

Journal of Geography

Publication details, including instructions for authors and subscription information:

<http://www.tandfonline.com/loi/rjog20>

The Canyons of Northeastern New Mexico

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Published online: 20 May 2008.

To cite this article: Willis T. Lee (1903) The Canyons of Northeastern New Mexico, Journal of Geography, 2:2, 63-82, DOI: [10.1080/00221340308985922](https://doi.org/10.1080/00221340308985922)

To link to this article: <http://dx.doi.org/10.1080/00221340308985922>

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The JOURNAL of GEOGRAPHY

VOL. II.

FEBRUARY, 1903

No. 2

THE CANYONS OF NORTHEASTERN NEW MEXICO*

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OUTLINE

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*Companion paper to that on "Canyons of Southeastern Colorado," *The JOURNAL OF GEOGRAPHY*, Vol I., pages 357-371.

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THE Canyons of Northeastern New Mexico are cut in the eastern and southern slopes of the broad uplift whose axis extends eastward from the mountains approximately along the Colorado-New Mexico boundary line. Along the crest of this uplift extends a series of lava-capped mesas, which rise to a maximum elevation of 9,586 feet (Fishers Peak), or about 3,500 feet above the general level of the plains. The mesa tops represent a former continuous surface, which has since been deeply dissected, leaving the mesas separated by short, rugged canyons. It is among these high mesas that the Rio Cimarron rises. While the Canadian River also drains a part of the mesa region, its waters are derived principally from the eastern slopes of the mountains. The tributaries of these rivers have all cut more or less extensive canyons. In the region shown, then, in the accompanying sketch map (Figure 1), the canyons occur in two systems, the Rio Cimarron and the Canadian.

The region here considered embraces the northwest corner of the area described by Mr. R. T. Hill as the Texas region, and the larger physical features have been described in his work.* He says of the general topography of the region: "The plateau plain of Northern New Mexico . . . resolves itself into three great topographic benches or levels standing one above another, which may be designated in descending series, the *Mesa de Maya*, the *Ocate* and the *Las Vegas* plain."

The upper bench, or *Mesa de Maya*, extends from Raton eastward at least to the junction of Carrizo Creek and the Rio Cimarron, a distance of 85 miles. Beyond this I cannot speak from personal observation. The maximum width of the mesa, north and south, including the outliers, is something over 40 miles. Fowlers Mesa and Mount Carrizot are outliers to the north of *Mesa de Maya* proper and various small lava-capped mesas south of Folsom, N. M., are isolated remnants to the south. This high plateau has been deeply dissected into more or less distinct mesas,

*U. S. Geological Survey, *Topographic Atlas*, "Physical Geography of the Texas Region."

†U. S. Geological Survey, Mt. Carrizo Sheet.

which fall naturally into two groups separated by Emery Gap. This gap is also known as Cimarron Pass, where the old Santa Fe trail passed the divide, and where the Colorado and Southern Railroad now passes it. The principal mesas of the western group are locally known as Chicorico

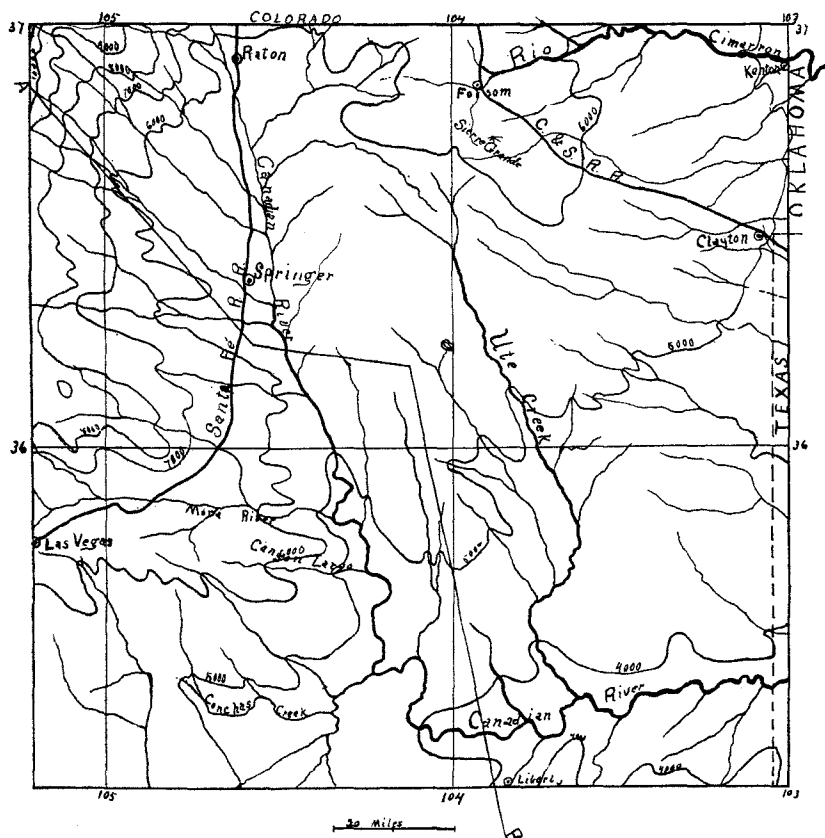


FIG. 1. Sketch Map of Northeastern New Mexico.

Mesa, 15 miles long, with a maximum width of about 10 miles[‡]; Bartlett Mesa, 6 by 10 miles, and Johnson Mesa, 15 by 25 miles. These mesas are separated by narrow passes and rugged precipitous valleys.

The eastern group consists of one large mesa—the Mesa de Maya proper—and several small isolated ones. The elevation of the eastern group is not so great as that of the western group, and is therefore not

[‡]See Sectional Map of Colfax and Mora Counties, N. M.

so extensively dissected. The canyons trenching the sides are narrower and not so deep as those further to the west.

