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THE COMANCHE SERIES OF THE TEXAS-ARKANSAS REGION.

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INTRODUCTORY STATEMENT.

The Comanche series of rocks has been partially described by the writer and others in several previous papers. They represent in time the marine sedimentation between the lacustral land epoch of Permo-Triassic red beds and the upper Cretaceous subsidence begun in the Dakota epoch. Without

attempting a minute correlation of its numerous horizons with any beds of the eastern hemisphere, it has been conceded generally that at least the upper portions of this series are of lower Cretaceous age because of their clearly defined stratigraphic position unconformably beneath the Dakota sands, which all authorities have conceded to be of Cenomanian affinities; a conclusion strengthened by the striking paleontologic resemblance of the whole upper Cretaceous (or Meek and Hayden Cretaceous) series to that of Europe. The lower beds of the Comanche series have affinities which entitle them to comparison with the upper Jurassic, while the upper beds have Neocomian and Cenomanian resemblances. The Comanche series as a whole, however, presents great paleontologic evidence at variance with every European standard, and it is premature to make paleontologic correlations with it. In this paper I shall endeavor to clearly define this series stratigraphically, and leave for others the discussion of the faunal resemblances and differences.

The main area of the Comanche series extends from western Arkansas through southern Indian territory to the meridian of 97° 30′, thence southward and southwestward across Texas to New Mexico, a distance of more than 1,000 miles, and then southward indefinitely into Mexico. Areas also exist in the California-Utah province and in eastern New Mexico, although they are as yet unstudied. The main typical area, however, is in central Texas, and is so extensive that deductions as to its subdivisions have required much time; and although I have been constantly studying it for many years, not until now have I felt justified in dividing it into well-defined terranes. I now propose to show by stratigraphic and paleontologic proof that the Comanche series is divisible into several separate and distinct terranes, the lower two of which may possibly be of pre-Cretaceous age.

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THE TRINITY OR BASAL DIVISION.

Separation.—In previous papers I have defined this as an arenaceous littoral deposit at the base of the Comanche series in Arkansas and Texas. During the past year, however, I have discovered that the beds described under this general term really include two stratigraphic subdivisions separated by distinct lithologic and paleontologic characteristics, the Trinity or basal sands, and the Glen Rose or alternating beds, respectively.

The Trinity Sands.—While in many places these vary in composition with that of the underlying floor, they are usually composed of fine, white, cross-bedded sand, mostly unconsolidated, very porous, calcareous, sometimes free from lime. In places there are deposits of small jasper and quartz pebbles, seldom exceeding a pigeon's egg in size, exceedingly rounded and worn, and often cemented by a matrix of iron and lime, sometimes harder than the pebbles. This pebble deposit is of various hues—white, black, and jaspery red—and often remains as a residuum, over large areas of the red beds and Carboniferous strata, from which the post-Trinity beds have been denuded, as seen in Taylor, Tom Green, Nolan, Montague and many other counties of the Abilene and gypsum country.* Silicified wood and occasional fragments of hard lignite occur, the latter seldom, if ever, in continuous beds or strata, but as if the remnant of some solitary log or tree floated out from shore.

These sands can be seen in contact with the underlying Carboniferous and the overlying Glen Rose beds all along the western margin of the Comanche area except around the immediate perimeter of the Burnet-Llano region, where in places the Paleozoic continent persisted above the Trinity shore-line until the Comanche Peak epoch. Fifteen miles south of Burnet, however, in another pre-Trinity topographic valley, now followed by Colorado river below Smithwick Mills, where the lithologic nature of the beds is entirely different, consisting of coarser rounded pebbles of Silurian and and Carboniferous limestone and Llano schists, as well as quartz from the Burnet granite, and fine cross-bedded sands and shell débris (resembling, as seen at Travis Peak post-office, in the bed of Cow creek, the Florida coquina). Here also there is an unstudied molluscan fauna including ammonitidæ, ostræidæ, trigoniadæ and other forms, not one of which occurs in the hitherto supposed Cretaceous and overlying beds. Here the Trinity beds are in contact unconformably with hard Carboniferous and Silurian limestones, and contain much débris of the Burnet granite. They also vary in composition and thickness with the irregularities of the floor.

West of the 98th meridian the Trinity sands are deposited unconformably upon the various beds of the "Triassic," or gypsiferous red beds, as seen

* In places these pebbles are cemented into large masses of conglomerate, as at San Angelo, in Tom Green county, where it attains a great thickness and areal development.

along the base of the remnantal Cretaceous mesas of the Colorado-Brazos divide, in Nolan, Taylor and Mitchell counties. Owing to the unconsolidated, pulverent nature of these sands, they are denuded more rapidly than the overlying or underlying strata. As a result of this rapid denudation, the main area of Trinity exposures north of the Brazos is in a narrow valley, seldom exceeding ten miles in width, which extends nearly five hundred miles irregularly northward from the Brazos to the mountains of Indian territory, and from thence eastward to Murfreesboro, Arkansas. This valley is bounded coastward by the escarpment of the more indurated material of the Glen Rose beds.

The Trinity valley is one of the most marked topographic features of the Arkansas-Texas region. Where the underlying beds are of unconsolidated material, however, as in the red bed region of northwestern Texas, the remnantal sands often occur as a thin sheet of loose sand over extensive upland areas, as seen east of Abilene in Taylor county, and in other places. Some of the sand hills along the western escarpment of the plains are also of this nature. This formation, although of limited areal exposure, has a wide range of occurrence along the interior border of the more calcareous beds of the Comanche series from southwestern Arkansas to New Mexico. It is usually absent along the eastern front of the Rocky Mountains from Las Vegas (New Mexico) northward, unless the *Atlantosaurus* beds at Cañon City (Colorado) are synchronous in age, which is not proven. The pink grits at Gallisteo (New Mexico), described by Marcou and Stevenson, and which occur northeast of Santa Fé at Rowe, and at other points near the intersection of the Pecos river, are probably of this formation, and may mark its western border. Upon careful comparison I am also inclined to think the upper half of *Tucumcari* mesa, New Mexico, which I have visited, is composed, below the cap rock, of the Trinity sands. Traces of this terrane are also seen between the Pecos and the escarpment of the Llano Estacado, in southeastern New Mexico, east of Eddy, indicating its extent beneath the Tertiary plains.

In southern Kansas the Cheyenne sandstones have been properly ascribed to this age by Cragin, but I am inclined to think from the anomalies of occurrence there that they are not of continuous sedimentation with that of the main Trinity sea, but were deposited in an embayment or inlet around the western end of a buried mountain system, of which the Wichitas are now the visible remnant.

South of the Colorado and east of the Pecos the occurrence and extent of the sands have not been determined; and, after many journeys in northern Mexico and southern Texas, I have been unable to find the base of the Comanche limestones exposed in this region.

The origin of the Trinity sediments is apparent. They are always derived

from the materials of the underlying contact beds, mostly the sandstones of the Carboniferous series, except in the valley of the Colorado east of the Burnet granite area, as previously noted. The origin of the fine, rounded quartzite and jasper pebbles, however, is still problematical; although I have some evidence that it is the redeposit of a conglomerate that belongs to the earlier beds, which was degraded and redistributed over and far west of the present Carboniferous area, as now revealed by the removal of the overlying Comanche series. When one considers the immense degradation of the sandstones of the Carboniferous system in Texas and Indian Territory, the source of the Trinity materials is obvious.

