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A Sketch of the Geology of the Chisos Country, Brewster County, Texas.

By

J. A. UDDEN, Ph. D., F. G. S. A.,

Professor of Geology, Augustana College; formerly Assistant Geologist, University of Texas Mineral Survey.

Entered at the Postoffice in Austin, Texas, as second class mail matter under Act of Congress, passed July 16, 1894

AUSTIN, TEXAS

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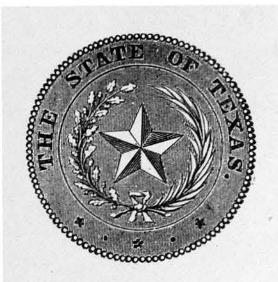

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Cultivated mind is the guardian genius of democracy. . . . It is the only dictator that freemen acknowledge and the only security that freemen desire.

President Mirabeau B. Lamar.

EDITOR'S NOTE.

This Bulletin, prepared for the University of Texas Mineral Survey, under the direction of Dr. William B. Phillips, was ready for publication in the spring of 1905, but, owing to the discontinuance of the Survey, could not be published at that time. Its high practical and scientific value leads to its issue now as a Bulletin of the University of Texas. Unfortunately, both the drawings and cuts originally prepared to illustrate it have been lost, and it has not been practicable to reproduce them.

CONTENTS

A SKETCH OF THE GEOLOGY OF THE CHISOS COUNTRY.

In studying the geology of the Chisos country, one must constantly bear in mind that the terranes which we now find exposed at the surface have been laid bare from under a covering of overlying rocks measuring from two to ten thousand feet in depth. This great thickness of vanished strata has been removed during a long lapse of time, which commenced with the closing stage of the Cretaceous age. We should also remember that during the time this work of disintegration and removal was going on, and even before it began, the whole ground has been subjected to forces which have thrown the strata into folds and flexures and broken them by great faults into blocks that are extensively tilted.

As a circumstance which has contributed to the effectiveness of erosion in this region, we must regard the fact that it lies on the border of the great Cordilleran plateau, where the drainage has had more or less direct outlets to the region of the Plains on the east. The descent of the streams has been relatively rapid and transportation correspondingly easy. For the Santiago and Carmen ranges, which make the east boundary of the Chisos country, must be regarded as the southernmost extension of the Rocky Mountains in the United States. To the west of these ranges we find that the geological structure is more like that of the Great Basin and to the east, though the superficial aspect is somewhat mountain-like, the structure is that of the bordering high plains.

A. GENERAL TOPOGRAPHY.

The Chisos mountains constitute the highest relief in a belt of somewhat interrupted and broken plains, which extend northwestward to and beyond Marfa. This belt has suffered a greater reduction from the erosive forces than the mountains around it, owing to the weak resistance of the clays and marls, which mostly constitute the bedrock within its limits. It may be regarded as a narrow extension of the Howard bolson* described by Prof. R. T.

*Physical Geography of the Texas Region, Topographic Atlas of the United States, United States Geological Survey, 1900, p. 9.

Hill. To the east and to the west of this plain more indurated rocks are now exposed and rise in ridges and table-lands. Toward the Rio Grande the plains gradually descend to an elevation of only about 2000 feet above the sea level. From the middle of this descending plain the Chisos mountains rise in a low, wide, and dissected dome, with long spurs to the south.

1. Differential Erosion.

The materials subjected to the work of the destructive forces during a long time in the past in this region consist for the most part of soft sediments, such as clay, deep-sea ooze, and sand. With these are extensive beds of limestone and frequent and variously shaped masses of igneous rock injected into the sediments and in places poured out over them. Almost all of the pronounced relief we meet with here, such as hills, ridges, mountains, and table-lands, are due to the greater resistance of the harder materials. These have been laid bare by the removal of the more readily yielding clays and marls, by which they were originally covered or surrounded. All the more enduring rocks now rise above the general surface of the land. In places where the indurated rocks are absent, the ground has been cut down to almost perfect plains. The relief of these plains is confined to a very gentle general slope towards the drainage channels, low scarps caused by transient adjustments to new erosion planes, and long, narrow and shallow gullies of the surface drainage.

2. The Graded Plains.

The controlling topographic feature of the country around the Chisos mountains consists of the plains just referred to. It is estimated that they make up from two-thirds to three-fourths of the entire area of the country. Their general slope averages a hundred feet to the mile, and varies from seventy-five feet, where it is the most gentle, to two hundred feet, where it is most steep. Only in few places, on some low divides, it is nearly horizontal.

(1) *Making of the Graded Plains.*

The origin of the high plains in the southwest, the so-called bolson plains, has been ascribed to different causes by different writers. R. T. Hill regards them as constructional detritus plains caused by filling of structural valleys.*

Keyes considers that the bolsons are a part of an upraised peneplain, practically untouched by stream action.** It does not appear that either of these explanations apply well to the plains of the Chisos country. The drift filling is everywhere of small depth, probably nowhere amounting to as much as two hundred feet. Nor is there any general level indicating a peneplain. If the graded plains here have once been a part of such a plain, this has later suffered extensive destruction by recent erosion. The present relief of the plains in this region must be regarded as expressing an equilibrium between recent erosion and transportation on the one hand and the resistance of the materials subjected to these forces on the other. It is the direct result of general erosion now in progress. This is always accompanied by local accumulations of land drift, owing to local variations in the factors which determine the effectiveness of the agents at work, and thus the plains are here the result of constructive work as well as destructive.

It will be perceived that the grade of plains whose existence depends on such nicely balanced conditions will be subject to some changes. Whenever weathering is progressing too slowly to furnish as much materials as the transporting agencies are able to remove, the grade of the plain will, of course, not be maintained, but the resistant rocks will begin to rise above its flat surface. This is the origin of nearly all of the prominent reliefs rising from the plains, such as ridges, buttes, mesas and mountains, which will be described directly. The sloping plains are developed only where the weathering equals the work of the transportation, which latter depends on several factors. In the main these determining factors are the size of the transporting current, and the mechanical composition (the fineness or the coarseness) of the materials transported.

(2) *Controlling Factors.*

The current which here consists of what is known as sheet flood, does not vary a great deal. It is true that the rainfall is slightly greater in the mountains and on their outer slopes than farther

*Reference as above.

**Keyes, Bolson Plains and the Conditions of their Existence, Am. Geol., Vol. 34, pp. 160-164, September, 1904.

out, and this no doubt makes the sheet flood slightly greater and hence more efficient near the mountains, and thus tends to render some of the talus slopes less steep than they otherwise would be. But the difference is probably so slight as to be quite negligible. There is another circumstance which sometimes renders transportation inefficient by reducing the sheet flood. If the ground of the plain consists of such coarse material as to allow the rainfall to immediately go down into the ground, there will be no sheet flood to perform any work at all, and transportation will be at a standstill, except on comparatively steep slopes where the work is considerably aided by gravitation. A belt of dissected hills, which extend northwest from the Dugout draw, appears to have been left in this way, rising above the graded plain. They are locally known as the "White Hills" and consist mostly of gravel and sand.

The variation in the mechanical composition of the eroded rock underlying the graded plains elsewhere is not very great. In fact, these rocks are uniformly so fine in texture as to make their products of disintegration easily transported even by a slow current. The slopes which are steep enough to produce such a current in the sheet floods resulting from the present rainfall, is about two feet in a hundred. But there remains on the surface very generally a residue of coarse material, in part derived from concretions in the bed rock and in part coming down from indurated rocks in the bordering mountains. This constitutes a land drift in a limited sense. Its coarseness has a noticeable relation to the slope. Except in places where the wind is at work, the most level parts of the graded plain consists of fine sand and silt and no pebbles appear on the surface. On the moderate slopes and away from the mountains the largest fragments seen seldom measure more than two inches in diameter, while on the higher slopes we find large boulders.

The surface of the graded plains is more or less trenched by arroyos that traverse them in the direction of their general slope. We find these radiating in all directions from the Chisos mountains. That the conditions under which these plains are formed are quite different from those attendant on base leveling is evident from these arroyos. They often run parallel and close together for miles. On the southeast side of the Chisos, Glen draw runs side by side with another arroyo for twelve miles, and the two are mostly less than a mile apart. Such conditions can not exist except where the attitude of the land surface is well adjusted to a steady rate of erosion, and where it is yet so far above the base level that very little side cutting is being done. Under such conditions the different drainage lines make no inroads on each other. The depth of the arroyos vary from almost nothing to two and three hundred feet. We usually find them from one-fourth to one-half a mile apart and this distance, too, is proportionate to the slope, but inversely, being least where the slope is most steep, and greatest where the slope is most flat. As we cross over the flats between them we notice that these have a very gentle slope to either side from a middle divide. It is evident that the flats are being cut down by sheet flood erosion, however slow the process may be. In their lower course these long arroyos often have an alluvial valley two or three hundred yards wide with a meandering channel, but in their upper course they are V-shaped.

(3) *Maintenance of the Eroded Plain.*

With erosion in general progress, it may be asked why the graded plains are not wholly dissected by the arroyos. The present writer believes that the answer to the questions is to be found in the fact that weathering in this region is very rapid and transportation comparatively slow. There is always ready and at hand, wherever the bedrock consists of soft cretaceous marls and clays, a surplus of load for the sheet flood. If now and then this should carve a trench on the surface of the graded plain, this trench will promptly be filled with surplus drift, up to the general grade. Thus there can be no trenching done on the plain itself. For a similar reason the backing of the arroyos and their branches is exceedingly slow. The long arroyos are overloaded with debris from the mountains and this is frequently supplied in such quantity as to bring about a re-filling of some of their valleys. About midway between Indianola peak and the old Reed camp the arroyos are now filling to such an extent as to make the beds appear more like alluvial fans than like alluvial valleys. Each arroyo maintains, as it were, a grade of its own, depending upon the nature and the quantity of its load, and this is usually so great as to leave but little energy for other work, especially in the upper part of its course. It is only farther down that wide cutting takes place. The automatic and uniform grading of the plains under a ready load for the sheetflood current results in the prevention of the water being gathered into currents which might start re-entrant gulleys on its scarps. Hence there is a lack of ramifications in the drainage valleys, and hence it is also that reduction of old levels often proceed by low and long scarps which mark the boundaries of new and lower grades, wherever these find an opportunity to establish themselves.

To sum up, we may say: the plains around the Chisos mountains probably mark the location of an old and higher plain. They have been cut out of this old plain by a slow process of erosion under conditions of an overloaded drainage and have long since reached an equilibrium of grade and load to the working current. The general direction of the grade is toward the Rio Grande and this stream must have been the prime agent in the destruction of the old plain.

3. The High Reliefs.

In a manner, all of the high reliefs in this region may be regarded as due to the greater resistance to erosion by the more indurated rocks in the faulted and folded complex of formations which have for a long time been subjected to erosion. With the possible exception of the Chisos mountains themselves, no part of the topography is inherited from the original configuration of the land, although this happens to be reproduced at the present time in several places. For we find that a fold or a fault often brings up the limestones of the Lower Cretaceous age above the surface of the graded plains, and they rise bared or only partially destroyed in their true structural relations as ridges or mesas. Thus we have the ridges of the Carmen and the Santiago ranges and the Mariscal mountain ridge extending northwestward across the Rio Grande toward the Chisos mountains from the southeast. These ridges mark lines of original uplifts. West of Terlingua creek the same rocks form an extensive tilted mesa and these again rise into a dome in the Christmas mountains to the northwest. The Boquillas flags are less resistant but their disintegration never keeps pace with that of the shales and marls, and thus we find them forming sloping benches bordering the ridges formed by the other limestones on which they rest. The sandstones in the Terlingua beds often form long, low, and narrow ridges, where their tilted edges are exposed, but on account of their limited thickness they cause no high reliefs. The igneous rocks, which are usually most resistant, form most of the high reliefs. Dikes and surface flows, as well as intrusives, have weathered out from their matrix of sediments and form reliefs of most varied forms. Ridges protected on one side by an intrusive sheet and presenting an escarpment of erosion on the other are very common. Domes formed by uplifted sills and loccolites are next in frequency. We also sometimes find walls and ridges of dikes and some mesas protected by cappings of surface flows. Many of the igneous intrusive bodies are so slightly affected by weathering that they exhibit, almost unchanged, their original molded form.

The main west body of the Chisos mountains, the so-called "rim rock," consists largely of an intrusive body which has once been covered by sediments, and which, so far as the present topography is concerned, must have had the same history as the other intrusives: it has been laid bare by the removal of superincumbent sediments and volcanic flows. Some of the latter are still left in patches on the highest summits, such as Rummel peak, Lost Mine peak, Crow mountain and a plateau south of the Emory peak. The fact that these remain as a cluster around the greatest laccolite in the region suggest that the volcanic covering was originally heavier at this point than farther away.

B. HISTORY OF THE DRAINAGE.

The Rio Grande is the master stream, and it has maintained its course across a number of faults and folds. With regard to the geological structure, its course is clearly antecedent and was determined before the present structures were all developed. Its main tributaries from the north in this region are Terlingua creek, Tornillo creek and Miravillas creek. The first one drains a large territory to the west and northwest of the Chisos, and it is clearly subsequent in its character. It has adjusted itself to the larger geological structures encountered. Thus its lower course is evidently determined by the great Terlingua fault. Tornillo creek drains the north and east slope of the Chisos and this stream has likewise been influenced by the geological structure, for it follows in the main the line of the outcrop of the softer strata. At its mouth it has carved a short cañon through an uplifted limestone and, so far, it here retains an antecedent character. The Miravillas is likewise in part antecedent and in part subsequent. The main stream follows the east side of the Santiago and the Carmen ranges and has no doubt been held in place by the great fold of the ranges. But two of its west tributaries cross over from the west side of the fold. These are antecedent. Persimmon gap on the Santiago range marks the former crossing of another tributary from the same direction, whose upper portion has later been captured by Dog creek. It may be that the upper part of the Tornillo creek once drained in the same direction, but this can only be a conjecture.

In general the drainage of the Chisos country is in a stage of adjustment to geological structure. Nearly all of the smaller streams are through this stage, the larger creeks are still in it, and the Rio Grande has hardly yet entered upon it.

C. STRATIGRAPHY.

In order to understand the geological structure of this country it is essential that we should first know the nature and the thickness of the strata from which the entire land has been built. It is well known that the bedded rocks, such as limestone, clays, marls, and sandstones have been laid down as sediments on the bottoms of seas and lakes, and lay originally in a horizontal position. The first task of a geologist working in any region is to make out the general section, or succession from below upward, of the several formations and strata which he finds exposed on the surface. He must measure their thickness and see if this is the same everywhere, or if it differs at different points. He must make out if all of the strata are present as originally laid down, or if any of them have been removed previous to the deposition of later beds. When this is done, he will be able to understand the structural features of the land. He will see where it has been elevated or where it has been sunken, where the strata have been folded or where they have been broken, and which strata have been cut away by erosion or which lie buried below the surface.

1. The General Section.

The oldest sedimentary rocks in this region belong to the Palaeozoic era. Above these oldest sediments we find the Lower Cretaceous limestones, which in turn are covered by various sediments of the Upper Cretaceous. These are overlain, in a few places, by flows of lava and by tuffs of a later age and by clays and gravels of the late Tertiary. The most recent formation consists of the land drift and the alluvium of the present stream valleys. These overlie all of the other rocks more or less persistently.

Within a radius of twenty-five miles from Emory peak in the Chisos mountains no older rocks than the Mesozoic appear at the surface on the north side of the Rio Grande, but farther north much older sediments cover an area of at least 700 square miles. As these throw important light on the structure of the region, being the nearest exposures of rocks which must underlie the entire Chisos country, a brief account of them is included in the general section, even though this account is necessarily incomplete and the outcrops lie distant from the Chisos mountains. The divisions of the entire section, thus more or less fully described, is as given in the table below.

Table Exhibiting the Formations Identified in the Chisos Country.

Group.	System.	Series.	Formations.
Caenozoic.	Pleistocene.		Land drift and alluvium.
	Tertiary.	Miocene and Pleiocene.	Dug-out clays and gravels. Igneous rocks and bedded tuff and gravels.
Mesozoic.	Cretaceous.	Upper Cretaceous.	Chisos beds? Tornillo beds. Rattlesnake beds. Terlingua beds. Boquillas flags.
		Lower Cretaceous.	Buda limestone and Del Rio clay. Undetermined limestones, shales and conglomerates.
Palaeozoic.	Carboniferous.	Upper Carboniferous.	Cibolo limestone.
	Ordovician.	Middle Ordovician.	Limestones, with cherts shales and conglomerates.

(1) *The Palaeozoic.*

In the immediate vicinity of the Chisos mountains the Palaeozoic sediments are, as already stated, buried under the Cretaceous rocks, but the Ord and the Santiago ranges mark the western limit of an uplifted area, where the Mesozoic rocks have been removed, and where the older sediments now are exposed. The nearest outcrop is in Persimmon gap, where dark shales and sandstones underlie the lower Cretaceous limestones unconformably. The area is apparently small and confined to the east end of the gap. No fossils were noted here and the age of these beds are unknown, except so far as it can be made out from their position.

(2) *The Ordovician.*

About fourteen miles to the north northwest of Persimmon gap, and nearly due east of Santiago peak, similar shales and sandstones appear again, and from this point, as we travel north, our road is on Palaeozoic rocks all the way to Marathon, and from there to Altuda. Marathon lies in the center of a triangular area, where the rocks of the Palaeozoic era are now uncovered. This area is bounded on the west by the Ord range, on the north by the Glass mountains, and on the east and south by a less well defined line, extending from the northeast to the southwest, and passing some distance east of Haymond.

There must be several thousand feet of sediments exposed in this area. They have been folded and faulted and dip, usually at high angles, either to the southeast or to the northwest. My trip over this country was hurried and no attempt could be made to measure the thickness of these deposits. In the south part of the area they consist largely of dark shales and limestones. These contain heavy ledges of cherty quartz, which rise in long ridges running from the northeast to the southwest. The chert is usually interbedded with ledges of dark limestone, which now and then contain round and loaf-like concretions of chert. The prevailing color of the chert is white, but it is sometimes black, green, bluish, or of a brown or a pinkish color. With some of the limestones there are thin seams of sandstones and conglomerates. The latter usually consist of well-worn pebbles, mostly of limestone, but also of hard quartzite. In some shales, which are associated with chert and limestones in a ridge on the south side of Edward's creek, about ten miles northeast of Santiago peak, there is one stratum which contains large concretionary aggregates of crystals of barite. Some of these aggregates are a foot in diameter, and consist of columnar crystals radiating from the centre of the concretions. The mineral was seen to follow a stratum about three feet in thickness, and the concretions in one place appeared to be present in large quantity. The limestones themselves are frequently bituminous. Some ledges consist of small worn organic fragments. From one of these some fossil fragments were taken which Dr. Charles Schuchert has identified as the outer portions of the glabella of a *Trinucleus*. Associated with this there were also a *Plectambonites* [*sericeus?*], a *Rafinesquina* and possibly a *Zygospira*. A gasteropod of the genus *Cyclora* was found in another ledge, and in still another limestone a *Nodosaria* was noted. All of these fossils were collected along the wagon road near Ridge spring and at different points south from this place for a distance of ten miles. The same kind of rocks continue north from this spring as far as to Peña Colorado, four miles south of Marathon. North from Peña Colorado we find shales, limestones, and thin conglomerates, but no chert beds. An *Athyris*, a *Fistulipora* (?), a *Dentalium*, and joints of crinoid stems were observed in the vicinity of Marathon, where the dip of these rocks is quite generally to the northwest. Evidently these sediments are younger than the formation which contain the chert south of Peña Colorado.