The elevated bench, then, which Mr. Hill calls the Mesa de Maya, is a deeply dissected table land, the original surface of which has been preserved in the tops of the basalt covered mesas. Mesa de Maya is the name given to the principal mesa of the eastern group, and has been borrowed to designate the whole group. The name is peculiarly appropriate, since it means to the Mexicans, who gave it, "the table of mail." The hard basalt caps, terminated by their columnar palisades, give in truth the appearance of armored mesas.

From Fishers Peak (9,586 feet), the highest point of this plateau, the surface slopes eastward and southward. Its elevation near the mouth of Carrizo Creek, Oklahoma, is 4,800 feet. The eastward slope, therefore, lowers the surface 4,786 feet within a distance of 86 miles—an average descent of about 55 feet to the mile. The northern edge of the mesa forms the divide between the waters of the Purgatory to the north and those of the Rio Cimarron and Canadian to the south. The mesa surface slopes more rapidly than the surfaces of the lower benches—the Ocate and the Las Vegas plains. In the vicinity of Folsom the mesa surface, represented now by isolated remnants, merges into the Las Vegas plains. (See Figure 2.) The same relation also obtains eastward from Folsom, where the mesa lavas rest upon the Dakota sandstone.

The Ocate bench is a comparatively elevated region, lying along the eastern front of the mountains. It is deeply dissected and is terminated on the east by a prominent escarpment. The cliffs of this escarpment are formed by a hard sandstone layer—probably the Fox Hills. Above this sandstone rests the Laramie formation, rich in coal, and beneath it lie the Pierre shales. This bench is the southward continuation of the one described in a former paper, "The Canyons of Southeastern Colorado"* and extends, according to Mr. Hill, from the Spanish Peaks, Colo., southward to Las Vegas, N. M. The divide at the top of this bench between the drainage of the Purgatory and that of the Canadian is locally known as the Raton Mountains.

The Las Vegas plains occupy the principal part of the area here considered. They may be described in general terms as forming a broad stratum plain controlled by the Dakota sandstone. Over a great part of the area the Dakota is covered only by a thin coating of soil. Near the mesas the overlying shales and limestones still remain, and to the south and east the surface is more or less occupied by a loose chalky

*Lee, *The JOURNAL OF GEOGRAPHY*, Vol. I., pages 357-371.

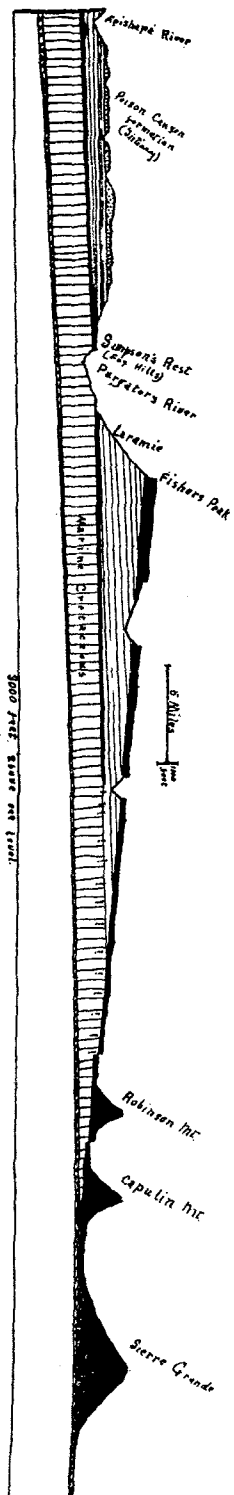


FIG. 2. Section extending from the Apishapa River, Colorado, southward through Fisher's Peak to Sierra Grande, New Mexico, illustrating the Ute bench which appears at the left, the Mesa de Maya in the center, and the Las Vegas plains at the right occupied by the volcanoes.

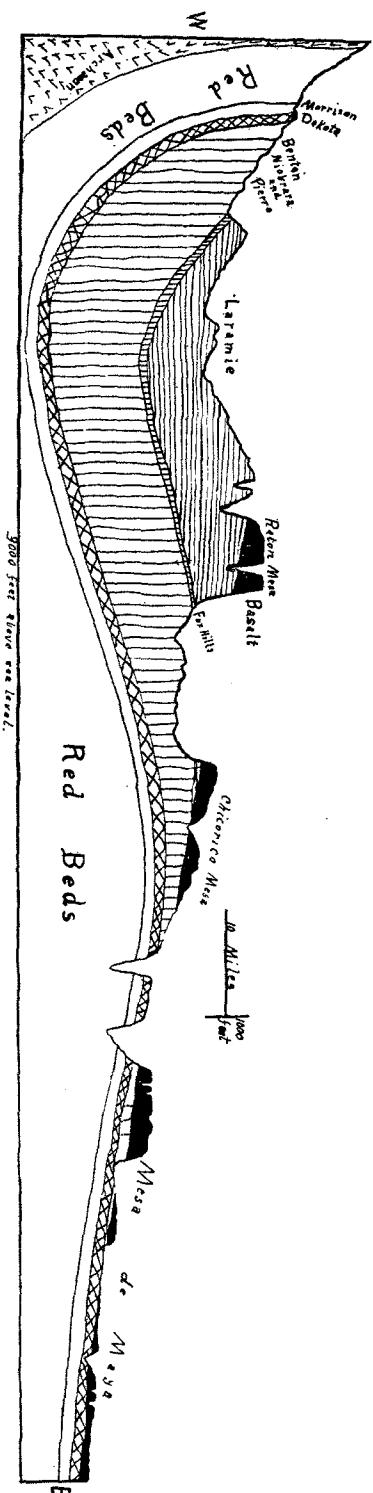


FIG. 3. Section along the Colorado-New Mexico boundary line, from the front range of the Rocky Mountains eastward. (The relative elevations are greatly exaggerated.)

material which answers the description of the "tepetate," described by Mr. Hill.* The Las Vegas plains are terminated on the south by the Canadian escarpment, formed by the breaking off of the Dakota sandstone. It rises to a maximum elevation of 1,500 feet above the bed of the Canadian River. It is this escarpment which Mr. Hill refers to as "one of the longest and most remarkable escarpments in America, extending a distance of nearly 300 miles."

