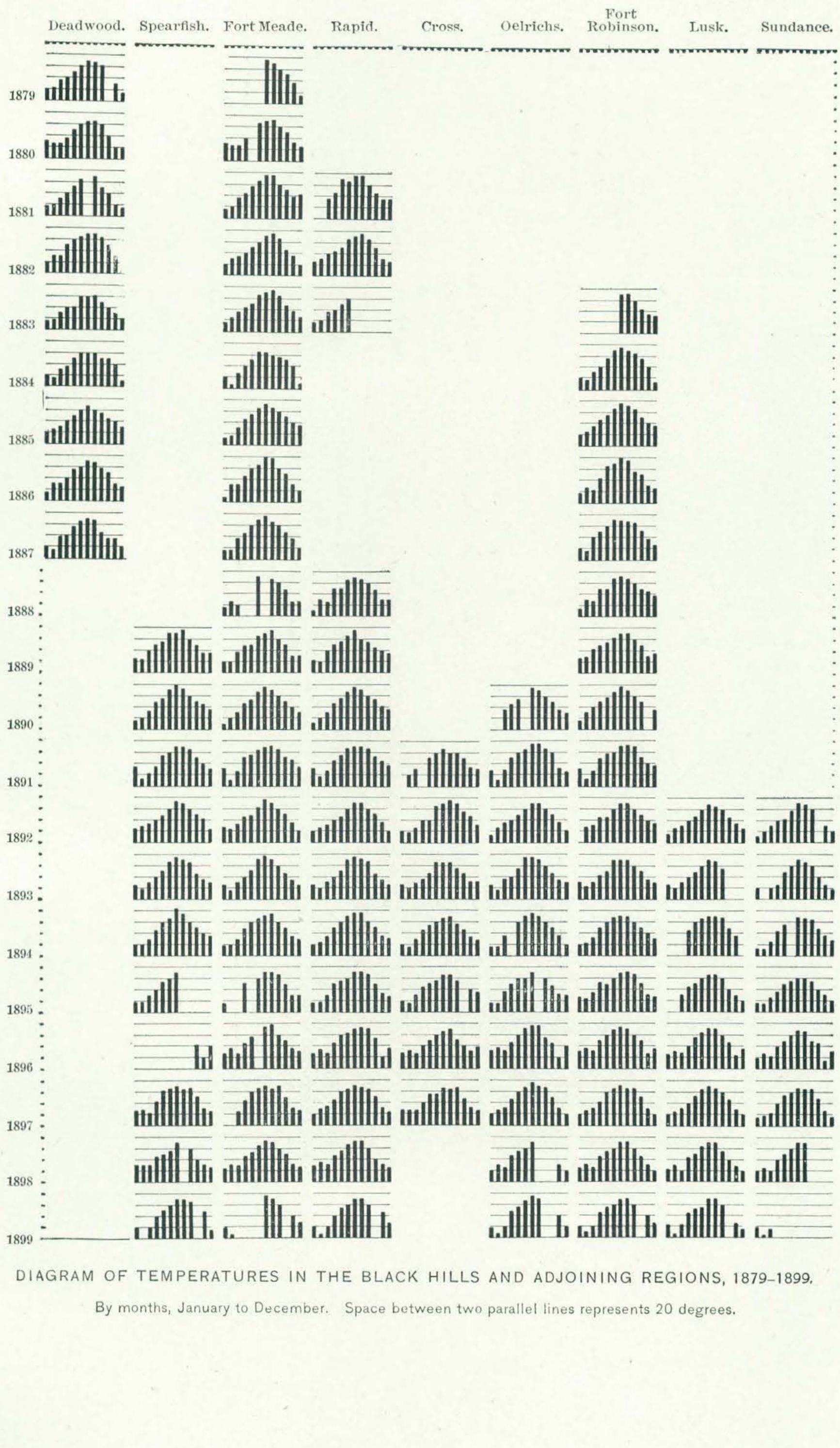


DIAGRAM OF TEMPERATURES IN THE BLACK HILLS AND ADJOINING REGIONS, 1879–1899.