These sands record the beginning of one of the most important events of Mesozoic time, to wit: The invasion of the area of the interior lake region of the red bed epoch (Triassic) by the marine waters of the Atlantic, and the degradation or base-leveling of the narrow continental divide which separated them. The extreme paucity of land débris in the sediments is indicative of the limited area of this divide, for where the Trinity waters bordered the Appalachian continent, as in Arkansas, plant remains are exceedingly abundant.

The Glen Rose Beds.—Immediately overlying the basal sands of the Trinity division just described, and no doubt succeeding them by continuous subsidence, lies a group of strata which are of great importance in our geologic history. These are composed of soft, yellow, magnesian fossiliferous beds, silicious at base, alternating in dimension layers with an exceedingly fine argillaceous sand, with occasional dimension layers of almost pure crystalline limestones, chalk, and magnesian limestones, often oölitic in structure. At Mount Bonnel, west of Austin, there is a distinct oölitic structure in many of the layers of indurated stone and marls, while nodules and geodes of beautiful anhydrite, calcite and strontianite crystals are also quite abundant.

The unequal weathering of the hard and soft layers produces in the eroded topography a beautiful bench-and-terrace effect, so much resembling ancient shore lines along the western escarpment of Grand prairie, where it overlooks the Trinity valley and the lower Paleozoic beds from which it has been eroded, that earlier geologists have often confused these features with shore topography. On fresh fracture these rocks are usually either white or of an intense orange or gamboge color, but weather into a dull gray.

North of the Colorado-Brazos divide the beds contain an abundant and unique molluscan fauna, composed in the lower part of littoral species described by me in a report on the Neozoic geology of southwestern Arkansas, to wit: *Pleurocera strombiformis*, Scloth; *Corbiculidæ*, sp.; *Ostræa franklini*, Coquand; besides numerous undescribed forms, but not one species of the great lower Cretaceous fauna, such as the characteristic *Gryphæa*, of the

pitcheri type, or ammonitidæ and echinodermata which appear so abundantly two terranes above in the base of the Comanche Peak beds and continue thence, with certain progressive variation, to the top of the Comanche series. The upper beds of this terrane are especially characterized by the immense numbers of abberant molluscs, such as *Monopleura, Diceras, Requienia*, etc., which form great masses of strata.

The upper beds of the terrane contain many deeper water beds, accompanied by a distinct marine fauna, which has never been described. Among the organisms are echinodermata and foraminiferæ (especially the large, strawberry-shaped *Goniolina* or *Parkeria*), together with innumerable casts of pelecypoda and gasteropoda, including species of very large size, such as *Natica* (*Tylostoma pedernalis* (?), Roemer) and related forms, together with occasional fragments of vertebrata. This fauna of the upper beds can be collected all along the western escarpment of stratification, especially in the Paluxy valley at and west of Glen Rose; in the slopes of the Brazos, north and south of Granbury; along the bluffs of the Colorado and Bull creek, west of the mouth of the latter steam; and in numerous other localities south of the Colorado, in Edwards, Sutton, Kerr, Uvalde, Kendall, Kimball, Blanco, Gillespie, and other counties.

The Glen Rose beds north of the Colorado-Brazos divide are exposed along a narrow area occurring as a prairie strip in the heart of the upper Cross-Timbers. Their first appearance northward is in the western part of Wise county, and they increase in area southward, in Parker, Hood, Erath and Comanche counties.

These beds do not occur in Indian territory, owing to the overlap of later deposits, but appear in Arkansas from Ultima Thule eastward to Murfreesboro; the limestones described in my report on Arkansas under the general classification of the Trinity sands belonging to this terrane. In the counties of southwestern Texas between the Pecos and the Colorado and south of the Burnet-Llano Paleozoic region, these rocks attain a thickness of over 2,000 feet, and form the remnant of a great plateau from 2,000 to 3,000 feet above the sea and larger in area than the states of Connecticut and Rhode Island. The Guadalupe, Comal, Nueces, Frio, Medina and Devils rivers have their origin in this sterile, rugged plateau, which is being rapidly base-leveled and cut up into horizontally stratified buttes and mesas by the head-water erosion of these streams.

In the mountains of northern Mexico the beds again appear projecting through the intervening Tertiary plain as a part of the Santa Rosa and Arboles ranges, but here they are metamorphosed into a hard blue limestone which has been mistaken for Silurian by some.* In the southern area these

* Report on San Rafael Mines, Santa Rosa district, Mexico, by Professor Adolphe Rock: Mobile, Ala., 1876.

beds are surmounted by the Walnut clays, or *Exogyra texana* beds, which I assume in this paper to be the base of the true Cretaceous. North of the Lampasas they are overlain by the Paluxy sands, an arenaceous terrane hitherto unrecognized and undifferentiated from the Trinity division.

There are in these beds many layers of dimension stone of almost identical lithologic character with that of the celebrated Caen quarries of France, so largely imported into our northern seaports. This stone is extensively quarried at Weatherford, Granbury, Belton, Oatmanville, Kerrville and other places, and will no doubt some day occupy an important position in the resources of our country.

The Thorp Springs limestone subdivision, found near the base of the alternating beds and overlying the Trinity sands, is *one* of the *Caprotina* limestones of Shumard. It is a massive stratum, composed almost exclusively of shells of the peculiar *Requienia* (*Caprotina*) *texana*, Roemer; a fossil not confined exclusively, however, to this bed. In thickness it is about twenty feet. It outcrops for many miles along the bed of the river at Granbury and Thorp Springs, and also in the bed of the Paluxy at Glen Rose. Near Travis Peak post-office, on the Colorado, this horizon is again seen, and is apparently persistent. Owing to the excessive faulting in the vicinity of Austin, it is impossible to say what relation this stone bears to the *Caprotina* limestone west of that city.

The different lithologic and stratigraphic features of the Glen Rose alternating beds, their position beneath the Fredericksburg division (separated in the north by a sandy, littoral terrane), and the entire absence of the great characteristic fauna of the hitherto recognized Fredericksburg division, entitle these beds to a distinct position, although they are separated by no structural unconformity. I cannot here enter into a discussion of paleontologic details, but I consider the deposits of Jurassic rather than of Cretaceous affinities. The question of age is secondary to definition, however, and I shall leave this to a future time. The fossils have not yet been studied critically; but I have in my possession a representative series of these fossils, which I propose to make the subject of a separate paper at an early day.

THE FREDERICKSBURG OR COMANCHE PEAK DIVISION.

General Composition.—This is the second of the great divisions of the Comanche series, and is distinguished from the others by its more chalky character and its unique molluscan fauna. The Paluxy sands are placed with this series only tentatively, for there are some few reasons which might be sufficient to class them with the Trinity division. The rocks of this division, although of wide extent, have their characteristic exposure and development in the region of Texas west of the meridian 97° 30′, and between the Trinity and Lampasas rivers.

