

ART. XXX.—*Events in North American Cretaceous History illustrated in the Arkansas-Texas Division of the Southwestern Region of the United States* ;* by ROBT. T. HILL.

DURING the last two years the writer has been permitted by the joint effort of Dr. John C. Branner, State Geologist of Arkansas, and the Director of the United States Geological Survey to investigate the stratigraphic and paleontologic conditions of the northern and eastern termination of the Texas Cretaceous, and to trace out its detailed relations to those of the Gulf and western states with their accompanying phenomena. The condition of knowledge previous to that time was fully set forth in this Journal for October, 1887. From later investigations I am able to present the following brief

* The southwestern region of the United States may be defined in stratigraphic terms as those portions of Arkansas, Texas, Indian Territory, southern Kansas, New Mexico and Arizona, south of the Uinta and Ozark uplifts and between the Sierras on the west and the great Atlantic timber belt on the east. Its principal divisions are the Arizona-Utah or Grand Cañon; the Rocky Mountain or New Mexican; the West Texan or Permo-Triassic; the Central Texas Paleozoic; and the eastern or Arkansas-Texas Cretaceous division lying between the last and the western borders of the Tertiary strata of the Mississippi embayment, as laid down upon Hitchcock's Geological Map of the United States.

sketch of the principal historical events recorded in their formations, and also a preliminary section which approximately outlines the Cretaceous history of the United States east of the Sierras.

Continental limitations at the beginning of the Cretaceous.

Early in these investigations it became apparent that the marine sedimentation of both divisions of the Cretaceous section had been limited on the north by an older continental shore line which must be defined before the subsequent history could be traced. The present remnant of this ancient shore line in the whole Neozoic history of the region was found to be a more or less connected orographic system, with a score of local names, which extends from the Ouachita river in the vicinity of Malvern and Hot Springs, Arkansas, almost due west through Indian Territory into the Panhandle of Texas. The remnant of this mountain system consists of some of the highest and most sharply defined ridges above the surrounding plain in America, as in western Arkansas, south of the Arkansas river, or again of strings of small knobs, as in the Potato hills of Indian Territory; but whatever their name or shape, it is every where evident that they are the now greatly degraded remnants of a series of nearly vertical folds which once constituted a continuous mountain system which was elevated at the close of the Paleozoic.

The former extent of this system can not be stated, for its present eastern termination was truncated abruptly and obscured by late Cretaceous and Tertiary deposits of the Mississippi embayment, while its western continuation is buried beneath Permian, Cretaceous and Quaternary sediments of the Texas Panhandle and obliterated by the later uplifts of the Rocky Mountain regions. The exact stratigraphic relations of this system to the Paleozoic area of Central Texas have not been determined, except that the latter's eastern margin presents a succession of sediments similar to those of the former, and its western border records an early Mesozoic history not seen along its eastern.* It is also evident that it was completely covered by sediments during the two great subsidences in Cretaceous time, while the eastern half at least of the Arkansas Indian Territory system remained above sea-level until present time.

* The western border of this Central Paleozoic region, which presents an entirely different system of strata from the eastern, will be treated in another paper.

The first Epoch of Subsidence.