By months, January to December. Space between two parallel lines represents 20 degrees.

particularly in rainfall. There is more snow in the Black Hills than on the adjoining plains, and, owing to more shade and shelter from sun and wind, it remains longer on the ground. Records of the weather at various points in the hills and their vicinity have been kept for many years. From these records have been compiled the diagrams constituting Pls. CVIII and CIX and figs. 298 and 299. Much information up to the end of the year 1891 was obtained from the report by Lieut. John P. Finley, on Certain Climatic Features of the Two Dakotas.[1] Pl. CVIII and fig. 298 illustrate the local and annual variations in temperature from month to month at points in or near the Black Hills. The prominent feature shown is a gradual rise of temperature in the spring to a maximum in July and August, as in most places on the same latitude. These two months often have an average of 70°, generally being a little more on the plains and somewhat less in the woods and on the high lands. Ordinarily July is hotter than August. The range in temperature in the twenty-four hours in summer is great, the heat often rising to considerably above 100° in midday and decreasing to below 60° at night. In the autumn there is a gradual decline in temperature for the first two months and then usually a rapid diminution to uniformly low temperature, which prevails throughout December and January. The average winter temperature is usually between 20° and 25°, but it varies more or less. As shown in fig. 298, the mean annual temperature varies considerably both by locality and from year to year. It is considerably lower in the northern part of the Black Hills, probably owing entirely to the difference of latitude.

The Black Hills exhibit a higher average temperature in winter and a lower average in summer as compared with the adjoining plains. The explanation that has been offered for this is that the region is protected by heavy forests from the high and dry cold winds which sweep across the plains.

The normal monthly temperatures for typical northerly Black Hills stations up to the end of 1891 were as follows:

Normal monthly temperatures in the Black Hills.

Locality.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Deadwood	21	23	32	40	50	60	65	65	54	44	33	23
Fort Meade	18	21	31	44	54	65	71	70	59	48	33	24
Rapid	20	22	33	46	53	64	71	71	61	48	34	31

The number of days in which the maximum temperature equaled or exceeded 90° were: Fort Meade averaged about 2 days in June, 7 days in July, 7 days in August, 1 day in September; at Deadwood the average is less than 1 day in June, 2 days in July, and 1 day in August.

[1] Published by United States Weather Bureau, 204 pages, 163 plates, 4°, Washington, 1893.

Precipitation in and about the hills is extremely variable, much of the variation being local. There is a rainy season in the spring, which in some years attains its culmination in May and in others in June.

