ENGINEER DEPARTMENT, U. S. ARMY.

REPORT

UPON

UNITED STATES GEOGRAPHICAL SURVEYS

WEST OF THE ONE HUNDREDTH MERIDIAN,

IN CHARGE OF

CAPTAIN GEO. M. WHEELER,

CORPS OF ENGINEERS, U. S. ARMY,

UNDER THE DIRECTION OF

BRIG. GEN. H. G. WRIGHT,

CHIEF OF ENGINEERS, U. S. ARMY.

PUBLISHED BY AUTHORITY OF THE HONORABLE THE SECRETARY OF WAR,

IN ACCORDANCE WITH ACTS OF CONGRESS OF JUNE 23, 1874, AND FEBRUARY 15, 1875.

IN SEVEN VOLUMES, ACCOMPANIED BY ONE TOPOGRAPHICAL AND ONE GEOLOGICAL ATLAS.

VOL. III.—SUPPLEMENT—GEOLOGY.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1881.

FORTY-THIRD CONGRESS, FIRST SESSION.

CHAPTER 455.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the following sums be, and the same are hereby, appropriated, for the objects hereinafter expressed, for the fiscal year ending June thirtieth, eighteen hundred and seventy-five, namely:

* * * * * * * *

For engraving and printing the plates illustrating the report of the geographical and geological explorations and surveys west of the one hundredth meridian, to be published in quarto form, the printing and binding to be done at the Government Printing Office, twenty-five thousand thousand.

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Approved June 23, 1874.

FORTY-THIRD CONGRESS, SECOND SESSION.

CHAPTER 76.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the act entitled "An act making appropriations for sundry civil expenses of the Government for the fiscal year ending June thirtieth, eighteen hundred and seventy-five, and for other purposes," approved June twenty-third, eighteen hundred and seventy-four, be, and the same is hereby, amended by adding to the clause of said act relating to the engraving and printing of the plates illustrating the report of the geographical and geological explorations and surveys west of the one hundredth meridian, the following words: "and that two thousand copies of the report shall be printed by the Congressional Printer," after substituting the word "dollars" in lieu of the concluding word of said clause.

Approved February 15, 1875.

FORTY-FOURTH CONGRESS, FIRST SESSION.

Mr. VANCE, of Ohio, from the Committee on Printing, reported the following resolution; which was read, considered, and adopted:

"*Resolved by the House of Representatives* (*the Senate concurring*), That the following distribution shall be made of the reports of the United States geographical surveys west of the one hundredth meridian, published in accordance with acts approved June 23, 1874, and February 15, 1875, as the several volumes are issued from the Government Printing Office, to wit: Nine hundred and fifty copies of each to the House of Representatives, two hundred and fifty copies of each to the Senate, and eight hundred copies of each to the War Department for its uses."

March 29, 1876. (See Congressional Record, vol. 4, part 3, page 2037.)

Agreed to by the Senate May 4, 1876. (See Congressional Record, vol. 4, part 3, page 2969.)

U. S. GEOGRAPHICAL SURVEYS WEST OF THE ONE HUNDREDTH MERIDIAN.

CAPTAIN GEO. M. WHEELER, CORPS OF ENGINEERS, IN CHARGE.

REPORT

UPON

GEOLOGICAL EXAMINATIONS IN SOUTHERN COLORADO AND NORTHERN NEW MEXICO, DURING THE YEARS 1878 AND 1879.

BY

JOHN J. STEVENSON, Ph. D.,

PROFESSOR OF GEOLOGY IN THE UNIVERSITY OF THE CITY OF NEW YORK, GEOLOGICAL ASSISTANT TO EXPEDITIONS OF 1873, 1878, AND 1879.

WITH AN

APPENDIX UPON THE CARBONIFEROUS INVERTEBRATE FOSSILS OF NEW MEXICO,

PREPARED BY C. A. WHITE, M. D.

IN FOUR PARTS AND AN APPENDIX,

ILLUSTRATED BY 4 PLATES, 3 MAPS, AND 49 TEXT CUTS

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LETTER OF TRANSMITTAL.

UNITED STATES ENGINEER OFFICE,
GEOGRAPHICAL SURVEYS WEST OF THE ONE HUNDREDTH MERIDIAN,
Washington, D. C., February 24, 1881.

Brig. Gen. H. G. WRIGHT,
Chief of Engineers, United States Army:

I have the honor to forward the manuscript of a report by Prof. John J. Stevenson, intended to be published in quarto form in pursuance of acts of Congress approved June 23, 1874, and February 15, 1875.

Mr. I. C. Russell accompanied the party, and his assistance is recognized in the body of the report.

The collections have been transmitted to the National Museum.

The work has been well and faithfully done, as the report attests, and the maps, based upon the topographical sheets as originals, afford a clear understanding of the geological formations.

Professor Stevenson acknowledges the desirable advantages of the map in hand to assist in prosecuting his examinations with more rapidity and certainty.

This report is the last of those from this office that bear especially upon geological examinations.

Very respectfully, your obedient servant,

GEO. M. WHEELER,
Captain of Engineers.

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UNIVERSITY OF THE CITY OF NEW YORK,
New York, January 15, 1880.

SIR: Herewith I submit my report upon work done in Southern Colorado and Northern New Mexico during the year 1878–'79.

Mr. I. C. Russell accompanied the party as collector in 1878, and the material sent in was obtained chiefly by him. Mr. Russell occasionally rendered some service in the geological work, as is mentioned in the report.

The officers at Forts Garland and Union gave generous assistance, which aided greatly toward the covering of a much larger area than would have been possible without the co-operation of those gentlemen. Especial mention should be made of the many favors received from Captain Shorkley, of Fort Garland, and Major Belger, of Fort Union.

Let me acknowledge the cordiality and the promptness with which you have furnished every facility for the work. Whatever of merit the report may possess is due very largely to your judicious co-operation.

Very respectfully yours,

J. J. STEVENSON.

Capt. G. M. WHEELER, *Corps of Engineers,*
In charge of United States Geographical Surveys
West of One hundredth Meridian.

NOTE.

The maps colored for this report were prepared by topographical parties under the command of Lieutenant (now Captain) Wheeler, and were in readiness before the writer took the field, so that the geology was sketched in while the examinations were in progress. It gives me much pleasure to bear testimony to the accuracy of the topography, which did much to lessen the labor of the geologist.

The cross-sections were constructed by Mr. Maxson, who made the topographical study of much of the area represented by maps 70 A and 70 C. The structure given in the southern section between the Rio Grande and the Truchas Peaks may be hardly exact. It was copied from reconnaissance sketches made by Prof. E. D. Cope and Dr. Oscar Loew while they accompanied the topographical parties; but errors in structure shown in the section cannot be charged against those gentlemen, since their original notes were not at hand for examination.

J. J. S.

U. S. GEOGRAPHICAL SURVEYS WEST OF THE ONE HUNDREDTH MERIDIAN.

CAPTAIN GEO M. WHEELER, CORPS OF ENGINEERS, U. S. ARMY, IN CHARGE.

PART I.

INTRODUCTION

BY

PROF. JOHN J. STEVENSON.

CHAPTER I.

GENERAL PHYSICAL FEATURES.

The region examined during the seasons of 1878 and 1879 extends north to north latitude 37° 20′, and embraces parts of North Central New Mexico, and South Central Colorado. It lies wholly east from the cañon of the Rio Grande, includes the mountain area of the Spanish ranges to their southern termination, and takes in the eastern plains to west longitude 104° 7′ 30″. But of this region a strip between the Rio Grande and the mountains, lying south from north latitude 36° 40″ was not visited; and the total area colored on the maps is not far from 10,000 square miles.

The Spanish ranges, which are virtually a continuation of the Sangre de Cristo Range of Southern Colorado, occupy the western side of the area and terminate near north latitude 35° 20′. They are narrow at the north, where but one range, the Culebra, exists; but that range divides and subdivides southward until the Santa Fé, Las Vegas, Mora, and Cimarron Ranges represent the Culebra, and the width of the mountain belt, barely ten miles at the northern border of the district, becomes forty miles at the latitude of Rayado Cañon. Thence southward, the gradual diminishing of the axes causes decrease of elevation in the ranges, which disappear at last in a great plain at the south. The ranges as designated on the maps were determined by the topographers, and they do not coincide in every case with the geological axes to which I have applied the same names.

A gently-sloping plain stretches from the mountains to the Rio Grande at the west; but broken country intervenes between the mountains and the Canadian Plains at the east, while southward beyond the termination of the great mountain axes is a mesa region, with here and there a short local axis marked by an abrupt ridge.

This district includes portions of two great drainage areas—that of the Arkansas and that of the Rio Grande—and lies wholly east from the continental divide.

The Arkansas River itself is not reached by the district, and that part of its area to be described in this report is drained by the Purgatory and the Canadian, the one entering the Arkansas at Las Animas, seventy miles east from Pueblo, while the other, flowing southward and then eastward, enters the river at about forty miles west from the eastern boundary of the Indian Territory.

The Arkansas area is separated from that of the Rio Grande by high mountains at the west and by an almost imperceptible divide at the south. It is shown on maps 70 A and 70 C, which exhibit also the peculiarities of its topography. The region embraced by map 70 A has a broken area between the mountains and the plains, which, at the southern line of Colorado, reaches eastward to beyond the limits of the district. This broken area, extending southward to barely beyond the border of that map and holding the important coal-beds of the Laramie group, has as its eastern boundary a bold bluff, from 300 to 500 feet high, which is unbroken both north and south from the Raton Plateau, save by narrow cañons through which the streams flow. The transition on the west side from the broken to the mountain region is as distinct as that to the plains.

The features are somewhat different within the space shown by map 70C; for there, instead of the chopped surface, a mesa intervenes between the mountains and the plains; the plains themselves are more forbidding than they are farther north, as the hard Dakota sandstone has not yielded readily to erosion, and the plain, instead of sloping to the rivers, is broken by the deep cañons in which the streams flow.

The Rio Grande is practically the western boundary of the district assigned, but unfortunately it could not be reached at any locality south from the line of Colorado Creek on map 69B. Narrow plains intervene between the west base of the mountains and the cañon of the river, which are cut by numerous streams to which reference will be made in another part of this chapter. Much of the Rio Grande area is covered with rugged mountains, but these break down southward into the mesa region, which is continuous with the great plains of the Arkansas in Colorado and the Indian Territory, and of the Rio Grande in Texas.

THE STREAMS.

The Purgatory River is formed by the union of several large streams near the foot of the Culebra Range, which drain the eastern slope of that range from the northern edge of the district almost to the southern boundary of Colorado. The river flows eastward through the Laramie area in a valley of varying breadth, which nowhere contracts into a close cañon below the mouth of the South Fork. It receives numerous tributaries from both sides, most of which have cañons varying in width from closeness to open parks. The course of the Purgatory through the plains is northeastward for about fifteen miles, beyond which it is southeastward.

The Canadian River of this region is the South or Red Fork of the Canadian, and is known locally as the Red River, a name given promiscuously by the Mexicans to any stream with reddish water. It was supposed by the early geographers to be identical with the Red River of Louisiana; but the error was detected by Colonel Long, and afterwards the true relations of the stream were determined by Captain Marcy during his Red River Expedition.

The Canadian River is formed by the union of Willow Creek with the Upper Canadian nearly due west from Eagle-tail Mountain, whence it follows a rudely southward course to beyond the region examined. It drains nearly the whole of the mountain slope between the Colorado line and north latitude 35° 45′, the whole of the Trinidad coal-field in New Mexico, the whole of the Ocaté Mesa, and the southern slope of the volcanic area in the northeastern part of the district. It receives many important tributaries, of which Mora River, Ocaté, Cimarron and Vermejo Creeks are the largest.

The river flows through the plains in a narrow and shallow channelway from the union of its forks to the old Leavenworth road, where its cañon begins.

Willow Creek, the more important fork of the river, is formed by the union of two streams which drain the southern face of the Raton Plateau and flow in close, short cañons from their heads to the plain, where their channel-ways are similar to that of the Canadian. The Upper Canadian, the other fork, rises midway in the Laramie area and flows through an ugly cañon, from 200 to 700 feet deep, which seldom widens until it approaches the plain. Thence the stream flows in a shallow trough to its junction with Willow Creek.

Vermejo Creek, which drains a large part of the mountain region and much of the Laramie area, is a bold stream, rising on the east slope of the Culebra Range and crossing the Laramie area by a fine cañon to the plain, where it flows to the Canadian in a shallow channel-way. Several of its tributaries pass through striking cañons, and the plateau drained by them is broken up into picturesque parks.

Cimarron Creek, formed in the trough between the Cimarron and the Taos Ranges, by the union of two important creeks, flows through a deep and impressive cañon to the plains. The cañon is divided by the valley of Ute Creek, a stream which heads on the side of Old Baldy not far from South Poñil Creek, another tributary to the Cimarron. Several important streams enter the creek after it reaches the plain, so that its drainage area includes much of the Laramie region, nearly the whole of the Cimarron Mountains, and much of the Taos Range. Its course is south of east across the plains to the Canadian River, which it reaches at but a little way above the head of the great cañon.

Ocaté Creek rises midway in the Ocaté Mesa and flows eastward to the Canadian, reaching that river at three miles below the head of its cañon. It runs through a narrow cañon to the plains, where the channel-way is shallow, until, within a few miles of the Canadian, it becomes a rapidly deepening cañon.

The Canadian River flows in a deep cañon from the Leavenworth crossing to beyond the southern limit of the district. It is joined by the Mora River very near the southeast corner of the region represented by map 70C, a stream which drains a huge scope of mountain region as well as much of the plateau area between the mountains and the plains. Like the Canadian, it flows for many miles in a close cañon, so close that for thirty miles above its mouth there is no break for a wagon-road, and but one or possibly two breaks suitable for even difficult trails. Farther up, however, the cañon widens somewhat, becomes less deep, and its walls are more or less irregular, so that wagon-roads may be constructed at not a few localities between the head of the main cañon, at Cherry Valley, and Coyote Creek. Occasionally, as at Golondrinos, Loma Parda, and Tiptonville, it opens into a park wide enough to admit of cultivation.

The several large streams going to make up the Mora River drain the whole of the Mora Range and so much of the Las Vegas Range as is north from north latitude 35° 45′. They are Coyote, Mora, and Sapillo Creeks, with some scarcely less important tributaries, known as Cebolla and Manuelitos Creeks. All of these flow in broad cañons, which occasionally become close, though for but short distances. For the most part they are below the upper limit of agricultural operations, and the broad parks afford opportunity for successful farming.

The deep cañon of the Rio Grande, following the western edge of the area, was not reached at any locality south from Los Cerros, at the mouth of Colorado Creek. Most of the tributaries to that river are insignificant, though some of them drain large parts of the mountain slope.

Culebra Creek, formed in a small park or outlier of the San Luis Basin by several small streams which unite at about eighteen miles south from Fort Garland, flows near the northern border of map 70 A, and drains the mountain area as far south as the New Mexico line. Its forks flow in deep cañons, which widen to neat little parks within a few miles of their junction, below which the main stream flows westward through the plains to the river, with but one rocky cañon on the way.

Costilla Creek, rising on the east side of the Culebra Range, breaks through those mountains, and reaches the Rio Grande plain at Costilla, nearly thirty miles south from Fort Garland and just on the New Mexico line. Its sources are separated by low divides from Culebra Creek on the one side and from Vermejo Creek on the other. The forks unite in a park, through which the stream flows southwardly to its junction with Comanche Creek, a tributary coming from the south, and rising in Moreno Pass. From the mouth of that stream the course is sharply northwestward to the plains, and the channel-way is through a magnificent cañon for somewhat more than eight miles. Costilla Creek carries a large amount of water, but this is wholly drawn off for irrigating the farms at Costilla, and the stream does not reach the Rio Grande except during extreme floods.

No other large stream exists southward until Colorado Creek is reached at twenty miles away. Several small ones issue from short cañons, but, like Costilla, they soon sink in the sands and are lost before reaching the river. Colorado Creek, however, crosses the plain and supplies water for irrigating farms which support a population of several thousands. It rises on the east side of Taos Mountain and flows northward for twelve miles through a deep and narrow cañon to almost west from Red River Pass, where its course is changed to westward. The channel-way from the head of the creek to the town of Colorado follows a cañon, which is one of the most impressive within the district. The drainage area is insignificant, as the walls of the cañon are very steep and the tributaries are few.

Some short rapid streams were seen between Colorado Creek and the Taos Basin, which carry much water and rise in the range which culminates in Taos Peak. They have digged out gloomy cañons in the side of that range, and a labyrinth of gorges occurs in the vicinity of the peak.

Several large streams unite in the Taos Basin to form Taos Creek. Pueblo Creek, formed by Lucero, Pueblo, and Ferdinand Creeks, flows across the northern part of the basin, while Frijole Creek comes from the south and drains the western slope of the Mora Range, as well as the eastern slope of the U. S. Mountain. These are rapid streams and carry a great body of water throughout the year.

Junta Creek rises near the crest of the Mora Range and flows westward through a succession of bold cañons past the southern foot of the U. S. Mountain, where it turns southwardly and enters Embudo Creek, which is a tributary to the Rio Grande. It drains much of the Las Vegas Range and the northern part of the Santa Fé Range.

Galisteo Creek rises near the southern extremity of the Santa Fé Range, flows southward to beyond Galisteo, and thence westward to the Rio Grande. It is an insignificant stream, though its arroyo seems to indicate that at some seasons it is greatly swollen. But there must be water at no great depth, for at many localities a dense growth of willow and cottonwood lines its banks. It drains an extended area within the mesa region into which the mountain ranges break down at the south, but has no tributary carrying a constant supply of water.

The Pecos River rises in the trough between the Las Vegas and the Santa Fé Ranges, and flows south and southeast to beyond the district. Its course for nearly twenty miles from the head is through a deep cañon, in which it receives many tributaries from both ranges. Within the district it receives Vaca Creek, rising on the west slope of the Las Vegas Range, and carrying scarcely less water than the upper Pecos. Farther east are Bernal, Tecolote, and Gallinas Creeks, large streams, entering the river beyond the southern limit of the district. Bernal Creek rises in the southern part of the Las Vegas Range and splits the anticlinal; but the others rise on the east slope of that range. The Pecos enters the Rio Grande near the Mexican border.

THE DIVIDES.

The divide between the area of the Rio Grande and that of the Arkansas does not coincide wholly with the ranges designated on the map as the Culebra, Mora, and Las Vegas; for in several instances streams break through those mountains, and the divide is found as often in the lower as in the higher ridges.

This divide enters the district at the north and follows the crest of the Culebra Range for twenty-two miles of latitude to the head of Costilla Creek, where it is thrown off toward the east; thence it continues irregularly southward for twenty-one miles of latitude to Moreno Pass, where it turns west for several miles to Red River Pass; but at that pass it resumes a southerly course, which is retained to the head of Mora Creek, a distance of thirty-seven miles of latitude; thence to Mount Solitario, thirty-three miles of latitude, the course is very tortuous, though in the main southward; but at Solitario its direction is wholly changed, and from the head of Sapillo Creek it passes east and southeast across the plains. The divide, therefore, is in five divisions, easily distinguishable by the changes in its course.

The *first division* is a great mountain range, deeply cut on each side by ravines, reaching far toward the interior of the range, and terminating near the crest in deep amphitheaters. A wall of Cretaceous sandstone follows the eastern foot of the range from the Spanish Peaks, behind which and stretching back to the abrupt portion of the mountain are low narrow hog-back hills through which the many streams flow in cañons. Culebra Peak is 14,049 feet high, and other peaks rise to more than 12,000 feet, so that this part of the divide is no less imposing than the Sangre de Cristo range farther north. No pass, practicable for loaded animals, exists, and the single imperfect trail, crossing immediately south from Culebra Peak, is so difficult that even the Indians used it but little. The crest-line of the ridge is simply a knife-edge overlooking vast amphitheaters in which there is more or less of snow throughout the year.

The *second division* is by no means so grand as the first. It lies east from the main range, which continues southward in a southwest direction to near Taos, where it breaks down very suddenly. The divide itself winds round among the headwaters of Vermejo and Costilla Creeks, seldom rising to more than 11,000 feet and showing only one conspicuous point—the dome-like mass of eruptive rock designated on the map as Costilla Peak. From that peak to Moreno Pass, the divide lies in the foot-hills. The only pass is by a saddle at the head of Costilla Creek at the west and of Vermejo Creek at the east. Following the gloomy cañon of Costilla Creek from the Rio Grande Plains, one reaches the summit by gentle approaches. The road crossing here was constructed at great expense, as the cañon, though more than 2,000 feet deep, is often hardly wide enough for the roadway, which for many yards at a time spans the chasm. The pass itself is low and broad, but the approaches on the Vermejo side, as used by the road, are not equal to those on the Costilla side, and at one place the descent is far too abrupt. An excellent road might be constructed here, which could be kept open during the greater part of the year, though some difficulty might be experienced, as the parks on Costilla Creek are apt to be filled with snow in October or early in November. No trails were seen which seem to have been used much, except one, now very dim, ascending Leandro Creek and passing in front of Costilla Peak to Comanche Creek.

This, however, has severe grades, and, for most of the way, is too marshy for use as a road-bed.

The *third division* has a southwest direction from Moreno Pass to Red River Pass, but from the latter pass to the head of Mora Creek its course is almost south. This division is utterly unimposing and follows the foot-hills of the Taos Range for more than half its length, while beyond that it follows the crest of the Mora Range, where the scenery is very tame. The rugged mountains of the Taos Range lie wholly within the Rio Grande area.

Though this division seldom rises to more than 10,000 feet above tide level, its slopes are not easily overcome. Moreno Pass, from Comanche to Moreno Creek, is at 9,770 feet, and has gradual approaches on both sides, but the summit is marshy and not altogether safe. No road has been constructed over this pass, but it is followed by an old Indian trail, which is still used. A road could be made without difficulty, though not a little labor would be needed to prepare the road-bed near the mouth of the creek above Elizabethtown.

Red River Pass leads from the West Fork of Moreno Creek to Colorado Creek, and its altitude at the summit is 9,764 feet. The approach from the east side is very gradual quite to the open summit, and the cañon is so wide that an unexceptionable grade can be obtained; but on the other side the grade is painful, even for riding animals, and the gorge followed by the road is so narrow that any improvement seems to be impossible. While the Moreno district was prosperous and Elizabethtown was an important distributing center, a toll-road, constructed at great expense, was maintained over this pass; but it has fallen into decay, and the floods of Colorado Creek have destroyed it utterly for miles. The trail over the pass is easily kept open during the winter.

Taos Pass leads from the Moreno Valley to the head of Ferdinand Creek, and its summit is at 9,095 feet above tide. The approach on the north or Canadian side is extremely difficult for several miles, but on the southern or Rio Grande side the approaches are gentle until within probably 300 yards of the summit, beyond which the grade is somewhat severe. This is crossed by the stage road from Cimarron to Taos. Much labor has been expended in constructing the road on both sides, and the limit of improvement seems to have been reached. The summit is sufficiently open to render long closing by snow altogether improbable.

At one time a government road crossed the Mora Range from Black Lake to the head of one fork of Frijole Creek, but, having been abandoned many years ago, it has become very dim. This road followed no pass, but was simply a roadway cut through the forest without regard to grade. Information respecting this is obtainable with difficulty, but such as could be obtained leaves no room for supposing that it possessed any of the characteristics usually supposed to belong to a convenient roadway.

A trail leads from Six-mile Creek over to the head of Lucero Creek and thence to Taos, but it is too difficult for any common animals, and it certainly was never employed except by foot-passengers. A trail was seen leading up the mountain side back from Elizabethtown, which crosses over to Colorado Creek. The grade is not severe until near the summit of the divide.

The *fourth division* is much like the third until the head of Las Casas Creek is reached. The mountains are low and their crest is regular. Mora Peak rises to 12,020 feet, but for the most part the elevation is barely 10,000 feet. Southward from Las Casas Creek, the eastern face of the divide is a rugged, almost precipitous wall, which extends to Mount Solitario. The course is southward, but the line of the divide is very irregular, and lies east from the crest of the ridge.

Though low and with a regular crest line, this part of the divide shows no good pass. A dim trail leads from the head of Mora Creek to a fork of Frijole Creek, but is useless to the traveler. A road, designated on the map as the Taos Freight-road, crosses to Junta Creek from Água Negra on Mora Creek; but the grade is difficult and long, for it follows a winding line up the declivity, so that for the last half mile it is difficult for even an unloaded animal. But the road is well constructed. The grade near the summit on the west side is by no means so severe, and within a mile it becomes gentle. This road unites at the forks of Junta Creek with the main road from Fort Union to Taos, which leaves Mora Creek at San Antonio and crosses the divide by an easier grade.

Trails are said to cross the range at the heads of Manuelitos and Sapillo Creeks, but these were not attempted, and no positive information could be obtained respecting them.

The *fifth division* of the divide is insignificant, and, for the most part, it is but a gentle roll in the plain. Good roads cross it at many places.

Most of the passes referred to have been used for wagon-roads at some time, and as they are indicated as wagon-road passes on the maps, it may be well to specify, for the benefit of travelers, such of them as are available. Costilla and Taos Passes at the north alone are now crossed by wagon-roads, and even on the Costilla road there are places where only a very expert driver could take a wagon through without upsetting. Red River and Moreno Passes are crossed only by trails, and a wagon cannot be taken over them; a wagon can be taken over the divide by the Taos Freight-road, but the passage will be slow. The road is very good, both by that line and by the regular route, from Fort Union to Taos.

The Taos Range is nearly related to the divide. It begins at Costilla Creek and ends at Ferdinand Creek. This should not be separated from the Culebra Range, and the distinction is purely artificial, being due altogether to the supposed necessities of the topographer. The range lies wholly within the Rio Grande area, and no stream entering the Canadian heads in it. Between Colorado and Costilla Creeks the mountains are very rugged, and the sides are deeply scarred by cañons whose walls are so abrupt that they cannot be climbed. No trail exists. South from the cañon of Colorado Creek the ridge is not harsh, but a congeries of deep amphitheaters clusters about Taos Peak, whose highest point has an altitude of 13,480 feet.

The divide between the Canadian and the Purgatory runs irregularly eastward and lies not far from the southern boundary of Colorado. It is crossed by good passes in the Stone-wall Valley at an altitude of 9,178 feet, at the head of Long's Cañon at 8,134 feet, at the Raton at 7,893 feet, and at Manco Burro at about 8,000 feet. Good wagon-roads follow these passes, and in all, except Manco Burro, the approaches are gentle throughout. The Raton Pass is followed by the Atchison, Topeka and Santa Fé Railroad, which avoids the short abrupt grade near the summit by means of a tunnel. Manco Burro Pass is little used, but that by way of the Raton has long been the highway from the north for all traffic going toward Santa Fé.

This divide, away from the immediate slope of the Culebra Range, shows no sharp hills, and is marked only by the low flat summits within the Raton Hills. Its highest portion is in the Raton Plateau, where the basalt cap has protected the lower rocks from erosion.

The divide between the Rio Grande and the Pecos is somewhat complicated, though for the most part not obscure within the district. At the north it extends westward from the Las Vegas Range as a narrow, sharply defined ridge, to the Truchas Peaks, with an altitude of nearly 13,000 feet, while the highest of those peaks is but 13,150 feet. From the Truchas Peaks it follows a southwest direction to the head of Piños Creek, where it bends to east of south and soon becomes the edge of the bold mesa, under which the Santa Fé and Las Vegas stage-road passes. It is exceedingly sharp all the way, but shows a gradually decreasing height from the Truchas southward. In this part, it coincides with the crest of the Santa Fé Range. Lake Peak rises to 12,405 feet, while the Cone and Old Baldy, the one immediately east and the other immediately west from the line of the divide, are respectively 12,690 and 12,661 feet above tide. After passing the stage-road at the head of Piños Creek one finds the divide even better marked than before, since it is the crest of the bold mesa bluff, which is continuous thence in a southeast direction to beyond the southern limit of the district.

No trail crosses the divide in its first division, but a strong trail passes over the second division immediately south from the cone. Another, still used, follows Santa Fé Creek to the summit, and thence descends one branch of the Pecos to Los Machos, at about eight miles above Pecos. This trail continues across the Las Vegas Range to the head of Gallinas Creek, and descends that stream to Las Vegas. Beyond this, southward, passes are numerous and several good roads cross the divide. The highest point is the Cerro Escobas, at 8,278 feet.

The short but bold Cimarron Range trends rudely east of south and forms the divide between the tributaries of the Cimarron, rising in the mountains, from those of the same stream which rise within the Laramie area or the Raton Hills. It breaks down suddenly at the south and is merged into the lava-covered plateau, which is designated in this report as the Ocaté Mesa. The range is narrow at the north, but being composed in great measure of dikes, which increase in number and size as they advance southward, it widens in this direction. North from Cimarron Creek it consists almost solely of the volcanic masses known as Old and Little Baldy, with lower hills farther north; but south from the cañon of that stream the width of the ridge is greatly increased, and several of its peaks rise to fully 11,000 feet.

This range is cut to the base by the deep and rugged cañon of Cimarron Creek, through which an excellent road passes. Immediately north from Old Baldy is a saddle, known as Poñil Pass, which is crossed by the Elizabethtown and Trinidad road. It has nearly the same altitude with Moreno and Red River Passes, being 9,750 feet above tide. The approach on the west side is very difficult, but much of the difficulty might have been overcome by making the road less direct. The approaches from the east are good and there is no difficulty on the road except at the descent from Poñil Park to South Poñil Creek, where the grade is long and painful. An old Indian trail crosses from American Creek, in the Moreno Valley, to Urraca Creek, in the plains, but it has fallen into disuse, and it cannot be followed by one unacquainted with the country. A good trail, passable for wagons, crosses the more elevated part of the Ocaté Plateau, from Rayado Creek to the Black Lake on Coyote Creek, not far below the divide between that stream and the headwaters of the Cimarron.

The divides between the tributaries to the Mora are comparatively insignificant, not because of their height, but because of their shortness. That between the Mora and the Coyote is an imposing range. All of these divides are crossed by easy trails and in some cases by wagon-roads. Excellent wagon-roads could be constructed at many localities, but the necessities of the present inhabitants call for little more than trails for pack animals.

CHAPTER II.

NOTES RESPECTING PREVIOUS EXPLORATIONS.

The region described in this report is not wholly unknown to geologists. Numerous parties of exploration have visited portions of it, and one party made a geological reconnaissance of the northern third. That the reader may understand how much of the ground is newly discussed in this report, it may be well to give here a brief *résumé* of the work performed by various expeditions.

The earliest American exploration of any part of the area was the wholly accidental one by Major Pike in 1806 and 1807. That officer was sent with a small party to explore the Arkansas River to its head, and to return thence to Natchitoches, La., by the Red River, which was supposed to have its sources near those of the Arkansas. He became confused amid the headwaters of the Arkansas, Platte, and Blue Rivers, and, crossing the Sangre de Cristo Mountains, came to the Rio Grande del Norte. Supposing that to be the Red River of Louisiana, he built a stockade for protection against the Indians. Only a short time elapsed before he was visited by some Spanish officers, who, explaining his geographical position, showed him that he was trespassing on the Spanish domain. They conducted him to Santa Fé, whence, as prisoner, he made an unwilling exploration southward to Chihuahua. There his papers were examined, and many of them were retained on the plea that they were dangerous to the Spanish Government. Major Pike returned to the United States by way of Texas in charge of the Spaniards. Though failing in the original object of his expedition, he added greatly to the stock of geographical knowledge, and the map, where based on the personal observations of Pike or his associates, is fairly accurate. No notes on the geology are given in Pike's report.

In 1845, Captain Frémont detached Lieut. J. W. Abert to survey Purgatory Creek, the waters of the Canadian, and the False Wishita. Starting from a trading post on the Arkansas, known as Bent's Fort, this officer followed the Santa Fé road southward across Raton Pass and camped on the waters of Willow Creek, one of the principal forks of the Canadian. Thence he followed that river to the head of its cañon at the old Leavenworth crossing, as it is now known, where he turned slightly eastward to avoid the long arroyos reaching back from the cañon. An extensive arroyo, the Arroyo de los Yutas, or Salt Creek, was followed down to the river, which was reached below the mouth of the cañon. Thence by a somewhat tortuous route the party traveled to Fort Gibson near the mouth of the Canadian.

In his report,* Lieutenant Abert describes the general features of the eruptive rocks near Eagle-tail Mountain, and plates are given illustrating the basalt on the Raton Plateau and the dikes on the Canadian River; while others of the plates are excellent illustrations of the peculiar bluff structure shown along the Canadian and Purgatory. The author surmises the existence of *coal* from the appearance of the bluffs near the junction of Vermejo Creek with the Canadian; he describes the lithological features of the Canadian Cañon, and gives some notes which he had received respecting the occurrence of gold in the Placer Mountains far toward the southwest.

In 1846, Dr. A. Wislizenus left Saint Louis, intending to make a scientific tour through Northern Mexico and Upper California; but the war between Mexico and the United States began while he was at Chihuahua, and the Mexicans compelled him to remain in "a passive" condition at that place until the arrival of Colonel Doniphan. He accepted the post of surgeon under Doniphan, with whom he returned to the United States by way of Monterey.

Dr. Wislizenus's course from the Arkansas was by way of the Dry Cimarron road, and he reached the Canadian at the old Leavenworth cross-

* Senate Document No. 438, Twenty-ninth Congress, First Session.

ing. Thence taking the route since followed by the Santa Fé and Fort Leavenworth road, he crossed Ocaté Creek, passed the Wagon Mound, crossed Wolf Creek and Mora River, and followed Gallinas Creek to Las Vegas. From Las Vegas he went to Santa Fé, passing through Tecolote, Bernal, San Miguel, and Pecos. His course from Santa Fé was southward through Galisteo, Albuquerque, Socorro, and El Paso to Chihuahua.

His Memoir * was an important contribution to science. It contains a botanical appendix by Dr. George Englemann, describing the plants collected by Dr. Wislizenus and Dr. Gregg; tables of meteorological observations extending from May, 1846, to June, 1847, and a geological map with special notes on geology; while geological notes are plentifully distributed throughout the memoir. The basalts northeast from the Canadian, as well as those on Wolf Creek and on Wagon Mound, are described; the Cretaceous is mentioned as occurring on Gallinas Creek; and some interesting details are given respecting the relations of Archean and Palæozoic rocks in the vicinity of Santa Fé. Dr. Wislizenus made a careful examination of the Placer Mountains; he mentions the existence of silver mines in the Cerillos, of copper and iron at many localities, and refers to the bituminous coal in the Raton region.

In 1846, Maj. W. H. Emory started from Fort Leavenworth and followed the Arkansas River, up which he went to Bent's Fort, where he joined himself to General Kearney's "Advanced Guard of the Army of the West." Thence he traveled southward, crossing Raton Pass and moving along the edge of the foot-hills to Las Vegas, whence his route to Santa Fé coincided closely with that previously followed by Dr. Wislizenus. From Santa Fé, the army went southward for 230 miles, and thence westward to the Gila and Colorado Rivers, beyond which it went northwest, crossed the Coast Range, and finally reached San Diego in California. Major Emory's report† contains a botanical appendix by Prof. J. Torrey; elaborate tables of meteorological observations; an appendix on general natural history by Lieutenant Abert; and geological notes are freely scattered throughout the report.

* Senate Miscellaneous Document No. 26, Thirtieth Congress, First Session.
† Executive Document No. 41, Thirtieth Congress, First Session.

But the more important report is that by Lieut. J. W. Abert, contained in the same volume. Though connected with the Army of the West, Lieutenant Abert was separated from it by sickness and was compelled to make independent explorations. His report gives much valuable information respecting the geology of the region bordering on the Santa Fé road, between the Purgatory River and Las Vegas. The existence of bituminous coal within the Raton region is announced; the frequent occurrence of basalt in the same region is discussed; the two benches of the basalt-covered Ocaté Mesa are recognized; the Placer mines south from Santa Fé are carefully described, and notes are given respecting the occurrence of eruptive rocks in their vicinity. Lieutenant Abert made extensive collections of impressions of deciduous leaves in the Raton region, which were submitted to Professor Bailey, of West Point, whose conclusions respecting them are given in the appendix to the report.

Prof. Jules Marcou accompanied Lieutenant Whipple in his exploration for a railway route in the vicinity of the thirty-fifth parallel. On his return Professor Marcou prepared a *résumé* of the geology, which was published in Lieutenant Whipple's preliminary report in 1855;* but no full report was prepared by him, as he was compelled by failing health to return to Europe. His notes and specimens were placed in the hands of Prof. W. P. Blake, and a report, compiled by that gentleman from various sources, was published as part of Lieutenant Whipple's final report upon the route.† To this was appended a literal copy and translation of Professor Marcou's rough field notes; an operation to which few field geologists would like to submit.

For the most part the area examined by the writer is north from the line followed by Professor Marcou; but some notes are given by that gentleman upon the Galisteo and the Pecos, which he visited during an excursion to Santa Fé. He places in the Jurassic the sandstones shown in the vicinity of Galisteo, and regards certain Cretaceous shales seen north from Galisteo as equivalent to the white chalk. The sandstones immediately north of Galisteo, and cut by the dike which separates the divisions of the

* House Document No. 129. 1855.
† Pacific Railroad Reports, Volume III.

Galisteo Valley, he places in the Triassic. The Jurassic of this author includes the Upper Dakota of this report as well as the Fort Benton and Niobrara shales of the Colorado group. The Carboniferous, Triassic, and Jurassic formations were found by Professor Marcou to be conformable to each other, but unconformable to the Cretaceous above them. The Trias was recognized by him in the Pecos Valley.

Professor Marcou made collections of fossils from the Cretaceous shales immediately north from Galisteo and from the Carboniferous limestone near Pecos. He places the latter rock in the Lower Carboniferous.

Dr. J. S. Newberry accompanied Lieut. J. C. Ives on the Colorado Exploring Expedition of 1857–'58, and Capt. J. N. Macomb on the San Juan Expedition of the summer of 1859.

The Colorado Expedition was disbanded at Fort Defiance, near the border between New Mexico and Arizona; but as Dr. Newberry continued eastward by way of Santa Fé to Fort Leavenworth, he entered the region examined by the writer at Galisteo Creek, and left it beyond the Canadian River. His route from Santa Fé to Las Vegas was along the road now followed by the stages, and thence by the old Leavenworth road to the Canadian crossing, coinciding therefore with that followed by Dr. Wislizenus in 1846. The Geological report* was by far the most important contribution up to the date of its publication. It was the first to give any clear conception of the geological structure of any extended part of the Territories.

Dr. Newberry placed the Galisteo coals in the Cretaceous, and referred the underlying rocks to the Trias, of which he recognized two groups—the Marl series and the Salt group. He obtained Cretaceous fossils at a little way north from Galisteo, and regarded the rocks from which they came as belonging to the same horizon with the shales on Ocaté Creek. He describes the Cerillos as volcanic cones, and speaks briefly respecting the many dikes in the vicinity. The sandstones on the crest of the Pecos bluff are referred to the Cretaceous, and the Carboniferous rocks of Santa Fé and the Pecos are recognized as equivalent to the Coal Measures. The geology between Las Vegas and the Canadian is briefly but suggestively described.

* Report upon the Colorado River of the West, by Lieut. J. C. Ives, Washington, 1861.

Unfortunately the breaking out of the Civil War prevented the publication of Dr. Newberry's report* on the San Juan, which was not issued until 1876. In the mean time, other investigators had studied the same region and had published their results; so that the importance of this report is not likely to be fully appreciated. Like that on the Colorado River region, this report is a clear and concise statement of the structure. Had it been published promptly, the labors of later explorers would have been lightened.

During this exploration, Dr. Newberry made careful sections of the Carboniferous in the vicinity of Santa Fé, and obtained many details in the vicinity of the Pecos, some of which led him to suspect the existence of Permian. He refers the gypsiferous beds of the Pecos Valley to the Triassic, and the sandstone capping the mesa there to the Lower Cretaceous. The coal-beds of the Galisteo are regarded as belonging to the Middle Cretaceous. The beds themselves are described in detail. The only Tertiary rocks recognized by the author are tufaceous limestones occurring in small patches.

During the summer and autumn of 1867, Dr. J. L. Leconte examined the region immediately bordering on the road leading from Trinidad to Las Vegas, and thence to San José. At the Pecos River his route diverged from the stage-road, and, rising upon the mesa, he continued in a south-of-west direction to Albuquerque, whence he went southward to Fort Craig. Though, like all the other explorations thus far mentioned, this examination was confined to but a narrow strip on each side of the route, the report† added much to the stock of information respecting the region between Trinidad and Fort Union, for little was known before, aside from what could be gathered from Lieutenant Abert's report of 1846.

Dr. Leconte visited and described the coal mines at Trinidad, as well as those between Trinidad and Raton Pass. He obtained an obscure *inoceramus* from one of the yellow sandstones above a coal-bed, and near it he collected some plant remains, referred by Mr. Lesquereux to *abietites*

*Report of the Exploring Expedition from Santa Fé, N. Mex., &c., with Geological Report, by Prof. J. S. Newberry, Washington, 1876.

†Notes on the Geology of the Survey for the Extension of the Union Pacific Railway, E. D., from the Smoky Hill River, Kansas, to the Rio Grande, by John L. Leconte, M. D., Philadelphia, 1868.

and *credneria*. He made sections of the coal-bearing rocks in Vermejo Cañon and some of its tributaries; mentions the placer mines of the Cimarron and the existence of copper in that vicinity; described the volcanic cones near Fort Union; identified the Cretaceous at Las Vegas, and obtained some interesting notes respecting the Hot Springs near that town, though the Carboniferous limestone of that locality escaped his attention.

During an excursion from Santa Fé, Dr. Leconte visited the Galisteo region, and a section was made of the coal-beds, which he referred to the Lower Cretaceous. During this excursion, also, he made full notes concerning the placer mines near the Galisteo.

In 1869, during his reconnaissance, Dr. F. V. Hayden entered the area under consideration at the Purgatory River, and continued southward along the stage-road to Las Vegas, making excursions up Purgatory, Vermejo, Ocaté, Mora, and Gallinas Creeks. From Las Vegas he followed the stage-road to Santa Fé, whence he made an excursion to Gallisteo Creek and the Placer Mountains. From Santa Fé he returned northward along the Rio Grande plains to Fort Garland.

The examinations in the Raton Hills showed the great extent of the coal-bearing group, and led Dr. Hayden to suppose that that group extends well up to the mountains all the way from the Spanish Peaks at the north to Cimarron Creek at the south. The whole group is referred to the Tertiary.

Dr. Hayden makes mention of the basalts south from Cimarron Creek, and described the volcanic craters near Fort Union. The Cretaceous shales, exposed south from Cimarron Creek, are referred to Cretaceous No. 2. During the excursion up Mora Creek, the great extent of Cretaceous No. 1 was ascertained, and the relations of the Carboniferous to the Archæan were determined. A section from the Dakota to the Archæan was made on Gallinas Creek.

The observations between Las Vegas and Santa Fé are very similar to those made by Dr. Newberry, but the sandstone on the mesa top along the Pecos is referred to the Jurassic. Some interesting notes were obtained respecting the geology of the Upper Pecos.

Dr. Hayden regards the coal-beds of Galisteo Creek as Tertiary. On that creek he recognized a new series of beds, which he terms the Galisteo group and places in the Tertiary. He states in his report* that this group rests conformably upon the coal-bearing rocks, and that it underruns unconformably a newer group, which he designates as the Santa Fé marls, and finds in great thickness throughout the Rio Grande Valley north from Santa Fé.

In 1874, Prof. E. D. Cope, connected with a division of Lieut. G. M. Wheeler's Expedition, went from Fort Garland to Santa Fé by way of the Rio Grande plains and made occasional studies of the geology along the west base of the mountains. These studies were extended to the Sandia Mountains, about forty miles south of Santa Fé.

Professor Cope traced the Santa Fé marls of Hayden along the base of the mountains, and, by means of vertebrate remains obtained near San Ildefonso, was enabled to refer them to the Loup River epoch of the Pliocene. The examination of the Galisteo Creek region led Professor Cope to place the coals in Cretaceous No. 3 and the Galisteo sandstone in Cretaceous No. 4.

In the same year Dr. Oscar Loew,† also connected with Lieutenant Wheeler's Expedition, crossed the mountains from Santa Fé to Las Vegas, and his notes first gave any information respecting the interior of the mountain area. From these we learn that, where crossed by the Santa Fé and Las Vegas trail, the mountains show no basalt, trachyte, or rhyolite, and that no rocks later than the Carboniferous occur, except in the "lower regions toward the base of the mountains," where the newer rocks are shown.

Before leaving Santa Fé, Dr. Loew visited the Galisteo region, where he collected specimens of the coals. Analyses of these coals and of the waters of the Las Vegas Hot Springs are given by Dr. Loew in Vol. III of the Wheeler reports.

In 1875, Lieut. W. L. Carpenter, in charge of a topographical party belonging to the Wheeler expedition, explored the mountain area from La

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* Preliminary Field Report of U. S. Geological Survey, Washington, 1869.

† The reports by Professor Cope and Dr. Loew are given in Lieutenant Wheeler's report, published in 1875. An appendix to the report, published in 1874, gives a preliminary report by Professor Cope.

Veta Pass to the Pecos. His report* was the first to exhibit clearly the general structure of the ranges. Mr. A. R. Conkling accompanied the party as geologist, but his brief report gives very little available information respecting the geology of the region. Mr. Conkling discovered Cretaceous rocks in the Moreno Valley and found Carboniferous rocks on Taos Pass, which he followed to Santa Fé. He mentions that Carboniferous rocks occur on the Pecos, and gives some notes respecting the coal-bearing group of the Raton Hills.

In 1875, Dr. F. M. Endlich, as geologist of the Southeast Division of the Geological Survey of the Territories, examined the northern part of the area under consideration as far south as Costilla Peak. His report is given in the Annual Report of that organization for 1875.

During this examination, Dr. Endlich succeeded in working out the complicated mountain structure as well as that of the Stone-wall Valley, which follows the Culebra Range southward from the Spanish Peaks to Costilla Peak, and his numerous sketches illustrate the structure admirably. He made a number of sections of the Laramie group near Trinidad and divided it into an upper and a lower coal-horizon. Dr. Endlich terms the coal-bearing group Post-Cretaceous or Pre-Tertiary, regarding it as a transition series.

The exploration by the writer was begun in 1878. During that year attention was paid especially to the stratified rocks, and only incidental studies were made within the mountain areas, the exact investigation of those areas having been deferred to be taken up in 1879. But no opportunity could be found for carrying out an investigation of the Archæan areas; and the only material respecting them, available for this report, is that which was gathered in 1878 during rapid passages across the mountains, made in order to determine the limits of the stratified rocks.

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*The reports by Lieutenant Carpenter and Mr. Conkling are given in Lieutenant Wheeler's report published in 1876.

U. S. GEOGRAPHICAL SURVEYS WEST OF THE ONE HUNDREDTH MERIDIAN.

CAPTAIN GEO. M. WHEELER, CORPS OF ENGINEERS, U. S. ARMY, IN CHARGE.

PART II.

SYSTEMATIC GEOLOGY,

BY

PROF. JOHN J. STEVENSON.

CHAPTER III.

DISPLACEMENTS OF THE STRATA.

SECTION I.—THE CULEBRA AXIS AND ITS BRANCHES.
II.—THE CIMARRON AXIS.
III.—THE SUBORDINATE AXES.
IV.—THE RELATIONS OF THE AXES.

The disturbances observed within the district naturally fall into three series: the Culebra axis and its subdivisions, the Cimarron axis, and the smaller axes lying east from the principal mountain ranges.

The Culebra axis enters the district from the north and is continuous southward to Bernal Mesa, at the extreme southern border of the area examined. Its course is shown by the Archæan core of the Culebra, Taos, Mora, and Las Vegas Ranges. For convenience of description it may be regarded as breaking up at a short distance north from Red River Pass, so as to throw off the Mora axis; and a still further breaking up is apparent on Ferdinand Creek, where the Santa Fé axis begins. Farther west there seems to be an additional axis passing through the U. S. Mountain, but no examination was made to determine this matter. Few details were obtained respecting the Santa Fé axis except near its terminations, as no opportunity was afforded for study of the Santa Fé Range from Junta Creek southward to Santa Fé. But both this and the Mora axis were followed out at the south to their disappearance. The latter involves both the Mora and the Las Vegas Range of mountains and it is directly continuous with the Culebra axis.

A wall of Dakota sandstone begins at the Spanish Peaks and extends southward without interruption along the eastern foot of the mountains to a little beyond Costilla Peak in New Mexico, where it ends abruptly.

Beyond the termination of this wall the rock has a regular eastward dip, and at a few miles farther south, one sees that the Stonewall is but the overlapping portion of another axis, designated in this report as the Cimarron axis. This forms a bold but short mountain range farther south, which is cut by Cimarron and Rayado Creeks. Beyond Rayado Creek the elevation marking the line of this axis is irregular, now and then a sharp ridge with Archæan core, but for the most part a gentle roll, which finally disappears near latitude 25° 20′.

Besides these bold mountain axes, several of less imposing character occur, which are important economically, since they keep the rocks of the Laramie group above the surface. The smaller axes of the Raton Hills or Laramie area belong to an extensive series of minor flexures; for one, evidently related to them, was found crossing the Canadian Cañon in the extreme southeastern part of the district, while another is crossed northeast from the district by the Atchison, Topeka and Santa Fé Railway at about fifty miles from Trinidad.

The trough between the Santa Fé and the Mora axis is termed in the report the Pecos synclinal; and that between the Culebra-Mora and the Cimarron axis is named the Coyote synclinal. The former is comparatively simple in structure, but the latter exhibits the most complicated stratigraphy found within the district.

SECTION I.

THE CULEBRA AXIS—THE MORA AXIS—RELATIONS OF THE CULEBRA AND MORA AXES—THE PECOS SYNCLINAL—THE SANTA FÉ AXIS—THE U. S. AXIS—THE TAOS SYNCLINAL—THE PLACER AND SANDIA MOUNTAINS—THE GREAT MESA REGION.

THE CULEBRA AXIS.

The Culebra axis follows a south of southwest course from the northern boundary of the district to beyond Costilla Creek. Its core is Archæan, mostly gneissoid granites and gneisses with some schists and bands of white quartzite. Numerous dikes of trachyte pass through it from north to south, and basalt occurs plentifully on its western side. The Archæan core is not fully shown, for much of it has been removed by erosion from the western slope, and the eastern outcrop of the unaltered rocks on that side lies west from the extreme limit of map 70 A. Igneous rocks rest directly on Archæan along both Culebra and Costilla Creeks.

Unaltered rocks are shown on the eastern slope, where the Carboniferous rocks rest on the Archæan; while above them and farther east are the Dakota and Colorado groups of the Cretaceous. Near Trinchera Peak at the north the Carboniferous rocks have an eastward dip from the Archæan to the Dakota, but farther south, on the South Fork of the Purgatory River, the dip is westward at the base but gradually changes to vertical, and then to eastward before one emerges from the cañon of that stream. This reversed dip continues southward along the face of the mountains until Costilla Peak is reached, where the Carboniferous rocks disappear, apparently running out against the granite. But here the rocks do not belong to the Culebra axis, for the Coyote synclinal begins northward from this locality, and the Costilla Peak region must be considered as involved especially in the Cimarron axis.

The main axis bends westward south from Culebra Peak, lies west from the park on the Costilla, and crosses that stream at some distance below the mouth of Comanche Creek or at four miles above the mouth of its cañon. Some igneous overflows near the divide between Vermejo and Costilla Creeks render the relations there somewhat obscure.

The uplift grows stronger south from Costilla Creek, and the Archæan area widens rapidly so as to form the bold mountain range designated on the map as the Taos Range. But this area suddenly contracts at nearly midway between Colorado and Taos Creeks and the Mora axis becomes distinct.

THE MORA AXIS.

This fault first becomes recognizable at a little way north from the Red River Pass, where a narrow strip of Carboniferous conglomerate is shown very near the summit of the Pass with Archæan rocks on both sides of it. This strip grows wider southward until at the head of Colorado Creek only Carboniferous rocks were seen, reaching eastward down the mountain slope into the Moreno Valley, and westward to beyond the space examined. Here, on the divide between Lucero and Colorado Creeks, the fault is well exhibited, with Carboniferous rocks dipping eastward at 56° on the east side and at 25° on the west side of the fault. But on the latter side the dip diminishes quickly as the distance from the line of fault increases and becomes only 10° within two miles.

The fault grows stronger southward, and on Ferdinand Creek, which crosses it, the Archæan rocks are well shown, with the Carboniferous beds on both sides.

The dips below this Archæan exposure on Ferdinand Creek are very irregular, but southerly dips predominate for several miles in the lower part of the cañon, as though showing that the Archæan of the Taos Peak region terminated abruptly not far off at the north. No distinct anticlinal or fault is shown in this part of the cañon. The U. S. Mountain, at a short distance southwest from the mouth of the Ferdinand cañon, appears to be made up of Archæan rocks.

The Mora axis is distinctly shown by its Archæan core southward from Ferdinand Creek, but the conditions do not exhibit the fault so directly as on the divide between Lucero and Colorado Creeks, for the space between the Carboniferous outcrops rapidly widens. The width of the Archæan area is barely one mile on Ferdinand Creek, but it is almost four miles on Cebolla. The axis trends almost north and south from the head of the East Fork of Mora Creek to where it crosses Cebolla Creek, crossing Mora Creek at but a little way below the City of Mora. In this portion it is marked by peaks ranging from 7,500 to 11,000 feet above tide. The course changes at Cebolla Creek, and thence to Sapillo Creek is almost southwest. There it is again changed, and thence to within a few miles of the stage-road leading from Las Vegas to Santa Fé the axis slowly bends south and at length to east of south. The Archæan area slowly decreases in width as well as in elevation, and finally the Carboniferous rocks ride over the line of break, apparently uninterrupted, at nearly ten miles north from Bernal Hill. No opportunity was had for examinations along Bernal Creek north from the stage road, and for that reason no details can be given respecting the character of the axis where the Archæan area ends. Analogy with the Santa Fé axis would lead to the belief that it terminates in a fault as it began at the north. But the axis is represented by a very gentle anticlinal immediately west from Bernal Station on the stage-road.

The conditions on the immediate slope of this axis along the east are not perplexing. The dips are very abrupt from Colorado Creek at the north to Tecolote Creek at the south, and vary from 35° to 85°; but the dip is not inverted at any locality.

The conditions are more complicated on the west side. The dip throughout is comparatively gentle, and it is quite regularly westward from Ferdinand Creek southward to the head of Mora Creek; but there a fault occurs which, though not of so great vertical extent as that along the main axis, is yet serious enough to render the geology somewhat perplexing. The rocks are almost vertical in the creek-bottom while on both sides of the narrow valley the same rocks are shown dipping gently away from the stream. The Archæan rocks are not far below the bed of the creek, for beds belonging to the lower part of the Carboniferous are exposed high above the creek on the western hill. The Mora Valley widens greatly below the junction of its forks and is covered with a thick coat of alluvium, so that no exposures occur. The rocks on both sides of the valley dip north of west at a comparatively gentle angle; but as one approaches San Antonio the valley becomes a broad cañon and shows an insignificant anticlinal, which doubtless represents the fault seen farther up the stream. This disappears below San Antonio.

Las Casas Creek enters the Mora immediately below San Antonio. There a great change appears. The mountains on the west side of Mora Creek, designated on the map as the Mora Range, are wholly Carboniferous from the head of the creek to within a short distance of Las Casas Creek, and are quite low. But they increase in height abruptly almost immediately north from that creek, and Archæan rocks are well exposed in Las Casas Cañon. Thence to the head of Manuelitos Creek these rocks are exposed in a bold precipice facing the east. The crest of the ridge from Las Casas Creek to Mount Solitario is a plain sloping toward the west and covered with Carboniferous rocks. Beyond that mountain the plain-character disappears, owing to extended erosion by streams on both sides; the Archæan area of the Mora axis joins the new area and becomes the

Archæan core of the Las Vegas Range, which continues to the flattening out of the Archæan on Bernal Creek. To this new fault is due the sudden bend of the Mora fault to the southwest at Cebolla Creek, as the pressure found relief along the western line. From Las Casas Creek the eastern or Mora Archæan decreases quickly in importance until it is merged with the other and thenceforward more important area.

This upthrow fault has affected the stratigraphy between Las Casas Creek and Mount Solitario. A well-defined synclinal was seen on Cebolla Creek, but this disappears quickly toward the south, so that on Manuelitos Creek the dip of the Carboniferous rocks is steadily westward to the last exposure. The southwestward bend in the Archæan area of the Mora leads to the pointing out of the Carboniferous between the two areas as it is shown on the map.

RELATIONS OF THE CULEBRA AND MORA AXES.

These two axes are really one great fault, and the apparent distinction between them arises solely from variations in the strength of the uplift.

The fault is much feebler north from the district than in any part of the Culebra division within the district. Within two miles north from the northern line of the area Carboniferous rocks are shown on the west side at say four miles west from the line of Trinchera Peak. But thence southward there is a marked increase of strength, for the eastern outcrop of the Carboniferous rocks quickly recedes toward the west until, at Costilla Creek, it lies not far from the Rio Grande Cañon. The force was exerted less strongly in the vicinity of Colorado Creek, and the Carboniferous rocks are exposed on both sides of the fault at the head of that stream. Beyond the latitude of Taos Peak the energy of the uplift is confined for a little to a narrower space, and the Archæan area on the west side of the fault disappears, so that on Ferdinand Creek one finds only the southward dip of the rocks curving round the termination of that area.

But the energy was not wholly expended, for the uplift along the main line of fault soon regains strength, and the division, which has been termed the Mora axis, attains to great height and shows a broad area of Archæan almost to the final disappearance of the disturbance on Bernal Creek.

At the same time this narrower area of the Mora axis is not all. The energy which raised the enormous Archæan area north from Pueblo Creek still remained, and in direct line with the western area of Archæan a new axis appears, which I have called the Santa Fé axis, as its Archæan makes up the bold range known as the Santa Fé Mountains. So that south from Ferdinand Creek we find two bold axes representing the single one forming the Culebra and Taos Ranges at the north, and previously described as the Culebra axis.

The Culebra axis, then, is a grand fault continuous from beyond the district at the north to near the Bernal Hill, a distance within the district of fully 120 miles. The Santa Fé axis must also be regarded as resulting from a division of the force, if one may so speak, south from the line of Ferdinand Creek, its appearance being coincident with great decrease along the main line of faulting.

THE PECOS SYNCLINAL.

Detailed examinations in this synclinal were made only along a few lines, and those are widely separated. Carboniferous rocks alone occur within it.

As the Santa Fé axis disappears before reaching Ferdinand Creek, or better, begins south from that creek, the Pecos synclinal cannot be fairly recognized on that stream. The dips are very irregular from the time one leaves the Archæan exposure above the forks of the creek until he passes the mouth of the cañon and emerges upon the plain in which Taos is situated. But immediately below the forks of the stream the western dip is reversed, and thence for some distance down stream the dip is eastward. Within a few miles of the mouth of the cañon the dips become confused, a condition possibly marking the disturbance produced by disappearance of the Taos Archæan at the north and the beginning of the Santa Fé Archæan at the south.

The synclinal is distinct on Junta Creek, twenty miles south from Ferdinand, and it is crossed by that creek at three or four miles above the forks. An insignificant anticlinal follows the axial line of the trough and is very distinct on this creek.

The Pecos River flows near the center of the synclinal and the conditions are well shown in its long cañon. The strata dip gently toward the axis from the east, but rise rapidly on the west side toward the crest of the Santa Fé uplift. The subordinate anticlinal seen on Junta Creek is very distinct near the mouth of Pecos Cañon, at a little way above the village of the same name.

The synclinal becomes wide at the south owing to the divergence of the Mora and Santa Fé axes, for the former bends toward the southeast while the latter follows an almost north and south course. A slight anticlinal was suspected near San José on the Pecos, but the dips are somewhat indefinite.

The structure throughout the Pecos synclinal is extremely simple.

THE SANTA FÉ AXIS.

This axis begins at the north within a short distance south from Ferdinand Creek. It is crossed by the branches of Frijole Creek, for Archæan pebbles are present in some small branches of that stream, which rise west from the Archæan of the Mora axis.

The uplift was exceedingly energetic in the vicinity of Junta Creek, and the Archæan, though little more than a mile wide, forms a ridge of high, sharp mountains, which are crossed by the creek at barely four miles below the forks. The dips on both sides of the Archæan are approximately the same, and the older rock has been thrust through the newer. No evidence of anticlinal structure exists, and if Carboniferous rocks ever capped the crest of these Archæan mountains they must have been only fragments torn from the mass, for the dips are such that the beds could never have curved over the crest.

The Archæan area widens rapidly south from Junta Creek. It is barely one mile wide on that stream, and the mountains, though sharp, are not prominent enough to have received local names; but within a few miles the area is as wide as that of the Mora, and the Truchas Peaks rise to somewhat more than 13,000 feet. Farther south are the high peaks known as the Cone, Baldy, and Lake Peak, all more than 12,000 feet high and giving rise to important tributaries of the Pecos.

The Archæan area continues to widen until a little way south from the latitude of Santa Fé, where it is fully ten miles wide. But thence southward it becomes narrower until it disappears suddenly on Galisteo Creek at about nine miles north from the village of Galisteo. Its course is marked by sharp hills, gradually diminishing in height toward the south.

But though the Archæan area disappears at nine miles north from Galisteo that locality does not show the termination of the axis. The dips on both sides are alike on Junta Creek, but farther south the dips on the east side become more abrupt than those on the west side, and the general resemblance to the Culebra-Mora axis becomes very close. The similarity between the two axis becomes more apparent on Galisteo Creek, where the Santa Fé axis breaks down into a double fault, which continues to a few miles below Galisteo, the curve in the creek following the edge of the faulted area.

The only rocks involved in this axis from its inception near Ferdinand Creek to within ten miles of the disappearance of the Archæan are the Carboniferous and the Archæan; but along Galisteo Creek the Trias and Dakota rocks are seriously disturbed, while just beyond them are the higher groups of the Cretaceous. All of the newer rocks have been involved in the fault terminating the axis. The conditions exhibited in this portion of the area can be best described in connection with the Great Mesa region.

THE U. S. AXIS AND TAOS SYNCLINAL.

No information whatever was obtained respecting the U. S. axis beyond that which could be obtained by simply viewing the mountain through a glass and at a distance of five miles. But there seems to be no doubt that the rock is metamorphic. The area of exposure must be very small if the axis be parallel to the Santa Fé, for it is cut off suddenly at the north by the Taos Basin, while at the south it is quickly ended by the Rio Grande Plains. If this be an independent axis, it is either very short or else, at no inconsiderable distance south from the line of Junta Creek, it unites with the Santa Fé axis in the widened Archæan area beginning not far from the Truchas Peaks.

The Taos synclinal, which was crossed only on Frijole Creek above Taos and on Junta Creek, lies between the Santa Fé and the U. S. axis. It is narrow and contains only Carboniferous and Quaternary rocks. This synclinal was followed from Junta Creek along a by-road leading from Real Pueblo to Old Camp Burgwin on Frijole Creek. A subordinate anticlinal was observed on Frijole Creek, which broadens northward and is probably the means whereby the trough is obliterated before crossing the Taos Basin.

The structure within this synclinal, as far as observed, is very simple, and suggests that the U. S. axis is a fault with relations to the Santa Fé axis, similar to those borne to the Mora axis by the fault extending from Las Casas Creek to Mount Solitario. Possibly the great and abrupt narrowing of the Santa Fé Archæan as it approaches Junta Creek may be due in some degree to the spreading of the force and the production of this fault, just as a similar narrowing is caused in the Mora Archæan by the Las Casas fault.

THE GREAT MESA REGION.

The Santa Fé and the Culebra-Mora axes terminate as bold mountain ranges very near the parallel of 35° 30′ north latitude. The latter continues thence as an anticlinal, gently decreasing in strength until it practically disappears not far south from Bernal Station on the stage-road between Las Vegas and Santa Fé. The other breaks down abruptly into a fault which continues to the Lower Galisteo and there ends.

Beyond 35° 20′ north latitude southward the region is a vast plain cut into mesas, which Dr. Newberry identifies with the Llano Estacado or Staked Plain of Texas. Toward the south and southeast the dips are very gentle and for the most part southward; but near the Rio Grande the plain is broken by "lost ranges," of which the Placer and Sandia Mountains may be taken as types. The former range is a granitic uplift with northwest and southeast trend, but the structure on the northeast side—the only one visited—is so complicated by dikes of trachyte and basalt that the hasty examination yielded no clew to the stratigraphy. The Sandia, a similar range, also with granitic nucleus, was not visited.

These short ridges lie west from the line of the Santa Fé axis and seem to bear no relation to that disturbance. Yet, in view of the origin of the Santa Fé axis, which is associated with a weakening of the Culebra-Mora axis lying next east, one may not deny relationship between these lost ranges and the Santa Fé, for the Placer Mountains begin at 35° 25′ north latitude, very near the parallel on which the Santa Fé axis subsides abruptly, and they attain their greatest elevation at almost due west from the final disappearance of that axis on the lower Galisteo Creek. In like manner the Placer Mountains break down suddenly, and the Sandia Mountains originate at a few miles west on very nearly the parallel of their disappearance.

This relationship will appear the more probable if the conditions attending the disappearance of the Santa Fé axis be considered. The Culebra-Mora axis terminates in an insignificant anticlinal and the disturbance ends in the gentle southeast and southwest dips of Bernal Mesa; but the Santa Fé axis breaks down into a double fault attended with violent disturbance of the rocks not immediately involved in the faulted space. It may be well to refer to the structure in detail.

The Archæan area of the Santa Fé axis ends abruptly at about nine miles north from Galisteo. A fault is easily recognizable along its eastern side, where the Carboniferous rocks are crowded into a narrow space between the Archæan and the Trias, only a small part of the series being brought to the surface. The dip on this side of the fault quickly becomes gentler toward the east; but on the south and southwest sides of the Archæan and near its termination the Carboniferous, Trias, and Dakota are turned up very abruptly, and the thickness of the Carboniferous exposed is clearly greater than on the eastern side of that area. This fault continues southward to and along the divide between the Upper Galisteo and the Arroyo de los Angeles quite to the mouth of that arroyo on the Lower Galisteo. It grows gentler southward, and within a very little way from the end of the Archæan the Dakota are the lowest rocks exposed by it. The whole series of Paleozoic and Mesozoic rocks as found in this region are involved in this fault and they appear to be conformable throughout.

But there are two faults, and between them the Dakota alone is exposed, while beyond each fault the Laramie rocks occur, the vertical displacement being at least 2,500 feet. The western fault is not traceable, for the Galisteo group of the Tertiary is not involved and so covers the whole mesa west and north from Galisteo Creek. But on the west side of the Arroyo de los Angeles the Dakota rocks are shown at a few places and dipping east. The conditions are sufficiently clear on the Lower Galisteo at the mouth of the arroyo, where the Dakota area is shown. The Colorado group is not present at the surface but the Laramie rocks are well exhibited along the creek, both above and below the faulted area.

The two faults come together somewhere in the broad "bottom" on the north side of the Lower Galisteo, forming a curved line, not a sharp angle. The structure from the west side of the Arroyo de los Angeles to the east side of the Upper Galisteo Valley is shown in the following diagram:

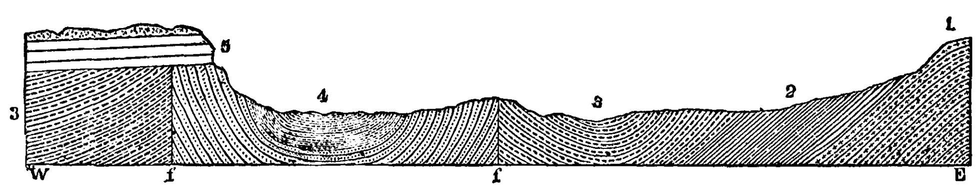

FIG. 1.—*Section across the valley of the Upper Galisteo.*—1, Dakota; 2, Colorado; 3, Laramie; 4, Middle and Lower Dakota; 5, Galisteo group; f, f, Faults.

The stratification under the Galisteo sandstone is not exposed along the line of section, but it is shown on the Lower Galisteo, not far from the mouth of the arroyo.

All evidence of this disturbance has disappeared on the south side of the creek in the southern division of the Galisteo area, and the succession is perfectly regular, as shown in the following diagram, which represents the structure along a line reaching nearly ten miles farther west than the last one does.

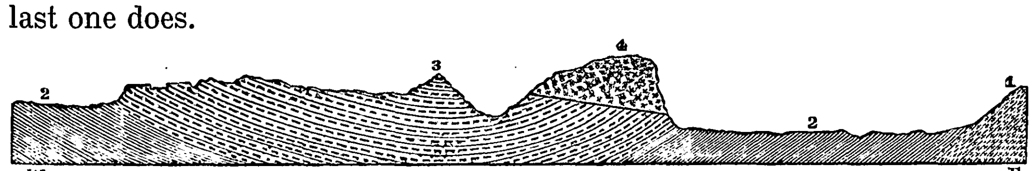

FIG. 2. *Section east and west along the Arroyo San Cristobal and the Lower Galisteo Creek.*—1, Dakota; 2, Colorado; 3, Laramie; 4, Trachyte.

Petty disturbances occur east from the line of Galisteo Creek and within its drainage area, one of which is partially indicated in the first diagram.

The violence here is in marked contrast with the quiet at the southern termination of the Culebra-Mora axis. The rending of the rocks may have sufficed to expend the force, but the abrupt union of the faults on the Galisteo seems to suggest that the force producing the Santa Fé fault did not cease to act after distorting the beds on Galisteo Creek, but that it was exerted also along the lines followed by the Placer and the Sandia Mountains farther west and south.

SECTION II.

THE CIMARRON AXIS—THE COYOTE SYNCLINAL.

THE CIMARRON AXIS.

The Cimarron axis may be regarded as beginning near the Spanish Peaks at the north and extending southward to very near latitude 35° 30′ in New Mexico. It is divided into the *stonewall* and the *anticlinal*, which require separate consideration.

The stonewall.—A wall of Dakota sandstone, from 200 to 300 feet thick, enters the district from the north directly at the east foot of the Culebra Range, and shows no break from the Spanish Peak to the South Fork of Purgatory, aside from gaps through which the streams flow. Throughout this part its dip is eastward, and the Carboniferous rocks behind it do not seem to be seriously involved in the disturbance until the Middle Fork of the Purgatory is reached. They dip eastward on Trinchera Peak at a by no means excessive angle. The wall is slightly faulted between the North and the Middle Fork of the Purgatory, so that the valley between it and the Laramie Bluff at the east becomes very narrow. This fault, though insignificant, is sufficiently distinct, for the Dakota rocks rise east from an exposure of Colorado shales in front of the stonewall. This northern part of the wall ends abruptly at the South Fork of the Purgatory, where it passes into a low anticlinal, which disappears at two or three miles farther south.

A new stonewall, cut by both branches of the South Fork, is shown at nearly a mile and a half west from the wall already considered. It dips east at about 50°. Along the north branch of this fork the dip of the Carboniferous rocks increases rapidly behind the wall until it becomes vertical, and before the Archæan is reached those rocks dip west at nearly 60°.

This new division of the stonewall begins at a little way north from the latitude of Culebra Peak and continues southward, or rather southeastward, to the summit between the South Fork of Purgatory and a small branch of Vermejo Creek. There, being almost accurately in a line with the northern division, it changes its course and extends southward with but little irregularity until it disappears beyond Costilla Peak. It is entangled among some dikes on the upper waters of Vermejo Creek, where it seems to be somewhat dislocated at several places; but these were too difficult of access to permit a determination of the matter.

As far south as the road coming over the divide from Costilla Creek the wall dips toward the east, though the rate of dip shows some variations; but there the condition changes, the dip becomes steeper, and at length before Leandro Creek is reached it is vertical. The change continues until at the gap made through the wall by that stream the rock dips westward at not far from 40°, and the Colorado shales underlie it at the east; while the coarse rocks of the Carboniferous overlie the Dakota, as they are on the west side of the wall and are dipping westward.

The dip again becomes vertical or nearly so beyond the gap of Leandro Creek, and thus continues to a short distance south from Costilla Peak, where the wall is cut off by a park. The Carboniferous rocks apparently end here against the granite.

Dikes of trachyte are intimately associated with the stonewall region from its first appearance to its final disappearance near Costilla Peak.

The Anticlinal.—From Costilla Pass to Poñil Pass, a distance of three miles, exposures are few, and such as do occur are not altogether satisfactory. The numerous dikes and overflows of eruptive rocks belonging to the Old Baldy group contribute much toward obscuring the structure. But it is sufficiently evident that from Costilla Peak to very near Poñil Pass the eastern slope of an anticlinal remains, the western slope having been removed by erosion. The dips on the western side were gentle, for the Coyote synclinal is very shallow and Archæan rocks are shown on the Moreno Pass, the divide between Comanche Creek and the North Fork of Moreno Creek, the streams by which the erosion was done. That synclinal is distinct at Elizabethtown, only a few miles farther south in the Moreno

Valley. The general structure in relation to the whole stonewall division is very like that observed on the South Fork of the Purgatory, where the northern part of the stonewall passes into an anticlinal.

The mountains forming the eastern wall of Comanche Park near the Moreno divide show only Archæan rocks. Fragmentary outcroppings of Dakota and Colorado occur farther east, but they are not clear, as the region is badly cut up with dikes. The outcrop of the Cretaceous rocks gradually moves westward, until at Poñil Pass the anticlinal becomes distinct; the lower rocks of the Laramie group cross the arch, while on the west side are shown the Colorado shales, and lower down are the Dakota rocks resting on the Archæan.

The axis trends south-southeastward from Poñil Pass, thus diverging from the Mora axis, which becomes distinct almost due west from Poñil Pass. Archæan rocks are exposed under the Cimarron axis in the cañons of Cimarron and Rayado Creeks.

The Cimarron axis is followed easily to the park near the head of Ocaté Creek, but it becomes feebler southward, for the Dakota rocks cross it on Ocaté Creek and the Archæan rocks are not reached, though the altitude is much less than on Cimarron Creek, where fully 1,000 feet of Archæan rocks are exposed in one bluff. Its course is changed in this park, and thence it is south-southwestward to the park on Coyote Creek, where the fold is still distinct. Thence the trend is southwest and the anticlinal is but a gentle fold until beyond Cebolla Creek. The southern portion of this axis may be most conveniently considered in connection with the Coyote synclinal.

It is noteworthy that this axis shows the Dakota rocks resting on Archæan, and that where the fold first presents itself as such the Carboniferous rocks suddenly disappear. The existence of the latter rocks is only doubtfully indicated on the east side of the axis, at the north, along a branch of South Poñil Creek, rising near Old Baldy. The course of the axis is followed by enormous dikes and overflows of eruptive rocks, the center of disturbance being in the Baldy Mountains and extending from Poñil Pass almost to Rayado Creek. South from that creek the axis loses its mountain character and breaks down into the Ocaté Mesa. Dikes radiate from the central portion toward the north, east, southeast, and south, as well as toward the west, but none was found following a southwest direction.

THE COYOTE SYNCLINAL.

This trough, lying between the Cimarron and the Culebra-Mora axis, begins almost immediately south from Costilla Creek and is followed by the valleys of Comanche, Moreno, and Cieneguilla Creeks, as well as by that of Coyote Creek above the plaza of Coyote. It is crossed farther south by Mora, Cebolla, Manuelitos, Sapillo, and Gallinas Creeks, while beyond the last it is followed by the valley of Tecolote Creek. It becomes indefinite near north latitude 35° 20′, beyond which it was not followed southward.

Archæan alone occurs on Comanche Creek and the North Fork of Moreno Creek; unaltered rocks first appear above Elizabethtown, and at a little way farther south the trough is found to be double. Carboniferous rocks occupy the west side of Moreno Valley and form a distinct synclinal on the east slope of the Taos Range; while Cretaceous rocks occupy the center and east side of the valley, resting at their western edge on the Carboniferous, but on the Archæan in the center and eastern side of the valley; for the axis of the Cretaceous synclinal is farther east than is that of the Carboniferous. This structure is clear between Six-mile Creek and the forks of Moreno Creek, though the whole of the details cannot be obtained along any one line of cross-section; but the valley is wide enough, north from Six-mile Creek, to embrace the eastern side of the Carboniferous synclinal and to show the Cretaceous resting on the upturned edges of the Carboniferous. A sharp fault occurs on Six-mile Creek at less than two miles from the road leading from Elizabethtown to Taos.

The structure in this valley is shown by the following diagram:

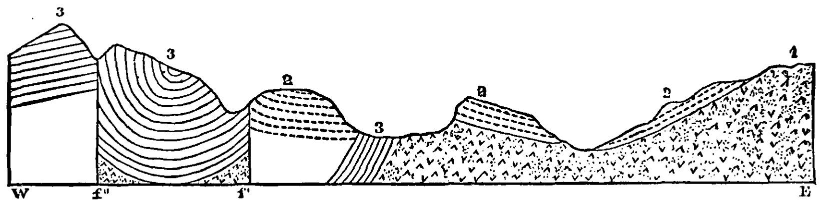

Fig. 3.—*Section across the Moreno Valley.*—1, Archæan; 2, Cretaceous; 3, Carboniferous; f′, Fault on Six-mile Creek; f″, Mora fault.

The valley becomes narrow at a few miles south from Six-mile Creek and lies east from the Carboniferous exposures. But fragmentary outcroppings show that the conditions exhibited in the diagram continue southward for seven or eight miles. Thence to the head of Cieneguilla Creek, the valley has been eroded from the Upper and Middle Dakota, which are shown ascending the west slope of the Cimarron axis.

Owing to the extensive overflows of eruptive rock in the cañons and to the thick coat of alluvium in the parks of the Upper Coyote, investigations can be made to but a limited extent along that stream above the village of Guadalupita. The expansion of the Mora Archæan thrusts the Carboniferous area eastward, so that it is followed by Coyote Creek from the head of the stream to Coyote. A fault was seen alongside of the road near the divide between Coyote and Cieneguilla Creeks, but no details could be gathered respecting it, as the alluvium destroys all continuity of exposure. The end of the basalt overflow is reached at about three miles above Guadalupita, and the relations of the Carboniferous rocks to the Archæan are as shown in the following diagram:

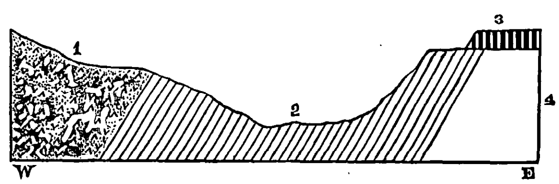

FIG. 4.—*Section on Coyote Creek at three miles above Guadalupita.*—1, Archæan; 2, Carboniferous; 3, Basalt on Ocaté Mesa.

A cross-section from the Ocaté Mesa to the Archæan is shown at nearly nine miles farther south, but details of absolute structure cannot be obtained, as the intervals between the massive Carboniferous sandstones are concealed and positive identifications of the limestones cannot be made. The structure as shown is represented in Fig. 5.

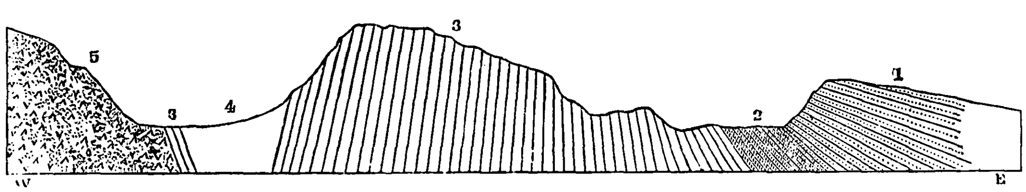

FIG. 5.—*Section on Coyote Creek above Coyote.*—1, Lower Dakota on Ocaté Mesa; 2, Trias; 3, Carboniferous; 4, Concealed; 5, Archæan.

In this section the Carboniferous rocks have a westward dip until very near Coyote Creek, where the dip becomes vertical; but a single exposure in the open space between the Carboniferous hills and the Archæan shows a limestone dipping eastward, so that the Carboniferous rocks very probably describe a synclinal and an anticlinal between the Archæan and the creek. The upper sandstones of the series are confined to the eastern part of the section. The dip of the Triassic rocks quickly diminishes from nearly vertical to 5° degrees eastward, and that of the Dakota becomes very gentle at the top of the mesa. The conditions become somewhat more complicated near Coyote, where the creek leaves this synclinal and turning eastward cuts its way through the Cimarron anticlinal. The diagram in Fig. 6 exhibits the conditions from the Archæan at the west to the eastern slope of the Cimarron axis on the east side of Coyote Park.

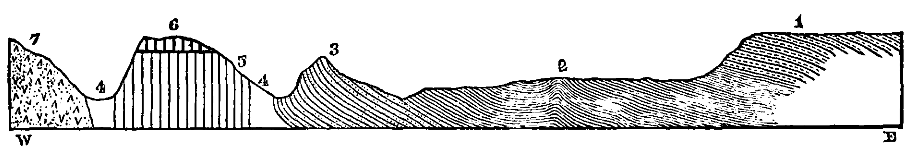

FIG. 6.—*Section through Coyote and Coyote Park.*—1, Upper Dakota; 2, Middle Dakota; 3, Lower Dakota; 4, Trias, concealed; 5, Carboniferous; 6, Basalt; 7, Archæan.

The space occupied by the Middle Dakota is the broad park eroded by Coyote Creek from the Cimarron anticlinal. The abrupt dip of the Lower Dakota, shown in this cross-section, first becomes apparent at but a very little way above the gap through it at Coyote. All the rocks within the synclinal show a more violent dip here, possibly due to the crowding which results from the western bend of the Cimarron axis. The Carboniferous and Trias are vertical, the latter being shown in the creek immediately behind the Lower Dakota. The dip in the Dakota wall is not far from 60°, but it diminishes eastward very rapidly toward the shallow synclinal between it and the axis of the Cimarron anticlinal.

The pressure on the rocks within the trough increases southward for several miles and the wall of Lower Dakota becomes vertical; but with the weakening of the Cimarron axis the crush at the east becomes less, so that at Mora Creek the dip in the wall is again eastward. The diagram in

Fig. 7 shows the structure along Mora Creek from the Archæan of the Mora axis to beyond the crest of the Cimarron anticlinal.

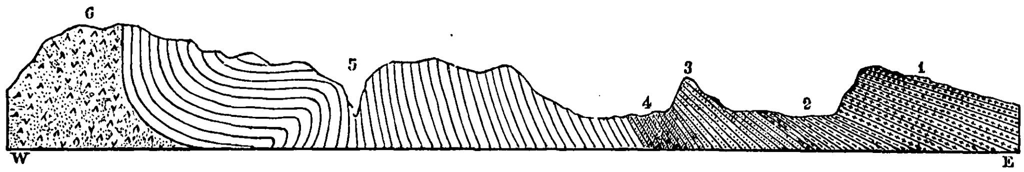

FIG. 7.—*Section on Mora Creek from above Cañoncito to the mouth of Coyote Creek.*—1, Upper Dakota; 2, Middle Dakota; 3, Lower Dakota; 4, Trias; 5, Carboniferous; 6, Archæan of Mora axis.

This section is barely six miles south from the last, and is the first thus far given which shows the structure fairly. The Cimarron axis has become extremely feeble, being merely an interruption of the dip in the Middle Dakota, too slight to be indicated in the figure. The Carboniferous rocks describe an anticlinal and synclinal near Cañoncito, and the east side of the anticlinal is vertical for a short distance below that village, thus showing a structure like that suspected on Coyote Creek. The dip diminishes quite regularly eastward until it becomes insignificant at the mouth of Coyote Creek.

A cañon, tributary to that of the Mora, but crossing the synclinal at three miles farther south, shows a similar section, but the folding is more energetic as shown in Fig. 8.

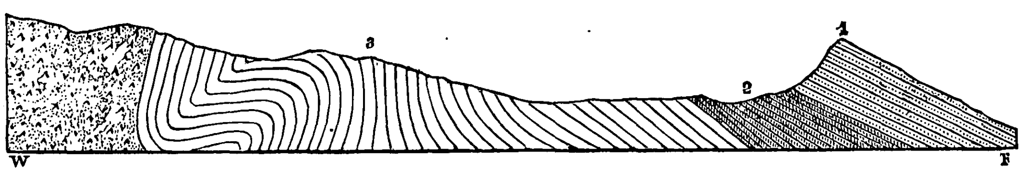

FIG. 8.—*Section on cañon south from Mora Creek.*—1, Lower Dakota; 2, Trias, concealed; 3, Carboniferous; 4, Archæan.

A change occurs between this and Cebolla Creek, a distance of barely four miles, for there, as shown in Fig. 9, the anticlinal is at nearly three

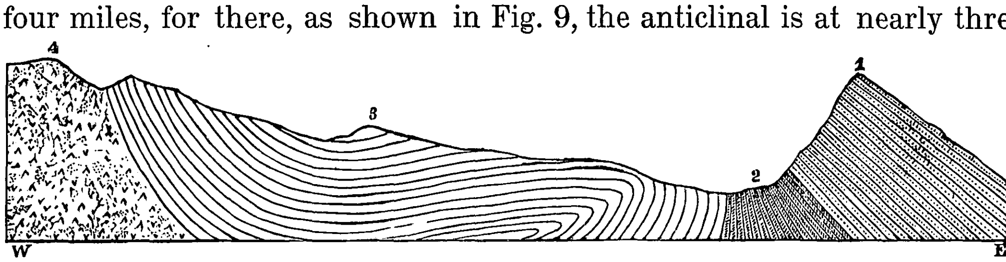

FIG. 9.—*Section on Cebolla Creek.*—1, Lower Dakota; 2, Trias; 3, Carboniferous; 4, Archæan.

miles from the Archæan, whereas on the Mora and in the cañon south from it the fold is at barely one mile from the Archæan. This Cebolla fold is the Cimarron axis, which has suddenly increased in importance. Thus far the Lower Dakota alone has been turned up so as to form a wall facing the east; but the condition soon changes south from Cebolla Creek. The wall decreases slightly for a little way, but soon rises again, and now the whole of the Dakota group stands on edge and even the Colorado shales are seriously disturbed. As the Mora axis bends southwest at Cebolla Creek the width of the trough is materially increased, so that on Manuelitos Creek the cross-section represented by Fig. 10 was observed.

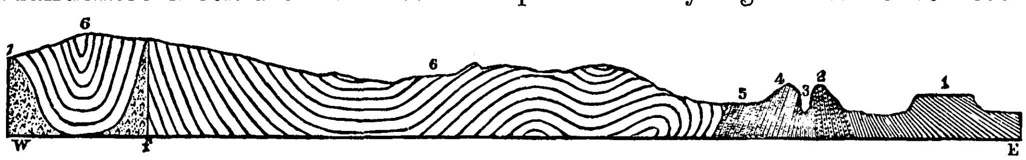

FIG. 10.—*Section on Manuelitos Creek.*—1, Colorado; 2, Upper Dakota; 3, Middle Dakota; 4, Lower Dakota; 5, Trias; 6, Carboniferous; 7, Archæan; f, Fault.

Here the Upper Dakota forms the east face of the wall. The interval between this and the Cebolla section is barely five miles. The fault occurs at somewhat less than a mile below the saw-mill at Santo Niño. The synclinal on its west side is distinct, as may be seen by reference to the detailed section obtained on that creek. The Carboniferous sandstones on the east side of the fault are vertical at the creek, but have a westward dip at the hill-top. The dip decreases quickly down stream and the beds are nearly horizontal until, at little more than a mile above Manuelitos, a sharp fold occurs with northeast and southwest strike. This is clearly an offshoot from the Cimarron axis and its strike would carry it into the main axis before Cebolla Creek would be reached. The Cimarron axis, with gentle dip on the west side but with inverted dip on the east side, is crossed almost immediately below Manuelitos. Thence to the plain the dip diminishes gradually and the Colorado shales become nearly horizontal. The Archæan is very near the surface under the Cimarron axis.

The conditions on Sapello Creek are similar to those observed on Manuelitos; the Cimarron axis is somewhat stronger, the new anticlinal has a less sharp dip on the western slope, and the fault is distinct on both forks of the stream.

The Cimarron axis becomes very strong between Sapello and Gallinas

Creeks, and Archæan rocks form bold hills for several miles north from the latter creek; while they are shown also in the deep cañon by which the creek crosses the axis. The structure above the Archæan cañon was not ascertained, as the exposures do not give it in detail. The fault seen on Manuelitos and Sapello Creeks seems to have disappeared, and the smaller anticlinal seen above Manuelitos is but faintly indicated. The sudden increase of the Cimarron axis may have afforded full outlet for the force here and so may have relieved the strain in other parts of the trough along this line. As far as observed the structure is as given in Fig. 11.

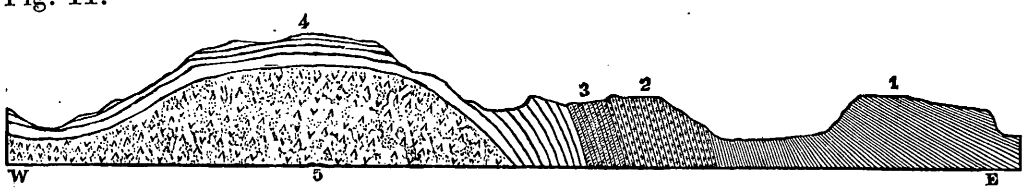

FIG. 11.—*Section on Gallinas Creek under Cimarron axis.*—1, Colorado; 2, Dakota; 3, Trias; 4, Carboniferous; 5, Archæan.

The Carboniferous is continuous over the arch, though in the lower part of the cañon it has been removed from the hillside near the creek. The series is very thin here compared with exposures at other localities farther north within this trough, and there may be a fault between it and the Triassic, though no indications of a fault were observed. The dips on the east side of the anticlinal increase toward the plain, and in the face of the wall become almost if not altogether vertical, while the lower shales of the Colorado group are inverted in front of the wall. But thence eastward the dip decreases rapidly, and within a short distance the Colorado beds are almost horizontal.

The valley of Tecolote Creek follows the synclinal. The Cimarron axis loses height, and no Archæan rocks are shown under it south from Gallinas Creek. The structure in Tecolote Valley is shown in Fig. 12.

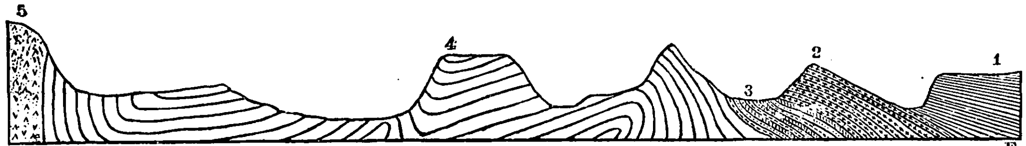

FIG. 12.—*Section across Tecolote Valley to the Plains.*—1, Colorado; 2, Upper Dakota; 3, Middle and Lower Dakota and Trias; 4, Carboniferous; 5, Archæan.

The Cimarron axis shows a decided change in character. The wall facing the plains is Upper Dakota and dips gently, while immediately behind it is a park eroded from Middle and Lower Dakota as well as Trias, the first dipping eastward at only 5° or 6°, while the dip of the Lower Dakota increases as it approaches the Carboniferous sandstones, which dip eastward at from 70° to 80°. The wall of Upper Dakota grows less and less abrupt southward as far as followed; the Carboniferous wall, though still abrupt, is less so than on Manuelitos Creek, where the dip is inverted; but farther south this, too, becomes gentle. The smaller anticlinal first seen on Manuelitos Creek is much closer than at any locality farther north, for the dips are from 50° to 70°, whereas on Manuelitos they are but 35°. The general structure across the Tecolote Valley is very nearly the same as that on Sapello Creek, though the fault is absent and the disturbance is evidently less throughout.

The Coyote trough was not followed farther south than the plaza of Tecolote, where the smaller axis shows a decided decrease in strength. Like the other axes at the west, all of those now under consideration become insignificant near latitude 35° 30′, and within a few miles farther south this trough becomes exceedingly obscure.

Abrupt dips in the Dakota first appear at Coyote, and the abruptness increases until midway between the Coyote Gap and that made by Mora Creek. The dip becomes gentler near Mora Creek, where the Cimarron anticlinal almost disappears, being but an interruption of the dips. That axis has a southwest trend through Coyote Park, a the Upper Dakota, previously dipping east or at most south of east, where exposed on the Ocaté Mesa, now dips southeast, and the western edge of the Colorado shales rapidly approaches the mountains. The anticlinal is very indistinct on Mora Creek, but it is well marked on Cebolla Creek, which it crosses at but a little way above the Placita de Don Tomas, and doubtless to its increased strength is due the disappearance of the petty anticlinal seen on Mora Creek above Cañoncito.

The Cimarron axis, therefore, like the other axes already considered, loses strength southward. It breaks up into two anticlinals between the Cebolla and the Manuelitos, and the eastern branch breaks up in its turn at no considerable distance south from Gallinas Creek; while the whole axis disappears very near the latitude marked farther west by the disappearance of those greater axes, already described as the Santa Fé and the Culebra-Mora.

SECTION III.

THE MINOR FLEXURES.

THE VERMEJO AXIS—LA JUNTA AXIS—THE RATON AXIS—THE CANADIAN AXIS—THE TURKEY MOUNTAINS.

THE VERMEJO AXIS.

This has an almost north and south trend from the Middle Fork of the Purgatory River to near Old Baldy Mountain; but it becomes insignificant south from Vermejo Creek and is soon overlapped by the Cimarron axis.

This fold is abrupt at all exposures found. Only its eastern slope remains on the North Fork of the Purgatory; it is unimportant on the Middle Fork of that river; its dips are very sharp on the South Fork, where it brings up the Colorado shales, out of which San Francisco Park has been eroded. In like manner it brings up the Colorado shales on Vermejo Creek, where erosion has formed Vermejo Park.

This axis was not observed on Poñil Creek or any of its branches, though it may have exerted some influence in keeping up the Colorado shales, which are well shown as far south as the slope of Old Baldy.

The synclinal between this and the Cimarron is full of perplexing problems, and the study of it was deferred until 1879, when no opportunity was found to take it up. The faults of the Cimarron Stonewall have been referred to, but in the valley near the South Fork of the Purgatory and east from the wall the Colorado shales are thrown into abrupt folds, so that, as the exposures are somewhat obscure, one hastily passing through the region might be led to conclude that the shales are not altogether conformable to the overlying beds of the Laramie. The space is very small, and it is indeed difficult to conceive how a series so thick as the Fort Pierre sub-group can be crowded into it. Possibly a fault exists immediately south from the South Fork of the Purgatory, but no direct evidence of its existence was obtained. The synclinal becomes very narrow southward, even before the divide between the Vermejo and the South Fork of Purgatory is reached.

The structure in the Vermejo region is very perplexing, especially near the Stonewall. No clue to it was obtained.

The relations between the Vermejo and the Cimarron axis are so intimate that the former is possibly but an offshoot from the latter.

LA JUNTA AXIS.

This axis is crossed by the Purgatory River at La Junta, the junction of the South Fork with the main stream. Its course seems to be north-northeast and south-southwest, for it was seen on the Canadian near its head and on the Vermejo at about two miles below Cameron post office. The fold is gentle, its dips being little more than 1°.

The synclinal between this and the Vermejo axis is crossed by the Purgatory at the mouth of its North Fork, and by the Vermejo at about a mile and a half above Cameron post office, so that its course is almost north and south. This synclinal is simple on the main Purgatory, but on the South Fork it is broken by a short anticlinal with dips of 3°. No anticlinal was seen on the Vermejo, where both this synclinal and La Junta anticlinal are insignificant.