The thickness of the ancient sediments, which are seen on these plains around Marathon, is no doubt several thousand feet, and they very likely contain formations of more than one age. For twenty-five miles the road from the Chisos runs over the edges of beds tilted at high angles. The fossils associated with the chert show that some of these strata belong to the Ordovician, and Dr. Schuchert infers that these are of the Trenton period. In his Physical Geography of the Texas region Prof. R. T. Hill expresses it as his opinion that the limestones, shales, etc., of these plains may be of Lower Helderberg age,* and there is no good reason to doubt that the Silurian rocks are represented in this extensive complex of folded strata. Proceeding to the northwest from Mara-

*Physical Geography of the Texas Region, R. T. Hill, U. S. Geol. Surv. Topographical Atlas of the United States, Folio No. 3, p. 4.

thon we find that the dips, which are prevailingly to the northwest, grow less steep. We are evidently going away from an axis of uplift and we are presumably coming to sediments which are later than those encountered nearer to this axis.

(3) *The Upper Carboniferous.*

Near Altuda, which is a station on the Southern Pacific Railroad at the west corner of the Marathon Palaeozoic area, we find shales and limestones that clearly belong to the Upper Carboniferous series. In the Altuda mountain these rocks form the greater part of the mass and to the south of it the series outcrop for a distance of two or three miles. Along a north and south line across this mountain the dip is to the north and increases in steepness as we approach a granite area lying two miles south of the mountain. The section of the Carboniferous as seen along this line is about as follows:

	Thickness in feet.
A cream-colored limestone almost without bedding planes and somewhat crystalline in texture, forming a high vertical escarpment all around the mountain. Obscure traces of organic fragments were frequently observed, but no identifiable fossils	600
Thin bedded limestone containing shaly and sandy strata. The limestone is mostly in layers from three to six inches thick. This member contains *Fusulina* in great abundance at times, but mostly only very minute young individuals. Other fossils noted on the north side of the mountain were: *Chonetes, Pugnax, Productus, Seminula, Meekella,* a pygidium of a trilobite, *Fistulipora,* a spine of a fish, and joints of crinoid stems....................................	200
A series of shales, sandstones and limestones, with a conglomerate near middle, probably as much as..............	2000

Fusulina cylindrica of a moderately large size occurs in profusion in some limestone ledges in the upper half of the lowest division. Near its middle there is a conglomerate twenty feet in thickness, which contains pebbles as much as three inches in diameter. The largest consist for the most part of a fine brown quartzite, while those of smaller size are of white quartz and black chert. All are well rounded. The conglomerate is cemented by a dark gray calcareous stony material, which was seen to contain some shells of brachiopods, some bryozoa, and a coral. Some hundred feet or more under this conglomerate there is a dark limestone which occasionally contains numerous specimens of an ammonoid, and associated with this were noted some stems of crinoids, some gasteropods, and an *Archeocidaris.*

This section is the equivalent of the Cibolo limestone at Shafter in Presidio county. It probably extends down into the Alta beds, which underlie the Cibolo limestone. The thin-bedded limestone described in the section above appears in a ravine to the northwest of Altuda mountains and the face of this outcrop is almost in itself a proof of the identity of this limestone with the thin-bedded limestone of the Cibolo formation near Shafter. Another evidence of the identity of the two is the presence at both places of a peculiar bead-like fossil stem of unknown relationship.

Whether beds of the Lower Carboniferous and of the Devonian ages will be found between Altuda mountain and Peña Colorado, or whether there is an unconformity between the Upper Carboniferous and the older formations is not yet known.

(4) *Rocks of the Cretaceous Age.*

Some time after the mountain folds of these older sediments had been leveled down by extensive erosion the region was again submerged and a new succession of sediments were laid down in an open sea, which is known to have had a continuous extension from Canada to Mexico and which covered Western Texas during nearly the entire Cretaceous age. The sediments in this sea have a great thickness, no less than 8000 feet in Western Texas. They consist of heavy limestones with some shale and conglomerate below; flaggy limestones, chalky rock, marls, and clays in their middle portion; and sandstones, clays and tuffaceous beds above. We will first describe the lower division.

The Lower Cretaceous Limestones.

In the Carmen and Santiago ranges, in the Christmas and the Mariscal mountains, and in the Mesa de Anguila the Lower Cretaceous limestones are extensively exposed, but the whole succession of all the beds has not been seen. It is estimated that a thickness of more than 2000 feet appears in the Carmen range. At the mouth of the Santa Helena canon the Lower Cretaceous limestones rise 1500 feet. But at neither of these places is the base of the formation exposed. This comes to view in Persimmon Gap and elsewhere farther north in the Ord and the Santiago ranges and on the borders of the Marathon Palaeozoic area, where only incomplete measurements have been made.

Persimmon Gap.

At Persimmon gap the lowest 100 feet of the Lower Cretaceous consist of shaly calcareous strata, which are not well exposed. Above this lies a sharply marked conglomerate, about twenty feet in thickness, consisting of well-worn pebbles, mostly of chert. The ledge may be seen for several miles to the north in the east face of the range. Above it there are two or three hundred feet of limestone, some ledges of which were seen to contain numerous imbedded tests of *Orbitulina texana,* Roem.

Altuda.

Another place where the basal members of the Lower Cretaceous may be seen is in the high limestone scarp west of Altuda, about seventy-five miles north of the Chisos mountains. At this place it rests on the undisturbed upper surface of the Cibolo limestone of the Chinati section. It consists of gray ledges of limestone only slightly different from the underlying formation. The boundary between the two is marked in some places by occasional fillings of yellow sandstone which appear at the base of the formation in depressions in the upper surface of the Cibolo limestone, and elsewhere it can be recognized only by a few well-worn pebbles of quartz, which may usually be found at the contact of the two limestones. The conglomerate and the shale seen farther south are absent at this place. The succeeding hundred feet are like the basal layers, consisting of gray limestone in moderately heavy ledges. These contain a large *Pecten* with complex folds, a large *Caprotina,* some gasteropods, *Modiola pedernalis* and a *Cardium.* Above this are some forty feet of stronger and heavier ledges, which contain silicified shells of a *Radiolithes* (like *sauvagesii,* D'Orb) in abundance and also a *Caprotina*, a large *Pecten*, probably *P. duplicosta* Roem., and various gasteropods. Again, above this there are some sixty feet of softer and thinner ledges of limestone. These are overlain by several hundred feet of heavy-bedded white limestone, the upper ledges of which are identical with the Edwards limestone of the south central part of the State. Near the base of this division some gasteropods and *Gryphaea marcoui* Hill & Vaughn were noted. The uppermost two hundred feet in the Cretaceous section here appear west of Ramsay creek and from two to five miles south of Strobel. They consist of more shaly limestones, in which no fossils were noted. In all, this section measures at least 800 feet. There is here an overlap on a height of an old land, where the lowermost beds of the Cretaceous system, in which conglomerate appears elsewhere, were never laid down.

Cienega Mountain.

The base of the Lower Cretaceous also appears flanking the dome-like uplift of the Cienaga mountains. The lowermost ledges here consist of sandstone and are overlaid by shales and shaly limestones, measuring about 150 feet. An impression of the stem of a plant was seen in the calcareous shales on the west side of the mountain. Above these there is a well developed conglomeritic sandstone about twenty-five feet in thickness. This contains streaks of pebbles which measure two inches in diameter. Most of the larger pebbles consist of white quartz, but there is also some dark chert. Above this conglomerate there are some 300 feet of somewhat impure limestones with shaly seams. In the lower part of these a *Caprina*, a *Nerinea*, a *Radiolithes* and a *Cardium* were noted. On the north side of the mountain this division is overlain by several hundred feet of massive pure limestone ledges, evidently corresponding to the Edwards limestone. The whole series, so far as seen here, has been heated by intrusives and turned into a fine-grained marble.

Mesa de Anguila.

The section in the great east escarpment of the Mesa de Anguila measures about 1500 feet. It is seen to consist of about 700 feet of massive limestone below, rising in an almost vertical wall, then about 200 feet of an impure and more readily disintegrating rock which contains some marly layers, and weathers into a slope, and highest up 600 feet more of massive ledges of white limestone rise in a nearly vertical wall to the top of the escarpment. Only the lowermost 100 feet were examined by the writer at the mouth of the canon. Just above the water in the river is a dark, almost black, limestone of very compact texture. It is in straight ledges and there are two or three layers of shale interbedded. One of the limestone ledges was almost filled with a small *Gryphaea,* probably *G. marcoui* Hill & Vaughn. A large *Pecten* and an *Exogyra texana* Roem., like one occurring in the Presidio beds near Shafter, were also found at this horizon.

Christmas Mountain.

In the Christmas mountain there is a thickness of about 1000 feet of these limestones. The same divisions are indicated here: two heavy bedded and strong limestones with a somewhat less enduring division between them. But the lowest division is not wholly exposed. At the south end of the mountain the same *Radiolithes* occurs that was seen west of Altuda. Farther to the north and on the west side I found a cast of a large gasteropod, a *Globichoncha planata* Roemer, a *Cerithium proctori* Cragin, and also another *Cerithium.*

Mariscal Mountain.

To the south of the Chisos the Lower Cretaceous has been lifted up and bared in the Mariscal mountain, which is cut across by the Rio Grande and extends eight miles north of the cañon of this river. On the west slope of this ridge just to the north of the west end of the cañon, the contact between the Boquillas flags and these limestones is well exposed and is very clearly marked. There is an abrupt change from a heavy bedded strong limestone to the flaggy layers of the upper formation. This is the dividing plane between the upper and the lower Cretaceous. The upper 100 feet of the lower series were hastily examined. The highest ledge consists of a rock of very compact texture exactly like the Buda limestone as it appears around Terlingua. Under a lens this rock is seen to consist of a matrix of exceedingly small and indistinct fragments in which lie imbedded occasional fragments of shells of gasteropods and also some shells of a *Globigerina*. About fifty feet below the uppermost ledge the rock weathers more rapidly and is less pure and compact. This apparently represents the zone of the Del Rio clay. Some fifty feet still farther down I found a large *Nerinea*, having a spire two inches wide, and a cast of a *Lunatia* (?). Not far from the same place *Kingena wacoensis* Roemer, and *Ostrea carinata* Lam, were noted, and with these was seen imbedded in one of the ledges some peculiar meandering dark plates, that on closer examination proved to be a sponge. On the east side of this ridge and from two to three miles south of Lindsey's mine, the uppermost compact limestone is about seventy feet thick and weathers out quite distinctly by the removal of more readily crumbling rock below it. This latter contains layers full of fragments of shells and occasional specimens of *Nodosaria texana* Conrad and of a *Gryphaea* like *G. mucronata* Gabb. It will be remembered that these two fossils occur in the Del Rio zone. In the solid ledges below this zone *Requienia patigiata* White is found associated with the same gasteropods that were seen on the opposite side of the mountain, and some distance still further down *Exogyra texana* Roem. was noted. In the cañon of the San Vincente mountains the same formations are exposed, but only to a small extent.

The Carmen Range.

The Carmen range consists of ridges of limestone of the Lower Cretaceous. In high escarpment on the east side it appears that they show a thickness of somewhat more than 2000 feet. The Rio Grande cuts across these ridges by the Boquillas cañon, and this cañon would show the best exposures for a continuous section. But in this survey it was not practical to take that route, and only a very general idea of the section can be given. It resembles the section in the Mesa de Anguila, but it is heavier. The ledges corresponding to the Buda and the Del Rio zones weather out on the west slope and are only some sixty or seventy feet in all. Below this is a heavy bedded limestone some six hundred feet thick, in the upper part of which I saw *Ostrea munsoni* Hill. Otherwise recognizable fossils in this division are rare. Under this there is a considerable thickness of ledges which weather somewhat more readily and which contains *Exogyra texana* Roem., *E. mathéroniana* Conrad, a *Gryphea, Pecten texanus* Roem. (?) and *Radiolithes cf Sauvagesu* D'Orb. These fossils were seen along the trail through the Ernst valley, eight or ten miles north of the Rio Grande. In the right bank of Heath creek, where it cuts through the last of the Carmen ridges, we find the same strata that were noted at the mouth of the Grand cañon: dark limestone with some shaly strata and containing *Gryphea marcoui* Hill & Vaughn. At a somewhat higher level in the east face of the escarpment and about three miles to the south, a *Nautilus* (near *texanus* Schum.) was noted. At the lower mouth of the Boquillas cañon the lowest rock seen consists of a very compact and close-grained limestone, in which tests of foraminifera are very numerous and in which a *Gryphea* and a small *Pecten* were noted. This rock is very much fissured and shows numerous veins of a columnar calcite, varying in width from two inches to two feet. Above this there is at least 1500 feet of the heavy bedded limestone which forms all of the ridges in this range, and at this place the variations of the ledges seen at different levels elsewhere are not very apparent.

At the upper mouth of the Boquillas cañon just below the old Mexican village of the same name, there are a thousand feet of massive yellowish-gray limestone with some dark and less heavy ledges below. A very compact and close-textured gray ledge shows, when examined in a thin section, that it is essentially an indurated ooze, in which minute particles of organic calcareous materials make up the greater part. Few of these particles are large enough to indicate the nature of the organisms from which they are derived, but there are some tests of foraminifera. Such tests are rather common in the entire series except in some ledges which have undergone secondary changes and have become granular and somewhat crystalline in texture. At this same place they were noted in great numbers in a ledge lying about 400 feet higher up in the section.

Characteristic Horizons.

It was not attempted to make out the succession of separate divisions in the Commanche Series, for this would have required much more time than was at our disposal, but it may nevertheless be worth the while to sum up the observations made bearing on this subject.

1. The base of the series consists of sandy or clayey beds containing calcareous material also, weathering rather easily. At Cienega mountain these strata have a thickness of about 150 feet.

2. At about 150 feet above the base there is a conglomerate or a pebbly sandstone measuring some twenty feet. These two members, and very likely a part of the succeeding beds above, are absent at Altuda, where they probably never were laid down, owing to an overlap.

3. At an unknown distance above this conglomerate there are some dark ledges of very compact limestone interbedded with some shaly seams, and these are followed upward by several hundred feet of heavy bedded limestones of lighter color. These lowest three divisions are equivalents of the Presidio beds in the Shafter section.

4. Then follow two or three hundred feet of more thin-bedded and less pure limestones, which weather more easily and contain a fauna resembling that found in the Shafter beds.

5. Above this there are several hundred feet of very massive light limestone, which is clearly the equivalent of the Edwards limestone.

6. The last and highest of the series is a compact limestone only some half a hundred feet thick, which is the equivalent of the Buda. It is separated from the massive beds below by some twenty feet of more easily weathering ledges which are frequently filled with organic fragments and which corresponds to the Del Rio clay.

At Terlingua both the Buda and the Del Rio zones are much heavier than to the east of the Chisos. These formations clearly thin out or entirely disappear in this direction.

Chemical Composition.

The limestones of the Lower Cretaceous are usually quite pure and this is true not only of the most massive ledges, but also of those of less development, as is evident from the analysis given below.

Analysis of Limestone from the Buda Horizon, One Mile East of Boquillas.

Silica	2.35
Alumina	.21
Ferric oxide	.24
Lime	53.90
Magnesia	.15
Carbonic acid	42.23
Water [hygroscopic]	.18
Water [combined]	.33
Sulphur	trace
	99.59

Characteristic Weathering.

The surface of the limestones of the Lower Cretaceous is sometimes etched in a manner that seems to be peculiar to the climatic conditions of the Southwest. On top of the highest ridges of this rock, and elsewhere when these limestones lie bare, we often find small hollows or basins, not altogether unlike so called pot-holes. But they have clearly not been produced by any process of wearing. They have been made by a unique process of etching, which takes place after showers and rains. At such times water is retained in them for a short period and some of the lower algae flourish in this water, while it lasts. These produce an abundance of carbon dioxide which dissolves the rock. Between rains this vegetation dries up, and can often be found as a dessicated crust of black mud on the bottom of the basins, ready to take up the work after the next shower. The Spanish name "tinahita" seems an appropriate one for such basins. It is the diminutive of Tinaha, the name of the common waterholes produced by corrosion in creeks and cañons.

The Tinahitas always have a flat or only slightly concave bottom with vertical or even overhanging sides, sometimes beautifully etched. They vary from three inches to six feet in diameter and from half an inch to two feet in depth. The common dimensions are a foot in width and three or four inches in depth.

The Upper Cretaceous Series.

At the top of the upper ledges of the Lower Cretaceous limestones there is quite a marked change in the character of the sediments of the age. The making of the heavy-bedded limestones seem to have come to a sudden end, and beds of this kind were not laid down again during this age in West Texas. There is yet some more limestone above, but this lies in thin flaggy beds and it contains a noticeable admixture of fine siliceous sand and clay. Later on the conditions changed so that chalk, marl, and clay were laid down and still later, sand and more clay, and at last, sediments containing a large amount of tuffaceous material. The deposits of each of these several and successive periods must now be described.

The Boquillas Flags.

In the vicinity of Boquillas postoffice, all along the west flank of the Carmen range, the beds immediately overlying the Lower Cretaceous limestones are probably exposed to the best advantage for study. These beds also lie all around both the Mariscal mountain, and on the south, east, and north sides of Christmas mountain. West of Terlingua creek they extend from Cuesta Blanca to the Reed plateau, and south of Terlingua, still farther west beyond the limits of the Chisos region. From two measurements made about three miles east of Terlingua and one measurement taken on the west side of Mariscal mountain, the thickness of these beds, which we will call the Boquillas flags, is 585 feet or a little less than 600 feet. They seem to have a quite uniform development and these three measurements did not vary by more than 50 feet, which perhaps is within the limit of probable error.

Chemical Composition.

The mixed character of the sediments forming the Boquillas flags is believed to be fairly constant, and the analyses given below are from typical specimens of rock, except that the ledge from which the first one was taken contained a more than normally high per cent of organic matter. In the specimen from near the Colquitt-Tigne mine some of the silica has probably been introduced secondarily by infiltration.

*Analyses of Limestone from the Boquillas Flags.**

	Cuesta Blanca.	Near Colquitt-Tigne Mine.
Silica	7.80 per cent.	20.72 per cent.
Alumina	1.30 per cent.	0.16 per cent.
Ferric oxide	1.30 per cent.	.45 per cent.
Lime	49.20 per cent.	43.15 per cent.
Magnesia	0.15 per cent.	0.52 per cent.
Carbonic acid	38.50 per cent.	34.20 per cent.
Organic matter	1.10 per cent.	....
Water (hygroscopic)	0.20 per cent.	0.10 per cent.
Water (combined)	0.50 per cent.	0.32 per cent.
	100.05 per cent.	99.62 per cent.

Clastic Texture.

The Boquillas flags consist of a copious matrix of very fine calcareous particles, sometimes so fine as to make the rock appear to be without structure, but containing some organic fragments up to one-half millimeter in diameter. With this some fine grains of quartz are usually imbedded, seldom exceeding one-fourth of a millimeter in diameter, and there are always present some shells of foraminifera. The admixture of sand varies considerably in quantity, and there are some thin layers which may consist of as much as one-fourth sand. The shells of the foraminifera are sometimes crushed flat and at other times entire and filled with crystalline calcite. Small fragments of the shells of *Inoceramus* are quite common, and may be recognized by their vertical prismatic structure.

Field Appearances.

In their field appearance the thin-bedded and flaggy habit is the most constant characteristic of these beds. The ledges of which the formation is built up average from four to eight inches in thickness. These ledges, or layers, are separated by delicate seams which may not appear in freshly exposed faces. Occasionally in the lower part of the formation there are ledges which measure a foot through. As we follow them upward the layers

*O. H. Palm, Analyst.

become gradually more thin. At certain horizons they have a chalky texture. This is especially true about the uppermost hundred feet. Another habit which is quite characteristic is the manner in which the flags have been affected by joints. They always break into blocks with straight faces and sharp angles, and the three diameters of these blocks are of a somewhat constantly unequal length. The blocks are always considerably longer than wide and they have a greater width than thickness. These proportions of the three dimensions are the same whether the blocks are large or small. One may find blocks which are four feet long and no more than eight inches wide and four or five inches thick. The color of the beds is quite variable. A cream-grayish white is the characteristic shade. In the Boquillas region they usually have a faint ferruginous red stain, often quite marked. On Cuesta Blanca, west of Terlingua creek, they are dark and almost black on fresh fractures in some ledges. The same color was noted north of Christmas mountains in the Corizones and on the north side of the Rosillos mountains.

Resistance to Erosion.