The rock formations penetrated by the canyons are:

1st. The extrusive sheets of igneous rock, principally basalt. The relation of these sheets to the underlying formations is shown in the accompanying sections (Figures 2 and 3).

The igneous sheets are of different ages. It will answer my present purpose to refer to the mesa caps as the *older series* of flows and to those in the degraded regions among the mesas as the *younger series*. From Fishers Peak, the highest point of the mesa, and situated a few miles north of the area shown in the sketch map, eastward and southward, the older flows lie upon the edges of the sedimentary formations from Laramie to Dakota, as shown in Figure 3. The older flows were deeply eroded and large portions of them, together with the underlying formations, as far down as the Dakota sandstone, were carried away in the process of canyon cutting. At a comparatively recent date volcanic activity was renewed and sheets of lava outpoured upon the floor of the degraded areas. These recent flows are small when compared with the older ones, and yet are, in themselves, of no mean proportions. One lava stream was followed for a distance of about 27 miles. Connected with this newer series are a number of volcanic cones with craters preserved in a high state of perfection. Figure 4 is a photograph of Capulin Mountain, the best known of these recent volcanoes. Its elevation is about 9,000 feet—2,500 feet above the plain upon which it rests. It stands near Folsom, N. M., not far from the head of the Rio Cimarron Canyon.

2nd. The Laramie formation is well developed in the western part of this region and is found on the Ocate bench, previously referred to. The Laramie also extends eastward in the Mesa de Maya region under the older lava sheets for a considerable distance, but its distribution in New Mexico cannot be accurately given at present.

3rd. The marine Cretaceous formations are represented in this region. In the escarpment which borders the Ocate bench is found the

*R. T. Hill, U. S. Geological Survey, "Physical Geography of the Texas Region," p. 3; also Nueces folio No. 42.

Laramie, the Fox Hills and the Pierre formations. The Pierre is here, as elsewhere, a soft, easily eroded shale. It is this soft shale combined with the overlying hard sandstone that maintains the escarpment. In the mesa region near the northern border of the territory the shales extend eastward beyond Folsom on account of the protection afforded by the mesa lavas. But south of the mesa region the Pierre occurs for the most part west of the Canadian River.

4th. Beneath the Pierre lies a series of limestones and shales, yielding fossils of Colorado Cretaceous type. This series has a wider distribution than the Pierre, but is mostly confined to the northern and western



FIG. 4. *Mount Capulin, a Volcanic Cone near Folsom, New Mexico. The photograph is taken from the top of a neighboring volcano about five miles distant.*

borders of the Las Vegas plains. The limestones are resistant layers a few feet thick and form flat-topped benches along the canyons, a few miles back from the rim of the canyons proper. These are especially prominent along the Canadian Canyon, where they form a nearly continuous bench for a distance of about 75 miles.

5th. The Dakota sandstone is the surface formation with minor, exceptions, of the great stratum plain known as the Las Vegas plains. It is the hard layer which forms the protecting rim of the canyons and of the great Canadian escarpment.

6th. Beneath the Dakota sandstone throughout this region is a soft shale and sandstone formation which seems to be an equivalent of the *Atlantosaurus* Beds. My reasons for so considering them are stated in articles previously published.*

7th. The lowest formation exposed in the canyons is the Red Beds

*Lee, *The Journal of Geology*, Vol. IX., No. 4, May-June, 1901; also Vol. X. No. 1, January-February, 1902.

It is composed of red sandstones of varying character, interstratified with red and purple shales.

Rio Cimarron Canyon.—The Rio Cimarron rises among the high mesas north and west of Folsom, N. M. It is the middle one of the three streams of the mesa region which have cut extensive canyons—the Purgatory lying to the north and the Canadian to the south. Unlike the latter two, which drain the eastern slopes of the mountains, the Rio Cimarron rises about 60 miles east of the mountains. Although it is called a river, the amount of water is so small under ordinary circumstances that one can easily step across the stream in places. Yet this is the stream, or perhaps what is left of a much larger stream, which has cut a canyon more than 60 miles long to a maximum depth of about 1,000 feet.

The headwaters of the stream occupy short, steep-sided canyons among the mesas. But near Folsom the river plunges into a narrow gorge cut in the Dakota sandstone. Thence eastward through New Mexico and about 30 miles into Oklahoma it flows in a canyon having a maximum depth of about 1,000 feet. This maximum depth is found about 10 miles east of Folsom, where an outlier of Mesa de Maya helps to form the canyon walls. At this point the upper 300 feet of the wall is composed of formations lying above the Dakota. Beyond this point the Dakota forms the rim of the canyon, with the exception of about 20 miles of the north wall in the vicinity of Kenton, where the lava sheets of Mesa de

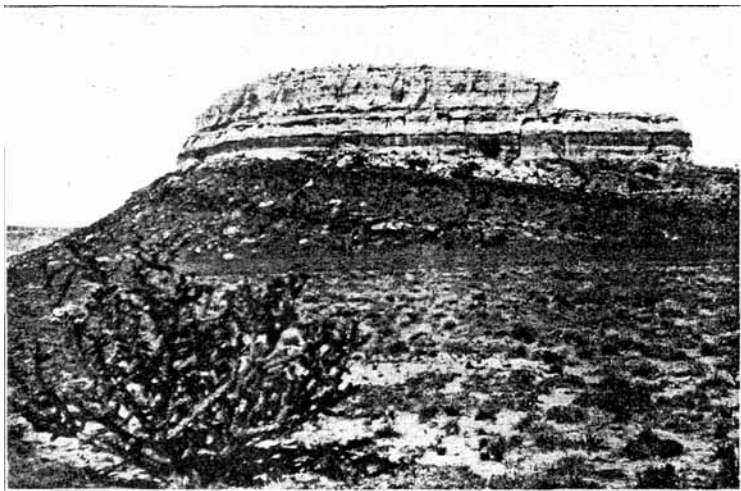


FIG. 5. One of the Mesa-Buttes in the Canyon of the Rio Cimarron. The cliff at the top is the Exeter sandstone, which rests unconformably upon the Red Beds. At the right it is still joined by a low ridge to the canyon side.