The synclinal east from La Junta axis is crossed by the Purgatory immediately above the village of Olguines, is hardly perceptible on the Canadian, but is distinct on the Vermejo at about eight miles below Cameron post office. No evidence of its existence could be found on Poñil Creek, while farther south, on the Cimarron, it is certainly absent. There seems to be a gentle rise southward in the Trinidad coal-field, so that although the anticlinal dies out, the rocks are not carried under.

THE RATON AXIS.

This strong axis was seen only on Raton Creek, which crosses it almost immediately below the mouth of Chicken Creek, where the base of the Laramie group is brought up and the *Trinidad* coal-bed is accessible. But the fold disappears quickly both toward the north and toward the south, for it was seen neither at Trinidad nor in Dillon's Cañon.

The Raton axis is abrupt but narrow, for on the eastern side the synclinal is reached within little more than a mile, and thence the rocks rise eastward. The dips are nearly 10°. The exact course of this axis could not be made out from the exposure.

No other axis was discovered between this and the eastern edge of the map in the region of the Raton Plateau, but in all probability there is one at but a little way beyond, as an axis is crossed by the railroad at about fifty miles east-northeast from Trinidad.

THE CANADIAN AXIS.

An anticlinal was seen on the east side of the Canadian Cañon, crossing the Texas road at twelve miles south from the old Leavenworth road. It has a northeast and southwest course, crosses the Canadian Plains almost directly east from the Canadian Hills, where it brings up the Upper Dakota sandstone, and it is distinctly perceptible on the Mora River. The dips are gentle on both sides and the axis keeps the Dakota sandstone at the surface over an extended area.

No synclinal was reached east from this, but the dip is very flexuous along the Canadian Cañon below where it crosses the Canadian axis.

THE TURKEY MOUNTAINS.

These lie east and northeast from Fort Union, and are directly in the line which the Cimarron axis would have followed had it continued without change in the course between Poñil Pass and Ocaté Park. The rocks in these hills form a quaquaversal, which is broken at the south by an old crater. The influence of these hills is shown at a considerable distance toward the southeast, but it is unimportant.

SECTION IV.

RELATIONS OF THE AXES.

The relationship between the axes is very intimate; they bear close resemblance in structure. Variations in one are associated with variations in the others, and they all practically disappear on very nearly the same parallel of latitude.

The Santa Fé axis is a bold thrust of Archæan at the north, rupturing the Carboniferous and upturning the rocks of that group at a high angle on both sides; but at the south it is a distinct fault, much better marked than at the north. The Culebra-Mora axis is a grand fault at the north, but appears to terminate at the south in an anticlinal. The Cimarron axis is a succession of faults from the northern edge of the district to very near Poñil Pass, beyond which the violence of the thrust was diminished, and thence to its disappearance the axis seems to be an anticlinal, although it shows some extensive faults on its east side near Cimarron Creek; so that it has essentially the same features with the Culebra-Mora, and differs from the Santa Fé only in the southward extent and violence of the thrust.

The answering variations of the axes are very clear. Thus the Cimarron first becomes an imposing range on the latitude where the Culebra-Mora uplift so far loses strength that the fault is apparent; but with the growing height of the Mora axis and the more rapidly increasing swell of the Santa Fé axis, the Cimarron dwindles to an insignificant anticlinal. On the space of latitude marking the extent of the Las Casas—Solitario fault, which afforded sudden local relief—the Cimarron axis almost disappears; but it suddenly exhibits great strength on Gallinas Creek almost due east from the union of the Mora fault with the other at Solitario.

The intimacy of relation existing between the ranges is such that there seems to be no room for doubting that in their present shape they are synchronous. The last great period of upheaval was later than the close of the Laramie, for the Laramie rocks cross the Cimarron axis at Poñil Pass and traces of them remain in the Moreno Valley near its northern termination, and much prior to the outpouring of the trachytes, for the line of contact between the Archæan and the vast overflows in Cimarron Cañon is an almost horizontal plane, showing that erosion had been long at work before the lavas overspread that region.

Equally, there seems to be no good reason for doubting that at the close of the Archæan, or certainly before the beginning of the Carboniferous era, islands of Archæan stood above the ocean level along the lines now occupied by the great axes. The Carboniferous rocks end abruptly against the Archæan at the termination of the Stonewall division of the

Cimarron axis, while the Dakota rests on Archæan for miles on the west side of that axis and in the northern part of the Coyote synclinal. The enormous conglomerates at the base of the Carboniferous along the Culebra and Taos Ranges, as well as for miles along the Mora Range, prove that the Culebra-Mora axis, if not marked by continuous dry land from where it enters the district to the southern end of the present Moreno Valley, showed at least long, though possibly narrow, islands; while the presence of conglomerates at the base of the same series on both sides of the Santa Fé axis indicate its existence also above the sea at the beginning of the Carboniferous. But the structure of the Santa Fé uplift and that of the Mora division of the Culebra-Mora axis prove that they must have been submerged at an early date in the Carboniferous era.

Respecting elevations during the long interval, beginning at some time between the close of the Archæan and the beginning of the Carboniferous, and ending not long after the close of the Laramie epoch, little can be said.

At nearly all localities where the full succession is shown the whole series appears to be conformable; but non-conformability seems to exist between the Cretaceous and the Carboniferous in the Moreno Valley. This, however, is the only distinct case, and the non-conformability may have been caused by a lateral thrust after the rocks had been faulted, whereby the Cretaceous rocks might have been pushed across the upturned edge of the Carboniferous. No stress can be laid on this instance, which stands alone.

But there is one condition well worthy of note. The Cretaceous rests directly on the Carboniferous at all localities north from the latitude of Taos Pass, in the Moreno Valley, and along the Culebra and Cimarron Ranges. The Trias is wholly absent. But that formation makes its appearance on Coyote Creek only a few miles farther south. It would seem, therefore, that the Carboniferous rocks must have been above dry land amid the Triassic Sea. No traces of any rocks newer than the Carboniferous occur in the Pecos synclinal until the broad space at the south is reached, where the greatly-diminished Santa Fé and Culebra-Mora axes diverge.

CHAPTER IV.

THE ARCHÆAN ROCKS.

Four areas of Archæan were seen within the district. The first or most western marks the course of the Santa Fé axis; the second, that of Culebra-Mora axis; and the third and fourth, that of the Cimarron axis.

UNDER THE SANTA FÉ AXIS.

The exposure along the line of the Santa Fé axis begins not far north from Junta Creek, and continues southward for fifty miles to within nine miles of Galisteo, on the creek of the same name, where it terminates even more abruptly than it began at the north. The width of this area increases slowly and is but one mile on Junta Creek; but thence southward it increases more rapidly and becomes ten or twelve miles near the latitude of Santa Fé; but beyond that line it narrows slowly to its disappearance on Galisteo Creek.

The only rock observed on Junta Creek was an exceedingly fine-grained soft gneiss, with little mica, white but weathering gray, and resembling an incoherent sandstone. Thin beds of mica schist were seen, but they are not numerous. Quartz veins are common and some of them are wide, but none of them appear to be metalliferous.

The prevailing rock directly east from Santa Fé is a red granite, which is compact and is susceptible of a high polish; but with it are bands of gneiss and mica schist, and the whole series, as far as observed, is micaceous. It is well shown along the stage-road south and southeast from Santa Fé. Beyond that road, toward the south, are frequent exposures of an exceedingly coarse granite, which resembles a metamorphosed conglomerate, the pebbles being thoroughly distinct. With this are many beds of almost black gneiss holding beds of snow-white quartzite. The rock in the Galisteo Cañon, where the area ends, is a fine-grained, reddish-gray granite, exceedingly hard, which receives a fine polish from the action of the stream.

UNDER THE CULEBRA-MORA AXIS.

The area under the Culebra-Mora axis varies in width. It forms the mass of the Culebra, Taos, and Mora Ranges, as well as of the Las Vegas Range south from the line of Las Casas Cañon. The width at the northern edge of the district is barely five miles, but it increases quickly southward, owing to growing strength of the uplift, until it becomes twenty miles in the latitude of Costilla; and in the latitude of Elizabethtown the Archæan exposure reaches from the Rio Grande Plains eastward to Elizabethtown. But, as the strength of the Culebra-Mora fault suddenly diminishes south from the last line, the area is interrupted for a few miles, and Carboniferous rocks are shown on both sides of the fault. The Archæan, however, reappears between Pueblo and Ferdinand Creeks, but the exposure is barely one mile wide. The area widens rapidly and soon forms a bold range, which separates the valleys of the Coyote and the Mora and continues southward to Mount Solitario, where, uniting with a subordinate area beginning at the cañon of Las Casas Creek, it follows the Las Vegas Range until nearly west from Tecolote. There it disappears.

Hornblendic rocks predominate at the extreme north along Trinchera Creek; but some micaceous rocks occur with them. Gneissoid grânite with occasional layers of gneiss was seen in the cañons of Culebra Creek. Quartz is present in but small quantity, and no hornblendic rocks were found until within a short distance of the interior of the range. In the many cañons of the Purgatory and of the Vermejo on the east side of the Culebra Range the Archæan is represented by gneiss and gneissoid granites. Fissile mica schists occur here and there, but they do not seem to bear any definite relation to other parts of the mass. The granite is coarse and sometimes includes fine crystals of feldspar. Very little hornblende was seen south from the North Fork of the Purgatory.

Costilla Creek, heading on the east slope of the Culebra Range, breaks through that range on its way to the Rio Grande Plains. Its drainage area lies chiefly east from the axial line and includes the northern part of the Coyote synclinal. The main cañon, at eight or nine miles above Costilla, has walls of very dark compact gneiss, quartzite-like in structure, but containing filmy lines of mica. Here and there it is replaced by gneissoid granite, which occurs not regularly but in masses, as though inserted, from which stringers pass, gradually decreasing in size as they recede. Mica schists occur in thin beds and contain small lumps of feldspar or of feldspar and quartz, more or less almond-shaped. Micaceous rocks prevail above the close cañon as well as in the mountains directly west from Costilla Park, and are associated with broad beds of snow-white quartzite, accompanied by silvery mica schist. Dark schists seldom occur north from the creek.

The Archæan exposures are practically continuous along the Coyote synclinal from Costilla Creek to almost ten miles south from Elizabethtown in the Moreno Valley, being interrupted only by the overflows of eruptive rocks near Elizabethtown. The series is represented on Comanche Creek and the North Fork of Moreno Creek by coarse gneissoid granites holding many bands of quartzite. Dark gneiss is by no means rare, and schists of silvery mica are a characteristic feature. Coarse granite alone prevails on the West Fork of Moreno Creek for three miles above its mouth, but gneiss prevails farther up; much of the latter is schistose and mottled with small blotches of white mica or with nodular concretions of feldspar or quartz and feldspar. Some beds of hard wood-like gneiss were found associated with beautifully-waved schists. The granite becomes very coarse below the junction of the Forks of Moreno Creek, where it resembles conglomerate and weathers into curious architectural forms. It contains very little gneiss, and quartzite appears to be wholly wanting.

The Archæan area becomes wider and bolder south from Costilla Creek, and stretches much farther toward the west than it does north from that creek. The erosive agency which removed so much of the Archæan rocks north from that creek was not exerted south from it, and the Archæan rises into a mountain range reaching to the Rio Grande Plain, and with eruptive rocks at the foot, or cutting it as dikes. Both micaceous and hornblendic rocks are present here, but the former class seems to predominate, and the latter occurs in small beds or patches included in the others. For the most part the mica is almost black; the lighter varieties exist only as crystals or scales included in lumps of quartz. The syenite occasionally contains crystals of pinkish feldspar measuring four by two inches. A wide bed of quartzite is continuous along the face of the mountains for six or eight miles, and its fragments are spread over the plain for a long distance toward the Rio Grande. An exceedingly compact granite of delicate gray color was seen in the cañon of Colorado Creek, and fragments of syenite occur frequently in stream-beds entering that cañon from the south. No examinations were made in the heart of this area between Colorado and Ferdinand Creeks.

In following the Culebra-Mora area one loses sight of Archæan rocks along the line of fault soon after leaving Red River Pass, but reaches them again at a little way north from Ferdinand Creek, whence the exposures are continuous to the end on Bernal Creek, almost west from Tecolote.

Hornblendic rocks alone were seen on Ferdinand Creek, where they are shown on the middle fork at but a little way above its mouth. Thence southward, exposures are imperfect until near the middle of the cañon on Coyote Creek, where mica granites are shown holding great beds of quartzite. Near Guadalupita and thence southward for several miles a soft schistose gneiss prevails, which contains silvery mica and blotches of quartz; but in the interior of the range this is succeeded by a dark gneiss, which so closely resembles a slightly altered sandstone that one, judging from a hand-specimen, would not hesitate to pronounce it such. It is crossed in all directions by narrow veins of quartz, shows many close flexures, and passes imperceptibly into dark mica schist with rare bands of gneiss and granite. The mode in which these bands occur suggests that they have originated from mere segregation of the minerals.

The Archæan exposure along Mora Creek begins at but a little way above Canoñcito at the east and continues to San Antonio at the west, while both north and south from the creek is a broad valley eroded in Archæan rocks. The highest bed of the series on the east side is an extremely coarse gneissoid granite, whose quartz is in large angular blocks and the mica in large plates. Underlying this, as one ascends the creek, are tender mica schists, which yield readily to the weather. With these is some gneiss, which is mottled handsomely with flecks of white feldspar. The gneissoid granite often occurs in great blotches on the hillsides as though it had been dashed there in a pasty condition; and the long tapering strings passing out from them in all directions lend countenance to such a conception. The compact fine-grained gneiss, to which allusion has been made in the description of other localities, is abundant up the creek as well as in the valley north from Mora. Mica schists prevail in the hills south from Mora, where they hold many thin veins of quartz and occasionally an irregular bed of gneiss.

A coarse gneissoid granite was seen on Cebolla Creek immediately underlying the Carboniferous, and below it are some dark gneisses and beautifully-waved schists. Gneiss prevails on Manuelitos Creek, but often, for considerable distances, is replaced by a reddish-gray, fine-grained, compact and greasy-looking granite, which is gneissoid in structure and bears not a little resemblance to a slightly altered sandstone. Narrow beds of white quartzite occur in the vicinity of Santo Niño on this creek.

The rock in the Las Vegas Range north from Mount Solitario is for the most part a gneiss with silvery mica, though here and there are bands of very light-colored gneissoid granite, contrasting strangely with the great mass exposed in the precipitous bluff which extends from Las Casas Creek to Solitario. Coarse granites with thin beds of gneiss prevail thence to the termination of the area on Bernal Creek.

UNDER THE CIMARRON AXIS.

Few exposures occur under this axis. The overflows of eruptive rocks in the Old Baldy or Cimarron Mountains conceal the Archæan except in the cañons of Cimarron and Rayado Creeks and along the east side of the Moreno Valley south from the Cimarron Cañon. Imperfect exposures along the East Fork of Comanche Creek show only mica schists with here and there a pocket of coarse granite. Cimarroncito and Urraca Cañons, on the east side of the axis, undoubtedly reach to the Archæan, as pebbles of rocks belonging to that age occur in *débris* along the streams, but the rocks are not exposed. Owing to the weakening of the axis southward the Archæan is not brought to the surface south from Rayado Cañon until beyond Sapello Creek, where the axis suddenly gains strength, so that for a few miles those rocks are exposed. But this exposure is short, and the Archæan soon disappears beyond Gallinas Creek to be brought up no more under the Cimarron axis.

The rock near the head of Cimarron Cañon is dark, compact gneiss, splitting like wood, and so fine-grained as to bear some resemblance to quartzite. Mica is distributed irregularly through it, and hornblende seems to be wholly wanting. This dark gneiss weathers with jagged surface and the walls of the cañon are gloomy. A similar rock is exposed along the east side of the Cieneguilla Valley for five or six miles south from the head of Cimarron Cañon.

The exposure in the upper part of Cimarron Cañon is very short, being cut off by an enormous dike. Another exposure farther down the cañon, and continuing for nearly four miles by the creek, shows a much darker gneiss, but this holds beds of quartzite and huge blotches of feldspathic granite.

The rock on Gallinas Creek is a hard reddish granite, which frequently approaches gneiss. No schists accompany it.

Another area is that of the Placer Mountains, which lies on the southern border of the district. But no opportunity was afforded for any examination of this area.

The dips of the Archæan rocks are much confused, and the distortion at most localities is so great that neither the succession of the strata nor the general structure could be made out during the brief examinations. A fault was suspected on Costilla Creek at about six miles below the mouth of Comanche Creek, but its existence was not determined. Positive proof of non-conformability to the overlying Carboniferous is not easily obtained; the main obstacle in the way of making the determination being the character of the rock. Usually, the disturbance near the junction of the two series is very violent and the rate of dip changes greatly within a short distance, sometimes becoming even reversed. But distinct non-conformability may be asserted as existing in the vicinity of Costilla Peak, where the enormously thick Carboniferous series terminates abruptly against the Archæan core of the Cimarron axis.

No absolute evidence exists to settle the age of these rocks. Lithologically, they bear close resemblance to the Laurentian series of the east, and at more northern exposures within the Rocky Mountain region they have been referred by all observers to that age. The coarse gneissoid and often conglomerate granite immediately underlying the Carboniferous at many localities may possibly be of somewhat later origin.

CHAPTER V.

THE CARBONIFEROUS ROCKS.

Parts of two principal areas of the Carboniferous lie within the district. The first or smaller enters from the north and follows the east slope of the mountains to Costilla Peak, where the Carboniferous rocks end abruptly against the Archæan. The second and much larger area is continuous at the south around the terminations of the several mountain ranges and reaches northward into the synclinals between the axes. This area extends northward under the Rio Grande Plains and is continuous with that whose outcrop is shown on the west side of the Sangre de Cristo and Culebra Ranges north from the district.

The Carboniferous rests directly on the Archæan at all localities examined.

THE NORTHERN AREA.

Carboniferous rocks are exposed along the east face of the Culebra Range almost continuously from the Spanish Peaks to Costilla Peak. The outcrop lies far up on the mountains at the north, reaching to the crest of several high peaks; but southward it retreats from the summit-line, owing to increasing strength of the uplift, until at Culebra Peak it is nearly a mile and a half away, and at the headwaters of the Vermejo Creek several miles away from the crest-line of the range.

A detailed section of the series cannot be obtained within this area without an expenditure of time and labor which would be unjustifiable in exploratory work. Continuous exposures are not wanting, but they occur in practically inaccessible localities.

The Carboniferous rocks are reached on the South Fork of the Purgatory River directly behind the Dakota Stonewall, which extends from the Spanish Peaks to Costilla Peak. The upper beds are reddish-brown conglomerate sandstones not far from 2,500 feet thick, whose dip, at first eastward, soon becomes nearly vertical. Large fragments of granite, gneiss, and quartzite prevail, but with them are some of sandstone and limestone. Several of the less coarse layers are tender and break down so readily as to prevent satisfactory study of the mass. This part of the section bears close resemblance to the upper division of the Carboniferous series seen on the Eagle River of Central Colorado.

Reddish sandstones, thin-bedded, fine-grained, and not far from 1,800 feet thick, and holding beds of red shales, underlie these coarse sandstones. Their dip passes beyond the vertical, and before their base is reached it becomes distinctly westward. These sandstones rest on a gray, not very hard limestone, which weathers bluish, contains many streaks of calcspar, is richly fossiliferous, and is not far from 100 feet thick. This is succeeded by 300 feet of red sandstone and reddish shale, similar to the last; under which is a blue, very compact limestone, of which twenty feet are exposed, showing some calcspar but no fossils. Beyond an interval of 700 feet, filled with red shale and sandstone, the lowest limestone is reached. As far as exposed it is seven feet thick, blue, slaty, hard, and contains some fossils. The base of the series is a conglomerate sandstone, not fully exposed, which evidently contains some beds of fine-grained red sandstone and red shale. It rests directly on the Archæan, is not far from 800 feet thick, and at contact has a dip of about 60° westward.

These rocks were observed along the several cañons in which the forks of the Purgatory flow. None but the three limestones was seen, and these retain the same features throughout. Exposures are very indefinite at the headwaters of the Vermejo and little can be found aside from the coarser sandstones at the few openings in the eruptive rocks. Fragments of the gray limestone frequently occur along the streams, but that bed was not found *in situ* at any locality examined.

THE SOUTHERN AREA.

Detailed study within this area was made only in the Coyote synclinal; the section was not fairly exhibited at any locality north from the head of Coyote Creek.

The Carboniferous rocks in Moreno Valley rest directly on the Archæan and occupy a synclinal on the west side of the present valley, where they seem to lie unconformably below the Dakota rocks. Apparently the lowest beds are exposed on the mountain side almost directly west from Elizabethtown, where they bear much resemblance to the coarse red sandstones closing the series on the South Fork of Purgatory. Two beds are shown, separated by a concealed interval, which evidently contains a limestone. The rock is an extremely coarse conglomerate with huge fragments of gneiss, granite, and quartzite, with limestone added in the upper bed. These conglomerates underrun reddish sandy shales such as underlie the coarse sandstones at the foot of Culebra Peak. The series is better shown along the face of the mountain farther south, though no good exposures were found until the valley of Coyote Creek was reached.

As has been shown in a previous chapter, the stratification on the east slope of the Taos Mountains is complicated. No detailed section can be made without the use of instruments, but the following succession was observed while ascending the mountain on the north side of Six-mile Creek:

1. Reddish sandstone and shale, not fully exposed, above which is a thin bluish limestone, partially altered and containing no fossils.

2. A cherty limestone, containing here and there a few less impure layers, in which are *productus*, *athyris*, and *fenestella*.

3. Sandy shale and thin sandstones. Impressions of roots are by no means rare in the more argillaceous portions.

4. A blue limestone, very compact, which contains many fossils; but these are not silicified and specimens could not be obtained for identification.

5. The interval cannot well be made out; it contains some shale and some compact sandstone, but no connected exposure of any sort could be found.

6. Limestone, gray, somewhat altered; contains much calcspar and is fossiliferous. It may be the same with the thick bed seen on the trail to Culebra Creek, to which it bears much resemblance. This, the most

marked bed in the whole series, is well shown on the south side of the creek, and in Moreno Valley between the base of the mountain and the creek.

7. A long interval, in which the exposures are unsatisfactory; much coarse sandstone and a little shale were seen.

8. Limestone, blue but weathering gray; it contains fossils, but the specimens are not silicified.

9. Conglomerate sandstone, like that seen on Culebra Peak, but much coarser. This reaches to the base of the section and probably is continuous with that seen on the mountain side opposite Elizabethtown.

The same section is present in the cañon leading to Taos Pass, for at the mouth of that cañon the reddish shales and thin sandstones are well shown; the cherty limestone and the gray limestone are seen farther up, and on the summit of the pass is a thin limestone, the lowest of the series, which rests against a coarse conglomerate extending to the Archæan rocks.

Carboniferous rocks are frequently exposed along Coyote Creek above the village of Coyote; but they are much distorted and the section could not be worked out in detail. The general character of the rocks is unlike that observed at more northern localities already referred to, for the coarse sandstones are no longer present at the base; the coarse sandstones at the top are not red and conglomerate, but merely coarse gray sandstone, while the red shales are almost absent, being only insignificant layers separating great beds of gray sandstone. But the gray limestone of Taos and Culebra Peaks seems to be conspicuous in all the sections. A short section at the base of the series on Coyote Creek is—

	Feet.
1. Sandstone	30
2. Limestone	25
3. Shale and sandstone	180
4. Sandstones and shales, with a limestone near the base	300

No. 2 is a grayish limestone and contains many fossils characteristic of the coal measures. The shales, No. 3, contain thin bands of limestone near the top; both shale and limestone are full of coal-measure forms. The limestone in No. 4 seems to be non-fossiliferous.

A section obtained at nearly four miles above Coyote gives a total thickness of nearly 3,000 feet, but there is good reason to believe that the section is doubled there by a synclinal. Four beds of limestone occur within the first 800 feet above the Archæan, and many thin streaks of limestone were seen in the shales, answering to No. 3 of the last section. At the top of those shales is a bed of gray limestone, which is very rich in fossils of species belonging to the coal measures.

Following the synclinal southward, one finds the features observed on Coyote Creek more clearly defined on Mora, Manuelitos, and Sapello Creeks. The following section, compiled from sections taken on Mora and Manuelitos Creeks, is characteristic of the series as exhibited within this synclinal:

Generalized Section.

	Feet.
1. Not fully exposed, but mostly sandstone	141
2. Limestone, blue, fossiliferous	12
3. Sandstones and shales, latter red, former light to dark gray, moderately coarse to conglomerate	320
4. Limestone and shale, non-fossiliferous	20
5. Sandstone, mostly dark gray, with some red shale	250
6. Imperfectly exposed; some sandstone	100
7. Dark-gray sandstone	90
8. Concealed	20
9. Yellow sandstone	25
10. Concealed	15
11. Limestone, blue, many fossils	10
12. Yellow sandstone, mottled with black	8
13. Dark-gray sandstone	40
14. Dark-red shale	12
15. Limestone, blue, cherty, fossiliferous	18
16. Red shale	20
17. Gray sandstone, mottled with brown	30
18. Red shale	10
19. Limestone, cherty	6
20. Red shale	20
21. Red shales and thin gray sandstone	90
22. Gray sandstone, with brown spots	70
23. Concealed	50
24. Flaggy to compact sandstone, with impressions of stems	20
25. Red shale	8
26. Limestone with some shale, gray, fossiliferous	18
27. Dark-brown shale	60

		Feet.
28.	Imperfectly exposed	150
29.	Dark shale	70
30.	Gray sandstone	15
31.	Shale	40
32.	Alternations of shale and sandstone	300
33.	Coaly shale	10
34.	Limestone, impure, non-fossiliferous	2
35.	Concealed	30
36.	Sandstone and shale	70
37.	Limestone, blue, few fossils	6
38.	Sandstone and shale	30
39.	Limestone, grayish, somewhat silicious	8
40.	Concealed	25
41.	Sandstone	15
42.	Concealed	60
43.	Limestone seen	10
44.	Concealed	20
45.	Sandstone and shale	180
46.	Limestone	70
47.	Sandstone	20
48.	Concealed	12
49.	Limestone with shale	200
50.	Sandstone	8
51.	Limestone	30
52.	Sandstone and shale	25
53.	Limestone	20
54.	Sandstone	25
55.	Limestone	15
56.	Sandstone	12
57.	Sandstone and shale	120
58.	Limestone	8
59.	Sandstone	15
60.	Limestone	35
	Total	3,276

And No. 60 rests on the Archæan.

In this section, which may be taken as typical for the whole southern region, two groups are shown; 317 feet of limestone occur in the lower 905 feet, while there are but 100 feet of limestone in the remaining 2,376 feet. The limestone group and the sandstone group recognized in southern New Mexico many years ago by Mr. Marcou, are well defined on lithological grounds, and are convenient for reference during description.

The limestones and some of the shales in the lower division are for the most part rich in fossils. No. 46 is very probably the gray limestone of Taos and Culebra Peaks; it is well shown on Coyote Creek above Guadalupita, in the cross-section above Coyote, on Mora, Manuelitos, and Sapello Creeks; the mass of limestone and shale, No. 49, is the characteristic and persistent series seen in both sections on the Coyote, as well as on the Mora, Manuelitos, Sapello, and Tecolote. The shales are always dark; the limestone is a variable quantity, being insignificant above Guadalupita, but occurring in bands from three to ten inches thick near Coyote; on the Mora many of the beds are two feet thick, while on the Manuelitos the limestone predominates. No. 51 is a compound bed, a more or less silicious limestone in the lower part, passing upward into a calcareous grit containing much iron. The upper layers break out in rectangular blocks, which split readily when the calcareous cement has been removed by long exposure to the weather. Fragments of this bed were first seen above Guadalupita on the Coyote, but the bed itself was not found until Manuelitos Creek was reached. The position and many of the features shown by this limestone lead to the suspicion that it may be equivalent to a cherty limestone seen farther north.

Fragments of No. 58 were seen on Mora Creek as well as on Cebolla, but the bed was not discovered north from Manuelitos Creek. No. 60 is the bed which dips eastward in the park between the Archæan and the Carboniferous hills at somewhat more than three miles north from Coyote. It is present also on Mora, Manuelitos, and Sapello Creeks. As the contact between Archæan and Carboniferous is not exposed at the base of the Las Vegas Range in the valley of Tecolote Creek, the presence of this bed there was not fully determined; but fragments of a rock closely allied to it are not rare in the *débris* at the foot of that range. This limestone varies from fine-grained, gray, compact, and pure, to light blue, hard, and very silicious, and passes almost imperceptibly into the overlying sandstone, which is much like quartzite at its base. No fossils were found in this rock.

Detailed observations were made at but few localities within the Pecos synclinal or within the extended area of exposures lying about the southern termination of the axes. Limestones 60 and 51 are shown on Cebolla Creek, on the west side of the Mora axis, and farther north the same beds are exposed near the head of Mora Creek. No section was attempted within the Pecos synclinal on Ferdinand Creek, for there was not sufficient time to admit of studying out the confused dips attending the disappearance of the Taos Archæan and the beginning of the Santa Fé Archæan. An enormous conglomerate at the base of the Carboniferous, similar to that found on the east slope of the Taos Range, is shown on Junta Creek within this synclinal, as well as on the west slope of the Santa Fé axis. Less limestone was seen in this synclinal than at the corresponding horizons on Mora and Manuelitos Creeks in the Coyote synclinal.

But the limestone increases southward in the Pecos synclinal, for beds of that rock are numerous and thick along the cañon of Pecos River. Those of the higher group evidently become more important southward, for a great limestone is exposed at many places along the Santa Fé stage-road between the Mora and the Santa Fé axis. The relations of the thick limestone curving round the southern termination of the Santa Fé Archæan were not determined.

Throughout the whole of this southern area the two groups observed on the Mora are distinct and retain the features there noticed.

A small area of Carboniferous is exposed in the Turkey Mountains; but there only the upper or sandstone group is brought to the surface. No limestones were seen, but lithologically the resemblance of the sandstones to those of the Mora is complete. No fossils were obtained by us, but Dr. Newberry procured a *Stigmaria* from one of the beds.

Even the most cursory examination of the preceding part of this chapter discloses the striking differences exhibited by this group in the two areas. Sandstone predominates throughout the series in the northern area, while limestones are few in number, and with one exception unimportant. A conglomerate occurs at both the base and the top of the column; the less coarse sandstones are red, and the shales almost without exception are sandy.

Somewhat similar conditions exist in the southern area on the west side of Moreno Valley, where a conglomerate begins and closes the column, while in the interval red shales and sandstones prevail. Yet even here a very material change is shown, for along Six-mile Creek five beds of limestone were seen, and there is good reason to suspect the presence of a sixth. But this change becomes distinct farther south in the Coyote trough.

At the first cross-section obtained in Coyote Valley the conglomerate is absent from the base of the series, and thence southward a silicious limestone rests on the Archæan; four beds of limestone were found in the lower 800 feet of the column, which is not fully exposed; shale predominates in this part of the section, and the proportion of sandstone shows a decided decrease. The great upper division of the column shows no conglomerate other than in little pockets; ordinary sandstones with beds of reddish shale separating them prevail, and several unimportant beds of limestone are introduced.

As one follows the series southward he finds this change much more marked in the lower than in the upper division of the section. On Manuelitos Creek the lower group, 905 feet thick, shows 317 feet of limestone, whereas the upper group, 2,376 feet thick, has but 100 feet of limestone. But while the limestone increases but slowly in the upper group, the sandstones have become less coarse in grain and the shales separating them have become thicker at their expense.

Crossing the Mora area of Archæan to the Carboniferous of the Pecos synclinal, one finds there contrasts equally striking. The conglomerate at the base of the series evidently disappears at but a little way south from Taos Pass on the west side of the Mora axis, but it prevails on the east slope of the Santa Fé axis to a considerable distance south from Junta Creek, fully fifteen miles farther south than its limit on the Mora axis. A clumsy conglomerate was seen very near the base of the series on the east side of the Santa Fé axis within a few miles of its southern termination.

But while this massive conglomerate at the base of the series seems to be persistent along the western side of the Pecos synclinal, the higher rocks are by no means like those of the northern area. Sandstones, it is true, predominate along Ferdinand Creek, but they are not coarse; the limestones there are not numerous, but they are comparatively pure. Southward the limestones increase in number and thickness, until at the mouth of Pecos Cañon the lower part of the section appears to be even richer than it is in the Coyote synclinal on Manuelitos Creek.

This condition prevails in the belt of Carboniferous fringing the southern termination of the axes, where even the limestones of the upper group attain to no inconsiderable thickness.

It is sufficiently evident, from the distribution of the conglomerates and limestones, that at the beginning of the Carboniferous era a body of dry land existed in the vicinity of the Culebra and Taos Ranges, as well as along the present course of the Santa Fé axis; and that this was still above water in the Culebra region during the greater part of the Carboniferous era; it is equally evident that during the earlier part of that era the southern part of the area either sank wholly below the sea or else became utterly insignificant in size, so that the wash was too slight to contaminate the ocean at any distance from the shore-line. But after an accumulation of barely one thousand feet had been made, the ocean became shoaled and the area of dry land or of land barely below water-line increased, for the limestone-making period closed abruptly. It seems, however, altogether probable, from the thickening of limestone in the upper group along the Santa Fé road, that farther south that group will show changes such as have been noticed in the lower division within the limits of the district.

On the map the Carboniferous has been colored as one series, no attempt having been made to recognize any subordinate groups. No subdivision is now possible on palæontological grounds. It may be that at some future time, when the country has been more closely examined and more extensive collections of fossils have been made, the relations of the several parts of the section may be determined with a considerable degree of accuracy. At present, however, all attempts to classify the series are premature. This will appear from the following facts.

The base of the group was reached at many localities and fossils were collected wherever any could be found.

A thin limestone rests on the conglomerate at the base of the series on the east slope of Culebra Peak. This contains *productus splendens, Spirifer lineatus,* and an undescribed *Naticopsis.*

A thin limestone occupying an analogous place in the section occurs on the summit of Taos Pass, and contains *Spirifer plano-convexus, Athyris subtilita,* and *Lophophyllum proliferum.*

The lowest limestone of the series shown on Coyote Creek and southward is an impure rock resting directly on the Archæan and containing no fossils. The next above is No. 58 of the general section which, on Manuelitos Creek, yielded *Orthis resupinata* (?) and some indistinct forms. No. 51, the next above, is a composite bed, somewhat ferruginous, and silicious below, but passing upward into a dark-blue ferruginous grit. It is well shown on Cebolla Creek on the west slope of the Mora axis, and on Manuelitos Creek within the Coyote synclinal. The lower division yielded the following species:

Lophophyllum proliferum.
Fenestella.
Stenopora.
Spirifer cameratus.
Spirifer lineatus.
Spiriferina kentuckensis.
Retzia mormonii.
Athyris subtilita.
Productus muricatus.
Productus semi-reticulatus.
Chonetes granulifera.

While the upper division gives—

Stictopora serrata.
Fenestella.
Discina.
Lingula.
Orthis pecosii.
Spirifer keokuk.
Spiriferina kentuckensis.
Athyris subtilita.
Athyris roysii.
Streptorhynchus crassus.
Productus costatus.
Productus punctatus.
Productus prattenianus.
Aviculopecten carbonarius.
Aviculopecten occidentalis.
Pinna.
Pterinopsis.
Avicula. (?)
Myalina subquadrata.

Similarly no fossils were seen on Coyote Creek in the limestone at the base of the series. The lowest fossiliferous bed contains the following species:

Fenestella.	*Productus splendens.*
Spirifer keokuk.	*Productus sp.*
Spiriferina kentuckensis.	*Chonetes granulifera.*
Retzia mormonii.	*Chonetes sp.*
Athyris subtilita.	*Streptorhynchus crassus.*
Athyris roysii.	*Nucula ventricosa.*
Productus costatus.	*Pleurotomaria spherulata.*
Productus prattenianus.	*Pleurotomaria grayvilliensis.*
Productus muricatus.	*Orthoceras rushensis.*

Of the species given in these lists, *Orthis resupinata* and *Spirifer keokuk* may be regarded as Lower Carboniferous forms, but all of the rest are either Coal Measures species or forms which are common to the Coal Measures and the Lower Carboniferous. Judging then from the fauna, the only available means of comparison, it appears that the Lower Carboniferous of the Mississippi region is wholly wanting in this district.

Similarly the Permian age of the upper part of the column has no positive basis. *Bakevellia* occurs near Pecos, but it is associated with *Meekella striatocostata*, *Athyris subtilita*, and other forms, which are thoroughly characteristic of the Coal Measures. It is altogether probable therefore that the epoch of the Coal Measures alone is represented in this area.

CHAPTER VI.

THE JURA-TRIAS.

The attempt to determine the vertical extent of this group within the district has resulted in little more than uncertainty. The relations of certain red beds to the Carboniferous below and to the Dakota above are so intimate that all lines of separation must be arbitrary to the last degree; the more so, since no fossils have been discovered which give any positive evidence respecting the matter. Still, these beds directly overlying the well-defined Carboniferous and evidently marking the passage from that series to the great mass, to be described in the next chapter as Dakota, may be placed in the Jura-Trias. Some Trias seems to be necessary to make the succession complete.

No rocks of this group were found in the Culebra Range, and the Carboniferous rocks underlie the Dakota along the whole mountain face to Costilla Peak at the south; while farther south along that line both Trias and Carboniferous are absent and the Dakota rests on Archæan. No clear proof of the presence of Trias was found in the Coyote synclinal north from the head of Coyote Creek. Some red shales were seen on Cieneguilla Creek at a few miles south from the cañon leading up to Taos Pass, but their relations are uncertain, and they may be only parting shales of the sandstone group of Carboniferous. The first distinct exposures were seen below Guadalupita on Coyote Creek, where the red shales and sandstones occur on the east side of the valley at the base of the mesa. Fragmentary exhibitions appear for several miles, until at nearly three miles above Coyote a long bend in the creek affords a connected section from the mesa to the Carboniferous hills in the middle of the valley. The series as exposed here is not far from 700 feet thick.* Red shales and red sandstones and impure limestones fill the upper third of the section, while the lower part consists of very coarse red sandstones, often conglomerate, alternating with bands of deep-red shale. Blocks of red sandstone, water-worn, and measuring eight by twelve inches, frequently occur in the sandstones. The limestones and the adjacent shales were searched carefully for fossils but without success. These beds are persistent from this locality southward along the east slope of the Cimmarron anticlinal, being well exposed behind the Lower Dakota Stonewall on Coyote, Mora, Sapillo, and Gallinas Creeks; but they are indifferently shown on Cebolla Creek and south from the gap of Gallinas Creek. On Mora and Sapillo Creeks the sandstones are finer in grain and have a deeper red color, while instead of the large fragments of rocks there are only rows of small rounded pebbles, seldom larger than a hen's egg. A few thin gray sandstones were seen on these creeks, but the limestones found on Coyote Creek are absent. The conditions shown on Gallinas Creek are much the same, but the gray sandstones have increased in importance. These beds were not recognized in the Turkey Mountains. The shales are somewhat gypsiferous, but the gypsum occurs in films and the quantity is insignificant.

No fossils were found by me in any part of the series, but Dr. Hayden† states that he obtained casts of *Mytilus* associated with a saurian tooth in the upper part of the section on Gallinas Creek, which he thinks suggest Jurassic age for that part of the group.

These red beds are well shown along the Santa Fé stage-road from Bernal Creek to Galisteo Creek, as they make up a great part of the mesa-wall on the southwest side of the Pecos Valley. Exposures there are distinct, and the section shows alternations of shales and sandstones in all not very far from 750 feet thick. The sandstones of the upper part are brick-red, while those lower down are gray to brownish-red; and the shales vary from red to blue or purple. No fossils were found in any part

* The thickness of inclined beds is given in all cases by estimate.

† Third annual report. Reprint, p. 163.

of the section, but some gypsum was seen. This section underlies the Lower Dakota sandstone, which is the rim of the mesa. The exposure on the Upper Galisteo, where the Archæan of the Santa Fé axis ends, is similar, except that the sandstones at the base of the group are for the most part gray, while red shales, both sandy and clayey, prevail in the upper part.

This series passes almost imperceptibly into the Carboniferous below at all localities examined, and the groups are wholly conformable wherever they have been seen in contact. The upper sandstones of the Carboniferous as exposed under the Cimarron anticlinal, as well as in the mesa along the Pecos, are separated by shales, mostly red, and some of them blood-red as any in the series here referred to the Triassic. The line of separation is placed arbitrarily at the top of the last bed of massive gray sandstones on the Mora, there being Carboniferous fossils at 140 feet below that bed; and the interval to the fossil layer is imperfectly exposed. The passage to the Lower Dakota is better marked, for at most localities the latter group contains no shale.

CHAPTER VII.

THE DAKOTA GROUP.

The grouping to be proposed in this chapter is merely provisional; dependence has been placed solely on lithological characters and stratigraphy, since testimony of fossils is either unattainable or indecisive. When the work shall have been prosecuted in detail and carried systematically toward the south and west to localities already well determined by evidence of fossils, this classification may prove to be somewhat arbitrary. For the present, however, it seems desirable to include under one group the Dakota of Meek and Hayden and the greater part of the Trias of authors as found in New Mexico. The whole series may be Triassic or it may be wholly Cretaceous. It is included under the Dakota here merely for convenience of description.

The exposures of Dakota are in two areas, which are partially disconnected by the great overflows of eruptive rocks in the Cimarron Mountains. The smaller area enters at the north and follows the east base of the Culebra Range to Costilla Peak, where it is cut off by the igneous overflow. The larger area begins at but a little way east of south from the other in some petty exposures, and thence continues southward. It forms a strip on each side of the Canadian Cañon below the old Leavenworth crossing, which widens westward until it embraces nearly the whole of the Canadian Plains south from a line passing through Fort Union, the whole region between Wolf Creek and the Coyote, and extends almost without interruption from the Sapello up Mora Creek to La Cueva. But the area contracts south from Mora Creek and the series is seen only in a Stonewall following the east slope of the Cimarron anticlinal and extending southward to ten or twelve miles beyond Las Vegas. This narrowing disappears with the axis, and the Dakota forms a continuous sheet south and southwest, covering much of the great mesa country drained by the Pecos and the Rio Grande.

No subdivision of the Dakota can be made conveniently in the northern or smaller area. There it forms the Stonewall to which reference has been made in previous pages, and, so far as exposed, it consists only of sandstone. The wall usually appears double at the top, but the space between the two plates of sandstone is invariably concealed. The peculiarities of this Stonewall have been described in another place, and no further description is necessary here.

Though apparently one mass, yet there are traces of the subdivisions which will be proposed for the southern area, where the thickness is vastly increased. Both plates of sandstone are alike in color and vary from gray to light yellow, but they are distinguished by peculiarities of composition and texture. The upper plate varies from fine-grained to moderately coarse conglomerate; its finer and more compact layers, which are best fitted to resist atmospheric erosion, are usually honeycombed with films of quartz, a feature characterizing this rock over a great area in both Colorado and New Mexico, and rarely seen in any sandstones except those of this upper division. Some of the lower layers are finely conglomerate and are cemented by a soft powdery material.

The lower plate of sandstone is, for the most part, fine-grained, but it sometimes shows small pockets of rather coarse conglomerate. The films of quartz are wanting at all localities examined. The shales supposed to exist between these plates of sandstone were not seen, but the mode of weathering is such as to leave little room for doubting their existence. The total thickness of the group is not more than 300 feet, and at some localities it is materially less.

In the larger area the Dakota is triple and is divided as follows:

	Feet.
1. Upper Dakota, sandstones	750
2. Middle Dakota, shales, sandstones, and impure limestones	600
3. Lower Dakota, sandstones	350
Total of Dakota group	1,700

No. 1 is the Dakota of Meek and Hayden, but Nos. 2 and 3 have been regarded as Trias by all previous explorers of this region.

THE UPPER DAKOTA.

The Upper Dakota is exposed over a great part of the southern area. It underlies the basalt of the Ocaté Mesa south from Ocaté Creek, forms both walls of the Mora and Canadian Cañons, covers the area stretching from Mora Creek eastward to the Canadian, and forms the eastern portion of the Stonewall south from Cebolla Creek. The northern outlier of a great area of this sub-group is reached on Galisteo Creek, near the village of that name.

It is represented only by sandstones within the greater part of the Canadian region, and its thickness, as measured near the mouth of the Canadian Cañon, is not far from 800 feet. The sandstone is fine-grained, hard, and resists erosion well, as is seen in the deep cañons of the Mora and Canadian, of which it is the rim. This sub-group crosses the Cimarron axis at both Poñil Pass and Ocaté Park, and fragments of it remain in the Moreno Valley. No fossils were discovered except near the top, where there are some thin shales and sandstones, the latter covered with rude casts of fucoids. These higher beds, however, may belong to the base of the Colorado shales.

The sandstones of the Upper Dakota form bold hills on Mora Creek, which cross that stream with a southwest trend. The rock is grayish-white, very hard, and so compact and fine-grained as to resemble quartzite. Sometimes one sees a pocket of conglomerate or of soft yellow sandstone, which yields readily to the weather. These beds are turned up sharply in the Turkey Mountains and show the same features as on the Mora, except that one of them has a peculiar grayish-yellow tint, by which it may be recognized from the other side of the Canadian Cañon, thirty miles away. The fucoid-bearing sandstones are shown on the Mora Plains at a little way south from the Canadian Hills.

The character of the mass changes somewhat in the Stonewall south from Cebolla Creek, for on Sapillo and Gallinas Creeks, as well as in the gap south from Las Vegas, through which the Santa Fé road passes, shales occur midway in the series. Two plates of sandstone were seen near Sapillo, each about 300 feet thick, separated by variegated shales with thin impure limestones, in all about 200 feet thick. A similar condition, though not so marked, occurs on Gallinas Creek; while in the gap south from Las Vegas the upper sandstone and the shales are much thinner than on the Sapillo, though otherwise showing no difference.

No exposure of the Upper Dakota was found south or west from that last mentioned before coming to Galisteo, where that series forms the eastern wall of a fine park. The rock is gray to yellowish-gray, with a reddish layer at the top; but it contains no fossils aside from rude casts of fucoids. There is much danger of confounding the Upper and the Lower Dakota along the Upper Galisteo, as that area is very badly faulted.

THE MIDDLE DAKOTA.

This is shown on Coyote, Mora, Sapillo, and Gallinas Creeks and on the Canadian and Mora Rivers; but is ill-exposed in the east slope of the Cimarron axis, where it is cut by the Santa Fé road south from Las Vegas. Incomplete or rather fragmentary exposures were seen in Ocaté Park and the Turkey Mountains. This sub-group is the gypsum formation of Blake and Marcou, and in part the Trias of Newberry and Hayden.

It is distinctly recognizable for the first time at the north in Ocaté Park, where, under the Upper Dakota, some red shales were seen wholly unlike those of the Triassic observed on Coyote Creek. A better exposure occurs on Coyote Creek below Coyote, and on Mora Creek below La Cueva, where this sub-group is made up of dull-gray, flaggy, and soft incoherent white sandstones, with variegated shales and some limestone which is excessively hard. Coyote Park has been digged out of this mass of soft rock.

The Turkey Mountain exposure gives but a fragment of the section which is shown in the cañons of the Mora and Canadian, as follows:

	Feet.	Inches.
1. Blue laminated limestone, hard, brittle; contains *bryozoans*, which are shown indistinctly on the weathered surface	2	0
2. Sandstone, olive and fine-grained, mostly massive, seldom shaly; a thin gray sandstone sometimes intervenes between this and the limestone	40–50	0
3. Limestone, gray, weathering bluish-white; conglomerate in appearance, owing to seams of clay; no fossils except tube-like stems	1	6
4. Red sandy shale, fine-grained, contains much clay and is mottled with white; seen	200	0

A coarse gray, somewhat shaly sandstone, which overlies No. 1, may possibly belong to the Middle Dakota. The limestones are not persistent in the sections, and frequently they have been removed during the formation of the overlying sandstones or by sub-aerial erosion previously. This section is shown at many places in the Canadian Cañon up to within eighteen miles of the old Leavenworth crossing at Franklin's ranch on the map. The middle sandstone has a beautiful olive color and often shows no seam. It is cross-bedded, but the lamination is so fine as not to affect the regularity of the weathered surface.

The limestone seen on Mora Creek near La Cueva was found also on Sapillo Creek, where a narrow valley intervenes between the Upper and the Lower Dakota, so that exposures of the Middle Dakota are very imperfect. The rocks, as incompletely shown on the south side of the creek, are chiefly red micaceous shales and gray sandstones. The conditions on Gallinas Creek are much the same as on Sapillo, but the limestone was not seen. In the gap south from Las Vegas the rocks are mostly soft gray sandstones and variegated shales with some silicious limestone. No gypsum aside from mere films was observed at any locality.

The Middle Dakota is imperfectly shown on Galisteo Creek immediately below the stage-road, where it has blood-red shales and an almost snow-white incoherent sandstone. A better exposure was found in the Arroyo de los Angeles nearer Galisteo, where there are blue, white, and red shales with a few thin sandstones, and a thick bed of limestone which contains indistinct fragments of crinoid stems. Some gypsum occurs in the shales along the Upper Galisteo in the vicinity of the bishop's ranch. But the best exposure in this region is on the Arroyo San Cristobal, a tributary to Galisteo Creek, where the mesa of the Upper Dakota is reached at barely three miles east from Galisteo and the Middle Dakota is shown immediately behind it. The lower series is represented by variegated shales with the limestone and sandstones, as on the Upper Galisteo. One bed of dark shale contains abundance of nodular limestone, very dark and with reticulate surface. Gypsum of good quality is said to occur here.

THE LOWER DAKOTA.

The Lower Dakota is exposed near the head of Cieneguilla Valley; forms the upper part of the mesa wall on the east side of Coyote Valley; is the bold stonewall extending from Coyote southward to midway between Cebolla and Manuelitos Creeks; and thence to the southern edge of the district is conspicuous as the inner portion of the stonewall. It is finely shown as the higher part of the mesa lying south from the stage-road between Bernal Creek and Galisteo Creek, and is equally well shown along the latter creek to within a few miles of Galisteo. It is not reached by Mora Creek below La Cueva, nor is it exposed at any locality within the district east from the immediate vicinity of the Cimarron anticlinal.

At all the gaps made by Coyote, Mora, and Cebolla Creeks through the stonewall, this sub-group offers no physical characters whereby it may be distinguished from the Upper Dakota, except one; the conglomerate is somewhat coarser and occurs in larger pockets. For the most part the rock is very fine-grained and compact, varies from light gray to grayish brown and light yellow, and at a few localities shows a net-work of quartz films like those characterizing the Upper Dakota. One familiar with the Upper Dakota would at once mistake this for that if this alone were exposed. But on Sapillo Creek the rock is coarser and its resemblance to the Upper Dakota is not so striking; while on Gallinas Creek some streaks of shale occur. The rock is not well exposed in the gap south from Las Vegas, but, as far as seen, it is fine-grained and hard, with a yellowish-gray color.

The Lower Dakota forms the rim of the mesa bounding the Pecos Valley at the southwest. At all exposures it is represented by yellow to yellowish-gray sandstones with occasional bands of white, all of them fine-grained. The same group is reached on the Arroyo San Cristobal at not far from six miles east from Galisteo, where it is said to hold some thin coal-beds. The coal from one of these has been tried by the United States forage agent at Galisteo, who reports that it is good fuel.

CHAPTER VIII.

THE COLORADO GROUP.

The Colorado group was proposed by Mr. King to include the Fort Benton, Niobrara, and Fort Pierre shales of Meek and Hayden, the Nos. 2, 3, and 4 of Mr. Meek's original section. It is equivalent to "Middle Cretaceous" as used by Dr. Newberry in his reports on New Mexico, and by the writer in his report on Southern Colorado.

The rocks of this series are exposed in the Stonewall Valley along the eastern foot of the Culebra Range from the Spanish Peaks at the north to Costilla Peak at the south, and there is every reason to believe that the outcrop is continuous thence to the head of Ute Creek, but concealed by *débris* of igneous rocks for much of the distance. This narrow area or strip is cut off by a fault before Cimarron Creek is reached, but exposures begin again within two or three miles farther south, on Cimarroncito Creek, whence the outcrop is unbroken along the edge of the Ocaté Mesa southward to and along the east face of the Turkey Mountains. The Colorado shales underlie the thin cover of alluvium on the plains north from the Canadian Hills, and good exhibitions frequently occur on those tributaries to the Canadian which enter the river above the head of its great cañon. The exposures are good on the sides of the Raton Plateau, east from Manco Burro Pass, where they directly underlie the basalt cap.

Erosion has removed this group from the region between Mora Creek and the Turkey Mountains, and fragments remain in mesas on the plain between the Canadian Hills and the Mora Cañon; so that this Canadian area, north from the cañon of the Mora, is fairly separate from all the others. The southern area of the Colorado shales begins on Mora Creek immediately above the mouth of Coyote Creek and quickly widens southward, until at a little way south from Sapillo Creek it covers all the vast plain lying east from the Cimarron axis and extending south and east far beyond the limits of this district.

A part of this southern area was reached on Galisteo Creek in the immediate vicinity of Galisteo, where is its northern termination. Another prong was seen on the same creek at sixteen miles below Galisteo, which extends thence to the Rio Grande. The fragments scattered over the Mora Plains show that at one time the group covered the whole region east from the Cimarron axis and that its absence is due wholly to erosion.

Small patches of this group have been preserved in the vicinity of Elizabethtown, but no traces were found elsewhere in the Coyote synclinal; nor were any seen at any locality within the Pecos or Taos synclinal.

The subdivisions of the Colorado shales are readily distinguished in all parts of the region examined. Both in physical features and in fossil contents they accord with the same sub-groups as exhibited at the typical localities on the Upper Missouri.

THE FORT BENTON SUB-GROUP.—CRETACEOUS No. 2, OF MEEK.

The Fort Benton is composed of dark shales with thin beds of sandstone, and seldom is more than 150 feet thick. The rocks are tender, yielding readily to the weather, and good exposures are rare.

The group was seen on the South Fork of Purgatory under the anticlinal in which one division of the Stonewall ends. The shales are dark brown, contain no fossils, and are distinctly separate from the overlying Niobrara. Indistinct and fragmentary exposures occur frequently in the Stonewall Valley, but none of them exhibits the base of the group. No exposure was found along the east face of the Cimarron Range; nor was the group recognized in the Moreno Valley.

The dip of the rocks in the Canadian Plains is so gentle that the lower part of the Colorado group is not reached anywhere near the Raton Plateau. Eastward from the Raton Hills or Laramie area one sees the Fort Benton shales for the first time as he approaches the head of the

Canadian Cañon, nearly thirty miles from the Laramie outcrop. There, near the old Leavenworth road, some fair exposures occur, which were examined by Mr. Russell, who reported the series non-fossiliferous. The transition from the shales to the underlying Dakota is very gradual; the thin slabs of sandstone become thicker, until at last the shales disappear and the Dakota sandstone is reached.

Some very imperfect exposures between the Canadian Hills and the Mora Cañon show the same features as at the Leavenworth crossing of the Canadian. One immediately southeast from the hills and very near the fork of the trail exhibits the thin-bedded sandstones at the base covered with rude casts of fucoids.

The shales are shown in front of the Dakota wall from Sapillo Creek southward. The exhibitions are very good on that stream as well as on Gallinas Creek, and at many other localities until ten or twelve miles south of Las Vegas, beyond which no observations were made. The shales are dark brown, and toward the base are the yellowish slabs of sandstone covered with fucoids.

An indefinite exposure was found on the Arroyo San Cristobal at barely three miles east from Galisteo. It is insufficient for determining the thickness of the group, but shows that the Dakota and the Fort Benton are as distinct here as at any other locality within the district.

THE NIOBRARA SUB-GROUP.—CRETACEOUS No. 3, OF MEEK.

The Niobrara is a well-marked group. It consists largely of gray or bluish-gray argillaceous limestones occurring in thin beds and separated by black shales or drab shales, which become predominant toward the top of the sub-group, so that the passage to the overlying Fort Pierre shales is gradual.

The limestones of this group are imperfectly shown in the Stonewall Valley, though partial exposures are numerous. Similarly imperfect exposures are shown in the Moreno Valley south from Elizabethtown, both in the hill and alongside of the creek. But the group is preserved only in the vicinity of that town and the area is insignificant. No other fragment was found in the Coyote synclinal.

The Niobrara beds are reached only near the southeast corner of map 70 A, there being no certain exhibition farther north within the district; but they are nicely shown for a long distance along the Cimarron and the Canadian, as well as on the Canadian Plains north from the Canadian Hills. The exposures along the Cimarron are hardly sufficient for satisfactory measurement, but the thickness is not far from 700 feet as determined by the barometer and calculations from the dip.

The rocks of this group are reached south from Mora Creek at but a little way east from the Dakota wall, and short sections frequently present themselves along the streams. The beds extend far eastward and become almost horizontal south from the line of Sapillo Creek and the cañon of Mora River. Fine exposures may be seen along all of the petty streams in the vicinity of Las Vegas, while within a few miles farther south the limestones are well shown in mesas beyond the end of the Cimarron anticlinal.

The limestones only of this group were seen on Galisteo Creek, where the exposures are far from being complete. But the rock has exactly the same physical characteristics there as on the Cimarron and in the Stonewall Valley; it is bluish-gray, is hard and brittle, and does not weather regularly, but breaks down into angular fragments like the "spalls" of stone-masons. The beds are thin and are separated by gray shales. The rock is impure, and efforts to burn it into good lime have not been successful.

Many of the limestones and some of the shale-beds are fossiliferous at all localities, but their richness in this respect is a variable quantity. Careful search for fossils will never be wholly unrewarded, but there are many localities where the reward will be small, while at others the fossils are present in great numbers. But the limestone has an irregular fracture and the larger fossils cannot be obtained in very good condition. *Inoceramus problematicus* and *Prionocyclus woolgari* are among the most common forms in the limestones, while *Ostrea congesta* is most frequently observed in the shales and shaly limestones. The best localities for the collector are along the Cimarron for six or eight miles above its mouth, along the south face of the Canadian Hills, and in the vicinity of Las

Vegas. The last two localities are easily accessible, being within a mile or so of the Atchison and Topeka Railroad.

THE FORT PIERRE SUB-GROUP.—CRETACEOUS No. 4, OF MEEK.

The Fort Pierre sub-group was seen at several localities within the Stonewall Valley, as well as in parks on the South Fork of Purgatory and on the Vermejo, where it has been brought up by the Vermejo anticlinal, and along Ute Creek on the eastern slope of the Cimarron Mountains. But it was not recognized in the synclinals west from the Cimarron anticlinal; nor is it reached in any portion of the great southern area within the district, except along Galisteo Creek.

The rocks of this group are shown constantly along the bluffs holding the eastern outcrop of the Laramie group, as well as in the Ocaté Bluff from Cimarroncito Creek southward to Ocaté Creek. This is the only part of the Colorado group shown in the Purgatory and Canadian plains until near the southeast corner of map 70 A, where they run out and the Niobrara beds come to the surface. The area of this group narrows southward, and the eastern outcrop runs rudely southwestward from Cimarron Creek to Ocaté Creek, reaching the latter stream very near the edge of the Ocaté Mesa. The lower beds have been preserved from erosion by the lava-cap of the Canadian Hills, but no other fragments remain south from Ocaté Creek.

The exposures in the vicinity of Galisteo are very satisfactory, as are also those on Galisteo Creek, beginning at sixteen miles below the village. There the beds cover an extensive area stretching toward the Rio Grande.

The thickness of this sub-group cannot be ascertained without close instrumental measurements. It seems to be not far from 1,100 feet on the Upper Canadian, while in the vicinity of the Cimarron it may be nearly 1,700 feet. The thickness is much less in the Stonewall Valley, unless, indeed, there be a fault there between this and the Laramie.

The Fort Pierre is a varied group. At its base are laminated sandstones and arenaceous shales, gray and drab to bright yellow, which are well exposed in Bragg's Cañon north from Eagle-tail Mountain and on the Canadian and Cimarron southwest from that locality. They crop out around the Eagle-tail Mesa, and are finely shown on the Cimarron where the road crosses at Blackman's Ranch. These shales for the most part are non-fossiliferous, but huge *Inocerami* occur plentifully in some of the layers, and with them are occasional specimens of *Ostrea congesta*. Other layers are crowded with comminuted vegetable matter, but no leaves were found, except a few fragments evidently belonging to some conifer. Little pockets and thin layers of brilliant lignite were seen, but the quantity is always insignificant.

Above these are about 600 feet of dark-gray shale, sometimes with drab shale and layers of ferruginous sandy limestone, of which good exposures occur in the Raton Plateau near the eastern edge of the district, and in the mesas scattered over the Canadian Plain from the mouth of the Upper Canadian Cañon to the Eagle-tail Mesa. The exposures in Johnson's Park, at the east edge of the Raton Plateau, those along Urraca and Rayado Creeks, as well as those farther south, along the bluff of the Ocaté Mesa, are very good. This part of the series is usually quite fossiliferous. Huge *Inocerami* abound in the darker and more sandy beds, while in the limestone layers are *Scaphites*, *Baculites*, and *Inocerami*, with teeth and scales of fish. But for the most part the specimens are far from being in good condition.

The higher beds, for say 250 feet below the shales and sandstones, which in this report are taken as the base of the Laramie group, are well exposed in the bluffs from the northern limit of the district almost to the southern edge of the Laramie area on Cimarroncito Creek. These are shales, fine-grained and brown to bluish-gray, with bands of red, gray, and brown sandstone. Concretions of iron ore are abundant in the lower part, while higher up are huge calcareous concretions with some of iron ore, and, higher still, near the base of the Laramie, are thin continuous beds of limestone. Some of the nodules weigh several tons. Occasional beds of white sand, from one to three inches thick, are found in the higher shales.

This part of the group is handsomely shown near Galisteo, where the ferruginous concretions predominate, though there are not a few of the calcareous nodules. The shales are somewhat more sandy and the gray sandstones are thicker and more numerous than in the Canadian area, but in the main the differences are slight. Many of the concretions show a cone-in-cone structure, which is not usual farther north. These shales are reached again at sixteen miles below Galisteo. The peculiarity already noticed is more marked here; for instead of the mere nodules of iron ore, one finds many beds of that ore; otherwise the conditions are the same.

Crystals of selenite occur plentifully in these shales at all localities. They are present in filmy layers between the laminæ of the sandy beds at the base of the group, but they are large and well formed in the higher shales, where they sometimes exceed six inches in length.

These higher shales are invariably more or less fossiliferous, but the concretions are by far the best lines for the collector. These, however, are not always richly productive. Sometimes the nodules are made up largely of great *Inocerami* broken into fragments, while again over extensive areas they appear to be almost wholly barren. At many localities the remains are plentiful and in excellent condition. *Ammonites, Scaphites, Helicoceras, Baculites, Inoceramus, Dosinia, Ostrea, Gyrodes, Fasciolaria, Aporrhais,* and other genera are well represented. The best localities for the collector are the bluff at two miles northeast from El Moro; Johnson's Park at the east end of the Raton Plateau; the cañons of Crow Creek, Vermejo Creek, Poñil Creek,—the last three being along the eastern outcrop of the Laramie beds and close to the plain; and in the vicinity of Galisteo, where the ferruginous concretions are shown in low ridges rising above the plain.

CHAPTER IX.

THE LARAMIE GROUP.

Parts of two areas of the Laramie group lie within the district; one occupies a rudely lozenge-shaped space between the mountains at the west and the plains of the Canadian and Purgatory Rivers at the east. The other is in the great mesa region south from the termination of the mountain axes and is cut near its northern edge by Galisteo Creek. Careful studies were made in the former, which may be termed the Trinidad coal-field, but investigations in the other were confined to a narrow strip along Galisteo Creek. The facts obtained do not afford the means for correlation of the coal-beds in the fields, and the areas must be considered separately.

TRINIDAD COAL-FIELD.

This, the most southern of the Laramie coal-fields along the eastern base of the Rocky Mountains, lies partly in Colorado and partly in New Mexico. It has its greatest breadth near the southern boundary of Colorado, whence it tapers in each direction, pointing out at the north near Cucharas Creek, forty miles north from the State line, and terminating at the south immediately beyond Cimarron, thirty-six miles south from the Colorado line. Its area is not far from 2,200 square miles, and the whole of it, except perhaps 150 square miles, is included within the district.

This field is separated from the Spanish Ranges by a meridianal valley, the Stonewall Valley of previous chapters, reaching southward to Costilla Peak and varying in width from nearly two miles to one-fourth of a mile. The eastern border of the coal-field is well marked by high bluffs facing the plains and showing the lower rocks of the Laramie group resting on the Colorado shales. The extreme breadth along the State line is due to the presence of a basalt plate on the Raton Plateau, whereby the rocks have been protected from erosion, and the lower members of the group reach to almost twenty-three miles south of east from Trinidad, Colorado. No part of the Laramie group exists on the plains of the Purgatory or Canadian.

This field is but a part of the great Lignitic region which has received so much attention from Mr. Clarence King and Dr. Hayden, and it has been shown by Mr. Lesquereux to be continuous from the Trinidad coal-field northward into Wyoming, where it is a part, at least, of the Fort Union group.

The Laramie rocks rest directly on the Fort Pierre shales and the passage from the lower to the upper group is extremely gradual. The higher shales have a brownish tint, which becomes more and more pronounced in the alternations of reddish-brown shales and sandstone underlying the *Halymenites* sandstone, the base of the Laramie group. The transition from the sandstones and shales to the Halymenites sandstone is sufficiently distinct at many localities, but at many others it is by no means marked, and that sandstone holds many beds of reddish-brown shale, resembling the lower shales and containing the same fucoids.

The Trinidad coal-field is cut by several long cañons extending from the plains to the base of the mountains, and by many short cañons reaching westward to varying distances from the plains. The exposures in nearly all of these are good, and satisfactory sections can be obtained without much difficulty. The chief source of annoyance is the absence of rocks which may be used as guides. Persistent limestones are wanting, and one is compelled to follow the massive sandstones; but as these are almost exactly alike throughout the section, many short sections are necessary to insure accuracy. Fortunately the cañons are near together, so that one's work can be checked readily and the risk of error can be reduced to the minimum.

The generalized section of the Laramie group within the Trinidad coal-field is approximately as follows:

Generalized Section.

1.	Great sandstone	440 feet.
2.	*Coal-bed* Z	Blossom.
3.	Sandstone and shale	77 feet.
4.	*Coal-bed* Y	Blossom.
5.	Sandstone and shale	75 feet.
6.	*Coal-bed* X′	2 feet.
7.	Shale and sandstone	45 feet.
8.	*Coal-bed* X	4 feet.
9.	Sandstone and shale	26 feet.
10.	*Coal-bed* W	6 feet to 4 inches.
11.	Sandstone and shale	47 feet to 70 feet.
12.	*Coal-bed* V	4 feet to 10 inches.
13.	Sandstone and shale	30 feet to 36 feet.
14.	*Canadian coal-bed* U	6 feet to 4 inches.
15.	Sandstone and shale	20 feet to 30 feet.
16.	*Coal-bed* T	6 feet to 2 feet 6 inches.
17.	Sandstone and shale	13 feet to 20 feet.
18.	*Coal-bed* S	4 feet 3 inches to 10 inches.
19.	Sandstone and shale	25 feet.
20.	*Coal-bed* R′	1 foot to 4 inches.
21.	Shale and sandstone	25 feet to 35 feet.
22.	*Caliente coal-bed* R	16 feet to 1 foot.
23.	Sandstone and shale	30 feet to 35 feet.
24.	*Raton coal-bed* Q	3 feet to 1 foot.
25.	Sandstone and shale	25 feet.
26.	*Coal-bed* P	2 feet 6 inches to 1 foot.
27.	Sandstone and shale	40 feet to 50 feet.
28.	*Coal-bed* O	10 inches.
29.	Sandstone and shale	30 feet.
30.	*Coal-bed* N	2 feet.
31.	Sandstone and shale	33 feet to 43 feet.
32.	*Cameron coal-bed* M	33 feet to 4 inches.
33.	Sandstone and shale	22 feet to 27 feet.
34.	*Coal-bed* L	1 foot to 8 inches.
35.	Sandstone and shale	64 feet to 70 feet.
36.	*Coal-bed* K	3 feet.
37.	Sandstone and shale	24 feet.
38.	*Coal-bed* J′	Blossom.
39.	Sandstone and shale	44 feet to 52 feet.
40.	*Long's Cañon coal-bed* J	8 feet to 1 foot.
41.	Sandstone and shale	45 feet to 83 feet.
42.	*Coal-bed* I	2 feet 6 inches to 2 inches.
43.	Sandstone and shale	50 feet.
44.	*Coal-bed* H′	1 foot.

45. Sandstone and shale	50 feet to 60 feet.
46. *Cat's Claw Cañon coal-bed* H	5 feet to 2 inches.
47. Sandstone and shale	90 feet to 111 feet.
48. *Upper Vermejo coal-bed* G	2 feet to 2 inches.
49. Sandstone and shale	60 feet to 110 feet.
50. *Lower Vermejo coal-bed* F	9 feet to 4 inches.
51. Shale	12 feet.
52. *Coal-bed* E''	1 foot.
53. Sandstone and shale	15 feet.
54. *Coal-bed* E'	6 inches.
55. Sandstone and shale	25 feet.
56. *Upper Reilly coal-bed* E	7 feet 8 inches to 2 inches.
57. Sandstone and shale	18 feet to 31 feet.
58. *Lower Reilly coal-bed* D	6 feet to 2 inches.
59. Sandstone and shale	12 feet to 54 feet.
60. *Willow Creek coal-bed* C	3 feet 6 inches to 1 foot.
61. Sandstone and shale	76 feet to 100 feet.
62. *Trinidad coal-bed* B	16 feet 6 inches to 1 foot.
63. Sandstone and shale	20 feet to 45 feet.
64. *Dillon coal-bed* A	16 feet 6 inches to 1 foot.
65. Shale	10 feet to 1 foot.
66. *Halymenites* sandstone	80 feet to 50 feet.
67. Sandstone and shale	70 feet.

The total thickness of the group is not far from 1,800 feet. Some of the intervals as given in this section may appear to vary excessively, and possibly some of the smaller variations may be due either to erratic movements or erroneous reading of the barometer. But a large number of local sections were secured, and these show that the greatest variations occur in sections obtained so near to each other that error in identification of the beds seems to be almost impossible. With few exceptions the local sections given in the chapters on descriptive geology were verified by repetition.

THE COAL-BEDS.

Coal-bed Z was seen only on the road from Trinidad to Elizabethtown, near the summit between Vermejo Creek and the Canadian River. Its horizon was reached on the Canadian, in Dillon's Cañon, on the summit of the plateau between Long's Cañon and the Canadian, at the head of Reilly's Cañon, and on the South Fork of the Purgatory, but its place is concealed at all of these localities. The blossom is very indistinct on the Elizabethtown road, and the decomposed portion at the outcrop is too thick to permit measurement of the bed. This may be a *coal-bed* or merely a bed of richly carbonaceous shale.

Coal-bed Y was seen only on the Elizabethtown road and near the head of Dillon's Cañon, its place being concealed at all other localities. It is unquestionably a *coal-bed* in Dillon's Cañon, but it may be represented only by carbonaceous shale on the Elizabethtown road, where the exposure is indistinct.

The interval between *coal-beds* X and Y is not well exposed at any locality within the field. *Coal-bed* X′ is represented in Dillon's Cañon by two feet of carbonaceous shale at seventy-one feet below *coal-bed* Y. It is forty-four feet above *coal-bed* X on the South Fork of Purgatory, where it is distinctly a *coal-bed*, although only its blossom is shown.

Coal-bed X was identified on Vermejo Creek and the South Fork of the Purgatory River. At the former locality only its blossom was seen, and it may be represented only by carbonaceous shale; but at the latter it is unquestionably a *coal-bed*, though the exposure does not show it to be of value. The blossom is indistinct, the measurement being—

	Feet.
Coaly shale	4
Not shown	8
Coal with shale	4

The place of this coal is concealed at all other localities where its horizon is reached.

Coal-bed W was recognized near the head of Raton Creek, in Reilly's Cañon, on the South Fork of the Purgatory, and on the Vermejo, but it is concealed in Dillon's Cañon and along the Upper Canadian. It is an insignificant bed of only four inches at the head of Raton Creek; in Reilly's Cañon it is five feet eleven inches, but consists of two petty streaks of *coal* separated by five feet of shale; on the South Fork of the Purgatory it is represented by six feet of inferior *coal*, while on the Vermejo only its blossom is shown.

Coal-bed V was seen on Raton Creek, Reilly's Cañon, South Fork of Purgatory, Dillon's Cañon, and the Vermejo, but its place is concealed on the Upper Canadian. It shows ten inches of good *coal* near the head of

Raton Creek; in Reilly's Cañon it is in two benches, twenty-two and twelve inches, separated by three inches of shale; and on the South Fork of the Purgatory it has two feet of good *coal*. In Dillon's Cañon it is represented by thirteen feet of carbonaceous shale containing only streaks of *coal*, which are especially numerous near the top. Only the blossom was seen on the Vermejo. This bed has been opened in Reilly's Cañon.

The *Canadian coal-bed* (U) was seen on the South Fork of the Purgatory and on the Upper Canadian. Elsewhere it is concealed. It is but four inches thick at the former locality; but in the Canadian Cañon it is by no means an unimportant bed, though the section is variable; at one locality in that cañon it shows three feet of *coal* resting on eight feet of coaly shale, while at another it has eight feet six inches of *coal*, separated by ten inches of clay from three feet of coaly shale; but in each case the exposure is incomplete.

Coal-bed T was identified on the South Fork of the Purgatory, on the Vermejo, and on the Upper Canadian. Its place is exposed in Dillon's Cañon and the bed is absent. Elsewhere its horizon is concealed. This is a double bed on the South Fork of the Purgatory, the benches being each one foot and separated by four feet of shale. It is double on the Vermejo also, where the benches are five and twenty inches thick, separated by four inches of shale. On the Canadian the bed shows two feet of coal, but it is certainly thicker, for the exposure is very poor.

Coal-bed S was observed in Dillon's Cañon, on the Canadian, and on the Vermejo. It is but six inches thick in Dillon's Cañon, but it shows a complicated section on the Canadian, being—

	Feet.	Inches.
Coal	0	4
Shale	2	0
Coal	0	5
Clay	0	6
Slaty *coal*	1	0

While on the Vermejo it is insignificant, having only ten inches of *coal*.

A *coal-bed* sixteen inches thick, which may be designated as *coal-bed* R′, was found at sixty-three feet above *coal-bed* Q in Dillon's Cañon. It was not observed at any other locality.

The *Caliente coal-bed* (R) is shown on the South Fork of Purgatory, on the Canadian, and on Vermejo Creek but it is wholly concealed on Raton Creek and in Dillon's Cañon. It is much expanded and broken up on the Canadian, where it shows—

	Feet.	Inches.
Coal	0	2
Carbonaceous shale	7	0
Coal	2	0
Coaly shale	7	0

It is of much importance along a branch of the Vermejo, followed by the Trinidad and Elizabethtown road, where it has two benches, thirteen inches and eight feet respectively, separated by seven inches of shale; on the divide between Vermejo and Caliente Creeks it is broken up and shows—

	Feet.	Inches.
Coal	0	5
Sandy shale	0	4
Coal	0	10
Coaly shale	1	2
Coal	0	2
Coaly shale	0	2

And on the South Fork of the Purgatory it has from one to four feet of solid *coal.*

This, which is one of the most important beds of the series, attains its greatest thickness along the Vermejo and its tributaries from the mouth of Caliente Creek to a little way west from the Trinidad and Elizabethtown road. Exposures are very frequent within that area, and in every case the blossom is extensive. No tests have been made to determine the value of the *coal*, which is compact, resists the weather well, and burns readily.

The *Raton coal-bed* (Q) was seen on Raton Creek, Willow Creek, South Fork of Purgatory, Dillon's Cañon, and the Vermejo, but it appears to be concealed at all localities examined along the Upper Canadian. It is well exposed at the roadside near the summit of Raton Pass both on Willow Creek and on the waters of Raton Creek, where it is not far from three feet thick. It is double on the South Fork of Purgatory, the benches being two feet and one foot, separated by four feet of shale. It is evidently thin in Dillon's Cañon, where the blossom only was seen. Several exposures were observed on the Vermejo, at one of which the total thickness is but one foot, while at another the structure is—

	Inches.
Coal	2
Clay	13
Coal	12
Clay	4
Coal	10

No openings were seen in this bed.

Coal-bed P was seen only on the Canadian and the Vermejo, its place being concealed at all other localities where its horizon is reached. It is two feet six inches thick on the former stream and yields excellent coal, but the roof is bad and mining is difficult. It is but one foot thick on the Vermejo, and the coal is inferior to that seen on the Canadian.

Coal-bed O, like the last, is seldom shown, and it was seen only on the South Fork of Purgatory and on the Vermejo. It is an insignificant bed, being only ten inches thick on the former stream and shown by only a petty blossom on the latter.

Coal-bed N was found on the South Fork of Purgatory, in Dillon's Cañon, on the Canadian, and on the Vermejo. It is much broken at exposures on the first stream, where it shows—

	Feet.	Inches.
Coal	1	2
Shale	0	10
Coal	0	6
Shale	4	0
Coal	2	0

It is two feet thick in Dillon's Cañon, but only its blossom could be found on the Vermejo and the Upper Canadian.

The *Cameron Coal-bed* (M) was observed on Raton Creek, the South Fork of Purgatory, in Dillon's Cañon, and on the Vermejo. The blossom only could be found along Raton Creek and the approaches to Raton

Pass, but on the South Fork of Purgatory the thickness varies from eighteen to twenty-eight inches. It varies little from three feet in Dillon's Cañon. This bed could not be recognized on the Upper Canadian, as the whole interval between *coal-beds* L and N is filled with black shale. It shows abrupt changes along Vermejo Creek; the thickness is but four inches on the summit above the mouth of Caliente Creek, whereas, at barely three miles below Cameron post-office, seven layers of *coal* are shown, aggregating five feet two inches, and separated by layers of clay, carbonaceous shale, and sandstone, in all thirty-three feet ten inches thick; but a little farther up the creek, its section is—

	Feet.	Inches.
Black shale	1	0
Coal	0	5
Black shale	0	8
Coaly shale	3	0

While between this and the Cameron post-office, where the bed has been mined, the thickness of *coal* varies from eighteen inches to nearly three feet.

Coal-bed L is shown on Raton Creek, the South Fork of Purgatory, in Dillon's Cañon, as well as on the Vermejo and the Upper Canadian; but its place is concealed on Willow Creek. It was seen also in a short cañon entering Long's Cañon. It is represented by eight feet of shale with streaks of *coal* near Raton Pass, where it is exposed in the eastern approach to the tunnel. It is insignificant at all exposures along the waters of the Purgatory, and seems to contain no more than one foot of *coal*. The thickness varies from twelve to eighteen inches along Dillon's Cañon; no good exposure was found along the Upper Canadian, but its blossom was followed there for a long distance; one full exposure on the Vermejo shows twenty-two inches of *coal*, but at all other localities only an obscure blossom was seen. The bed seems to be unimportant everywhere.

Coal-bed K is exposed on Raton and Willow Creeks, on the South Fork of Purgatory, and on the Vermejo, but it was not seen in Dillon's Cañon or on the Upper Canadian, its place being concealed at all localities examined. The blossoms seen on Raton and Willow Creeks do not indicate a bed of any importance; one foot of *coal* is shown on the South Fork of Purgatory; on the Vermejo the bed is double, the benches being eighteen and two inches, separated by two inches of clay.

A thin bed of *coal* was seen on the South Fork of the Purgatory at twenty-four feet below *coal-bed* K. The place of this bed, which may be designated as *coal-bed* J′, is usually concealed elsewhere, but the bed seems to be hardly persistent, and it is wanting at two localities where its place is distinctly exposed.

The *Long's Cañon coal-bed* (J) is shown on Raton Creek, in Long's Cañon, on the South Fork of Purgatory, in Dillon's Cañon, as well as on the Upper Canadian and the Vermejo; but it was not found on Willow Creek. Its blossom only was seen on Raton Creek. This bed becomes important in Long's Cañon, where the section is—

	Feet.	Inches.
Coal	0	4
Drab shale	4	0
Coal	4	3

But on the South Fork of Purgatory it is only one foot thick. It has two feet of good *coal* in Dillon's Cañon, and varies little from eighteen inches along the Upper Canadian. It is double on the Vermejo, the benches being three and four inches, separated by eight inches of clay. The *coal* seems to be fairly good at all localities.

Coal-bed I was recognized on Raton Creek, the Canadian, and the Vermejo, and without doubt it is present on the Purgatory. Its blossom is frequently shown along Raton Creek, but the structure of the bed is exhibited only in the approaches to the railroad bridge above the stage-station, where there are two benches of *coal*, each four inches, separated by two feet of clay. It was not recognized on the Purgatory below the mouth of the South Fork, for some uncertainty still remains respecting the relations of the coal-beds along that stream from the mouth of Burro Cañon up to the South Fork; but a large *coal-bed* is shown in the hills at two miles below Olguines, which comes down to the river at but a little way farther up. The measurements made at the two exposures show much variation, though the structure is the same in them both.* They are as follows:

	Feet.	Inches.	Feet.	Inches.
1. *Coal*	1	2	1	6
2. Clay	0	3	0	2
3. *Coal*	1	0	0	6
4. Clay	0	1	1	3
5. *Coal*	0	8	0	6
6. Clay	1	2	1	0
7. *Coal*	0	8	1	0
8. Clay	0	3	0	8
9. *Coal*	0	4	5	6
10. Carbonaceous shale	1	0	0	0
Total	6	7	12	1

It may be that this is the same with the thick bed referred to in the chapter on the Purgatory as occurring above Olguines and again just below the mouth of the South Fork of the river, though the position renders probable the supposition that that is the *Long's Cañon bed.* The blossom of *coal-bed* I is seen in the river bank near La Junta, and it is shown in Long's Cañon. This bed is utterly insignificant on both the Canadian and the Vermejo, being but ten inches on the former and two inches at the only exposure seen on the latter.

A bed which may be designated *coal-bed* H′ was seen nearly midway between H and I in Long's Cañon and on Raton Creek; but it was not observed at any other localities, though its place is frequently exposed. It is double on the Raton, the benches being three and eight inches, separated by four inches of clay; but in Long's Cañon it seems to be one foot of solid *coal.*

The *Cat's Claw Cañon coal-bed* (H) was fully identified on Raton and Willow Creeks, in Long's Cañon, and on the Canadian and Vermejo. It is certainly present on the Purgatory below the mouth of the South Fork, but in the present uncertainty respecting details along that line none of the beds can be referred to a place in the section.

*The structure along the Purgatory was left to be re-worked during 1879, but the work was cut off abruptly and there was hardly time to complete the coloring of the southwest corner of the maps, so that details respecting the Purgatory region have not been obtained. It is not improbable that a slight anticlinal is crossed by the river not far from Burro Cañon.

This bed is insignificant on the Raton, never more than four inches at the exposures seen, but is much thicker along Willow Creek on the opposite side of the pass. The only distinct exposure on the Willow Creek side is in a railroad cutting, where the somewhat decomposed out-crop measures five feet and seems to be composed almost wholly of *coal*. Indistinct blossoms marking the place of this bed were observed at several places on the hillsides along Willow Creek, but they were not such as to afford good measurements.

The bed shows a thickness of three feet two inches on Long's Cañon, broken as follows:

	Inches.
Coal	4
Clay	14
Coal	2
Clay	2
Coal	4
Clay	10
Coal	4

The *coal* is thicker and better at the mouth of Cat's Claw Cañon on the Canadian than it is at any other locality. There it shows two benches, fifteen and twenty inches thick, separated by four inches of clay. It becomes thinner farther up the Canadian, and it is utterly insignificant on the Vermejo.

Usually the interval between *coal-beds* H and G is filled with sandstone without any considerable quantity of shale, but above the mouth of Cat's Claw Cañon on the Canadian the character of the rocks is different, and in the mass of shale are two *coal-beds*, which may be designated as G′ and G″; the upper of these shows two benches, one foot and eight inches, separated by eighteen inches of clay; the benches of the other bed are four and fifteen inches, parted by four feet of shale.

The *Upper Vermejo coal-bed* (G) was seen on Raton Creek and several other tributaries to the Purgatory, on Willow Creek, in Dillon's Cañon, as well as on the Canadian and the Vermejo. It attains its chief importance on the Vermejo.

Only the blossom of this bed was found on Raton Creek, Willow Creek, and in Long's Cañon, but in Reilly's Cañon the *coal* is one foot thick. The bed was not identified on the Purgatory above the mouth of Burro Cañon, but it certainly is one of the numerous beds seen there. It does not exceed six inches at any exposure in Dillon's Cañon, and on the Canadian it varies little from ten inches; but on the Vermejo it varies from four inches to two feet six inches.

The *Lower Vermejo coal-bed* (F) is exposed at all localities where its horizon is reached except on Raton Creek, but it is exceedingly variable.

It is shown only by its blossom on Willow Creek and the Purgatory; it is one foot thick in Reilly's Cañon and ten inches in Long's Cañon. It varies little from ten inches in Dillon's Cañon, is but three inches on the Canadian, and only four inches on Crow Creek. The variations are extreme on the Vermejo, for the bed is only one foot thick at several exposures along the lower part of the creek, whereas in the upper part of Vermejo Park it shows the following structure :

	Feet.	Inches.
Coal	0	8
Parting	–	–
Coal	5	0
Clay	0	3
Coal	1	0
Shale	2	6
Coal	0	5

The *coal* at this exposure is good, but the bed seems to have escaped the attention of the farmers in the park.

Two little *coal-beds* occur in the interval between the *Lower Vermejo* and the *Upper Reilly coal-bed*, and they appear to be persistent. The lower one, E′, is shown both above and below the mouth of Reilly's Cañon on the Purgatory, and seems to vary little from one foot. It is shown also on the Vermejo near the eastern edge of the area, where it is eighteen inches thick. At this latter locality E″ is six inches thick, but in Vermejo Park it shows eighteen inches of good coal.

The *Upper Reilly coal-bed* (E) is concealed on Willow, Poñil, and Cimarron Creeks, as well as on the Upper Canadian, but it is one of the most persistent beds in the series.

It is well exposed at many places on the Raton and its thickness is seldom less than three feet, while at one locality it becomes four feet ten inches; but the outcrop is always such that no estimate of the quality of the *coal* could be made. On the Purgatory it varies from ten inches to four feet, but when thick the bed is usually represented by carbonaceous shale. In Long's Cañon this bed is but six inches thick, whereas in Reilly's Cañon barely two miles away, it is greatly expanded and has the following structure:

	Feet.	Inches.
1. Carbonaceous shale	0	5
2. *Coal*	0	4
3. Clay	0	2
4. *Coal*	2	0
5. Clay	0	2
6. *Coal*	1	6
7. Clay	0	1
8. *Coal*	3	0
Total	7	8

And the *coal* is good. The partings are too thin to prove a serious hindrance to mining.

Elsewhere the bed is insignificant in thickness, being eight inches in Dillon's Cañon, twenty-three inches on Crow Creek, and eighteen inches on the Vermejo, though the blossom at the lower end of Vermejo Park seems to indicate a greater thickness than is shown at the exposures farther down the creek.

A *coal-bed*, one foot thick, was seen on Raton Creek between this and the *Lower Reilly coal-bed*. It may be designated as *coal bed* D′.

The *Lower Reilly coal-bed* (D) is concealed on the Canadian and the Lower Vermejo as well as on Cimarron and Poñil Creeks.

It seems to vary little from one foot on Manco Burro Pass, on Willow Creek, and on Raton Creek; on the Purgatory the limits are twenty inches and three feet, and the *coal* seems to be good at all exposures. Its blossom was seen on the South Fork of Purgatory. The greatest thickness is in the cañons opening into the lower part of the Purgatory Cañon. In Long's Cañon it shows—

	Feet.	Inches.
Carbonaceous shale	0	6
Coal	0	8
Carbonaceous shale	2	4

And is worthless. But in Reilly's Cañon the section is—

	Feet.	Inches.
1. *Coal*	0	3
2. Clay	1	2
3. *Coal*	1	0
4. Clay	0	3
5. *Coal*	3	4
Total	6	0

Giving somewhat more than four feet of *coal* in practically one body. The bed becomes insignificant farther south, being two inches at the only exposure seen in Dillon's Cañon and making but a small blossom on Crow Creek. A fair blossom was found at the lower end of Vermejo Park.

The *Willow Creek coal-bed* (C) was found in most of the cañons near the plains. It should be present along the western edge of the Laramie area, but the *coal-beds* are much broken up there and satisfactory identifications can hardly be made.

This bed is three feet thick on Willow Creek, but it could not be identified on Raton Creek. It has been opened between Trinidad and Fisher's Creek, where, as far as exposed, it is two feet six inches thick, the benches being six and fifteen inches, separated by six inches of clay. The *coal* is inferior. Exposures were seen at several localities between Trinidad and the mouth of Long's Cañon, where it varies little from two feet six inches and contains poor *coal*.

This bed is three feet thick at one locality in Dillon's Cañon, but within a short distance the structure changes and the bed becomes—

	Feet.	Inches.
Coal	2	0
Sandstone and shale	8	0
Coaly shale	1	2

While the interval between the *Dillon coal-bed* and the base of this bed is the same at both localities. A somewhat similar variation occurs on the Canadian, for near the mouth of the cañon the bed is one foot thick, whereas at about two miles farther up the section is—

	Feet.	Inches.
Coal	0	6
Sandstone and shale	8	0
Coal	0	8
Black shale	5	0

The bed is concealed on Crow and Poñil Creeks, and it makes but a small blossom on Cimarron and the Vermejo.

A *coal-bed*, one foot thick, was seen on the Vermejo at fifty-three feet below the *Willow Creek bed.*

The *Trinidad coal-bed* (B), that mined at Trinidad, is perhaps the most important bed of the whole series; but it is as variable as any other of the column.

This bed is partially exposed near Manco Burro Pass on San Isidro Creek, where it is said to be three feet six inches thick. It is shown also on the opposite side of the pass, along Chico Rico Creek, where the blossom indicates a large bed. It is mined extensively in the vicinity of Trinidad by the Denver and Rio Grande Railway Company as well as by many individuals. The variations along Raton Creek are interesting. Two measurements made in the vicinity of Trinidad and barely one mile apart gave the following results:

	Feet.	Inches.	Feet.	Inches.
1. *Coal*	0	8	0	8
2. Shale	7	0	8	0
3. *Coal*	1	8	0	4
4. Bony *Coal*	0	2	0	4–5
5. *Coal*	2	8	5	5
6. Clay	0	4	1	4
7. *Coal*	2	6	0	4–10

As the exact interval between Nos. 1 and 2 at the second locality could not be ascertained, it is regarded as approximately the same as that shown in the first measurement. A parting occurs in No. 5.

Farther up Raton Creek the bed shows additional changes, which are of some interest as showing that these later coal-beds bifurcate as do some of the older beds in the Appalachian coal-field. The Trinidad bed has been opened at two or three miles above Trinidad, and the Scandinavian Company have made test openings several miles farther up, near the crossing of the Raton anticlinal. The measurements at these localities are as follows:

	Feet.	Inches.	Feet.	Inches.
1. *Coal*	0	10	4	0
2. Sandstone and shale	21	10	24	0
3. *Coal*	3	0	5	0
4. Sandstone and shale	14	0	13	0
5. *Coal*	6	0	9	6
6. Shale	8	0	12	0
7. *Coal*	1	0	1	0
Total	54	8	66	6

Here are the divisions of the bed as shown near Trinidad, but the refuse layers are greatly thickened and the *coal* is greatly increased. No. 5 is divided here by a parting as in the other sections.

A very similar condition exists on the Purgatory at say three miles above Trinidad, where the bed shows—

	Feet.	Inches.
1. *Coal* and shale	4	0
2. Shale	7	0
3. *Coal*	0	8
4. Shale	25	0
5. *Coal*	0	3
6. Shale	22	0
7. *Coal*	1	0
Total	59	11

The blossom of this bed is insignificant on the South Fork of the Purgatory, and the bed was hesitatingly identified on the western edge of the Laramie area along the headwaters of the Purgatory River.

Only the blossom of the Trinidad bed is shown on Willow Creek and in Dillon's Cañon, and the bed is certainly wanting at one locality on the Upper Canadian.

The variations are extreme on Crow Creek; at one locality the bed is wanting, while at two others about four miles apart the following measurements were obtained:

	Feet.	Inches.	Feet.	Inches.
1. *Coal*	0	6	0	5
2. Shale	0	2	0	11
3. *Coal*	1	2	1	11
4. Shale	0	11	0	0
5. *Coal*	0	4	1	8
6. Clay	0	2	0	2
7. *Coal*	1	3	2	0
8. Clay			0	11
9. *Coal*			0	8
10. Clay			0	11
11. *Coal*			0	10
12. Clay			0	2
13. *Coal*			0	6
Total	4	6	7	9

The quality of *coal* at both localities is inferior, and at the best the numerous clay and shale partings so break up the bed as to destroy its value.

The bed is equally variable on the Vermejo, but it nowhere becomes economically important. One exposure in the lower part of the cañon shows it double, with benches thirty and twenty-four inches thick, separated by six feet of red shale; while at another near the head of the stream the benches are fourteen and nineteen inches, separated by ten feet of richly carbonaceous shale containing many streaks of *coal.*

The bed is present on Poñil and Cimarron Creeks, but appears to be very thin.

The *Dillon coal-bed* (A) is as persistent as the Trinidad and rivals it in importance. Like that bed it is exposed in nearly all of the cañons opening upon the plains, and it is distinctly identifiable along the western edge of the Laramie area.

This bed is one foot thick on San Isidro Creek, near Manco Burro Pass. The exposures are very indistinct between Trinidad and Fisher's Peak, but the bed varies greatly in thickness. Near the Denver and Rio Grande works it is comparatively thin, whereas an incomplete exposure in a ravine immediately back from the city shows two benches of *coal* two feet and two feet six inches thick, separated by a concealed interval of twelve feet. Elsewhere the blossom only was seen. No good exposures were found along the Purgatory until at three miles above Trinidad, where the bed is only two feet six inches thick. It is equally variable on the headwaters of the Purgatory, where no exposure affords means for complete measurement. A blossom on the South Fork of the river indicates a thickness of not less than ten feet, while at an old opening near the North Fork three feet of good *coal* are shown.

The bed is double near the mouth of Willow Creek Cañon, the benches being two and four feet thick, separated by six feet of variegated shale. Its greatest thickness is in Dillon's Cañon, where some mining has been done. Two measurements were made below Dillon's Ranch, which show a material variation in structure. One gives—

	Feet.	Inches.
1. *Coal*	0	4
2. Shale	1	8
3. Carbonaceous shale	1	4
4. *Coal*	1	2
5. Clay	0	1
6. *Coal*	3	4

At the other exposure the bed is more seriously broken up and the disposition of the *coal* is far from being so advantageous. The structure is—

	Feet.	Inches.
1. Carbonaceous shale	0	4
2. *Coal*	2	10
3. Shale	0	4
4. *Coal*	0	10
5. Drab shale	2	8
6. *Coal*	3	1
7. Clay	1	0
8. *Coal*	0	6

The coal at both exposures is of moderately good quality, and it has been mined to supply the wants of the farmers.

The bed makes an imposing blossom on the Canadian, but it is of little value, being much as on Willow Creek, though the quantity of *coal* is less. At one exposure the upper bench shows two feet of *coal* and *coaly* shale, while the lower one has two feet of fair *coal*, but the benches are separated by seven feet of shale. Another exposure shows—

	Feet.	Inches.
1. *Coal*	0	5
2. *Coaly* shale	5	0
3. Black shale	2	0
4. Red shale	0	6
5. Black shale	1	6
6. *Coal*	2	0

The bed is much injured at all exposures on this stream by intrusions of basalt.