Along the southern border of these mountains from the Little Missouri in Arkansas westward to the 98th meridian, thence southward to the Brazos along the eastern border of the Central Texas Paleozoic region, can be seen, resting with a slight dip upon the highly disturbed Carboniferous rocks and beneath the more calcareous chalky sediments of the Fredricksburg Division of the Comanche series, a littoral formation which marks the beginning of Cretaceous history in the region and whose beds, as far as the writer knows, are the oldest undoubted Cretaceous in the United States, except what are perhaps its eastward continuation, the Tuscaloosa and Potomac formations of Alabama and Maryland. This formation, as seen in its typical exposures along the Murfreesboro-Ultima Thule road in Arkansas, is composed of several hundred feet of variegated sands and clays, resembling in color the Potomac formations as seen in the railroad cuts at Baltimore, and, in addition, then fissile layers of shell-bearing limestone and great beds of gypsum and lignites, associated with a vertebrate and molluscan brackish-water fauna, which, notwithstanding our prejudices against trans-oceanic correlations, is unmistakably identical in general lithologic and stratigraphic features with the Purbeck and Wealden of England and Germany. This fauna, in addition to a profuse and unstudied flora, consists of Dinosauridæ and brackish water Mollusca including millions of individuals of a few species such as Corbiculidæ, Viviparus, *Ostrea Franklini* of Coquand and the undoubted *Pleurocera strombiformis* Schloth., so characteristic of the Wealden of Europe and not before found in America. These fossils with a single Ammonite are all indicative of its Wealden or transitional Jura-Cretacic age. West of the Paleozoic area of Central Texas, the writer has found only the sediments of this formation, but not its fossils. Its eastern termination is covered by the Upper Cretaceous and Quaternary. South of the Brazos, as at Austin, its position is occupied by a great deep marine chalk formation, now metamorphosed into hardest marble, which has strong Jurassic affinities. The Trinity formation, as it has been named, can be directly seen underlying the more calcareous and deeper marine beds of the Comanche series at many places, and clearly marks the interior shore line of the oldest American Cretaceous, as well as the beginning of a great subsidence which initiated that epoch and gradually covered the whole of the Texas Paleozoic area. How far the waters of the Atlantic extended southward and westward is yet unknown. Its northern limit was the unnamed mountain system above mentioned; for none of the lower (Fredricksburg) sediments of this division of the Creta-

ceous have until recently been found north of it. [Since this paper has been prepared for press, Prof. Crogin has noted the occurrence of rocks which belong, in my opinion, to the undoubted Comanche Series and probably the Trinity.] This subsidence, which has been overlooked in previous geological history, was profound and long continued. The evidence of its depth is recorded in the rocks and fossils of the Comanche series, which throughout consist of a deep infra-littoral deposit of chalk with and without flints, impure chalk and chalk marls often hardened into limestone, uniformly extending over wide areas and gradually succeeding the littoral Trinity beds. The thickness of these sediments increases southward, sometimes reaching 2000 feet. At Austin they are over 1500 feet. The evidence of a greater subsidence southward and absence of sediments northward indicate a continental condition in the latter region during Jurassic time and the possible continuation of deep sea conditions during that period in southern Texas and northern Mexico—a possibility which, as will be shown in another article, may be a fact, as indicated by an undescribed system of rocks in those regions.

The long continuation of this subsidence is well shown by its fauna. First, by the remarkable uniformity in the distribution of its successive horizons. The fauna of the Washita limestone horizon, in the section at the close of this paper, is almost identical at El Paso and at the Arkansas-Choctaw line, some 900 miles apart. The horizon of the remarkable and unique *Exogyra arietina* clays extends from Indian Territory to Presidio del Norte nearly 500 miles, with no perceptible variations in the outcrops. The long continuation of this subsidence is also shown by the gradual change which the species, a large number of which are identical with European Cretaceous forms, underwent without sedimental break. The species of Echinodermata, Ostreidæ, Gasteropoda, etc., of the Fredricksburg division are replaced in the Upper or Washita limestone by other forms of the same or allied genera, so similar in some predominant feature and at the same time so specifically different as to clearly show a line of progressive evolution in this epoch.* The time of this subsidence, as shown by paleontological evidence was Neocomian and Middle Cretaceous. It is also shown from its absence that this subsidence was not so extensive along the margins of the Appalachian regions. In fact, there is some circumstantial evidence that its northern shore limit, a portion of which is preserved to us in the Arkansas-Indian Territory orographic remnant, must have continued eastward without deflecting northward,

* The writer has in press a complete revision of the species of this division which will contain further mention of this fact.

as shown by the phenomenal outcrops in the salines of Louisiana and on the island of Jamaica.*