The Paluxy Sands.—North of the Colorado-Brazos divide the alternating beds of the Trinity division are succeeded by a terrane of fine, white pack-sand, oxidizing red at the surface, about 100 feet in thickness, resembling very much the Trinity sands and hitherto confused with them. They outcrop along the eastern edge of the Brazos valley, in Parker and Hood, and also in Erath, Comanche, Coryell and Bosque counties. South of the Colorado-Brazos divide they disappear, the Comanche Peak beds resting directly upon the Glen Rose beds. These beds are especially conspicuous southwest of Granbury, forming the timbered upland of that region.

The Paluxy sands, which are so called from the town and creek of that name in Somerville county, can first be separated from the Trinity sands in Wise county at a point between Decatur and Alvord. At Decatur the beds are well developed. In general character they are somewhat similar to the Trinity sands. There are differences, however: the Paluxy sands have none of the fine pebbles which characterize the base of the Trinity; and the Paluxy beds are rather calcareous and argillaceous in places, while those of the Trinity are more ferruginous.

At Decatur the Paluxy sands contain some layers of honey-combed and very argillaceous limestone. The gradation from the Paluxy to the overlying and underlying beds at Decatur is also rather gradual. At Comanche peak the sands form the plain upon which the butte stands, making a belt of forest region surrounding its base. Here the beds have a thickness of about a hundred feet, and are of character similar to that at Decatur. West and south of Comanche peak they occupy a considerable area, while they extend many miles down the Brazos, finally disappearing at the Bluff mills, near Kimball, where they make the shoals over which the river runs. Jonesborough, Coryell county, is situated directly on the outcrop of these sands, and the Lanham road northward from the town crosses it several times. A few miles north of Jonesborough the sands have a thickness of only about fifteen feet, showing their decreasing thickness southward. The transition from the sands to the underlying Glen Rose alternating beds is rather sharp, but that of the overlying beds is a little more gradual, for which reason these sands are placed in the Comanche division.

The sand is stratified, and occasionally cross-bedded, and there are local hardenings. The color varies from gray to yellowish, and the amount of ferrugination which is here found is variable. The sand is also marked by the growth of forest timber, largely post-oak, though smaller growths, such as sumac, also occur. The sands probably extend for a considerable distance down the Leon valley, although it is difficult to determine their exact extent on account of confusion with the drift of the Leon river, composed of this débris. The sands appear only in scattered spots further toward the south. Thus, east of Burnet, on the Mahomet road, they appear as

occasional areas of reddish sandy lands, bearing a growth of post-oak. Sometimes these localities are very small, and may be seen on one side of a slight valley of erosion but not on the other at the same level. Elsewhere, however, they have a very considerable and unmistakable outcrop, as for instance, near the junction of the northern and Russell forks of San Gabriel river.

To the northward, the Paluxy sands increase in development, overlapping interiorward on the Glen Rose and Trinity beds, and abutting against the Paleozoic area in Indian territory from a point west of Ardmore eastward to the Arkansas line, where they occupy the escarpment valley of the basal Comanche Peak beds or Preston limestone. They also appear at Preston bluff, near Denison. These sands, which the writer has hitherto classed as Trinity, and which may yet prove to be inseparable from them, have been traced out by him during the past year from the Arkansas line westward. At no place in Indian territory east of the 97th meridian do the Glen Rose beds outcrop, and it is my opinion that they still remain concealed there by this uneroded overlap of the Paluxy sands; for the alternating beds are again exposed beneath them in Arkansas.

The absence of these sands south of the Colorado-Brazos divide is an interesting feature, which can best be explained on the hypothesis that the littoral sedimentation diminished away from the main land area to the southward, and by the existence of a buried pre-Trinity and pre-Paluxy topographic protuberance of Carboniferous limestones, which persisted above the Trinity waters in the Burnet area until the basal Comanche Peak epoch, and which extends from northern Burnet and Llano counties eastward into Lampasas county, and which then divided the country into a northern embayment and a southern open sea. The presence of this ridge is shown by the difference of level in the pre-Comanche floor, as exposed by the erosion of the Comanche sediments at Lampasas and Burnet, and also by the horizontal deposition of the latter upon its unequal altitudes. This is especially well shown in the profile from Burnet to Smithwick Mills post-office, the Carboniferous floor being revealed in unconformable contact with the Trinity at all altitudes from 650 to 1,200 feet. This Paleozoic barrier of central Texas has little or no arenaceous strata upon its southern side, and hence the absence of the Paluxy sands in that direction, the existence of which would imply the occurrence of a pre-existing arenaceous terrane. These sands mark a return to land conditions in northern Texas at the close of the Trinity epoch, and the beginning of the main great subsidence as recorded in the Comanche Peak, Washita and Denison beds of the overlying division. No fossils have been found in the Paluxy sands, save silicified wood, which occurs in great abundance, and has been mistakenly considered Quaternary in age.

The Gryphœa Rock and Walnut Clays.—The Paluxy sands are everywhere succeeded throughout their extent by a stratum of grypheate oysters, occurring sometimes in solid masses from ten to fifty feet thick, in some places imbedded in a calcareous matrix. This terrane is sometimes underlain and overlain by yellow laminated clay marls containing *Exogyra texana*, Roemer. Hence the *Gryphœa* rock and *Exogyra* clays must be discussed as one terrane. The yellow clays also contain occasional flags of hard, crystalline limestone, composed largely of shells of *Exogyra texana*. For these the name of *Walnut clays* is proposed, after their characteristic occurrence at Walnut, Bosque county.

At Comanche peak the beds encircle the base of the butte, forming a well-marked bench around the mountain. Below them are the timbered Paluxy sands. The stratum is here fifty feet thick, and composed entirely of the shells of a small *Gryphœa* resembling *G. incurva* of Europe, but as yet not differentiated from the various species called *G. pitcheri* in our nomenclature. The shells are more or less loosely cemented, and form one of the most unique rock-sheets in the region. This stratum extends from the Trinity to the Lampasas, and is beautifully exposed in the counties of Parker, Wise, Hood, Erath, Comanche, Hamilton, Coryell, Bell and Lampasas, forming a foundation for the Walnut clays, whose exposure is coincident with it.

The Walnut clays, or *Exogyra texana* beds, overlying and underlying the *Gryphœa* beds, are alternating strata of thin limestone flags and yellow clay marls, accompanied by inconceivable numbers of *Exogyra texana*, Roemer (= *Ostrœa virgula*, Goldfuss, and *Exogyra matheroniana*, D'Orb.), the lowest and first unmistakably Cretaceous form in the Comanche series. These clays weather into an exceedingly fertile, chocolate-colored soil, forming the chief agricultural lands of the Fredericksburg division. In extent these beds coincide with the *Gryphœa* breccia. North of the Lampasas they are separated from the Glen Rose beds by the Paluxy sands. South of that river they rest directly upon these sands, and constitute a prominent topographic bench or plain near the summit of the buttes, as seen west of Austin, in Travis county.