The variations of the bed on Crow Creek are sufficiently great. In a tributary cañon entering near the plains the bed is represented by five feet of carbonaceous shale, but at four miles away the structure is—

	Feet.	Inches.
1. *Coal*	0	4
2. Clay	3	0
3. *Coal*	1	6
4. Bony *coal*	0	2
5. *Coal*	1	0

And the *coal* is far from being of excellent quality.

An exposure on the Vermejo at a short distance from the plains gave the following measurement:

	Feet.	Inches.
1. *Coal*	0	4
2. Clay	1	2
3. *Coal*	1	2
4. Clay	0	6
5. *Coal*	2	6
6. Black shale	2	0
7. *Coal*	1	0

The bed makes an enormous blossom in the upper part of Vermejo Park, but the outcrop is so badly decomposed that no measurement is possible. Some *coal* has been taken from this exposure, and it has proved to be an excellent fuel. The bed is badly broken up along the western edge of the area near the head of Vermejo Cañon, where the following section was obtained:

	Feet.	Inches.
1. Black shale	4	0
2. Drab shale	1	8
3. *Coal*	2	6
4. Black shale	1	2
5. Drab shale	2	6
6. Black shale	2	0
7. *Coal*	0	4
8. Clay	0	1
9. *Coal*	0	8
10. Black shale	3	0
11. *Coal*	1	0
12. Black shale	2	0
13. *Coal*	1	2
Total	22	1

With a total of five feet eight inches of *coal.*

This bed has been mined on Poñil Creek at a little way from the plains, and also in a side cañon entering at say two miles below the forks of the creek. The bed seems to be extensive, if one may judge from the blossom, but the available thickness is not far from three feet. Here, as at other localities, the quality of the *coal* varies annoyingly, being very good in the side cañon but poor at the opening on the main stream. Exposures are rare in this cañon as well as in that of Cimarron Creek. The *coal* was seen on the latter creek at three or four miles above Cimarron, but the thickness of the bed could not be determined from the blossom. The Laramie sandstones are shown for a little way above the mouth of Ute Creek. A large blossom was seen in these, but its relations were not determined.

A thin *coal-bed* was found on the Canadian, in the upper part of the *Halymenites* sandstone, at thirty feet below the *Dillon coal-bed.* A very thin *coal-bed* occurs back from Trinidad in the same position. This horizon is usually well exposed, but the little bed was not seen elsewhere.

THE SANDSTONES.

The sandstones of this group have a marked general resemblance throughout in color and texture. Many of them change from sandstone to shale and back again abruptly, so that sections obtained in close proximity to each other often show little similarity. For the most part, the sandstones become coarser toward the mountains, where the shales become thinner or are altogether wanting.

The peculiar feature of this great sandstone series is the absence of persistent beds of limestone; not that limestone is wholly absent, for layers, very impure indeed, are present in many of the sandstones, but they are irregular in distribution and are far from being persistent. No traces of limestone were found above the sandstone underlying *coal-bed* J. The limestone is dark to light flesh-color, but weathers yellow, owing to the presence of iron. Some beds are little better than calcareous iron ore, while others are fairly good. This rock was searched at every exposure, but it seems to be non-fossiliferous.

The sandstones vary from compact to flaggy and even shaly. Impressions of dicotyledonous leaves are found in the flaggy beds; but the distribution of these leaves is very uncertain, for at many localities, where the structure of the rock is favorable, leaves are absent, whereas at but a little way off the same bed is crowded with such remains. Ordinarily, however, the leaves are not abundant in any of the sandstones; they are more or less fragmentary, and many of them evidently underwent long maceration before they were finally embedded. The whole appearance suggests that these leaves were either transported by the wind to the body of water under which the sandstones were forming, or else that they were carried down by small streams. Perhaps both of these suggestions may be true—one in one place, the other in another. It is certain that the leaves did not fall from trees growing where these fossils are found.

Careful examination was made of all sandstones and shales immediately overlying *coal-beds*, and in but one case were leaves found in close proximity to a *coal-bed*. There are within the Trinidad coal-field no plant layers such as are so common as coal "roofs" in the Appalachian and Illinois coal-fields.

Capping the Laramie group in the Trinidad field is a great sandstone, which is shown best on the divide between the Vermejo and the

Canadian in the center of the area. It varies from very fine-grained to moderately coarse conglomerate, from light buff to light gray. For the most part it is massive, but occasionally, as on the Vermejo and in Dillon's Cañon, it shows thin beds of shale. It is well exposed on top of the higher hills forming the summits at the head of the Canadian, of Long's and Dillon's Cañons. It follows the center of the area from the northern edge of the district to the Cimarron. Careful search for leaves was made at all exposures, but none were found.

The sandstones below this to that overlying the *Cat's Claw Cañon coal-bed* are by no means persistent, as may be seen by reference to local sections given in the chapters on descriptive geology. Sandstones prevail in this portion of the section along Dillon's Cañon; but in the adjoining cañon, that of the Canadian, they are replaced in great measure by shales, as is the case on the Vermejo also. But southward from the latter stream the sandstones are more persistent, until on Cimarron and Poñil Creeks they appear to displace all else. The exposures on the Cimarron seem at several places to be complete for more than 700 feet vertically, yet there appears to be neither *coal* nor shale, other than petty beds of the latter, separating the great beds of sandstone. These higher beds are seldom reached along the western edge of the Laramie area.

A very persistent sandstone overlies the *Cat's Claw Cañon coal*, which is distinct on Dillon's, Canadian, and Vermejo Cañons. It is certainly present on the Purgatory, though it was not identified among the many sandstones shown there above the mouth of Burro Cañon. Like the other beds it is light gray, but weathers to light grayish-yellow. It contains layers of ferruginous limestone at several localities on Vermejo Creek. Some of these are more than one foot thick, and they were followed along the whole exposure of the sandstone, somewhat more than two-thirds of a mile. Shale occurs in this sandstone on the Canadian.

The sandstone overlying the *Upper Vermejo coal-bed* is even more nearly persistent than the last, though it, too, on the Canadian, breaks up into shale. Like the other it is light yellowish-gray on the weathered surface, is usually compact and cliff-like, though commonly it is so soft as to weather with rounded surface, in which are deep recesses. It is often rich in plants, and at some localities holds logs of silicified wood. This sandstone is the cliff capping the hills in the cañons where the Colorado shales come down to the creeks.

The great sandstone overlying the *Lower Vermejo coal-bed* is thoroughly persistent, having been seen at all localities where the horizon of that bed is reached. It varies from bright yellowish-gray to grayish-red on the weathered surface, is usually compact, though occasionally flaggy in some parts. Its texture varies materially at different localities. Near the plains the rock is commonly fine-grained and soft, so that it yields readily to the weather and the exposed surface often shows great cavities; but toward the base of the mountains it becomes very coarse, contains many pebbles of gneiss and quartzite, while some of its layers are honeycombed with thin seams of quartz like those in the Upper Dakota sandstone. This important bed forms bold cliffs, which are shown in every cañon at but a short distance from the plains. At all of these exposures it contains thin irregular beds of limestone, which are usually purer than those seen in the sandstone overlying *coal-bed* H; but no limestone was found at any exposure along the west side of the field. Plant-leaves are by no means rare in the flaggy parts of this bed, and they occur plentifully at a few localities. Obscure impressions of a *Cardium*-like shell were obtained from this sandstone on a branch of Poñil Creek.

The lower sandstones are far from being persistent, but at most localities a variable sandstone overlies the *Trinidad coal-bed* and contains some conglomerate layers. On Crow Creek this rock is coarsely conglomerate for several feet from the base, and its under surface is covered with a close mat of small cylindrical bodies one inch long and one-fifth of an inch in diameter. They may be casts of fucoids.

A huge and thoroughly persistent sandstone, which I have called the *Halymenites* sandstone, is found near the base of the series. For the most part it is light-gray and compact, though sometimes it holds thin beds of shale and occasionally pockets of conglomerate. The characteristic feature of this sandstone is a nodose fucoid, named *Halymenites major* by Mr. Lesquereux, and thought by him to be an unquestionably Tertiary species. This fossil appears to be especially characteristic of this rock, and it was not found at any higher horizon within the Trinidad coal-field. It is wanting at the exposures in Dillon's Cañon, but it is abundant at all other localities. On Poñil Creek some fish-teeth and a *Cardium*-like shell were found, the latter evidently the same with the shell found in the *Lower Vermejo* sandstone on the same creek. This sandstone passes gradually into the shales and sandstones below. Thin beds of shale were seen in the lower part of this rock at some localities.

The shales and sandstones at the base of the Laramie group are well shown everywhere along the eastern edge of the area, as well as at many localities within the Stonewall Valley on the western edge. They have the same features at all exposures. The shales are brownish-red and soft, containing more or less sand, while the sandstones are thin, distinctly reddish, and contain but little clay. The flaggy sandy layers are covered with casts of a characterless fucoid. The thickness of this mass is given with some uncertainty, for the exact base of the Laramie group cannot be ascertained, and it has been fixed arbitrarily. These shales pass imperceptibly into the Fort Pierre shales below, and usually in the same manner into the *Halymenites* sandstone above.

THE GALISTEO COAL-FIELD.

This coal-field reaches northward barely to Galisteo Creek, and only an insignificant part lies within the region examined. It is fifteen miles wide from east to west along Galisteo Creek, and the eastern boundary passes through Galisteo.

The disturbances connected with the faults of the Upper Galisteo render the geology very perplexing on the north side of the creek from Galisteo to the Arroyo de los Angeles, and the character of the Laramie beds can be ascertained best along the south side of the creek, where they occupy the plateau between the Placer Mountains and the creek. There the stratigraphy is simple and unaffected by any disturbances save those caused by dikes of eruptive rock.

In a general way the Laramie group is the same here that it is in the Trinidad field. It is a great sandstone, broken by thin shales and thinner *coal-beds*. The sandstones have the same yellowish tint and for the most part are very soft, yielding readily to the weather. But in detail, few resemblances were found.

The work in this field was necessarily that of reconnaissance only, and comparisons between the two fields must be made by means of the fragmentary material obtained in the southern one. The following section was measured near the western edge of the area:

	Feet.	Inches.
1. Sandstone	30	0
2. *Coaly* clay	0	2
3. Dark clay with rootlets	0	3
4. Shale with nodular iron ore	38	0
5. Shaly sandstone	5	0
6. *Coaly* clay, like cannel shale, contains much vegetable matter	0	10
7. Dark shale	4	0
8. Sandstone	8	0
9. Concealed	6	0
10. Sandstone	18	0
11. Drab shale	4	0
12. Iron ore	1	3
13. Sandstone	10	0
14. Iron ore	1	3
15. Drab shale	3	0
16. *Coal-bed*	2	10
17. Shale, sandstone, and iron ore	16	0
18. *Coal-bed*	0	10
19. Sandstone	5	0
20. Shale and iron ore	8	0
21. *Coal-bed*	0	10
22. Shale, sandstone, and iron ore	32	0
23. *Coal-bed*	1	0
24. Shale	4	0
25. *Coal-bed*	0	3
26. Sandstone, shale, and iron ore	20	0
27. *Coal-bed*	blossom.	
28. Concealed	6	0
29. Sandstone	14	0
30. *Coal-bed* with shale	5	9
31. Shale, sandstone, and iron one	9	0
32. *Coal-bed*	0	2
33. Sandstone and shale	25	0
34. *Coal-bed*	0	6
35. Sandstone and shale	9	0
36. *Coal-bed*	0	8
37. Sandstone, shale, and iron ore	13	0

	Feet.	Inches.
38. *Coal-bed*	blossom.	
39. Sandstone, shale, and iron ore	45	0
40. *Coal-bed* with shale	0	5
41. Shale and sandstone	29	0
42. Sandstone	60	0
43. Shales, sandstones, and bands of iron ore belonging to the Fort Pierre group	–	–
Total measured	433	0

This is the lower part of the group. The higher beds are shown farther east, toward the bottom of the synclinal, but no detailed sections were obtained, as the exposures are too incomplete for one working rapidly. The shales and sandstones above No. 16 continue for ninety feet, but above them for 100 feet everything is concealed. The group appears to close here with 360 feet of sandstone, in which there is but little shale.

The sandstones are like those of the Trinidad coal-field, but are more nearly persistent as far as followed. They are soft, yield readily to the weather, and are yellow or grayish-yellow on the weathered surface. A noteworthy feature of the section is that shales greatly preponderate over sandstone in the first 400 feet of the section, there being no such enormous sandstones as are seen in the Trinidad field. Impressions of dicotyledonous leaves are not wanting here, but they are by no means abundant. Limestone is practically absent and its place is taken by beds of iron ore from two to twenty inches thick. These are scattered throughout the section and nodular ore is abundant in most of the shale beds.

The sandstone at the base of the series is by no means so decided in its characteristics as is the *Halymenites* sandstone; for it is a variable mass, sometimes a compact gray sandstone of the thickness given, but at others double, with a thick bed of shales between the plates of sandstone. It contains red bands, and is sometimes broken by beds of iron ore. *Halymenites major* seems to be wholly wanting here, not even a trace of it having been seen on either side of the field.

The beds of iron ore are not without interest. Some of them have a concretionary structure such as is shown by the lines of concretions in the upper part of the Fort Pierre group. The similarity in color, composition, and structure is so close that one making an examination of the ore-beds without paying close attention to the adjacent rocks would refer them to the Fort Pierre group. This condition is distinct for fully 200 feet above the assumed base of the group, and it is especially well shown along the eastern edge of the field at but a little way south from Galisteo.

Besides the ore-beds, there are argillaceous beds cemented by oxide of iron, which show a cone-in-cone structure and are in every respect like the similar beds found in the Fort Pierre. Fossils sometimes occur in the concretionary ore-bed, but never in the cone-in-cone beds of either the Laramie or the Fort Pierre.

The lower limit of the Laramie group cannot be determined in the Galisteo region. Arbitrarily, I have placed it at the base of the large sandstone, No. 42 of the section, below which are shales, sandstones, and concretions undistinguishable from those of the Laramie except by the greater number of fossils found in the concretions.

The available *coal-beds* are confined to the western side of the field along Galisteo Creek, for there seem to be no *coal-beds* of any kind along the eastern outcrop in the lower 250 feet of the section. At the best, the *coal-beds* are thin and excessively variable, so that their economic importance is questionable. Two of the beds deserve notice here. No. 39 has the following structure:

	Feet.	Inches.
1. *Coal*	0	2
2. Clay	0	4
3. *Coal*	0	5
4. Black shale	2	6
5. Gray sandstone	1	0
6. *Coal*	0	4
7. Shale with streaks of *coal*	1	0

But of this only eleven inches are *coal*, so that the bed is worthless here. A bed of anthracite, said to be two feet thick, occurs not far from the line of this section, and its place is near that of this bed. But it was not seen, and its thickness is given according to the report.

The *coal-bed* No 16 has the following structure:

	Feet.	Inches.
Coal	0	6
Clay	0	1
Coal	2	3

And its *coal* is certainly very good. This seems to be the same with a bed seen at two miles farther east, in which the *coal* has been altered to anthracite. There it is four feet thick and retains its thickness well, having been mined for several years to supply a large quartz-mill at the Old Placer mine.

Aside from these the *coal-beds* are utterly unimportant.

CHAPTER X.

THE RELATIONS OF THE LARAMIE GROUP.

Two great areas of the later coals exist—one on the Pacific coast, the other within the Rocky Mountain region and the Colorado Plateau. Each has been broken by erosion into numerous fields, which are isolated in such a way that direct determination of their relations cannot be made by tracing, and the questions respecting their relationship must be settled in great measure by palæontology.

It is unnecessary here to enter into any discussion of the coals which are found on the Pacific coast. Those occurring in California have been described by the geologists of that State and by them finally referred to the Cretaceous. Those of Vancouver have been carefully studied by Selwyn, Dawson, and Richardson. The fossils have been discussed in detail by Billings, Whiteaves, and Meek, and all the evidence points to the Cretaceous age of the formation.

Within the Rocky Mountain region there are clearly two important horizons at which coal-beds occur; one in the lower portion of the Cretaceous, extending from the far north, in British America, southward with more or less irregularity into New Mexico and Arizona; the other reaching barely beyond the northern line of our territory into British America, and extending southward into New Mexico, covering a vast area immediately east from the Rocky Mountains as well as within the disturbed region and beyond it at the south in New Mexico.

For a proper understanding of the conditions here it may be as well to give a brief description of the various formations as they are exposed along the east flank of the mountains.

Silurian strata rest on the metamorphic schists, and above them come the Carboniferous rocks, the Devonian being for the most part absent. Frequently overlapping and concealing these rocks is a very persistent mass of red beds containing marls and gypsum, which have been referred to the Trias. Occasionally, they are succeeded by shales with thin limestones containing Jurassic fossils. Upon this last rests the Cretaceous, of which five well-marked divisions were recognized by Mr. Meek in the Upper Missouri region, which were described by Meek and Hayden as—

No. 5. The Fox Hills group, sandstones more or less calcareous.

No. 4. Fort Pierre group, shales with nodules of clay iron stone.

No. 3. Niobrara group, limestones and calareous shales.

No. 2. Fort Benton group, usually argillaceous shales.

No. 1. Dakota group, sandstones, shales, and lignites.

In New Mexico these subdivisions are not always sufficiently distinct, and those who have worked in that territory have used the following classification:

Upper Cretaceous, equivalent to No. 5, and part of 4.

Middle Cretaceous, equivalent to Nos. 2, 3, and part of 4.

Lower Cretaceous, equivalent to No. 1.

Mr. King, finding the same difficulty in his field, proposed that the shales should be grouped together, and that the coal-bearing sandstones at the top of the series should be grouped together also. He proposed this classification:

The Laramie group, including the lower portion of the Fort Union or coal-bearing group of Meek and Hayden.

The Fox Hills group, of equal extent with the same group of Meek and Hayden.

The Colorado shales, including the Fort Pierre, Niobrara, and Fort Benton.

The Dakota, of equal extent with the Dakota of Meek and Hayden.

This classification has been adopted in this report with but little modification.

The Lower Cretaceous yields animal remains at but few localities, but it frequently contains immense numbers of impressions of dicotyledonous leaves, strikingly resembling the Miocene flora of Europe. Lignite beds occur at many localities.

The Colorado group is variable in character, but at nearly every exposure many of its beds are fossiliferous. In much of Utah it contains important beds of lignite or coal toward the base.

The Fox Hills group is composed of shales and sandstones, the latter usually predominating. The rock is rusty-yellow to bluish-gray in color and many of the sandstones have a concretionary structure. Dr. Hayden notes the interesting fact respecting both this and the Fort Pierre group that there are zones or belts in which the rock is almost non-fossiliferous. The group is marked by a rich fauna largely of Cretaceous forms but mingled with many types of more recent character.

Thus far the Cretaceous age of the section is freely acknowledged by all. But above this comes the great coal-bearing group, termed by Dr. Hayden the Fort Union group and by Mr. King the Laramie group. This is an immense mass of sandstones, shales, and beds of coal having a maximum thickness of not far from 4,000 feet according to Dr. Hayden. This holds the coal-beds of the upper series. Its relations to the Fox Hills group have long been in dispute, and even now the boundary between the two parts of the column can hardly be regarded as finally determined.

The Laramie or Fort Union group has been studied at the north, within the territory of the United States, by Mr. King and his assistants Messrs. Hague and Emmons, by Professor Lesquereux, and by Dr. Hayden and his assistants; in Colorado by Mr. King, Mr. Hague, Dr. Hayden and his assistants, Professor Lesquereux, and the writer; and in New Mexico by Dr. Newberry, Dr. Leconte, Professor Cope, Dr. Hayden, Mr. Holmes, and the writer. There seems to be no room for doubt that the coal-fields of the Galisteo area and of Southern Colorado are precisely the same in age with those of Northern Colorado and Wyoming.

THE LOWER COAL-BEARING GROUP.

Dr. Hector* found a well-defined series of coal-bearing strata on the North Saskatchewan or Red Deer River and on Battle River. On Red Deer River he obtained the following section:

1. Sandstones and dark clays.
2. Banded marlites, clays, and limestones.
3. Shell conglomerate.
4. Clay.
5. Banded clays with clay iron stone.
6. *Coal*, six feet thick.
7. Clays.
8. Silicified wood and brown *coal*.
9. Sandy clays.

Total thickness of section, 600 feet.

The shell conglomerate contains vast numbers of *Ostrea cortex*, while the overlying banded clays exhibit *Ostrea cortex*, *O. vellicata*, and *Cytherea texana*, and one of the limestone layers yielded *Ostrea anomiæ-formis*, *Mytilus* (two species), *Cardium multistriatum*, *Crassatella*, *Venus*, *Rostellaria*, and *Paludina*. In tracing this group from Red Deer to Battle River no change was observed in the section, but at the latter locality and somewhat higher in the series a concretionary limestone was found containing *Avicula*, *Cardium*, *Cytherea*, and *Baculites compressus*.

Dr. Hector recognized coal-beds at other localities which he thought to belong to the same horizon with those of the Red Deer section, but his conclusions, offered with some hesitation, have not been fully accepted by Dr. Dawson, who during his connection with the Northwest Boundary Commission examined the geology of the region with much care.

East from the Rocky Mountains within the United States the coal of this group is small in quantity and poor in quality. Dr. Hayden menticns its occurrence at numerous localities, but states that it is used as fuel at only one. Professor N. H. Winchell, in his second report on the geology of

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* Journal of the Geological Society, 1861.

Minnesota, makes reference to several localities at which impure coal occurs within the Dakota group. In 1873 the writer observed a deserted opening in impure coal of this group at a locality about midway between Denver and Colorado Springs.

This group carries coal within the Rocky Mountains. Professor Marsh, in 1870, discovered a bed of coal on Brush Creek, a tributary to Green River. Overlying it is a sandstone containing a layer full of *Ostrea congesta*, and farther up another which yielded a crinoid. Below the coal, *Coprolites*, cycloidal scales of fish, together with teeth resembling Megalo-saurus were found. This locality was afterward visited by Mr. Emmons, who ascertained that the coal belongs to the Dakota group. Major Powell and Mr. Gilbert make note of several localities where coal occurs.

Dr. Newberry* found this group at many localities in New Mexico carrying thin beds of lignite. At his camp 92 there is an alternation of coal and shale, twelve feet thick, resting almost directly on Triassic marls and underlying a yellowish sandstone filled with dicotyledonous leaves. At camp 96 and at Oraybe he found above this bed green and blue shales 250 feet thick. This series contains toward the base *Ammonites percarinatus*, *Inoceramus cripsii*, and *Gryphæa navia*, while toward the top it shows *Pinna* (?) *lingula*, *Gryphæa pitcheri*, with beds of lignite, above which are impressions of *Platanus*, *Alnus*, *Quercus*, &c., along with *Sphenopteris*. From the Moqui country eastward for about twenty miles these rocks are continuously in sight; but at length they underrun a mass of tertiary rocks, which Dr. Newberry thinks may prove equivalent to the White River group of the Upper Missouri region. At camp 100, beyond the eastern border of the Tertiary basin, a group of lignite and brown sandstones was seen at the very base of the Cretaceous, but it is not persistent. The Lower Cretaceous series is seen near Fort Defiance, where it consists of "green and dove-colored shales, brown and greenish sandstones, brownish-yellow concretionary limestone containing *Gryphæa pitcheri* and beds of *lignite*." At Campbell's Pass, 700 feet of Cretaceous sandstones, shales, and *lignites* were seen resting on the Triassic.

*Ives Expedition; Report on Geology, pp. 81, 85, 87, 89, 94.

At a little higher, probably in the Fort Benton, is the coal group observed by Mr. G. K. Gilbert* on the West Fork of the Paria Creek in Utah, where the section is:

			Feet.	Inches.
1. Argillaceous shales with *coal*			635	0
A. Blue-gray shale, *Inoceramus problematicus*	50	0		
B. *Coal*	4	0		
C. Bituminous shale	1	0		
D. Soft gray shale	25	0		
E. Yellow shale	3	0		
F. Shell limestone, *Ostrea*, *Inoceramus*, *Trigonia*	1	0		
G. Soft yellow-gray shale	2	0		
H. *Coal*	0	4		
I. Soft gray shale	6	0		
J. *Coal*	1	0		
K. Soft gray shale	30	0		
L. *Coal*	3	0		
M. Shale	15	0		
N. *Coal*	1	6		
O. Bituminous shale	1	0		
P. *Coal*	2	4		
Q. Arenaceous shale	17	0		
R. *Coal*	2	2		
2. Cream shale with occasional fillets of red shale and of sandstone			300	0

This rests on the Triassic rocks.

Mr. E. E. Howell makes many references to this group in his report to Lieutenant Wheeler. He finds† the following section of the Cretaceous underlying about 3,000 feet of Tertiary rocks, of which a detailed section is given.

	Feet.
1. Cream-colored sandstones and shales, with much shale and some *coal*	700 to 800
2. Same as last; contains *Cardium*, *Corbula*, *Inoceramus*, *Neritina*, crocodile's tooth, &c.	700
3. *a.* Dark argillaceous shale, with *Hamites*, *Baculites anceps*, *Ancyloceras*, *Ammonites percarinatus*, *Turritella*, *Cardium*, *Inoceramus problematicus*, *Lima*, *Ostrea congesta*, *Corbicula*, *Lucina*, and many other fossils	500
3. *b.* *Coal* series; mainly dark carbonaceous shale with *coal*, but containing some cream sandstone and shale, the whole capped with an oyster bed which varies in thickness from one to five or six feet, but is never absent, and is usually one complete mass of shells of several species, one of which is hardly distinguishable from the common edible oyster, *Ostrea virginiana*. *Exogyra ponderosa*, and *Gryphæa pitcheri* are also very common, and *Turritella* and *Ammonites* are occasionally seen	150

* Wheeler, Vol. III, p. 159.

† Wheeler, Vol. III, p. 271.

	Feet.
4. Light-colored conglomerate and sandstone above, changing to red below, with banded red and slate-colored shales at base. A few leaves and one cast of gasteropod were found near the top, and, on the Dirty Devil River, *saurian* bones were seen.............................	500

Below these are the Jurassic rocks.

Dr. Newberry makes frequent reference to this series in his report upon the San Juan Expedition. The features given in detail by him show no material difference from those already mentioned.

Professor Marcou, while with Lieutenant Whipple's party exploring the thirty-fifth parallel, discovered the coals of this group at the Ojo Pescada near Fort Defiance and thought them of Jurassic age. Dr. Leconte's notes add little to the observations made by Dr. Newberry, which, however, they serve to confirm.

THE UPPER COAL-BEARING GROUP.

This is the Laramie group of King, the Fort Union group of Hayden. It extends northward beyond the limit of the United States, and it has been studied in British America by Dawson and Selwyn as well as by Hector and Hind; in the territories of the United States by King, Meek, Hayden, Lesquereux, Emmons, Hague, Leconte, Powell, Newberry, the writer, and by others.

The earliest reference to coal-beds belonging to this group is found in the records of Lewis and Clarke's Expedition. The coal-beds are described as existing along the Missouri River between Fort Mandan and the Muscleshell River as well as in the vicinity of Judith River. The beds along the Yellowstone River are mentioned in the second volume.

It is somewhat strange that the coal-beds in the vicinity of Colorado Springs as well as those on the Arkansas River near Cañon City escaped the attention of Dr. James, who accompanied Major Long. The same beds escaped also Captain Frémont, but he discovered the coal on North Platte River not far from Medicine Butte. The beds on Raton Creek above Trinidad in Colorado, as well as those on the waters of the Canadian River in Colorado and New Mexico, were discovered by Lieut. J. W. Abert in 1846, during his journey from Bent's Fort on the Arkansas to Santa Fé, in connection with the Advanced Guard of the Army of the West. Lieutenant Abert made collections of leaf-impressions from the Raton beds, which were submitted to Professor Bailey, of West Point Military Academy, by whom they were regarded as proving that "the deposit of coal at the Raton is not the equivalent of the great coal formation of the United States, but is of a much more recent date, perhaps corresponding to the Brora coal."

Dr. Hector saw some beds of lignite at La Roche Percée, not far north from the United States boundary, which he regards as the northern extension of the Missouri lignite basin, and therefore places them in the Tertiary, though he thinks they may possibly be Cretaceous. Professor Hind thinks that they belong to the Fox Hills group of Meek and Hayden. Dr. G M. Dawson, however, shows on his map that the group extends much farther north than was supposed by Dr. Hector. He regards these beds as belonging to the Tertiary. The Fox Hills group was but partially recognized by him, and it seems to be of but insignificant importance* within the area examined by Dr. Dawson.

Throughout the Upper Missouri region this lignitic group is perfectly conformable to the Fox Hills group, and the line of separation cannot be determined with any degree of certainty. During many years of exploration only one instance of non-conformability has been discovered, and that is evidently local. The relations of these groups are so intimate that in the description of one constant reference to the other is necessary.

On Gardiner's River the intimate relations of the two groups are well shown. At one locality, where 1,200 feet of strata belonging to them are exposed, it seems impossible to draw any line of division,—"this great group of beds, simply alternate beds of sandstone and arenaceous clays, passing down into the dark, sombre clays of the Cretaceous." At Cinnabar Mountain, above the mouth of Gardiner's River, "the dark laminated clays of the Cretaceous passing up into the Upper Creta-

*See *Report on the Geology of the Region in the Vicinity of the Forty-ninth Parallel,* by G. M. Dawson, Montreal, 1875.

ceous, are well shown with perfect continuity, then passing up into a great thickness of the sombre brown sandstones of the coal group. There is a great uniformity between the Upper Cretaceous and Tertiary series. We can detect some variations in color and texture, but they are of minor importance and could not easily be described in words."*

On Box Elder Creek, not far from Fort Fetterman, the lignite series consists of rusty sands and sandstones and arenaceous clays, with some seams of lignite. On Deer Creek, twenty-seven miles from the fort, the black clays of the Fort Pierre group are capped by a thin bed of ferruginous arenaceous clays, above which are two beds of sandstone. The lower one of these is concretionary throughout, being filled with sandstone concretions embedded in an indurated clay, which also shows a tendency to concretionary structure. A few specimens of *Baculites*, *Inoceramus*, &c., were found in the harder portions. The upper bed has a similar rusty-yellow color, but yields no fossils. Both rocks, but especially the lower one, tend to weather into architectural forms. Near old Fort Casper a yellow ferruginous sandstone, containing *Inoceramus* and huge concretions, is seen resting on black shaly clays, which Dr. Hayden assigns to the horizon of Cretaceous No. 2.

On the North Platte River, from Sage Creek to Medicine Bow and thence to Bridger's Pass, the sandstones and the associated clays lying at the base of the Laramie group are almost continuous. They rest directly on Cretaceous clays. This region has been carefully examined by Dr. Hayden, Mr. Meek, and Mr. Lesquereux in connection with Dr. Hayden's organization, and by Messrs. King, Emmons, and Hague of the Geological Survey of the Fortieth Parallel.

Within this region the sandstones of the Laramie group are irregularly concretionary and occasionally yield *Inoceramus* or *Baculites*. Some rusty calcareous beds contain *Ostrea*. Four beds of the sandstone can be distinguished along the Platte. The first, second, and third, beginning at the base, are in all fifty to eighty feet thick, drab-brown, and quite mass-

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* Hayden. Report for 1871, p. 62.

ive. The fourth is yellowish-gray, full of large rusty-brown concretionary masses, which are laminated and in reality are arenaceous limestones. Between the beds are thin layers of sandstone and sandy limestones. At Cooper's Creek the rusty arenaceous beds of No. 5 pass up gradually into the coal-bearing layers without any perceptible break and without any marked change in the sediment. The latter series is from 1,500 to 2,000 feet thick, and consists of rusty-yellow sandstones, alternating with greenish-gray indurated sands and clays. In the neighborhood of Fort Steele the sandstones seen at Medicine Bow are found resting on Cretaceous clays and passing up into the coal-bearing strata. These contain a characteristic fucoid, which Mr. Lesquereux has described as *Halymenites major*.

Along the Pacific Railroad from Como to Saint Mary's, nearly fifty miles, the lignitic rocks prevail, and the thick sandstone at the base is traceable to Carbon, where a coal-bed overlying it is worked. This is the fucoid-bearing sandstone showing the fucoid just referred to. The overlying rocks contain vast numbers of deciduous leaves.

South from the Union Pacific Railroad one reaches the Colorado and New Mexico portion of the area at about twenty miles from Cheyenne. This area has been examined in detail by Dr. Hayden southward to beyond the latitude of Long's Peak. He finds that the Fox Hills and the Laramie group are conformable everywhere, and that the two groups have no definite line of division. He followed the series from their western outcrop to the Denver Pacific Railroad, and ascertained that the *Laramie beds are those immediately underlying the plains.* The two groups have great similarity in composition, both being made up of yellowish sandstones.

In 1873 the writer made a cursory examination of the sandstone beds along the Platte River from the mouth of Saint Vrain's Creek to the town of Greeley, a distance of about twenty miles, and obtained a number of fossils which Mr. Meek pronounced to be of Fox Hills age. Mr. Hague had previously collected fossils of the same character from the neighborhood of Greeley, and in the following year collections were made by Dr. Hayden's corps. The writer again visited this vicinity in 1878 and made a more detailed examination of the beds and their relations.* The section obtained on the bluffs along the west side of the South Platte is as follows:

	Feet.
1. Yellow sandstone	450
2. Blue sandstone	200
3. Concealed	200
4. Yellow sandstone	100
5. Gray to blue sandstone	50

No. 1 is the sandstone from which the fossils were obtained. It is bright yellow and for the most part extremely friable, weathering easily and breaking down into loose sand; but at irregular intervals it shows thin layers of darker sandstone, some of which are quite compact, while others are flaggy, but they all resist the action of the weather. The unequal resistance is so marked that the bluffs between Saint Vrain's and Thompson Creeks are known as the Monument Bluffs. For the greater part the soft yellow sandstones are devoid of fossils, but here and there *Halymenites major* occurs in great abundance and occasionally one stumbles on a nest of *Ostrea.* The harder layers are different; many of the more compact are crowded with the *Halymenites,* while most of the flaggy layers contain Fox Hills fossils in excellent state of preservation, among which are *Ammonites lobatus, Nucula cancellata, Mactra warrenana,* and numerous other species. Other layers are crowded with comminuted fragments of carbonized wood. In 1873 the writer's companion discovered a thin layer with impressions of deciduous leaves. No coal was seen in any part of the section, but borings begun at the base of No. 5 passed through *coaly* material.

On the east side of the Platte River, at about five miles *southeast* from the village of Evans and perhaps three miles *east* from the Denver Pacific Railroad, borings were made during 1874 in search of coal. One boring was begun in dull-yellow sandstone like that seen on the west side of the river, and containing *Halymenites major* and shells. The boring was carried to a depth of 268 feet without finding coal, the rock being mostly

* American Journal of Science, May, 1879, p. 369.

sandstone or arenaceous shale. At a little distance northeast from this, and at barely 100 feet higher, another boring was made in which the following section was obtained:

	Feet.	Inches.
1. Dirt	10	0
2. Sandstone	10	0
3. Fire-clay	2	0
4. Sandstone	14	0
5. *Black shale*	16	0
6. Sandstone	21	0
7. Fire-clay	1	0
8. *Coal* with a little shale	2	10
9. Interval	28	3
10. *Coal*	0	2

A shaft was begun to reach the coal-bed in No. 8, but after it had been sunk twenty-eight feet another boring was made to test the character of the coal. In this new boring, which is but a little way from the other, two feet seven inches of coal were found in the upper part of the shale, No. 5. The shaft shows eighteen feet of the sandstone, No. 2, in which are several fine-grained ferruginous layers crowded with fossils, well preserved, among which are *Ammonites lobatus*, *Cardium speciosum*, *Nucula cancellata*, *Mactra alta*, *Mactra warrenana*, *Lunatia moreauensis*, and undetermined species of *Anchura*. In still another boring, made within 200 yards from the last, eleven beds of coal were found varying in thickness from two to thirty-one inches. These beds are very near the summit of the Laramie group.

Farther south, nearer the mountains, the Fox Hills group becomes very obscure, and indeed it cannot be recognized by any fossil remains which are beyond dispute. On Boulder Creek the sandstone at the base of the Laramie series is separated but little from the Middle Cretaceous shales, and contain impressions of deciduous leaves along with *Halymenites major*. Near Colorado Springs this rock contains a variable seam of coal and affords the fucoid and dicotyledonous leaves. Below it are layers of clay and shale, yielding *Baculites* and other Cretaceous forms, and passing downward into the Cretaceous dark shales.

The succession is clearly shown along the Arkansas below Cañon

City, where the Fort Pierre shales gradually merge into a mass of clay and argillaceous sandstones, which passes upward imperceptibly into the *Halymenites* sandstone. In the upper part of this loose-grained mass the writer found indefinite impressions of mollusca, and in one of the clay beds belonging to it Dr. Hayden found an imperfect *Inoceramus*. In the Trinidad coal-field the *Halymenites* sandstone at the base of the Laramie group is shown continuously in the bluffs facing the plains from Cucharas Creek in Colorado to Cimarroncito Creek in New Mexico, a distance of not less than sixty miles of latitude. At every locality except one it is rich in *Halymenites major*, and on Poñil Creek it contains also a *Cardium*-like shell along with fish-teeth. Throughout this field the Laramie group may be described as an enormous sandstone, divided by thin layers or beds of shale and thinner beds of coal. Its thickness is not far from 1,800 feet. Irregular limestone beds from two to eighteen inches thick occur in the lower half of the section, but they contain no fossils. Many of the sandstone beds are filled with impressions of deciduous leaves, and in one of them, about 200 feet from the *Halymenites* sandstone, indistinct impressions of a shell were found, closely allied to the form occurring in the *Halymenites* sandstone.

Throughout this Trinidad field the coal-bearing group rests directly on shales belonging to the Fort Pierre sub-group. Lithologically the transition from the latter to the former group is so gradual that the line of separation must be assumed arbitrarily. The dark shales pass upward into brownish shales and argillaceous sandstones, which in turn shade away into the *Halymenites* sandstone above. The transition requires not far from 200 feet of rock. Both groups are absolutely conformable.

No further exposure of the Laramie group occurs toward the south until Galisteo Creek is reached, beyond the southern termination of the Santa Fé range and at about twenty miles south from Santa Fé. This region was examined by Dr. Newberry during his connection with Captain Macomb's San Juan Expedition, by Dr. Hayden in 1869, by Professor Cope in 1874, and by the writer in 1879. The field is evidently an extensive one, extending along the Placer and Sandia Mountains to a long distance southward, and including probably the coals seen on the Rio Puerco by Professor Marcou and Lieutenant Abert.

On Galisteo Creek the whole Cretaceous section is exposed from the Dakota to the Laramie group, but the Fox Hills group cannot be recognized by its fossils. The Fort Pierre shales are handsomely exposed in the immediate vicinity of Galisteo, and the sandstones of the Laramie group form a wall passing immediately west from that village. The rocks of that group are sandstones such as are shown in the Trinidad coal-field and have the same yellowish color. The total thickness of the series as exposed along Galisteo Creek is probably not far from 800 feet, though on the north side of the creek, where the rocks are standing on edge, the thickness appears to be much greater. Impressions of deciduous leaves are not wanting, but *Halymenites major* appears to be absent. The relations of these rocks to the Middle Cretaceous are so intimate that Dr. Newberry and Professor Cope, who made detailed examinations of the Cretaceous rocks farther west, referred them to the Middle Cretaceous. Dr. Hayden has well said that along the east face of the Rocky Mountains the passage from the Fort Pierre shales to the Laramie is so gradual that he could never discover any well-defined line of separation; but along Galisteo Creek the difficulty of distinguishing the boundary line between the Fort Pierre and the coal-bearing group is infinitely greater than it is in Colorado at the east base of the Rocky Mountains. Indeed, there is no boundary line between the groups. The great sandstone, which I have assumed as the base of the group, is not a decided mass like the *Halymenites* sandstone farther north, but is variable, sometimes divided by a thick bed of shale. It contains red bands, and at some localities is divided by beds of iron ore. Many of the latter have a concretionary structure precisely like that of the ore-beds occurring in the upper part of the Fort Pierre. Besides these, argillaceous beds cemented by oxide of iron and having a cone-in-cone structure are by no means rare above the bottom sandstone, while ore-beds with concretionary structure were seen at a long distance above the lowest coal-bed. The Fort Pierre group becomes more and more sandy toward the top and passes imperceptibly into the sandstones of the coal group; so that one failing to find the coal would not for a moment suspect that he had passed beyond the Fort Pierre group. *Ostrea congesta* and *Inoceramus* occur well up in the series.

Professor Newberry followed the group still farther west and northwest while on the San Juan Expedition. He finds the same yellow sandstones along the Chama and beyond until near Pagosa Springs, and again farther west on the Animas and the San Juan. At several localities he discovered beds of coal in the upper part, while in the lower part there is an abundant representation of the Upper Cretaceous fauna. In that region he saw *Halymenites major* in the Lower Cretaceous or Dakota sandstones. He places this whole mass of sandstone above the Galisteo coal-beds.

Professor Cope found extensive deposits of coal in the area between the Chama and San Juan Rivers, which he described in the appendix to Lieutenant Wheeler's report for 1874, as well as in the report for 1875. He regards them as equivalent to the Galisteo beds and places them in Cretaceous No. 3, or the Niobrara of Meek and Hayden. His language respecting this locality as given in Lieutenant Wheeler's report for 1874 is as follows:

> The shore of this lake was formed by rocks of the Cretaceous formation of an age near the No. 3 of Meek and Hayden. In approaching it from the east we traverse the sandstones of Cretaceous No. 1, both horizontal and tilted at various angles, and find No. 2 resting upon it, frequently unconformably, and tilted at higher angles, frequently 45°, sometimes 50°, to the west and southwest, and containing numerous fossils, as *Inoceramus*, &c. The upper sandstones of this formation pass into a brackish or fresh-water formation, which includes a bed of lignite of sometimes fifty feet in thickness. Above this rests conformably, where seen, a moderate thickness of soft marine rocks, containing numerous shells, *Acephala*, *Gasteropoda*, and *Cephalopoda*, including *Oysters*, *Baculites*, and *Ammonites* resembling *A. placenta* most, with sharks' teeth. Resting unconformably upon these, with a much reduced dip, is a mass of brown and reddish sandstone some 1,500 feet in thickness, inclining perhaps 10° south and southeast. These pass continuously into the superincumbent red and gray marls, alternating with brown and white sandstones of the fossiliferous beds of the Eocene. The observed part of these beds is about 1,500 feet in depth.

These upper beds are clearly Dr. Newberry's Upper Cretaceous, and the same with those which the writer, in his report on Southern Colorado, also recognized as Upper Cretaceous; and they are the same with the lignites and bright sandstones of Galisteo Creek. They are very far from being Cretaceous No. 3, for at Galisteo the fossils of No. 4 are plentifully distributed through hundreds of feet below them.

Mr. Holmes and Dr. Endlich have recognized the Fox Hills group in Southwestern Colorado, where it contains *coal*-beds, and the former somewhat hesitatingly identifies the Laramie group above the Fox Hills.*

RELATION OF LARAMIE TO FOX HILLS.

The relation between the Laramie and Fox Hills groups is evidently one of the most perplexing problems in American geology, and there is no room for surprise that so many observers have shown vacillation in their opinions. Dr. Hayden finally refers the Laramie to neither the Tertiary nor the Cretaceous, but regards it as a transition group with closer affinity to the Tertiary than to the Cretaceous. Mr. Meek refers nearly the whole of the group to the Cretaceous, but thinks that perhaps a part of the Bitter Creek series of Western Wyoming may be Tertiary. Professor Cope places the top of the Cretaceous far up in that series, and, indeed, is inclined to place the Laramie as a higher division of the Cretaceous than the Fox Hills, calling it Cretaceous No. 6. He found a reptile of Cretaceous type far up in the section, and discovered unconformability between the Laramie of Northern New Mexico and the unmistakable Eocene of the same region. Mr. King and his assistants place nearly the whole of that group in the Cretaceous on stratigraphical grounds, there being distinct unconformability between the Laramie group and the clearly Eocene Green River beds. Dr. White, after study of the invertebrate remains, is inclined to think the group a transition series, and approves of the term "Post-Cretaceous." Dr. Leconte and the writer have referred the group in Colorado and Northern New Mexico wholly to the Cretaceous.

Dr. G. M. Dawson has discussed the whole question elaborately in

*No reference has been made to the coal-bearing groups of Northern Utah and Western Colorado and Wyoming. The relations of those groups require more extended discussion than would be in place here, but the writer is engaged upon a monograph of the North American Cretaceous, in which the whole question will be fully discussed.

his report on the Geology of the Forty-ninth Parallel, and, as the result of his studies, has been led to place the whole of the Laramie group in the Tertiary. Mr. Lesquereux has published many able papers upon the flora of this group, which he finds has very close affinity to the Miocene of Europe. He divides the group into Miocene, Upper and Lower Eocene, the first being represented at Carbon, the second at Evanston and Sage Creek, and the third at Raton Mountains, Golden, Black Butte, Spring Cañon, and Fort Union. As a whole, he regards the vegetation as Oligocene. He finds Miocene also at Green River, Elko Station, and South and Middle Parks.

Dr. Newberry has referred the coals of New Mexico to the Middle and in part to the Upper Cretaceous, partly on stratigraphical and partly on palæontological grounds. In 1868 he published a careful discussion of the Extinct Floras of North America, in which he described a number of species obtained by Dr. Hayden from the vicinity of Fort Union, Dak. These he found to be very closely allied to the Miocene of Europe and accordingly referred the group to that period. Dr. Hayden maintains that these beds are, in part at least, equivalent to the Laramie group, and Mr. Lesquereux identifies some species as common to Fort Union and some undoubted Laramie localities. There seems to be, however, a marked difference between the flora found at Fort Union and that obtained from the Laramie group at other localities, and it may be well to wait until detailed stratigraphical studies have been made before any positive assertions respecting the relations be offered. Respecting the conditions in Colorado east from the mountains and along the Union Pacific Railroad, Dr. Newberry is sufficiently clear. He does not regard the plants within that region as having any distinct bearing on the question and is very much inclined to think the beds Cretaceous.

In the midst of these conflicting determinations it becomes necessary to look for a little at the value of the several kinds of evidence presented. Some appeal to the stratigraphy, others to the testimony of animal remains, and others still to the evidence given by the plant remains.

In every case, where it is applicable, stratigraphy is final, for so long as a rock can be traced continuously one may not doubt its identity. But stratigraphy in this simple form is not often available to any great extent. So variable are the rocks in extensive areas, owing to the different conditions under which material may be deposited synchronously at distant localities, that direct comparison of sections by lithological characters or even by tracing becomes impossible. We are compelled, therefore, to resort to palæontology in addition. The geological column is based on the succession of marine invertebrata.

The stratified rocks, with the exception of comparatively insignificant portions, were deposited under the ocean; and of those which contain the remains of terrestrial organisms a great part was formed along the sea-border, exposed to frequent irruptions of sea-water. The lacustrine or purely fresh-water deposits are small both in extent and duration and are confined chiefly to the later portions of geological time. As the sea always covered the greater part of the earth and afforded an easy medium of migration for water-breathing animals, one would expect to find in rocks of marine origin the most satisfactory record of changes in animal life. This would be a close record of material changes in physical conditions, for animals are of a high type of organization and very sensitive to alteration of circumstances. The record is remarkably complete. From the base of the Silurian to our own time the gaps are few and usually of limited extent. Many of them occur in sandstone, out of which the fossils have been merely leached.

So distinct is the succession of invertebrate life, so sharp the breaks at the close of many periods in the world's history, that geologists, by common consent, have adopted this form of life as the foundation stone of the system. By stratigraphy the order of the rocks was ascertained, but by the succession of invertebrate life the great mass was divided into groups and geological history could be written. Rocks containing a certain fauna were called Silurian, others with a different fauna were termed Cretaceous, others Miocene, and so on through the list. These divisions were based on the fauna and on nothing else. This should be borne in mind.

The same basis is employed in making the minor divisions. In the Upper Missouri region a mass of rocks is found possessing a fauna closely resembling that of a series in Europe, termed Upper Cretaceous. This all accept as proving that the two series hold equivalent positions in the geological column. Closer investigation shows that the Upper Missouri series is made up of distinct groups, each characterized over an immense area by a peculiar assemblage of invertebrate remains. These groups make the section. If in any part of the western region we find the fossils of any one of these groups, we may legitimately expect to find the others over or under it, as the case may be. It may happen that over large areas a group thus established may be utterly barren of animal remains. This does occur in the Cretaceous groups. The Dakota group is often barren and can be identified only by its previously determined stratigraphical relations. The Fort Pierre and Fox Hills groups, as we are told by Dr. Hayden, show extensive barren zones. Illustrations of this condition can easily be drawn from other formations. Over thousands of square miles the Lower Carboniferous shows no fossils, yet from the last great wave of the Appalachian system westward the group is filled with fossils.

It is true that some species of invertebrates show a marvellous tenacity of life. *Strophomena rhomboidalis* lived from the Lower Silurian almost to the base of the Carboniferous; *Atrypa reticularis* existed from near the beginning of the Upper Silurian to near the close of the Devonian. In each group these species show marked peculiarities, which almost suffice to determine the horizon from which the specimens were obtained. But no palæontologist would be reckless enough to identify the horizon with these shells as his only data. They are not characteristic. While we find five or six instances of this sort, no characteristic forms belonging to the Carboniferous have been found in the lower rocks. But if they should be so found, their evidence would be nothing. *Spirifer cameratus* associated with a Devonian fauna in rocks holding the Devonian place would be a worthless witness. So, if the thing were possible, should *Ammonites* be found at a Silurian horizon, its testimony would be rejected and the stronger evidence for Silurian would be accepted. Even invertebrate life must yield to stratigraphy if the two conflict.

The record of vertebrate life is far from being complete; but the remains which do occur are so striking in character that they have always attracted the attention of students and their peculiarities have been carefully determined. The relative positions of the families and genera have been well fixed both in Europe and America, and it has been discovered that the vertebrates of the American Cretaceous and Tertiary are closely allied to those occurring at the same horizons in Europe. These forms, then, will prove greatly serviceable in the attempt to correlate American and European formations.

Vegetable life shows no such history as to entitle it to equal consideration with animal life. So patent is this fact, that little use has been made of plant-remains in determining the succession of rocks. Land plants are unsatisfactory because they are preserved in disconnected fragments and because the areas on which they grew were widely separated and formed but a small part of the earth's surface. This objection holds more strongly in the periods when variations in climatic conditions became sharply defined.

But vegetable relics are very useful to the geologist. The character of the Carboniferous flora has been so well studied for many years that it is thoroughly understood. The horizon of these plants is now fixed, their general type is understood, and they can be used without hesitation as evidence where animal remains are absent. The day may come when impressions of deciduous leaves will be understood equally well. Even as matters now are, they are by no means without value. The flora of the Dakota group serves to identify that group where the formation is barren of animal remains. The position of this flora has been fixed by means of its occurrence in and below rocks containing the ordinary Cretaceous types of animals. In like manner the flora of the Laramie group avails for the identification of that group in different portions of the same area.

But why is one flora called Cretaceous, or another Triassic, or a third Tertiary? Simply because it is in rocks *previously* determined to belong to the period by which the flora is called. Let it not be forgotten that the group is not named Cretaceous or Tertiary because of the flora. Stratigraphy determined the general succession of the rocks; animal life determined the division into groups.

The floras of our later geological eras cannot afford a satisfactory basis for generalizations looking to a determination of equivalent horizons in Europe and America. The conditions on the two continents were widely different. This general statement has been practically accepted as true by our palæobotanists, Dawson, Lesquereux, and Newberry, all of whom have acknowledged that the testimony of plants is inferior to that of invertebrates.

The collection of plant remains made by Dr. Evans at Nanaimo and adjacent parts of Washington Territory were submitted to Mr. Lesquereux* for examination. Out of these specimens he made a number of species, and recognized some as identical with species already published in Europe. So closely allied are these plants to the flora of the Miocene of Europe that Mr. Lesquereux refers the coal-bearing rocks of both Nanaimo and Bellingham Bay to the Miocene. Somewhat later† he published a letter from Professor Heer fortifying his position. Both of these gentlemen unhesitatingly referred the rocks to the Miocene. The editor of the American Journal of Science felt it necessary to append to this letter an apology for Professor Heer, in which he stated that the professor had not had access to the paper of Meek and Hayden on the Vancouver fossils.

The collections made by Mr. Geo. Gibbs, of the Northwest Boundary Survey, were submitted to Dr. Newberry,‡ who at that time regarded the Bellingham Bay deposit as most probably Miocene. The molluscan remains occurring with the leaves at Nanaimo induced him to believe that the Nanaimo coals are Cretaceous. But it is very clear from his language that nothing in the plants would lead him to suppose that they belong to a Cretaceous horizon, but, on the contrary, that enough was shown by them to cast doubt on any such conclusion were other evidence lacking.

The Nanaimo locality was visited in 1871 by Messrs. Selwyn and Richardson, and afterwards in 1872 by Mr. Richardson, who made detailed examination of the area. The collections of plants made by these gentle-

*American Journal of Science, Second Series, Vol. 27. †Ibid., Vol. 28.
‡Boston Journal of Natural History, Vol. 7.

men were submitted to Dr. Dawson, who said respecting the collection of 1871:

They belong to a flora which has occasioned some controversy. It was originally described by Lesquereux and Heer as Tertiary, being indeed very nearly allied to that of the Miocene of Europe. Newberry, however, on the evidence of the associated marine fossils and on the analogy of the Cretaceous flora of Nebraska, regards it as of the latter age, and this, I believe, is the view more generally adopted. The present collection is too imperfect to throw much light on these questions, and it will be better to await the arrival of larger collections before describing any of the species which it contains.

But respecting the collections of 1872 he speaks with assurance:

The fossils from the coal-field of Vancouver embracing, in addition to coniferous trees, both wood and leaves of several species of angiospermous exogens, coincide with those of the Cretaceous of other parts of America, for example of Nebraska. The fossils from Hornby Island, in shales believed to overlie those of Vancouver Island, are also Cretaceous, and there is nothing to preclude their belonging to the upper part of that system.*

The evidence given by the animal remains shows that the coals are not far from the horizon of the Fort Pierre group, possibly reaching up to the lower part of the Fox Hills, as has been shown by Meek, Billings, and Whiteaves.

In 1858 Mr. Meek and Dr. Hayden submitted to Dr. Newberry a collection of leaf-impressions which they had obtained from the Dakota group of Nebraska. Dr. Newberry found great resemblance between these and the Tertiary flora of Europe, but regarded them as of Cretaceous age, being convinced by the stratigraphy and the testimony of invertebrate remains in the overlying rocks. Sketches of some of these were sent to Professor Heer, who, in a letter to Mr. Lesquereux,† very positively asserted that Newberry erred in his conclusions, and that the plants are all of Tertiary forms. His language is as follows:

It is true that I have seen only some drawings which were sent to me by Messrs. Hayden and Meek, but they are all Tertiary types. The supposed *Credneria* is very like *Populus leuce*, Ung. of the Lower Miocene, and the *Ettinghausiana* seems hardly rightly determined. Besides, it is a genus badly founded, and as yet has no value. All the other plants mentioned by Dr. Newberry belong to genera that are represented

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* Canadian Reports for 1871-'72 and 1872-'73.

† American Journal of Science, Second Series, Vol. 28, p. 88.

in the Tertiary and not in the Cretaceous. And it is very improbable that in America the Cretaceous flora had the characteristic plants of the Tertiary, and this would be the case if these plants did belong to the Cretaceous.

To this the editors of the Journal append a note, stating that similar leaves had been collected by Professor Cook from the base of the Cretaceous, as well as by Dr. Newberry from the same horizon in New Mexico, so that if the leaves are Tertiary our Cretaceous is abolished.

Dr. Newberry replied,* stating that he had collected such dicotyledonous leaves from the Lower Cretaceous sandstones at Galisteo Creek in New Mexico, where the Upper Cretaceous sandstones also are exposed, and at various localities east to the Canadian River, where characteristic Cretaceous 2 and 3 are seen resting upon the sandstones.

Mr. Lesquereux's rejoinder was sharp, defending Professor Heer's conclusion and fully indorsing it.

In 1863 Professors Marcou and Capellini undertook a journey to Nebraska to effect a final determination of the question. On their return, they pronounced the Dakota group Cretaceous, and not only Cretaceous, but at the base of that series as accepted in America. In his work describing the leaves collected by these gentlemen, Professor Heer acknowledged the superior value of the faunal evidence and placed the leaves in the Cretaceous. In 1868 Mr. Lesquereux did the same, and described a number of species from the Dakota group; but he announces that a remarkable generic affinity exists between the Cretaceous and Tertiary flora of America. In 1874 he published his quarto volume on the Cretaceous flora of the Dakota group.

The plants of the Laramie are little better. Of these a great number of species have been described by Mr. Lesquereux. They have close relations to the European Miocene, and a large part of those identified with European forms are Miocene; so that most of the group is placed in the Eocene. According to some observers the testimony of the plants conflicts with that given by stratigraphy, and the same group is sometimes Upper, sometimes Lower Eocene.

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*American Journal of Science, Vol. 29, p. 299.

Evidently, then, the relations of our strata must be determined by the evidence of animal remains. Stratigraphy will give assistance. This being understood, we may look at the facts as they are.

First. The Fox Hills and the Laramie group are everywhere conformable to each other, and the latter is unconformable to the fully recognized Tertiary above it. Professor Cope has observed the lack of conformability to the Eocene in New Mexico, and Mr. King has shown that a similar unconformability exists in the Wasatch region.

Secondly. From the beginning of the Fox Hills to the close of the Laramie there was no change in the general conditions that would be of even epochal value. The whole succession is continuous, and the groups can be separated only by arbitrary lines. The variations above the fucoidal sandstone, which rests on the Fort Pierre sub-group in New Mexico, are unimportant, and are precisely similar to those which occur farther north in the Fox Hills group. The marine conditions sustained no violent change, for *Halymenites major*, beginning its existence in the Fox Hills group, continues into the Laramie. True, great changes did occur locally, as in the Trinidad coal-field, where marine fossils practically disappear at the base of the coal-bearing rocks; but elsewhere, for the most part, there was no such change, for farther north in Colorado characteristic Fox Hills fossils were obtained in abundance near *the summit of the fully recognized Laramie.*

Thirdly. The conditions observed in the Laramie are but a repetition of those commonly observed in the other divisions of the Cretaceous. The sandstones are very like those of the Lower and Middle Cretaceous; coal-beds are found in the Lower Cretaceous of Utah and New Mexico, throughout the whole of the Cretaceous series in the Wasatch region, in the upper part of the Middle Cretaceous on the Pacific coast, in the Fox Hills and Laramie within the Green River basin, and in the San Juan region, and occasionally in the Fox Hills, but usually in the Laramie along the east base of the Rocky Mountains. The coal-beds in all the divisions of the Cretaceous are variable, and those of each group are often wanting over extensive areas.

Fourthly. The fauna is either marine or brackish water. At the base of the series beginning with the Fox Hills group the species are all marine; at many localities some brackish-water forms are found among the coal-beds, marine forms being absent; while at others the marine types continue in abundance to the very summit of the whole series. True enough, fresh water and even land forms are sometimes found, but their presence has little if any bearing on the subject. Such forms must have existed on the upland away from the marshes which fringed the ocean, and they might easily be brought down to the shore during floods so as to be spread over the limited spaces where they are now found. A commingling of faunas like this is not unknown in the Carboniferous.

Fifthly. The fauna wherever found is Cretaceous or of such a character as to render its testimony neutral, its relations being unknown. That barren zones occur in the Upper Cretaceous was observed years ago by Dr. Hayden in the Upper Missouri region, and others have found this to be true of the whole Rocky Mountain region north from New Mexico. But the fauna is to be determined by what one has, not by what he has not. The productive localities must tell the story. At the east the barren areas of Carboniferous rocks are more extensive than are any that have been found in the Cretaceous at the west. The Lower Carboniferous rocks of Pennsylvania are practically barren at two-thirds of the exposures, but in the southwest part of the State they become fossiliferous and thence to the Mississippi they are rich in fossils. So in the anthracite field of Pennsylvania the Coal Measures rarely yield fossils, whereas in the western part of the State and in Ohio there are several fossiliferous beds, while farther west fossils occur in prodigious quantities. But, on the other hand, fossils disappear southwardly along the west base of the Appalachians, for in West Virginia south from the Baltimore and Ohio Railroad not one fossiliferous bed occurs in a vertical section of nearly 2,000 feet of Coal Measures.

A similar condition occurs in the Laramie group at the west. In the Trinidad and Cañon City coal-fields fossils rarely occur, but in the Galisteo area they are sometimes obtained, *Inoceramus* and *Ostrea* having been seen by the writer in the Laramie of that area. At Evans and Greeley, as well as along Saint Vrains and Thompson Creeks in Colorado, fossils are abundant and the species are typical of the Fox Hills group, though they were obtained from the very *summit of the Laramie* and at the top of a section containing eleven coal-beds. If these fossils are not proof of the Fox Hills age of the rock, palæontology is useless and geologists will do well to seek a more trustworthy guide.

Sixthly. There is an utter absence of any definite evidence to show that the Laramie group is newer than the Cretaceous. True, it is a group proving that the ocean was filling up in that region, and there are great coal-beds showing the presence of land vegetation. This condition began with the Fox Hills along the east base of the Rocky Mountains. But this shoaling of the sea cannot be good ground for separating the Laramie from the Cretaceous any more than the similar shoaling during the Coal Measures time would justify separating the Coal Measures from the Carboniferous and thrusting it into the Triassic. It is true, also, that a vast array of plants has been presented, an array that without doubt would be vastly reduced if there were any means of ascertaining how many of the so-called species are synonyms. But it has been seen already that the evidence of these plants is worse than worthless, for it is misleading. The Vancouver plants showed the Fort Pierre group to be Miocene, and the Nebraska plants did the same for the Dakota group. Mr. Lesquereux is good authority respecting fossil plants; let us see how valuable their testimony becomes in his hands. Here are seven species of Vancouver plants recognized by him as present in the Rocky Mountain region. Their distribution in the latter region is as follows:

Sequoia langsdorfii, A. Br.—Lower Eocene, Upper Miocene.
Salisburia polymorpha, Lesqx.—Upper Miocene.
Sabal grayana, Lesqx.—Lower Eocene.
Populus mutabilis, A. Br.—Lower Eocene.
Cinnamomum heeri, Lesqx.—Dakota Group.
Andromeda grayana, Lesqx.—Lower Eocene, Upper Eocene.
Diospyros lancifolia, Lesqx.—Upper Eocene.

It will at once be seen that these seven species not only prove the equivalence of the Nanaimo and Rocky Mountain coal-bearing rocks, but also that they settle beyond all dispute the question of their geological horizon.

But there is said to be a great difference between the flora of the Dakota and that of the Laramie. There should be. But the difference is not greater than that between the flora of the Millstone-grit and the flora of the Upper Barren Coal Measures in Southwest Pennsylvania, and this difference is not thought by any to justify a removal of the Upper Barrens from the Carboniferous. No more should the second great Carboniferous age, that of the Cretaceous, be broken up because of the specific variation of the flora.

The occurrence of fresh-water or land shells has no bearing on the question. Very little is known respecting the vertical distribution of either the genera or the species of such forms.

But may it not be that the whole discussion thus far has been made on an insufficient basis? The work done up to this time, east from the Rocky Mountains, is merely that of a reconnaissance, and no detailed sections have been carried from the base of the mountains out to the eastern edge of the Laramie rocks except in the Trinidad and Cañon City coal fields, which, however, are cut off too soon at the east to afford full data. A discussion respecting the relations of the Lower Carboniferous rocks to the Coal Measures conglomerate, if based only on observations made in Eastern Pennsylvania, would be far from satisfactory; and the conclusions to which such a discussion would lead would be very different from those to which one would come after studying the two series in Western Pennsylvania or West Virginia.

It is by no means improbable that variations occur in the Laramie group east from the Rocky Mountains very like those seen in the Carboniferous groups within the Appalachian field. The sandstones are coarse near the mountains, but become finer toward the east, and have occasional thin beds of impure limestone. The only fossils of conclusive character which have been obtained from the Laramie group in Eastern Colorado were found near the summit of the group and at a long distance east from the mountains.

In view of these facts—

1st. That the series above the Colorado shales to the top of the Laramie is conformable within itself;

2d. That no change of importance occurred in the general conditions during the formation of this series;

3d. That the Cretaceous from the beginning was a coal-bearing series;

4th. That the fauna, wherever of a character to be compared with known standards, is Cretaceous, even to the very summit of the series;

5th. That the hypothesis that this group or any portion of it is of later date than Cretaceous is unsupported by definite evidence—

It seems necessary to regard the Laramie as but the upper part of the Fox Hills group.

CHAPTER XI.

THE TERTIARY ROCKS.

THE GALISTEO GROUP.

The series which, in this report, is termed the *Galisteo group*, was seen in the vicinity of Galisteo Creek, where the section so far as observed is—

	Feet.
Trachyte breccia	150
Soft light-gray sandstone	40

In the chapter of the descriptive geology relating to this region the statement is made that the rocks of the Galisteo group are confined to the north side of Galisteo Creek and do not occur on the south side between the creek and the Placer Mountain. Possibly, so broad a statement is not wholly accurate, for on the elevated bench extending from the creek toward the mountain a thick deposit underlies the marly limestone which I have regarded as belonging to the Santa Fé marls. Whether or not this belongs to the marl group was not ascertained; but without doubt the Galisteo group at one time extended beyond the creek southward.

The application of the name to this group has been made with some hesitation. Dr. Hayden* states that he found on Galisteo Creek a series of rocks which seemed to be wholly new to him and therefore were named the Galisteo group. The description given in the report for 1869 appears to be applicable rather to the upper sandstones of the Laramie group than to these rocks. It is evident that Professor Cope regarded those sandstones as the Galisteo group, for he, as well as Dr. Hayden, states that the

*Preliminary Field Report, 1869.

Galisteo group is altogether conformable with the underlying coal series; and he therefore places them in a higher division of the Cretaceous, making them Fort Pierre, as he had previously identified the coal-bearing rocks with the Niobrara. The writer sought information respecting this group from Dr. Hayden early in 1879, and was shown a photograph of the Wasatch group, which was said to exhibit the characteristic features of the Galisteo group. These features are well shown by the rocks to which the name has been applied in this report, and not at all by the higher sandstones of the Laramie, which, however, possess in some measure the peculiarities mentioned by Dr. Hayden in the report for 1869. In any event, the name Galisteo group cannot be applied to the rocks on the south side of the creek, as they are clearly members of the Laramie or coal group. If it were originally applied to them, it must be dropped as a synonym, and newly applied to the rocks designated by it in this report.

The breccia is well shown on the Lower Galisteo from the Santa Fé and Old Placer road to the mouth of the Arroyo de los Angeles. It is very dark gray or even lead-colored, and is composed altogether, where examined, of trachyte in angular fragments, cemented by finer material, apparently of similar nature. This breccia was followed up the Arroyo de los Angeles to the Galisteo and Santa Fé road; but there it practically ends, and the evidence shows that it was worn away by the erosion which produced the broad mesa. Its fragments litter the surface of that mesa. The thickness assigned to this mass is that seen at the mouth of the Arroyo. It may be greater toward the northwest.

The sandstone is very light gray, excessively soft and incoherent, so that it yields to the weather as though it were loose sand, weathering, indeed, more freely than do the tough alluvial deposits along the creeks. This is the lowest bed of the group found within the area examined. It was followed up the creek for more than seven miles above Galisteo, and its ashen color gives a strange appearance to the deeply eroded face of the mesa.

The relation of the Galisteo group to the underlying rocks is finely shown at the head of the Arroyo de los Angeles, where the Lower Dakota beds dip westward at 65°, while the lower sandstone of the Galisteo rests on their planed-off edges and dips in the same direction at less than 1°. A more curious illustration of the unconformability is shown immediately below the mouth of the Arroyo, where the breccia was deposited around a projecting wall of Dakota which dips at nearly 60°; and the contrast in color is as great as would be that between a trachyte dike and a surrounding mass of basalt. Both the breccia and the underlying sandstone are exposed here and are conformable.

The Galisteo beds are not affected by the faults found in the Arroyo de los Angeles, whereas the Laramie beds are involved in them; the breccia is composed largely of trachyte from Los Cerrillos, a group of trachyte hills shown on the north side of Galisteo Creek at sixteen miles below the village. But the outburst of trachyte, forming those hills, caused frightful contortion of the Laramie beds. It is clear, then, that the Galisteo group cannot be conformable to the Laramie.

The relation of the Galisteo to the Dakota, shown in the Arroyo de los Angeles, renders the appearance on the eroded face of the mesa farther up the Galisteo very deceptive. The vertical yellow and almost white sandstones of the Lower Dakota yield readily to the weather, and the *débris* from the light-gray Galisteo sandstone mingles with that from the others; so that to one ascending the creek and following the line of the eastern fault the Galisteo sandstone seems to be triple, white, yellow, and gray, whereas the white and yellow belong to the Lower Dakota, on which the Galisteo sandstone rests unconformably.

At one time I was inclined to suppose that perhaps this Galisteo group might be only a part of the Santa Fé marls; but it must be unconformable to that series. This appears from the variation of the breccia, which is very thick at the mouth of the Arroyo de los Angeles, but becomes thinner northward, while the sandstone retains its thickness to the head of the Arroyo. But this variation is not due to thinning out. The two beds of the section rise in that direction and the breccia has been cut away by erosion. The Santa Fé marl covers the mesa and is spread out over the edges of the breccia and sandstone, which were leveled off during the formation of the mesa.

Whether the Galisteo group belongs to the Miocene or to the early Pliocene could not be determined. It certainly antedates the great flow of basalt, for as far as examined it shows no included fragments of that rock. It no doubt is long posterior to the trachyte outburst, for it rests on the leveled edges of the rocks which were turned up during that outburst. It cannot be older than early Miocene or newer than early Pliocene.

THE SANTA FÉ MARLS.

The Santa Fé marls are recognizable within the district by means of a tufaceous limestone, which seems to have been deposited over a vast area. Dr. Hayden states that the group is finely exposed in the Rio Grande Valley north from Santa Fé, where it is hundreds of feet thick; and the writer has been informed by Dr. Newberry that at a locality on Jemez Creek, west from the Rio Grande, this limestone is exposed with a thickness of not less than 150 feet. As the observations on which this report is based did not extend northward beyond Santa Fé, it is not possible here to say anything respecting the extent of the group in that direction. It clearly covers the plains between Santa Fé and Galisteo Creek and involves the loose deposit covering the older rocks. At many places where the surface deposit is but fifteen or twenty feet thick it is honeycombed by the marly limestone, which looks as though it had filled up broad shrinkage-cracks. At the head of the Arroyo de los Angeles the section above the Galisteo group is—

	Feet.
Silt	1
White marly limestone	1
Conglomerate	3
Clay	10
White marly limestone	3
Total	18

All of which, no doubt, may be included properly in the Santa Fé marl group of Dr. Hayden.

The marly or chalky limestone is present beyond Galisteo Creek southward on the bench reaching toward the Placer Mountain, and very possibly the whole of the loose material seen there, consisting of fragments of trachyte, granite, &c., with sands, clays, and irregular layers of the marly limestone, may be included in this group; the thickness being between fifty and seventy-five feet. Erosion has been busily at work among these beds on this bench, for on the table-land beginning at about six miles south from Galisteo the chalky deposit is thick.

The same material was seen in the Taos Basin, a recess in the range, which, according to Professor Cope, was originally filled with these marls. There the limestone occurs as it does near Santa Fé, being apparently deposited in shrinkage-cracks.

This tufaceous limestone occurs in small patches at many localities south and east from the mountainous area. Evidently it is very thick in the Pecos Basin near the village of Pecos, and it was observed also on Vaca Creek at Las Colonias. Small patches were seen near Las Vegas, and an extended area lies between the Canadian Hills and the Mora Cañon, reaching westward to beyond Fort Union. Fragmentary exhibitions were seen much farther north.

Professor Cope has determined that the Santa Fé marls belong to the Loup River epoch of the Pliocene. The group is certainly newer than the basalt, for fragments of that rock cemented by it occur on the Ocaté Mesa near the Wagon Mound. It overlies the basalt in the Upper Valley of the Rio Grande.

A mass of conglomerate was seen along the west base of the Culebra, Taos, and Santa Fé Ranges, which will be described in the following chapter. Unfortunately the writer's examinations along the west side of those ranges ended at the Taos Basin, so that he was unable to follow these conglomerates southward. Possibly they may be closely related to the Santa Fé marls, but in this report they are provisionally regarded as belonging to the Quaternary.

THE ERUPTIVE ROCKS.

As few of the specimens collected have been examined microscopically, it is possible to speak only of the distribution of these rocks and of their relations to each other and to the stratified deposits.

The Trachytes.

Trachytic rocks occur abundantly within the mountain area but very sparingly on the plains. Basalt covers extensive areas in the plains-region and is found to but a slight extent within the mountain region.

At the extreme north several trachyte dikes were seen, which appear to radiate from the Spanish Peaks. One of them, double, follows the Stonewall Valley from Cucharas Pass to beyond the Middle Fork of the Purgatory River. Others were seen in San Francisco Park, on the South Fork of that river. The dike within the Stonewall Valley bears no relation to the stratification and stands out as an almost vertical wall, but those in San Francisco Park dip at various angles; the relation these dips bear to those of the beds, through which the dikes were thrust, could not be ascertained, as the soft shales of the Fort Pierre have yielded to the weather and the slopes of the low hills are covered deeply with *débris.*

Many dikes were seen at the headwaters of Vermejo Creek, where they are entangled amid the distorted Cretaceous and Carboniferous beds in such a way that nothing could be determined respecting the relations. But immediately south from the Vermejo a strong dike appears associated with the Stonewall, and thence to Costilla Peak the wall and the dike have the same dip. This dike contains many fragments of gneiss.

Several groups of dikes begin at a little way north from the latitude of Costilla Peak, and they become stronger southward to about the latitude of Taos Pass, beyond which they soon disappear. One group appears to have its center in the Taos Range not far from Colorado Creek. Rhyolyte prevails along the lower part of the cañon of that stream, but trachyte is the prevalent rock farther up, though even there rhyolyte dikes occur in the trachyte. The rhyolyte is a hard, compact rock, somewhat resembling quartzite on the weathered surface, and containing small crystals of feldspar. The trachyte is sometimes compact, greenish or bluish in color, with scales of mica and small spherules of sanidin or large blotches of feldspar; at others, the general appearance is the same as in the last, but the sanidin occurs in large spherules; while again the feldspar paste is coarse as though decomposed, contains scales of mica, large drops of sanidin, and twin crystals of feldspar, which are occasionally two inches long. A dike of similar material occurs on the east side of Red River Pass. The dikes continue northward to beyond Costilla Creek, but there the rock is soft throughout and readily breaks down on exposure, covering the hillsides with a variegated mud. Southward the dikes soon disappear, there being none on Ferdinand Creek or in the approaches to Taos Pass from the north side. But an extensive dike follows the east side of the range from near Red River Pass to within a very short distance of Taos Pass.

Another center of disturbance lies immediately east from the Colorado Creek area and follows the line of the Cimarron axis. The main eruptions were between Poñil Pass at the north and Cimarron Creek at the south, and the masses known as Old and Little Baldy are but the overflow from two enormous dikes well exposed in Cimarron Cañon. The eastern or broader dike is composed of a massive rock, which resists the weather and forms a bold wall to the cañon for fully four miles; but the western dike seems to be composed of a softer rock, which readily disintegrates, so that the hillside is deeply covered by variegated mud. Dikes radiate in almost all directions from this center. Those going northward end somewhat abruptly near Costilla Peak. They are so numerous that all attempts to work out the geology of the stratified rocks between them were unsuccessful. The rock is for the most part compact and very fine in grain. Its composition cannot well be ascertained without resort to the microscope, but it is a trachyte. The dike terminating in the Bare Cone is somewhat perplexing; its rock contains minute specks of sanidin, and under the microscope seems to be made up of quartz grains. Possibly this rock may prove to be metamorphic, but the dike is there, and it passes into one of the Old Baldy group. Dikes passing from Old Baldy cross the Moreno Valley in an almost due west direction. They are composed of a mottled trachyte, of which the paste has a grayish color and is very hard. Associated with a small dike of this group is a narrow dike of porcelain-like rhyolyte, which, however, is exposed for but a short distance.

The Baldy dikes and their overflow continue southward from Cimarron Creek to the cañon of Rayado Creek, beyond which the basalt-covered Ocaté Mesa begins and cuts off all further tracing toward the south. But the dikes evidently extended much farther southward, for at one locality on the mesa, several miles south from the Rayado Cañon, a small knob of trachyte was seen projecting above the basalt; and in the cañon of Coyote Creek, following the western edge of this mesa, occasional croppings of trachyte appear where the basalt has been removed by erosion; while on the west side of that cañon a great fragment of a trachyte overflow rests on the Archæan rocks.

The edge of an extensive area of trachyte-like rocks was reached east from the Canadian River; but this is covered for the most part by the later basalt overflow, and there are few localities where the older eruptive rocks are exposed. No details were obtained respecting the distribution of the trachytes (if such they be) in this area.

No trachyte was seen in the Santa Fé Range where it is crossed by Junta Creek or where crossed by the Santa Fé and Las Vegas trail; nor is there any in the Mora and Las Vegas Range, so far as observed, south from the head of Mora Creek; and similarly the rock is absent from the Archæan area of the Mora axis. Indeed, these ranges seem to be almost wholly free from eruptive rocks of any kind south from the latitude of Taos Pass. But at a little way south from Santa Fé the evidences of massive eruptions become very distinct.

Los Cerillos, at probably twenty miles south from Santa Fé, are a group of irregular hills, which, so far as examined, are composed of trachyte with occasional dikes of what appears to be decomposed rhyolyte. To the writer these hills seemed to be relics of great dikes, but Dr. Newberry and others who have visited the region suggest that they may be ancient volcanic cones. There is nothing in their structure which necessarily militates against such a conclusion. The mass is an upthrust, which was accompanied with much violence, and the Cretaceous rocks surrounding it have been greatly disturbed. The Colorado shales and the Laramie sandstones are sometimes more than vertical on the north side of Galisteo Creek. A vast dike of trachyte passes in front of the Placer Mountains, and to it no doubt is due the metamorphosis of the coal at more than one locality between Galisteo Creek and the mountains. The overflow from this dike remains in part at the Cerro Pelon, where it is shown resting on the Laramie sandstones. A broad dike crosses the southern edge of the Galisteo Park and has an almost east and west direction.

The trachytes are newer than the Cretaceous, for they rest on the Laramie rocks at some localities and break through them at others; but, in the absence of all Eocene deposits within this district, their age can be ascertained only by secondary evidence. The Cimarron Range in its present shape certainly originated not earlier than the close of the Cretaceous, for Laramie rocks cross the crest of the arch at Poñil Pass. But, as shown in Cimarron Cañon, the crest of the Archæan area had been planed off to a plateau before the overflow occurred, for the contact between Archæan and trachyte follows an almost straight line for several miles. The overflow, therefore, must have been long posterior to the close of the Cretaceous. In like manner it is seen that it long antedated the basalt overflow.

Respecting the trachyte-like rocks seen near the Raton Plateau east from the Canadian River, little can be said. The examinations in that vicinity were not such as to give much detail. Only the western edge of the eruptive area was visited, and even its extent was determined only approximately.

The basalts.

Areas of basalt exist on both sides of the mountain region, but within that region the rock occurs very sparingly.

The eruptions took place partly by volcanoes and partly through fissures. Intruded sheets of basalt are common, while those of trachyte rarely were seen. As observed by Mr. King within the area embraced by the Survey of the Fortieth Parallel, the basalt was poured out during the latter part of the Tertiary and covered benches and plateaus which had been already formed.

The Rio Grande Valley is overspread by basalt and the river flows through a deep cañon in that rock. The original thickness of the basalt was enormous, for the rock reaches well up the sides of the range from

Fort Garland southward to Costilla Creek, and high mesas remain on the plain, while two great domes are still preserved near the southern border of Colorado. The variations in color and structure are great, for at some localities the rock is fine-grained and compact, while at others it is granular and soft. It is frequently amygdaloid. The color varies from dark-brown to bluish-gray, or on the weathered surface to reddish-brown. No scoriaceous material was found on the west side of the mountains, and no dikes were discovered within the Rio Grande Valley until Galisteo Creek was reached, where some of insignificant size were seen. In these the color is earthy-brown.

The dip of the basalts in the northern part of the Rio Grande area is eastward, as is well shown in the mesas near Fort Garland and along the base of the Culebra Range. It is altogether probable that the overflow came from the western side of the valley. As already stated, no dikes were found on the east side of the valley, nor was anything seen which could be regarded as an extinct volcano.

Basalt is present at many localities along the eastern base of the mountain areas from the Turkey Mountains northward.

A few dikes were seen on the Purgatory and the Vermejo within the Laramie area, but the rock occurs there chiefly as intruded sheets, which are from one foot to twenty-five feet thick. Some sheets observed along the Purgatory are continuously exposed for miles and are not involved in the petty anticlinals crossed by the creek. Occasionally, however, they follow a line of slight resistance such as the contact between shale and sandstone, or are intimately associated with a coal-bed for a long distance, and so appear to have the same dip as the coal-bearing rocks. It is not altogether improbable that the basalt overflow may have extended over much of the Laramie area at the north, for some hills rising higher than their neighbors are capped by a thin block of basalt. The basalt-covered Raton Plateau is higher than any part of the Laramie area, whose elevation has been determined by the topographical parties of this survey.

Passing eastward along the Purgatory, one reaches the Raton Plateau, which lies east from Raton Creek and is the same with that which is designated as the Chicorica Mesa on the map of the Geological and Geographical Survey of the Territories. This plateau extends eastward to beyond the limits of the district, but is narrow from north to south. It is covered with a basalt sheet from 400 to 600 feet thick, which is exposed to its base on Manco Burro Pass and at a few localities in Johnson's Park at the head of Uña de Gato Creek. The rock for the most part is hard, compact, dark-gray, and shows much olivine; but there are many evidences that a second eruption of basalts occurred within this space, for dikes of scoriaceous lava were seen in Johnson's Park, which break through the Fort Pierre shales and the plate of older basalt. A breccia follows the walls of these dikes, containing fragments of the Cretaceous shales and of the older basalt. The later overflow must have been by no means inconsiderable, for although at present only insignificant cones of the cindery rock remain on top of the plateau, yet its fragments are among those most frequently occurring amid the *débris* covering the plain. Dikes of basalt were seen on Willow Creek near the mouth of the cañon leading up to Raton Pass, and many little hills of the same rock remain on the plain between Willow Creek and the base of the plateau.

The basalt was poured out over a great mesa rising from the Canadian Plains as distinctly as it does now. The old mesa was covered with alluvium, in which are bowlders of granite, gneiss, and quartzite, which must have been brought from the mountains at the west. This deposit is well shown in Manco Burro Pass and on several ridges in Johnson's Park where the basalt has been worn through. The flow came from the east, and on the Capulin Vegas, only a few miles beyond the eastern border of the map, are several ancient cones. These are admirably preserved and the craters seem to have suffered very little from erosion.

But erosion has been energetic since the outpouring of the basalts, for of those rocks no trace remains in the plains between the Eagle-tail Mesa and those outliers of the Ocaté Mesa, known as the Gonzales and Rayado Mesas. The Ocaté Mesa is reached at Rayado Cañon, whence it extends southward to the Turkey Mountains, while it stretches eastward from the cañon of Coyote Creek to the Canadian Plains. It has an outlier at the southeastern end, known as the Canadian Hills, which extends eastward from the mesa toward the Canadian Cañon.

The basalt on this mesa occurs in two steps or benches as though it had been poured out on an already benched area. The higher bench is on the western side of the stage-road from Rayado to Apache Hill, where the road rises to the lower bench and thence follows it to the Turkey Mountains. The higher bench does not extend so far south as to Ocaté Creek. It is covered by a thick plate of basalt whose edge is a bold cliff. The plate is thinner on the lower bench, being less than ten feet thick where the road rises on it. Erosion has been active here, for at many places south from Ocaté Creek hills of basalt rise to the height of the higher bench, while the Wagon Mound, the Canadian Hills, and other outliers on the eastern side, together with hills near the Turkey Mountains north from Fort Union, show the great thickness of the plate which originally covered the whole of the mesa.

The sheet on the Canadian Hills is thinner at the east than at the west, and the hills appear to be somewhat higher at the former than at the latter extremity. The rock on these hills varies much in texture and color; one layer is dark bluish-black and very compact; another with a bluish tint has a fracture much like some of the trachytes; a third is dark-gray, very compact, and shows much olivine with a little sanidin; another is bluish-black, hard, and amygdaloid; while a fifth is cinder. The last seems to prevail on top of the hills, and there are little cones of it on the southern side. A dike-like ridge follows the central portion of the hills and is composed of steely-gray vesicular basalt which has some tendency to be slaty. On the northeastern side of the hills a gray slaty basalt with much olivine occurs near the top. The basalt cap of these hills rests on an alluvial deposit similar to that observed on the Raton Plateau, and bowlders of gneiss and quartzite are abundant at several exposures along the northern bluff of the hills, immediately underlying the lava.

The rock on the Ocaté Mesa is for the most part hard, bluish-gray, and contains much olivine. Dikes are very rare, and the only large one seen is that in the northern part of Ocaté Park. The basalt poured over the leveled mesas and into valleys such as those of the Ocaté and the Coyote, where it now remains as the floor of the basin or as an overflow wall. The only volcano observed here is that indicated as the Ocaté

Crater, which is on the east side of Ocaté Park and at but a little way south from the creek. It is a truncated cone with a slope of not far from 20°, which is well preserved except on the west side, where an overflow or breach has destroyed its symmetry, and on the south, where erosion has broken down the wall of the cup. The cone is naked of vegetation aside from scattered tufts of grass, and loose fragments of lava are strewn over the sides. The surface within the crater is covered with cinder, but the rock in the walls shows great differences in color and texture. In one series of specimens the color is dark-gray, almost black, and there are many large blotches of sanidin; in another, the color is bluish-gray and the sanidin occurs in smaller quantity; in a third, the rock is reddish-brown, scoriaceous, and contains zeolites; a fourth series shows dingy cinder with apparently the same minerals as those in the last; while in a fifth, the rock is steel-gray and compact, like that which prevails over the greater part of the Ocaté Mesa. From this volcano a stream flowed southward into the valley of Wolf Creek and continued to beyond the stage-road south from Fort Union. Traces of it still remain at several localities within the valley, which is hemmed in by high walls of Dakota sandstone.

It seems hardly probable that this volcano was the source of the enormous basalt flow which covered the Ocaté Mesa and filled the broad valleys of Ocaté and Coyote Creeks. But, as already stated, the basalt dikes are few and for the most part insignificant. The flow issued from a line passing not far from Ocaté Crater, as the dip of the basalt shows; so that in all probability this volcano was an important source.

Another extinct volcano was seen at the southern extremity of the Turkey Mountains. It is wholly separated from the Ocaté Mesa, and there is no evidence that the flow from the Ocaté Crater ever touched that from this crater of the Turkey Mountains. This crater is even better preserved than is the other, for the cone is complete and the rim of the cup is broken only by a narrow gap on the south side. The predominating rock is a hard steel-gray basalt, which rings like pot-metal when struck, but with it are other varieties similar to those found in the cañons of the Mora and Canadian Rivers.

The flow from this crater was almost wholly southward, and the lava-stream can be followed from the south side of the crater across the plains to Cherry Valley, where it entered the Mora Cañon. Thence down the cañon only fragments remain for several miles, but beyond that the mass is continuous. The thickness is 400 feet within a mile of the mouth of Mora Cañon, where a vertical measurement was obtained. This flow occurred at a time when the Mora Cañon, at its mouth, had been eroded to a depth of 860 feet below the top of its present walls. The basalt poured down, filling the chasm to the depth of 400 feet and backing up into the Canadian Cañon to a distance of three miles. Even now the mass is hardly affected in the side cañons where erosion has been slight, and it is shown handsomely in a group of arroyos at five or six miles from the Canadian Cañon. But in the main cañons the channel-way has been re-eroded and its bottom is now 230 feet below the base of the basalt. At the same time no appreciable effect has been produced on the surface of the basalt bench, which, for miles at a time, has been divided by the stream. The rock at the mouth of Mora Cañon is excessively hard and nearly all of the specimens have a pitchy look.

No basalt was seen in the mountain region south from Costilla Creek, aside from some utterly insignificant dikes which cut the trachyte and rhyolyte of Colorado Creek, and one broad dike which extends from Coyote Creek to Mora Creek, and thence through the Mora Range to Junta Creek. Some curious dikes were seen in the Archæan rocks on Cimarron Creek, but their relations to the trachytes could not be determined with certainty. One of them, at the lower edge of the Archæan exposure, is clearly spread out under the trachyte.

THE METAMORPHIC INFLUENCE OF THE ERUPTIVE ROCKS.

The effect of these eruptive rocks upon the adjacent beds is variable. Thus in Dillon's Cañon, at but a little way below the ranch, a sheet of basalt several feet thick has been intruded into sandstone, but along a distance of twenty feet no effect whatever has been produced on the latter at the line of contact; whereas at but a few yards farther the sandstone shows vapor-tubes. At a little way higher up the cañon the same sheet rests on a massive sandstone, which has been changed into a structureless quartzite to a distance of several feet from the contact.

A very positive metamorphism is shown on the east side of Old Baldy Mountain in the Cimarron Range, where the Colorado shales are broken by many dikes. The shales themselves have been converted into slate with distinct cleavage, while the sandy layers have been converted into quartzite or into an imperfect gneiss or granite, according to their grade of purity. Some of the sandstone beds, which must have been micaceous originally, have been so changed that they are now regarded by the miners as true granite.

Still, such changes are of rare occurrence. The Cerillos were thrust through the Colorado shales, but though the contact between those shales and the trachyte was examined at many localities, yet no distinct metamorphism was observed anywhere. No change was seen in the Cimarron Cañon, where the trachyte overflows and in some cases even envelopes the sandstone. So with the basalt sheets within the Laramie area, the extent of change is insignificant. But the instances are few in which eruptive rocks have come into contact with coal without producing a material change in its structure.

At but a little above the crossing of the Raton anticlinal by Raton Creek a sheet of basalt has been intruded immediately above the *Upper Reilly coal-bed*, which there is but two inches thick. The coal and the overlying shale have been thoroughly baked, and the former has been converted into a prismatic coke with occasional fragments of anthracite.

A fine illustration of this coking is shown on the Purgatory at a short distance above the mouth of Raton Creek, where the upper part of the *Trinidad coal-bed* is badly broken up by basalt. The interval between this upper division and the next bed above is twenty-four feet. The two beds of coal and the intervening shale are baked by basalt sheets and the coals are coked. The coke is dense, very like that made in Belgian ovens. The upper division of the *Trinidad bed* is split into layers three inches thick, separated by layers of basalt with like thickness. The coke is not prismatic, and no anthracite was observed at any place along the exposure, which continues for nearly two miles.

A sheet of basalt has baked carbonaceous shale near Olguines on the Purgatory, but it has not affected a coal-bed at two feet below it. A thick sheet of basalt rests directly on *Coal-bed* J, near the mouth of the South Fork of Purgatory, and has exerted no influence of any sort on it.

The *Dillon coal-bed* at three or four miles above the mouth of the Upper Canadian Cañon is badly distorted by strings and bunches of basalt, which have baked the clay partings and have converted the coal into prismatic coke. No anthracite occurs there. On the same hill the *Willow Creek coal-bed* is separated from a sheet of basalt by one foot of sandstone and is unaffected. But at the mouth of Cat's Claw Cañon the same bed is distinctly affected, for some of the coal is wholly changed, and the clay partings have been converted into slate. No anthracite was observed, but some fragments of *graphite* were obtained in *débris* from the bed. At four miles farther up the Canadian Cañon *Coal-bed* I has been hardened to some degree by a thin sheet of basalt immediately underlying it.

The small dikes of basalt seen in the Galisteo area exert no influence on the coal-beds through which they pass; but an enormous dike of trachyte, which passes in front of the Placer Mountains, has converted much of the coal into anthracite. The change extends to fully a mile from the dike.

CHAPTER XII.

SURFACE GEOLOGY.

SUPERFICIAL DEPOSITS.

The extent of Quaternary deposits in the area under consideration cannot be determined with any degree of certainty. The Santa Fé marls, if of the age assigned to them by Professor Cope, fix most of the superficial material as not later than the Pliocene. The châlky limestones of that group occur, filling cracks or fissures in the surface deposits of the Taos Basin, as well as at many other localities within the Rio Grande area; they occur frequently in the same manner on the Ocaté Mesa and on the plains between Las Vegas at the south and the Canadian Hills at the north. As already intimated, the writer has referred the conglomerates to the Quaternary with no little hesitation.

There are, however, some localities at which the deposit is certainly posterior to the Santa Fé marls. The thin coating of alluvium seen in the Taos Basin, that in the Culebra Park, and the silt covering the river "bottoms," must be regarded as Quaternary. Possibly, too, not a little of the material covering the Canadian Plains north from the Canadian Hills is Quaternary, for those plains in their present shape are much later than the basalt, which at one time doubtless overspread the greater part of the area. The material covering the plain is for the most part alluvial, and consists of silt mingled with water-worn pebbles or alternating with layers of such pebbles, while the surface is strewn at many localities with fragments of the basalt. A similar deposit covers much of the mesa region and is found also in the parks of the Laramie area. Along the streams, all of which are terraced, this alternation is distinct, and the terraces themselves bear a silt very like that seen on the plains. But at many places they have also a conglomerate cemented by carbonate of lime. A section made on Piños Creek, a tributary to the Pecos, is thoroughly characteristic, and with changes only in the thickness of the several members it can be duplicated on almost every stream. It is—

1. Soil	3 inches to 5 inches.
2. Stiff clay	3 feet to 6 feet.
3. Conglomerate	2 feet to 3 feet.
4. Bedded rocks, exp	5 feet.

At a little way below the spot where the measurement was made the soil is wanting, and No. 2 is ten feet thick, the conglomerate and bedded rocks having been cut away. The conglomerate occurs on the second terrace also. The cemented conglomerate is shown handsomely on the benches of the Purgatory, being found to a greater or less extent on each of the terraces near Olguines, and attaining a very considerable thickness on the main bench of the plain in the vicinity of Trinidad. It covers the mesas north from the Raton Plateau, and is probably continuous with the thick conglomerate seen alngside of San Isidro Creek far up toward Manco Burro Pass. A similar cemented conglomerate was seen on a terrace in the Lower Canadian Cañon at probably 600 feet below the crest of the cañon walls, and it occurs on many branches of the Canadian.

The stiff clay of the section is very dark gray, almost lead-colored. It is precisely similar to the material found nearly everywhere on the plains, in the parks, and in the high valleys between the mesas. It is tough, weathers slowly, and the shallow ravines made in it by streams flowing only during floods have almost vertical walls, while miniature cañons enter them from all sides. It is certainly newer than the conglomerate, for it rests on that rock. It may be as late as the glacial period, and possibly it may be in some degree the result of glacial action, as has been suggested; but there are localities in which it antedates the Santa Fé marls, for the chalky limestone rests on it. So much of it as covers the present river "bottoms" is doubtless comparatively recent in its present position. On Piños Creek, above Koslowski's station, some ashes were seen below this material, and resting on the conglomerate, which are said to have yielded human remains. The ashes are present in considerable quantity, though the space covered by them is only a few square yards.

