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NOTES
ON THE
GEOLOGY OF NORTHEASTERN NEW MEXICO.
BY
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In the region of the headwaters of the Canadian is embraced a territory which, for the completeness of its geological record and the interest of its concomitant topographical and scenic features, is not excelled perhaps by a similar extent of country in the West. It is bounded on the west by the Spanish range, which in this part of its course consists of a densely-wooded watershed-divide, 9,000 to 11,000 feet in altitude, from which at intervals lofty lateral spurs are thrown off, whose bald summits overtop by 1,000 to 2,000 feet the actual watershed, which latter extends in a general north-south direction. Near the Colorado line, the range is intersected by the Raton Mountains, a range of gladed hills extending eastward forty or fifty miles, and constituting, with the still easterly prolongation in the Chicorica Mesa, the northern limits of the district, which opens out to the southeastward into the great plain. Thus defined, the district comprises an area of about twenty-five hundred square miles.

During the season of 1869, in the progress of his extended reconnaissance of the Rocky Mountains, Dr. Hayden visited this region, from whom we have authentic account of its general geological features, and their intimate relation to those prevailing in other and similar districts to the north and south. A few months' residence in this part of the country in 1874-'75* afforded the writer opportunity to become somewhat familiar with its geological features; and the purpose of the present communication is to present such facts as may tend to contribute something toward a similar knowledge of remote and perhaps hitherto rarely-visited localities, and their connection with already-examined districts.

THE UPPER BASIN OF THE CANADIAN.

In the mountains along the western boundary of the district, many little streams take their rise, which, flowing southeasterly across the great Tertiary plateau, whose surface they score with rugged gorges and beautiful little valleys, finally emerge into the upper basin of the Canadian. This basin forms one of the peculiar and interesting features of the region, and which deserves passing notice, as well on account of its scenic surroundings as the important part it must eventually take when the time arrives for utilizing its thousands of acres of fertile irri-gable lands. Among the most important of these tributaries are the Vermejo and the Cimarron; the affluent which retains the designation of the principal stream rising in the plateau, its drainage being entirely derived from the Raton ridge. A short distance below the mouth of the

* It is with peculiar pleasure the writer seizes the opportunity to express his acknowledgments to his friends Messrs. Frank Springer and W. R. Morley: to Mr. Springer he owes the possibility of a pleasant sojourn of several months at Cimarron; and to Mr. Morley he is indebted for valuable data, especially relating to the topography and hypsometry of the country.

latter, the Canadian glides into its great cañon, and thence, far to the south, its channel is said to be walled in by precipitous bluffs of red and variegated sandstone. At the entrance to the cañon, the lowest point in the basin, the stream has an altitude of about 5,700 feet above tide-water. In the distance of forty-five miles direct, or to the confluence of the Rio Mora, the stream has a descent of probably 700 feet, along a part of its course but little known, and, it is believed, as yet unexplored by the geologist. Above the cañon, the stream traverses a broad valley, which gradually slopes from the base of the Tertiary plateau on the west; its eastern border being less uninterruptedly defined by the confused range of volcanic hills and basalt-capped mesas, which rest upon and pierce the sedimentary formations south and east of the Chicorica Mesa, a shallow, triangularly-shaped basin, with an area of about nine hundred square miles, its sharp angle terminating near the southern foot of the Raton Pass, amidst the gorges which mark the western limits of the great basaltic table-land, where the valley reaches near 6,500 feet altitude.

Dr. Hayden has already noted the peculiarities of the basin, attributing its origin to the erosion of the Tertiary lignitic formation, which at a former time doubtless occupied the entire extent of the valley, and stretching far eastward into what is now comprised in the plains, where its ancient border, if at all recognizable, is obscured by superficial accumulations.

Cretaceous.—This upper basin is everywhere underlaid by the Cretaceous, the upper deposits of which here consist of heavy measures of shale, with intercalated thin bands of indurated and calcareous matter, attaining approximately a thickness of 800 to 1,000 feet. These deposits have been recognized as the equivalent of formation No. 4 of the series on the Upper Missouri, and it is to their yielding nature that the gentle slopes and comparatively uniform surface which characterize the basin are attributable.

In the vicinity of the Cimarron, where they exhibit the greatest vertical extent of any single exposure in the abrupt declivity of the Tertiary plateau, underlying the sandstone of that age, they afford a section of above 500 feet, constituting quite half the entire elevation of these border hills. The deposit is here seen to consist of generally dark-blue shales, the upper 190 feet being more of a grayish blue, with little, if any, arenaceous material intermixed. Ninety feet below the base of the Tertiary, concretionary argillo-calcareous masses, generally of small size, are met with, affording fragmentary specimens of *Baculites*, *Inoceramus*, &c.; and 180 to 190 feet from the top occurs a thin band of shale, from which have weathered numerous and beautifully-preserved fossils, characteristic of this period. Below the latter horizon there occurs a rather marked band of large concretionary masses, also containing similar fossils to those mentioned above, below which, however, evidences of life are rarely met with until reaching a horizon some 370 feet below the top; and thence 200 feet lower occasional fossiliferous bands occur, always characterized by the peculiar Cretaceous *facies* of their faunæ.

Between the latter point and the Canadian, twenty-five miles to the east, similar shales apparently compose the bulk of the strata, with, however, as we approach the lower levels, more frequent interpolations of calcareous bands, which often form regular layers of blue argillaceous limestone of a foot or more in thickness. Near Mr. Henry M. Arms's (Loomis's ranch), a few miles above the mouth of the Vermejo, and near the confluence of Crow Creek, one of these thin limestone beds outcrops in the base of a low outlying mound, which affords an

interesting association of Cretaceous forms, consisting of numerous *Inocerami* and *Ostrææ*, besides *Ammonites*, *Scaphites*, *Baculites*, and the fragmentary remains of fishes, representing at least two Teliostean genera and a Squaloid *Galeocerdo*. In the plains east of the Canadian, similar and more extensive limestone deposits are known to occur, which are reported as containing the same faunal assemblage.

Post-Tertiary.—From the base of the abrupt western boundary of the basin, the Cretaceous shales descend in gentle interrupted slopes far out into the valley, and which at one time must have formed a continuous shelving beach-like declivity along the flanking hills. But in the process of the drainage of the basin and the consequent deepening of the channels of the numerous streams which come down from the mountains and neighboring table-lands, this sloping terrace was subjected to extensive erosion, until it now presents the condition of so many terrace-benches descending into the plain between the embouchures of the little valleys. They present all the phenomena of the Terrace epoch, notwithstanding they are wrought out of the Mesozoic deposits, and the mouths of the larger valleys are occupied by series of terraces in all respects resembling in form and position those which, in other parts of the country, are entirely made up of re-arranged drift materials.

The terrace-benches which fill the mouth of the Cimarron Valley may be regarded as typical examples of these formations, in the molding of which the waters of the Cimarron have played an important part. Here there are at least four or five well-defined benches, ranging in height above the present level of the stream from a few feet to 300 feet. The two highest of these benches, which now occupy the divide between the Cimarron and Cimarroncito, are, however, themselves probably but remnants of the old lacustral beach which once extended continuously along the foot of the Tertiary plateau. The lower and by far the most extensive of these *old* benches attains an elevation of about 200 feet, forming a low mesa extending along the south side of the stream a distance of three miles. Its summit gradually slopes toward the plains, and, like the preceding, is clothed with a thin layer of coarse drift, the degradation of which has thickly strewn the declivities with small boulders and pebbles, effectually concealing from view the Cretaceous shales upon which it rests. This mesa has been pierced by two or three lateral arroyas, besides the little valley which intervenes between its western extremity and the foot of the Tertiary-capped hills, in the sides of which natural sections of the fossiliferous Cretaceous shales are exposed at various points. The next distinct bench is that which occupies so considerable an area along the south side of the stream, and which drops to the level upon which the town is principally built, though it continues to follow the stream lower down, but much diminished in width. Above the town, this bench reaches the height of 50 to 60 feet, and at a point where its base is washed by the stream an interesting section is exposed, showing the character of the superficial deposits which here deeply cover the terrace. The lower 30 feet or more of the exposure is made up of dark-blue shales of the Cretaceous period. Resting upon these occurs a heavy deposit of modified drift, the lower portion of which is apparently largely composed of sand with streaks of gravel; the upper six or seven feet exhibit a distinct deposit, made up of water-worn boulders, pebbles, and gravel, which seems to immediately underlie the fine soil with which the terrace is mantled.

Similar exhibitions of terrace-formations, as before stated, are met with in the mouths of all the valleys penetrating the great Tertiary plateau, and perhaps nowhere are they more conspicuous and symmetrical

in contour than in the recess into which the Cimarroncito opens out on leaving its picturesque mountain-hemmed valley. Here, in consequence of the rapid pitch of the valley, the terraces have a more marked inclination with the stream than is observed on the Cimarron, and where they present several distinct levels, often isolated, forming low drift-covered mesas or wide slopes rising upon the flank of Urac Mountain.

Besides these more strictly fluvial formations, in places the borders of the basin are marked by low benches of considerable extent, and which are distinguishable from those occurring immediately along the water-courses by their more level surfaces. Between the Rayado and Cimarron, as also between the streams to the north of the latter, these benches form several levels connected with the main slope flanking the Tertiary plateau, and which are usually distinctly defined by the abrupt descent facing the plain, as shown in the sketch of the Baldy range and that of the Tanaja Mountains. Their tops are covered by a thin sheet of fine drift-material, or the soft Cretaceous shales constitute the subsoil. At other places, limited tracts of barrens are encountered, where deposits of loose sand have accumulated, which the winds mold into ever-varying miniature downs, and whose vegetation, if not peculiar, is distinguished by the prevalence of cacti and those plants which thrive in a sterile soil.

The latter system of terraces probably are more properly referable to an earlier time, when the drainage of the basin was effected; while the modifications resulting in their present conformation is as probably due to the combined erosive action of the Canadian and its numerous affluents, when their volume of waters, issuing from the vast reservoirs in the mountains, was far greater than at the present time.

The nature of the loose materials covering the terraces in the mouths of the valleys plainly indicates the source of their derivation in the mountains to the west, and which were brought down at a period antecedent to the time when the streams had deepened their beds to their present level. The coarser materials and bowlders (the latter generally of small size) largely consist of granitic and gneissic rocks, with a variety of igneous and metamorphic material, whose parent ledges, from which they were torn during the Glacial epoch, are met with in the mountains a few miles distant. But these plains accumulations are insignificant compared with the vast deposits which fill some of the park-like valleys in the heart of the mountains, and which rise high upon the enviroing declivities.

Besides this comparatively thin sheet of drift-material, the plain is here and there occupied by low buttes and mesas of limited extent, remnants of the Cretaceous shales, the summits of which are often covered by a sort of concrete, consisting of coarse gravel cemented with lime. One of these outcrops occurs on the summit of the elevation near Mr. Arms's, forming a coping to the little mesa upward of three feet in thickness, its presence serving to protect the soft underlying shales from atmospheric erosion. Similar deposits are met on the lower course of the Poñil, a tributary of the Cimarron, where the outcrop appears in the low bluff-banks, at a level possibly not much higher than the exposure on the Canadian just mentioned. It is evident that this concrete deposit is of quite modern origin, but its relations to the drift and late Tertiary deposits are not so clear. It would, however, appear to antedate the drift, the modified strata of which its comparatively limited extent recalls, from the fact of its occurrence on the tops of the outlying remnants of the Cretaceous in the midst of the basin; while it is undoubtedly of much more recent origin than the sandstones at the base of the Lignitic formation, from which it widely differs in the char-

acter and mechanical and chemical aggregation of its components. It would appear highly probable that these deposits prove to be identical in age and origin with similar accumulations observed by Dr. Hayden on the plains bordering the foot-hills in Colorado.

Besides these, the superficial deposits occurring in the basin proper are all referable to the disintegration of the immediately subjacent strata; and these consisting in the main of the soft Cretaceous shales, the soil resulting plainly bears the stamp of its origin in the extremely finely-comminuted condition of its components, and which are in places mixed with a greater or less percentage of arenaceous material derived from the Tertiary formation. This soil supports a fine growth of the peculiar gramma-grass, which affords throughout the year excellent pasturage. The country is already occupied by many enterprising stock-growers, whose herds and flocks roam the broad plains and are counted by thousands. Along the water-courses, wherever water can be easily conveyed by means of acequias for irrigation, the soil produces abundant crops of corn, the cereals, and various vegetables, demonstrating its fertility and the adaptability of the climate for agricultural as well as pastoral pursuits.

Manifestations of igneous phenomena.—Incidental reference has already been made to the basaltic-capped mesas and isolated volcanic cones which constitute the northern and northeastern limits of the basin, and we would here refer to similar deposits and other evidences of comparatively modern igneous activity, which are manifested within the limits immediately under consideration. Forming a natural boundary along the south line of the district, the mesas of Rayado and Gonzalitas extend far out into the plain, above which they rise a thousand feet or more. The great bed of basalt with which their summits are protected once plainly formed an unbroken sheet of igneous matter with that lying immediately to the west, and forming a narrow belt here reclining upon the granitic or metamorphic deposits, which spread over a considerable tract surrounding the Black Mountain group, a section which is intersected by mountain-ridges, marking the denuded crests of gigantic dikes, the evidences of an earlier epoch of igneous activity, a mountain-building epoch in contradistinction to that in which originated the great basaltic mesas, and still later scoriaceous volcanic cones. It is here these modern and ancient products of igneous activity are most intimately associated; the great Chicorica overflow being some fifty miles distant from the igneous manifestations seated in the main range, with the extensive plateau of the Tertiary intervening, which bears no observed evidence of having been involved in the basaltic inundation, the vestiges of which occupy so large a region to the east and south.

While the basin of the Canadian is partially surrounded on two sides by the immense basaltic-capped mesas, the flat summits of which rise 1,000 to 1,500 feet above its surface, the plain itself is everywhere traversed by dikes, the similarity of the components of which would refer them to the same age as that to which belong the enormous overflow in the table-lands. These dikes are of all dimensions, the majority varying in width from 1 to 2 feet, though sometimes much greater, and bearing, if not always, at least in all those at present known, nearly east-west. Their presence and course are plainly discernible by the low ridges of dark basaltic *débris* marking their outcrop in the surface of the plain; in few instances exhibiting rude horizontal crystalline structure, a fine example of which occurs near the southern entrance of the Raton Pass, which has been mentioned by Dr. Hayden. Usually, however, they present an amorphous structure in great variety,

scarcely two dikes having precisely the same mineral constituents and aggregation, though all agreeing in their more or less somber hues. Practically vertical, in several instances a slight northerly inclination from the perpendicular has been noted, while an opposite pitch has not been observed, although such may occur.

