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M. Q. SHARPE, Governor

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A GEOLOGY *of* SOUTH DAKOTA

PART I.
THE SURFACE

by
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Vermillion, South Dakota

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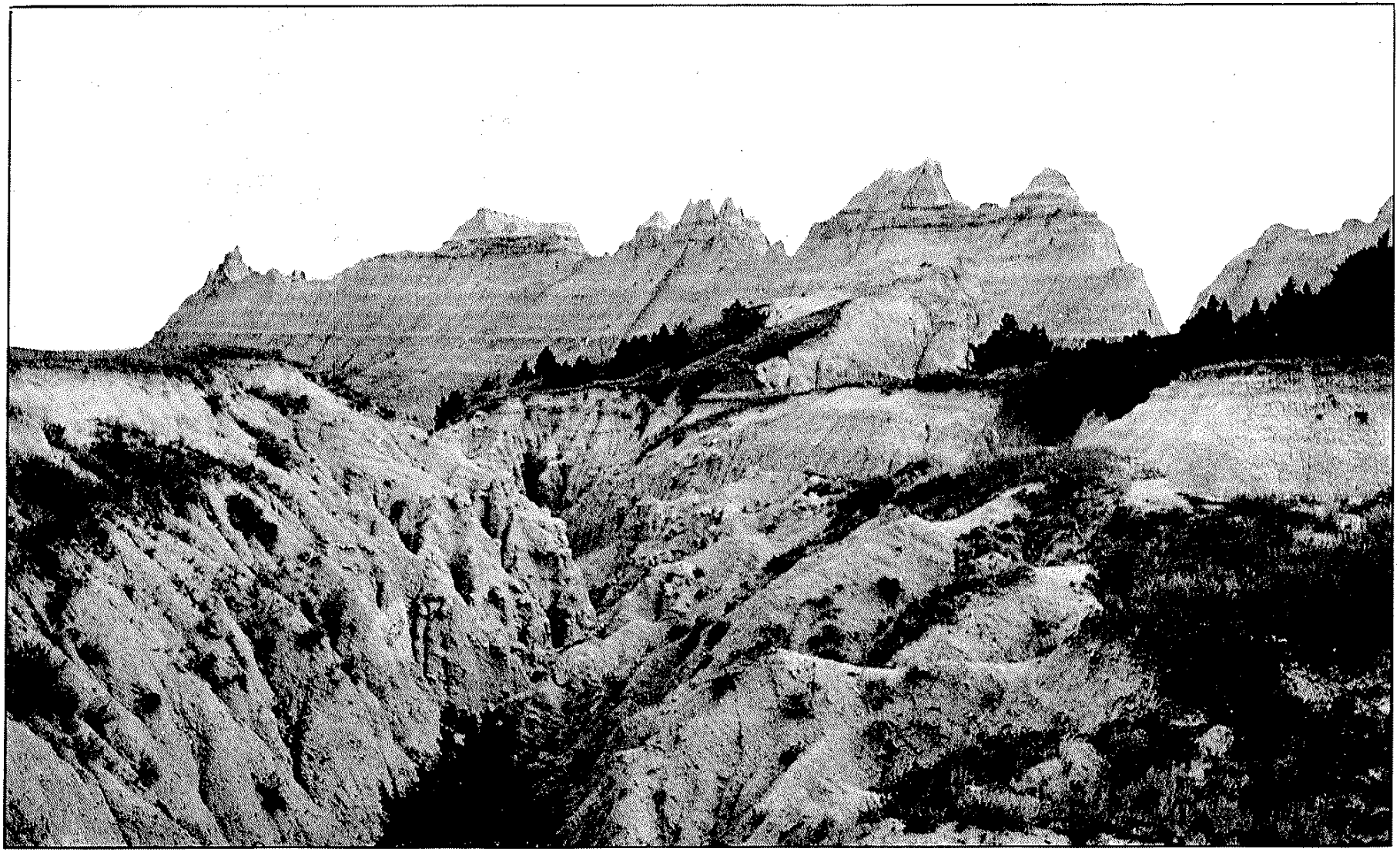

A PORTION OF "THE WALL"
Near the Pinnacles, White River Bad Lands, Pennington County

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DEDICATION

To James Todd, first State Geologist of South Dakota, who had the vision;

To those farsighted legislators, who made its partial fulfillment possible;

To the company of geologists whose devotion to their science has furnished the material contained herein, and

To that other company whose painstaking clerical work on files and manuscripts has made this information available,

This compilation is dedicated.

A GEOLOGY OF SOUTH DAKOTA

FOREWORD

The complete story of South Dakota geology has never been told nor can it be told now. The puny efforts of us humans to read the history written in the rocks beneath our feet will not lead to unraveling the whole tale for many years to come. Three generations of geologists have struggled with its problems and though they have not been able to solve them all, they have uncovered much that is of popular interest, scientific value, and commercial usefulness. The present attempt, therefore, is intended only to set forth the things which their research has thus far revealed about the surface features, rock and mineral deposits, and past history of our state. It is hoped that this may serve as a source of information for those interested in the things which are of the earth and as a foundation on which future generations of geologists and nature lovers can build the more complete structure.

Should you ask whence this information I would point out to you those sturdy pioneers who braved the perils of a wilderness country and savage men to glean what they could on long and painful trips with pack saddle and wagon. Their contribution is noteworthy in that they had little to gain but the satisfaction of giving to the world something which they hoped would be of use to others. Among those we should thus honor should be mentioned Dr. V. F. Hayden, who presented the main geologic features of the Badlands (1853-66); Professor William F. Keating of the University of Pennsylvania, who examined the hill country in the northeastern part of the state as early as 1823; D. W. Featherstonehaugh, who explored this region during the summers of 1834 and 1835; and Henry Newton whose explorations of the Black Hills and Great Plains region were published by the federal government in 1880.

For the foundation of our modern geological knowledge we look to a group of men who worked in the state about the turn of the last century—Dr. N. H. Darton of the U. S. Geologic Survey whose broad vision pictured the first outline of geological conditions as we know them today; J. E.

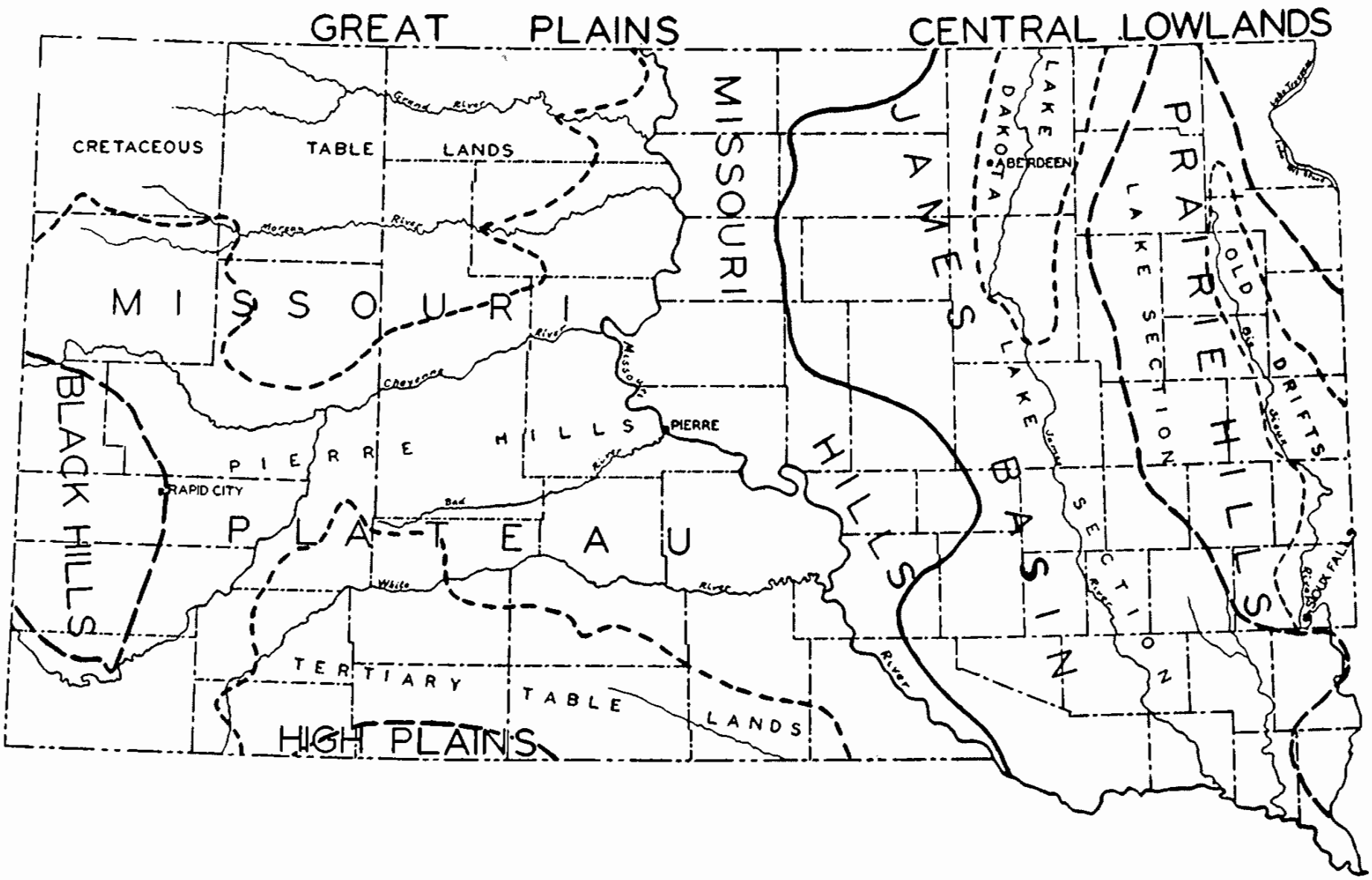
Todd, the first State Geologist; and Dr. C. C. O'Harra, for years President of the State School of Mines, who, collaborating with Dr. Darton, made early attempts to apply available scientific knowledge to the problem of developing the resources on which our commonwealth will stand or fall.

These pioneers were followed by a score or more of workers, using more modern methods of exploration, who have built into the picture the conditions which we can now pass on for your inspection as a fairly accurate representation of the geologic conditions under which we live and from which we can not only derive a living but also much enjoyment if we put them to proper use.

Modern contributors include geologists from the federal Geological Survey, a long list of employees of the State Geological Survey, teachers of geology, and commercial geologists, all of whom have done their part in bringing to light the stratigraphic, structural, and economic conditions in our state.

Like most scientific achievement this report is a contribution of many workers, each of whom has added his bit to its completion. The author considers himself fortunate in being permitted to assemble the work of such an illustrious group and to add his own contributions where possible. For the many things which are not published here that we ought to know and would like to know he humbly asks your indulgence and promises that, as long as the scientific spirit exists in the state, someone will be trying to unearth them. This compilation is presented to you, therefore, as our best efforts with the information now available.

PHYSIOGRAPHIC DIVISIONS OF SOUTH DAKOTA



PART I.
THE SURFACE

A. INTRODUCTION

Plains, rolling plains and then more plains! "I'll never forget South Dakota as long as I live!" wrote an eastern tourist exasperated at the monotonous repetition of hills and hollows. This, unfortunately, is the impression of our State carried away by many visitors. Part of the reason for this is that the most uninteresting country offers the fastest travel and is, therefore, followed by the main highways. A second reason is that South Dakota is a plains state, lying in the middle of the continent and near the middle of the great Mississippi basin.

In this region, for various and sundry political reasons, the rectangle, 460 miles east and west by 260 miles north and south, was set aside by surveyed lines to be the State of South Dakota. In the extreme northeastern corner the boundary line follows Lake Traverse and Lake Big Stone for fifty miles and in the southeastern corner it follows the Big Sioux and the Missouri valleys for about 190 miles. Of the total 1,420 miles of South Dakota's boundary, only 240 miles follow natural boundaries. The rest is an arbitrary, surveyed line corresponding to meridians and parallels and paying no attention to hills and valleys, mountains and plains, or other natural divisions.

This is fortunate, for the meridians and parallels enclose a great many kinds of country. In fact, there are few states which can offer as great a variety of interesting topographic features as can South Dakota. Rolling plains are characteristic, but are varied by steep escarpments, lofty buttes, rugged canyons, lakes, badlands, and mountains—all adding to the variety of things of interest to the visitor who cares to look at them, and of geographic significance to those who live here.

To get a general picture of this topography let us consider the surface of the state as a great table with about the proportions of an ordinary office desk or a kitchen table. The northwest corner has been raised so that there is a

general slope from the northwest to the southeast. The highest part of this slope, then, will be in Harding county on the divide between the Little Missouri and the Grand rivers where precise level lines, run by the United States Coast and Geodetic Survey, give elevations of nearly 3,400 feet. The lowest point on this general slope is in the southeast corner of the State at the junction of the Big Sioux and Missouri rivers with an elevation of 1,100 feet.

This latter point is not the lowest point in the State, however, for due to a glacial accident, a trench, now occupied by Lakes Traverse and Big Stone, was cut in the northeastern corner, whose elevation (960 feet) is some 140 feet lower than the elevation at the mouth of the Big Sioux river. This is but a small chip off the corner of the state, however, since less than twenty miles to the west of these lakes the surface rises 1,000 feet in a great escarpment to an elevation of 2,000 feet above sea level.

The highest point in the state is not in the northwest corner of the state though this is the top of the general slope. In the southwest corner is a tidy little mountain mass, the Black Hills, whose highest peak, Harney Peak, reaches an elevation of 7,242 feet.

With this general picture of a sloping plain across which streams drain eastward and southward, a small deep chip off its northeast corner and a mountain mass sticking out of the southwest corner, in mind, let us look at the details of the topography.

Geographers have divided the basin of the Mississippi river into several large provinces.[1] South Dakota includes a portion of two of these; namely, the Central Lowlands occupied by the eastern half of the state and the Great Plains occupied by the western half. The line dividing these two is not as sharp as might be desired but roughly lies about the position of the one hundredth meridian. The one hundredth meridian, however, is only what the schoolboy called "an imaginary lion running around the earth." Therefore, in order to separate the Great Plains from the Central Lowlands we should have something more tangible; —some hills or valleys which can actually be seen.

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[1]Nevin Fenneman, "Physiographic Divisions of the U. S.," **Annals of the Association of American Geographers,** Vol. VI, 1916, pp. 19-98.

Fortunately for us the boundary in much of our state follows prominent highlands lying a short distance east of the Missouri river. From these summits one can stand on the Great Plains and gaze far eastward over the Central Lowlands beneath him. The southernmost landmark on this boundary is the Bijou Hills in Brule county south of Chamberlain. South of these hills the line follows a rough ridge to Lake Andes where it crosses the Missouri river into Nebraska. North of the Bijou Hills it crosses a large, flat area following a low glacial moraine between Kimball and Pukwana to the bold east-facing escarpment of the Wessington Hills. There it can be traced northward past Ree Heights to Highmore where it takes a thirty mile jump across another broad flatland to a great rough ridge of glacial drift known as the Lebanon and Bowdle Hills. These carry it past Bowdle and Mound City, and into North Dakota where it joins the great Missouri Escarpment.

West of this boundary lies a country of deep valleys and canyons, broad upland flats, and buttes which are characteristic of the northern Great Plains. East of it lies the low rolling hills and undrained, often lake-filled depressions of the glaciated portions of the Central Lowlands.

Within these two large provinces lie a dozen different kinds of country, each with characters sufficiently distinctive to make it worthy of a special designation. Because of this the surface of South Dakota can be divided into the following parts:

Provinces	Divisions	Sections
Central Lowlands	Prairie Hills	1. Old Drifts 2. Lake
	Minnesota Valley	
	James Basin	1. "Lake Dakota" 2. Lake
Great Plains	Missouri Hills	
	High Plains	1. Sand Hills
	Missouri Plateau	1. Pierre Hills 2. Cretaceous Table Lands 3. Tertiary Table Lands
	The Black Hills	1. Great Hogbacks 2. Red Valley 3. Limestone Plateau 4. Crystalline Basin

B. THE CENTRAL LOWLANDS PROVINCE

Two large features distinguish the surface of the Central Lowlands Province of South Dakota. One is a hilly, lake-dotted highland some sixty or seventy miles in width lying along the eastern border. Its surface is so rough that it was known to the early French fur traders as the Coteau des Prairie or Prairie Hill Country. The other is a great lowland trough about the same width as the Coteau with a very flat or slightly rolling surface extending the entire length of the state, down whose center sluggishly flows the world's longest unnavigable stream—the James river.

1. THE PRAIRIE HILLS DIVISION

(Coteau des Prairie)

The early French fur traders returning from trips into South Dakota referred to a land they called the Coteau des Prairie—the Prairie Hills. It is a rough highland, an "A shaped plateau, the apex of which lies about 40 miles west of Lake Traverse and attains a maximum elevation of a little over 2000 feet above sea level."[1] This highland thrusts its point northward into North Dakota and spreads out southward occupying about half of the portion of the state included in the Central Lowland Province. Its southern limit has never been very clearly defined, probably because the rough high parts characteristic of the country lay in its northern section. The southern portion, however, is just as hilly but not as rough.

The east side of the Coteau is sharply marked by a 600-foot escarpment overlooking the Minnesota valley. This can be traced from near Clair City, in the northwestern part of Roberts county, southeastward past Sisseton and Peever in Roberts county, Twin Brooks, Albee, and Revillo in Grant county. It leaves the state at Gary in Deuel county. It is a bold escarpment and viewed from the Minnesota valley looks like a mountain range which stretches to the north and south until it is lost in a blue haze. It is so steep that a special locomotive is kept in Milbank by the Chicago,

[1]T. C. Chamberlain, U. S. Geol. Surv. Third Annual Report, 1883, p. 390.

Milwaukee and St. Paul railroad to assist in hauling the trains up this slope. Where the Milwaukee railroad crosses it, the slope averages 100 feet to the mile, though farther south in Grant and Deuel counties it lessens to about forty feet to the mile.

The western side of the Coteau is equally well marked. A bold, west facing escarpment 300 feet high overlooks the James basin from such a height as to give the beholder an airplane view of that great flat lowland. So steep is this escarpment in its northern part that brakes grind and wheels slide as one's auto descends on any but the carefully selected routes of the main highways.

This escarpment can be traced on any map of the state by the turns and twists which railroads and highways have to make in order to get useable grades up its face. About six miles west of the city of Britton in Marshall county, Highway 10 makes a sharp, right angle turn at the slope. Farther south, just west of Andover in Day county, the Milwaukee railroad makes a four mile detour in order to haul its heavy trains up from the lowland of the James valley. At Crandall, in the southwestern corner of Day county, the Minneapolis and St. Louis railway makes a similar curve, while between Raymond and Clark, in Clark county, both the Chicago, Northwestern Railway and U. S. Highway 212 make sharp turns in crossing it. In Kingsbury county the escarpment is shown by a sharp turn in the Great Northern railroad at Bancroft and in the Chicago and Northwestern railroad and U. S. Highway 14 at Manchester. Further south the escarpment is much more gentle, but the observant eye can readily see the long slope up to the highland as it passes through Winfred in Lake county and Montrose in McCook county. From Montrose the escarpment swings southeastward passing a point just south of Sioux Falls and stopping at the Big Sioux River.

One small area which should be included in the Hill country lies south of the region just bounded. It lies between the Big Sioux River, which is the state line at this point, and Brule creek. This little area, known locally as the Newton Hills and covering some 360 square miles, is separated from the main body of the Coteau by a broad open lowland whose flat surface offers sharp contrast to the hills of the Coteau north and south of it.

"We never thought we could get a road through these hills," remarked an early resident of the Coteau and in spite of the fact that roads have been built, his remark still characterizes the surface of the highlands. It is truly a hilly country, rough, knobby hills in the north and south and long, smooth hills in the middle.