The Comanche epoch of subsidence was closed by the great elevation of an extensive land area of which little is as yet known, except that it must have endured a length of time sufficient for the complete modification of species, for not one of those of the Comanche series has thus far been found to pass upward into the later beds of America, although one or two are found in Europe. The records of this elevation are two-fold. First, an unmistakable and omnipresent unconformity between its beds and those of the succeeding Upper Cretaceous—the Meek and Hayden section of the northwest and its Atlantic coast equivalents. Second, the littoral conditions indicated by the land flora of the Dakota sandstone which must have been deposited along its shore line, marking the next great epoch to be described. This unconformity is seen not only in the absolute lack of parallelism in beds and the complete lithologic and faunal changes, but also in the fact that the same basal horizons of the Upper Cretaceous rest at different places, owing to unequal erosion, upon different horizons of the eroded surface of the lower Comanche series. The elevation at the close of the Comanche epoch is also illustrated by the disturbances recorded in the strata of southwestern Texas as shown in the following trans-section of the Austin-New Braunfels unconformity at Austin, the Upper Cretaceous series resting unconformably upon the greatly disturbed strata of the lower. The Comanche series are here greatly faulted along the fold of what could be appropriately termed the most eastward of the series of American monoclines and which marks the first plateau, the eastern margin of which continues westward to the Rio Grande. This elevation evidently took place before the beginning of the Upper Cretaceous.

* The peculiar occurrence of Cretaceous limestone in certain salines of Louisiana, some two hundred miles coastward from the main area of the Cretaceous exposures, was noted by Dr. Eugene W. Hilgard in various publications, but before the presence of any marine beds, except the Upper of the Cretaceous system, had been admitted in this country. Some two years ago, Judge Lawrence C. Johnson of the U. S. Geological Survey showed the writer some specimens of the material recently collected from these "Cretaceous Islands." They were found to be both lithologically and paleontologically identical with the marine Cretaceous of the Comanche series of the west Central Texas. The nearest outcrop of the main area of the formation is at Cerro Gordo, Arkansas, on the Choctaw line, and all the area intervening is covered by Quaternary deposits. Why these islands should occur along this Cretaceous "backbone" of Louisiana as Hilgard has termed it, can only be explained upon the hypothesis that there exists in that vicinity some ancient and as yet undescribed disturbance. Another datum which adds interest to this inquiry is the fact that upon the island of Jamaica, as personal observers and the reports of the Geological Survey of Great Britain have led me to believe, there are also Cretaceous rocks of the same horizon, directly in the strike of the Louisiana outcrops. In view of these facts, the investigation of Cuba is awaited with much interest, for it is probable that these outcrops were once continuous.

The second Epoch of Subsidence.

Following this mid-Cretaceous land epoch there was another profound subsidence. This epoch may be said to include geographically, stratigraphically, and paleontologically what was lately known as all of American Cretaceous history and which with slight modifications in correlation, is the section of Meek and Hayden and includes all the Upper Cretaceous of the Northwest, New Jersey and Alabama, except the basal, Tuscaloosa and Potomac beds, in the two latter regions. The paleontologic and sedimental sequence is continuous. In all these regions the grand development of the Lower Cretaceous strata of the Comanche series is missing, and the upper division rests either unconformably upon the basal littorals, equivalents of the Trinity beds, as in New Jersey and Alabama, or upon the pre-Cretaceous rocks of the mid-Cretaceous continent, as in the northwest. In Texas, however, this Upper Cretaceous system, which attains an even greater development



Fig. 1. Section across the Austin-New Braunfels unconformity, Travis county, Texas, showing disturbances at close of Upper (A) and lower Cretaceous (B), and unconformity between these systems. Basaltic extrusion (Pilot Knob) at D.

than in the typical "Nebraska" region, rests every where unconformably upon the Comanche series. The unbroken succession of the formations of this Upper Cretaceous, recorded both in Texas and the northwest by its sediments, is as follows:—(1) sands, (2) clays, shales changing upward into calcareous shales, (3) chalk, (4) chalk marls, (5) sandy marls, (6) sands with littoral fossils indicating a period of slow prolonged subsidence and gradual emergence.