GLACIERS.

The evidence of the former existence of glaciers in this region is indefinite. A dense forest covers the mountains to more than 11,000 feet above tide, and the prolonged action of water and frost has removed all traces of glacial action from the exposed spaces above the timber line. The only evidence is found in the form of excavations which exist near the crest of the mountain-ranges.

Above the altitude of 10,000 feet the Culebra and Taos Ranges are deeply carved, and the crest-line is a narrow blade with short knife-edge ridges projecting on both sides, which separate enormous cup-shaped excavations. These amphitheatres, whose bottoms are rudely benched, contract at the lower side and merge into broad boat-shaped troughs, which continue down the mountain side. The amphitheatre is sometimes absent and the trough begins directly under the crest. A small stream, fed by the slowly melting snows, flows along the middle line in a shallow V-shaped channel-way, and in some instances it has changed the form of the trough very materially.

These troughs are shown handsomely on both sides of the Culebra Range, where they come down almost to 10,000 feet above tide. Equally fine amphitheatres and troughs occur on and around Taos Peak, while the excavations in the Santa Fé Range as far south as Santa Fé are such as to suggest that possibly glaciers had been at work in that range also.

No well-defined moraines were recognized on the east side of the Culebra Range within the Purgatory or Canadian areas, though a vast accumulation of *débris* was found on the South Fork of Purgatory, near the Dakota Stonewall, at more than 200 feet above the stream. A great mass of *débris* covers the pass between Vermejo and Costilla Creeks and bears not a little resemblance to moraine. It is at 10,150 feet above tide, its surface is covered by irregular hummocks and shows numerous rudely cup-shaped shallow depressions, many of which hold little ponds of water. But there are distinct moraines on the east side of the Culebra axis at the headwaters of Costilla Creek, near north latitude 37°. These line the eastern side of Costilla Park and close the mouths of troughs which extend back almost to the crest-line of the range. The features here shown resemble in all respects those observed on the east side of the Sangre de Cristo Mountains in the Wet Mountain Valley of Southern Colorado.

No moraines or anything resembling them were seen farther south along the east side of the mountain area; nor were any recognized satisfactorily at any locality on the west side of that area. But on this side is the interesting conglomerate whose relation to the boat-shaped troughs is so intimate that I am led to describe it in this connection.

THE CONGLOMERATE.

The foothills along the west side of the Culebra Range are covered with a conglomerate, cemented by material which is so easily removed that to a considerable depth the rock is merely *débris*. This accumulation reaches far up from the plains along Sangre de Cristo Creek; has its eastern edge at fully two miles above the forks of Trinchera Creek; extends to the close cañons of the forks of Culebra Creek, and has its upper edge almost on a level with the floor of a huge trough-like excavation near Culebra Peak; but the width of its area decreases southward from that peak until the conglomerate disappears near Costilla Creek. The Culebra Park has been digged out of this mass.

But the conglomerate reappears south from Costilla Creek on the west side of the Taos Range; though there it is loose. It was not seen compacted at any locality between Costilla and Colorado Creeks. Beyond the latter stream it forms a long sloping bench extending from the foot of the mountains to the Rio Grande, and is persistent thence to the Taos Basin, though for short distances it has been wholly eroded. Fine exposures occur in the hills surrounding the Taos Basin as well as on Frijole Creek and over the divide to and beyond Junta Creek.

Though removed from the broad recess in which Fort Garland is situated, the conglomerate remains on the basalt mesa directly east from the fort. It is well preserved along Sangre de Cristo Creek, where it has been carved into fine terraces. Low hills covered by this deposit were seen on Trinchera Creek immediately behind that basalt mesa, but erosion has been so energetic that the conglomerate does not appear in mass until at nearly two miles farther east, where those hills begin, which continue almost without interruption to Costilla Creek. The rock has a brownish-yellow color, and a straggling growth of piñon and cedar is scattered over the hills, which in some cases rise to fully 10,600 feet above tide, giving an apparent thickness of 1,600 feet to the conglomerate. But the real thickness is from five to five hundred feet, and crags of basalt frequently jut through the conglomerate. The fragments in this rock are invariably water-worn and belong to Archæan and Eruptive rocks.

The conglomerate is well shown on the west slope of the Taos Range, where, between Costilla and Colorado Creeks, it reaches to fully 900 feet above the plain. As far as observed, it is uncemented here; at least the loose material is very thick and no exposure of compact rock was found. In all characters except that of compactness, this is similar to the conglomerate seen on the Culebra Range. The mass extends for some distance up Colorado Creek, where the fragments of Eruptive rock predominate. No detailed examinations were made between Colorado Creek and the Taos Basin, but the conglomerate was seen immediately south from the former creek, where it is cemented and forms a long sloping terrace from the base of the mountains almost to the Rio Grande.

Good exposures occur around the Taos Basin and along the several streams which go to form Taos Creek. The hills on the south and southwest sides of the basin are covered by the brownish-yellow gravels and conglomerate, which are occasionally exposed along Ferdinand Creek below its forks; but the exposures on that creek are not detailed until within a very little distance below its forks, at about ten miles from Taos. There the hills are rounded, and fragments belonging to the conglomerate occur in vast numbers on their slopes. A great mass of the conglomerate caps these hills, which continue southward and occupy much of the broken area along the west side of the Mora Range. A fine exhibition was observed on the North Fork of Ferdinand Creek, where the fragments have been derived wholly from eruptive rocks and represent every type of those rocks to be found within the district. The material varies in coarseness, so that for a considerable vertical distance there are alternating fine and coarse layers, the latter containing bowlders of trachyte, which in some instances weigh several tons. The exposures are less satisfactory on the Middle Fork, which heads near Taos Pass, for there the rock is seldom cemented and the disintegrated material is evidently very thick. But here it consists mostly of Archæan pebbles mingled with fragments derived from the carboniferous rocks. The palæozoic pebbles increase in number toward the pass, and in the same direction the Archæan pebbles become fewer. Good exposures occur on the South Fork, where the rock is compact as on the North Fork. The color is grayish and the weathered surface is rounded. Huge fragments of trachyte, quartzite, and sandstone are embedded in the finer material, which seems to have been derived chiefly from eruptive rocks.

The conglomerate has a distinct eastward dip on both the North and the South Fork, wherever the bedding is distinctly shown,—a condition which renders very doubtful the propriety of referring the rock to the glacial period. The top of the mass on the North Fork is higher than the summit of Taos Pass.

In ascending Frijole Creek, which enters the Taos Basin from the south, one finds low terrace-like hills rising eastward from the creek toward the mountains and covered by the conglomerate, which evidently extends for miles in that direction, though not so indicated on the map, as no opportunity was afforded for following it to its eastern edge. It rises high up on the eastern slope of the U. S. Mountain and continues along the road leading to Junta Creek until the divide is reached. The upper limit is not far from 9,000 feet above tide. The same mass occurs on Junta Creek.

Along Frijole Creek and the road leading thence to Junta Creek the local origin of the conglomerate is sufficiently well shown. Between Taos Basin and Old Camp Burgwin there is a mingling of Archæan, palæozoic, and igneous fragments, embedded in coarse sand; but above that old camp palæozoic fragments become less numerous, and before the summit has been reached none but Archæan bowlders occur. The tributaries to Frijole from the east rise in the Mora Range and cut through the there insignificant Santa Fé axis; but the road runs for some distance near the summit on the Archæan of that axis.

These pebbles are numerous all the way to the bluff immediately overlooking Junta Creek. On approaching that creek the road follows a gap cut down in a thick plate of basalt and paved with loose water-worn bowlders, the finer material of the conglomerate having been removed. The pebbles are shown in the bluff, 700 feet above the creek at Real Pueblo. For somewhat more than 100 feet above the stream the rock is fine-grained, very compact, and has narrow streaks of chalcedony. It is somewhat vesicular in some places and seems to have been derived in great measure from eruptive rocks. It lines both sides of the valley up to the mouth of the deep cañon through the Santa Fé axis; but no traces of it were seen in the cañon or on the east side of the axis.

No examinations were made along the west side of the Santa Fé axis between Junta Creek and Santa Fé, but the conglomerate is reported by other observers to be present in that interval. It was not seen south from Santa Fé, and it does not occur anywhere east from the crest of the mountains facing the Rio Grande Plain except in the region drained by Frijole Creek, where, however, the Santa Fé Range is insignificant and has little influence on the topography. The rock appears to be absent from the Pecos synclinal at all localities south from the headwaters of Frijole Creek.

Some features of this conglomerate suggest that it may have been a lake deposit. The observations made by the writer are insufficient to determine this matter. It is possible that a barrier reaching to 10,600 feet above the sea existed at one time across the Rio Grande Valley not far from the mouth of Colorado Creek, and that it has been removed by erosion since the formation of the conglomerate. But in the absence of detailed observations along the east side of the Rio Grande Valley from the latitude of Taos Creek, and on both sides of the valley south from the latitude of that stream, any positive assertion respecting the origin of this conglomerate would be without sufficient basis to render it worthy of consideration.

ALLUVIAL AREAS WITHIN THE MOUNTAIN REGION.

Alluvium covers a narrow irregular area extending from Cucharas Pass southward to the extreme limits of the district.

Beginning near Cucharas Pass, the alluvium covers the Stonewall Valley, is continuous across Costilla Pass to the broad park on Costilla Creek, across the pass between Bare Cone and Costilla Peak to a park on Comanche Creek, which is connected at the north with the park on Costilla Creek; from the park on Comanche Creek it continues over Moreno Pass and along the whole of the Moreno Valley to the head of Cieneguilla Creek; it covers the divide between that stream and Coyote Creek, is the surface deposit in the Coyote Valley above the cañon, and covers a terrace alongside of the cañon far above the bed of the creek. This terrace was traced to within three or four miles of Coyote, but the area practically ends with the cañon of Coyote Creek at about four miles above Guadalupita.

Another open area at a lower altitude than the one just considered, but connected with it by the cañon of Coyote Creek, begins at the mouth of that cañon and is continuous thence to Gallinas Creek where it passes out to the plains. It is connected with parks on Mora, Cebolla, and Manuelitos Creeks by broad swales stretching from Chupadero to Santo Niño; while gaps through the Lower Dakota Stonewall connect it with the Coyote Park, which extends southward across Mora Creek almost to the Cebolla.

This whole space from Cucharas Pass at the north to Gallinas Creek at the south is covered with alluvium holding water-worn stones and composed chiefly of fine silt very similar to that observed on the plains. It crosses the divide between the Arkansas and the Rio Grande by Moreno and Costilla Passes, and is joined to the plains by the broad "bottoms" of the larger streams.

Let us now look at it in detail.

The altitude of Cucharas Pass is 9,994 feet. The deposit near its summit seems to be due more to eolian disintegration than to wear and distribution by water; and rocks evidently worn by flowing water are seen first where the road crosses the most northerly branch of North Fork of Purgatory. Thence southward to Spring Valley farm the broad valley is covered by a thick coat of pebbles and fine silt. The Laramie bluffs bound the valley at the east and the Stonewall at the west. The altitude of the eastern wall at many places does not exceed 8,500 feet, but only a part of the original bluff remains, for barely one-third of the Laramie column is shown; its height, when the erosion began, could not have been less than that of Cucharas Pass.

Crossing the North Fork, one rises by five handsome terraces to the summit between that and the Middle Fork of the Purgatory; and a similar series is shown in descending from that summit to the Middle Fork. Rolled and polished stones of varying size are abundant on all of the terraces, and the alluvial coating is so thick as to conceal all of the older rocks except where a dike stands above the surface or where a fault has brought up a wall of the Dakota sandstone.

A subordinate valley lying behind the Stonewall extends from near Cucharas Pass almost to the South Fork of the Purgatory. Its features conform closely to those of the main valley, and narrow gorges through the Stonewall afford outlet for its waters.

The surface gradually rises beyond the Middle Fork toward the South Fork and at length becomes a terrace of the latter stream. Everywhere it shows pebbles varying in size from one inch to two feet, all of them water-worn; but no cemented conglomerate was found anywhere. This part of the park is ill-drained, and has two ponds fed by alkaline springs which issue from the Colorado shales.

The valley becomes a wide park on the South Fork, and a broad open area is followed by the creek southeastward for somewhat more than four miles. But this extension ends quickly, as the stream, making an angle of nearly 110°, bends sharply toward the northeast. This arm, designated in the preceding pages as the San Francisco Park, has been eroded in

Colorado shales brought up by the Vermejo anticlinal, and the broad space connecting it with the Stonewall Valley is due only to the proximity of the anticlinal. Farther south under the same axis is the Vermejo Park, which, however, is joined to the Stonewall Valley only by a narrow cañon, as the Culebra and Vermejo axes diverge southward. Fine terraces were seen in San Francisco Park as well as in Vermejo Park. They remain as low mesas in the latter and are covered with conglomerate which in many instances is cemented; but those in the San Francisco Park have not the cemented conglomerate. The main valley has an irregular outline on the South Fork, owing to a fault in the Stonewall, to which reference has been made in a preceding chapter. The alluvium reaches westward to a mile farther than it does at localities on the other forks, and very positive terraces are shown along the creek below the Stonewall.

The valley becomes narrower toward the Vermejo, and its surface rises until, at the divide between the Purgatory and the Vermejo, the altitude is 9,173 feet, while the Laramie bluff on the east side rises to fully 600 feet higher. Water-worn fragments are thickly strewn over the surface to and beyond this divide. Crossing that, one reaches the broken area drained by the Vermejo, in which the Stonewall is clearly faulted more than once and dikes stand out in all directions. But between the many walls flow the streams which unite to make Vermejo Creek; and along these are broad swales, all joining to make a broad, somewhat uneven valley, followed by the road descending from Costilla Pass. Terraces occur between all the streams, and the low hills are truncated pyramids, their summits being remnants of a terrace. This condition continues along the valley to where it, so to speak, points out on the almost imperceptible divide between Leandro and Rock Creeks, in the saddle between Bare Cone and Costilla Peak. Leandro Creek flows mostly along its eastern side, and is separated by a gravel-covered terrace from a low ill-drained strip following the base of the Stonewall and holding many alkaline ponds.

A road leads from Vermejo to Costilla Creek by way of Costilla Pass, whose summit is 10,147 feet above tide. Following this road one finds rolled stones strewn abundantly over the surface all the way. On the divide they vary from one inch to two or even three feet in diameter, and are made of granite, gneiss, quartzite, or trachyte. The coating of *débris* in the pass and on its eastern approaches is very thick, and for a long distance on the Vermejo side it is hummocky, with oval hollows containing little ponds of water which cannot be drained. This enormous deposit bears no little resemblance to a moraine and its relations are somewhat obscure.

Descending the west side of the pass, one comes to a park which extends for several miles along Costilla Creek. It is double, the main division, into which the road descends, being separated from a smaller and narrower division by a short cañon. The smaller park was not visited, but as examined from a distance it shows the same features as the other, except that terraces line its sides and no terraced hills occur along its middle line. The creek is formed about midway in the lower park by branches flowing at the sides of a hill which shows five terraces, the upper two being twenty feet apart. Similar and equivalent terraces line the sides of the park. They all slope in the direction of the creek's flow, but not so rapidly as does the stream, the lowest one being fully 100 feet above the creek at the gap closing the park below. The channel-way at this gap has been cut down solely by corrasion, and the lower terraces there are very narrow; but the higher ones are continuous beyond to the mouth of Comanche Creek, while the lower benches below the gap do not correspond with those of the park above. These terraces in all cases show a decided slope toward the stream as well as in the direction of its flow. A higher terrace than any of those referred to is shown on the hillsides and merges into the moraines on the west side of the park. The alluvial deposit is very thick everywhere, and it continues along the narrower valley below to the mouth of Comanche Creek, as well as along the valley of that creek to the wide Comanche Park.

Comanche Park begins at barely two miles above the mouth of the creek. Its surface is so irregular that one might not suspect its presence if he merely consult the map. Long tapering terraces which jut out from the mountains at the west bear a dense growth of timber and are broken by the channel-ways of many insignificant streams. But the eastern side is open and a broad swale stretches toward Costilla Peak, passes over the ridge immediately south from that peak, and, first crossing the head of South Poñil Creek, joins the marshy park in which Rock Creek has its sources. An almost imperceptible divide separates the latter creek from Leandro Creek. The terraces on the west side of Comanche Park, as well as the open space immediately east from the creek and the swale leading toward Costilla Peak, are covered with alluvium holding water-worn fragments of rocks belonging to the neighborhood.

Moreno Pass, at the summit of the divide between Moreno and Comanche Creeks, is a broad depression at 9,770 feet above tide, and is covered with ill-drained alluvium in which water-worn pebbles are plentifully distributed. From the head of the North Fork of Moreno Creek, which rises in the pass, to its junction with the other forks, the stream flows in a narrow cañon; but at from 100 to 600 feet above it is a bench, extending for fully a mile and a half toward the west, which carries a thick coat of alluvium loaded with water-worn fragments. The depth of this deposit could not be ascertained. The bench breaks down abruptly not far above the Forks of Moreno Creek, but the alluvium covers the mountain at the east side of the valley to the top of Poñil Pass, where the altitude differs by but a few feet from that of Moreno Pass, being 9,750 feet. The alluvium could not be traced on the west side toward Red River Pass, which also is very nearly of the same height with Moreno Pass, being 9,764 feet. These three passes are much alike, being broad open spaces with higher elevations on each side at a considerable distance from the line of travel.

Moreno Valley really begins at Moreno Pass, but the topographical valley begins at a little way above the Forks of Moreno Creek and continues southward to the summit between Cieneguilla and Coyote Creeks, where it merges into Coyote Valley. Some dikes crossing immediately below Elizabethtown divide the Moreno Valley into two parks, which are connected by two passages; through one Moreno Creek flows, while the other, with greater elevation, lies behind the hill below Elizabethtown. The length of the former is about a mile and a half. The upper limit of alluvial deposit follows the eastern wall from Moreno to Poñil Pass, at no time more than a mile away from the cañon of the creek, while on the western wall it is continuous from the pass to the west fork of the creek, diverging all the way until its western edge is nearly two miles away from the north fork. On the east side the upper line follows the side of Old Baldy and maintains its altitude until beyond the gorge, beyond which to Cimarron Creek it descends, so that at the cañon it is probably 400 feet lower than at Poñil Pass. Thence to the head of Cieneguilla Creek it rises. On the west side its upper limit south from the west fork is indefinite. Much of the deposit has been removed by erosion, and as the exposure is toward the north of east, timber encroaches upon it. Traces remain, however, which show that the deposit reaches the altitude of Taos Pass, or 9,095 feet. Thence to the head of Cieneguilla Creek the deposit is poorly shown on the west side and the timber comes down into the valley.

Terraces are distinct in both divisions of the valley, but they are broken now by broad grassy swales in which secondary terraces are commonly present. The thickness of the deposit varies, being not less than sixty feet at some localities north from Elizabethtown, but becoming insignificant in the gaps, where dikes project and erosion has been energetic. The maximum thickness is found in the central part of the valley from the Elizabethtown gorge to nearly two miles south from the Cimarron Cañon; but along the sides, and especially southward toward the head of Cieneguilla Creek, many small exposures of Archæan and Dakota rocks were observed. On the east side and in the bottom of the valley this alluvium is covered with bunch-grass, and timber encroaches on it very slowly.

A similar condition prevails on Coyote Creek, though rock exposures occur more frequently there than in the Moreno Valley, for the Carboniferous beds are turned up sharply and project in walls above the alluvium. The surface in this park falls gradually to the basin holding Black Lake, and many fragments of terraces remain. The mesa at the east has its bluff at from half a mile to two miles from the creek, and a broken slope, covered with alluvium in which pebbles occasionally occur, stretches thence to the stream. The immediate basin of Black Lake shows no terraces, but the surface rises from the lake to a fine bench, which is continuous southward along the side of the Coyote Cañon to beyond its mouth. Many small rock basins were seen in the Black Lake area, but that which holds the lake is the only one with an outlet.

BASINS ON THE RATON HILLS.

Rock, Van Bremmer, and Poñil Parks on the Raton Hills south from Vermejo Creek are intimately related to the Stonewall Valley, and have close resemblance to the rock-basins or pot-holes so common on mesas covered with basalt or hard sandstone; the only material difference is in size.

Rock Park is immediately east from the marshy basin under the stonewall in which Rock Creek has its source. It is crossed by that stream and is separated from the Stonewall Valley by a broad regular bench covered with alluvium, which is crowded with water-worn fragments, and bears a dense growth of timber. The basin is rudely terraced, but much of it marshy, and is lower than Rock Creek itself—a feature observed also in the Stonewall Valley above the head of Leandro Cañon. For the most part the alluvial deposit is fine silt, such as is found on the plains, but rolled and polished fragments are scattered irregularly through it, most of them belonging to the Bare Cone dike, though Archæan, Carboniferous, and Cretaceous rocks are well represented.

A low ridge, much lower than the bench between Rock and Leandro Creeks, is the divide between Rock and Van Bremmer Parks, and is covered with a thin deposit similar to that in the former basin.

Van Bremmer Park is wholly undrained, unless there be a subterranean outlet for its waters. It is surrounded by hills except toward Rock Park and the Van Bremmer Cañon; but the divide from the former is far above the great body of the basin and much below the rim at the east and southeast side, which is approximately on the same level as the bench between Rock Park and the Stonewall Valley. The rim of the basin seems to be rock everywhere, and no evidence that any old break exists could be discovered. The only outlet must have been by way of

Rock Park, and in that direction only when the basins were full of water, reaching to the height of the Leandro bench. The park is truly basin-shaped, though the outline of the western side is somewhat irregular. The surface declines all the way to the base of the foot-hills and is covered everywhere by fine silt, in which pebbles are plentifully distributed. Nine lakelets were seen, varying in size from an acre to one-fourth of an acre, all of which are said to be alkaline, though in some the quantity of salts is comparatively small.

Poñil Park is at a little distance south from Van Bremmer, and, as far as could be ascertained, is in no wise related to it. This park is double, the parts being associated much as are Rock and Van Bremmer Parks. The northern part is drained by Poñil Creek, but the southern part is undrained and contains numerous lakelets.

THE LOWER SERIES OF PARKS.

This series is connected with the other by the "bottom" of Coyote Cañon, but the well-defined terrace following the walls of the cañon and traceable for several miles below its mouth evidently was the bed of a stream which at an early day joined the two series when the lower one had not been cut down to its present grade.

Below the mouth of Coyote Cañon there begins a wide park, which continues for seven miles and is divided longitudinally by a line of low irregular hills. The eastern division follows the Lower Dakota stonewall and is a narrow valley crossing the divides as far south as Gallinas Creek, where it breaks through the wall and is lost in the great plain. By gaps in the stonewall at Coyote, between Coyote and La Cueva and at La Cueva, it communicates with Coyote Park, which again merges into this valley by a long narrow gap leading from La Cueva to Cebolla Creek, in front of the stonewall. The western division, evidently the channel-way of Coyote Creek before the basalt overflow, is continuous by wide swales with parks on Mora, Cebolla, and Manuelitos Creeks, which in turn communicate with the other division by means of park-like cañons, through which those streams flow.

Terraces are distinct in all the parks of this lower series except on

Mora Creek, where later erosion has worn the park down to a plain sloping from each side toward the creek. The coating is alluvial throughout.

All the features lead to the belief that at one time a chain of lakes, practically continuous, extended from Cucharas Pass at the north to the Upper Coyote Park at the south, communicating by means of depressions at Costilla and Moreno Passes, as well as at Costilla Peak and at the head of Coyote Creek; and that while the lakes existed in communication, the cañons by which the basins are now connected with the plains had not been eroded.

The cañons were not eroded deeply enough to drain the water from any of the basins until long after the basalt outflow, for in all the cañons sheets or dikes of basalt have been worn away. It is not altogether impossible that these may have been fed by glaciers.

TIME OF EROSION.

As the Cimarron Range was formed at the close of the Cretaceous, erosion must have been at work with great energy during the Eocene, for the Archæan crest was reduced to a plateau prior to the trachyte overflow which covered the range from Old Baldy southward to Rayado Creek; the line of contact between Archæan and trachyte is almost straight for a distance of several miles.

The Ocaté Mesa was formed at a later date than the plateau on the Cimarron Range, for south from Rayado Cañon the trachyte dikes are covered by basalt which has overspread that mesa. During this erosion the Cimarron anticlinal between Rayado and Coyote Creeks was reduced to a plain, and the synclinal east from it, as is well shown on Ocaté Creek, was leveled. Possibly the mesa of the Raton, now covered by a thick plate of basalt, was formed at the same time, though in the absence of trachyte dikes its age cannot be defined so clearly. A thick deposit of alluvium crowded with bowlders of Archæan rocks, evidently transported from the mountains at the west, underlies the basalt on this mesa; and a similar deposit occurs under the basalt of the Canadian Hills, which are outliers of the Ocaté Mesa; so that the two mesas may have originated at the same time. The surface in each case slopes toward the west and bears no relation to the dip of the bedded rocks.

But these mesas themselves had suffered very materially from erosion before the basalt overflow. The deep cañons of Coyote and Chicorico Creeks had been formed; the Canadian Plains between the Eagle-Tail Mesa and the Laramie area had been cut down to very near their present form, for at many localities in the cañons and on the plain great masses of the basalt still remain. That the cañons of the Mora and Canadian Rivers had been deeply cut down before the basalt outpouring is abundantly clear, since at the mouth of Mora Cañon the basalt sheet, which is very nearly 400 feet thick, rests on rocks 860 feet below the top of the present walls; while the Colorado shales had been removed from the greater part of the plain between the Mora Cañon and the Canadian Hills, and only insignificant areas remained as mesas; for the basalt streams from the Turkey Mountain Crater rest on Dakota sandstone all the way between the crater and the Mora Cañon.

It is altogether probable that at the beginning of the Pliocene the surface of the Canadian Plain was little different from what it is now.

During the early Pliocene the basalts were poured out, covering the mesas, flowing down to the plains and filling the cañons, so that the aspect of the region was wholly changed. The erosion since that time has been little less extensive than that performed during the Eocene and Miocene, though it has been confined very largely to the re-opening of the old channel-ways. But the basalt plate has been removed from the plains bordering on the Upper Canadian.

The cañons in the mountain area were closed by basalts, or else they had been eroded previously to but a shallow depth; for in all of the cañons through the Laramie area sheets of basalt have been cut, while in the great cañons of Costilla, Colorado, and Cimarron Creeks dikes of basalt are shown in both walls. The cañon of Coyote Creek has been re-eroded to a depth of five or six hundred feet directly in basalt, and that rock has been removed from the park on the same creek below Guadalupita, though the creek, being dispossessed by the flow, chose another channel-way somewhat farther toward the east.

One of the finest illustrations of this re-erosion of channel-ways is shown in the cañons of the Mora and Canadian Rivers. The corrasive power of the Mora River has worn a new channel-way through the basalt and to a depth of 230 feet below the bottom of that sheet. The result has been due wholly to the corrasive power of the stream, for the top of the basalt bench shows little wear from erosion. The plains in the vicinity of the cañons have suffered little from erosion since the basalt flow. The full thickness of the Upper Dakota sandstone is exposed in the cañon walls, and the basalt, which backed into the side cañons of the Mora, has still a regular surface as though no stream had ever flowed through those cañons. This condition is beautifully shown in a group of arroyos entering the cañon from the north at but a few miles above its mouth.

The character and extent of the erosion gives some conception of the length of time which has elapsed since the date of the trachyte overflow. The great mesas were leveled by excessively slow wear in a climate which must have been comparatively dry.

U. S. GEOGRAPHICAL SURVEYS WEST OF THE ONE HUNDREDTH MERIDIAN.

CAPTAIN GEO. M. WHEELER, CORPS OF ENGINEERS, U. S. ARMY, IN CHARGE.

PART III.

DESCRIPTIVE GEOLOGY,

BY

PROF. JOHN J. STEVENSON.

CHAPTER XIII.

THE AREA OF THE PURGATORY RIVER.

CHICOSO CREEK AND THE PLAINS; NORTH SIDE OF THE RATON PLATEAU; RATON CREEK; PURGATORY CAÑON BELOW REILLY'S CAÑON; REILLY'S CAÑON; LONG'S CAÑON; PURGATORY CAÑON BETWEEN REILLY'S CAÑON AND THE SOUTH FORK; SOUTH FORK OF PURGATORY; UPPER PART OF PURGATORY CAÑON; MOUNTAIN REGION.

Purgatory River is formed by streams rising in the Culebra Range, and flows eastward through the Lignitic region and the plains to beyond the limit of our map. The plains north from the Raton Plateau are covered with Tertiary and Quaternary materials resting on shales of the Middle Cretaceous or Colorado group, while here and there are low hills or mesas of the latter rocks.

CHICOSO CREEK AND THE PLAINS.

Chicoso Creek enters the Purgatory from the north near El Moro and drains a considerable part of the Laramie area near the northern edge of the map; but no satisfactory sections could be obtained on it or on any of its numerous tributaries. The long gap, known as the Cañon De Agua, along which the road to Simpson's mill passes, affords no exposures whatever until near its head, where *Coal-bed* X is exposed by its blossom, which seems to indicate a thickness of not far from one foot. It is buried in black shale, and the thick sandstone below it contains a thin sheet of basalt. The great sandstone, which in this region forms the summit of the Laramie group, is reached on top of the mesa, where it remains the immediately underlying rock until the surface falls off toward Apishpa Creek.

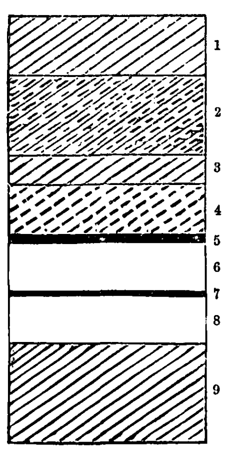
The *Halymenites sandstone* is well exposed in the bluff at the mouth of this cañon, where it rests on shales of Cretaceous No. 4, containing the characteristic septaria and fossiliferous concretions. Fragments of *Inocerami* and *Heteroceras* were obtained from the *débris* on the plains, and Mr. Russell collected specimens of *Inocerami*, *Baculites*, *Scaphites*, and

Ammonites from the septaria themselves. Some low mesas of Colorado shale were seen on the plain beyond the creek.

The bluff facing the plains shows no change from the northern line of the map to the mouth of the Purgatory Cañon; the *Halymenites sandstone* is a conspicuous band on its face, while higher up on the bluff the blossoms of the *Dillon* and *Trinidad coal-beds* are occasionally shown. Low bluffs along the streams frequently give short exposures of the Colorado shales, from some of which fossils were obtained.

THE NORTHERN SIDE OF THE RATON PLATEAU.

Only rocks of the Colorado group are exposed in the slope of the plateau and in the plains east from San Isidro Creek. This creek rises in Manco Burro Pass and flows northward to the Purgatory. The following section of the lower portion of the Laramie group was obtained near the pass:



	Feet.	Inches.
1. Sandstone	30	0
2. Shale and sandstone	40	0
3. Sandstone	15	0
4. Shale	25	0
5. *Trinidad coal-bed* (B)	3	6
6. Concealed	25	0
7. *Dillon coal-bed* (A)	1	0
8. Concealed	25	0
9. *Halymenites sandstone*	50	0
Total	214	6

The sandstones, except No. 9, are bright yellowish-gray, weather with a honeycombed surface, and are very soft. No. 1 contains multitudes of weather-beaten tree-trunks, shows vertical borings like *Scolithus*, and occasional obscure impressions somewhat resembling *Halymenites major*.

The *Trinidad coal-bed* is no longer exposed, but it was worked many years ago by the Mexicans, and the thickness is given according to report. The coal is said to be good, and fragments, plentifully scattered on the old dump, support the statement. The *Dillon coal-bed* is poorly exposed and the thickness is probably greater than the imperfect exposure suggests.

The *Halymenites sandstone* varies from soft, massive, and bright yellow to hard, flaggy, and dull rusty yellow; but throughout it shows numerous impressions of *Halymenites major*.

The edge of the basalt sheet, which covers the plateau and is broken only by Manco Burro Pass, is reached at about two hundred feet above the top of the section. The interval is imperfectly exposed, nothing being shown aside from some massive yellow sandstones.

The *Lower Reilly coal-bed* (D) is in the road at the summit of the pass, where it seems to be barely one foot thick; but the exposure is not altogether definite. Many water-worn fragments of gneiss and quartzite were seen at the same place within a few feet of the basalt.

In descending San Isidro Creek from the pass one at first sees on each side only the steel-gray, somewhat vesicular basalt resting on the Laramie rocks, but he soon falls into the cañon of the creek, where only the very dark-brown shales of Cretaceous No. 4 are shown. Calcareous concretions prevail in the higher parts of this sub-group, but at a little distance lower ferruginous concretions alone occur and are so abundant that they can be mined at comparatively slight expense. Fossil remains are rare in the ferruginous, though by no means so in the calcareous nodules. Bands of yellow, slightly calcareous sandy shale, containing *Scaphites* and *Ammonites*, are shown somewhat farther down the cañon, and the drab and dull-brown shales of the same sub-group are reached before the cañon opens out upon the plains. Long terrace-like mesas, with crests sloping toward the Purgatory, stretch out from the base of the mountain, giving occasional exposures of the Colorado shales covered by the Quaternary conglomerate. The same conglomerate was frequently seen along San Isidro Creek, where it was deposited somewhat irregularly, the shale having been cut away before the conglomerate was formed.

The north face of the Raton Plateau from San Isidro Creek almost to Raton Creek affords occasional exposures of the Laramie and Colorado groups, but Quaternary deposits reach well up the slope and conceal the earlier rocks. The Colorado shales extend in terraces far out on the plain toward the Purgatory, and on the road from El Moro to La Barela the ferruginous concretions are well exposed for several miles. The nodules occur in vast numbers and mining by "stripping" would be inexpensive.

Exposures along this line are so poor that the Raton anticlinal could not be found; but that axis is by no means so abrupt here as on the road leading to Raton Pass, for the northwest dip prevails. The Laramie rocks descend from San Isidro Creek so that, before the waters of Raton Creek are reached, the *Halymenites sandstone* is at but a short distance above the road. The upper 250 feet of the Colorado group is shown at several places. A coal-bed has been opened near the sharp curve in the Denver and Rio Grande Railroad leading to the coal mines of the company, but its relations were not satisfactorily determined. It may be the *Trinidad bed.*

A small stream, rising near Fisher's Peak, enters the Purgatory from the east at one mile from Trinidad. The *Trinidad coal-bed* is shown in part on its western branch, and the *Dillon coal-bed's* blossom is exposed at a little way below. The former bed is mined on the other branch by the Denver and Rio Grande Railway Company, at whose mine the following section was obtained:

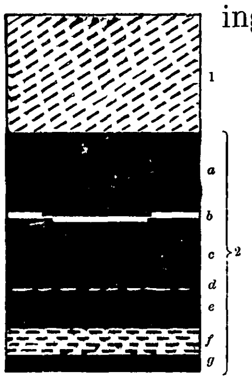


FIG. 13.—*Denver and Rio Grande Railway Company's mine.*

1. Shale		6 feet.
2. *Trinidad coal-bed*		11 feet 7 inches.
a. Coal	4 feet.	
b. Bony *coal*	4 inches to 5 inches.	
c. Coal	3 feet 4 inches.	
d. Parting		
e. Coal	2 feet 1 inch.	
f. Clay	1 foot 4 inches.	
g. Coal	4 inches to 10 inches.	

A thin streak of *coal* occurs just above the shale, and is shown in a small shaft sunk very near the mouth of the main drift. A trial opening was made in the *Dillon coal-bed* at a little way from this mine, but it had fallen in and the thickness of the bed could not be ascertained. The coal obtained here is very good, and it is shipped in large quantities to places along the railroad both for fuel and for the manufacture of illuminating gas. The slack is coked in bee-hive ovens, and the coke, though burned for only twenty-four hours, is so good that it finds a ready market in the smelting regions of Utah and Colorado. The loss in coking is said to be only two-fifths, but this seems to be hardly possible, unless the process be incomplete, for Dr. Loew's analysis showed fifty per cent. of volatile combustible matter in the coal.

The *Halymenites sandstone,* which is well exposed on this stream, passes downward into brown shaly sandstone, containing many casts of irregular fucoids; while this in its turn passes almost imperceptibly into the dark shales of Cretaceous No. 4. These form the banks of the stream thence to its mouth, but the only fossils observed in the concretions were fragments of huge *Inocerami.*

A dry channel-way reaches the river road just above Trinidad and extends thence up the mountain to Fisher's Peak, an isolated fragment of the igneous cap, which there shows a precipitous bluff and is not less than 500 feet thick. The following section was obtained in this ravine:

	Feet.	Inches.
1. Sandstone	30	0
2. Concealed	225	0
3. Sandstone	44	0
4. Concealed	330	0
5. Sandstone	22	0
6. *Coal-bed* I	Blossom.	
7. Concealed	235	0
8. Sandstone not fully exposed	135	0
9. Concealed	45	0
10. Sandstone and shale	45	0
11. *Willow Creek coal-bed* (C)	2	6
12. Concealed	5	0
13. Sandstone	33	0
14. Concealed	10	0
15. Sandstone	22	0
16. Shale	6	0
17. *Trinidad coal-bed* (B)	16	10
18. Concealed	33	0
19. *Dillon coal-bed* (A)	16	6
20. Concealed	8	0
21. Sandstone	3	0
22. *Coal-bed*	1	0
23. Concealed	6	0
24. *Halymenites sandstone*	0	0
Total	1,273	10

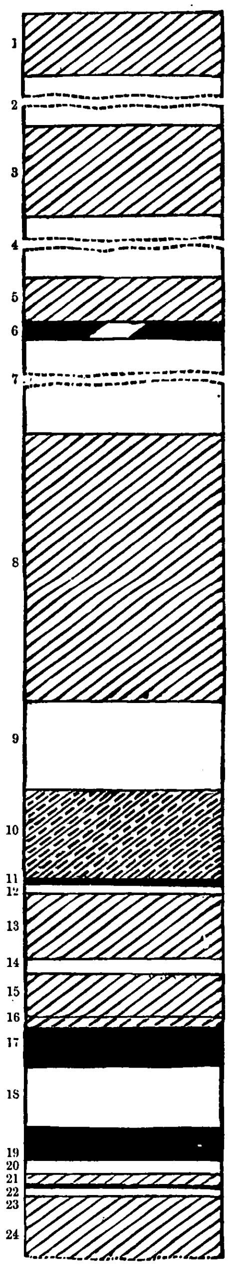


FIG. 14.—*Near Trinidad.*

The exposures end with No. 1, but the distance to the Peak is not inconsiderable. Some petty exposures of sandstone were seen in the concealed intervals, but they are all indefinite. The sandstones of the section are for the most part yellowish-gray to bright yellow and moderately coarse grained.

The blossom of *coal-bed* I is large, but the coal could not be reached for measurement. The *Reilly coal-beds*, E and D, should occur in the interval No. 8, which is not fully exposed. *Willow Creek coal-bed* has been opened, but the exposure is not complete, the measurement being *coal*, six inches; clay, six inches; *coal* seen, one foot three inches; and the coal so far as shown is not good. The *Trinidad bed* is well exposed at two openings, both of which had been deserted before the examination was made. The lower one afforded the following section:

	Feet.	Inches.
1. *Coal*	0	8
2. Shale	7	0
3. *Coal*	1	8
4. Bony *coal*	0	2
5. *Coal*	5	0
6. Drab clay	0	4
7. *Coal*	2	0
Total	16	10

Thus showing exact resemblance in structure to the same bed as exposed at the mine of the Denver and Rio Grande Company, though there is a material difference in the thickness of the several divisions. In the little rider *coal-bed* the coal is poor. The main coal is divided by two partings into three benches, respectively one foot, two feet four inches, and one foot eight inches thick. The *Dillon coal-bed* is imperfectly exposed, the section as obtained being *coal*, two feet; concealed, eight feet; shale, four feet; *coal*, two feet six inches, and bottom not seen.

The bed had been mined, but the coal is probably inferior, for the opening had been abandoned and suffered to fall in, so that the exact thickness and the character of the coal cannot be given. The lowest coal-bed of the section is exposed in the channel-way, and the sandstone overlying it is the only rock found overlying a coal-bed and containing impressions of leaves. The *Halymenites sandstone* exhibits its usual features, runs out in the hills before reaching Trinidad; thence to the river one finds only mesas or terraces of Cretaceous No. 4 covered with Quarternary conglomerate.

RATON CREEK.

Raton Creek enters the Purgatory River at about three miles above Trinidad. Its channel-way, from its mouth to a short distance below where it is crossed by the Santa Fé road, has been cut through terraces of Cretaceous shales capped by a compact conglomerate of water-worn pebbles cemented by crystalline carbonate of lime.

The *Halymenites sandstone* is exposed at the Santa Fé road, is very light-gray in color, quite massive, soft, and shows the usual abundance of *Halymenites major*. The blossom of the *Dillon coal-bed* appears at a short distance farther up the creek, and openings into the *Trinidad coal-bed* are numerous in the vicinity.

The following section of the *Trinidad coal-bed* was obtained on the east side of the creek within a mile above the disappearance of the *Halymenites sandstone:*

	Feet.	Inches.
1. Flaggy sandstone	3	0
2. Shale and concealed	4	0
3. *Coal*	0	10
4. Shale	1	10
5. Sandstone	2	0
6. Shale	18	0
7. *Coal*	3	0
8. Shale	6	0
9. Sandstone	8	0
10. *Coal*	6	0
11. Shale	8	0
12. *Coal*	1	0
13. Shale and sandstone to creek	12	0
Total	73	8

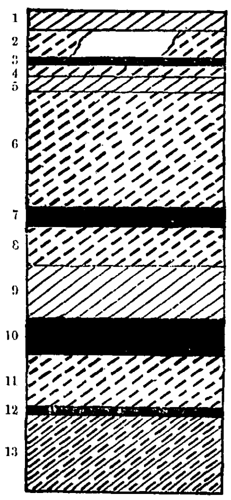


FIG. 15. — *Trinidad coal-bed on Lower Raton Creek.*

The *Trinidad coal-bed* has undergone a great change within three miles, for the section clearly represents the several divisions of that bed with the layers of refuse greatly thickened. The coal is good in all, but only that of No. 10 is mined.

A coal-bed is exposed in the first railroad cutting on the opposite side of the creek, which may be the *Willow Creek coal-bed;* but its relations were not determined as satisfactorily as could be wished, for the exposures are poor and the dip is somewhat irregular. The bed, which is one foot thick and embedded in black shale, is faulted six times in this cut, the total extent of the faulting being ten feet, and several of the faults are associated with clay veins which reach below the track.

The rocks rise gently up the creek from this point, the dip coinciding closely with the fall of the stream; and the following section is exposed alongside of the stage-road at a few rods above the mouth of Clear Creek:

	Feet.	Inches.
1. Shale	10	0
2. *Upper Reilly coal-bed* (E)	4	10
3. *Sandy shale*	15	0
4. *Coal-bed* (D′)	1	0
5. Shaly sandstone	10	0
6. *Lower Reilly coal-bed* (D)	1	0

The sandstone overlying the shale No. 1 is fully thirty feet thick and is very white. This series is imperfectly exposed several times in the long side-cutting made for the Atchison, Topeka and Santa Fé Railroad. The sandstone overlying the *Lower Vermejo coal-bed* (F) is well shown in the hills here, as is also that overlying the *Upper Vermejo coal-bed* (G); but neither of the coal-beds is exposed.

The whole section from the horizon of *coal-bed* H to that of *coal-bed* E seems to be a continuous sandstone at the first bridge below the mouth of Chicken Creek, where the sandstone forms a massive wall on both sides of Raton Creek. The rocks begin to rise rapidly at Chicken Creek, and the dip becomes quite abrupt at two miles below the stage station. The Raton anticlinal is crossed by the creek at somewhat less than two miles below the station, and the dip southeastward is equally abrupt on the opposite side. The following section of the *Trinidad coal-bed* was obtained only a few rods below the crossing of the axis:

	Feet.	Inches.
1. *Coal*	4	0
2. Clay	6	0
3. Clay and shale	16	0
4. Black shale	2	0
5. *Coal*	5	0
6. Shale	5	0
7. Sandstone	8	0
8. *Coal*	9	6
9. Shale	12	0
10. *Coal*	1	0
11. Concealed	20	0
12. Sandstone at creek	0	0
Total	88	6

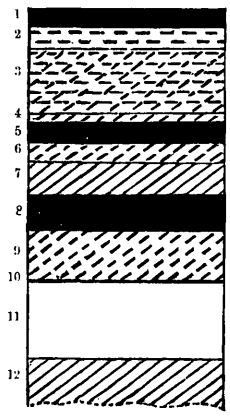


FIG. 16.—*Trinidad coal-bed.*

This section is the same with that obtained farther down the creek, but all the beds except the lowest have become materially thicker, and there is an important thickening of the interval between that and the main coal-bed. The latter itself shows a tendency to break up still further, for the depth of the coal remains the same, while that of the bed has increased to nine feet six inches, the structure being as follows: black shale, 2 feet; *coal*, 2 feet; shale, 1 foot six inches; *coal*, 4 feet.

It is quite probable that the *Dillon coal-bed* occurs in the interval No. 11, and that the sandstone No. 12 is the *Halymenites sandstone*. Quite a number of prospecting holes had been made here, it being the intention to mine the coal extensively as soon as the railroad could be completed to the place.

The dull-brown shales underlying the *Halymenites sandstone* are exposed where the anticlinal crosses, and the section just given should be repeated on the eastern slope of the axis; but there everything is concealed, and the rapid dip soon carries the section below the creek. The synclinal southeast from the Raton anticlinal is crossed at the second bridge below the stage station, where a massive sandstone was quarried by the railroad company for use in building the bridge. The following section was obtained there:

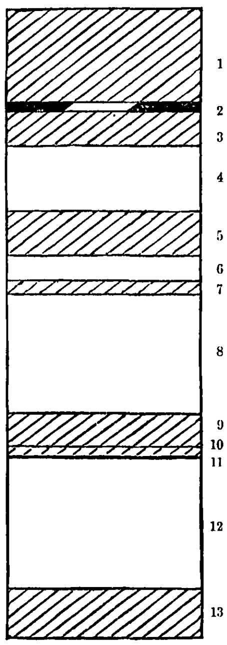


FIG. 17.—*Raton Creek.*

		Feet.	Inches.
1.	Sandstone	45	0
2.	*Upper Vermejo coal-bed* (G)	Blossom.	
3.	Sandstone	22	0
4.	Concealed	33	0
5.	Sandstone	22	0
6.	Concealed	12	0
7.	Sandstone	11	0
8.	Concealed	60	0
9.	Sandstone	17	0
10.	Shale	5	0
11.	*Upper Reilly coal-bed* (E)	0	2
12.	Concealed	65	0
13.	Sandstone	22	0
	Total	314	2

No. 3 is the rock employed in building the bridge. Very probably the section from No. 3 to No. 7, inclusive, is a continuous mass of sandstone. A thin sheet of basalt has been intruded immediately above *coal-bed* E, whereby the coal and shale have been baked thoroughly, the former having been converted into a prismatic coke. The basalt has a concentric structure and breaks down readily on exposure to the atmosphere.

Beyond the synclinal the rocks rise gently toward the southeast, and at the first bridge below the stage station the following section was obtained:

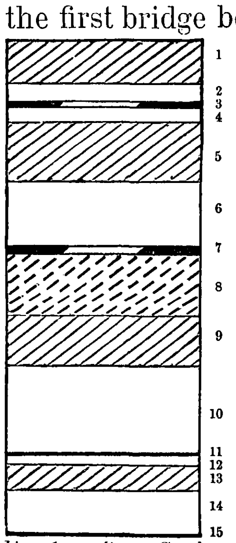


FIG. 18.—*Raton Creek below stage station.*

		Feet.	Inches.
1.	Sandstone	21	0
2.	Concealed	11	0
3.	*Coal-bed* K	Blossom.	
4.	Concealed	11	0
5.	Sandstone	30	0
6.	Concealed	33	0
7.	*Long's Cañon coal-bed* (J)	Blossom.	
8.	Shale	38	0
9.	Sandstone	25	0
10.	Concealed	46	0
11.	*Coal-bed* H′	1	3
12.	Concealed	5	0
13.	Sandstone	11	0
14.	Concealed	23	0
15.	*Cat's Claw Cañon coal-bed* (H)	0	2
	Total	255	5

The little coal-bed, No. 11, shows two benches, three and eight inches, respectively, separated by four inches of clay. The sandstone, No. 9, is used in the bridge. *Coal-bed* H was seen in a ravine entering from the east, just below the bridge.

The following section was compiled from measurements made by Mr. Russell and myself along the creek above the stage station:

	Feet.	Inches.
1. Sandstone	26	0
2. Concealed	66	0
3. Sandstone	66	0
4. Concealed	420	0
5. Sandstone	36	0
6. Concealed	75	0
7. *Coal-bed* W	0	4
8. Concealed	66	0
9. Sandstone	5	0
10. Concealed	6	0
11. *Coal-bed* V	0	10
12. Concealed	150	0
13. *Raton coal-bed* (Q)	3	0
14. Concealed	77	0
15. Sandstone	10	0
16. Concealed	50	0
17. *Cameron coal-bed* M	Blossom.	
18. Concealed	70	0
19. Sandstone	10	0
20. Concealed	140	0
21. *Shale and coal-bed* (I)	2	8
Total	1,279	10

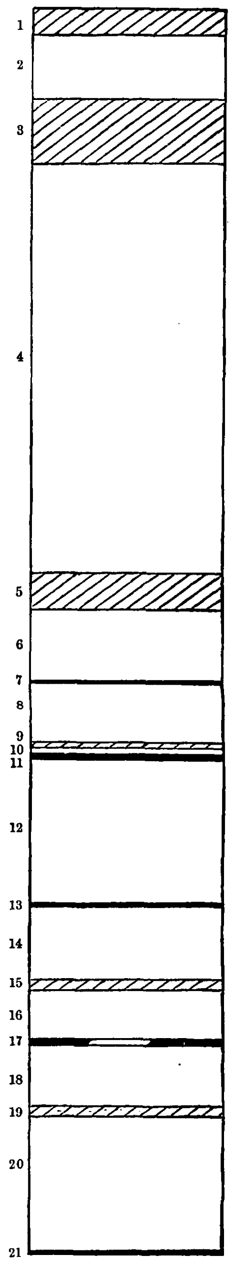


FIG. 19.—*Upper Raton Creek.*

The only coal-bed well exposed is I, which was seen in the bridge approaches immediately above the stage station. It consists of two equal benches separated by two feet of shale, and underlies a dark shale. It is badly faulted on one side of the cut by a clay vein, which comes from below and tapers rapidly toward the surface of the hill; while a wedge of sandstone is inserted between the coal and the overlying shale on the opposite side of the cut, pushing the shale upward for several feet. Some of the higher sandstones of the section contain numerous impressions of *leaves*, a few of which were collected.

The following measurements were made in following the road from the stage station to the summit of Raton Pass:

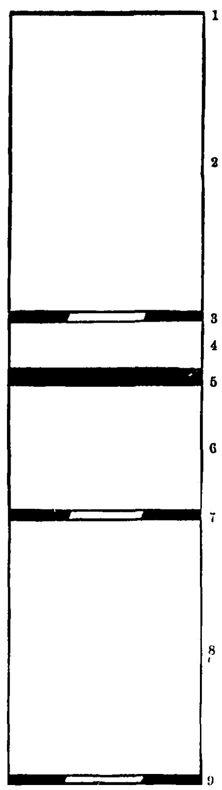


FIG. 20.—*Raton Pass.*

	Feet.	Inches.
1. *Raton coal-bed* (Q)	2	0
2. Interval	150	0
3. *Cameron coal-bed* (M)	Blossom.	
4. Interval	23	0
5. *Coal-bed* L	8	0
6. Interval	64	0
7. *Coal-bed* K	Blossom.	
8. Interval	140	0
9. *Coal-bed* I	Blossom.	
Total	387	0

The *Raton coal-bed* is at the summit of the pass and is exposed at the roadside where the sharp curve is made. The interval, No. 2, seems to contain only a tender shale, which causes great annoyance to the contractors who are putting through the tunnel for the railroad company; but the interval is not fully exposed. *Coal-bed* L is shown in the approach to the tunnel, where it is very irregular, contains little coal, and consists mostly of black shale. Only the blossoms of the other coal-beds were seen and no estimates of their thickness could be made.

Chicken Creek enters the Raton at somewhat more than two miles below the stage station. The exposures along this stream are very poor, and though several blossoms of coal-beds were seen their place could not be determined. The great sandstone is reached at the head of this creek.

PURGATORY CAÑON BELOW REILLY CAÑON.

The Laramie rocks are well shown in the cañon of the Purgatory River from Trinidad to the base of the mountains. The Colorado shales are exposed in the mesa opposite Trinidad, but pass under the river at a short distance above the mouth of Raton Creek. Mr. Russell made the following measurement opposite Trinidad:

	Feet.
1. *Halymenites sandstone*	115
2. Thin-bedded sandstone and shale	11
3. Shaly sandstone	11
4. Shale and sandstone	5
5. Sandy shale	17
6. Thin-bedded shaly sandstone	13
7. Colorado shales	250
Total	422

The passage from the Colorado shales to the compact *Halymenites sandstone* at the top of the section is gradual, and the line of separation between the two groups is drawn somewhat arbitrarily at the base of No. 6, the fucoids being common that far down.

The following section at the base of the Laramie group was obtained at a short distance above the mouth of Raton Creek and illustrates the breaking up of the coal-marshes in the neighborhood of Trinidad:

		Feet.	Inches.
1. Sandstone		–	–
2. Concealed		5	0
3. *Willow Creek coal-bed* (C)		Blossom.	
4. Shale		25	0
5. *Coal-bed*		0	10
6. Shale		24	0
7. *Coal* and shale	*Trinidad coal-bed* (B).	4	0
8. Shale		7	0
9. *Coal-bed*		0	8
10. Shale		25	0
11. *Coal-bed*		0	3
12. Shale		22	0
13. *Coal-bed*		Blossom.	
14. Concealed		20	0
15. Sandstone		15	0
16. *Dillon coal-bed* (A)		2	6
17. Shale		6	0
18. *Halymenites sandstone* to stream		35	0
Total		192	3

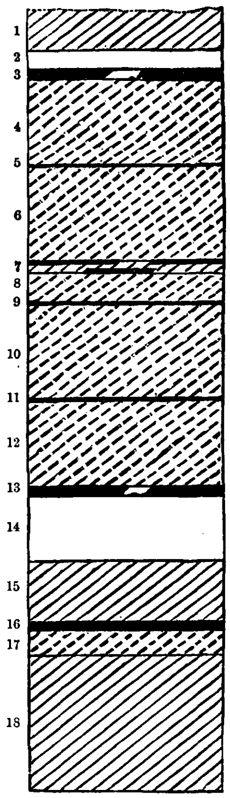


FIG. 21.—*Lower Purgatory*, 1.

The conditions here are not altogether dissimilar to those observed on Raton Creek, but the coal-beds are far from being so important, and the lowest division of the *Trinidad bed* seems to be barely one foot thick. Nos. 5, 6, and 7 are thoroughly baked by intruded sheets of basalt, the coals being coked. No. 7 is split into layers three inches thick, which are separated by similar layers of the basalt. This bed does not pass under the river until within a mile of Long's Cañon, and the igneous layers seem to accompany it persistently. Another section, showing some higher beds, was obtained just above its place of disappearance. It is—

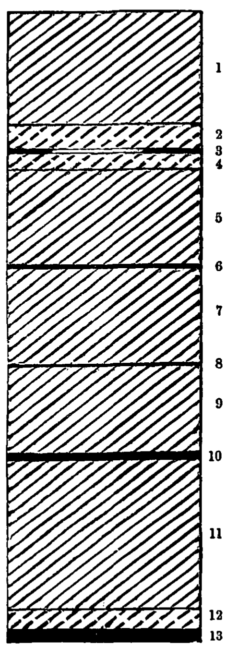


FIG. 22.—*Lower Purgatory, 2.*

	Feet.	Inches.
1. Sandstone	28	0
2. Shale	6	0
3. *Lower Vermejo coal-bed* (F)	Blossom.	
4. Shale	5	0
5. Sandstone	24	0
6. *Coal-bed* E′	1	0
7. Sandstone	24	0
8. *Upper Reilly coal-bed* (E) seen	0	10
9. Mostly sandstone	22	0
10. *Lower Reilly coal bed* (D)	1	8
11. Imperfect exposure, much sandstone	38	0
12. Shale	5	0
13. *Willow Creek coal-bed* (C)	2	6
Total	136	0

No. 6 is a variable bed occasionally found between *coals* E and F. The *Willow Creek coal-bed* is exposed at the mouth of Long's Cañon.

REILLY'S CAÑON.

The *Reilly coal-beds* show an abrupt increase in thickness at a little distance up the cañon, as appears from the following section:

Reilly Cañon, 1, (Fig. 23.)

	Feet.	Inches.
1. *Upper Vermejo coal-bed* (G)	1	0
2. Shale and thin sandstone	28	0
3. Sandstone	55	0
4. *Lower Vermejo coal-bed* (F)	Blossom.	
5. Shale and sandstone	44	0

	Feet.	Inches.
6. *Upper Reilly coal-bed* (E)	7	8
7. Shale	5	0
8. Sandstone	18	0
9. Shale	8	0
10. *Lower Reilly coal-bed* (D)	6	0
11. Shale	10	0
12. Sandstone to creek	6	0
Total	188	8

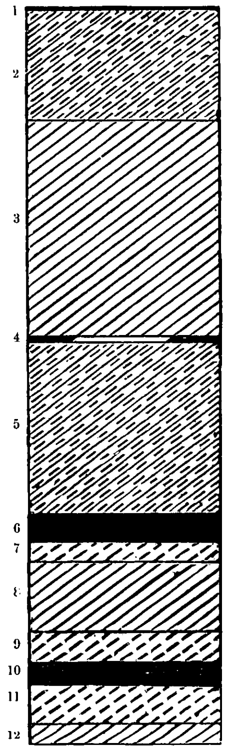


FIG. 23.—*Reilly Cañon*, 1.

Coal-bed E, which is accessible for nearly two miles along the cañon, has the following structure:

	Feet.	Inches.
1. Carbonaceous shale	0	5
2. *Coal*	0	4
3. Clay	0	2
4. *Coal*	2	0
5. Clay	0	2
6. *Coal*	1	6
7. Clay	0	1
8. *Coal*	3	0

No openings have been made in it, but its thickness, five feet six inches of available coal in a total of five feet nine inches, with a waste roof of six inches, makes it locally a very important bed. The measurement given was obtained on the west side of the cañon, directly below where the road turns off toward Burro Cañon. *Coal-bed* D was measured on the east side of the cañon opposite that road, where it gives—

	Feet.	Inches
1. *Coal*	0	3
2. Clay	1	2
3. *Coal*	1	0
4. Clay	0	3
5. *Coal*	3	4

But it seems to be quite variable, and is much thinner at a little way farther down the cañon. A small bed occurs in the base of No. 8, but it is altogether local.

In ascending the cañon the exposures above the *Upper Vermejo coal-bed* were found to be extremely imperfect, and no definite measurement could be obtained above *coal-bed* H, which was seen by its blossom at 105 feet above *coal-bed* G. A blossom was noticed at an estimated interval of 195 feet above H, which probably represents *coal-bed* K. It is midway between two beds of yellow sandstone, which unite at a little way above the exposure of the blossom. This bed is shown near the first hay-ranch. A curious pot in the rocks occurs below this ranch, and perhaps it marks the place of a sink, the structure being as follows:

	Feet.
1. Shale	2
2. Shale	6
3. Black shale	1
4. Shale	6

Or possibly this may show the line of an ancient stream.

Much basalt was seen at two miles from the Zarcillo Cañon road, which seems to be part of a sheet exposed at a little way east from Reilly's Cañon. *Coal-beds* V and W were observed at a short distance below Champion's saw-mill, the following section being exposed:

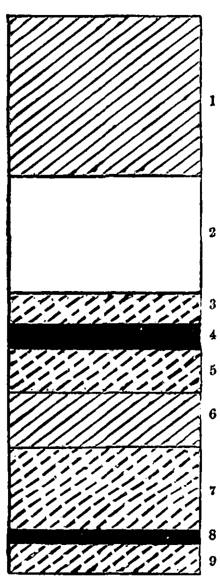


Fig. 24.—*Reilly Cañon, 2.*

	Feet.	Inches.
1. Sandstone	40	0
2. Concealed	30	0
3. Shale	8	0
4. *Coal-bed* W	5	11
5. Black shale	11	0
6. Flaggy rusty sandstone	14	0
7. Fissile brown shale	22	0
8. *Coal-bed* (V)	3	1
9. Variegated shale	9	0
Total	143	0

An attempt has been made to explore *coal-bed* V, but the result seems to have been unsatisfactory, as the pit was abandoned. The bed shows, *coal*, one foot ten inches; clay, three inches; *coal*, one foot; while the other bed shows two benches, eight and three inches, respectively, separated by five feet of shale. The exposures are very unsatisfactory from this point up to Champion's Mill, but the Great Sandstone was reached not far beyond that mill. It is, as far as exposed, 190 feet thick, and rests on thirty feet of rusty-brown shale. It is gray to bright yellow, and for the most part is soft and fine-grained, though it contains some conglomerate layers. This sandstone forms the crest of the hill and is continuous to the Cañon de Agua on the road to Simpson's Mill.

LONG'S CAÑON.

Long's Cañon enters that of the Purgatory from the south and almost opposite to the mouth of Reilly's Cañon. The *Willow Creek coal-bed* is exposed at the entrance to the cañon, and the following section is shown along the lower two miles, ending at a branch cañon followed by the road to Dillon's Cañon.

	Feet.	Inches.
1. Sandstone	50	0
2. *Lower Vermejo coal-bed* (F)	0	10
3. Shales and sandstone	42	0
4. *Upper Reilly coal-bed* (E)	0	6
5. Shale, imperfect exposure	10	0
6. Sandstone	9	0
7. Black shale	8	0
8. Sandstone	10	0
9. *Lower Reilly coal-bed* (D)	3	6
10. Sandstone	12	0
11. *Willow Creek coal-bed* (C)	3	6
12. Sandstone and shale	10	0
13. *Coal* and shale	0	6
14. Sandstone and shale	12	0
Total	171	10

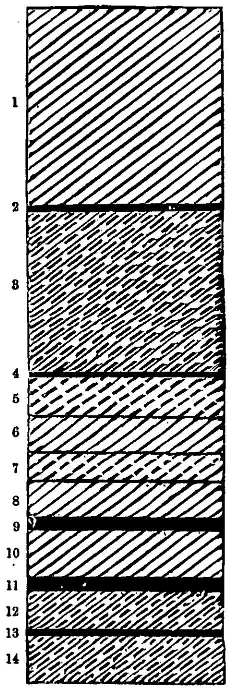


FIG. 25.—*Long's Cañon.*

This contrasts very strongly in many respects with the same part of the series as shown in Reilly's Cañon. The *Lower Reilly* bed has the following structure: *coaly* shale, six inches; *coal*, eight inches; *coaly* shale, two feet four inches; and therefore is altogether worthless. The *Willow Creek coal-bed* shows—*coal*, six inches; clay, one foot six inches; *coal*, one foot six inches, and is of no value at the mouth of the cañon, though at but a little way lower down the Purgatory the thickness is greater and the bed has been opened. The interval between *coal-beds* C and D varies abruptly, for at half a mile above the mouth of the cañon the relations are as given in the section, whereas at the mouth of the cañon the interval is twelve feet greater, and the bed D is somewhat thicker. The sandstone, No. 10, swells near the river so as to cut out Nos. 11, 12, and 13, and to rest on No. 14; but within a few rods it decreases to the thickness given in the section. A dike three feet six inches wide was seen at about half a mile up the cañon.

The sandstone, No. 1 of the section, remains above the stream for about two miles, to the branch cañon through which the road to Dillon's Cañon passes. The exposures on Long's Cañon are poor above this, though that cañon reaches to the summit of the plateau, while in the branch cañon referred to there are many exposures. But these are not easily followed. The blossom of the *Upper Vermejo coal-bed* was seen at ninety-five feet above that of the *Lower Vermejo*, and the *Cat's Claw coal-bed* is exposed at about two miles up the cañon, where its structure is—

	Feet.	Inches.
1. *Coal*	0	4
2. Shale	1	2
3. *Coal*	0	2
4. Clay	0	2
5. *Coal*	0	4
6. Clay	0	10
7. *Coal*	0	4
Total	3	2

Being a total of one foot two inches of inferior coal. *Coal-bed* H′ occurs at forty-five feet above the *Cat's Claw coal*, and is one foot thick. *Coal-bed* I was not fully recognized, but a coal blossom which may represent that bed was seen at nearly fifty feet above H′, and included within a massive sandstone. The *Long's Cañon coal-bed* J occurs at the base of the abrupt hill which the Dillon's Cañon road ascends, and, as appears from the structure, it is important,—*coal*, four inches; drab shale, four feet; *coal*, four feet three inches; total, eight feet seven inches. But no attempt has been made to determine the quality of the coal, and the blossom is not such as to yield any definite information respecting that matter. Numerous coal blossoms were seen between this locality and the summit, but none of them indicates the thickness of coal. The Great Sandstone is reached at the summit, and it is continuous thence to the head of Dillon's Cañon.

PURGATORY RIVER FROM LONG'S CAÑON TO THE SOUTH FORK.

Returning now to the Purgatory, one finds the *Upper Reilly coal-bed* exposed at the roadside not far above the mouth of Reilly's Cañon. Owing to a slight change in dip both of the *Reilly coal-beds* remain above water level until beyond Burro Cañon; and at Tijeres the upper one shows four feet of carbonaceous shale, while the lower one has three feet of good coal resting on two feet of fire-clay. Above them is the blossom of E′. The relations of the coal-beds between Tijeres and the mouth of the South Fork of the Purgatory are somewhat obscure, as for two miles above Burro Cañon the rocks dip rapidly and the exposures are imperfect. A *coal-bed* four inches thick was seen in sandstone at nearly a mile below the second bridge east from Olguines, and a large bed is exposed on the south side near the hill-top just below the bridge. It has the following structure:

	Feet.	Inches.
1. *Coal*	1	6
2. Clay	0	2
3. *Coal*	0	6
4. Clay	1	3
5. *Coal*	0	6
6. Shale	1	0
7. *Coal*	1	0
8. Clay	0	8
9. *Coal*	5	6
Total	12	1

The bed is again exposed in the creek bank at the first bridge below Olguines, with the following structure:

	Feet.	Inches.
1. *Coal*	1	2
2. Clay	0	3
3. *Coal*	1	0
4. Clay	0	1
5. *Coal*	0	8
6. Clay	1	2
7. *Coal*	0	8
8. Clay	0	3
9. *Coal*	0	4
10. Carbonaceous shale	1	0
Total	6	7

And resting on twelve feet of fire-clay and shale. An exposure near this, on the north side of the cañon, shows—

	Feet.	Inches.
1. Gray sandstone	–	–
2. *Coal-bed*	Blossom.	
3. Shale	10	0
4. Sandstone	40	0
5. *Coal* and shale	6	0
6. Shale	15	0
7. *Coal*	6	0
8. Shale	10	0
9. Sandstone	15	0
10. Shale	8	0
11. *Coal-bed*	Blossom.	
Total	100	0

But the measurements are very indefinite. A synclinal is crossed by the river almost immediately below Olguines, above which at say two-thirds of a mile the following section was obtained:

	Feet.	Inches.
1. Carbonaceous shale	2	0
2. Sheet of basalt	9	0
3. Dark shale	2	0
4. *Coal-bed*	0	8
5. Black shale	0	8
6. Variegated shale	3	0
7. Sandstone	3	6
8. Drab clay	8	0
9. *Coal-bed*	0	6
10. Black shale	1	0
11. Sandy shale	3	0
12. Black shale	0	2
13. *Coal-bed*	3	0
14. Clay	4	0

The sheet of basalt makes its first appearance at rather more than a mile below Olguines, where the road runs on it for some distance. It is irregular in its course and breaks through the rocks, so that it is higher in the section below Olguines than it is above that village. Many pieces of carbonaceous shale have been entangled in it and, where the section just given was obtained, the *coal* in bed No. 4 is imperfectly coked.

Distinct terraces were seen at 5, 10, 80, 110, 140, and 180 feet above the bed of the river at this locality, and water-worn fragments occur on them all, though they are less numerous on the highest two. Such fragments are abundant on the eighty-foot terrace, forming a deep layer, cemented, as is the conglomerate on the benches above and below Trinidad. Two higher benches were seen, but their height was not determined.

The coal-bed No. 13 is exposed in a ravine, where it shows—

1. *Coal*	2 inches.
2. Clay	2 inches to 4 inches.
3. *Coal*	6 inches to 8 inches.
4. Clay	2 inches to 5 inches.
5. *Coal*	1 inch to 2 inches.
6. Clay, with streaks of *coal*	7 inches to 11 inches.
7. *Coal*	3 inches.
8. Clay	10 inches.
9. *Coal*	1 inch.

And small lenticular bunches of *coal* from one to two inches thick occur in the clay below the bed. Another bed is exposed at the roadside at nearly a mile above Olguines, showing—

	Feet.	Inches.
1. *Coal*	3	0
2. Clay	1	0
3. *Coal*	0	4
4. Clay	1	6
5. *Coal*	2	0
Total	7	10

while at barely a mile below La Junta, apparently the same bed shows—

	Feet.
1. *Coal*	3
2. Shale	6
3. *Coal*	4
Total	13

but immediately back of the hill the bed is much distorted, the result of causes operating before the formation of the overlying sandstone.

SOUTH FORK OF THE PURGATORY.

The South Fork enters the river at La Junta. A gentle anticlinal is crossed directly below that place, and thence to San Isidro (the mouth of the Middle Fork) the rocks dip toward the west.

The following section was obtained on the South Fork at only a few rods above the mouth of its cañon:

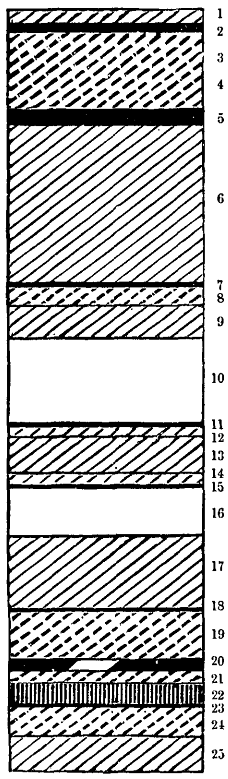


FIG. 26.—*South Fork Purgatory*, 1.

	Feet.	Inches.
1. Sandstone	6	0
2. *Caliente coal-bed* (R)	4	0
3. Black shale	5	0
4. Shale	33	0
5. *Raton coal-bed* (Q)	7	0
6. Mostly sandstone, imperfect exposure	79	0
7. *Coal-bed* (O)	0	10
8. Shale	11	0
9. Sandstone	15	0
10. Imperfectly exposed	43	0
11. *Cameron coal-bed* (M) seen	1	6
12. Shale	7	0
13. Sandstone	18	0
14. Shale	5	0
15. *Coal-bed* (L) seen	1	0
16. Concealed	24	0
17. Sandstone	36	0
18. *Coal-bed* (K)	1	0
19. Shale	24	0
20. *Coal-bed* (J′)	Blossom.	
21. Shale	13	0
22. Basalt	10	0
23. *Long's Cañon coal-bed* (J)	1	0
24. Shale	18	0
25. Sandstone	19	0
Total	382	4

The highest sandstone of the section caps a little dome on the hill-top, whereby the *Caliente coal-bed* has been preserved from erosion. That bed seems to be solid coal, and streaks of *coal* occur in the underlying shale. No. 5 is in two benches, two feet and one foot respectively, which are separated by four feet of shale containing some *coaly* matter. The interval, No. 6, holds chiefly sandstone and no *coal*, but No. 10 shows indications of *coal* at only a few feet below the top. No. 22 is a massive rock and at one place it has entangled the underlying coal, which there is thoroughly baked. The sandstone No. 7 contains pots of *coal* at its base, which have been torn from the bed below.

The rocks of this section pass slowly under the creek, and another section was obtained at somewhat more than three miles farther up, as follows:

	Feet.	Inches.
1. Sandstone	23	0
2. Concealed	25	0
3. *Coal-bed* (X′)	Blossom.	
4. Concealed	44	0
5. Shale and *coal-bed* (X)	16	0
6. Shale and shaly sandstone	21	0
7. Sandstone	20	0
8. Concealed	10	0
9. Shale and *coal-bed* (W)	6	0
10. Concealed	23	0
11. Sandstone	19	0
12. Concealed	10	0
13. *Coal-bed* (V)	2	0
14. Sandstone	8	0
15. Shale	17	0
16. *Canadian coal-bed* (U)	0	4
17. Shale	30	0
18. Shale and *coal-bed* (T)	6	0
19. Shale, imperfect exposure	60	0
20. *Caliente coal-bed* (R)	1	0
21. Sandstone and shale	36	0
22. *Raton coal-bed* (Q)	Blossom.	
23. Concealed	70	0
24. Sandstone	5	0
25. Clay	1	0
26. *Coal-bed* (O)	1	8
27. Shales	30	0
28. Shale and *coal-bed* (N)	8	6
29. Shale and thin sandstone	36	0
30. Basalt	4	0
31. Shale	5	0
32. *Cameron coal-bed* (M)	2	4
33. Shale to creek	6	0
Total	556	10

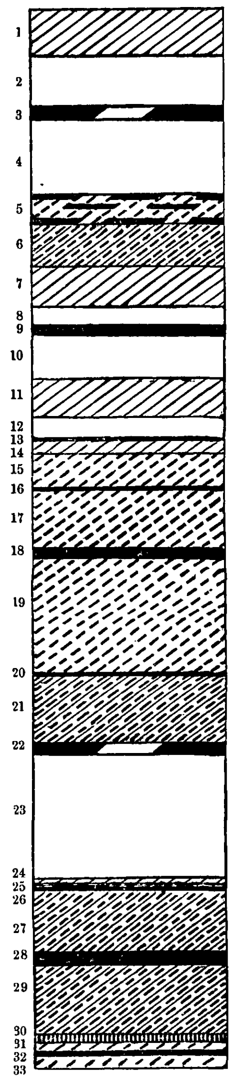


FIG. 27.—*South Fork Purgatory, 2.*

The exposures of coal-beds in this section are very indistinct and definite measurements could be obtained of but few. No. 5 shows *coaly* shale, four feet; concealed, eight feet; *coal* and thin layers of shale, four feet. There is much shale in No. 9, but No. 13 is evidently good. No.

18 has two benches, each one foot, separated by four feet of shale. No. 28 has the following structure:

	Feet.	Inches.
1. *Coal*	1	2
2. Shale	0	10
3. *Coal*	0	6
4. Shale	4	0
5. *Coal*	2	0

And No. 32 shows

	Feet.	Inches.
1. *Coal*	0	5
2. Clay	0	5
3. *Coal*	1	6

The rocks begin to rise gently with the stream at the first bend indicated on the map; but within two or three miles of San Francisco Park the rise becomes quite rapid and the lowest coals of the former section are soon well up in the hills, which are heavily covered with *débris* and show little aside from the thicker sandstones. The following measurement was made within a mile and a half of the park:

	Feet.	Inches.
1. Sandstone	–	–
2. *Upper Reilly coal-bed* (E)	Blossom.	
3. Interval	60	0
4. *Willow Creek coal-bed* (C)	Blossom.	
5. Interval	80	0
6. *Trinidad coal-bed* (B)	Blossom.	

The blossom of the *Upper Vermejo coal-bed* (G) was seen higher up, and the sandstone overlying *coal-bed* H is exposed near the crest of the hill. The dip again changes at not far above this place, and is westward at the rate of somewhat more than 3° until within less than half a mile of the park; but there the rocks are turned up abruptly toward the west and the dip increases toward the park, so that at the head of the cañon a mass of the *Halymenites sandstone* stands midway in the gorge, dipping almost east at about 30°. This sharp axis, the Vermejo, brings up the shales of Cretaceous No. 4, out of which the park has been scooped. On the west and southwest sides of the park the *Halymenites sandstone* dips westward, and in the park are hills of the Cretaceous shales, cut by dikes or sheets of igneous rock. The anticlinal is crossed before the head of the park is reached, and on the western edge of the Laramie area the rocks of that group are dipping eastward at almost 75°.

The *Dillon coal-bed* is frequently exposed along the south branch of this stream, on the west side of the plateau, and at one locality it seems to be almost ten feet thick. The sandstones above it have become very coarse, and an apparently continuous mass of conglomerate, 130 feet thick, caps the hill.

UPPER PART OF PURGATORY CAÑON.

The dip is westward along the Main Fork of Purgatory from La Junta to San Isidro, at the mouth of the Middle Fork. The following section was obtained between these points, but the intervals are estimated, not measured, as the exposures are incomplete:

	Feet.	Inches.
1. Sandstone	30	0
2. Shale	10	0
3. *Coal-bed*	Blossom.	
4. Shale	11	0
5. Sandstone	6	0
6. *Coal-bed*	Blossom.	
7. Shale	10	0
8. Sandstone	12	0
9. Shale	10	0
10. *Coal-bed*	Blossom.	
11. Shale	20	0
12. Sandstone	30	0
13. Shale	15	0
14. *Coal-bed*	Blossom.	
15. Sandstone	25	0
16. *Coal-bed*	Blossom.	
17. Shale	25	0
18. Sandstone	40	0
19. Shale	25	0
20. Concealed	30	0
21. Sandstone	25	0
22. Shale	10	0
23. *Coal-bed*	Blossom.	
24. Shale	20	0
25. *Coal-bed*	1	3
26. Shale	8	0
27. Sandstone	35	0
28. Shale	5	0
29. Sheet of trap	8	0
30. *Coal-bed*	Blossom.	
31. Shale and sandstone	20	0
Total	426	3

The rocks ascend westward on the North Fork of the Purgatory, with the dip increasing toward the mountains. An effort was made to obtain a detailed section on the west side of the synclinal, but the exposures proved insufficient.

THE MOUNTAIN REGION.

Directly behind the Laramie Plateau is a narrow valley, covered with Quaternary deposits, and extending from Cucharas Pass at the north to Costilla Peak at the south. It has been cut out, for the most part, from the Middle Cretaceous or Colorado shales. It is split midway by a double dike of trachyte, reaching from Cucharas Pass southward to beyond the Middle Fork of the Purgatory.

The Laramie rocks are constantly exposed near the crest of the wall along the east side of this valley, and the blossom of the *Dillon coal-bed* is a black band for long distances. That bed has been opened at several places, but the coal is not mined, as pine wood can be obtained with less labor. The Colorado shales are first exposed in this bluff at a short distance south from Cucharas Pass, and remain in sight thence to the divide between the waters of the Purgatory and those of the Vermejo.

The dikes running longitudinally through this valley enter it at the north by Cucharas Pass, evidently originating in the Spanish Peaks, which are just beyond the extreme northern border of the map. They are unequal in size and of different composition, one being composed of a heavy dark rock, while that of the other is lighter in color. The former is the broader one, and in the narrow area of the North Fork it has been split by erosion. The dikes expand between the North and Middle Forks, where they almost fill the narrow valley; while south from the latter fork they form huge hog-back ridges, which continue for nearly two miles toward the South Fork and then suddenly disappear.

The superficial deposits in the valley are quite thick, especially near the North Fork, and cover all of the older rocks except the dikes. The valley is well terraced near the several streams, there being four fine terraces on both sides of the North Fork near Spring Valley, while a fifth is very distinct on the south side. Water-worn fragments occur in great numbers on all of these, and similar fragments are plentifully strewn over the surface of the valley northward until very near Cucharas Pass. Subordinate terraces were seen between the branches of this North Fork.

The valley shows little of interest between the North and Middle Forks. It becomes quite narrow near the latter, and the divide between the two streams is reached on both sides by a succession of fine terraces, all carrying enormous numbers of water-worn fragments of gneiss, granite, and other rocks which occur on the sides and slopes of the mountains. The valley becomes a beautiful park south from the Middle Fork, whose surface gradually rises until within a short distance of the South Fork, from which it is separated by an abrupt divide. For the most part this valley is covered with a pulverulent soil more or less alkaline and containing many pebbles, the last feature becoming more marked southward toward the South Fork. Two small ponds, ill-drained and alkaline, were seen near the Middle Fork. This valley becomes an irregular park on the South Fork, and is much broken by small mesa-like hills, which are remnants of former terraces and are now covered with a good growth of trees.

The western boundary of the valley is a wall of Dakota sandstone, commonly known as the "the stonewall," which is looked upon as a curiosity of no mean order. It appears to originate in the southern Spanish Peak, and extends quite regularly south or east of south to the North Fork of Purgatory, beyond which the direction is almost south to the Middle Fork, where it curves to very slightly west of south; this course is retained to within a very short distance of the South Fork, where the wall suddenly disappears. The sandstone shows the characteristic features, having the honeycombed and conglomerate layers. It is not far from 250 feet thick and contains, as far as could be determined, no fossil remains of any sort.

The narrowing of the valley north from the Middle Fork is due in part to a fault in the wall, whereby the sandstone is brought up again almost midway in the valley; but this new hog-back is of short duration and is not more than three miles long. A slaty bluish limestone with birdseye points was seen underneath the sandstone of this wall. The dark shale of Cretaceous No. 2 and the limestone of No. 3 were seen in the angle between this hog-back and the main wall, and the shale of No. 3 has been prospected for *coal*. A narrow valley intervenes between the Stonewall and the Carboniferous rocks, which form the lower part of the mountain slope. It stretches from Cucharas Pass to near the South Fork of Purgatory and ends with the northern division of the Stonewall.

The Laramie rocks on the South Fork of Purgatory dip very sharply toward the east-northeast. The shales of Cretaceous No. 4 form a compressed anticlinal at perhaps 400 yards west from the Laramie bluff, and the limestones of No. 3, dipping eastward and resting on the dark shales of No. 2, are shown somewhat farther up the stream. Here it is seen that the Stonewall, thus far followed southward, passes suddenly into an insignificant anticlinal barely strong enough to expose the base of No. 2. Thence to the forks of the creek the dip is westward, but there the dip is reversed, and within 400 yards the Dakota sandstone again comes up, forming a wall which is cut by both forks of the creek. This wall trends in an almost southeast direction for nearly two miles, but then turns southward and follows a line practically continuous with that of the northern wall. Before the divide between this stream and the Vermejo is reached the interval between the Stonewall and the Laramie bluff is much less than it is beyond the Middle Fork of the River, and the two subordinate anticlinals have disappeared.

The dip in this wall shows no great variation. It is invariably eastward, and is from 40° to 60°. A fine exhibition of rain sculpture is shown immediately north from the South Fork.

The Mountain Slope.—The axis of the Culebra Range is composed of metamorphic rocks, but within the area of the Purgatory the Carboniferous series is exposed along its eastern side, while, as already stated, the Dakota sandstones are upturned at its base. The Carboniferous rocks reach quite to the summit of the axis near the northern border of the map, but southward the upper limit of the stratified rocks moves eastward, so that south from Culebra Peak it lies at a considerable distance from the crest. Attempts were made on all the forks of the Purgatory to obtain sections, but, except on the South Fork, they were wholly unsuccessful, owing to poverty of exposures.

The exhibitions are distinct on the South Fork of the Purgatory, but unfortunately the cañon cannot be followed, and the only practicable trail lies well up on a hog-back leading to the crest of the range, which, though within sight of the exposures, is too far away to admit of measuring them. Frequent partial exposures occur along the trail, which show the character of the rocks and afford a basis for approximate estimates of their thickness.

Ascending the north branch of the South Fork one soon reaches the Stonewall, dipping nearly northeast at 60°. The bluffs behind this for about 200 yards are covered with *débris*, but beyond that interval the coarse reddish-brown sandstones of the Carboniferous are seen. Pebbles of granite, gneiss, and sandstone are not rare in the coarser layers of this rock, but most of the pebbles are quartzite. The color varies from reddish brown to gray; the dip is about 50° and the thickness is not far from 3,000 feet.

This coarse rock gradually passes downward into a fine-grained reddish sandstone, containing occasional layers of not very coarse conglomerate. In this are many dull-red ferruginous layers, and its thickness is estimated at 2,500 feet. The dip increases toward the center of the axis and at length becomes somewhat more than 80°. Next is a hard granular gray limestone, weathering bluish, containing many streaks of calcspar, and, as exposed, about 100 feet thick. It is fossiliferous, and the following species were obtained: *Productus semireticulatus; Spirifer; Nucula parva; Athyris subtilita; Macrodon; Aviculopecten*, and *Fenestella*. The rock is fetid when struck. This rests on red sandstone similar to that above it, and about 300 feet thick; below which is a dark-blue compact limestone containing veins of calcspar, non-fossiliferous, and, as exposed, twenty feet thick.

The next interval, estimated at 700 feet, is ill-shown, but it contains much red sandstone like that already referred to. It ends at timber line, where a limestone seven feet thick is exposed which is blue, slaty, hard, and contains *Productus splendens, Spirifer lineatus, Naticopsis*, and many bryozoans. It rests on a coarse conglomerate, not fully exposed, but evidently interstratified with reddish shales. This, which is probably 800 feet thick, reaches to the Archæan rocks and, like the overlying beds to the gray limestone, dips toward the center of the axis.

This conglomerate ends at the eastern extremity of a long knife-edge leading to the base of a cone, which terminates the crest line. It separates two deep amphitheaters, in one of which heads a branch of the South Fork and in the other a branch of the Middle Fork of Purgatory, and is composed of gneiss and gneissoid granite. It is barely twelve feet wide at the base of the cone, where its edges overlook the deep amphitheaters extending below timber line. The summit of the divide, lying nearly a mile farther west, sends out a prong, ending sharply in a triangular precipice more than 2,000 feet high, which joins itself to the knife-edge already referred to, that it may be climbed. But when the top of this cliff has been reached the climber must follow the higher knife-edge for a mile to arrive at the little pyramid known as Culebra Peak, the highest point in the Spanish Ranges east from the Rio Grande. The rock forming the walls is for the most part a felspathic granite, which at times becomes porphyritic. This prevails along the axis from the northern edge of the map.

CHAPTER XIV.

AREA OF THE CANADIAN RIVER.

SECTION I.

THE CANADIAN CAÑON AND PLAINS.

From Clifton, on the stage-road to the Leavenworth Crossing, the Canadian River flows through the plains, and its channel-way has been worn in the Quaternary and the underlying Colorado shales. Here and there on the plain a marly, travertin-like limestone underlies the Quaternary and probably marks the place of some later Tertiary lakes, but its extent is insignificant. The river enters a cañon immediately below the Leavenworth road, which rapidly deepens to beyond the mouth of the Mora River. The area of the Mora will be described in a separate chapter.

The cañon of the Canadian is 1,090 feet deep at the mouth of the Mora, and its rim throughout is the Upper Dakota sandstone, which is so hard and resists erosion so well that it remains practically unbroken for miles at a time.

The Upper Dakota rocks are yellow to gray, fine-grained sandstones, with some coarser beds at the base, the whole being about 620 feet thick. A brittle, laminated blue limestone occasionally occurs below this group, and is but a few feet above a massive gray sandstone, which passes gradually into a handsome fine-grained, massive, olive sandstone about forty feet thick. A thin limestone is sometimes shown below this, which is blue on the freshly exposed surface, but weathers whitish, and rests on 200 feet of a red shale, which has white blotches. The whole of this lower series, which represents the Middle Dakota, is without distinct fossils.

A sheet of basalt, seen at the mouth of Mora Cañon, extends three miles up the Canadian. It rests on the Middle Dakota sandstone and fills up the old channel-way in that rock. It is confined for the most part to the right bank of the Canadian, but at two miles above the Mora it is shown for nearly half a mile on both sides. The cañon is wide for a number of miles above this, and ranches occupied by Mexicans are numerous, but the wall remains so steep that few localities exist where even a rugged trail can be made which would be practicable for loaded animals. The dip is northwest as far up as San Felipe, but near that village it becomes undulating. This dip carries the Middle Dakota rocks under, below San Felipe, and the height of the cañon wall is reduced to barely 600 feet. The rim is broken by long arroyos on both sides, and a wagon-road crosses the cañon at San Felipe; but no other place for a wagon-road can be found below the village until beyond the Mora, or above it within sixteen miles.

The cañon remains open above San Felipe for somewhat more than twelve miles, but there it closes, and thence, for the present at least, is impassable. The rocks continue to dip southward, so that at Mill's Ranch, eight miles above San Felipe, the Middle Dakota is exposed again and is shown to be fully conformable to the overlying sandstone of the Upper Dakota. The wall is 800 feet high at this place, and a trail has been constructed leading out of the gorge.

Mesas of the Colorado shales and limestones are numerous on the plains east from the cañon, and the Upper Dakota sandstones underlie the thin Quaternary deposits. Northward from the road leading to Mill's Ranch trail the Texas road crosses a number of arroyos, most of which are dry or contain but a little impure water. The Upper Dakota sandstone is shown in the first three, dipping southeast, but in the fourth the

Niobrara limestones are exposed, also dipping southeast, though at nearly 200 feet below the nearest exposure of Dakota at the southeast. As the cañon cannot well be reached here, the linear extent of this fault cannot be determined, but its vertical extent is not less than 600 feet.

The shales and limestones of Cretaceous Nos. 2 and 3 soon run out near the road, and no mesas exist west from the eastern edge of the map; but at about eight miles south from the Leavenworth road a gentle anticlinal, the Canadian, is crossed, and within a short distance the mesas again occur. Thence they gradually approach the river, and the head of the cañon is reached at Franklin's Ranch, where the Upper Dakota sandstone is in the river-bed, while the Colorado shales and limestones are in the bluffs within 300 yards of the stream.

The conditions are somewhat more varied between Ocaté Creek and the Mora River. The plains south from the line of the Canadian Hills are gently rolling, with here and there a mesa of Colorado shales and limestone, capped by a thin coating of Quaternary silt and gravel; but for the most part that recent deposit, though very thin, effectually conceals all of the older rocks. Many lakelets, without outlet, occur on these plains, especially within four or five miles of the Mora, where the Upper Dakota sandstone is the immediately underlying rock. The water in these ponds is alkaline, either because of constant accumulation of salts through evaporation, or because the springs flowing on the hard sandstone and directly under the superficial deposit, abstract alkaline salts from the silt of which the latter is composed.

The Canadian anticlinal passes but a short distance east from the Canadian Hills, bringing up the Dakota sandstone so as to form a low irregular hill, which reaches from the Canadians almost to the Canadian Cañon, and affords a long exposure of the sandstone in the hills and in the arroyos leading thence to the cañon. The upper layers of the sandstone are covered by dense mats of a characterless fucoid, and the rock passes imperceptibly into the sandy shales of Cretaceous No. 2. The limestones of No. 3 are poorly shown around the base of this hill, but in a mesa, not far south from the hills, the lower part of that subgroup is well exposed.

A large area of Nos. 2 and 3, directly south from the Canadian Hills, has escaped erosion, and the dark shales of No. 4 are exposed underlying the lava-cap at several places in the wall of the mesa. But at a little way farther west the recent deposits approach the hills and effectually conceal all of the Cretaceous, though scattered fragments show that the Niobrara limestones are near the surface. A cañon between the two parts of the Canadians exhibits the limestone dipping almost due east.

Exposures are fragmentary on the north side of the hills and are found only in small mesas scattered over the plain. These are made up, near the Canadian, of the shales and limestones of Nos. 2 and 3; but farther west the shales of No. 4 are occasionally shown above the limestones of No. 3.

The Canadian Hills, which are about ten miles long by from two to four miles wide, are merely outliers of the great igneous overflow extending for many miles west and north along the line of the Cimarron anticlinal. They are separated from the Ocaté Mesa by a narrow valley leading southward from the Apache Swamps, which lie north from the Wagon Mound, an outlier of the Canadian Hills. The basalt cap on the hills is 460 feet thick at the west end, but becomes less toward the east. It rests on the Colorado shales; but many water-worn pebbles of gneiss and quartzite were seen at 200 feet above the southern base of the hills, and they appear to underlie the basalt.

OCATÉ CREEK AND MESA.

Ocaté Creek rises in the great basaltic area extending from the Canadian Plains at the east to Coyote and Cieneguilla Creeks at the west. It flows eastward and enters the Canadian at about six miles below the head of the cañon. In the plains it flows through the Colorado shales and limestones until within a short distance of the Canadian River, where it enters a rapidly deepening cañon in the Dakota sandstone. Exposures of the Colorado group are few and fragmentary, but the shales of its lower divisions are present almost to the base of the Ocaté Mesa.

The cañon of this stream through the Ocaté Mesa, from Las Gallinas to the plains, is close though not deep, and is open only in the neighborhood of Ocaté and the stage-station where it is crossed by the Santa Fé road. The higher shales of the Colorado group are shown at the mouth of the cañon, but these soon disappear, and the walls show no rock other than basalt until near the head of the cañon, where the Upper Dakota sandstones come up and rise toward the west-southwest, so as soon to form hog-back ridges on both sides of the creek. At its head the cañon opens into a broad park with hills on the northeast, north, and northwest sides, but these gradually fall southward, in which direction the surface of the park rises until the latter merges into the mesa. Ocaté Creek is formed near the head of its cañon by the union of several small streams which issue from deep gorges. On all sides except the northeast the basalt sheet covers the hills, while under it are seen the Dakota sandstones, which extend up the several cañons to their heads, forming bright bands in their walls. On all sides of the park a talus rests against the bluffs, concealing all except the Upper Dakota sandstones; but at three localities red to brownish shales are imperfectly shown, which evidently belong to the Middle Dakota.

A great dike of basalt comes down between the two easterly forks and is continuous with the basalt underlying the silt in the park, so that in all probability that rock at one time filled the whole excavation. The massive trap floor is exposed in petty gorges cut by the streams as they issue from their cañons. The main part of the park is bounded at the south by a low wall of basalt, beyond which southward the surface, as already stated, rises gradually until it is lost in the mesa. The Upper Dakota sandstone underlies the basalt in the wall, while the latter rock forms the floor in the open area.

The drainage is defective in all portions of the park, and many rock basins containing ponds of alkaline water were seen, none of them having an outlet. But some excellent springs issue from the low trap-ridge dividing the park.

The name "Ocaté" may be applied to the whole of the great lava-capped mesa extending from Rayado Creek southward almost to Fort Union, and from the Canadian Plains westward to Cieneguilla and Coyote Creeks. With its outliers, the Gonzales and Rayado Mesas, the Canadian

Hills, and the crater in the southern portion of the Turkey Mountains, it really extends almost to the Canadian River at the east and to the Mora River at the south. It is drained by Rayado, Ocaté, Gallinas, and Wolf Creeks on the east, and by Cieneguilla and Coyote Creeks on the west. The Santa Fé stage-road skirts the eastern border of the mesa from Rayado Creek to the Apache Hill, and the basalt is shown for the whole distance resting on the shales of Cretaceous No. 4. For some distance north from the Apache Hill the road follows up a ravine between the higher mesa at the west and the lower one on the east, which is especially designated on the map as the Ocaté Mesa, but at the Apache Hill it rises upon the latter. The eastern mesa is continuous with the other, but is much lower, the relation of the two being that of terraces, each having a flat surface, though that of the eastern one slopes slightly toward the plains. The lava-cap on the latter is thin, being only ten feet thick where the road rises upon it, and rests directly on the higher shales of the Colorado group near the stage-road; but on the southeast side the base of No. 4 is reached and the limestones of No. 3 are very near the surface of the plain.