The Old Drifts Section

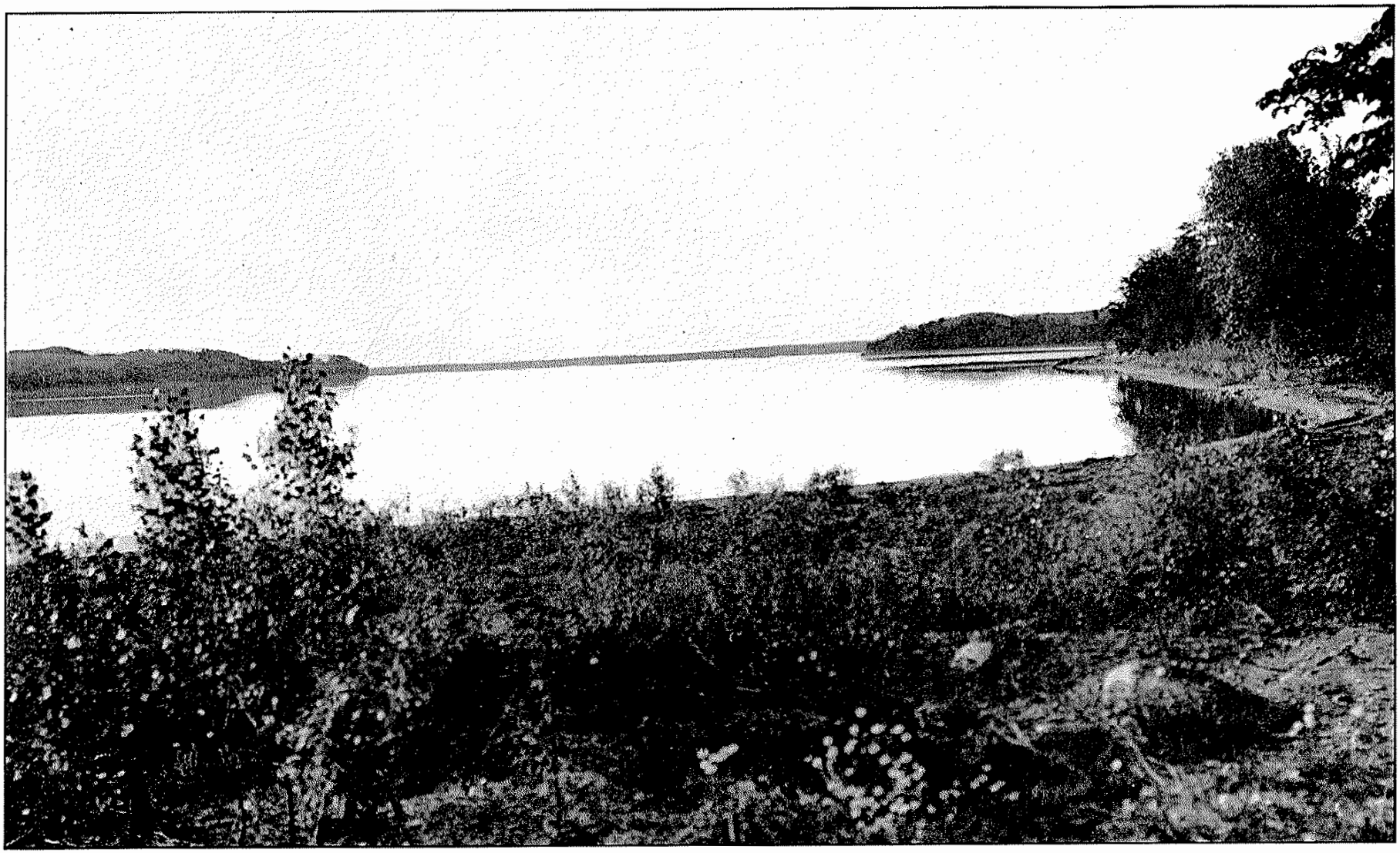
Geographers have divided this hilly highland into two sections: The "Dissected Till Plains" in the Big Sioux Basin and "The Western Lake Section."[1] In the basin of the Big Sioux river old glacial drifts have long been exposed to the action of wind and streams and have been seamed with many valleys. These valleys are still pathways for streams in the southern part of the basin and account for the scenic roughness of the Newton Hills in the vicinity of Alcester in Union county and of the country north and east of Sioux Falls in Minnehaha county. Farther north, however, the valleys have been partly covered with a veneer of glacial drift left by the second great ice sheet to visit the Coteau. The ancient stream valleys are still visible as broad, shallow depressions all trending toward the main drainage of the region—the Big Sioux. This part of the Coteau is not so rough, the hills and valleys appearing as great swells on the surface.

The Lake Section

The stream cut country of the Big Sioux basin is bordered by a rough hill country which straddles the basin like a huge wishbone whose prongs fork from a tangled mass of hills in Roberts and Day counties, at the head of the Big Sioux river. From this fork the prongs extend southeastward and southwestward in great arcs of hilly country which rise above the valley of the Big Sioux, their surfaces characterized by long ridges of very rough hills separated by wider spaces in which the surface is somewhat smoother.

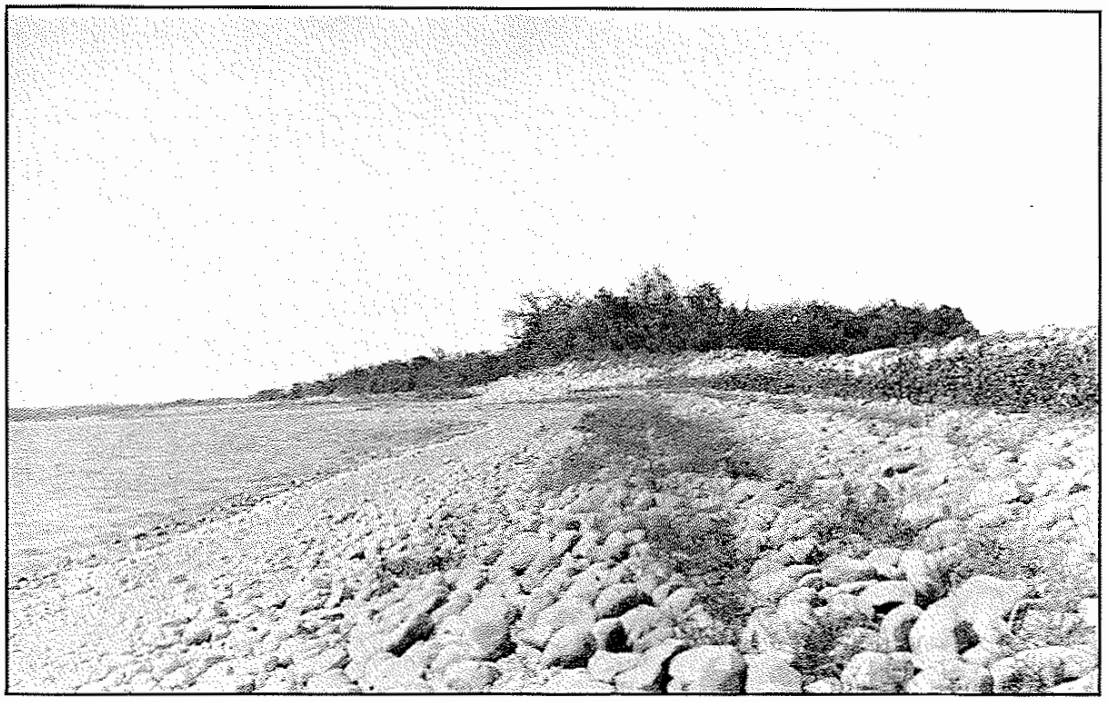
Because this country is doted with lakes it has been assigned to the Western Lake Section of the Central Lowlands by American geographers. Large and small lakes abound. Some of them are very deep and hold water during

[1]Nevin Fenneman, **op. cit.**



PICKEREL LAKE
from the south

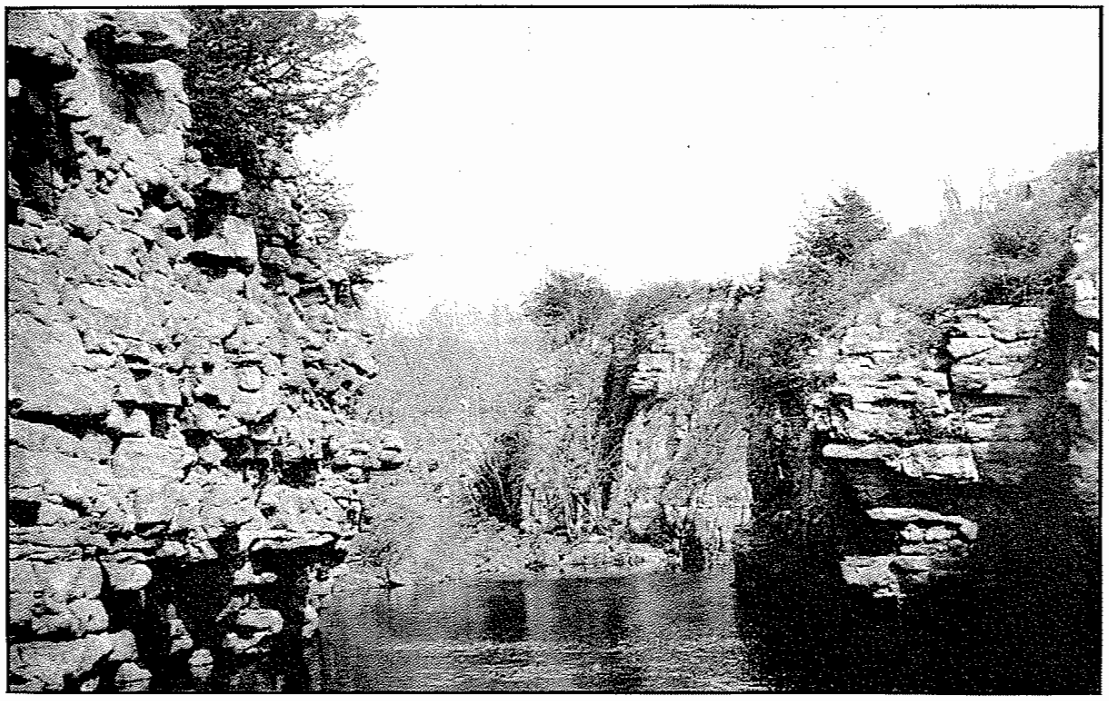
A typical spring-fed glacial lake of the Prairie Hills lying in the moraines of northeastern Day County.



BOULDER WALL

Enemy Swim Lake, Day County

Glacial boulders trapped in lake ice during cold winters are shoved onto the shore and piled up as shown by the expansion of the ice caused by cracking and refreezing.



THE DEVIL'S GULCH
Garretson, Minnehaha County
Cut by a small stream from solid quartzite rock.

the longest dry spells, and others are very shallow and hold water only during wet seasons. They vary from large lakes, several miles across, like Lake Kampeska at Watertown, which appears to be spread out on a nearly flat plain, to small lakes, but a few yards in diameter, nestling deep in the kettles between knobby glacial hills.

Most of them are spring-fed and drained. A few, however, are miniature oceans being fed from gravel channels but having no way for the water to escape except by evaporation. The evaporation from these lakes through the thousands of years that have elapsed since the lake basins were formed has left behind the salt brought into them by spring water until they have become notably alkaline. Two lakes in point are Medicine lake, in Codington county, on whose shores the water beats to a soapy foam, offering interesting possibilities to the mothers of certain small boys, and Bitter lake in Day county which serves as an evaporating pan for the seepage waters from four large lakes—Blue Dog, Enemy Swim, Rush lake, and Minnewasta —entering it through gravel channels. With these few exceptions, however, the lake waters are fresh, offering splendid habitats for fish,, game, and wild fowl and restful resorts for harried members of the human race.

Elevations on the highlands vary from 1,300 to 2,000 feet above sea level, the higher points being on the northern part of the highland. A glance at the following table of cities on the Prairie Hills will show its general southward slope and the relative heights of the portion belonging to the Old Drifts and Lake Sections.

City	Physiographic Location	Approximate Sea Level Elevation
Webster	Lake Section	1841
Clark	Lake Section	1792
Watertown	Old Drifts Section	1735
Brookings	Old Drifts Section	1628
DeSmet	Lake Section	1726
Madison	Lake Section	1676
Dell Rapids	Old Drifts Section	1500
Sioux Falls (downtown)	Old Drifts Section	1406
Alcester	Old Drifts Section	1400

An idea of the Coteau's height above its surroundings can be gained by comparing the elevations of the Coteau

cities with those of the cities of the James and Minnesota valleys in the same latitude.

James Valley		Prairie Hills		Minnesota Valley	
Aberdeen	1300	Webster	1841	Milbank	1142
Redfield	1301	Watertown	1735		
Huron	1306	Lake Preston	1719		
Mitchell	1293	Dell Rapids	1500		
Centerville	1230	Alcester	1400		

The story of the origin of the Coteau is a story of glaciation. Its surface features as well as its foundations are due to the action of ice. A comparison of elevations of the bed rock surface across the northern part of the Coteau in Grant and Day counties showed it to be a plain surface sloping gently to the east. Bed rock outcrops at the foot of the western escarpment of the Coteau at an elevation of 1,450 feet. A well at Webster struck it at an elevation of 1,360 feet. It outcrops again near Milbank at 1,092 feet. The 400 feet of material between the bed rock surface and the ground surface at Webster is all glacial material. Thus it appears that the Coteau owes its height to these deposits.

After studying the Coteau in Minnesota and as far west in South Dakota as the Big Sioux valley, Dr. Frank Leverett came to the conclusion that most of the drift was deposited during an early ice invasion, probably the Kansan. He states, "The prominent Coteau des Prairies, in the southwestern part of Minnesota, was for some time interpreted by geologists as owing its great prominence chiefly to Cretaceous strata, which were thought to fill in the gaps between the high areas of Sioux quartzite noted above. But studies by Meinzer along the Coteau and later studies by the present writer have shown that the filling between the quartzite areas consists chiefly of glacial material, borings having been put down to depths of 400 to 500 feet without encountering rock. The quartzite areas thus seem to stand above the general level of the bordering Cretaceous formations, much as the Baraboo quartzite of southern Wisconsin stands above the surrounding Paleozoic formations. The highest altitude reached by the Cretaceous of southwestern Minnesota may not exceed 1,300 feet. The Coteau surface has an altitude of 1,700 to 1,900 feet or more along the highest part of its crest in Minnesota. The morainic ridges of Wisconsin age, which to some extent follow the crest of

the Coteau, stand only about fifty feet above the district outside. It thus appears that the great bulk of the glacial material on the Coteau was laid down in earlier stages of glaciation."[1]

After streams had formed a well developed drainage system in the Kansan drift, a second invasion of ice (Iowan) spread a thin veneer of drift over the eastern part of the Coteau. It mantles but does not obliterate the old valleys and is the cause of the smooth, rolling country between Brookings and Watertown. The rough country of the original Kansan drift can still be seen south of this point and is particularly well developed in the vicinity of Sioux Falls and Alcester.

The last step in the building of the Coteau and the one which accounts for the roughness of so much of the surface was the invasion of both the east and west sides by the last or Wisconsin ice sheet. This ice left a sheet of drift fifty or more feet in thickness, piled about in such irregular fashion and so recently that it forms the surface irregularities as we see them today. Long piles of debris were formed where the ice front halted in its retreat, forming rough morainic belts of hill country between which a more even distribution of the drift left smoother surfaces of ground moraine.

In the southern part of the Coteau, in the vicinity of Sioux Falls and Alcester, the early drift (Kansan) is not so thick as farther north and was not covered by Wisconsin drift. Here the height of the Coteau is accentuated by large, deep valleys near by, which are now occupied by the Vermillion and Missouri rivers. These allowed a network of deep ravines to roughen the surface, thus giving it the right to be classed with the Prairie Hill Country.

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[1]Frank Leverett, "Quaternary Geology of Minnesota and parts of Adjacent States," U. S. G. S. Prof. Paper 161, p. 11.

2. THE MINNESOTA VALLEY DIVISION

Nestling at the foot of the eastern escarpment of the Prairie Hills is a lowland whose gently undulating surface has such low relief it seems flat in comparison with the surface of the Coteau. It lies on the continental water shed, the southern part draining through Big Stone Lake and the Minnesota river into the Mississippi basin while the northern part drains through Lake Traverse, the Bois de Sioux river and the Red River of the North into Hudson Bay. So low and indefinite is the divide, however, that in times of high water Lake Traverse will overflow sending part of its waters southward, through Big Stone Lake to the Mississippi. This is readily accomplished since the divide between Big Stone and Traverse lakes is only five or ten feet above the normal Lake Traverse level. The normal level of Big Stone, however, is about ten feet below that of Lake Traverse so that when the water level of Lake Traverse has reached the divide it readily flows over it.

According to topographic maps of the U. S. Geological Survey, the surface at Lake Traverse normally is 975 feet above sea level and that of Big Stone 966 feet; the divide between the two is between 980 and 985 feet above sea level.

The dominating feature of the Minnesota Valley lowland is the big trench which forms the eastern boundary of the state and in which Lake Big Stone and Lake Traverse lie. It is fifty miles long, averages a mile in width, being two and a half miles wide at its northern end and tapering to three-quarters of a mile at its southern end. Its walls are so steep as to appear vertical and so high that the surface of the lake rests 100 feet below the upland.

It looks like the great spillway that it is, since it owes its origin to torrents of water which overflowed from the great glacial lake (Agassiz) which covered the valley of the Red River of the North during the retreat of the last (Wisconsin) ice sheet. Lake Agassiz drained southward through this channel and the valley of the Minnesota river, reaching the Mississippi at Minneapolis.

When the water levels of Lake Agassiz were highest, this channel could not carry all the water, and a part was

shunted westward where it cut a second channel about a half mile wide, twenty miles long, and eighty feet deep. This smaller channel now is known as Cottonwood slough. The surface of the swamps and small lakes in its bottom lie at sea level elevation of 1,025 feet, about 50 feet above the normal level of Lake Traverse. Some of the beaches and part of the floor of the extinct glacial Lake Agassiz can still be seen in the extreme northeastern corner of the lowland. They are well preserved in White Rock township (T 128 N, R 28 W), Roberts county near the end of Lake Traverse.

The surface of the rest of the 720 odd square miles in South Dakota's portion of the Minnesota basin is typically glacial, the swells and swales of ground moraine being varied here and there by short belts of slightly rougher topography, some of which were formed during minor halts of the retreating ice sheet. Some of these are of sufficient size and distinctness to be listed as recessional moraines.

The most striking figure of the entire lowland is Big Tom, Mount Tom, or the Mount Tom Range as it is variously called. As seen from the highway, between Milbank and Big Stone, Big Tom appears to be a great round-topped mountain rising boldly above the surrounding plains. The lack of vegetation, except short grass and low brush, gives it a bald appearance which is especially noticeable during the drier parts of the year. In reality Mount Tom is a ridge ending abruptly in the bald knob to which the name is usually applied. It lies in the great bend of the Yellow Bank river four miles south of Lake Albert. From this point it trends about 30 degrees east of south, crossing the state line into Minnesota three miles from the northern boundary of Vernon township, Grant county. It is very steep-sided and is composed largely of medium to coarse gravel. Its width is not more than half a mile at the base, and this makes its 100 or more feet of height appear more conspicuous than it would if the same dimensions were spread over a wider territory. The southern end of the ridge in Lac Qui Parle county, Minnesota, is known locally as the Antelope Hills; therefore, the name Antelope moraine was given to the entire ridge years ago by Dr. T. C. Chamberlain.[1]

[1]T. C. Chamberlain, U. S. Geol. Surv. Third Annual Report, 1883, pp. 388-893.

Besides the large lakes already mentioned, small lakes and swamps abound in the lowland, for the most part nestling in kettles between glacial hummocks. Therefore, the region has rightly been placed by geographers in the Western Lake Section of the Central Lowlands along with the lake portions of the Coteau des Prairie and James Basin. The deep trenches, reaching the lowest elevations in the state, the glacial hills, of which Mount Tom is the most striking example, and the beaches of ancient Lake Agassiz make this lowland one of the most varied areas, topographically, in the state.

3. THE JAMES BASIN DIVISION

Between two hilly highlands, the James basin swings as a great arc of very flat, monotonous country, the entire north-south length of the state. Over its surface, highways lead for scores of miles with no turning and without encountering hills worthy of the name. Vast stretches of country dotted with farms greet the eye. So level is it that it takes water three weeks to travel the length of the state in the James River. At Yankton the tops of the higher hills reach elevations of 1,300 feet above sea level. At Mitchell the city is 1,300 feet above sea level. Fifty miles farther north Huron has the same elevation and 100 miles still farther north the city of Aberdeen is built on a great flat 1,300 feet above sea level. The entire fall of the James river in its 250 miles of length in South Dakota is about 100 feet. It is no wonder that this stream is sluggish and wanders aimlessly about over the great flat lowland.

From the James river the basin surface rises imperceptibly on the east until it ends abruptly at the foot of the Prairie Hills escarpment at elevations between 1,400 and 1,500 feet. On the west it rises to similar elevations against the escarpment of the Missouri Hills section which will be described later. The James valley is thus a large, shallow trough—fifty to seventy-five miles wide and 250 long, its axis lying about 200 feet lower than its edges. The James river lies in the center of the trough and flows, if you can call it flowing, toward the south.

Its tributaries flow into it from both sides of the basin in festoons, draped from the north. Their courses are largely determined by low glacial moraines which were formed at the retreating edge of the last (Wisconsin) sheet of ice. The festoon pattern is especially noticeable in the creeks which join the James river between Huron and Mitchell. The upper courses of these creeks parallel the Wessington Hills on the west and the edge of the Coteau des Prairie on the east for some miles, then swing in long curves toward the James river.

To tourists, making the greatest possible speed from here to there, monotony may be the keynote of the surface of the James Basin, but to those who take the trouble to

look, many interesting variations present themselves which fill a trip through this region with pleasant little surprises. The main highways dip again and again into shallow, broad-bottomed, steep-sided troughs like the valley of the James river and its tributaries. Belts of low, rolling, terminal moraine festoon its surface. Here and there sharp rounded knolls and short ridges, rising abruptly above their surroundings, form perches from which farm houses more fortunate than their neighbors can overlook a vast sea of land. Here and there over the basin small but important rock-cored ridges form landmarks of sufficient magnitude to guide the tourist and the aviator. In the northern end of the basin a great, flat, silt covered area, flatter than the flattest floor, has been interpreted as the bed of a glacial lake like the great Lake Agassiz which once covered the basin of the Red River of the North.

The ice which covered the region still dominates the surface, for there is scarcely a topographic feature which is not directly traceable to the action of this glacier. The festoon pattern of the courses of the smaller stream valleys has been mentioned. These courses follow low spots between recessional moraines which formed at the rounded end as the ice tongue halted here and there in its retreat up the valley. Since they flow from higher land on the sides of the James Basin, they have cut sharp little v-shaped valleys which in some places expose the bedrock over which the ice moved. Such exposures are common in the vicinity of Mitchell and the southern end of the James Basin. The inroads of the streams on the basin have been slight, however, for they drain only narrow strips of territory in the immediate vicinity of their channels.

Water falling on most of the basin never reaches the stream valleys at all but lies in glacier-built hollows until it evaporates or soaks into the ground. Viewed from an airplane or on a map, therefore, the stream pattern in this country is strikingly different from that on the Prairie Hills near Sioux Falls or on the Great Plains west of the Missouri river. The few straggly streams coursing the poorly drained surface of the James valley form a sharp contrast to the intricate network of valleys in these two neighboring areas where the streams have had time to drain the surface completely.