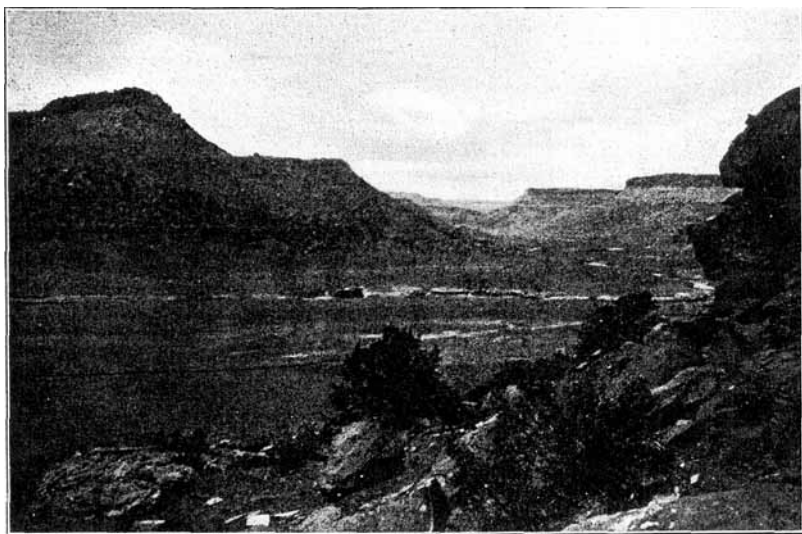


FIG. 6. *The Canyon of the Rio Cimarron, illustrating the graded floor.*

Maya appear above the Dakota and form the protecting rim. The rim rock in either case is a resistant layer and maintains the canyon walls in a precipitous state. The soft shales beneath the Dakota sandstone are easily eroded and the Red Beds are composed also of soft shales and sandstones. In the eastern half of the canyon a firm, light-colored sandstone, which I have elsewhere called the Exeter*, appears between the Red Beds proper and the Atlantosaurus shales. This sandstone is moderately resistant and appears as a light-colored band along the canyon sides, forming nearly perpendicular cliffs about 100 feet high.

The canyon widens down stream until it attains, in places, a width of several miles. The bottom is so well graded that in times of flood the water sometimes covers an area nearly a mile wide. The great regularity of the floor, in places, suggests the possibility that it may be due to a hard stratum, since the dip of the strata and the grade of the river are practically the same. But this explanation will not apply for all places, since there is one region where the Red Beds are unconformable with the overlying formations and their upturned edges have been planed off, forming a canyon floor which does not differ materially from that where the strata lie more nearly horizontal. (See Figure 5.)

From this comparatively level floor the canyon walls rise abruptly, as shown in Figures 6 and 7. There is very little talus to be found. The

*Lee, *The Journal of Geology*, Vol. X., No. 1, p. 45.

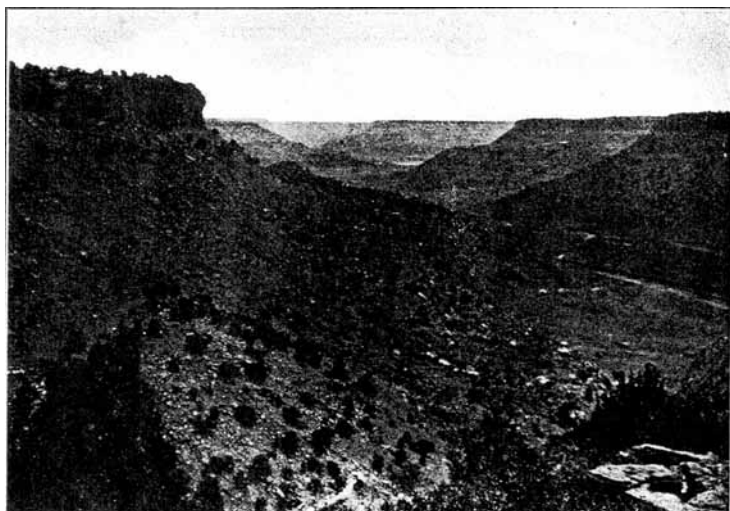


FIG. 7. Canyon of the Rio Cimarron, near the mouth of Long Canyon. The cliff at the top is of Dakota sandstone; the gentle slope beneath is occupied by the Morrison shales, and the lower slopes are Red Beds.

sandstones of the Red Beds are not resistant enough to form talus. The Exeter sandstone, while resistant enough to form nearly perpendicular cliffs, does not form talus to any notable extent. The rim rocks—the basalt and the Dakota sandstone—keep the slopes beneath more or less strewn with debris. The basalt is usually found in small fragments, while the sandstone breaks off in huge blocks, sometimes 40 feet or more in diameter. These blocks are found from top to bottom of the canyon sides, but seldom in sufficient quantity to form accumulations. The lower slopes of the walls are more free from them than the upper slopes, while the floor of the canyon is almost entirely free from them, as if all debris had been swept from the floor up to a comparatively recent time. The canyon sides are singularly well exposed and the formations may be studied with ease.