This was the most profound submergence in all Mesozoic time, the Atlantic ocean having extended continuously, as shown by the remarkable identity of sediments similarly situated in relation to the shore line and by its fossils, from British America southward around the Appalachian continent. Its history is similar to that of the lower division—a long continued and gradual submergence, the sedimentation of which is marked by an immense chalk* deposit followed by a gradual transition upward without break into arenaceous littorals.

* The question of chalk in the North American Cretaceous is fully discussed in my report on the Geology of Southwestern Arkansas. It is sufficient to say that in sections of this basal Upper Cretaceous chalk, kindly prepared by Mr. J. S. Diller of the U. S. Geological Survey, were found almost a repetition of the foraminifera of the European Upper Cretaceous chalks.

Disturbances and Differentiation at the close of the American Cretaceous.

The uniformity of the littoral fauna at the close of the Upper Cretaceous is shown by a comparison of the species of the Ripley, Navarro and Pierre-Fox Hills beds. This similarity is in remarkable contrast with the great differentiation which followed it; for at the close of the Cretaceous, that emergence so well known to American geologists took place, which lifted the western interior region permanently above oceanic invasions. That the southern trans-Mississippi Gulf-Cretaceous was also slightly lifted above sea level is shown by a slight but unmistakable unconformity found in Arkansas, at Elmo, Texas, and elsewhere between the beds of these periods. The oldest littoral beds of the marine Tertiary (Lignitic), which are mostly composed of sediments derived from the soft strata of the underlying Cretaceous, are distinguishable from them only by a slight non-conformity sometimes accompanied by a thin sub-stratum of siliceous pebbles. This unconformity is made more certain, however, by the recent discovery of unmistakable paleontologic evidence. As in the case of the mid-Cretaceous non-conformity, the basal Tertiary rests upon different horizons of the Upper Cretaceous, owing to inequalities in its erosions. In Texas, southwest of Bastrop and Austin to the Sabinas river in Mexico, for a distance of 300 miles, there is a more conspicuous and unmistakable sign of the disturbances at the close of the Cretaceous than this unconformity, and this is an elevation accompanied by a line of many basaltic outbursts* in close proximity to, but not immediately connecting with the line of elevation along the Austin-New Braunfels unconformity above mentioned, which seems to have been a line of weakness since Jurassic times. The basaltic outcrops occur at no less than fifty places in a line from near Yegua Hills in Bastrop County southwest via Hays, Kendall, Bandera, Kerr, Nueces and Val Verde counties to the Santa Rosa mountains in Mexico. Pilot Knob, seven miles southwest of Austin, is a typical example. This is a small dome-shaped protuberance of columnar basalt rising through the Upper Cretaceous chalks which surround it on all sides and producing in them a quaquaversal dip of ten degrees, and metamorphosing them into saccharoidal marble at the contacts. In decomposing, the basalt becomes amygdaloidal and zeolitic. The whole exposure has the appearance of a truncated laccolite. Throughout the whole region, as seen in fig. 1, there are other evidences of the presence of these igneous rocks beneath, as seen in the dome-like disturbances and meta-

* Conjointly with Mr. E. T. Dumble, the writer will publish at an early day, a paper upon this remarkable igneous area.

morphism. It is evident that the extrusions took place at or after the close of the Cretaceous, and probably belong in the same category with similar phenomena reported at Rockwall in north Texas, in the Chickasaw Nation, and in Arkansas.

Post-Cretaceous events which have concealed Cretaceous history.

The inequalities between the two great formations of the Cretaceous have been greatly obliterated by subsequent history, as illustrated in the following section along the Arkansas-Choctaw line, across Little and Red rivers, wherein can be seen the leveling and concealment produced by an early Quaternary subsidence, which has also worn away much of the mountains.