Whether the Colorado shales are present or not in the bluff above the level of the lower mesa could not be ascertained, for no exposure of any sort was found. This upper bench points out, so to speak, just north from Ocaté Creek, where the road turns sharply toward the west, and thence southward the lower mesa is continuous to Nolan's Ranch at the southeast, and to within ten miles of Fort Union at the south. Its surface is almost unbroken north from Ocaté Creek, but south from that stream to the Turkey Mountains it shows here and there a hill of igneous rock which has escaped erosion. The hills of Upper Dakota sandstone near Ocaté Park, which are on the eastern slope of the Cimarron axis, rise to beyond the level of the upper mesa, while some mountains north from the park, themselves lava-capped, extend to beyond Rayado Creek.

The old volcano, marked Ocaté Crater on the map, is on the edge of the mesa and forms part of the eastern boundary of the park. It is a truncated cone, and its original slope is well preserved on the north and east sides. A dike has destroyed the symmetry on the west side, while erosion has broken down the rim on the south side, so that a stream now has its head in the crater. The surface of the cup is covered with loose cinder and the cone itself is wholly naked of all vegetation aside from a few scattered bunches of grass.

Many little ponds in shallow depressions without outlet were seen on the mesa. Further reference will be made to this mesa in the chapter on the area of the Mora River.

SECTION II.

THE REGION BORDERING ON CIMARRON CREEK.

Cimarron Creek, formed in Moreno Valley by the union of Moreno and Cieneguilla Creeks, flows eastward through a succession of cañons to the plains and thence to the Canadian River, which it reaches at two miles above the head of the Canadian Cañon. It receives Cimarroncito and Rayado Creeks from the south and Poñil Creek from the north.

In the plains the Cimarron flows through the Colorado shales and limestones, of which almost continuous exposures exist from the river up to the mouth of Rayado Creek. The limestones are well shown near the Canadian, and they remain constantly in sight until within two miles of Blackman's Ranch, where, on some curiously eroded hills, the highest bed of limestone is seen underlying a black fissile shale. The exposures have but slight vertical extent and afford no basis for accurate measurement, but the dip of the rocks and the fall of the stream lead to the estimate that this subgroup, No. 3, is about 700 feet thick. From this locality to the mouth of Cimarron Cañon exposures of No. 4 occur occasionally in the creek's banks and in low mesas on the plains. These shales are fissile at the base, but higher up they become sandy with thin beds of sandstone. Overlying these are dark-brown and occasionally drab shales with irregular layers of bright-yellow sandy limestone and some concretions, while toward the top, as exposed along the face of the bluff fronting on the plains, the concretions become large, numerous, and are arranged in regular lines. Both No. 3 and No. 4 are more or less fossiliferous throughout. The thickness of No. 4 could not be determined with certainty, for there may be a slight anticlinal at three or four miles below Cimarron. But this subgroup is not far from 1,800 feet thick on the Cimarron.

RAYADO CREEK enters the Cimarron at fifteen miles from the Canadian River. The conditions in the plains along this stream are similar to those observed on the Cimarron above Blackman's Ranch, only the shales of No. 4 being exposed, as the channel-way is not cut deeply enough to reach the lower divisions of the Colorado group. Just south from this stream and east from the stage-road are two mesas, known as the Gonzales and Rayado Mesas, outlying fragments of the great Ocaté Mesa, which have a thick basalt cap resting on the shales of No. 4. The creek itself flows from a deep recess in the Ocaté Mesa leading to a dismal cañon, which has not been explored with sufficient care to justify detailed description.

URRACA CREEK rises in the Cimarron Range at the base of Black Peak and enters Rayado at eight miles east from the stage-road. Low mesas of No. 4, covered with recent conglomerate, were seen between the streams, while near the mountain is a large mesa resembling those beyond Rayado Creek.

The Cretaceous shales continue on both streams to the base of the mountain, where they are cut off by a broad dike of rhyolite (?), containing blotches of sanidin with some mica and hornblende. The Archæan rocks are reached at the headwaters of both creeks, for pebbles of gneiss and quartz are abundant in the terraces; but no exposures could be found on Urraca Creek and the cañon of Rayado was not fairly explored. The sandy shales near the base of No. 4 are reached at nine miles south from Rayado Creek and they remain in sight thence to beyond Bahia. At the mouth of the first cañon north from Bahia some extensive ponds were seen, all strongly alkaline and without outlet.

CIMARRONCITO CREEK also has its source at the base of Black Peak and enters the Cimarron at two miles below Cimarron. It flows for several miles above its mouth on the side of a broad trough in which are some mesas of Upper Colorado shales; but just west from the stage-road it emerges from a broad, well-defined basin, which is separated from the mountains by a long narrow wall of rhyolite (?) reaching quite to Black Peak. A series of similar dikes, passing across the head of the basin in a north-

northwest and south-southeast direction, is continuous from Old Baldy Mountain to the cañon of Rayado Creek. The north wall of the basin is a bluff of Laramie rocks resting on Upper Colorado shales, and breaks down eastward until, at little more than two miles above Cimarron, only the Cretaceous shales remain. This strip of Laramie is the southern termination of the great Colorado-New Mexico coal-field, which stretches unbroken from this locality to the Denver and Rio Grande Railroad, passing up Cucharas Creek. Hills of Cretaceous shales occur in the Cimarroncito Basin, and the shales reach to the dikes, behind which there are no exposures except of igneous rocks; and another series of dikes exists farther up in the mountains. But there can be no doubt that Archæan and Dakota rocks are reached by the stream, for pebbles from both series are plentifully distributed in the terraces; but no fragments of Carboniferous rocks were discovered.

CIMARRON CREEK issues from a cañon in the Laramie rocks which opens at about two miles above Cimarron. The ridge separating this stream from the Cimarroncito is very narrow at the east, but owing to the divergence of the streams it widens rapidly westward. Northward, to Poñil Creek, the bluffs facing the plain are deeply indented, and show about 250 feet of Laramie rocks resting on an equal thickness of Colorado shales. The shales remain in sight along the Cimarron to about four miles above the mouth of the cañon, where the creek-bed at length rises to the Laramie rocks. The concretions in the upper portion of the shales are exceedingly abundant and are crowded with fossils, among which *Inoceramus* and *Baculites* seem to be the most abundant.

The Laramie rocks, though apparently well shown along this cañon for twelve miles, give absolutely no sections, and they run out at the west just below Ute Creek. At about five miles above Cimarron the blossoms of the *Dillon*, *Trinidad*, and *Willow Creek coal-beds* were seen at forty and eighty feet apart, but all of the beds seem to be very thin and no effort has been made to ascertain their economic value. Only sandstones were found above this all the way to Ute Valley, though at one place slight indications of a *coal-bed* were seen; but its position in the section could not be ascertained. An attempt was made to obtain a section on the northeast side of Ute Valley, but nothing except sandstones is exposed there and the intervals are hopelessly concealed. The sandstones are much coarser than on the east side of the area and bear close resemblance to the Dakota sandstones exposed in the Stonewall, described in a former chapter. The lowest sandstone exposed is evidently that which overlies the *Lower Vermejo coal-bed.*

Ute Creek, heading in Old Baldy Mountain, enters the Cimarron at about twelve miles from Cimarron. It flows through Ute Valley, a pleasant little park eroded from the Colorado shales and the lower rocks of the Laramie group. Its northeastern wall is a bluff of Laramie sandstones, and the Baldy Mountains rise on the southwest side. At the base of Little Baldy the Laramie sandstones are dipping northeast at 30°, but farther north these are covered by trachyte, of which dikes have been thrust out almost to Ute Creek. The valley is terraced and is littered with fragments of trachyte, of sandstones belonging to the Lower and Upper Cretaceous, and of metamorphosed shale from the Colorado group.

A broad dike appears above the forks of the Ute Creek, but it is not shown in the park. It remains in sight along the road leading up the creek, until at a short distance below the old Aztec mill it is crossed by the road and soon after passes into Old Baldy. An exposure of Upper Dakota sandstone occurs near the forks of the creek, but the rise in the road is so much more rapid than that of the rocks that one soon comes to the Colorado shales, which remain in sight until the foot of Old Baldy is reached.

On a ridge extending southeastward from Old Baldy several small dikes cut the Colorado shales. Some of these contain many fragments of gneiss, while in others there are fragments of a very silicious limestone or slightly calcareous sandstone, which are not unlike a bed seen in the Carboniferous farther west.

The Colorado shales, as far as exposed here, vary from drab to dark-brown, and evidently belong to the base of No. 4. Ferruginous concretions are numerous in the upper parts, but the fossils are indistinct. Many layers of sandstone from one to seven feet thick were seen high up on the mountain, and these are clearly interstratified with the shales.

The exposures are indefinite, while layers and dikes of trachyte are so interwoven with the shales that not even an approximate estimate of thickness can be made.

The dikes have exerted an unusual amount of metamorphic influence in the neighborhood of Old Baldy, for the shales at some places have been converted into slates with regular cleavage, while the purer sandstones are often quartzite, and the micaceous sandstones in the altered condition resemble gneiss so closely that one, examining only hand specimens, might easily be deceived. The miners on the mountain stoutly maintain that this rock is true granite.

The Old Baldy district was at one time an important mining region, extensive operations having been carried on both in gulch and quartz mining. At present, however, little is doing. Two companies are engaged in hydraulic washings on the creek, but the gravels are so poor as hardly to pay fair wages. The supply of water is ample, and the descent is so rapid that one need carry water but a short distance in order to obtain a fall of 100 feet. Much prospecting has been done near the mouth of the creek, and at one time extensive operations were contemplated; but the poverty of the gravels evidently necessitated early abandonment of the work. In the lower claim, where hydraulic work is now carried on, the whole detrital deposit is washed down, and for some time it has proved to be quite lean; but before the present owners obtained possession one thin layer yielded enormously, though now it is utterly worthless.

The "quartz" mines, to which the region owes its reputation, are on Old Baldy, and occur in the Colorado shales. The Aztec, on the east side of the mountain, is the oldest and by far the best known. It was worked many years ago by Maxwell, the inheritor of the celebrated Bovien grant, and under his management it proved very profitable. The ore was reduced in a fifteen-stamp mill and the yield during one week reached $15,000 in fine gold. But the mine seems, to all intents and purposes, to have been worked out before it passed from Mr. Maxwell to the English company now owning it, as it was soon abandoned by that concern, and for years it has been worked by a squatter. Occasionally the ore is good for a little while, but the pay portions are insignificant compared with those which are worthless, so that the money made from a rich pocket is soon spent in dead work. Several other mines are worked in a small way, and the ore from the whole district is reduced in three arrastras with a total capacity of not far from two and a half tons per diem.

No contact deposits were observed between the dikes and the shales; and the ore seems to be in streaks between the thin sandstone layers which, as already mentioned, are often thoroughly metamorphosed. Everything looks as though, during the disturbance attending the formation of the dikes, the beds had been forced apart, so that permanent crevices were made in which the gold was afterward deposited. Some of the streaks have considerable extent, lateral as well as vertical, but they are by no means regular. The ore is obtained in a promiscuous manner, and systematic mining seems to be impracticable. The Aztec mine covers several acres and "shafts" are very numerous. A similar condition exists at the other old mines, but attempts have been made to do the work more systematically at some of the newer ones. The degree of success is not wholly encouraging.

Native copper and malachite are by no means rare, and not a little oxide of copper has been found in the shales. Small nuggets of gold have been obtained away from all contact with the sandstones and apparently away from all signs of crevice. Gold is said to occur in the dike at the Montezuma mine. In all cases the metal occurs in pockets and the quantity is uncertain. Possibilities exist that good and rich mines may yet be found here, but the probabilities are altogether against permanence, and one may not speak hopefully respecting the future of this district.

The Cimarron emerges from a second cañon immediately above the mouth of Ute Creek. The Laramie sandstones are shown at the mouth of the cañon in a wall dipping northeast at nearly 30°. This wall extends southeastward, but does not seem to reach Cimarroncito Creek. The sandstones remain in sight for a mile or more up the cañon; but at the entrance they are cut by a trachyte (?) dike, while farther up they are covered by an overflow of the same rock.

The great trachyte dike is practically continuous along the creek for fully two miles, as it is broken at but one point, where for a few yards the Cretaceous sandstone is shown. The rock is light-gray, with blotches of feldspar and crystals of hornblende and mica, and is typical of the great mass capping the Baldy Mountains as well as others south from Cimarron Creek. Many dikes issue from this, some of which extend northward into the area of the Rio Grande. Where the dike forms the wall of the cañon, the space is very narrow and the wall reaches from 400 to 1,800 feet above the bed of the stream, showing a serrated top which bristles with rude architectural forms, while the face is jagged with prismatic columns protruding as pilasters.

The cañon widens materially above this dike, and a long bench of metamorphic rocks with almost level top is thrust out from the north wall. This Archæan exposure continues for fully four miles along the creek. Gneiss prevails, but there are beds of quartzite and not a few blotches of feldspathic granite. The gneiss is dark and is often coated with a dull yellow lichen. Petty dikes of basalt form a complicated network on the face of the cliff. This rock varies in texture, for in some of the dikes it bears the exposure well, while in others it breaks down quickly into a coarse sand. The color of the weathered surface is dull reddish-brown, and the rock usually has a pitchy look, which avails nothing toward relieving the gloom of the cañon.

Below the western edge of this Archæan exposure the trachyte overflow rests on the upper surface of the Archæan, and for no small part of the distance the line of contact between the two series is practically horizontal. The effect is picturesque, for the cathedral-like capping mass contrasts strangely with the dark gneiss, which in its weathering has given a less irregular wall.

Another large dike is reached at barely two miles from the head of the cañon. In composition it resembles the other, but is softer and yields more readily to the weather, so that a little park has been eroded whose north wall is covered with variegated *débris*. This dike continues for somewhat more than a mile along the stream and ends sharply against the Archæan rocks, which, if that were possible, are even more gloomy in appearance than are those seen lower down the stream. A very fine-grained compact gneiss prevails, which often resembles quartzite, is almost wholly free from hornblende, and splits readily along three planes. The cañon closes quickly when this rock is reached, and the walls surpass in ruggedness anything shown in other portions of this, which in many respects is the finest cañon in the Spanish Ranges east from the Rio Grande.

Passing this narrow area of Archæan, one reaches the head of the cañon and enters the Moreno Valley, where the Cimarron is formed by the union of Moreno and Cieneguilla Creeks.

Moreno Creek is formed about three miles above Elizabethtown by the union of three small streams. Its north or main fork heads against Comanche Creek, a tributary to Costilla Creek, and flows for the most part in a narrow cañon cut in Archæan rocks, which near the mouth of the stream are terraced and covered with water-worn fragments. Three miles up this stream Cretaceous rocks were seen dipping westwardly and within a few yards of extensive Archæan exposures, which are shown high up in the hills on both sides of the stream. Evidently the Cretaceous rests directly on the Archæan. Several narrow dikes of trachyte are crossed by the creek, which seem to be continuous with similar dikes on Poñil Pass.

The rocks on the west branch of this little stream are ill-exposed, but such as were seen are Archæan with broad bands of white quartzite. The exposures on the east branch are somewhat better and show the rocks to be Archæan quite to its head; but these are occasionally cut by dikes belonging to the Baldy series. This branch heads east from the line of the Dakota Stonewall, but neither in the pebbles nor in the exposures could any traces of that sandstone be discovered. Nor is there any evidence that Carboniferous rocks exist on this stream.

The West Fork of Moreno Creek heads near Red River Pass and flows in a deep narrow cañon to near its union with the North Fork. Coarse gneissoid granite with narrow bands of quartz prevails at the mouth of its cañon, and as far up as the second forks only Archæan rocks are shown. Much silvery micaceous schist was seen, in which are occasional bands of dark gneiss. A narrow dike of mottled trachyte was crossed at the second forking, and at the next above is a wider dike containing both blue and green mottled trachyte in which are large crystals of feldspar, many of them twinned. A broad dike of coarse rock, containing large blotches of sanidin, crosses at the summit of the pass, and seems to be continuous with the dikes crossing the divide between Lucero and Colorado Creeks on the east side of Taos Peak. The gneiss in this cañon is often mottled with blotches of silvery mica, and the schists are many times handsomely waved. The gneiss is compact, and the little mica in it is arranged in film-like layers.

The East Fork of Moreno Creek, which is short, heads near Poñil Pass and flows with rapid fall to its junction with the other forks. It crosses several dikes of trachyte and andesite (?) extending from Old Baldy, some of which are clearly continuous with dikes seen on the North Fork. Between these the Colorado shales are shown in fragmentary exposures, and near the mouth of the stream the Archæan rocks are occasionally thrust through the Quaternary.

A park begins with Moreno Creek, in which the Quaternary reaches far toward the crests of the mountains on both sides. Several insignificant tributaries enter the creek above Elizabethtown, but these expose only Archæan rocks. This park becomes narrow almost directly below Elizabethtown, and dikes from Old Baldy reach to the stream, while some of them pass beyond it into the dome-shaped hill south from the town. This hill is thoroughly composite, for on its southern face the Lower and Middle Cretaceous rocks are entangled among dikes, while on the crest is a plate of, probably, Laramie sandstone dipping at 10° toward the east-northeast and coming down to Moreno Creek at somewhat more than a mile and a half below Elizabethtown. From this point to Elizabethtown the hill is a congeries of dikes whose direction could not be made out, as the surface is mostly buried under fragments of trachyte. This seems to be the southern limit of dikes extending from Old Baldy into Moreno Valley. The exposures on the east side of the valley south from Elizabethtown are very poor, but dikes are numerous, and between them are insignificant exposures of the Middle Cretaceous. The limestone of No. 3

is shown in a side-cutting at little more than a mile below the town, and there contains *Ostrea* and *Inoceramus*.

Moreno Valley proper begins below this narrowed space and continues to the head of Cieneguilla Creek. Its rocks for the most part are deeply buried under Quaternary deposits.

The hill immediately south from Elizabethtown has good exposures on its southern side, where it looks on a small tributary to Moreno Creek. A broad dike of mottled trachyte running almost east and west through this hill has entangled the Dakota sandstone and the Colorado shales so as to throw them into all conceivable positions, and finally the distortion is complete when, by a downthrow fault, the Dakota sandstone is tossed into a vertical position so as to abut against earlier rocks which appear to be undisturbed; but north from this fault the sandstone is shown near the crest of the hill dipping eastward.

The little stream makes a cañon in passing by this hill, which opens at its head into a park, where reddish shales and sandstones are shown dipping toward the northwest. A wide double dike crosses this park from east to west, as though it came from Old Baldy; but the rock is unlike anything seen in that group of dikes. One portion is a porcelaineous white rhyolite with small specks of sanidin, while the other is a dull dark rock with large crystals of feldspar and large tears of sanidin. Neither dike contains fragments of the rock making up the other.

Following this stream into the mountain one comes to the Archæan rocks at not more than half a mile from the mouth of the small east and west fork. The Archæan is represented by coarse gneissoid granite, weathering into architectural forms. A clumsy conglomerate rests on the granite, dipping southeast, and containing fragments of gneiss, granite, and quartzite. Above this and separated from it by a concealed interval of 125 feet is another and similar conglomerate, containing in addition fragments of a blue, hard, non-fossiliferous limestone. The presence of these fragments indicates the existence of a limestone bed between the conglomerates. Northward the stratified rocks are carried out by their strike, so that beyond Elizabethtown only Archæan rocks occur.

No definite data respecting the age of these conglomerates could be obtained, but they resemble closely the coarse rocks in the upper part of the Carboniferous on the east slope of the Culebra Range, so that the whole series exposed in this little park most probably belongs to the Carboniferous.

Exposures are not of too frequent occurrence southward from this stream along the west side of the valley; but on the second wooded hill north from Six-mile Creek, a tributary to Cieneguilla Creek, the Dakota sandstones are shown dipping gently east-northeast. Below this no rocks are shown, but in the rounded point immediately south there is an exposure of Carboniferous rocks showing them to be dipping very sharply westward, while north from the hill, between it and the first water-course, several exposures of Carboniferous limestones were seen, also dipping westward. As the dip of the Carboniferous must be the same in the hill as it is on both sides, there seems to be no good reason to doubt that the Cretaceous and Carboniferous are not conformable.

Cieneguilla Creek heads against Coyote Creek, a tributary to Mora River, and flows northward to the head of Cimarron Cañon, where it unites with Moreno Creek. It receives few tributaries, the most important being Six-mile Creek, entering from the west at about seven miles south from Elizabethtown, and American Creek, entering from the east at about five miles from Cimarron Cañon.

Ascending Six-mile Creek, one soon reaches an exposure of the Dakota sandstone dipping almost northeast at somewhat less than 10°. The rock is soft, yellowish-gray, and varies from very fine to very coarse. It continues in sight until more than a mile above the saw-mill, where it breaks off and one finds himself in the Carboniferous rocks, the fault being distinct. (See Fig. 3, page 54.)

The Cretaceous rocks are shown in contact with those of the Carboniferous. The rock at the base of the latter is a compact sandstone twenty feet thick, on which rests a thin granular limestone, gray but weathering blue, containing only indistinct fossils and, like the sandstone, dipping at almost 40° toward the west. The Carboniferous sandstone is somewhat metamorphosed, but the Dakota sandstone is wholly unaffected.

Following up the ridge on the north side of the creek one finds reddish sandstone containing coarse beds and some shales, the dip rapidly increasing until it becomes almost vertical. No other rock appears until, at some distance farther up the stream, a cherty limestone, thirty-five feet thick and dipping northeast at 30°, is reached. This dip seems to exist at the edge of the creek, but the rock mounts the ridge so quickly that the dip must be somewhat greater, as indeed is evident from the extreme dip of the rocks seen farther up the ridge. From this point the eastward dip is constant. Crinoidal stems are common in the cherty limestone, and the more calcareous layers are covered with a delicate *Fenestella*, which, however, is usually injured by weathering. The slaty layers contain *Athyris subtilita* and *Productus cora.*

A very hard blue limestone eight feet thick, and directly underlying a quartzite, was found farther up the ridge and from 150 to 200 feet below the last, the interval being filled with reddish-brown sandy shales which show root-like markings. This limestone is full of cleavage planes and breaks so badly that a fresh surface showing the color is obtainable only with the utmost difficulty. No fossils aside from a single valve of *Spirifer lineatus* could be procured from this rock, though the weathered surface shows it to be full of bryozoans and exhibits many sections of *Productus* and *Athyris.*

At about 600 feet farther up the ridge, the interval being wholly concealed, a gray limestone was seen, of which sixty feet are exposed. It is materially altered and much of it is almost saccharine. Streaks of calcspar and limestone pebbles converted into calcspar are common. The rock is evidently richly fossiliferous, but, unfortunately, the fossils are not silicified and no perfect specimens were obtained aside from a few individuals of *Athyris subtilita.* Fragments of *Productus semi-reticulatus,* of a *Spirifer* allied to *Spirifer rockymontani,* and of a *Fenestella,* were broken out. The dip is not less than 40°.

Only reddish shales with thin-bedded coarse sandstones occur below this limestone until a fifth limestone is reached, which bears some resemblance to the second, but is light-gray on the freshly exposed surface. It is crowded with bryozoans and spines of *Productus,* but the specimens are not silicified, and nothing was obtained except one indistinct univalve. Behind this to the crest of the divide only occasional exposures of coarse sandstones were seen.

Mr. Russell ascended to the crest of the divide, following up a ridge which separates the forks of Six-Mile Creek and becomes the divide between Lucero and Colorado Creeks—streams leading to the Rio Grande. Immediately beyond the divide he found the following section:

	Feet.
1. Gray sandstone	5
2. Limestone with fossils	8
3. Red and gray sandstone and shale	30
4. Brown sandstone with fine micaceous layers	40
5. Gray limestone with fossils	10
6. Coarse gray sandstone with pebbles	150
7. Reddish sandstone	100
8. Fine thin-bedded micaceous sandstone	350
Total	693

This section is on the west side of the Mora fault, and the rocks are dipping west at 20°.

Coming down the ridge, he found a gray to bluish-gray, compact to granular limestone, twenty feet thick, and dipping east-northeast. No further exposure was found until, at 870 feet lower down the mountain face, a brown sandstone was seen fifteen feet thick and resting on a gray limestone of which fifteen feet were exposed. This rock dips east-northeast at 35°, and is evidently the limestone seen on the north side of the creek, the structure being the same and only perfect fossil found being *Athyris subtilita*. There is some room for supposing this to be the same with the limestone seen near timber-line. At 915 feet lower down the ridge he observed a limestone, gray on fresh surface, full of obscure shells and bryozoans, in all respects resembling the limestone on the opposite side. No further exposures were found below this to the forks of the creek except fragmentary outcrops of sandstone and conglomerate.

Archæan pebbles occur in such numbers along Six-mile Creek that I supposed the stream has its source amid Archæan rocks. But I ascertained that they are derived from a coarse conglomerate which is shown at the head of the creek.

An exposure of Dakota sandstone was observed near the Taos road at about two miles south from Six-mile Creek, and at a little way farther south is an exposure of the Archæan rocks. Several exposures of the Archæan were seen in the road at somewhat more than four miles south from the creek, and between them is a fragmentary exposure of Dakota sandstone. Many small patches of Dakota were found west from the road, the largest being on the first stream south from Six-mile Creek. In all cases these rest directly on the Archæan. Exposures of Archæan are given on a stream entering from the west at a little above the mouth of the American. These, which begin almost immediately west from the Taos road, have an almost northwest and southeast strike. Fragments of the conglomerate at the base of the Carboniferous are very numerous on the hills above the Archæan, but no connected exposure could be found. From this point until within a short distance of the cañon leading up to Taos Pass one rides almost continually upon the Archæan rocks, of which, however, there are but few good exposures. But nearer the cañon reddish shales are shown, which closely resemble those seen on Six-mile Creek above the fault. Exposures are much broken in the cañon and no exact measurement could be made.

Not far from the junction of the Taos road with that leading up the valley some yellowish-brown sandy shales are shown dipping north-northeast at about 50° and resting on a flaggy sandstone. This exposure continues along the road for nearly half a mile. A little valley intervenes between this and the next exposure, which is a cherty limestone, thirty to forty feet thick, containing *Spirifer cameratus* and other characteristic Carboniferous fossils. At probably half a mile farther up the pass is a gray limestone, nearly 100 feet thick, more or less crystalline, and containing imperfect fossils. This is the gray limestone seen on Six-mile Creek. Between it and the summit are massive and shaly sandstones interstratified with shales. An exposure near the summit seems to suggest a compressed anticlinal, there being a very sharp curvature in the rocks, but the exposure is fragmentary and possibly the condition may be due to a slide. A thin light-blue limestone with *Spirifer plano-convexus*, *Athyris subtilita*, and *Lophophyllum proliferum* occurs immediately on the summit. Other species were observed, but as the fossils are not silicified the species could not be identified. Beyond this are coarse sandstones, reaching to the head of Ferdinand Creek on the southern side of the pass. The dip throughout is toward the north-northeast and varies from 40 to 80°, increasing toward the summit of the pass.

Almost everything is concealed on the mountain slope south from the Taos road to the divide between Cieneguilla and Coyote Creeks, but on the east side of the valley the Archæan rocks are shown at the head of Cimarron Cañon, and occasional croppings of the same rock are seen southward up to some distance above the mouth of American Creek. Patches of Dakota sandstone are shown on American Creek and along the trail leading to Urraca Creek, which rest directly on the Archæan, while not far south from American Creek is a large area of the same sandstone, evidently resting also on the metamorphic rocks. Beyond this southward a rim of basalt approaches the valley, and the east wall, beginning at Agua Fria Peak, becomes the edge of a mesa.

The valley itself is covered with a coat of Quaternary from two to twenty-five feet thick, but here and there within two miles of the divide from Coyote Creek many exposures of Middle Dakota shale were found, in all of which the dip is very sharp and toward the south of west. These shales are occasionally exposed on the east side at the foot of the hill, while higher up the coarse Upper Dakota sandstone is shown dipping southwestward at barely 10°. Exposures of Upper Dakota sandstone are by no means rare on the west side of the road south from the forks. No connected exposures could be found on the slopes leading up to Agua Fria Peak, but occasional exposures of Upper Dakota show that that group reaches far toward the summit.

At one time gulch-mining was carried on extensively in the northern part of Moreno Valley, for soon after Moreno district was organized it had 10,000 inhabitants and Elizabethtown was a brisk trading center. Excellent roads were constructed to Cimarron, Colorado, Taos, Fort Union, and Trinidad. But the district has lost its importance and is now utterly insignificant. At first the many petty streams flowing down from the mountains yielded a liberal supply of water, but for some reason as yet unascertained the springs feeding those streams failed and free water can no longer be obtained. A ditch, forty-seven miles long, was constructed, leading from the head of Colorado Creek near Taos Peak, and minor ditches have been taken out of the North and West Forks of Moreno Creek as well as from the stream entering below Elizabethtown, but the supply is insufficient and comparatively little mining is done. Willow Creek, below Elizabethtown, affords an uncertain supply for some small operations.

It is unfortunate that this insufficient supply is all that can be obtained, for the gravels in the northern part of the Moreno Valley are very rich, and in the earlier days many claims proved valuable. It is asserted that one firm, now engaged in hydraulic mining, obtains $15 a day for each hand employed.

Some have supposed that if water could be obtained the gravels along Cieneguilla Creek might be worked to profit. No effort has been made to test this matter, but the probabilities are against any such supposition. The gold evidently comes from the disturbed area on the west slope of the Baldy Mountains, which practically ends at Cimarron Cañon. Trachyte frequently contains more or less of gold, and possibly some paying gravels may be found along American Creek, which heads in among the dikes issuing from the Baldy Mountains. There seems to be little likelihood of profitable working anywhere else along Cieneguilla Creek.

Poñil Creek rises in the Laramie area and enters the Cimarron at eight miles below Cimarron. It flows in the plains through the shales of Cretaceous No. 4, of which occasional exposures are given in its banks as well as in low mesas between this stream and the Cimarron. The creek is formed at six miles from the plains by the union of the Main and South Forks, and the Colorado shales remain above the stream almost to that place. The lower rocks of the Laramie group cap the bluff facing the plain, and the higher members of that group are shown toward the head of the main creek.

The upper part of the Colorado group is exposed in the bluff from Cimarron Creek to Poñil, as well as to Cerososo Cañon farther north, which may be regarded as a tributary to Poñil. These shales are richly fossiliferous for more than 100 feet from the top, and at one locality on Poñil Creek I obtained from them *Ammonites placenta*, *Inoceramus*, and other species characteristic of Cretaceous No. 4. The same species occur also on the bluff between Poñil and Cimarron Cañons.

The exposures of the Laramie group along Poñil Creek are almost as unsatisfactory as those on Cimarron. The *Dillon coal-bed* has been mined to some extent in a cañon entering from the south at about a mile below the forks of the creek, but when visited the opening was in bad condition and the exposure was too imperfect to admit of measurement. A great mass of dark shale with thin streaks of *coal* was seen, but the workable part of the bed seems to be little more than three feet. The blossom of the *Trinidad coal-bed* was seen farther up the cañon, but above that no section could be made, the only exposure being that of the *Lower Vermejo coal*. The sandstone overlying that bed contains indistinct impressions of a *cardium*-like shell similar to that discovered in the *Halymenites sandstone* near the mouth of the cañon, where that rock contains also fish-teeth and abundance of the fucoid *Halymenites major*.

The *Dillon coal-bed* has been opened near the forks of the creek, but the *coal* is inferior to that from the opening already referred to and is no longer digged. No exposures of coal-beds were seen on the hill at this locality.

The Laramie sandstones are well exposed on the north fork of the creek, but even blossoms of *coal-beds* are so rare that the section could not be carried. A narrow dike crosses the stream just below the Elizabethtown road. Poñil Park, near the head of the stream, is a curiously eroded area extending to the base of the foot-hills, which contains several lakelets without outlet. There are numerous wooded hills of Laramie rocks, but they afforded no material for either measurement or identifications.

The foot-hills separating this region from that of South Poñil Creek are made up of Laramie rocks, broken by several trachyte dikes, which stand out as bold walls with serrated crests and belong to the Baldy series.

SOUTH POÑIL is formed by the union of several branches, some heading near Costilla Peak, others on the sides of Old Baldy. No examinations were made along this stream except in the vicinity of the Trinidad and Elizabethtown road. On that road one rides constantly among Laramie rocks from Poñil Park to the summit of Poñil Pass. The sandstones are very coarse, and at the summit of the pass they hold thick layers of large pebbles. Many dikes are crossed by this road, all of which issue from Old Baldy.

SECTION III.

THE REGION BORDERING ON VERMEJO CREEK.

Vermejo Creek rises in the Culebra Range and runs irregularly south of east through the Laramie area and the plains to the Canadian River, receiving on the way Leandro, Rock, Blattmer, and some other small streams from the south, and Caliente with some insignificant tributaries from the north. Van Bremmer Cañon, immediately south from that of the Vermejo, contains a petty stream which sinks before reaching the plain, but its arroyo leads to the Vermejo.

In the plains, Vermejo Creek flows through the shales of Cretaceous No. 4, which are exposed there in numerous mesas; they remain above the creek to about four miles above the stage station. The following section was obtained where the *Halymenites sandstone* first comes down to the creek:

Vermejo Creek, 1, (Fig. 29.)

	Feet.	Inches.
1. Sandstone	95	0
2. *Upper Vermejo coal-bed* (G)	1	0
3. Shale	5	0
4. Sandstone	31	0
5. Imperfect exposure	24	0
6. Sandstone	44	0
7. Concealed	16	0
8. *Lower Vermejo coal-bed* (F)	1	0
9. Sandstone	9	0
10. Drab shale	4	0
11. Black shale	3	0
12. *Coal-bed* (E″)	0	6
13. Red shale	2	0
14. Sandstone	1	6
15. Drab shale	2	0

	Feet.	Inches.
16. Black shale	1	0
17. *Coal-bed* (E′)	1	6
18. Imperfect exposure	11	0
19. Sandstone	17	0
20. Concealed	2	0
21. *Upper Reilly coal-bed* (E)	1	6
22. Variegated shale	41	0
23. Sandstone	1	4
24. Concealed	5	0
25. Sandstone	16	0
26. Shale	6	0
27. *Willow Creek coal-bed* (C)	Blossom.	
28. Shale	11	0
29. Imperfect exposure	42	0
30. *Coal-bed* (B′)	1	0
31. Imperfect exposure	11	0
32. Black shale	1	0
33. Imperfect exposure	29	0
34. *Trinidad coal-bed* (B)	Blossom.	
35. Shale and thin sandstone	19	0
36. Black shale	1	0
37. Imperfect exposure	25	0
38. *Dillon coal-bed* (A)	3	6
39. Blue shale	1	3
40. *Halymenites sandstone*	90	0
41. Brown shale and sandstone	30	0
Total	619	9

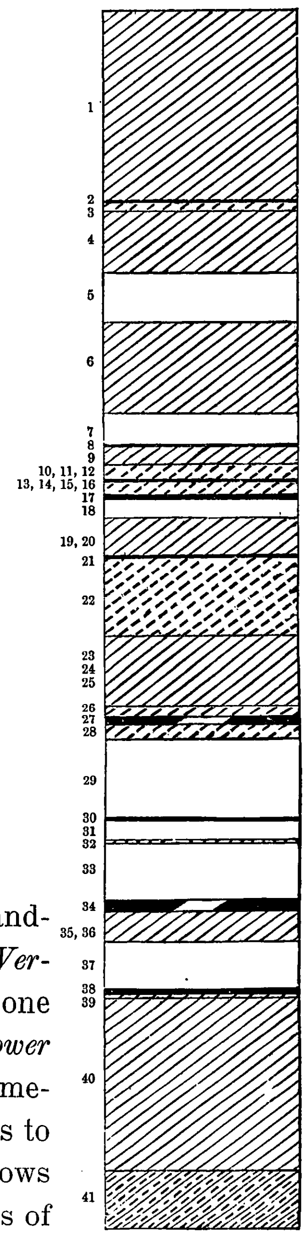


FIG. 29.—*Vermejo Creek*, 1.

No. 1 caps the bluff and is the persistent sandstone which almost invariably overlies the *Upper Vermejo coal-bed.* Nos. 4 to 7, inclusive, are no doubt one mass, the equally persistent sandstone above the *Lower Vermejo coal.* No. 4 contains some ferruginous limestone, which is impure, slightly silicious, weathers to dull-yellow, and contains no fossils. No. 19 shows pebbles of milky quartz with many large concretions of clay iron-stone. A six-inch bed of apparently very fair ore occurs in No. 22.

The coal-beds are all imperfectly shown and the thickness of several of them may vary materially from what is given, as the estimates were made from blossoms or from such exposures as could be digged out with the hammer. The abrupt breaking up of coal-beds is well shown by a comparison of the section just given with the following, which was obtained at barely half a mile farther up the stream:

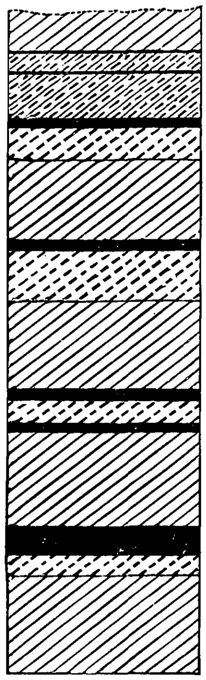


FIG. 30.—*Vermejo Creek*, 2.

	Feet.	Inches.
1. Sandstone	–	–
2. *Coal-bed*	0	6
3. Sandy shale	5	0
4. *Coaly* shale	0	10
5. Sandy shale	11	0
6. *Coal-bed*	2	3
7. Shale	8	0
8. Sandstone	20	0
9. *Coal-bed*	Blossom.	
10. Shale	16	0
11. Sandstone	22	0
12. *Coal-bed*	2	10
13. Red shale	6	0
14. *Coal-bed*	2	0
15. Shale and sandstone	24	0
16. *Dillon Coal-bed*	7	9
17. Shale	5	0
18. *Halymenites sandstone*	25	0
Total	158	2

In this section No. 6 shows—

	Feet.	Inches.
1. *Coaly* shale	0	10
2. Shale	1	0
3. *Coal*	0	5

And No. 11 has two benches of black shale, each one foot, with ten inches of coal between them. The *Dillon coal-bed* is seriously broken up, showing—

	Feet.	Inches.
1. *Coal*	0	4
2. Clay	1	2
3. *Coal*	1	2
4. Clay	0	6
5. *Coal*	2	6
6. Black shale	2	0
7. *Coal*	0	1

The *Upper Vermejo coal-bed* is shown at half a mile below the first creek entering from the north, but the exposure is imperfect, as a mass of sandstone has slidden down over it. A block of the coal, thrust out by the slide, shows the bed to be not less than two feet six inches thick. The *Lower Vermejo coal-bed* is well exposed at 90 feet below it, one foot thick and embedded in dark shale.

The following section was obtained at two miles below the mouth of Caliente Creek:

	Feet.	Inches.
1. Concealed	200	0
2. Sandstone	24	0
3. *Coal-bed* (I)	0	2
4. Shale	1	10
5. Sandstone	23	0
6. Concealed	13	0
7. Limestone	1	0
8. Imperfect exposure	60	0
9. *Cat's Claw Cañon coal-bed* (H)	0	2
10. Sandstone	100	0
11. Shale	11	0
12. *Upper Vermejo coal-bed* (G)	0	4
13. Sandstone	50	0
Total	484	6

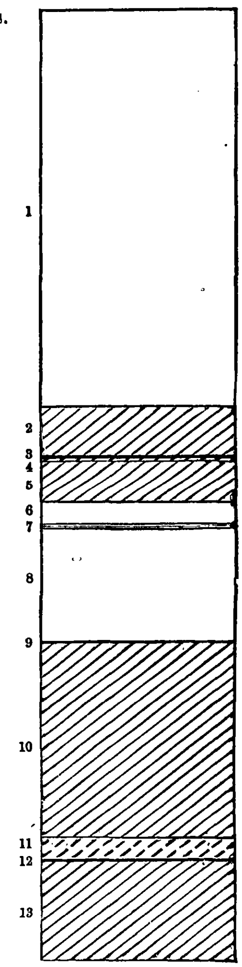


FIG. 31.—*Vermejo Creek*, 3.

The sandstone No. 13 is bold and cliff-like here, but at a little way farther down the creek it is much shattered. The coal-beds of the section are fully exposed and the thickness is as given. Three inches of fire-clay underlie *Coal-bed* I. The limestone is similar to that seen lower down the creek and seems to be somewhat irregular.

The section from No. 5 to No. 8, inclusive, is shown to be almost wholly sandstone at an exposure farther up the cañon. Limestone layers are numerous, but they yield no fossils. The rock is always dark-blue on the fresh surface, but weathers rusty-yellow, owing to the presence of much iron. Only the highest sandstone of the section is shown at the mouth of Caliente Creek, the others having passed below the surface. There the road leaves the Vermejo and does not return to it for nearly three miles, in the mean time passing over a summit. The following section was obtained between the mouth of Caliente Creek and the summit:

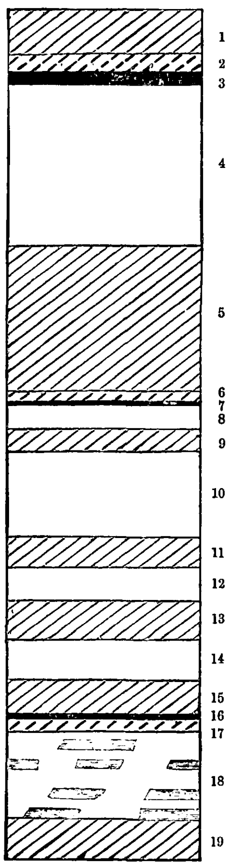


FIG. 32.—*Vermejo Creek, above Caliente Creek.*

	Feet.	Inches.
1. Sandstone	22	0
2. Shale	9	0
3. *Caliente coal-bed* (R)	6	10
4. Concealed	77	0
5. Sandstone, imperfect exposure	77	0
6. Shale	6	0
7. *Cameron coal-bed* (M)	0	4
8. Concealed	13	0
9. Sandstone	11	0
10. Concealed	45	0
11. Sandstone	16	0
12. Concealed	17	0
13. Sandstone	19	0
14. Concealed	22	0
15. Sandstone	17	0
16. *Long's Cañon coal-bed* (J)	1	3
17. Shale	4	0
18. Imperfect exposure, much limestone	45	0
19. Sandstone	22	0
Total	430	5

The *Caliente coal-bed* shows the following structure:

	Feet.	Inches.
1. *Coal*	0	6
2. Sandy shale	4	0
3. *Coal*	0	10
4. *Coaly* shale	1	2
5. *Coal*	0	2
6. *Coaly* shale	0	2

Toward the middle of No. 5 the blossom of *Coal-bed* P is indicated. The *Long's Cañon coal-bed* is double, with benches of three and four inches separated by eight inches of shale.

In descending from the summit one finds the *Cameron coal-bed* falling toward Vermejo Creek, the fall being thirty feet in somewhat less than a mile; at the creek it begins to rise westward, there being a synclinal at the road-crossing. The bed shows an extraordinary expansion here, and at three and a half miles below Cameron post office it is fully exposed in the bluff as follows:

	Feet.	Inches.
1. *Coal*	0	6
2. Drab shale	11	0
3. Black shale	1	3
4. *Coal*	0	4
5. Sandy shale	4	0
6. *Coal*	1	0
7. Shale	5	0
8. *Coal*	0	8
9. Shale	2	0
10. *Coal*	0	4
11. Shale	2	0
12. *Coal*	1	0
13. Shale	1	0
14. Sandstone	1	3
15. Shale	1	2
16. *Coal*	1	4
Total	33	10

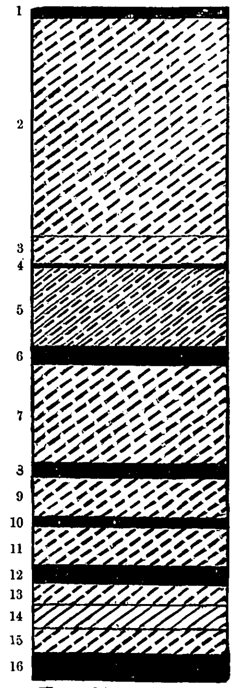


FIG. 33.— *Cameron coal-bed on Vermejo Creek.*

Giving in all five feet two inches of *coal.* The rise in the rocks from this place is rapid to where the road comes in from Blattmer's Cañon; but an anticlinal is crossed there, and thence the rocks descend very gently toward the west. A section was obtained at the crest of the anticlinal, which shows some beds concealed in that already given, and is:

	Feet.	Inches.
1. Sandstone	28	0
2. Gray shale	3	0
3. *Cameron coal-bed* (M)	5	1
4. Concealed	19	0
5. Shale	3	0
6. *Coal-bed* (L)	1	10
7. Concealed	22	0
8. Sandstone	14	0
9. Concealed	17	0
10. Sandstone	12	0
11. Concealed	7	0
12. *Coal-bed* (K)	3	8
13. Shale	10	0
14. Sandstone to creek	5	0
Total	143	7

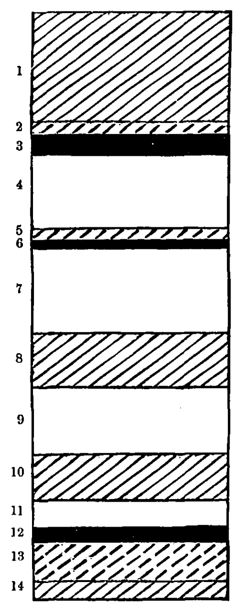


FIG. 34. — *One mile below Cameron post-office.*

Leaf-beds were found in Nos. 1, 8, and 10. The *Cameron coal-bed* shows a very decided shrinking here, its section being—

	Feet.	Inches.
1. Black shale	1	0
2. *Coal*	0	5
3. Black shale	0	8
4. *Coaly* shale, seen	3	0

But there may be more of it in the concealed interval below. *Coal-bed* L has two benches, eighteen and four inches, separated by one inch of clay. *Coal-bed* K, also, is double, the benches being eighteen and two inches, separated by two inches of clay. The coal in these beds is good, but is too thin to be of any economical importance.

The anticlinal is very gentle, amounting to little more than an interruption of the dip, and the rocks are almost horizontal to very near Cameron post-office. The following measurements were made at half a mile below Cameron's:

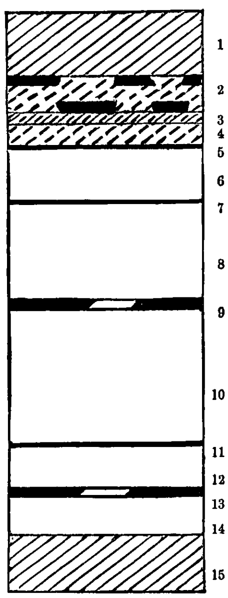


FIG. 35.—*Near Cameron post office.*

	Feet.	Inches.
1. Sandstone	38	0
2. Shale with *Caliente coal-bed* (R)	18	0
3. Shaly sandstone	5	0
4. Shale	11	0
5. *Raton coal-bed* (Q)	1	0
6. Concealed	25	0
7. *Coal-bed*, slaty (P)	1	0
8. Concealed	48	0
9. *Coal-bed* (O)	Blossom.	
10. Imperfect exposure, mostly sandstone	72	0
11. *Cameron coal-bed* (M)	1	8
12. Concealed	22	0
13. *Coal-bed* (L)	Blossom.	
14. Concealed	25	0
15. Sandstone to creek	30	0
Total	292	8

The *Caliente coal-bed* is evidently quite large, but it contains much shale, and the blossom was in such bad condition, owing to recent heavy rains, that no definite measurement could be made. The *Raton coal-bed* is not much thicker than is given, but *Coal-bed* P is a large bed, for it has an extensive blossom above and below the exposure of coal. Very probably *Coal-bed* O is represented here only by black shale, and there may be a coal-bed at ten feet below it, where much black shale was seen. The exposures are very imperfect, and the measurements serve only to indicate the succession of the beds.

The road leading from Elizabethtown to Trinidad crosses the creek at Cameron's. It passes over the summit between the Vermejo and a small tributary at the north, and thence goes to the summit between that tributary and the Upper Canadian. A section was obtained between Vermejo Creek and the first summit, which confirms those already given. It is as follows:

	Feet.	Inches.
1. Sandstone	18	0
2. *Coal-bed* (T)	2	5
3. Shale	13	0
4. *Coal-bed* (S)	0	10
5. Shale and flaggy sandstone	54	0
6. Concealed	9	0
7. *Caliente coal-bed* (R)	Blossom.	
8. Sandstones and shales, not fully exposed	135	0
9. *Coal-bed* (N)	Blossom.	
10. Concealed	25	0
11. Sandstone	14	0
12. Shale	4	0
13. *Cameron coal-bed* (M)	2	3
14. Drab shale	6	0
15. *Coaly* shale	3	0
16. Shale	8	0
17. Sandstone	6	0
Total	300	6

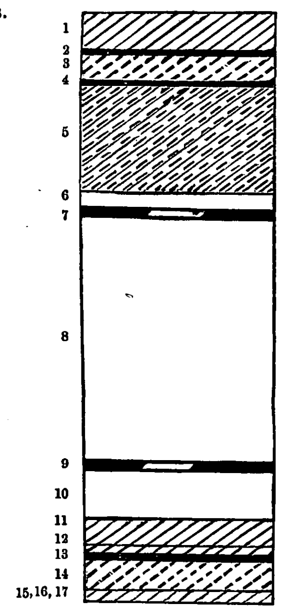


FIG. 36. — *Elizabethtown road,* 1.

Coal-bed T shows two benches, five and twenty inches, with a clay parting of four inches. It is well exposed directly at the summit, on the west side of the road. *Coal-bed* S is apparently an insignificant bed, though the exposure in a ditch is very deceptive. As usual, the *Caliente coal-bed* has a large blossom, but it is so mixed with slate that exact measurement is impossible. The *Cameron coal-bed* has been mined on the south side of Vermejo Creek, opposite Cameron post office, where it is three feet thick and yields excellent coal.

Descending from this summit one finds the last section repeated down to within a few feet of No. 7, and in ascending to the Canadian summit one reaches the top of the series as seen in Southern Colorado and Northern New Mexico. The succession is—

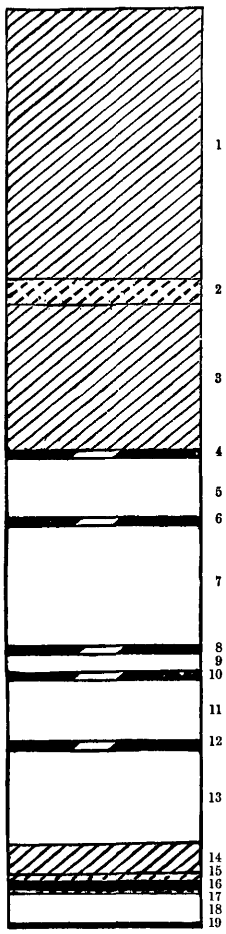


FIG. 37.—*Elizabethtown road, 2.*

		Feet.	Inches.
1.	Sandstone	270	0
2.	Shale	25	0
3.	Sandstone	145	0
4.	*Coal-bed* (Z)	Blossom.	
5.	Imperfectly exposed	77	0
6.	*Coal-bed* (Y)	Blossom.	
7.	Imperfectly exposed	120	0
8.	*Coal-bed* (X)	Blossom.	
9.	Imperfectly exposed	26	0
10.	*Coal-bed* (W)	Blossom.	
11.	Imperfectly exposed	70	0
12.	*Coal-bed* (V)	Blossom.	
13.	Imperfectly exposed	105	0
14.	Sandstone	30	0
15.	Shale	6	0
16.	*Caliente coal-bed* (R)	9	8
17.	Clay	1	0
18.	Imperfectly exposed	[illegible]0	0
19.	*Raton coal-bed* (Q)	3	2
	Total	917	10

No. 1, a coarse yellow rock, which contains no fossils, is the Great Sandstone, which caps the series, and is shown on all the divides in the central part of the Laramie region. The first three members of the section blend and the line of division is arbitrary, having been seen at but one locality, while at others no such separation occurs at the horizon given. The coal-beds above the *Caliente* are shown only by their blossoms, and there is room for supposing that more than one of them are represented here only by Carbonaceous shale; but the *Caliente coal-bed* is very thick, being in two benches, one foot one inch and eight feet thick, with a clay parting of seven inches. It is exposed at two places near the little creek, but it has not been opened. The *Raton coal-bed* has the following structure near where the road crosses the tributary creek:

		Feet.	Inches.
1.	*Coal*	0	2
2.	Clay	1	1
3.	*Coal*	1	0
4.	Clay	0	4
5.	*Coal*	0	10

The coal in both of these beds seems to be decidedly good.

At or very near Cameron's post-office on the Vermejo the rocks begin to rise westward and, within a mile, the eastward dip becomes steep, about 8°. The lower members of the Laramie group are brought up in succession, so that at the mouth of Vermejo Park the sandstone overlying the *Lower Vermejo coal-bed* is above the creek. Within 500 yards the *Halymenites sandstone* is up, and in the short cañon all the coal-beds belonging to this part of the section are more or less well shown. The shales of Cretaceous No. 4 soon come up, and with their appearance the cañon widens into the park. Midway in the open area 200 feet of the shales are shown, forming the lower part of the bluffs surrounding the park, while in the park itself are flat-topped mounds composed of the shales and covered with a coarse conglomerate cemented by carbonate of lime.

The creek forks almost midway in the park and the axis of the Vermejo anticlinal crosses just below the forks. Thence the rocks dip westward and the park closes as rapidly as it opened, so that within two miles on the north fork, the *Halymenites sandstone* is at the creek. Here the *Dillon coal-bed* makes a great blossom and evidently contains little aside from coal through a thickness of ten feet. At five feet below it is a dark shale six feet thick and resting on the *Halymenites sandstone*. The sandstone overlying the *Lower Vermejo coal-bed* caps the hills and makes an imposing cliff. The coal is directly under it and is much thicker than at any other locality examined, the section being as follows:

			Feet.	Inches.
1. Sandstone			80	0
2. Shale			3	0
3. *Lower Vermejo coal-bed* (F)			9	10
Coal	0	8		
Parting	–	–		
Coal	5	0		
Clay	0	3		
Coal	1	0		
Sandy shale	2	6		
Coal	0	5		
4. Shale			5	0
5. Sandstone			12	0
6. *Coal-bed* (E)			1	6
7. Concealed to creek			90	0
Total			201	4

As far as may be determined from mere optical examination the coal from this bed is good; but neither this nor the *Dillon coal-bed* has been opened, for the supply of wood is more convenient.

On the other or main fork of the creek the rocks come down at a somewhat greater distance. No good exposures, however, occur within the Laramie area, but at a little distance one passes beyond that area and into the Stonewall Valley, between it and the Dakota Stonewall. Here the creek is formed by the union of several small streams, most of which rise in the Culebra Range. One, however, flows southwardly along the valley, heading against a similar branch of the South Fork of the Purgatory. The Laramie rocks reach to the base of the east wall of the valley at the head of Vermejo Cañon, but the shales of Cretaceous No. 4 are shown at a short distance up the valley, and they remain in sight to the divide. Mr. Russell obtained the following section at about a mile above the head of the cañon:

	Feet.	Inches.
1. Sandstone	10	0
2. Concealed	30	0
3. *Coaly* shale	0	10
4. Sandy shale	3	0
5. Black shale	4	0
6. Sandy shale	2	0
7. *Coal-bed*	1	2
8. Shale	15	0
9. *Coaly* shale	0	6
10. Shale	11	0
11. Black shale	12	0
12. *Coal-bed*	1	0
13. Shale	10	0
14. *Coal-bed*	0	3
15. Black shale	3	0
16. *Coal-bed*	0	6
17. Black shale	0	4
18. Drab shale	12	0
19. *Coal-bed*	0	6
20. Black shale	6	0
21. Shale	19	0
22. *Coal-bed*	1	2
23. Black shale	10	0
24. *Coal-bed*	1	6
25. Dark shale	8	0
26. Shale	20	0

	Feet.	Inches.
27. Black shale	2	0
28. Sandstone	15	0
29. Black shale	4	0
30. *Coal-bed*	0	8
31. Black shale	0	10
32. Drab shale	1	8
33. *Coal-bed*	2	6
34. Black shale	1	2
35. Drab shale	2	6
36. Black shale	2	0
37. Clay	0	1
38. *Coal-bed*	0	8
39. Black shale	3	0
40. *Coal-bed*	1	0
41. Black shale	2	0
42. *Coal-bed*	1	2
43. Dark shale	10	0
44. *Halymenites sandstone*	84	0
45. Sandstone and shale	20	0
46. Shale of Cretaceous No. 4	280	0
Total	617	9

The exposure here is complete, every inch being shown in the bed of a little stream. The section is given in detail, as it affords an interesting illustration of the extent to which the *coal-beds* of this series sometimes divide. The highest sandstone has the place of that overlying the *Lower Vermejo coal-bed*, and the *Dillon coal-bed* is represented by Nos. 29 to 43, inclusive. This coal-bed is easily traceable along the entire bluff, from a few rods above the head of Vermejo Cañon to very near Cucharas Pass at the northern limit of the district.

The highest sandstone of the section is wholly unlike any seen elsewhere in this group except on the east side of Poñil Pass and in the northeast wall of Ute Valley. Some parts are extremely coarse, containing great fragments, while others are less coarse, but are honeycombed with veins of quartz, so that the rock closely resembles the Dakota sandstones shown in the Stonewall. The concretions in the Cretaceous shales are not rich in fossils.

The Niobrara limestone was not found in place along this upper portion of the Vermejo, but fragments of that rock are plentifully distributed over the surface. The Fort Benton shale is not reached in the Stonewall Valley, being covered by *débris* from the Dakota sandstones. Those sandstones stand up sharply, dipping eastward at nearly 70° and forming the western boundary of the valley. In this wall the yellowish-gray conglomerate and honeycombed sandstones of the group are well exposed; while behind it are the varied sandstones and the limestones of the Carboniferous. But the lower rocks of the latter group are not well shown and the line of the contact with the Archæan is ill-defined, for plates of trachyte are spread over the upper face of the mountain.

The main fork of Vermejo heads against Costilla Creek, a tributary to the Rio Grande, and the summit between the streams is crossed by several broad dikes of trachyte. The surface is covered with *débris* in which are many ponds without visible drainage. This deposit bears much resemblance to moraine, but water-worn fragments are strewn over the surface even to the summit of the divide.

Vermejo Creek receives Rock and Leandro Creeks above Vermejo Park, both having their head under Costilla Peak.

LEANDRO CREEK flows through the Laramie area for a few miles in the lower part of its course, but from its source to where it breaks into that area it runs through a series of narrow parks. The Stonewall Valley, beginning near Cucharas Pass at the north, continues southward beyond the cañon of the Vermejo, but gradually narrows along Leandro Creek until it ends in the saddle between Bare Cone and the Stonewall. The area of open region, however, practically crosses the saddle and is continuous with the park on Moreno and Cieneguilla Creeks, which in its turn is continuous with that on Coyote Creek in the Mora area.

The Dakota Stonewall continues southward to a very short distance beyond Costilla Peak, but its dip gradually changes, becoming vertical where the wall is first drained by Leandro Creek, and soon westward at nearly 60°. The dark shale of Cretaceous No. 2 is exposed occasionally on the east side of the wall, and fragments of the Niobrara limestone are numerous in the saddle between the wall and the Bare Cone dike, though the rock is not shown in place.

The surface of the park through which Leandro Creek flows is very irregular. At a little distance above where the creek enters the Laramie area a small stream comes into it, which drains imperfectly a long narrow space along the Stonewall, where there are many alkaline ponds occupying shallow depressions and without outlet. A high flat bench separates this space from the valley of the creek, and is covered with a thick deposit of Quaternary containing, among others, numerous fragments of Archæan rocks. The park becomes very narrow along the main creek owing to the intrusion of dikes. Some enormous fragments of gneiss were seen in the narrow space between Bare Cone and the Stonewall, most of them angular and showing little evidence of water-wear.

Two dikes split this park from the Leandro Cañon southward and appear to extend from Bare Cone, though the character of the rock is very different. Another follows the Stonewall for several miles and at last breaks through it to pass into Costilla Peak, which itself is but an overflow from a dike of the Old Baldy group. This dike dips with the Stonewall, and the trachyte of which it is composed contains many small fragments of gneiss.

Bare Cone is the northern termination of an enormous dike which is easily followed southward to where it crosses a fork of South Poñil Creek and is lost in Old Baldy. It is composed of an exceedingly fine-grained quartzite-like rhyolite, (?) weathering yellow; but farther south this is succeeded by the trachyte characterizing the Old Baldy series of dikes.

A low divide composed of Laramie rocks separates Leandro Park from Rock Park on

Rock Creek.—This stream rises under the east slope of Costilla Peak in an ill-drained park, which is separated by low, almost imperceptible divides from Leandro Creek at the north and from South Poñil and Comanche Creeks at the south. This basin is terraced and contains many lakelets so poorly drained that throughout nearly the whole of its extent the floor is a marsh. The creek breaks through Bare Cone and two other dikes and flows in an irregularly southeast direction through Rock Park to the Vermejo, which it reaches within the Laramie area.

Rock Park has a rudely terraced surface and much of it is marshy, some parts being lower than the bed of the creek. A handsome terrace covered with pine trees separates this from the park through which Leandro Creek flows amid the Laramie rocks. The detritus on this terrace is thin, but contains fragments of Carboniferous and Dakota rocks as well as of the Bare Cone rhyolite, all of them water-worn. Attempts were made to obtain sections of the Laramie rocks surrounding the park, but no exposures other than of sandstones could be found. Some huge masses of sandstone lie scattered in the open space, and from these the park derives its name. The soil is a fine silt and contains fragments of the rocks seen at the west.

A low divide separates this from Van Bremmer's Park, which in like manner is on the top of the Laramie Plateau. This is a large rudely terraced basin, more or less marshy throughout and holding many alkaline lakelets, all of which, with but one exception, become dry during the prolonged dry season. The basin is hemmed in by hills on all sides except toward Rock Park and Van Bremmer's Cañon, and toward these there are rocky walls. The surface gradually rises toward the cañon and the covering of recent deposits diminishes in the same direction until, at a short distance east from the Trinidad and Elizabethtown road, it practically disappears. The eastern or southeastern edge, as determined by the aneroid barometer and Locke's level, is very nearly of the same height with the terrace separating Rock and Leandro Creeks. No drainage is possible through Van Bremmer's Cañon to the plains or through Blattmer's Cañon to Vermejo Creek. Laramie rocks surround this park on all sides, but near the foot-hills they are badly cut by dikes of the Old Baldy group.

SECTION IV.

THE CAÑONS OF CROW CREEK AND THE UPPER CANADIAN.

CROW CREEK.

This insignificant stream flows through a deep cañon opening upon the plains at about eleven miles north from Vermejo Creek. The bluff fronting upon the plains between the two cañons shows the lower rocks of the Laramie group resting on shales of Cretaceous No. 4; but, owing to the height of the terrace stretching toward the Canadian River, the exposure of the shales is of slight vertical extent for much of the distance. They are well shown at the mouth of Crow Creek Cañon and do not pass under the stream until fully four miles above the stage-station. A fine exposure was found near the first spring, whence were obtained *Baculites*, *Inoceramus*, *Dosinia*, *Mactra*, and other forms. The concretions contain enormous *Inocerami*, some of which are more than twenty inches long. Many small shells occur in the shales, and a layer of limestone near the *Halymenites sandstone* contains *Baculites* and other genera, all of which retain the nacre. Fine crystals of selenite are abundant, and some of them are five inches long. Thin layers of yellowish sandy limestone and of white clay are present at varying intervals.

The following section was obtained just above where the shales are at water-level:

	Feet.	Inches.
1. Sandstone	110	0
2. Concealed	12	0
3. Sandstone	80	0
4. *Lower Vermejo coal-bed* (F), seen	0	4
5. Shale	9	0
6. Sandstone	22	0
7. Concealed	19	0
8. *Upper Reilly coal-bed* (E)	1	11
9. Sandstone	26	0
10. Concealed	5	0
11. *Lower Reilly coal-bed* (D)	Blossom.	
12. Concealed	50	0
13. Sandstone	66	0
14. *Trinidad coal-bed* (B)	3	8
15. Drab shale	9	0
16. Sandstone	33	0
17. *Dillon coal-bed* (A)	6	0
18. Dark shale	1	0
19. *Halymenites sandstone*	80	0
20. Sandstone and shale	70	0
Total	600	11

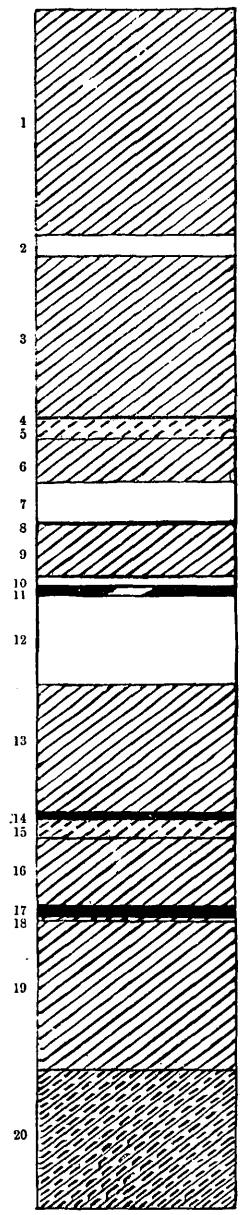


FIG. 38.—*Crow Creek.*

The highest sandstone is that immediately overlying the *Upper Vermejo coal-bed*, and it forms the crest of the hill just above the first spring. It is reddish gray, fairly compact, though some parts are soft and on exposure weather readily into rounded forms. Flaggy layers containing impressions of leaves are not rare. The second sandstone varies from red to gray, is soft and massive, and as usual forms a fine cliff. The place of the *Vermejo coal-bed* is between these sandstones, but its blossom is not shown. The lower of the sandstones has irregular layers of dark reddish-blue limestone, weathering bright yellow and containing no fossils.

The *Lower Vermejo coal-bed* is of no value though its coal seems to be good. The *Upper Reilly coal-bed,* too, is unimportant as it is nothing but a rich carbonaceous shale.

The interval in which the *Willow Creek coal-bed* should be found is wholly concealed at all the localities examined. The thick sandstone resting on the *Trinidad coal-bed* is rusty yellow except near the top, where some of the layers are gray; some of the layers at the base are coarse, with pebbles of white quartz, and the under surface of the rock is covered with cylindrical bodies one to two inches long and one-eighth to one-fourth of an inch in diameter, which seem to be casts of fucoids. This sandstone becomes thinner near the forks of the creek, where it is flaggy and contains impressions of leaves.

The *Trinidad coal-bed* is exposed only near the forks of the creek on the north side of the cañon, where it shows

	Feet.	Inches.
1. *Coal*	0	6
2. Blue clay	0	2
3. *Coal*	1	2
4. Sandy shale	0	1
5. *Coal*	0	4
6. Sandy shale	0	2
7. *Coal*	1	3
Total	3	8

The coal is slaty throughout, and as shown here is of no value; but on a tributary cañon, entering at about a mile above the stage-road, the bed is much thicker, as appears in the following section:

	Feet.	Inches.
1. Conglomerate sandstone	10	0
2. Shale from zero to	0	1

			Feet.	Inches.
3. *Trinidad coal-bed* (B)			7	9
Coal	0	5		
Sandy shale	0	11		
Coal	1	1		
Parting	–	–		
Coal	1	8		
Clay	0	2		
Coal	2	0		
Clay	0	1		
Coal	0	8		
Blue clay	0	1		
Coal	0	10		
Clay	0	2		
Coal	0	6		
4. Blue shale			5	0
5. Sandstone			14	0
6. *Dillon coal-bed* (A)			5	0
Total			42	8

In the former section only that portion of the bed is present which in this lies above No. 6. The coal at the lower exposure is very good, and it can be worked to profit as the partings are very thin. The blossom in the side cañon is extensive, making a broad band which can be seen from the stage-road.

The *Dillon coal-bed* is exposed at many places. Just above the first spring in the cañon it shows

	Feet.	Inches.
1. *Coal*	0	4
2. Clay	3	0
3. *Coal*	1	6
4. Bony *coal*	0	2
5. *Coal*	1	0

But its variations are serious, for in the side cañon already referred to it is represented by five feet of Carbonaceous shale.

The *Halymenites sandstone* varies from gray to buff, and toward the base it contains conglomerate layers. Many parts are crowded with the fucoid, *Halymenites major*. This rock rests on seventy feet of reddish-brown shale which holds many layers of sandstone in which are rude characterless casts of fucoids. These shales pass almost imperceptibly into those of Cretaceous No. 4 below.

THE UPPER CANADIAN.

The Upper Canadian, or West Fork of the Canadian River, rises within the Laramie area very near the Trinidad and Elizabethtown road and flows eastwardly to the plains, where, uniting with Willow Creek, it forms the Canadian River. The conditions observed in this cañon are very similar to those observed along Crow Creek and the Vermejo. The *Halymenites sandstone* makes a broad band on the bluff between the mouth of the former cañon and that of the Canadian, while above it the wide blossom of the *Dillon coal-bed* is frequently shown. The lower part of the bluff is made of Cretaceous No. 4.

The Cretaceous shales remain above the creek in this cañon to the first side cañon on the south. They contain the usual concretions; but Mr. Russell, who examined them, reported that they are not so rich in fossils as at some localities farther south, and he procured only a single *Baculites* and a few *Inocerami*.

The *Dillon coal-bed* makes an enormous blossom at the mouth of the cañon, where it caps a promontory between this and Dillon's Cañon. The following section was obtained near the point where the Cretaceous shales disappear:

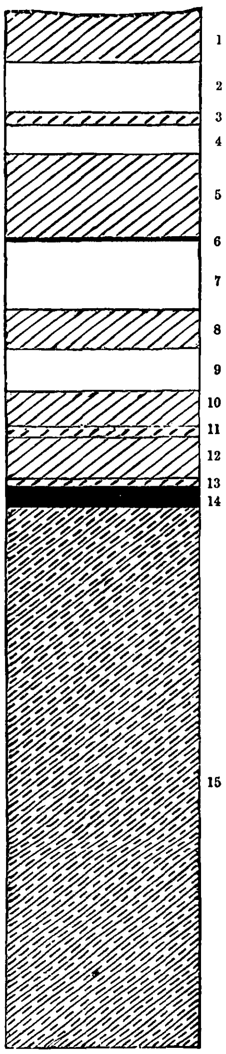


FIG. 39.—*Upper Canadian*, I.

	Feet.	Inches.
1. Sandstone	–	–
2. Concealed	27	0
3. Shale	6	0
4. Concealed	15	0
5. Sandstone, with basalt at the base	42	0
6. *Willow Creek coal-bed* (C)	1	0
7. Concealed	36	0
8. Sandstone	19	0
9. Concealed	22	0
10. Sandstone	18	0
11. Shale	5	0
12. Sandstone	22	0
13. Shale	3	0
14. *Dillon coal-bed* (A)	11	5
15. Sandstone and shales	280	0
Total	507	5

The sandstone at the top of the section is that overlying the *Lower Vermejo coal-bed*, which is concealed here; it contains thin sheets of limestone, blue on the fresh surface but weathering to rusty yellow. They contain no fossils.

The sheets of basalt associated with the *Willow Creek coal-bed* vary from very soft to very hard, some layers weathering brownish-red and breaking down on exposure, while others seem to resist all action of the weather. Intruded basalt has caused serious disturbance in the *Dillon coal-bed*, where it occurs in strings and bunches, distorting and coking the coal, so that a section was obtained only with much difficulty. This basalt is brownish-red, concentric, and peels off in layers, so that the surface is mammilated. The section of the coal-bed is—

	Feet.	Inches.
1. *Coal*	0	5
2. *Coaly* shale	5	0
3. Black shale	2	0
4. Red shale	0	6
5. Black shale	1	6
6. *Coal*	2	0

The coal seems to be good, but the bed is so badly broken up as to be worthless. Another section was obtained at nearly a mile farther up the cañon, as follows:

	Feet.	Inches.
1. *Coal-bed*, seen	2	0
2. Shale	18	0
3. Sandstone	4	0
4. *Coal-bed*	0	4
5. Sandstone and shale	13	0
6. Basalt	4	0
7. Sandstone	10	0
8. Black and drab shale	28	0
9. Sandstone	2	0
10. Black and drab shale	11	0
11. *Coal* and basalt	4	0
12. Shale	3	0
13. *Dillon coal-bed* (A)	11	0
14. Shale	5	0
15. Sandstone	30	0
16. *Coal-bed*	1	6
17. *Halymenites sandstone* to creek	20	0
Total	166	10

The relations of the coal-beds in this section are not wholly clear. The *Dillon coal-bed* has the following structure:

	Feet.
1. *Coal* and *coaly* shale	2
2. Shale	3
3. Sandstone	1
4. Shale	3
5. *Coal.*	2

And it is not altogether improbable that the *coal* entangled in the trap should be included in this bed. In this upper bench the coal has been coked. The higher bed of basalt has exerted no influence upon the rocks adjacent to it.

A very fair exposure was found at the mouth of Cat's Claw Cañon, two miles farther up the creek, where the following section was obtained:

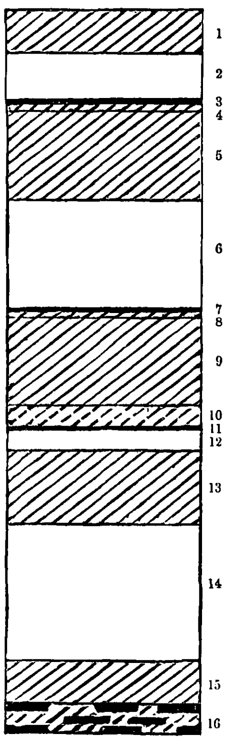


FIG. 40 — *Mouth of Cat's Claw Cañon.*

	Feet.	Inches.
1. Sandstone	22	0
2. Concealed	22	0
3. *Cat's Claw Cañon coal-bed* (H)	3	3
4. Shale	3	0
5. Sandstone	44	0
6. Concealed	55	0
7. *Upper Vermejo coal-bed* (G)	0	10
8. Shale	3	0
9. Sandstone	45	0
10. Shale	12	0
11. *Lower Vermejo coal-bed* (F)	0	3
12. Concealed	11	0
13. Sandstone	38	0
14. Concealed	72	0
15. Sandstone	22	0
16. *Willow Creek coal-bed* (C)	14	2
Total	367	6

Coal-bed H is thicker here than at any other locality seen during the season, and has two benches fifteen and twenty inches, separated by four inches of clay. The interval between the *Vermejo coal-beds* is smaller than observed elsewhere, but there seems to be no room for doubting the accuracy of the identification of the lower bed, for the sandstone above it was traced up the cañon, and here it has the usual layers of limestone, which are rarely wanting. The measurement given for the *Willow Creek coal-bed* is very indefinite, for sheets of compact trap have distorted the bed seriously. The section seems to be

	Feet.	Inches.
1. *Coal*	0	6
2. Sandstone and shale	8	0
3. *Coal*	0	8
4. Black shale	5	0

and the black shale at the base contains many thin streaks of *coal*.

Another section was obtained at a mile farther up the cañon, showing

	Feet.	Inches.
1. Sandstone	33	0
2. Gray sandy shale	11	0
3. Concealed	19	0
4. Shaly sandstone	5	0
5. Concealed	22	0
6. Sandstone	1	0
7. Shale with *coal-bed* (H)	36	0
8. Sandstone	6	0
9. Shale	3	0
10. *Coal-bed* (G″)	3	2
11. Shale	1	6
12. Sandstone	5	0
13. Shale	1	0
14. *Coal-bed* (G′), with shale	5	7
15. Shale	6	0
16. Sandstone	11	0
17. Shale	16	0
18. Sandstone	11	0
19. *Upper Vermejo coal-bed* (G)	0	10
20. Sandy clay	1	6
21. Sandstone and shale	25	0
Total	223	7

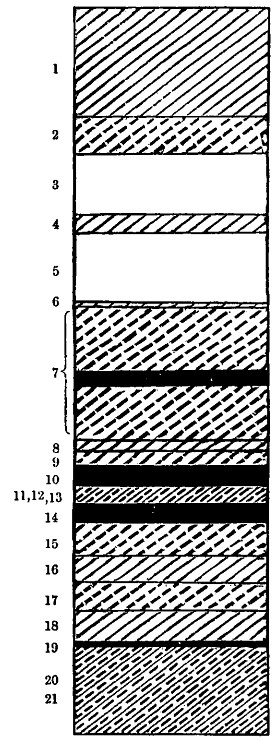


FIG. 41.—*One mile above Cat's Claw Cañon.*

The blossom only of *Coal-bed* H is shown here, and it is indefinite. No. 10 is double, the benches being one foot and eight inches, separated by eighteen inches of shale. The benches of No. 14 are four and fifteen inches, with four feet of shale intervening. No. 21 varies much between the mouth of Cat's Claw Cañon and this place, changing abruptly from sandstone to shale and back again.

Above this to within three or four miles of the Elizabethtown and

Trinidad road only fragmentary exposures in the creek's bank could be found, and these are not too close together. The sandstone No. 1 of the last section was followed for four miles above the mouth of Cat's Claw Cañon, and thence to near the open park reaching almost to the head of the creek. The following section was made out from the petty exposures:

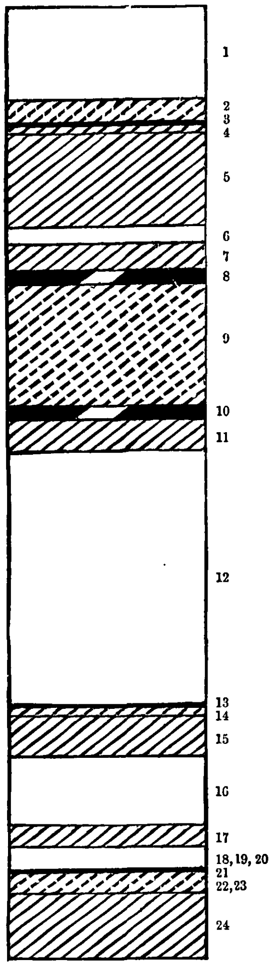


FIG. 42.—*Along the Upper Canadian.*

	Feet.	Inches.
1. Concealed	45	0
2. Shale	11	0
3. *Coal-bed* (P)	2	6
4. Shale	2	0
5. Sandstone	45	0
6. Concealed	9	0
7. Sandstone	13	0
8. *Coal-bed* (N)	Blossom.	
9. Dark shale	67	0
10. *Coal-bed* (L)	Blossom.	
11. Sandstone	23	0
12. Concealed	125	0
13. *Long's Cañon coal-bed* (J)	1	6
14. Shale	3	0
15. Sandstone	22	0
16. Concealed	34	0
17. Sandstone	11	0
18. Clay	1	0
19. Carbonaceous shale	1	0
20. Shale	11	0
21. *Coal-bed* (I)	0	10
22. Black shale	3	0
23. Drab shale	8	0
24. Sandstone	33	0
Total	469	10

No. 3 is an excellent *coal-bed*, and is accessible at a little distance below the second ranch east from the park. No. 12 evidently contains a *coal-bed* midway, but the hill-side where the measurement was made is deeply covered with *débris*. The same is true of No. 9, which is very imperfectly exposed. An irregular layer of trap, which underlies No. 18, is from eight to fourteen inches thick and has baked the shale below it. A similar bed underlies No. 22, and another is shown under No. 23, each of which has exerted a decided effect on the adjacent rocks. This exposure is at nearly four miles above the mouth of Cat's Claw Cañon or Potato Cañon. Just above the second ranch referred to the following additional section was obtained:

			Feet.	Inches.
1. Shale and flaggy sandstone			40	0
2. *Caliente coal-bed* (R)			16	2
Coal	0	2		
Carbonaceous shale	7	0		
Coal	2	0		
Coaly shale	7	0		

The coal in this bed is fairly good, but it cannot be mined except at serious cost, as the roof is insecure. Two other coal-beds were seen at a little way farther up the creek and just below the next ranch, the section being—

	Feet.	Inches.
1. *Coal-bed* (T)	Blossom.	
2. Concealed	4	0
3. Flaggy sandstone	10	0
4. Concealed	14	0
5. Shale	4	0
6. *Coal-bed* (S)	4	3

Coal-bed S shows the following structure:

	Feet.	Inches.
1. *Coal*	0	4
2. Shale	2	0
3. *Coal*	0	5
4. Clay	0	6
5. Slaty *coal*	1	0

A thin shale intervenes between it and the sandstone at the top of the preceding section, making the total interval between *Coal-beds* R and S not far from fifty feet. At the lower end of the park, or about four miles from the Trinidad road, *Coal-bed* T makes a wide blossom, and it is fairly well shown about midway in the park, where the following section was obtained:

	Feet.
1. Coarse sandstone	–
2. Concealed	55
3. Sandstone	11
4. Concealed	11
5. Sandstone	22
6. Shale	9

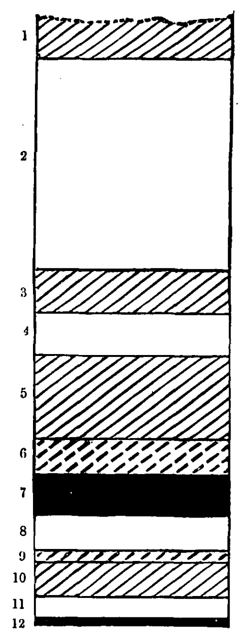


FIG. 43.—*Three miles from Elizabethtown road.*

		Feet.
7.	*Canadian coal-bed* (U)	11
8.	Concealed	9
9.	Black shale	3
10.	Sandstone	9
11.	Concealed	5
12.	*Coal-bed* (T)	2
	Total	147

No. 12 is the higher coal of the last section, and it doubtless has a much greater thickness than is given, for fragments of coal were seen among the *débris* covering No. 11. The *Canadian coal-bed* shows three feet of coal and eight feet of coaly shale, but the exposure is not complete, for at another exposure it shows

		Feet.	Inches.
1.	*Coal*	2	6
2.	Clay	0	10
3.	*Coaly* shale	3	0

The last resting on sandstone, so that it is not improbable that layers of coal are distributed through Nos. 7, 8, and 9. This bed is frequently exposed in this park. Thence to the head of the stream exposures are few and unsatisfactory. Black shales with thin layers of trap were seen at two miles from the Trinidad and Elizabethtown road, and beyond these one soon comes to the Great Sandstone, of which the yellow portion is shown to a thickness of 270 feet.

SECTION V.

DILLON'S CAÑON AND THE REGION BORDERING ON WILLOW CREEK.

DILLON'S CAÑON.

Dillon's Cañon is directly northeast from that of the Canadian, and the two cañons open together. The *Dillon coal-bed* is well exposed on the bluff between them, where it rests on the *Halymenites sandstone*, below which are the brownish shales and sandstones overlying the Cretaceous.

The shales of Cretaceous No. 4 remain in sight along this cañon to within a mile and a half of Dillon's Ranch, while fragments of the concretions belonging to it cover the ground. The following section was obtained where the *Halymenites sandstone* comes down to the stream:

	Feet.	Inches.
1. Sandstone	5	0
2. Yellow sandy shale	22	0
3. Sandstone	112	0
4. Concealed	33	0
5. *Upper Vermejo coal-bed* (G)	0	6
6. Shale	11	0
7. Sandstone	80	0
8. Concealed	135	0
9. *Willow Creek coal-bed* (C)	2	0
10. Drab shale	8	0
11. Carbonaceous shale	1	2
12. Shale	11	0
13. Concealed	66	0
14. Sandstone	22	0
15. Carbonaceous shale	1	0
16. Brown shale	10	0
17. *Dillon coal-bed* (A)	9	11
18. Drab shale	3	0
19. Concealed	8	0
20. *Halymenites sandstone*	80	0
Total	617	7

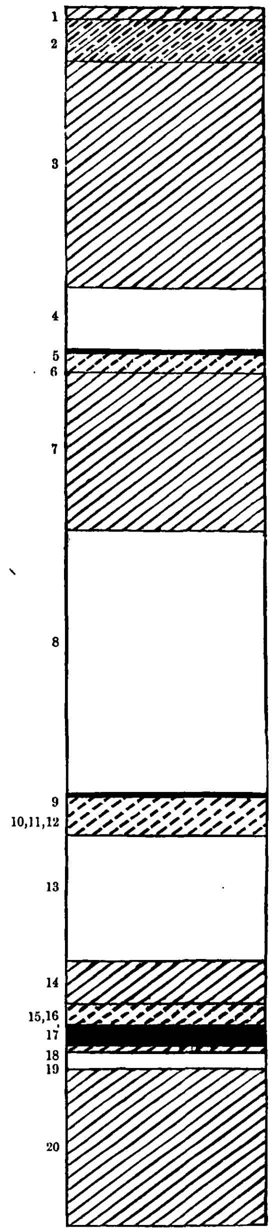


FIG. 44.—*In lower part of Dillon's Cañon.*

Coal-bed H should be found at the base of No. 2, but the exposure is not complete. The great sandstone overlying the *Upper Vermejo coal-bed* is much broken by thin layers of sandy shale, varies from hard, flaggy and rusty yellow to soft, massive and light-gray or buff, the latter weathering into marked architectural forms. Many layers contain battered fragments of wood and others are full of comminuted vegetable matter. Some show many impressions of dicotyledonous leaves. The interval, No. 4, evidently contains much sandstone, and has also an intruded sheet of trap similar to that occurring in No. 7, the persistent sandstone over the *Lower Vermejo coal-bed.* This sandstone is soft, light-yellow, shows deep cavities on its face, and forms a fine cliff. The trap sheet is irregular, but the sandstone near it is distorted and shows vapor or gas-holes, though no metamorphism is apparent even along the line of contact. The *Upper Vermejo coal-bed*, at only two or three feet below the higher sheet of trap, is unaffected. The *Dillon coal-bed* is quite important and has the following structure:

	Feet.	Inches.
1. *Coal*	0	4
2. Shale	1	8
3. Carbonaceous shale	1	4
4. *Coal*	1	2
5. Clay	0	1
6. *Coal*	3	4

Thus giving four feet six inches of *coal* in one body, and the coal is good. The *Halymenites sandstone* is gray, cross-bedded, laminated, and soft. It contains some thin layers of conglomerate and shows rude casts of fucoids, but no specimens of *Halymenites major* could be found.

Somewhat farther up the cañon, probably half a mile below Dillon's Ranch, a little ravine coming in from the east affords a good section, exhibiting the interval below No. 8 of the last section. The succession is—

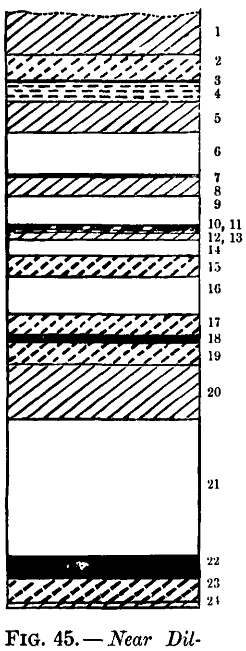


FIG. 45.—*Near Dillon's Ranch.*

	Feet.	Inches.
1. Sandstone	–	–
2. Shale	13	0
3. *Lower Vermejo coal-bed* (F)	0	10
4. Sandy fire-clay	11	0
5. Shaly sandstone	16	0
6. Concealed	22	0
7. *Upper Reilly coal-bed* (E)	0	8
8. Flaggy sandstone	9	0
9. Concealed	16	0
10. Black and drab shale	2	6
11. *Lower Reilly coal-bed* (D)	0	2
12. Shale	1	0
13. Sandstone	4	0
14. Concealed	8	0
15. Shale	12	0
16. Flaggy sandstone	20	0
17. Shale	9	0
18. *Willow Creek coal-bed* (C)	3	0
19. Shale	13	0
20. Yellow sandstone	28	0
21. Concealed	72	0
22. *Dillon coal-bed* (A)	11	8
23. Shale	10	0
24. *Halymenites sandstone* to creek	2	0
Total	287	10

The interval between *coal-beds* A and C is practically the same as in the preceding section, and the increased thickness of the latter bed may be accounted for by supposing that the drab shale has disappeared, thus permitting the two parts of the bed to come together. A basalt dike, breaking through the hill near the mouth of the ravine, has baked the clays below No. 18 into a hard brick-like rock, which is dark and speckled with white blotches. The *Dillon coal-bed* has been opened just above this ravine, and it shows an increased thickness, though the coal is not so well disposed as in the preceding section, the condition being

	Feet.	Inches.
1. Carbonaceous shale	0	4
2. *Coal*	2	10
3. Shale	0	4
4. *Coal*	0	10
5. Drab shale	2	8
6. *Coal*	0	10
7. Parting	–	–
8. *Coal*	0	8
9. Parting	–	–
10. *Coal*	1	7
11. Clay	1	0
12. *Coal*	0	6
Total	11	7

Thus showing two main benches of the coal four feet four inches and three feet two inches thick; but the clay parting must prove a very serious hindrance to economical working, although the coal is clearly good. The clay next the bottom contains many roots. It is irregular and frequently swells so as to cut away ten inches from the overlying bench. Two feet of drab shales overlie the *Dillon coal-bed* here, but in them no leaf-impressions could be found.

An imperfect exposure on the opposite side of the cañon shows that the interval No. 23 contains mostly sandstone; there a poor blossom of the *Trinidad coal-bed* was seen at thirty-five feet above the *Dillon bed*.

The trap sheet first seen in the sandstone above the *Lower Vermejo coal-bed* is well exposed along the cañon for nearly two-thirds of a mile above Dillon's Ranch; but its course is far from being regular, for at one-third of a mile above that ranch the sheet is very near the place of the *Willow Creek coal-bed* and is twenty feet thick. It rests directly on a flaggy sandstone whose upper layer has been converted into quartzite.

The first section disappears about two miles above Dillon's Ranch and there the following section was obtained:

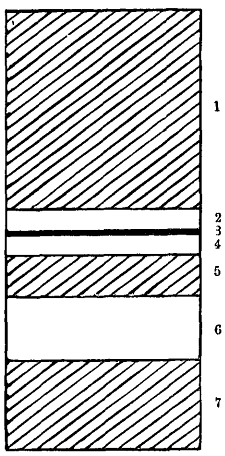


FIG. 46.—*Above Dillon's Ranch.*

	Feet.
1. Sandstone	100
2. Concealed	11
3. *Long's Cañon coal-bed* (J)	2
4. Concealed	12
5. Sandstone	23
6. Concealed	33
7. Sandstone	40
Total	221

No. 1 contains huge knotted fucoids and is yellowish-gray. The *Long's Cañon coal-bed* is imperfectly shown where this section was obtained, but an exposure farther up the cañon shows it to be of the thickness given. The highest sandstone remains in sight for somewhat more than a mile above this locality, and as its top comes down an exposure near the road gives the subjoined section:

	Feet.	Inches.
1. *Cameron coal-bed* (M)	3	0
2. Dark shale	27	0
3. *Coal-bed* (L)	1	3
4. Drab shale	7	0
5. Sandstone	8	0
Total	46	3

The *Cameron coal-bed* is represented here by carbonaceous shale containing thin streaks of coal. The shales below it are very dark and are crowded with nodules of iron ore, many of which are lined with calcspar. *Coal-bed* L is utterly unimportant. Two sections were made at nearly four miles above Dillon's Ranch, one of them by Mr. Russell. From these the following section was compiled:

		Feet.	Inches.
1.	Sandstone	15	0
2.	*Coal-bed* (Y)	Blossom.	
3.	Sandstone	36	0
4.	Sandstone	35	0
5.	*Carbonaceous shale* (X′)	2	0
6.	Sandstone	8	0
7.	Dark sandy shale	12	0
8.	Sandstone	1	0
9.	Concealed	75	0
10.	Compact sandstone	40	0
11.	*Carbonaceous shale* (V)	13	0
12.	Concealed	35	0
13.	Flaggy sandstone	55	0
14.	Drab shale	8	0
15.	*Coal-bed* (S)	0	6
16.	Black shale	12	0
17.	Sandstone	4	0
18.	*Coal-bed* (R′)	1	4
19.	Black shale	21	0
20.	Sandstone	30	0
21.	Concealed	13	0
22.	*Raton coal-bed* (Q)	Blossom.	
23.	Drab shale	14	0
24.	Concealed	40	0
25.	Sandstone	35	0
26.	Concealed	17	0
27.	*Coal-bed* (N)	2	0
28.	Shale	22	0
29.	Sandstone	11	0
30.	*Cameron coal-bed* (M)	3	0
	Total	560	10.

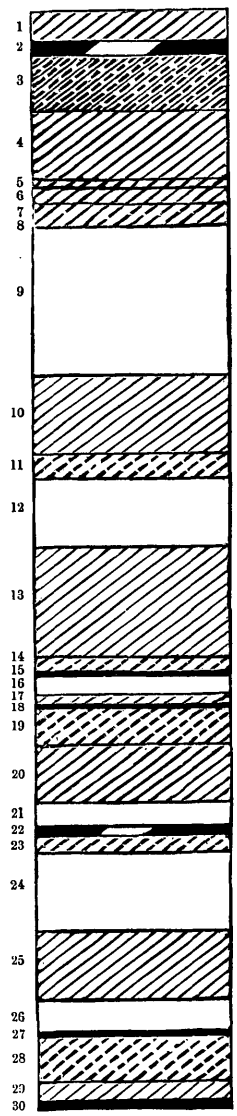


FIG. 47.—*Four miles above Dillon's Ranch.*

The blossom of No. 2 is at best very doubtful and in all probability there is here only carbonaceous shale. No. 5 is more nearly a *coal-bed*, for the shale contains many thin streaks of coal throughout. The same is true of No. 11, which is well exposed and contains some *coal*, but the carbonaceous matter is confined for the most part to the top three feet; so that the interval between it and the first *coal-bed* below is not far from 108 feet. The flaggy sandstone No. 13 is not fully exposed and there may be another *coal-bed* in this interval. The sandstones of the section, except No. 1, are soft massive rocks, usually light yellowish-gray, weather readily, and form fine cliffs. No. 1 was followed for some distance up the cañon and as far as could be ascertained it is about forty feet thick. A concealed interval of somewhat more than fifty feet comes between it and the yellow sandstone, which is at the top of the series and is reached on the summit between Dillon's and Long's Cañon.

THE REGION BORDERING ON WILLOW CREEK.

Willow Creek, the Eastern Fork of the Canadian River, is formed by the union of two branches, one rising near Raton Pass, and the other, known as Chico Rico Creek, rising near Manco Burro Pass. A large stream, Uña de Gato Creek, rises in Johnson's Park near the eastern edge of the Raton Plateau and flows westward to Willow Creek. The main creek unites with the Upper Canadian near the northwest extremity of the Eagle-tail Plateau. In the plains all of these streams flow through the shales of Cretaceous No. 4, and occasional exposures of those shales appear on the sides of the mesas. The greater part of the higher land drained by Willow Creek and its tributaries is covered with basalt.