In the wider portions of the canyon numerous mesa-buttres rise abruptly from the floor. The larger ones are still capped with the Dakota sandstone and rise to the level of the surrounding country. The smaller ones are either pointed or capped with some hard layer of a lower horizon, as in Figures 5 and 8. These mesa-buttres are somewhat numerous and vary in size from table lands many acres in extent to small pointed mounds just ready to disappear. Some of these may have been left as “cut-off spurs” by the entrenched meanders of the river, but on the

whole the gradient of the Rio Cimarron seems to be too great to admit of extensive meandering and the mesa-buttres are conceived as due mainly to the cooperation of the main stream and its tributaries, as illustrated in the diagrams, Figures 9 and 10. A part of the original surface may be left in the one case by the swinging of the entrenched main stream and a tributary, together cutting the intervening wall and leaving an *island mesa*; and in a second case the swinging of two entrenched tributaries cutting away the wall at some point between them, leaving what was formerly the projecting point, cut off as an island mesa. In either case the mesa may be partially or completely separated. The action is represented in the diagrams as having gone to the extent of diverting the tributary into the main stream back of the island mesa. This has no doubt occurred in a number of cases in the Rio Cimarron, where the mesas stand out boldly in the midst of the canyon, as in Figure 8. In other cases a more or less elevated ridge connecting the mesa with the canyon wall indicates that the neck was not entirely cut away, as in Figure 5. Such a mesa may be called a "*head-land mesa*," as distinguished from "*island mesa*."

From Folsom to Kenton the eastward dip of the formations is much the same as the grade of the river and the depth of the canyon remains approximately the same for many miles. It gradually widens downstream to a point near Kenton, where the Dakota sandstone descends more rapidly, bringing the base near the canyon bottom. Thence eastward the river flows in a narrow gorge between walls of Dakota sand-

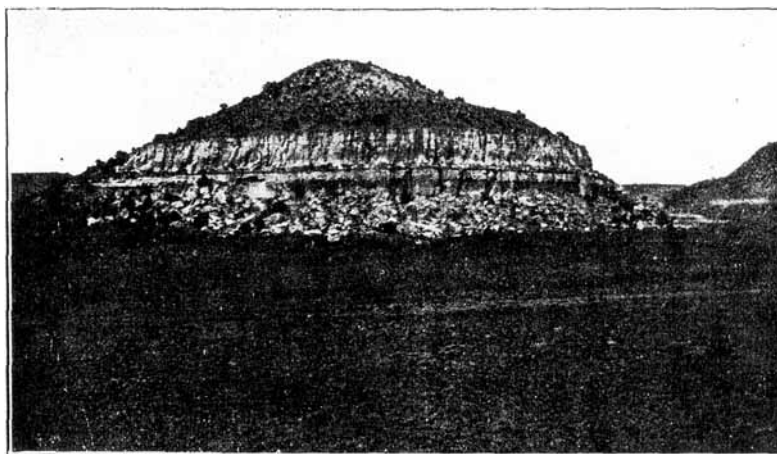
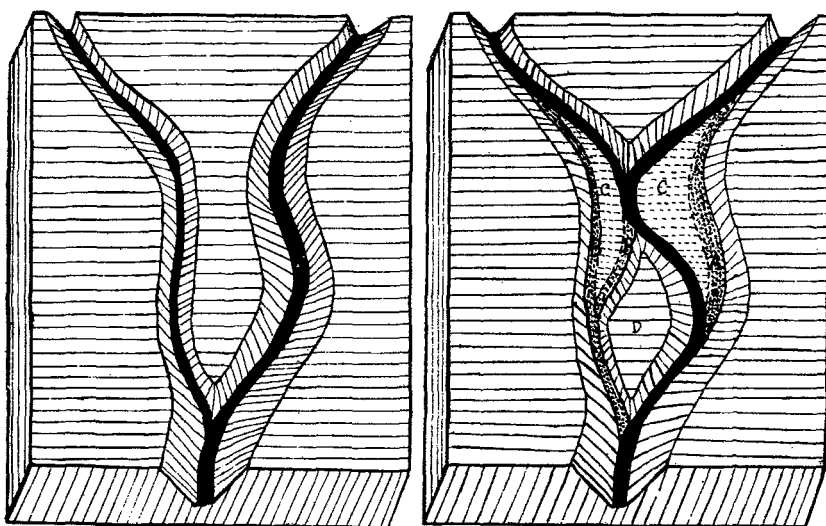


FIG. 8. One of the "*Island Mesas*" of the Rio Cimarron Canyon.

stone, until about 30 miles east of Kenton the sandstone gradually gives way and the river emerges from its gorge upon the broad open plain.

The Canadian Canyon.—The Red or Canadian River rises east of the mountains, near the northern border of New Mexico, and flows south-eastward to a point near Raton. Here it turns sharply to the south and flows parallel to the mountains, 50 miles or more from them, for a distance of about 125 miles, when it turns to the east and passes through Texas, Oklahoma and Indian Territory to the Arkansas River. In its southward



FIGS. 9-10. Diagrams illustrating the Formation of the Mesa Buttes of the Rio Cimarron canyon. (A) Old river channel. (B) Old tributary channel. (C) Graded floor. (D) Island-Mesa.

course along the mountains it receives several tributaries of considerable size, the more important of which are the Vermejo, the Ocate, the Mora and the Cimarron (not to be confused with the Rio Cimarron just described). These enter the Canadian from the west and bring the drainage from the eastern slopes of the mountains. In addition to the above named tributaries there are several of minor importance. Many of these do not reach the mountains. They represent the plains drainage and have little or no water except in times of flood.

The structure of the region drained by the Canadian is shown in the accompanying sections, Figures 11 and 12. The mountain streams from the west flow across, or rather cut through, the Ocate bench. From thence they flow for a time upon the surface of the Las Vegas plains,

but soon cut into them, forming canyons which open into the Canadian Canyon. In the neighborhood of these larger streams the Ocate bench is deeply dissected. But in places the surface is comparatively flat, with numerous alkali encrusted hollows, which contain water only in wet weather. This character of surface is well illustrated in Van Bremmer Park and Poñil Park, lying near the source of Poñil Creek. The greater part of the bench, however, is more or less deeply trenched by the streams flowing across it. After emerging from the Ocate bench they flow for a time over the marine Cretaceous shales and limestones, where broad valleys rather than canyons are formed. But when the Dakota sandstone is reached, a canyon proper always begins. The sandstone forms the rim with more or less perpendicular cliffs, while the softer shales and sandstones beneath the Dakota form more gently sloping sides, according as the layers are soft or hard. (See Figures 13 and 14.)