The master stream, the James river, meanders about in a trough formed by torrents from melting ice. Its valley was the main spillway through which all the water from an enormous sheet of ice escaped toward the Gulf of Mexico. The present stream, therefore, is but a puny remnant of the great flows which formed the valley. The James valley has the typical spillway shape—that of a miner's sluice box. Its bluffs are steep, so steep as to appear vertical in some places, but never very high. North of Huron they are less than sixty feet high; opposite Aberdeen they are scarcely twenty feet high. Farther south, however, the valley deepens until near Alexandria it reaches a depth of 100 feet, which depth is continued nearly to its mouth. In true spillway fashion the bluffs meet the wide flat bottom of the valley at a very sharp angle. There is little evidence of the smooth curve by which bluffs of an ordinary stream-made valley grade into their valley flats.

The flat bottom is characteristic the entire length of the James spillway in South Dakota, and the width is remarkably uniform for a stream of its length. In the northern part of its course it averages about half a mile across, while toward the southern part it widens until it reaches nearly a mile in some places. A valley 250 miles long, of such uniform width, so steep-sided and so flat-bottomed and falling only 100 feet in that distance is truly a remarkable topographic feature.

James Basin Highlands

Ridges and hills on such a plain surface as that of the James basin become conspicuous landmarks and, therefore the few that break its surface have been given names and used as reference points for travelers since pioneer days. Four such conspicuous elevations occur in the basin; Turkey Ridge, James Ridge, the Mitchell Hills, and the Redfield Hills. These are all remnants of rocky prominences which once formed high points on the divides between ancient stream valleys but have subsequently been covered with glacial debris which has veneered their slopes and left a tumbled mass of glacial knobs along their crest.

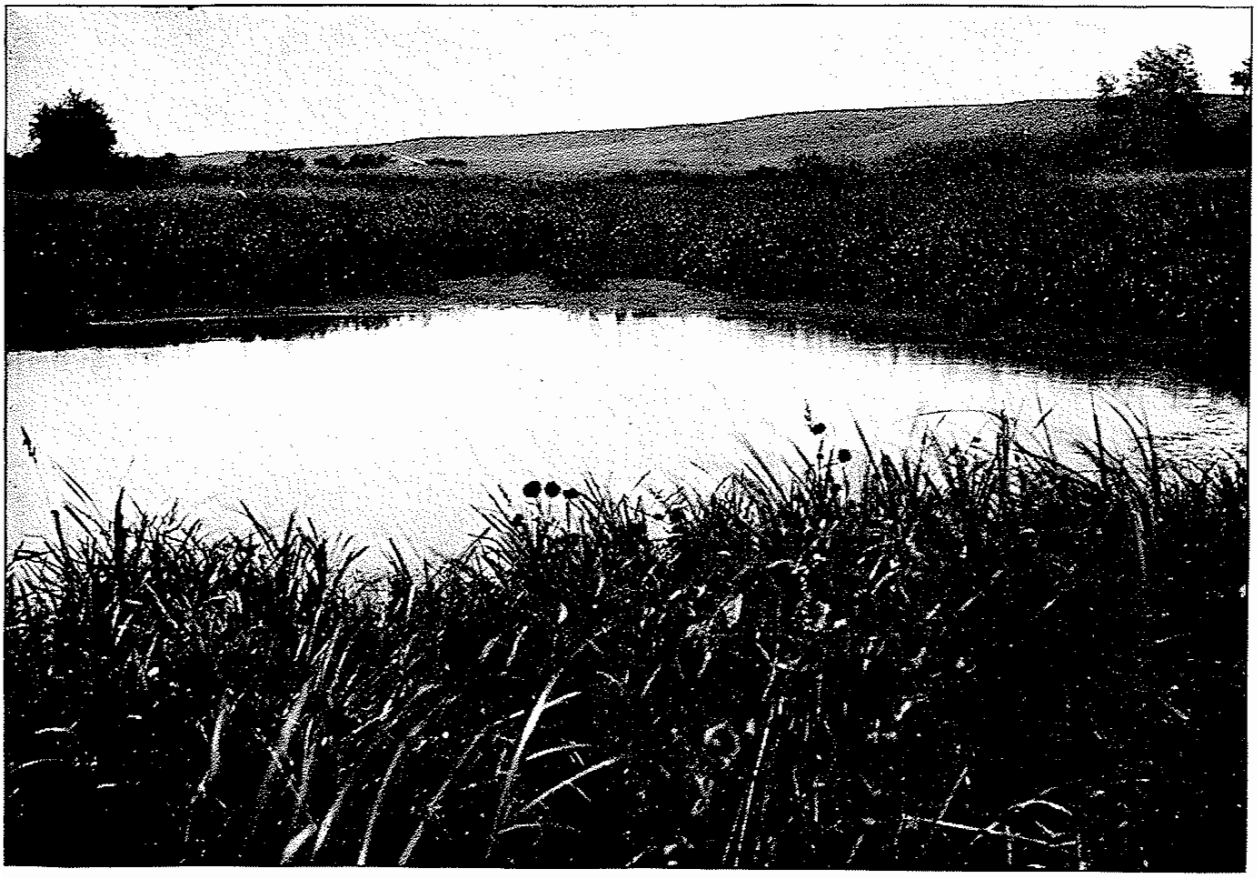
Turkey ridge is the longest and highest of these landmarks. It forms the divide between the James and Vermillion river valleys in their southern courses. Beginning at

the town of Freeman in Hutchinson county, Turkey Ridge stretches southeastward as a broad, flat highland eight or ten miles wide near its middle. Its southern half tapers until it ends in a sharp mound widely known among Indian tribes as Paha Wakan, the hill of the little spirits, who were greatly feared because of their evil propensities. This haunted mound lies seven miles northwest of Vermillion in Clay county and is now called Spirit Mound. The total length of Turkey Ridge, therefore, is forty miles. It stands about 400 feet above the surrounding country, its highest points reaching elevations of 1,700 feet, the highest elevations in the James Basin.

The southern edge of the ridge is split by the sharp little canyon of Turkey creek, whose valley cleaves the top of the ridge for nearly twenty miles. The most unusual characteristic is that in the lower part of its course, it is the deepest canyon in the state outside of the Black Hills. Its water flows at the narrow bottom of the dark walled rift 200 feet below the top of the ridge in the vicinity of Volin.

Ten miles west of the foot of Turkey Ridge and on the opposite side of the James river lies a similar but much shorter ridge. It is known as the James Ridge, probably from its proximity to the James river, and is about seven miles long. This ridge rises 260 feet above its surroundings at its highest point and is a mile wide. It is cut into two parts by Beaver creek which has made a deep gorge three miles from the southern end. The southern part of the ridge rises to a bald round-topped hill known as Mount Pisgah, probably because from this hill one can see a vast stretch of plain in nearly every direction.

Both Turkey Ridge and James Ridge are rock-cored hills, the former carved out of chalk rock which is well exposed at the southern end in the bluffs of Turkey creek valley and is encountered in wells near Freeman, and the latter out of the chalk, capped with a shale, which is exposed in a recent roadcut at the top of the ridge near its northern end. These hills were originally carved by streams which flowed through the region before ice covered it. The ice sheets overrode them, rounding off the sharper corners and extending their elongated shapes. This action is well shown on Spirit Mound at the southern end of Turkey ridge. Its northern side shows the typical long slope formed as ice



LAKE FROM ARTESIAN WELL IN THE JAMES VALLEY
Near Mitchell

The spillway shape of the valley is well shown; a wide flat bottom with steep bluffs (in background).

rides up the stoss side of a rock hill. Chalk rock is exposed on a large portion of this slope. On its south side the slope is much steeper due to the breaking off of large chunks of rock as the glacier slipped over its crest.

Over these ice shaped hills the retreating glaciers spread a veneer of debris, piling it high on the tops of the ridges and making hummocks and hollows more prominent there than in the surrounding country . Large and small gravel deposits attest to torrents of water let loose by the ice as it lay enfolding the ridges. Apparently Turkey Ridge was high enough to split the ice at least during its last stages for we find a great deal of the material on the top of the ridge laid by water which escaped southward along its crest between the fronts of the ice. This water carved a trench for Turkey creek which has been used by the stream ever since.

A much shorter but equally conspicuous ridge lies four miles south of Mitchell where it forms the south bluff of Enemy Creek for about two miles. Its western end crosses the creek and continues for a mile in a northwesterly direction as a series of large knobby hills which stand high above the plain. So sharp is the ridge that highways and roads cross it with very steep grades on both sides. Its width is nowhere more than one-half mile and its height is between sixty and eighty feet. At the eastern end, sandstone bedrock outcrops half way up the hill, disclosing part of the reason for this ridge since it is the core upon which the ridge was built. The rock core held the ice front over it for some time during the glacier's retreat, for a deep cover of drift overlies most of the ridge, and the hummocks on its crest are of typical glacial origin.

The fourth notable ridge in the James Basin lies just south of Redfield. It is known locally as the Redfield Hills and Bald Mountain. The northern extremity of the Redfield Hills is a steep escarpment, twenty to sixty feet high, which can be traced for two miles in an east-west direction. South of this escarpment lies a rough hilly country having about the same elevation as the top of the escarpment and trending four miles to the southwestward where it ends in a series of four lake basins.

An old roadcut crossing the ridge a mile east of Redfield exposed chalk bedrock very much the worse for glacial

wear but sufficiently well exposed to explain the reason for the Redfield Hills. The core is concealed everywhere else over the region by the veneer of drift. This outcrop so high above the plains to the north is evidently one end of a ridge of rock which is responsible for holding up the ice front long enough to make the hilly country south of it.

Six miles west and one mile south of Redfield is Bald Mountain, the most conspicuous landmark in the northern James Basin. It occupies about one and one-half square miles of territory and rises to a great round top 140 feet above the surrounding plain at its highest point. South of it is another country roughened by glacial hills and ending at Cottonwood Lake three miles south of the mountain. Bald Mountain is well veneered with drift and it is not known what its core may be. Judging from the similarity of this hill to the Redfield and Mitchell Hills, however, and from the distribution of glacial topography south of it, it is reasonable to infer that it is another rock-cored hill, high enough to deter advancing glacial ice.

An interesting region, made entirely by deposition at the edge of glacial ice, lies twenty miles east of Redfield and immediately south of Doland. Because of its proximity to the last named town, the feature is called the Doland ridge. It runs directly south of Doland for about ten miles, the lower five miles being a very conspicuous ridge fifty to eighty feet above its surroundings. The Doland ridge owes its existence to the fact that it is a prominent section of a terminal moraine which can be traced much farther both north and south. Its top shows the characteristic hummocks and kettles of this type of glacial topography.

"Lake Dakota"

In the northern end of the James Basin lies a great flat area covering nearly 1,700 square miles in South Dakota and extending on northward into North Dakota. On a map, this area appears like a great south-pointing funnel of which the James valley is the outlet. This outlet lies twelve miles south and twelve miles east of Redfield. The fact that this great area is so flat and is covered almost entirely by a sheet of very fine silt has led to the idea that it is the bottom of an old lake which was formed in front of the last retreating

ice sheet when this front stood somewhere in North Dakota. J. E. Todd describes and explains the lake as follows:

"This plain is largely covered by the deposits of Lake Dakota and its surface varies less than fifteen feet in altitude except where ancient and modern streams have excavated their shallow valleys. The general plain, which for many square miles is as level as a floor, slopes slightly downward near the James river and toward a few other prominent channels. * * *

"Toward the south it resembles a flat area of till, with boulders and pebbles, but this southern portion consists largely of delta deposits * * *. The most characteristic feature of this portion is that it is covered on the uplands for a depth of five to thirty-five feet with a fine yellowish or cream colored silt or loam in which boulders and pebbles are very rarely found except toward the base. In the deeper channels crossing this silt area boulders appear at many places on the bottoms and lower slopes but the shallower channels are covered throughout with the fine lake deposits.

"The Lake Dakota silt closely resembles the loess that covers wide areas in southeastern part of South Dakota and in Iowa and Nebraska, and is apparently of the same composition. It consists mainly of very fine quartz sand, of which the grains are mostly clear quartz, though yellowish ones are found. The grains are perfectly rounded and vary in size from less than 0.008 to 0.04 millimeter, the average size being not far from 0.01 millimeter. Like the loess, the silt effervesces slightly with acids and contains calcareous concretions with cracked interiors, very like the "loess kindchen" * * *. The silt shows very little trace of stratification except in the lower portion, where, as also in the loess, sand and coarser materials are locally imbedded. It has vertical cleavage, like the loess, and is found also at varying levels in much the same way. It differs from the loess in being less coherent and of a lighter shade, with its lower portion usually of a gray color, and in having a well-defined upper limit on the sides of the valley. Toward the base of the deposit in some places the silt passes more or less abruptly into fine sand several feet in thickness.

"These deposits usually have a massive structure from top to bottom, but in many places they exhibit thin layers

of a darker and more clayey nature. In some locations where the conditions of deposition may have been more tranquil than usual there are numerous alterations of clay and loam in somewhat regular series, suggesting that successive layers might be the result of an annual or seasonal variation of conditions. * * *

"The relations of this deposit clearly show it to be of flood origin and indicate that for some time the James River valley was occupied by a lake."[1]

There may be some doubt as to this interpretation because of a notable lack of beaches, wave cut cliffs, and other shore line phenomena. In material such as that which borders this old lake waves can make cliffs and beaches in a two-month period. The similarity of the silt to loess, which is known to be a wind-blown deposit, suggests that the silts may be wind-blown. The silts, in places, are bedded like water-laid deposits, but their general massive character suggests wind deposition rather than water. If the lake existed, as certain evidence seems to indicate, it must have been very short-lived, and the silts on the bottom must have been reworked by the action of the wind.

James Basin Lakes

The James river basin is included by the Association of American Geographers in the Western Lake Section of the Central Lowlands Province.[2] In wet seasons lakes and swamps abound in the numberless glacial depressions of its surface. In dry seasons, however, they usually disappear. A few large lakes hold water most of the time and have served as important recreational spots, but these are much farther apart than are the lakes of the Prairie Hills. Noteworthy among them are Scatterwood Lake near Mellette in Faulk county; Cottonwood Lake, a short distance southwest of Redfield; Lake Byron, 12 miles north of Huron; and Lake Andes in Charles Mix county. This handful of lakes sprinkled through such a large country hardly justifies its being called a lake region. Their absence, however, is more a matter of climate than a lack of basins.

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[1]J. E. Todd, Aberdeen-Redfield Folio, U. S. Geol. Surv. Folio 165, 1909, p. 6.

[2]Nevin Fenneman, **op. cit.**

Thus a general picture of the James basin reveals more variety than is at first evident. The great flat area of the Basin floor is broken by features of considerable geologic interest. The great trench of the James valley, the low belts of hilly, subdued terminal morainic ridges, the rock-cored landmarks like Turkey Ridge and the Redfield Hills rising abruptly above its surface, and the flat floor of the so-called Lake Dakota all add their bit of variety to this great stretch of country.

C. THE GREAT PLAINS PROVINCE

In the mind of the general public the Great Plains is a vast stretch of flat country inhabited by nothing, and unfortunately, the routes of some of our highways tend to heighten this impression in the mind of the visitor. This is unfortunate for few countries offer so many surprises to those interested in the face of the earth and the processes that work on it. A composite picture of the surface of the Great Plains in South Dakota would show a rolling topography, surmounted in places by lofty buttes and seamed with rough canyons. There are few places west of the Missouri River where the canyon and butte type of topography is not in evidence.

Sufficient variation occurs, however, to divide the region into four sections on the basis of topography. The eastern section, lying between the eastern boundary of the Great Plains and the Missouri river, is a belt of hill country about thirty miles wide. West of the Missouri most of the state is occupied by the rolling, butte-crested Missouri Plateau Division. In the extreme south a very small portion of the High Plains Division, a region of sand hills, occupies 400 square miles along the Nebraska border. The fourth division, the Black Hills Division, lying in the extreme southwestern corner, is a mountain region occupying an area of about 5,000 square miles.

1. THE MISSOURI HILLS DIVISION
(Coteau du Missouri)

The upheaval which raised the Rocky Mountains tilted a great flat ocean floor which lay in front of them so that it sloped eastward. This slope, some 400 or 500 miles wide, is the region known to physiographers as the Great Plains. Along part of its length it grades smoothly into the plains of the Central Lowlands, but in South Dakota it ends in a hilly country called by the French explorers and fur traders the Coteau du Missouri or Missouri Hill Country. This hill country, twenty-five to thirty miles in width, lies between the gorge of the Missouri river and the James Basin.

Its hills are partly of glacial origin, like those of the Prairie Hills country, and partly a result of stream carving

by the tributaries of the Missouri river. The surface, therefore, presents a picture of rolling glacial hills in the east and rugged river "brakes" in the west.

The eastern boundary is marked by a belt of rough glacial hills called by early investigators the Altamount moraine.[1] Its rough surface contrasts sharply with the smoother moraines of the James Basin and forms a divide between the James and Missouri drainages. For eighty miles south of the state line this moraine is very prominent, being known locally as the Bowdle and Lebanon Hills. It passes through Eureka in Campbell county, Bowdle in Edmunds county, and Lebanon in Potter county, and dies out near the post office of Karpas in northwestern Hyde county. The smooth surface of the James Basin rises gradually from the east until it terminates in this rough morainic belt four or five miles wide. So knobby are the hills, so sharp the basins, and so rough the entire surface that it is difficult to construct roads across it. Elevations at the top of the moraine reach to 2,000 feet above sea level, 700 feet higher than the bottom of the James Basin near Aberdeen.

South of this moraine is a thirty mile gap where the topography of the James Basin grades smoothly into that of the Missouri Hills and no sharp boundary can be drawn. Then for seventy-five miles a bold east-facing escarpment rises 200 feet above the James valley leaving no doubt as to the location of the Coteau boundary. At its northern end this escarpment is known as the Ree Heights and includes a length of six or eight miles of escarpment immediately south of the village of that name. The rest of the escarpment is known as the Wessington Hills. This part of the escarpment trends southeastward for over thirty miles and then makes a long turn and trends southwestward for fifteen miles toward the Bijou Hills. It dies out in a great flat plain, similar to the one north of Ree Heights, immediately northwest of the city of White Lake in Aurora County.

The lower part of this escarpment is bedrock, the shales of the Pierre formation being visible at the city of Wessington Springs and some other points along the escarpment and white Tertiary beds being exposed on the north end near Ree Heights. The upper half is made of glacial drift

[1]J. E. Todd, U. S. Geol. Surv. Bulletin 144.

piled on top of the bedrock to depths varying from fifty to 100 feet. At the city of Wessington Springs, at the contact of the shale and glacial drift there occurs a zone of glacial sands from which issues the spring water for which this town is well known. Morainic hills in a belt several miles wide follow the edge of this escarpment.

A low terminal moraine in Brule county passing between Kimball and Pukwana carries the boundary southward to the eastern end of the Bijou Hills. South of this point this boundary moraine is not seen again.

West of the morainic belt bordering the eastern edge of the Coteau lies a broad stretch of large rolling hills, separating depressions which look like broad shallow stream valleys. In most of them the stream is missing, however. This type of topography is characteristic of most of the Coteau.

Great flat areas which funnel into deep troughs emptying into the Missouri and which are underlain by sand and gravel are interesting features. These "outwash plains" cover several townships each and are particularly conspicuous in the northern part of the Coteau. One such plain lies in the vicinity of Mound City in Campbell county and covers an area of about three townships, draining through Glenham, a little south of Mobridge. Another extremely large plain lies between Bowdle and Hoven and covers a similar area. It drains past Swan Lake and into the deep gorge in which Lowry and Akaska are situated. The Blue Blanket Valley in which Lebanon is located is well known. A fourth plain occupies two or three townships in Potter and Sully counties at the head of Okobojo creek. Large gravel plains also occur in the valleys on the uplands west of Wessington Hills. These are crossed by state highways passing the head waters of Smith and Elk creeks. They drain southward into the Missouri through the gorge north of Chamberlain which is now occupied by Crow creek.

A tattered fringe of high hills separated by sharp canyon-like valleys makes the western edge of the Coteau. In local parlance this fringe is known as the "brakes" of the Missouri. Scores of small streams have eaten three to five miles back into the upland from the Missouri valley, cutting through glacial drifts and bedrock alike. Since the Missouri

river lies 300 to 700 feet below the uplands, the streams have cut rapidly and as a result a network of small gullies and canyons has been formed.

Stream cutting has left a few prominent landmarks. The Bijou Hills on the border between Charles Mix and Brule counties are perhaps the most prominent. These are typical buttes nearly ten miles long, in an east-west direction, and about a mile across at the top. They have very flat tops caused by a hard sandstone caprock which forms a cliff about the buttes and lies strewn over their slopes as great boulders of sandstone. The buttes are split into two parts by a gap through which the highway has been routed. They are visible nearly twenty miles away because their crests, 2,300 feet above sea level, rise over 300 feet above their surroundings.

Four miles north of Pierre is Snake Butte. This long, narrow butte is not so high as the Bijou Hills, but its crest reaches an elevation of 1,911 feet, making it stand about 200 feet above its surroundings. It is only three miles long, but is sufficiently prominent to have been a landmark for travelers in the Missouri river country since the earliest exploration. A smaller but much more prominent landmark is Medicine knoll, three miles south of Blunt in Hughes county. This is a small butte occupying scarcely a square mile, whose sharp crest rises more than 200 feet above its surroundings to a sea level elevation of 2,020 feet. This butte overlooks a very large area, and it was here that the young Indian boys were said to have come for their first night lone camp to make medicine in preparation for their coming manhood. Glacial ice has modified these buttes by erosion and by veneering their slopes with drift, but these changes have made only slight alterations of the original stream carved forms.