The Comanche Peak Chalk.—Overlying the Walnut clays and succeeding them rather abruptly there is a more chalky terrane, for which Dr. Shumard proposed the name of the Comanche Peak beds. This chalk is hard, but readily disintegrates, and usually occurs as the slope or escarpment of the buttes and mesas. It is exceedingly fossiliferous, and its numerous and characteristic species are given in my check-list. The thickness of this bed averages about 100 feet in central Texas, but it thins rapidly to the northward and thickens to the southward. The beds grade upward into the *Caprina* limestone, from which it is differentiated, however, by displaying more regular and frequent lines of stratification, by crumbling nature, and

by a unique fauna. The typical occurrence of the Comanche Peak horizon is along the sides of the buttes and mesas of central Texas which are capped by the *Caprina* limestone, such as Comanche peak and others. The bed is usually covered with a growth of rather thin, scrubby oaks; the soil is thin or absent, and the angular fragments of the weathering rocks make up the surface. Frequently, however, there are large areas over which the Comanche Peak horizon extends as the surface formation.

The Caprina Limestone.—The next member of the Comanche Peak group is the *Caprina* limestone of Shumard. This is the direct continuation of the Comanche Peak chalk, only the limestone is harder and more persistent, and the fossils less numerous and characterized by the occurrence of a few peculiar forms, especially *Rudistes*, which have already been referred to by me in other writings. Genetically it is inseparable from the underlying and overlying beds, since there is no sharp demarkation between them. It is a deposit of deeper waters than the underlying Comanche Peak chalk, however, as shown by its lack of lamination and stratification planes.

At Comanche peak the limestone is between thirty and forty feet thick, and though it increases to the southward it does not change greatly. It can correctly be called an indurated chalk. It is more or less stratified, although usually a great massive bed from top to bottom. Some parts are harder than others, and so make up a curved outline to the bluffs; others are materially softer, and frequently are eroded away, leaving either honey-combed cavities or shelves under the overhanging harder layers.

Topographically, the *Caprina* limestone is one of the most important factors in Texas, since its superior hardness and resistance have preserved it as the capstone of the innumerable buttes, mesas and plateaus of the central portion of the state, where it forms a great plane of resistance to denudation. So perfectly does this limestone find expression in the topography that its extent can readily be traced by the highest contours of the United States Geological Survey topographic sheets of Coryell, Bell and other counties. It may be said to be the determining factor in the topography of the region. All of the buttes or so-called mountains north of the Colorado are capped by it; the great scarps which often run for miles overlooking the prairies to the west represent the same stratum; the walls of the cañons which many of the streams have cut are almost invariably composed of the *Caprina* limestone.

But little need be said in regard to the distribution of the *Caprina* limestone. In northwestern Texas the Double mountains of Stonewall county are capped by the *Caprina;* so are also Comanche peak, the mesa and almost all the buttes east of the Brazos opposite Glen Rose, the high bluffs marking the cañon of the Brazos from the Bluff mills near Kimball far down the river, the buttes and mesas about Walnut and Iredell and toward the south,

those about Meridian, Jonesborough and Valley mills, and the Jehosaphat plateau of Travis county and western Williamson county. It is seen in grand bluffs along the Nolan river at Blum, and in some of the smaller streams near Fort Graham; it outcrops in the creek at Belton, and makes up the whole surface of the broad mesa, extending thence westward for several miles to the point where it makes the cap of the great bluff facing westward—a magnificent illustration of the relations of uniform and gentle dip, together with comparative hardness, to the processes of erosion. It caps the buttes as far west as Kempner and southward toward Florence, where it makes again the level surface of the mesa. Pilot knob, north of Liberty hill, Williamson county, and many of the buttes high up the Colorado about Anderson mills, are capped by it. The *Caprina* terrane is usually covered with a thick growth of scrubby oaks and similar trees, especially where the outcrop is not of large area and the rock comes near the surface. In places there are broad fertile prairies upon its outcrop, as about Pancake and Turnersville.

It has been stated that the *Caprina* is uniform throughout. In the southern portion of its area there is an exception to this rule, and it might be divided into an upper or flinty member, and a lower or chalky subdivision. The flints first appear in the vicinity of Meridian, but only as a few fragments; and they increase very rapidly southward, being seen in grand development about Belton. In the northern part of the region they are comparatively large, oval, flattened nodules, usually of black flint. These occur throughout the larger part of the region studied, extending southward at least as far as Pilot knob, a few miles north of Liberty hill, and thence on to the Rio Grande.

The Goodland Limestone.—Like all the other deeper deposits of Texas, the Comanche Peak group thickens southward and thins northward. In no place does its thickness as a whole exceed or even attain 500 feet; and from the Colorado northward it decreases in thickness until, one subdivision gradually disappearing at a time, it is represented in southern Indian territory by a single persistent layer, which in my Paris-Kiamitia section I have given the name *Goodland limestone.** This formation resembles the *Caprina* limestone in hardness, but has the Comanche Peak fauna; the *Exogyra texana* layers do not appear until 200 miles west of the Arkansas line. Proceeding westward along the ancient Ouachita shore-line from Arkansas into Texas, the *Exogyra texana* beds (the Walnut clays and *Gryphæa* breccia) are missing until the escarpment is reached north of Marietta, in the Chickasaw nation, where they first appear, thinly represented, beneath the Goodland limestone and above the sands which, as before stated, are supposed to be the homologue of the Paluxy sands.

*After the town of Goodland in Indian territory.

That this gradual deepening of the Comanche Peak waters continued southwestward into Mexico and perhaps South America, there is every evidence, although in northern Mexico and the trans-Pecos region there has been such extensive disturbance and extreme metamorphism that the identity of the paleontologic and stratigraphic subdivisions is lost.

THE WASHITA OR INDIAN TERRITORY DIVISION.

General Aspect.—This division has its prevalent and characteristic development in southern Choctaw and Chickasaw nations of Indian territory, and in northern Texas, in Grayson, Cook and Tarrant counties, where it is the predominant formation. It extends southward to the Rio Grande at Del Rio, but becomes greatly changed in lithologic character, assuming a more calcareous aspect and decreasing in thickness.

The *Caprina* limestone is apparently the culmination of the great subsidence of the Comanche series, for above that terrane the strata begin to display more and more a littoral aspect, and new faunas appear. To this division I give the name of *Washita*, after old Fort Washita, in the Chickasaw nation, where the beds were first noted and described as Neocomian by Marcou. In order to appreciate this division in the region of its greatest development, we must transfer our attention from central Texas to southern Indian territory and the Red river basin.

The Kiamitia Clays or Schloenbachia Beds.—In southern Indian territory and northern Texas the chalky Goodland (Comanche Peak) limestones, which I consider the northern attenuation of the Comanche Peak beds, are succeeded by another large development of marly clays, often stiff and black before oxidation, and accompanied by thousands of individuals of the variety of *Gryphæa pitcheri* so accurately figured by Marcou and White (*G. forniculata* of White), as I have determined by visiting the original localities of Morton, the plains of the Kiamitia. Another conspicuous and characteristic fossil of these beds is the *Schloenbachia acutecarinatus*, Shumard (= *Ammonites pedernalis*, von Buch). Alternating with the clays there are firm, hard, thin dimension layers, composed almost entirely of these shells imbedded in a matrix of yellow lime. The buildings at old Fort Washita are constructed of this stone. These clays were first seen by me at Cerro Gordo, Arkansas, where at first I confused them with the *Arietina* clays; and they are developed westward through Indian territory continually to the great southward deflection of strike west of Marietta (Chickasaw nation), whence they continue southward into Texas.

