DEPARTMENT OF AGRICULTURE, INSURANCE, STATISTICS AND HISTORY.

GEOLOGICAL SURVEY OF TEXAS.

JNO. E. HOLLINGSWORTH, Commissioner. E. T. DUMBLE, State Geologist.

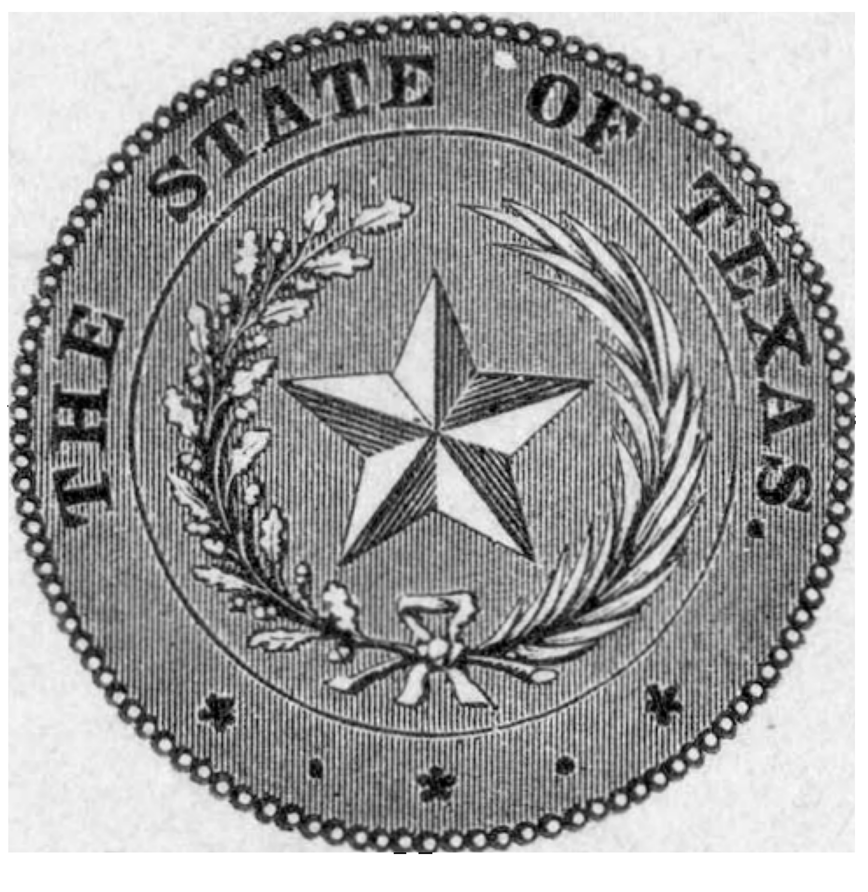
BULLETIN NO. 3.

RECONNOISSANCE

OF THE

GUADALUPE MOUNTAINS,

BY R. S. TARR.



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LETTER OF TRANSMITTAL.

DEPARTMENT OF AGRICULTURE, INSURANCE, STATISTICS AND HISTORY.
GEOLOGICAL SURVEY OF TEXAS.
AUSTIN, TEXAS, December 15, 1891.

Hon. Jno. E. Hollingsworth, Commissioner of Agriculture, Insurance, Statistics and History.

DEAR SIR—I herewith transmit for publication the report of Mr. R. S. Tarr on his "Reconnoissance of the Gaudalupe Mountains."

Owing to the amount of material on hand this report, with others, was crowded out of the Second Annual Report in which it was intended to appear and is therefore presented for publication in the form of a Bulletin.

Yours very truly,
E. T. DUMBLE,
State Geologist.

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PREFACE.

The following pages, descriptive of the results of a trip across Central Texas and into the Gaudalupe mountains, which lie some seventy-five miles west of the Pecos river stretching northwest and southeast across the line between Texas and New Mexico, were intended for publication in the Second Annual Report of this Survey. On account of the number and length of the papers on hand it was necessary to omit several which will be issued as Bulletins.

The work assigned Mr. Tarr contemplated a much more detailed investigation than is here recorded, but circumstances prevented its completion. His return to Cambridge and consequent separation from the materials he had collected on the trip has prevented anything like a complete study of them, and it must be considered, therefore, that the opinions expressed are, as Mr. Tarr says, tentative only, being simply the ideas formed during the field study which, while it was done as carefully as possible, was necessarily of a somewhat rapid character. The facts observed, however, are of considerable interest and add their quota to our knowledge of the topography and geology of this hitherto little known region.

During the present summer further explorations have been made of this range by Prof. Cummins who followed down it from the north. The results of this will be found in his paper in the Second Report of Progress, now in press, and in greater detail in the Third Annual Report of the Survey.

E. T. DUMBLE,
State Geologist.

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RECONNOISSANCE OF THE GUADALUPE MOUNTAINS,

BY R. S. TARR.

INTRODUCTORY.

GENERAL STATEMENT.

The object of this work was to determine the age of the Guadalupe mountains, their geological structure and relation to the strata east of the mountains with particular reference to the artesian water supply of the Plains, and the prospects of the district for coal and other minerals. Circumstances prevented the completion of these plans and consequently the work was done in much less detail than was at first intended. Instead of four months, as was at first planned, only two months were spent in the field and less than one month in the mountains. Furthermore, there being no topographic map of the region and it being impossible to make detailed observations in consequence, the work has necessarily been general rather than of a detailed nature. For these reasons this report is no more than a reconnoissance. Still it has been possible to add something to the knowledge of this region, both of the geology and the economic resources as revealed by the geology.

In order to become familiar with the Permian beds of Central Texas so that they might be recognized, if they existed in the Guadalupe mountains, as reported, it was considered desirable to make a hurried trip across the Permian, thus connecting the Carboniferous area which the writer had previously studied with the Carboniferous of the Trans-Pecos region. In this reconnoissance journey more than a month was spent in constant driving westward and the country from Lampasas to the Guadalupe mountains was hurriedly traversed. The advantage of this in the subsequent work was inestimable. The remaining time at my disposal, less than a month, was spent in and about the mountains.

PREVIOUS WORK IN THE GUADALUPE MOUNTAINS.

The first authentic information about the geology of these mountains came from Dr. George G. Shumard,* who was, in the year 1855 appointed geologist to the expedition under Capt. John Pope, of the U. S. A., ordered by the War Department to test the practicability of obtaining artesian water on the plains of Texas and New Mexico. This eminent geologist and explorer described quite accurately, as was his custom, the region which he traversed, and there are but few points in which my observations, in any essential particular, disagree

*Observations on the Geological Formations of the Country between the Rio Pecos and the Rio Grande, etc., G. G. Shumard. Trans., St. Louis Academy of Sciences, 1858, pp. 273–289.

with his made thirty-five years ago. This paper is in the form of a detailed report of the geologic features of the route followed. His full report was not published by the War Department, but in the year 1886, this was published by the Department of Insurance, Statistics and History of the State of Texas.*

The first announcement of the supposed Permian age of the Guadalupe mountains is made by Dr. Shumard on p. 277 of the Trans. St. Louis Academy of Sciences for 1858, the announcement being based on the paleontologic researches upon his collections by Dr. B. F. Shumard. The latter announces† the Permian age of the Guadalupe mountains by the description of new Permian fossils.

Later another paper‡ based upon the same collections gives a list of all the fossils obtained, many of which are announced to be identical with Permian fossils from Europe and Kansas. Since then I know of no publication which refers these mountains to the Permian age.

Prof. Jules Marcou, in the year 1858, published his geological map|| in which the mountains are colored Carboniferous.

A review of the papers published by Dr. B. F. Shumard, expresses§ some doubt of the conclusions arrived at by Dr. Shumard.

Nothing has appeared since then so far as I know except a paper by Walter P. Jenney, briefly describing some geologic features of the south end of the mountains along the route travelled. Without giving reasons, he speaks of the rocks as Carboniferous.**

There is in the archives of the Geological Department at Austin a manuscript report by Dr. G. G. Shumard upon the artesian water supply of the region east of the Guadalupe mountains. My results agree almost directly with his. This report was never published by the War Department, nor was his advice heeded, but much money and time were wasted in a futile search for water contrary to it.

I have divided this report into two sections. First. A brief statement of the reconnoisance of the Central Texas Permian. Second. A description of the geology of the Guadalupe mountains.

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*A Partial Report on the Geology of Western Texas, etc., by Dr. Geo. G. Shumard, Assistant State Geologist of Texas, p. 145, Austin State Printing Office. 1886.

The portion particularly referring to the Guadalupe Mountains and vicinity is in Chap. V., pp. 88-96.

†Notice of New Fossils from the Permian Strata of New Mexico and Texas. B. F. Shumard, Trans., St. Louis Acad. Sciences, March 8, 1858.

‡Notice of Fossils from the Permian Strata of Texas and New Mexico. B. F. Shumard, Trans., St. Louis Acad. Sciences, 1859.

||Geology of North America. Zurich, 1858.

§American Jour. Science, Vol. XXIX., 1860, pp. 125-126, signed "M."