The Missouri Coteau is called the glaciated section of the Missouri Plateau by physiographers. This is probably a correct designation though the hills are not all due to glaciation. The surface is rolling, a characteristic of the rest of the Missouri Plateau, and the effects of ice invasion are evident over most of it. The steep escarpment, the rugged morainic belt in the east, the outwash plains, the ragged brakes, and prominent buttes make the Missouri Hills a most varied and interesting country.

MISSOURI VALLEY AND BRAKES

In the Pierre Hills Section

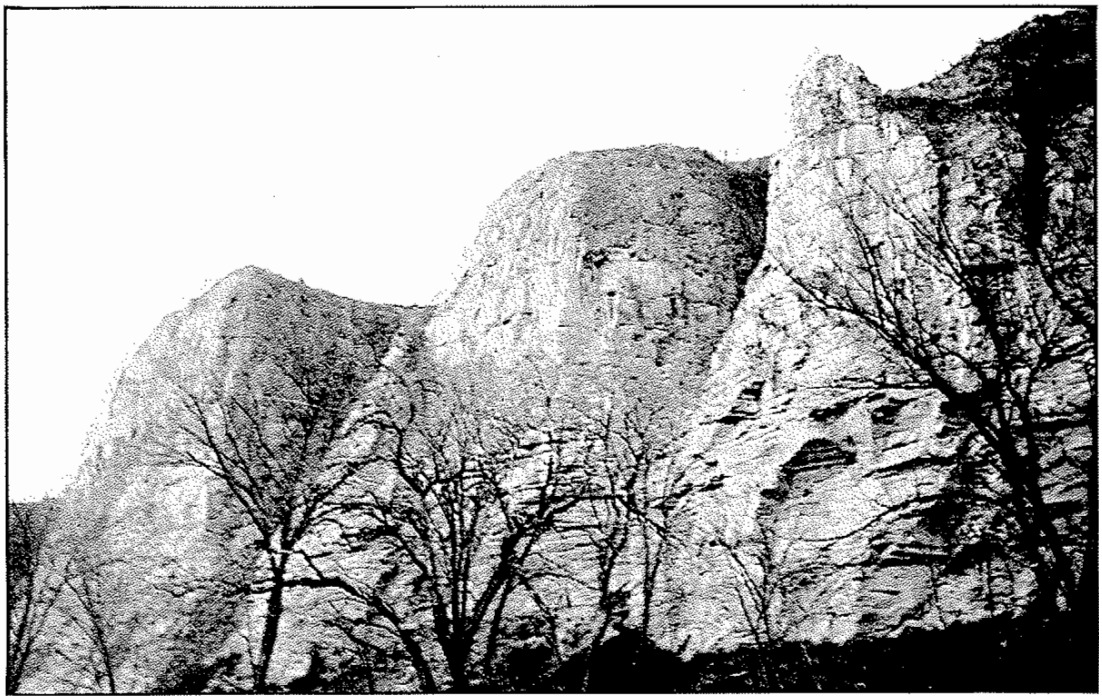
The Missouri Valley

While not a distinct topographic region in itself, the Missouri valley is of such importance geographically and physiographically that no description of South Dakota would be complete without mentioning it. Most of its course in South Dakota lies in the Great Plains Province, where it forms the boundary between the Missouri Hills and the Missouri Plateau sections. South of the Bijou Hills it swings eastward and emerges onto the Central Lowlands which it follows until it leaves the state.

The valley may be divided into two parts. The upper section runs from the North Dakota line to Yankton and is characterized by its steep rugged bluffs and narrow flood plain. This is known as the gorge of the Missouri. Along most of its length it averages about 400 feet in depth. Toward its southern end, however, the Missouri cuts through a highland where the valley reaches a depth of 700 feet. This is in the vicinity of the Bijou-Iona Hills; the Bijou Hills being that part of the highland on the east side of the valley and the Iona Hills the part on the west. South of these hills the valley becomes less deep until at Yankton it is little more than 300 feet.

In most of the gorge the valley does not exceed a mile and a half in width. Near Mobridge it averages a mile in width, near Pierre and Chamberlain a mile and a half. Myriads of small streams cutting back into the bluffs in a labyrinth of gullies form fringes on both sides of the valley locally known as "the breaks," which extend from one to five miles back of the valley proper.

The mouth of the gorge lies six miles above Yankton and is known as Gavin's Point. Below this point the valley widens rapidly until at Yankton it meets an ancient valley of the Niobrara river which swings into it from the north. From there to Sioux City, Iowa, the valley is characterized by very wide flood plains, four miles across at Vermillion and eight miles across at Elk Point. The bluffs are still steep, but breaks such as are known along the gorge of the Missouri are wanting. In this wide flat valley the river loops back and forth changing its course with every big flood. Farm land in this valley, though of excellent quality,



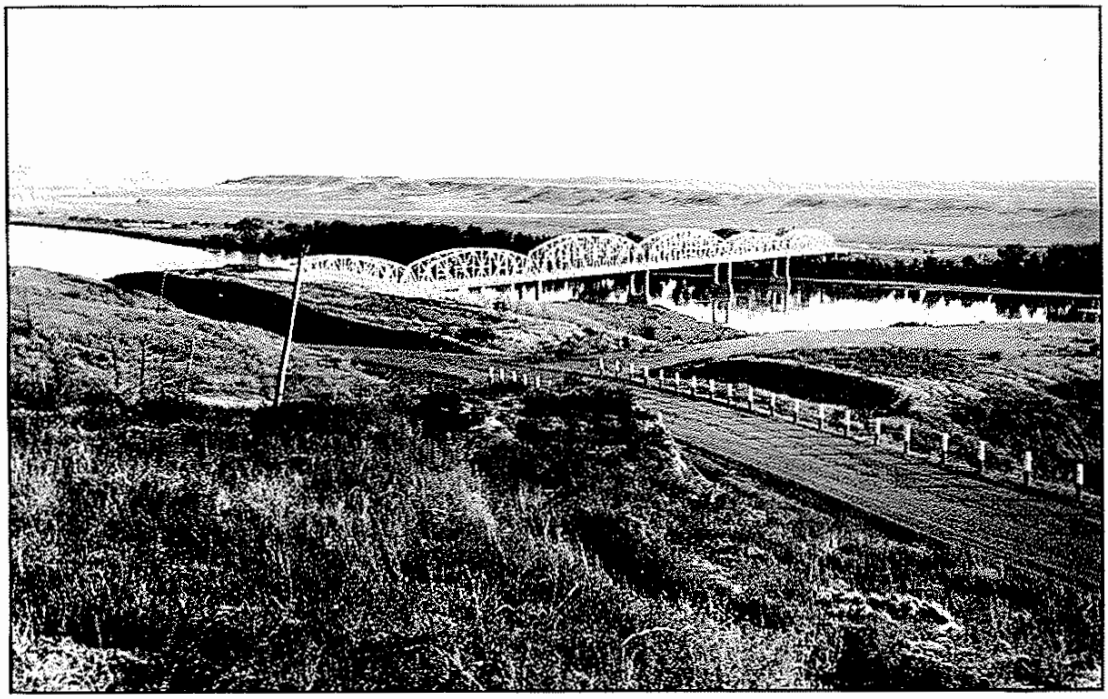
CHALK CLIFFS

Making Lower Part of the Missouri Bluffs
above Yankton

is never entirely safe from the River. As much as 160 acres have been taken from a single farm by one spring flood.

The course of the Missouri valley seems to have been set by glacial ice which blocked the eastward flowing streams of the Great Plains. From the directions these streams now take and the small amount of information that is available on subsurface geology east of the present Missouri, it appears that the Grand, Moreau, and Cheyenne rivers worked their way eastward into what is now the James Basin and then northward into Hudson Bay by a route which may be roughly paralleled by the Red River of the North. Apparently the Cheyenne and the White rivers were turned southward by a very low divide in the James Basin and, joining the old Niobrara river, worked their way southward toward the Gulf through the wide part of the present Missouri valley.

Glacial ice blocking these eastward flowing streams where they crossed the present Missouri Hills apparently sent their waters southward around the ice edge and thus set the course of the present Missouri valley. Certain old drifts found on terraces well down in the present Missouri valley indicate that this must have been done by one of the earlier ice sheets. Big gravel terraces on the inside of each bend in the valley also indicate that the valley was a spillway for glacial waters. These gravels are made of materials that have been transported into this region by ice. From the position of these terraces and the patches of old glacial drifts it is evident that only the lower half of the valley has been carved since the retreat of the last ice sheet.



THE MISSOURI VALLEY

At Whitlock's Crossing, Potter County, looking east.

The wide terraces of glacial gravel such as are found on the insides of all big bends in the valley appear on the east side of the valley.

WEST BLUFFS OF THE MISSOURI VALLEY

At Whitlock's Crossing, Potter County, looking north.

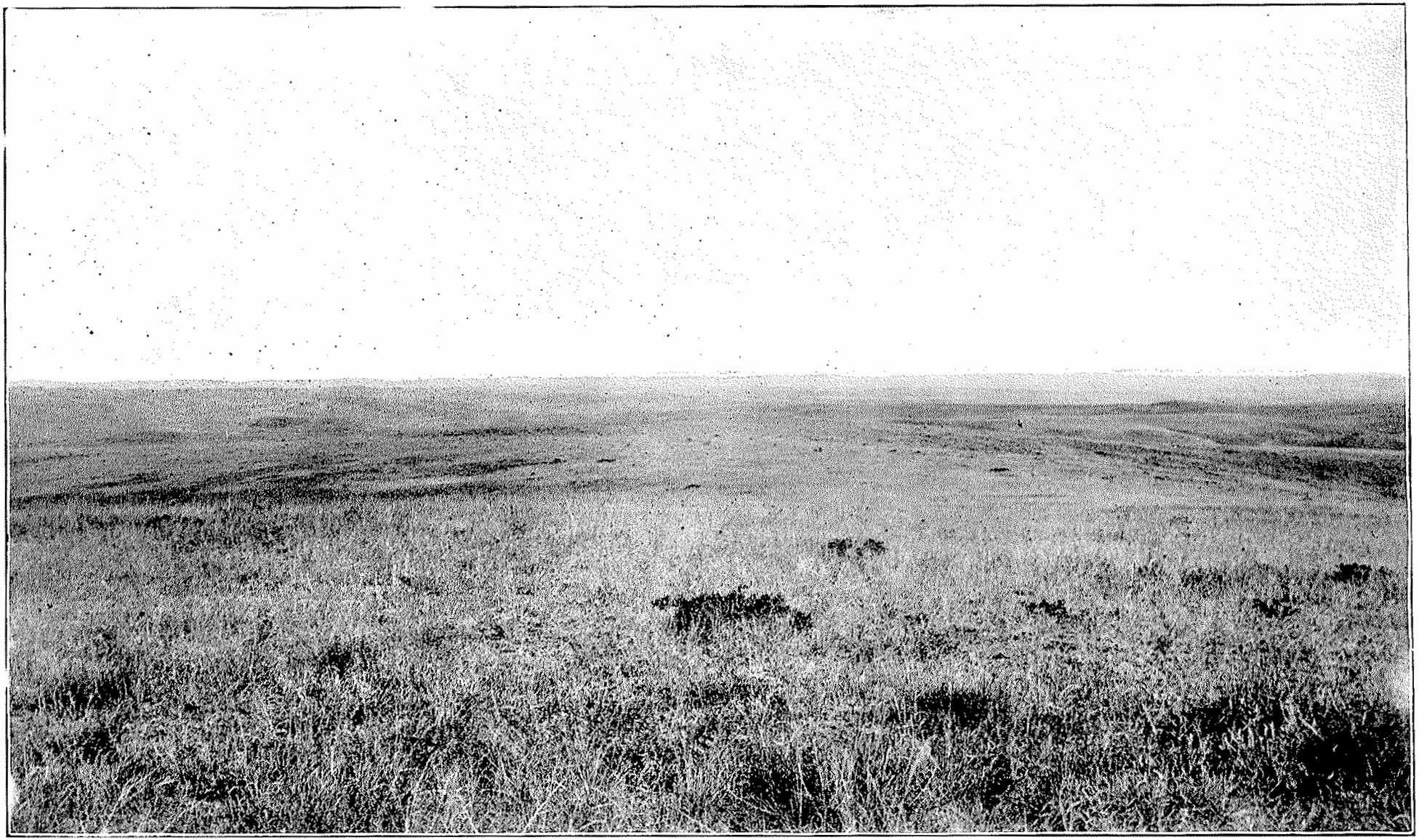
MISSOURI VALLEY
North of Chamberlain, looking north.
Typical "brakes" on the bluffs in the foreground.

2. THE HIGH PLAINS DIVISION

In the early days of wagon travel the term "Great Plains" became associated with the plains of western Kansas, Oklahoma, and Texas which were so flat and featureless that in parts of Texas stakes were driven to mark the routes of travel across them. This type of plain extends northward through Nebraska and the very northern tip of it reaches twelve miles north of the South Dakota line in Bennett and Shannon counties. "The high plains are limited on the north by the Pine Ridge Escarpment, a north facing scarp, locally 1,000 feet high, at the northern limit of the later Tertiary formations."[1] The name Pine Ridge was given this escarpment because it is locally so high that it is covered with pine trees. Few pines exist in the South Dakota section of the escarpment, however, as it is not high enough in these regions to cause the necessary rainfall.

About 400 square miles are included in the High Plains in South Dakota which is known locally as the Sandhill region. Sand dunes and hummocks abound because the underlying sandy bedrock is easily loosened and blown about by the wind. The dunes give the surface of the Sandhills an undulating appearance but the relief is not great, barely over twenty feet. Some of the depressions hold fresh water lakes.

[1]Nevin Fenneman, "Physiographic Divisions of the U. S.," **Annals of the Assoc. of American Geographers,** Vol. VI, 1916, p. 70.



UPLANDS OF THE PIERRE HILLS SECTION

3. THE MISSOURI PLATEAU DIVISION

The butte and canyon topography, which occupies all of the state west of the Missouri river except the Black Hills and the little portion of the High Plains just described, covers by far the largest area of any single topographic division in South Dakota. Buttes are always in evidence. There is no place on the upland from which some cannot be seen, and in certain sections they become so numerous that they dominate the topography. The name Butte county might have been applied appropriately to several counties other than the one that was so named. All the large streams and most of the small ones flow in canyons 200 or more feet in depth. Wide stretches of hilly upland fringed by a network of water channels make the divides between the main streams. Badland areas are common. This region, therefore, truly belongs to that portion of the Great Plains known as the Missouri plateau. "The Missouri Plateau has a topography resulting from deep degradation."[1]

The Pierre Hills Section

The heart of the region, between the Moreau and White River valleys, is a land of smooth, rounded hills which give travelers in our modern high-speed cars some of the thrills of the roller-coaster in spite of the highway engineers ingenuity in leveling steep grades. The rounded tops and smooth contours of these hills are due to the uniform character of the dark shale of the Pierre formation which makes the bedrock of this entire region, frowning at you from every roadcut and stream bank. This material breaks down into a sticky clay which has caused the region to be dubbed the "gumbo area." Occasional sharp crested buttes rise above these smooth hills, their sides strewn with boulders of white or gray sandstones which once made the caprock of the butte but which is now almost entirely removed by erosion. Medicine Butte, in Lyman county, rising 400 feet into the air, is one of the most conspicuous landmarks of the state. White Clay and Stony Buttes, whose names describe the caprock, lie farther west. Willow Creek Butte, an old landmark on the Pierre to Deadwood trail, ten miles west of Fort Pierre, and Rattlesnake Butte, thirty miles west of the

[1]Fenneman, **op. cit.,** p. 71.

Cheyenne Agency all answer the description of buttes in the gumbo area.

The Cheyenne and Bad rivers have cut trenches 200 to 300 feet below the upland through this region. Their bluffs, exposing great masses of dark shale, make a country picturesque for its rugged wildness.

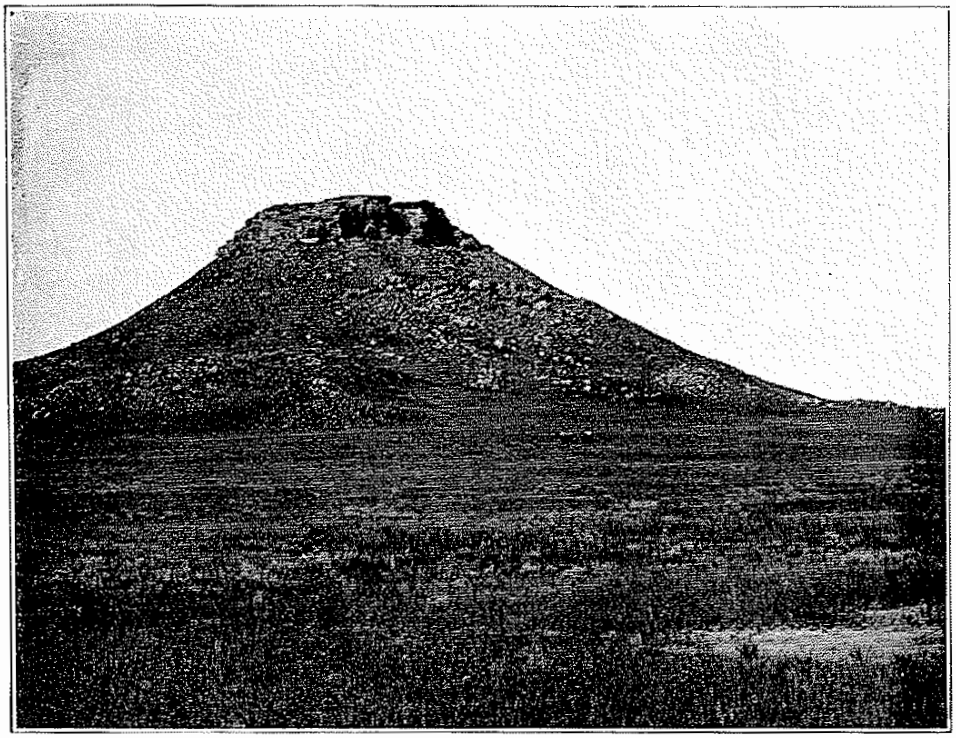
A unique type of butte found in the western part of the gumbo region is the tepee butte. These are very symetrical cones varying in height from three or four feet up to twenty or thirty feet. There is usually a fossiliferous limestone at the apex. The name tepee butte refers to the similarity of their shape to that of an Indian tepee. Sometimes they occur singly and sometimes in groups. In the latter case a little imagination can picture a very extensive Indian encampment. Tepee buttes occur most abundantly within thirty miles of the Black Hills and can be found swinging entirely around the Black Hills from Butte county on the north through Custer and Fall River counties. Though these are never large enough for landmarks they are very interesting land forms since the buttes seem to be developed about vertical pipes or cores of limestone instead of from a flat caprock such as forms most buttes.

The Cretaceous Table Lands

In the northwestern quarter of the state, north of the Pierre Hills, the surface rises by a series of steps or broad terraces from the Missouri river to the Montana line. The edge of each terrace is fringed with flat-topped buttes, each capped with sandstone. In fact it is the sandstone that caused the terraces, each step being the result of a sandy rock blanket left during the withdrawal of the Cretaceous sea from South Dakota. These broad terraces and flat-topped buttes suggest the name "table lands" to distinguish this country. This region covers all of the state north of the divide between the Moreau and Cheyenne rivers, and it is here that typical buttes reach their best development. A butte is the result of erosion of soft rock beneath a resistant cap. Streams try to undermine the hill while the cap prevents erosion of its top. Thus steep sides are formed below the cliff of cap rock and the top of the butte remains flat. Where resistant sandstone alternates with soft sands and

BRAKES OF THE MOREAU VALLEY
Near the mouth of Green Grass Creek.

Such topography is characteristic of the large valleys crossing the Pierre Hills Section.



THUNDER BUTTE

A typical butte of the Cretaceous Table Lands in northern Ziebach County.

clays we find ideal conditions for butte formation, and in this northwestern country these conditions prevail.