These miniature dike exhibitions offer a most interesting field for investigation, both on account of the variety in mineralogical combinations as also the phenomena connected with their occurrence. Although more apparent in the plains where the soft shales have weathered away, leaving the more rugged basalt standing up in long ridges above the surface, strongly contrasting with the prevalent green and drab herbage tints, they are probably equally well represented in the Tertiary plateau. Indeed, in the great slide in the point of bluffs between the Cimarron and Poñil, a small dike may be traced up through the Cretaceous shales into the overlying Tertiary sandstone, where it is lost to view in the *débris* accumulated upon the slope. Mr. Morley has observed in the cañon of the Canadian, in the vicinity of the Raton divide, a similar dike, connected with which he reports most interesting phenomena. The dike is thrust up through the Tertiary strata, and at the locality referred to, it is exposed at a point where it crosses a thin bed of lignite, which it has converted into graphite. The extent of this intense metamorphism was not ascertained; but it is probably limited to a few inches either side of the protruded igneous matter, unless the dike be a large one, in which case its metamorphic action would be proportionately extended laterally. Wherever these protrusions of igneous matter are favorably observed, they are seen to have exerted to a greater or less degree metamorphic action in changing the immediately contiguous strata through which they pass. Thus, in the Cretaceous deposits, the shales are converted into tough slate, the effects of the metamorphism gradually diminishing the farther removed from the originating cause. When the dike crosses a calcareous deposit, the intense heat has had the effect, to a limited extent, of partial calcination, by which whatever organisms it may have contained are obliterated almost past recognition, while the mass of the rock is more or less hardened.

An instance where the lateral extent of metamorphic action may be readily examined occurs in the foot of the little mesa near Mr. Arms's, on the west side of the Canadian. At this locality a couple small dikes protrude above the surface, forming miniature parallel ridges about eighteen yards apart, with a strike nearly east and west. They vary somewhat in width, averaging about fifteen inches, and nearly vertical. At frequent intervals, they are interrupted by abrupt fractures, sometimes resulting in an oblique break; in other instances, the dike is completely dislocated, the overlapping extremities being attenuated, the intervening shale much broken and polished, with slickenside surfaces. The shales otherwise exhibit no indications of disturbance, the igneous matter having been admitted through a simple fracture or parting of the strata. Immediately contiguous to the dike, the shales are much altered, becoming very hard, and showing distinct cleavage-structure, the metamorphic action extending three to five inches either side. The shales are charged with a species of *Inoceramus* and fish-scales, which occur equally abundant in the hard metamorphosed portion.

Perhaps three miles below Cimarron, in the interval between the high terrace-mesa which extends along the north side of the stream, and which is here interrupted by a shallow arroyo, a narrow dike, averaging perhaps two feet in thickness, may be traced upward of three hundred yards in a nearly east-west direction. Its course is less direct or

regular than is usually observed, and near the middle occurs a sort of miniature crater, or "blow-out", as these phenomena are familiarly termed here. The annexed diagram indicates the relation of the crater-vent (α) to the main dike. (Plate 43, Fig. 1.)

Here the metamorphism is also very apparent, the shales being changed to slate a distance of twelve to twenty inches either side of the dike.

Following down the arroyo a short distance southward, the low bluffs immediately bordering the north bank of the Cimarron are reached, and which are here capped by a bed of basalt two to four feet thick. This bed seems to conform to the planes of stratification of the Cretaceous shales, which in places overlie the intruded igneous deposit, and which are changed for a few inches in depth above and below. In the main, this bed is quite regular, extending above half a mile in the face of the bluff, at the upper end of which it has been wrought for building-material. But at one point it seems to be connected by a sort of "blow-out" with another and higher bed, which latter occupies a position fifteen to twenty feet higher, outcropping at the surface over a considerable extent, but overlaid by seventy-five feet or more of shales in the mesa at the lower extremity of the bluffs. The igneous matter of these basaltic beds appears to have followed the planes of stratification in the Cretaceous shales, so that their outcrop in the face of the bluff has all the appearances of a sedimentary deposit; and, but for the nature of its composition and the prevalence of minute crystals of quartz, and perhaps one or two zeolites, together with the singular concentration or "blow-out" of molten matter by which some sort of connection is established between the two masses, their true character might be entirely overlooked in a cursory examination. Whether the horizontal fissures have any connection with the beforementioned vertical dike could not be ascertained; but that they owe their origin to some such relationship hardly admits of a doubt.

THE TERTIARY PLATEAU.

Occupying the angle between the main range on the west and the Raton Hills to the north, comprising an area of about six hundred square miles within the borders of New Mexico, occurs the great Lignite formation of the Tertiary. This formation, in consequence of its vast mineral wealth, consisting of deposits of coal and iron, has received perhaps even more critical examination than has been bestowed upon the older sedimentary formations with which it is associated throughout the region south of the Colorado divide; and the little we may add from the present examinations is rather designed to show its extent in this particular region than further details relating to its stratigraphy.

The eastern border-limits of the formation appear in the line of lofty bluffs which flank the western margin of the basin of the Canadian, extending from the Raton Pass in a southwesterly direction above forty miles to the Cimarroncito; thence stretching northwesterly some ten or fifteen miles to Ute Valley. To the south of the Cimarron River, the formation occupies a narrow belt, where the strata show apparent signs of having participated, at least to a slight degree, in the uplift parallel to the Urac ridge, a spur extending eastward from the Black Mountain group and terminating in the plain between the Cimarroncito and Urac Creeks, forming a lofty granitic barrier 2,000 to 2,500 feet above the plain, and which defines the southern limits of the Raton coal-field.

The rounded condition of the quartz particles in the granitic mass of

the Urac ridge would seem to indicate the mechanical origin of these deposits, though metamorphism has entirely obliterated every other trace of their original character. The same metamorphic action may yet be found to have extended to the more recent formations which rest upon the flank of this great lateral spur. But the Cretaceous, as also the Tertiary beds, have been removed by the erosion of the valley of the Cimarroncito, so that the slope of the granitic ridge is barred, except perhaps insignificant outliers of inclined Cretaceous strata, which have escaped degradation, as if to afford a clew to their former extent and intimate relation to the subordinate axis of upheaval. Indeed, in the low ridge through which the Cimarroncito has cut its lower cañon, and not more than a mile north of the Urac Mountain, the Tertiary sandstones are gently upraised, and bear unmistakable evidences of metamorphism in their semi-quartzose character. Just beyond this point, at the foot of a charming grassy nook, through which the merry little stream winds in the descent of its boulder-strewn bed, a picturesque escarpment of light granitic rock rises over the stream, forming a craggy battlement along its northern margin. So it would appear that we have already gained the threshold of that old igneous belt which had its seat of origin or culmination in Great Baldy, at the head of the Moreno Valley, twenty miles to the northwest—an outburst of igneous activity similar to, though less marked than, that in which originated the twin cones of the Spanish Peaks, to the north of the Purgatory.

From the eastern flank of Great Baldy northward, the Tertiary deposits follow the somewhat irregular zigzag trend of the main watershed separating the drainage of the Canadian from the basin of the Rio Grande, until reaching the Francisco Pass, at the initial point of the Raton Hills, on the northern boundary of the Territory, or about thirty miles in a direct line nearly due north of Baldy. To the east, the entire country is occupied by the Lignite formation, which is abruptly terminated in the lofty escarpments bounding the valley of the Canadian.

The Raton Hills form a broad-topped ridge, culminating in the watershed between the Purgatory, an affluent of the Arkansas, and the headwaters of the Canadian, and which attains an altitude of between 8,000 and 9,000 feet. From the point where it impinges upon the main range, it stretches nearly due east forty miles, and abruptly terminates amidst the wild ravines and pretty glades at the foot of the basaltic wall capping the Chicóricá Mesa, in the neighborhood of the stage-road over the Raton Pass. From a high point near the summit of the pass, at an altitude of near 8,000 feet, the topographical features of the ridge and its relations to the great Tertiary plateau are advantageously displayed. The main divide perceptibly rises to the westward in rounded wooded heights; but to the southwestward files of successively lower undulations or ridges appear, clothed with pine and a variety of dwarfish deciduous growth, marking the courses of the numerous drainage-channels which traverse the plateau from their sources in its western border. Here, too, are observed those conspicuous terrace-like steps which are the records of early shore-lines in the drainage of the ancient waters which occupied the region bordering the eastern flank of the mountains during the epoch preceding our own. These benches—variable in height and distinctness of definition, often forming considerable escarpments or sharp declivities, according to the nature of the deposits, whether arenaceous shales or more consolidated sandstone, out of which they are wrought—constitute interesting features in the topography of the plateau, distinctively peculiar to this formation. Hence it is that when the great eastern escarpment is viewed from a short distance out in the plains, the formation reveals

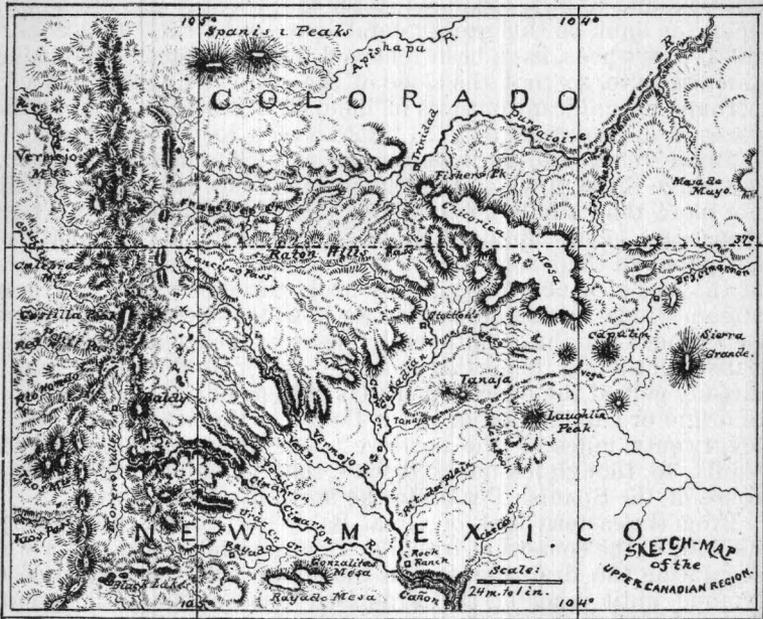
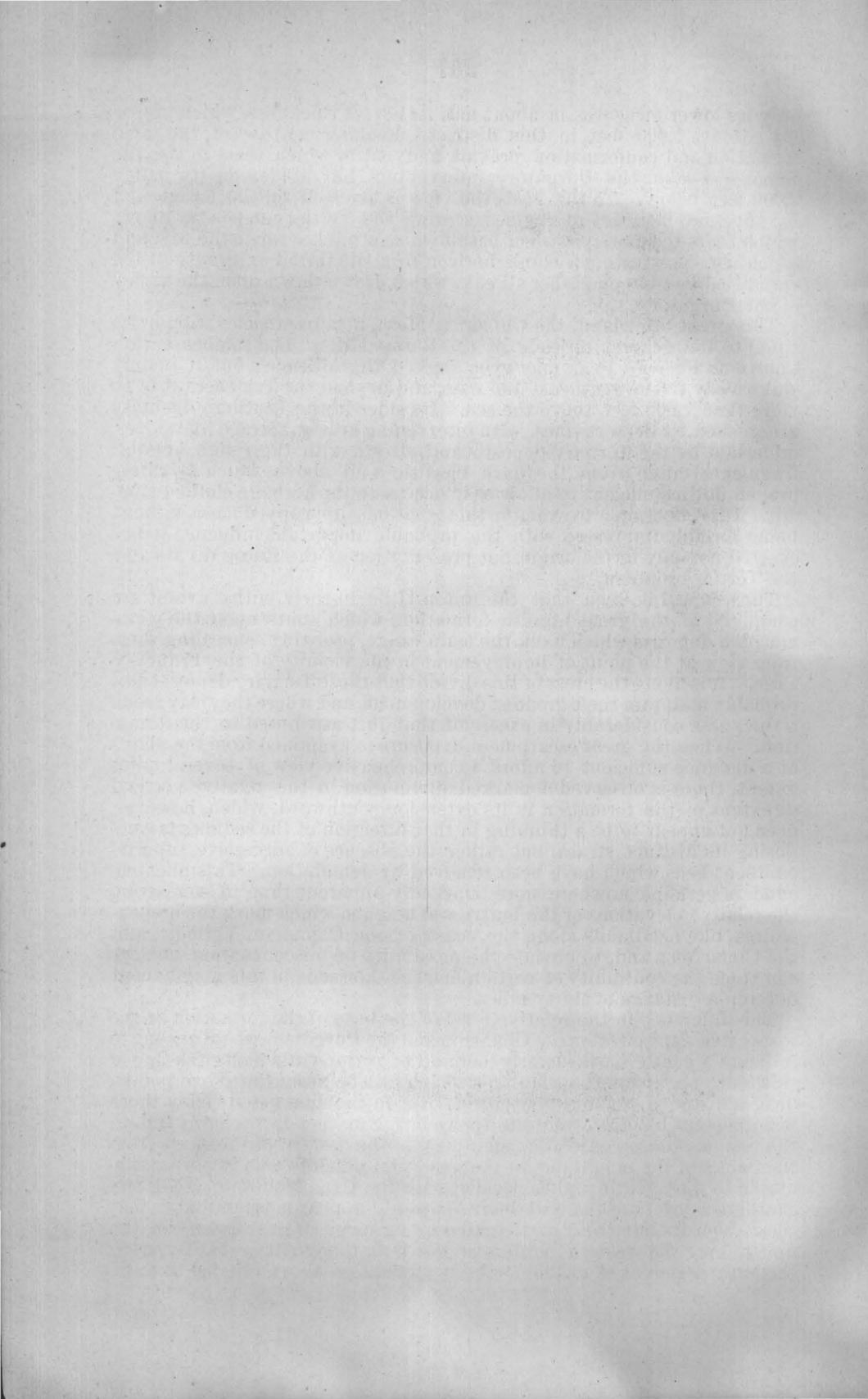


Fig. 1

Fig. 2



Great Baldy Range, from near mouth of Pottil Creek; looking N.W.W.
 Black Mt. Little Baldy. Great Baldy. mouth of Pottil Cañon.
 south of Cimarron Cañon. Blackhorse Pass.
 side-exposure of Cretaceous shales, overlaid by Tertiary



only its lower measures, or about half its actual thickness, which probably reaches 1,000 feet in this district. Looking northward, the same formation and conformation prevail, and out of which seem to rise the Spanish Peaks, the Purgatory intervening, but hidden in its valley 2,000 feet below. To the east, the view is arrested in the foreground by the wild intricacy of ravines scoring the Tertiary deposits, above which rears the massive wall of basalt which stretches far to the east and southeast, constituting a blank horizon from its initial extremity in the embattled heights of Fisher's Peak, which frown down upon the valley of the Purgatory.