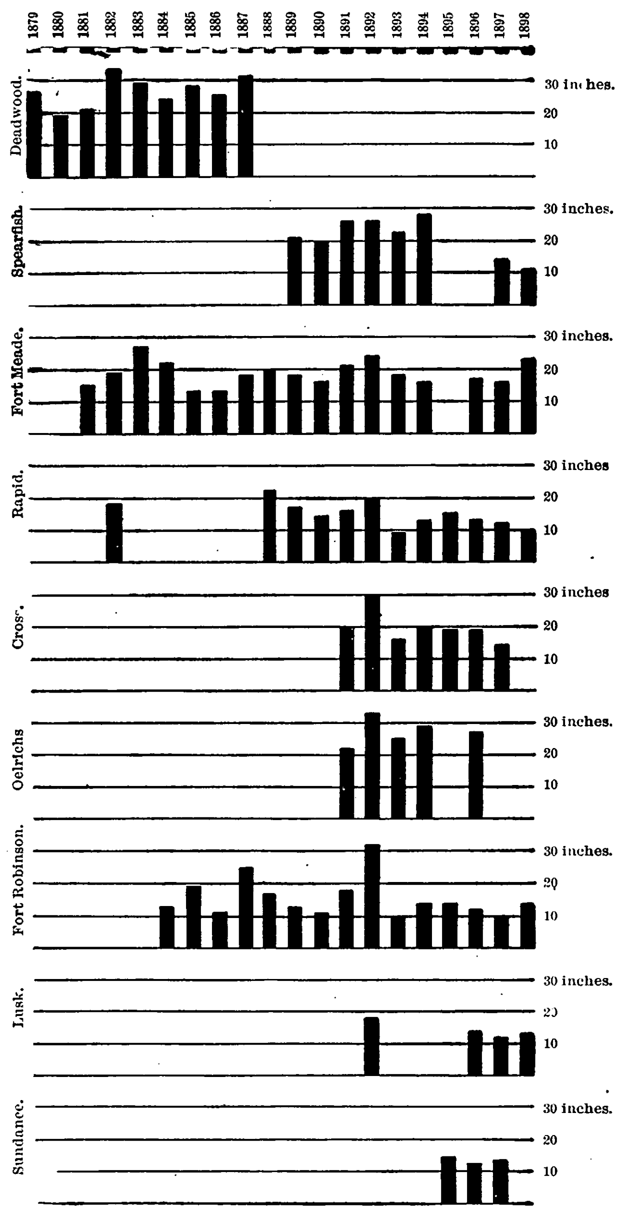


FIG. 299.—Diagram of total precipitation in the Black Hills and adjoining regions.

It is usually followed by a period of drought in July and generally with numerous scattered showers in August and September. Snow is