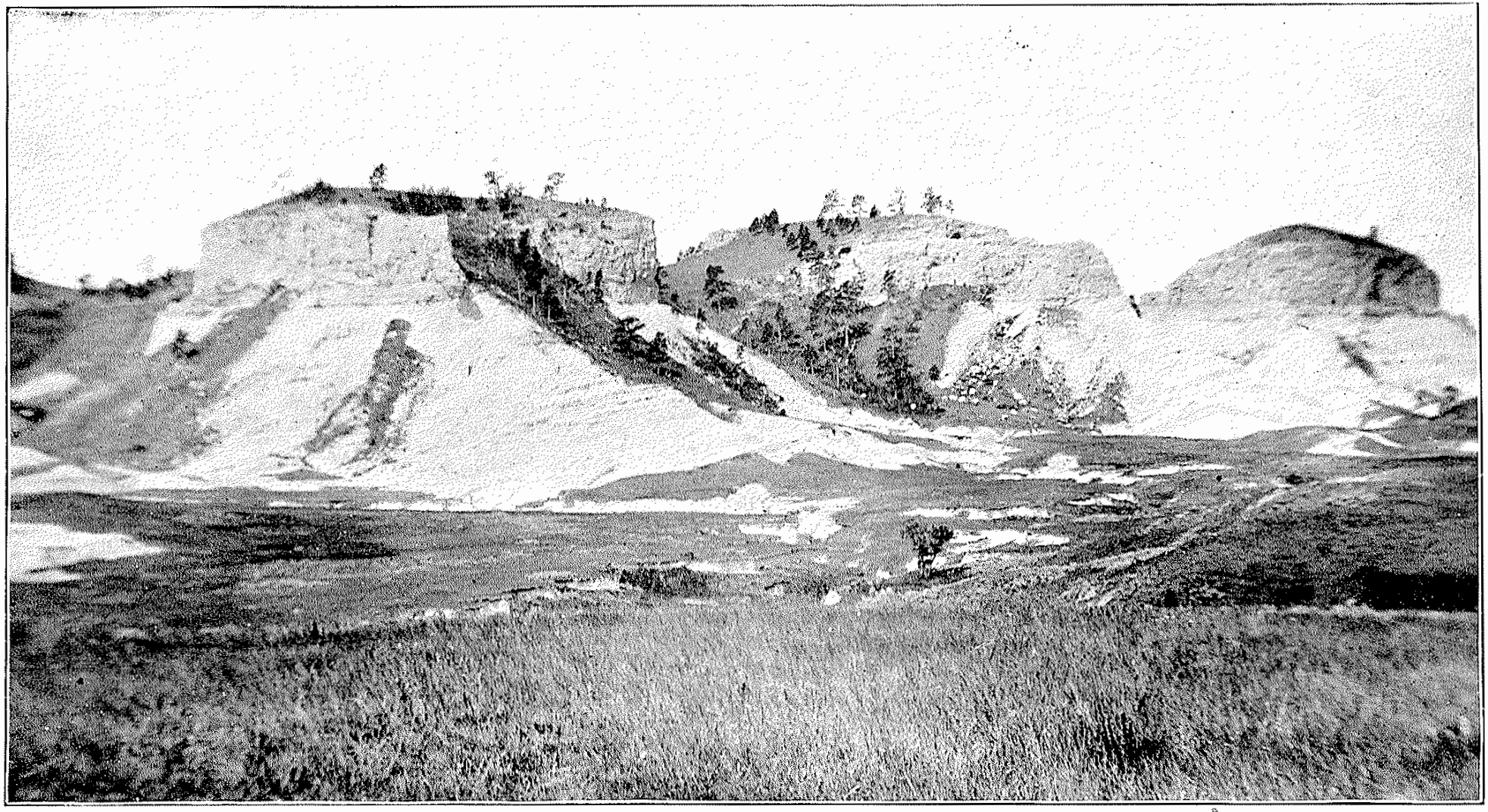
At the edge of the region a sandstone, the Fox Hills sandstone, overlies the gumbo-forming shales of the Pierre formation, causing a belt of large and small buttes with Fox Hills caprock to fringe the upland from McLaughlin in Corson county through Timber Lake and into the Moreau valley in Dewey county. Similar patches of buttes occur along the Lower Grand river. The larger buttes wear their sandstone caps sedately square, but some smaller ones are tipped crazily at various sporty angles.

Farther west the region is infested with somber gray buttes made of gumbo sands and clays of a uniformly gray color. Mud Butte, in the western corner of Meade county, is well named, and this should be the name of many another gray hill which occupies this region. Such buttes are particularly noticeable in western Perkins, northern Butte and Harding counties, their somber color adding to the weirdly beautiful effect of this strange topography.

The most picturesque and largest buttes in the state are in Harding county. These are the Cave Hills, East and West Short Pine Hills, and the Slim Buttes. The Cave Hills were so named because of a large cave in the northern one which was explored by Captain Ludlow of the Custer Expedition of 1874. Above their somber colored boulder strewn sides red or salmon colored sandstone caps rise in cliffs 40 or 50 feet high. The Cave Hills are nearly 12 miles long and 3 miles wide at the widest point and lie near the northern boundary of Harding county.

The Short Pine Hills and Slim Buttes are much more picturesque, for their caprocks are gleaming white clays and sand, set off by evergreen trees. From a distance they appear more like white clouds than buttes because their 400 feet of height carries the caprock up into the sky from most points of view. The West Short Pine Hills are about nine miles in length and two miles across while their eastern neighbor is some five miles by three.

The Slim Buttes were well named for they rise as a long narrow barrier running north and south for nearly thirty miles. In most places they are less than a mile in width while the headwaters of many of the canyons in their



NORTHERN END OF THE SLIM BUTTES
In Harding County

Showing typical sandy cap rock overlying easily eroded clays.

sides come so close as to threaten to cut the Buttes in two. The gleaming white caps of the Slim Buttes as well as those of the Short Pine Hills are white stream-made muds and sands which at one time covered the entire region but have since been entirely removed save for these remnants left high and dry by the all devouring streams.

The Slim Buttes rise 600 feet above the surrounding plains. This, combined with their length, would make them a formidable barrier for travel were it not for two gaps which allow passage across the Buttes. The northern gap is known as Reva Gap and offers a pass with easy grades on both sides which saves a 100 to 200 foot climb to the top of the Buttes. This gap is used by the main highway through the region. Toward the southern end of the ridge is another gap which is known as J. B. Gap from the old J. B. ranch opposite it on the eastern side of the Buttes. A good graded road runs through this pass but does not reach the top of the Butte. It is a much higher pass than Reva Gap but is reached by fairly easy grades on both sides.

A smaller edition of the Slim Buttes lies thirty miles to the southeast across the Moreau river and is known as the Fox Ridge. It is so flat topped that at one time it was proposed to make an airport on its summit. The same steep slopes and white caprock exist but the evergreen trees are absent. Fox Ridge is only five miles long and less than a quarter of a mile wide. An interesting peculiarity of this butte is the fact that fresh water limestone occurs in the top of its caprock in whose interstices are small masses of moss agate.

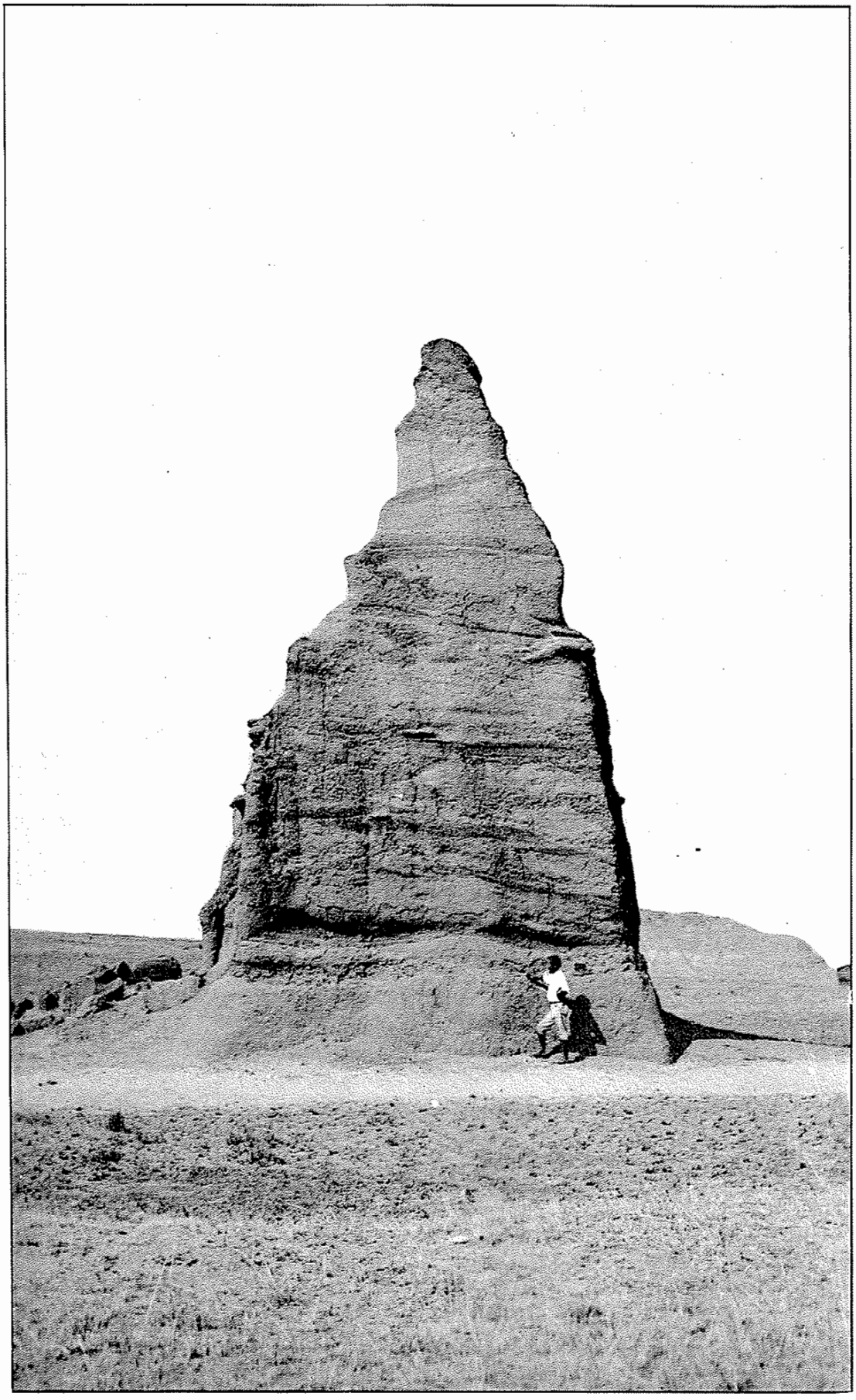
The butte country should not be left without a word about an interesting string of sharp pointed buttes which lie on the divide between the Moreau and Belle Fourche drainages in northern Butte county. The rocks in these buttes have much the same composition as those in the Slim Buttes and their origin is much the same. Probably they would have been another Slim Butte had we come upon them a few thousand years sooner. They have been eroded down to sharp pointed hills which made excellent landmarks, visible from long distances. One has but to mention Antelope Butte, Two-Top Butte, Flat-Topped Butte, or Castlerock Butte to get a knowing response from anyone who has traveled this region. Owl Butte, a little to the

TIMBER LAKE

Once called Soda Lake

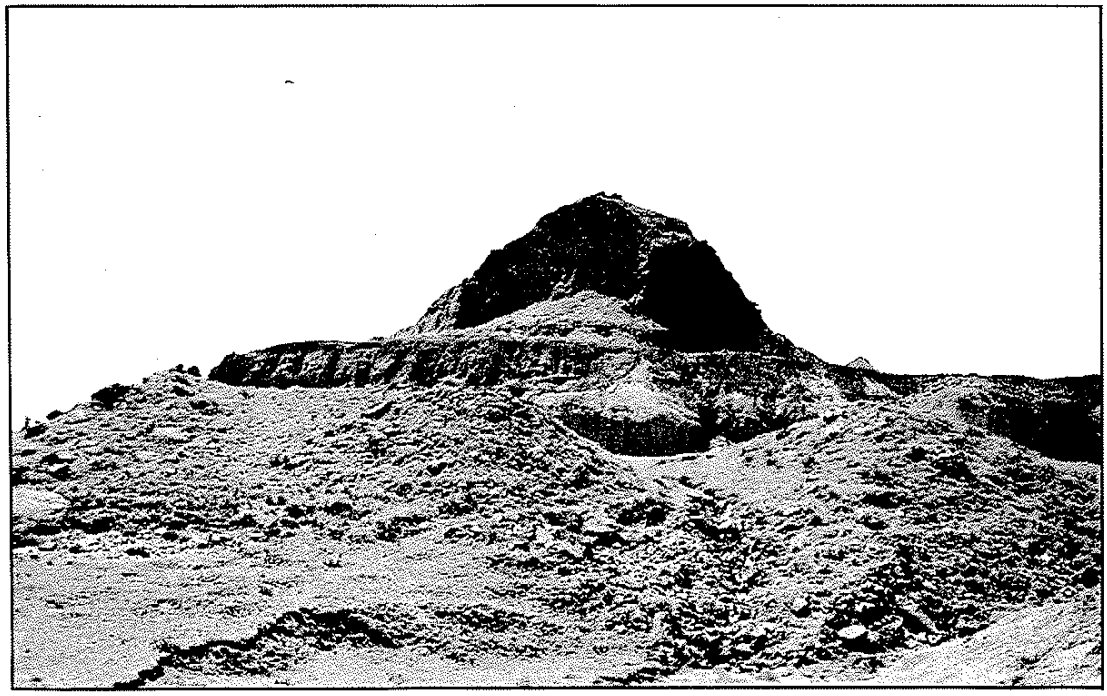
A shallow lake basin without outlet. Ground water seeping from the surrounding hills fills the lake during wet seasons. During dry times it is dry, the bottom covered with a white alkaline deposit which gave it its name of Soda Lake.

Such depressions are common on the Cretaceous table lands though most of them do not make large lakes.



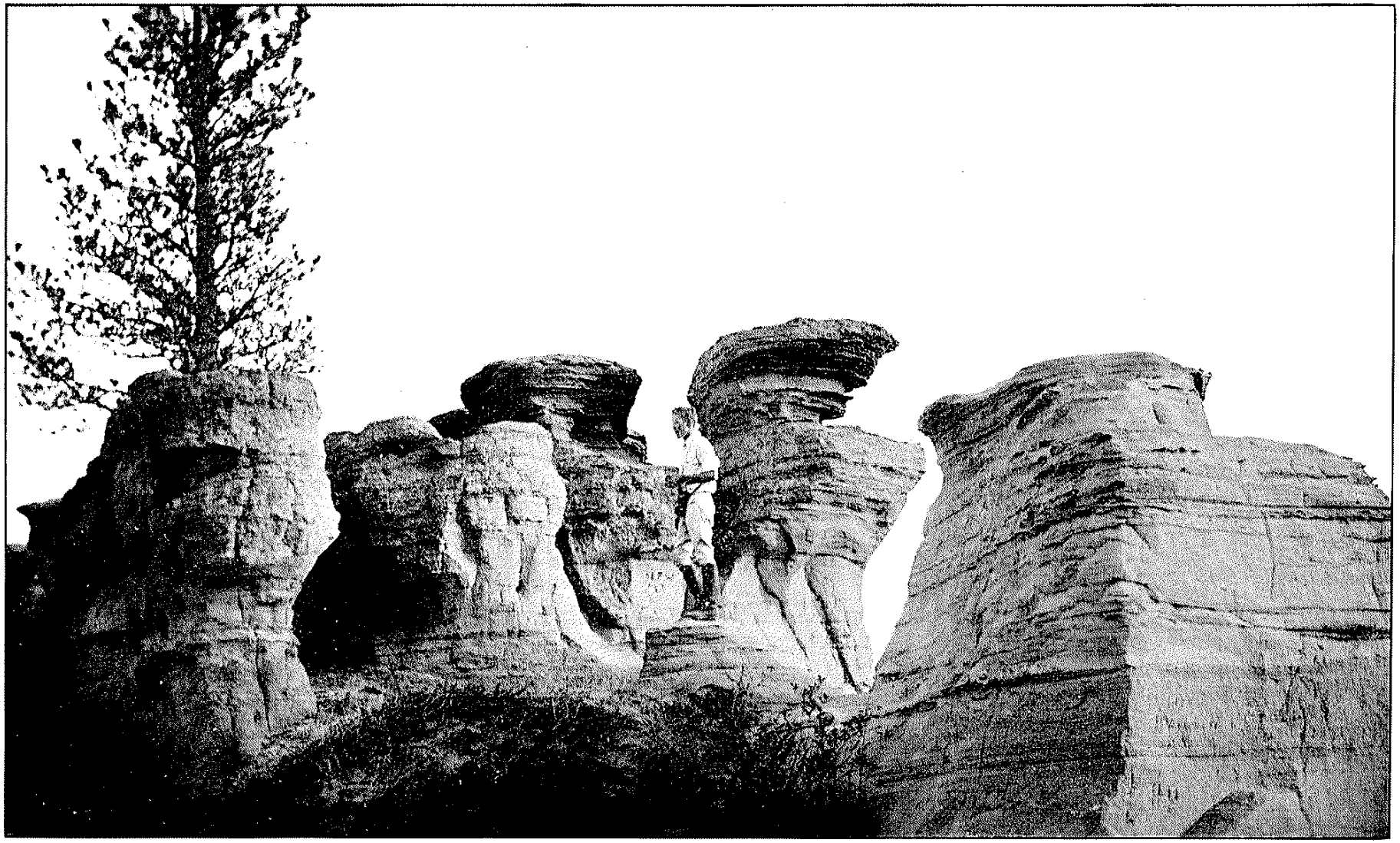
A MUD BUTTE IN THE "JUMP OFF" BADLANDS

Head of the Moreau River, Harding County



BAND SHELL BUTTE
Southern Harding County

Erosion has removed the resistant cap rock, pieces of which lie strewn about the base of the butte. The soft clays beneath the cap rock were quickly rounded by rain storms and a block slumped out from its face giving it the appearance of a band shell.



EROSION FORMS
IN SANDSTONE CAPROCK OF NORTH CAVE HILLS
Riley's Gap, Harding County

south, is an equally well known landmark, and the twin butte known as Deer's Ears protrudes above the horizon from points as far away as the Cheyenne river and the Black Hills.

The Tertiary Table Lands

South of the Pierre Hills Section is a second region of table lands. Most of it lies south of the White River, but at its western end it crosses this river and extends northward nearly to the Cheyenne river where it is separated from the Cretaceous Table Lands described above, by less than ten miles of gumbo. This is a region of young rocks, Tertiary in age, which were formed of the debris made in carving the present Rocky Mountains and Black Hills. The rocks, therefore, are predominantly sands and clays brought from the west by streams and blown into dunes by the wind. They are predominately light in color. Some are dazzling white and where there are many exposures the traveler moves through a very white country. This is the region which is known locally as the Rosebud and Pine Ridge country because of the two large Indian reservations which occupy a large part of it.

Like the northern table lands this Tertiary section is also a region of buttes and badlands separated by wide level uplands cut by deep narrow canyons.

In the Pierre Hills area close to the edge of this country, sandstone lies on top of the gumbo forming some very large buttes. The Iona Hills, Battleyoun Butte, and the Red Hills near Winner are good examples. On the upland itself, however, the surface is characterized not so much by buttes as by great level topped hills and broad flat terraces, which form divides between streams, on which lie areas of sand dunes anchored by prairie grasses except in times of unusually dry weather.

Streams have cut deep gorges into this country from whose sandy bluffs a supply of clear, sparkling water maintains a flow even in the driest times. The Little White, Bear-in-Lodge and Wounded Knee valleys are examples. They head at the base of the Pine Ridge escarpment and extend entirely across the Tertiary area to the White River valley. The Keyapaha (Turtle Butte) river has a similar but

much wider valley draining the southeastern part of the region and holding a straight course for more than fifty miles in a southeasterly direction toward the Niobrara river into which it drains.

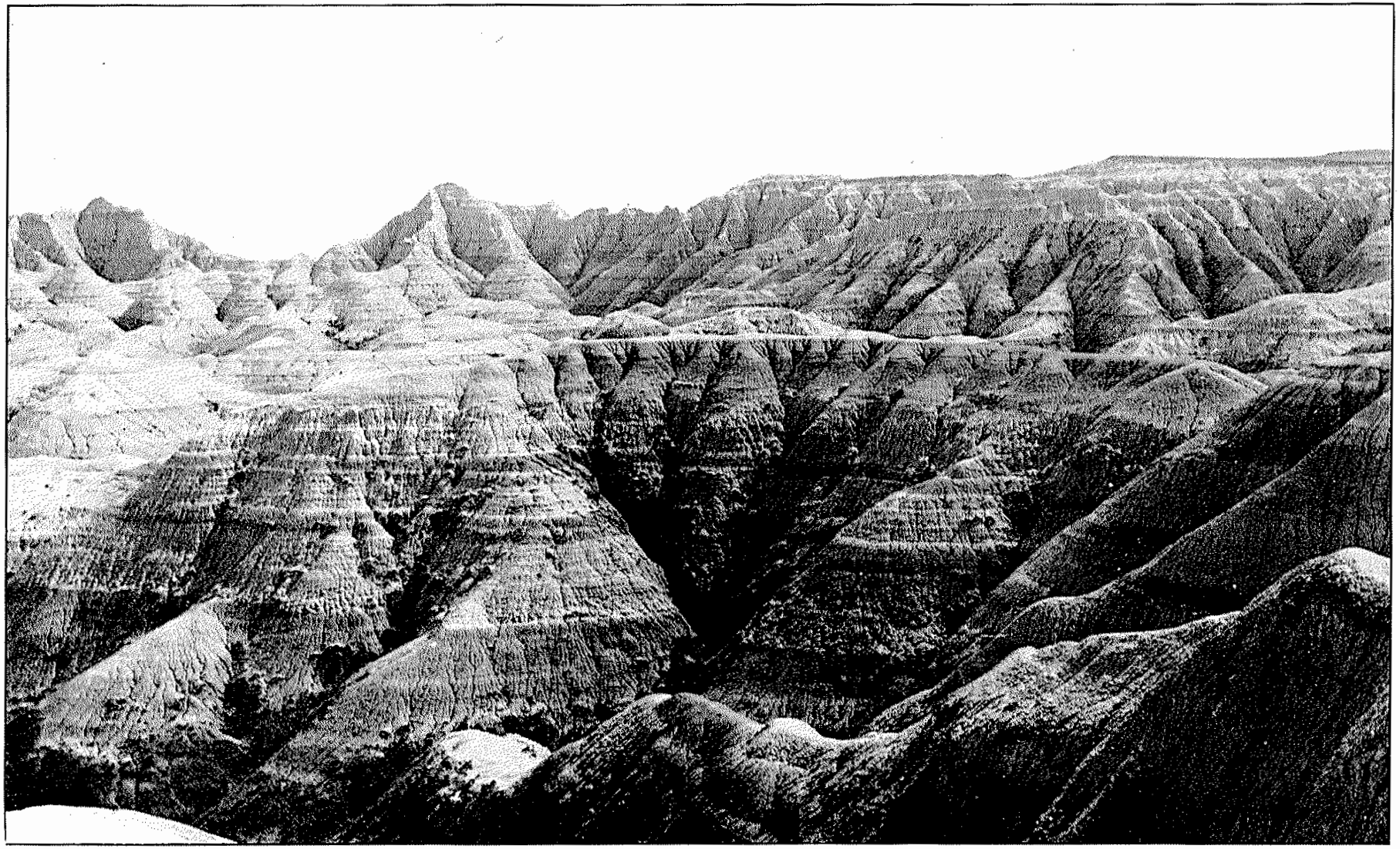
Between these streams are wide expanses of level or nearly level country with here and there a butte to break the monotony and far to the south the shadow of the Pine Ridge. More careful inspection, however, reveals the fact that these uplands all drain into stream valleys and this warrants classifying the country with the stream-made Missouri Plateau.