Among the typical localities in Indian territory where the Kiamitia clays are unmistakably seen and constitute large areas of land are the following: At and around the town of Goodland, on the St. Louis and San Francisco railway north of Paris; thence westward to Fort Washita; at the Folsom

crossing of Blue river; and five miles north of Marietta, in Indian territory. There are intervening areas forming the surmounting plane of the Goodland limestone escarpment, constituting, with the Duck Creek and Fort Worth limestones, the only black prairies of Indian territory, including the historic plains of the Kiamitia, near Fort Towson, from which Dr. G. Pitcher, in 1830, collected and sent to Dr. Morton, of Philadelphia, the first fossils ever procured from the American lower Cretaceous (Comanche series). The same beds occur south of Red river, in northern Grayson county, at Dr. Marshall's house, two miles south of old Preston, and in other places, and also northwest of Gainesville, presenting the same topographic dip planes. West of Gainesville and southward to Fort Worth they also occur, but in less conspicuous areas. They outcrop ten miles west of Forth Worth, near Benbrook station, and also in Williamson county, where, being thicker and more calcareous, they form the black lands around Bagdad. This horizon dips beneath the surface in the beds of Duck creek three miles north of Denison, where, with the characteristic ammonite (*Schloenbachia peruvianus*, von Buch), it is seen in the bluffs of the creek.

These clays are the basal beds of the Washita division, and represent a shallower deposition than the chalky *Caprina* beds.

The Duck Creek Chalk.—The Kiamitia clays are surmounted in Indian territory and in Grayson and Cooke counties, Texas, by another chalky terrane, which, from its occurrence on the southern slope of Duck creek north of Denison, I have named the *Duck Creek beds.* This terrane is about 100 feet in thickness, and is composed of a crumbling, white chalky limestone and alternating chalky marls, accompanied by a unique fauna, especially characterized by the fossils *Hamites fremonti*, Marcou; *Ammonites*, sp. nov.; *Inoceramus* (*Aucella?*), sp. nov.; all of which are found only in these beds.

The Duck Creek beds are principally developed in northwestern Grayson county and northwestern Cooke county, in Texas, and along the southern border of the Kiamitia clays, in Indian territory. They have not been differentiated south of Cooke county, although I have seen them west of Fort Worth, near the cement works. The fauna of this terrane is so entirely different from those above and below that I am sometimes inclined to believe this member should be considered a distinct division.

*The Fort Worth Limestone.**—The Duck Creek chalk beds underlie a series of firmer and less pure yellow limestones and marls in alternating strata of from one to two feet, and of great persistency. These limestones are less chalky and of creamy tints, owing to the slight amount of oxidized pyrites they contain, and they also contain a little arenaceous matter. After a little familiarity with them and their unique fossils, they will always be readily distinguished from the other terranes. They are seen in the Den-

* Washita Limestone, old classification of Hill.

ison section, two miles north of Main street, where they form a slight escarpment with overlying dip plane. They are best shown, however, at Fort Worth, where the characteristic structure of their alternating dimension layers and marly clays is shown in the bluff north of the public square, at the quarries near the Union depot, and in the Texas and Pacific railway cuts, as well as in the Union Pacific cut at Hodge station, three miles north of the city. They are also displayed in Indian territory and in Cooke, Tarrant, Denton, McLennan, Bell, Williamson and Travis counties. Two hundred miles southwestward, at Del Rio, near the mouth of the Pecos, they are very pure chalks. The railroad cut in West Austin is another typical locality. Four miles west of El Paso, at the corners of Texas and New Mexico on the Mexico line, the Washita limestone is seen, greatly broken and disturbed. The formation is distinguished by the occurrence of many unique and characteristic species, like the large *Macraster elegans*, Roemer; *Ammonites leonensis*, Conrad; *Gryphæa washita; G. sinuata; Ostræa carinata;* and other species mentioned in my check-list.

This terrane, together with the Duck Creek limestone and clays, constitute the typical Neocomian of Marcou as described at Fort Washita, a fact of importance, inasmuch as it is near the top of the Comanche series and far above the Comanche Peak and lower divisions, which must be older.

The lithologic and stratigraphic features of these beds show shallower sedimentation than the underlying Duck Creek chalks and deeper deposition than the overlying Denison beds; they are sublittoral in characteristic features, indicative of shallowing which continues into the next terrane. These beds are also an important economic landmark, for they occupy a hypsometric position in which artesian wells can always be obtained.

The Denison Beds.—The Fort Worth semi-chalky beds are overlain in the Red river district by a series of shallower deposits of laminated arenaceous clays (the *Arietina* clays), at the base grading upward into sandy clays and occasional limestones, the chalky element of all the underlying Comanche series having finally disappeared. The detail of these beds, as seen with slight variation in Grayson, Cooke, and Denton counties and in Indian territory, presents a threefold division. At the base they are composed of a blue marly clay weathering brown, with occasional layers of immense, rounded fissile indurations, generally brown in color. Above these the beds are more sandy and ferruginous, oxidizing into ironstone and almost indistinguishable from adjacent Dakota sandstones, but separated from them by the uppermost bed of impure yellow limestone, which underlies Main street in Denison.

At Austin the sediments, almost pure clays and limestones, are void of silica and most of the littoral fossils, and from thence to the Rio Grande at Del Rio are represented by marly clays (the *Exogyra arietina* clays of my

previous classification), while still further southward, where the open sea continued during the pre-Dakota land epoch, it is very probable that there is no break between these clays and the marly beds of the basal upper Cretaceous. At El Paso, however, the Denison beds are again represented by arenaceous littoral beds, which suggests that there was a shore-line in the vicinity.

At Denison and throughout northern Texas these beds are unconformably overlain by a magnificent development of the Dakota sands. I have failed as yet in Texas to find a single species extending from one formation into the other. In Kansas, however, there are some apparent exceptions to this rule, as has been shown by Cragin.

Variation in Character of the Deposits.

From a study of four parallel sections based upon actual measurements at intervals of from 100 to 200 miles, extending from Indian territory southward to the Rio Grande, the following deductions may be made:

1. That these beds were laid down against the Ouachita mountain system of Indian territory and over the whole preëxisting area of Texas, except the insular mountain areas of the Organ and Guadalupe mountains;

2. That the more littoral terranes of the Trinity and Paluxy beds and the Washita division increase in thickness and littoral character to the northward and diminish to the southward;

3. That the deeper water or chalky terranes, such as the Comanche Peak, the *Caprina* limestone and the Glen Rose beds, thin out northward and enormously increase in thickness southward, thus demonstrating that the profound subsidence was to the southward, in which direction the open sea prevailed, while oscillations of level are recorded only in the northern littoral areas.

Subsidence recorded in the Comanche Series.