Upper Willow Creek rises near Raton Pass and flows east of south to its junction with Chico Rico Creek. The Cretaceous shales are shown in the bluff from the mouth of Dillon's Cañon to about a mile north from the Willow Springs Ranch and exhibit the same characters as at other localities already referred to. A number of small dikes were seen near the ranch. The *Dillon coal-bed* is exposed by the roadside at little more than a mile farther up the stream, where it has the following structure:

	Feet.
1. *Coaly* shale	2
2. Red shale	2
3. Drab shale	4
4. *Coal*	4
Total	12

Several attempts were made to obtain sections on the hillsides along this stream, but the exposures are so imperfect that no details could be gathered. The succession was made out by means of the roadside exposures and is approximately as follows:

	Feet.	Inches.
1. Sandstone	–	–
2. *Raton coal-bed* (Q)	2	0
3. Concealed	125	0
4. Sandstone	22	0
5. Concealed	87	0
6. *Coal-bed* (K)	Blossom.	
7. Concealed	255	0
8. *Cat's Claw Cañon coal-bed* (H)	5	0
9. Concealed	38	0
10. Sandstone	35	0
11. Concealed	17	0
12. *Upper Vermejo coal-bed* (G)	Blossom.	
13. Concealed	21	0
14. Sandstone	70	0
15. Concealed	7	0
16. *Lower Vermejo coal-bed* (F)	Blossom.	
17. Imperfect exposure	77	0
18. *Lower Reilly coal-bed* (D)	1	0
19. Sandstone	33	0
20. Concealed	11	0
21. *Willow Creek coal-bed* (C)	3	0
22. Sandstone	27	0
23. Concealed	69	0
24. *Trinidad coal-bed* (B)	Blossom.	
25. Concealed	35	0
26. *Dillon coal-bed* (A)	12	0
27. Shale	2	0
28. *Halymenites sandstone*	50	0
Total	1,004	0

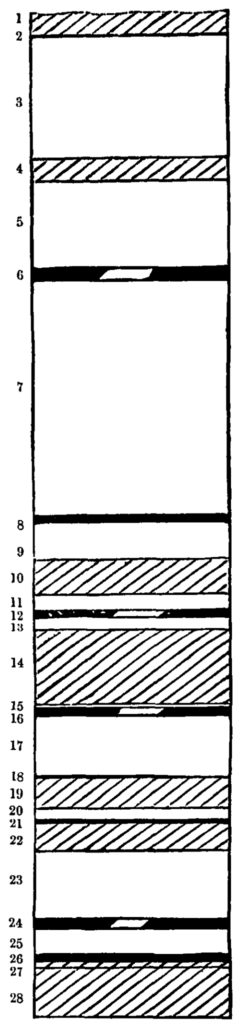


FIG. 48.—*Willow Creek.*

The *Raton coal-bed* is exposed directly at the approach to the summit of the pass. *Coal-bed* H is exposed in a railroad cutting about three miles below the summit and seems to be not far from five feet thick, but the outcrop is too much decomposed to exhibit the structure of the bed or the character of the coal. No. 18 contains several sheets of trap, and No. 20 is shown in a cut just below it. The *Willow Creek coal-bed* is exposed in a deep cut, but the outcrop is so badly decomposed that nothing can be learned respecting the character of the coal.

A thick plate of basalt covers the Raton Plateau and forms a distinct rim from Raton Pass to Manco Burro Pass, though it is deeply indented by erosion. Eastward from Raton Pass the rocks rise in a southeast direction, so that as one goes east along the southern base of the plateau from Willow Creek to Chico Rico he finds the Cretaceous shales rising higher on the face of the mesa, while at the same time the surface of the plain rises so that the exposure of the shale retains about the same thickness and is little greater than in the bluff south from the mouth of Dillon's Cañon.

The Laramie rocks are exposed along Chico Rico Cañon quite to the summit of Manco Burro Pass, where the *Lower Reilly coal-bed* is exposed in the road. Two *coal-beds* are shown in the cañon of Chico Rico Creek, west fork, the lower ten feet and the upper four feet thick, according to report; but neither is exposed for measurement. A bold mass of basalt, like that covering the plateau protrudes from the wall of the main cañon at nearly five miles from the pass. Its layers slope toward the creek. Great numbers of water-worn fragments of gneiss and quartzite were seen on the summit of the pass, all of which must have been brought from the mountain range at the west.

Occasional insignificant exposures of Cretaceous shale were seen in this cañon below the basaltic hill, and the surface of the valley is littered with fragments of concretions belonging to the shale.

Following the base of the plateau southeastward toward Uña de Gato Creek one soon finds the Laramie rocks running out, so that the basalt rests directly on Cretaceous shales. Several large hills of basalt lie between the road and Willow Creek, of which the largest is broken into several small hills with sloping crests, all directed from a central point.

Johnson's Park is an irregular area made up of narrow valleys scooped out by the several forks of Uña de Gato Creek, and separated by rounded divides, from most of which the basalt has been removed. In the walls of this park the basalt rests on the Cretaceous shales, which are fairly well exposed. The lava consists for the most part of a tough bluish rock containing some sanidin and much olivine. At one locality a dike 150 yards wide, of more recent lava, has been thrust through the sheet, and at a little distance from it are others of similar character. Branches of these are thrust on each side into the adjoining cap. This lava shows surfaces of flow, is dull rusty-brown, very porous, and crackles under foot like hard cinder. It contains half-fused fragments of the older sheet, while along the walls it has torn that rock badly, so as to form a breccia in which are fragments of the older basalt as well as of the Cretaceous rocks. Little cones of this later flow remain on top of the plateau and its fragments are among those of most frequent occurrence on the plain.

Pebbles of gneiss and quartzite were seen up to within twenty feet of the mesa cap or within 300 feet of the top of the plateau, and they are very numerous on the divides separating the valleys of which the park is made up. The Cretaceous shales are rich in concretions near the top, while below these are dark shales with thin seams of yellow sandy limestone containing abundance of *Baculites*, *Inocerami*, *Avicula*, as well as of scales and bones of fish. Lower down in the series are thin-bedded clays and sandy shales containing few fossils, though in some layers a large *Inoceramus* is abundant. These shales are exposed in the creek bank near the road leading to Willow Springs.

The country rises in mesas south and east from Uña de Gato Creek, and soon becomes one enormous lava-capped mesa, really continuous with the Raton Plateau, and rising eastward beyond the limit of the map to the Capulin Vegas, where there are three volcanic cones.

Several volcanic hills were seen on this mesa, of which Laughlin's Peak and Eagle-tail Mountain are not wholly unlike volcanic cones much disfigured by erosion. The rocks on this mesa are closely allied to those on top of the Raton Plateau.

The laminated sandy shales belonging to the base of Cretaceous No. 4 are exposed in Bragg's Cañon with a thickness of seventy feet. They are yellow above and gray below, the latter part weathering to dull brown, probably because of the large proportion of vegetable matter. *Inocerami* are numerous, and occasionally one finds with them a small oyster. Layers of minute crystals of selenite are present between the laminæ of shale and there are numerous films and small pockets of *lignite*. Many portions are crowded with comminuted vegetable matter, but no leaves were found aside from fragments probably belonging to a conifer. The Cretaceous shale extends around the mesa southward.

CHAPTER XV.

AREA OF THE MORA RIVER.

MORA CAÑON AND PLAINS—TURKEY MOUNTAINS—WOLF CREEK—COYOTE CREEK—MORA CREEK—CEBOLLA CREEK—SAPILLO CREEK—MANUELITOS CREEK—UPPER SAPILLO CREEK.

MORA CAÑON AND PLAINS.

The *Mora River* rises near Mora Peak, flows southwardly along the Mora anticlinal to near Mora, thence eastwardly to near the mouth of Coyote Creek, and thence southward to the mouth of Sapillo Creek. From that place it flows eastwardly in a deep cañon through the plains to the Canadian River. This stream, which drains a large part of the region involved in the Cimarron and Mora anticlinals, receives Coyote and Wolf Creeks from the north and Cebolla and Sapillo Creeks from the west. No important tributaries enter during its course through the plains, though deep arroyos have been eroded on each side by streams flowing only during spring-time.

The Mora Cañon really begins immediately below the mouth of Coyote Creek and deepens thence until, at the Canadian, its wall is 1,090 feet high. This cañon is practically impassable from Cherry Valley to within three miles of its mouth, and often there is not room for even a narrow footpath between the river and the rocky wall; but it widens above Cherry Valley and becomes less deep, so that thence to the head there is ample room at most localities for a wagon-road, though the wall remains abrupt and few outlets exist.

The basalt referred to in the chapter on the Canadian Cañon is continuous to the Mora; but the latter cañon near its mouth has been digged out alongside of the basalt. A low cone of sandstone projects above that rock at a short distance up the Mora and marks the southern wall of the cañon as it existed before the lava flowed into it. No basalt occurs on the south side of the cañon below the sharp bend except at one locality, where a little remains in a fragmentary condition on a rocky point. But above that bend the channel-way of the present stream has been cut down through the lava, which forms the walls on both sides.

The basalt rests on an olive, massive sandstone belonging to the Middle Dakota. From the river to the base of the lava-wall is 230 feet;* to top of sheet, 620 feet; to brink of chasm, 890 feet; and to top of first bench directly back from the brink, 1,090 feet. The base of the lava sheet is given as 230 feet above the river-bed, but this is at the lowest point, and the bottom of the mass is very irregular. When the lava flowed down the Mora the cañon had been eroded to a depth of 860 feet below the top of the present wall. The then existing gorge was terraced, for the basalt often rests against a low wall of sandstone and overflows the bench of which that is the escarpment. Occasionally the bottom of the mass is a breccia, as though *débris* of gravel and water-worn stones had been caught up by the molten rock in its course. The depth of the cañon was diminished 390 feet by the intrusion of the lava, so that since the time of that flood corrasion has removed material to the thickness of not less than 620 feet.

But the new channel-ways do not follow the course of the old ones near the junction of the cañons. Originally, as is shown by the lava-terrace, the Mora flowed directly to the Canadian instead of making the sharp bend now seen in its cañon, the protruding hill of sandstone having formed part of the right wall; while in like manner the Canadian flowed on the west side of its present channel-way.

The basalt is well shown in the first group of arroyos entering the north side of the cañon, and fragmentary exposures were found as far up as the arroyo entering at Cherry Valley.

The Middle Dakota is represented at the mouth of the cañon by—

1. Blue laminated limestone. This is hard, brittle, and contains

* These measurements were made with the aneroid barometer and are only approximate, there having been no opportunity to verify them by repetition.

bryozoans, which are shown on the weathered surface; but they are very indistinct.

2. Sandstone. This is olive and fine-grained, for the most part massive, though occasionally becoming a little shaly. At some places a gray sandstone intervenes between it and the limestone. At the mouth of the cañon the basalt rests on this rock.

3. Limestone. Gray, weathering bluish-white. It is almost conglomerate in structure, owing to seams of clay. No fossils were observed in it aside from tube-like stems, bearing some resemblance to *Phytopsis* of the Trenton in New York.

4. Red shale. Mostly fine-grained sandy shale, but it contains much argillaceous matter and is handsomely mottled with white.

In all, 360 to 370 feet thick.

The limestones of the section are far from being persistent. The upper one is frequently wanting, having been torn away during the deposition of the overlying sandstone, while the olive sandstone seems to have been equally effective in removing the lower limestone and in cutting into the red shale below.

The Upper Dakota sandstone, which is 620 feet thick here, forms the rim of the cañon from the mouth to Coyote Creek, and owing to the several anticlinals is kept up on the plains so as to be shown in arroyos for several miles both north and south from the cañon. As the Quaternary deposits are very thin on the Mora Plains north from the river, the sandstone is frequently exposed. Traces of a travertin-like limestone were seen in many small depressions in the sandstone upon the plain, and over by no means inconsiderable areas loose fragments of sandstone are incrusted with this calcareous material.

The general features of the Mora Plains between the cañon and the Canadian Hills have been described already in the chapter on the Canadian area.

THE TURKEY MOUNTAINS.

The Turkey Mountains, or Gallinas Hills, rise from the plain at a few miles west from the Canadian Hills and show the Dakota sandstone dipping away on all sides from a central point.

The road from Nolan's Ranch to the Turkey Mountains crosses the southern extremity of the Ocaté Mesa. The travertin-like limestone is exposed in the road near the ranch, where it cements fragments of basalt underlying the thin cover of Quaternary. Two hills project above the mesa immediately south from the road, and seem to be of equal height with Wagon Mound at the western end of the Canadian Hills. The mesa tapers southward and is narrow where crossed by the road.

This road enters the mountains at Jaroso. Many exposures of limestones belonging to Cretaceous No. 3 were observed in the plain near that village, and near the base of the mountains, where the rock lies scattered in huge fragments, some of which have been used in building walls.

The Upper Dakota sandstone forms a bold hog-back at Jaroso, which extends along the face of the mountain southward from the Gallinas road to that leading up from Chorro de Pinavete. Near the Gallinas road the dip is northeast, at Jaroso east of northeast, and the hog-back reaches nearly two miles toward the center of the mountains. The sandstones are light-buff to light-gray, and one member of the series forms a bright band on the hill-side, which is visible for many miles away toward the east. The dip at Jaroso is about 3°, but it increases slightly toward the southwest. The cañon leading up from Jaroso enters a park behind the hog-back, which reaches from very near the Gallinas road southward to the cross-roads in the southern part of the area; but before the cross-roads have been reached the dip of the Dakota sandstone changes, becoming east, then south of east, and finally southeast, while the hog-back itself dwindles away or is merged into the slope which leads to an old volcanic cone at the southern extremity of the mountains.

The Middle Dakota rocks are shown at the head of Jaroso Cañon, but the section is short, exhibiting only the lower sandstone and limestone and the underlying shale. Two insignificant dikes cut the rocks at this place. Some fragmentary exposures of very coarse reddish sandstone were seen at probably a mile farther south, but owing to the change of dip all rocks underlying the Upper Dakota in this hog-back go under the surface before the cross-roads are reached.

A second series of hog-backs directly west from the former extends southward from near the northern limit of the mountains for about seven miles. Coarse gray sandstones only are exposed in these, which are evidently conformable with those of the Dakota, though their dip is more rapid. As they bear close resemblance to the sandstones of the Carboniferous, shown farther west, they are colored on the map as belonging to that age, though no limestones or fossils were found. The rocks are dipping south at the southern end of this interior group of hills and the Dakota sandstone is caught at the extremity.

The surface rises gradually from the Chorro de Pinavete road southward to a low bald mountain, indicated on the map as the "Crater." Some small patches of Upper Dakota remain on the slope, but they are, for the most part, too small to be indicated on the map.

The flow from this crater was almost wholly southward, and the northern limit of volcanic rocks is barely two miles away. The cup is perfect except at the southeast, where the wall has been broken down and an arroyo begins which leads to the Mora River. Cinder prevails in the bottom of the crater, but the rocks in the rim resemble those obtained at the mouth of Mora Cañon. A steel-gray variety occurs with these, and is closely allied to one taken from the Canadian Hills, which rings like pot-metal when struck.

The flow from this crater entered the Mora Cañon by way of an arroyo opening at Cherry Valley, for the basalt can be followed directly from the mountain to the river, resting all the way on the Dakota sandstone, which has been changed into quartzite near the plane of contact.

Though the rocks clearly shade off toward the south as though these mountains are not part of an anticlinal, yet the influence of the uplift is very distinct in a southeast direction; for the Cretaceous sandstone dips northeast at Ojo de Vermejo as well as on the Mora at Cherry Valley, while in the gap through the Canadian Hills the limestone of No. 3 dips sharply in the same direction.

The conditions are the same on the west as on the east side of the mountains, except that the dips are westward, being southwest along the road to Fort Union but northwest at a little distance north from Collier's Ranch. On this side of the mountains one reaches the area of

WOLF CREEK,

which is an insignificant stream rising on the edge of the Ocaté Mesa and flowing southward to the Mora.

A solitary hill capped with basalt stands on the southern edge of the Ocaté Mesa, northwest from the Turkey Mountains and just beyond the Fort Union and Gallinas road. Its summit is at very nearly the same level with the higher portion of the Ocaté Mesa north from Ocaté Creek, so that, like the Wagon Mound and the other hills west from the Canadians, it doubtless tells the height to which the lava rose on the mesa.

The Ocaté Mesa gradually breaks down toward Wolf Creek and fades into the valley of that stream; but the valley was certainly filled by igneous rocks, for the northern limit is well-defined by a low bench of basalt reaching from the mesa at the west across very nearly to the base of the Turkey Mountains, while small patches still remain along Wolf Creek to some distance south from Fort Union, the sheet clearly following the outline of the valley. The Upper Dakota sandstone is frequently exposed on the east side and north from Fort Union, being everywhere very near the surface. Here and there some travertin-like limestone occurs, sometimes cementing fragments of sandstone and at others appearing as a mere incrustation.

The sandstone is exposed many times southeast as well as south from Fort Union, and the marly limestone is abundant in depressions in that rock, especially on the plain reaching from Wolf Creek eastward. Quaternary deposits prevail along the middle of the valley and show depressions holding ponds of alkaline water. The accumulation seems to be thick east from Wolf Creek, for the post well at Fort Union, though sixty feet deep, does not reach the bottom of this deposit and ends in loose red sand.

The broad mesa between Wolf Creek and Mora Creek extends northward and is merged into that part of the Ocaté Mesa which borders on Coyote Creek. Its southern portion shows only Upper Dakota sandstone covered with a thin layer of Quaternary, which either contains or rests on a marly limestone. The southern boundary of the igneous area of the Ocaté Mesa is distinct here. It fails to reach the road leading from Fort Union to Coyote, but touching the valley of Wolf Creek it curves away northwestward until it crosses Coyote Creek near Guadalupita. The sandstone mesa extends southward to junction of Sapello Creek and the Mora. It bears no transported fragments, and the detrital covering is clearly of local origin. Shallow depressions without outlets are numerous and some of them hold permanent ponds of water.

COYOTE CREEK.

This stream heads near Cieneguilla Creek and flows southward to the Mora, which it reaches at a few miles below the village of Coyote. Its valley follows the Coyote synclinal to Coyote Park, where the stream breaks through the Cimarron axis.

The Fort Union and Coyote road, crossing the mesa, follows on the east side a long arroyo in which the Upper Dakota sandstone is almost horizontal. On the west side of the mesa the road descends through a short arroyo into Coyote Park. The sandstones have a slight eastern dip at the head of this arroyo, but the rate increases to about 7° near the park, where the sandstone runs out and the Middle Dakota rocks are exposed. The dip diminishes southwestwardly, so that where the Coyote leaves this park the sandstone is very near the creek and the insignificant exposure of the lower rocks is almost wholly covered by *débris*. But the rate of dip increases toward the northeast corner of the park, where the igneous plate of the Ocaté Mesa appears and its *débris* conceals all of the stratified rocks.

The southern wall of this park is a bold hill of Upper Dakota sandstone, beginning at Coyote Creek and ending somewhat abruptly at the west, so that the park reaches to Mora Creek at La Cueva. Quaternary material forms the northern rim of the park except near Coyote, where the Lower Dakota sandstone is exposed.

The Cimarron axis crosses the park about midway between the eastern mesa and Coyote Creek, where a little hill shows red shales and sandstones of the Middle Dakota dipping northwest. The anticlinal practically disappears in the south wall of the park, where it is little more than an interruption of the dip.

A wall of Lower Dakota sandstone, forming the western boundary of the park, rises immediately east from the village of Coyote and is broken by the creek. The dip of the sandstone is 2° at the east end of the gap; but the rate increases quickly to 5° to 10°, and at the head of the gap the lower beds of the series are turned up at nearly 60°, while just beyond the narrow valley behind the Dakota hog-back is a hill of Carboniferous rocks capped with basalt.

Where the Coyote and La Cueva road breaks through the wall the dip has passed a vertical and the rocks are dipping westward at 85°. Farther south the westward dip is very pronounced on the east side of the wall, but some exposures in the park at one-fourth of a mile from the base of the wall are dipping eastward. At one mile north from La Cueva the whole wall dips eastwardly, and an exposure little more than one-fourth of a mile off in the park shows the rocks dipping westward; but from the Mora Gap eastward to Coyote Creek the dip is distinctly eastward.

The Carboniferous rocks are vertical. The gray sandstones of that series are well shown along the road leading up the creek, and many of them stand up in ragged walls like trap dikes. The dip of the Lower Dakota sandstones apparently disappears within three miles above Coyote, as the channel-way is pushed toward the east and erosion has removed the disturbed part of the beds.

The valley is divided at, say, four miles above Coyote. A fine little park begins immediately west from the Carboniferous hills and continues almost to Guadalupita. Only Archæan rocks occur along the west side of this valley except near Chupadero, where the Carboniferous rocks are imperfectly shown resting on the Archæan core of the Mora anticlinal. The road ascending the creek breaks through the Carboniferous hills at three miles north from Chupadero, and the following section was made out from the road exposures. It begins at the creek, and the beds are seen in the order given in going westward:

		Feet.
1.	Shale and sandstone with thin *limestone*	90
2.	*Limestone*	3
3.	Sandstone and dark shale	70
4.	*Limestone*	7
5.	Shale	10
6.	Sandstone	6
7.	Shale	20
8.	*Limestone*	3
9.	Sandstone and shale, imperfect exposure	225
10.	Gray *limestone*	7
11.	Sandstone and shale, imperfect exposure	550
12.	Concealed	160
13.	Sandstone	180
14.	Mostly concealed	275
15.	Gray *calcareous* sandstone	15
16.	Imperfect exposure, much sandstone	375
17.	Shaly sandstone, imperfect exposure	120
18.	Gray *limestone*	7
19.	Concealed	23
20.	Shale	17
21.	Blue *limestone*	7
22.	Shale with *calcareous* layers	25
23.	Coarse sandstone	75
24.	Shale with thin gray *limestones*	180
25.	Blue *limestone*	6
26.	Coarse sandstone	50
27.	Concealed	100
28.	Dull-brown shale with *calcareous* layers	30
29.	Concealed, estimated	300
30.	Blue *limestone*	5
	Total	3,041

No. 1 is in the west bank of Coyote Creek, and on the opposite side of the stream, barely 200 feet away, are the shales and sandstones of the mesa series, dipping eastward. From No. 8 to the top of the section the rocks dip westward at 80°, while the rocks of the mesa series dip eastward at 10°. The Carboniferous rocks show a gentler dip toward the west just north from this road.

The dip increases from this road southward to the trail or road from Chupadero to the creek, and where the stream makes a sharp bend farther down it becomes eastward, though the variation from the vertical is slight. This sharp bend affords a series of exposures connecting the mesa with the Carboniferous hills. The Dakota sandstone on the mesa dips very gently eastward, but in a bench at the base of the wall the dip of the lower rocks increases rapidly from 2° to 10°. Very coarse reddish sandstones are shown in the south bank of the creek, alternating with reddish shales and containing water-worn blocks of red sandstones. These beds, which are not far from 500 feet thick, may be Triassic. Two hundred feet of sandstones and shales with thin beds of impure limestone overlie these and may represent the Jurassic. The coarse gray sandstones of the Carboniferous, alternating with irregular limestones and dark-red shales, are well exposed where the road comes down to the creek. Apparently there is no want of conformability here, but the succession of the Carboniferous rocks, as shown in the section given, proves a duplication of the series and suggests the existence of a compressed synclinal and anticlinal.

The Carboniferous section as given above is repeated in the gap through which the Chupadero road passes. The rocks are vertical near Coyote Creek; within a short distance they dip toward the west, but soon are vertical once more. The exposures of the limestones are more satisfactory here than on the other road. That at the base of No. 7 is gray, 20 feet thick, and contains many fossils. The following forms were observed: Crinoidal stems, *Rhombopora*, *Stenopora*, *Fenestella*, *Synocladia*, *Discina*, *Terebratula bovidens*, *Spirifer keokuk?*, *Spirifer cameratus*, *Spirifer lineatus*, *Spiriferina kentuckensis*, *Athyris subtilita*, *Productus punctatus*, *Productus nodosus*, *Productus muricatus*, *Productus semi-reticulatus*, *Chonetes*, *Avicula longa*, *Aviculopecten occidentalis*, *Aviculopecten* sp., *Nucula parva*, *Nucula ventricosus*, *Leda bellistriata*, *Yoldia* sp., *Myalina swallovi*, *Myalina subquadrata*, *Allorisma costata*, *Cypricardella* sp., *Cyclonema* sp., *Eunema* sp., *Bellerophon* 2 sp., *Conularia*.

The Archæan as exposed along the face of the range from near Chupadero to beyond Guadalupita is a soft slaty gneiss containing silvery mica and small blotches of quartz. Within the range the gneiss differs somewhat from that seen on the face of the mountain, and resembles a micaceous sandstone so closely that one examining only hand specimens might well be puzzled to determine its relations. This passes into a dark mica schist, which continues to near the heart of the axis and shows only rare bands of gneiss and gneissoid granite. The mode of occurrence suggests that these bands may have originated by segregation on a large scale. A small patch of basalt was seen near the Mora road, resting on the gneiss and covering not far from 1,500 square yards. It is similar to that on the Ocaté Mesa.

The Archæan is thrust eastward at a little way south from Guadalupita and the Carboniferous lies there only on the east side of Coyote Creek; but at nearly two miles above the village the latter is again shown on the west side, and the following section was obtained where the road turns away from the creek.

	Feet.
1. Sandstone	30
2. *Limestone*	25
3. Shale	40
4. Sandstone	4
5. Shale	10
6. Conglomerate sandstone	6
7. Variegated shale	120
8. Sandstones with blue *limestone* near base	300
Total	535

This brings one to the creek. The Carboniferous rocks are shown on the east side, but no section can be obtained. No. 8 rests directly on the Archæan, and the dip throughout the section is toward the heart of the axis, northwest at nearly 50°. A limestone is exposed at the roadside not far below this, which overlies No. 1, is thirty-five feet thick and very rich in fossils, the following species having been obtained during a brief examination: *Spirifer lineatus*, *Spirifer keokuk?*, *Streptorhynchus crassus*, *Productus muricatus*, *Productus cora*, *Myalina*, *Platyceras*.

The shales No. 3 contain thin layers of limestone and are rich in fossils throughout. The following forms were found: Crinoidal plates, *Fenestella*, *Spirifer keokuk?*, *Spiriferina kentuckensis*, *Retzia mormonii*, *Athyris subtilita*, *Athyris pectenifera*, *Productus costatus*, *Productus prattenianus*, *Productus muricatus*, *Productus splendens*, *Productus* sp., *Chonetes* *granulifera*, *Chonetes* sp., *Streptorhynchus crassus*, *Nucula ventricosa*, *Pleurotomaria spherulata*, *Pleurotomaria grayvilliensis*, *Orthoceras ruskensis*.

The limestone at the base of No. 8 is blue and evidently non-fossiliferous, but it was not found in place. No. 2 answers well to the gray limestone near the base of the section previously given.

The basalt plate covering the Ocaté Mesa ends near the head of an arroyo at nearly two miles east from Coyote Creek, on the trail from Ocaté Park to Turqui. From the edge of the basalt to the Coyote the trail passes over the Lower Dakota sandstone, in which are many ponds, occupying rounded depressions with unbroken rock walls. The basalt comes down at about three miles above Guadalupita and fills up the valley of the Coyote, so that for several miles the stream flows through a deep close cañon which begins at eight miles above Guadalupita. This cañon is separated by but a short interval from another, which begins at twelve miles above Guadalupita and is eroded in like manner from the basalt. The east wall of the valley shows only the gloomy basalt, but the sheet cannot be very thick, for fragmentary exposures of Carboniferous rocks are not rare. These are doubtless relics of projecting bluffs. A mass of light-colored eruptive rocks covers the mountains on the west side of the cañon within two or three miles of its head, and continues northward to the Black Lake Park. It is easily distinguished beyond the west wall of the cañon, and rests directly on the Archæan, which contains many broad bands of snow-white quartzite.

There seems to be no room for doubting that the valley now followed by Coyote Cañon was filled by trachytic lavas, and that it had been re-eroded before the time of the basalt overflow, for the trachytes distinctly underlie the basalt at several localities within the cañon. The widening of the Archæan area is well shown in the cañon, for the Carboniferous limestones and shales are shown only on the east side of the creek, whereas northward they reach much farther westward.

A fine terrace at 185 feet above the creek was seen at three miles below Guadalupita, and was seen again alongside of the lower cañon with a grade up-stream of nearly forty-five feet per mile. The detrital covering consists mainly of Archæan pebbles.

The country opens into a handsome park above the upper cañon, and there the basaltic area ceases to extend beyond the creek toward the west, though the plate still remains on the mesa at the east. Black Lake, near the head of this upper cañon, is an insignificant pond, which no doubt was once much larger than now; but the springs feeding this pond are strong and the water overflowed the rocky wall, so that by erosion a channel-way opened for draining the pond. Small ponds are common near the Forks of Coyote Creek, and many pot-holes or rounded depressions were observed in the neighborhood.

The low hills of the Mora Range forming the western wall of this park have a regular slope eastward, and extend northward until they become the foothills of Taos Mountain. Immediately southwest from Black Lake are the sharp cones of trachyte, already referred to as shown west from the cañon, which rise high above the crest of the hills directly north. The Mora Hills show few exposures. Carboniferous rocks reach to their base, and in many places quite to their summit, while Archæan rocks are exposed by many of the streams which flow down the slope.

The Carboniferous sandstone appears first just below the forks of the creek. This underlies a blue limestone full of fossils. Over it is a shale with root-like markings.

A limestone very rich in fossils was seen at probably two or three miles above the forks of the creek. Only a few specimens were collected, among which are the following species: *Spirifer cameratus*, *Spirifer plano-convexus*, *Spirifer keokuk?*, *Productus prattenianus*, *Productus costatus*, *Productus muricatus*, *Aviculopecten carbonarius*, *Aviculopecten occidentalis*, *Schizodus* sp., *Pleurotomaria carbonaria*, *Naticopsis*.

Another limestone, in thin layers and embedded in shales, is shown where the road leaves the East Fork. Both the limestone and the shale are rich in fossils, and the following species were collected in a few minutes from specimens which had weathered free from the rock: *Athyris subtilita*, *Productus costatus*, *Productus prattenianus*, *Streptorhynchus crassus*, *Macrodon obsoletus*, *Aviculopecten occidentalis*, *Aviculopecten* sp., *Myalina swallovi*, *Myalina subquadrata*, *Astartella arata?*, *Astartella vera*, *Leda arata*, *Nucula ventricosa*, *Schizodus wheeleri*, *Bellerophon percarinatus*, *Macrocheilus ventricosa?*, *Macrocheilus primigenius*, *Naticopsis* sp., *Eunema* sp., *Pleurotomaria*, 2 sp., *Polyphemopsis* sp.

Thus far the dip in the region above the basalt has been northeast and comparatively gentle; but where the road turns toward the West Fork the dip suddenly increases in sharpness and the Carboniferous rocks extend across the valley, dipping north of east or south of west at nearly 70°. The exposures are not such as to afford definite sections, but everything suggests the presence of an almost north and south fault in the Carboniferous beds. Above this, toward the head of the creek, Carboniferous rocks are occasionally shown, but the alluvial coat is so thick that these exposures are neither numerous nor extensive.

The basalt plate covering the Ocaté Mesa at the east is continuous beyond the head of the Creek. At probably two and one half miles above Black Lake the Lower Dakota sandstones are shown underlying the basalt. They continue in sight to near the Forks of Coyote Creek, opposite Black Lake, where the basalt rolls down and conceals them. But almost south from the east fork of that creek two small patches of the sandstone remain on the very edge of the mesa, although the basalt prevails on the broken area extending from the edge of the mesa down to the park. The basalt covering this broken area is for the most part vesicular and much of it still retains the flow-surface as freshly as though the eruption were very recent. But the color of the weathered surface is rusty red. The Ocaté Mesa along the road from Black Lake to Rayado is evidently a basalt-covered plain, though here and there are outcroppings of older lava with an occasional hillock of Lower Dakota sandstone. It is altogether probable that the great dikes of the Old Baldy group do not disappear until at some distance from the Rayado Cañon. But this matter can be determined only with difficulty, for the alluvial deposit on the mesa, though not very thick, is nevertheless evenly distributed and effectually conceals the underlying rocks.

MORA CREEK.

The Mora River is known as Mora Creek above its junction with Sapillo Creek. From a short distance above that junction to the mouth of Coyote Creek it flows in a not deep but very rugged cañon. From the mouth of Coyote Creek almost to the mouth of Cebolla Creek its course is through a fine park in which is the plaza of Golondrinos. From Golondrinos to within two and a half miles of La Cueva it flows through a horseshoe cañon eroded amid the sandstones of the Upper Dakota. Above that to La Cueva it flows through a park in the Middle Dakota, bounded at the west by the Lower Dakota wall, already referred to as first seen at Coyote. The Cimarron axis is turned toward the southwest in Coyote park and is but faintly perceptible south from Mora Creek, for it is soon merged into the Manuelitos axis beyond the Stonewall.

This wall, so conspicuous at La Cueva, continues southward with diminishing dip to the divide between Mora and Cebolla Creeks. Its rock varies from fine-grained very light-gray sandstone to similarly fine-grained yellow sandstone, with here and there a pocket of very coarse conglomerate. The Middle Dakota consists of red shales, light-gray soft sandstones, and a limestone-bed associated with a conglomerate limestone and without fossils. The limestone is well shown in the village of Buena Vista, and the conglomerate is shown on the road leading east on the north side of the creek and immediately below La Cueva.

The Upper Dakota is a great mass of sandstone, for the most part hard and very light gray, almost as compact and fine-grained as imperfect quartzite, and contains pockets of soft yellow sandstone, which yield readily to the weather. Thin beds of conglomerate are not rare, and many of the finer beds contain obscure casts of fucoids. Some of the harder layers weather dark brown. The whole series is not far from 1,000 feet thick.

The outcrop of this upper sandstone crosses the creek at a little way west from Golondrinos and continues southwestward, owing to the bend of the Cimarron axis. The dip on Mora Creek below La Cueva is very gentle, but at a few miles southwest from Golondrinos it becomes very abrupt, so that almost midway between Cebolla and Sapillo Creek it is reversed and the whole group is shown within a horizontal space but little greater than the vertical thickness of the series.

The Colorado shales are exposed in the Golondrinos Park, the northern termination of an extensive area underlaid by those shales, which reaches southward far beyond the limits of the district.

The valley of Mora Creek becomes very narrow immediately above La Cueva, and so continues until the Archæan area of the Mora axis is reached. The dip increases less rapidly in the gap at La Cueva than it does in the Coyote gap through the Lower Dakota, and the lowest bed of the group forms the crest of the wall, with a dip of barely 20°. The Triassic rocks come immediately behind the wall and form the western slope of the comb. They consist of soft fine-grained red sandstones and variegated shales. Lines of pebbles occur at variable distances in the sandstones. These beds dip at 40°.

The dip increases as one goes up the creek, for, after passing a narrow gap in which no exposures occur, the Carboniferous sandstones are reached and show a dip of nearly 50°. These rocks are coarse to fine, and in color vary from gray to brown. The shales separating them are often of deep red color and frequently hold beds of limestone. The following section was obtained below Cañoncito on this creek:

	Feet.
1. Sandstone	3
2. Concealed	40
3. Sandstone and shale	30
4. Concealed	25
5. Sandstone	10
6. Concealed	30
7. Sandstone	3
8. *Limestone*, blue, fossiliferous	12
9. Sandstones and shales, the latter red, former light to dark-gray, conglomerate; dip from 60° to 70° east	320
10. *Limestone* and shale, seen immediately above second ranch; the limestone is blue, non-fossiliferous, and weathers into nodules	20
11. Sandstone, at third ranch; mostly dark-gray, with some layers of red shale	250
12. Imperfectly exposed. Some layers of sandstone	100
13. Sandstone, dark-gray	90
14. Concealed	20
15. Sandstone, yellow	25
16. Concealed	15
17. *Limestone*, blue; many fossils	10
18. Sandstone, yellow mottled with black, flaggy	8
19. Sandstone, dark-gray	40
20. Shale, dark-red	12

		Feet.
21.	*Limestone*, blue, cherty, fossiliferous, flaggy; seen at fourth ranch	18
22.	Shale, red	20
23.	Sandstone, gray, mottled with reddish-brown	30
24.	Shale, red	10
25.	*Limestone*, cherty	6
26.	Shale, red	20
27.	Shales red, with thin gray sandstones	90
28.	Sandstone, gray, with brown spots	70
29.	Concealed	50
30.	Sandstone, flaggy to compact; contains impressions of stems of plants	20
31.	Shale, red	8
32.	*Limestone*, in thin layers, with intervening shale; gray, fossiliferous	18
33.	Shale, dark-brown	60
34.	Imperfectly exposed	150
35.	Shale, dark; seen at fifth ranch	70
36.	Sandstone, gray; dip 85° east	15
37.	Shale	40
38.	Alternations of shales and sandstones to the sixth ranch	300
39.	Coaly shale	10
40.	*Limestone*, impure, non-fossiliferous	2
41.	Concealed	30
42.	Sandstone and shale	70
43.	*Limestone*, blue; few fossils	6
44.	Sandstone and shale	30
45.	*Limestone*, grayish, somewhat silicious	8
46.	Concealed	25
47.	Sandstone	15
48.	Concealed	60
49.	*Limestone*, seen	10
50.	Concealed	20
51.	Sandstones and shales	180
52.	*Limestone*	25
53.	Sandstone	30
54.	Dark shale and *limestone*	70
	Total	2,649

No. 47 is reached at the road coming from the north and touching the creek below Cañoncito; No. 48 is the space occupied by a broad swale along which the road passes; No. 49 is imperfectly exposed, but seems to be dipping westward.

An anticlinal crosses the creek between the first and the second little cañon above the road, and No. 54 is shown in the second cañon. The westward dip is very gentle and continues to the third cañon, where it is suddenly reversed and the rocks dip sharply eastward. The exposures beyond this cañon are not continuous and the section to the base of the column could not be computed. The distance to the Archæan rocks is not far from 450 feet as shown on Cebolla Creek. A silicious limestone rests on the Archæan or very near it. The dip increases up the creek and becomes vertical before the Archæan rocks are reached.

A cañon heading near the Mora and Placita del Oro road shows the same conditions but somewhat exaggerated. The anticlinal and overturn are more distinctly exposed than they are on the Mora.

The Archæan rocks are reached at barely a mile above Cañoncito, where a coarse conglomerate-like bed of gneissoid granite underlies the Carboniferous. The quartz of this rock is in angular blocks with faces exceeding a square foot, and the mica is in patches frequently three by five inches. Mica schists, very tender and readily breaking down, prevail farther up the stream. They contain little feldspar and less quartz, but here and there is a bed of very dark schistose gneiss, which is handsomely mottled with flecks of feldspar. Occasional beds of gneissoid granite and not rarely huge blotches of the same material were seen on the hill-sides, the latter looking as though masses of pasty material had been splashed against the hill and had adhered to the surface. These rocks continue to the sharp curve in the creek just below San Antonio; but a great thickness of sandstone comes down to the creek at midway between Mora and San Antonio and dips a little east of south at 20°. It is evidently a slide from the Carboniferous, which has its outcrop in the hill on the west side of the Mora axis.

The axis of the Mora Archæan area passes almost directly through Mora. A broad valley lies north from the city, having on each side a high ridge with Carboniferous rocks on its crest. The Archæan rocks are light-colored and silvery, but much fine-grained compact gneiss occurs, not unlike sandstone in structure. Mica schists prevail on the hill immediately south from Mora, in which are many quartz veins and some irregular patches of gneiss. Coarse gneissoid granite is present at the base of this hill.

The cañon of Mora Creek opens into a neat park at a mile above Cañoncito, with a broad valley entering from the north and a somewhat narrower one from the south. This park is covered with fine detritus below Mora and in the northern valley; but toward San Antonio the surface is littered with pebbles brought down by Las Casas Creek, so that for the most part it is not fitted for cultivation.

The outcrop of the Carboniferous rocks on the west side of the Mora axis is shown on the crest of the ridge at a little way above Mora, but the rocks do not come down to the stream until very near San Antonio, where the course of the creek is changed. The stream flows almost southward from its head to that place. The Carboniferous rocks reach quite to the summit of the ridge on the east side of Mora Creek until near the forks, where the outcrop curves to west of north and thence lies west from the East Fork. The exposures are very bad in this ridge, only an occasional outcrop of limestone having been seen above San Antonio.

The cañon of Las Casas Creek, on the west side of the Mora Creek Valley, exposes the Archæan rocks in bold precipices; but within a very short distance north from that creek the Carboniferous passes unbroken to the crest of the ridge. The Mora axis on the east side of the valley becomes stronger northward and shows some bold Archæan mountains beyond the head of the creek, whereas on the opposite side the Las Vegas Peaks are covered by the Carboniferous.

A slight anticlinal was observed not far above San Antonio, and the valley of the creek seems to have been eroded from this axis. The dips become irregular above the village of Agua Negra, and before the head of the stream has been reached they appear to be wholly toward the northwest. Carboniferous sandstone, dipping northwest at 70°, was seen on the West Fork, while in the hills on both sides the rocks seem to dip gently away from the valley. Fragmentary exposures show that this condition prevails southward to very near the forks of the creek. Apparently, a fault runs through this region, for limestones, belonging low down in the Carboniferous, were found far up on the hill-side on the west side of the stream.

The Quaternary deposit begins at two miles above the forks and the valley of the creek is wide thence to the cañon below Mora. High level benches were seen near the head, and the ridge at the west has been well planed off.

A broad dike of basalt, running northeast and southwest, crosses the creek at its forks and continues along the wide eroded area to the western wall. Though it could not be found on the summit of the ridge, yet it clearly extends beyond that westward, for fragments of it were seen on Junta Creek, a tributary to the Rio Grande.

CEBOLLA CREEK.

This stream, formed at the town of Cebolla by the union of two forks rising in the Las Vegas Range, flows eastward and joins Mora Creek at somewhat more than a mile above Golondrinos, very near the lower end of the Horseshoe Cañon described by that creek in its passage through the Upper Dakota sandstones.

Following this creek from its mouth one passes through a cañon in the Dakota until somewhat less than a mile below Placita de Don Tomas. The dip of the sandstones is gentle at the mouth of the creek, but increases until, at the western outcrop, it becomes almost 65°. The Triassic rocks are not exposed behind the Dakota wall, and a broad swale occupies their place. The concealed interval cannot hold much more than 300 feet of rock, if the dips on both sides may be taken as basis for calculation.

The Carboniferous rocks are reached directly west from this swale, and thence they remain in sight up to the Archæan area beginning at a little way below Placita del Oro. Unfortunately the exposures are very imperfect and every attempt to procure a detailed section was unsuccessful.

Where first seen in ascending the creek the Carboniferous sandstones are dipping eastward and are almost vertical. Not much farther up they are vertical. An overturned anticlinal is nicely shown on the north side of the creek, at barely one-fifth of a mile above Placita de Don Tomas. On the east side the rocks are dipping westward, having been pushed about 5° beyond a vertical, while on the west side they have a gentle dip of not more than 4°.

This gentle westward dip continues until very near the head of the little cañon, but there for not less than one-sixth of a mile it is more rapid. Beyond that the strata are turned up abruptly, the dip is reversed and becomes nearly 60° eastward. This is retained to the contact with the Archæan rocks. A gray limestone was seen at about sixty-five feet above the base of the group, and a mass of dark shales and thin limestones occurs at probably 450 feet. The latter is the same with that seen near Cañoncito on Mora Creek.

The valley of Cebolla Creek below Placita del Oro is narrow, but opens out into little parks affording ample room for small ranches. These parks are neatly terraced, and the alluvial deposits, full of pebbles and larger polished fragments, reach to forty feet above the stream. Beyond the terrace an irregular deposit with polished fragments extends to fully 200 feet above the creek, and occurs even on the divide between Cebolla and Mora Creeks along the road from Placita de Don Tomas to La Cueva.

The Archæan rocks are reached at a little way below Placita del Oro and are well shown on the east side of the broad valley followed by the road leading from that place to Mora. They form sharp hills on the west side of the same valley and remain in sight along Cebolla Creek to the village of Cebolla. A road from Cebolla to Mora follows a park along the axial line, and Archæan rocks alone are exposed on both sides of this park; but the outcrop of the Carboniferous on the west side of the Mora axis reaches very nearly to the crest of the western ridge as it approaches Cebolla Creek. Archæan rocks are shown on the point of the hill between the forks of Cebolla Creek, where they consist of coarse gneissoid granite with some dark schistose gneiss and mica schists, the latter being beautifully waved.

An irregular bluish limestone imperfectly exposed on this hill rests directly on the granite. Some parts of it are very silicious while others are evidently pure limestone. The whole mass seems to be non-fossiliferous. Exposures are very bad along the North Fork, for only the coarse gray sandstones are well shown. These have a glazed appearance on the weathered surface, as though they had been semi-vitrefied. Some of them have impressions of tree-trunks, and from one an imperfect specimen of *Sigillaria* was obtained.

A hard limestone, ferruginous and for the most part silicious, is exposed on the north side of this stream at about one-third of a mile below the bend. It is rich in fossils, the following species having been obtained within a few minutes: *Lophophyllum proliferum*, *Fenestella*, *Stenopora*, *Spirifer cameratus*, *Spirifer lineatus*, *Spiriferina kentuckensis*, *Retzia mormonii*, *Athyris subtilita*, *Productus muricatus*, *Productus semireticulatus*, *Chonetes granulifera*.

This bed seems to be about 200 feet above the lowest limestone.

It passes upward into a sandy calcareous shale exceedingly hard, grit-like, and blue, which is ferruginous, occurs in layers two to three inches thick, and breaks out in regular blocks. It does not crumble on long exposure to the weather, but its carbonate of lime is leached out and the rock becomes tender so as to split readily. It is literally crowded with fossils, and every blow of the hammer yields slabs covered with good specimens. An excellent outcrop, continuing for 300 or 400 yards, begins on the west side just below the bend in the stream. From this were obtained crinoid stems, *Stictopora serrata*, *Fenestella* 2 sp., *Discina* sp., *Lingula* sp., *Orthis pecosii*, *Spirifer keokuk*, *Spiriferina kentuckensis*, *Athyris subtilita*, *Athyris roysii*, *Streptorhynchus crassus*, *Productus costatus*, *Productus punctatus*, *Productus prattenianus*, *Aviculopecten carbonarius*, *Aviculopecten occidentalis*, *Pinna* sp., *Pterinopsis?*, *Avicula?*, *Myalina subquadrata*.

The sandstones dip almost due west above the bend in the stream, but at probably two miles the dip is reversed. A limestone, non-fossiliferous and resting on drab shale, is exposed near the line of the synclinal and is dipping eastward at nearly 5°. This was followed for nearly a mile to the forks of the creek, beyond which it runs out. Exposures practically cease at the forks, and the Archæan rocks rise precipitously within a mile. They are represented mostly by micaceous schists.

The conditions on the other fork of Cebolla are the same as on this, but the exposures are very bad.

Archæan rocks appear suddenly at the cañon of Las Casas Creek and form a bold wall thence southward to Mount Solitario, while the area of Carboniferous is narrowed in that direction.

The divide between the forks of Cebolla is an irregular and imperfectly drained plain, which holds several ponds.

SAPILLO CREEK BELOW SAPILLO.

Sapillo Creek rises in a basin north from Mount Solitario and, flowing eastward, enters the Mora River at La Junta, seven miles south from Fort Union. It receives, near the village of Sapillo, Manuelitos Creek, a large stream heading near the South Fork of Cebolla Creek.

Sapillo Creek breaks through the Dakota wall immediately below Sapillo. This wall, the same with that already described as occurring on Cebolla Creek, breaks down quickly at the east into a plain reaching to Mora Creek and dotted with mesas of the Middle Cretaceous. Some of the mesas are high and, where the slopes are not concealed by *débris* of Quaternary deposits, they have a somewhat striking appearance. The *débris* of the limestones is a marked feature, and its grayish tint has given the name to Loma Parda, "The Gray Hill."

Where the shales have been cut away the plain is covered with a thick coat of Quaternary, in which are pebbles of gneiss, granite, and quartzite, as well as of all other rocks found along Sapillo and Cebolla Creeks. Pebbles of Archæan seem to predominate, and there are comparatively few from the Middle Cretaceous. The marly travertin-like limestone, already referred to in previous sections, is occasionally shown underlying this material, and small undrained depressions are of frequent occurrence.

The structure of the Dakota wall changes between Cebolla and Sapillo Creeks. In approaching it from the east one crosses the limestones of No. 3 and the dark shales of No. 2. The latter pass gradually into the Upper Dakota, having at their base the thin beds of sandstone covered with mats of fucoids. The dip increases rapidly, so that at the mouth of the cañon through the wall the sandstone dips at 70° east. But the dip becomes vertical midway in the gap, and at its head the rocks are dipping westward at 85°. The whole length of the cañon is barely half a mile.

The Upper Dakota is well exposed near the mouth of the little cañon, where the section is—

1. Sandstone, underlying the dark shales of Cretaceous No. 2, and not far from 250 feet thick. It is mostly fine-grained, light yellowish-gray, and shows thin films of quartz breaking across the bedding.

2. Shales, 220 feet thick; light-gray to blue and almost black; contain thin sandstones and thin layers of argillaceous limestone, the latter showing dendritic markings to two inches from the surface.

3. Sandstone, 200 feet thick; soft, flaggy to shaly, with some massive layers; very fine-grained and closely honeycombed by films of quartz. Contains some drab shale; color for the most part grayish-yellow.

A gap occurs beyond this sandstone. It is narrow on the south side of the creek, where, at an interval of 90 feet below the last sandstone, red micaceous shales are exposed, which are underlaid by light-gray sandstones very similar to those seen at the mouth of the gap. The west side of the wall is made up of coarse conglomerates. The gap is much wider on the north side of the creek, and the conglomerate limestone seen below La Cueva, on Mora Creek, is shown very near its western edge. Red shales, which may represent the Triassic, were observed immediately back from the wall at some distance north from the creek

MANUELITOS CREEK.

Manuelitos Creek enters the Sapillo almost directly behind the Dakota wall. The Carboniferous sandstones are vertical, or very nearly so, at its mouth, possibly pushed over so as to dip toward the west, the character of the exposures not being such as to settle the question. But the dip diminishes westward until below the village of Manuelitos it is about 50° east. The Cimarron anticlinal crosses at Manuelitos, and thence to the sharp bend the dip is northwest at about 12°. But a very abrupt anticlinal crosses at the bend and the rocks dip at very nearly 35° on each side. This anticlinal has a northeast and southwest strike and crosses at about a mile above Manuelitos.

From this place up the creek the dip is westward to the Las Tusas road, becoming gentler all the way. Thence, however, the rise is westward to within a mile of the saw-mill; but at somewhat more than a mile below that mill the dip, previously gentle, increases rapidly to 5°, then 10°, 25°, 30°, and at last to 70°. For two-thirds of a mile below the saw-mill the structure is complicated. A carefully measured section was made from the mill down the creek for more than a mile. It is as follows:

	Feet.
1. Archæan rocks, well exposed on the hill-side at the mill, and consisting mostly of mica schists with some gneiss.	
2. Concealed interval, estimated at	25
3. Limestone	35
Dip, 35° east, strike very near north and south, very irregular in bedding, quite silicious, containing some chert and holding some conglomerate layers. Color gray to bluish; not fossiliferous; passes upward into a quartzite.	
4. Sandstone	20
Gray below, red above; fine-grained throughout and quartzite below; transition from No. 3 almost imperceptible.	
5. Sandstone and sandy shale	60
Not fully exposed, for near base is a grayish limestone, with *Orthis resupinata* (?), *Productus*, and other forms, which is shown in fragments just above No. 4 in the creek-wall. The sandstones are fine to coarse, red to gray, and in thin beds. Some layers contain flakes of zinc blende. The shales are red, micaceous, and more or less ferruginous; occasionally a fossiliferous layer occurs. A conglomerate sandstone closes the series.	
6. Concealed interval, some sandstone	45
7. Coarse sandstone	10
8. Limestone	8
Irregularly bedded; coarse, granular, very hard; weathers with fluted surface; gray; fossiliferous.	
9. Red sandy shale	10
10. Gray sandy shale	6
11. Limestone	6
Gray, silicious, and passes up into sandstone. Contains some fossils of the more common species.	
12. Concealed interval, some shale	30
13. Gray coarse sandstone	5
14. Shale	8

		Feet.
15.	Limestone	40
	Gray to blue; more or less silicious; slaty, with layers of very sandy limestone; passes upward into a blue, somewhat calcareous micaceous sandstone, which splits readily, contains much iron, and weathers soft and reddish-yellow. This is the same with the rock seen on Cebolla Creek and is extraordinarily rich in fossils.	
16.	Sandstone	12
	Coarse and gray; forms a ridge on west side of first water-course below the mill.	
17.	Limestone, seen	8
	Dark-gray to blue and flesh color; weathers yellow with uneven surface; very tough, but becomes shaly near the top; fossils numerous but imperfect. The first water-course below the mill is eroded in part from this limestone.	
18.	Concealed interval; evidently much limestone	150–200
19.	Limestone	70
	Strike N. 50 E., dip 55° southeast; dark-blue; tough, breaks with conchoidal fracture; is in thin layers, three to six inches, alternating with similar layers of sandy shale. The proportion of limestone increases toward the top, where the shales become dark and the limestone somewhat ferruginous. The limestone layers are fossiliferous throughout.	
20.	Sandstone	50
	Gray, coarse; contains rude impressions of plants; forms comb on hill between first and second gaps below the mill and comes down to the creek at the old mill.	
21.	Limestone and shale	65
	Strike N. 20 E. and dip 70° eastward. This interval is not fully exposed, but the limestone is like No. 19 in all respects.	
22.	Sandstone	20
	Shaly and micaceous at base, but compact and conglomerate at top. Dip and strike the same as last. This is on the west side of the second water-course.	
23.	Concealed interval	12
24.	Limestone and shale, estimated	200
	Strike N. 25 E. and dip 80° south of east. Limestone hard, light-blue, and very compact at base, with irregular fracture; higher up it becomes gray and some of the layers are cherty. This great mass occupies the second water-course and comes down to the creek at the old mill. It is very rich in fossils throughout, the following species having been obtained from it: Crinoid stems, *Lophophyllum* sp., *Fenestella* sp., *Synocladia* sp., *Spirifer lineatus*, *Spirifer* sp., *Spiriferina kentuckensis*, *Athyris subtilita*, *Chonetes verneuilii*, *Productus nebrascensis*, *Productus semireticulatus*, *Productus nodosus*, *Productus muricatus*, *Productus punctatus*, *Streptorhynchus crassus*, *Myalina swallovi*, *Nucula* sp., *Avicula* sp., *Platyceras* sp., *Bellerophon* sp., *Phillipsia* sp., and some undetermined univalves. *Productus nodosus* is so abundant in some layers that many perfect specimens can be obtained from a small block.	

	Feet.
25. Sandstone	8
Coarse, gray; exposed on east side of the water-course.	
26. Limestone and shale	30
Strike very nearly north and south; dip 80° almost due east. Silicious, light-gray to blue; some shale, dark-brown to drab; fossiliferous.	
27. Concealed	20
28. Gray coarse sandstone	5
29. Limestone	20
Coarse, irregular, very hard and somewhat silicious. Weathers with a pitted surface; strike as in No. 26, dip westward but almost vertical.	
30. Sandstone	25
Dip distinctly westward; gray and coarse, with films of quartz on cleavage planes; graduates into finer and red shaly sandstone below.	
31. Limestone	15
Strike N. 20 W. and dip 65° south of west. Coarse gray to blue, fossiliferous.	
32. Sandstone	12
Coarse and light gray for the most part, but becomes micaceous and laminated on western edge of outcrop.	
33. Limestone, possibly not in place	?
34. Shale; red, micaceous, with bands of sandstone	120
35. Limestone	8
Dip west; coarse, somewhat sandy; light gray on fresh surface, weathers red; fossiliferous.	
36. Sandstone	15
Dips west; red to gray; fine grained throughout.	
37. Limestone	20
Dips west; gray to blue; not fully exposed.	
38. Shale; dips west	25
39. Interval, wholly concealed	25

Thus far the section is distinct, and the succession shows clearly that, in No. 37, No. 3 is again reached, so that the concealed interval, No. 30, must be very close to the Archæan rocks. Nos. 37, 38, and 39 are shown in the third little gap below the saw-mill, which is very small and comes down to the creek at the first road-crossing below the old mill. Here a very material change takes place, and one comes to coarse sandstones with only occasional limestones, the conditions being such as were observed on Mora Creek at a short distance above La Cueva. Crossing the concealed interval and continuing down stream, the following succession was found, the section being an ascending one:

		Feet.
1.	Sandstone	100
	Coarse, yellowish-gray; stands in combs; is vertical on top of hill between third and fourth water-courses, but at the creek level dips eastward at a high angle.	
2.	Imperfectly exposed	40
	Contains some shale, coarse sandstone, and a blue limestone with *Fusulina cylindrica.*	
3.	Sandstone	80
	Gray, massive to shaly; much of it conglomerate.	
4.	Limestone	2
	Seen in fourth water-course; blue, hard; contains *Streptorhynchus crassus.*	
5.	Gray, coarse sandstone	10
6.	Shale, reddish-brown, slightly calcareous	5
7.	Concealed interval in fourth water-course	45
8.	Sandstone	30
	Dip 80° north of east; coarse to conglomerate; gray to red; contains fragments of carbonized wood.	
9.	Concealed interval	20
10.	Sandstone like No. 8	6
11.	Sandstone	40
	Strike N. 50 W. and dip 60° eastward; red, micaceous, shaly.	
12.	Sandstone and shale	500
13.	Limestone	5
	Seen in run near first ranch below old mill; fine-grained to granular, flesh-colored to light gray; not fully exposed; non-fossiliferous.	
14.	Concealed interval	60
15.	Gray, coarse sandstone	40
16.	Concealed interval	50
17.	Sandstone	90
	Similar to the other sandstones of the section. Just below the first ranch its dip suddenly diminishes within a few rods from 55° to 30°.	
18.	Sandstones estimated	250
	These continue along the stream with eastern and constantly decreasing dip. They are separated by thin beds of shale, some of which must contain limestone, as fragments of that rock occur frequently. The dip diminishes to 3°.	
	Thickness of this part of section	1,373

The sandstones of No. 18 are the highest rocks exposed on Manuelitos Creek above Manuelitos. But the whole thickness of the Carboniferous is not given in the two sections, for without doubt a very material gap exists between No. 20, the highest rock of the first section, and No. 1, the lowest rock of the second. But no way exists whereby this gap can be filled.

No details were obtained respecting the area east from the Mora anticlinal to the Stonewall and lying between Sapillo and Cebolla Creeks, as that region was not visited.

At Cebolla Creek the Mora axis, previously trending almost north and south, changes its course, and thence southward trends almost southwest. A broad swale has been eroded from the arch of this anticlinal, which extends from Cebolla Creek to Manuelitos Creek and expands on the latter stream into a wide park, in which is the village of Santo Niño. A ridge of low hills, reaching from one creek to the other, marks the southwestern slope of the arch and holds near its crest the northwest outcrop of the Carboniferous rocks. The confused hills on the west side of the swale show only Archæan rocks on their eastern edge, but hold a considerable area of Carboniferous, which extends quite to the Archæan wall at the west.

The Santo Niño Park on Manuelitos Creek is imperfectly terraced, and is covered by silt precisely similar to that which covers the Canadian Plains.

Santo Niño is not far from the axis of the Mora anticlinal. The synclinal seen on Cebolla Creek is rapidly shallowing, for Archæan rocks are exposed on both sides of the creek to above the village of San José. The Carboniferous rocks come down with a dip somewhat more abrupt than that on Cebolla Creek, and remain in sight to the forks of the stream above Upper Tecolote, where all exposures cease until the Archæan rocks are reached near the head of the creek. The dip of the Carboniferous rocks is still westward at the last exposure, which suggests either that the west side of the synclinal is extremely short or that the sudden elevation of the Archæan rocks south from Las Casas Creek is due to a fault.

The Archæan is represented by gneiss containing silvery mica. One especially light-colored portion is distinctly visible at ten miles away, looking like a dike of Old Baldy trachyte.

The conditions are similar on the South Fork of the creek. A small area of Carboniferous lies between the streams and ends at nearly two miles above their union, while a tongue of Archæan reaches to that point and ends almost directly behind Santo Niño. This contains much of a greasy-looking gneiss, which resembles fine-grained sandstone and shows broad bands of white quartzite. The valley of the South Fork receives a wide swale from the west, between which and the creek the Carboniferous rocks are caught at about three miles west from the saw-mill. The extent of this patch cannot be determined accurately, since the forest is so dense between Manuelitos and the North Fork of Sapillo that the outcrop could not be traced.

The southern side of Santo Niño Park is wholly Archæan.

SAPILLO CREEK ABOVE SAPILLO.

Few observations were made on Sapillo Creek above the mouth of Manuelitos Creek, but such as were made show that the general features are the same with those on Manuelitos. The axis of the Cimarron anticlinal is crossed near Las Tusas and the other anticlinal crosses at a little way farther up. The eastern slope of the latter axis is very short, as on the other creek, but the western slope is very much longer, extending to a mile and a half below Tecoloteños. Thence the rocks rise gently toward the west for two miles, but they soon assume the sharp dip noted on Manuelitos Creek, and at three miles above the forks of the creek the Archæan rocks are reached under the Mora arch.

The forks of Sapillo Creek are separated by low knife-edges of Archæan rocks, the Carboniferous having disappeared wholly from the Cebolla sub-synclinal, which certainly terminates here, while the Mora arch passes into or directly in front of Mount Solitario. The east face of that mountain is a rugged precipice of Archæan. The crest is an inclined plane sloping westward and probably covered with stratified rocks, the same with those seen in similar position at the head of Sapillo, Manuelitos, Cebolla, and Las Casas Creeks; but the mountain was not climbed, and the conclusion respecting the rocks on top was reached by means of a field-glass.

CHAPTER XVI.

AREA OF THE RIO GRANDE.

SECTION I.—FROM FORT GARLAND TO THE ARROYO HONDO.
II.—THE REGION DRAINED BY GALISTEO CREEK.
III.—THE REGION DRAINED BY THE UPPER PECOS AND ITS TRIBUTARIES.

Fragmentary studies only were made in the Rio Grande area.

SECTION I.

TRINCHERA CREEK—CULEBRA CREEK—COSTILLA CREEK—COLORADO CREEK—TAOS CREEK—VICINITY OF SANTA FÉ.

TRINCHERA CREEK.—This important creek is formed by the union of two forks at four miles beyond the northern edge of the district and three miles west from longitude 105° 15′. The southern fork rises directly under Trinchera Peak, while the other rises at probably five or six miles north from that peak. Before reaching the Rio Grande this stream is enlarged by the addition of Sangre de Cristo Creek, which flows south and west from Sangre de Cristo Pass. Owing to extended erosion by Trinchera Creek and its tributaries the alluvial area shown in the northwest corner of map 70 A becomes wider northward, and the great San Luis Park extends eastward to the base of the Sangre de Cristo Mountains, with the Sierra Blanca as the northern boundary of this recess.

A rude basaltic mesa begins immediately south from Sangre de Cristo Creek and extends southward for more than four miles along the east side of the park. The basalt varies from hard, compact, bluish-gray to vesicular or amygdaloid and almost blue. The beds dip distinctly eastward. Overlying the rock are coarse compacted gravels, but here and there are narrow swales, old water-courses, now half filled with alluvium in which are regular lines of pebbles. Silt predominates in this deposit, which bears a dense growth of sage-brush, while the mesa carries a forest of pinon and red cedar.

Trinchera Creek flows in a broad level basin for more than three miles behind this mesa. It is clearly subject to sudden and extensive floods, and the plain is broken by deep arroyos which divide it into islands during flood-time.

The compacted gravels re-appear at a little way behind the mesa, though they are not shown fairly until at two miles and a half up the stream, where they are seen covering some bold hills north from the creek and forming a continuous line of hills southward to and beyond Culebra Creek.

The eastern outcrop of the Carboniferous rocks is reached at somewhat more than four miles above the Garland City road. They dip westward at nearly 20° and are well exposed in the drift-covered hills on the north side of the creek, though they are concealed on the south side, where everything is deeply buried under the gravels. A small patch of these rocks may exist on the crest of the high ridge north from the South Fork of Trinchera, but the dip at the most eastern exposure appears to be sufficient to carry them far above that ridge.

The Archæan rises from the creek immediately above the forks and thence exposures are almost continuous quite to the head of the South Fork. The rocks of this age are mostly hornblendic, though not a little of ordinary gneiss was observed. The syenite varies from fine-grained to very coarse and holds many masses of feldspar and quartz, which have a faint trace of gneissoid arrangement, for they contain minute flakes of mica arranged in rudely parallel lines.

The gravels have their eastern outcrop at little more than two miles above the forks of Trinchera Creek.

Fine terraces line the north bank of Sangre de Cristo Creek and are composed wholly of the compacted gravels shown along the base of the mountains. An almost level plain stretches from beyond Sangre de

Cristo Creek southward to a mile or more beyond Trinchera Creek, and is broken only by the shallow channel-ways through which the streams flow. This plain is covered deeply by alluvium and carries a dense growth of sage-brush and *cactus.*

South from Trinchera Creek the surface rises from the narrow "bottom" to the first terrace—the plain already referred to; then to a wide second terrace, and finally to a third terrace, which extends as a regular plain almost to San Luis, where it falls off to the San Luis basin on Culebra Creek. All of these benches are covered by alluvium containing fragments of basalt and of other rocks occurring along Trinchera Creek and its tributaries.

A low mesa of basalt begins southwest from Fort Garland and almost immediately south from Trinchera Creek. It has a bold bluff on the eastern side, but the surface gradually fades away on the western side into the Rio Grande Plain, which is continuous with the great San Luis Park at the north. It trends southeastward to the forks of the road, nine miles south from Fort Garland. There the surface of the Culebra Park rises to the third bench and the mesa itself breaks down to the level of that bench; but beginning again within two miles, it continues southward to Costilla Creek, showing an abrupt wall on its eastern side to within two miles of Costilla Creek, where the park ends and the divide between the creeks becomes continuous with the mesa. Culebra Creek passes through a broad gap in this wall immediately below the plaza of San Luis.

Basalt, more or less vesicular and closely resembling that observed on the Raton Plateau, is exposed in the wall on the east side of the mesa. No exposures occur on the surface or west side of the mesa north from Culebra Creek.

The Rio Grande Plain between the edge of the wall and the cañon of the river shows no rocks in place. The alluvial deposit is very deep. Basalt forms the walls of the cañon, and therefore in all probability underlies the plain.

Culebra Creek.—The more important forks of Culebra Creek rise on the west slope of the Culebra Range and unite midway in a broad basin at three or four miles above San Luis. The stream passes through the higher part of the basalt mesa and emerges upon the Rio Grande Plain.

Southward from the Culebra the plain is as forbidding as it is farther north. The loose alluvial sand is blown by the wind in dense clouds, and the only vegetation consists of sage-brush, cactus, and grease-wood, with scanty bunches of grass. The basalt mesa becomes bolder on its west side, south from Culebra Creek, and long before Costilla Creek is reached the bluff is very abrupt. The rock is gray, weathers pitchy black, and contains much olivine. No trachytic rocks were seen in place, but some fragments of what may be either trachyte or rhyolite were seen at but a little way south from Culebra Creek. As, however, this rock was not found in place, no reference has been made to it in coloring the map.

The forks of Culebra Creek, after emerging from the mountains, flow in a basin, which is covered with fine silt containing water-worn pebbles. At the north this basin rises until it disappears in the main floor of the park which forms the divide between the basin of Culebra and that of Trinchera, and is continuous with a gravel bench on the east side of the former basin, rising to seventy feet above San Luis. This terrace is merged into the gravel hills which line the western base of the range from very near Costilla Creek to beyond the northern limit of the map. These hills have a dull brownish-yellow color, are hummock-like in shape, and bear a straggling growth of pine and red cedar. They continue along the North Fork of Culebra to the cañons of both branches. At that of the north branch, the gravel forms a fine bench, 1,100 feet above San Luis, which continues as a terrace down the stream on the north side to beyond the junction. The hills north from this terrace rise to 1,600 feet above San Luis, while just north from these are others still higher, reaching to 10,600 feet above tide. All of these are gravel covered. Igneous rocks rise above the gravels at various places along this stream.

The nature of the *débris* on the south side of this branch is not well shown until, at somewhat more than half a mile from the mouth of the cañon, the gravels are well exposed again. But they are thinner here than on the opposite side, for a broad terrace stretches between the branches of the North Fork from the face of the mountain to the union of the streams.

No stratified rocks are exposed on this side of the mountain along the streams forming the North Fork of Culebra Creek. Gneissoid granite, alternating with layers of gneiss, is exposed at the very mouth of the cañons and reaches to the summit of the mountain. This rock is almost wholly feldspar, containing very little quartz and only thin laminæ of mica. A layer of mica schist or a small patch of hornblendic gneiss is occasionally seen. The north branch cuts some dikes of basalt, and fragments of amygdaloid basalt are common in its *débris*. Carboniferous rocks are shown at the head of the creek in what seems to be Trinchera Peak.

The plain between the branches of the North Fork shows few transported fragments, though its escarpments toward the streams are covered with them. The hills along the base of the mountain, between the branches, are quite as characteristic as those on the right side of the north branch. They continue to the forks of the south branch, where they are cut off by the cañon of the stream; but they begin again on the other side and, are continuous in front of Culebra Peak and thence southward. The depth of gravel varies from two to two hundred feet. Outcroppings of rock in place were observed at several localities.

The cañon of the North Fork of Culebra is narrow until near the forks of the creek, where it widens into a north and south park behind the first line of gravel-covered hills. On the north side of the creek this is a gradually rising plain, like that between the forks, but on the south side it is the valley of a small stream and narrows toward its head. Beyond this park the gravels are continuous on both branches to their cañons. The high hills at some distance away from these streams are crowned with bee-hive like domes, below which their slopes are narrow radiating plains separated by gulches deepening toward the streams. The gravels extend up the mountain-side to near a broad trough in the side of Culebra Peak, which opens at timber-line and holds the headwaters of the south branch.

The conditions on the South Fork of Culebra Creek are like those observed on the North Fork. The gravels continue along the face of the range until within a short distance of Costilla Cañon. The Quaternary deposit covering the basin of the creek in the park seems to have been derived in great measure from these gravels.

Much of the basin is marshy and sustains a limited growth of feed.

COSTILLA CREEK.

Costilla Creek, rising on the east side of the Culebra axis, flows irregularly south and west to the Rio Grande Plains, in which it sinks, though its strong arroyo shows that at some seasons it reaches the river. The creek flows in an almost unbroken cañon from the Fort Garland and Costilla Pass road to the village of Costilla. The rock throughout shows little variation and is the same with that of the mesa fronting the plains. The cañon widens into a narrow park where the Fort Garland road comes down to the creek.

The wall of eruptive rock continues on each side until, at six miles below the lower cañon, the park and the lava end together and the stream issues from a dismal cañon, eroded in a remarkably compact dark gneiss, which might readily be mistaken for quartzite were it not for the filmy layers of mica. This is replaced sometimes by a feldspar porphyry or gneissoid granite, and is cut by narrow irregular dikes of basalt. The walls rise to nearly 1,200 feet above the stream.

At four miles below the mouth of Comanche Creek the cañon widens into a park, where the stream cuts two wide dikes of trachyte, which are separated by several hundred feet of very dark gneiss. The rock in the dikes is soft and readily breaks down into mud. A broad belt of quartzite is exposed on both sides at probably a mile below Comanche Creek, but it is broken by dikes, one of which, resembling the last, either includes or rests on a black rock not altogether unlike diorite. The quartzite gradually shades off into a silvery mica shale, waved as though ripple-marked, which continues to the mouth of Comanche Creek, where it is interrupted by two dikes.

For three miles above Comanche Creek the stream flows through a narrow gorge exposing many trachyte dikes. Much quartzite and silvery micaceous shale occur on the sides of the gorge, but there are few exposures in detail.

A park begins at three miles above the mouth of Comanche Creek, which continues for seven miles along Costilla Creek, and is separated by a short cañon from another and narrower park at the north. High mountains on its west side show enormous excavations opening above the floor of the park; but the mouths of two of these are closed by moraine-like heaps, through which small streams have worn narrow channel-ways. On the eastern side the mountains slope gently toward the park and broad swales mark the courses of petty streams flowing down their sides.

The pass from Costilla Creek to the Vermejo, a tributary to the Canadian, is a rolling plain, bearing few trees and covered with water-worn fragments.

Comanche Creek heads against Moreno Creek, and, flowing north, enters the Costilla at twenty miles above the village of Costilla. At its mouth is a curious dike, whose imperfect columns are so grouped and curved that the exposed bluff resembles a fan. The valley of this stream opens into a park with Archæan rocks on each side, though near the summit of the ridge, on the east side, the Carboniferous rocks are reached. In this range the dip is westward.

At little more than four miles above the mouth of the creek the park widens and shows long sloping terraces with frequent exposures of Archæan rocks on each side at the forks of the creek. The East Fork flows from the south-southeast along a narrow park, of which an outlying division reaches northeastward, so as practically to merge into a little park beyond the Dakota Stonewall, in which one fork of South Poñil Creek heads. On the west side of the ridge forming the east wall of this little park the exposures are few and for the most part the slope is covered with *débris*. But at the base of the ridge and along the stream Archæan rocks alone are exposed, though this is along and east from the line of the ridge containing the outcrop of the Carboniferous rocks. Below the forks of the creek these rocks reach southward to the line of Quaternary, but no traces of them were observed anywhere above the junction.

Near the top of the ridge separating this stream from South Poñil Creek the Dakota sandstones are imperfectly shown, dipping eastward, though, where the Stonewall is cut by the extension of the little park, those sandstones are almost vertical, and at a little way farther north they are dipping westward. The rock is much coarser than at the gap made through the wall by Leandro Creek.

Several dikes were seen in the park of Comanche Creek, but the exposures in all cases are fragmentary and the strike could not be ascertained; but for the most part it seems to be west of north, so that these dikes are probably continuous with those of the Old Baldy series, to which they are closely related in composition.

Between Costilla and Colorado Creeks.—Basalt continues along the face of the mountains southward from Costilla Creek to the Cañon Cedros, where a petty exposure of trachyte was observed beneath it, which in turn rests on the Archæan rocks.

The Archæan area shows a sudden expansion westward as soon as Costilla Creek is passed—a condition which justifies the belief that Archæan rocks underlie the basalt of Culebra Basin and the Rio Grande Plains between Trinchera and Costilla Creeks.

An insignificant patch of basalt remains on the south side of Cañon Cedros, where it is shown at some distance from the plain resting on Archæan. The latter rocks are well represented in the Cañon La Jara at six miles south from the mouth of Costilla Cañon, where granites and gneiss, both micaceous and hornblendic, are present. The hornblendic beds occur in layers within the others. For the most part the granite is extremely fine-grained and hard, with minute scales of mica. Feldspar porphyry, such as occurs in the Arkansas Range of Colorado, is common here, and shows crystals of greenish feldspar four inches long by two inches wide. Small crystals of mica are often shown included in milky quartz. Several narrow dikes of rhyolite are crossed by the southern branches of the main cañon.

Thus far, coarse *débris* covers the mountain side, and it is similar to that seen on the hills north from Costilla Creek; but no compact conglomerates were seen.

Archæan rocks alone occur beyond the Cañon La Jara until the Cañon Latir is reached; but, beyond the latter to the Cañon Cabresto, trachyte dikes are very numerous though usually very narrow There seems to be an area of trachyte or rhyolite covering the hills at the head of the longer cañons, but in the absence of direct information from personal examination it has been thought best to color the whole area referred to as Archæan. Between the Cañon La Jara and the Cañon Cabresto the exposures are fragmentary, and the relations of the Archæan and the dikes are not clearly shown. A fine bed of white quartzite passes along the face of the mountain and its fragments are spread widely over the plain. With this is gneiss containing nodules of silvery mica and feldspar.

A gray eruptive rock, weathering deep yellow, makes its appearance at the mouth of Cañon Cabresto and extends up that cañon for more than a mile, but the cañon heads in Archæan. This eruptive rock forms the wall facing the plain to the mouth of Colorado Creek.

The plain south from Costilla Creek shows little change. It is covered with alluvium, which doubtless rests on basalt at no considerable distance from the foot of the mountains. The wall of the Rio Grande Cañon shows no change in character, and some hills of basalt rise from the plain at but a little way north from the mouth of Colorado Creek. The alluvial deposits increase in importance southward until, beyond that creek, they are found in splendid benches rising 250 feet above the stream and extending to a long distance as gently sloping foot-hills.

COLORADO CREEK.—This stream has its sources on the east side of Taos Mountain, flows northward for nearly eleven miles through a deep close cañon, and afterward westward for seventeen miles to the Rio Grande. Its cañon, from the head to the plaza of Colorado, is one of the most remarkable in the whole region.

The yellowish eruptive rock seen at the mouth of Cabresto Cañon is an extremely hard rhyolite, light gray, but weathering yellow. It forms both walls of the cañon from the mouth up to within a short distance of the first tributary entering from the south, where granite appears and forms the south wall. The change from eruptive to metamorphic rocks is admirably shown by the changed character of the wall. The former rocks occur in harsh overhanging cliffs almost wholly naked of vegetation, whereas the softer gneisses and granites break down so as to give a slope on which soil may be held. Soft spots occur in the rhyolite, but these weather into a variegated mud which supports only occasional spruces.

Archæan rocks prevail along the first tributary coming from the south, but they are cut by slender dikes of mottled trachyte. Opposite the mouth of this tributary some slender dikes of basalt were seen following irregular fissures in the rhyolite.

Above this a remarkably beautiful granite is shown in both walls for a mile and a half, but the rhyolite is very near the creek and at that distance comes down again for a little way. The granite quickly resumes its place and lines the creek until within two miles of the deserted mining-camp, where the cañon widens into a park. The structure of the granite suggests that it may be a metamorphosed conglomerate, for pebbles are very distinctly shown. Quartz of greenish tint with glassy fracture predominates.

Dikes of mottled trachyte, cut by narrow dikes of basalt, are very numerous in the park, and the rhyolite is shown in the hills at a mile or more north from the creek. A dike of the rhyolite cuts one of trachyte and both are cut by a dike of basalt. The eruptive rocks prevail until some distance above, where the road to Red River Pass leaves the creek. At three miles above that point the forest become very dense and thence exposures are rare. Archæan fragments are common, mingled with those of Carboniferous rocks. Dikes still exist, but they become less important southward. Toward the head of the creek only the Carboniferous rocks are exposed, and the great Mora fault is reached on the divide between Colorado and Lucero Creeks.

In ascending from the creek to Red River Pass one crosses many narrow dikes of trachyte, separated by insignificant exposures of gneiss. On the summit is a narrow line of Carboniferous conglomerate, marking the course of the Mora fault. A broad dike of rhyolite occurs on the summit. The rock closely resembles granite in general appearance, and contains grains of sanidin often nearly half an inch in diameter.

Terraces were seen in all the parks within this cañon, but they seem to have been made by re-erosion of the valley after it had been filled with drift material. The gravels at some localities are nearly 200 feet deep. They are cemented by oxide of iron and calcareous matter and are of local origin.

The structure of the region immediately about Taos Peak was not ascertained in detail. When the attempt was made to reach the peak the snow was still so deep as to prevent any detailed examination and to conceal the rocks at some of the most critical points. The details of the Mora fault as shown on the divide between Colorado and Lucero Creeks have been given in the description of the Moreno Valley. Carboniferous rocks appear to cover the higher hills of this massive mountain, but the tributaries to Colorado Creek, rising within the ridge, show only rare fragments of Carboniferous rocks, and Archæan pebbles predominate. The dip of the Carboniferous beds on the west side of the Mora fault is very gentle and diminishes westward. At the fault it is 26°, and at two miles farther west it is barely 10°. If this condition continue these rocks can be found only on the very highest points of the mountain. The coloring of the map in this vicinity is partly conjectural.

TAOS CREEK.

Taos Creek, a short stream entering the Rio Grande below Taos, is formed by the union of Taos Creek, Pueblo Creek, and the Rio Grande de Taos, the latter being formed by the junction of Frijole Creek and several other streams to which no names have been assigned.

Pueblo Creek rises under Taos Peak and, as it emerges upon the plain in the Taos Basin, receives Lucero Creek from the north and Ferdinand Creek from the south. No examinations were made on either Pueblo or Lucero Creek.

Ferdinand Creek heads near Taos Pass and flows almost westward to the Taos Basin, where it turns toward the north and soon joins Pueblo Creek. At the entrance to its cañon the Carboniferous rocks are shown dipping sharply toward a little south of east, which direction is the prevailing one up the stream for nearly three miles; but thence for three miles the dip is irregular, now southeast, then southwest, and occasionally for very short distances northwest. The southerly dips prevail and the rocks rise rather quickly toward the north. At about six miles from the mouth of the cañon the dip is southeast at 12°, but the direction changes gradually to south of east, then to east, then to north of east, and at the forks of the creek the dip is distinctly northeast.

Thus far the Archæan is not exposed along the creek and no rocks newer than the Carboniferous occur. Carboniferous limestones are almost constantly in sight, and a huge one just below the forks of the creek contains *Spirifer*, *Athyris subtilita*, *Productus semi-reticulatus*, *Productus pratteniamus*, and many other characteristic species.

An exposure of sandstone at the mouth of the North Fork shows the rocks to be dipping west or south of west. Half a mile up the first little stream entering this fork from the east, hornblendic gneiss was seen, and in the next gap above syenite occurs, showing the course of the Mora fault.

The hills become rounded at a short distance below the forks, and this is the condition on all the forks. They are covered with compacted gravels and conglomerates similar to those seen along the west base of the Culebra range from Fort Garland southward almost to the cañon of Costilla Creek.

This conglomerate is well exposed on the North Fork, where its material is wholly derived from eruptive rocks. It varies there from excessively coarse to very fine and is distinctly laminate in the finer portions. Sometimes it shows alternating layers of very fine and moderately coarse material for several feet, above which come enormous blocks of trachyte, weighing from 100 to not less than 1,000 pounds. Every block is rounded as by water-wear. Among the fragments are specimens of every rock found in the Old Baldy series, in the Comanche and Costilla dikes as well as in the dikes of Colorado Creek, while some fragments were seen belonging to rocks not observed in place. Even the basalts of more northern areas seem to be well represented here.

The character of the conglomerate on the South Fork is similar in a general way to that observed on the North Fork, though the rock is for the most part much finer and contains in addition occasional fragments of sandstone and a few of quartzite. The character of the rock leads to the supposition that this stream heads among the Archæan rocks.

The exposures of the conglomerate on the Middle Fork are poor, but suffice to show that its composition is different from that found on the other forks, for here one finds much quartzite, gneiss, and Carboniferous conglomerate. The Quaternary conglomerate reaches almost to the crest of the Taos Pass, while on the North Fork it reaches to a greater elevation than that of the pass.

At the foot of the slope leading directly to the pass the Carboniferous rocks are shown, and a thin limestone containing Carboniferous fossils is exposed on the summit. The western edge of the Archæan exposure crosses this fork at about a mile above its junction with the North Fork and lies about a mile and a half east from the line of the South Fork. It is well defined, and the course of the Archæan area is distinctly shown by a high ridge.

The recent conglomerate has a dip between east and northeast on the North Fork, but the direction could not be accurately determined, as the lamination of the rock is somewhat irregular.

On the face of the low bluff or mesa between Ferdinand and Pueblo Creeks, and looking toward Taos Basin, the Carboniferous rocks are exposed up to the mouth of Pueblo Cañon, while on the north side of that cañon there is clearly a change in the character of the rocks, and those on that side seem to be Archæan. No direct examination could be made to determine the relations.

In the Taos Basin, which has been excavated by the several streams forming Taos Creek, the surface is covered by an irregular deposit of fine silt with here and there thin layers of pebbles. At several places a white chalky marl was observed about two feet below the surface, under which silt not unlike that overlying it was observed. This marl is similar to that seen at many localities within the Canadian and Mora areas.

Frijole Creek flows by the southern edge of the Taos Basin, and is formed by the union of several considerable streams flowing down from the west slope of the Mora Range, with others which drain U. S. Mountain and an extensive area southward toward Junta Creek. Examinations were made only along the stream coming from the south.

The creek emerges from its cañon at a little way above Placita Chiquita or the Francisco Ranches. Conglomerate sandstones containing opal-like quartzite pebbles are exposed at the mouth of the cañon. Farther up the creek, some red shales and occasionally an impure limestone occur with these, but no fossils were found to indicate positively the age of the rocks. The U. S. Mountain, lying west from this cañon, is a huge mass of which no examination could be made in detail. It evidently has a core of metamorphic rocks.

At the mill on Frijole Creek, probably a mile and a half above Francisco Ranches, a petty anticlinal is cut by the stream and evidently divides the synclinal separating the U. S. axis from that lying next east. From this point up to Old Camp Burgwin exposures of the older rocks are few and unsatisfactory, only sandstones and reddish shales having been seen.

At a little way above the mill the cañon widens, and compacted gravels, such as were seen on Ferdinand Creek, are well shown. These continue along the road leading to Junta Creek at Real Pueblo, and extend up the mountain side on this road to 8,500 feet above tide. The upper limit is certainly higher than this, but no measurement was made on the side of U. S. Mountain. All of the older rocks are deeply buried under these conglomerates, except at the first fork above Old Camp Burgwin, where the Archæan is shown underlying them. There the conglomerate contains fragments of Carboniferous sandstone and limestone mingled with those of gneiss and schists; whereas farther up the mountain side along the road to Real Pueblo no fragments were found of any aside from Archæan rocks. Below Old Camp Burgwin the conglomerate contains fragments of all rocks existing in the U. S. Mountain and in the northern part of the hills along the Mora axis.

JUNTA CREEK.

Junta Creek is formed by the union of several small streams near Jicarilla Peak, in the Las Vegas Range, and flows west and northwest to the southern edge of the U. S. Mountain; whence it follows a somewhat serpentine course to the Rio Grande. The examinations along this stream were merely those of a reconnaissance, and extended from Real Pueblo up to the head of the fork followed by the old Taos freight road.

At Real Pueblo, four miles above Picuris, a basalt sheet was seen, which covers the hills eastward to about two miles from the Pueblo. This cap is 400 feet thick and rests on an old bench. At one time it filled the valley, and even now the sheet bends over the edge of the bluff above Real Pueblo.

Water-worn transported fragments are very numerous up to 700 feet above the stream on the hill back from the Pueblo, and in all probability belong to the gravel conglomerates.

Junta Creek issues from a deep cañon at little more than two miles above Real Pueblo; and the conglomerates are shown in the sides of the park immediately below the cañon. There they rise to not less than 250 feet above the stream, and contain fragments of all the older rocks occurring along the creek. But no fragments of the basalt were seen except near the Pueblo.

For two miles up the cañon one rides amid Archæan rocks, marking the course of the Santa Fé axis, which is not clearly shown on Ferdinand Creek. The rock here is, for the most part, a very fine-grained, soft, almost white gneiss, containing silvery mica in filmy laminæ. It is cut by many veins of quartz, some of them large, but without ores, so far as examined. The stream makes a sharp bend toward the west in this cañon, and there the Santa Fé axis is crossed.

On the east side of the Archæan area one reaches a very coarse conglomerate sandstone, so coarse and so light in color that often it is not unlike gneissoid granite. Farther up, the rock becomes less coarse, shows many comparatively fine-grained beds, and varies in color from light gray to reddish. The dip is abrupt, being 20° east-northeast or north of east at the forks of the creek. This rate diminishes gradually until, at two and a half miles above the forks, the synclinal is reached, that between the Santa Fé and the Mora axes. Thence to the next fork the dip is undulating but mainly westward.

Along the main stream thus far only Carboniferous rocks were seen.

The limestones are rich in the characteristic species, and several of the sandstones are crowded with *Spirophyton*. Along the northern fork, which is followed by the road crossing the range to Agua Negra, the same rocks are present to the summit of the range. Several thin limestones were seen, all of which show *Spirifers* and fragments of Crinoidal columns.

The vicinity of Santa Fé.—Southward from Taos Creek to Santa Fé no examinations were made, and the western limit of the Archæan area along the Santa Fé axis was not determined. The Archæan reaches quite to the plains opposite Santa Fé, but the Carboniferous rocks are shown at the base of the mountains at a little way farther north.

Going southward from Santa Fé, on the stage-road leading to Fort Union, one soon reaches the Archæan area of the Santa Fé axis, and does not pass beyond it until within less than two miles of Cañoncito on Galisteo Creek.

Leaving this road at the Arroyo Hondo and taking the road which leads to the Bishop's Ranch on the Galisteo, the Archæan area is soon passed and the road lies almost immediately west from the western limit of that area. But no exposures of the stratified rocks are shown until within a mile of Galisteo Creek, where one comes to the Carboniferous limestone, which is described in the next section of this chapter. The Archæan is represented by a coarse granite varying in color from gray to red, associated with fine-grained granites and very dark gneiss alternating with white quartzite. Much of the granite is pebbly, as though it were a metamorphosed conglomerate.

The Galisteo sandstone was not recognized anywhere along either road. The alluvium in the vicinity of Santa Fé and along the Bishop's road is very thick and shows near the top much marly material. At one locality, two miles south from Santa Fé, this marl is distributed throughout a thickness of thirty feet of alluvium.

SECTION II.

THE REGION DRAINED BY GALISTEO CREEK.

Galisteo Creek has its source in the southern part of the Santa Fé Range, flows southward to the village of Galisteo, near which it is increased by the Arroyo San Cristobal, and thence flows westward to the Rio Grande, which it reaches at, say, ten miles above Albuquerque. It drains a considerable portion of the Santa Fé Range and very much of the plateau between the Pecos and the Rio Grande, on which are Los Cerillos and the Sandia and Placer Mountains. No examinations were made west from Los Cerillos, and the study of the northeastern slope of the Placer Mountains was left very incomplete.

The area of this stream may be considered conveniently in two divisions—the upper, embracing the region drained by the creek in its southward course, and the lower, the region drained by the Arroyo San Cristobal and Galisteo Creek in its westward course.

Los Cerillos are rudely conical hills, relics of huge dikes thrust through the shales of Cretaceous No. 4, which are well exposed on the south and west side of the hills. Westward toward the Rio Grande these shales form mesas, in which the dip is eastward and gentle. But in the vicinity of Andrews' smelting works, nearly eighteen miles below Galisteo, the dip changes, the rocks being disturbed by small dikes. For a mile above those works exposures along the creek are very indifferent, but some little hills north from the creek exhibit the lower shales of this sub-group. They are dark, more or less sandy, and contain thin layers of reddish-yellow sandstone. The latter are often covered with casts of fucoids, while fragments of huge *Inocerami* are common amid the shales. The higher beds of this sub-group are shown in a broad arroyo, reaching the creek at nearly a mile above the works, where they are very dark, contain many *Inocerami*, much gypsum, and numerous beds of iron ore; the last being equivalent to the beds of ferruginous concretions occurring at this horizon in other localities.

This arroyo follows the western side of Los Cerillos, and the effects of the dikes on the shales are well shown. The shales are twisted into every conceivable condition and the ore-beds are frequently vertical. The thrusts in most cases were short and very abrupt, for the up-turn of the beds sometimes occurs within six feet, the change in dip being from almost horizontal to almost vertical.

As might be suspected, from the similarity of conditions, ores occur here as in the vicinity of the Old Baldy Range of the Cimarron. Many years ago some streaks of galena were mined by Spanish residents; but the quantity of ore obtained seems not to have been very large, for the mines were abandoned after they had been barely prospected. Within a few years the mines were reopened and the Andrews' works were erected for smelting the galena, which is said to be richly argentiferous. The smelting works were shut down in August, 1878, owing to lack of ore.

Mining operations have been begun again on the west side of Los Cerillos. The crevices in the shales have been filled in many instances with galena. The calc-spar filling shrinkage cracks in the ferruginous concretions often shows flakes of galena. Besides these modes of occurrence, that mineral occasionally appears in narrow streaks between small dikes and the shales, thus resembling contact deposits. The last offer some encouragement to the prospector, but the ore-streaks vary in width from one-eighth of an inch to barely two inches.

Mining has been carried on more energetically on the east side of the Los Cerillos and there are more reasons to look for success here than there are on the western side. The rock is trachyte, cut by many narrow streaks of kaolin-like material. Outcroppings of argentiferous galena are numerous, but for the most part the streaks are very thin.

The western outcrop of the Laramie rocks on the south side of Galisteo Creek is at a little south of east from the Andrews' works. It curves eastward under the influence of the Cerillos outburst as it approaches the creek, and though touching the creek at barely one mile above the works it does not fairly cross it until three miles. The following section was obtained in a double arroyo nearly two miles southeast from the smelting works:

	Feet.	Inches.
1. Sandstone, soft, flaggy, very light gray; breaks down into loose sand	30	0
2. *Coaly* clay	0	2
3. Dark clay, with rootlets	0	3
4. Shale, dark, much nodular iron ore, the nodules weighing from one ounce to 100 pounds	38	0
5. Shaly sandstone	5	0
6. *Coaly* shale, comes out in blocks; contains much vegetable matter	0	10
7. Dark shale	4	0
8. Sandstone, red and yellow, flaggy to shaly	8	0
9. Concealed	6	0

			Feet.	Inches.
10. Sandstone, light gray, ripple-marked, soft			18	0
11. Drab shale			4	0
12. Iron ore, calcareous			1	3
13. Sandstone, soft, massive, gray			10	0
14. Iron ore			1	8
15. Drab shale			3	0
16. *Coal-bed*			2	10
Coal	0	6		
Clay	0	1		
Coal	2	3		
17. Drab shale			3	0
18. Sandstone, soft, yellow			8	0
19. Shale and iron ore			4	0
20. Light-gray sandstone			1	0
21. *Coal-bed*			0	10
22. Argillaceous shaly sandstone			5	0
23. Shale and iron ore			8	0
24. *Coal-bed*			0	10
25. Shale			1	0
26. Argillaceous sandstone			2	0
27. Shale with iron ore			10	0
28. Sandstone			17	0
29. Drab shale			2	0
30. *Coal* and shale, the *coal* brilliant and in streaks one inch thick			1	0
31. Drab shale			4	0
32. *Coal-bed*			0	3
33. Drab shale			2	0
34. Drab sandstone			12	0
35. Sandstone, shale and iron ore			6	0
36. *Coal-bed*			Blossom.	
37. Concealed			6	0
38. Sandstone, shaly, soft, yellowish-gray			14	0
39. *Coal-bed*			4	9
Coal	0	2		
Clay	0	4		
Coal	0	5		
Black shale	2	6		
Gray sandstone	1	0		
Coal	0	4		
40. Shale, dark, with streaks of *coal*			1	0
41. Sandstone, argillaceous, flaggy; many small nodules of iron ore			6	0
42. Sandy shale			3	0
43. *Coal-bed*			0	2
44. Shale			3	0
45. Sandstone			12	0

	Feet.	Inches.
46. Shale	10	0
47. *Coal-bed* coked by basalt dike	0	6
48. Sandstone and shale	9	0
49. *Coal-bed*	0	8
50. Drab shale and iron ore	3	0
51. Sandstone, gray, speckled with nodules of iron ore	10	0
52. *Coal-bed*	Blossom.	
53. Shales, with thin sandstones and iron ore	23	0
54. Concealed	8	0
55. Sandstone	6	0
56. Concealed	7	0
57. Shale	1	0
58. *Coal* and shale	0	5
59. Clay	4	0
60. Yellow shaly sandstone	10	0
61. Dark shale and iron ore	15	0
62. Sandstone	60	0
63. Sandstones, shales and beds of concretions belonging to Cretaceous No. 4	–	–
Total	433	0

The dip is east-northeast and gentle.

A narrow dike of basalt has cut the beds from No. 28 to No. 34, inclusive, but it has produced no effect on them, and the coal in Nos. 30 and 32 is altogether unchanged. The insignificant bed No. 58 makes a huge blossom, as the underlying clay is very dark. The sandstone No. 62 is frequently broken midway by a thick bed of shale. Its upper part is quarried here for building purposes, and is used in the United States hospital at Santa Fé, twenty-five miles away. The lower part contains bands of deep-red sandstone and beds of iron ore more or less concretionary in structure. One cannot easily determine the line of separation between the Laramie rocks and those of Cretaceous No. 4, and it is possible that No. 63 may belong in part to the Laramie.