The side canyons, while small in proportion to the Canadian Canyon, are yet in themselves well worthy of attention. Unfortunately, satisfactory topographic maps of this region are scarce. The one compiled by R. T. Hill (Topographic Atlas, Folio 3) gives a general view of the topography, and a comparatively small area in the vicinity of Las Vegas is covered by a series of the more detailed topographic sheets of the United States Geological Survey. The Watrous Sheet gives an excellent example of the Las Vegas plains and of the side canyons opening into the Canadian (see Figure 15, frontispiece). The surface of the plains is so nearly level that large areas exist in which there are no well defined stream courses and in which "dry lakes" abound. In my journey over this region I found stretches of 25 and 30 miles where not so much as a spring was found from which drinking water could be obtained. But wherever the streams have cut through the surface sandstone (Dakota) deep canyons are formed, such as the Conchas Canyon and Canyon Largo. At the point where the Canyon Largo joins the Canadian, the canyon is about 1,500 feet deep.

The main canyon of the Canadian begins a few miles south of Springer, where the river enters a narrow gorge in the Dakota. Thence southward for 50 miles or more the stream is confined in a narrow canyon, having a maximum depth of about 1,500 feet. In no place observed within this distance has the river widened the canyon to any considerable extent. The stream is comparatively swift and is still rapidly abrading its bed. Within a distance of 50 miles it falls approximately 1,000 feet. Soon after emerging from this young canyon in the Las Vegas plains, the river turns to the east and occupies what is termed the Canadian Valley as distinguished from the Canadian Canyon. This valley is only a very

much widened canyon. The Canadian escarpment, previously referred to as one of the most wonderful escarpments in America, forms the northern wall of the valley, while the northern edge of the Llano Estacado, 50 to 75 miles to the south, forms the southern walls. The wall or escarpment at the west of the river, instead of extending to the south and east to form the southern wall of the valley, extends westward across the course of the Pecos River. In other words, that part of the Las Vegas plains which formerly extended southward and eastward between the Canadian and Pecos Rivers and probably joined the staked plains, has been cut away for a distance of about 50 miles, merging the two valleys virtually into one for that distance.

The valley bottom is not so well graded as are the Las Vegas plains. The rock formation is the Permian Red Beds, and instead of one especially hard layer controlling the surface, numerous moderately hard layers of sandstone occur, which cause the formation of many buttes, flat-topped mesas and stratum benches, making a rough and uneven surface. This is illustrated in the part of the Corazon sheet reproduced in Figure 15.

If we turn our attention to the history of these canyons, we must consider the Rio Cimarron and the Canadian together. If the data which I have at hand are not misleading, these rivers have not always been independent of each other. Some of the facts which must be taken into consideration in this connection are as follows:

1st. I have previously called attention to the extensive uplift in Southern Colorado and Northern New Mexico. The part which concerns the present discussion is the eastward and southward slope of the strata in the region drained by the Rio Cimarron and the Canadian Rivers. The surface formation of the northeastern part of the area covered by the accompanying sketch map—about one-fourth of the whole area—is the Dakota. The direction of slope of this formation is shown by the direction of the stream courses and by the contour lines.

2nd. I have already mentioned that the size of the Rio Cimarron Canyon is somewhat surprising when compared with the size of the stream which now occupies it. While it can scarcely be called a mature canyon, since the canyon bottom as a whole is far from grade, the broad floor and the comparative slowness with which the stream is now abrading its bed indicates that it is well on toward maturity. In some places the stream flows in a channel cut in flood plain deposit.

3rd. The Cretaceous formations probably extended at one time over the entire area discussed in this paper. The thickness of these formations, about 5,000 feet, according to Hills,* can scarcely be taken as

*R. C. Hills, U. S. Geological Survey—Elmoro Folio.

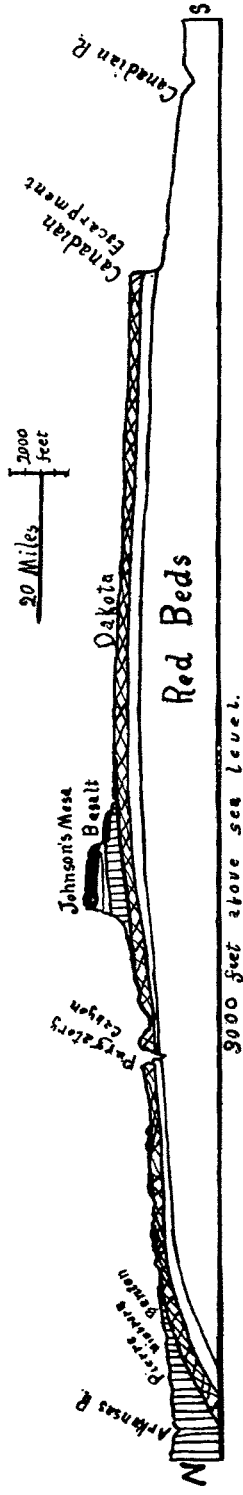


FIG. 11. A North-South Section from the Arkansas River to the Canadian River along the 109th Meridian.