Reviewing the sections mentioned, the series resolves itself into stratigraphic groups representing stages of subsidence, but of varying degree and period. The topography of the pre-Trinity continent is not difficult to interpret, a slight land barrier of Carboniferous and Silurian rocks in Texas projecting southward, peninsula-like, from the Ouachita mountains and separating lake from ocean. But little base-leveling was required to transform this peninsula into an island or islands, smaller and smaller, until completely covered by the Comanche Peak sediments. Beyond this barrier the ancient lake bottom, whose inequalities had long since been overcome by the sedimentation, stretched a comparatively unbroken plain to California, with a few mountainous exceptions, like the old post-Silurian islands in the Organ and Franklin ranges.

The Trinity division records in its basal grits the beginning of the great Comanche subsidence, and the disappearance of the wonderful Permo-Jurassic seas of the red bed epoch. The Trinity sands were soon followed by a brackish fauna of the *Pleurocera* beds, which gradually, as the ocean bottom deepened, became sublittoral and marine in character, as shown in the chalkier alternating beds, which indicate a long period of moderate depth. What happened at the close of the Trinity is somewhat more problematic. The Paluxy sands indicate the recurrence of shallower conditions. Toward the south these beds become less and less arenaceous and more argillaceous, foraminiferæ (*Nodosara*) and plant remains (*Equisetum*) having been found associated in them at Del Rio on the Rio Grande. To this southern argillaceous continuation I have previously applied the name *Exogyra arietina* beds.

The Comanche Peak division is, *par excellence*, the deep-water deposit of the series, as attested both by its sediments and by its fossils. The Paluxy sands no doubt represent the beginning of its subsidence, which is further recorded by the succession of the marine *Exogyra texana* clays and the Comanche Peak chalks, which covered all of the Texan and Mexican and no doubt a large part of the South American area, during an epoch perhaps longer than that in which thousands of feet of littoral sediments would have been deposited.

The Washita division, composed principally of laminated calcareous clays (marls), often alternating with impure chalky limestones, with its comparatively deep-water fauna, indicates a shallower condition than the Comanche Peak epoch. This shallowing was the forerunner of the sublittoral conditions that followed the Denison beds. As in the Comanche Peak division, the limestone and chalky characters of the Fort Worth beds increase southward until (as at Del Rio) they become pure chalks.

The Denison beds are preëminently, in their northern portion, a near-shore and shallow-water marine deposit, as illustrated in the character of sediments, in their assortment, and in their gradual lithologic change from argillaceous to a ferruginated arenaceous character, and in the presence of a fauna of littoral species mixed with lignite and other land débris.

Stratigraphic Value of the Terranes.

Having defined the units of the Comanche series so that they may be intelligently discussed, I now propose to present a few general deductions therefrom:

1. Each of these divisions presents a complete and distinct stratigraphic and paleontologic aspect, and they should no longer be discussed as a single geologic unit. In addition to the broad lithologic differences I have enume-

rated, not one species of the Trinity division passes upward into the Fredericksburg division; only one or two unmistakable species of the Fredericksburg passes upward into the Washita; while in the Washita division each of the terranes has a unique fauna. The paleontology of the whole series has been sadly confused by the fact that specific descriptions have been made by investigators who have not seen the stratigraphic and faunal association.

2. The foregoing facts being true, each of these terranes, especially those of the Washita division, should be considered a stratigraphic unit; for there is a far greater difference between each of them than there is between the Hamilton and the Chemung (or Ithaca), or between the Carboniferous and the sub-Carboniferous, or between any of the Paleozoic groups of the New York-Pennsylvania region.

Topographic Expression of the Comanche Terranes.

Having described the stratigraphic units which compose the Comanche terranes, attention is invited to the unique topographic forms which are characteristic of them, and to the extensive erosion which they record. Primarily the system, as a whole, may be conceived as a great sheet of strata dipping coastward from the interior at an average rate of twenty feet per mile, and coinciding in strike with the shore-line against which they were deposited. This strike is, first, due east-and-west from Murfreesboro, Arkansas, to Marietta, Indian territory, a distance of 300 miles. From the latter point it is a little west of southward to San Antonio, Texas, whence it deflects westward to the trans-Pecos mountains. The area of this sheet is marked by three long, simple fault lines, which produce the only topographic inequalities due to disturbance. The first of these begins at the angle of the intercepting strike in Indian territory and Texas, and extends northwestward and southeastward through a point north of Denison, Texas, for over fifty miles. The downthrow is 600 feet to the northward, and Red river flows along the line of this fault for twenty miles or more. The second great fault extends from near Dallas to Del Rio, Texas, passing by Austin, New Braunfels and Uvalde, with increasing downthrow as we proceed westward. The third is along the eastern border of the trans-Pecos mountains, and is frequently disconnected, but has a regular northwestward and southeastward trend. The whole series, in common with the post-Cretaceous coastal strata, has been elevated along the interior edges by the post-Cretaceous continental uplifts and trans-Pecos mountain disturbances.

There have been at least three great epochs in the destruction and denudation of this ancient Comanche rock sheet. The western border was faulted and much elevated during the northern Mexican, trans-Pecos and southern New Mexican mountain-making epoch, for its rocks enter into

their disturbed structure in increasing quantity southward. The sediments of the great Neocene lake epoch, which constitute the Llano Estacado formation, and which were laid down horizontally between the mountain blocks of the above area, are largely composed of Comanche débris. So extensive was the denudation and erosion of this little appreciated Neocene lake epoch that the western two-thirds of the Comanche series was degraded, and entered into the composition of these lake deposits. It has been my pleasure during the past year to find several remnants of the Comanche series west of the Llano Estacado outcropping beneath its escarpment of Tertiary beds.

That this first great denudation of the Comanche series took place since the Eocene is further demonstrated, first, by the utter absence of Eocene débris in the sandy littoral beds of the latter formation: the base-leveling of Eocene time did not cut down to the Comanche series. Secondly, by the fact that the Comanche débris again enters into the composition of the post-Eocene formations of the coastal region, of probable synchronous age with the Llano Estacado epoch.

The second epoch of destruction of the Comanche series by denudation thus far recognized was in late Quaternary time, when the Gulf coast coincided with the present eastern border of the Cretaceous. By this process the older strata are exposed, and the escarpments of all the terranes are slowly receding eastward.

It is impossible at present to enter into a discussion of the evolution of the present drainage, across the strike and with the dip, which has produced the unique and characteristic topography, further than to say that there are two important stages in its history independent of the above-mentioned Neocene Llano Estacado epoch, when the extension of the Comanche terranes westward from the 100th meridian were almost entirely degraded, and their débris entered into the composition of the Llano Estacado sediment: The older is the system of rivers embracing the Red, Colorado, and Brazos, all of which have, by headwater erosion, cut their way completely across the Comanche area and deep down into the Paleozoic floor. The second and later epoch of erosion belongs to a superimposed drainage system composed of such streams as the Trinity, Paluxy, Lampasas, Guadalupe, Nueces, Frio and Devils rivers, which are now carving the great plateaus once separating the streams of the older system into remnantal buttes and mesas and reducing them to base-level.

By this double erosion and degradation by far the greater part of even the post-Llano Estacado remnant of this magnificent series has been eliminated and what is now exposed, although covering an immense area of country, is only a remnant of the previous extent.

The present topographic forms of this erosion can be readily understood.