Several narrow dikes were seen in the immediate vicinity of this section, and a huge dike passing in front of the Placer Mountains crosses these arroyos near their head. A bed of excellent anthracite has been worked in one of these arroyos, but the mine was abandoned some time ago and I was unable to find it. It is said to be two feet thick. The coal, of which fragments were seen at Andrews' smelting works, is handsome, compact, and breaks with conchoidal fracture. The area of anthracite in this bed is doubtless insignificant, as it extends for but a little way down the arroyos.

Nearer Galisteo Creek the dip of the Laramie rocks is very seriously affected by the Cerillos outburst, for it is south-southeast. At three miles above the smelting works the following section was obtained near the road:

			Feet.
1. Sandstones and shales, much iron ore			80
2. Dark shale			10
3. Sandstone			5
4. Dark shale			5
5. Sandstone, gray, soft, cross-bedded; contains huge concretions			20
6. *Coal-bed*			Blossom.
7. Concealed; contains much iron ore			25
8. Gray, soft sandstone			5
9. *Coal-bed*			2
Coal	0	8	
Shale	1	3	
Coal	0	1	
10. Shale			10
11. Soft gray sandstone			12
12. Imperfect exposure; contains many calcareous ferruginous concretions and others with cone-in-cone			30
13. Sandstone, gray, with deep red bands			35
Total			239

Very possibly this does not reach the base of the group, for at a little way below this locality a large *coal-bed* was seen in the creek bank, which seems to underlie No. 13. But the rocks are so disturbed that the relations cannot be ascertained without resort to instrumental survey. The dip is almost due south where the section was measured.

A broad arroyo opens into the valley of Galisteo Creek at about three and one-third miles above the smelting works. In this the following section was observed:

	Feet.
1. Sandstone	20
2. Concealed	30
3. Sandstone	150
4. Drab shale and thin sandstones	70

		Feet.
5.	Sandstone	10
6.	Concealed	20
7.	Sandstone	60
8.	Concealed	100
9.	Shales and sandstone	90
10.	*Coal-bed*	4
11.	Shale	6
	Total	560

The dip at the mouth of the arroyo is southward or east of south, but at a little way farther up it changes to eastward or north of east, and the whole section is shown to be higher in the series than the one obtained on the creek. The sandstone No. 3 is exposed at the mouth of the arroyo, dipping southward at a high angle, and it is well shown for some distance up the arroyo. Nos. 1, 3, 5, and 7 are almost exactly alike, being yellow, soft, and easily affected by weathering. No. 3 shows occasional pots of conglomerate, with here and there a thin shale holding nodular iron ore. All of them have irregular, honeycombed surfaces with sometimes very deep recesses. They hold also great sandstone concretions which are harder than the enclosing rock, though they, too, are of variable composition and weather with a pitted surface. These sandstones are very notable features, and No. 7 remains in sight to beyond the old coal-road. A few indistinct impressions of dicotyledonous leaves were seen below the exposure of *Coal-bed* No. 10, which are not unlike those observed in the Trinidad coal-field. There seems to be a *coal* blossom below the middle of No. 8.

The *Coal-bed* No. 10 is shown in an arroyo entering the last from the west and is reached at probably a mile and a half from the immediate valley of Galisteo Creek. As exposed it is somewhat less than four feet thick, though it is said to reach five feet. It was mined extensively at one time to supply the stamp-mill of the New Mexico Mining Company at Real de Dolores or the Old Placer; and the old entry, reported to be a mile long, extends eastward from this opening to the old mine on the next arroyo. But since that company suspended work at its mill the coal-mine has been idle and neglected, so that it no longer exhibits the detailed structure of the bed or the quality of the coal. Some openings on the west side of the arroyo, working up the dip, have "caved" so as to show the structure fairly to a distance of twenty feet from the outcrop. Clay "horsebacks" from the roof appear to occur frequently and cut away fully one-third of the coal. A vein of hard blue clay, four inches wide, crosses the bed at a few feet from the outcrop and distorts the coal on both sides. For eight or ten inches from the vein the coal shows a bedding parallel to that of the vein. If these troubles prevail in the bed they detract very materially from its value.

The coal at this mine is a semi-anthracite and is very slaty. Some of it is very good and compact, but a large part is imperfectly metamorphosed and its layers separate on long exposure to the weather. This mine is said to yield coal inferior to that obtained from the old mine, and certainly the material found on the dump is far inferior to that from Mr. Andrews' mine and used at his smelting works. The exposures along this arroyo, nearer the Placer Mountains, are very indistinct, but the anthracite bed seems to be the same with No. 16 of the section first given. No dike of eruptive rock passes very near this locality, but the enormous dike of trachyte, already referred to, rises high above the plateau at probably a mile nearer the base of the mountains.

The arroyos east from this give no satisfactory exposures, only the coarser sandstones of the Laramie group being shown. These are constantly in sight along the arroyos until the eastern outcrop of the group is reached near Galisteo, but all other beds are concealed except near El Chorro, where a small *coal-bed* is shown. A long broad plain stretches from the Placer Mountains toward Galisteo Creek and is covered by a deep coat of coarse *débris* more or less firmly cemented. Immediately underlying the soil is a white marl of unascertained thickness, in which are many rounded pebbles incrusted with the marl. These deposits, yielding to the weather, cover the slopes of the arroyos by which the plain is broken, and thus render the making of sections impossible. The eastern outcrop of the group is reached near the junction of Galisteo Creek and the Arroyo San Cristobal, whence it runs almost south. It will be described in another connection.

The frequent occurrence of dikes in this area causes much perplexity by distorting the dips. The great trachyte dike has been referred to already. On the northeast face of the mountain it was planed off with the other rocks during the formation of the broad bench, and its fragments are more numerous than those of any other rock in the conglomerate covering that bench. But at the northwest, beyond the termination of the Placer Mountains, it stands out as an immense comb or hog-back stretching toward the Rio Grande. Petty dikes diverge from it in all directions. Basalt dikes are not unfrequently seen, and one of large size passes close to the mountains near Real de Dolores, disturbing the stratified rocks so that they dip away from it on both sides.

Unfortunately no examination of the Placer Mountains could be made in detail. A curious conglomerate sandstone was seen above Real de Dolores, which contains a small amount of free gold varying from $3 to $12 per ton. Its relations were not ascertained. The axis of the mountains is made up of bluish syenite, a very compact and beautiful rock, with some gneiss. It contains some gold-bearing quartz veins, several of which have been mined for many years, but without much system. The mill of the New Mexico Mining Company at Real de Dolores has twenty stamps in position, with frames and capacity for twenty more. It is not operated now by the company, and the mines have not been opened sufficiently to supply it. The ore is of low grade. Fine specimens of hematite were seen in this vicinity, but no details were obtained respecting the quantity. The gravels at Real de Dolores, or the Old Placer, have been worked nearly forty years and much gold has been obtained from them. But the supply of water is so small and so uncertain that work cannot be prosecuted vigorously.

The eruptive rocks in Los Cerillos form the north wall of the Galisteo Valley until, at three miles above Andrews' smelting works, their eastern boundary bends toward the north. On this north side of the creek the shales of Cretaceous No. 4 are shown pushed beyond the vertical and resting directly against the trachyte, while in front of them toward the creek are the Laramie sandstones, also pushed over. An effort was made to obtain a section here, but, with rare exceptions, the narrow gaps between the sandstone walls are grass-covered and the place of the two little *coal-beds* seen could not be ascertained. Where first reached on this side of the creek the Laramie sandstones strike N. 70° E. and their dip is reversed to west; at less than a mile farther east the strike is N. 60° E. and the dip is eastward; immediately below the Santa Fé and Real de Dolores road the strike is N. 15° W. and the dip eastward. The lower sandstones of this series, as on the south side of Galisteo Creek, contain many deep-red bands, and beds of iron ore are imperfectly exposed in several of the swales between the sandstones. Most of the ore-beds have the concretionary structure characteristic of those seen in the Fort Pierre subgroup, and some of them contain obscure fossils. Many of the higher sandstones hold great pockets of conglomerate, and the last sandstone seen before reaching the Santa Fé and Real de Dolores road contains a thick bed of extremely coarse conglomerate.

At a little way below the Santa Fé road the valley widens into a park and exposures are very poor on the north side of the creek until beyond that road, where a short exposure of Laramie rocks occurs. Just beyond this is a dark breccia resting conformably on a soft light-gray sandstone, the whole apparently conformable with the Laramie rocks, though the contact is nowhere exposed. As appears from considerations presented elsewhere the conformability is impossible. This new group, the Galisteo group, crosses the Santa Fé road northwest from this exposure at somewhat more than one mile north from the creek. The breccia contains fragments of nearly every form of trachyte found in this region, all of them angular and cemented by what seems to be a volcanic ash. No fragments of any other kind of rock were observed. This series is cut by a north and south dike passing through the hamlet of La Vaca. It does not cross the Galisteo, and the western fault of the Upper Galisteo, concealed here under the Galisteo rocks, ends not far from La Vaca, where the Laramie rocks are much distorted.

The Galisteo series touches the creek at probably a mile above La Vaca, where it incloses a bed of Lower Dakota sandstone, partially metamorphosed and dipping westward, though almost vertical. This resembles a trachyte dike in basalt, for the breccia is very dark. Near this locality, the mouth of the Arroyo de los Angeles, the outcrop of the Galisteo rocks bends northeast and follows the northwest side of that arroyo.

Here the Dakota rocks, brought up by the Upper Galisteo faults, are reached. They are so badly broken and distorted that no understanding of their dips can be obtained without detailed study. The end of the double fault is well shown on the south side of the creek opposite this locality, for there the Laramie rocks are almost vertical, dipping south. The eastern edge of the faulted area is passed at probably a mile and a half below Galisteo and the Laramie rocks are again reached, now dipping westward. These continue in sight until the eastern outcrop is passed at the village of Galisteo. The intervals between the sandstones are concealed and no traces of the coal-beds were seen.

The alluvial deposit in the valley of the Galisteo is very deep below the village of that name, but it contains very little coarse material as compared with similar deposits along other streams. It was laid down as the bed of the creek was shifted from side to side, for in many places stratified rocks form the wall on one side for a long distance, while the other bank shows only alluvium from the bottom to the top. The influence of the Colorado shales is shown in the alkaline water and in the saline efflorescence covering the broad sub-bottom, which is wholly covered by the streams during seasons of high water.

Galisteo is at the northwest corner of a park which extends for fully seven miles southward from the Arroyo San Cristobal and for nearly three and a half miles east from the village. Its area north from that arroyo widens eastward, as the northern boundary is a dike trending northeastward. The Laramie rocks form its western wall and their eastern outcrop follows a line passing almost through Galisteo in a north-northeast direction. South from the Galisteo that outcrop lies almost immediately west from the Galisteo and New Placer road, until at nearly six miles from the former place that road rises upon the Laramie beds. These are mostly grayish-yellow sandstones with bands of deep red, and separated by shales in which are beds of great septaria. The septaria resemble those of the Fort Pierre shales. Nearly all of them are ferruginous, but some are argillaceous and show the cone-in-cone structure. Fossils are not numerous, but *Ostrea congesta* occurs at 150 feet above the base of the group, along with fragments of *Inoceramus*.

Débris from the sandstones practically conceals all the intervals between them until somewhat more than half a mile south from Cerro Pelon, where, at about seventy-five yards west from the road, a *coal-bed* eight inches thick was seen underlying a bed of iron ore. Another bed of ore is shown at twenty-five feet higher up the hill. The blossom of a second *coal-bed*, also small, is exposed near the forks of the road beyond. The lower bed is very probably the same with that which was seen near El Chorro.

Cerro Pelon is a clumsy hill of gray trachyte resting on Laramie rocks, whose outcrop is continuous below it. A dike of similar rock crosses the park near its southern edge.

The thin coating of soil in the park is underlaid by the Colorado shales. Those of the Fort Pierre subgroup are reached on the New Placer road almost at once after leaving Galisteo; and thence to where the road ascends the southern edge of Cerro Pelon the exposure is continuous. As at all other localities north and east within the district, this subgroup far exceeds in thickness any of the other subgroups of the Colorado shales, and its area occupies fully one-half of the park south from the Arroyo San Cristobal. For nearly 200 feet below the base of the Laramie group the rock is dark shale with beds of ferruginous concretions. Under this are sandy shales, yellow and gray, with thin bands of grayish-brown shale, thin beds of shaly sandstone, and beds of calcareous iron ore. These lower beds pass gradually into darker, somewhat fissile shales, in which appear the argillaceous limestones of the Niobrara subgroup.

The ferruginous beds stand out in low ridges rising from two to four feet above the level of the plain. Not all of them are continuous, and most of them seem to be merely lines of great concretions, three to ten feet in diameter. Huge calcareous concretions are scattered through the upper part of the shales. All of these, both ferruginous and calcareous, are septaria-like. The majority of them are septaria, and the others have that appearance because of the fibrous shells of immense *Inocerami*. Some beds show only concretions with cone-in-cone structure. These are argillaceous and have but enough of iron to give them color. They are invariably non-fossiliferous. But the other concretions are richly fossiliferous, containing species of *Ammonites*, *Baculites*, *Inoceramus*, *Ostrea*, *Trachitriton*, *Gyrodes*, and *Fasciolaria*, which are thoroughly characteristic of the group. In the sandy shales *Ostrea congesta* occurs, though by no means so abundantly as in some parts of the Niobrara subgroup. It is associated with a large *Ammonites* not figured in Mr. Meek's work. Some fragments of reptilian teeth and bones were seen. The higher shales are crowded with arrow-head crystals of gypsum.

Exposures of the Niobrara limestones and shales are not numerous, but such as do occur are thoroughly satisfactory. They are well exhibited at probably a mile and a half southeast from Galisteo, on the south side of the creek, where the limestones have been quarried and burned into a poor lime. They contain the characteristic *Inoceramus problematicus*. East from these are some petty exposures of dark shales belonging to the Fort Benton subgroup, which pass gradually into the sandstones of the Dakota in the east wall of the park.

In ascending the Arroyo San Cristobal on the north side one finds the outcrop of the Laramie group crossing northeastward toward the dike, which is the northern wall of the park; the curve being due probably to the influence of the thrust preceding the eruption of the dike. Above this outcrop are the sandstones and shales of the Fort Pierre subgroup, with the ferruginous concretions, the sandstones bearing close resemblance to those of the Laramie series. Few exposures of the Niobrara limestones and shales are shown; indeed exposures of any sort are very rare until one reaches the Upper Dakota rocks at somewhat more than three miles east from Galisteo, or somewhat less than one mile below Eaton's Ranch. The Upper Dakota forms a hog-back, made up of yellow and almost white sandstones, capped by a reddish-brown bed. These rocks contain no fossils other than indistinct markings resembling casts of fucoids. Underlying the sandstones are shales, near the top of which is a gray limestone without fossils, which is well shown on the south side of the creek. The shales below this are very dark, holding a gypsum-bed near the top and a conglomerate of limestone and iron ore near the bottom. Blue shales and thin sandstones underlie these and rest on sandstones of the Lower Dakota, which closely resemble those of the Upper Dakota. The shales immediately above the lower sandstones contain vast numbers of lenticular nodules of limestone with reticulate surface, and showing birdseye points when freshly broken open. A thin bed of gypsum is said to occur in these shales at a little way above Eaton's Ranch, but it was not seen. The gypsum is good and it has been used at Galisteo. Thin streaks of coal have been observed above Eaton's Ranch, one of which, according to the statement of the U. S. Forage Agent at Galisteo, yields good coal.

A slight anticlinal is crossed by the arroyo almost immediately below Eaton's Ranch, but it soon dies out southward. It was followed northward to beyond the Galisteo and Koslowski road, where it was seen in the mesa which bounds the park at the northeast. The shales with the nodular limestone are well exposed there, capped by the sandstone, which describes a short and gentle synclinal. The dip of the sandstone increases westward, soon becomes very abrupt, and the mesa breaks down toward the basin of the Upper Galisteo.

The structure of the region south from the Arroyo San Cristobal and Galisteo Creek, from the east wall of Galisteo Park to beyond the western outcrop of the Laramie group, is shown in the following diagram:

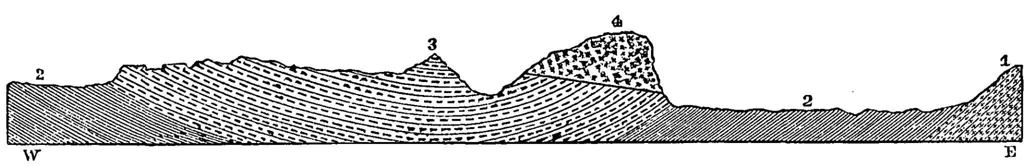


FIG. 49.—Section along Arroyo San Cristobal and the Lower Galisteo. 1. Dakota; 2. Colorado; 3. Laramie; 4. Trachyte of Cerro Pelon.

THE UPPER GALISTEO.—A narrow dike, barely ten feet wide, follows a northeast direction from the mouth of the Arroyo de los Angeles for miles and forms a well-defined ridge, separating the two portions of the Galisteo area. That arroyo falls properly within the northern division, which, south from the Cerro Colorado, is an open park, stretching from that arroyo eastward almost to the Galisteo and Koslowski road, its eastern boundary being the abrupt face of the Dakota Mesa referred to in the last paragraph but one.

An arroyo begins on the southern face of that mesa and follows the northwest side of the dike to very near the gap by which Galisteo Creek breaks through the dike. The Fort Benton and Niobrara subgroups are concealed in this arroyo, but the Fort Pierre is finely exposed in it as well as on the plain on both sides. It shows the same characteristics as in the southern portion of this area. Univalves are very numerous in the concretions, and bivalves prevail especially in the more calcareous shale-beds. No *Ammonites* were found in the concretions, but they occur frequently in the shales. Gypsum crystals are plentiful. Exposures of this group are common northward to within a short distance of the Cerro Colorado.

The Laramie sandstones are well exposed near the Galisteo gap and are dipping westward. They are coarse-grained, contain some carbonaceous matter, and are separated by dark shales, but show no *coal*. Careful search was made for *Halymenites major*, but that fossil seems to be altogether absent both here and in the field south from the Galisteo. Beyond the alluvial basin of the Galisteo the Laramie sandstones are shown on the low divide between the creek and the Arroyo de los Angeles, but there they have an eastward dip, which increases toward the crest of the divide, where they are almost vertical. This condition continues northward almost to the Cerro Colorado, and the western edge of the narrow synclinal seems to pass just south from that hill.

The Lower Dakota rocks are shown on the western side of this divide, where they dip toward the west at from 60° to 80°. The line of this fault passes either immediately south or immediately north from the Cerro Colorado, where the rocks are Dakota and have but a gentle dip; but the exact course of the fault cannot be ascertained unless detailed sections are run. This could not be done at the time of examination.

The Lower Dakota rocks are well exposed in the Arroyo along an east and west section, and in all respects, as far as they go, resemble the rocks seen at and below Eaton's Ranch on the Arroyo San Cristobal. The limestone-bed is nearly vertical, shows crinoid stems with indistinct traces of mollusks, varies in color from light gray to dove, and in structure from coarse granular to fine-grained with conchoidal fracture. The sandstones are rather coarse-grained and for the most part very light gray, though a few of the beds are bright yellow, and occasionally a red bed is seen. The shales of the Middle Dakota are red, blue, and gray, some of them quite sandy, while others are argillaceous. This series continues to the mouth of the arroyo, but in that direction the exposures are less definite owing to overlapping by the Galisteo series.

Near the western edge of the arroyo the Dakota rocks dip eastward at a very high angle. This condition is especially well shown near the Santa Fé road. Exposures are poor on this side, and are found only where the Galisteo rocks have been removed by erosion. It is clear enough, however, that the Dakota rocks are thrown into a synclinal, and they are cut off on the west by a fault, as they are on the east side; which readily explains the absence of the Fort Pierre shales along the Lower Galisteo above La Vaca, and equally explains the distortions observed in the Laramie rocks for nearly two miles above that placita on the south side of the creek. This fault cannot be followed out toward the north, as the mesa is covered by alluvium and the Galisteo series, neither of which is affected by the fault.

The Galisteo group is easily followed along the western and northern walls of the Arroyo de los Angeles from the Lower to the Upper Galisteo. It is double, consisting of the breccia above, not less than 150 feet thick where examined, and the light-gray sandstone below, 40 feet thick, as shown in a full exposure at the head of the arroyo. The breccia is not present at the head of the arroyo, and no exposure of it was found at any locality north from that where the Santa Fé road ascends the mesa. The sandstone is very light-gray, very soft, and much of it is friable. It contains many small rounded pebbles.

The relation of this group to the Dakota sandstones is well shown in the bluff at the head of the arroyo; for there the Dakota sandstones dip westward at 65°, while the Galisteo sandstone rests on their planed-off edges and dips westward at barely one degree. Immediately overlying it are three feet of marl and fifteen feet of alluvium. The latter consists of—

	Feet.
1. Soil	1
2. Marl	1
3. Conglomerate	3
4. Clay	10

The conglomerate is compact and contains pebbles of trachyte as well as of the La Vaca Dike, all of which are well water-worn. The marly material closely resembles that immediately overlying the Galisteo sandstone, which is similar to that observed at so many other localities within the district. This alluvial deposit covers the mesa west and north from Galisteo Creek toward Santa Fé.

The valley of Galisteo Creek contracts at the Cerro Colorado and thence to the head of the stream it is comparatively narrow, though immediately above that hill the bottom is quite wide. Up to the Bishop's Ranch, about six miles above Galisteo, the Lower Dakota rocks are well shown on both sides of the valley, forming a fine mesa on the east side, in which the strata have an eastward dip. They form the lower portion of the wall on the west side and are nearly vertical, the dip increasing up to the Bishop's Ranch, where they have been pushed beyond the vertical. Some of these Dakota sandstones are very soft and yield readily to the weather, so that the white and yellow beds when covered by *débris* are very apt to be regarded as part of the Galisteo sandstone, which forms the upper part of the wall. This sandstone, the lower member of the group, is ashen-gray and excessively soft, so that it weathers as readily as though it were alluvium or loose sand. The *débris* from it forms a high talus, and the vertical white and yellow sandstones of the Dakota are exposed in the gullies in such a way that the casual observer is very apt to think the whole series conformable. The upper group is easily followed round the mesa from the head of the Arroyo de los Angeles to the Upper Galisteo and thence to near the Bishop's Ranch, where its outcrop is pushed off toward the northwest.

The base of the Dakota is reached immediately above the Bishop's Ranch, and one soon comes to the red sandstones and shales which may represent the Triassic. Above these, along the creek, are the Carboniferous beds, among which a magnificent limestone is the most conspicuous. This is well exposed on the road leading from the Bishop's Ranch to Santa Fé. Archæan rocks are reached at about 500 yards above the ranch.

Here is the southern termination of the great Archæan area marking the course of the Santa Fé axis; and the eastern fault, referred to in describing the Arroyo de los Angeles, is probably followed by the creek for more than a mile below this locality. The stratified rocks—Carboniferous, Trias, and Dakota—have been pushed into a vertical position around the Archæan, so that the lines of outcrop resemble half an ellipse. It seems as though the Carboniferous must be faulted against the Archæan on the east side, for there is not room here for the great mass of that series as shown on the Upper Pecos.

The Archæan is represented by a very hard fine-grained granite, which takes a beautiful polish, as is shown in the narrow cañon by which the creek passes through the axis.

The valley becomes somewhat wider above the Archæan. On the west side are the Triassic and lower rocks dipping very sharply eastward, a condition which continues to the mouth of the Arroyo Alamoso. The eastern limit of the Archæan runs almost northward to and beyond the Santa Fé stage-road and lies very near the western side of the Arroyo, being crossed by the stage-road at little more than a mile west from Cañoncito. Between that point and Cañoncito the Carboniferous and Triassic rocks as well as the Lower Dakota are turned up in a succession of hog-backs with dips of from 30° to 50° toward the east-southeast. The Carboniferous is represented by limestones and sandstones with some conglomerates, and is very well shown on the rocky hill west from Cañoncito. One conglomerate, exposed on the west side of the Arroyo Alamoso and apparently belonging to the Carboniferous, is filled with granite bowlders one to three feet in diameter and all much water-worn. The Trias is represented by red to brown shales with thin bands of gray sandstone.

The Lower Dakota forms a bold wall of gray and yellow sandstone on the west side of Galisteo Creek from the mouth of Arroyo Alamoso to some distance above Cañoncito and is dipping east-northeast. Occasional exposures along the creek exhibit the Middle Dakota, consisting of gray, sandy, and red argillaceous shales. The Lower Dakota rocks on the east side of the creek dip very abruptly toward west-southwest, and the creek flows in a synclinal down to the mouth of Arroyo Alamoso.

Following the stage-road northeastward from Cañoncito one sees the Lower Dakota well exposed in the walls of the Little Cañon. Its beds rise rapidly to the top of the mesa, which is continuous with that followed by the stage-road to Bernal Station. The rate of dip diminishes quickly, and the Lower Dakota forms the top bed of the mesa to San José on the Pecos. Its thickness is not far from 250 feet.

Underlying this are the Triassic beds, red shales and red to gray sandstones, in all estimated to be about 600 feet thick. These show changes in dip similar to those of the Lower Dakota. A slight anticlinal is crossed at probably a mile and a half above Cañoncito, and thence the rocks have a southerly dip.

Archæan rocks are reached in Apache Cañon at but a little way above Cañoncito. Both branches of Galisteo Creek rise amid rocks of that age.

The detrital deposit in the upper part of the Galisteo area is thick. It shows a conglomerate at the base, but the silt overlying that contains few little coarse material.

SECTION III.

THE UPPER PECOS RIVER AND GALLINAS CREEK.

The Upper Pecos.—The Pecos River rises in the trough between the Mora and Santa Fé axes and flows southward and southeastward to beyond the southern limit of the district. Vaca Creek, rising on the western slope of the Las Vegas Range, is the only important tributary entering the river north from the Santa Fé stage-road. No examinations were made south from that road.

One rides almost constantly on Carboniferous rocks from Bernal

Station to San José along the stage-road, though, as the immediate valley of the Pecos is approached at two or three miles from the latter place, the higher beds which have been referred to the Trias are reached. The gray limestones of the former series frequently crop in the road and yield the characteristic fossils abundantly. The Triassic rocks are brick-red sandstones and dull-red shales, which are well shown in the Bernal Mesa underlying the sandstone of the Lower Dakota.

The course of the Pecos River above San José to very near Koslowski's Station is from the northwest, and a high mesa forms the southwest wall of the valley. This mesa continues in the same direction to where the stage-road leaves Piños Creek, which enters the river from the west below Koslowski's and reaches to the cañon of Galisteo Creek, beyond which, as already shown, it breaks down. This mesa is capped by the hard yellowish sandstone of the Lower Dakota resting on not far from 600 feet of alternating brick-red sandstones and shales, which in turn rest on light-gray sandstones forming the upper part of the Carboniferous.

Carboniferous rocks are exposed along the whole distance from San José to the divide between Piños and Galisteo Creeks. One exposure of limestone begins at barely six miles above San José and continues for a long distance. The rock is gray with some blue layers, varies from fine-grained with conchoidal fracture to coarsely granular. Crinoidal stems and *Athyris subtilita* are abundant in it, and *Productus* occurs less commonly. An equally good exposure was found at the point of the mesa near the station of Ojo de los Pajaritos, and others between that place and Koslowski's. Several short exhibitions of Carboniferous limestone were observed between the latter place and the forage agency, five miles farther west.

Opposite Koslowski's the mesa shows some hills, indicated on the map as Cerro Escobas, which are made up of alternating sandstones and shales belonging in part to the Middle Dakota. The mesa is deeply indented west from Koslowski's for several miles, but the capping of Lower Dakota is continuous to Galisteo Creek.

The stage-road follows Piños Creek from Koslowski's almost to the head of that stream. The creek basin is neatly terraced, and a broad plain, somewhat cut by erosion, stretches from this stream to the Pecos. The upper terrace shows a cemented conglomerate underlying the soil and resting on the Carboniferous sandstone. The deposit on the lower bench consists of—

1. Soil	3 inches to 4 inches.
2. Stiff clay	3 feet to 6 feet.
3. Conglomerate	2 feet to 3 feet.

The last resting on Carboniferous rocks, of which five feet are exposed in the creek bank. An ashen deposit occupies in part the place of No. 2 near the road crossing above Koslowski's, from which some human remains have been obtained.

A broken bench lines the Pecos from San José to but a little way below Koslowski's, and reaches from the base of the mesa almost to the river. Water-worn fragments of rocks in cemented conglomerate were seen on this bench at 120 feet above the river, and loose fragments, also water-worn, were seen at much greater height near the stage-road.

Vaca Creek is a bold stream, entering the Pecos at ten miles above San José. It flows through a narrow cañon, which, however, opens into a small park at the hamlet of Las Colonias, five miles above its mouth, and there shows a marl underlying the soil, which is very similar to that seen near Las Vegas and Santa Fé. The Eastern Fork of this creek rises in the Archæan of the Las Vegas Range, but soon reaches the Carboniferous, and for the greater part of its course flows amid rocks of the latter age. The Western Fork seems to flow almost wholly through Carboniferous beds.

The narrowing of the Archæan area of the Las Vegas Range begins at but a little way south from the head of the East Fork. Following the old Santa Fé trail toward Las Vegas one finds the Carboniferous beds well exposed, and dipping westward or southwestward very gently to their outcrop at somewhat less than six miles east from Las Colonias, where the Archæan is reached.

Between Vaca Creek and the Pecos only Carboniferous rocks are exposed along the old Santa Fé trail.

The Pecos flows in an obscure anticlinal from its source almost to the stage-road. Carboniferous rocks are well exposed in the cañon above Pecos to a considerable distance above Los Machos, beyond which the cañon was not followed. Excellent sections of those beds are shown at many localities, and the limestones almost without exception are richly fossiliferous. The Western Forks of the river rise amid Archæan rocks of the Santa Fé axis, and their cañons show the dip of the Carboniferous rocks to be extremely abrupt on the eastern slope of that range.

The river cañon opens into a handsome park at a little way above Pecos, which is of interest to the geologist, owing to the thick deposit of white marl underlying the soil.

Gallinas Creek.—The direction of the drainage is changed as soon as the divide between the Mora and the Pecos is crossed, for instead of flowing eastward, as in the Mora area, the streams of the Pecos area follow a rudely north and south course.

Gallinas Creek heads in a number of ravines immediately south from Solitario Mountain, flows eastward to the Dakota Stonewall, and thence flows southeastwardly to beyond the limits of the district.

The eastern edge of the Archæan area marking the Mora axis passes near the village of Las Gallinas, and thence to the road leading from San Geronimo to Las Tusas the Carboniferous rocks are fairly well exposed in the walls of the valley. The Cimarron anticlinal is much stronger below that road on this creek than it is on Manuelitos or Sapillo Creek, and the stream crosses the axis through a close cañon with walls of Archæan capped by the lower beds of the Carboniferous. This Archæan exposure continues along the creek to the Hot Springs, where it passes below the surface and is succeeded by the Carboniferous. The axis seems to be stronger at a little way north from Gallinas Creek, as the Archæan hills become higher, and for some distance toward Sapello Creek they are not capped by Carboniferous. The Archæan is represented by a compact fine-grained granite, with sometimes a slightly gneiss-like structure, which cleaves readily along its planes, but otherwise yields very slowly to the weather. The walls of the cañon are jagged and for a mile or more the upper part is almost impassable.

The Las Vegas Hot Springs are at the foot of the Archæan exposure, close to its junction with the Carboniferous. There are twenty-two of them, the greater number being found on the south side of the creek. The quantity of water discharged is considerable, but no effort has been made to ascertain it. As will be seen by reference to Dr. Loew's analyses, given in another portion of this report, the water of these springs is weak in mineral matters, and therefore the supposed medicinal qualities must depend largely upon the cleansing properties of the warm water. The temperature varies from 90° to 130° Fahr. A commodious hotel is in course of erection and extensive bathing-houses have been planned.

The Carboniferous rocks are exposed immediately below the springs; but the whole series is not shown here, and the probabilities favor the supposition that that group is faulted against either the Archæan or the red shales of the Trias. The Dakota Stonewall is passed at barely a mile below the springs and one emerges upon the plain.

The complication of dips in the Stonewall increases rapidly southward from Sapillo Creek. The eastern face of the wall soon shows a vertical dip, and at a little way farther is pushed over so as to show a western dip. At the gap made by Gallinas Creek the outer beds in the wall are vertical, but just outside of those are the dark shales of the Fort Benton, dipping distinctly toward the west. The whole of the Dakota group is shown in the gap, as are also the reddish and gray beds of the Trias. The dark-brown shales of the Fort Benton are shown in a shallow ravine in front of the wall as well as for a considerable distance along the road following the west side of the creek toward Las Vegas. The conditions are the same as on Sapillo Creek, for beds of passage, thin shales, and sandstone are shown, the latter being crowded with obscure, almost characterless casts of fucoids.

From the gap of Gallinas Creek to Las Vegas one rides mainly on the shales and limestones of the Niobrara division of the Colorado shales, which extend far toward the east. Fine exposures of the group were found in the vicinity of Las Vegas and southward. The dips quickly decrease toward the east until, in the plains beyond Las Vegas, the rocks are almost horizontal. This subgroup is the only one exposed northward toward Fort Union until beyond the divide between Sapillo and Gallinas Creeks, where the Upper Dakota sandstones are shown. Pot-holes are numerous along the road from Fort Union to Las Vegas, and some of them are of great size.

The Stonewall follows the course of Gallinas Creek until opposite Las Vegas. Thence its course is almost south to probably five miles south from Puertocito, or say twelve miles south from Las Vegas. Beyond that place it was not followed, but it seems to disappear at no considerable distance farther south.

Following the Santa Fé road from Las Vegas one rides for several miles on the shales and limestones of the Niobrara and Fort Benton sub-groups at the base of the Stonewall. Where the road breaks through the eastern portion, or the Upper Dakota, the following section is exposed:

	Feet.
1. Sandstone	70
2. Shales and thin impure limestones	80
3. Sandstone	200

No. 1 contains many impressions of a characterless fucoid. No. 2 is made up of variegated shales and thin beds of argillaceous limestone, the conditions being the same with those shown at the gaps made by Sapillo and Gallinas Creeks, though the shales are much thinner here. No. 3, as far as exposed, is coarser than the upper beds, and varies in color from very light gray to almost brown.

Behind this is a narrow park, which narrows northward and disappears before reaching the Hot Springs, but widens southward and opens into the great mesa country within a few miles. The exposures along the stage-road are unsatisfactory, there being only a few combs of light gray sandstone belonging to the Lower Dakota. A trail leads diagonally across the park from the plain to the gap on the west side of the park, through which the stage-road passes to Tecolote Creek. Some exposures were found along this trail.

The dip in the Dakota wall facing the plains is not far from 25° eastward, but along the trail it soon diminishes and is barely 5° at less than one-fourth of a mile from the crest of that wall. The rocks with such slight dip evidently belong to the Middle Dakota. They are sandstones, shales, and silicious limestones, and some of the sandstones are crowded with comminuted fragments of vegetable matter.

This park is bounded on the west by a wall of Carboniferous sandstones dipping eastward at from 70° to 80° and forming the eastern slope of the Cimarron anticlinal. Passing through a gap in this wall one comes to the area drained by—

Tecolote Creek, a tributary to Gallinas Creek, which rises at but a little way south from Mount Solitario. It flows southward within the Coyote trough on the west side of the Cimarron anticlinal to beyond the limits of the district.

The Archæan area along the Cimarron axis disappears at but a short distance south from Gallinas Creek, and the Carboniferous rocks continue unbroken from their western outcrop at the base of the Las Vegas Range to near the Dakota rocks, as already described. The Archæan core of the Las Vegas Range forms a line of bold mountains southward to very nearly west from the Cerro Tecolote, a small isolated hill north from the plaza of Tecolote on the Santa Fé road. But there they break down and, within a very short distance farther south, the Archæan rocks go below the surface and the Carboniferous rocks pass unbroken over the axis.

The easterly dip of the Carboniferous rocks near the Archæan of the Las Vegas Range is very sharp, but lasts for only a short distance. A shallow synclinal is crossed and the rocks rise gently toward Tecolote Creek. A short abrupt anticlinal is cut by the creek at the west base of Cerro Tecolote, which is the same with the sharp fold observed on Manuelitos and Sapillo Creeks, though here it is much more abrupt, the rocks being closely folded and almost vertical. The westward dip is soon regained and the rocks rise eastward until very near the Carboniferous wall, where the Cimarron axis is reached. On the east side of this axis, as already mentioned, the dip is from 70° to 80°.

Following the stage-road southward one finds the smaller axis crossed by the creek at not far from the village of Tecolote. Thence the exposures are very poor, but Carboniferous limestones and sandstones are occasionally shown. This whole area is Carboniferous, and the dip along the road after leaving Tecolote is barely 2°. A short ride from Tecolote carries one over the divide to—

Bernal Creek, another tributary to Gallinas Creek, which rises very near the southern extremity of the Las Vegas Archæan and flows south of southeast to beyond the limits of the district.

Looking up this stream from Bernal Station on the stage-road one can easily discern the Mora axis by means of the hog-back hills bounding the valley. The axis terminates as a bold ridge at several miles above the stage-road crossing, and where crossed by that road immediately west from the station it is but a gentle fold. The dips are insignificant and southward—southeast and southwest. Indeed the stage-road seems to pass very near the southern edge of the region marked by distinct folds—for beyond it southward the whole country is broken into mesas in which the dips are slight.

Carboniferous sandstones and limestones with the characteristic fossils are exposed in the road near Bernal directly under the Mora axis, while in Bernal hill and the mesa south from the road the gray sandstones belonging to the higher part of the Carboniferous are well shown.

The reddish shales and sandstones of the Trias are shown in the mesa bluff. They contain no fossils, at least none was found though careful examination was made. There seem to be narrow seams of gypsum in the shales, but they are not persistent. Above these beds is the sandstone of the Lower Dakota.

The dip becomes so gentle south from this line that the section exposed in this mesa is shown for many miles southward.

U. S. GEOGRAPHICAL SURVEYS WEST OF THE ONE HUNDREDTH MERIDIAN,

CAPTAIN GEO. M. WHEELER, CORPS OF ENGINEERS U. S. ARMY, IN CHARGE.

PART IV.

ECONOMIC GEOLOGY.

BY

PROF. JOHN J. STEVENSON,
GEOLOGICAL ASSISTANT TO EXPEDITIONS OF 1873, 1878, AND 1879.

CHAPTER XVII.

CAPABILITIES FOR SETTLEMENT.

CLIMATE—AGRICULTURAL RESOURCES OF THE RIO GRANDE AREAS AND OF THE CANADIAN AND PURGATORY AREAS; SUMMARY OF FARMING, GRAZING, AND TIMBER LAND—OUTLETS TO MARKET.

CLIMATE.

Two distinct regions are embraced within this district, bringing the subfrigid and the temperate climates into close proximity.

The two seasons, one wet, the other dry, are recognized within the mountainous portion of the area; but no such distinction is fairly shown at the lower altitudes. Rains are frequent during the summer months in the mountains, beginning in June and increasing in number as well as in violence until September. Snow falls there early in November, sometimes soon after the middle of October, and remains until the following June. The waste of snow at the higher altitudes appears to be very small, and every slight storm adds its pile to that previously accumulated. These storms, confined almost wholly to the mountains, are practically only heavy showers which come up suddenly in the after part of the day. They leave but temporary traces in the lower valleys, which disappear altogether within a couple of hours after the rain ceases to fall. The more violent storms sometimes reach the plains, but these are due to great atmospheric disturbances, such as find their way across the continent.

No records exist whereby the rain-fall in the mountain region may be compared with that on the plains; on the latter it does not exceed fifteen inches per annum at from four to ten miles east from the base of the mountains. At Santa Fé, between the Rio Grande and the west foot of the Santa Fé Range, the rain-fall for the year ending June 30, 1878, was 12.94 inches, while at Mesilla, in the great mesa region beyond the southern limit of the district, the rain-fall during the six months ending June 30, 1878, was 5.91 inches, so that the rain is almost evenly distributed throughout the year in the southern Rio Grande area.

The Pueblo Indians assert that the present condition did not always prevail, and that not very long ago their country was not arid as now; and the numerous ruined cities, evincing the existence of a much larger population in former times, seem to prove the assertion not altogether unfounded. But the rain-fall has decreased, and at present the region is certainly arid except in the immediate vicinity of the mountains. Comparison of the wet and dry-bulb thermometers sometimes shows a difference of nearly 40°. Dew is not a common phenomenon, though it occurs much more frequently than an indifferent observer might suppose, as the quantity is always small and except when frozen it disappears quickly after sunrise. Evaporation goes on rapidly; a temperature of 95° fails to produce a sensible perspiration as it does in the moist atmosphere of the sea-border; and streams diminish in size as they leave the mountains to a much greater extent than can be accounted for by the looseness of the soil.

Under such a condition one is not surprised at the violent contrasts of temperature which occur within a few hours in higher as well as in the lower altitudes. There being no blanket of moisture to prevent too rapid absorption or radiation of heat, the climate is like that of the Great Sahara, which Tyndall well described as "an oven by day and an ice-house by night." Variations of 45° within seven hours are not unusual in June and July at the east base of the Culebra Range, while farther south and in the plain region the temperature many times is oppressive at mid-day but lower than the freezing point at midnight. Yet the dryness of the air which permits these abrupt changes is itself the protection against them, and they cause little inconvenience to the traveler or settler.

These changes are especially noteworthy in summer. In the field season of 1878, lasting from the middle of July to the middle of November, a camp-fire was necessary for comfort in all but four evenings, and two or more thicknesses of blankets were needed on all but two nights. The contrast is not always so great during winter, for occasionally the temperature on the plains falls very low under the influence of cold waves from the mountains. But such depressions of temperature are of comparatively short duration, and fortunately they are separated by considerable intervals, so that the ill-clad lazy Mexicans suffer very little. The average temperature of the plains is not far from that of the inland region at the latitude of New York or Philadelphia, though near the mountains the thermometer shows extremes of temperature not often known on or near the Atlantic coast. At times during summer the mercury rises to 100° at Fort Garland in Colorado, while during the winter it occasionally falls to 30° below zero. The extremes at Santa Fé during the year 1877–'78 were 90.5° and 2°, and at Mesilla, farther south, they were 104° and 13°.

Hard frosts appear in the mountain area 8,000 feet or more above tide early in September, and the season for growth of annuals may be regarded as closing there in August, though occasionally, as in 1878, it may continue until the middle of September. But frosts severe enough to injure vegetation rarely occur on the plains before the first of October, and spring opens fairly about the middle of May. A slight difference in altitude causes a marked change in the time of the seasons. Commonly 300 feet of ascent should cause a change of 1° in the average temperature, but locally the rate of change varies. The advent of spring is two weeks later in Chico Rico Cañon, on the south side of the Raton Plateau, than it is on Uña de Gato Creek, only 600 feet lower and less than twelve miles farther east. A similar contrast was observed between the plains and the upper cañons within the Trinidad coal-field. The wheat harvest was over and the grain had been trodden out before the harvest began on the Upper Purgatory or in any of the cañons beginning at the Stonewall Valley.

Violent wind-storms prevail, as one might expect in a region characterized by marked and sudden variations in temperature. These continue for months on the plains and sweep with great force through the cañons. They prove a serious drawback to the traveler's comfort and lead to much perplexity in the choice of camps. The low "bottoms" of the streams are moist, and frequent camping in such situations is liable to induce malarial trouble; but the higher benches are exposed to the constant wind, which sweeps dust and gravel into the tents and not seldom produces severe illness. These winds sometimes do severe injury to the crops.

The rarity and excessive dryness of the atmosphere possess many attractions for invalids, who in nearly all cases find at least a temporary relief after reaching this region. Without doubt the conditions are favorable to those suffering from asthma or from phthisis in its less advanced stages. But more caution is needed than the invalid seems ordinarily to possess. The contrast with lower altitudes is very marked. The novelty of conditions awakens a strange nervous excitement, which unless restrained leads to over-exertion and thence to depression too great for invalids already enfeebled by long contest with disease. Asthma, dyspepsia, and phthisis in its earlier stages are palliated in this climate and in some cases perhaps cured. But nervous diseases and those of the heart are aggravated, so that patients suffering from such affections will do well to avoid this region.

Certain diseases prevail. Rheumatism is liable to attack the white man soon after his arrival, though the Mexicans seem to be unaffected, or at least to suffer very little from it. Pneumonia is easily induced by exercise in the higher altitudes, where, indeed, it is far too prevalent. Inflammatory diseases are easily contracted and not easily thrown off. A peculiar disease, the "mountain fever," frequently attacks the newcomer, and it is supposed by some to be merely part of an acclimatization process. It is closely allied to malarial fevers, and is thought by some physicians to be due to decayed vegetable matter in the streams.

AGRICULTURAL RESOURCES.

The district contains very little of absolutely barren land. Above timber line on the mountains, along the walls of abrupt cañons, strips of rock exposure occur which can never be utilized under existing conditions of climate. Aside from these the whole area may be regarded as possessing value for timber, grazing, or tillage.

The cañons within the mountain ranges or close to its base on both sides have a thick covering of fine silt, which is good soil and similar to that which is found on the plains as well as in the cañons through the Trinidad coal-field. To the eye the soil is the same everywhere, a dark brown or slate-colored silt resting on reddish clay or on a cemented conglomerate in case the clay does not reach to the bedded rocks. But being of local origin its variations must be considerable. Thus within the Arkansas area the soil shown in the cañons near the base of the mountains is composed mostly of material from the Carboniferous and Archæan, while farther east, between the base of the mountains and the plains, it consists of these materials mingled with others from the Cretaceous, and on the plains the Cretaceous materials predominate. The basaltic overflows, of which the plates covering the Raton Plateau and the Ocaté Mesa are fragments, have done much toward enriching the soil of the Mora and Canadian Plains, while the basalts commingled with materials derived from the Archæan and Carboniferous have made the soil on the west side of the mountain ranges exceedingly rich. Wherever water can be obtained for irrigation the soil proves to be remarkably fertile and it yields good crops to even the imperfect cultivation performed by the shiftless Mexican.

But the soil of New Mexico and of South Central Colorado has never been tested fairly. The Mexican is contented with such a crop as rewards plowing with a crooked stick. He plants his crop and practically expects it to take care of itself until harvest time comes. His hoes are so cumbrous that to do a little cultivation involves a vast amount of physical labor, for which the indifferent crop seems hardly to be a compensation. No manure is applied to the soil, and continued fertility depends wholly on new material added by the water used for irrigation.

The climate of the whole area is agriculturally dry, and the rains are barely sufficient to encourage the growth of wild grasses on which the cattle feed. Irrigation is necessary, and the extent of tillable land depends mainly upon the supply of water for irrigation.

Farming operations are practicable only below the altitude of 8,000 feet. A few attempts have been made at localities of greater altitude, but they have not been successful. During exceptional seasons wheat and oats ripen, but during ordinary seasons the early frosts of autumn suffice to cut down the grain before its maturity.

For the present, stock raising and wool growing are more important than purely agricultural pursuits. The great plains and the grassy parks in the mountains afford such admirable opportunities that both the American and the Mexican regard farming as of secondary importance.

In considering the distribution of land for farming, for grazing, and for timber, let us look separately at the drainage areas.

THE RIO GRANDE AREA.

The Rio Grande area within this district occupies the west and south sides of the mountains and reaches to the river. So much of it as lies between the river and the mountains was examined only so far south as Taos Creek, and the important region between that stream and Galisteo Creek was not visited. Each of the numerous streams flowing across the plain to the river has a strip of tillable land on each side. The two portions examined are widely separated and differ in some respects, so that they may best be considered separately.

The Northern Portion.—The Rio Grande enters a dismal cañon near the southern boundary of Colorado and thence southward for many miles it is of no agricultural value except to irrigate the narrow "bottom" of the cañon; while the broad plain stretching from the brink of the chasm to the base of the mountains is irreclaimable, except where some small stream renders a narrow strip available. The plain is but the continuation of the San Luis Park of Colorado, and its plain character is retained until within a very short distance of Colorado Creek; but thence southward the surface is badly broken by low foothills to near the Taos Basin, where the several streams forming Taos Creek have eroded a broad recess between the Taos Range and the U. S. Mountain. A narrow valley, beginning near Costilla Creek, follows the base of the Culebra Range northward to near Trinchera Creek, where it opens into the San Luis Valley. This subordinate valley, which is referred to in the previous pages as the Culebra Park or Basin, is separated from the main plain by a low basaltic mesa.

Trinchera Creek is immediately beyond the northern limit of the district. Agricultural operations are impossible above the forks of the stream, but below them the bottom is broad and the climate favorable. An extensive plain stretches from Ute Creek, directly north from Fort Garland, to somewhat more than a mile south from Trinchera Creek, and is well watered by three large creeks—Ute, Sangre de Cristo, and Trinchera. Only a small part of this space is under cultivation, though the whole of it might be placed under ditch at a trifling cost. A high plain intervenes between Trinchera and Culebra Creeks, both in the park and on the Rio Grande Plain. It is the divide between the creeks, and lies so far above them both that it cannot be irrigated except by an expenditure which the extent of the area would not justify.

But beyond this divide is the basin of Culebra Creek, through which the numerous tributaries of that stream flow to unite near the plaza of San Luis. The soil in this basin is very rich; sage-brush and greasewood thrive admirably, some specimens of the former having been seen which were six feet high; bunch grass covers great patches in the higher and drier parts; cactus occurs in profusion, and low flowering plants are numerous enough to prevent any appearance of desolation. Much of this basin is cultivated, but more of it remains untouched, especially in the southern part, where the ground is somewhat marshy and at present is good only for pasture. This could be reclaimed without difficulty. The creek breaks through the mesa below San Luis and continues to the river, giving ample supply of water throughout for the irrigation of several times as much land as is now under cultivation. The population along this stream and its tributaries is said to be not far from 3,000.

The Rio Grande Plain from Trinchera Creek southward almost to Colorado Creek is dismal. Too high above the streams to receive any moisture from them, it supports only sage-brush and cactus, with straggling bunches of grass. The loose sand covering the surface is caught up by the winds and hurled about in intolerable clouds. Yet this loose material is the same with that which along the stream "bottom" proves so productive when properly irrigated.

Much of the region drained by Costilla Creek lies far above the climatal limits of farming, and agricultural operations really begin at the mouth of the cañon where the stream emerges upon the Rio Grande Plain. There is the village of Costilla, which lines the creek for fully two miles. The tillable area in all is not far from eight square miles, but it is limited only by the supply of water, for the stream is barely capable of irrigating the land now under cultivation. Indeed, it is wholly absorbed under ordinary circumstances, so that it rarely reaches the river. Were the supply of water ample the tillable area could easily be doubled.

The streams issuing from the mountains south from Costilla Creek are insignificant and for the most part are uncertain in flow. Within three miles of Colorado Creek the water from three small creeks has been turned into a large *acequia* or ditch, which affords water for irrigation of several square miles near Los Cerros. The soil here, though precisely like that on the arid forbidding plain north from Costilla Creek, is exceedingly fertile and as productive as the apparently better material distributed over the broad "bottom" of that creek. A strong stream issues from the Cañon Cabresto and is lined with fine farms thence to Colorado Creek. The broad bottom of that creek immediately below the mouth of its cañon has been utilized to but a small extent. Much of it is covered to the depth of a foot with gravel. Farther down the character of the "bottom" improves, and, though not very wide at any place, it is rich enough to support a population of several thousands.

Some small streams issuing from the Taos Range between Colorado Creek and the Taos Basin afford water for irrigation of narrow strips of land, but the irregularity of the surface forbids farming on an extensive scale.

The Taos Basin has, perhaps, a larger amount of tillable land in one compact body than is to be found similarly situated in any other part of the area. The soil is admirable, being derived from the Archæan and Carboniferous with no small admixture of volcanic material; while at but a few inches below the surface is a tufaceous limestone, which cannot fail to be a constant amendment to the soil. Water is supplied by large streams—Pueblo, Ferdinand, and Frijole Creeks. A population of not far from 10,000 inhabits this basin, and yet a large part of the land is still wild. No attempt has been made to cultivate the bottoms of Ferdinand Creek, which, up to within two or three miles of Taos Pass, are below the climatal limit; nor has any farming been done on the broad "bottoms" of Frijole Creek or its many branches, all operations having been confined thus far to the basin and to the immediate vicinity of the creeks as they flow across it.

The region south from the Taos Basin is one of surpassing fertility. The Pueblo Indians have cultivated the strips for centuries and still excellent crops are obtained. Numerous streams flow across the plain and each affords an ample supply of water, while the constant flooding adds new material and keeps up the strength of the soil. The cañon of the Rio Grande widens, the river "bottom" becomes broader, and the farming operations within the cañon suffice for the support of several large villages.

Throughout this whole region the conditions are favorable to agriculture. Wheat, corn, oats, and barley thrive well at all localities, even at the very base of the foothills in the Culebra Basin; but potatoes succeed only on the higher farms and all attempts to raise them on the Lower Culebra or on Costilla Creek have failed utterly. Owing, however, to the abrupt changes in temperature and to the shortness of the season of warm nights, the corn cultivated in the Mississippi Valley and farther east fails to mature, and the small hard Mexican corn alone succeeds, as, wasting little time in the formation of stalk and devoting its energies to the production of grain, it matures speedily.

This area offers, for the present, much greater inducements to the stock-raiser than it does to the farmer; and this, too, in spite of the fact that, owing to long pasturing of sheep, the Rio Grande Plain is no longer a good winter range. The loose sand affords but scanty physical protection to the roots of grasses, which grow in scattered bunches, and the sharp hoofs of sheep soon complete the destruction which the teeth began. Many years must elapse before the range can be restored.

But excellent summer ranges are found in the cañons everywhere above the limit of cultivation, and many parks are found amid the timber, where the perennially moist ground is covered with a dense growth of grasses. The several cañons of Culebra Creek afford the best of pasture, and the whole space covered by the conglomerates, lining the base of the mountains from Costilla Creek northward, is one continuous pasture lot. Less abundant growth of grass was found on the slopes of the Archæan hills, but it seems to be more acceptable to cattle than that on the lower hills, since they make great efforts to reach it. The grazing in the cañons practically ends at but a little way beyond the eastern edge of the conglomerate, for in the Archæan the gorges are choked by a growth of aspens so dense that cattle cannot force their way through it.

The conditions are somewhat different on Costilla Creek, which opens up a more extensive grazing area. Pasture land begins at the very mouth of the cañon, and thence to its head are little meadows which have been fenced in for hay. Large parks were seen on both the main creek and its tributary, Comanche Creek, in which the grass is so abundant as to impede the passage of loaded mules. The many cañons opening into these parks and much of the higher ground are well grassed. Hundreds of cattle could be supported along this stream during at least half the year. But the range is useless during the winter, as the parks are covered with snow early in November and remain covered until May. Stockmen state that the snow in the parks is rarely so deep as that on the hill-sides lower down.

Excellent grass was found in nearly all of the petty cañons along the west side of the Taos Range as far south as Colorado Creek. Excellent grass grows in Colorado Cañon, where large flocks of sheep are pastured. The hills near the head of this cañon are covered with bunch grass, which is from two to three feet high in June.

Equally good grazing was found along the streams which unite to form Taos Creek. Indeed, the whole of the broken land drained by Ferdinand Creek and the numerous forks of Frijole Creek may be regarded as pasture land of the best quality, though not a little is valuable also for its excellent timber. Much of this grazing land, however, should be placed under the head of tillable land, and very probably the more available parts of it would soon be placed under cultivation were it not that difficulties exist respecting the title.

No information was obtained respecting the grazing land southward toward Santa Fé.

Timber is abundant on the mountains from Trinchera Creek southward to the termination of the ranges. Piñon and cedar prevail on the foothills, and especially on mesas of volcanic rock. At higher altitudes the forests are made up of yellow pines, spruces, and firs; but the pines descend to lower altitudes than do either the spruces or the firs, and they occur in some cañons below the level of the Rio Grande Plains. Those seen at the mouth of Colorado Cañon on the broad "bottom" are not inferior to those that grow on the mountain side. Aspen trees dispute the ground with the conifers in the mountain region and take quick possession of all new openings, where they soon form almost impassable thickets. They occur abundantly above 8,000 feet and choke the narrower cañons, so that the explorer is compelled to hew his way. A scrubby oak has its highest limit at somewhat more than the lower limit of the aspens, and the provinces of the two plants overlap at many places within the mountain area.

Trees are almost unknown on the plain except along the arroyos or water-courses. Here and there are clumps of cedar or piñon growing on the loose *débris* washed out from the cañons and spread in fan-shape over the plain; but they doubtless obtain their moisture from the water which trickles down the petty cañons and is absorbed by the *débris*. Where the stream-"bottoms" are broad a vigorous growth of cottonwoods is often seen forming groves, as at Costilla or near Fort Garland on Ute Creek. For long distances the larger streams are lined on each side with cottonwoods, with which in many places there occur also birch, alder, cherry, plum, and willow, forming a dense thicket on both sides of the stream, through which one can cut his way only with difficulty.

The Lower or Southern Portion.—Very little of this is embraced within the district, and the Rio Grande itself was not reached.

The region drained by Galisteo Creek is far from being inviting. The creek itself is intermittent and is dry for the greater part of its course. Even in the lower part it shows little water except during the night, for during the day evaporation carries off the water more quickly than the springs supply it, so that even the bed of the creek is dry. At or just before sunrise a great number of little rivulets can be seen at almost any season of the year. Within an hour after sunrise they have disappeared. But the water is at only a slight depth, for wherever a rock-bottom occurs within a few inches of the surface the water flows throughout the day. The main tributary to this creek is from the Arroyo San Cristobal, a constant stream, supplying enough water for the irrigation of a small area after the wasteful manner of the Mexicans. Throughout the broad plain in which the village of Galisteo is situated, water occurs abundantly at from ten to fifteen feet below the surface, and wells never fail to reach it at that depth—a strange feature, apparently, for this region is so arid as to be the most forbidding part of the whole district.

Galisteo Creek rises in Apache Cañon at very near the southern extremity of the Santa Fé Range. At Cañoncito it receives a small tributary from the east, which is followed by the stage-road. The soil in both cañons is very moist and irrigation is not absolutely essential. Some large patches of corn were seen near the stage-road, which could not be irrigated, situated as they were on islands surrounded by arroyos; yet the corn was thrifty. But I was informed that this is an uncertain experiment, which is liable to fail in two seasons out of three. Ample supply of water is supplied by Galisteo Creek from its head to a distance of four or five miles south from the stage-road; as soon as it has cut through the Archæan area at the extremity of the Santa Fé axis and has entered the faulted region at the south, the water disappears and no more is shown in the creek-bed until its junction with the Arroyo San Cristobal has been reached. But the water is very near the surface along the bed, for lines of thrifty trees follow the arroyo.

Very little land is available in the narrow valley of the Galisteo north from its close cañon in the Archæan above the Bishop's Ranch; but below that cañon there is a wide space of almost level land which would be admirable for farms if there were water for irrigation. Enough water is permitted to sink within half a mile below the Bishop's Ranch to irrigate this whole plain if it were only collected in a reservoir and used with proper economy.

Some ranches were seen in the immediate vicinity of Galisteo which depend for their irrigation upon wells. An extensive ranch is cultivated by an American at nearly four miles east from Galisteo, using the water of the Arroyo San Cristobal. A petty tributary of that arroyo has been utilized near Galisteo and irrigates somewhat less than 300 acres.

Near Galisteo the Arroyo San Cristobal from the east and the Arroyo de la Jara from the south join the Galisteo, which comes from the north. Thence the resulting stream flows westward. A fine park of probably thirty square miles has been digged out of the Colorado shales by these streams. But there is no water for irrigation south from the line of the Arroyo San Cristobal. A ranch on the La Jara is cultivated without irrigation and the crops rarely fail. There, as nearer Galisteo, water occurs within a few feet of the surface, and possibly the looseness of the soil permits the vapor to reach the plants.

The value of the apparently transient supply of water in the Galisteo has been thoroughly tested by a resident of Santa Fé, who dammed the broad arroyo at several miles below Galisteo. The water, instead of disappearing, gradually accumulated until a large quantity became available, with which a large farm is irrigated. By a repetition of this at three miles lower down the creek the broad bench on both sides of the arroyo could be cultivated, and its soil, rich enough to produce enormous clumps of branching cactus, could be made to yield fine crops of grain.

The soil throughout the Galisteo region is excellent. It is derived from the decomposition of the whole series of rocks as found within this district, for the complete section is exposed on the Galisteo. Wherever cultivated it yields enormously; wheat gives forty bushels to the acre, corn gives thirty bushels. Potatoes fail utterly, giving no tubers, but exhibiting remarkable development of vine. The difference between the yield of wheat and that of corn may appear anomalous to the eastern agriculturist, but it must be remembered that the corn raised here is the Mexican corn, whose yield is small compared with that of the eastern corn. The latter cannot be cultivated here, for although the thermometer rarely falls below 12° or 13° Fahr., yet the nights during even August and September are so cool that the "States corn" cannot mature.

The insignificant rain-fall in this region, barely twelve inches per annum, renders the grazing poor, for the soil is so loose as not to retain even a moiety of the scanty fall. Yet here and there the grazing is excellent, especially near the arroyos and in sheltered cañons among the mesas or in the foothills of the mountains.

Timber is abundant in the higher portions of this region. The Placer Mountains are covered with noble trees, while pines, piñon, and cedar cover the broad bench stretching from those mountains to the Galisteo. The Great Mesa, reaching from the Galisteo northeast toward the valley of the Pecos, is for the most part densely wooded. Cottonwoods and willows are sufficiently abundant along the streams north from Galisteo. Cactus grows well on the plains, where, indeed, it is the predominating form of vegetation.

The Pecos region as embraced within this district is characterized by many large streams, which rise in the Santa Fé and Las Vegas Ranges and flow south or southeast. The extent of tillable land is large, villages are numerous, and most of the streams are lined with ranches.

The Rio Pecos rises between the Santa Fé and the Las Vegas Range at thirty miles south from Taos and flows in a narrow cañon for twenty miles, receiving branches from both ranges. Here and there little openings in the cañon have a "bottom" wide enough for farming, but none of these have been utilized above Los Machos, at eight miles above Pecos; thence to Pecos the land is well taken up. The cañon opens above Pecos into a wide park, of which only the lower part, which is easily placed under ditch, has been cultivated. Below this park the valley becomes a broad cañon, whose northeast wall rises irregularly toward the low range separating the river from Vaca Creek, while the other is a broken slope leading to the broad mesa which is drained by Galisteo Creek. The cañon becomes wider below the mouth of Vaca Creek and contains a greatly increased area of available land. Vaca Creek has but little land, as the cañon is narrow and the tillable area is confined to a narrow strip, now on one side, now on the other side of the stream. Piños Creek is a small stream entering the river at probably three miles below Pecos. Both of its forks flow through a narrow strip of farming land.

The available area of agricultural land along these streams is far from being inconsiderable. From Los Machos to beyond the limits of the district a strip, one to two miles wide along the Pecos, could be placed under ditch at comparatively slight expense. Much of the land along Piños Creek is already under cultivation. The arroyos in which the branches of that creek flow are deep and narrow, so that they could easily be dammed to serve as reservoirs. The Pecos is a large stream with rapid fall, and a ditch taken out immediately below Pecos and carried five or six miles would irrigate a great area which now seems to be beyond the reach of the farmer.

The soil along these streams is admirably good. The thick limestones of the Carboniferous have contributed much toward enriching it; thin beds of gypsum belonging to the Trias have been washed into it along Pinos Creek and the Pecos below the mouth of that creek. The large villages of Pecos, San José, and San Miguel are situated on the river; many ranches were seen on Pinos Creek; while the limited space on Vaca Creek supports the village of Las Colonias. This is one of the most productive areas within the district.

Bernal Creek, rising near the southern extremity of the Las Vegas Range, flows through a cañon to very near the stage-road leading from Las Vegas to Santa Fé, and the quantity of farming land is very small within the district. But even of that very little has been utilized, as the broader valleys of the Pecos at the west, and of Tecolote Creek at the east, seem to have been more inviting to the early inhabitants. The soil is precisely similar to that of the Pecos Valley, and where cultivated it proves to be exceedingly fertile. The stream is large and at all seasons carries ample supply of water for irrigation.

Tecolote Creek, rising in the Las Vegas Range, flows southward through a broad undulating valley to beyond the limits of the district and carries a large body of water throughout the year. Broken mesas jut out from the Las Vegas Range and contract the valley near the stage-road, but perhaps two-thirds of the area north from that road may be regarded as fairly tillable land. The soil is marvelously rich, and is composed of materials derived from the Archæan and the Carboniferous. Two large villages, Tecolote and San Geronimo, were seen north from the stage-road, and much of the land is under cultivation. Irrigation seems to be hardly necessary on the west side of the valley above San Geronimo, where large plots of ground, lying wholly above any possibility of irrigation, were seen covered with wheat. It is clear enough that the ground on that side is constantly moist, for though the arroyos leading through it have only occasional pools, yet they all have running water farther toward the mountain as well as in the short cañons in the mountain side, all of which soaks into the *débris* underlying the soil. To this, no doubt, is due the fertility on that side of the valley. The sandstones on the hill immediately east from San Geronimo are covered by a thin coating of soil, which is kept constantly moist by some insignificant springs and needs no irrigation to nourish crops.

Gallinas Creek rises on the east slope of the Las Vegas Mountains, and, after crossing the Coyote trough and the Cimarron anticlinal, emerges upon the great plain, which continues unbroken into Texas. A narrow park in the Coyote trough affords room for farming, but the cañon through the Cimarron anticlinal is too close even for grazing. The soil on the plains is of great excellence, and is derived in great measure from the decomposition of limestones and shales belonging to the Fort Benton and Niobrara subgroups. A marly limestone underlies the soil at many localities, and often is so close to the surface that ordinary deep plowing suffices to mix it with the soil. The creek is a large stream and capable of irrigating an enormous area. Its fall is rapid and its arroyo is comparatively deep, so that reservoirs by dams could be constructed cheaply and at short intervals. Not a little land is cultivated in the vicinity of Las Vegas, but it is only a small part of what can be utilized without difficulty.

Throughout the whole of this lower Rio Grande area wheat, oats, barley, corn, and garden vegetables grow luxuriantly, the yield of the grains being very similar to that obtained near Galisteo, and the farming is done in the most primitive manner. The ground is scratched with a bent stick, the grain is permitted to become too ripe, is cut with a sickle, tumbled about carelessly, and at last trampled out by goats or horses. Not a little of the crop is lost in the process of saving it; and the yield is probably one-fifth greater than is returned, and under proper cultivation it might be increased almost one-half. Fruit thrives well at nearly all localities where it has been tried, though sometimes it is injured by severe storms on the plains. Potatoes fail almost uniformly along the streams, though they succeed on the mountain sides where irrigation is unnecessary. Where irrigated they produce vines only, and the tubers are seldom larger than an ordinary marble.

The whole region drained by the Pecos is one magnificent grazing area. Flocks of sheep have been driven over it for centuries, but stock-raising is still in its infancy. The land lying above irrigation is usually covered by grasses and the mountain region is dotted with parks containing the very best of pasture. But grass is wanting near the more important highways, where ox-teams of freighters have cut the feed down to the minimum. Elsewhere, even amid the forest, stock find an ample supply.

The timber is similar in character and distribution to that seen in the northern part of the Rio Grande area, but it is present in vastly greater quantity, except on the plains east from Gallinas Creek, where it seems to be wholly wanting, even cottonwood groves along the streams being rare. Piñon and cedar are easily obtained for fuel, and at the higher altitudes pines, spruces, firs, and aspen occur in dense forests. Pines three feet in diameter, aspens of one foot, and cedars of eighteen inches diameter are frequently seen.

THE CANADIAN AREA.

This great area embraces nearly the whole region east from the Culebra, Mora, and Las Vegas Ranges represented on maps 70 A and 70 C. Fully five-sixths of it is below the climatal limit of farming; many large streams cross it, bearing abundance of water for irrigation; and the available land is far greater than what is already under cultivation.

The Canadian and Mora Rivers flow below the plains in deep cañons. That of the Mora is practically closed from less than three miles above its mouth until near Cherry Valley, but some ranches are cultivated near its mouth. The Canadian Cañon begins almost immediately below Franklin's Ranch and continues to beyond the limits of the map. For probably fifteen miles it is so close or so choked with trees that no farming is possible; but at eight miles above San Felipe it widens and thence to the mouth of Mora Cañon ranches are numerous, there being indeed several small villages. The "bottom" varies greatly in width, but the soil is good everywhere and farming operations seem to be very successful. These cañons have some advantages over the plain in that the climate is more equable, but the difficulty of getting into them, or of getting out if once in, is a serious drawback. Centipedes and tarantulas were seen in great numbers as we traveled through the Canadian Cañon, but the natives seem to be as indifferent to them as the denizen of the Appalachian region is to the copperhead or rattlesnake.

For the most part the Canadian and Mora Plains of map 70 C are arid, but some moist places occur in the vicinity of the Ocaté Mesa, where ranching is carried on in a small way. Water is almost wholly wanting south from Cimarron Creek and east from the line of the Ocaté Mesa, so that for the present those plains must be regarded as agriculturally without value. Occasionally pools of water are found in the side cañons, but they are only pools; the water bubbles up through one crevice in the sandstone only to disappear in another within a few yards or even feet. Yet these pools could be utilized if necessary for irrigating the little parks which occur in these cañons.

The Canadian Plains north from Cimarron Creek have an irregular surface, and irrigation of any extensive area would involve engineering problems of no mean order. But at present the matter is wholly out of the question, as the amount of water immediately available would not suffice for more than a small portion of the area. Narrow strips along the Cimarron, the Vermejo, and the Canadian can be irrigated by short inexpensive ditches; wider strips lie well for irrigation, but the necessary ditches would be costly.

Much more of available land is found in the foothill region than in the plains. The Mora and its tributaries have broad inviting "bottoms" within the Coyote trough, while Mora, Manuelitos, and Cebollà Creeks, which rise on the west side of the Mora axis, show wide parks under that axis.

The strip along Sapillo Creek above the mouth of Manuelitos is irregular, nowhere opening into a broad park, but everywhere showing a good "bottom," covered with rich loamy soil, and sometimes one-fourth of a mile wide. The strip on Manuelitos is wider and it expands into a fine park below Santo Niño, most of which could be placed under cultivation. The whole of the broad "bottom" of the North Fork is available, certainly as far as Upper Tecolote. Below the mouth of Manuelitos, Sapillo Creek flows for miles through a plain, of which a strip two or three miles wide might be placed under ditch, for the creek is large and carries much water throughout the year. The cañon of Cebolla Creek has good farming land from about a mile below Placita De Don Tomas to its head. A broad park has been eroded by this stream in its passage through the Mora axis, much of which is already under cultivation, there being several small villages between Placita Del Oro and the head of the park above Cebolla. Good farming land borders the creek for nearly four miles above Cebolla on the South Fork and for nearly twice that distance on the North Fork, while lakelets on the divide between the forks afford ample supply of water for the irrigation of a considerable area there.

Coyote Creek is north from Mora Creek. The farming area begins at a little way above Guadalupita, and thence to the mouth of the creek the valley is studded with ranches. The space for farms is narrow at Guadalupita, though broad enough to support two villages; but at a short distance farther down it widens into a broad valley, divided midway by low hills and having a width of not far from three miles. The western strip, ending at seven miles south from Guadalupita, has no stream flowing through, but the ground is moistened by springs, so that not a little of it is somewhat marshy. The creek affords ample supply for irrigating the other strip. The area of good tillable land between Guadalupita and the mouth of the stream is not far from sixteen square miles.

Mora Creek rises near Mora Peak, flows southward through a broad cañon to San Antonio and thence eastward through a wide park to a cañon beginning barely two miles below Mora. This little cañon opens at Cañoncito into an irregular park which continues to La Cueva, where it opens into Coyote Park. The land is tillable up to the forks of the creek and the stream is lined with ranches. A good compact area of farming land continues for two or three miles below La Cueva, beyond which to Puerto del Cañon the creek flows in a cañon which opens into parks at Golondrinos and Loma Parda. At Puerto del Cañon one emerges upon a fine plain extending to two miles below the mouth of Sapillo Creek. Narrow strips of tillable land were seen north from this on Wolf Creek, which enters the river at about two miles and a half below La Junta.

The soil throughout the region drained by the Mora is excellent. Behind the Stonewall, which passes through Coyote, La Cueva, and Sapillo, it is derived from the Archæan and Carboniferous, the latter group containing many thick limestones. East from that wall the soil is more sandy, but the rapidly flowing streams spread over it the finely-divided silt from the upper part of their channel-ways, while in the parks at Loma Parda and Golondrinos the Niobrara limestones contribute not a little to the fertility of the soil. That this region is exceedingly fertile is clearly shown by the population which it supports in spite of the negligent methods of cultivation. Sapillo, Manuelitos, Santo Niño, Cebolla, San Juan, San José, Placita del Oro, Mora, San Antonio, Cañoncito, La Cueva, Buena Vista, Golondrinos, Coyote, Tiptonville, and La Junta are large villages, some of them even aspiring to the dignity of old cities. Yet the cultivated area is confined to a mere strip along the creeks and not one-third of the land is utilized. The soil is kept in good condition solely by the irrigation, whereby new material is added each year. Though cultivated for centuries and never plowed more deeply than two or at most three inches, the soil is still capable of sustaining this population.

Ocaté Creek drains a large part of the Ocaté Mesa, but its farming land is confined to the cañon above the stage-station and to the park in which its forks unite. The soil in the park is derived chiefly from disintegration of basaltic rocks and is fertile; but the supply of water for irrigation is not always certain. Most of the available land is already under cultivation.

Cimarron Creek drains a broad area on the Taos and Cimarron Ranges as well as on the Raton Hills or Laramie area. The Moreno Valley lies too high for successful farming except near the head of Cimarron Cañon, where wheat has been raised successfully. Ute Valley contains several hundreds of acres already under cultivation, and its soil, derived from decomposition of Cretaceous and eruptive rocks, is very productive. The cañons of Cimarron Creek are so narrow that until within a few miles of Cimarron there are no "bottoms" for cultivation. But within three miles of that town the cañon opens to the plain, and there large farms are already under cultivation. The tributaries to this creek—Poñil, Cimarroncito, and Rayado—render much land available, but only a little of it is farmed. The high land of the Laramie area is usually supposed to be above the climatal limit of cultivation, but a good wheat farm was seen on Poñil Creek near the Elizabethtown road. Not a little excellent land was found there, and we were informed by a farmer that wheat rarely fails to mature. At the same time this must be regarded as very near the upper limit of cultivation although considerably less than 8,000 feet above tide.

Vermejo Creek drains the eastern slope of the mountain region from Costilla Peak northward to the Colorado line, and it receives some important tributaries during its passage through the Laramie area to the plains.

The Stonewall Valley, beginning at Costilla Peak, continues northward along the base of the mountains and the mountain streams unite in it to form the main creek. This valley, near the junction of those streams, must be regarded as practically marking the upper limit of cultivation. A few Mexican ranches were seen there, and the owners said that ordinary grain crops can be raised there successfully. The cañon of the creek is narrow from the Stonewall Valley to Vermejo Park, a distance of three miles, where a number of American families have made a settlement. Below the park the cañon varies in width from 100 yards to half a mile, and nearly all the land which can be placed under ditch without any difficulty is already cultivated. But much land along the tributaries remains untouched.

The shorter cañons, those of the Canadian, Chico Rico, and Uña de Gato Creeks, are in no wise inferior to the others except in this, that the soil contains no limestone, being derived from disintegration of the Laramie shales and sandstones. Little has been done along these streams, but there is ample supply of water in them all. Crow Creek and Dillon's Cañons have broad "bottoms" and excellent soil, but water is wanting. Still there must be plenty of water very near the surface, for trees grow luxuriantly alongside of the water-courses.

Throughout the whole of the Canadian area wheat, corn, oats, and garden vegetables do well. Potatoes fail almost uniformly along the streams, but yield fine crops in sheltered spots on the mountain sides, where the ground is moist and irrigation is unnecessary. Wheat yields twenty fold and other crops are proportionately large,—this, too, in spite of negligent farming. "States corn" invariably fails to mature. It produces enormous stalks, but does not begin to make grain until autumn, when it is soon cut off by the frosts. Watermelons and other vegetables are raised with profit in the cañon of the Canadian despite of the difficulty of getting them to Fort Union and Mora, the nearest markets. Fruit does well at all localities where tried. Apples have proved a thorough success on Mora Creek under untoward circumstances. No efforts have been made to raise any domestic grasses, and hay is obtained from wild meadows along streams or from "sinks," most of which are merely depressions without outlet into which springs discharge.

Beyond all dispute the Canadian is the grazing area of the district. Moreno Valley, from the head of each fork of Moreno Creek to the head of Cieneguilla Creek, is covered with a dense growth of bunch grass. The broad valley of the Coyote from its head to beyond Black Lake is scarcely inferior to Moreno Valley, and much of it is a natural meadow from which hay is obtained to supply Taos. Wide swales extend from Coyote Valley across all the streams southward to Manuelitos Creek. The whole of the Ocaté Mesa and of the Laramie area abounds in nutritious grasses; the gramma grass is found everywhere on the plains; while scattered over the mountain sides are almost numberless little parks, which, though too small to be noted individually on the land-classification maps of this area, collectively make up many square miles. Nine-tenths of the area indicated on these maps as timber land is equally valuable for grazing purposes. But much of the grazing on the plains is inferior. Sheep have gnawed the grass on the Mora Plains until it is almost worthless and in many places the hoofs have utterly ruined extensive ranges.

Timber is plentiful. The whole of the Laramie area bears yellow pine, groves of that tree being scattered everywhere, while piñon and cedar are abundant on all the bluffs; cottonwoods, willows, alder, plum, and scrubby oak line the bottoms of the streams; spruces, pines, and aspens cover the mountains, and small aspens choke up the cañons. Trees are wanting on the plains, though here and there along the streams clumps of cottonwoods and willows occur. The overhanging walls of the Mora and Canadian Cañons are covered with piñon and cedar.

THE PURGATORY AREA.

This occupies the northern part of map 70 A and embraces the region east from the Culebra Range and north from the New Mexico line. The gorges in the mountain side are very narrow and contain but little "bottom" land, and of that very little is useful for grazing, as aspens choke the cañons. Timber, consisting mainly of pines and spruces, grows densely on the mountains, and aspens occupy spots from which the conifers have been removed by fire. The conifers eventually regain the ground, but the process is a slow one.

Immediately beyond the first foothills the streams flow through the Colorado shales and their valleys become wider, no longer close gloomy gorges, but broad swales carrying a dense growth of the grasses characterizing this region.

The Stonewall Valley follows the base of the mountains northward from the Vermejo area to Cucharas Pass and lies between the Dakota Stonewall and the Laramie bluffs. Much of it is covered with grass and is good grazing land. Broad "bottoms" line the streams and can be irrigated without difficulty. A similar though narrower valley lies immediately behind the Stonewall from near the South Fork of Purgatory almost to Cucharas Pass. The soil in both of these valleys is very rich, having been derived from decomposition of Carboniferous and Cretaceous rocks with no inconsiderable admixture from the Archeæan and volcanic rocks. Wherever irrigated it yields good crops, though at a few localities it is too stony to admit of successful cultivation. The climate is severe and the most profitable crop is potatoes; but usually the frosts of autumn are late enough to permit wheat and barley to mature in the main valley. Owing to the abundance and excellence of the grass dairying and sheep-raising have become important interests, and the valleys are rapidly filling up with American settlers. The breed of sheep is slowly improving, but for the present most of the sheep belong to Mexicans, and are destroying the range only to produce a very inferior quality of wool. The grazing land extends up the cañons of the Middle and North Forks for some distance and is cut off only when the aspen groves begin. Grass-covered parks of small size are numerous in the mountains, and though individually very small they are so numerous that they may not be overlooked in any summary of resources.

The Purgatory River follows a long cañon through the Laramie area, in which it receives many tributaries from both sides; arable land is confined to a narrow strip of "bottom" land on both sides of the stream and to similar though narrower strips in the side cañons. The main cañon varies much in width—often being a gorge with abrupt walls, while again it is a broad valley with wide level "bottoms" well fitted for farming operations.

This part of the area embraces all the region between the base of the mountains and the plains. For the most part it is broken up by almost innumerable small valleys, which unite and reunite to form the larger cañons and honeycomb the whole area. In the valleys and cañons there are parks covered with rich grasses, and not a few of them are natural meadows which are cut for hay. On the higher parts of this area one is often at a loss to determine whether the region is more valuable for timber than it is for grazing, since timber of most excellent quality is found on all the hills in somewhat sparse groves, while grasses are abundant everywhere.

Here and there in the parks of the larger side cañons the water supply is sufficient for irrigation, but ordinarily the streams are too uncertain for extended operations. Along the Purgatory, however, the supply is ample at all seasons for the irrigation of a large area; but only a small part of the land is under cultivation, and the farms might easily be doubled at slight cost. This is true especially of the lower part, where the soft shales of the Colorado group are reached and the cañon opens out into the plains. The climate is favorable to farming, and even on the upper waters of the river wheat, barley, oats, and potatoes yield good crops. Farther down the cañon one finds the climate becoming milder with the diminished altitude, so that Indian corn and many of the less hardy garden vegetables are cultivated successfully. But even here the available land is far from being taken up, and the indolent Mexicans are satisfied to cultivate only the broad "bottoms," which are easily reached without much cost for irrigation. The soil is decidedly good and the crops are remunerative.

The plain is a rolling prairie. It is bounded at the south by the Raton Plateau and at the west by bluffs holding the eastern outcrop of the Laramie group. For the most part it is a dreary, arid waste, without trees and with only a scanty coating of grass; but the grass, though small in quantity, is of great excellence and is valuable to the last degree for grazing. Much of the range has been injured by sheep-pasturing, but there is still a large area uninjured. Good grass is found everywhere on the slopes of the Raton Plateau and even on its top. Natural meadows were seen on San Isidro Creek up to within half a mile of Manco Burro Pass.

SYNOPSIS.

The Eastern farmer, doubtless, would find many drawbacks to this region. The area of farming land is limited; the high winds are apt to do serious damage to the crops; hail-storms are apparently more frequent than they are at the East; grasshoppers occasionally make sad havoc; everything depends on irrigation, and the water-supply might be cut off; above all, the best part of the whole region is covered by land grants.

Of these drawbacks the last is by far the most serious, and indeed it is the only one deserving of much thought. The Mexican government made numerous grants of land to favorites or to men who had popular influence; and it was expressly provided in the treaty of Guadaloupe that all such grants should be confirmed by the United States Government. Grants of this character cover much of the best land in New Mexico: one takes in the Culebra basin at the northwest corner of the district; another embraces nearly the whole of the Trinidad coal-field, and covers the mining region along Cimarron Creek and its tributaries; a third holds a large part of the region drained by Mora Creek; a fourth is claimed for the valuable mineral lands in the vicinity of Galisteo Creek; and many smaller grants absorb much of the farming land along the larger streams. Newly-discovered grants are constantly appearing, and it is surmised that not a few of them are fraudulent. Some of the more important have been confirmed by our Government, but many remain undetermined. Unfortunately the terms of these grants are frequently so indefinite that they may apply to one place as well as to another, and not the least difficulty is found in shifting the boundaries so as to absorb a region whose value has been but recently discovered.

Amid this uncertainty titles are in confusion. Very little good public land remains near the mountains, and a farmer runs the risk of building where another has a prior claim. If the grants were confirmed no such uncertainty would exist.

The remedy for this difficulty is simple. Either the courts should have absolute control of the question, or the Surveyor-General should have additional advantages for carrying on the investigations. Beyond all doubt the establishment of a temporary court would be good economy. Fraudulent claims would be detected quickly, while just ones would be confirmed. The business would require but a few years for completion, and then the Territory would become really inviting to the immigrant. The owners of land-grants would be only too willing to encourage immigration.

It is very true that in the foregoing part of this chapter only a very limited area of land available for cultivation has been recognized. But thus far reference has been made to that which can be placed under ditch with small expenditure, and the really available area is vastly greater than has been suggested by the description. If capital, directed by good engineering talent, be applied, the extent of farming land will be limited solely by the supply of water for irrigation. The reader must remember that the population of New Mexico is almost wholly native; that the average Mexican is sluggish and utterly regardless of the future, seldom, indeed, caring much for the present. A little corn, some tomatoes, some red pepper, and an occasional feast on flesh suffice to supply his wants. No cultivation is done beyond what a gentle necessity compels. Reservoirs are beyond the ordinary Mexican's capacity; none but insignificant ditches are made for irrigation, and even where water is scarce the method of irrigation is wasteful to the last degree.

One finds difficulty in determining even approximately the extent of the region which could be made available for the farmer. With but small expenditure the area could be vastly increased beyond what now seems to be possible. The supply of water in Galisteo Creek appears, during the greater part of the year, to be insufficient for irrigation of a few gardens; but a reservoir constructed at a few miles below Galisteo by merely casting a dam across the arroyo secures ample water for irrigation of a large farm. Another illustration was seen on Mora Creek. At two or three miles below La Cueva that creek enters a deep cañon, and the fine land bordering on it seemed to be far above the reach of any ditch; but an American living at Mora constructed a long ditch at no great expense and emptied it into a reservoir, whence small ditches flow. The extensive irrigating projects of central Colorado are well known.

A great ditch supplying the settlement of Evans, Col., is forty miles long and wide enough for an ordinary skiff-boat. It irrigates thousands of acres.

But no enormous expenditures are necessary within this district, as the streams fall rapidly. The Purgatory, Vermejo, Cimarron, Sapillo, Mora, and Gallinas are large streams, always carrying much water, and swollen by every storm on the mountains. Wide ditches can be taken from any of these by which to irrigate broad strips on each side of the creek. The Cimarron could be made to irrigate 25,000 acres between the bluffs and the Canadian River; the Canadian and the Vermejo could be made to water 50,000 acres in the plains; and some of the smaller streams could be utilized to add greatly to the area. And this could be done by means of comparatively short ditches, without resort to reservoirs other than such as could be constructed cheaply by damming the broad arroyos through which most of the streams flow. But enormous expenditure would be needed to bring the Canadian Plains under ditch between Cimarron Creek and the Mora Cañon, for the cañons of the Mora and the Canadian are very long and the surface of the plain is irregular.

There are many localities where water is practically inaccessible under present conditions. But frequently this is not irremediable. The amount required by an acre is not great; so that where water is at an inconsiderable distance below the surface wells might be sunk and windmills might be employed for pumping into the cisterns or reservoirs. This method is feasible in the vicinity of Galisteo, where wells are but ten or fifteen feet deep and water is reached at that depth everywhere. So also in the elevated plains along the stage-road between Mora Creek and Las Vegas, where wells are rarely more than thirty feet deep and find a good supply of water.

Artesian wells have proved successful on the Great Sahara, and many regard them as the one means by which this whole region is to be turned into a huge grain field. Unfortunately, artesian wells cannot be obtained everywhere. Dikes of lava may intervene between the reservoir and the parched locality; or faults in the strata may afford outlets for the water as it flows from a high altitude to a lower one. But they may prove successful at more than one place within this district. The fine park south from Galisteo might be supplied in this way, for it would receive the drainage from the great plain stretching northeastward, in which the rocks are dipping toward the park. An artesian well might be obtained at or immediately west from Fort Union, as the drainage from the whole region westward to the Stonewall passes toward the fort. But there is little probability that borings would be successful on the Canadian Plains north from Cimarron Creek, for dikes cut off the drainage and the dip is from the east or the disturbed region.

Grasshoppers did much injury to the crops at many places during 1875, 1876, and 1877, but since the last of those years they have appeared in insignificant numbers and have not been hurtful. Hailstorms are undoubtedly frequent, but they seem to do comparatively little damage, and they prevail only in the immediate vicinity of the mountains. The winds damage corn somewhat, and beyond all doubt cause no slight loss of wheat and oats. But the loss of small grains is due mostly to the sluggishness of the farmers, who, fearing no rain, are in no haste to complete harvest; so that the grains are seldom gathered until they have become over-ripe. Lack of water for irrigation seems to be almost impossible; storms occur regularly on the mountains, and the streams carry abundance of water throughout the whole of the agricultural season.

On the whole there is no room to doubt that, where land can be placed under ditch with a proper supply of water, the crops will be better than those raised at the east on equal areas—the same degree of skill being employed at both localities. True, there are occasional visits from grasshoppers, and hailstorms do some injury; but comparisons of the crops east and west during the last ten years show that the western farmer suffers less from grasshoppers and hailstorms than the eastern farmer suffers from drouth or excessive rain-fall.

But, as already intimated, the region is one more for the stock-raiser than for the farmer. Immense areas exist which cannot be placed under irrigation except at a cost not justifiable while so much land nearer to market remains untouched. These great areas are rich grazing land, dotted with little oases, so to speak, where springs moisten acres of ground and convert them into natural meadows covered with a dense growth of wild grasses. Unlike the domestic grasses at the east these become cured while standing, so that hay is cut indifferently at any time between July and May.

The principal occupation of the Mexican, when he has any occupation whatever, is sheep-raising. The sheep are degenerate descendants of the Spanish merino and their wool has become much like goat's hair. The quality is very inferior and a single fleece rarely weighs as much as three pounds. But when crossed with good merino rams from Pennsylvania and Ohio a flock of these sheep gradually improves, and usually the Mexican strain disappears within a few years. Not a few Americans have gone into the sheep business and the wool shows a decided improvement.

Sheep injure a range very quickly, and one may hesitate before deciding that those commonly seen repay by their wool the injury done to broad ranges which at one time were covered with a luxuriant growth of grass. The great plains of the Mora between that river and the Canadian Hills, the region adjoining Ocaté Park, and many others have been occupied for many years by sheep, and now one is puzzled to find how the flocks obtain subsistence. What the teeth spare the sharp hoofs tear out, and eventually the range becomes little better than a desert. A range once occupied by sheep, even though the feed be not materially injured, is destroyed for other purposes, since stock will not remain on it; and for this reason the stockmen, most of whom are Americans, are perpetually at enmity with the sheepmen, of whom by far the greater number are Mexicans.

Within New Mexico sheep need to be corralled and fed for but a short time during winter. It is true that feeding is seldom done and that the habit is to drive the sheep constantly; but this method is injurious to the wool and the loss far more than counterbalances the gain.

As already intimated, by far the greater number of American settlers east from the mountains are stockmen. The winter range for stock embraces the great Canadian Plains, extending far beyond the eastern limit of the district and uniting southward with the broad plains of the Rio Grande and Pecos which reach into Central Texas. The wild grasses, sparse enough to one accustomed to the meadows of the eastern States, are so nutritious that they afford ample nourishment to enormous herds; while the mountain parks are a summer range of whose extent and value stockmen seem to have little knowledge. The whole area of the Trinidad coal-field is covered with excellent grass.

Cattle are practically left to themselves. Turned loose after having been marked with their owners' brand they roam over the plain undisturbed for six months. They are then driven in by the associated stockmen, the calves following the cows are branded, and the whole herd is again turned loose. Stock are permitted to wander at large during the whole year, as the loss by severe weather during the winter is too slight to justify the expenditure necessary for the sheltering and feeding of enormous herds. The breed of cattle now raised in New Mexico has for its basis the great horned cattle of Texas, but better stock has been introduced and signs of improvement are manifest everywhere. Some of the stock ranches are of great extent, but the business is practically still in its infancy, and New Mexico shows nothing to compare with the immense stock ranches of Texas.

The vast timber area is for the present valueless; but the day is not far distant when railroads will afford a proper outlet for the magnificent pine, which is so abundant. Some action is needed to stop the frightful waste now going on. Many square miles of the mountain show only dead trees standing, while the surface is covered with fallen timber so interlaced that to ascend to any of the higher peaks involves an almost incredible amount of nervous exhaustion. Each autumn finds the Indians at their work of destruction. They set fire to the timber on the Mora, the Las Vegas, and the Santa Fé Ranges that the game may be driven down into the cañons. Careless camping parties leave fires burning, the wind carries coals into tall grass or amid pine-needles, and a forest fire results which may continue for weeks before a heavy rain comes to quench it.

OUTLETS TO MARKET.

The Denver and Rio Grande Railway reaches southward to Trinidad along the eastern base of the mountain region, while its main stem crosses the mountains by La Veta Pass and, in the Rio Grande area, runs but little north from the district. The main stem is to be continued along the Rio Grande southward to beyond Santa Fé, possibly to the mouth of Galisteo Creek, and it will afford sufficient outlet for all products of the upper valley.

The Atchison Topeka, and Santa Fé railroad enters the district at the extreme northeastern corner, passes through Trinidad, crosses the divide by Raton Pass, and thence follows an almost direct line to Las Vegas. Between Trinidad and Raton Pass it has opened up an important coal region, while southward from Raton Pass its line lies within striking distance of the fine coal exposures along Dillon's and Vermejo Cañons, to which short roads could be constructed cheaply. The road is to be extended to the Rio Grande, possibly by way of Galisteo Creek; should that route be selected it will give value to the anthracite coal and the iron ores of the Galisteo region and the Placer Mountains. Already the road has proved itself of great service to the stock-raisers of the Canadian Plains.

Ample facilities exist for inter-communication. The mining interests of the Moreno Valley caused the construction of good roads radiating from that valley in all directions, crossing the Rio Grande divide by Red River and Taos Passes, leading across the Laramie area to Trinidad, while fine roads followed Cimarron Creek to the plains and along Cieneguilla and Coyote Creeks to Forts Union and Mora.

A good road crossed Costilla Pass, but like that crossing the Red River Pass it has fallen into decay. Wagon roads were found along all of the larger streams. Natural roads can be obtained anywhere in the plains except within three or four miles of the bluffs or foot-hills, where the surface is badly cut up by deep arroyos. Water is abundant along all of the mountain roads, but it is not too plentiful on the plains.

CHAPTER XVIII.

SUMMARY OF MINERAL RESOURCES.

COAL — IRON ORE — LIMESTONE — GYPSUM — SALT — GOLD — SILVER — TURQUOIS — MINERAL SPRINGS.

COAL.

No coal was discovered in rocks belonging to the Carboniferous age, the nearest approach to it being some coaly shale seen on Mora Creek within a mile of Cañoncito. Thin seams of coal are said to occur in the Middle and the Lower Dakota at a few miles east from Galisteo, and the coal is reported to be good.

The valuable coal-beds belong to the Laramie group, which occur in the two areas already described as the Trinidad and the Galisteo coal-fields. The features being different in these fields they may be discussed separately.

The Trinidad Field.—The coal-beds given in the generalized section of this group are undoubtedly continuous. Full sections of the group were obtained in the four main cañons crossing the field at intervals of about twelve miles, while excellent partial sections illustrating all parts of the column were obtained in ten shorter cañons; so that the area has been fairly well worked up, considering that nothing more than a comparatively close reconnaissance was attempted. As may be seen by reference to the local sections given in the chapters on descriptive geology, the coal-beds are as nearly persistent as are the beds of Carboniferous age in the Illinois or Appalachian field.*

*The names applied to the several coal-beds in the general section are first given in this report, for no attempt had been made previously to classify the series or to determine the relations of the beds. Other names may have been applied locally to some of the beds, but if so the fact is unknown to the writer. It is hoped that future explorers will accept these names.