This great table-land, the Chicorica Mesa, attains an elevation quite equal to the general altitude of the Raton Hills. The somber outlier known as Fisher's Peak may even exceed this altitude; but it plainly sinks away to the southeast and east, and beyond the Trinchera it is no more than 7,000 feet above the sea. Its sides in the southern declivity are gashed by deep ravines, with intervening grassy, terrace-like slopes, underlaid by the Tertiary deposits and strewn with the rough angular fragments fallen from the dark basaltic wall above, which is rarely broken down sufficient to allow easy access to its herbage-clothed summit. It is impossible to examine this great basaltic-capped mesa without being forcibly impressed with the probable important influence it has exerted not only in the origin but preservation of the Raton divide and the Tertiary plateau.

Thus, it will be seen that the Raton Hills in their entire extent are composed of the great Lignitic formation, which abuts upon the metamorphic deposits which flank the main range, probably concealing them from view at the point of impingement in the vicinity of the Francisco Pass. It is along the crest of this divide that these Tertiary deposits also probably maintain their greatest development, and where they may reach a thickness considerably in excess of that just attributed to the formation. When the great escarpment-exposure is examined from the plains at a distance sufficient to afford a comprehensive view of several miles extent, there is observed a marked diminution in the relative vertical in extent of the formation in its extension southward, which, however, does not appear to be a thinning in that direction of the sediments composing its distinct strata, but rather the absence of successive superincumbent beds which have been removed by denudation. This phenomenon is perhaps nowhere more markedly apparent than in comparing the relative elevations of the buttressed heights, which mark the embouchures, like headlands along the coast, of the Canadian, Vermejo, and the Cimarron; and, to obviate the possibility of misconception, the eye can trace the continuity of certain marked horizons in this magnificent outcrop a distance of thirty miles.

The difference in the relative level of the base of the formation at the respective exposures on the Cimarron and the Purgatory would appear to indicate a gentle northeasterly inclination of the strata along the line of this outcrop, amounting perhaps to 700 feet between the above points, or in a distance of about fifty miles. But to the unassisted vision there is no perceptible dip, while the apparent inclination is probably due to the line of outcrop extending obliquely to the descent of the strata from the flanks of the mountains to the west, and possibly also in part attributable to the gentle uplift parallel with the Urac Mountain along the southern borders of the coal-field. It would appear most probable that these deposits have also participated to a greater or less extent in the uplift along the western borders of the field, though it is hardly more certainly apparent than the northerly inclination above alluded to until

arriving at the base of the mountains, where, in places, it may yet be demonstrated that these comparatively modern deposits have been suddenly tilted and more or less changed by metamorphism in the upheaval of the great lateral spurs, as instanced in the eastern flank of Great Baldy. In the shallow recesses between the outbursts of igneous activity, which threw up the gigantic masses domineering the range, these beds may extend up to the old metamorphic ridge, upon the flank of which they may rest in comparative undisturbed condition.

The following profile-section (Plate 43, Fig. 2) is introduced to show approximately the superposition of the Tertiary and Cretaceous formations as they appear in the eastern border of the Raton plateau between the Purgatory near Trinidad, and Urac Mountain south of the Cimarron, and the relation of the plateau to the Spanish range.

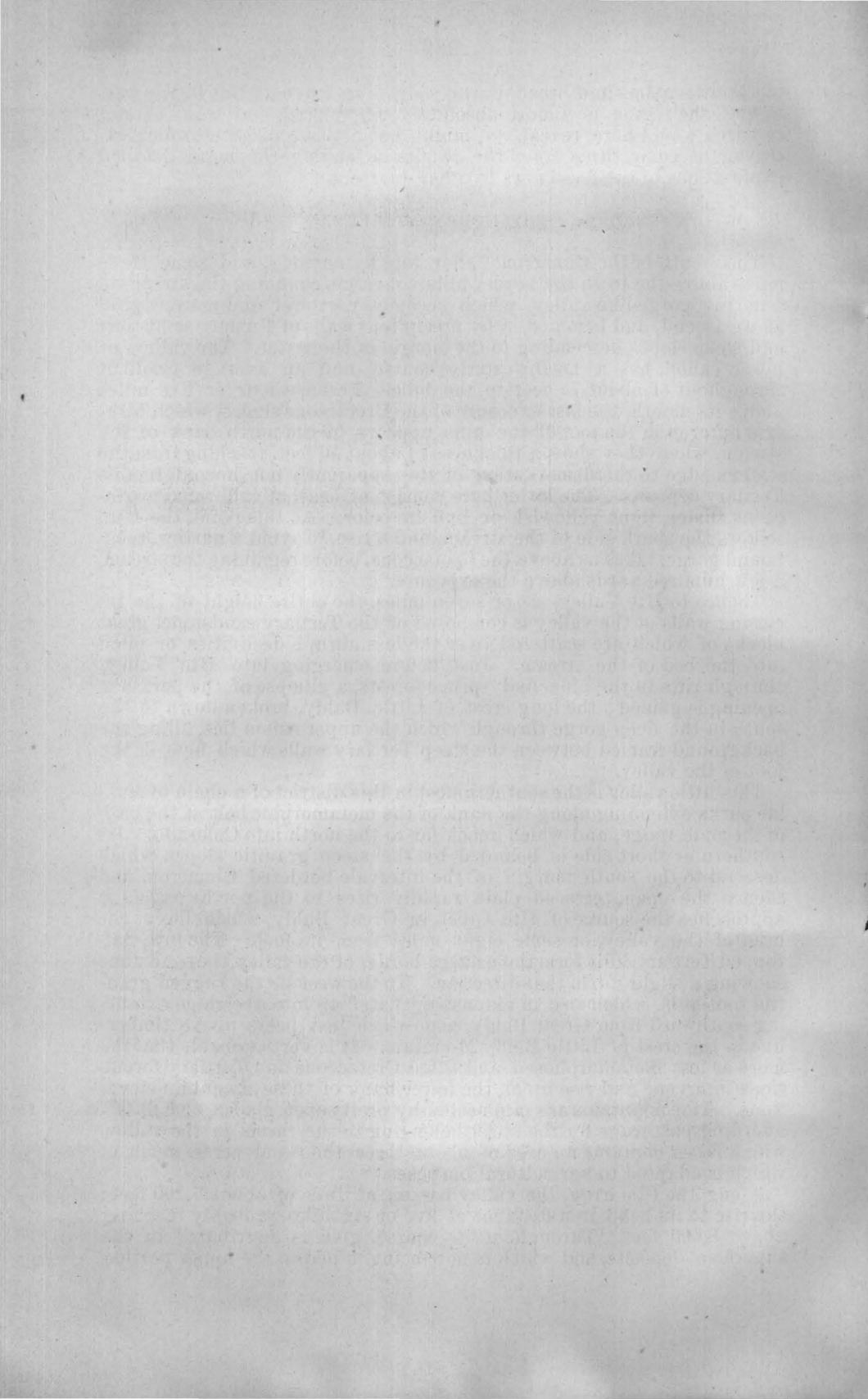
The heavy line indicates the watershed, the dotted line showing the position of the lofty spurs diverging into the basin of the Rio Grande, the broken line the Baldy range, the lower dotted line showing the upraised western border of the Tertiary at the base of the mountains.

Respecting the mineral wealth entombed in this formation, its deposits of coal and iron have already become famous. Besides the sections alluded to by Dr. Hayden in 1869, and those observed by Dr. LeConte and other gentlemen in different parts of the extensive region occupied by these deposits, we are especially indebted to Mr. Morley, and later to the distinguished Dutch engineer Herr Cornelius De Groot, who has prosecuted special examinations in this direction with the view of developing these resources, and upon whose observations I have mainly relied for the facts relative to the occurrence and aggregate thickness of the coals here met with.

The base of the formation is sharply defined from the immediately subjacent dark-gray shales of the Cretaceous by the sudden introduction of arenaceous material. This primary deposit consists of 20 to 25 feet of thin-bedded dark-brown or rusty ferruginous sandstone, upon which rests a massive bed of light-yellowish sandstone, which latter often forms precipices of 20 to 40 feet vertical. Above this occur alternations of more or less micaceous sandy shales and coarser sandstones, which, in the vicinity of the Cimarron, reach, all told, a thickness upward of 400 feet to the topmost ledges in the neighboring hills.

The same association and succession of strata again appear in the valleys of the Poñil and Vermejo, the latter of which was visited by Dr. Hayden. These sections all indicate the lower portion of the formation as the productive coal-bearing measures. The heaviest bed, which ranges from 4 to 7 feet in thickness, occurs early, though probably preceded by one or two minor carbonaceous horizons. Thus, near Mr. John Dawson's estate, at the mouth of the Vermejo Valley, the section exhibits seven beds of coal, of an aggregate thickness of 22 feet, included in about 160 feet vertical thickness of strata. At the base of this section occurs a heavy deposit of excellent coal, which is little more than 7 feet in thickness; 13 feet above this occurs a bed about $4\frac{1}{2}$ feet thick, separated by thin partings; and 40 and 20 feet respectively still higher a couple of 3-foot beds of coal are met with, the intervening strata consisting of slightly arenaceous shales, above which three 18-inch beds are found in a vertical thickness of about 65 feet.

The fine under- and roof-clays associated with some of these coals often contain vegetable remains, but which generally so readily crumble on coming in contact with the air as to render it exceedingly difficult to secure specimens. Higher in the series, the sandstones afford the usual vegetable representatives peculiar to the formation, amongst which nota-



bly are the palms and broad linear sedge-like leaves. But in this particular, the region is almost absolutely unexplored, and what careful research would here reveal, we might be justified in entertaining extravagant conjectures from the results attending the more detailed explorations of the fossil flora in other quarters.

THE MORENO VALLEY.

The mouth of the Cimarron Valley rapidly narrows, and some three miles above the town the border-hills converge, confining the stream to a narrow gorge-like valley, which becomes narrower and more rugged as we ascend, and hemmed in by precipitous walls of Tertiary sandstone and steep slopes descending to the margin of the water. The valley, or lower cañon, has a northwesterly course, and an average gradient throughout of about 75 feet to the mile. Perhaps four or five miles above its mouth, the last exposure of the Cretaceous shales, which hitherto outcrop in the foot of the hills, appears in the north bank of the stream, where they show a thickness of about 50 feet, reaching from the water's edge to the demarkation of the apparently not unconformable Tertiary deposits. The latter here consist, at base, of indurated arenaceous shales, light yellowish or buff in color. At this point, the road follows the south side of the stream, and a rise, to avoid a narrow, rock-bound gorge, takes us above the Cretaceous, before regaining the stream, a few hundred yards above the exposure.

Thence to Ute Valley, six or seven miles, the entire height of the inclosing walls of the valley is composed of the Tertiary sandstone, great blocks of which are scattered over the less abrupt declivities or piled into the bed of the stream. Just before emerging into Ute Valley, through rifts in the pine- and spruce-forests, a glimpse of the park-like opening is gained; the long crest of Little Baldy, broken down to the south in the deep gorge through which the upper cañon lies, filling the background framed between the steep Tertiary walls which hem in the foot of the valley.

This little valley is the southernmost in this district of a chain of similar parks extending along the flank of the metamorphic belt at the base of the main range, and which reach far to the north into Colorado. Its southern or short side is bounded by the steep granitic slopes which descend to the south margin of the intervale-bordered Cimarron, and thence the open, terraced plain rapidly rises to the northwest, as it approaches the source of Ute Creek in Great Baldy, which lies at the head of the valley, or some eight miles from its foot. The low, flat-topped Tertiary hills form the eastern border of the valley, the sandstone showing a slight dip in that direction. To the west lie the rugged granitic foot-hills, which rise in extensive "flats" up into the ridge extending southward from Great Baldy, and which just peers above timberline in the crest of Little Baldy Mountain. It is very probable that the more or less metamorphosed and tilted Cretaceous and Tertiary formations intervene and rise up on the lower flank of these mountain-elevations. The mountains are intersected by pretty open glades, or "flats", affording pasturage for the stock belonging to the farms in the valley, which latter contains an area of about three thousand acres, much of which is adapted to agricultural purposes.

Along the Cimarron, the valley has an altitude of about 7,200 feet; the rise to its head, in a distance of five or six miles, probably reaching above 8,000 feet. Throughout its course, gold is distributed in the superficial deposits, and which is now being mined in the upper portion

of the valley. The placers are mainly worked in the immediate vicinity of the stream, whose waters are husbanded with greatest care. At one of the lower mines, to which we were conducted by Mr. Keep, an old and experienced miner, we had opportunity to examine the nature of the "bed-rock", which had been laid bare over several square yards' extent. Here it is composed of the partially-metamorphosed dark shales of the Cretaceous, containing *Inoceramus*, &c., which dip to the north-east at an angle of about 30°. The slaty shales were nowhere planed smooth, their ragged upturned edges presenting innumerable "riffles", between which the gold is lodged. Some of these "rims" afford very rich "pay-streaks", and the entire surface, after having been laid bare by the ground-sluice or hydraulic, both of which methods are here in operation, is carefully gleaned for the auriferous earth. It is said that the sources of these precious particles are readily recognized, the wire-gold having been derived from the celebrated Aztec lode, while the finer scales come from the Montezuma lode, the parent ledges which outcrop in the eastern or southeastern flank of Great Baldy.