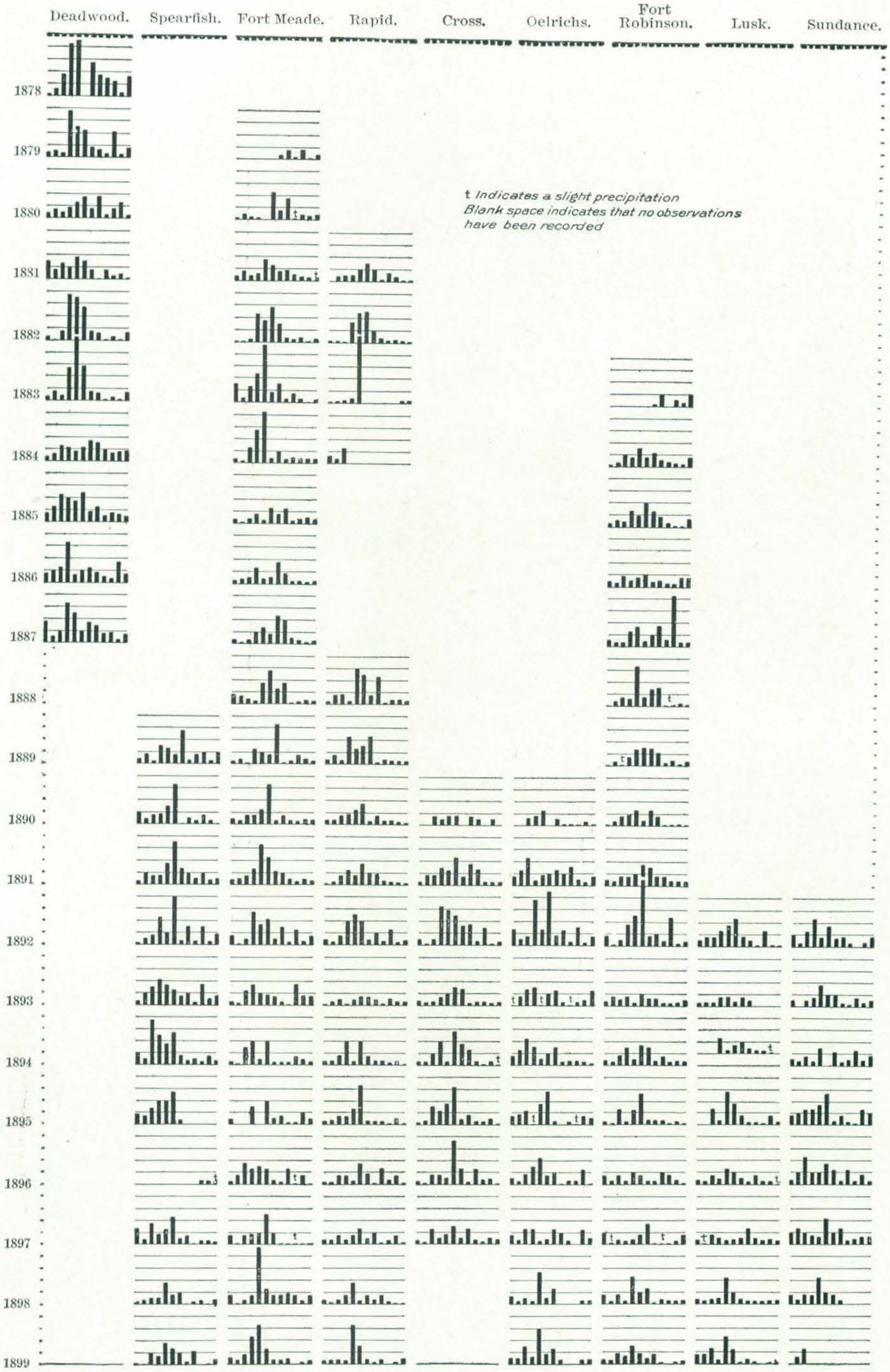


DIAGRAM OF RAINFALL IN THE BLACK HILLS AND ADJOINING REGIONS, 1878–1899.

By months, January to December. Space between two parallel lines represents 2 inches.

usually expected early in October, but the first snows are light and do not lie long on the ground. The midsummer precipitation in the Black Hills is not large in volume, but there is scarcely a day without light local showers at one point or another. They usually fall out of small clouds moving in narrow zones, and are a very small factor in agriculture. The rain often falls from one stratum of air and is absorbed again in another before reaching the ground. The idea that the climate of the region is changing—a theory which many people hold—is not borne out by the meteorological records. The great variation from month to month and from place to place seems to recur through recent seasons with the same range and averages as is shown in the earlier records. The average number of rainy days in which the precipitation equaled or exceeded 0.01 inch are as follows:

Rainy days on which precipitation equaled or exceeded 0.01 inch.

Locality.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Deadwood	11	11	12	14	14	13	10	11	7	8	6	5
Rapid	5	9	11	9	12	13	9	10	4	7	6	5

The average number of clear days per month, or those in which less than one-third of the sky was obscured by clouds, are as follows:

Average number of clear days per month.

Locality.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Deadwood	12	9	10	8	9	11	15	16	18	15	14	11
Rapid	13	6	6	10	6	6	9	9	14	11	14	13

At Deadwood the mean annual precipitation from 1878 to 1887 was 28.4 inches. At Rapid from 1881 to 1891 it was 18.46 inches. The following excessive precipitation has been recorded:

Excessive precipitation at points in the Black Hills, South Dakota.

RAPID.

May 1–31, 1883	10 inches.
June 7, 1888	0.27 inch in 12 minutes.
August 10, 1890	1.17 inches in 1 hour and 6 minutes.
July 5, 1891	1.33 inches in 43 hours.

DEADWOOD.

July 27, 1872	1.16 inches in 45 minutes.
August 8, 1875	1.7 inches in 1 hour and 5 minutes.
April 16, 1877	2.52 inches.
April 17, 1878	3.20 inches.

Excessive precipitation at points in the Black Hills, South Dakota—Continued.

DEADWOOD—continued.