**Notes on the Geology of Western Texas near the 32d Parallel. Walter P. Jenney, Am. Jour. Science, 3rd series, Vol. VII., Jan., 1874.

PART I.

RECONNOISSANCE SECTION ACROSS THE PERMIAN OF CENTRAL TEXAS.

In the section made by the writer during the winter of 1888-89, across the Central Texas Carboniferous area of the Colorado Valley the section ended a few miles northwest of Coleman, where the Carboniferous is covered by Cretaceous. The Carboniferous is there dipping gently northwest while the Cretaceous lies uncomformably with a very gentle southeast dip. The Carboniferous beds at the point where they are covered by the Cretaceous, belong to the Colemán division and consist of mottled and vari-colored clays interbedded with limestones containing considerable clay. A description of these beds appeared in the First Annual Report.

ROUTE FOLLOWED.—From the point where the last section ended I travelled northwest to Abilene and thence W. S. W. along the line of the Texas & Pacific R. R. to the Pecos river, a distance of 279 miles. With the exception of certain small Cretaceous areas and some beds of Carboniferous between Coleman and Abilene, the strata along this route are all Permian.

CRETACEOUS AREAS.

The first of these Cretaceous areas was seen northwest of Coleman where it forms a divide between the head-waters of the south branches of Jim Ned creek and some small creeks directly tributary to the Colorado river. It is a very much degraded area consisting chiefly of beds of the Trinity division capped in the higher parts by limestones of the Comanche series. On the southeast side the base of the Cretaceous is 1930 feet above sea level but three miles northwest the contact between the Cretaceous and the Carboniferous is found at an elevation of 2025 feet.

Cedar Gap is a pass in the range of Cretaceous buttes formed by the combined erosion of two creeks, one tributary to the Colorado and the other to the Brazos. A range of these Cretaceous buttes or mesas extends from near the Colorado eastward, several miles beyond Cedar Gap and mark the divide between that river and the Brazos, and are remnants of the old Cretaceous plateau remaining in degraded form in the region of slow erosion, or at the head-waters.

Above the general level of the gap, in the lowest part of the butte are about twenty-five feet of red beds, evidently Permian. Above this are one hundred feet of Trinity Sands capped by twenty-five feet of thick bedded limestone (Comanche series). The lower Trinity beds are yellow and gray sands and clays with a considerable admixture of red clay. This red clay is so abundant as to give the lower part of the buttes on both sides of the gap a distinctly red appearance, thus giving additional evidence to the extremely local derivation of the varying Trinity beds.

From Big Spring westward for one hundred miles the geological structure is undoubtedly Cretaceous though in a few small isolated patches the Permian may come to the surface. The first indication of the undoubted Cretaceous is in a railway cut two miles east of Big Spring. A small syncline here exposed in section has a southeast axis and a dip in one place as great as ten degrees southwest and five degrees northeast.

The width of the syncline is not more than 100 feet in the exposed section.

Beginning at the base the section is:

Dark red cross-bedded sandstone	3 feet
Red sandy clay streaked with white	1½ to 3 feet
Dark red, very much cross-bedded, sandstone, slightly conglomeritic .	4 feet

Conglomerate grading into the lower sandstone, and composed of pebbles generally as large as a nutmeg and larger. Pebbles are quartzite and other metamorphic rocks (hornblendic, etc.,) and considerable limestone, resembling that of the Coleman division. The small pebbles are generally well rounded, but the larger ones are often quite angular. The cement is limy and in places magnesic.

This conglomerate resembles quite closely the Trinity conglomerate of the Cretaceous, and it may belong to this age. Several specimens of oysters were found in the conglomerate, but they are in such a poor state of preservation that it is quite impossible to determine them.

On the railway, 2½ miles west of Big Spring, there is a cut in an impure clayey greensand, from which bones were collected. No other fossils were found in this vicinity. Above this sand is a yellow sand overlaid by an unfossilliferous magnesic limestone. Chiefly from the character of the overlying beds I conclude that this stratum is a member of the Trinity division of the Cretaceous, and this conclusion is rendered the more probable from the occurrence of the oyster-bearing bed beneath it east of Big Spring.

CRETACEOUS NEAR MARIENFELD.

The strata in the bluffs bordering the valley of Girard creek have a general reddish hue toned down in intensity by lighter colored sands. These may be Trinity beds with a red color derived from the underlying Permian, though of this I can offer no definite proof.

From this point westward the country is a gently undulating plain without any abrupt rises or marked hills, but with a general ascent westward. There is little to indicate the geological structure in this section, but the soil is sandy, and it is probable that the strata exposed in Girard creek continue for this distance. Three miles east of Marienfeld a peculiar mottled limestone appears above the sand. It has a very pretty marbled appearance due to concentric rings of white and pink, the latter being no doubt derived from an oxide of manganese. As it is very soft and fades in the sun, it is probable that this will not be of any value in the arts, although in a fresh piece it is very beautiful. Above and below it is a reddish sand. No fossils were found in this rock. In some cases it contains small scattered conglomeritic pebbles. This resembles, in certain respects, a banded alabaster appearing above the Carboniferous near the head of Delaware creek on the west of the Pecos, and may be a contemporaneous, or, perhaps, a continuous stratum.

At and near Marienfeld, particularly west of that town, a comparatively pure stratum of water is found at moderate depth (45 feet, differing according to location) beneath this limestone in a stratum of sand. It is not artesian, but is pumped by windmills. Indeed, there is a water-bearing stratum at about this horizon for many miles west of Marienfeld. As it is cut on the east and west by deep valleys, and as the surface of the country is above the source of water supply, no artesian water is to be expected in or near this bed.

West of Marienfeld the bed rock appears from the soil to be entirely limestone and sand pebbles finely conglomeritic in places. The limestone first encountered east of Marienfeld still continues, outcropping occasionally but always unfossiliferous. The persistence of this layer for thirteen miles on a country sloping eastward seems to indicate an easterly dip, though a very slight one. At the section house at Germania, ten miles west of Marienfeld, an oyster bearing bed is found above the banded gypsiferous limestone. At the Warfield section house, twenty miles west of this, another gryphaea bed is found, possibly the same as that last mentioned.

Numerous sink holes occur between Midland and Odessa indicating that probably here is one chief source of supply for the water contained in the water bearing stratum so frequently encountered hereabouts.

The undulating prairie ceases about five miles east of Metz, ending abruptly in a somewhat degraded mesa bluff facing westward and this is the eastern boundary of the Pecos valley along my line of section. Douro, the highest point on the T. & P. R. R. east of the Pecos, is about 3100 feet above sea level and 500 feet above the Pecos River. It is on the divide between the Pecos and Concho but there is much country hereabouts which is almost entirely without surface drainage.

At Douro there is a gryphaea bed made up almost of these fossils. The section exposed on the face of the bluff west of Douro is approximately as follows, beginning at the top:

Marbled magnesic limestone, unfossiliferous.
Gryphaea Pitcheri (?) beds.
Unfossiliferous limestone much discolored by iron.
Very fosiliferous limestone, rusty.
Sandy limestone.
Sand, yellow and red in places.

The total thickness from one to five inclusive, is about 150 feet, but the thickness of the sand was undetermined. The fossiliferous limestone beds, except the gryphaea beds were not detected farther east, but this is not strange since the greater part of the country is covered with a deep residual soil.

From the base of the mesa bluff just east of Metz to beyond Monahan, a distance of nearly twenty miles, the Trinity sands cover the surface in the form of sand dunes. This strip of sand extends many miles north and south averaging in width from twelve to fifteen miles. It is a striking development of blown sand and with every breeze the sand is shifting position. The conical hills, and crater like pits so typical of similar æolian deposits, are strongly developed here where they are rendered possible by the aridity of the climate and the presence of an abundant supply of sand furnished by the Trinity beds, as the bluff recedes and partly protected from removal to the eastward by this high bluff. The sand is chiefly white, having been bleached during its long exposure to sun and wind and is scantily clothed in places by such native plants as greasewood, sagebrush, mesquite, cactus, soapplant and sandgrass. These in part hold the sand in place, but only partially so, since in this region every moderate breeze carries along clouds of sand before it.

CARBONIFEROUS.

COLEMAN BEDS.—Where the Trinity beds disappear, northwest of Coleman, the Coleman beds of the Carboniferous are found beneath them. At this point there is a blue, very much rusted, clayey limestone containing many specimens of a large *Pinna*, *Myalina*, *Bellerophon* and *Bryozoa.* One *Pinna* on a slab near the road had a length of 23 inches, with a greatest width of 3 inches. A portion of the small end was gone.

The region hereabout is but recently uncovered by the erosion of Jim Ned creek In the valleys the Carboniferous rocks are exposed, but to the north and west, as well as south, hills and buttes are found. Some of the hills from which most of the Cretaceous has been removed are still partly covered by small patches of Trinity Sand.