Ascending Ute Creek some eight miles above its confluence with the Cimarron, on either side of one of the steep gulches with which Great Baldy is furrowed, are found the mines opened upon the Montezuma and Aztec lodes. The former lode has a strike little north of east and south of west, and along its discovered course it traverses a porphyritic rock, such as apparently constitutes a great bulk of the eastern declivity of the mountain. The Aztec, which is opened in the north side of the ravine, about a mile distant, runs in a northwesterly and southeasterly direction. At one of the lower galleries, which is being driven into the hill with the view of penetrating to the lode, opportunity was offered for observing the character of the deposits penetrated a distance of 100 feet or thereabouts. The gallery penetrates the hill in a northeasterly direction, probably nearly at right angles to the strike of the sedimentary deposits, and in the direction of their dip. At the entrance, and extending several yards along the gallery, occurs a considerable thickness of dark Cretaceous scales, which are changed to a brittle slate by partial metamorphism, in which have been observed *Inoceramus*, *Ammonites*, &c. Then the excavation encounters a dark-gray quartzose rock, the end of the gallery having reached a crevice, which was charged with pyrite and fragments of partially-changed bituminous material. The slaty shales at the entrance of the gallery are unquestionably Cretaceous, and it seems reasonable to infer that the quartzose rock may be referable to the Tertiary formation, or the highly-metamorphosed sandstone occurring at its base; the changed bituminous seam representing one of the thin lower lignite beds, such as are known to exist just above the heavy-bedded inferior sandstone.

The mines are opened at an elevation of about 9,500 feet above the sea, thus showing that the Cretaceous shales have been tilted in the upheaval of the Baldy range at least 3,000 feet above the level they occupy in the borders of the plain at the mouth of the Cimarron Valley. In the passage of the trail over the Blackhorse Pass, which diagonally ascends the eastern declivity of the mountain to the saddle between Great and Little Baldy for perhaps a distance of nearly a mile, rusty-weathered fragments of porphyritic rock, apparently identical with that inclosing the Montezuma lode, are met with, completely strewn the surface. Above this nearly to the summit, a distance of half a mile, the mountain-side is equally thickly covered with large and small angular fragments of a schistose rock, the composition of which closely resembles the quartzose ledge noticed in the Aztec tunnel; and higher still

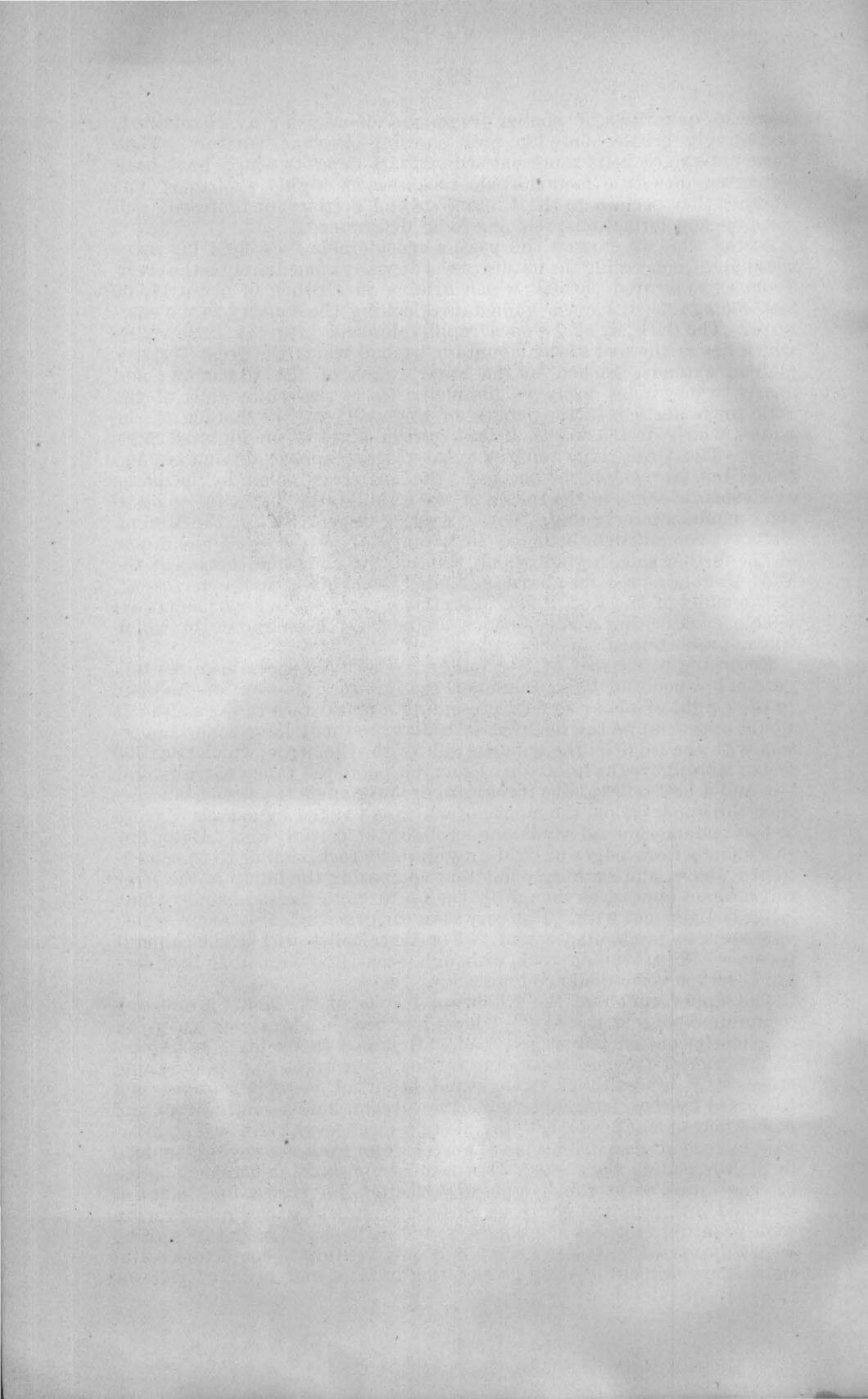


Upper cañon of the Cimarron;
Lower cliffs, looking down.

Fig. 2



Costilla Peak, looking N.W., from mouth of
Potril Cañon.



immense quantities of similar fragments of bluish-gray, laminated, exceedingly brittle, slate-like rock, showing cleavage-structure. That these uppermost belts represent sedimentary deposits which have been converted into true metamorphic rocks seems highly probable; but whether they pertain to the Cretaceous and Tertiary, or represent still more ancient formations, remains to be determined.

At the time we crossed the pass, a considerable snow-field lay upon the summit, concealing the nature of the deposits immediately in the crest. From this elevated outlook, which attains an altitude of about 11,000 feet, a magnificent view is gained, overlooking the country to the eastward. The dark, fir-clad slopes rapidly descend into the little valley which lies at the foot of the mountain, beyond which the great Tertiary plateau extends, gashed by the lower cañon of the Cimarron; and nearly twenty miles away we distinctly descry the white walls of the little town nestled in the mouth of the valley on the border of the plains, which stretch to the distant horizon sixty to one hundred miles away. The Urac ridge and the great plateau appear diminutive and tame; but far away to the northeast the horizon is broken by the mesas and volcanic cones in the region of the Capulin, the beautiful plain of the Canadian intervening. To the west, a large extent of the Moreno Valley is commanded, bounded by a range of low, wooded mountains on the farther side, beyond which the massive snow-clad domes of the Taos Mountains rise far above the timber-line. Away to the northwest, in the midst of the Red River Mountains, great white escarpments are visible, constituting a conspicuous landmark, the character of which was not ascertained.

Returning to the foot of Ute Valley, a short distance above the toll-gate, a low comb of light, columnar, granitic rock rises out of the plain to the height of about 50 feet, presenting a mural face to the south: it would appear to be the remnant of a dike, and may have some connection with the ridge on the opposite side of the Cimarron, which rises 300 feet or more above the interval. From this point, the valley narrows, and two and a half miles above its eastern or lower angle the stream emerges from the upper cañon, the mouth of which is flanked by masses of more or less metamorphosed sandstone, probably of Tertiary age. But a few yards farther on, ledges of light-gray granitic rock, similar to that mentioned above, and strikingly like that composing the hump in the Urac ridge, again appear, as though thrust up through the sandstone, which latter is again met with. But very soon the granitic ledges recur, which now seem to predominate, and two or three miles within the cañon it becomes the prevailing rock, although occasional sandstone boulders are observed some distance higher up.

The upper cañon of the Cimarron is one of the most interesting mountain-defiles in the West, which has been made accessible by an excellently-constructed wagon-road. Hemmed in by high mountains and enormous inclines, abounding in dizzy precipices and picturesque crags, with a wealth of strange and beautiful vegetable forms, and traversed by the changeable mountain-stream, here a mad torrent and now a murmuring brook eddying along a brief level, refreshed at intervals by incoming contributions of purest water from sources hidden deep in the surrounding fastnesses: what it must appear in midsummer, when its vegetation is at the height of perfection, its yuccas and cactuses crowned with rich and gorgeous blossoms, its rocks and shrubs overrun with beautiful creepers and climbers, and its nooks of fresh turf smiling with tiny varied-hued flowers, we may only venture to conjecture. But its autumn raiment of deep greens, rich browns, and brilliant yellows,

and its spring habit of russet, soft grays, and emerald, together with a sky inimitable and as varied as the seasons, are as fertile in promise as sufficient in contrasts.

The cañon has a general westerly direction, and is some eight miles in length. About midway, a chain of lofty granitic escarpments borders the north side of the stream, along which they extend nearly a mile in truly Gothic grandeur. The lower mass occupies an angle in the cañon, and viewed from below it may be imagined to bear striking resemblance to a cathedral-pile. The upper cliffs form a sort of amphitheater extending several hundred yards along the stream, and whose pierced and pinnacled heights rise 500 or 600 feet above the water in a sheer precipice, the face of which is vertically ribbed by the tendency of the rock to assume a columnar structure; however, in places it is solid, clustering in monumental groups in the steep declivities, or towering like castellated ruins in some promontory overlooking the gorge.

Toward the upper end of the cliffs, a huge boulder-like mass of dark-green stone protrudes like an enormous excrescence from their base, and which continues along the north side of the stream about one-fourth of a mile. It then loses its distinctive character, and thence appears like trap of various shades of dark brown and green, which may be traced two or three miles up the cañon. This gigantic dike is traversed at various angles by fractures, which have been filled with various mineral substances, as black trap, quartz, &c.

This portion of the cañon is frequently bordered by immense inclines, descending from heights of a thousand feet or more, and composed of the angular *débris* resulting from the atmospheric degradation of igneous ledges seated high up in the mountain-sides. These talus-slopes are sometimes quite destitute of vegetation, though generally sparsely grassed over and covered with pines, spruce, and cedar. The latter, with a sparser representation of the piñon at this elevation (8,000 feet), generally prevails in northern declivities, the pine and spruce occupying the opposite and more exposed slopes. Even here the dwarf-oak is met with; but the prevalence of the quaking-asp, which forms thickets beside the stream and high up in the adjacent mountains, plainly indicates the altitude, as also does the occurrence of dense tracts of spruce.

Just before reaching Macelroy Creek, by which an old trail gains the Moreno Valley, a ledge of red feldspathic granite outcrops in the north side of the cañon, and a short distance above detached masses of gray syenitic rock were observed. A few hundred yards above Macelroy Creek, and perhaps a mile and a quarter from the upper entrance of the cañon, in a high ridge, round which the stream makes a sharp curve, a reddish contorto-laminated gneiss occurs, and which also appears in the little valley of Macelroy Creek. This rock continues thence nearly to the Moreno Valley, apparently constituting an immense thickness, perhaps interbedded with micaceous schists, and succeeded on the west by a very hard red quartzose rock. These deposits appear to constitute the high hills along the east border of the Moreno Valley (at least in the neighborhood of the entrance of the Cimarron Cañon), and may possibly also be found in Little Baldy. Similar rocks are said to occur in the summit of Great Baldy, although none such were observed in the saddle over which the Blackhorse trail passes.

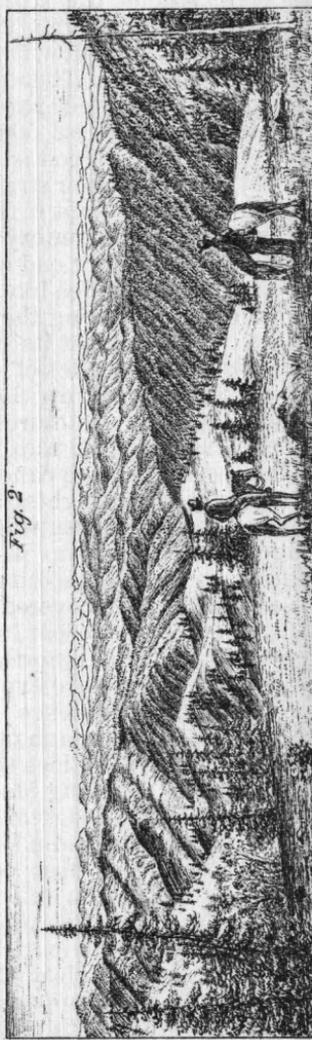
The Moreno Valley extends in a north-south direction nearly eighteen miles, with an average width of two miles. It properly does not belong to the system of shallow park-basins which were excavated out of the Cretaceous and Tertiary formations, and to which Ute Valley belongs; but it rather pertains to the possibly older lake-basins, environed by the