The Boquillas flags are less resistant to weathering and erosion than the heavy limestone which underlie them. This is no doubt chiefly due to their thinner bedding and more close jointing, both of which properties cause them to break into smaller blocks that yield more readily to the agencies of disintegration. Around the flanks of the uplifted domes and ridges of the underlying limestones the tilted edge of this formation usually rises only a part of the way up, leaving the upper surface of the older rock bare. To underground waters it is, however, more resistant than the purer rock on which it rests. On account of the clay constituent which it contains, it is more impervious to water and hence it very rarely contains convernous fissures, and for the same reason, also, the contact between these two formations near Boquillas marks a line of hot springs, where waters coming from below are carried out to the nearest point of emergence of the base of the overlying less easily penetrated formation.

Minor Characteristics.

One or two other characteristic features should perhaps not be passed by. On the upper surface of some of the ledges clusters of cubic crystals of limonite are to be seen. These are pseudomorphs after pyrites, which sometimes have formed in the dark ledges. A two-inch seam of amorphous limonitic material was noted in the upper part of the beds south of Cuesta Blanca.

At several places there were found on some of the layers in these beds a peculiar kind of markings, which consist of straight grooves when on the upper surface of a layer, or straight raised lines when on the lower surface. They measure from one-half to two or three inches in length and are usually connected by similar but diverging structures at one or more points. Sometimes they are crowded together into a network. These structures have a marked resemblance to some markings observed on a ledge of sandstone in the Middle Cretaceous on the south side of the Black Hills in South Dakota and described as fossil frost cracks.* Whatever their origin may be, they are quite peculiar in appearance and certainly different from the structure generally known as mud cracks. Their occurrence at the same horizon in two as widely separated localities as the Black Hills and the Chisos mountains entitles them to our notice. The present writer has also noted their occurrence in the Boquillas flags at Ochinaga, in Mexico, and in Val Verde and Kinney counties in Texas.

Fossils.

Though rich in individuals of a few species, the fauna of these beds is meager in the number of species. No close search was made for fossils and this circumstance no doubt helps to make the list of forms which were observed very small. It is as below:

1. *Globigerina.*—Several species were noted in one of four rock specimens which were examined, and one or two species were seen in the other three. This shell occurs everywhere throughout the whole formation.

2. *Textularia.*—This is less abundant than *Globigerina* but is usually found with it.

*See Scientific American, Vol. LXXII, p. 102, 1895.

3. Small ammonoid, undetermined.

4. *Inoceramus confertim-annulatus* Roem.—This is the most common fossil in the formation and occurs throughout its extent, apparently increasing somewhat in size from below upward.

5. *Inoceramus exogyroides* Meek. Rare.

6. *Inoceramus umbonatus* Meek. Infrequent.

7. *Crioceras cf. latus* Gabb.—This fossil is quite common on the upper surface of one or two somewhat indurated ledges a little above the middle of the formation.

8. A cycloid fish scale, two inches in diameter, was noted on the upper surface of a rather thick ledge of limestone in the bottom of an arroyo near the Colquitt-Tigne mine.

Correlation.

The Boquillas flags are the western equivalent of the Eagle Ford shales in the east part of the State. Though they are more calcareous in this region than farther east, the resemblance of the two is quite evident. Both are made up of thin and straight layers, separated by thin clayey seams. Both contain sand and bituminous material. And both follow directly on top of the Buda limestone. There is, however, a difference in the fauna. In the east part of the State sharks' teeth and large ammonoids characterize the Eagle Ford horizon, but these seem to be absent here. The physical conditions were evidently not quite the same. In East Texas the formation has a much smaller development. The shore of the middle cretaceous sea must have been nearer there and deposition lasted for a shorter period. Indeed, there is some evidence of work of submarine currents strong enough to have prevented sedimentation for some time after the Buda stage. No such conditions were noted in the Chisos country and thus, probably, this formation here reached a greater development and came to have a somewhat different aspect, faunally as well as physically.

The Terlingua Beds.

There was no very abrupt change attending the physical conditions which brought the Boquillas epoch to a close. The upper hundred and fifty feet in the Boquillas beds contain a very considerable amount of chalky ledges, only slightly more indurated than the deposits of the following epoch, which first consist of a yellowish white, indurated, stratified chalk. This gradually changes upward to an impure gray marl, which becomes less and less calcareous, until it is a true clay. In the uppermost strata of these clays there are some thin layers of concretionary limestone and calcareous sandstones. We shall designate this entire succession of somewhat heterogeneous deposits "the Terlingua beds," as they are well exposed along the creek which bears this name. From a structural as well as from a topographic point of view the different members of which it is made up are practically a unit. In all they comprise a thickness of about 1250 feet.

Distribution.

As the Terlingua beds rest on the Boquillas flags, we always find them outside of the latter in going from centers of local uplifts. The nearest lowlands around the mountains and hills of the Lower Cretaceous limestones are mostly overlaid by readily yielding clays of this formation. This habit is probably best illustrated in the case of Mariscal mountain, southeast of the Chisos, where these beds underlie a belt from one-half to two miles wide, on all sides of the ridge. A similar belt follows around the north end of San Vincente mountain and then turns around and follows the west side of the Boquillas range northward. There is likewise an irregular belt coming around the Christmas mountain on the east. Along the Terlingua creek they underlie a wide and irregular area which is peripheral to a general uplift to the west. A few minor areas are isolated and do not occur with outcrops of the lower beds. One of these lies north of Burro mesa, another just to the east of Paint Gap hill, and still another north of Laguna inside of the "rim-rock" in the Chisos mountains.

Cottonwood Creek Section.

Along Cottonwood creek there is a nearly entire section of this division. This creek is a branch of Rough Run, and comes in from the east around the north end of Burro mesa, joining Rough Run opposite Dogis mountain. At a place known as Chisos Pen this creek has cut across the long ridge that extends in a curve north from the north point of Burro mesa. The Terlingua beds appear in a continuous section along this creek, extending from the west side of this ridge to about a mile beyond. They are tilted to the east, which brings the lower part of the section to the surface about a mile out from the ridge. At this point there is a fault, and the section comes to an end just a little above the Boquillas flags.

The lower one hundred feet consist of thin chalky ledges in every way resembling the Austin chalk. Some flat concretions of impure limonite lie in the marly layers and perfectly resemble the concretions in the Niobrara chalk in West Kansas. Fragments of *Haplascapha grandis* Conrad with attached valves of *Ostrea congesta* (Con.) Hall, are frequent. *Inoceramus undulato-plicatus* Roem., another *Inoceramus* of large size, measuring nearly two feet across, and an *Ammonites* were noted. These beds dip east at angles of about 10°. They are followed by some four hundred feet of soft and gray marly sediments, in which the same fossils appear, and which dip at a higher angle in some places. Going further in the same direction we find several hundred feet of clays, in which there are some layers of large calcareous concretions, some thin sandy ledges near the top and also a sheet of intrusive rock measuring fifteen feet in thickness. This clay is overlain by a sandstone, ten feet in thickness, which will be classified as belonging to the Rattlesnake beds, the next member in the section. The concretions which are common about 100 feet below this sandstone ledge, contain now and then ammonoid shells, among which *Placenticeras Whitfieldi* Hyatt and *Nautilus dekayi* Meek were recognized. The clays just below this layer of concretions are extensively exposed for a mile on each side of the creek, where they form a perfectly bare country. They were seen to contain a considerable amount of gypsum, mostly in the form of clear fragments of selenite crystals. Fossils seemed to be wanting.

A measurement of dips and outcrops makes the thickness of this division here not less than 1280 feet.

South of Cuesta Blanca.

On the south side of Cuesta Blanca to the southwest of Study Butte is another place where the Terlingua beds lie in an entire continuous exposure suitable for measurements. They overlie the

Boquillas flags which form the table-like hill, called Cuesta Blanca, and they dip to the south at angles varying from 25° to 50°. The measurement here falls a little short of 1200 feet. The same divisions may be noted at this place as in the section just described. The lower calcareous strata are succeeded by more pure clays, and uppermost these contain strata bearing large concretionary lentils of calcareous material, some eighty feet below the capping sandstone which begins the overlying formation. *Haploscapha grandis* Con., *Ostrea congesta* (Con.) Hall, and a large *Inoceramus* occur about 400 feet below the top, and also farther down in the section.

To the south from here there is an extensive belt where these beds outcrop, reaching almost to the Rio Grande, south of the Rattlesnake mountains. *Exogyra costata* and *E. ponderosa* were found on the bare flat surface of a uniformly tilted outcrop of the upper part of this formation east of Dryden's ranch. Each lies in a seam of rock which is slightly indurated, and which could be seen on the ground as a straight narrow ridge less than a foot high, but extending for half a mile or perhaps farther. The two ledges were perhaps 100 feet apart in the section and *E. ponderosa* was in the lower one of the two. I estimate that these ledges lie here about 200 feet below the lowest ledges of sandstone of the next division.

Other Sections.

Following the Rio Grande downward we next encounter the formation about a mile and a half west of Talley's ranch, where the lower chalky strata appear in the east bank of the creek which comes into the Rio Grande from the north. The exposure reaches out northeastward for at least two miles and at a point one and two-thirds miles to the east of the ranch the upper clays were found to contain *Exogyra costata*. All along the west side of Mariscal mountain the formation underlies a belt varying from one to two miles in width, following the base of the ridge. About five miles north of Talley's ranch and near the U. S. bench mark having the elevation of 2217 feet, a hurried measurement was made across the outcrop of the greater part of the formation, leaving out one or two hundred feet of the lower beds. This measurement makes the vertical distance from the overlying sandstone to the indurated beds below about 1100 feet. Two ledges about fifty feet apart and lying some two or three hundred feet below the top of the formation, consist of a large and sometimes continuous layer of concretions of calcareous material mixed with some sand, and these contain in some places abundant specimens of large ammonoids, among which *Schloenbachia conensis* Conrad (?) seemed to be most frequent. North of this place, where the wagon road crosses the ridge formed by a sill following the west side of the mountain, the lower calcareous division of the formation is well exposed in the side of the road and exhibits a number of more or less entire valves of large *Inocerami,* some of which measure two feet across. North from the end of this ridge and at the foot of Talley mountain, the concretionary layers in the upper division have reached an unusual development and are well exposed. Some of the concretions measure four feet in diameter. This same horizon was also noted in the east bank of Tornillo creek at a point midway between the village of San Vincente and Boquillas postoffice, and the same ammonoid occurs there. Again these strata come into view at Banta Shutup, where the concretions consist of an impure clay ironstone and have large shrinkage cracks which are often filled with black calcite. The beds here follow the west side of the Stillwell ranch intrusive, dipping to the west. They are also uncovered in the valley around this ranch, where *Exogyra ponderosa* was again noted and likewise the zone of large *septaria.*

In the valley which lies along the west side of the Carmen range, about three miles east of Stillwell's ranch, there is a gray and somewhat indurated marl or soft limestone which belongs in the lower part of this division. It contains abundant specimens of a few fossils, one of which I think is new. This is a sponge which consists of a loaf-shaped body of folded plates radiating from a central point. It is undoubtedly closely related to, if not identical with, the sponge already noted in the horizon of the Buda limestone. The plates contain a fine network of hexactine spicules. There was at the same point numerous specimens of *Inoceramus undulato-plicatus* Roem., and of *Schloenbachia leonensis* Conrad. Other *Inocerami* and a *Baculites asper* Morton (?) were noted. The formation extends with some interruptions for several miles in a belt northwestward from this place, passing Muskhog spring.

In the country between the Corizones peaks, Box spring, and the Christmas mountains, the Terlingua marls and shales are frequently seen, and some of the fossils noted at other places were observed here, but this region is more broken up by igneous intrusions and sections suitable for description are less common.

The Laguna is a shallow depression which is caused by the presence of these easily disintegrating beds, a half mile west of the highest peak in the Chisos mountains. By the folding to which the ground has been subjected here, the shales are drawn out lengthwise and shrunk in other directions so as to be greatly reduced in thickness. They are likewise more indurated and more fissured by joints.

Topographic Relations.

In their relation to topography the Terlingua beds invariably maintain the habit of appearing on the lowest ground. In the center of the Chisos mountains, where they have been raised by a high fold, they occupy valleys among the peaks. On the lowlands they form the flattest and most desert-like stretches in the entire region. They have yielded more readily to erosion than any other member of the Upper Cretaceous series. This is due no less to rapid weathering, caused by the weak coherence of the clastic elements, than to the promptness with which these are capable of being carried away by the sheet flood current, owing to their small size. The effectiveness of the sheet flood is increased by the imperviousness of the clays, which causes the rainfall to be shed as from a roof.

Organic Remains.

The lower part of the formation is largely composed of organic sediments. The chalky beds consist almost entirely of a deep sea ooze, quite free from mechanical ingredients. This ooze consists mostly of comminuted fragments of delicate calcareous shells of foraminifera, but entire tests may always be found by proper crushing and washing of the rock. Fragments of the shells of *Inoceramus* form an appreciable ingredient in some strata. Including some four hundred feet in this lower division of the formation, it yielded the following fossils:

1. *Globigerina.*
2. *Textularia.*
3. Other foraminifera.
4. Sponge.
5. Sea urchin.
6. *Radiolithes,* like *socialis* D'Orb. This fossil is smaller than *Hippurites texanus* Roemer, which it otherwise somewhat resembles. Unlike the latter, it consists of a cluster of several individuals which are grown together. It was found in the marls north of Laguna, west of Emory peak.
7. *R. austinensis* Roem., found in the lowermost ledges.
8. *Haploscapha grandis* Conrad.
9. *Inoceramus undulato-plicatus* Roem. There were several smaller *Inocerami,* which were not identified.
10. *Ostrea congesta* Conrad.
11. *Baculites asper* Morton.
12. Ammonoids, two undetermined species.

In the midde division of the formation no fossils were observed. The upper three or four hundred feet contain occasional arenaceous seams and layers along which calcareous material has gathered into large concretions, which are sometimes separate and distant and at other times lie close together, or even join, so as to form a continuous bed. In some of these concretions fossil cephalopods are quite plentiful, but only a few forms have been observed. *Exogyra* has not been noted in connection with the concretions, but it seems to be limited in this region to certain individual layers not far from the horizon in which these occur.

The forms noted in the upper three hundred feet are as below:

1. *Exogyra costata* Say.
2. *E. ponderosa* Roem.
3. *Nautilus dekayi* (Mort.) Meek.
4. *Placenticeras Whitfieldi* Hyatt.
5. *Schloenbachia leonensis* Conrad (?).

Chemical Composition.

It will be clear from what has already been said that the composition of the three divisions in this formation presents two extremes. The lower division is a chalk and the upper part is a clay.

An analysis of the chalk shows only a small amount of clayey material and an analysis of the clay would no doubt show only small quantities of calcareous material. Frequently the clays in the upper part of the section give no response to acid. No analysis has been made of these clays but the composition of two specimens of the chalky beds was found to be as below:

*Analyses of Specimens of the Lower Chalky Ledges of the Terlingua Beds.**

	West of Chisos Pen.	South of Cuesta Blanca.
Silica	4.54 per cent.	19.34 per cent.
Alumina	0.75 per cent.	3.00 per cent.
Ferric oxide	1.40 per cent.	2.16 per cent.
Lime	52.04 per cent.	39.50 per cent.
Magnesia	0.24 per cent.	1.00 per cent.
Carbonic acid	40.70 per cent.	31.50 per cent.
Water (hygroscopic)	0.10 per cent.	.30 per cent.
Water (combined)	0.40 per cent.	2.00 per cent.
Sulphur		trace.
Organic matter		.90 per cent.
	100.17 per cent.	99.70 per cent.

Correlations.

The lower part of the Terlinqua beds clearly corresponds to the Austin chalk in the eastern part of the State. The two formations are alike and in their lithological characters the beds are practically of the same kind. There is a slightly greater admixture of elayey material in the western section than in the eastern. especially above. The middle clays, which are destitute of fossils, are with equal certainty the equivalent of the Taylor marls in the Austin region, and there is no good reason why the upper member should not be referred here also. But the upper limit of the Taylor marl has so far not been definitely made out for the eastern region, and until this can be done a more particular comparison would be premature. The upper two hundred feet herald the coming change of conditions, by the isolated arenaceous bands which it

*Analysis by Mr. O. H. Palm.

contains, but its fossils, so far as known, do not indicate any close relationship to those which occur in the formation that lies above.

The Rattlesnake Beds.

Up to the end of the Terlingua period the sediments of the Cretaceous age in this region were laid down in open waters that extended beyond the shore belt, but at this time the sea began to be encroached upon by the land, at least so far that its waters were more or less hemmed in by inlands and other shore structures. These conditions prevailed for some time. The shore belt evidently slowly subsided and thus allowed littoral deposits to accumulate to a considerable thickness. The resulting sediments are entirely different from those of the preceding periods. They consist of sandstones, muddy and peaty clays and silts, now and then some limestone, and occasionally some thin beds of gravel. The littoral conditions were such that vegetable accumulations occasionally were laid down and buried among other sediments. These have been changed into coal. From the nature of the conditions attendant upon the making of these deposits they are necessarily quite variable in composition and texture, and individual strata do not persist for any great distance horizontally.

The Zone of Change.

While there is no difficulty in making out the general line of division between the Terlingua and the Rattlesnake formations, as this is well marked in a general way, still the particular level of the change in each local section must be selected somewhat arbitrarily owing to the frequent variations of the beds in the upper member. Usually the change is ushered in by a thin stratum of sandstone, which may be overlain by fifty or more feet of clays of the same kind we find below it. Then there may be another ledge of sandstone with another stratum of clay. Or the sandstones may be replaced by arenaceous limestone. These beds may truly be said to make a zone of change, since they lead up to the variable deposits above. The sandy and calcareous layers are frequently fossil bearing, and their fauna is clearly related to that above. Yet it is somewhat different. To make close comparisons possible with the Cretaceous strata elsewhere by other students, the fossils observed in the transition beds are here listed separately:

1. Coral (?).
2. Bryozoan, adhering to the outside of a cup-shaped tube, probably from a coral.
3. *Gyrodes* sp. (?).
4. *Natica* sp. (?).
5. *Rostellites texana* Conrad (?).
6. *Scurria* sp.
7. *Spironema* sp.
8. *Volutomorpha,* like *poderosa* Whitfield.
9. *Camptonectes burlingtonensis* Gabb. (?).
10. *Thracia* sp.
11. *Dentalium gracile* M. & H.
12. *Baculites* sp.
13. *Lamna,* like *elegans,* Agaz.
14. *Lamna texana* Roem.
15. Vertebrae of fishes.

Thickness.

Including a hundred feet of this zone of change the Rattlesnake formation contains about 600 feet of strata, as delimited in the description which follows. It must be stated, however, that the division between these beds and the sediments which overlie it is much less well defined than the base of the formation. No attempt could be made to definitely mark its upper limit.

The Sandstones of the Rattlesnake Beds.

The sandstones of the Rattlesnake beds made the most conspicuous outcrops in these sediments. Single beds measure as much as fifty and sixty feet in thickness. While they vary considerably in color—which may be white, gray, yellow, brown and even bluish—they possess some features which are rather constant. They are, as a rule, quite free from coarse admixtures. Pebbles, even of small size, are quite unknown. These sands hardly ever contain any mica and they are quite well sorted. In seven samples which were specially examined with regard to texture, there was only one specimen in which the greater part of the material consisted of grains measuring a half millimeter in diameter; in one sample the maximum ingredient consisted of grains measuring one-fourth of a millimeter; in one of grains measuring about one-sixth mm.; in two, about one-eighth; and in one most of the grains were less than one-sixteenth millimeter in diameter. Compared with other sandstones of the same coarseness, the grains are rather little rounded. Some magnetic grains may usually be found. Otherwise the constituent is quartz, of which some is chert, especially among the grains of the largest sizes. With the coarse admixtures organic calcareous fragments are sometimes also imbedded. Very rarely these form thin seams between finer strata, where the sorting has been affected by strong currents. Some calcareous material is quite generally present, and the sandstones grade into almost pure ledges of limestone, which, however, are infrequent.