The character of the Carboniferous rocks is identical with that described in the report on the Carboniferous under the head of the Coleman beds. There seems to be very little clay, but its apparent absence may be due to the talus covering formed by the down dropping of the limestone on the hill sides This feature is quite typical of the

Coleman beds in other sections, the bluffs being on the outcrop (S. E.) side, and the chief erosion being that of the soft clays and the consequent breaking down of the harder limestone layers. This process has entirely obscured thick and numerous beds of clay where other evidence has proved their existence. Furthermore much of the exposed Carboniferous has not suffered extensive denudation, since it has been only recently uncovered.

The fossils of these beds are not varied in the number of forms, but some beds contain a great abundance of individuals belonging to such groups as *Pinna*, *Myalina*, *Bellerophon*, and certain *Bryozoans*. Everything indicates that fossils fitted for hardy life were the only ones to flourish under the conditions that then existed. A specimen of *Pleurophorus*, found just northwest of Coleman, points to the approach of Permian times.

TRANSITION FROM CARBONIFEROUS TO PERMIAN.

Just northwest of the fork of Jim Ned creek the approaching change from Carboniferous to Permian previously indicated by the change in fauna receives further confirmation by a lithologic change. The dip of the strata, however, appears to remain unchanged. No unconformity or overlap appears in this line of section, and if such phenomena exist, they can be detected only by continued work along the line of contact. One would infer from all the evidence that appears in the single section traversed that the red beds of Central Texas directly and conformably succeeded the Carboniferous with a line of contact that must be arbitrarily drawn. Certainly, however, the Permian is foreshadowed in the Carboniferous and in the Permian, relics of the Carboniferous are found, so that the break, if any existed, was small indeed.

The Permian in its best development is in nearly every way distinct from the the typical Carboniferous and in many ways from the upper beds of the Carboniferous. There is only a tract of a few miles in breadth about which any doubt can be entertained. The beginning of the Permian epoch was indicated in Central Texas at the close of the deposition of the beds of the Brownwood division. The seashore deposits of the Waldrip division with its accompanying bed of coal apparently marked the beginning of the great inland sea which reached its best development in Permian times. Throughout much of the Coleman strata seashore deposits reappear at frequent intervals as the section is studied upward and everywhere the presence of an abundance of clay is indicated. The faunal features still remain Carboniferous throughout the Coleman beds, but the life is in many ways different from that which existed during the deposition of the Brownwood beds in the clear deep water.

The apparent transition stage between Carboniferous and Permian begins one half mile northwest of the south fork of Jim Ned creek. Here a bed of red sandy clay forty feet thick appears both overlaid and underlaid by a rusty clayey limestone. This in itself in no way differs from similar beds observed southeast of this in the typical Coleman, but this marks the beginning of a change in which finally nearly all the beds assume a reddish hue. The transitional beds should probably properly be classed with the Coleman beds of the upper Carboniferous, and the whole Coleman series may be possibly classed as Permo-Carboniferous.

TYPICAL PERMIAN.

A few miles northwest of the south fork of Jim Ned creek appear thin bedded shaley, red sandstones and red clays with geodic concretions.

From this on to Abilene the soil is everywhere of the peculiar red Permian hue. Occasionally limestone fragments indicate the proximity of this rock to the surface. It is invariably magnesic and in the creek bed six miles south of Abilene there is a typical exposure of the clayey pure white dense magnesic limestone of the Permian.

A deep red soil covers nearly all the country, derived no doubt by the wash from the abundant Permian clays. In places the soil is a fine grain sandy conglomerate, possibly derived from the decay of some Trinity conglomerate, but more probably from the decay of Permian.

From Abilene my course followed approximately the Texas & Pacific railway first a little north of west, then west-southwest to Pecos City.

Around Abilene and westward for six miles no bed rock outcrops, but the country is a comparatively level, deep soil prairie covered with mesquite. The soil is chiefly a sandy fine grained conglomerate. Seven miles west of Abiline near the railway there is an outcrop of Permian conglomerate and it is very likely from this bed that the soil to the east is derived. Fossils were collected in a bluish gray clayey limestone eleven miles west of Abilene in a railway cut. The fossils belong in the genera *Pinna*, *Myalina*, *Productus*, *Bellerophon* and *Lima* (?). They appear to be in no way different from the fossils of the Coleman division.

The level country continues westward to Merkel, twenty miles west of Abilene, but at this point the prairie character is lost and is succeeded by hills. This change has been brought about by the erosion of Sweetwater creek and other branches of the main Elm Fork of the Brazos. This change commences just west of Merkel where the east facing mesa rises to a height of more than seventy-five feet. The face of the Merkel mesa exposes alternating red and white strata of clays, sandstones, conglomerate and limestone. A peculiar purple conglomerate appears near Trent, consisting of sandy and breccia layers with a purple cement colored probably by maganese.

As far as Merkel and eight miles west of this the water in wells is of good quality, but at the latter point the character of the water changes and gypsum water begins to be found. Just beyond this, one and one-half miles west of Trent is a gypsiferous pulverulent white limestone with occasional (generally small) pebbles. Just west of Trent a small bluff reveals alternating red and white (gypsum) beds overlaid unconformably by recent conglomerate.

From Trent to Sweetwater, a distance of ten miles, the country is very rough being either much cut up sandy mesquite flats, or hills with a surface coating of recent conglomerate. The soil is chiefly reddish, but most of the rock outcrops are of white pulverulent limestones. Two miles west of Trent there is a stratum of gypsum, and gypsum is also associated with the white limestone in thin bands and layers. Near Sweetwater in Sweetwater creek there are alternating strata of red clays and white gypsiferous beds. No fossils were noticed in any of these beds.

From Sweetwater westward, the country rises quite rapidly for eighteen miles, this being the divide between the Colorado and the Brazos. The divide at the point crossed is a nearly level prairie with some mesquite, but in large measure without any brush growth. While apparently quite level, it slopes gently eastward, though no drainage is apparent for a distance of four miles east and west. This is succeeded westward by gently rising land to the top of its divide when the gentle eastern slope is succeeded by a rapid descent into the valley of the Colorado In less than three miles the descent is two hundred feet. Beyond this the slope is more gradual, but from the top of the divide to the bed of the Colorado, the country is much broken, being there very different from the country on the Brazos side of the divide.

Between Sweetwater and Loraine, few outcrops occur, but the surface is chiefly sandy and conglomeritic, its soil always having a reddish hue. Three miles west of Sweetwater there is a conglomerate with a very limy cement closely resembling certain Trinity conglomerates in Brown and adjoining counties The pebbles are quite angular and often large, sometimes weighing several pounds. These pebbles are chiefly limestone and many of them resemble the Coleman and the Brownwood limestone. There are also limestone pebbles closely resembling the Silurian rock of San Saba county. Certain flint pebbles aid in this resemblance, but no fossils have been found in them. It seems difficult to account for the presence of these large, quite angular pebbles so far from any known outcrop.

It is quite probable that this and other similar conglomerate layers are the source of supply for the abundant recent conglomerate here and at various places east of this point. This common conglomeritic soil may have been derived either from residual decay or transportation or more likely from both causes combined.

At Colorado City, on the Colorado river, there is a great development of sandstone and conglomeritic sandstone appearing both in the broken hills and bluffs and as a residual soil on the surface. A well bored to the depth of nine hundred feet at Colorado City passes chiefly through sandstone to a stratum of water which rises to within two hundred feet of the surface. A bed of rock salt encountered in the boring changes the water to a brine and this is pumped to the surface and used in the manufacture of salt.

Throughout much of the sandstone there is some salt, and in a creek bed four miles west of Colorado City the water is saline.

The dip of the Permian strata has been uniformly northwest but at a decreasing angle. So small is the angle of dip that it is almost impossible to tell in which direction the rock is tilted, and this difficulty is increased by the peculiar nature of the beds. many of which are so easily eroded that the exact outcrop edge is either very irregular or entirely covered. Near Colorado City the strata are so nearly horizontal that I have been unable to make any determination of the direction of dip.

DOUBTFUL BEDS NEAR WESTBROOKE

The mesa country commences just west of Westbrooke in the valley of the Colorado. At this point a gentle undulating prairie is succeeded westward by a mesa with broad prairie-like top and with abrupt faces on the southwest side. Here the beds are chiefly red clay with bands of red shale and some thin limy layers. The lithologic appearance of this country is so much like the Permian farther east that one would not suspect that there was a possibility of its being of a different age. The occurrence of selenite crystals in the clay is worthy of note. The abundance of clay in these beds is quite noticeable in distinction to its absence in the upper beds of the Permian just passed over.

At Iatan, another more marked mesa facing eastward is encountered. A broken wall varying from fifty to one hundred and twenty-five feet in heighth extends in a general north and south course. The lower seventy five feet of the mesa wall consists chiefly of red clay with occasional bands of red shale and sometimes bands of limestone. This is overlaid by twenty feet of white sandstone very much cross bedded, the layers in some instances dipping at diverse angles as high as ten or fifteen degrees. This sandstone is limy with occasional small pebbles. Above the sandstone on the top of the mesa is twenty feet of a remarkable quartzitic comglomerate very hard and flinty, quite compact, and breaking into angular pieces. It contains many small pebbles, generally less than the size of a pea, though with a few as large as a nutmeg. The cement is in places magnesic. The Iatan mesa appears to dip as much as two degrees S. E., and a southeast dip has been quite noticeable since leaving the Colorado.