April 21–22, 1879	2.86 inches.
April 22–23, 1886	3.32 inches.
May 2, 1874	4.55 inches.
May 7–8, 1882	3.33 inches.
May 17–18, 1883	2.77 inches.
May 18–19, 1888	2.62 inches.
June 9–10, 1874	2.51 inches.
June 23–24, 1883	3.34 inches.
October 15–16, 1879	3.47 inches.

FORT MEADE.

July 1, 1888	1.40 inches in 1 hour.
July 11, 1889	1.40 inches in 35 minutes.
June 4–5, 1890	3.8 inches.

SPEARFISH.

June 14, 1891	3 inches in 2 hours and 40 minutes.

The average quarterly precipitation for three points in the Black Hills is as follows:

Average quarterly precipitation at Deadwood, Fort Meade, and Rapid, South Dakota.

Month.	Deadwood.	Fort Meade.	Rapid.
	Inches.	*Inches.*	*Inches.*
January, February, March	4.45	2.42	2.44
April, May, June	13.55	9.61	10.24
July, August, September	6.13	4.92	4.46
October, November, December	4.35	1.62	1.30

This apportioned between the dry season or winter, comprising January, February, November, and December, and the wet season, from March to October, inclusive, is as follows:

Average precipitation during wet and dry seasons at Deadwood, Fort Meade, and Rapid, South Dakota.

Locality.	Dry season.	Wet season.
	Inches.	*Inches.*
Deadwood	5.23	25.25
Fort Meade	2.30	16.27
Rapid	2.07	16.37

MAP SHOWING DISTRIBUTION OF FORESTS IN THE BLACK HILLS

COMPILED MAINLY FROM REPORT BY H.S. GRAVES WITH LATER INFORMATION FOR AREAS OUTSIDE OF THE RESERVE

SCALE

5 0 5 10 MILES

HEAVY TIMBER 2000–10000 FEET B.M. PER ACRE

LIGHT TIMBER UNDER 2000 FEET B.M. PER ACRE

SCATTERING TIMBER

The average monthly precipitation, deduced from observations to the end of 1891, is as follows:

Average monthly rainfall at Deadwood, Fort Meade, and Rapid, South Dakota.

Locality.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Deadwood.....	1.25	1.21	1.99	5.17	4.65	3.73	2.84	2.23	1.06	1.58	1.26	1.51	28.48
Fort Meade....	0.73	0.63	1.07	2.38	4.02	3.22	2.40	1.96	0.56	0.68	0.48	0.46	18.59
Rapid	0.45	0.83	1.16	2.03	4.30	3.91	2.14	1.59	0.74	0.51	0.35	0.45	18.46

TIMBER.

The Black Hills owe their name to their dark appearance when viewed from a distance, due to the extensive forests of pine by which they are covered. The forests occupy all of the higher land, but vary greatly in density. The principal tree is *Pinus ponderosa* Lawson, or yellow pine. Large areas are densely timbered, but there are numerous open parks in the woods, and lumbering and forest fires have made deep invasions in them at some points. The principal forest growth lies within the encircling rim of Minnekahta limestone. The Red Valley is destitute of trees, but there are scattered pines on the ridges of the hogback range and in places along the Graneros shales. The principal area of timber has been made a reservation by Presidential proclamation, in order that the cutting of timber might be controlled and more thorough vigilance exercised in preventing devastation by fire. The timbered area and the boundary of the forest reserve are shown in Pl. CX, which has been compiled from a description of the reserve by Mr. H. S. Graves, forester,[1] with later data for some outlying areas. On this map an attempt has been made to classify the timber as heavy, thin, and scattering, but it has been done in a somewhat arbitrary manner and necessarily with considerable generalization, on account of the small scale of the map. Besides the yellow pine there occurs in the hills a greater or less quantity of the following species:

Trees occurring in the Black Hills, South Dakota.