But while occurring persistently within the region under consideration the beds vary annoyingly, so that although any given bed is almost certain to be found at its horizon in any cañon north from South Poñil Creek, yet there is no certainty that it will be found of workable thickness, or, if workable, of sufficiently good quality to repay the cost of mining. Reference to the detailed sections amply proves this statement. Even the *Dillon* and *Trinidad* beds, which usually are thick, possess economical importance at but few localities. The best beds become exceedingly inferior in the quality of their coal and sometimes degenerate into carbonaceous shale. Some of them subdivide so as to be valueless; and this bifurcation is more frequent in beds of this group than in those of Carboniferous age. Excellent examples are shown in the variations of the *Trinidad* bed near Trinidad and on Raton Creek; of the *Dillon* and *Trinidad* beds along the western edge of the field; the complete breaking up of the section on the Lower Vermejo; and in the remarkable change in the *Cameron* coal-bed on the Vermejo.

The coal-beds are utterly insignificant on Cimarron Creek, only unimportant representatives having been found there. But the coal increases in quantity northward and many blossoms were seen on Poñil Creek, though owing to defective exposures the beds could not be identified. Beyond that cañon northward identifications are easily made, for on Cerososo and Vermejo Creeks the relations become distinct.

Much available coal was found on Vermejo Creek. The *Dillon* bed has not less than six feet in Vermejo Park, where the *Lower Vermejo* is fully seven feet thick; the *Cameron* bed shows from three to four feet near Cameron post office; the *Caliente* coal-bed has from three to eight feet of good coal between the mouth of Caliente Creek and the Elizabethtown road; the *Raton* bed is fully three feet thick near that road; while several other beds are thick enough to be worked for domestic use should the region become closely settled.

The available coal on Crow Creek is limited in quantity. The *Trinidad* coal-bed has a thickness of five feet ten inches at one locality, but the slates are too numerous and the coal is poor.

Few beds have much value on the Canadian. The lower beds, except the *Cat's Claw Cañon* bed, are unimportant. That bed is three feet thick and yields good coal. Toward the head of the stream *Coal-bed* P has two feet six inches of good coal; the *Caliente* is two feet thick, with seven feet of carbonaceous shale beneath it, which might be used as fuel; while the *Canadian* bed shows three feet of decidedly good coal.

The only bed of real importance in the Dillon's Cañon is the *Dillon*, which shows four feet six inches of coal at one exposure and seven feet in two benches at another. The coal is good at both localities. The *Long's Cañon* coal-bed and the *Cameron* bed are shown at the forks of the creek, the former two feet and the latter three feet thick, while at a little way farther up the creek is *Coal-bed* N, somewhat more than three feet thick, the coal in each case being good. The *Dillon* bed has four feet of coal in one bench at an exposure near the mouth of Willow Creek Cañon.

Many of the beds have their greatest development on the waters of the Purgatory River. The importance of the *Trinidad* bed in the vicinity of Trinidad and along Raton Creek has been shown in other parts of this report. The *Reilly Coal-beds* are both of workable thickness in Reilly Cañon, while in Long's Cañon is the large bed to which I have given the name of that cañon. A large bed, whose relations have not been determined, is exposed on the Purgatory below Olguines, while between Olguines and the South Fork of the river large beds are not wanting. Several beds seen on the South Fork seem to be large, but for the most part the exposures are not such as to admit of accurate measurement. Enough is shown, however, to prove that more than one of them are large enough to be worked for supply of local needs.

But this summary must be regarded as imperfect, as useful merely in so far as it tells where the beds are thick. The variability is such that some of the beds said to be unimportant may prove to be as valuable as the *Trinidad* bed. The reader must remember that the survey was incomplete, that detailed work was out of the question, and that the sections were constructed from such exposures as presented themselves. A detailed survey, such as has been made of parts of the Pennsylvania coal-fields, would doubtless show that the number of available beds and localities is far greater than has been admitted in this summary. The region is deserving of close survey, as its economical importance to the whole mining region of Colorado and New Mexico is extreme.

No chemical analyses have been made to determine the quality of the coal at any locality except in the immediate vicinity of Trinidad. Dr. Loew* gives the following as the result of analysis of coal from mines at Trinidad belonging to the Denver and Rio Grande Railway Company:

Water	0.80
Gas	50.32
Fixed carbon	40.18
Ash	8.70
Total	100.00

The coal is soft as compared with that obtained at Cañon City and in the South Park, and it is said to be too tender to bear shipping well, though it is shipped extensively. This, as appears from the analysis, is an excellent gas-coal. According to Dr. Loew, the Denver gas-works paid $12 per ton for freight on this coal before the railroad was constructed; and that, too, though excellent coal is within easy reach of Denver. But the chief value of this *Trinidad* coal depends on its coking qualities, and the manufacture of coke is attaining some importance in the vicinity of Trinidad, where the Denver and Rio Grande Railway Company have erected a number of beehive ovens after the Pennsylvania pattern. The burning is continued for twenty-four hours and the loss is said to be but two-fifths. If the latter statement be true the coking, as appears from the analysis, must be incomplete and the coke therefore inferior to that shipped from Connellsville, Pa. In any event the quality must be inferior and the coke itself a comparatively poor fuel. An analysis of Connellsville coke by Mr. A. S. McCreath, chemist of the Pennsylvania Geological Survey, gave the following result:

Water at 225	0.030
Volatile matter	0.460
Fixed carbon	89.576
Sulphur	0.821
Ash	9.113
Total	100.000

* Geographical and Geological Surveys West of the 100th Meridian, Vol. III, p. 634.

No analysis of the Trinidad coke is available, but experiments show that the loss of fixed carbon in the manufacture of coke in the Connellsville region, beehive ovens being used, is about nine per cent. If the coking be complete at Trinidad the fixed carbon remaining cannot exceed thirty-six per cent., which added to the ash gives about forty-five per cent., the total loss of weight, therefore, being fifty-five per cent. But in the Connellsville coke nine-tenths of the whole weight is fuel, whereas in the Trinidad coke the proportion is but four-fifths. But in view of the great advantage in point of freight-charges the quality is acceptable, and the coke is used at the smelting works of Leadville and Denver. A considerable trade has sprung up with the mining region of Utah and the demand exceeds the supply.

The coal of the *Reilly* beds in Reilly Cañon, of the *Caliente* bed on the Elizabethtown road near Vermejo Creek, of the *Dillon* and *Lower Vermejo* beds in Vermejo Park, and of the large bed below Olguines on the Purgatory, bears a closer resemblance physically to that of the *Trinidad* bed at Trinidad. It is soft and most of it seems to be coking coal. But if it be as rich in gas as is that at Trinidad the price received for the coke must be high to insure profit.

The Galisteo coal-field.—The coal-beds in this field are from two inches to nearly five feet thick; but there appears to be not more than one really workable bed in that part of the field which was visited. As in the Trinidad field the coal is bituminous, the beds show unpleasant tendency to vary both in thickness and quality of the coal, and a very imperfect estimate of their value can be made.

Two of the beds possess some interest. They both contain coal altered to anthracite. One of these, not discovered by us, is reported to be two feet thick. The coal which was seen at the smelting works on Galisteo Creek is hard, brilliant, and apparently of excellent quality; and it was used as fuel at the smelting works. But none had been mined for nearly a year, as the works had been idle for that length of time.

A much more important bed, one which may be of very material importance in the not far-distant future, is that which was mined to supply the stamp-mill of the New Mexican Mining Company. It is said to be five feet thick, but the openings, now deserted and much decayed, show not more than four feet. These mines were visited by Dr. Loew in 1873, when they were in operation. As described by him,* "the coal is hard, dense, of brilliant luster, and resembles anthracite in every respect. Its specific gravity is 1.43." Unfortunately only the newer openings were seen by me, and the coal from those does not fully answer to the description given by Dr. Loew. It is far from being of superior quality, and seems not to be wholly changed. It is slaty, and after exposure the laminæ tend to separate. But the coal from these pits is confessedly much inferior to that from the older pits, which, according to Dr. Loew, has the following composition, specimens having been taken from three openings:

Water	2.10	2.12	1.91
Gas	6.63	7.20	11.74
Fixed carbon	86.22	84.33	70.52
Ash	5.05	6.35	16.46

These show a material variation; the first two are semi-anthracite, but the third is a semi-bituminous coal. The last is decidedly inferior.

For the present these coals are unimportant; but in case a railroad pass along Galisteo Creek they will be extremely valuable. If the mining interests of Central New Mexico should prove to be one-half as valuable as some seem to believe, these coals will be of no little economical interest.

IRON ORE.

Iron ore occurs in the Archæan rocks of the Placer Mountains, in the Fort Pierre shales, and in rocks of the Laramie group. No analyses have been made to determine the quality of the ore at any locality.

Hematite and magnetic ores are said to abound in the Placer Mountains near the Old Placer. But that region was visited in only the most casual manner, and there was no opportunity to ascertain either the quantity of the ore or its mode of occurrence. Fragments of excellent red hematite are scattered plentifully over the surface at some places, and

* Geographical and Geological Survey West of the 100th Meridian, Vol. III, p. 635.

specimens of good magnetic ore which were shown to us are said to be from this vicinity.

Carbonate ore occurs in the upper part of the Fort Pierre shales. It is nodular within the Arkansas area, but is present both in nodules and in beds along Galisteo Creek. The nodules as found in the former area are usually non-fossiliferous and vary in diameter from a few inches to several feet. They occur in prodigious quantity, so that mining would be comparatively inexpensive. The road from Trinidad eastward toward La Barela passes for miles over these shales and exposes an enormous amount of ore, which could be obtained at insignificant cost by stripping. As this locality is within two or three miles of the Trinidad coking coal it is well worthy of investigation by capitalists. Equally available localities were seen on the waters of the Canadian south from the Raton Plateau. The line of this nodular ore lies at but a little way east from the Laramie Bluffs and the Ocaté Mesa and extends almost to Ocaté Creek.

The nodules are fossiliferous and of immense size on Galisteo Creek in the vicinity of Galisteo, but the ore contains so much silica and alumina as to be practically worthless. Nodules are not common in these shales near Los Cerillos on the same creek, where the ore occurs in beds and seems to be much less impure than it is near Galisteo. Fossils are less frequent here than at localities farther up the creek, and possibly the ore carries less of phosphorus.

Much nodular ore was seen in the shales of the Laramie group within the Arkansas area, and many beds of carbonate are present in the same group along the Galisteo. Thin beds occur also in the former field, and some of the limestones in the Trinidad field are so ferruginous that they might be classed as calcareous ores rather than as limestones. Nodular ore is distributed plentifully through the shales associated with the *Cameron* coal-bed at several localities, notably in Dillon's Cañon; and a bed of ore six inches thick was found in Vermejo Cañon at a few feet below the *Upper Reilly* coal-bed. Much of the ore in the Galisteo region is very good. The proximity of anthracite coal and of good limestone adds much to the economical value of ores in that region.

LIMESTONE.

Limestone for all purposes is abundant. That rock makes up a large part of the Carboniferous column as well as of the Niobrara subgroup of the Colorado shales; but the calcareous beds of the latter group are too argillaceous to yield good lime, and at most localities care in burning is necessary to procure even inferior lime. These beds are exposed at many localities along the east side of the Culebra Range and at many places on the Canadian Plains between Vermejo Creek and the Canadian Hills, and they are the surface rocks for long distances on Gallinas Creek as well as on Galisteo Creek farther south. The lime obtained from them seems to be good enough for ordinary agricultural purposes; but its value for this purpose has not been tested to any material extent. It is, however, too impure for building and it would be worthless in the manufacture of iron.

The Carboniferous limestones are exposed along the east base of the Culebra Range from the northern edge of the district to near Costilla Peak; along both slopes of the Mora and Santa Fé axes and under the Cimarron axis south from Mora Creek, as well as everywhere in the Coyote trough from Elizabethtown southward to the end of the district. Reference to the chapter descriptive of the Carboniferous rocks will enable the reader to judge of the enormous quantity of limestone in the group as well as of its ready accessibility over a large part of the district. In passing from Las Vegas to Santa Fé by the stage-road one is almost constantly in sight of one or more large beds of excellent limestone, while in the vicinity of Galisteo immense quantities are within reach both on the Placer Mountains and along the upper waters of the Creek. Many of the beds belonging to this series yield lime of superior excellence, which would be of the highest value in reduction of the iron ores which occur so abundantly in many parts of the district.

Limestone fitted for use in smelting of iron ores can be taken to Trinidad by way of the Atchison, Topeka and Santa Fé road from Sapillo or Gallinas Creeks; unless, indeed, the rates of freight in that western region should be prohibitory. The distance is barely 100 miles.

No attempts have been made to determine the value of the Niobrara limestones for cement, but there seems to be no room for doubt that not a few of the beds exposed along the lower Cimarron would give a very fair cement.

GYPSUM.

No gypsum was found in economical quantities within the Arkansas area, where it occurs only as isolated crystals in the Fort Pierre shales or as films in the Middle Dakota and Trias. But it occurs somewhat abundantly within the Rio Grande area, there being beds of it in the mesa which form the southwest wall of the Pecos Valley from San José to the head of Piños Creek. Very probably the white efflorescence which covers the broad bottom of Galisteo Creek consists largely of this mineral. Thin beds of gypsum are present on Galisteo Creek as well as on its tributary, the Arroyo San Cristobal. But the great gypsum deposits described by Newberry and later explorers are wholly beyond the western limits of the district.

SALT.

Salt does not occur in economical quantities within the district, but an extensive salt marsh exists at probably seventy miles south from Galisteo, whence salt is obtained to supply the whole region for 100 miles north and west. This was visited by Dr. Loew, whose analysis is as follows:

Chloride of sodium	82.57
Sulphate of soda	6.89
Chloride of magnesium	5.88
Water	4.66
Sulphate of lime	Traces.
Total	100.00

"As the medium table-salt of commerce rarely contains above one per cent. of chloride of magnesium and sulphates this salt, must be considered very impure; still there is no serious objection to its use." *

GOLD.

Gold mines were seen on both slopes of Old Baldy Mountain in the Cimarron Range, and on the eastern or southeastern slope of the Placer Mountains.

*Geographical and Geological Surveys West of 100th Meridian, Vol. III, p. 627.

The Placer Mountains.—The Old Placer or El Real de Dolores is on the eastern side of the Placer Mountains at about twenty-five miles west of south from Santa Fé; and the New Placer or El Real de San Francisco is in the Tuerto Mountains, the termination of the Placers at the south, and nearly thirty-five miles west of south from Santa Fé. These mines were visited by Dr. Wislizenus, Lieutenant Abert, Dr. Newberry, and Dr. Hayden, all of whom have made more or less extended reference to them in their reports.

Gregg in his "Commerce of the Prairies" says that gold at the Old Placer was discovered in 1828 by a native of Sonora, who had his mules in the vicinity. While searching in the mountain for some stray animals his attention was attracted to a rock which he recognized as similar to that of the Sonora Gold region, and a little further examination proved the presence of gold. The locality was at once prospected and the mine was incorporated as El Real de Dolores, though the locality soon became known simply as the Placer. Gold was discovered at the New Placer within four or five years afterwards, but I have been unable to ascertain the exact date.

El Real de Dolores is a small town situated in a somewhat secluded part of the mountains. The creek on which it is built is an uncertain stream and is dry during the greater part of the year. A few springs were seen in the vicinity, but the water issuing from them is little more than is needed for domestic use.

Placer-mining only was done at the Placers until 1840, when a vein of decomposed pyrites was discovered which carried a good deal of gold. This ore was mined and reduced in an arastra. The property afterward passed into the hands of an American company by whom a stamp-mill was erected.

Gold occurs in the gravel both in the bed and in the banks of the creek. Pits have been digged near the village to a depth of fifty or sixty feet without reaching the "bed-rock." The Mexican process of washing is even more primitive than that employed in California during the early days, though in principle it is the same. A wide, shallow bowl, termed *batea*, receives the gravel and water and is shaken until all the coarser materials have been removed, leaving the gold and fine sand in the bottom. The yield obtained in this manner was insignificant, for according to Wislizenus a day's work amounted usually to a quarter of a dollar or sometimes to half a dollar, though occasionally a large piece of gold was found which served to raise the income for one day.

When visited in 1848 by Lieutenant Abert the conditions were evidently worse than when Dr. Wislizenus saw the mines. A few starveling Mexicans were at work provided with bits of iron for digging and with gourds or horns of mountain goats for washing. Nor was the matter any better when the locality was visited by Dr. Newberry ten years later; and since his time the placer interest has shown little improvement, for when visited by us in 1879 the spot seemed to be wholly deserted.

Here as well as at the New Placer scarcity of water is the difficulty. That the gravels are rich admits of no doubt. The annual product in the earlier days varied, according to the best estimates, from $40,000 to $250,000; so that were hydraulic or even ordinary sluice washing possible the gravels could not fail to prove profitable workings. The gold from the Old Placer has a better reputation than has that obtained at the New Placer; but the latter is by no means inferior, as appears from the following analysis by Dr. Wislizenus:

Native gold	92.5
Silver	3.5
Iron and silica	4.0
Total	100.0

But extensive operations are impossible. The New Placer was not visited by us, but the statement made by Dr. Wislizenus was fully confirmed by information given us by persons at the Old Placer. No water is found at the New Placer, and all the water used there thirty years ago was carried in barrels from the Old Placer or was obtained by melting snow. Even now the latter is the principal source of supply. At the Old Placer the stream is very intermittent, and in even its best estate supplies hardly enough water for a few Mexicans working with *bateas*. The rains are so uncertain and so fitful that they cannot be depended on. Even were they more regular than now they would avail little, owing to the short and abrupt slopes of the range. The amount of gold obtained from the Placers is said to be barely sufficient to meet the necessities of the jewelers at Santa Fé.

As already intimated, quartz mining is done at both Placers; but at present the condition of the interest can hardly be called prosperous. The first lode in the vicinity of the Old Placer was discovered about 1840, at between one and two miles above the village. It yielded a decomposed pyritous ore, which was mined by a Frenchman named Tournier and reduced in an arastra. The yield was not far from $24 per ton. In later years the property passed into the hands of an American company, by whom little was done until after the close of the rebellion, when a stamp-mill with capacity for forty stamps was erected, though only twenty stamps were put in place. The venture proved unsuccessful and the mill lay idle for some time. When visited by us it had been started up as an experiment by some miners.

Though mining has been carried on here for nearly forty years yet the veins are opened in but an indifferent manner, and even when the mill was erected the supply of ore in sight must have been insufficient. The lodes are exceedingly irregular in thickness and variable in quality of ore. The gangue is quartz and carries a somewhat complicated series of minerals, among which sulphurets of iron and copper predominate and bear the gold.

The persons now running the mill gather a curious brecciated rock which seems much like a sandstone conglomerate; but no opportunity was afforded for determination of its relations. Dr. Newberry thinks it is the gossan of the gold-bearing vein. This rock yields from $3 to $12 per ton.

No information was obtained respecting the present condition of mining operations at the New Placer.

The Aztec District.—This, sometimes known as the Creek district, is on the eastern side of the Baldy Mountains in the Cimarron Range. It was organized in 1868, but placer-mining had been done before that time along Ute Creek, a small stream which flows through the district to Cimarron Creek.

Auriferous gravels occur along Ute Creek for several miles above its mouth; but they are not very rich, and of the many arrangements begun with a view to extensive work very few seem to have been completed. The yield in 1869 is said to have been $86,000, but for several years it has been quite small, and only two concerns were at work in 1878. The gravels are so lean now that even hydraulic mining pays barely average wages. The supply of water is ample, and the creek falls so rapidly that a head of 100 feet for hydraulic work can be obtained with only moderate outlay.

Quartz mining is confined to the immediate vicinity of Old Baldy. Work had been practically suspended for two or three years prior to 1876, but it was begun again in that year and a large number of new mines were discovered.

This district falls within the limits of the Maxwell grant, which was sold to a company of foreign capitalists, whose central office is in England. The oldest mine, known as the Aztec, was worked successfully by Mr. Maxwell for a number of years; but soon after it was transferred to the English company its richness disappeared. When that company became involved and its agents were withdrawn the deserted mine was occupied by an enterprising miner who has worked it energetically for several years. Other persons entered the district at the same time, and some of the mines then opened have proved fairly profitable.

During Mr. Maxwell's management the ore was reduced in a light fifteen-stamp mill, the stamps weighing 400 pounds each and dropping twenty-four times per minute; one ton of ore to the stamp being the capacity for a day of twenty-four hours. The yield while the mine was in Mr. Maxwell's possession is said to be not far from $800,000; during one week the mill showed a run of $18,000. But, as intimated, the yield fell off rapidly after the English company took possession of the mine, and it averaged barely $15,000 per annum. The present operator thinks it a very uncertain piece of property, which occasionally yields well but usually yields nothing.

This region is badly broken by dikes issuing from Old Baldy. The country rock is Fort Pierre shale, which has been so much affected by the intrusion of the dikes that many of its more micaceous sandy layers bear not a little resemblance to loose-grained granite. At some places the shales have been converted into slates with definite cleavage.

No true veins occur here; fissures are numerous enough in the shales and these carry the ore. But they are indefinite. Systematic mining is impossible, and the Aztec Hill is covered by "shafts" of varying depth. Nuggets of gold sometimes are found in the slates altogether beyond any trace of crevice. The ore is worked in two arastras with a total capacity of about 3,000 pounds per diem.

No contact deposits were found between the shales and the dikes, and the ore occurs almost solely in crevices amid the shales at varying distances from the dikes. The conditions are precisely like those observed in the silver mines of Rock Creek, Colorado, and of Los Cerillos, New Mexico, which belong in part to the same geological period. All the phenomena seem to suggest that the crevices were made during distortion of the rocks attending the eruption of the lava.

Moreno District.—This embraces the Moreno Valley from the mouth of the creek to Elizabethtown and extends eastward to near the top of the Baldy Mountains. The district was organized in 1867, and soon the valley had a population of nearly 10,000. At that time all the petty streams descending from the mountains on both sides of the valley were full and water was abundant for all; but, for some reason, the water supply diminished and mining seemed impossible. A ditch forty-seven miles long and bringing water from the head of Colorado Creek, on the other side of the divide, was then constructed. This involved an expenditure of more than $300,000; but it, too, soon failed, and instead of giving 400 inches it now gives barely fifty inches of water, miners' measurement. The ditch was sold eventually for less than $20,000. Small ditches have been taken out of both the West and the North Fork of Moreno Creek, as well as from a stream entering the main creek below Elizabethtown; but these afford an uncertain supply.

The season, owing to the altitude, is very short and washing continues for only half the time, as the water supply is insufficient. The gravels are very rich, and one firm engaged in sluice mining below Elizabethtown obtains $15 a day for each hand employed.

SILVER.

Silver is said to be present near Culebra Peak, at the head of the South Fork of Purgatory River, but the vein was not seen by us. Quartz veins are comparatively rare in the Culebra Range and of those observed none carries any ores.

Some work was done during 1874 or 1875 in the cañon of Colorado Creek, where argentiferous galena occurs. The ore is said to be in paying quantity and to yield $75 per ton; but the work seems to have been unsuccessful, as the mines were soon abandoned and now there is difficulty in finding them. Rude smelting works were erected on the West Fork of Moreno Creek for reduction of the ore. The locality was never prospected thoroughly, and it deserves careful examination, as it is easily accessible and is well supplied with wood and water.

Los Cerillos are irregular jagged hills at about twenty miles west of south from Santa Fé. The hills themselves are trachyte, while Colorado shales form the saddles between them. The shales are seriously distorted, are full of crevices, and are broken by many narrow dikes.

Many years ago the Spanish residents worked some mines on the southwest edge of these hills. The operations were planned after true primitive fashion and the intentions of the miners seem to have been indefinite. After the region had been deserted for many years one of the old mines was re-opened and a small smelting establishment was built for reduction of the ore; but the works were closed and the mine abandoned in August, 1878, as the ore supply was not sufficient. More recently, in 1879, attention has been drawn again to this region and a large number of miners are at present in the hills. A thrifty energetic camp had begun operations on the west side at the time of our visit, and several prospecting shafts had been sunk to a depth of from 20 to 35 feet. Some of these followed upturned beds of iron ore, in which flakes of galena and blende are not uncommon; others had followed films of galena filling crevices in the shale; while others again had distinct though insignificant contact deposits between the shales and the dikes. But in all cases the amount of ore was utterly insignificant, as the streaks rarely exceeded half an inch in thickness.

The occurrence of the ore is much like that seen at the Aztec mine on Old Baldy, in the Cimarron Range. It is by no means impossible that a valuable deposit of argentiferous galena may be discovered here, but one may only hope for such a discovery; the probabilities hardly favor it.

Work has been carried on more extensively and for a longer time on the east side of these hills. There galena croppings are very numerous and the number of prospect holes is almost incredible. Some prospecting shafts had reached a depth of sixty feet at the time of examination, but the ore-streaks were very thin, though some of them occasionally become four or six inches thick—this, however, for very short distances. At the same time the prospect is more encouraging here than it is on the west side. But the degree of development at the time the locality was visited was insufficient to justify one in making any positive assertion respecting the value of the mines. Much of the ore is rich, and some reported assays show ore of almost fabulous richness.

TURQUOIS.

In speaking of Los Cerillos one may not omit reference to the turquois, which occurs there in irregular seams, seldom more than one-eighth of an inch thick. The locality has been a favorite one with the Indians, as is shown by the excavations made in search of the gem. The thicker seams seldom contain a piece of pure color and fragments of rich blue tint seem to be exceedingly rare. This is the "chalchuitl" of the ancient inhabitants, by whom it was held in high esteem. It is still much prized by the Indians of New Mexico and Arizona. Dr. Newberry says: "I have seen ornaments of it worn by the Apaches, Mohaves, the Navajoes, and Pueblos, and so highly prized that a fragment of fine quality, and no larger than the nail of one's little finger and one-eighth of an inch in thickness, was regarded as worth a mule or a good horse. The Indians are excellent judges, too, of the quality of the article, discriminating accurately between the different shades of color and not to be deceived by any base imitation."*

* San Juan Expedition, p. 41.

This mine must have been worked during a long period, for the excavation is enormous.

Dr. Loew ascertained that this turquois differs notably from that of Persia in that it contains much silicic acid. The analyses compared are as follows: No. 1 being that of Cerillos turquois by Loew, and No. 2 that of Persian turquois by Church.*

Phosphoric acid	29.57	32.86
Alumina	29.17	40.19
Water	18.85	19.34
Oxide of copper	4.04	5.27
Protoxide of iron	4.35	2.21
Lime	1.61	–
Silicic acid	12.57	–
Protoxide of manganese	–	0.36
	100.16	100.23

LEAD AND COPPER.

Neither of these metals occurs in sufficient quantity at any locality within the district to deserve more than merely passing notice.

Galena is present in the Fort Pierre shales and the trachyte of Los Cerillos; also in the same shales in the Aztec mining district; and small quantities, so far as known, occur on Colorado Creek. But at all of these places it is argentiferous and the quantity is not such as to give to the galena itself any economical importance.

Copper occurs in the Aztec district as carbonate associated with galena. Its sulphuret is found in considerable quantity at the Old Placer as well as at the New Placer Mines. In the latter district, which is wholly outside of the region examined, the quantity is said to be very great.

MINERAL SPRINGS.

The Las Vegas hot springs are on Gallinas Creek at somewhat more than four miles above Las Vegas, at the mouth of an exceedingly close cañon. They issue from very near the line of contact between the Archæan and the Carboniferous.

No count was made of the springs, but the number was given as

*Annual Report of Geographical and Geological Surveys West of 100th Meridian, 1875, p. 107.

twenty-two. They occur on a narrow "bottom" which extends to the base of the cañon-walls and is divided by the creek. This locality was visited by Dr. Loew,* who was fully prepared to make careful investigation of mineral waters. His observations were more detailed than mine and his description is given here without change. His notes make mention of but four springs; only that number has been utilized for bathing purposes.

"The temperature of these springs ranges from 90° Fahr. to 130° Fahr.

"No. 1. Temperature, 130°; basin, six feet deep, five feet long, four feet wide; taste, weak saline; no odor observable; bubbles of carbonic acid constantly rising; yield, about fifteen gallons per minute.

"No. 2. Temperature, 123° Fahr.; basin, three by three and a half feet.

"No. 3. Temperature, 100.5° Fahr.; basin, two by three feet.

"No. 4. Temperature, 123° Fahr.; basin, two and a half by one and a half feet.

"In 100,000 parts of water are contained parts as follows:

Sodium carbonate	1.72	1.17	5.00
Calcium carbonate / Magnesium carbonate	9.08	10.63	11.41
Sodium sulphate	14.12	....	16.27
Sodium chloride	27.26	24.37	27.34
Potassium	Traces.	Traces.	Traces.
Lithium	Strong traces.	Strong traces.	Strong traces.
Silicic acid	1.04	Traces.	2.51
Total solid constituents	53.22	52.10	62.53

"These springs are doubtless weaker than many other hot springs of New Mexico and Colorado."

Rude bathing-houses and a small hotel have been provided for visitors; but more commodious buildings are in course of erection.

* Report of Geographical and Geological Surveys West of 100th Meridian, Vol. III, p. 623.

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U. S. GEOGRAPHICAL SURVEYS WEST OF THE ONE HUNDREDTH MERIDIAN,
CAPTAIN GEO. M. WHEELER, CORPS OF ENGINEERS U. S. ARMY, IN CHARGE.

APPENDIX.

REPORT

ON THE

CARBONIFEROUS INVERTEBRATE FOSSILS OF NEW MEXICO.

BY

C. A. WHITE, M. D.

REPORT

ON THE

CARBONIFEROUS INVERTEBRATE FOSSILS OF NEW MEXICO.

By C. A. White, M. D.

The fossils embraced in this report were collected by Prof. J. J. Stevenson and his assistant, Mr. I. C. Russell, during the seasons of 1877 and 1878; and in part, also, by Prof. E. D. Cope in 1874; all having been obtained from the Carboniferous strata of Northern New Mexico. The whole collection, although obtained at different localities, belongs essentially to one and the same fauna, which is plainly the representative of that which characterizes the Coal-measure division of the Carboniferous system as it is developed in the great valley of the Upper Mississippi. It should also be remarked that this New Mexican fauna is much more closely allied to the Upper than to either the Middle or Lower divisions of that group. The following partially descriptive catalogue, together with the succeeding more formal descriptions and illustrations of the new and little known species, constitutes an approximate synopsis of this Upper Coal-measure invertebrate fauna as it is developed in New Mexico and the adjacent region, so far as it is at present known.

The identification of the species in the following lists is not in all cases entirely satisfactory, which fact is expressed either in words or by the addition of an interrogation point. This uncertainty in most cases arises from the imperfect condition of the specimens; but in some cases it is due to their evident varietal differences from the typical forms of the species respectively, as they are known at other and more or less distant North American localities.

These differences, however, as will be shown further on, are surprisingly few and unimportant.

In the following catalogue a separate list of the species is given for each locality, but the entries are numbered continuously through the whole catalogue for the convenience of cross-reference. The sum of these numbers does not therefore represent, but exceeds, the total number of the species contained in the collections. A few additional species, belonging to the fauna represented by these collections, are published in Volume IV of the reports of this survey; and a few others have been published in the reports of other explorations which have been made in that region under the auspices of the United States Government.

CATALOGUE OF FOSSILS.

LOCALITY No. 1.

NEAR THE HEAD OF MORA CREEK.

The fossils of this list are contained in fragments of impure limestone, and are mostly in an imperfect condition of preservation.

1. *Fusulina cylindrica* Fischer.

The specimens consist of pieces of limestone crowded with and almost wholly made up of these bodies, which differ from the typical forms of the species only in being smaller than the average size. In this respect they agree with a small variety which occurs abundantly in Southern Iowa.

2. *Productus semistriatus* Meek.

This species is very prevalent in Northern New Mexico and the adjacent region, as well as in the plateau region farther northward. It has sometimes been confounded with the form, common in the Upper Coal-measure strata of the Upper Mississippi River region, which is generally referred to *P. costatus* Sowerby; but its peculiar characteristics are found to be as constant as those of any of the other recognized species of the Productidæ. (See Nos. 6, 35, 51, 65, 88, and 114.)

3. *Spirifer rockymontanus* Marcou.

This species is so abundant that specimens of it are seldom wanting in any collection of Carboniferous fossils made within the region where these collections were obtained; and its general geographical distribution is also known to be very great in the Carboniferous strata of North America. (See Nos. 9, 28, 38, 56, 70, and 120.)

4. *Spirigera* ——— ?

Probably immature examples of *S. subtilita* Hall.

5. *Macrodon* ——— ?

Imperfect; probably identical with the *Arca carbonaria* of Cox. (See also Nos. 15, 44, 78, and 97.)

LOCALITY NO. 2.

FERDINAND CREEK.

The fossils from this locality are preserved in a more or less compressed condition; in an argillaceous indurated shale, mostly in the form of casts.

6. *Productus semistriatus* Meek.

Identical with No. 2; from "Head of Mora Creek." (See Nos. 35, 51, 65, 88, and 114.)

7. *Productus prattenianus* Norwood.

Characteristic examples of this common and widely-distributed species. (See Nos. 50, 67, and 112.)

8. *Hemipronites crinistria* Phillips.

(See remarks on this protean species on page 124 of Volume IV of the Reports of this Survey. See also Nos. 36, 55, 89, and 118.)

9. *Spirifer rockymontanus* Marcou.

(See remarks under No. 3, and also Nos. 28, 38, 56, 70, and 120.)

10. *Spirigera subtilita* Hall.

Characteristic specimens of this abundant and widely-distributed species. (See Nos. 29, 39, 58, 72, 91, and 121.)

11. *Pteria longa* Geinitz.

The few examples of this form contained in this collection seem to be specifically identical with those which were obtained by Professor Marcou from the Upper Coal-measure strata of Nebraska, and described by Dr. Geinitz under the name *Gervillia longa*. The shell is, however, evidently referable to *Pteria*, as that genus is recognized in the Carboniferous strata of this country.

12. *Aviculopecten hawni* Geinitz.

Several examples of this well-marked species are contained in this collection. It is characteristic of the Upper Coal Measures of Iowa and Eastern Nebraska. (See No. 43.)

13. *Aviculopecten neglectus* Geinitz?

A few imperfect examples; probably belonging to this species.

14. *Nucula* ——?

15. *Macrodon carbonarius* Cox.

Probably identical with Nos. 5, 44, 78, and 97.

16. *Pleurophorus?* ——?

A very narrow form of small size, and probably an undescribed species.

17. *Edmondia* ——?

18. *Allorisma subcostata* Meek & Worthen.

(See description on a following page, and figure on Plate III.)

19. *Bellerophon* ——?

20. *Pleurotomaria grayvillensis* Norwood & Pratten.

This identification is apparently correct, although the example is imperfect. It is supported by the fact that the species has been recognized in the Carboniferous strata of Northern Arizona.

21. *Pleurotomaria haydeniana* Geinitz?

The identification of this species is in doubt in consequence of the imperfection of both our example and Dr. Geinitz's type.

22. *Murchisonia* ——?

23. *Polyphemopsis inornata* Meek & Worthen.

24. *Loxonema semicostata* Meek and Worthen.

The identity of the two last-named forms seems to be unmistakable. They have hitherto been known only in the Coal-measure strata of Illinois.

Locality No. 3.

TAOS PEAK.

The few specimens from this locality were obtained from an "upper" and a "lower" limestone; but the species are common to both, and those of the two local horizons thus indicated in the collector's notes being parts of one and the same restricted fauna, they are not separated in this list.

25. *Zaphrentis?* ——— ?

26. *Meekella striato-costata* Cox.

A single imperfect example only is found among these collections; but the species is well known to exist in the Carboniferous strata of the region adjacent to Northern New Mexico, as well as over a large region farther north.

27. *Spirifer cameratus* Morton.

This widely-distributed species is, next to *S. rockymontanus*, the most common *Spirifer* found in the Carboniferous strata of the region in and around Northern New Mexico; and it is also one of the most characteristic and widely-distributed of American Carboniferous species. (See Nos. 90 and 119.)

28. *Spirifer rockymontanus* Marcou.

(See Nos. 3, 9, 38, 56, 70, and 120.)

29. *Spirigera subtilita* Hall.

(See Nos. 10, 39, 58, 72, 91, and 121.)

30. *Myalina permiana* Swallow.

(See description on a following page, and figures on Plate III. See also Nos. 42, 76, and 93.)

31. *Aviculopecten occidentalis* Shumard.

Characteristic specimens of this common and widely-distributed Coal-measure species. (See Nos. 60 and 95.)

32. *Allorisma* ——— ?

33. *Bellerophon inspeciosus* White.

(See description on a following page, and figures on Plate IV. See also No. 136.)

Locality No. 4.

CEBOLLA CREEK.

The fossils of this list are all in the form of natural molds in strongly ferruginous sandstone; but they are so well preserved as to be readily identified, especially by the help of artificial casts of the natural molds.

34. *Discina* ——— ?

Apparently identical with *Discina nitida* Phillips, and also with No. 47.

35. *Productus semistriatus* Meek.

Identical with Nos. 2, 6, 51, 65, 88, and 114.

36. *Hemipronites crinistria* Phillips.

(See remarks under No. 8; and also Nos. 55, 89, and 118.)

37. *Orthis pecosii* Marcou.

Professor Marcou obtained the types of this species from the same region which furnished the specimens in this collection. This species, however, has a very wide geographical range in the Coal-measure strata of North America. (See No. 117.)

38. *Spirifer rockymontanus* Marcou.

(See Nos. 3, 9, 28, 56, 70, and 120.)

39. *Spirigera subtilita* Hall.

(See Nos. 10, 29, 58, 72, 91, and 121.)

40. *Fenestella* ——— ?

These collections contain numerous fragments of Fenestelloid Polyzoa, but they are all too imperfect for either generic or specific identification.

41. *Ptilodyctia triangulata* White.

These specimens are all in the form of natural molds, and are interesting as showing that the species is a profusely branching one. (See description on a following page, and figures on Plate IV. See also No. 74.)

42. *Myalina permiana* Swallow.

Specifically the same as Nos. 30, 76, and 93. (See description on a following page, and figures on Plate III.)

43. *Aviculopecten hawni* Geinitz.

(See remarks under No. 12.)

44. *Macrodon* ——— ?

Probably identical with Nos. 5, 15, 78, and 97.

45. *Phillipsia* ——— ?

Locality No. 5.

MANUELITOS CREEK.

The fossils of this locality are imbedded in fragments of impure limestone; all being in a more or less imperfect condition of preservation.

46. *Fistulipora* ——— ?

A branching form; not specifically indentifiable. (See Nos. 64 and 87.)

47. *Discina* ——— ?

Probably identical with No. 34, and with *D. nitida* Phillips.

48. *Chonetes platynota* White.

The type specimens of this species were obtained from New Mexico; and so far as I am aware it has not yet been recognized to the northward of that region.

49. *Productus muricatus* Norwood & Pratten.

This form is, doubtless, identical with *P. muricatus* as that species is known in the Valley of the Upper Mississippi. In Iowa and Missouri it is more prevalent in the Middle Coal Measures than either above or below that division. (See No. 68.)

50. *Productus prattenianus* Norwood.

(See Nos. 7, 67, and 112.)

51. *Productus semistriatus* Meek.

(See Nos. 2, 6, 35, 65, 88, and 114.)

52. *Productus nebrascensis* Owen.

The identification of this species is undoubted. (See Nos. 69 and 113.)

53. *Productus nanus* Meek & Worthen.

The collection contains a considerable number of examples of this species, which are apparently all adult, and all agree in size and with the description of that species as given by Meek & Worthen.

54. *Orthis resupinoides* Cox?

(See description of this species, with remarks, on a following page, and figures on Plate III.)

55. *Hemipronites crinistria* Phillips.

(See Nos. 8, 36, 89, and 118.)

56. *Spirifer rockymontanus* Marcou.

(See Nos. 3, 9, 28, 38, 70, and 120.)

57. *Spiriferina octoplicata* Sowerby.

This species I recognized among collections of this survey made near Santa Fé several years ago, as shown in Vol. IV, p. 139. I have also recognized it among some Carboniferous fossils sent by Prof. L. C. Wooster from Northern Colorado.

58. *Spirigera subtilita* Hall.

(See Nos. 10, 29, 39, 72, 91, and 121.)

59. *Myalina? swallovi* McChesney.

Among the fossils from this locality is a single large imperfect example, upward of fifty millimeters in length. Although it is so much larger than usual, it is apparently identical with McChesney's species as above indicated. (See Nos. 75 and 92.)

60. *Aviculopecten occidentalis* Shumard.

(See Nos. 31 and 95.)

61. *Bellerophon montfortianus* Norwood & Pratten.

The specimens are imperfect, but they apparently belong to this species. (See Nos. 100 and 135.)

62. *Platyceras* ——— ?

63. *Phillipsia* ——— ?

Locality No. 6.

COYOTE CREEK.

The specimens of this collection are mostly imbedded in impure limestone, the greater part of them being imperfectly preserved.

64. *Fistulipora* ——— ?

Apparently identical with Nos. 46 and 87.

65. *Productus semistriatus* Meek.

(See Nos. 2, 6, 35, 51, 88, and 114.)

66. *Productus punctatus* Martin.

67. *Productus prattenianus* Norwood.

(See Nos. 7, 50, and 112.)

68. *Productus muricatus* Norwood & Pratten.

(See No. 49.)

69. *Productus nebrascensis* Owen.

(See Nos. 52 and 113.)

70. *Spirifer rockymontanus* Marcou.

(See Nos. 3, 9, 28, 38, 56, and 120.)

71. *Spirifer (Martinia) lineatus* Martin?

This species is somewhat common in the Coal-measure strata of the Upper Mississippi River region, and it is not unfrequently met with in Carboniferous strata farther west. There is much reason to doubt its specific identity with the European form known as *S. lineatus*. It will probably have to take the name *S. perplexus*, given it by McChesney.

72. *Spirigera subtilita* Hall.

(See Nos. 10, 29, 39, 58, 91, and 121.)

73. *Terebratula bovidens* Morton.

Characteristic specimens. (See No. 122.)

74. *Ptilodyctia triangulata* White.

A single example; doubtless identical with No. 41; but the stipes or branches are not so broad as some of those from Cebolla Creek. There seems to be much variation in the size of the branches of this species in different localities, although they are usually nearly uniform in size at the same locality.

75. *Myalina? swallovi* McChesney.

The examples from this locality are of the size usual with that species as it is known in the Coal-measure strata of the Valley of the Upper Mississippi. This shell is evidently not a *Myalina*. Its hinge has never been satisfactorily seen, but I am somewhat inclined to regard it as belonging to *Mytilus* or a closely related generic form. (See also Nos. 59 and 92.)

76. *Myalina permiana* Swallow.

(See Nos. 30, 42, and 93; and also the description on a following page, and figures on Plate III.)

77. *Aviculopecten coreyanus* White.

The type specimens of this species were also obtained in Northern New Mexico; and the species has not yet been recognized at any more northern locality. (See No. 96.)

78. *Macrodon carbonarius* Cox?

Probably identical with Nos. 5, 15, 44, and 97.

79. *Schizodus* ——?

A large imperfect example, probably identical with *S. amplus* Meek & Worthen.

80. *Pleurophorus subcostatus* Meek & Worthen.

(See description on a following page, and figure on Plate III.)

81. *Edmondia* —— ?

82. *Bellerophon carbonarius* Cox?

The one or two imperfect examples here indicated are apparently specifically identical with Cox's type specimens of *B. carbonarius,* which I have examined in this connection. There are, however, in the Coal-measure strata of North America two or three distinct varieties of that species; and probably more than one species among those which are usually assigned to it.

83. *Bellerophon* ——?

84. *Conularia* —— ?

The only example in this collection is very small and imperfect; apparently the apex of a larger shell. Its apical angle indicates a much more slender shell than that represented by the specimens No. 131, found by Professor Cope near Taos, and which I have referred to *C. crustula* White. It is probably a different species.

85. *Aclis stevensoni* White.

(See description on a following page, and figures on Plate III.)

86. *Goniatites* —— ?

Locality No. 7.

COYOTE CREEK, NEAR BLACK LAKE.

The specimens from this locality are mostly imbedded in nodular masses of hard, dark calcareous rock; but a part of them have been fully weathered out.

The strata which inclosed them are evidently exactly equivalent with those from which the fossils of the next list were obtained, near Taos, as a large proportion of the species are identical at both localities.

87. *Fistulipora* ?———

Apparently identical with Nos. 46 and 64.

88. *Productus semistriatus* Meek.

(See Nos. 2, 6, 35, 51, 65, and 114.)

89. *Hemipronites crinistria* Phillips.

(See Nos. 8, 36, 55, and 118.)

90. *Spirifer cameratus* Morton.

(See remarks under No. 27, and also No. 119.)

91. *Spirigera subtilita* Hall.

(See Nos. 10, 29, 39, 58, 72, and 121.)

92. *Myalina ? swallovi* McChesney.

(See remarks under No. 75, and also No. 59.)

93. *Myalina permiana* Swallow.

(See Nos. 30, 42, and 76; and also description on a following page, and figures on Plate III.)

94. *Aviculopecten McCoyi* Meek & Hayden ?
95. *Aviculopecten occidentalis* Shumard.

(See Nos. 31 and 60.)

96. *Aviculopecten coreyanus* White.

(See remarks under No. 77.)

97. *Macrodon carbonarius* Cox ?

Apparently identical with Nos. 5, 15, 44, and 78.

98. *Soleniscus brevis* White.

(See also No. 132.) It is described on a following page, and figured on Plate IV.

99. *Soleniscus planus* White.

The same as No. 133. (See description on a following page, and figures on Plate IV.)

100. *Bellerophon montfortianus* Norwood & Pratten.

(See Nos. 61 and 135.)

101. *Bellerophon* ——— ?

102. *Pleurotomaria sphærulata* Conrad.

The collection contains a single specimen only, which is much more depressed than the typical forms of that species; but it is referred to *P. sphærulata* because it is well known to be quite a variable species as to form.

103. *Loxonema rugosa* Meek & Worthen.

(See description on a following page, and figures on Plate III.)

Locality No. 8.

NEAR TAOS.

This collection was made by Prof. E. D. Cope in the summer of 1874. A large proportion of the fossils are completely weathered out and in a fair state of preservation; and the remainder are imbedded in nodular masses of a dark, hard calcareous rock. The horizon is doubtless exactly equivalent with that of locality No. 7.

104. *Fistulipora* ——— ?

A single specimen, in the shape of a depressed-convex mass, such as are frequently found in the Upper Coal-measure strata of Iowa and Missouri.

105. *Fistulipora* ——— ?

This form occurs as an incrustation upon the stems of crinoids and other bodies.

106. *Axophyllum ?* ——— ?

The examples of this species are somewhat numerous in the collection, but they are all so very imperfect that the internal structure cannot be satisfactorily determined; and they are therefore referred to *Axophyllum* with much doubt.

107. *Lophophyllum sauridens* White.

This species, which has hitherto been found only in Northern New Mexico, was originally described and figured in Volume IV of the Reports of this Survey as a variety of *L. proliferum* McChesney. The constancy of its characteristics, however, warrants its separation under a full specific name.

108. *Syringopora multattenuata* McChesney.

Examples of *Syringopora* have been obtained by various parties from the Carboniferous strata of the region northward from New Mexico, the tubes of which are larger than those of the typical forms of *S. multattenuata*, but the single example which this collection contains evidently belongs to that species.

109. *Erisocrinus typus* Meek & Worthen.

A single example only, consisting of the calyx and second radial pieces.

110. *Zeacrinus mucrospinus* McChesney?

A single large second radial piece in the form of a long, strong spine. It probably belongs to *Z. mucrospinus*, but it is not certain that it does not belong to some other species.

111. *Archæocidaris triplex* White.

(See description on a following page, and figures on Plate IV.)

112. *Productus prattenianus* Norwood.

(See Nos. 7, 50, and 67.)

113. *Productus nebrascensis* Owen.

(See Nos. 52 and 69.)

114. *Productus semistriatus* Meek.

(See Nos. 2, 6, 35, 51, 65, and 88.)

115. *Productus longispinus* Sowerby?

116. *Chonetes mesoloba* Norwood & Pratten.

117. *Orthis pecosii* Marcou.

(See remarks under No. 37.)

118. *Hemipronites crinistria* Phillips.

(See Nos. 8, 36, 55, and 89.)

119. *Spirifer cameratus* Morton.

(See Nos. 27 and 90.)

120. *Spirifer rockymontanus* Marcou.

(See Nos. 3, 9, 28, 38, 56, and 70.)

121. *Spirigera subtilita* Hall.

(See Nos. 10, 29, 39, 58, and 91.)

122. *Terebratula bovidens* Morton.

(See No. 73.)

123. *Pinna* ——— ?

A mere fragment.

124. *Nucula parva* McChesney ?

This form seems to be identical with *N. parva*, although our examples are considerably larger than either the type specimens of McChesney or those figured by Meek & Worthen.

125. *Solemya radiata* Meek & Worthen ?

126. *Edmondia* ——— ?

127. *Allorisma subcuneata* Meek & Worthen.

128. *Astartella varica* McChesney.

Imperfect examples, apparently belonging to this species.

129. *Astartella concentrica* McChesney.

These appear to be typical forms of McChesney's species, both as regards size and surface characteristics.

130. *Dentalium canna* White.

This large fine species was described and figured in Volume IV of the Reports of this Survey. It has not hitherto been recognized among any collections except those made in New Mexico and the adjacent region.

131. *Conularia crustula* White.

A couple of imperfect examples only; but they are apparently specifically identical with *C. crustula*, the type specimens of which were obtained by Prof. G. C. Broadhead from Kansas City, Missouri. (See description on a following page, and figures on Plate III.)

132. *Soleniscus brevis* White.

The same as No. 98. (See description on a following page, and figures on Plate IV.)

133. *Soleniscus planus* White.

The same as No. 99. (See description on a following page, and figures on Plate IV.)

134. *Platyceras* ——— ?

A large species, probably undescribed; but the specimens are too imperfect for satisfactory identification or description.

135. *Bellerophon montfortianus* Norwood & Pratten.

(See Nos. 61 and 100.)

136. *Bellerophon inspeciosus* White.

The same as No. 33. (See description on a following page, and figures on Plate IV.)

137. *Bellerophon* ——— ?

A medium-sized smooth species.

138. *Pleurotomaria perizomata* White.

(See description on a following page, and figures on Plate III.)

139. *Murchisonia copei* White.

(See description on a following page, and figures on Plate III.)

140. *Euomphalus subrugosus* Meek & Worthen.

This is the common Coal-measure species to which Professor Hall gave the name *E. rugosus* (not *E. rugosus* Sowerby); and by which name it has been somewhat generally known.

141. *Naticopsis Wheeleri* Swallow. Var.

(See description on a following page, and figures on Plate IV.)

142. *Naticopsis monilifera* White.

This species is represented in these collections by only one imperfect example; but it is doubtless identical with *N. monilifera.* The type specimens of this species were obtained by Prof. G. C. Broadhead from the Upper Coal-measure strata of Cass County, Missouri, one of which is figured on Plate III.

143. *Naticopsis altonensis* McChesney.

This large fine species, originally found in the Coal Measures of Illinois, is represented in this collection by two very good but somewhat crushed examples, one of which is figured on Plate III.

144. *Loxonema rugosa* Meek & Worthen ?

(See figure on Plate III.)

145. *Macrocheilus* ——— ?

146. *Rotella verruculifera* White.

(See description on a following page, and figures on Plate IV.)

147. Four undetermined species of Gasteropods.

148. *Orthoceras* ——— ?

149. *Nautilus latus* Meek & Worthen ?

Several fragments apparently belonging to this species.

150. *Phillipsia* ——— ?

Taken as a whole the fossils of the foregoing lists are especially interesting because they make a considerable addition to our knowledge of the Carboniferous Invertebrate fauna of North America, and also to that of the hitherto known geographical range of many of the species which have been well known as characterizing the strata of other and somewhat distantly separated localities. They are also interesting as showing the contemporaneous prevalence of a greater profusion of specific forms than has hitherto been discovered in any one Carboniferous locality so far westward and southwestward. Although the strata of the great Carboniferous series of the western portion of North America are almost everywhere more or less fossiliferous, they have nowhere furnished fossils in so great profusion and variety as have many of the Coal-measure localities in the

States of Illinois, Iowa, and Missouri. It is, therefore, interesting to note the large number of species, nearly one hundred, that are represented in the foregoing lists; and these are evidently, in each case, only a part (in some cases only a small part) of the species that actually exist there. This is indicated by the fact that at the single locality of Taos alone Professor Cope obtained fifty species of invertebrate fossils, as shown by the last list; and he was not then making special investigation in that direction.

It is true that a distinctive Subcarboniferous fauna has been recognized at a few limited localities in Utah and Nevada; but it is also true that throughout the whole of the great Carboniferous series as it is at present known in the far western mountain and plateau region, there is found to be a commingling of the invertebrate types which characterize respectively the different clearly recognized divisions of the Carboniferous system as it is developed in the great valley of the Mississippi. In other words, in those far western Carboniferous strata there is a commingling of Subcarboniferous, Lower Coal-measure, and Upper Coal-measure types, the latter generally predominating in all the strata except those at the Utah and Nevada localities just referred to.

In the case of these collections from New Mexico, the species not only have decided affinities with those of the Upper Coal-measure fauna of the Upper Mississippi River region, but quite a large number of the New Mexican species are identical with those which characterize the Upper Coal Measures of Illinois, Iowa, Missouri, and Eastern Nebraska. Indeed, with half a dozen exceptions besides the few which are herein described as new, the species are all identical with those which, among others, characterize the Coal-measure strata of the region just mentioned.

Moreover, these excepted species are all, save one, closely related respectively to such as are also found in that region. There is, therefore, excellent reason for referring all these New Mexican fossils to the Coal-measure period as it is represented by North American strata. The one species referred to is that to which I have given the name *Rotella verruculifera*, and which is, so far as I am aware, the only species of the genus *Rotella* which has yet been recognized in Carboniferous strata. Further remarks upon this interesting form will be found in connection with a description of the species on a following page.

Volume IV of the Reports of this Survey contains descriptions and figures of a few other Carboniferous species, not included in the lists of this report, which were obtained from Northern New Mexico and the region adjacent.

DESCRIPTION OF SPECIES.

ECHINODERMATA.

Genus ARCHÆOCIDARIS McCoy.

Archæocidaris triplex (sp. nov.)

Plate IV, Figs. 3, *a*, *b*, and *c*.

Among the collections from near Taos are some fragments of spines and plates of an Echinoid, probably referable to the genus *Archæocidaris*, which are of such peculiar character as to render a description desirable although the specimens are so imperfect. The spines are large, strong, subtriangular in cross-section, and spinulose. The spinules are strong, short but prominent, rather distant, and ranged in three rows upon the three obtuse angles of the spine; the rows extending from a little above the basal ring to the apex, the remainder of the surface being plain. The basal ring is prominent, oblique, finely crenulate at the edge, and placed very near the basal extremity.

Associated with these fragments of spines are some more or less imperfect, not very large, interambulacral plates which doubtless belong to the same species with the spines. They are rather thin, apparently without a raised marginal border; areolar surface apparently plain or bearing a single circular raised line between the central tubercle and the outer border; central tubercle small, perforate at center, and surrounded by a prominent raised border which varies much in diameter in different plates. The larger spines were probably not less than 130 millimeters in length.

Figure 3*a* on Plate IV is a restoration from the fragments of the collection. It probably represents one of the larger spines with approximate accuracy. The large size of the spines, the subtriangular cross-section of the same, and the tri-serial arrangement of the spinules are features by which the species may be readily recognized.

BRACHIOPODA.

Genus ORTHIS Dalman.

Orthis resupinoides Cox?

Plate III, Figs. 2, *a* and *b*.

Orthis resupinoides Cox, 1857. Geol. Sur. Kentucky, Vol. III, p. 570.

Shell not very large, resupinate, gibbous, sub-circular in marginal outline, usually a little wider than long, and generally a little emarginate in front; hinge line much shorter than the greatest transverse diameter of the shell. Ventral valve much less convex than the other, its greatest convexity being in the umbonal region, while toward the front it is approximately flattened, but seldom depressed to form a distinct sinus; cardinal area small, arched, well defined; foramen a little higher than its width at its base; beak small, arched, and projecting a little beyond the hinge line. Dorsal valve gibbous and nearly regularly arched both antero-posteriorly and transversely; umbo strongly incurved, beak small; cardinal area very small; anterior margin usually more or less sinuous or emarginate, corresponding with the slight depression or medial flattening of the other valve; but sometimes this emargination is of considerable depth. Surface marked by fine radiating striæ of apparently nearly uniform size in all parts.

Length, 19 millimeters; breadth, 21 millimeters. The thickness of a specimen of this size, both valves in position, would be about 12 millimeters.

This species is referred with some hesitation to *O. resupinoides* Cox; but so far as describable characteristics are concerned no differences appear that may be regarded as necessarily of specific importance. It is, however, a considerably smaller shell, as shown by our examples, than the type of *O. resupinoides* as figured by Cox (loc. cit.) The surface of our examples is not perfectly preserved, and it does not show any of the small spines mentioned by Cox; nor is the front of any of our examples so deeply emarginate as that of his type.

A resupinate *Orthis* is so unusual a form among Carboniferous fossils and so common among Devonian forms that one might well doubt the Carboniferous age of these examples until they are seen embedded in the same rock with well-known Carboniferous species. Indeed, in comparing this species with others, it is necessary to mention Devonian forms only. Our species may thus be compared with *O. iowensis*, *O. tulliensis*, and *O. propinqua*.

Locality.—Manuelitos Creek, New Mexico.

POLYZOA.

Genus PTILODYCTIA Lonsdale.

Ptilodyctia triangulata White.

Plate IV, Figs. 2, *a*, *b*, *c*, *d*, and *e*.

Ptilodyctia triangulata White, 1878, Proc. Acad. Nat. Sci. Philad., p. 35.
Ib., 1879, Bull, U. S. Geol. Sur. Terr., Vol. V., p. 214.
Ib., 1880, An. Rep. U. S. Geol. Sur. Terr. for 1878, Part I, p. 131.

The type specimens of this species were obtained from the Coal-measure strata of Danville, Ill., by Mr. Wm. Gurley, and described by me as above cited. I afterward obtained some examples from the Carboniferous strata of Yampa Plateau in Northwestern Colorado, which, although the stipes or branches are considerably smaller than those of the type specimens, are doubtless specifically identical, since they are identical in all characteristics except size. The specimens contained in this collection are all, except one fragment, in the form of natural molds in strongly ferruginous sandstone; but they are thus very well preserved, so far as external form and the arrangement of the mouths of the pores is concerned. Although these specimens indicate the size of the stipes or branches to be considerably greater than that of the type specimens, and very much greater than that of the Colorado specimens, there seems to be no good reason for separating them under a different specific name. Therefore, in the absence of any knowledge of the details of the internal structure of these specimens I regard them as merely a variety of *P.*

triangulata. The following is a description of the type specimens, modified to include the characteristics of the New Mexican forms.

Corallum ramose, the branches comparatively few and not varying materially in size, and not at all in character, from those portions from which the branches proceed; transverse section triangular, all three sides being poriferous; the edges moderately sharp, more or less wavy, or sometimes distinctly scalloped; the laminar axis, consisting of three divisions which end respectively at the three edges and meet and blend at the center of the corallum; pores well developed, but they are not arranged in regular order, nor are they bounded by any longitudinal or transverse lines or ridges. Their mouths are moderately prominent, slightly oval, the direction of the longer diameter of each being subject to no regularity.

This species differs from typical forms of *Ptilodyctia* in having three nearly equal flat or concave sides instead of two convex sides, in the axis being consequently tripartite, and in the irregular disposition of the pores upon the surface.

Locality.—Cebolla Creek; where the specimens are all in the condition of natural molds; and Coyote Creek, where a calcareous fragment was obtained.

CONCHIFERA.

Genus MYALINA de Koninck.

Myalina permiana Swallow.

Plate III, Figs. 1, *a*, *b*, *c*, and *d*.

Mytilus (*Myalina*) *permianus* Swallow, 158, Trans. St. Louis Acad. Sci., Vol. I, page 187.
Myalina permiana Meek & Hayden, 1864, Pal. U. Missouri, p. 52.
Compare *Myalina deltoidea* Gabb, 1859, Proc. Acad. Nat. Sci., Philad., p. 297.
Compare *Modiola wyomingensis* Lea, 1852, Jour. Acad. Nat. Sci., Philad., Vol II, 2d ser., p. 205.

Shell rather large, moderately thick, apparently nearly equivalve, abruptly convex along the umbonal slopes, in front of which the valves are bent at nearly right angles with their plane, producing a concave flattening of the front; cardinal margin nearly straight or slightly convex, moderately long but much shorter than the axial length of the adult shell, yet it is proportionally longer in the young than in the adult state; posterior side compressed and sloping away regularly from the umbonal ridge to the posterior borders; front margin concave above, and rounding to the somewhat narrowly rounded basal margin; posterior margin nearly straight or slightly convex in its upper half or more, rounding to the basal margin below and forming an obtuse angle with the cardinal margin above; front and cardinal margins forming an acute angle at the beaks which, with the umbonal portion of the shell, project considerably beyond the front; cardinal area distinctly striate, moderately wide, and ending at the front (in the right valve) against an oblique, rather strong pseudo-dental ridge; just beneath this ridge there is a short flattened space about equal in width with the area; anterior adductor scar small, situated well forward but considerably behind the pseudo-dental ridge; pedal scar of about the same size as the anterior adductor and situated a little behind and above it. Surface marked by somewhat obscure lines of growth.

The largest example in the collection measures something more than 100 millimeters in axial length, and has a maximum breadth of 55 millimeters.

There is probably little room for doubt that the shell here described is specifically identical with the *Mytilus permianus* of Swallow, although his type specimens were obtained from strata supposed by him to belong to the Permian period; especially as Meek & Hayden report its existence in Coal-measure strata also.

It is probably also specifically identical with *M. deltoidea* Gabb, the type specimens of which were obtained from Carboniferous strata in Texas. It is true that the outline of our examples has different proportions from those attributed by Gabb to *M. deltoidea* in his description and figures. His examples were all imperfect, and his assumed proportions seem to be unnaturally short in the axial direction.

This species should also be compared with the *Modiola wyomingensis* of Lea, which is doubtless a *Myalina*, and with which it may, after all, prove to be specifically identical, as suggested by Meek & Hayden.

Locality.—The collections contain specimens from Coyote Creek, Coyote Creek near Black Lake, Cebolla Creek, and Taos Peak; all in Northern New Mexico.

Genus PLEUROPHORUS King.

Pleurophorus subcostatus Meek & Worthen.

Plate III, Fig. 8*a*.

Pleurophorus subcostatus Meek & Worthen, 1866, Ills. Geol. Reports, Vol. II, p. 347.

Shell rather small, moderately gibbous, greatest convexity of the valves in the anterior half and above the mid-height; basal and dorsal margins nearly straight and subparallel, or a little divergent, so that the shell is a little wider behind than in front; posterior end somewhat regularly rounded, or subtruncate; front rather more abruptly rounded than the posterior; cardinal margin long and straight; beaks depressed, and not elevated above the range of the cardinal margin, placed very near the anterior end of the shell. Surface marked by fine lines of growth, and extending from the beak of each valve to the posterior margin there are three or four faintly raised lines.

Our examples do not show either the hinge or interior markings; but Meek & Worthen describe the latter as follows: "Scar of the anterior adductor muscle deep, trigonal, sub-ovate, pointed above, and strongly defined by the prominent vertical ridge just behind it; those of the pedal muscles small, nearly marginal, and located directly over the anterior adductors; posterior adductor scars larger and more shallow than the anterior, subquadrate in outline, and placed close up under the posterior hinge-teeth. Pallial impression well defined."

Length, 19 millimeters; breadth, 8 millimeters.

The specimens in this collection seem evidently to belong to the species described by Meek & Worthen from the Upper Coal Measures of Illinois, under the name of *P. subcostatus*.

Locality.—The only examples in the collections are from Coyote Creek, New Mexico.

PTEROPODA.

Genus CONULARIA Miller.

Conularia crustula White.

Plate III, Figs. 4, *a* and *b*.

Conularia crustula White, 1880, An. Rep. U. S. Geol. Sur. Terr. for 1878, Part I, p. 170.

The type specimens of this species were obtained by Prof. G. C. Broadhead from Upper Coal-measure strata near Kansas City, Missouri, of which the following is a description: Shell rather small, having the usual four-sided pyramidal shape, the four sides being equal and flat, or nearly so, near the apex, but slightly convex toward the aperture; the four angles distinctly furrowed, and a slender faint furrow also marks the median line of each side; which furrow is more distinctly discernible on the cast of the interior of the shell than upon the external surface of the test. Surface marked by the numerous transverse raised striæ common to *Conularia*, which arch gently forward from each of the four angles; the majority of the striæ are continuous across the median line of the sides and also across the angle-furrows, in crossing which they bend slightly backward.

The two imperfect examples which the collection from near Taos contains appear to be specifically identical with *C. crustula*, but one of them shows the transverse striæ to be finely crenulate. This feature does not appear upon the type specimens, but it is probably due to their imperfectly preserved condition. This is the only described species of *Conularia* yet known in North American strata of the age of the Coal Measures; and if it had not been found associated with characteristic Coal-measure forms both in Missouri and New Mexico, it would doubtless have been referred to a horizon at least as low as the Subcarboniferous.

Locality.—Near Taos, New Mexico.

GASTEROPODA.

Genus SOLENISCUS Meek & Worthen.

Soleniscus brevis (sp. nov.)

Plate IV, Figs. 5, *a*, *b*, and *c*.

Shell subglobose, spire short, its length being less than one-third the full length of the shell, pointed, its sides slightly concave; volutions six or seven, those of the spire small and slightly convex, the last one ventricose; suture distinct but not deep; test moderately thick; fold of the columella strong, placed somewhat nearer to the proximal than to the distal end of the aperture, and having, especially in the case of old examples, a distinct, rather broad and deep concavity or revolving furrow in the columella immediately at the distal side of the fold; callus of the inner lip upon the space behind the fold and furrow moderately thick and broad. Surface smooth or marked only by faint lines of growth.

Length, 17 millimeters; diameter of the last volution, 11 millimeters.

This shell has much the outward aspect of a *Macrocheilus;* and indeed it closely resembles *M. ventricosus* Hall, from the Coal Measures of Iowa. The presence of a strong fold upon the columella, however, clearly separates it from that genus; and although it is very much more robust in form than the type-species of *Soleniscus* it is evidently congeneric with it.

Locality.—Coyote Creek, north of Black Lake, and also near Taos, New Mexico.

Soleniscus planus (sp. nov.)

Plate IV, Figs. 4, *a*, *b*, and *c*.

Shell subfusiform; spire nearly one-half the full length of the shell, pointed, its sides nearly straight; volutions eight or nine; those of the spire gently convex; the last one large but not really ventricose; suture distinct but not deep; test moderately thick; fold of the columella well developed and placed a little forward of the mid-length of the aperture; the callus forming that portion of the inner lip which lies behind the fold moderately thick and broad. Surface smooth, or marked only by faint lines of growth.

Length, 29 millimeters; diameter of the last volution about 11 millimeters. All the examples of this species yet discovered having been more or less distorted by pressure, the exact diameter cannot be accurately determined, but the restoration, Fig. 4*c*, on Plate IV, is doubtless approximately correct in proportions, except that the sides of the spire are perhaps a little too convex. A fragment brought by Mr. Russell from Coyote Creek, apparently belonging to this species, indicates that it sometimes reached a much greater size than that of the examples from which the foregoing dimensions were taken.

This shell, like the species last described, has the outward aspect of a *Macrocheilus*, but the presence of a fold upon the columella distinguishes it as a *Soleniscus*. It was found by Mr. Russell associated with *S. brevis*, the species last described. It resembles that form in some respects, but it is distinguished by being more elongate and in having a proportionally much longer spire. The discovery in New Mexico of two new species of *Soleniscus*, of which genus only one species has hitherto been known, is an interesting addition to the Coal-measure fauna. In both these species the characteristics which were relied upon by Meek & Worthen as distinguishing that genus are well developed and show it to be a well-defined one.

Locality.—Coyote Creek, north of Black Lake, New Mexico.

Genus BELLEROPHON Montfort.

Bellerophon inspeciosus (sp. nov.)

Plate IV, Figs. 1, *a*, *b*, *c*, and *d*.

Shell moderately large, much expanded laterally near the aperture when adult; dorsum somewhat narrowly and regularly rounded in the earlier stages of growth, but in the case of the adult shell there is, toward the outer margin, an obtuse median angulation with a shallow depression at each side of it and a faint linear groove along its median line; but none of these features extend much farther back than one-half of the last volution; aperture wider transversely than in the direction of the plane of the coil; umbilici closed by the great thickening of the test at those points, but no callosity extends across the dorsum of the penultimate volution in the form of an inner lip. There is a prevailing tendency to irregularity in the coiling of the volutions of this shell, the turning being more abrupt at some parts of the coil than at others, two or three of these abrupt bendings being usually visible in adult shells. This gives them the appearance of having suffered accidental distortion; but it is evidently a natural distortion of growth. Surface marked by numerous revolving raised lines, which are distinct and regular upon the earlier volutions, but they become irregular and obsolete upon the greater part of the outer volution.

When fully adult this shell reached a full diameter of coil of not less than 35 millimeters, its extreme axial diameter being a little more than that of the plane of the coil.

Locality.—Near Taos, and at Taos Peak, New Mexico.

Genus PLEUROTOMARIA Defrance.

Pleurotomaria perizomata (sp. nov.)

Plate III, Figs. 5, *a*, *b*, and *c*.

Shell of medium size, the extreme axial length and greatest transverse diameter of the last volution being about equal, or the latter sometimes a little the greater; spire nearly regularly conical, the slope of its sides being only slightly interrupted by the adjustment of each successive volution; outer side of the last volution forming a flattened periphery of the shell; proximal side of the last volution gently convex; umbilicus minute or wanting; spiral band distinctly crenulated and occupying the prominent angle formed by the vertically flattened outer side and the obliquely flattened distal side of the volutions; surface upon all sides marked by numerous distinct raised revolving lines, which are a little wider apart upon the proximal side than elsewhere. These revolving lines are crossed by numerous close-set raised lines of growth, giving the surface a somewhat reticulated appearance under the lens, and being a little stronger upon a narrow space adjacent to the suture, they there produce a more or less distinctly crenulated appearance.

Diameter and length each about 25 millimeters; but one of the fragments in the collection indicates a considerably larger size.

Locality.—Near Taos, New Mexico.

Genus MURCHISONIA d'Archiac.

Murchisonia copei (sp. nov.)

Plate III, Figs. 10, *a* and *b*.

Shell slender, apical angle 20° to 25°; full number of volutions apparently about fifteen, all strongly angulated, the angle being more or less distinctly carinated; carina not crenulate; angle situated nearer to the proximal than the distal border of the volutions; spiral band occupying the middle of the outer flattened side of the volutions, of moderate width, inconspicuous, and bordered on each of its sides by a raised line; the remainder of the outer surface of the volutions marked only by fine lines of growth; the proximal side of the last volution marked by one distinct revolving raised line near the carina.

Length of adult shells from 25 to 30 millimeters.

This shell so closely resembles *M. terebra* White, from the Carboniferous strata of Northern Arizona, that it may be readily mistaken for that species. It differs, however, in being proportionally shorter than that species, having fewer volutions, its angle not crenulate, and in not having the outer side of its volutions marked by numerous revolving lines as in *M. terebra*. The condition of the type specimens of the latter species was not such as to show the spiral band, but it appears to occupy the angle instead of the middle of the outer side of the volutions.

Locality.—Near Taos, New Mexico, where it was obtained by Prof. E. D. Cope, in whose honor the specific name is given.

Genus ROTELLA Lamarck.

Rotella verruculifera (sp. nov.)

Plate IV, Figs. 7, *a*, *b*, *c*, and *d*.

Shell small, depressed, broadly convex above and flattened or partially concave below; periphery somewhat abruptly rounded; volutions four or five, all visible in the spire, but only the last one visible below; inner volutions small, the upper surface of all of them only slightly more convex than the general broad convexity of the spire; suture slightly impressed; a moderately large, very prominent wart-like callus occupies the umbilical space and forms the inner lip, which is slightly concave; aperture subelliptical in outline, being a little wider transversely than vertically. Surface smooth or marked only by obscure lines of growth.

Full diameter of coil, 6 millimeters; full height of shell, 3½ millimeters. These are the dimensions of one of the more perfect examples, but there is among them a fragment which indicates that the species sometimes, at least, reached a considerably larger size.

In general aspect this little shell is much like a form described by Meek & Worthen in Vol. V, Illinois Geological Reports, p. 597, under the name of *Anomphalus rotulus;* but our shell is generically separated from that form by the presence of the prominent umbilical callus just described. One may well raise the question whether it is probable that any Carboniferous form is strictly congeneric with any living one; and, consequently, whether this species is a true *Rotella*. So far, however, as the characteristics of the shell alone are concerned, those of the form here described are precisely such as distinguish the various living species of *Rotella*.

The *R. helicinæformis* of Goldfuss, of Devonian age, is doubtless congeneric with our shell, but in that case, as well as in the present one, the type seems to be strangely isolated. That is, there seem to be no nearly related forms, either associated with these species in the strata in which they are respectively found, nor are such known to exist in any of the strata of immediately preceding or subsequent age.

Locality.—Near Taos, N. Mex., where it was found by Professor Cope associated with the Upper Coal-measure fossils mentioned in the list of Locality No. 8.

Genus NATICOPSIS McCoy.

Naticopsis wheeleri Swallow. Var.

Plate IV, Figs. 6, *a* and *b*.

Compare *Littorina wheeleri* Swallow, 1860, Trans. St. Louis Acad. Sci., Vol. I, p. 658.
Compare *Naticopsis wheeleri* Meek & Worthen, 1873, Ill. Geol. Reports, Vol. V, p. 595.

Shell rather small, obliquely subrhomboidal in outline when laterally viewed; volutions about four, the last one moderately gibbous and composing more than two-thirds the entire length of the shell; aperture subovate; test moderately thick; surface covered thickly with small tubercles, which on the small volutions of the spire are very minute, but they increase in size with the growth of the shell; tubercles of uniform size in the same part of the volution, except those which form a prominent revolving row near the distal border of the volutions, and which are all larger than the other tubercles. Between this revolving row of tubercles and the suture there is a narrow, plain, concave space without tubercles, and marked only by ordinary lines of growth.

Extreme length from the apex to the front border of the aperture, 16 millimeters; greatest transverse diameter, measuring across the aperture, 13 millimeters.

This shell is regarded as only a variety of *N. wheeleri* as that species was identified and figured by Meek & Worthen in Vol. V of the Illinois Geological Reports. I have compared our examples with authentic specimens of that form sent me for that purpose, by Professor Worthen, from Illinois, and find them to agree too closely with each other to warrant a separation under different specific names. Our examples differ from the Illinois specimens mainly in the presence of the prominent revolving row of larger tubercles near the distal border of the volutions which has just been described.

Locality.—Near Taos, N. Mex., where Professor Cope obtained two or three dozen examples, part of which are well preserved.

Naticopsis monilifera White.

Plate III, Figs. 3, *a*, *b*, *c*, and *d*.

Naticopsis monilifera White, 1880, An. Rep. U. S. Geol. Sur. Terr. for 1878, Part I, p. 168.

The collection made by Professor Cope near Taos contains a single example, which, although imperfect, seems evidently to belong to the species described by me (*loc. cit.*) as *N. monilifera*. The type specimens of the species were obtained by Prof. G. C. Broadhead from the Coal-measure strata of Cass County, Missouri, the following being the specific description:

Shell small, subglobose; spire short, obtuse, and having its immediate apex flattened; volutions about six, but the apical ones are very small—the last one constituting the greater part of the shell, broadest at its basal or proximal portion, the proximal side of which is somewhat abruptly rounded inward to the aperture; the small volutions of the apex are plain, but upon the distal border of the two last volutions, adjacent to the suture, there is a conspicuous row of small nodes, constituting a pretty ornamentation of the shell; the remainder of the surface is smooth and has a polished aspect, upon which a good lens reveals fine striæ of growth; aperture suboval in outline; inner lip having a distinct callus, especially in front; outer lip thin, its border sinuate, having an almost distinct notch just in front of the row of nodes.

Extreme length, 10 millimeters; extreme diameter of the last volution nearly the same.

Naticopsis altonensis McChesney.

Plate III, Fig. 6 *a*.

A couple of examples of this fine large *Naticopsis* were obtained by Professor Cope near Taos, one of which is represented by Fig. 6 *a*, Plate III. The discovery of these three species of *Naticopsis*, which among others characterize the Coal-measure strata of the Upper Mississippi River region, associated together in equivalent strata in New Mexico, is an interesting circumstance in its relation to the geographical distribution of species.

Genus LOXONEMA Phillips.

Loxonema rugosa Meek & Worthen.

Plate III, Fig. 7 *a*.

Among the fossils from near Taos, and also among those from Coyote Creek near Black Lake, there are several imperfect examples of a species of *Loxonema* which are probably referable to *L. rugosa*, Meek & Worthen. They, however, indicate a much larger size than that of the types of that species, and also show some variation of external characters. For example, there is a considerable variation in the size of the vertical varices in different specimens and upon different parts of the same specimen,—those of the distal volutions being, as a rule, more numerous and narrower than those of the proximal volutions.

Genus ACLIS Loven.

Aclis? stevensoni (sp. nov.)

Plate III, Figs. 9, *a* and *b*.

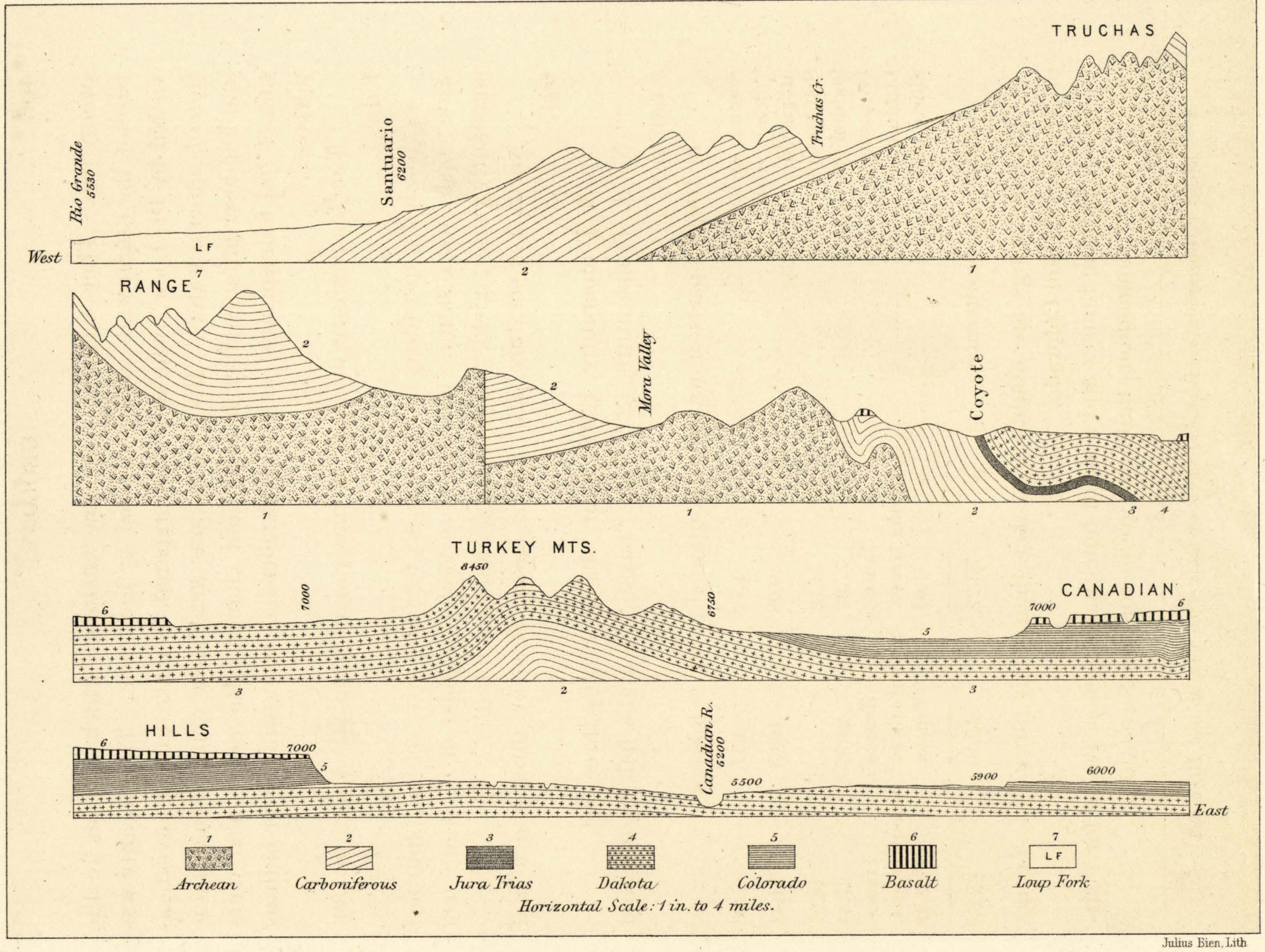
Shell small, but not minute; apical angle about 30°; volutions eight or ten, gradually increasing from the apex; those of the spire marked by about eight or ten revolving impressed lines of nearly uniform size, but the three or four which are nearest to the suture upon the distal border of the volutions are a little nearer together than the others; similar revolving lines also mark the surface of the proximal side of the last volution.

The largest example in the collection indicates a length of about 12 millimeters, and a diameter of the last volution of 5 millimeters.

In some respects this shell resembles a small *Murchisonia*, but no trace of a spiral band has been detected on any of the examples. It has the apparent characteristics of an *Aclis*, in consequence of which, and also of the fact that other Carboniferous species have been referred to that genus, the shell here described is so referred, at least provisionally.

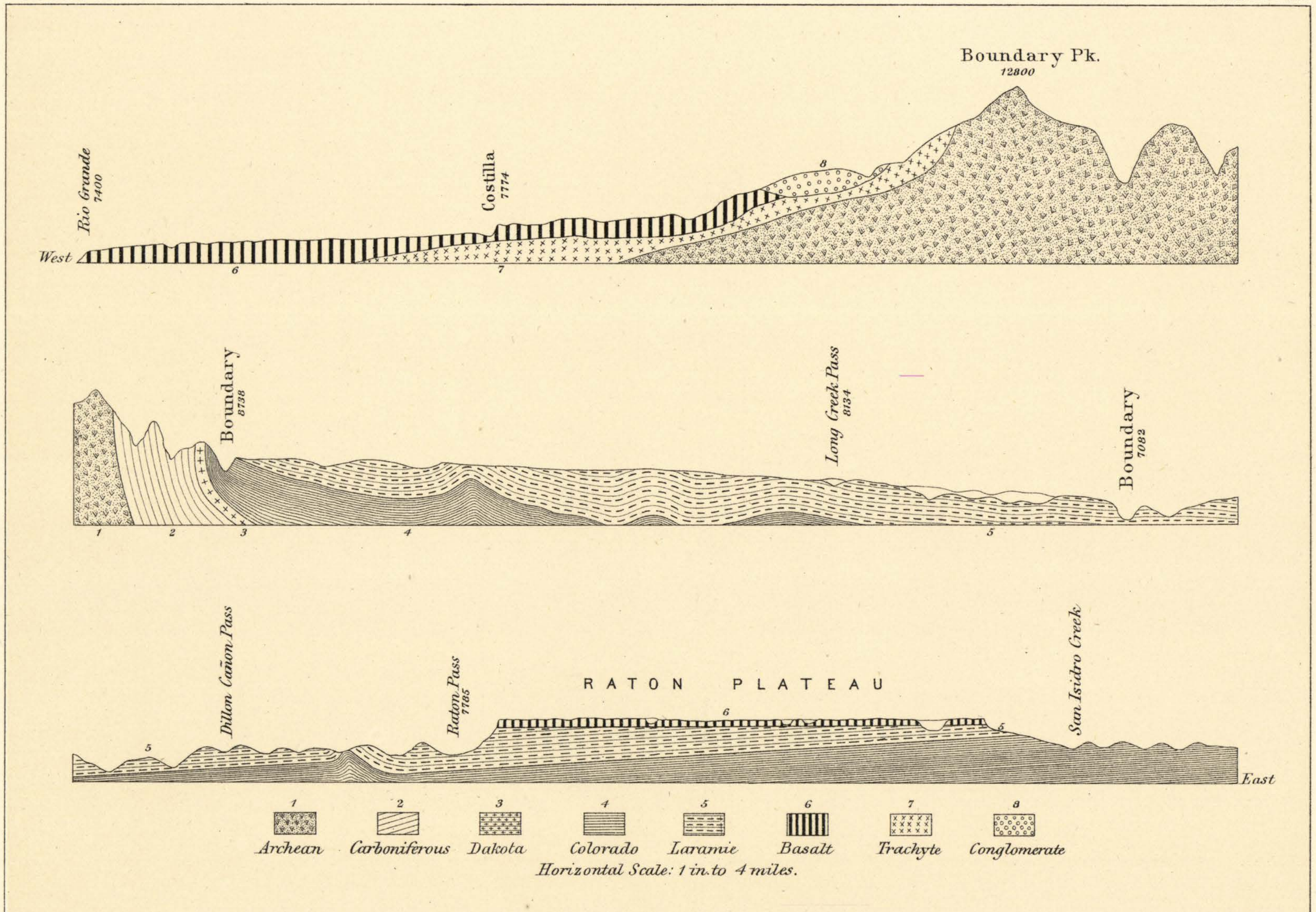
Locality.—Coyote Creek, New Mexico.

INDEX TO APPENDIX.



Julius Bien, Lith.

SECTION ALONG 36TH PARALLEL FROM THE RIO GRANDE TO THE CANADIAN PLAINS
(ATLAS SHEETS 69 D & 70 C)



Julius Bien, Lith

SECTION ALONG 37TH PARALLEL FROM THE RIO GRANDE TO SAN ISIDRO CREEK
(ATLAS SHEETS 69 B & 70 A)

PLATE III.

FIG. 1. MYALINA PERMIANA. (Page XXV.)

a. Restoration of an imperfect specimen of a right valve; natural size.
b. Fragment of a right valve; showing the area and internal markings.
c. Exterior view of the same.
d. A small left valve; from a natural cast in sandstone.

FIG. 2. ORTHIS RESUPINOIDES? (Page XXIII.)

a. Ventral valve; natural size; from a specimen from New Mexico.
b. Dorsal valve; from the same locality.

FIG. 3. NATICOPSIS MONILIFERA. (Page XXXIV.)

a. Lateral view of the type specimen; from Missouri; enlarged to 1½ diameters.
b. Apical view of the same.
c. Portion of the surface enlarged; the striæ of growth indicating the character of the border of the outer lip.
d. Imperfect example from New Mexico.

FIG. 4. CONULARIA CRUSTULA. (Page XXVIII.)

a. Lateral view of the type specimen; from Missouri; natural size.
b. Fragment from New Mexico; enlarged to 4 diameters to show the crenulation of the transverse striæ.

FIG. 5. PLEUROTOMARIA PERIZOMATA. (Page XXXI.)

a. Lateral view of a rather small example; natural size.
b. Basal view of the same.
c. Lateral view of a larger, but imperfect example.

FIG. 6. NATICOPSIS ALTONENSIS. (Page XXXV.)

a. Lateral view of an imperfect example from New Mexico; natural size.

FIG. 7. LOXONEMA RUGOSA? (Page XXXV.)

a. Lateral view of a fragment from near Taos, New Mexico; natural size.

FIG. 8. PLEUROPHORUS SUBCOSTATUS. (Page XXVII.)

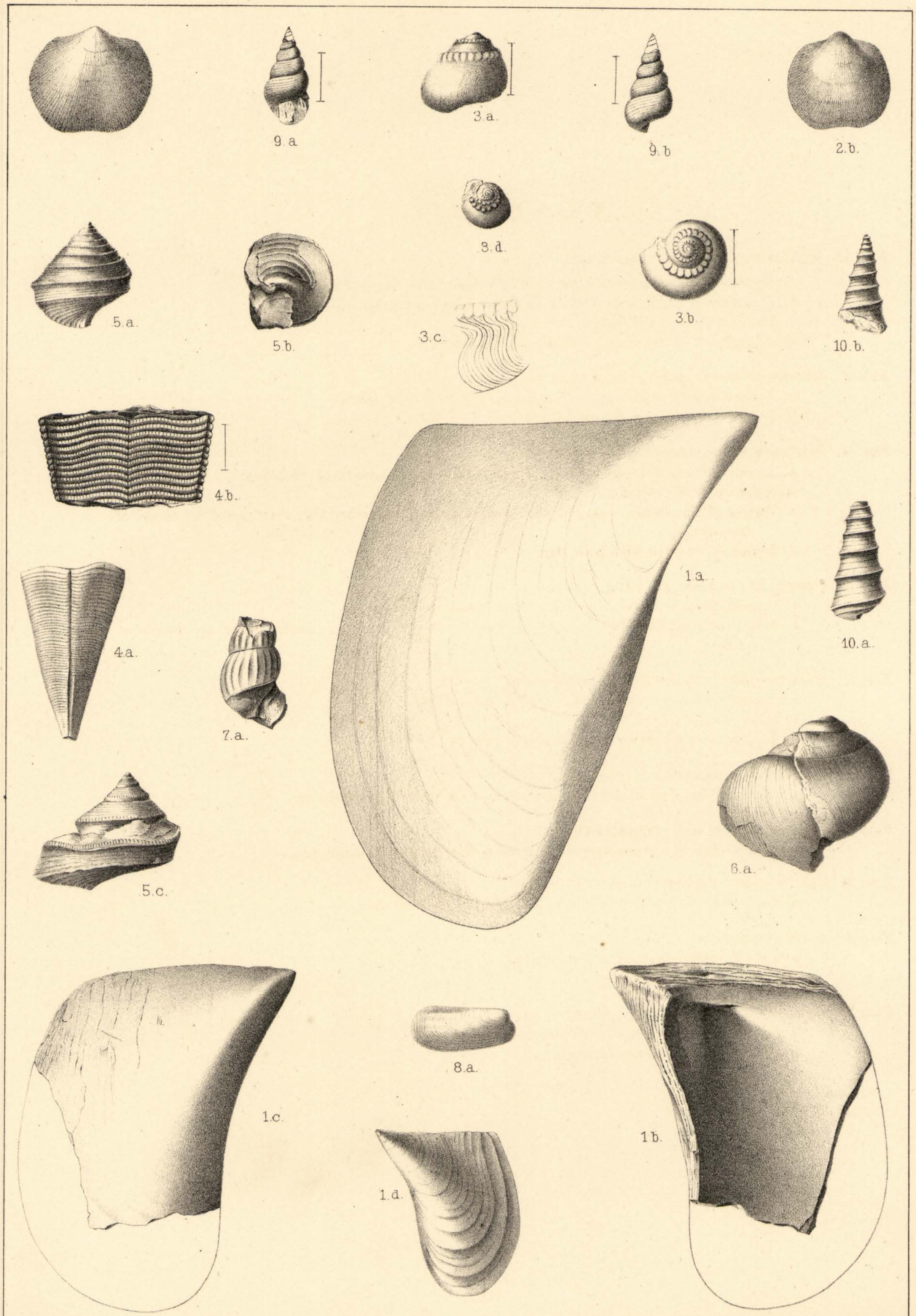
a. Right valve; from Coyote Creek, New Mexico; natural size.

FIG. 9. ACLIS STEVENSONI. (Page XXXV.)

a. Lateral view; enlarged to 2 diameters.
b. Opposite view of the same.

FIG. 10. MURCHISONIA COPEI. (Page XXXI.)

a. Lateral view of a broken example; natural size.
b. Similar view of another example.



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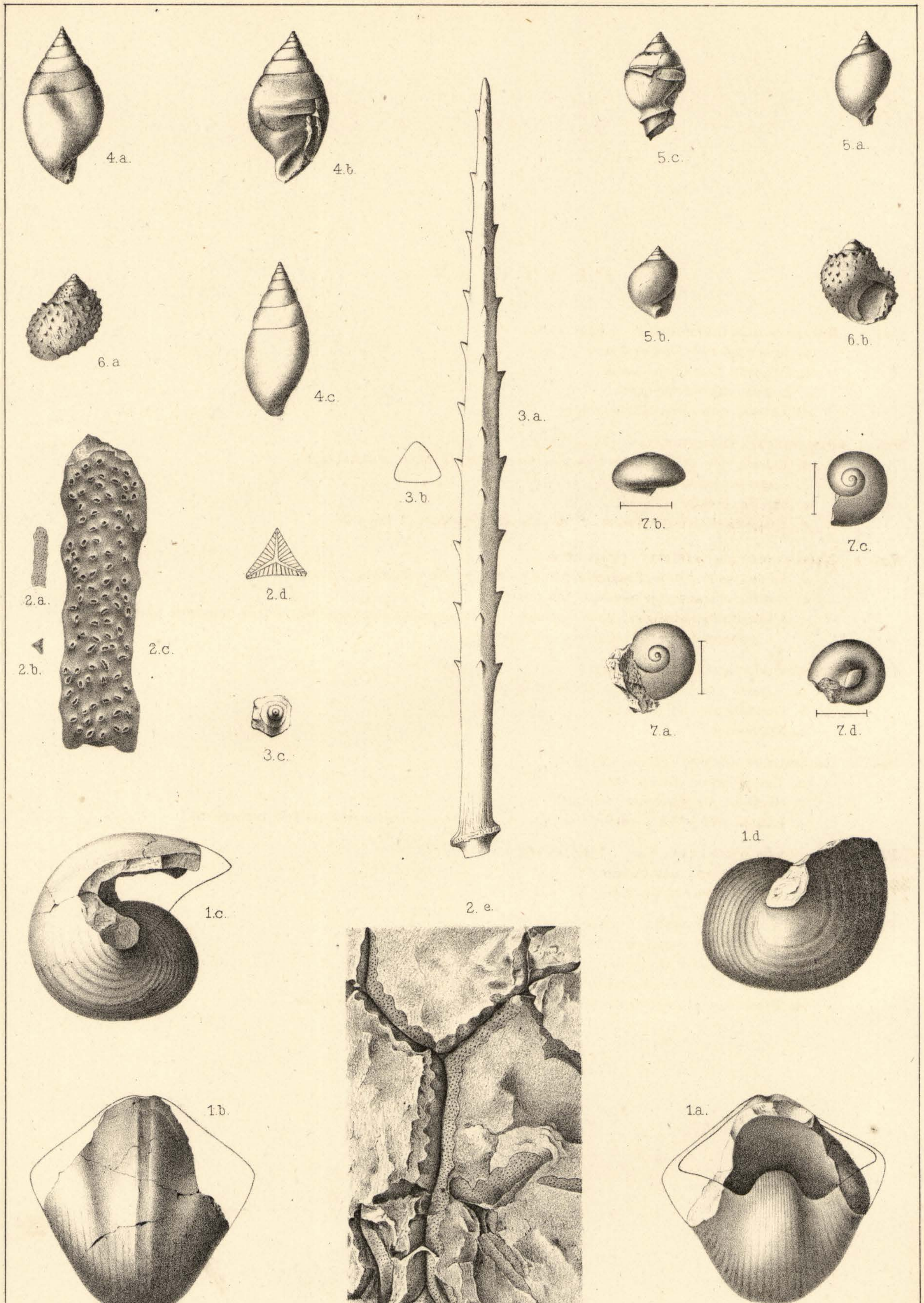

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