Fig. 1

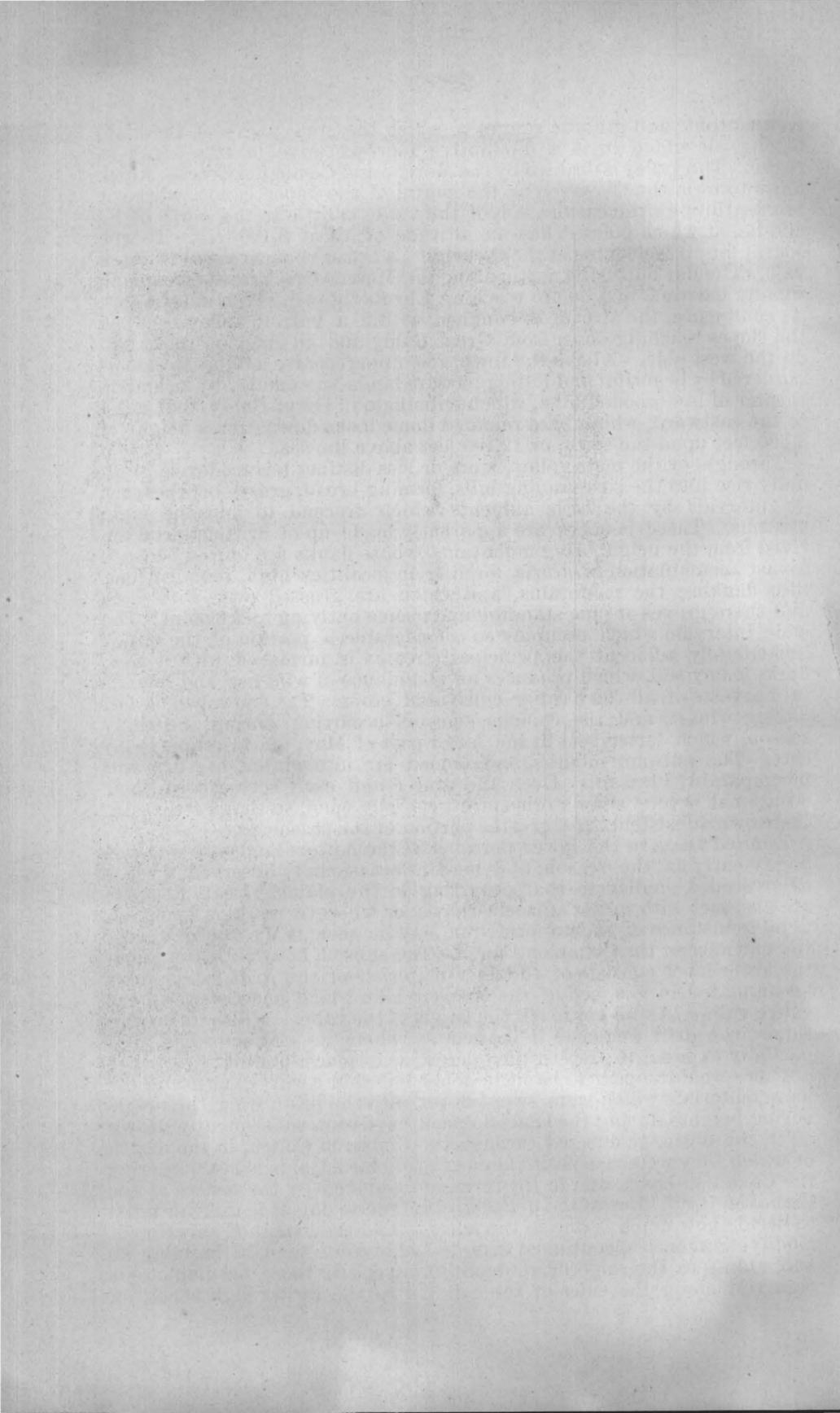


wooded water-shed
 View in Vermojo Park; looking northward.
 Calabra Mt. New Tertiary mass and ridge.
 Vermont Mountain.
 Raton Hills.

Fig. 2



Raton Hills.
 Eastward from Cortilla Pass.
 Fisher Peak. Chierica Mesa.
 Capulin region.



metamorphic and granitic ranges to which the great parks of Colorado belong, of which it is a diminutive representative in this southern region. The valley is drained by the Moreno and Cienegilla Creeks, which unite to form the Cimarron at the portal of the upper cañon, where it breaks through the eastern rim of the valley a little to the north of its middle, at which point it has an altitude of about 8,100 feet. To the south, far up the course of the Cienegilla, a broad vega, or meadow-intervale, extends; but to the north, along the Moreno Creek, the bottom-land rapidly narrows, and before reaching Elizabethtown, seven miles above its confluence, the stream is confined within a narrow valley between the slopes reaching down from Great Baldy and an outlying rocky hill on the west side. Above the town, the upper course of the stream is bordered by beautiful undulating pasture-lands, surrounded by an amphitheater of low wooded hills, which culminate in Great Baldy, four miles to the eastward, whose bare rounded dome looks down from a height of 3,500 feet upon the town, or 12,100 feet above the sea.

Throughout the main valley, more or less distinct terrace-levels gradually rise into the surrounding hills, forming broad, grassy benches, cut at intervals by the little affluents which descend to join the main streams. These benches are apparently made up of drift-material derived from the neighboring mountains, whose flanks are buried beneath a vast accumulation of *débris*, forming in localities high, rounded foothills flanking the mountains, and which are grassed over, with here and there groves of pine standing upon some outlying rocky point. The wide intervale which occupies so considerable a portion of the valley immediately adjacent the principal streams is furnished with a rich, dark, loamy soil, which produces an abundance of wild hay and bountiful harvests of all the hardier cultivated crops. The snows which fall during winter, and the copious showers occurring during the rainy season, which latter sets in the latter part of May, afford ample moisture. The autumn months, and indeed far into winter, are dry and incomparably pleasant. Even the winter and early spring, with their occasional severe snow-storms, are generally open, so that cattle gain their own subsistence the greater portion of the season.

Limited areas in the lower portions of the bottom-lands are wet and boggy early in the season, and here is occasionally observed a white efflorescence, similar to that occurring in the plains. Peaty deposits are also met with in the adjacent slopes, or wherever springs issue. A notable instance of such a formation may be seen at Mr. Pascoe's, near the entrance of the Cimarron Cañon. The subsoil, however, throughout the lower level consists of the finer materials of the drift, which have accumulated in the bed of the ancient lake which once occupied the entire valley. As we approach the heads of the valley, as also its borderslopes, the drift increases in coarseness, where its character has been partially exposed to view in the operations of placer-mining.

There would appear to be little doubt but that a vast quantity of the loose materials which were swept down into the basin from the neighboring heights during the Glacial epoch have been subsequently drawn off in the drainage effected through the Cimarron Cañon, in the mouth of which they were redeposited upon the old lacustral benches bordering the Canadian basin, and in the terraces fashioned by the waters of the Cimarron itself. But of the deposits observed to-day, it is difficult often to decide how much is due to the ancient and the extent of subsequent modifying agencies, continued even to the present time, in building up and adding to the superficial deposits, especially those accumulations occurring along the sides of the valley. In the rather high bench on

the east side of the Moreno, upon which Willow Gulch embouches, the part performed by the little tributary up to a very recent date is plainly indicated by the long train of *débris* which its floods have swept out into the valley, like the tailings of some immense placer-washing.

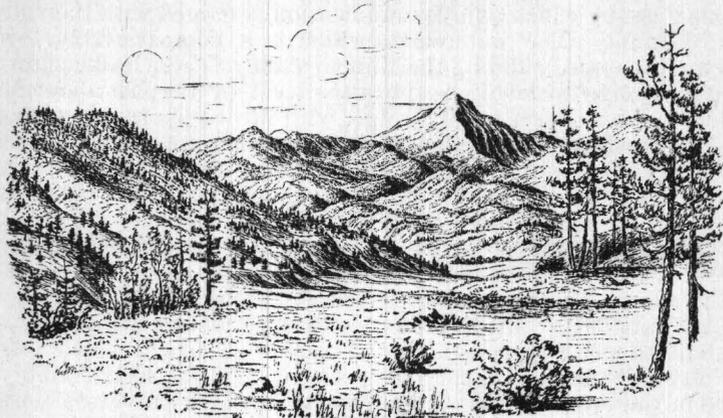
Some ten miles across from the Cimarron Cañon, in a southwesterly direction, a well-constructed Government road leads to the summit of Taos Pass, by which exit communication is gained with the valley of the Rio Grande. The watershed, which is a comparatively low divide, along its course bounding the Moreno Valley, is here broken down, affording a passage in elevation above the level of the sea about 8,850 feet. The pass lies over a narrow ridge, with rather sharp descents on either side for a short distance, when its approaches are so gradual as scarcely to give a premonition of proximity to one of the great natural highways across the Spanish range. On the summit are observed fragments of partially-metamorphosed reddish sandstone, together with other erratic masses. Looking off to the east, a part of the Moreno Valley is overlooked, and just beyond rise the mountain-masses on the east side of the valley. These consist of immense broad-based, low-crowned summits, dark with tracts of spruce-forests, amidst which are scattered extensive mountain-meadows and groves of aspen, which lessen their otherwise somber, monotonous aspect. These hills forcibly remind one of the broad-crested mountain-range which traverses Vermont and Western Massachusetts; a resemblance which will probably be found to possess even closer relationship in the similarity of geological structure.

It affords me much satisfaction to be permitted to announce in this place the discovery, by my friend Mr. Frank Springer, of Carboniferous strata *in situ* in the Taos Cañon, on the western declivity of the main range. On a recent journey (April) across the range to Taos, Mr. Springer was struck by the familiar appearance of certain deposits along the hemmed-in valley down which the Government road passes from Taos Pass, and, dismounting to prosecute a hasty examination, he found himself in the midst of a rich fauna, the *facies* of which indicate the most intimate relationship of the strata in which it occurs to the Upper Coal-Measure deposits in the region of the Lower Missouri. Among the forms recognized by Mr. Springer are *Spirifer cameratus*, *Athyris subtilita*, *Retzia Mormonii*, several species of *Productus*, and numerous Crinoidal remains. The fossils are associated in a dark calcareous shale, which extends from the lowest outcrop examined, at a point some eight miles from Taos, up the cañon several miles. The strata bear evident indications of great disturbance, being tilted in various directions, and which apparently exist in considerable thickness. The discovery of these beds affords ample confirmation of the suppositions expressed by Dr. Hayden in 1869 that the Carboniferous and older Palæozoic formations "once existed all along the western side of the mountains".

On the upper course of the Moreno, in the vicinity of Elizabethtown, is situated one of the famous mining-centers of the Territory. The auriferous lodes intersecting Great Baldy have squandered their wealth, distributing it in the beds of the gulches furrowing its sides, and which the denuding agencies have transported far down into the neighboring valleys. In former years, vast mining-schemes were projected, and large sums expended in carrying them out; but to-day, if the operations are less stupendous, they are certainly conducted in a most thorough and systematic manner. In the lower course of Grouse Gulch, Messrs. Lowthian and Middleton are working an extensive placer-claim, by the

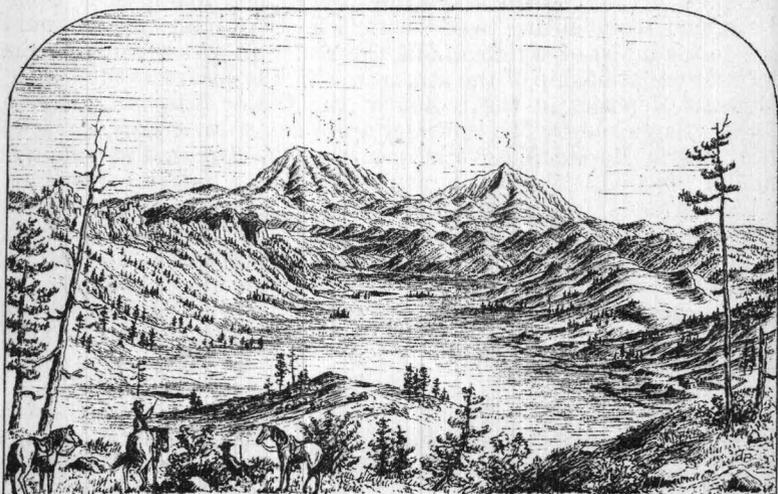
Plate 46

Fig. 1



Costilla Peak, from summit of Francisco Pass; looking S. S. W. Tertiary Hills. at Baldy. metamorphic (Palaeozoic) ridges.

Fig. 2



Spanish Peaks, from Francisco Parks; looking N. N. E. Great Dyke or hog-back of metamorphosed Cretaceous sandst.

Tertiary hills, largely composed of sandstone, and presenting different levels of erosion.

hydraulic method, with most satisfactory results. At the time this mine was visted (May, 1875), the entire width of the bed of the gulch, 200 to 300 feet, was being worked, the breast of variable height, 10 to 20 feet. Here was afforded an excellent opportunity to examine the character of the superficial deposits, which are exceedingly variable both in the fineness of their components and their distribution in irregular layers. The coarse materials, pebbles and bowlders, are rounded by abrasion, coarser and finer interstratified, often inclosing "pockets" filled with gravel, and all resting upon the so-called "bed-rock". The latter consists of partially-indurated, tenacious, red clay of considerable though variable depth, and which in turn rests upon the true bed-rock, which is here a coarse-textured, light or grayish, granitic rock, very like that occurring in the opposite or southeastern flank of Great Baldy. This rock is exposed at one or two places near the foot of the claim, and where much weathered it was slightly iron-stained red. The indurated red clay, which it is said is met with in nearly all the gulches on this side of Baldy, may have resulted from the disintegration of this rock.*

Very similar rock crops out in low ragged ridges or "rims" on the west side of the Moreno opposite Grouse Gulch, above and below Elizabethtown. The red clay is said to contain gold, but its exceeding tenacity prevents the working of only the upper portion, in which rich "pay-streaks" are encountered. The mining-season lasts about five months, beginning in May. The supply of "free" water, which is collected in private reservoirs during the winter and early spring, lasts four to six weeks, when the supply is drawn from the big ditch, a canal deriving its waters from springs at the source of Red River on the west side of the watershed, and, circumventing the head of the Moreno, is carried high up on the flank of Great Baldy, terminating near the head of Grouse Gulch. A single season's expense for water drawn from this source in working this mine amounted to \$5,000. The results of a season's operations at the "cleaning up" indicated an average of about one dollar per cubic yard; it is claimed that the mine can be profitably worked for one-tenth the yield above recorded per cubic yard. Other placer-mines are being worked on this side of the mountain, though none quite as extensively as the claim above noticed.

Passing up the grassy hill-side which rapidly ascends from the Moreno, and which is gashed by the unsightly washes of sluices and accidental breaks from the several supply-ditches which have been carried round the mountain, we gain a wooded shoulder perhaps a thousand feet above the town, and are fairly set out on the trail to the head of Willow Creek and the Blackhorse Pass. The way traverses a steep wooded declivity on the southwest flank of Baldy, part of the way alongside the Moreno ditch, which terminates near here and gradually ascends to the elevated flats in the vicinity of the head of Willow Gulch, which were once populous with mining-camps, as the numerous deserted log-cabins on every hand attest. The mountain-side is perforated with prospect excavations, treacherous pit-falls to the unwary horseman, and stripped of its once fine forests, either for the use of the mines or destroyed by the fires. Placer-mining obliterates whatever attractiveness a locality may have originally possessed, and these once wild picturesque ravines and high aspen-fringed mountain-glades are not only

* It is strikingly analogous to some of the deposits resulting from the still (so to speak) disintegration observed in the Brazilian mountains, where the process may be examined in all its various stages, from the unchanged granitic and gneissose native ledges up into the thoroughly-comminuted red paste, with its overspreading sheet of drift at the surface.

desolated but forbidding spots, even whose crystal waters are turned to mud, desecrated by the prosaic results of the search for treasure.