The bedding is variable. In few instances faces of ledges were seen measuring twenty feet and apparently without bedding seams. As a rule, thin bedding prevails. In thin ledges the seams are usually straight and even. But cross bedding is very general, and fine ripple-bedded layers are not uncommon.

Being the most open in texture of all the sediments in this formation the sandstones have been the highways of underground water, and this has often worked secondary changes. The most frequent change is the introduction of interstitial calcareous material, giving the rock greater hardness and toughness. This interstitial material is sometimes a pure calcite with continuous cleavage planes of large size. The change is very generally accompanied by development of concretionary structures, also of large size. A frequent form of these is large circular disks, measuring sometimes three feet in diameter, and exhibiting the original bedding planes on the edges in weathering. They frequently split along these planes into thin plates, an inch or less in thickness, extending across the entire disk. Spherical concretions have also developed, the sizes most commonly seen being from two to six inches in diameter.

In some of the sandstones, and especially in the lower part of the formation, cementing material is present in small quantity only, and mostly confined along the joints, leaving the central part of the delimited blocks soft and ready to crumble under the influence of the weather. This gives rise to a habit of weathering which has a very unique appearance and develops some most irregular cavities on the surface of the stone. Ultimately these run together and leave bent and irregular plates and cusps projecting out from the face of the ledge, in the most fantastic forms and resemblances.

About three hundred feet above the base of this formation the sandstones have some peculiar markings, which are the imprints of the fucoid *Halymenites.* They can be most readily described as closely resembling moulds that might be made by pressing the side of a small ear of popcorn into sand. They usually appear as semi-cylindric depressions on the weathered surface of the sandstone, frequently bending and sometimes branching, varying in width from three-fourths of an inch to nearly twice that width and having a length of sometimes as much as six or eight inches. The surface of the impressions is studded with shallow pits that measure about three-sixteenths of an inch in diameter and that tend to be arranged in rows running diagonally across the cylindric depression. In cross-section, these pits may be seen to extend all around the cylindric cavities and in a few instances a smooth and straight central core of sandstone was seen to protrude from one end of the otherwise empty mould. In another place the filling in these moulds had for some reason become more indurated than the matrix around it, and as this weathered away the casts in the original form of the fossil were left bare. In cross and longitudinal sections these exhibited a smooth central core of unaltered sandstone. Ne vestige of organic material could be found in any of the specimens examined. In the casts just mentioned the sand was held together by a dark ferruginous cement, which was lacking in the surrounding more rapidly weathering matrix.

These markings are so abundant in some sandstone ledges that they may be said to fill them. They have been noted in the coal bearing beds of the Upper Cretaceous at Eagle Pass, and they are reported from the Fox Hills sandstone in Eastern Colorado by N. H. Darton. Their real nature must at present be left to conjecture. The cylinders usually lie in a horizontal position. This, as well as their mode of branching, suggests that they may be impressions of root-stocks of some water plant. Perhaps they are the burrows of some animal living in the beach sands of this period.

Finer Sediments.

The finer sediments which are interbedded with these sandstones consist mostly of silts below, and of clay of finer texture higher up. The muddy silts contain more or less of carbonaceous material, which is sometimes present in such quantities as to make the deposits appear perfectly black. Occasionally the silts as well as the clays are marly and at times we find the calcareous ingredient gathered into concretions with forms of all degrees of regularity. At times these form continuous layers many feet in extent and from four inches to a foot thick. These usually oxidize to black impure limonite, as the original concretionary mass contains a large per cent of carbonate of iron. At other places the concretions form perfectly circular leaves and disks. The finer clays are usually gray, but baking by igneous intrusions and also weathering may have turned them yellow, brown, or red. Bluish and greenish tints are also in evidence. The finer sediments constitute the bulk of the formation.

Original Calcareous Deposits.

Original calcareous deposits played a very subordinate part in the sediments of this period. But there are a few ledges of limestones which consist of organic fragments, in the form of ill assorted calcareous sand and of mud containing larger shell fragments. Some of the clays as well as some of the sandstones also contain a calcareous ingredient which is present as an original constituent.

Special Sections.

A description of some local sections will give a better idea of the character of this formation as a whole. In the ridge which extends north from the north end of Burro mesa we find the lower part exposed. Cottonwood creek crosses this ridge almost exactly at the latitude of 29° 20′ N., and at the east foot of the ridge its bed contains a tinaha, near which there is an old camping place known as Chisos Pen. The creek crosses the ridge along a line of fracture and the section in the ridge is considerably broken up and obscured. The beds dip to the east from 10° to 30° and are essentially as follows:

Section near Chisos Pen.

		Thickness in feet.
13.	Soft gray ledges of sandstone containing occasional shells of two species of oysters	140
12.	An intrusive sill	20
11.	Silt and clay with some carbonaceous material	60
10.	Sandstone, gray	20
9.	Sand, mixed with clay and carbonaceous material	40
8.	Coal	1½
7.	Silty mud or fire clay	2
6.	Sandstone containing some mud and in places showing clear lamination, a large oyster present	50
5.	Not exposed	?
4.	Sandstone, irregularly bedded, and weathering to a very irregularly cavernous or pitted surface, and containing large specimens of *Inoceramus cumminsi* Cragin	30
3.	Clayey and muddy sand	?
2.	Yellow hard sandstone containing fish remains and various lamellibranchs	10
1.	Clays of the Terlingua beds.	

About a half mile east of the Chisos Pen some ledges of soft sandstone rest on clays which contain silicified wood, and concretions of clay ironstone, and at one place a layer of a fine grained white sediment which is evidently a tuffaceous deposit. These ledges here lie in a horizontal position, and taking into account the low pitch to the east which shows in the nearest exposures on the west, the sandstone apparently belongs to a horizon about two hundred feet above the highest member in the section just given. In the sandstone are moulds of various lamellibranchs, among which a *Leda,* a *Corbicula,* and a *Cardium* were noted, and it also contains remains of saurians, fishes, and turtles and some silicified wood.

About one and one-half miles farther north the same section is seen on the west side of the ridge and may be given thus:

Section north of Chisos Pen.

		Thickness in feet.
12.	An igneous sill	17
11.	Gray clay or shale	55
10.	An igneous sill	20
9.	Clay and silt containing *Ostrea*, cf. *glabra* M. & H.	20
8.	Sandstone	14
7.	Indurated sandy silt	45
6.	Sandstone with *Inoceramus cumminsi* Cragin	10
5.	Sandy clay	28
4.	Sandstone containing many fragments of shells	16
3.	Clay	20
2.	Hard yellow sandstone with teeth of sharks and shells of lamellibranchs	5
1.	Clays of the Terlingua beds.	

Again, a mile south of Chisos Pen the same beds on the east side of the ridge were measured and described as follows:

Section south of Chisos Pen.

		Thickness in feet.
12.	Igneous sill	150
11.	Sandy shale	40
10.	Igneous sill	10
9.	Sandstone with fragments of *Ostrea glabra* M. & H.	42
8.	Coaly shale	8
7.	Sandy shale	40
6.	Soft sandstone containing a large oyster, probably *Ostrea contracta* Conrad	12
5.	Sandy shale	40
4.	Sandstone, with *Inoceramus cumminsi* Cragin	12
3.	Shale	30
2.	Yellow hard sandstone with occasional fish remains	5
1.	Terlingua beds.	

Number 2 and 3 in all these three sections are the same, and they belong to what has already been described as the "transition beds." They were seen in many other places, as in Rough run to the northwest of Maverick mountain, south of the same mountain near Dawson creek, near the junction of Rough run and Terlingua creek, in several places between this point and the mouth of Terlingua creek, west of Mariscal mountain, and also on the Tornillo creek south of Boquillas postoffice. At nearly all of these places the sandstone numbered 4, is found lying right above, and it almost invariably contains the characteristic fossil *Inoceramus cumminsi* Cragin. This fossil is quite variable in shape and size. It varies from three to four inches to twelve or even fourteen inches in length, and the larger forms are more gibbous than the smaller. Frequently the sandstone is profusely filled with these large shells and their imperfect casts weather out in abundance. This ledge frequently presents a surface honeycombed with cavernous hollows that are separated by irregular plates consisting of indurated material along its joints. For three or four hundred feet above this sandstone the beds are made of variable strata of clayey and sandy silts, in which there are frequently some peaty seams, and occasionally these develop into seams of pure coal. This is the coal-bearing horizon of the Upper Cretaceous in the west part of the State. It is characterized principally by a lamellibranch fauna to which also belongs at least one brachiopod and some gasteropods and a turtle. The forms most frequently observed resemble those named in the following list:

Lingula cf. *rauliniana* d'Orb.
Mytilus [?] sp.
Veniella cf. *conradi* Whitfield.
Mactra texana Conr.
Thracia gracilis M. & H.
Ostrea cf. *glabra* M. & H.
O. contracta Conr.
Cardium carolinense Conr.
C. cf. *congestum* Conr.
Crassatela cf. *obliquata* Whitfield.
Fragment of the carapace of turtles.
Impressions of plant (?) [described above].

The coal is bituminous and has a fine texture. It is also characterized by containing small irregular pockets filled with a reddish resin.

Fossil Wood.

Above these coal-bearing strata the sediments become less sandy and contain more clay and more calcareous material. This is a horizon which almost everywhere is characterized by the presence of silicified wood, bones of vertebrates, and stray layers of tuffaceous sediments. Fragments of silicified wood are almost universally present and entire trunks are not infrequent. Some trunks were seen measuring more than three (in one instance six) feet in diameter and as much as forty feet in length. The tree trunks almost invariably occur several together and usually they lie on or under some ledge of sandstone or along some particular layer in the clays. In one instance all the trunks belonging to one such layer were seen to be angiospermous exogens, probably all of one species. More than two-thirds of the wood otherwise shows the tracheid tissue of gymnosperms.

Vertebrate Remains.

Associated with these tree trunks are the remains of some saurians. Many of these are of large size. Long bones and vertebrae are most common and the centrum sometimes measures as much as five inches in diameter. Fragments of the carapace of turtles are quite common. At a point about a mile south of the mouth of Dawson creek the vertebrate remains were found to be associated with a *Viviparus,* like *V. raynoldsanus* M. & H. The clay in which these vertebrates most frequently occur usually contains a number of rough yellowish concretions, varying in sizes from a half to two inches in diameter.

Tuffs.

In these clays we often find layers of white impalpable volcanic tuff more or less mixed with other sediments. Usually some fragments of bones may be found near such layers. Instances of this kind were noted on the south side of Dawson creek, two miles south of Big Bend postoffice; in the hills a half mile south of Dryden's ranch on lower Terlingua creek; at a point about four miles west northwest of Talley's ranch on the Rio Grande south of the Chisos; in the hills about two miles east of Neville springs, and on Cottonwood creek about a mile east of Chisos Pen. The tuff beds are usually only two or three feet thick and often less than this. They thin out, and thicken in short distances. Their association with the vertebrate remains suggest that the eruptions which produced them may occasionally have been destructive to life in the coastal regions of the Cretaceous sea.

One of the thickest beds of such tuff was seen in a small sharp-pointed butte, which rises from the plain about two miles east of Chisos Pen. The section which is exposed on all the sides of this butte is as below:

	Thickness in feet.
4. Soft gray sandstone	20
3. A brecciated mixture of sand, gravel, and lumps of clay and sandstone measuring as much as a foot in diameter. Many of the clay lumps are from a white tuff composing the next number below	30
2. A white compact fine clay which largely consists of an impalpable volcanic dust. It breaks into angular chips and was seen to contain a fragment of a bone and a piece of pumice. This stratum is separated by a sharply marked line from the number below	38
1. Dark shaly clay with sandy layers. Some silicified wood noted	60

On the southwest end of Slickrock mountain the clays and sandstones of this division are overlain by similar tuff beds and brecciated mixtures, measuring some seventy-five feet in thickness The change from the clays to the tuffs has the appearance of an unconformity. The sharp line of contact between numbers 1 and 2 in the section given above suggests at any rate a great change in conditions. It may very well be that at both these places an apparent unconformity might have been produced by currents in the bottom of waters where the volcanic sediments fell. Such currents may very well have been strong enough to tear up and rearrange loose volcanic mud, especially as the eruptions were probably not far distant.

About two miles west of Ash spring and at a place where an arroyo approaches the south base of a low cuesta, there is a layer of yellow limestone underlying a tough sandstone which belongs to these clays. The calcareous layer is only some twenty inches thick, but it has a very peculiar brecciated appearance, as if the material had been broken up and twisted or kneaded in some way before hardening into solid rock. A similar layer was noted in the same beds a mile east of the Grapevine hills on the east side of the

Chisos. This rock seems to be peculiar to the upper part of the Rattlesnake beds, and may help in tracing their extent.

Topographic Features.

The Rattlesnake beds have been named from the Rattlesnake mountain, which is a dissected low dome on the east side of lower Terlingua creek and about four miles south of Big Bend postoffice. These beds are exposed in an almost continuous but irregular belt encircling the Chisos mountains, and it varies in width from less than a mile to several miles. It is a belt of greater relief than we find where the Terlingua marls constitute the bed rock. In the Rattlesnake mountains it presents its most rugged appearance topographically. In most places we find these beds more or less tilted and the exposed edges of the sandstones form long and narrow ridges, seldom more than a hundred feet high, and mostly less than this. The effect of this unequal resistance to erosion by different strata is frequently increased by the fact that igneous rock sills have been injected between them, and these protect still more effectually the sandstones. This is the case in the Rattlesnake mountain, in Dogis mountain, in Slickrock mountain, in Chili Cortal and Talley mountains, and in the Grapevine hills. Where the strata lie in a horizontal position the sandstones sometimes cap low buttes and mesas and we find a few of these along the Tornillo creek west of McKinney springs and also on the flats west of Oak cañon.

Fossils.

Fossils are usually well preserved in the clays and limestones. In the sandstones they occur mostly as moulds, the original substance of the shells having been removed by solution. In such cases identification is difficult and uncertain. A list is appended which includes all the forms believed to have been noted in the formation, including the "transition" beds.

Plants.

1. Impressions of the fucoid Halymenites.
2. Silicified wood. Fragments and entire trunks of trees lie in the sandstones and in the clays. About fifty out of seventy

specimens from different localities are gymnosperms. The other twenty exhibit the tracheary tissue of exogenous angiosperms.

Invertebrates.

3. Bryozoan, a small fragment attached to a probable coral.

4. Coral?

5. *Lingula,* cf. *rauliniana* d'Orb. In a mud layer, six feet under the coal seam in Cottonwood creek.

6. *Ostrea* cf. *contracta* Conrad. This is a large oyster of an elongated form. One specimen measured twenty-seven inches in height and seven inches in width. The hinge in one measured nearly five inches from side to side, seven inches in height and was an inch thick.

7. *O. elegantula* Newb.

8. *O.* cf. *veleniana* Con. This is a species which also resembles *O. prudentia* White, *O. Wyomingensis* Meek, and *O. coalvillensis* Meek. It is the most common of all oysters in these beds and varies in form as well as in size. It occurs mostly in carbonaceous, muddy clays.

9. *O. subtrigonalis* Ev. and Shum.

10. *O.* cf. *tecticostata* Gabb.

11. *Lima* sp.

12. *Inoceramus cumminsi* Cragin. Always in sandstones in the lower part of the formation. Usually much larger than the specimens described as types.

13. *I. crispii?* var. *subcompressus* M. & H.

14. *Mytilus* [?] sp.

15. *Leda,* sp.

16. *Crassatela* cf. *obliquata* Whitfield.

17. *Cardium carolinense* Conrad [?].

18. *C.* cf. *congestum* Conrad.

19. *Cardium,* undet. A species very common in some sandstones.

20. *Corbicula cytheriformis* M. & H.

21. *Corbicula,* sp.

22. *Cyprina.*

23. *Veniella* cf. *conradi* Whitfield.

24. *Veniella,* sp.

25. *Thracia gracilis* M. & H.
26. *Mactra texana* Conrad [?].
27. Undetermined lamellibranchs.
28. *Buccinopsis parryi* Conrad [?].
29. *Viviparus* cf. *raynoldsanus* M. & H. This species occurs in association with saurian remains north of the Rattlesnake mountains.
30. Undetermined gasteropods.
31. *Baculites grandis* [?] Meek. Only two rather poorly preserved specimens were observed in one single locality: in the hills west of Dryden's ranch.

Vertebrates.

[Determined by Dr. S. W. Williston.]

32. *Claosaurus* [several limb bones and several vertebræ].
33. Ceratopsid? [Lower extremity of a tibia.]
34. *Dryptosaurus* [several teeth].
35. Crocodile [not previously known].
36. Several turtles [fresh water types].

Below I append a letter from Prof. S. W. Williston of the University of Chicago, who kindly undertook to examine the vertebrate fossils from the Rattlesnake beds.

CHICAGO, January 30, 1905.

DEAR PROFESSOR UDDEN: I am not yet sure of the determination of some of your specimens. There are a number of limb bones and vertebræ of a moderate-sized herbivorous dinosaur, which clearly belong in the genus Claosaurus, with solid limb bones. A lower extremity of a large tibia I believe to belong with the Ceratopsia, but I find no other indications of that group. The bone is solid and hence can not belong with the Hadrosauridae; it is either a Ceratopsid or a very large Claosaur of a new form. I find a number of carnivorous teeth, quite like those so common in the Laramie and referable to Dryptosaurus—but they are not of much value for correlation. The large crocodile is new to science, and hence of no value in correlation. The turtles also are of fresh-water type, but their determination is impossible until the material is restored. So far then: the fossils are of the land and fresh-water Cretaceous, and would have been referred until recently unhesitatingly to the Laramie or Judith river. But, these forms also occur in the Belly River deposits, which are now known to be contemporary with the Ft. Pierre.

However, I have very little hesitation in saying that the deposits are from near the top of the Cretaceous, though the collection lacks not a few things characteristic of the Laramie and Judith River that I should expect to find in it, and has an undue preponderance of Claosaurus-like dinosaurs, which are relatively rare in the Laramie or Judith River.

I am inclined to believe that you have either a new vertebrate horizon, or some very decidedly new facies of a known horizon which will repay thorough investigation.

Very truly yours,

S. W. Williston.

Correlation.

Whatever will prove to be the equivalents of the Rattlesnake beds in the Rocky mountain section farther north, I believe that they are certainly identical with the coal-bearing horizon at Eagle Pass, and also with the coal-bearing beds in El Paso county.

The Tornillo Clays.

Sandstones become less and less important from the middle part of the Rattlesnake beds upward. The highest part of the formation consists largely of clays alone. Parallel with this change is a disappearance of nearly all of its characteristic fossils. There are at least some six hundred feet of such barren clays resting on the Rattlesnake formation, but they can not be separated from it by any sharp limit. As these upper sediments are well exposed for many miles along Tornillo creek, they will here be called the Tornillo clays.

Characteristic Coloring.

These clays may usually be recognized by the peculiar sombre colors: gray, dull olive green, dull blue, dull red, dull yellow, dull purple, dirty brown, and at times black and white, only now and then heightened by the oxidizing influence of heated intrusives to brighter shades of red and yellow. Their stratification is rendered conspicuous chiefly by these colors, which alternate promiscuously in different layers, and sometimes also change in the same stratum. On the sides of many bluffs sapped by arroyos and creeks the different strata usually appear as color bands varying in width from one to twenty or thirty feet. Otherwise the stratification is not very apparent. All is a fine clay throughout, with only now and then some thin lentils of sandstone. These sandstone ledges are nearly always characterized by great toughness due to cementing material, which makes them hard to break.

Mechanical Composition.

The clays have a very fine texture. They contain a large admixture of exceedingly fine particles, less than one sixty-fourth of a millimeter in diameter. This renders them quite impervious to water. But they also contain a small ingredient of sand grains, some of which are magnetic iron. Their clastic elements are really not as well sorted as the sediments in most extra-littoral waters. They resemble in this respect more such clays as are laid down in hemmed-in waters, where currents are absent and where all the elements in suspension are thrown down. The small quantity of sand which is mixed in the clay as well as the sand which makes up the stony layers, consists of grains that are rather more angular than usual. This fact no less than the presence of magnetite grains and the copious ferruginous ingredient which causes the coloring, suggests that a large part of the sediments have been derived from disintegrated terranes of volcanic origin.