Between Iatan and Big Spring the surface of the country undulates considerably with a general rise to the west to within six or seven miles of Big Spring, when the valley of Girard creek, a large branch of the Colorado, is reached. The soil is chiefly sandy with some red clay. Near Girard creek the soil is very sandy, the sand being derived from a calcareous or magnesic white sandstone, which outcrops for some distance east of Big Spring. To the south and west are a series of buttes and mesas, the most remarkable of these being Signal mountain on the west side of Girard creek. This butte, apparently perfect in outline from any view, stands out as an outlier entirely isolated from the mesa. From the base of the mesa, south of Big Spring, a great body of constantly flowing water comes to the surface, forming the water supply of that town.

While the conglomerate east of Girard creek is plainly post Permian and probably lower Trinity, and the beds described west of the creek are probably of corresponding age, it is quite possible that the white sands of Girard creek are still Permian.

EROSION AT SOUTH BORDER OF LLANO ESTACADO.

The type of erosion west of Big Spring is interesting. Girard creek, so called, is not a creek in any sense of the word. There is a broad valley, but without extraordinary floods water cannot flow in it. For six miles the railway follows up this valley, then the valley turns northward into the Llano Estacado. The average width of the valley is not more than a mile, and the borders are more or less degraded bluffs, sometimes quite abrupt, and generally from 50 to 100 feet in height. There is no channel, but here and there a lagoon, generally no more than a bog or an alkaline flat without vegetation of any kind. The valley has apparently been deeper, and it is now filled with sediment probably in part brought down from time to time whenever excessive rains furnish water enough to permit of its flowing, as I am informed is sometimes the case. Much of the detritus with which the valley is at present clogged is derived from the neighboring cliffs in time of rain, and is deposited in the form of local and temporary deltas. The general appearance of the valley is that of a shallow estuary in the marshy country of the seacoast of the northeastern states. This resemblance is increased by the presence of barren flats without vegetation and the presence in places of a coarse salt grass, whose habitat is a damp clayey alkaline soil. Much of the valley is occupied by low mounds (cone deltas) and mesquite flats, and one would not suspect that water ever flowed in the valley.

How to explain this comparatively deep valley, and the clogged up channel is difficult. The stream, when one flows, is plainly overburdened. In some way it may be connected with the Quaternary lake deposits of the Llano Estacado. It may even be a case of reversed drainage, or, if not, a valley formed in times when the water supply was greater than at present.

South of Big Spring the valley is quite different, being here cut into the bed rock not only in the channel proper but runs into the surrounding country. The sharp erosion at this point indicates a young drainage and it seems very much as if the headwater erosion of a rejuvenated stream was now employed in removing the detritus with which the stream bed has been clogged in earlier times. The Concho river farther west is a similar instance of this peculiar drainage.

PROBABLE PERMIAN NEAR PECOS CITY.

Beyond Arroya rocks appear, the geological position of which I am unable to give. These are white limestone, weathering chalky white. They may be a part of the lower Trinity.

Beneath these, near Quito, east of Pecos City, a compact well-jointed red sandstone occurs, dipping gently southeast. This, I believe, to be Permian, though I can offer no definite proof of this, since there are no fossils and I have not studied their relation with beds above and below which may be possible further south.

A company recently organized has commenced developing this sandstone, which promises to be one of the best in Texas, and to rank well with the building stones of the west. It is of a beautiful red, uniform in color and texture, easily worked, yet durable and in every way adapted to the best uses in building. Considerable stone has already been contracted for The company was, at the time I passed, engaged in boring a well which had already passsed through one hundred feet of red sadstone. This, coming as it does, below what appears to be the base of the Trinity, seems to indicate a Permian age.

PART II.

GEOLOGY OF THE GUADALUPE MOUNTAINS.

GENERAL STATEMENT.

For reasons which will appear later, I believe the Guadalupe mountains to be carboniferous in age contrary to the opinion of the Shumard Brothers, the only other geologists who have ever studied the mountains *

The lower rocks are yellow, clayey sandstone, with beds of black limestone, in places almost a slate. The middle beds are thick bedded fossiliferous white magnesian limestone and the upper beds sandstone chiefly. These will be described in more detail later. No Permian beds appear between the Guadalupe mountains and the Pecos in the section studied, but wherever the Carboniferous is covered by later formations these deposits are either Quarternary or Cretaceous. In the mountains proper, the rocks are all Carboniferous, but on the northern end in New Mexico Cretaceous beds exist in the foot hills, and from this point a scarp of Cretaceous rocks covers the Carboniferous at a progressively increasing distance toward the southwest being, at the head of Delaware creek, about twenty miles from the base of the mountains. Quarternary conglomerate appears both on the Carboniferous and Cretaceous at places.

Topographic Features of the Guadalupe Region.

The chief part of the Guadalupe mountains lie in New Mexico, and this end was visited only in so far as was necessary for a correct understanding of certain general features.

The general form of the Guadalupe mountains is prow shaped. Commencing in New Mexico, at a moderately low elevation and more than twenty miles wide, they become progressively higher followed southward, at the same time becoming narrower until the point of the mountain is reached. This, the southern part, is just south of Guadalupe Peak the highest point, which is eight thousand feet above sea level. The point of the mountains is a precipice in the white magnesian limestone fully two thousand feet high which suddenly terminates the mountains. South of this the line of disturbance is continued in the form of foot hills with an abrupt face to the west.

On the northern end in New Mexico the mountains continue for many miles becoming progressively lower until they are really no more than foot hills. The dip of the strata in the mountains is very

*Mr. W. P. Jenney speaks of them as carboniferous, but without giving reasons. Mr. Jenney's report to the railway company has never been published, and merely a brief mention of the mountains appears in his paper Am. J. Sci., 1874, previously mentioned.

nearly east on the average, being in some cases N. 70° E. At places the amount of dip is widely different, but in general it is from three to five degrees a few miles away from the mountains and become in some cases twenty to thirty degrees in the heart of the mountains. The direction of dip is quite variable locally because of numerous small folds. The Guadalupe are monoclinal in structure, the dip being diagonal to the eastern exposed face. That is, the mountains as seen from the east trend N. E. by N. while the dip is N. E. by E. This, therefore, accounts for the progressive increase of elevation southward as well as the rise to the westward, in other words, it accounts for the mountains as seen from the east.

A gradual increase of dip westward to the heart of the mountains is then followed by a general decrease in amount of dip, and this gentle easterly dip on the west face of the mountains quickly, in two miles, and in some cases even less, changes to a sharp westerly dip, in some cases as high as thirty degrees. Numerous small faults and folds were detected in the area, which has a linear extension in the region examined of at least twenty-five miles. A valley marks this apparent anticlinal crest for the entire distance and occupies the site of what I believe to be a great fault. The evidence both for and against this hypothesis will be given later. On this basis the Guadalupe mountains are considered to be a Carboniferous monoclinal fold dipping eastward and terminated to the west by a great north and south fault. The anticlinal appearance being due to dragging up of the strata on the downthrow side. These points are mentioned in this place on account of the bearing which they have upon the development of the topographic features; but their discussion is reserved for the chapter upon the geologic structure.

Sharp and rapid erosion has deeply carved these hard rocks. One of the most striking features is the remarkable roughness of the mountains and the innumerable great precipices everywhere existing in the mountain canons. There are hundreds of distinct precipices over a thousand feet high, nearly vertical. These are observed in every canyon and many large gorges heading in the interior of the mountains. This feature is rendered possible not alone by the youth of the drainage and the massive hardness and uniformity of the magnesic limestone forming the greatest part of the center of the mountains, but also by the character of the joint planes which are strongly developed to great depths. Possibly, also, fault lines may have aided in this, but of these I have found no evidence in any part of the mountains, except the western face.

DARK CANYON.

The Guadalupe mountains are drained by five important creeks, three of which flow eastward into the Pecos and two westward into the

Crow Flat Valley, where any water that they may ever carry is lost. The easternmost of the east flowing tributaries is Dark Canyon, which heads well up toward the Texas line and flows a little north of east through New Nexico into the Pecos. Everywhere in the mountains and in the foot hills beyond, this creek has for its valley a precipitous canyon. There are several small springs in its course, but it carries no flowing water. From a ranchman living in this valley I learned that for three years the creek, in its middle course, had never carried flowing water. Yet that it sometimes does carry running water in the form of great floods is attested to not alone by the depth of its valley, but by the vast number of large well rounded pebbles with which its channel is littered.

BLACK RIVER.

The next creek southward toward the point of the mountain is Black river, rising by a number of tributaries in the mountains and flowing about North 70° East along the dip of the rocks to the Pecos. There are several canyons of importance among its mountain tributaries, but the southwesternmost, McKitterick canyon, is the most important, and may be taken as a type of the mountain streams in the Guadalupes.

MCKITTERICK CANYON.