Badlands: Badlands are common on the Missouri Plateau, usually occupying the bluffs of the large river valleys or the sides of the larger buttes. In the headwaters of the Moreau just west of the Little Missouri river lies a rough somber colored badland country known as the "Jump-Off." Small patches of badlands also occur along the edges of the Slim Buttes and Cave Hills and in the valleys of the Grand and Moreau Rivers.

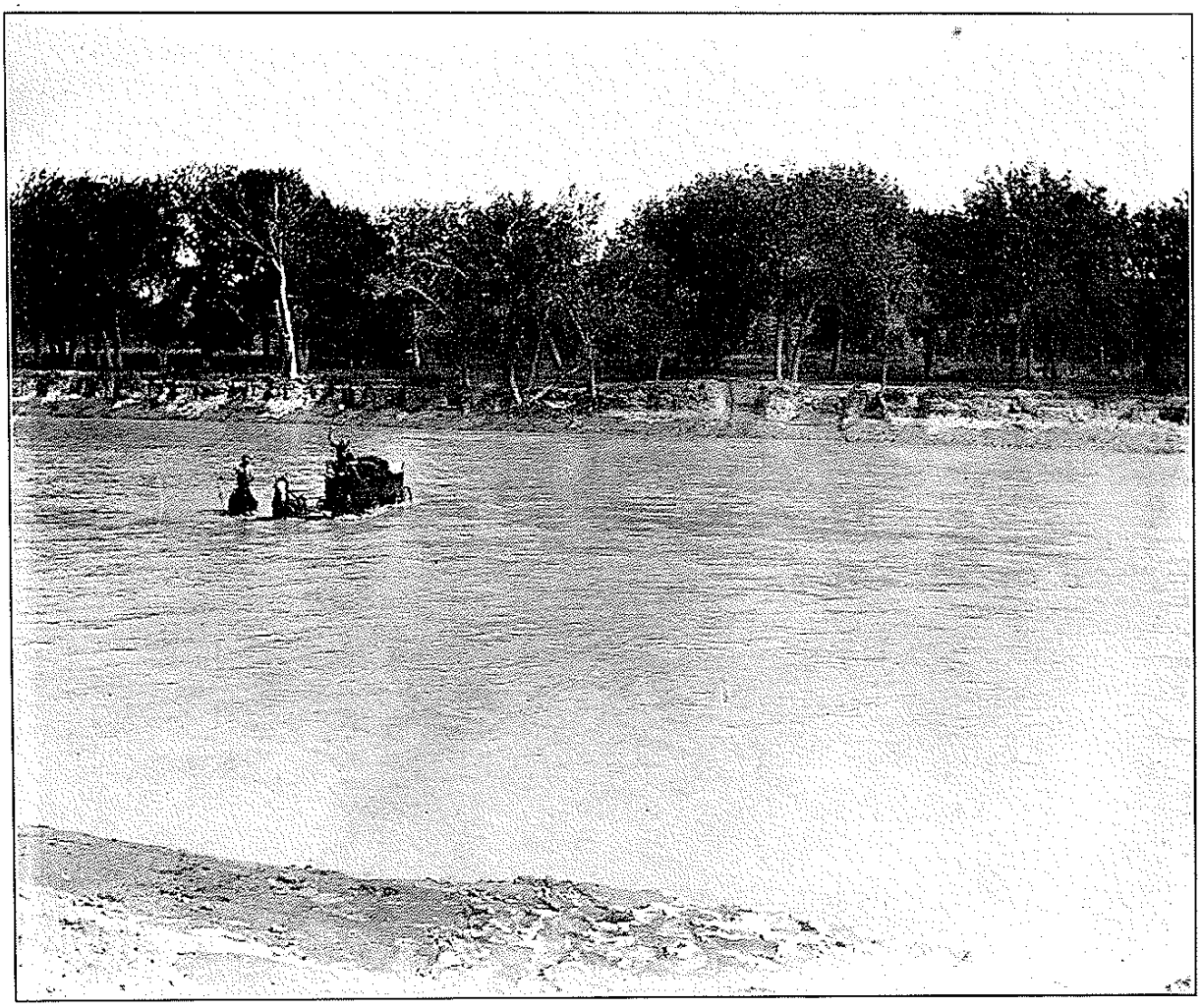
The largest and most picturesque area of badland topography in South Dakota, however, is the world famous Big or White River Badlands which lies at the western edge of the Tertiary Table Lands and can be traced down the White River valley more than one hundred miles. Gleaming, light colored rocks exposed in labyrinths of small valleys, fantastic peaks, castelated buttes, and the strange fauna which lies entombed in its sands and clays make the badlands one of the most weird and interesting bits of topography on the face of the earth. It has been described as the "magnificent ruins of a great silent city painted in delicate shades of cream, pink, buff, and green. Domes, towers, minarets, and spires decorate gorgeous cathedrals and palaces and present dimensions little dreamed of by the architects of the ancients. At first there may come a feeling of the incongruous or grotesque, but study more closely the meaning of every feature, the spirit of this marvelous handiwork of the great Creator develops, and vistas of beauty appear."[1]

Badlands are a result of the balancing of an unusual set of geological circumstances. The big towers and other gro-

[1]C. C. O'Harra, **The Badland Formations of the Black Hills Region,** Bull. No. 9, South Dakota School of Mines, 1910.

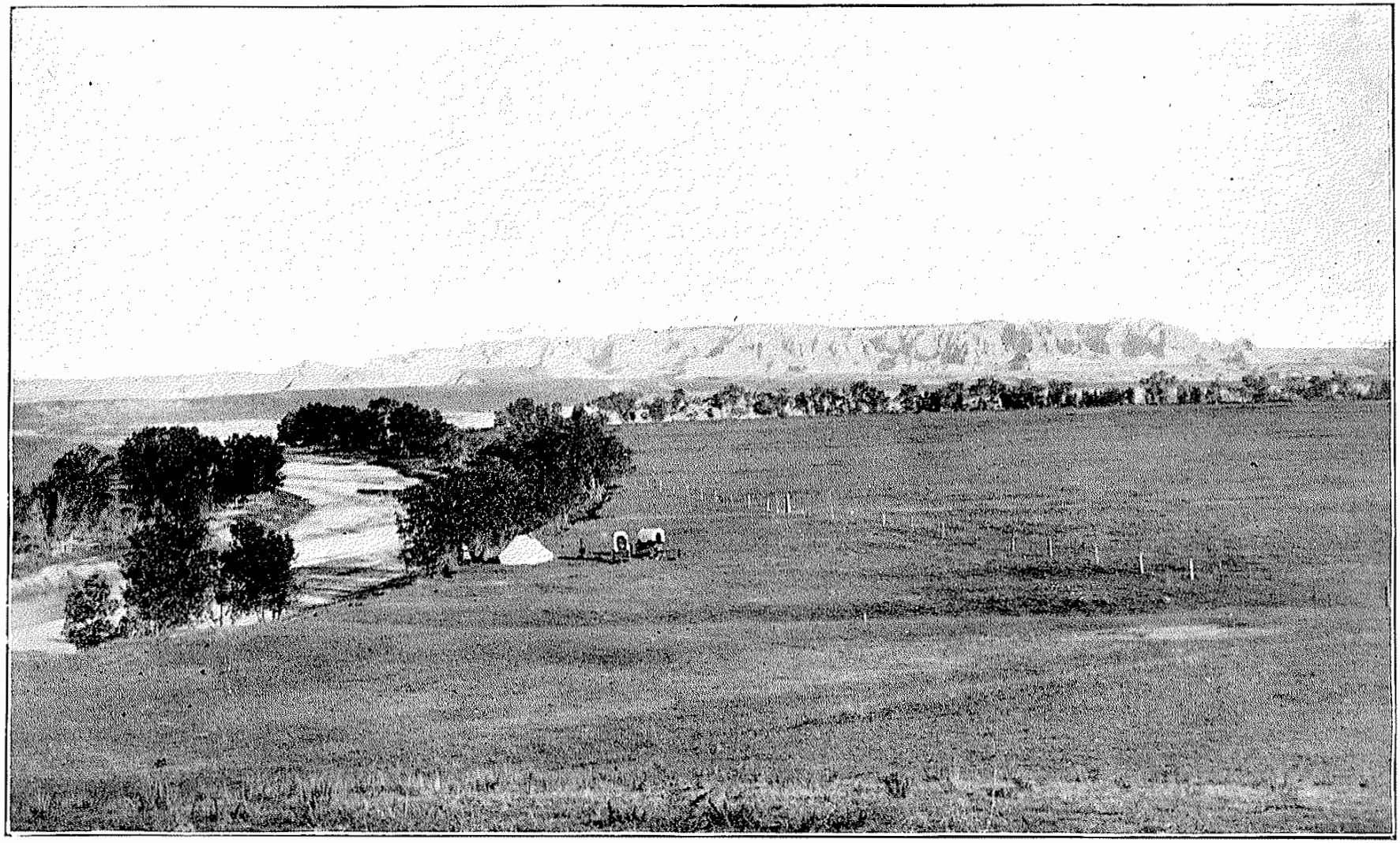


MA-KOO-SI-TCHA
"The Impassable Land" of the Dakota Indians



FORDING THE WHITE RIVER IN FLOOD

The water is white from the Bad Land mud it carries. Most of the summer season the broad shallow channel is nearly dry. Thunder showers in the Bad Lands send torrents of milky white water swirling through the channel which prevents crossing except where gravel bars give a solid footing.



CEDAR MOUNTAIN
From the East

This is the smallest of a group of "Tables" in central Washington County, which are really Bad Land mesas. The White River is in the right foreground.

tesque forms have all been carved by streams, but the kind of material on which the streams had to work, the type of rainfall, and the elevation of the badland area all played a part in making the fantastic topography.

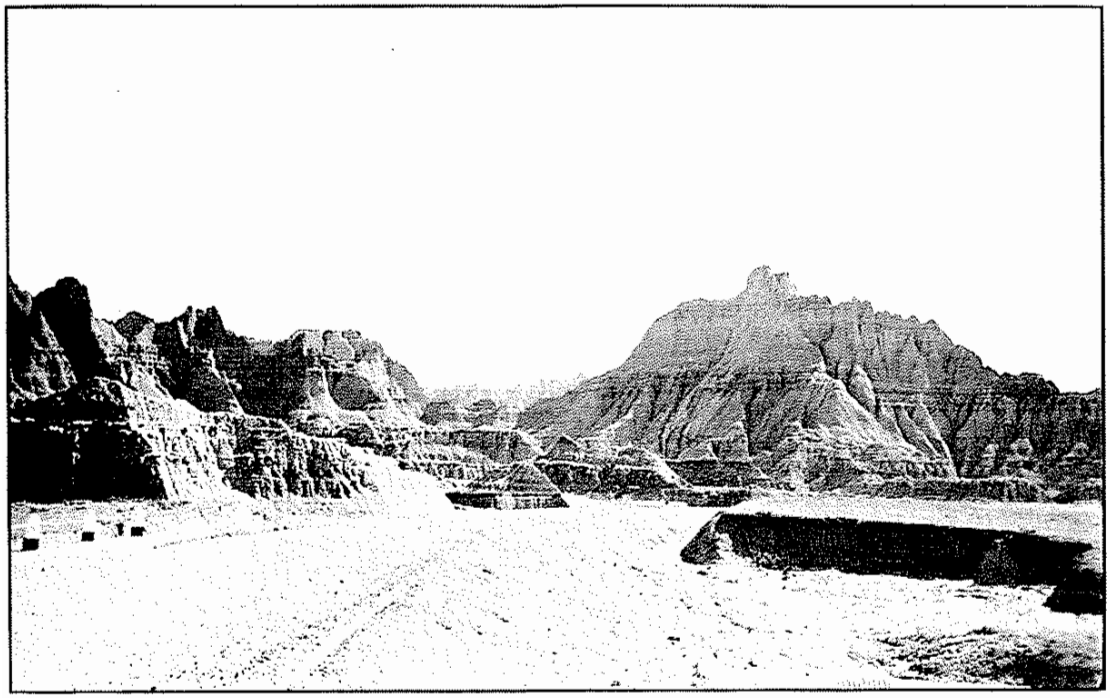
The same rain falls on the Badlands that falls on the gumbo shales north of the White River, but in the latter area it produces only smooth, rounded hills while in the Badlands it makes peaks and gorges so steep and narrow that one may, in places, stand on the floor of the valley with his shoulders touching both bluffs. This is due, in part, to the alternation of easily eroded clays with less easily eroded beds of sand and volcanic ash. The sand and ash beds protect the softer underlying clays and can be seen standing on top of the pinnacles as jaunty bits of caprock or making ledges and shelves down in the side of the canyon. Beneath them the clay walls fall almost vertically to the next hard ledge.

A second factor which makes badland topography is the presence of gumbo in the clay. This gumbo cracks upon drying leaving a mass of loose rubble a foot or more deep during dry weather. As much of the rain in this section comes in thunder showers during the dry season this loose material is washed rapidly into the gullies and out into the White River leaving steep bare slopes.

The third factor is the height of the Badlands above the White River. When land is high it drains rapidly and streams cut the bottoms of their channels faster than they do the sides and thus form deep and narrow gulches and arroyos.

A fourth factor is the summer rainfall mentioned above which comes largely in thunder storms that send torrents of water down the narrow gulches and deepens them faster than they can be widened.

Thus the Badlands have been formed along the edges of the great valley which they overlook by the combined action of these four factors. One of the striking things to a person interested in earth sculpture is the sight of small badland buttes not over four feet in height and of such small area that they could be covered by a good sized hogshead, showing the typical white rocks, pinnacles, and canyon structures of their big brethren on the valley bluff. These agents,



WHITE RIVER BAD LANDS

At Cedar Pass.

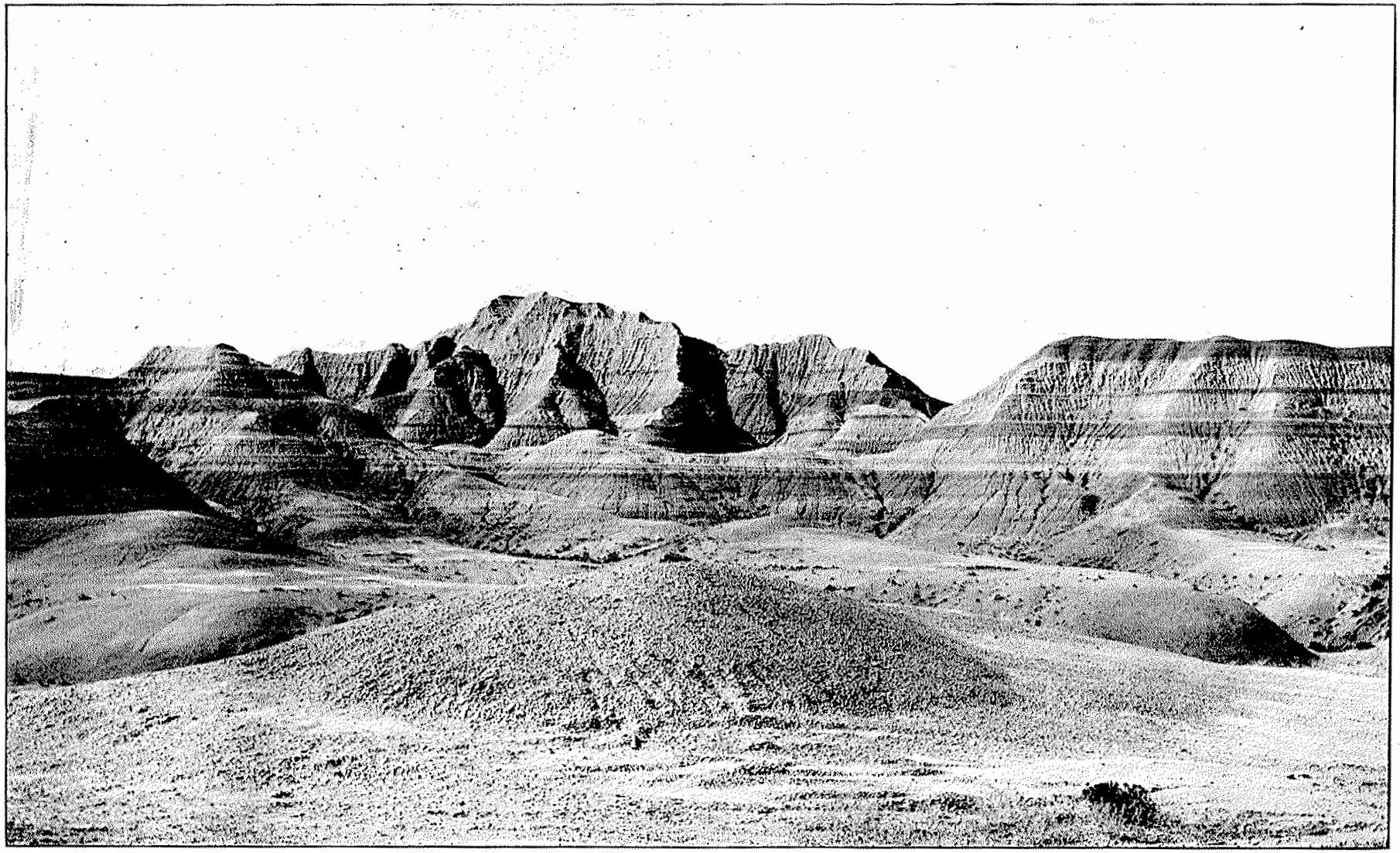
A labyrinth of peaks and arroyos typical of the Bad Land Wall, Jackson County.

then, have formed a country which well deserved the name Ma-koo-si-tcha of the Dakota Indians, Mauvais Terres of the French Canadian trappers and hunters, which is interpreted "Bad Lands" in plain English; all indicating that the country was a difficult region in which to travel because of its rough surface and lack of good water. The Big Badlands are in reality the frayed edge of the Tertiary Table Lands.

At the western end of the Big Bad Lands on the divide between the Cheyenne and White rivers is a group of wide-topped buttes and mesas locally called "Tables." On their broad flat tops small farming communities are perched like medieval strongholds surrounded by high, badland cliffs which allow access to the top in but one or two places. Cooney Table, Sheep Mountain, Heart Table, Kube Table, Seventy-One Table, Quinn Table, and a multitude of smaller buttes all belong to this group. They rise 400 feet or more above their surroundings, and are four to six miles long and approximately the same width. Their sides are cliff-like and fringed with a labyrinth of sharp arroyos.

The north bluff of the White River valley is a formidable line of badlands cliffs and pinnacles known as the Great Wall. It is sixty miles long, so steep and cut with such a labyrinth of valleys, small gullies and arroyos that it can be crossed in only a few places. Big Foot and Cedar pass are probably the best known since these passes are used as highways. The former was so nearly impassable that United States cavalrymen were unable to follow the Indian chief Big Foot through it. A wagon trail led down Cedar pass for a good many years, but its grades were so steep that it was impossible to take a wagon over the road without blocking its wheels securely. Highway engineers have now leveled the steep grades till they can be crossed easily by automobiles. Other passes are still largely usable only on foot or horseback. Of these, Sage Creek pass and Chamberlain pass are noteworthy.

"One approaching the Badlands may gradually ascend a rolling, grassy surface, until he suddenly comes to the crest of a ridge and finds himself gazing from a height of 200 to 400 feet upon a labyrinth of winding ravines and narrow ridges, which, in some places, widen into broad buttes, capped with tables formed by harder strata, or surrounded with slender pinnacles, reminding one of the spires of a cathedral.



BANDED BEDS IN THE BAD LANDS

Varicolored clays and a lack of resistant beds made a topography devoid of the pinnacles and ledges characteristic of the White River Bad Lands.