Calcareous material is scarce. Usually these clays do not effervesce on the application of acid. But occasionally a stratum of lime rock may be found, and it is apt to be associated either with sand or gravel and mixed with carbonate of iron. North of Nugent peak a stratum of this kind was seen, which consisted of a mass of lenticular grains of carbonate of lime and iron, cemented into a hard rock, in which there were also some quartz pebbles. It had the appearance of a conglomerate of calcareous lumps. These measured from one to four millimeters in diameter. Some had the appearance of being original in the rock, while others were more like true subsequent concretions. The largest had central radiating shrinkage cracks filled with calcite. This stratum belongs in the upper part of the formation. About a mile east of the Grapevine hills a stratum near the base of these clays contains a lentil of sandstone, twenty feet thick, which is conglomeritic at intervals. The pebbles in this conglomerate are well worn and round, some measuring an inch in diameter. Among the pebbles in this conglomerate, rocks of different kinds were represented about as follows:

Limestone [½ of Lower Cretaceous age]	65 per cent.
Chert	23 per cent.
Silicified wood	5 per cent.
Quartzite	3 per cent.
Worn calcareous concretions	2 per cent.
Shale	1 per cent.
Marble	1 per cent.

Chemical Composition.

The variations in color, which these beds exhibit is no doubt due to their high percentage of iron. Some of this iron is in the form of black magnetic grains. From this circumstance and from their rather large content of potash and soda it may be inferred that these clays consist of the finest debris resulting from the disintegration of volcanic rocks. Below is an analysis of a dark clay from the hills on the east side of Rough run, about two miles east of Dogis mountain.*

Analysis of Tornillo Clay.

Silica	64.14
Alumina	18.81
Ferric oxide	6.05
Lime	.74
Magnesia	.30
Potash	1.28
Soda	.58
Water [hygroscopic]	6.00
Water [combined]	2.50
	100.40

*O. H. Palm, analyst.

Concretions.

Almost at every place where the clay is subjected to rapid erosion its surface is covered by small concretions of carbonate of lime and of iron, which are left behind as the loose clay is washed away. These concretions are usually of small size ranging from that of a pea to that of an apple. They have a rough exterior and are mostly of a dark or yellow color. Sometimes they show shrinkage cracks inside. In a few places, as south of the mouth of Dawson creek, there are large concretionary nests of yellow crystals of calcite, which have a radial arrangement. These nests measured from six to ten inches in diameter.

Weathering and Creeping.

The Tornillo clays weather in a most singular fashion. It has already been noted that they are so fine in texture as to be quite impervious to water. Inversely they will not yield enough moisture to enable plants to grow, except where their surface has been mixed with or covered by some land drift. When rain falls the surface of the bare clay swells up into an exceedingly sticky mud, which renders the land practically impassable to man and beast. Pools of water will stand on the ground after heavy showers and they will evaporate away by heat and sunshine while only a small part of the moisture filters into the clay. When the ground dries, the clay shrinks and cracks extensively, but as the moisture only affects the upper one or two feet, the cracks are limited to the same depth. The clay retains the moisture with such tenacity that the outer layer of a moist lump will warp and break off while the kernel is yet somewhat plastic. As a result, the drying clay breaks up into irregular angular hard lumps, less than an inch in diameter. These cover the unweathered strata beneath to depths of from one to three feet on hills and slopes where the clay is bare. They are hard and tough, sometimes wholly separate from each other, and sometimes partly adhering. With every rain the process is repeated, the lumps swell up and are again dried and warped. The swelling as well as the warping produces a small creeping motion among the clay lumps, small in extent but evidently powerful. On slopes, gravity aids all movements in a downward direction and counteracts all other movements. In the long run the accumulated effect of this influence results in a motion in the direction of the slope. The whole bed of clay lumps thus creeps forward like a glacier. The movement is evidently very slow, but many of the clay hills show unmistakable indications of its reality in their rounded flowing contours. Such conditions are especially frequent in the hills along Rough run northeast of Maverick mountain, along Tornillo creek, northeast of Paint Gap hill, and in the country to the north and east of Rattlesnake mountain. They seem to be the result of some nicely balanced adjustment between clay texture on the one hand and particular climatic conditions on the other, and we must regard this creeping as a very exceptional phenomenon in nature. On Dawson creek, south of Maverick mountain, I found a place where the front end of such a creeping body of clay lumps had embraced a dead mesquite tree and was still holding this in an upright position, after the base of the clay cliff had been washed away by the creek. It will be understood from this that the moving body of the clay consisted of a tangle of lumps of such shape and consistency that they adhered sufficiently to hang together, when dry, without support. Where two such creeping bodies of clay come down from opposite sides of a small gully they will sometimes bridge the gully and allow the water to escape beneath them. Miniature low natural bridges formed in this way were noted north of the Rattlesnake mountains, along the margins of some of these "clay creeps." At other places small caves have evidently been formed in a similar manner.

Geographical Distribution.

In a general way the Tornillo clays may be said to underlie a circular belt of land just inside that of the Rattlesnake beds, surrounding the Chisos mountains. Its most typical outcrops are to be found along the east bank of Rough run, south and east of Dogis mountain, where they weather into the peculiar rounded contours which have just been described. At a point northwest of Chisos pen a fresh cut in the left bank of the creek the bedding indicated, clearly, an unconformity. Some of the layers had been cut away and the hollow was filled with the same clay or with a clay identical in appearance. The structure was too high up in the bank to be accounted for by the action of the present stream. It appeared like an unconformity in the original bedding. No similar feature having been observed elsewhere, it does not seem likely that there is any general unconformity at this horizon.

The clays underlie much of the country west of Burro mesa. South of Dawson creek, on a line nearly south of the west end of Maverick mountain, some streaks of tuff are imbedded, and the uppermost part of the section exhibits two seams of peaty material about thirty feet apart, each of which is overlain by a layer of sandstone from two to four feet thick. Again, we find these clays to the northeast and to the east of Rattlesnake mountain, and along Willow creek. North and northwest from Reed's camp they are seen in most arroyos and also over part of the flat country between this place and Lindsey's quicksilver claim. They constitute the bed rock over large areas between and around Talley mountain and Chili Cortal mountain, and around the Dugout wells. From here northward they underlie some later gravels, appearing north of these in a belt which extends north to the Tornillo creek, on the east side of the Grapevine hills. In the valley of this creek they frequently contain plates of gypsum with a fibrous structure. From this point the outcrops follow the south side of Tornillo creek westward and appear last on Onion flat.

Physiographic Character.

From the above account it is clear that the Tornillo clays invariably occupy the widest stretches of the graded plains in the Chisos country. The reason for this is clear. The clays are soft and yield promptly to the agents of erosion. Transporting currents most easily hold them in suspension. No stream in this entire region carries water so tenaciously muddy as does the Tornillo. Intrusives seem to have avoided these clays, and there are but few igneous sills present to break the monotony of the even plains to which they have been reduced.

Thickness.

It was not practicable to satisfactorily make out the thickness of Tornillo clays. About a mile and a half above the mouth of Dawson creek the combined thickness of these clays and Rattlesnake beds is not far from 1400 feet. In Ash cañon on the northwest flank of the Chisos mountains the dip and the outcrop of the clays alone indicate that they measure at least 800 feet. But the exposures here are not continuous, and there may be some faulting. On the east side of the Chisos there seems to be more of these clays. West of the eruptives which surround Stillwell's ranch and about four miles north of Banta shutup, there is a continuous exposure of the tilted edges of the Rattlesnake beds and the Tornillo clays, which dip from 15° to 25° to the west for a horizontal distance in the same direction of nearly a mile. This indicates a thickness of the two formations of at least 1500 feet. But the upper limit of the Tornillo clays does not appear. Six or seven hundred feet seems a very conservative estimate for this formation. Possibly it is nearer to a thousand feet.

Fossils.

Very few organic remains were observed. Silicified wood is occasionally present in the lower strata. About one-half mile northeast of Rock hut, or about two miles nothwest of Oak spring, fragments of some large saurian bones with very coarse texture were noted in an exposure of a varicolored clay. A little distance from this place a ledge of sandstone in the same beds was indented on its upper surface with curving grooves resembling tracks made by fresh-water clams. They were certainly marks of some organic origin. These are the only indications noted of the existence of life during the Tornillo epoch. There can hardly be any doubt that plants and animals were less abundant in the seas where these clays were laid down than in the waters depositing the Rattlesnake beds. Nevertheless, it is believed that a more thorough search in the dark clays may result in the discovery of more fossils.

The Chisos Beds.

The uppermost and latest great formation in this region consists of a heavy deposit of tuffaceous sediments, which I shall call the Chisos beds, as they form by far the greater part of the sediments seen in the Chisos mountains.

In their make-up the Chisos beds are quite unique. They are everywhere clearly stratified in thin and well-defined ledges and layers. These measure from an inch to one and two feet in thickness, and persist for long distances. The exposures appear somewhat like those of stratified limestones. But the color is usually of a brighter hue than is common in limestones. The great bulk of the strata consist of a bluish gray or white stratified rock, which lies in even, thoroughly consolidated ledges. Among these there are occasional layers of clay and sandstone, and even thin layers of conglomerate. The sandy layers often show cross-bedding and occasionally also ripple marks, and the sand is quite well sorted.

The Typical Rock.

Examining the texture more closely we find that the typical rock appears almost structureless to the naked eye. With a hand lens one can distinguish scattered grains of quartz, slightly rounded, imbedded in an obscurely fragmental mass, which contains small cavities or vesicles filled with various minerals, evidently of secondary origin, such as crystals of quartz, amorphous quartz, or a greenish silicate resembling serpentine, or more rarely crystalline calcite. Under the microscope small specks of this greenish mineral are seen quite frequently throughout the rock. The sand grains sometimes show round contours, evidently due to wear, and again they exhibit original crystal faces. Worn fragments of feldspar may also be observed, and there are even now and then minute grains of magnetite and more or less well defined specks of limonitic material. The mass or matrix of the rock is usually too fine in texture to enable us to recognize the individual minerals of which it is composed, even with the microscope. But it is essentially siliceous, for it gives no response to acid.

By crushing the rock and washing out the sand we may find the same minerals: quartz in rounded and angular grains, seldom exceeding one-fifth millimeter in diameter, sometimes of a very clear variety and sometimes opalescent: feldspar in clearly worn fragments or of unabraded crystals; magnetite and limonitic grains, the latter evidently a secondary product from the former. Very rarely we may discover fragments of scoriaceous glass.

In chemical composition these sediments are somewhat variable owing to secondary changes by which they have been affected. A specimen which was taken from the exposures in the hills south of Ward's spring, where the beds appear to be comparatively little altered, was submitted to Mr. O. H. Palm for analysis. His report is as below:

Analysis of the Chisos Tuffs.

Silica	53.42
Alumina	9.17
Ferric oxide	2.33
Lime	17.15
Magnesia	.30
Carbonic acid	16.00
Water [hygroscopic]	.22
Water [combined]	1.02
Sulphur	trace.
	99.51

Frequently these ledges have been considerably altered, even when not much changed in their superficial appearance. Minute crystals of quartz, rather long and slender, have formed throughout the fine clastic matrix. Small angular spaces of irregular shape have been filled with chalcedonic quartz, or with minerals resembling serpentine and limonite. Or entire ledges have been affected by solution to such an extent that large irregular cavities have been formed, and filled with calcite. In such ledges no magnetic sand is present, but it seems to be replaced by the limonitic material.

The Sandstones.

The sandstones, which constitute less than one-fifth of these deposits, are seldom very heavy but consist of mostly isolated ledges a foot or so in thickness, and these rarely are more than two or three in succession. The grains are largely angular quartz, averaging perhaps one-fifth millimeter in diameter. But well rounded grains occur also. Feldspar and magnetite grains are present. The interstices between the grains are filled either with some fine tuffaceous material or by calcite or by a siliceous deposit, evidently brought by the ground water. In one specimen taken south of

Ward spring magnetite grains were plentiful along some thin seams following a slanting and curving seam through the ledge.

The Clays.

Clayey strata are most frequent and heaviest in the lower part of the formation where they resemble the Tornillo clays. They have a chocolate color and contain small dark calcareous concretions. Higher up they become thinner and acquire a dark dirty gray color. On weathering, the higher shaly strata break up into cubical pieces; and concretions, when present, are apt to be larger and to have a more smooth surface than in the lower clays. Near Government spring some clay seams in these beds are deep black from the presence of organic material. An analysis of a sample from a typical layer of clay from the exposures west of the Chisos mountains is as below:

Silica	72.64
Alumina	12.11
Ferric oxide	3.45
Lime	1.46
Magnesia	.25
Potash	1.40
Soda	1.70
Water [hygroscopic]	2.60
Water [combined]	4.60
	100.21

The Conglomerates.

Conglomeritic seams are sometimes present, especially in the middle and upper part of these sediments. But they constitute an insignificant fraction of the whole. Some of the conglomeritic seams are associated with the sandy ledges, and their pebbles, which consist mostly of well-worn limestone, average from one-fourth or a half inch in diameter to two or three inches. Elsewhere we find well-worn and rounded small boulders of limestone as well as igneous rock from three to six inches in diameter, imbedded in the stony ledges of finer texture. The limestone boulders are sometimes partly silicified on the surface, so that this is protected, as it were, by a more or less continuous crust of chert.

Description of Exposures.

South of Oak Cañon and about two and a half miles to the southeast of Rock Hut there is a high cliff of the Chisos beds, which here lie in a nearly horizontal position. Some 600 feet are seen and the exposure shows two igneous sheets, one of which is about thirty feet thick. The other is much thinner and in places exhibits some vesicles like those in a lava flow. One sandy ledge contains rounded limestone pebbles. The lower part of the cliff exposes considerable clay but the upper part consists mostly of sandy tuffaceous sediments with thin strata of clay.

South of Ward spring the beds dip toward the south at angles from 5° to 35° and in the ridge between this spring and Blue creek, in all some 1200 feet are in view, consisting of rapid alternations of the main type of rock with sandy and clayey layers. Some boulders and streaks of gravel occur in the upper part of this section. In the Blue creek valley the formation rises in the hills on both sides to several hundred feet, and they have been carved into beautiful pillars and towers which adorn especially the lower part of the slopes. Sandy layers are frequently in evidence and occasionally these contain pebbles. In the country which lies south of the mountains between this valley and Juniper creek the Chisos beds mostly constitute the bed rock, dipping usually at low angles. In the bed of the arroyo which runs to the east about two miles south of Lower Juniper Spring, sandy ledges are rather frequent. The more fine-grained ledges have here been altered by the ground water to such an extent that they are sometimes difficult to recognize. Calcareous material and quartz has been gathered into pockets and concretions which stud the surface of many of the ledges in odd forms. The upper part of Juniper valley is eroded from the strata of this formation, and they form the lower slopes of Crow mountain. At the base of the easternmost spur of this mountain a ledge of a coarse and well-worn conglomerate was interbedded between the white siliceous strata. Rummel peak and Nugent mountain consist of the same strata capped by igneous flows. An estimate of their thickness as shown in the east slope of Rummel peak makes them at least 2000 feet and possibly 2500 feet at this place. On the north side of the mountain they appear in the lower part of the slopes and cover the territory between Lone mountain and Panther spring on the east, and Moss well and Government spring to the west. In brief, we may hence say that the Chisos beds underlie the east half of the mountains, and extend in a narrow crescentic belt around them on their west side. They also appear in several places in the country southwest of the mountain, so far out as south of the Mule Ear peaks.

Limits and Thickness.

The dividing plane between the Tornillo clays and the Chisos beds it was not found practicable to accurately fix. Judging from appearances there is a gradual change in two hundred feet, from variously colored clays through yellow and gray clays and to white tuffaceous sands and stratified tuffs. This horizon of change may be seen two miles south of Oak spring and also near the east base of Nugent mountain. At both of these places some irregularities in dips were noted, but it could not be satisfactorily ascertained whether these were due to an unconformity or to some orogenic displacements. The evidence seemed to favor the latter view. The upper limit of the Chisos beds is still more uncertain. Near Oak spring and Ward spring the upper part of the formation has been removed by erosion. West of the Lower Juniper spring the Chisos beds are overlain by an igneous sheet, which lies in a horizontal position, while the strata below dip to the east. In Rummel peak the sediments seem to contain some lava flows farthest up in the section, but there was no opportunity to make this point certain. The general statement seems alone warranted at the present time that the Chisos beds consist of at least two thousand feet of strata consisting of highly tuffaceous sediments.

Topography.

The Chisos tuffs are more resistant to destructive agencies than the underlying Tornillo clays and they weather less promptly. Gullies and arroyos which drain their surface are yet far from having reached the limit of their transporting power, and the greater part of their energy is spent in the corrosion of their channels. And so these tuffs have a very broken topography, their surface rising and falling in ridges and slopes that often curve up into vertical cliffs on the outer sides of the Chisos mountains. The area of their outcrop is the most picturesque part of the entire landscape.

Life and Age.

No fossil remains of any kind were found in the various phases of the Chisos beds. But the considerable quantity of lime present in some of the strata and the rare occurrence of some dark carbonaceous clay seams indicates a probability of the existence of such remains in some ledges. Under the circumstances a determination of their age is not possible, and their reference to the Cretaceous is only provisional and tentative. But it is probably correct. There is no clear evidence of the existence of an unconformity with the clays below, but there appears to be a gradual transition or change from the lower to the higher beds. This change consists chiefly in a gradual increase of the volcanic debris upward.

The Crown Conglomerate.

In the base of Crown peak at the east end of Green gulch the uppermost sediments consist of three conglomerates, which are interbedded with strata resembling the typical Chisos beds. These conglomerates measure each some ten or twenty feet in thickness, and a great many of the pebbles and boulders are well rounded. Most of them consist of various kinds of lavas and trap rocks, but limestones are also well represented and some of these contain fossils of Lower Cretaceous age. The strata dip here about 45° to the north northeast.

Conglomerates of the same kind are frequently seen in large blocks which have come down on the slopes of the hills on the east side of Oak creek north of Oak spring. We also find them in Ash cañon to the west of the "Rim Rock." At these places the greater part of the pebbles and boulders in the conglomerate consist of limestone. All are thoroughly worn and rounded, even the boulders which measure eight or ten inches in diameter. Carboniferous fossils were noted in some of the boulders, but the Lower Cretaceous limestones are also represented.

Again, this conglomerate was seen at Burro spring on the west side of Burro mesa, where it dips to the east in the hill north of the spring and is it least forty feet thick. All the boulders are well worn and some measure a foot in diameter. Probably the greater number are limestone. Here, as at the other places, the limestone boulders have been silicified or sometimes otherwise altered to a depth of about one-fourth of an inch from their surface.

Boulders and pebbles of this kind are seen in several places along the road between Castillon peak and Reed's camp, and these must have come from exposures of similar gravels in the region between this road and the mountains.

From the fact that these gravels are interbedded with sediments quite identical in appearance with the Chisos beds, and since they overlie these and have the same dips, we must suppose that both are of the same age, and that the Crown gravels represent the latest episode in the Chisos period. The further fact that the Chisos beds have occasional layers of the same kinds of gravels, containing rounded pebbles of limestone and of igneous rocks, emphasizes this supposition. The gravels were probably made during the time of the last emergence of the land from the Cretaceous sea.

The Burro Gravels and Tuffs.

Some gravels, breccias, sandstones, and tuffs are of a later but unknown age. Such are the sediments which directly underlie the lava flows that cap the Burro mesa, and which were noted under a lava sheet about a mile and a half southeast of the mouth of Dawson creek. The east escarpment of Burro mesa exposes near Rock Hut several strata of this kind, which dip to the south at quite high angles. In the arroyos that drain the mesa west of this place, there are heavy beds of sandy tuffs associated with the lavas. In the hills southeast of the mouth of Dawson creek, at the locality already mentioned, a well-worn conglomerate is seen filling a small arroyo or stream bed, cut in tuffs and again covered with tuffs. Upward and outward on both sides of the buried dimunitive channel the conglomerate runs into the sand. In the base of the west side of Crown mountain the edges of the dripping strata of the

Crown conglomerate are buried under tuffs which underlie horizontally the igneous cap of the mountain. Other conglomerates and sandy tuffs of this class were noted in the hill which rises to the southwest from Ward spring and in Burro mesa along Smuggler's cañon.