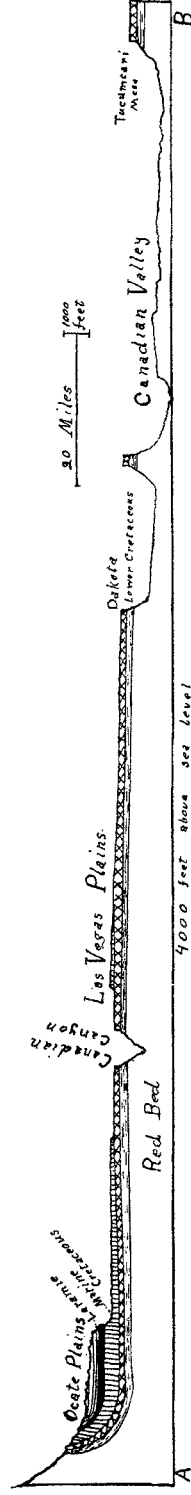


FIG. 12. Section from the Mountains southeastward to the Staked Plains along the broken line A B of Fig. 1 (page 65), illustrative of the relation of geographic form to geographic structure.

a measure of the original thickness further east. The Laramie and Pierre at least are variable and thin toward the east. The formations preserved by the lava caps of Mesa de Maya show a gradual thinning from top downward in an easterly and southerly direction. How much of this thinning is due to non-deposition and how much to degradation previous to the welling out of the lava cannot now be stated.

4th. In the Raton Mountains, a few miles north of the area covered by the sketch map, something near the original thickness is preserved. The maximum thickness of sediments now resting on the Dakota is about 5,000 feet. The average thickness would probably be between 3,000 and 4,000 feet.

5th. At various places underneath the lava sheets of the Mesa de Maya are found more or less extensive beds of river gravels. I have observed these beds particularly at Carrizo Springs, Colo., and in the vicinity of Folsom, N. M. At Carrizo Springs an exposure was found showing a thickness of sand, gravel and boulders, 100 feet or more in thickness. At a number of places along the sides of the mesas I have observed scattered pebbles and boulders in quantities indicating that they exist quite generally beneath the lava sheets, although not always in extensive beds. The thickness of the gravel deposits is difficult to obtain, owing to the readiness with which they crumble wherever exposed. The materials found in these gravel beds are the same as those found now in the beds of the streams which rise in the crystalline areas of the mountains. There are boulders of quartzite, gneiss, schist and various kinds of the more resistant granite rocks. These boulders were observed up to a foot or more in diameter, and all were well rounded and polished. At Carrizo Springs, Folsom and elsewhere large and permanent springs of pure cold water issue from the gravel beds. In several places where I found springs of more than ordinary size, I found also evidence of gravel beds beneath the lava.

The gravels are within the drainage area of the Rio Cimarron, but the source of that river is 60 miles east of the crystalline areas. It may be said in this connection also that the crystalline debris found in considerable quantities in the bed of the Rio Cimarron must come from these old gravel beds. There is no other obvious way for the material to reach the stream. It seems clear, therefore, that changes of considerable moment have taken place in the drainage of this region. The gravel beds seem to show that after the inauguration of the Tertiary and before the time of the lava outbursts, a strong stream rising in the mountains had established its course near the present course of the Rio Cimarron. The lava floods filled the valley, buried its gravels and

covered the surrounding country. When the drainage was reëstablished it seems to have been, in general, along the old lines, for parts of the lava-covered surface are found, both north and south of the present Rio Cimarron Canyon.

Another fact worthy of note in this connection is that the Rio Cimarron drops almost immediately into a broad canyon whose sides are in places nearly 1,000 feet high. Had the present stream been the sole agent in cutting the canyon, it is improbable that it would have pushed the canyon back so near its source.

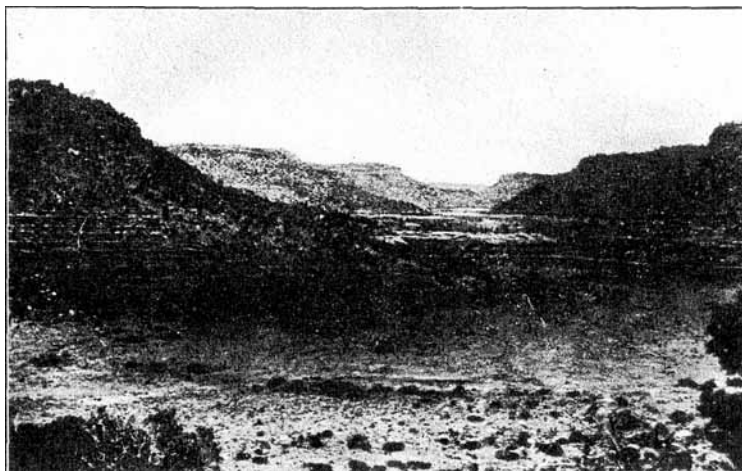


FIG. 13. Canyon of the Canadian near Mills Ranch, showing the Dakota River in the distance and the gentler slopes of the shales and Red Beds in the middle ground.

6th. The course of the upper Canadian for 35 miles is a little south of east. If it continued 20 miles further in this direction, it would form the headwaters of the Rio Cimarron instead of the Canadian. A few miles from Raton the river turns southward, making almost a right angle. For about 40 miles of this southward course, although it flows over the soft shales and thin limestone layers of the marine Cretaceous, it has cut but a shallow valley. A few miles south of Springer, however, it plunges into the young canyon just described. This canyon is in marked contrast with that of the Rio Cimarron and in still greater contrast with that which I have called the Canadian Valley. The volume of water in the Canadian is many times greater than that in the Rio Cimarron, and yet a canyon has been cut for only about 50 of the upper 125 miles of the river's course, while the Rio Cimarron plunges

into its canyon within about 12 miles of its source. The Canadian Canyon, then, is in its youth, while that of the Rio Cimarron is well on toward maturity. The Canadian Canyon opens abruptly into the Canadian Valley, with the escarpment or valley side passing across the canyon's course. It seems evident that the broad valley, 50 to 75 miles wide, is something more than the downstream continuation of the canyon.

7th. Between the upper Canadian and the headwaters of the Rio Cimarron lies a district of recent volcanic activity. Numerous volcanic cones and lava sheets occur there. Some of the craters indicate considerable age, while others, like Capulin (Figure 4), are but recently extinct. The relation of these volcanic outbursts to the canyon cutting is shown near Folsom. The Rio Cimarron Canyon has been cut to nearly its present dimensions through the old mesa lavas and the underlying sediments when the head of the canyon was flooded to a depth of 200 to 300 feet by a lava stream. This lava was then cut away, leaving portions of it along the canyon sides to mark its former level, and the canyon cut to its present dimensions. At a very recent time a lava stream poured down the canyon and still occupies the floor for some 15 miles or more.