At other points the harder beds stand out as cornices and buttresses around the more prominent buttes. While this may appear nearby, farther away he may see graceful, rounded domes and ridges, which remind one of haystacks or railroad embankments, where they continue as narrow ridges, with their tops extending on the same level for some distance."[1]

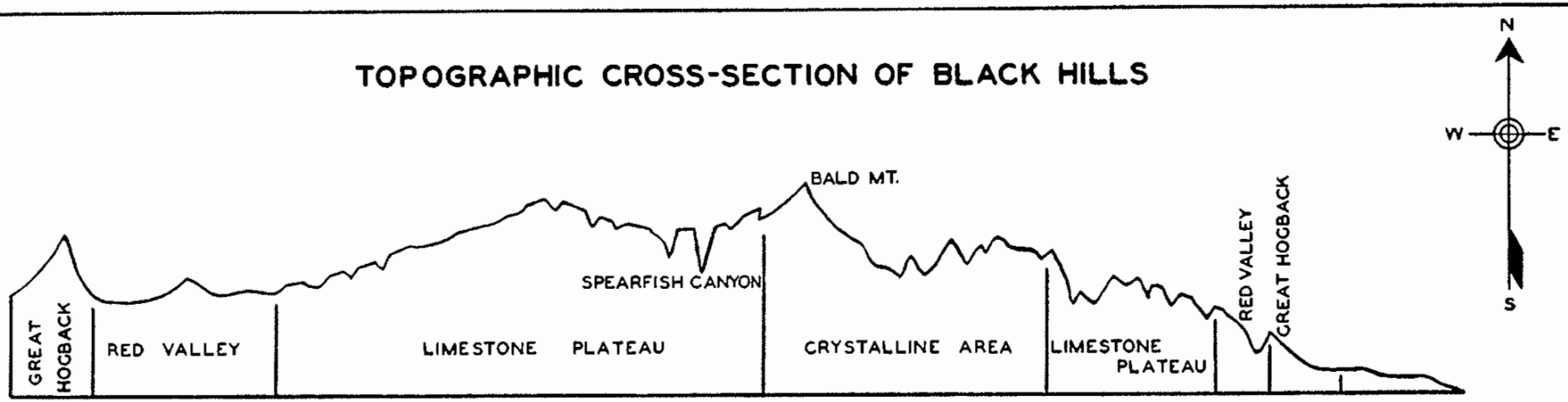
The Wall is the part of the Badlands usually seen by tourists since the main routes of travel by both highway and railroad follow its base through most of their route in the Badlands.

Besides the Tables and the Great Wall a large area of badlands can be followed along the south bluff of the White River valley for nearly 100 miles dying out a little east of the Little White River in Mellette county. These Badlands are fully as picturesque as the Badlands of the Great Wall and the Tables but are spread over a larger territory and differ somewhat in character. The labyrinths of sharp valleys which characterize the badlands of the Great Wall and Tables are not so conspicuous in the Badlands south of the White River, their place being taken by the great buttes which are everywhere in evidence. Travel is not difficult through these badlands and an ever changing vista of castleated forms greets the traveler as he twists and turns on the divides between the shallow arroyos. This fringe of Badlands is six or eight miles wide and as one proceeds southward the buttes become less and less prominent until they merge into the broad flat uplands.

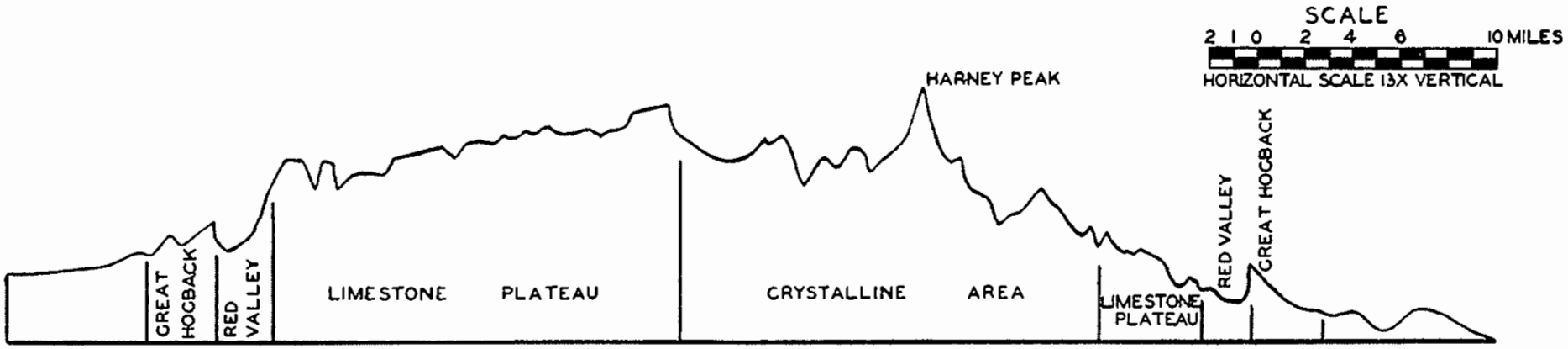
The Badlands have combined the Tablelands, the impassable Wall with its labyrinth of canyons and arroyos, and the region of stately buttes into a most gorgeous topographic fringe for the great area of white Tertiary rocks which makes the southern part of the Missouri Plateau in South Dakota.

[1]J. E. Todd, South Dakota Geological Survey, Bulletin 1, 1894, p. 103.

TOPOGRAPHIC CROSS-SECTION OF BLACK HILLS



NORTHERN BLACK HILLS NEAR LEAD



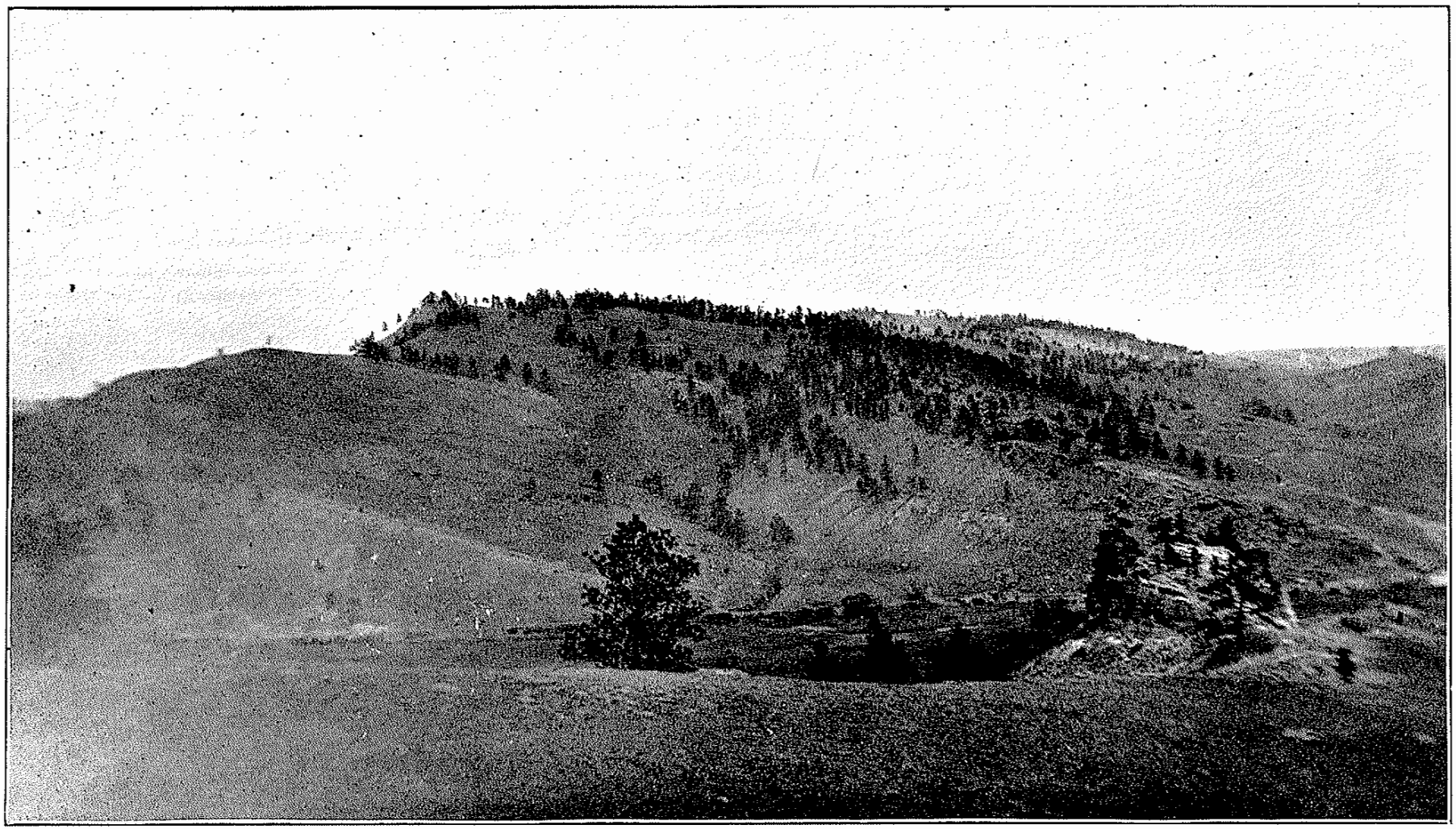
SOUTHERN BLACK HILLS NEAR CUSTER

4. THE BLACK HILLS DIVISION

The Pahasapa, (Hills of Shadows), of the Sioux Indians is a vest pocket edition of the Rocky Mountains, thrust through the plains at the same time and by the same forces that made their great western brothers. These relentless forces caused a buckle in the earth 300 miles long which starts at Glendive, Montana, passes through the Black Hills and is finally lost in northwestern Nebraska beneath an earth blanket of young rocks at the base of the Pine Ridge escarpment. The brunt of the attack along this long front was borne by the rocks in southwestern South Dakota, which were forced to yield by buckling upward, forming a great bulge in the earths surface, three miles into the air at its highest point.

Thus there was formed a great earth block in the center of the long fold and from this block were carved the mountains we know. The portion physiographically known as the Black Hills section of the Great Plains, is elliptical in shape, about 100 miles long by fifty miles wide and having a total area in South Dakota of more than 3,000 square miles. It is sharply separated from the surrounding plains by a wall of hogbacks which forms an effective barrier, as entrance to the mountains is possible only through gaps which have been cut through these hogbacks by the larger mountain streams. Between Rapid City, and Sturgis, a distance of about thirty miles, there are but four roads leading through the hogbacks while in other parts gaps are even fewer. Two thirds of the area thus enclosed lies in South Dakota while the other third crosses an arbitrary political boundary line into Wyoming.

Approaching the Black Hills from the east one sees them for the first time about fifty miles from Rapid City. They appear as a dark, cone-shaped outline against the western horizon. The cone slopes symmetrically to the north and the south from an apex formed by Harney Peak near the center of the mountain mass. The outline from the south is similar but not so extensive and this general slope away from a high point in the middle of the mountain mass has led geologists to call the Black Hills a domed area. If the dome be considered as simply an exaggerated bulge on a long fold the picture will be correct. The elliptical outline



THE GREAT HOGBACK
At Rapid City

Looking north across the gap cut in the hogback by Rapid Creek. The top of the steep slope facing the Red Valley can be seen at the left side of the picture.

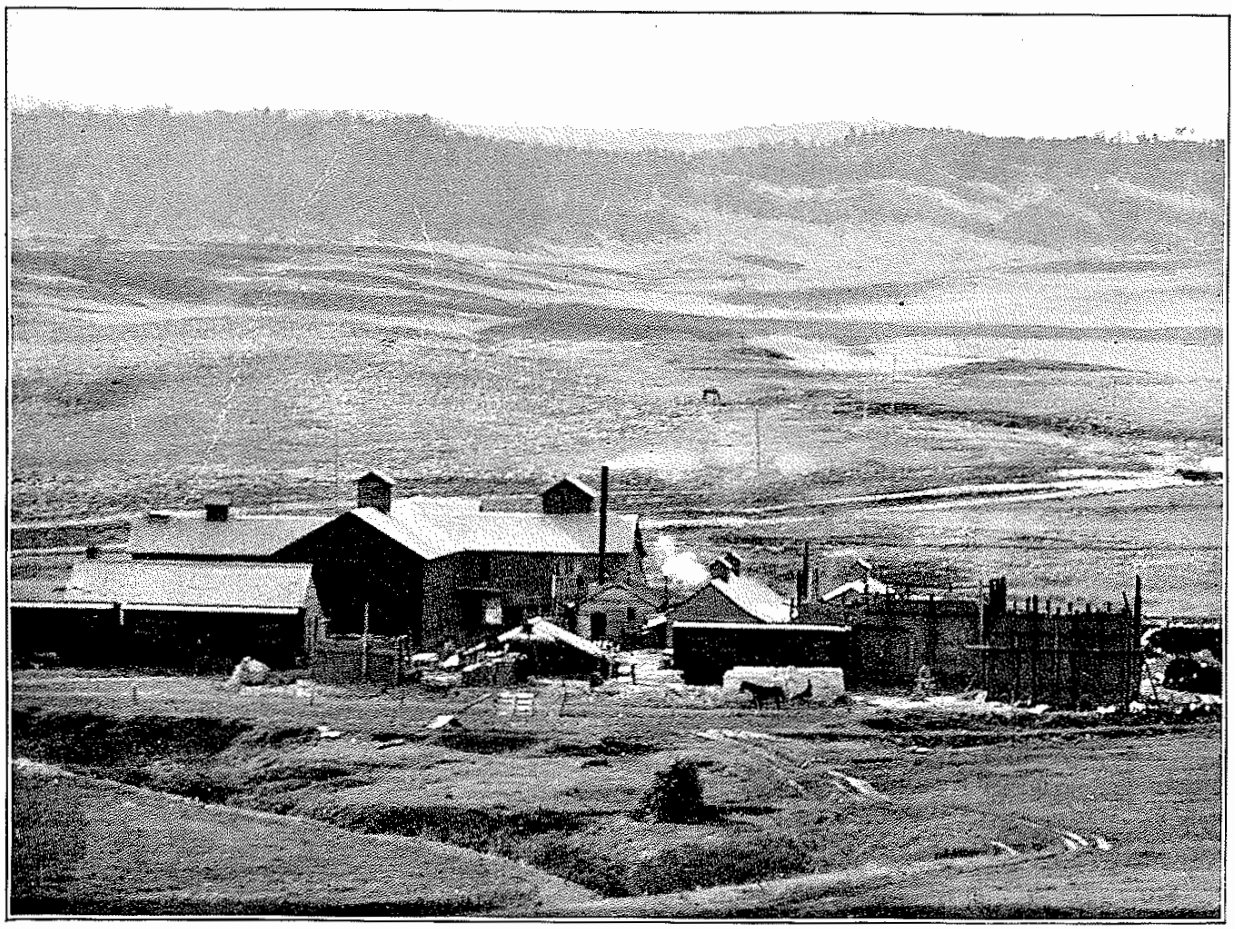
and conical cross sections fit into this picture and agree with the conception of the mountains which structures extending beyond them indicate.

Upon entering the mountains one finds four distinct topographic divisions, a wall of hogbacks surrounding the mountain mass and overlooking a great valley known as the Red Valley. Inside the Red Valley is a plateau-like region of limestone seamed with deep precipitous canyons—the Limestone Plateau. The Plateau surrounds an area of true mountain peaks scattered irregularly and apparently without organization, which is known as the Crystalline Area and makes the core of the mountains. Each of these has its own scenic and geologic features giving the Black Hills a variety which is seldom found in so small an area of mountain country.

The Great Hogbacks: The outer wall, sometimes called the Great Hogbacks or the Dakota Hogbacks is taken as the outer boundary of the physiographic province. "The size and physiographic importance of this dome-mountain uplift requires that it be treated as a separate section of the Great Plains Province. It is surrounded by residual monoclinal ridges, the outermost of which indicates the proper boundary of the section."[1] Though other monoclinal ridges occur outside the Hogbacks at some places about the Black Hills their inconspicuousness rules them out as boundary markers and the Great Hogbacks are commonly conceded to be the outer edge of the mountains.

The long back slopes of the Hogbacks rise out of the plains with grades as high as ten degrees to elevations 600 feet above their base and end in sharp ridges overlooking the broad Red Valley. Steep inward facing cliffs fifty to 100 feet or more in height mark the top of the inside slope of the hogbacks. Below the cliffs steep slopes reach down into the valley. The term hogbacks is well applied to these forms as they bring to mind the sharp spines of razor-back hogs. They stand out boldly because they are supported by several layers of heavy sandstone which resists erosion much better than the soft sands and clays above and below them. These sandstones are the ends of the rock blankets which underlie large areas of the state and which have been upturned here

[1]N. M. Fenneman, "Physiographic Divisions of the United States," **Annals of the Association of the American Geographers,** Vol. VI, p. 71.



THE RED VALLEY

Looking west near Rapid City

The unforested area is underlain by brick red sands and shales (Spearfish formation) which give the soils their distinctive color. Forested slopes in the background are underlain by the limestone (Minnekahta formation) which makes the inside wall of the valley.

by mountain folding so that they rise out of the plains, at angles of about ten degrees, toward the center of the Black Hills. Since the overlying clays have been stripped from them, their upper surfaces give the pitch to the long outside slopes of the hogbacks.

Once the streams have cut through these sands they rapidly undermine them by taking out the unresising clays and shales beneath and thus on the inside of the ridges we find very steep slopes surmounted by sandstone cliffs. The sandstone can be seen in many of the water gaps where streams have cut through the hogbacks. The gap at Rapid City is an excellent example. On the north side three distinct layers of sandstone can be seen climbing up the ridge while on the south, the famous Hang Man's Hill exposes nearly 100 feet of one of these sandstone formations.

The Red Valley: The Red Valley lies like a moat between the hogbacks and the main castle of the Black Hills. Its name is well chosen for it is indeed a red valley. Red railway grades, red highways, and red soils are everywhere in evidence as though it were a portion of the mythical land of Oz. It is a broad open valley bounded on the outside by the steep towering ridge of the hogbacks and on the inside by gentler slopes made by a heavy limestone that comes out from beneath the red formations which make the valley floor. This valley is sometimes referred to as a Race Course by the Indians, "because of its open and smooth character affording easy and rapid passage around the Hills."[1] Its bottom lands which are a mile or two in width lie about 500 feet below the crest of the hogbacks.

The valley is red because it has been carved out of brick red sands and shales geologically known as the Spearfish Red Beds. Eleven hundred feet of sand and shale lie between the heavy sandstone which caps the hogbacks and the heavy limestone which makes the inside wall of the valley. The lower 700 feet are the brick red beds of the Spearfish formation. These poorly cemented rocks offer little resistance to erosive forces and are easily washed out from between the heavy layers above and below them leaving the great valley encircling the Hills in true race course fashion.

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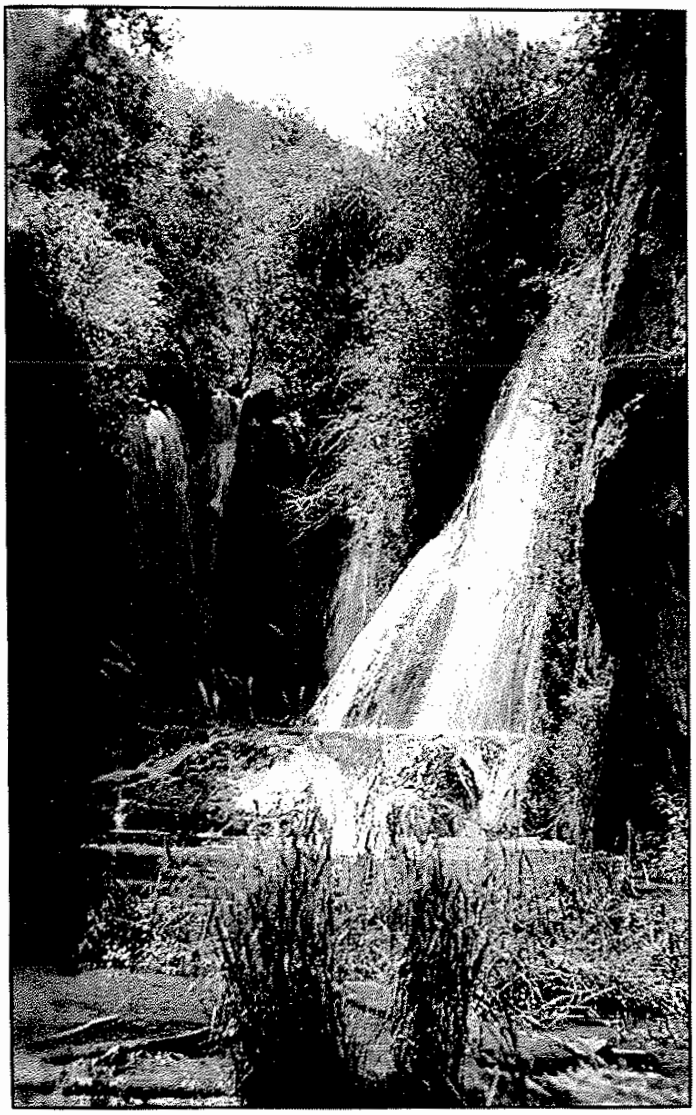
[1]J. E. Todd, **A Preliminary Report on the Geology of South Dakota,** South Dakota Geological Survey, Bull. 1, p. 8, 1894.

The Limestone Plateau: Inside the Red Valley lies the high limestone country seamed with deep, dark canyons. On the western side of the Black Hills this plateau is wide, in some places stretching fifteen or twenty miles eastward from the Red Valley to the precipitous cliff which makes its inner border. On the east side, however, it narrows down until it becomes little more than a ridge in the stretch between Rapid Canyon and Buffalo Gap. Along most of its length it ends abruptly on its inner side in precipitous cliffs which descend from the plateau like a wall 600 to 800 feet in height.

The true plateau character can best be seen in the broad western part which reaches elevations of 7,100 feet, a little lower than the highest peak in the mountains. This area slopes gently westward, southward, and northward conforming with the general cross section of the mountains until it finally reaches the Red Valley in Wyoming. The eastern ridge ranges in altitude from 5,000 to 6,000 feet and is much more like a large hogback with a limestone cap than like a plateau.

All the large streams of the Plateau have cut canyons whose walls appear to rise vertically from the banks of the stream that made them, 800 to 1,000 feet to the top of the plateau. Spring canyon, Redbird canyon, Gillet canyon, Buck Spring canyon, Hell and Dark canyons all tell the tale of impassable water ways which start as inconspicuous depressions on the surface of the plateau and within a very short distance become formidable canyons walled by cliffs of gray limestone. The largest of these is Spearfish canyon in the northern part of the plateau. For twenty miles limestone cliffs shut off the sunlight from the valley bottom, and its bluffs and those of its tributaries present some of the most rugged scenery in the mountains. Bold cliffs and sparkling waterfalls where the canyon forks at Savoy have been an attraction to tourists for many years. In its upper reaches some of the most beautiful virgin forests in this part of the country still survive.