At the base of the mountains, near the mouth of McKitterick canyon, this stream has a moderately deep valley with quite precipitous sides. From this point the canyon becomes rapidly rougher, proceeding upstream, and at a distance of two miles from its mouth it is inaccessible to wagons. In a very short distance it is inaccessible to a horseman, and is traversed on foot only under great difficulties. About one and one-half miles from the mouth the canyon forks, and it is by the southernmost of these two forks that the greater part of the Texas end of the mountains is drained, while the northern branch drains a great area in New Mexico. These two forks, one from the south the other from the north, flow nearly parallel to the trend of the mountains, and meet at an angle of about 125 degrees, then the stream cuts through the mountains to the plateau on its way eastward to the Pecos. Irregular in course in the mountains, and with many small tributary gorges, these two forks of McKitterick canyon have done much toward sculpturing the mountains into their present form, and have thus acquired a large and very much broken drainage area.

The hill gorges and canyons in this drainage area are scantily timber covered. A general absence of soil and the aridity of the climate are adverse to any other condition. Yet in the canyons, sheltered from the sun, and upon the higher hills and valleys, much pine and cedar timber is found. Other vegetation is very scanty, and of the usual arid land types, so that upon the steep slopes there is little or no protection to soil that might have a tendency to form under more favorable circumstances.

Although in the midst of a truly arid region, the elevation lifts the general mass of the mountains above this condition into the subhumid belt. Several months are liable to pass without rain, but during May, June, July and other warm months the higher parts of the mountains are frequently capped with rain clouds, and the rain gathered in there often falls well out upon the surrounding plateau and foot hills. During the winter the mountains contain considerable snow, which in the higher and more protected canyons lasts sometimes as late as the middle of April.

During excessive rains the creeks carry water to the Pecos, but this is very rare, and for the greater part of the year the plateau channels are simply dry creek beds; but that they are simply sleeping giants is proved by the broad channels filled with large pebbles and even boulders of white limestone, whose only source of supply is the heart of the mountains often several miles distant.

Numerous springs in the main canyon and its tributary gorges in the mountains furnish a supply of pure clear water, which flows nearly to the mouth of the canyon, where it sinks into the gravelly creek bed.

All along the canyon and its tributary gorges hills of circumdenudation rise abruptly to an elevation often exceeding 2000 feet. The slope is rarely less than 30 degrees, and frequently there are grand perpendicular walls almost vertically rising from 1000 to 1800 feet above the talus. All of the larger precipices are in the massive white limestone. Many of the mountain peaks are absolutely inaccessible from the canyon, and all are ascended only with great difficulty.

This is a young mountain stream, and has been a very active one. This is shown not alone by the rapid fall in the channel and the wonderfully precipitous sides, but also by the presence of a cemented conglomerate, a remnant of the old stream bed, found in fragments clinging to the side of the canyon upon the limestone wall, in one case fifty feet above the base of the channel. The climatic conditions greatly favor rapid erosion in spite of the fact that very little rain falls. One mountain torrent will remove in a few hours more detritus than could be removed in many months by water which collects in a stream by the ordinary rains of a humid climate. Another factor is, of course, the great elevation above base level. Then also the ordinary processes of sub-aerial denudation act strongly in such a region, and the chief work of erosion is the down cutting of the channel, which is not retarded by the necessity of removing a load imposed upon it by the wasting away of the valley sides.

The great amount of rock removed in McKitterick canyon alone cannot be appreciated. The valley for five miles will average 1000 feet deep and one quarter mile wide at the base, increasing in width at an average angle of 35 to 40 degrees toward the top. To this must be added innumerable small and large tributary gorges, all of which are and have for a long time been at work sculpturing the mountains. All of this has an important bearing upon a geologic feature to be noticed later.

The great floods which sometimes flow from these mountains are not only laden with sediment, but roll along quantities of pebbles, in some cases more than 100 pounds in weight. Reaching the plateau, and thereby coming to a region with a smaller angle of slope, the overburdened stream can carry the load no farther, and there it is deposited in or near the channel. These stream channels near the mountains are sometimes a quarter of a mile wide and completely littered with pebbles. This is, I believe, the true cause of origin of some of the Quaternary and recent conglomerates on the plateau. Indeed, in some cases it is undoubtedly so.

Another important factor among these mountain streams is corrosion. All the springs are impregnated with lime, and in a short distance, on flowing over the limestone bed, the water becomes saturated. Shortly becoming overcharged by evaporation, the lime is deposited, and much of the bed of the creek in McKitterick canyon in its lower course has a tufaceous deposit by which pebbles, leaves and sticks are cemented together into a stream bed conglomerate. Much of the conglomerate in the plateau east of the mountains has a similar cement. Thus in the lower two or three miles this mountain brook flows in a cemented pebbly bed, while in the upper course it runs upon irregular rounded bedrock, which it is rapidly eating up by chemical solution.

Corrosive work is also noticed on the hill sides, where the "mountain type" of corrosion is well shown. It is so called on account of the simulation by chemical solution of a relief map of a mountain chain with its gullied ranges and parallel valleys. In the Carboniferous limestone the ridges are rarely more than two or three inches apart, and the valleys not more than an inch in depth. This added to the projection of fossil remains produces a very rough surface. So hard and rough are all the weathered rocks that they are called granite and porphyry by the ranchmen, and compared in cutting power to glass.

Owing to the steeply sloping sides and the hardness of the white limestone there is very little soil anywhere in the white limestone region, but everywhere the surface is strewn with angular corroded fragments of rock.

While McKitterick canyon has gained possession of much of the drainage area of the center of the range other small branches are engaged in a struggle for territory on the eastern face. For several miles south of the Texas line there is a narrow ridge which, from the east, appears to be the highest part of the mountains at this place. It is nearly 8000 feet high and 2500 feet above the base. This is the divide between some small northwest flowing gorges tributary to McKitterick canyon and some east flowing gorges tributary directly to Delaware creek. The divide is for some distance (about two miles) a narrow rocky ridge, often not more than five feet wide. On both sides of the ridge is a small precipice rapidly crumbling down and falling as a talus. In this way the ridge is rapidly losing elevation.

PINE CANYON.

A tributary to Delaware creek, Pine canyon, south of McKitterick canyon, is the only other branch of any importance tributary to the Pecos. It heads in or near the base of Guadalupe Peak, and it is the erosion of this creek which has given to this part of the mountain its sharply defined topographic relief—a feature which is rendered possible by the high elevation of that region. The description of McKitterick canyon applies in all its essential features to this stream.

DRAINAGE ON THE WEST SIDE OF THE GUADALUPE MOUNTAINS—DIFFERENCE BETWEEN THIS TYPE AND THAT ON THE EAST SIDE.

The east face of the Guadalupe mountains, while rugged and steep, is in very few places inaccessible. The northern end is low and not difficult of access, but as the high southern end is approached the ascent becomes more and more difficult, and at the precipitous Point it is impossible to reach the top. Furthermore, the eastern side is cut by gorges and canyons, some of which, as has been described, reach well into the heart of the mountains. The base of the mountains is not bordered by foothills, as is frequently the case in similar ranges, but eastward to the Pecos is a plateau with a quite rapid descent in that direction.

This plateau is carved into hills and valleys by stream erosion, but is not excessively broken. The slope both of the plateau and mountains on the east in general corresponds with the dip of the underlying rocks.

On the western side, however, a difference in geologic structure has produced a difference in topographic character. The western face is precipitous and inaccessible wherever the white limestone outcrops on that side. Furthermore the sharp western dip of the rocks at the base of the mountains on that side has rendered the existence of a series of foot hills in this region possible, and their condition has been favored by the existence of a valley marking the approximate site of the line of geologic weakness. This line, whether fault or fold, is now marked by two valleys in the region which I have studied. One, Guadalupe canyon, on the south, heads in two forks, one on either side of the precipice called "Point of the Mountains." A spring exists near the head of the northernmost of these, but neither fork carries running water for any distance at ordinary times. It seems an inadequate cause for the remarkable precipice, and I am inclined to explain it by other causes than recent erosion. This explanation will appear in its proper place. The drainage of this canyon is into Crow Flat valley.

DOG CANYON.

Dog canyon, the only other stream of importance draining the west side of the Guadalupe mountains in this section, heads very near the headwater of the southern fork of the Guadalupe canyon and at the western base of the point of the mountains. It certainly seems impossible that this small stream, in which no spring even exists, could have carved the precipitous western face of the mountains into its present form and removed all the rocks that are absent. This seems still more impossible when compared with the amount of erosion done by better armed streams on the eastern side. Dog canyon, after flowing parallel with the face of the mountains for fully fifteen miles, cuts through the foot hills and is lost amid the sands and gravels of Crow Flat valley. Several small tributaries encroach upon the mountains somewhat, but in general the drainage area is confined to the foot hills and the precipitous slope of the western mountain face. A very little timber, chiefly cedar, exists in this valley.

CROW FLAT VALLEY.