The foregoing data are confessedly inadequate for the purpose of drawing definite conclusions. The region is large and much remains to be learned of it. Accurate detailed maps are wanting. I venture the following postulates, with a knowledge of the limitations, and subject to revision as future investigation shall throw light on the problems.

There seems to have been a river of considerable size flowing from the mountains eastward over the surface now represented by the lava-capped mesas of Southern Colorado and Northern New Mexico, previous to the outbursts of the mesa lavas—the older flows. This river degraded the land extensively, cutting as far down as the Dakota sandstone to the east and south. This degraded area was flooded with lava, forming a sheet which was probably continuous over something like 4,000 square miles. The lava-covered mesas extend now for a distance of 85 miles east and west and something over 40 miles north and south. There is every indication that the lava sheets originally extended for a great, though unknown, distance beyond the areas where they now occur. There are wide areas covered with lava flows south of Folsom, but it is uncertain whether they belong to the older or to the younger flows. If these should be included, the estimate of 4,000 square miles should be greatly increased—perhaps doubled.

At the time of the older lava flows, or soon thereafter, the surface

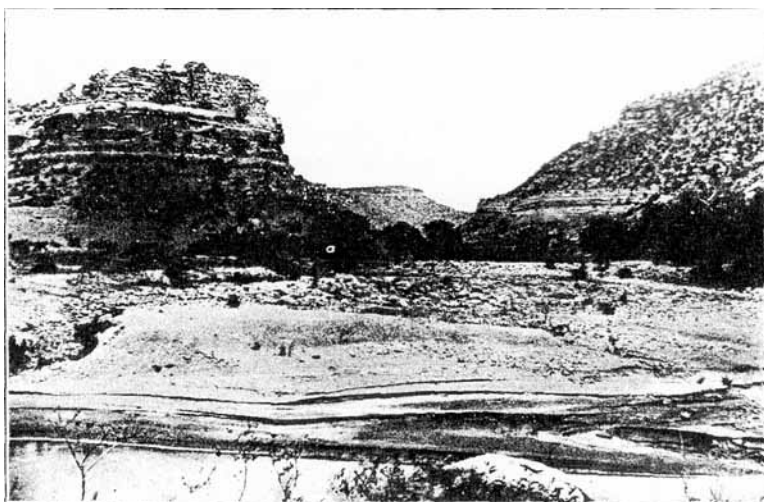


FIG. 14. *Red Beds in the Canyon of the Canadian. The floor is wholly submerged in times of flood.*

seems to have been elevated and the newly formed or reestablished streams began the colossal work of canyon cutting and mesa forming, which appears in this region. The Rio Cimarron at this time probably extended westward to the mountains and was a much larger stream than it is at the present time. At a much later date, when the Rio Cimarron Canyon was practically complete and the general surface degraded to something near its present condition, came the later and more restricted volcanic disturbances in the vicinity of Folsom. The disturbed district is directly in the path of the postulated old Rio Cimarron. It is probable that these later volcanic disturbances, and possible crust movements accompanying them, cut off the headwaters of the Rio Cimarron and deflected them to the south. There may also have been a tilting of the surface to the south at the same time, which gives the southward trend to all of the tributaries of the Canadian as far south as Conchas Creek. Whether from tilting or from some other cause, it is probable that at a comparatively recent date the headwaters of the Rio Cimarron were turned southward into the Canadian River and the cutting of the Canadian Canyon begun.

The quantity of material removed from this region, as indicated by the mesas and canyons, is well worth attention. The amount of work done may not be especially remarkable when compared with that of other rivers, but the present topography is such as to present the amount of

degradation to the mind of the observer in a somewhat remarkable way. Take, for example, the journey from the Canadian Valley northward to the mesa region. From the valley, 50 to 75 miles wide, one ascends the escarpment, 1,000 to 1,500 feet, to the Las Vegas plains. Fifty to eighty miles to the northward stands the escarpment of the Ocate bench, and still further north appear the great lava-capped mesas. Between the level represented by Fishers Peak and that of the Canadian River, where it emerges from the escarpment into the Canadian Valley, a thickness of about 5,000 feet of rock has been removed. From Fishers Peak to the general level of the plains a depth of about 3,500 feet is obtained within a horizontal distance of a few miles. At the mouth of the Canadian Canyon the walls are about 1,500 feet high. These two figures alone make up the 5,000 feet, irrespective of some depth represented by the gentler slopes of the plains.

While something near the original thickness of the formations is preserved in the western part of the region, there is nothing in the eastern part to indicate the amount of surface degradation. As I have already pointed out, the rivers of early Tertiary time degraded the region to a great though unknown extent. The actual amount of degradation, therefore, for the entire region cannot be estimated in any satisfactory manner. Not so, however, with the broad valley of the Canadian. While it represents but a small part of the total amount of erosion of the region, a rough estimate may be of use in gaining some conception of the amount of work done over the entire region. An inspection of such topographic maps as are available indicates that more than 5,000 square miles are included in the Canadian Valley within the territory of New Mexico and between the bounding escarpments. The depth of the valley below the surface of the high plains in which it is carved is 600 to 1,000 feet at the eastern limit and something over 1,500 feet at the western limit of the region. Along the line of the accompanying section (Figure 12), the river bed is about 2,000 feet below the rim of the escarpment to the north. The roughness of the valley floor makes anything but a rough approximation of the average depth impracticable at present. But it is certainly conservative to estimate that an area of 5,000 square miles has been degraded to an average depth of 1,000 feet. Accepting this estimate, about 947 cubic miles of material have been carried away in the excavation of the Canadian Valley alone. But this amount, great as it is, seems small when one tries to realize the amount of material which must have been carried away in the process of carrying out the Las Vegas plains and lava-capped mesas.