Along Willow Gulch, which is here a narrow defile bordered by steep acclivities, the placers are still being worked to the extent of the water-supply. One is struck with the vast quantities of coarse materials predominating in the drift *débris* of this high mountain-gulch. However, in some of the shallower lateral ravines, finer deposits are observed, and at one point, during the winter, tunnels were drifted into the bank along or in quest of pay-streaks upon the "bed-rock". The climb of half a mile or so out of the gulch, by a trail sufficiently precipitous for practicable traveling, and the summit of Blackhorse Pass is gained, nearly six miles by the route due east of Elizabethtown. The crest of the saddle, now bare, was formerly clothed with a dense forest of small spruce, whose naked blanched trunks, prostrated by the fierce gales that sweep the summit, form formidable abatis over extensive tracts of the mountain-side, with here and there clumps of bare poles still standing, weird evidences of the devastation wrought by the fires.

THE VERMEJO PARKS.

In October, 1874, I was favored with the opportunity of joining a party of gentlemen on a week's hunting and pleasure excursion to the interesting region of the sources of the Vermejo, in the northwestern portion of the district under consideration. Our route led up the valley of the Van Brimmer, the entrance of which is reached some twelve miles to the northward of the Cimarron, passing on the way the Poñil and Cerososo, up whose valleys we have a distant view of the long ridge of Costilla Peak. The entrance to this little valley seems to foreshadow at the outset its character throughout, a promise which is fully verified.

It can hardly with propriety be termed a cañon, although its lower course and intervals above are bordered by the high bluffs of the Tertiary formation, from the base of which a talus over the Cretaceous shales sweeps down into the valley for a short distance above its embouchure. The greater extent of the valley lies entirely in the Tertiary deposits, as is the case with all the streams intersecting the great plateau; but the Van Brimmer may be distinguished from the others by the mild expression, so to speak, of its topographical features, and which render it a favorite route to the park country. Rising just on the edge of the park at its head, it would appear to have been less actively engaged in the drainage of the chain of old reservoirs than many of its companion streams; consequently, acting the office of a quiet waste-escape for the waters which flowed over the barrier at its head, its bed exhibits scarcely any of those bold features which are attributable to violent erosive action. Indeed, for a distance of several miles its bed and surroundings become almost monotonous from their repetition every mile of the way, presenting a shallow trough gently flaring up into the bolder acclivities which hem in the valley, but which is redeemed by those accessories which nature so effectively employs in embellishing alike the level plains and rugged hills. The pine- and piñon-covered heights form a pleasing contrast with the light shades of the close herbage carpeting the lower depressions, relieved on the steeper slopes by patches of the rich-hued autumn foliage of the dwarf-oak, designs excelling the most beautiful tapestries, which seem to have been conceived in imitation of these natural patterns so prevalent in the valleys and on the mountains of New Mexico and Colorado.

About midway of the valley, the hills approach from the opposite

Plate 47

Fig. 1



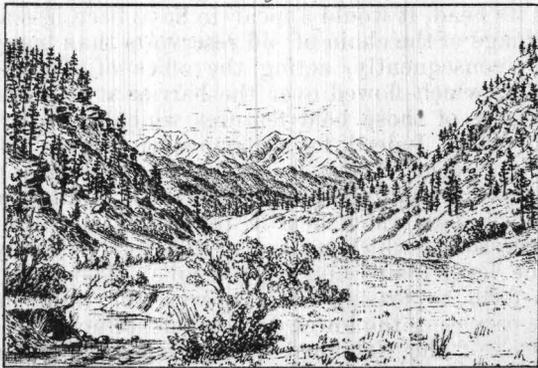
Hog-back cañon on the
Vermejo, looking N. E.

Fig. 2



Francisco Valley, Col? - looking down, N.E.

Fig. 3



Vermejo Mts. - northern peak; looking N.W., up
through gap in Tertiary sandstone at foot of park 3 miles
above Trinidad and Elizabethtown crossing on the Vermejo.

sides, interrupting the sameness by a low range of highlands, through which the stream has cut a veritable cañon in miniature. This sandstone barrier forms rather the sudden limits of a horizon of the Tertiary formation, possibly indicating a shore-line of the earlier stages of the drainage and erosive action which finally resulted in the present configuration of the country. Below this point, in the north side of the valley, a group of curious little monument formations are noticed, which recall those to which Monument Park in Colorado owes its peculiarity; only these are fashioned out of the clayey *débris* resulting from the disintegration of the arenaceous deposits of the adjacent Tertiary, their tops capped by fragments of sandstone detached from higher ledges, and which have retarded their demolition by the elements, reproducing, on a smaller scale, the same phenomena witnessed in the fantastic shapes which cluster in the acclivities of the little park at the base of Pike's Peak.

Above the gateway, the valley again widens, and, as we advance, beautiful glade-like depressions open charming vistas into the neighboring uplands. Soon, to the westward, a range of low mountains files across the gap in the distance, their rounded summits and declivities covered with evergreen forests and great plats of yellow-leafed aspen; this is the watershed which preserves the continuity of the Spanish range in the diminished altitude and bulk of its extension southward, and which is here 10,000 to 11,000 feet above the sea. At the heads of the Poñil and the north branch of the Vermejo, the divide sags, opening passes 9,600 and 9,500 feet in altitude, and which are perhaps the lowest in the range north of the Taos Pass.

Leaving the bed of the stream to the left, the trail rises a low upland, and, in a short distance, gains the park-like basin at the head of the valley, in which also rises an affluent of the south branch of the Vermejo. The eastern rim is quite low at this point, which either indicates a very shallow basin or the comparatively limited extent of its area drained by the Van Brimmer. A slight descent leads to the borders of a little pond, near the margin of which highly ferruginous ledges outcrop, and quantities of limonite nodules are scattered over the surface. The evaporation of the water has left it margined by a shelving beach, which is whitened by an efflorescence which renders the water unpalatable, although the flocks which are pastured here are said to relish both the water and the saline-impregnated earth. This point, which is some twenty-five miles from the lower entrance of the valley, has an altitude of about 8,000 feet. Clumps of pine—many of which are girdled by the Utes in quest of condiments for their pottages—are scattered over the park, the undulating surface of which is broken by low, flat-topped hills or ridges, which are apparently composed of Tertiary sandstone and shales. To the west, southwest, and northwest lies the wooded crest of the main range, in the direction of which the park country becomes more and more diversified on approaching the outlying ridges of tilted sedimentary deposits reclining upon its flanks.

Our route passes along the eastern edge of the basin, in a direction a little west of north, amidst varied local scenery and glimpses of sublime mountain views. Twelve or fourteen miles from the lakelet, at the head of the Van Brimmer, we reach the main or north branch of the Vermejo, at a point just above the gorge by which it makes its exit from the park, and where the altitude is about 7,700 feet. About midway between the above points, a diminutive tributary of the south branch winds through an extensive level vega-tract, which is surrounded by low mesas and ridges, between which communication is had with other basins by pretty

little grassy valleys. From the acclivity on the southeast side of this meadow-basin, looking toward the northwest, a magnificent view of the range is gained, beginning in the rounded contours of the lower divide to the south of Costilla Pass, and sweeping thence round into the north-northwest, where it culminates in the lofty peaks of the Vermejo Mountains. A little to the south of northwest, the snow-clad summits of the Culebra Mountains just appear in a low depression in the watershed; to the south of which, and occupying a re-entering angle in the watershed to the westward, the Costilla Peak is seen in profile, a massive ridge gradually culminating in a lofty cone, which appears to be suddenly broken down to the northward in a nearly vertical wall of a thousand feet or more. To the northward, and extending eastward across the open space, lies the comparatively low ridge of the Raton Hills, flanked by mesa-like ridges, which form a marked barrier along the east margin of the park-basin. In the foreground, a long line of table-topped Tertiary hills hide from view the "hog-back" ridges which lie parallel to the range. These low mesa-hills constitute a marked characteristic in the topography of the parks. They are apparently made up of arenaceous shales and sandstones, in quite horizontal position, and of various levels, as though they owe their configuration to aqueous denudation. Indeed, these low table-hills present the same contours, though on a much diminished scale, which prevail in the great escarpment-outcrop bordering the basin of the Canadian, in which a thousand feet thickness of the Tertiary and Upper Cretaceous deposits are revealed. In their declivities are occasionally encountered monumental outliers of sandstone, and it seems not improbable the region may prove fertile in these lesser and singular freaks of atmospheric denudation.

The pebbles and bowlders, of which the thin sheet of drift spread over these hills is largely composed, are perceptibly less smoothly abraded than the coarser materials which have been transported to the lower portions of the valleys, and which were derived from the same sources in the mountains immediately to the west. Wherever these deposits have been removed from the upland tracts, as is often the case over large areas, the disintegration of the subjacent micaceous shales and sandstone has produced a light loamy soil, which supports a fair growth of herbage. In the lower levels, or low benches, the soil is mixed with a large percentage of ferruginous fragments; and in the little intervalles along the streams, as well as in the meadows occupying the larger valley-expansions, considerable tracts of exceedingly fertile, dark, finely-comminuted soil frequently occur. These little valleys penetrate far into the base of the neighboring range, where they are unexpectedly encountered, often of limited extent, but always surpassingly beautiful nooks, with clean, verdure-clothed surfaces and pine-fringed slopes.

From the camp near the gorge by which the main branch of the Vermejo enters the Tertiary plateau—a charming spot, nestled between the wooded declivity which forms the eastern rim of the park-basin and the low mesas rising out of the basin, opening out into a little park just to the south, with glimpses of the glistening crests of the Costilla and Vermejo Peaks—the trail strikes across the park in a westerly direction, gaining the crest of the massive hog-back ridge in a distance of some three miles. The eastern-declivity is paved with the angular blocks of the reddish-gray quartzitic rock which outcrops in the crest, where it shows a steep inclination to the northwestward, or nearly vertical. This is the great dike-like ridge of the lower sandstone of the Cretaceous, which constitutes so marked and persistent a topographical feature along the eastern foot of the Rocky Mountains for several hundred miles'

Plate 48

Fig. 1

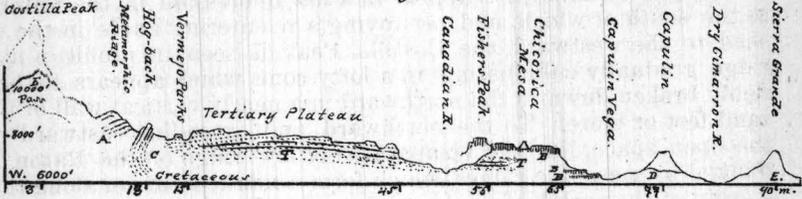


Fig. 2

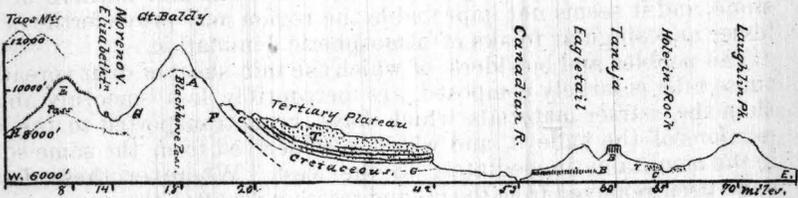
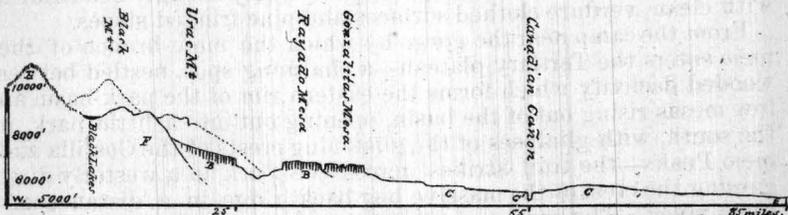


Fig. 3



B. Basalt, reclining upon flank of granitic mountains, F. Granitic rocks.
 C. Cretaceous occupying plains. C. Lower Cretaceous sandstone, exposed in
 Canadian Cañon. E. Water shed.

extent. But at this point, in its broken-down condition, it has lost somewhat in the distinctive character which lends so picturesque a feature to its outcrop in other localities. Where the Vermejo breaks through the ridge to the south of the trail, in the walls of the picturesque little cañon, the edges of the metamorphosed sandstone are finely displayed, steeply tilted beyond the vertical, with weathered niches and pinnacled crest.

To the west, and parallel with the hog-back, a belt of rolling country two or three miles in width is crossed, in which occasional outcrops of deep-reddish and variegated micaceous sandstone and beds of conglomerate are observed, gently dipping north-westward at an angle much less than the quartzite in the outlying Cretaceous ridge. Here the surface is rough, the soil poor, and covered by bunches of coarse herbage and a straggling growth of gnarled pines and low undergrowth. Finally, the trail enters the gorge of the Vermejo at the foot of the range, and begins the ascent to the summit of the Costilla Pass amidst a wild confusion of rugged igneous masses, rent by a labyrinth of deep, narrow ravines. The walls of the passages are composed of a dark-brown vesicular, lava-like rock, with huge masses of greenstone, piled in irregular rugged ridges or isolated domes. A steep climb of about two miles, and the trail emerges upon the high undulating mountain-meadows, which here occupy the summit of the range, winding through groves of aspen and spruce, and over grassy slopes, in whose bosom dark alpine lakelets mirror the sky. Our approach frightens up a few small teal, who seek refuge in the coarse grasses which grow around the peaty margins. The rude shelters and corral inclosures, half hidden in the neighboring copses, give evidence of occupancy, during the summer months, by flocks which are driven from the valleys to graze the abundant pasturage, and which do much toward lessening the sense of the solitude that reigns around.

The transition from the wild, chaotic belt to these open heights is sudden and unexpected; and thence to the summit the trail pursues a comparatively easy way over a rolling surface, apparently molded in the drift, to the sag or lowest point of the pass, where it attains an altitude of 9,500 feet. To the north and south, the range rises into somewhat higher wooded heights, and to the west the massive snow-clad summits of the Culebras rise out of a mountainous tract just beyond a little valley, which steeply descends to join the Rio Costilla in the basin of the Rio Grande. The snow-fields crowning the Culebras are in places deeply discolored, as though with dust. To the south, the eye wanders over a succession of wooded ridges, which reach down into the Rio Grande basin, finally resting upon the white crowns of the Red River and Taos Mountains, twenty to thirty miles away.