All of these deposits are closely associated with lava flows and some are apparently interbedded with them. Their general field appearance is quite different from that of the Crown conglomerate and of the Chisos beds. They are less regularly bedded and they vary much more in composition and in texture. The tuffs are frequently yellow or even red and sometimes filled with concretionary structures entirely unlike anything seen in the lower beds, from which they are separated by an unconformity. If we regard the igneous rocks as of Tertiary age, it follows that the interbedded sediments should be of this age also.

The Dugout Clays and Gravels.

On the west side of Tornillo creek and northwest of Boquillas there is an oval area about twelve miles long and four miles wide with its longer axis extending from northwest to the southeast, where the sediments of the Cretaceous age are covered by from one to three hundred feet of clays, silts, sands, and gravels of a reddish color. The finer sediments constitute the greater bulk of the formation, as one sees it along the road to the Dugout wells from Boquillas. In Rice's cañon, a few miles to the north, there are mostly gravels. The formation rises in a flat ridge, which extends northwestward from the Dugout wells. Its finer sediments resemble the Equus beds of the Great Plains and also the Pleistocene river silts in the valley of the Rio Grande. No fossils were found, but as the formation rests on a topography which has been developed long after the cessation of volcanic activities in this region, it must be of quite recent age as compared with the igneous rocks of the Chisos mountains. But it is no doubt older than the alluvial deposits in the valley of the Rio Grande, for it lies at a higher level and has itself suffered extensive erosion. Possibly the Dugout clays and gravels are an old alluvial drift laid down by Tornillo creek.

Recent Alluvium and Land Drift.

The alluvial deposits consist of clay, sand, and gravel that cover the lower flats of the streams and at times rise into level branches on the sides of the valleys. It is nowhere very deep. Along the Rio Grande it is usually a loose sandy silt, but there are also finer clays of a darker and brownish color. These are deepest just above the cañons which the river is cutting through the mountain ridges it traverses, and at points where tributaries come in from either side. At the former places the alluvium is silty and has evidently been laid down during great floods, when the water has backed up against the narrow cañons and has stood as high as seventy feet above low water, or even higher. Near the junctions of tributaries with the main stream the alluvium is usually gravel, mostly brought down by the smaller stream. A considerable deposit of such gravel is seen along the lower course of Fresnal creek near Solis ranch. As a rule, the alluvial deposits are not very heavy, indicating a condition of comparatively active corrosion.

The land drift, which covers the greater part of the plains, is usually also thin. On Burro mesa it may reach a depth of two hundred feet in some places, but this is an old drift, which is now being removed by erosion and which must have been laid down by an earlier drainage quite different from the present. In the arroyos the land drift consists of gravel and sand, which is alternately laid up in banks and again torn down and rolled by the angry water which fills their channels after heavy showers. Away from these smaller streams it consists of silt and sand, fine enough to be carried along by the sheet flood, and with this is an admixture of pebbles, which are small enough to be slowly rolled by the same agent. The size of these pebbles seems to bear a pretty constant relation to the slope of the plain. On the average slope they seldom exceed an inch and a half in diameter. Sometimes there are no pebbles, and in such places the drift is apparently accumulating. Elsewhere they are so plentiful as to form a thin continuous pavement, and this usually occurs on slopes where erosion is quite active.

5. The Igneous Rocks.

No more than a mention of the most important occurrences of igneous rocks in this territory can be attempted in this paper. My field studies would not warrant anything further. Observations on the volcanics were made only so far as they had a bearing on the general geological structure. Notes on some thin sections have been furnished by Mr. B. F. Hill, who kindly examined these and made such determinations as were possible on short notice. It is believed, nevertheless, that the brief descriptions based on his notes and on such observations as were made in the field, may help to give a general idea of the nature of the volcanics in this region and may be of some service to future observers.

Igneous rocks are frequently exposed and appear as deep intrusives, as laccolites, as sills, as dikes, as plugs and as surface flows.

The Altuda Granite.

An intrusive granite boss lies uncovered over an area of somewhat more than a square mile, four miles north of Mt. Ord, southwest of Altuda. It is a moderately coarse-grained rock of reddish gray color, and it weathers into large blocks, sometimes twenty feet in length. It rises in a hill several hundred feet high. The Carboniferous sediments which surround this hill dip away from it and have evidently at one time formed a continuous cover over the whole area.

Laccoliths.

Some laccolites of the dome-shaped type occur in the region north and east of Terlingua. Maverick mountain is a conspicuous instance. It is a mass of intrusive rock rising 800 feet from the plain and covering an oval tract extending two miles east and west and about one mile north and south.

The Rosillos mountains must likewise be regarded as a laccolite broadly oval in form and with diameters measuring respectively about four and six miles. This rock consists of a feldspathic porphyry occasionally almost granitic in texture. The feldspar is largely orthoclase and is most copious in the ground mass, which also contains some magnetite. Augite and mica are present in visible crystals. The dull red tint which this mountain shows when seen from a distance is due to the presence of large spheroid kernels in the main rock, which are more resistant to weathering than the main mass and hence are left covering the surface of the hills. These kernels measure from a few inches to several feet in diameter and they weather to a dull red.

The mountains around Stillwell's ranch north of Banta shutup consist of another laccolitic intrusion less regular in form than that just described, but of a somewhat similar rock. In a specimen taken from near the ranch there was a decided porphyritic structure. The ground mass consisted of feldspar, quartz, pyroxene and magnetite. The phoenocrysts were mostly augite. Olivine was also noticed. In places this intrusion is cut by dike-like traversions of a lighter rock, apparently a quartz diorite. These dikes run in a northwest-southeast direction and are usually only two or three feet thick. In weathering, the main body of the rock in these hills has the same habit as that in the Rosillos mountains.

The northeast projection of the Chisos mountains contains a partly uncovered laccolite, which extends over several square miles in the vicinity of Panther springs. This consists of a porphyritic andesite in which the ground mass has been extensively silicified, and whose phoenocrysts appear to be chiefly plagioclase and augite. The rock is fissured by joints which run N. 35° E.-S. 35° W., and which in some places are only an inch apart, thus cutting the rock up into thin vertical slabs.

A rock of nearly the same character forms the laccolitic intrusives known as the Corazone peaks, but a specimen of the material in one of these peaks from near the Marlay wells was seen to contain some orthoclase crystals and some original quartz. One of these masses rises in a sharp peak, which is a thousand feet high.

The largest intrusive mass in this entire region is the so-called "rim-rock" of the Chisos mountains. This rises to a height of more than two thousand feet and covers eight or ten square miles of territory. A specimen from the main mass of this intrusive, taken above the falls in Oak cañon, may be called a quartz porphyry, in which the groundmass as well as the phoenocrysts consist of quartz and feldspar, with a preponderance of the former mineral in the groundmass. The groundmass was somewhat de-composed and there was evidence of silicification by infiltration. The joints in the rock are close together and they have nearly the same bearing here as at Panther spring, about N. 30° E.-S. 30° W.

Sills.

There may be some other igneous masses of a laccolitic nature, but those already mentioned are the most important. Igneous sills are even more common. These are thinner sheets that have been injected as molten material between the ledges of the bedded rocks and which run parallel with these ledges, sometimes for many miles.

There are several different types of rock among these sills. On the east side of Mariscal mountain at a point about two and one-half miles west and a half mile south of Solis' ranch, there are two sills in the Boquillas flags, each measuring about five feet in thickness. They are separated by about forty feet of the flags. The lower sill consists of a dioritic rock. The upper one is a greenish black obsidian which breaks into more or less rectangular blocks. It is plainly intrusive, but along the contacts of the sheet with the sediments there is hardly a suggestion of change in the latter by baking. The obsidian is almost a perfect glass except for a few spherulites, which may be seen in a thin section, and for some few crystals of orthoclase and augite, some of which are large enough to be visible to the unaided eye.

The greater number of sills consist of either of two types of rocks. They are andesitic or dioritic. A sill of andesitic rock is exposed in a line of hills extending to the southeast from the east side of Terlingua creek opposite Dryden's ranch. This sill is about seventy feet thick. It consists of greenish dark and heavy rock, of moderately fine texture, fissured vertically by joints which are only two or three inches apart, and weathering into a multitude of round boulders, from half an inch to three inches in diameter. In a thin section one finds that it is porpyhritic in structure, with a very fine groundmass. The latter consists of pyroxene [augite?], plagioclase, and much magnetite. The phoenocrysts are augite and plagioclase, with a few crystals of mica. Perhaps this rock may be regarded as intermediate between andesite and basalt. Other sheets like this, or extensions of the same sill, appears in several ridges to the west, to the south, and to the east of this place and also in the Rattlesnake mountains and on the east side of Willow creek. Another instance was noted in the Chisos Pen ridge and in the Dogis mountain. West of the Chisos mountains, sills of this rock have quite generally been injected among the strata of the Rattlesnake beds.

A much more extensive sill of dioritic rock follows the Boquillas flags on the east side of the mountains. This sheet is particularly conspicuous on the west side of the Boquillas ranges north of Stillwell's ranch and about three miles east of Mailbox tank. At a point about four miles east and one mile north of McKinney's spring this sill is some fifty feet thick. It is a dark, coarse-grained rock with nearly one-half of its bulk consisting of augite. The feldspar is prevailingly orthoclase. Magnetite is abundant, and the sand in the arroyos which cut the sheet is often black from the abundance of its magnetite grains. Pyrite is also present, especially in the lower two feet of the sheet, when freshly exposed. Olivine was noted, and in a thin section it was seen to be changing to serpentine. Apatite is present in a sheet of the same character and in the same beds high up in the Chisos mountains about a mile west of Emory peak. Along the west side of Mariscal mountain we have apparently the same sill, but here it is often considerably altered. The olivine is mostly changed to serpentine and the magnetite to hematite or limonite. A sheet which covers a hill lying about three miles northwest of Dugout Wells and northeast of Nugent mountain consists of a more acidic rock which lacks distinct groundmass and contains much magnetite. The feldspar is mostly orthoclase and there is some quartz. The sills in Lone mountain and in Grapevine hills are of the same nature.

Dikes.

Three specimens may be taken as types of the dike-forming rocks. One is from a dike about four miles east-southeast of Reed's camp on the Rio Grande, south of the Chisos. This is a porphyry of dark color. The phoenocrysts consist of a few but large feldspar crystals, mostly orthoclase, and a mineral resembling acamite. There are also crystals of augite. The groundmass is of ophitic texture, partly of the same minerals as the larger crystals, but containing also apatite and magnetite.

Another specimen is from the system of dikes which radiate toward the southeast from Christmas mountains. This may be called a basic andesite. It is a dark rock with a fine, almost felsitic groundmass, consisting mostly of plagioclase and magnetite. Its phoenocrysts are quite large and consist of plagioclase, augite, and magnetite.

The third specimen is from one of three dikes near Ward spring and may be called a quartz porphyry. There are several dikes of this kind in the foothills of the Chisos mountains. Three cut the Chisos beds to the southeast from Rock Hut and extend toward Ward spring. This specimen is a highly siliceous rock, quartz appearing in the groundmass as well as in the larger crystals. In another specimen from the same dike quartz and feldspar was seen to be present in about equal proportion. Several dikes of the same nature follow the same trend to the southeast of the mountains.

Plugs.

A sharp-pointed butte locally known as the "black peak," which rises from the plain about four miles northeast of Box spring, is clearly a remnant of a vertical plug-like intrusion. It may or may not have been connected with a volcanic vent. It is an almost perfectly black porphyry, which in many respects resembles the rock of the dioritic sill intruded among the Boquillas flags east of Tornillo creek. It consists almost entirely of plagioclase, magnetite, and augite, and these minerals make up the visible crystals as well as in the groundmass. Olivine is an accessory mineral.

Surface Flows.

In the upper part of the Chisos beds there are some igneous sheets which evidently are interbedded with the strata of the formation. They may have been flows on the shores of the waters in which these beds were deposited. These sheets lie parallel with the strata of the sediments and at the same time exhibit vesicular structure. The heavy sheet in the high bench east of Ash spring and north of Oak spring appears to be of this kind. A specimen of this rock was seen to have a porphyritic structure with some very large slat-like crystals of plagioclase in a fine grained and even felsitic groundmass. Magnetite is present in considerable quantity and there is a filling of a green structureless mineral not unlike chlorite, which lies in many interstices among the other minerals, especially in the basal part of the sheet. This rock forms a sheet more than a hundred feet in thickness, and it extends as a vertical cliff a distance of at least a half mile in the side of the mountain. Between Oak spring and Ward spring other thinner flows with vesicular structure lie in the white ledges of the tuffaceous sediments.

The lava sheet which forms the peak of Mount Emery is a quartz porphyry with a matrix which is occasionally almost glassy, exhibiting spherulites. The specimen examined had evidently been silicified through secondary changes. The flow which surmounts the high mesa to the southeast of this peak is of the same nature.

There are other flows of still greater extent in Burro mesa. In the north point of this mesa no less than five flows appear in the north escarpment, and these dip to the south. Tuffs are interbedded with these, some of which have a fine compact texture, while others grade through volcanic sands into breccias. At a point about a mile southwest of Rock Hut one lava sheet appears, which is only a few feet thick. Its upper surface is checked by cracks, an inch wide and from six to seven inches apart, and these are filled with volcanic sand. In Smuggler's cañon on the west side of this mesa, the sheet which is exposed in the brink of the falls is a hard felsite, and this rests on a soft and yellow volcanic sand. A half mile east of this place some lavas contain occasional small streaks of black obsidian with inclosed large crystals of feldspar.

Various other surface flows are to be seen southwest of the Chisos mountains. One was observed dipping at a high angle with the sediments in the north part of Green gulch.

D. GEOLOGICAL STRUCTURE.

The country traversed lies between the Southern Pacific Railroad and the Rio Grande river in the longitude of the Chisos mountains. Only a few days were spent in that part of this tract which lies north of 29° 30′ north latitude. But here I found structural features of such unusual interest that I can not pass them by without mention. These have been in part described by R. T. Hill before this. The area as a whole is traversed diagonally from north northwest to south southeast by the southernmost extension in the United States of the great Rocky mountain fold. This mighty system of mountains is here represented by a narrow and sharp and for the most part single fold, less than two miles wide. It is known at the north as Altuda mountain, at the south as the Carmen range, and between these two as the Ord and the Santiago ranges. East of the line of these ranges the great plains have their beginning, though they here more resemble a plateau. On the west side we meet with the typical structure of the Basin region, and this is continued westward beyond the limits of the State. North of Altuda the structures representing the Rocky mountains flare out and apparently soon have a width of many times three miles. With the beginning of the Carmen range on the south there is again an abrupt increase in the width of the continental "backbone" and this increase is continued into Mexico.

The question at once suggests itself: what caused this principal crest of the great mountain range to contract to such insignificant dimensions between Altuda and the Carmen range? I believe that the right answer to this question is to be found in the fact that the Rocky mountain axis here crosses, almost at right angles, another and much more ancient mountain system represented by the Caballos ridges.

E. THE CABALLOS RIDGES.

The town of Marathon lies near the center of a triangular plain, which extends for about fifty miles to the northeast from the Ord range. Against this range the plain abruptly terminates on the west. On this plain the Cretaceous sediments have been entirely removed and the ancient floor, on which these were laid down and which they once covered, is now bared. This floor consists of sharply folded and highly tilted strata of Palaeozoic sediments. All around the plain the slightly raised edges of later sediments form a well-marked escarpment. The folds of the older strata trend in a northwest-southeast direction and extend the whole length of the plain. They exhibit such regularity and persistency of direction that they have all the appearance of being a small part of an extensive system. Their axes point on the one hand straight to the Solitario uplift, which is forty miles distant to the southwest, and which exposes similar sediments, underlying Cretaceous strata, folded in nearly the same trend. In the opposite direction the folds point toward the Ouachita system of mountains in Oklahoma. Prof. R. T. Hill, who has described these ridges,* believes that this folding was produced contemporaneously with the great Appalachian movements in the eastern part of the continent. His observations are given in the following words: "These (the Caballos ridges) are low ridges of Palaeozoic rocks rising from the floor of the Marathon plain south of the Comanche mountains. They are composed of the degraded vertical edges of Palaeozoic limestones, shales, and cherts occurring in closely folded, buckled ridges, trending northeast and southwest. The cherts are often white in color and over 100 feet thick, and form the backbone of long, low ridges, such as the Peña Colorado, occupying the low area between the Santiago Sierra on the west, the Glass mountains on the north, the Maravillas Plateau on the south, and the Stockton Plateau on the east. Caballos Sandia, a beautiful hill of white chert about 15 miles south of Marathon is the highest of these summits, and rises about 1000 feet above the plain to an altitude of about 5000 feet.

"The Caballos and Glass mountain are exposures of ancient post-Palaeozoic structures of Appalachian type and age, which have been revealed by the erosion of the Cretaceous sediments that probably once embedded them."

The same author says of the Ouachita mountains** that these "are in general old and represent the remnants of once more lofty and extensive ranges, which have undergone degradation since early Mesozoic time." While there is probably no continuity between the Caballos folds and the Ouachita system there seems to be good ground for the belief that they were made at the same time. The Caballos ridges were made and cut down by erosion during the time which elapsed between some period (probably the late Carboniferous) of the later half of the Palaeozoic era and the beginning of

*R. T. Hill, Physical Geography of the Texas Region, U. S. Geol. Surv. Topographic Atlas of the U. S., Folio 3, p. 4.
**Reference as above.

the Cretaceous age. They no doubt furnished a part of the material in the making of the Triassic and Jurassic deposits elsewhere.

It was after the Caballos ridges had been cut down to almost a peneplain and after this peneplain had been buried under all but the latest Cretaceous sediments, that the movements began which resulted in the making of the Rocky mountains. Folds and faults were made, which crossed diagonally the axis of these earlier flexures. Now it seems clear that where a fold is developing along an axis which crosses a belt that has been previously compressed and folded in a direction more or less vertical to the axis of the later disturbance, the belt so affected will less readily yield to the forces at work than the country on either side. For on either side of such a system of folds the strata lie more nearly horizontal, while they stand edgewise in the folds. One can easily bend a block of paper in a direction which is vertical to the plane of the sheets, but not in a direction which is parallel with this. Rather than to bend in this direction the sheets will break. Between Altuda and the Carmen range the rigidity of the folded Palaeozoic strata caused them to break in a single sharp dislocation forming the Santiago and the Ord ranges, rather than bend into several folds or fissures by several smaller faults as seems to have happened on either side of this belt of the ancient mountain structure.

F. OVERLAP OF THE CRETACEOUS.

Another structural feature due to pre-Cretaceous mountain making in this region is the evidence of an overlap in the basal strata of the Cretaceous formation. The nature and extent of the overlap is not known, but there is no doubt that it exists. The base of the Lower Cretaceous at Altuda does not include a conglomerate which is a pronounced feature of Persimmon gap and at the Cienega mountain. The same conglomerate is also absent in the Solitario, which, as already stated, lies on the axis of the Caballos uplift but it reappears at Shafter, which is to the west of this. It is evident that the old mountain axis still stood somewhat higher than the country on either side of it, when the Cretaceous sea was advancing, and in this way its lowermost sediments are present on the flanks of the uplift but not on its highest elevations.