Spruce (*Picea canadensis* Mill.).
Aspen (*Populus tremuloides* Michx.).
White birch (*Betula papyrifera* Marsh).
Bur oak (*Quercus macrocarpa* Michx.).
Box elder (*Acer negundo* Linn.).
White elm (*Ulmus americana* Linn.).
Ironwood (*Ostrya virginiana* (Mill.) Koch).
Cottonwood (*Populus deltoides* Marsh).
Cottonwood (*P. angustifolia* James).
Red cedar (*Juniperus virginiana* Linn.).

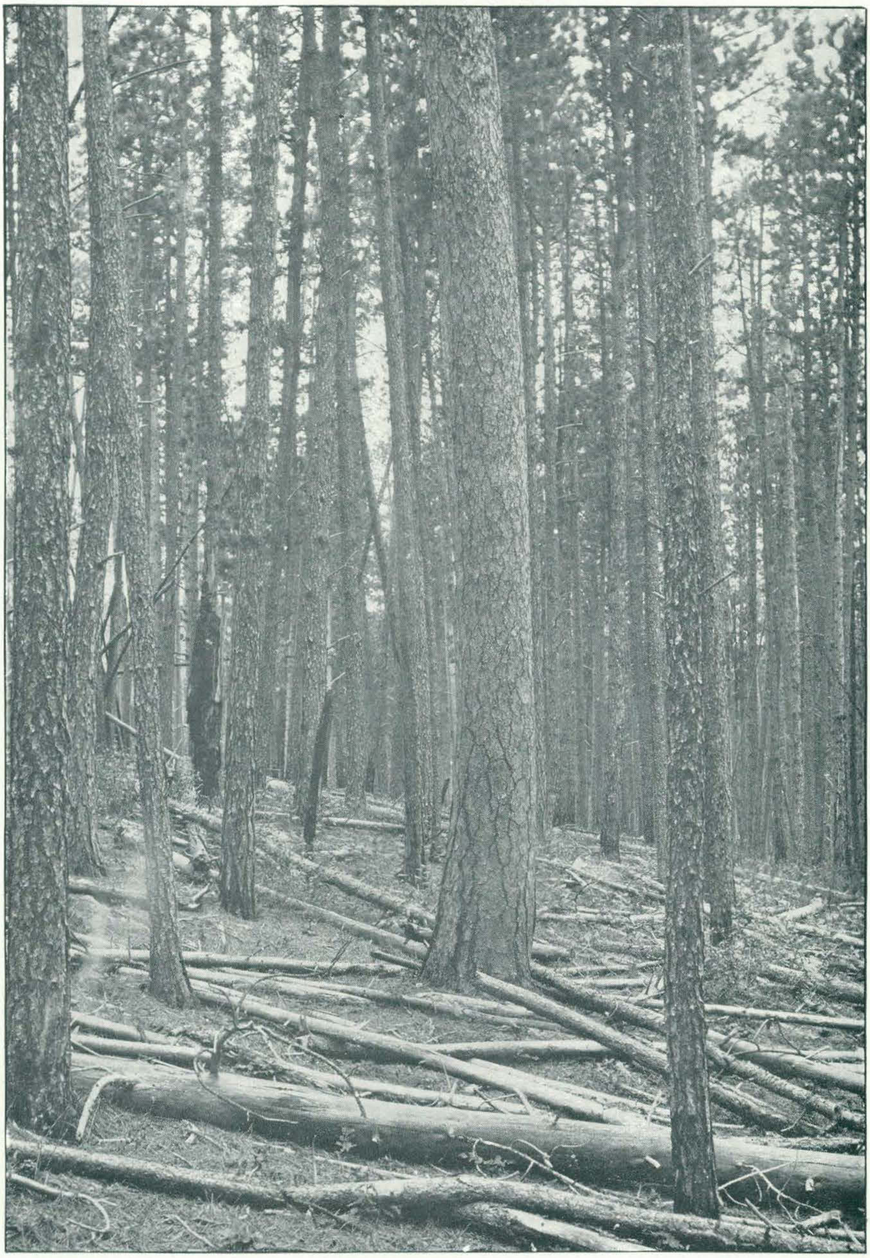
The larger pine timber attains a height of 100 feet, but it is estimated by Mr. Graves to average not over 80 feet, with an average diameter of about 20 inches. Timber of this kind is found "on the divide west

[1] The Black Hills Forest Reserve, by Henry S. Graves: Nineteenth Ann. Rept. U. S. Geol. Survey, Part V, pp. 67-164, Pls. XIX-XXXVI, and maps.