But it is to the eastward we are mainly concerned, and here a revelation meets the gaze. In a broad gap, bounded by long, abrupt, spruce-clad mountain-spurs, whose sides have been devastated by the fires, lies the middle ground, filled by the massive undulations of the metamorphic belt, and just beyond the great Tertiary plateau, whose surface is corrugated by the numerous tributaries of the Canadian flowing to the southeast, the plateau having a very perceptible general descent in the same direction from its culmination in the watershed of the Raton Hills on the north. The intervening ridges often flatten out into level expanses, interspersed with an open growth of pine and extensive upland pastures. In the distance, the view is limited by the Chicorica Mesa, whose level summit, here and there interrupted by conical elevations resembling volcanic cones, stretches from Fisher's Peak far to the

southeastward, where it merges into the haze-obscured, flat-topped buttes and conical peaks in the region east of the Canadian basin. The latter is hidden from view by the high bounding Tertiary plateau, while the great mesa as effectually shuts out the view of the more distant plains. It is a region marked by long lines of parallel ridges, diversified by immense tableland and isolated volcanic cones, to which the mirage lends its illusory repetition of phantom mountains, which one moment are so real as almost to deceive, but the next to melt into strange fantastic shapes, until one can scarce believe they have aught to do with things terrestrial, but rather strange creations of the sky.

From the camp on the Upper Vermejo, a little valley leads by a gradual ascent to the summit of the Francisco Pass over the Raton Hills. In a distance of about four miles, the rise is about 900 feet, the summit of the pass being 8,600 feet in elevation, and situated just within the borders of Colorado. To the west, a rather high, rugged ridge, which is apparently composed of metamorphic rocks, possibly the tilted Cretaceous, continues for some distance along the valley, when it is replaced by the low Tertiary ridges, which latter continue to bound the eastern side of the valley to the summit, often rising 300 to 500 feet above its bed, and in whose sides thin beds of lignite are known to exist.

Looking back over the depression of the park country into which the little valley opens, one of the finest views of Costilla Peak is gained, which, from the north, presents a pyramidal outline, the abrupt northern face bastioned and rent by profound chasms reaching nearly to the summit, which rises between one and two thousand feet above the forest-line. Away to the southward, in a notch to the right of a prominent cone marking an angle in the watershed, or main range, the dome of Great Baldy just rises into view, mantled by a recent fall of snow. To the northwest, and quite near at hand, the diverse and lofty summits of the Vermejo Mountains tower above the nearer hills; and northward, overlooking a succession of low ridges with indications of narrow valleys and park-like openings similar to those south of the pass, the Spanish Peaks appear; the eastern peak peculiar on account of its symmetrical, conical outline, the western and apparently highest mass arching up into a jagged crest, which falls off in an abrupt descent to the west. The lower hills flanking the broad basis from which the Spanish Peaks spring, and which pertain to the Tertiary plateau in its extension north of the Raton Hills, gently slope eastward toward the plains, precisely in the same manner observed in the plateau south of the Ratons. No considerable extent of the latter ridge is commanded from this point, the nearer eminences hiding from view as well the plateau extending southward. To the west, the Tertiary formation apparently abuts upon the metamorphic ridges in the near vicinity, and which it may partially conceal. There is, however, marked dissimilarity in the accompanying topographical features here observed as compared with the great Colorado divide, with which the Raton Hills possess a marked resemblance in many other respects. Here there is no marked valley of erosion intervening between the Tertiary and the granitic mountain-wall, such as exists in the pass at the initial point of the Colorado divide; consequently, in the immediate vicinity of the Francisco Pass, the connection between these later sedimentary deposits and the older metamorphosed formations, as well as their relation to the granitic and igneous nucleus of the main range, is not so clearly manifest. Whether they extend over the Cretaceous hog-back, concealing its tilted ledges from view, or whether this ridge is curved to the westward

close in upon the base of the main range, thus crowding the intervening still older sedimentary formations into a much more contracted belt than that over which they extend along the course of the Vermejo, by steeply tilting or bodily lifting them up on the summit of the axis of elevation, are questions which remain for future explorations to determine. But, as we have already seen to the south, in the Vermejo Park, so to the north, in the Francisco Park, the great dike-ridge of lower Cretaceous sandstone re-appears, where it presents, as shall be shown farther on, a much nearer resemblance to the topographical appearance it exhibits still farther to the north, where it is crowded up and sometimes toppled over, as along the foot of the outlying mountains surrounding Pike's Peak.

From the open glade-like depression, over which lies the Francisco Pass, the trail at once begins the descent through a narrow valley inclosed between steep Tertiary hill-sides, the bed of which, now dry, bears ample evidence of violent floods during the rainy season. Perhaps five miles to the northeast of the summit, the valley suddenly opens out into a charming little park of some three or four hundred acres extent, which is traversed by the Francisco, or an independent affluent of the Purgatory, from the point where it emerges from the hog-back ridge at the head of the park. The valley has an altitude of about 7,800 feet, indicating a descent of 800 feet from the Francisco Pass. Its bed is occupied by a level bench, the stream being bordered by a narrow interval, from which a range of low sparsely-wooded mesas immediately rises on the north side, extending to the foot of the park, which are apparently composed of Tertiary deposits and overspread with the boulder and pebble-charged drift. A pretty little open valley separates this low ridge from the high Tertiary table-land immediately on the north, which sweeps down in a long gradual descent from the mountain declivity on the west, and which occupies the upland interval between the park and one of the main branches of the Francisco or Purgatory to the north. In the gap to the west, the Vermejo Mountains burst into view, their nearness permitting a careful study of the topographical features which diversify their eastward aspect; profound gulches, sharp buttress-spurs, steep *débris*-covered inclines springing from the foot of bastioned escarpments and inaccessible walls, over which tower sharp cones, enormous dismantled heights, and massive domes to the height of 5,000 or 6,000 feet above the little valley which nestles at their base; it is one of the most varied and sublime near-mountain scenes in the West.

Beyond the massive metamorphic hills, here and there appear wooded peaks and rounded crests to the south of the Vermejos. The foot of the park is closed in by long grassy slopes, gradually ascending to the steeper declivities of the sandstone hills which descend from the Raton ridge just to the south, and which a mile or so lower down close in upon the stream, confining it to a narrow valley, but only to open out into a similar park-like expansion a few miles lower down, in which is established a little placita, or Mexican hamlet. The stream, a beautiful clear trout-brook, flowing over a bed of gravel and bowlders, and fringed with willow and cottonwood, is turned into an intricacy of channels and pools by the damming at the foot of the valley—the solid structures of the beaver, which abounds in all these mountain-streams. The irrigating acequias, which are taken out along the stream and carried across the high bottom-terrace, reveal in their deep washes the red clayey nature of the superficial deposits which accumulated in these open spaces when they constituted so many little lake-basins, and whose drainage, the result of slow, persistent erosion, by which means the intervening sand-

stone barriers were pierced by narrow gorges, prepared these secluded and often beautiful spots in the midst of a rugged country for occupancy and utilization by man. The origin of these park-expansions along the courses of the streams traversing the Tertiary plateau may be attributable to the erosion of the softer arenaceous deposits, which are known to constitute horizons of considerable vertical extent in this formation.

Crossing the high table-land to the north, which presents an open growth of handsome pines and an extensive pasturage extending eastward in a distance of about three miles, we gain the northern edge of the upland, where it suddenly breaks down into an extensive park-valley, which stretches several miles to the northward, and which is here and there occupied by shallow lakelets. To the left, the park is bounded by a rather abrupt ridge, along the crest of which rises a narrow, much-broken, dike-like escarpment, which is composed of the highly-tilted and metamorphosed Cretaceous sandstone, here nearly set on edge, the dip being to the eastward. To the north, this great dike-wall trends round to the northwestward, where it is lost to view behind the nearer escarpments. The ridge must attain the height of near 500 feet above the valley, of which perhaps 100 feet or more are made up of the nearly vertical escarpment, from the foot of which a steep talus-accumulation, covered by a sparse growth of pines and shrubs, and strewn with great blocks of rock, descends into the valley. On the east, a gradual ascent gains the summits of the bounding Tertiary hills, which, however, to the north become more abrupt, stretching across the farther end of the valley in broken, flat-topped hills, of which there are several (at least four) distinct terrace-levels, all sloping gently eastward. Their slopes facing the valleys are sparsely wooded, and often grassed over to the summit, but in the main they support quite a dense evergreen growth.

Beyond the Tertiary plateau, which crowds into the bay-like recess around the trend of the hog-back ridge, the surface swells up into a high undulating mountain-tract, from the summit of which, nearly twenty miles away in a direction a little east of north, those peerless cones, the Spanish Peaks, seem abruptly to spring. The isolation of these mountain-masses, lying some fifteen miles to the east of the main range, with which they are apparently connected by the elevated mountain-plateau, has much to do with the grandeur of their appearance, and which they always present, viewed from whatever direction. As seen from the plains in the valley of the Purgatoire, sixty miles to the east, they are blended in a single cone resembling, when clothed with snow, a pyramidal mass of cumulus resting upon the horizon. But approached from that direction, their double summits become more and more distinct, often flushed like a purple-tinted cloud; and, from the summit of the Raton Pass, their duality becomes fully established, and as seen from the highlands as far south at least as the Urac ridge, south of the Cimarron.

Regaining the Upper Vermejo, whose diversified park-scenery has lost nothing in interest by the brief sojourn on the other side of the Raton Hills, the trail leads across low hill-flats, through narrow shallow valleys, beside willow-fringed rivulets and ponds, out upon the upland rim of the basin, amidst open pastures dotted with pine, in whose branches families of pretty gray squirrels are busied garnering the season's supplies, and overhead troops of magpies take their vagabondish flight. A shallow depression leads by a gradual descent into the main valley, which we regain at an open space five or six miles below our former camp. Looking back up the valley, isolated flat-topped outliers of Ter-

tiary sandstone rise on the margin of the parks, low terrace-levels extending along the borders of the valley; beyond are seen the metamorphic ridges, and over these to the northwest the cloud-capped southern peaks of the Vermejo Mountains. It only lacks the presence of civilized homes, which no other region more cordially invites and which could in no degree detract from the beauty of its parks or the grandeur of the mountains, to render this one of the most attractive resorts in the country.

The Vermejo, which has here gathered to a fine mountain-brook, soon plunges into the hills, which for six or seven miles closely hem the valley in. The topographical features of nearly all these little valleys along the margin of the parks, where they enter upon that part of their course lying across the Tertiary plateau, are peculiar and quite persistent in their manifestation. The uplands terminate in steep bluff declivities along the stream, 100 to 300 feet or more in height; and wherever they afford vistas of any considerable extent, the rapid descent of the valleys is very appreciable in the lines of successively lower ridges, which close in upon the lower course of the stream. This is markedly exhibited on the Vermejo, as also in the Francisco Valley on the north side of the Raton Hills; and what the view in that direction, looking down the valleys, lacks in mountainous grandeur, is often amply made up in picturesqueness. The steep, wooded heights frequently present a coping of light-red sandstone; sometimes their abrupt declivities are broken by an outlying mass resembling a dismantled fortress or watch-tower guarding the approaches of some little interval-expansion hidden in the seclusion of the narrow valley, or rounded summits, clothed with open forest-growth and herbage, indicate the presence of a shaly horizon of the formation.

The little stream is clear and cold, its pools furnishing abundant contributions of delicious trout, whose individual variableness is almost as striking as that of some aquarial species; but on our return, three days later, no amount of dexterity and patience, coaxing and piscatorial wickedness, could prevail on the finny gormands to take the fly, so satiated were they of a day's feasting provided by the sudden invasion of locusts that swept down from the north. Where the stream flows through an interval-bordered expansion, its banks reveal a depth of rich soil, which rests upon the coarse materials of the drift. Frequently, the alluvial or lacustral deposits extend up on the valley-sides on approaching a contraction in the valley, where the stream forces its way through some gorge, which apparently indicates their accumulation when a barrier extended across the foot of the valley, backing its waters into a little lake-basin.

Some seven miles below the point where we regained the Vermejo, the valley widens out into quite an extensive park, in which a number of American families have established comfortable homes, surrounded by pleasant fields, whose fertility is evidenced by stacks of grain and well-filled vegetable-cellars. The park is formed by the union with the main valley of a considerable lateral valley, which rises in the divide south of the headwaters of the Canadian. A low terrace-bench occupies the angle between the two valleys, which is made up of darkish shales, covered by accumulations of drift. The surrounding flat-topped hills are composed of the Tertiary sandstones, which, in the cañon above, dip gently northwest. Here, as also below, in the dark shales in the foot of the hills, a thin layer of lignite occurs. At the lower end of the park, the hills approach the stream, forming a sort of gateway, in the foot of which gray shaly sandstone outcrops, in which were observed the im-

pressions of long linear leaves and endogenous root-like bodies, together with small fucoidal markings. Higher in the bluffs, heavy ledges of buff and reddish sandstone appear, showing a slight inclination down the valley, or southeastward, indicating, in connection with the opposite dip observed at the head of the park, a gentle undulation in the strata, more or less parallel to the metamorphic ridges ten or fifteen miles to the west.

Looking up the valley from this point, we gain a beautiful view of the Vermejos, showing the peaks to the north of the great truncated pyramidal cone, framed in between the walls of the gateway. It is with peculiar emotions each re-appearance of their familiar domes is hailed; and so constantly have they attended our progress through the parks that it is with equal reluctance we now turn our backs in *adios* to these majestic mountains. Thence the valley continues, closely pressed by the hills, a distance of two or three miles, when they suddenly diminish in altitude, and recede as we approach Cameron's, on the Elizabethtown and Trinidad road, where the stream enters a broad depression occupied by low upland undulations, which are clothed with pine and piñon and extensive grazing-range. This undulating belt probably marks the breaking-down or eastern limits of one of the terrace-levels of the Tertiary plateau, or a stage in the drainage of the Post-Tertiary basin, whose waters for a time swept the base of this low escarpment.