The firm persistent limestones and harder chalks outcrop as escarpments of stratification, producing landmarks which can be traced for immense distances. Thus, the outcrop of the Goodland limestone in Indian territory forms an escarpment some 200 miles long, overlooking the valley of the Trinity and Paluxy sands. The Duck Creek, Denison, Fort Worth and *Caprina* limestones produce similar landmarks. The softer disintegrated chalks nearly always occur on the slopes or faces of these escarpments; while the clays and sandy terranes, such as the Walnut clays and Trinity and Paluxy sands, weather into extensive plains or semi-valleys extending interiorward from the escarpments. Where the headwater erosion of the superimposed drainage above mentioned encroaches upon the shorter and more precipitous drainage slopes of the older and deeper incised drainage, buttes and mesas are evolved. When the Comanche Peak beds, surmounted by the *Caprina* limestone, constitute the divide, these buttes are invariably of the following types: (1) Flat-topped mesas surrounded by precipitous escarpments; (2) Slopes of 45° composed of the Comanche Peak chalk; (3) Basal plains or pediments composed of the *Exogyra texana* clays and the *Gryphæa* beds. If the divide is composed of the Glen Rose beds the resulting buttes are usually conical, encircled by benches resulting from the alternating soft and hard layers. The great difference of induration in the respective terranes is also productive, especially in the eastern half of the area, of extensive plains coincident in slope with the dip, and terminating eastward against an escarpment of the overlying beds, which invariably deflects the drainage parallel to the strike, and on the west by a jump-off or escarpment of its own foundation strata. These dip planes are beautifully shown in northern Texas and southern Indian territory, where they constitute the prevalent topography and extend over vast areas. So extensive have been this planing-off in central Texas from higher to lower dip planes and the successive pauses at harder strata in the process of base-leveling that in the Burnet-Llano district the old plains can be traced where the drainage valleys have widened or narrowed and cut through from the *Caprina* limestone to the Glen Rose beds, the Glen Rose beds to the Carboniferous limestones, the Carboniferous limestones to the upper Cambrian, until finally the Archean and granite rocks are reached in which the Colorado is now cutting some 700 feet below the base of the Trinity and 4,000 feet below the former level of the upper Cretaceous.

It has been denied* by those who have not studied the Mesozoic and Cenozoic history of the Texas region that this erosion has taken place, and that this central Paleozoic district was ever covered; but he who restores the denuded strata or studies the topography so beautifully recorded in the

*Preliminary Report on the Geology of the Central Mineral Region of Texas, by Theo. B. Comstock: First (Second) Annual Report of the Geological Survey of Texas, Austin, 1889, pp. 314–316.

topographic sheets of the United States Geological Survey, or has seen the remnantal buttes of the Cretaceous, red bed, Carboniferous and Cambrian formations standing as mute witnesses above the older rocks will see most undisputably recorded their deep burial beneath the Cretaceous seas.

The Age of the Comanche Series.

To me, the age of the Comanche series has and ever will be a question of secondary consideration to its stratigraphic and faunal definition. I cannot refrain, however, from calling attention to a few data which must be of interest to those who insist upon trans-oceanic correlation.

It being admitted by all students that the Dakota sands, which rest unconformably upon the Denison beds in Texas, are the base of the upper Cretaceous and show remarkable specific identity with the upper Cretaceous beds of Europe, the stratigraphic position of the Comanche series as a lower formation cannot be doubted. In my check-list of the invertebrate fossils of the Texas Cretaceous, I have endeavored to give the history and stratigraphic range of each known species. Since that work was prepared I have made many additions and a few corrections. If the paleontologist will compare the species and faunas enumerated in that list with those of Europe, he will soon come to the conclusion that there is no specific similarity in the beds below the *Exogyra texana* clays, and that there are the most radical differences in stratigraphic occurrence. He will find that in the lower half of the Comanche series (the Glen Rose and Trinity beds) there is not a single species of characteristic Cretaceous age, and that while there are no criterional forms, such as ammonitidæ, echinodermata, etc., any of the genera can be as well referred to the Jurassic as to the Cretaceous.

In the Fredericksburg or Comanche Peak division, the lowest occurring and most abundant species, the *Exogyra texana* (*E. matheroniana*), which occurs here only in the very lowest beds of the undoubted lower Cretaceous, are characteristic of the very uppermost member of the European Cretaceous, the Senonian. This is the only species of the Comanche Peak division, however, which is known positively to occur in Europe. The two Ammonites (*Ammonites pedernalis*, Roemer, and *Schloenbachia peruvianus*, von Buch) are unknown in Europe, and the first is of a Triassic ceratitic type, while the other is found only in South America and Benguela land, Africa, in beds of undetermined age. The echinodermata have been pronounced by Professor Louis Agassiz to be of Neocomian type, while the variety of *Gryphæa* is a Jurassic type in Europe. Again, in the *Caprina* limestone occurs the only *Hippurite* in all the north American Cretaceous, while in Europe the genus ranges through the middle and upper divisions. In the Washita division, however, there are many species of undoubted European similarity

if not identity, and Mr. Jules Marcou, in his geology of North America, has shown many of these to be of Neocomian occurrence. There are other species, however, which are characteristic of the Gault. The upper, or Meek and Hayden, section of the North American Cretaceous shows, in its dicotyledonous plants, its ammonitidæ, its echinodermata, its ostræidæ, its inocerami, and in its other fossils, a remarkable resemblance to the European upper Cretaceous faunas, *i. e.*, the Cenomanian and Senonian. But in the American upper Cretaceous strata there is an utter absence of *Hippurites* and *Nerinœa*, genera which so abundantly occur in Europe.

This discordance of paleontologic occurrence of species, however contrary to the tenets of ancient descriptive paleontology, is in thorough harmony with modern biologic and stratigraphic doctrines; for the species would require great intervals of time to migrate the long distance between Texas and Europe, during which intervals wide differences in sedimentation and stratigraphy would occur.

The writer fully realizes that, notwithstanding the years of labor of his able predecessors and himself, we have as yet only begun the study of this great series, and that there still remains in them an extensive field for patient investigation.

DISCUSSION.

Dr. C. A. WHITE: The Trinity beds, to which Mr. Hill refers as lying at the base of the Comanche series, I have, in a work now in press, provisionally referred to the base of the North American lower Cretaceous. They contain, besides some undetermined dinosaurian remains, a few species of non-marine mollusca; but I am at present unable to say whether these forms are more suggestive of Cretaceous than of Jurassic age.

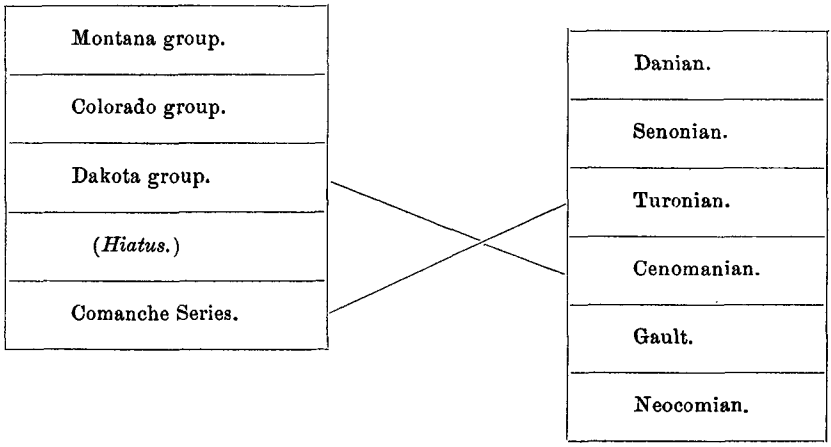
The fossils which Mr. Hill has exhibited as coming from strata beneath the Comanche, I am at present unable to specifically identify. If they really came from the horizon indicated, I think they represent a hitherto unknown molluscan fauna, and that they are of very great interest.