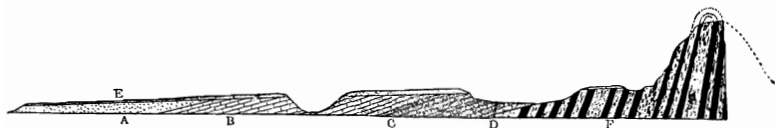


Fig. 2. Section forty miles in length north and south, along the Arkansas-Choctaw line showing the sequence of the Cretaceous formations, their relation to the Paleozoic Mountain axis F, and their post-Tertiary degradation by the Quaternary subsidence E. Upper Cretaceous, A; Comanche series, B; Trinity formation, C; Intrusive dike, D.

The whole Cretaceous history, as seen in the region of its most typical sediments, can be summed up as two profound subsidences, separated by a land epoch. These have left in their sediments two great chalk formations, as shown in the following table. The history of these subsidences has hitherto been confused owing to the fact that the littorals of one of them in regions favorable for study have been mistaken for the whole. Although each of the faunas and sediments of the two formations represents an unbroken series, I have mentioned for each horizon distinguishing species of Ammonites, Ostrea and Echinoderms.

University of Texas, March 7, 1889.

| Events. | EPOCHS. | Distinguishing Fossils. | Prevailing Sediments. | Thickness W. Texas. |
|---|---|---|---|---|
| V. Tertiary Land EPOCH. | | | | |
| IV. Second profound Marine Subsidence. | <p><i>Northwest U. S.</i> 1 } Fox Hills- Pierre. 2 Niobrara. 3 Benton. 4 Dakota.</p> <p><i>Texas.</i> Navarro beds. Exogyra ponderosa Marls. Austin-Dallas Chalk. Eagleford Shales (fish beds). Lower Cross-Timber beds.</p> <p>UPPER CRETACEOUS. Continuous sediments.</p> | <p>Am. placentaeras. O. vesicularis. O. costata. Cassidulus aqueoreus. { Inocerami. Nautilus.* Radiolites Austinensis. Hemicidaris Texanus Roem. Scaphites, fish teeth. Inocerami. { Leaf imprints. Few casts.</p> <p>Sedimentation unbroken.</p> | <p>Calcareous sands. Marly clays. Chalk marls. Chalk gradating upward into next. Clay shales becoming more calcareous upward. Sands, Lignites, etc.</p> | <p>1) 1000 2) 600 3) 300 4) 200</p> |
| III. Mid-Cretaceous Land EPOCH. | | | | 2100 |
| II. First profound Marine Subsidence. | <p><i>Washita Division.</i> Denison beds. Vola, or red chalk Limestone Exogyra Arietina clays. Washita limestone <i>Fredericksburg Division.</i> Hippurites limestone Caprotina Comanche Peak limestone. <i>Trinity Beds.</i></p> <p>LOWER AND MIDDLE CRETACEOUS. Continuous sediments.</p> | <p>O. crenulimargo Roem Vola quinquecostata Sow. and undescribed fauna Exogyra arietina Roem G. Pitcheri, var. Navia Terebratula Wacoensis Macraster elegans Sh. O. carinata Lamk. and O. sinuata Caprotina (Requienia) Am. pedernalis V. B. Toxaster Texanus Roem O. fiabellata (E. Texana) Gold. Am. Walcottii, sp. nov. A. Franklini Coq. Pleurocera strombiformis Schlot. Dinosaurs</p> | <p>{ Alternations of clay, lime and sand { Massive lime bed with oxidizing iron. Calcareous, green clay shales Impure chalk Metamorphosed chalk " with flints</p> | <p>100 50 100 100 750 300 300</p> |
| I. Jurassic Land north of Texas. Deep seas to west and south. | | | | <p>1800 2100 3900</p> |