Considerable tracts of bottom-land, or low, shelving terrace-benches, continue from this point down the valley some nine miles to Mr. Stout's, the border upland gradually increasing in elevation above the deepening bed of the stream, and drawing nearer on approaching the great bend, where they present bold bluffs and escarpments, often made up of immense beds of sandstone. Here the Vermejo nearly doubles upon itself in the distance of about one and a half miles, and in the course of ages it has excavated its channel deep into the Tertiary deposits, which rise in precipitous and frequently vertical walls to the height of several hundred feet above the shadows that dwell at their base, and which no ray of sunlight penetrates. A practicable bridle-trail traverses the cañon, crossing and recrossing the impetuous stream, whose bed is blocked by immense masses of sandstone dislodged from the ledges above, and paved with boulders, which afford treacherous footing for our animals, winding beneath overhanging ledges, now crossing a thicket-grown miniature intervale, then rising high up on the shoulder of a steep talus of *débris*—a bit of journey performed with some degree of misgiving, but remembered with liveliest satisfaction. Below the great bend, a distance of four miles, the stream continues walled in its narrow valley by sandstone escarpments, when it sweeps round a low ledge and opens out below into the gradually-widening level intervale, which extends thence some three miles to the embouchure of the valley into the plains.

Rounding the high point in the angle south of the valley, the road passes up through shallow depressions, past deep alcoves studded with picturesque castellated rocks and tottering watch-tower pinnacles, out upon the long piñon-covered slope bordering the basin of the Canadian.

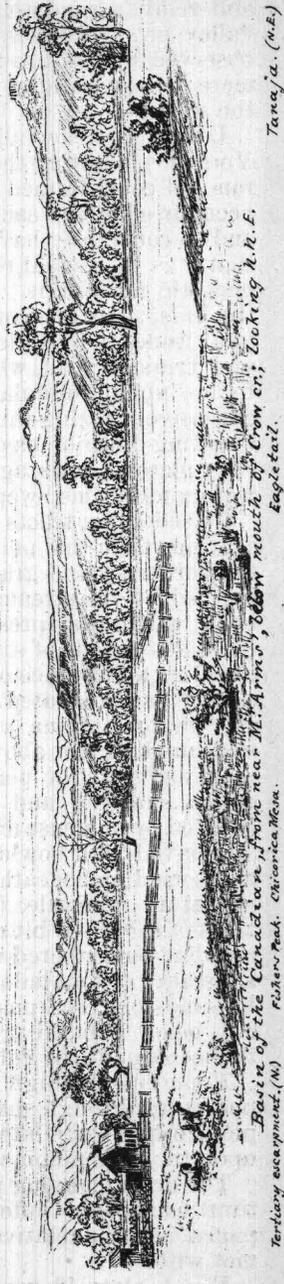
The accompanying profiles are intended to exhibit the general structural features in different parts of the region noticed in the foregoing pages, and the relative position of the various geological elements there met with.

Fig. 1, plate 48, represents a profile extending easterly from Costilla Pass in the main range, across the narrow belt of overturned Palæozoic and Mesozoic strata at the base of the mountains, out upon the Tertiary of the Raton plateau, crossing the head of the Canadian basin, the

Fig. 1



Fig. 2



Chicorica Mesa, and terminating in the plains at the foot of Sierra Grande, ninety miles east of the initial point.

A, metamorphosed Mesozoic and Palæozoic strata; B, basaltic mesa and benches; C, Cretaceous, Nos. 1-4; D, scoriaceous eruptive rock; E, watershed, or main range; T, Tertiary deposits, with coal.

Fig. 2, plate 48, shows a similar profile from the main range (E) west of the Moreno Valley, across Great Baldy, upon whose eastern flank the Cretaceous and Tertiary (C, T) deposits are upraised high above their outcrop on the borders of the Canadian basin, which latter is bounded on the east by the volcanic hills which rest upon the sedimentary deposits on the borders of the plains, some seventy miles to the east of Taos Pass.

Besides the same elements indicated by corresponding letters in the preceding profile, the following additional ones are here noticed: F, granitic; G, gneiss and quartzite at head of Cimarron Cañon; H, Carboniferous in Taos Cañon.

Fig. 3, plate 48, exhibits a profile still farther to the south of the former, extending above eighty miles to the east of the main watershed into the plains beyond the Canadian, and showing the great basaltic overflow, reclining upon the outlying flanks of the Black Mountain group, and terminating in the mesas of Rayado and Gonzalitas, which were evidently at one time connected with the Tanaja and Chicorica table-lands.

The sections traversed by the above profiles, which are simply an approximation, with no attempt at the representation of details, may be traced by reference to the sketch-map.* Plate 42, fig. 1.

THE CAPULIN.

Late in the autumn of 1874, in company with Messrs. Springer, Morley, Arms, and Porter, a brief visit was made to the Capulin country, which lies to the east of the Canadian, and some sixty miles out from the Spanish Range. The route followed one of the old Santa Fé freight roads, via the Dry Cimarron, crossing the Canadian a short distance below the mouth of Crow Creek. The road rises by a gradual ascent the prairie upland to the south of Tanaja Creek, the higher portions of which command extensive views of the distant mountains—the dome of Great Baldy to the south, the long cumulating crest of the Costilla, and to the north the groups of the Vermejo Mountains, the peculiar topographical features of which are as strikingly exhibited from this great distance as when viewed from the parks at their base—beyond and overtopping the Tertiary plateau, which forms an abrupt wall in the middle distance along the western border of the plain of the Canadian, whose clean carpet of gramma-grass is seldom intruded by the fields of *Artemisia* so characteristic of the plains in other quarters.

Pursuing an east-northeast course, in a distance of about fifteen miles, the road regains the valley of Tanaja Creek, passing on the way the Tanaja and Eagletail Buttes, two considerable outlying basaltic elevations lying between the former stream and the Canadian, along which their broad-spreading basis forms a low range of basaltic bluffs. The valley is here a shallow depression, inclosed by low bluffs resting upon shales, and terminating above in a considerable deposit of yellow-

* It is proper, and besides a positive pleasure, to state my indebtedness to Messrs. G. A. Bushnell and Harry Whigham, as also to Mr. Lewis Kingman, and my friend Mr. Morley, for the data embodied in the sketch-map, by which I have no desire to make these gentlemen responsible for the inaccuracies, but whatever is good I gladly acknowledge is their own contribution.

ish sandstone, which often forms picturesque castellated masses, in which the elements have wrought miniature caverns, and which are covered with cedar, piñon, and low pines. The shales are undoubtedly of Cretaceous age, and it would appear equally probable that the overlying sandstone prove to be the base of the Tertiary formation. A few miles farther on, and perhaps twenty miles from the crossing of the Canadian, Hole-in-Rock is reached, a little pool at the foot of a low ledge of very tough, grayish, phonolitic rock, which seems to be a dike pushed up through the sedimentary strata, along an east-west line, and which here crosses the head of a little branch of the Tanaja.

From this point, the road passes over a sort of low divide, and yet within the depression, which is here bordered by similar topographic and stratigraphic features observed on the upper course of Tanaja Creek. In the course of a few miles, a more open country is reached; to the left or northwest, lowish basaltic-capped mesas, in which a branch of the Una de Gato rises, and in the opposite direction the huge eruptive pile culminating in Laughlin's Peak. The latter mountain rises from a broad, undulating, grassy swell in the plain, and in which Mr. Kingman reports the occurrence of sandstone similar to that appearing in the bluffs bordering the old valley-depression, which lies to the northwest. A gentle descent amidst surroundings which every step become more emphatically marked by the evidences of igneous phenomena which here abound, and in a distance of fifteen miles from Hole-in-Rock, we gain the Capulin Vega, and camp beside a little pool which oozes from the swelling, peaty soil in the midst of the plain.

The Capulin Vega is quite an extensive shallow basin, surrounded by gentle acclivities, low basaltic terraces, and isolated mountains whose summits rise above the plain 1,500 to 1,800 feet, or about 8,000 feet above the sea. Its surface is quite level, with here and there shallow ponds; the mud of their sloping shores whitened by an efflorescence which renders the water brackish at this season, and their margins unrelieved by a solitary tree. In the low places flooded by the rains, considerable tracts of coarse herbage, suitable for hay, occur; the drier portions of the vega possess a loamy soil, which is largely made up of the sand derived from the degradation of the surrounding igneous rocks. To the southwest, the surface gradually ascends into the upland at the base of Laughlin's Peak; and, on the northwest, the basin is hemmed in by low basaltic escarpments. To the east, the prairie rises into what appear to be broken-down volcanic cones, and beyond lies the broad-spreading mass of the Sierra Grande, to the right of which, and much nearer, a nearly perfect crater-cone appears—the latter some eight miles and the former fifteen miles distant—which are destitute of trees, and grassed over to their summits with a tough reddish wire-grass, which gives a delicate pleasing tint to their smooth sides. But the most interesting feature of the environments is the Capulin Mountain, a perfectly symmetrical cone, rising from a broad low basis of scoriaceous rock to the height of near 1,800 feet above the vega. The summit is truncated, and occupied by a funnel-shaped crater between 200 and 300 feet in depth, and which is said to be grassed over to its bottom; on the southwest, the rim is slightly broken down, revealing the character of the crater to best advantage. The outer wall on the east side, as seen from the vega, presents an abrupt escarpment perhaps 50 feet in height; otherwise, the slope is very uniform, and covered with herbage and a growth of shrubs or dwarf-pines. The appearance of the mountain as seen from the vega, to the southwest, is shown in the middle section of the foregoing sketch. The eruptive material occurring at the

base of the cone is coarsely vesicular and of a dark-brownish color, entirely dissimilar in appearance from the basalt in the neighboring mesas, which latter varies from reddish to dark brown, specked with light gray, and homogeneous in texture. To the eastward, the low, uneven platform drops down into the depression between the Capulin and Sierra Grande, in which is gathered the drainage of the headwaters of the dry Cimarron.

The lines of low basalt-capped bluffs on the west and northwest borders of the vega present at least two distinct benches, of which the lowest is about 75 feet in height, the other or highest (that shown on the left of the Capulin in the sketch) perhaps as high again above the vega. The lower one presents along its crest frequent abrupt outcrops, but in the higher bench the basalt forms a low uninterrupted wall, showing very irregular columnar structure, below which the *débris*-strewn talus descends to the lower levels. There is also here observed a lower basaltic outcrop, which forms a third irregular bench, somewhat less than half the height of the next higher bench; but whether it represents a distinct deposit, independent of those appearing in the higher terraces, was not determined. Indeed, the thickness of the basaltic beds was in no place satisfactorily exhibited, though in places the upper one shows a solid outcrop of 20 to 30 feet without revealing the nature of the deposits upon which it rests.

Nearly due north of the Vega Spring, overlooking the intervening basaltic beds above alluded to, another volcanic cone rises to view, which, though not so perfect as the Capulin, is yet unmistakable in its origin; the western rim is deeply broken down, showing the crater-depression, while the opposite wall still remains perfect, and is much like that of the Capulin. Perhaps not quite as high as the latter cone, it rests upon a similar uneven upland eminence, and is grassed over to the summit. The formation of these high spreading bases seems to be directly attributable to the volcanoes themselves, and may have been built up in the early stages of the eruption, which terminated in the building-up of the conical elevations around their orifices.

The Sierra Grande, like Laughlin's Peak, when seen from the west, presents a broad-based mass gradually culminating in a blunt or rounded summit, which attains an altitude of about 8,000 feet. Laughlin's Peak, however, viewed from the northwestward, shows a deep depression extending half-way from the summit to its broad base, and which has all the appearances of a crater, the northwestern rim of which has been demolished. The contour of both these mountains, as also that of the Eagletail, suggests their possible origin as centers of volcanic eruption; but they probably mark the sites of much larger and possibly older craters than the Capulin and others, which still retain their symmetrical form and undoubted character. Their conical shape would seem to indicate a different origin from that of the basaltic overflows, which distinction, in the case of the Capulin, is also quite manifest in the difference in the physical character of the igneous products ejected, and out of which the cone surrounding its crater was built up.

There would appear to be several distinct basaltic deposits in this region, as evidenced by the presence of at least three or four benches, or terraces, of different levels. As stated above, there are at least two such deposits, occupying comparatively low elevations, bordering the Capulin Vega; and probably a third and lowest bench, which latter, from the character of the material thrown out from the excavations of some burrowing animal (perhaps the prairie-dog) in the edge of the vega, apparently rests upon light, indurated, marly shales, probably

referable to the Cretaceous. These benches occupy too considerable areas, and are too uniform in their relations to one another (although slightly undulating, as though deposited upon an uneven surface), to admit of their present position being referred to the subsidence or settling of portions of the same basaltic level. Yet they may have originated in one and the same outpouring of molten matter, which was deposited upon or spread over the inequalities of the surface, preserving, as it were, the topographical features wrought at the close of the Tertiary, and immediately preceding the epoch during which the present contours were fashioned, and which latter involved alike the wasting of the basaltic overflows and the old terrace-levels in the Tertiary and Cretaceous, which were flooded by the igneous matter.

Besides these less conspicuous deposits, there is the great basaltic bed capping the Chicorica Mesa, in the midst of which there occur what appear to be distinct volcanic cones and craters of later origin. The Tanaja is probably an isolated remnant of the same great overflow, which involved an immense extent of territory along the eastern flank of the Spanish range, the actual extent of which may be inferred from the wide distribution of the comparatively insignificant areas which still exist in the mesas of Rayado and Gonzalitas, between the Cimarron and Ocaté, and probably other similar outliers farther to the southward. As has been suggested by Dr. Hayden, the origin of these immense outpourings of igneous products is probably due to immense and innumerable fissures in the earth's crust, the direction of which seems to have been determined by forces acting nearly at right angles to the old axis of upheaval in the range to the west. Through these fissures the molten matter escaped, overflowing extensive areas of the Tertiary plateau and perhaps lower levels of the Cretaceous, as would appear from the evidence afforded by the several distinct benches seen to-day in which these basaltic deposits vary in relative level at least 1,500 feet, comparing the extremes, as represented by the lowest bench on the borders of the Capulin Vega and the great bed forming the summit of the Chicorica Mesa, a few miles to the northwest. This great outburst of basaltic-making materials probably antedates the formation of the volcanic cones, which latter, it would appear, more properly pertain to a later time, or during the subsidence of the active period of overflow, representing, as it were, the expiring throes of volcanic action, where the forces were concentrated, and only manifesting their existence in isolated centers of true volcanic crater-building phenomena.

When we come to review the few facts elicited during a flying visit, they seem merely to approach the threshold of a field the investigation of which would clear away all uncertainty respecting the origin and relations existing between the various and diverse phenomena there manifested.