Crow Flat valley. which has been mentioned several times, is a remarkable valley which I am entirely unable to definitely explain. In order to understand it a much broader study than I was instructed to make will have to be made, extending both into New Mexico and far south of the Guadalupe mountains, and including the mountains on either side. That it is originally a valley of construction is plain, but in just what manner I cannot say. Its linear extension is in general north and south, extending, to my knowledge, fifty miles. The elevation near the point of the mountains is 4300 feet, thus being more than a thousand feet lower than a corresponding point on the east side of the mountains at an equal distance from the base. The valley rises toward the north and apparently heads in the gap between the Guadalupe and Sacramento mountains in New Mexico. I know nothing of the valley south of the Guadalupes, but am informed that it gradually loses elevation in that direction. The Guadalupe mountains form the eastern wall, and this is continued in a line of foothills with a precipitous western face far to the southward. These foothills lack elevation, in part by the absence of the white limestone which forms so much of the mountains proper. On the west side of the valley is a mesa having a high east-facing wall, with a gentle dip appearing to be eastward as viewed from the west side of the valley. Whether this trough is closed at the southern end or not I cannot say, although the uplift of the Davis mountains may have raised the southern portion.

PROBABLY LACUSTRINE.

The Crow Flat valley is filled with a great accumulation of very fine silt and sand. The borders are coarser and contain gravel and rounded pebbles, but from my limited examination I cannot pronounce these lake-shore deposits, for they differ in no apparent way from the delta deposits formed by the mountain gorges at present when they reach more level ground. Other evidences exist in favor of lacustrine origin, though I do not consider them conclusive. The deposits, from one side of the valley to the other, for a distance of from ten to fifteen miles, consists of a very fine silt, in the center at least forty-five feet deep. No channel exists to indicate fluviatile origin nor does it seem possible that a river could produce such a sediment over so broad an area. This is rendered still more doubtful when it is considered that there is a considerable, though gentle, rise on both sides toward the valley borders. Near and south of the point of the mountain the center of the valley is occupied by a series of shallow lagoons, in which water collects at times. The water is alkaline and gypsiferous, and crystals of selenite sparkle in the sand. One lake is a salt lake, supplied by a spring of brine, which, upon evaporation, produces a crust of salt—the source of supply of all the salt used by the ranchmen in a radius of a hundred miles or more. A stratum of alkaline water is found in this valley at shallow depths wherever sought after. Near the northern border of the alkaline lagoons is a bed of white gypsum, apparently interstratified with the clay deposits. This is exposed by recent erosion in a semicircle, and is apparently horizontal, or nearly so.

These various facts indicate a recent large lake, now in the last stages of desiccation; but, upon so incomplete a study, I hesitate to pronounce it one, but prefer to leave this to a later study by one who can give it a more extended examination than I was able to do; and this will serve merely as an indication of the possible existence of such a lake.

ORIGIN OF THE VALLEY.

The cause of this valley is also doubtful. It may possibly be a valley of erosion. Certainly much erosion has taken place on its borders, but no more than could be easily accounted for by lacustrine shore erosion. The southward slope is not counterbalanced by a barrier on the south, and might be considered evidence in favor of the erosion theory and fluviatile origin of sediment. Still, even this would not be conclusive, since the orographic movements to which this section has been subjected in late geologic time may have tilted the basin. A critical study will undoubtedly settle these points.

A simple explanation, though as yet without satisfactory proof, is that it is a valley of construction. Under a discussion of the stratigraphy this will be more carefully considered. On this theory a supposed fault near the western base of the Guadalupe mountains has dragged up the west-lying strata, and produced a synclinal trough in the otherwise nearly horizontal strata.

SPRINGS SUPPLIED FROM THE MOUNTAINS.

From the above discussion it will be seen that the general dip of the strata in the Guadalupe mountains is a little north of east. Both the surface and underground water is guided eastward by this cause. The surface water flows away only in times of heavy rains, while the greater part of the water sinks into the rocks and passes away beneath ground. This appears upon the plateau at favorable places in the form of numerous large springs. Under the head of artesian water these springs will be described in connection with a discussion of the underground water supply.

STRATIGRAPHY OF THE GUADALUPE MOUNTAINS.

According to my observations Dr. Shumard's description is somewhat faulty in places. The dip of the strata is given by him as E. S. E., whereas I find that the dip is nearly east, and in places N. 70° E. The general succession of strata I find to be about as he has given. His section in descending order is as follows:

		Feet.
1.	Upper or white limestone	1000
2.	Dark colored or thinly laminated and foliated limestone	50–100
3.	Yellow quartzose sandstone	1200–1500
4.	Black, thin-bedded limestone	500

An approximate section at the point of the mountains where I understand his section to have been made is also in descending order, according to my observation, as follows:

		Feet.
1.	Upper or white limestone	1200–1500
2.	Dark colored limestone	50
3.	Yellow, clayey sandstone, with numerous bands of black and white limestone	1200
4.	Black limestone shale and slate	200

I saw no such development of black limestone as he mentions (4), though possibly he may have found other evidence elsewhere. Faulting and folding have duplicated the lower beds near the Point of the Mountain, and it may be that he overlooked these disturbances. The hurried nature of Dr. Shumard's journey and the difficulties attending geologic work at that time in the west would excuse an oversight of this nature.

As the dip is northeastward the beds are much higher at the Point of the Mountains than farther north. Above the massive limestone is another series of limestones and sandstones found only on the highest points in Texas, but, farther to the north, in New Mexico, these are well developed and form the bulk of the mountains. I have made no section of these beds, but they cannot be less than 1000 feet in thickness.

Near the mouth of McKitterick canyon I made a detailed barometric section. The greater part of the sandstone beds (No. 3, previous section) are beneath this section which is in an ascending order.

		Feet.
1.	Thick bedded white limestone	30
2.	Fine grain massive thin bedded bluish grey limestone	15
3.	Massive thick bedded white limestone	20
4.	Shaly yellow limestone	1
5.	Thick bedded white limestone	6
6.	Yellow magnesian limestone	4
7.	Yellow magnesian limestone (shaly)	5
8.	Contorted greyish white limestone (*Fusilina*)	40
9.	White chalky limestone with ironstone concretions	10
10.	Yellow limy sandstone with ironstone concretions	8
11.	White limestone	12
12.	Yellow limy shale with much ironstone	30
13.	Thick bedded yellow magnesian limestone	30
14.	Yellow shaly magnesian limestone	50
15.	Thick bedded magnesian limestone	4
16.	Shaly magnesian limestone	2
17.	Thick bedded magnesian limestone	3
18.	Shaly magnesian limestone	31
19.	Massive blue limestone with flint nodules	10
20.	Hard flinty sandy limestones	2
21.	Massive dark blue limestone	5
22.	Slate and blue slaty limestone	28
23.	Fossiliferous (*Spiriferina*, *Bryozoa*, etc.), blue limestone with chert	5
24.	Similar limestone shaly with nodules and layers of chert	4
25.	White crystalline limestone fossiliferous in places sometimes thin bedded but generelly massive	26
26.	Dark blue slaty limestone	2
27.	Fossiliferous white granular thick bedded limestone	38
28.	Thick bedded grey blue limestone	4
29.	Similar magnesian limestone, shaly in places	21
30.	Shaly stinking limestone very fossiliferous	5
31.	White fossiliferous thick bedded limestone	25
32.	Shaly stinking dark blue very fossiliferous limestone	2
33.	Thick bedded white limestone (No. 1, previous section).	

It will be observed that the dark blue limestone spoken of by Dr. Shumard, and mentioned provisionally in the previous section, does not appear just below No. 33 in this section of detail, although numerous bands of dark blue limestone are found at various points beneath the white limestone. The total thickness of the above section is 478 feet. The upper 123 feet (No. 25 to 32 inclusive) belong, I believe, to to the white limestone series as exposed in the precipice at the Point of the Mountain. The next lower 54 feet (No. 19 to 24 inclusive) are probably the equivalent of the dark blue limestone at the Point of the Mountain. The lower part of the section is the equivalent of the upper part of the lower sandstone series and indicates the gradation from one to the other. It is better developed at McKitterick canyon than at the Point of the Mountains The remaining sandstone series consists chiefly of yellow sandstone with many bands of limestone generally narrow and usually black or dark blue with a few layers of light colored limestone.

Still below this, is the series of black shales, dark blue limestones, and even slates, as far as the section is exposed at this point. Neither the true sandstone nor the underlying black shales appear in the mountains, except at the very point where they underly the precipice. Followed northward they quickly dip out of sight, but southward along the line of foothills the continuation of the mountains, both the sandstone and shales, appear. The total section exposed in the Guadalupes, approximately stated, cannot be less than 4000 feet, including the New Mexico series, which exist above the white limestone.

POSSIBLE CORRELATION WITH CENTRAL TEXAS CARBONIFEROUS.