G. THE ROCKY MOUNTAIN UPLIFT.

As already stated, the structure which represents the Rocky mountain uplift in this region consists of the Ord, the Santiago and the Carmen ranges. In general the line marked by these ranges is a line or belt of displacement, to the west of which the ground has sunk, and to the east of which it has been elevated. Farthest north the displacement is most gentle. West of Altuda the limestones of the Carboniferous age and the Lower Cretaceous limestones dip to the west at angles of most frequently about 15°, until in about three miles they disappear under the eruptives. Farther south the dip west of the face of the Ord range becomes more steep and probably changs to a fault. At Persimmon gap in the Santiago range the main Lower Cretaceous limestone is thrown into an abrupt fold with a nearly vertical dip on the west side and a fault on the east side with the downthrow to the east. Evidently the range was here originally a sharp anticline, which fractured on the east side. On the whole, the range here involves a displacement, along which the terranes lying on the west side have been let down at least 2500 feet more than the terranes on the east, while the narrow block which forms the ridge has been elevated some 1500 feet more than the latter. At Dog cañon, which cuts across the range at a point about five miles farther south, the range is clearly a compressed fold, in which the ledges of the Lower Cretaceous limestones now stand in a vertical position. The arch of the fold has been fractured and removed by erosion and its base exhibits even a fan structure due to lateral compression. Eight miles south of this point the Carmen range begins. This is clearly a continuation of the dislocation we find in the ranges to the north, but the lateral thrust has here given rise to a number of folds of more gentle build. The downthrow to the west is quite as great but less abrupt, and the faulting is more frequent, but nowhere is violent. This condition gives a hint as to the location of the present course of the Rio Grande. A stream which backs across the lowest sag of a developing moutain crest will naturally outstrip other streams in capturing tributaries. It has less cutting to do at the start, and after a larger drainage area has once been acquired, the greater volume of water is likely to insure the retention of the advantage gained, even if conditions at first existing should be reversed, as they are in this case. At present the Carmen range is higher than the south part of the Santiago range, and it is several times as wide, but it must have been the lowest part of the Rocky mountain fold in this region at the beginning.

H. THE GREAT TERLINGUA FAULT.

At the mouth of Terlingua creek the Rio Grande crosses a great fault, which runs a course about N. 36° W. for some ten miles north of the river and at least as far to the south of the river. At this point the total displacement is about three thousand feet. This decreases as we follow the fault northward and it increases for some distance when followed into Mexico. The fault is marked by a high escarpment, facing the east. This is caused by a rise of the Lower Cretaceous limestone above the present plain of erosion of the more readily yielding clays and marls of the Upper Cretaceous sediments. This fault clearly illustrates a feature recently described by Keyes.* The friction against the rising block has been sufficient to abruptly bend upward the edge of the more flexible strata on the side of the downthrow. On the face of the great escarpment south of the mouth of the Grand cañon a thin block of the limestone measuring several hundred feet in length, is rotated in the plane of the fault in such a manner as to suggest that one end of the block has been held down by the sunken block while the other has been more free to follow with the great wall from which it has been disengaged by a fracture.

I. THE SUNKEN BLOCK.

If we limit the Chisos country to the region lying between the ranges representing the Rocky mountains on the east and the great fault at the mouth of Terlingua creek on the west and regard it as extending from the Rio Grande river on the south to the Corazones and the Rosillos mountains on the north, we may say that it covers a part of a sunken block, which measures about thirty-nine miles from east to west and which has settled from four to six thousand feet below the level of the terranes on either side.

*Journal of Geology, Vol. XIII, No. 1, p. 68.

While this block clearly maintains the nature of a structural unit, it has itself suffered extensive and in places violent deformation by faulting and folding. These deformations are so numerous that a detailed account of them is out of the question at this time, though there is no doubt that it would throw important light on the nature and the distribution in time of the orogenic forces which have been at work in this region. But it has been necessary to limit attention to a few of the more salient features.

1. Faults.

To the northeast of the Rattlesnake mountains several nearly vertical faults cut the almost horizontal strata into narrow blocks. Two of these are on either side of an elevated block which appears in the north bank of Terlingua creek about a mile south of the mouth of Dawson creek. The downthrow on either side is at least two hundred feet. The creek turns and follows the east side of this block for nearly a half mile above this point. Both faults are vertical and both show the edges of the strata on either side turned up against the fault plane as by friction against the raised walls. Their course is about N. 22° W. and the distance between them is about 900 feet. Within a mile, as we go east, are two more faults, parallel with these. These have the downthrow to the east and in the case of the farther one this amounts to several hundred feet. They bear about N. 14° W., and apparently continue for several miles. These four faults are clearly genetically related, lying in one parallel system, and this system continues for at least a few miles south and two or three miles north.

The east side of Burro mesa is another fault-line, which extends from Rock Hut to south of Blue creek in a direction about N. 5° W., with the downthrow to the west. This mesa is a block which has settled deeper than any other part of the great sunken Chisos country, and as a consequence the lower members of the great lava complex which once covered the entire country has so far escaped destruction by erosion. It has let these down some two thousand feet below their former level on either side, and southwest of Ward spring they are seen to lie against the Chisos beds. The west side of the mesa is a monocline where the Chisos beds rapidly rise from under, as we proceed in that direction. Between the north end of this mesa and the south end of the Christmas mountain is a belt where disturbances are frequent. At a point about three and a half miles south and one mile east of Christmas spring, an arroyo locally known as Cottonwood creek crosses a fault which runs a course nearly due north and south and which has a downthrow to the west of not far from two thousand feet. It brings the Tornillo clays down to the level of the base of the Terlingua beds, and it can be traced for nearly two miles, but it seems to turn to the west farther north and to become continuous with a great fault which follows the west side of the Christmas mountains.

To the southeast of the Chisos mountains and crossing the Rio Grande there are several faults which bear nearly due north and south. Thus between Mariscal and San Vincente mountains there is a block about one and one-fourth mile wide, which has been dropped down from one to two thousand feet. It is marked off on the west by a vertical faulted wall forming the east side of Mariscal mountain and on the east by a fault which crosses the river directly east of the Solis ranch. Another fault crosses the river to the east of the village of San Vincente and from there it runs almost due north, passing on the west side of the U. S. benchmark, having an elevation of 1881 feet. Three miles farther north it passes just to the east of the benchmark with the elevation of 1925 feet. The downthrown in this case is on the west side, and it measures somewhere from 500 to 1000 feet, decreasing to the north.

North and northeast of the Chisos is a group of faults which have the same general trend as those on lower Terlingua creek. One of these is the Muskhog spring fault. It runs S. 23° E. and points straight in a continuous line with the west line of the first fold of the Carmen range. At Muskhog spring the Rattlesnake beds have been lowered by this fault to the level of the upper ledges of the Boquillas flags, against which they now abut. The downthrow is to the west. This fault is one of the best developed deformations of its kind in the country, and it was traced for several miles. Two small abrupt folds with the same trend follow it in the vicinity of the spring, at a distance of some two hundred yards to the east. These folds are next to another smaller fault which brings up the lower ledges of the Boquillas flags. Several faults with this trend cut the ground in the mountains around the Stillwell ranch and the Rosillos mountains are rent by at least three: one to the east and one to the west of Stroud's ranch and one in the arroyo of Cottonwood spring. The latter, which is rather a fissure, extends southeast across Tornillo creek and through the Grapevine hills, where it clearly is compound and has let down a small block, cutting the sill which caps these hills.

It will be noted that the trend of the axes of the displacements so far described is more or less parallel with the sides of the sunken Chisos block. Some faults have been noted which run a course that is vertical to this direction. At a point about one-half mile north of Muskhog spring, three faults, which are not two hundred feet apart, bear W. 10° S.-E. 10° N. A thin block is raised some three hundred feet between two of these faults, and the third one [the one farthest south] has the downthrow on the north side. To the southwest of McKinney's spring a fault cuts across the igneous sill at its north end. An unusual form of faults was seen on the north side of Cuesta Blanca. Here the Rattlesnake beds have been let down to the level of the Boquillas flags along a line which is concave to the north but otherwise has a general direction from east to west. On the south side of the Rosillos mountains an east-west fault runs about a mile south of Stroud's ranch. But the most singular of all faulting in this entire region was noted in Grace cañon about half a mile northeast from the McKinney and Parker mine. A block, about 300 feet square, has been let down some 500 feet, so that the Rattlesnake beds, which compose it, lie against the lower part of the Terlingua beds. The fault marking the outside of the block is distinct enough to be traced with the point of a knife.

In general, it is true that the faults whose trend is vertical to the direction of the axes of the principal dislocations have an irregular development. This may be taken as an indication that the making of some of these was incidentally the result of the forces which produced the faults trending N. N. W.-S. S. E.

2. Folds.

But a very small part of the sunken Chisos block, if any, has not been affected by folding. The sediments only exceptionally lie horizontal. Even when apparently undisturbed, they are usually found to be tilted a few degrees in some direction. The most frequent dips are from 10° to 30°. A detailed representation of these deformations would show a number of synclines, anticlines, and monoclines of varied length, mostly trending in a northwest-southeast direction.

Among the disturbances whose trend is parallel with the great structures of this region we find an anticline west of the Rattlesnake mountains. It is fully three miles wide. The west side of Burro mesa exposes a belt of Upper Cretaceous sediments which dip a little north of east. Along a line that points about 10° east of south from Indianola peak runs the axis of another anticlinal fold. Several folds of unknown extent are in the country between the Chisos mountains and Boquillas postoffice, and all appear to have a northwest-southeast trend. An extensive syncline with the same trend has its axis about midway between McKinney's spring and Neville spring. Banta Shutup is on the southwest periphery of the south half of a quaquaversal, and this may be the south end of an anticline extending northward. For three miles to the southeast of Maverick mountain the dip is quite uniformly to the south and southeast. The fault on the east side of Burro mesa marks an axis from which the strata dip away on either side. This anticlinal feature of the fault appears at a point west-southwest from Ward spring in the north side of a high butte. A similar anticlinal arrangement is seen in Cottonwood creek, a mile west of Chisos Pen. The block on the west side dips west at a low angle, and the block on the east is tilted away from the fault first gently and farther out more rapidly.

Many folds trend in various other directions. Hayes ridge, which forms the easternmost spur of the Chisos mountains, is an anticline trending nearly east and west. North and northeast of Moss wells the Chisos beds dips to the north, and south of Paint Gap hill the Rattlesnake beds often pitch to the south. Changes in direction and amount of pitch are frequent and often rapid. The entire sunken block is broken, folded, and twisted in an almost bewildering complexity and the manifold attitudes of the sedimentary strata defy brief detailed description.

If we divide the great sunken block into two halves by a straight line extended midway between the Rocky mountain fold and the face of the great Terlingua escarpment, and nearly parallel with the latter, we will find that this line connects the three greatest deformations affecting the block. These are the Christmas moun tains at the north, the Chisos mountain uplift in the middle and the Mariscal mountain farthest south.

3. Christmas Mountain Fold.

As seen from the south end, this mountain is an elliptic dome-shaped uplift a little more than three miles long and not quite two miles wide, with the longer axis extending N. 36° W.-S. 36° E. The Lower Cretaceous limestones are raised 2200 feet above the surrounding plain and are lifted 3500 feet above their position under the Upper Cretaceous sediments on the surrounding plains. The dome is fractured on the west side by several faults and has here an abrupt slope, which in places is a vertical scarp. On all sides it has suffered considerably by erosion, but the form of the dome is still quite apparent. In all probability the uplift is due to an intrusive mass which is nowhere exposed but lies concealed under the folded limestone strata that yet forms the roof of the dome. At the south end the principal fault, which is marked by a vertical cliff, is associated with an extensive fissuring of the limestone, and the fissures are filled with large quantities of calcite. These fissures have the same trend as the fault.

4. The Mariscal Mountain Fold.

From the top of Mount Emery two long mountain ridges may be seen to the southeast, extending north across the Rio Grande from Mexico. One of these, lying farthest east, is called the San Vincente mountain. It stops nearly short of the international boundary and the river has just begun to cut into its north foothills. The other is known as the Mariscal mountain and this pushes its north end across the Rio Grande nine miles into Texas. The river has cut a cañon diagonally across this ridge and this cañon is 1400 feet deep at the crest of the ridge. The ridge is an unsymmetrical fold, whose west limb has in places been tilted into a vertical position and whose east limb is much less inclined but is abruptly faulted, at its east end, farthest to the south. Several minor faults cut the limbs of the fold. The ridge comes to a cuspidate point at its north end. At its widest place the ridge measures about three and a half miles across. It consists entirely of the Lower Cretaceous limestones, but the Upper Cretaceous beds have also been involved in the uplift, as their dips adjust themselves to that of the fold over a belt from one to three miles wide on all sides.

5. The Chisos Mountains Fold.

The most violent of the deformations of the great sunken block is an abrupt fold caused by the intrusions of the "rim-rock" of the Chisos, and this may be regarded either as an enormous plug or as an unusually high laccolite. The evidence is inconclusive in regard to which it most resembles. On the west side the Chisos beds lie nearly horizontal. As we follow them up to the great igneous mass, we find them thrown into small but abrupt folds close to the vertical wall of the mountain. On the south side the same relation is maintained: the sediments run up abruptly against the igneous mass. But on the east and on the north sides it is different. Here the sediments have been elevated and they rise from the east in the form of a half arch, which bends over the top of the "rim-rock," and from the north they rise along a sharp contact, which stands at an angle of 75° from the horizontal. This attitude of the sedimentary rocks on the east and north sides is decidedly like their habit around laccolitic intrusions, but their position to the south and west, where there is no regular tilting, is much more like the behavior of stratified terranes around plugs or near dike-like intrusions. The fact that this igneous mass has been seen to take on a brecciated structure in one or two places [as at a point about one mile west of Laguna] favors the hypothesis of a volcanic vent. Such a theory would also explain the present physiographic feature of the mountains, for a volcanic cone would naturally effectively retard the erosion of the country it covered and cause this to stand higher than the surrounding country for a long time after the cone itself were carried away by erosion. But even on this theory the south "rim-rock" may be regarded as to some extent laccolitic in its nature. For it is very well known that molten magmas may stop short of reaching the top of their vent and may find their way out far down under the surface and form intrusive masses more or less distant from the source of the supply. If a vent should form over a sharp fold the underground stresses might very well be such as to favor the accumulation of an intrusion near the vent itself and close to the fold, or even within it. The fissure through which the molten material escaped may have been under the west side of the "rimrock." At the south it was then forced in under the Middle Cretaceous sediments and these were elevated, but at the north the intrusion which forms the north "rim-rock" apparently found an outlet at a higher level and perhaps on the concave north and upper side of the flexure produced by the uplift to the south. This intrusion, or other intrusive flows from the same source, appear to have been forced far out under the latest Cretaceous sediments to the north and east. Everything considered, this seems to the present writer the most probable structure of the Chisos mountains. The whole round cluster of peaks, including an area ten miles in diameter, is a remnant pedestal under a volcanic pile, protected from erosive destruction by the endurance of the ancient cone, which once covered it and is now all but wholly removed. The two "rim-rocks" and other scattered laccolitic masses are the roots of the cone itself, or, to carry the comparison farther, they are tuberous swellings on these roots, now more or less uncovered by erosion. What we find in the Chisos mountains today is then the structure developed at a depth of several thousand feet under the surface of ancient lavas. These lavas were at least in part forced up through fissures in the strata which are now exposed.

J. SUMMARY OF GEOLOGICAL HISTORY.

The earliest record known is that of an open sea, during the Trenton age, on the bottom of which sea calcareous sediments and fine mud were deposited. Marine conditions continued, whether with or without interruptions is not known, until near the end of the Carboniferous age or possibly somewhat later. Then a disturbance occurred which resulted in the making of a folded mountain range, whose axis extended in a northeast-southwest direction an unknown distance beyond the limits of the ridged plains now surrounding Marathon. During the time which elapsed after the making of these moutains and until the beginning of the Cretaceous age—essentially during the Triassic and the Jurassic ages —this mountain range was reduced almost to a peneplain, so that when the Cretaceous sea advanced the old folds did not rise much above the rest of the land, probably not more than a few hundred feet. The Cretaceous sea endured for a long time. At first on open and wide ocean held its sway and on its bottom heavy deposits of calcareous mud and ooze settled. In time the waters became less deep and the sediments gave indications of a slowly approaching shore line, as they changed to marls and clays. Distant volcanoes on the yet distant land occasionally mingled their ashes with the clays of the sea. Later on the shore line came near. Clay and sand and sometimes even gravels and vegetal accumulations were laid down. An equilibrium was maintained for some time between the forces tending to elevate and those tending to sink the land. The latter prevailed so far as to make possible a practically continuous addition of littoral deposits, throughout the Rattlesnake and the Tornillo periods. These beds do sometimes exhibit minor unconformities without tilting, due perhaps to the making and unmaking of low bars and islands. They can hardly have any other significance. Volcanic eruptions became more frequent and also less distant in place, as shown by the greater frequency and thickness of occasional ash beds. At last these materials became copious and largely exceeded the other ingredients of the deposits of the sea. Land was evidently near, if not right here. But the bottom of the sea continued to sink under the weight of the Chisos tuffs. Meanwhile many new volcanic vents were opened and they sometimes emptied their contents under the waters of the sea as well as on the near lands. New mountain folds were already forming, involving the earlier limestone formations of the age, for worn pebbles of these are found in the Chisos beds. The making of the Rocky mountains had now begun.

At the end of the Cretaceous age, or perhaps during the early part of the Tertiary age, the sea receded and an extensive land rose to take its place. There were volcanoes and mountain folds. Molten magmas were injected among the sediments and poured out over their surface. Blocks of sediments whose dimensions are measured in miles, adjusted themselves to orogenic forces into most varied positions, and were folded and fractured promiscuously.

This mountain-making period continued through the greater part of the Tertiary age. With the gradual cessation of volcanic disturbances, destructive forces attained to the ascendency and these have since reduced the formerly much higher mountains and plateaus to their present condition.

K. MINERAL RESOURCES.

So far, cinnabar is the only material in this region which has proved to be of economic importance. The mining of quicksilver is now an established industry in Brewster county. But silver and coal have also been found. Attempts at the mining of silver have not been entirely discouraging and the mining of coal on a small scale, to supply the local demand for fuel, may prove profitable.

1. Quicksilver.

It is proposed to here briefly state such general conclusions regarding the occurrence of the quicksilver ore as now seem to be clear.

The Big Bend mine explorations now (1904) show that the ore occurs in a dike of andesitic rock as well as in the fissures in the Cretaceous shales and limestones surrounding the intrusive. The dike is, in common with other such structures when injected into soft sediments, irregularly developed, running out in a short distance when followed to the west and changing into a sill above. It is a filling in an irregularly developed fault and the ore is in a place where the ground water or the mineralizing solution following the dike upward would be impeded, consequent upon a change of route.

It will be remembered from earlier reports of this survey that in the Marfa and Mariposa mine and in the old Terlingua mine much of the ore has come from brecciated fissures in the upper surface of the Edwards limestone. This was originally directly covered by the next to impervious Del Rio clay, which at the present time is mostly removed. Evidently in this case, also, the ore was precipitated from rising solutions at a level where these were hemmed in by the impervious cover of the clay. As cinnabar has been found in this mine also in a porphyry, the ore is in that respect in a situation quite similar to that at Big Bend. If the mineralized solution followed the course of a body of an intrusive in the limestone it would be likely to have a comparatively open and unimpeded passage along this intrusive, as long as this traversed the limestone. For in limestones dikes are quite uniform in their development. But reaching the overlying clay the solution would find the dike less regular and the clay also would hinder its ascension. The solution would naturally follow the upper surface of the limestone and precipitates would find lodgment in its fissures under the clay.