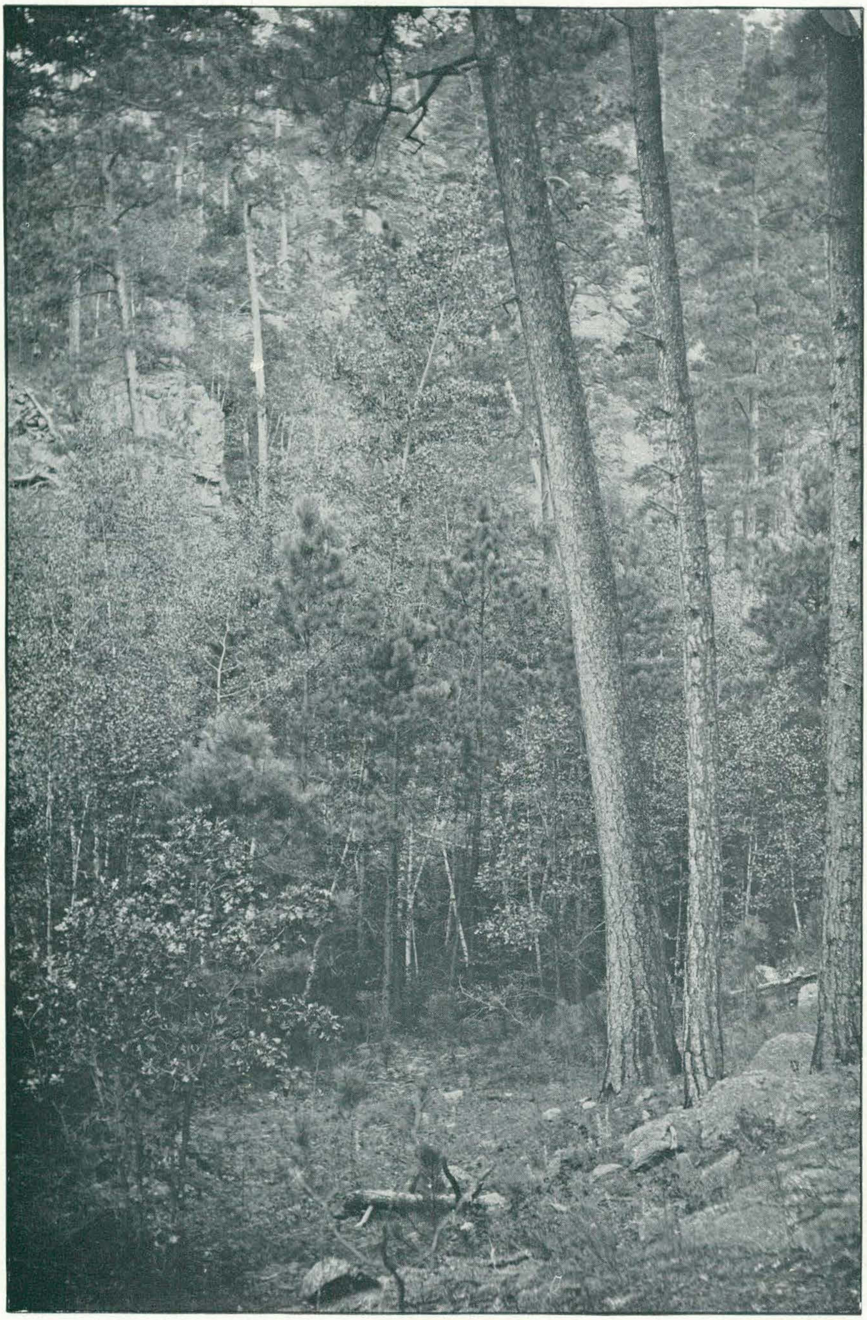
of Spearfish Canyon, on South Box Elder Creek, at the head of Spring Creek, on Soldier, Cold Springs, and Sand creeks, and elsewhere in small amounts. It has an average yield of 4,000 to 8,000 board feet per acre." The second class of original timber is that which covers the greater portion of the Black Hills. "It has about the same development in diameter, but it is not so tall as the first class. It averages about 65 feet in height" and is less dense. "The third class of timber is found on ridges and steep slopes and is both smaller and shorter than the first two classes. The diameter averages 14 to 17 inches."