No attempt will be made at a division of the strata on the insufficient data at hand, nor will any attempt be made to correlate these beds with the Carboniferous of the Central Texas Palæozoic region of which they are an undoubted westward extension. Such a correlation may never be possible, owing to the diverse condition of sedimentation under which they were laid down. This certainly cannot be done without a very careful comparative palæontologic study. Still I wish to point out a rather striking resemblance between the order of deposition of the two series. In Central Texas there was first a shallow water sandy deposit, followed by a deeper water limestone of quite uniform character, and thirdly, a shallow water sandy deposit—an exact repetition of what is observed in this series. The first includes the Richland and Milburn divisions, the second the Brownwood division, and the third the Waldrip and Coleman divisions. In the case of the Central Texas region we find both the top and the bottom of the series, but in the Guadalupe mountains neither end of the series is exposed in the studied section. Apparently the western series is the thinner of the two, although this cannot be asserted until more is seen of it; yet this is what we would expect, since all conditions of sedimentation in this region were apparently less favorable than to the eastward.

Compared with the Central Texas Carboniferous the lower series might be considered the Richland sandstone, the middle the Brown wood, and the upper the Coleman divisions, with the narrow Milburn or Waldrip divisions either merged into the other or wanting. This is simply a suggestion, which may sometime be of value. The absence of any indication of the immediate proximity of a shore line is marked. The sandstone does not appear rippled nor cross-bedded, nor is there any conglomerate in the mountains, or even a coarse-grained sandstone. All the sandstones contain much clay and limy matter, and were apparently deposited in quiet water off shore. A carbonaceous shale has been found in both the upper and lower sandstone beds, but no indication of coal or coal plants are found elsewhere.

There was a gradual subsidence, followed, after a long interval, judging by the thickness of the limestone, by a corresponding emergence. It is doubtful if Permian beds were ever deposited upon these rocks, which may very probably have formed one border of the Permian sea.

AGE OF THE STRATA.

Dr. B. F. Shumard* has described fossils from these mountains, and pronounced them Permian. Without good evidence I would hesitate to pronounce an opinion contrary to his, especially with the limited knowledge at my command. But stratigraphic evidence is almost conclusively against his opinion. I travelled completely across the Central Texas Permian, and became familiar with the peculiar aspect of these rocks, and unhesitatingly state that there is no stratum in the Guadalupe mountains, which, upon lithologic grounds, could be mistaken for Permian. Lithologic grounds for correlation of age is, in general, bad; but in this case it is not so, for the red color of the Permian beds is so distinctive that its absence in neighboring beds is almost indisputable proof of a difference in age. The red beds are traced to within seventy-five miles of the Guadalupe mountains—a small distance in the consideration of a broad geologic question in a region of simple geology like this. Furthermore, the rocks are below the Permian. The Permian in Central Texas is found resting upon and probably grading into the upper Coal Measure rocks. It is a lacustrine deposit, with beds of salt, gypsum, conglomerate, red clays and limestone, generally unfossiliferous. Fossils are found in the Permian only in a few beds. On the other hand, the fauna of the Guadalupe beds is rich and varied, living in clear, open water. To be contemporaneous with the rocks now admitted to be Permian in Texas a barrier followed by deep sea would all have to exist in seventy-five miles between the westernmost Permian and the easternmost Carboniferous outcrop which I have seen. Such a condition is out of the question, and it seems to follow that the Guadalupe mountains form one end (the western) of a syncline, with the Central Texas Carboniferous for the eastern end and the Permian deposits resting in the trough.

The palæontologic evidence offered by Dr. Shumard shows a striking faunal resemblance to the Permian of Europe, and at that time he

*Trans. St. Louis Acad. Sci.; 1858, p. 387; 1859, p. 290.

was justified in his correlation, though I am certain that had the Central Texas Permian been known to exist he would have classed the rocks of the Guadalupe mountains as Upper Coal Measure, instead of Permian.

Dr. Shumard describes from these strata forty-four species of fossils, twenty-seven of which were new. Of these not one species has been recognized in the Permian of Central Texas.* In Miller's North American Geology and Palæontology four of these are given as Coal Measure fossils, three are referred doubtfully to the American Permian, and the remainder are referred to the Permian chiefly upon the authority of Dr. Shumard, though two or three of the species are recognized European Permian forms. I believe that a number of Dr. Shumard's species, from this locality, will be found identical with Upper Coal Measure fossils. There is certainly a striking resemblance between these fossils and the fauna of the Central Texas Coal Measures, and a marked difference from the species found in the Permian. Stratigraphic, palæontologic and lithologic features, therefore, all seem to prove that these rocks are Coal Measures, rather than Permian.

MONOCLINAL STRUCTURE.

The general stratigraphy of the mountains is simple, though complicated in places by small folds. No faults in the mountains have been detected, and a careful instrumental survey will be necessary to detect them, if any exist, for there is such a remarkable uniformity in character of many of the rocks, and a repetition of similar beds, that their discovery will be difficult.

Near the mouth of Dark canyon, in New Mexico, at the base of the mountains, the general dip is from 2° to 5° east, gradually increasing toward the mountains. The increase in dip is frequently quite sudden (25° in one case), followed by a more gentle dip, and thus the strata rise in a series of short monoclines, rarely more than one-fourth to one-half mile in length. Occasionally a very short, crumpled anticlinal fold is noticed, but the general structure is a large monocline, including the entire range, made up of numerous small monoclines. This is better shown in New Mexico among the alternating upper beds than in the Texas end, where the chief rock is the massive white limestone, in which small disturbances cannot be noticed.

In Dark canyon the greatest general dip that I saw was N. 75° E., 10° to 15°. In this section a great part of the mountains are little else than foot hills, but toward the Texas end the mountains become higher and here also the angle of dip increases. From the general dip of from 3° to 5° on the off-lying plateau, there is at the base of the mountains a rapid increase in angle

*See list by Dr. C. A. White, Am. Nat., Vol. XXIII, No. 266, Feb., 1889, p. 115.

towards the center of the mountains, where it reaches as much of 25° as a general dip toward the east. Small folds are present and noticeable in the less massive layers, which are sometimes quite crumpled. As the western border of the mountains is approached the an gle of dip becomes less—in some cases not more than 5° to 8°.

PROBABLE FAULT ALONG WEST FACE.

Passing over the mountains, on the west side, a sudden change in dip is noticed. The foot hills on this side have a general westerly dip averaging fully 10°, and often more. Small folds and faults are also abundant, and this character is noticeable for more than fifteen miles to beyond the Point of the mountains. The change in dip occurs in less than two miles, and is so sharp that it seems impossible to account for it by folding. Still, I am unable to prove a fault, owing to the lack of facilities and time at my command. It is true that the rocks on the west side resemble those upon the east side of the disturbance, in both cases being black shale, blue limestones and yellow sandstone; but this series of beds occurs at two places below the white limestone, and also above it. If the rocks dipping west are the equivalent of the uppermost series, then there has been a fault of fully 2000 feet throw, and the white limestone so strikingly shown in the precipice of the mountains is here beneath the Crow Flat valley. If the dark limestones are the equivalent of the series of beds just beneath the white limestone, there has been a throw of about five hundred feet. In the latter case the great thickness of white limestone has been removed by denudation, and the same is true if the disturbance is a simple anticlinal fold.

Tentatively I interpret this to be a great fault terminating the monocline of the Guadalupe mountains. I will not attempt to estimate the amount of throw, but the direction of the line of weakness is southeast and northwest, and is marked along its entire course by a valley bounded on one side by the precipitous Guadalupe mountains, on the other by the disturbed and faulted foothills, having an opposite dip west. The suddenness and sharpness of the change in dip, the disturbed character of the rocks which, on this theory, have been dragged up with the rising mountains, and the evident line of weakness, are my reasons for this conclusion, which is advanced tentatively. An instrumental section of the mountains is all that is necessary to determine this.

On the west side of Crow Flat valley, fifteen miles from the foot hills, the rocks appear to be dipping very gently eastward.

DELAWARE CREEK DISTURBANCE IN CRETACEOUS.

Shumard describes a disturbance in the strata of the Cretaceous*

*A Partial Report on the Geology of Western Texas. G. G. Shumard, 1886. Also Trans. Acad. Sci., St. Louis, 1858.

rocks near the mouth of Delaware creek, which is pre-Quaternary, as proved by the conglomerate of that age resting upon it. The rocks are tilted at various angles from 20° to 50°. I did not see the place he describes, but found a similar condition at two places southwest of the mouth of the Delaware. There seems to have been a line of disturbance in a N. E. and S. W. direction, for one of the places where the disturbed rocks were observed is south of the head of the Delaware and twenty-five miles S. E. of the place which Shumard describes. This line of disturbance is marked by the presence of a range of high hills for the entire distance. What connection this bears to the Guadalupe mountain uplift I am unable to determine, but the Carboniferous strata near the head of the Delaware, as well as the overlying Cretaceous, have a dip E. S. E. instead of N. E. by E., as is the case in the mountains. The trend of this line of disturbance is nearly parallel to the east face of the Guadalupe mountains, though at right angles to the supposed fault line above described and to the strike of the strata in the Guadalupe mountains. It may be that the plateau between the disturbance and the Guadalupe mountains is the upper end of a synclinal trough between the Guadalupe monocline and Delaware creek disturbance. The change in dip of the Carboniferous strata indicate this.

PRE-CRETACEOUS EROSION.