This theory finds verification in alomst every instance of known occurrence of ore in this territory. In the region of the Colquitt-Tigne mine, where the ore occurs in fissures in the Boquillas flags, it has been observed that the veins are occasionally enriched immediately under the more argillaceous strata which these flags contain. In Christmas mountain, where cinnabar was discovered last summer, it is likewise associated with a dike of andesite and is in a fissure in the uppermost ledges of the Lower Cretaceous limestone near the summit in the dome. There can be no doubt that this limestone was covered by the more impervious sediments of the Middle Cretaceous at the time the ore was deposited. Thus the conditions here would be like those at the Marfa and the Mariposa mine and the old Terlingua mine. The rising solutions deposited ore on encountering a more impervious overlying formation. Again in Mariscal mountain, at Lindsey's claim, we find the ore at the same horizon, and likewise on the crest of a fold. At this place, as on Christmas mountain, the Del Rio clay is absent, but the base of the Boquillas flags is still left and ore occurs in seams between some of the ledges of this formation. In one of the openings made a small offshoot of an andesitic dike was followed by a thin stringer of cinnabar on its upper surface. These occurrences show that the fracture produced by the offshoot has served as a conduit of the mineralized solution and that precipitation has occurred at a place where it met with resistance in its slow upward percolation along the small "stringers" of the dike and in the less pervious sediments by which the stringers of the dike are surrounded. In one of the openings in the Boquillas flags on the north end of the mountain there were three seams of cinnabar about one-fourth inch thick and twenty inches apart, following joints which cut the sediments running transversely to the axis of the mountain.

Another circumstance points to the correctness of the same view. This is the fact that the principal ore deposits have been discovered on crests of anticlines or else on lines of changing dips, where the flexures are convex upward. The deposits on Christmas mountain and on the north end of Mariscal mountain are examples of the former instance, and the ore at the Marfa and Mariposa mine, that in the Chisos mine, and that on the east side of Mariscal mountain, illustrate the latter mode of occurrence. This last mentioned occurrence is at a point about three miles west and one mile south of Solis' ranch. The cinnabar is here, as elsewhere, frequently in and near a dike. The dike in this instance cuts the lower edges of the Boquillas flags.

According to this view of the origin of the ore, we shoud expect the principal deposits to lie in places toward which ascending currents have converged, as on the "hips" and crests of anticlines. The presence of cinnabar in the intrusives is due to impregnation, which has introduced the cinnabar as a secondary mineral. We have seen that profound changes have been effected in this manner in other volcanics of this region. There is all the more reason to regard the quicksilver ore as a secondary deposit, for we always find the rock altered in a peculiar way in the vicinity of the ore deposits. The exact nature of this alteration is not known, but it causes the dikes to weather with a characteristic bleached yellowish color, different from that which characterizes the same weathered rock in its usual condition. This bleached appearance of the igneous rock happens to be especially well shown near the two mineral localities on the east side of Mariscal mountain. It is noticeable in some places where cinnabar is not known to exist. One instance of this sort was seen at a point about three miles west and one mile north of Mailbox tank, at the east foot of the Rosillos mountains. An intrusive here weathers to a resemblance of the dike associated with the cinnabar in the Christmas mountains. But an analysis of the rock failed to show the presence of any trace of the mineral. This analysis is as below:

*Analysis of an altered igneous rock from the east side of the Rosillos Mountains.**

Silica	62.00 per cent.
Alumina	15.49 per cent.
Ferric oxide	6.00 per cent.
Ferrous oxide	1.08 per cent.
Magnesia	0.10 per cent.
Lime	1.78 per cent.
Soda	5.10 per cent.
Potash	3.68 per cent.
Water above 105-110 C	2.95 per cent.
Water below 105-110 C	0.80 per cent.
Carbonic acid	0.88 per cent.
Titanium dioxide	0.86 per cent.
Phosphorus pentoxide	trace.
Manganous oxide	trace.

In some parts of the world quicksilver deposits are found in close association with hot springs.** While the Brewster county ore can not be said to now have very close associations of this kind, it is interesting to note the presence of several hot springs on the Rio Grande river in the Carmen range, only ten miles distant from a known occurrence of cinnabar. Three of these springs emerge from near the zone separating the Boquillas flags from the heavy bedded limestones of the Lower Cretaceous, and thus demonstrate the fact that the more clayey overlying flags may cause the ground water to follow their under-surface in seeking a higher outlet. Some of the fissures which these springs have followed are now filled with materials that must have been deposited from their solutions, and they resemble in every respect the gangue of some of the cinnabar leads in the limestone at Terlingua, except that the ore is absent as is also often the case at Terlingua. It consists of crystalline calcite and of amorphous carbonate of lime, in which fragments of the country rock are imbedded. In its chemical composition it resembles the tufa which is now forming around the hot springs.

*O. H. Palm, analyst.

**Becker, Quicksilver Deposits of the Pacific Slope, U. S. Geol. Surv., Monograph XIII, p. 52.

Analysis of Precipitations from hot springs in the Carmen range on Rio Grande river.

	Deposit in a fissure of an old spring near mouth of Tornillo creek.	Tufa from a hot spring near the mouth of Tornillo creek.
Silica	19.26 per cent.	19.00 per cent.
Alumina	1.00 per scnt.	4.02 per cent.
Ferric oxide	1.30 per cent.	1.60 per cent.
Lime	42.95 per cent.	40.60 per cent.
Magnesia	0.60 per cent.	1.10 per cent.
Sulphur trioxide	0.10 per cent.	trace.
Carbonic acid	32.80 per cent.	30.16 per cent.
Water [hygroscopic]	0.20 per cent.	0.80 per cent.
Water [in combination]	1.35 per cent.	2.00 per cent.
	99.56 per cent.	99.28 per cent.

The knowledge we now possess of the cinnabar deposits in Brewster county seem indeed to bear out the conclusions reached by Geo. F. Becker in the study of similar deposits elsewhere, who ascribes them to mineralized and probably hot rising solutions. He says:*

"The mineral associations in which cinnabar is found" (in different parts of the world) "seem to show conclusively that it has been deposited from solutions. A very large part of the known deposits of cinnabar are extremely similar in character, a fact which seems indicative of a similar origin. It is certain that some of the deposits are due to precipitation from hot volcanic springs, and it may fairly be inferred that many of them were found in this manner. The diversity of the country rocks in which the deposits occur is evidence that only a part of them can have derived their metallic contents from their own wall rocks; the remainder must owe their cinnabar to some source between the point at which the waters acquired their heat and the surface. Between the depth at which volcanic foci lie and the surface of the earth there must be substances of world-wide distribution which frequently contain mercury in some form as an original ingredient. These substances

*Reference as above, p. 55.

are probably massive rocks, and the only known rock of correspondingly wide distribution is granite."

On this theory the significance of the association of the quicksilver with volcanic rocks in this region is also quite clear. The sills and especially the dikes traverse the sediments to great depths and are frequently so placed that they must have furnished in the past, as they do at the present, the most direct passage ways for underground waters which traverse the formations from below upward. Intrusive sheets and dikes cause several springs and seeps in the country today. Indeed, it was on the basis of the association of the igneous rocks with the Lower Cretaceous limestones that the director of the survey, Dr. Wm. B. Phillips, was able to predict the discovery of cinnabar east of the Chisos three years ago.

2. Coal.

The existence of coal in the Chisos country has been known for some time, but its field relations, its quality and general development have been matters of uncertainty.

From the stratigraphic data already set forth, it will be remembered that the Rattlesnake beds contain the coal.

The several places at which coal has been observed extend from the Rosillos mountains to the mouth of the Terlingua and from the west side of the Carmen range to near the Cigar mountain. Below some of the localities are enumerated:

1. In the north side of a hill on the south side of the road leading southwest from Stroud's ranch and about two miles from this ranch, the face of this coal has been laid bare by three short drifts, but it is at present concealed. The seam is reported to have measured eighteen inches. Over the coal are some sandy and bituminous dark silts, and under it are first some three feet of clay and then a black carbonaceous sandstone. Some silicified trunks of trees were noted close by the explorations. The strata dip about ten feet to the south. The intrusives of the Rosillos mountains are not far distant and have evidently baked the coal to some extent. Some of the coal taken out from the pits was left on the ground, and this exhibited a cubic fracture, an unusually bright luster and a very compact texture. A few pieces were picked up which had these characteristics in a superlative degree,

and in which no flaws could be seen, although they had been exposed to the weather clearly for a long time. These have the appearance of jet, and have great crushing strength. Some show very faint but unmistakable evidence of woody structure on a cylindrical outer surface. A small block, which was shown to the writer by Mr. Carruthers, of Alpine, probably came from this place. It measured nearly four inches in diameter. It was clearly a coal formed from some species of wood. A well known gem expert, who examined some of this material for the writer, says that, if found in blocks of sufficient size, this mineral may be valuable as a substitute for jet. It resembles jet in its luster, but it has the composition of anthracite, as is shown by the following analyses:

*Analyses of coal from two miles southwest of Stroud's ranch.**

	Anthracite from two miles southwest of Stroud's ranch.	Anthracite with jet luster from two miles southwest of Stroud's ranch.
Moisture	2.44	1.47
Ash	4.23	1.93
Volatile combustible matter	15.38	13.07
Fixed carbon	77.95	83.53
	100.00	100.00
Sulphur	.93	1.26

The jet-like anthracite represents entire tree trunks which form a part of the coal seam. The coal is quite different from the other seams in the region in having so small a percentage of ash. Its high content of fixed carbon is clearly due to baking by the intrusives in the Rosillos mountains.

2. On the north side of Tornillo creek, north from the Grapevine hills, a small seam of coal was uncovered in a surface pit some years ago. Peaty and bituminous shales have been observed in several places in the west part of the Tornillo flats.

3. In the country immediately west of the Slickrock mountain two pits have been made in which coal was found. In neither place the seam measured quite twenty inches in thickness.

4. The Kimble pits are some openings made on a seam which is exposed on the south side of a hill at a point two miles north of the

*Analyst, Mr. O. H. Palm.

Chisos pen north of Rough run. This seam of coal measures about twenty inches. It has a considerable dip and the ground is somewhat broken. It is associated with bituminous and sandy shales or clays. An analysis of this coal shows that it contains:

Moisture	4.68
Ash	16.60
Volatile combustible matter	24.20
Fixed carbon	54.52
	100.00
Sulphur	.88

5. What is probably the same seam as that seen in the Kimble pits is exposed in the bottom of Cottonwood creek at Chisos pen, where it measures eighteen inches. The creek follows a line of displacement at this place and the coal also appears about two hundred yards away from the arroyo on the north side, in a gully, where it has about the same development. In a piece of this coal which was more closely examined, some pitted Tracheids of gymnospermous wood could be discerned. Some very small grains of marcasite were seen along some horizontal seams. Above as well as below this coal we find carbonaceous and bituminous silts and clays. Its composition resembles that of the coal in the Kimble pits, with somewhat less ash and somewhat more of volatile material, viz.:

Moisture	6.12
Ash	14.42
Volatile combustible material	34.72
Fixed carbon	44.74
	100.00
Sulphur	1.32

6. In the flats which lie about one and one-fourth mile southeast of the southeast side of Maverick mountain there are some exposures of a thin coal seam. One of these which appeared in the east bank of a creek showed eight inches of good coal with nearly two feet of "bone" or coaly shale below. An analysis of this coal is as below:

Moisture	6.46
Ash	25.90
Volatile combustible matter	34.88
Fixed carbon	32.76
	100.00
Sulphur	1.00

This coal contains frequent small grains or pockets of a yellow resin, from the size of a mustard seed to that of a bean. They are reddish-brown in color, very irregular in shape, and usually fractured by weathering. Mr. O. H. Palm, who has examined them, finds that "they easily melt and burn if brought near the flame. They are soluble in chloroform, ether, and alkalies. Their melting point is between 205° and 210° C."

7. Some coal seams were noted in the hills on the west side of Terlingua creek about three and a half miles south of Study butte. None of these seem to be more than a foot in thickness, but the coal is associated with a "bony" shale, which is highly bituminous. Grains of resin are present in the shales as well as in the coal.

8. The same seam of coal appears again in the hills on the opposite side of the creek about a mile to the south, where it dips at a high angle.

9. In the low ridges of the flats between Terlingua Abaja and the mouth of Terlingua creek [about three-fourths of a mile to the south, and a little west of the village] a coal seam crops out, which is eighteen inches thick. It dips 30° to the southwest. This coal is associated with some sandstone ledges and it is about in the same horizon as the Chisos pen coal. A piece taken from the weathered face of this outcrop contained:*

Moisture	9.10
Ash	21.50
Volatile combustible matter	37.38
Fixed carbon	32.02
	100.00
Sulphur	0.90

*O. H. Palm, analyst.

10. On the north side of the Rio Grande, about seven miles west of Mariscal mountain, the Rattlesnake beds contain some bituminous clays, that have thin seams of coal.

11. Apparently trustworthy reports say that coal has been seen in some of the arroyos north of Talley's ranch and southwest of the north end of Mariscal mountain and also in the country northwest of Banta Shutup. In both of these localities there are extensive outcrops of the Rattlesnake beds.

The writer believes that the Rattlesnake beds and their included coals are the near equivalents of the coal-bearing beds at Eagle Pass. Both overlie the marine clays of the Middle Cretaceous, the Upson clays and Terlingua beds. The coals are somewhat alike in composition and they both contain small grains of resin. Some very characteristic impressions of plants are common to both formations, as shown on a previous page, and some fossils are common to both. Still there is a difference in the fauna as well as in the nature of the sediments themselves. The latter are somewhat more variable in the Chisos country, where the sandstones are slightly coarser and have a more open texture. The sandstones are here also less persistent when traced horizontally. All this indicates less open waters in which sedimentation took place in the Chisos region. This view is corroborated also by the difference in the two faunas. At Eagle Pass ammonoids are quite common, while in the Chisos country these are rare and the oyster family is much more frequently in evidence. This has a bearing on the economic features of the coal seams. We should not expect to find these as constant in the more variable sediments in the Chisos country as they have proved to be in the Eagle Pass region. They were made nearer to the shore in the western country and will naturally be more variable and uncertain. On the other hand, it has been shown that the Rattlesnake beds belong to the true coal-bearing horizon of the Upper Cretaceous series in the West, and that they will bear exploration. They outcrop in a circular belt around the Chisos mountains, and this belt can not yet be regarded as sufficiently explored. It is true that all the outcrops which have been examined, show only thin seams. The variability of the beds proves that local and sudden changes are to be expected. Such variations may be for the better as well as for the worse.

At any rate, some thin seams are already known, and in a country where fuel is as scarce as here, some of these might prove profitable to work on a small scale under present conditions.

3. Silver.

On the north side of Altuda mountain some silver-bearing galena has been mined. The workings are on both sides of an arroyo, which comes from the west and runs on the north side of the mountain. The workings consist of some three hundred feet of drifts and shafts, some of which follow the contact of the ore-bearing rock and the Cibolo limestone, which forms the country rock. On the south side of the arroyo there rises from this limestone a wedge-shaped peak of partly silicified material, which clearly at some time was a filling in a cavern in the limestone above which it now rises. This peak consists of an altered conglomerate or breccia, containing pebbles, boulders, and large blocks of sandstone, of various kinds of igneous rocks, of granite, and of limestone from the Cretaceous as well as from the Carboniferous strata. The infiltration of siliceous material has rendered this mass somewhat resistant to the agencies of weathering and erosion, and so the country rock has suffered more rapid removal by these agencies while the more enduring filling remains in part intact. Most of the ore occurred in irregular leads near the contact of this filling with the limestone in the wall of the ancient cavern. On the north side of the arroyo a siliceous tufa, probably a precipitate from underground hot solutions, is largely in evidence over a part of the surface of a large hill. Its contact with the limestone can be traced in several places, and occasionally it takes on the appearance of an igneous intrusive. Some very rich ore has been taken out from one of the explorations near the contact at this deposit with the limestone.

In the mind of the writer there is no doubt that the mineral deposits at this place, whatever their value, have essentially the same origin and history as the lodes in the Shafter mine near the Chinati mountains.* The material filling the ancient caverns is

*See the Geology of the Shafter Silver Mine District, Presidio county, Texas, Bulletin The University of Texas Mineral Survey, No. 8, p. 54 et seq.

much more extensive here at Altuda, and it possibly consists in part of intrusive material. What bearing this may have on the quantity of ore no one can say. Lodes vary from barrenness to the richest deposits known. They are always expensive to explore. The explorations at Altuda are as yet not extensive enough to give an estimate of the quantity of the ore, which in a pocket on one of the drifts was very rich.

4. Phosphate.

Some of the rock samples taken from the strata of the Trenton age near Ridge spring, south of Peña Colorado, were found to have specimens of the small gasteropod *Cyclora*. This fossil is common in the phosphate-bearing ledges of the Trenton horizon in Tennessee, and its existence here suggested the desirability of having an analysis made in order to see if the limestone would contain phosphate in this western field. Two small specimens of the lot brought from the field were analyzed and one yielded 6.03 and the other 1.70 per cent of phosphorus pentoxide. This is clearly in excess of the usual phosphate content of limestones, and suggests the possibility of workable phosphate rock. The author had no suspicion of the existence of any phosphate in these rocks at the time he was in the field, and the specimens analyzed were collected as types of the rock and taken for the fossils they contained. The regularity and persistence of the bedding of the Palaeozoic sediments will render exploration for phosphate-bearing rock easy, and should any strata prove to be of sufficiently high grade there is little doubt that they will be extensive. The field that should be explored is coextensive with the Caballos ridges between Warwicks and Del Norte gap and for some distance to the northeast of Warwicks. In appearance the phosphate-bearing rocks do not differ much from other limestone.

5. Brick Materials.

The reduction of the quicksilver in the Terlingua mines has created an unsteady market for brick. This market has been supplied by Mr. John Dryden, who finds a suitable clay on lower Terlingua creek. His clay consists of the upper three or four feet of wash, or alluvium, near this stream. The clay is tempered by the addition of a "sand," which is really the soil formed from a thoroughly disintegrated intrusive andesitic rock. The brick is of excellent quality and has proved to stand a white heat for sixty hours. It is free from cracks and has a dirty gray or cream color. It is hand-made, sun-dried, and burnt in square up-draught kilns with thick adobe walls. The total output up to this time (1904) is 1,250,000 bricks. The brickyard and kilns are located a short distance north of Dryden's ranch.

BULLETIN

OF THE

UNIVERSITY OF TEXAS

SCIENTIFIC SERIES

VOLUME ONE

AUSTIN, TEXAS

1905-1907

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Bulletins 1, 2, 3 and 4 are reprints properly belonging in the *Reprint Series,* and are therefore not to be bound with this volume.

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1. *The University of Texas Record*, vol. v, no. 3, March, 1904.
2. *Alumni Notes.* 13 p., March, 1904.
3. *Some Wholesome Educational Statistics*, by W. S. Sutton. 12 p., illus. March, 1904. 10 cents.
4. *Courses of Study in Law Pursued in The University of Texas*, by J. C. Townes. 16 p. March, 1904. o. p.
5. *Notes Concerning the Progress of the University*, by Wilson Williams, Register. 3 p., 1904. o. p.
6. *The University of Texas Record*, vol. v, no. 4, July, 1904.
7. *The Consolidation of Rural Schools*, by Una Bedechek and G. T. Baskett. 38 p., illus. October, 1904. 25 cents.
8. *The Pride of Texans and Their University*, by T. H. Montgomery, Jr. 5 p. November, 1904. o. p.
9. *Letter to Alumni Regarding the Proposed Law School Building.* 2 p. December, 1904. o. p.
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13. *School Buildings*, by A. C. Ellis and Hugo Kuehne. 119 p., illus. pl. June, 1905. 30 cents.
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5. *The Grotesque in the Poetry of Robert Browning*, by Lily B. Campbell. 41 p. April, 1907. 25 cents.

*The *Record* is no longer issued in this series, but bears its volume and number, as heretofore.

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11. *A Sketch of the Geology of the Chisos Country,* by J. A. Udden. In press.

REPRINT SERIES

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3. *The 1903 Epidemic of Yellow Fever in Texas, and the Lesson to be Learned from it,* by Dr. G. R. Tabor. 22 p. June, 1905. 15 cents.

In addition to the bulletins named above are the following:

a. The Official Series, which includes catalogues, Regents' Reports, and administrative bulletins.

b. About 35 bulletins issued before March, 1904, when the division into series began. An important group among these are the nine University of Texas Mineral Survey bulletins.

c. The University of Texas Record, formerly, but no longer, included in the General Series. Numbers of the Record have been issued from two to four times a year since December, 1898, and it is now in its 7th volume. A general index to the first six volumes may be found in volume 6.

*Future numbers of *Contributions,* first published elsewhere, will appear in the Reprint series.