The spruce grows in the highest valleys and mainly on the northern slopes, where the coolest and most moist conditions are found. It occupies considerable bodies on the high limestone plateau, notably about the head of Castle Creek. It is scattered along some of the higher ravines which head against Harney Peak. It often attains a height of 100 feet and a dimeter of nearly 3 feet, but it averages much less than this. Aspen is scattered over the hills, especially where there have been forest fires, and the white birch occurs in similar manner.

The parks occurring along the higher ridges of the Black Hills are usually found in the heads of valleys where the declivity is small and there is a large accumulation of decomposed rock detritus. Young pines are often found in these parks, especially around their edges, but they do not grow to any great height, apparently on account of the lack of the firm rootage which is essential to the growth of the pine. The existence and perpetuation of the parks is not due to fires, as has been suggested, but to the depth of the decomposed material which is too soft to afford proper conditions for the growth of the roots of the tree. In the lower portions of the valley the streams have sufficient volume to clear out the decomposing rock, so that most canyons through the hills are well wooded. This is also thought to be the principal reason for the absence of the pine in the Red Valley and the plains adjoining the Black Hills. The characteristic feature in the occurrence of the pine is its growth where there are rocky ledges to give suitable attachment for its roots.



A DENSE FOREST OF POLES 8 TO 10 INCHES IN DIAMETER, WITH ONE OF THE MOTHER TREES IN THE CENTER, REYNOLDS GULCH, SOUTH DAKOTA.



A CHARACTERISTIC FOREST IN A DEEP, NARROW RAVINE AT AN ELEVATION OF ABOUT 4,000 FEET.

Stream gaging by John T. Stewart in 1900.

Stream.	Location.	May.	June.
		Second-feet.	*Second-feet.*
Cheyenne River	Edgemont	14	.5
Do	do	10	.3
Do	Above Cascade Creek	12	.7
Do	Below Beaver Creek, southeast of Buffalo Gap.	47	49
Do	Above Fall River	39	.19
Stockade Beaver Creek.	2 miles above LAK ranch	11	12
Do	Mouth	9.4	3.5
Salt Creek	East of Newcastle	.2	.2
Big Oil Creek	Burlington and Missouri River Railroad bridge.	.2	.03
Little Oil Creek	Newcastle	.05	.02
Cascade Creek	Mouth	25	20
Fall River	do	33	25
Do	Below Hot Springs	25	29
Iron Creek	Glendale	3.8	1.6
Beaver Creek	3 miles northwest of Buffalo Gap.	12	15
Do	7 miles southeast of Buffalo Gap.	1.2	6
Battle Creek	Keystone	3	2.3
Do	Hermosa	9	2.3
French Creek	10 miles northeast of Fairburn.	13	5
Do	At Fairburn	3.3	.2
Spring Creek	Fremont, Elkhorn and Missouri Valley Railroad bridge.	.4	.1
Do	North of Rockerville	6.5	.7
Squaw Creek	Otis	8	2.8