In a section from the eastern base of the mountains southeastward toward the head of the Delaware, the lower sandstones and dark, slaty limestones are exposed, but the thick-bedded massive white limestone does not appear, though to the east the lower portion is found just beneath the Cretaceous. Upon these lower beds rest the Cretaceous limestone. This points to a vast amount of erosion in pre-Cretaceous times, during which not only have 1200 to 1500 feet of massive limestone been removed, but also an upper series of beds of fully 1000 feet, and any Permian that may have existed. This enormous amount of erosion may all have taken place in post-Permian times, but it is quite likely that the Permian lake which existed east of this had near here its western shore.

The entire absence of the white limestone at the contact with the Cretaceous, not more than twenty miles from the Point of the mountains, where it exists in the form of a striking precipice, suggests that the precipitous ending of the mountain may be thus accounted for. There is a sudden jump, almost vertical, from high mountain to foot hills. The precipitous Point is fully 1500 feet above the top of the hills, which are a direct southward continuation of the line of disturbance and the difference in elevation, is approximately the thickness of the white limestone, which is not only absent on the hills south of the point, but is proved to have been removed at a point twenty miles southeast in pre-Cretaceous times. Quite likely, then, the Point of the Mountain represents approximately the most southwestern extension of the white limestone at the time of the great uplift. It has undoubtedly fallen back some by erosion, but judging by the backward retreat of the rest of the eastern mountain face this retreat has not been very great. The backward erosion on the eastern face has been small. as can be proved by the gentle dip of the rocks near the mountain base.

It thus seems probable that the southern and southeastern precipice at the Point is the result of pre-Cretaceous erosion, while the western precipice and its northward extension is possibly to be accounted for by a great fault. In both these cases the precipitous character is aided by the massiveness and uniformity of the rocks and the strongly developed N. E. and S. W. joint planes.

QUATERNARY ROCKS.

Quaternary rocks are present in many places on the plateau east of the Guadalupe mountains. The Quaternary deposits of Crow Flat valley west of the mountains have already been described. The Quaternary conglomerates which Dr. Shumard mentions* as several hundred feet in thickness are present as he describes them, and I will not repeat his description of them. The study of these deposits is a broad one, which cannot be made in a limited area, but must be connected with other similar deposits in widely different areas. The Quaternary deposits of Texas furnish a great study in themselves.

There is one point, however, that I am able to make. It is, that many of the so-called Quaternary deposits in this section are not Quaternary but recent. There is a class of conglomerate particularly well developed near the mountains, though extending, in some cases, far out upon the plains, which have neither been formed in lake nor sea, but are simply creek beds and mountain torrent deltas. I will not say that all the conglomerates are of this class, but there are many which are undoubtedly so. Every gradation may be seen between the present creek bed and the old creek beds now capping hill tops. It is furthermore an interesting fact, that most of the conglomerates, while often not exactly in the creek bed, are nevertheless in the stream valley, and the farther one goes from the stream the less frequent the conglomerate deposits become. Hill tops out of the stream valley are sometimes capped with conglomerate, even upon the plateau far from the mountains, but these may be old creek beds, as is certainly the case frequently nearer the mountains. The capacity for carrying large pebbles long distances that these mountain torrent streams and creeks possess is remarkable and the evidence of it is present at every hand. Still a general study of all the Quaternary deposits is necessary in order to unravel many obscure problems.

* Geology of West Texas, G. G. Shumard, 1886.

PART III.

ECONOMICS OF THE GUADALUPE MOUNTAINS.

ARTESIAN WATER.

The dip of the strata being to the east, all underground water has a tendency to flow in that direction. The effect of this tendency is shown in the presence of numerous large springs on the east side of the mountains and their almost complete absence on the west side. In general, these springs are pure water though invariably heavily charged with lime, the presence of which is shown by the tufaceous deposits about the springs. Often these beds are of considerable extent, showing that the deposits have been for a long time forming.

Frequently these springs come from the sandstone of the lower series, and in nearly all cases this is the direct source of supply, though the bed which supplies them is sometimes hidden by later formations. At the head of Delaware creek there are two springs within twenty feet of each other which posses widely different characters. One is so strongly sulphurous and saline as to be disagreeable to the taste, while the other is entirely free from such impurities. Shumard states that the former comes from the sandstones, the latter from the conglomerate. Such is not the case, however, for the surface rock from which they both escape is sandstone. At present a boulder of conglomerate, a remnant of the old stream bed, rests upon the sandstone near the fresh water spring. This conglomerate may have been more extensive at the time Shumard passed through the country, thus giving rise to his explanation of the phenomenon. Undoubtedly the supply of water for the two springs is in different layers of the sandstone.

The structure of a large part of the mountains is such as to form a good source of supply for artesian water. Beneath the white limestone is a great thickness of alternating soft sandstone, natural reservoirs, and hard black limestones, which form impermeable walls. The quite strong and uniform eastward dip furnishes a good head. There are two conditions, however, which are adverse to the extension of the water supply eastward. In the first place, Black river and Delaware creek form deep valleys of erosion, which have tapped some of the water-bearing strata. The other accident is the line of disturbance extending southwestward from the mouth of the Delaware. This has thrown all the rocks into a series of short folds, but the extent to which this has interfered with the artesian supply is at present unknown.

To make exact calculation with the present data is out of the question. In fact, it is doubtful if such calculations can be made under any circumstances without actual boring, since the region east and southeast of the Guadalupe mountains is one of great complication.

In the first place, the amount of pre-Cretaceous erosion will be difficult, if not impossible to determine, since the region is buried beneath the Cretaceous. In one place it is found that 1200 or more feet of white limestone has been removed, but how far this extends can hardly be told. Secondly, the amount of Permian beneath the Cretaceous, east of the mountains, if any exist, cannot be ascertained, since from the end of Permian times to the beginning of the Cretaceous, this country was apparently a land area subjected to denudation Nor is the former Permian extension known. The thickness of the Cretaceous has never been measured in this section, though this is a much easier task. Still, even this is complicated by the probable irregularity of the pre-Cretaceous surface.

Thus it will be seen that an exact estimate of the probability of finding water at certain depths are out of the question. Captain Pope's unfortunate experience in searching for artesian water in this section, contrary to the advice of Dr. Shumard, seems to indicate an absence of artesian water. Still, he did not get down to the series of rocks which would be influenced by the Guadalupe mountains uplift. This much can be said, that in Texas, east of the Guadalupe mountains, there is very little chance of finding artesian water in the Carboniferous rocks without going to great depths, and even then the finding of water is a matter of uncertainty, owing to the disturbed condition of the rocks described above. Toward New Mexico, and northwest of the line of uplift noticed at the mouth of the Delaware, the chance of finding artesian water is much better, and I should expect in Southern New Mexico, west of the Pecos, and possibly also some distance east of it, to find artesian water at no great depth. In this place there is probably no Permian, the Cretaceous rocks are not very thick, but the amount of upper Carboniferous rock is a matter of uncertainty.

If water is found in the Carboniferous, it will in all probability be good, though the single spring at the head of the Delaware shows that there is some mineral water in these rocks. Water from the Permian is almost certain to be saline or gypsiferous, and water from the Cretaceous to be gypsiferous. The lower Cretaceous beds near and west of the Pecos are gypsum-bearing, some strata being a pure alabaster. The Trinity Sands seem to be absent here, though present but fifty miles east of the Pecos.

The lower Cretaceous beds in favorable place furnish artesian water, but I have not seen enough of the stratigraphy of these rocks to form any conclusion either upon the extent or source of supply of this water. At Pecos City is an abundant artesian supply of saline water from this source.

On the west side of the Guadalupe mountains there is little chance of finding artesian water. The Crow Flat valley is apparently a syncline, but the amount of country drained seems inadequate for artesian supply. Yet without seeing the country west and north of this valley no final conclusions can be drawn. The lacustrine supply found in shallow wells, springs and lagoons is the accumulation of the surface drainage in the Quaternary deposits of clay and sand, and is not of deep-seated origin.

BUILDING STONES.

There is an abundant supply of limestone in these mountains for ordinary purpose of construction, but I saw no fine building stones—neither marble, sandstone, nor granite. An alabaster, probably of lower Cretaceous age, though possibly Jura-Trias, occurs at numerous points southeast of the head of the Delaware. It overlies the Carboniferous, but no fossils were found by which its age could be determined.

MINERALS.

Conditions seem to be unfavorable for the occurrence of mineral veins, though indications of a low-grade galena, copper and iron were found at several points.

COAL.

In the mountains proper there is no coal. The character of the rocks is such as to preclude the possibility of finding such deposits, being chiefly of off-shore origin. A carbonaceous shale, however, was found south of the point of the mountains in the lower dark limestone series, and again in a similar rock near the head of Delaware creek. I found no plant remains to indicate whether this was a marine or coal shale The general absence of coal plants in the series is strikingly noticeable, and is rather a proof against the possibility of coal even there. In the upper beds, however, conditions approach much more nearly those suited to the formation of coal, and here coal may be found; but as these rocks lie entirely within the territory of New Mexico it is not in our province to discuss them here.

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