The limestone plateau is cave country. Openings of small size are literally strew over the cliffs of all canyons. Most of them are small, crystal lined cracks or solution cavities, but a few of them are large enough to be classed as caverns. No one knows the number of large caves in the



ROUGHLOCK FALLS

Spearfish Canyon near Savoy, Lawrence County

Black Hills nor the extent of those that are known. The explorer who enjoys poking into subterranean caverns and recesses has ample opportunity to apply his talents in the limestones of this plateau.

Most of the caves which have been opened and are easily accessible to visitors are in the eastern part of the plateau. North of Rapid City in the valley at Elk canyon lies Crystal Cave. "The mouth of this cave is overlooking the canyon of Elk Creek, about six miles above Piedmont. It is about 200 feet above the level of the stream, and approximately 4,202 feet above the sea. * * * The chambers present the usual irregularities of vaulted caverns and narrow, winding passageways. They are commonly covered with crystals of calcite of the usual form, known as Dog Tooth spar. Some chambers present beautiful examples of stalactites and stalagmites, and a few samples of a particular form of surface, known as 'box work' are found, but are so deeply covered with calcite that they do not appear prominently. The passages, so far visited, rarely showed traces of dripping water and nowhere running streams or large ponds. * * * Crystals were of quite uniform size, generally with a diameter of one-half to three-quarter inches. Another evidence of occupation by water, and which indicated also that the form of the crystals was probably due to solution rather than imperfect crystallization, was the coating of the crystals, very generally, with a thin film of clay. * * * Beautiful specimens of spongy shaped masses of crystals, formed in shallow basins of standing water, have been found in this cave, sometimes of a straw color, but more frequently of snow white or a pearly luster. * * * The length of passages may safely be put down as several miles * * *. The depth at the lowest point visited below the entrance was about 150 feet. The larger chambers in some cases may roughly be estimated as having a length of 200 or 300 feet, the breadth fifty to sixty feet, and the height thirty to forty feet. There are reports of several other caves in the vicinity which have not yet been explored."[1] Crystal cave was opened to the public in 1890 and has been on display ever since.

One of the caves indicated by Professor Todd has been opened up recently and is now on display as Wonderland

[1]J. E. Todd, **op. cit.**, p. 47.

Cave. Its general character is much like that of Crystal Cave.

The largest and best known of the caves is Wind Cave, twelve miles northwest of Hot Springs, discovered in 1881 by Tom Bingham. In 1903 Congress set it aside as a national park and now maintains an excellent guide service which takes care of thousands of visitors each year. Wind Cave gets its name from "its alternately throwing out and drawing in vast quantities of air."[1] Strong drafts blow in and out of the opening, changing with the conditions of the atmosphere. This cave, therefore, belongs to that class of caverns known as blowing caves. The phenomena is variously explained, most observers attributing it to some vague performance of barometric pressure. The best explanation of these caverns, however, seems to be that of Humphreys.[2]

According to this author the opening of the cave must be connected with another opening higher up on the mountain. The cool air in the cave tends to settle and blow out of lower openings since it is heavier than the warmer air at the same level outside the cave. Thus a circulation is set up which will blow cold air out of the cavern when the outside air is warmer than that in the cave and reverse the process when the temperatures are reversed.

No one knows the full extent of Wind Cave. Some ten miles of passageways have been explored without finding the end. For the most part they are long, narrow crevices trending toward the southeast and sloping at the same rate as the limestone in which they are formed. Some parts of the passageways appear to have a definite roof while in others the ceiling is lost in the blackness far above the floor of the cavern. Cross passageways connect the main passages here and there. At intervals, the main passages open into large rooms which were once given names and dedicated to various organizations. The Fair Ground is the largest of the rooms and covers an area of several acres; there was also the G.A.R. Hall, Capitol Hall, the Assembly Room, the Masonic Temple, and the Garden of Eden.

The Postoffice is one of the most interesting of these rooms for its walls are lined with rows on rows of "boxes"

[1] J. E. Todd, **op. cit.,** p. 48.
[2] W. J. Humphreys, **Physics of the Air,** p. 117.

into which visitors would thrust bits of paper inscribed with their names and address. The boxes are vein formations which are particularly well developed in this cave. According to Todd[1] the "boxwork" has formed in the following manner: "The rock is an impure limestone which has been cracked into small polygonal masses more or less rectangular in cross-section. These blocks vary in size from an inch or two to a foot or more. The cracks have at some time been filled with calcite, often in thin plates, though in other places thick and heavy. * * * In the atmosphere of the cavern the process of disintegration of the original limestone by dissolving away the natural cement, * * * allows the grains of sand to run out of the polygonal spaces formed by the calcite seams, somewhat as in an hour glass. Since the boxes were emptied, the calcite partitions have been coated with calcite and aragonite crystals of various sizes and colors. Colors vary from snow white to chocolate brown and honey yellow, and display not only a "drusy" appearance and beautiful tufted and clustered forms, some resembling grapes, and others like branching corals, but also forms most perfectly resembling hoar frost. The boxwork abounds as the lining for most of the passages and chambers, and is found to be limited to certain layers. All stages in the process described may be found illustrated."[1]

The walls of most passageways are bare, but in some passages and rooms a beautiful frost-like covering of aragonite crystals adorns the walls. This growth is "as delicate as the frost gathering about the mouth of a well in winter."[2] It is called by various names—aragonite frostwork, popcorn coating, and mineral cotton. One cluster of these crystals, said to be eighteen inches long, has been called Noah's beard."[2]

Three miles southwest of Wind Cave lies Onyx Cave, a small cave which is characterized by thick deposits of Mexican onyx on its walls. It is doubtless but one of many caves which can be opened in this vicinity.

Only a few caves have been opened in the western side of the limestone plateau. The best known of these is Jewel

[1]J. E. Todd, **op. cit.,** p. 49.
[1]J. E. Todd, **op. cit.,** p. 49.
[2]J. E. Todd, **op. cit.,** p. 50.

Cave, thirteen miles south west of Custer, which has been set aside as a national monument. Its opening is in the bluffs of Hell canyon and "leads into several miles of narrow passageway along which are irregular wide chambers similar to those in Wind Cave. * * * the walls are in many places encrusted with crystals of Dog Tooth Spar."[1] The shiny points of these crystals are good reasons for giving this cave its name.

This is probably but one of many caves in this region but only one other, Jasper Cave, a mile west of Jewel Cave has been opened and partially explored.

The Crystalline Basin

The heart of the Black Hills is a region of peaks and gulches, scattered over the landscape in hopeless confusion. Reason and plan seems to have been thrown to the winds when this section was created. The only order that seems to prevail is in the network of divides and drainage areas which flow north, east and south from the center of the western side of the basin.

Those who have described this region have called it a basin because it seems to lie below the top of the high limestone plateau to the west. Looking eastward from the top of the vertical cliffs bounding this part of the plateau, one sees below him a maze of peaks whose tops lie about 5,500 feet above sea level. The only peak higher than this plateau rim is Harney Peak which rises less than fifty feet above the highest point on the plateau. On the eastern side of the basin the limestone plateau is lower than most of the peaks of the basin but the basin idea is preserved by west facing limestone cliffs and by the steep descent which roads and highways make in entering it.

Though the surrounding limestone cliffs give this region the appearance of a basin, it is really a high land. Lead, in the northern part of the crystalline area, is sometimes called the mile high city because of its elevation above sea level. Many peaks in the region reach elevations of 6,500 feet and a few 7,000 feet. The following list includes the highest peaks in the Crystalline Basin:

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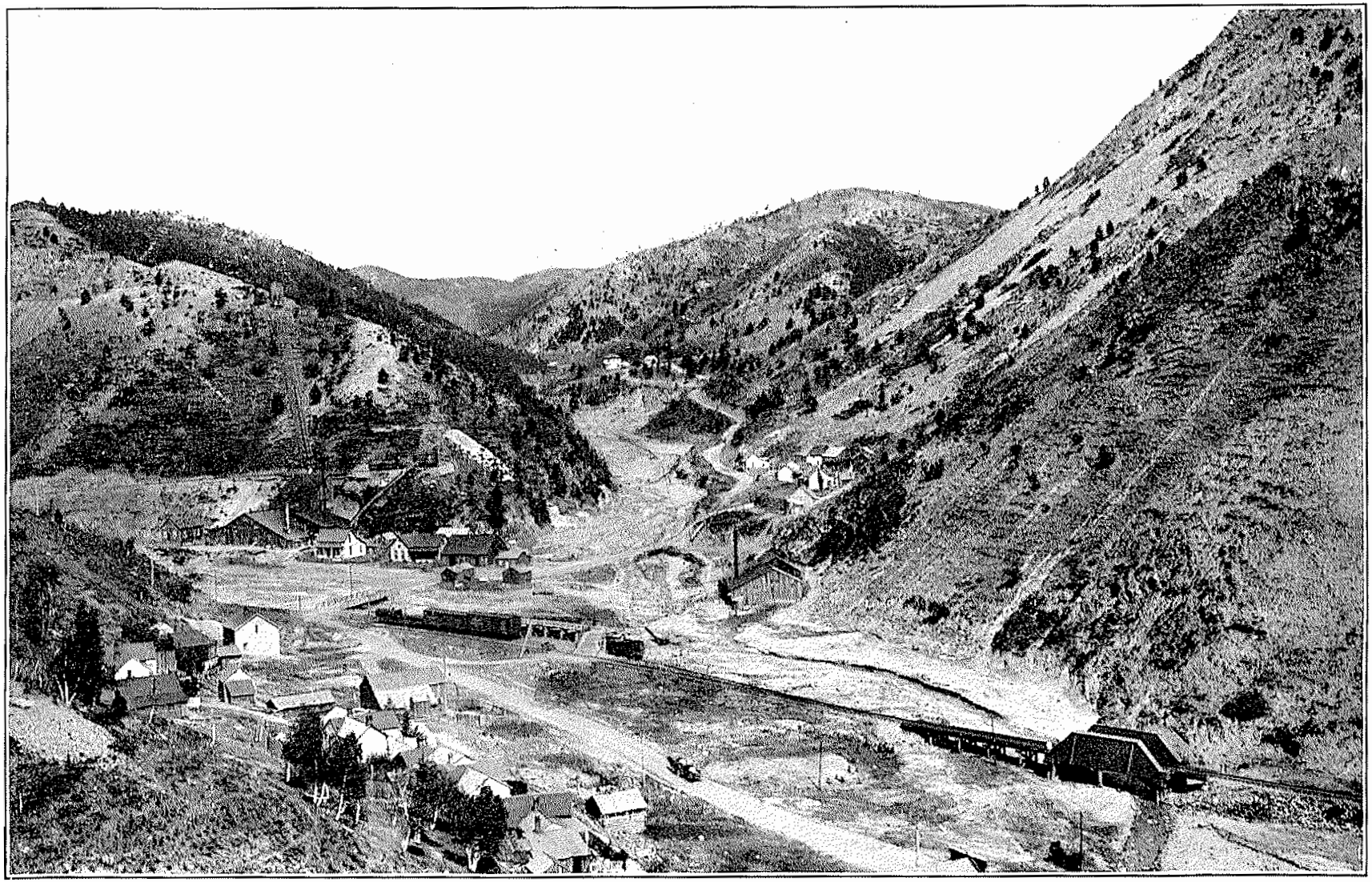
[1]N. H. Darton, **The Central Black Hills Folio,** U. S. Geol. Surv. Folio 219, p. 8.



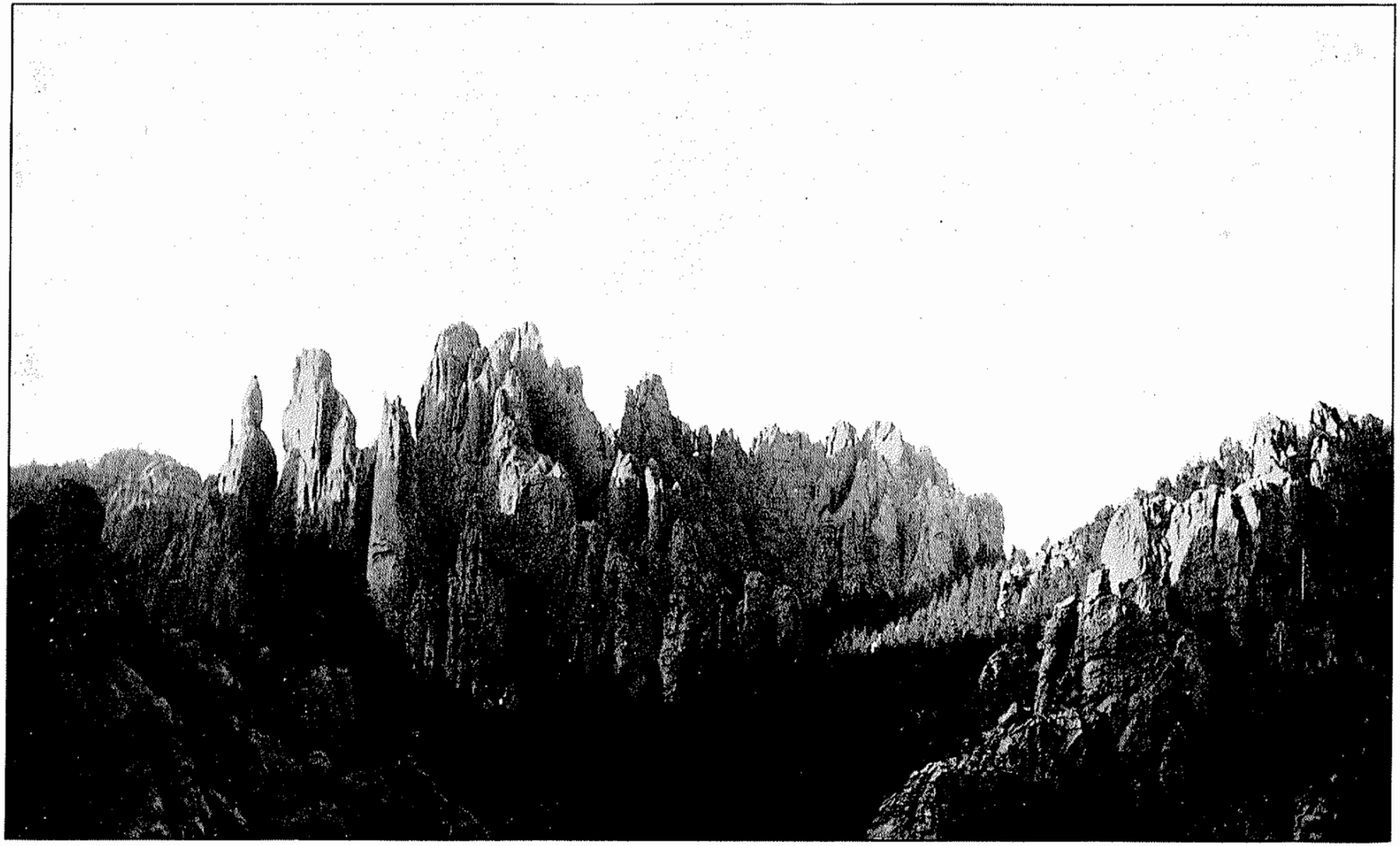
BLACKTAIL GULCH

Typical of the topography in the Crystalline Basin of the Black Hills.

Northern Black Hills	Feet
Terry Peak	7,071
Bald Mountain	6,613
Mount Theodore Roosevelt	6,576
Custer Peak	6,794
Southern Black Hills	
Harney Peak	7,242
Chief Mountain	6,000
Saint Elmo	6,400
Buckhorn	6,300
Iron Mountain	6,000
Summit Peak	5,700
Storm Hill	5,700

The highest part of the Black Hills is near the center of the Crystalline Basin. It is the great bald top of Harney Peak—7,242 feet above sea level. This is the highest point in North America east of the Rocky Mountains. From this vantage point, on a clear day one can see to the west, the bold cliffs of the Limestone Plateau sloping slightly northward and southward until they become lost in the distance. Toward the east, north and south, across a maze of peaks, the course of the encircling hogbacks lies far below. Beyond them the limitless expanse of hazy prairie reaches, apparently, into infinity.

To the physiographer, this is known as the Crystalline Area because it has been carved from crystalline rocks. Some have welled up from deep within the earth as hot lavas invading other rocks which had been crushed in the relentless jaws of mountain making forces—forces so strong that they destroyed the rock entirely and made it over into masses of sparkling mica flakes and stubborn quartzite. These rocks offer very different resistance to the erosion of the streams. The soft, sparkling mica erodes rather easily into deep gulches while the harder masses of volcanic rock and quartzite remain as peaks high above them. Harney Peak projects as it does because it is a mass of granite shot into the mountain mass as molten lava. At Mount Rushmore a granite sill of the same lava forms the top of the mountain and is so dense and resistant that a massive carving has been made in it. This sill protects schists beneath it, so soft that they can almost be dug with a spade, and shiny mica flakes can be rubbed off with the hand. Terry Peak and Bald Mountain near Lead are formed similarly by a great intrusion of light colored lava which now forms their crests.



THE NEEDLES
Harney Peak, Custer County
A Majestic Achievement in Granite Sculpturing.

A unique freak of erosion carved "needles" in the granite area of Harney Peak. These needles are long spires of granite pointing skyward, making the skyline, from certain viewpoints, "look like a saw with its teeth upward."[1] Individual needles rise three score or more feet into the air and have about the proportions of a very thick lead pencil. Some spires are separate, standing out in lone grandeur, but usually they form in groups being separated from each other by narrow crevices. The Needle's eye, which is visited by most travelers on the Needles Highway is typical of such openings. In it, it is possible for a person to stand with feet and hands placed against the opposite walls of the crevice.

These carvings are the results of erosion along vertical cracks and crevices in granite. The long vertical joints allow water to enter readily and a slow process of weathering the rocks on both sides of the crevice begins. This is forcibly brought to the attention of anyone trying to use the highway tunnels for shelter from rain. Water pours through these cracks into the tunnels so rapidly that they are very little protection. The longer exposure of the upper parts of the joints have widened the crevices more at their upper end than lower down thus giving blunt points to the needles. Since two sets of vertical joints cross each other nearly at right angles, weathering has left columns of rock which are being rounded and smoothed by the action of wind, rain, and sun. Why the granite has cracked vertically in this locality is still a mystery but its effects are none the less real and have given a weird topography which is one of the scenic attractions of the Black Hills.

A backward glance will show why the Black Hills holds the interest of travelers and residents alike. A great variety of topography has been packed into a relatively small territory. The grandeur of mountain peaks and parks in the Crystalline Basin is surrounded by the rugged canyon and cave region of the Limestone Plateau. This in turn is encircled by the Red Valley and the entire section walled in by the Great Hogbacks which separate the Black Hills from the rest of the Great Plains.

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[1]A. T. Andreas, Historical Atlas of Dakota, p. 107, Chicago, 1884.

D. SUMMARY

In early descriptions of South Dakota the surface was divided into mountains, table land, river valleys, and badlands.

"The Surface may be classified, according to topography, as follows:

"First, the Black Hills, which rise as a mountainous, much eroded, dome shaped uplift, pushed up above the nearly horizontal beds which cover the region around.

"Second, the Table Lands, which occupy most of the region west of the Missouri, and smaller isolated areas east of that stream, formerly designated by the French as the 'Plateau du Coteau du Missouri,' and the 'Plateau du Coteau des Prairie,' but more frequently spoken of nowadays as the West and East Coteaus.

"Third, the River Valleys, including both the high terraces and the present flood plains, for example those of the Missouri, Cheyenne, White and James rivers of which I shall speak more in detail farther on.

"Fourth, limited areas of unique characteristics as the 'Badland' areas about the White river and also between the Moreau and Grand rivers."[1]

Such is the picture that presented itself to the early physiographers and such a grouping of features would be sufficient if this state only were to be considered. The grouping which has been given here, however, is an attempt to fit the different physiographic features into the topographic picture widely accepted by American geographers for the United States as a whole.

The two great provinces in which South Dakota lies, the Central Lowlands and Great Plains, stretch far beyond the borders of the state, as do most of the subdivisions indicated as divisions in this report. The Old Drifts division is the northern end of a large physiographic unit known as the "Dissected Till Plains" which extends southward and eastward through Iowa and beyond. The Lake Section of the Prairie Hills and the James Basin are both included in

[1]Todd, **op. cit.**, pp. 7-8.

the "Western Lake Section" of the physiographic divisions of the United States.

The subdivisions here indicated for the Great Plains Province are included in three "sections" of the standard classification for United States. The High Plains, of which we have only a small representation on the extreme southern border of the state, are the northern end of a great subdivision, that reaches south into Texas. The "Missouri Plateaus" of the standard classification include the Cretaceous Table Lands, the Tertiary Table Lands, and the Pierre Hills. The Black Hills is usually considered a separate section of the Great Plains Province and so is classified here as a division of that province.

Classifications, however, are at best only convenient handles to be used in description and have nothing to do with the use made of such a country as ours. The important thing is to recognize the great variety of topographic features this state presents and to appreciate somewhat the tremendous forces that have labored so many millions of years to bring about this variety. The coteaus with their lakes and escarpments, the rolling Great Plains with their canyons, buttes and table lands, and the mountains all give a variety to the state which is equalled in few places in the Mississippi basin. With such an appreciation the traveler may well exclaim, "I will never forget South Dakota as long as I live!" not in exasperation at the tremendous stretches of the plains but in wonder at the variety of land forms these plains have to offer. There is no lack of interest in the face of South Dakota.

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STATE PUB. CO., PIERRE