I quite agree with Mr. Hill in the opinion that the different subdivisions of the Texan Cretaceous cannot be definitely correlated with subdivisions of the European Cretaceous. I also think that the assumption of such correlations as have been published, by various authors both in Europe and America, is much to be deplored, because it retards rather than advances true scientific knowledge. For example, the venerable and distinguished Professor Roemer, of Breslau, who has published so much upon the fossils of the Texan Cretaceous, and who knows the paleontology of the European Cretaceous as well as any person living, has referred a collection of Comanche species to the upper Turonian. He does not merely say that the forms which he published are analogous to those of that subdivision of the European Cretaceous, but he refers them definitely to the same, as if it were as clearly recognizable here as in Europe. On the other hand, the Dakota group, after the early claims that its flora indicate Tertiary age subsided, has by common consent among a large number of geologists been regarded as of Cenomanian age.

Comparatively late investigations have shown that strata equivalent to the Dakota group in Texas not only overlie the Comanche series, but that there is a wide time-hiatus and unconformity between them; that is, the assumed correlations, referred to above, place one assemblage of strata far beneath another when in reality its true place is far above. The accompanying diagramatic table will illustrate the case in hand.

The right-hand column represents in their order the subdivisions of the European Cretaceous, and the left-hand column those of the general Cretaceous section of the southern interior portions of North America. The positions of these two portions of the table with relation to each other is not intended to show the taxonomic relation to one another of their respective

subdivisions, because I am not yet in possession of any very clear ideas upon that subject. It is only intended to show graphically the effect of the assumed correlation to which I have referred; that is, if we draw a line from the space representing the Dakota to that representing the Cenomanian, and another line from the space representing the Comanche to the upper part of the one representing the Turonian, they will cross each other. The shifting of the relative position upward or downward of the right-hand and left-hand portions of this table to meet the views of different persons as to the general correlation of the American and European Cretaceous will not affect the fact intended to be expressed by the crossing of the lines between them.



Many similar cases of theoretical paleontology at fault might be cited, to some of which I have already called attention in my writings, but which I have not now time to consider. I think I am justified in saying that theoretical attempts like these at special correlation of subdivisions of any geological system for different continents are unscientific, and, with due respect to those who hold different views, that it is time we were done with them.

Professor HILL: All analogies between the American and European formations seem to cease when we reach the Comanche group; yet there are many species of the Comanche which are almost indistinguishable from European forms, and afford the paleontologists of the old world a foundation for their attempted correlations.

Mr. C. D. WALCOTT: Professor Hill has brought up the question debated by many geologists—whether the Cretaceous and later formations ever extended over the central Paleozoic area of Texas. A few years since I examined the latter rocks of this area and saw the escarpments of the Cretaceous strata facing the central Paleozoic area. As the last report of the

Texas state survey takes the ground that this Paleozoic area was an island in the Cretaceous sea, it is interesting to see how far the facts accord with this theory. From the statements communicated by Professor Hill and from analogy it seems that he must be correct, and that the Cretaceous overlapped this central area; otherwise it would now be reduced to base-level by erosion. I should like to hear what the geologists of the Texas state survey who are present have to say about this theory.

Mr. E. T. DUMBLE: I am not personally acquainted with the geology of the central area save in a general way. Dr. Comstock, who is in charge of the district, has given in his report some of the reasons why he considers this area to never have been covered with the Cretaceous rocks; among other reasons, urging that many points of this area are higher than any points of the surrounding Cretaceous area.

Professor HILL: Generally one can look over the Paleozoic area from the Cretaceous escarpment. It may be true that the Paleozoic does, in some places, rise to the level of the Cretaceous escarpment; but it is necessary to have at least 4,000 feet of Cretaceous strata removed to bring the two horizons on a level, and consequently the Paleozoic would require to be at least that much higher than the present escarpment to have been uncovered by the Cretaceous sea.

Dr. COOPER CURTICE: To what has already been said in regard to the erosion of the escarpment surrounding the central basin of Texas, I wish to contribute the following remarks:

In going from Burnet, Texas, situated on the edge of the escarpment, southward to Marble falls, on the Colorado river, one successively crosses the following strata: lower Cretaceous, Burnet marble series (either Carboniferous or Silurian), Potsdam, Capitol granites, and Carboniferous. The Burnet marble appears to abut against the Potsdam sandstone. The sandstones rest horizontally upon the granites, and their lower beds are made of small masses of feldspar and quartz entirely like that of the granite. The summits of the sandstone beds rise over a hundred feet higher than the Carboniferous at Shinbone ridge, which they approach to within a couple of miles.

The semi-crystalline limestones of Shinbone ridge abut against the granites, but dip away from them. Carboniferous fossils were found within a very short distance from the contact, in an abandoned prospect hole. These limestones were on a level with the granites, or about on a level with the base of the Potsdam sandstone.

On the road westward from Burnet to Bluffton the following exposures were observed: Near Spring creek, a contact of the Burnet marble with Potsdam (*Lingula*-bearing) sandstones, with the Potsdam lying on granites; between Spring creek and Clear creek, apparently stratified granites; at

Clear creek, upturned Packsaddle schists, with inclosures of the granites. The granites underlying the Potsdam and intrusive into the Packsaddle schists were apparently of the same mass.

Potato hill lies about a mile north of the Clear creek crossing and two miles west of the escarpment. It is entirely composed of Potsdam sandstone, and its top is on a level with the crest of the adjacent escarpment. Its strata dip gently toward the northwest. *Conocephalites tripunctatus* (or *roemeri*), a fossil peculiar to the middle of the Potsdam series, occurs in its topmost bed. At the foot of the escarpment, a little north of east of Potato hill, Potsdam shales lie in contact with Burnet marbles. Toward the top of the escarpment, fossils said by Professor Hill to be from the horizon of the Trinity sands, the base of the 4,000 feet of Cretaceous strata, are quite plentiful. These are about on the level of the Potsdam fossils not two miles away.

The contact of the Carboniferous with granites, which are overlain by horizontal sandstones, and of the Potsdam sandstones and shales with Burnet marbles at three different localities, suggest the presence of a system of faults—vertical displacements—which must be taken into account while considering the level of the central area when the Cretaceous was deposited.

The injection of granitic material into the Packsaddle schists; the clean, fault-like contact of the "Shinbone" Carboniferous with the granites; and the apparent formation of the lower beds of the nearly horizontal strata of the Potsdam from the decomposed constituents of the underlying granites, all point out the post-Packsaddle and pre-Potsdam age of the latter.