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THE MORRISON FORMATION AND ITS RELATIONS WITH THE COMANCHE SERIES AND THE DAKOTA FORMATION[1]

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The beds now generally designated on U. S. Geological Survey maps as the Morrison formation have been a subject of interest and discussion since 1877, when abundant remains of dinosaurs were found in them. The first extensive collections of the vertebrate fauna were obtained in the neighborhood of Morrison near Denver, in Garden Park, near Canyon City, Colorado, and at Como, or Aurora, Wyoming. Since then the formation has been recognized by means of its fossils, its lithologic features, and its stratigraphic relations in the Black Hills, on the Laramie Plains, and elsewhere in Wyoming, in Montana, in western Colorado, in southeastern Colorado, and in adjacent parts of Oklahoma and New Mexico.

Of the various names that have been applied to the formation Atlantosaurus beds is, perhaps, most frequently seen in the literature, but Como stage, Beulah shales, Morrison formation, and Gunnison formation have been locally applied. In recent publications Darton has used the term "Morrison formation" in all the areas mentioned.

The formation is non-marine throughout, so far as known, and consists of variegated marls and shales with irregular beds of sandstone and sometimes thinner layers and lenses of siliceous limestone.

[1] Published by permission of the Director of the U. S. Geological Survey.

The colors of the shales and marls are greenish-gray, purplish, maroon and red, very irregularly distributed, while the sandstones are usually gray, sometimes weathering brown or with small brown spots. The limestones are gray, in some cases weathering with a reddish tinge. The general appearance of the formation is remarkably uniform over large areas, and yet the individual elements are so variable that no two detailed sections are exact duplicates of each other. The total thickness is seldom more than 200 feet, though it is possibly more than 400 feet at Canyon City.

Stratigraphically the Morrison is always rather closely associated with the Dakota formation. When the huge Morrison dinosaur bones were first discovered it was announced that they came from the Dakota, and after it was learned that they really came from a lower horizon it was generally believed for many years that there was no unconformity nor visible stratigraphic break between the two formations. Through the work of Ward, Jenney, and Darton in the area north of Colorado the Lakota and Fuson formations have been recognized between the true Dakota and the Morrison and referred to the Lower Cretaceous. I shall presently show that in southern Colorado, New Mexico, and Oklahoma the so-called Dakota should also be divided because it includes a marine Lower Cretaceous horizon. It is nevertheless true that the base of the Dakota is usually not more than 100 to 200 feet above the top of the Morrison, and it is often less than that. Darton has recognized a general unconformity at the top of the Morrison in Colorado and eastern Wyoming, but he believes that the interval represented by it is unimportant. The base of the restricted Dakota also rests on an uneven surface wherever the actual contact has been seen.

While the Morrison formation is thus almost invariably accompanied by the Dakota, the converse is not true; for the Dakota has a much wider distribution to the east and southeast, and, in the typical Dakota area extending southwesterly from the Missouri River in eastern Nebraska to the Arkansas in Kansas, the Morrison formation does not occur. The Dakota is fairly well recognized in northern Texas near Denison, where it rests on the Comanche series, here developed to a thickness of several hundred feet. This area was doubtless originally continuous with the Cretaceous in

southern Kansas (Kiowa, Comanche, Barber, and Clark Counties), where the Dakota sandstone is separated from the Red Beds by 100 to 150 feet of Comanche shales and sandstones, representing not the whole series but probably only its upper, or Washita, group. The attenuated margin of late Comanche deposits has been recognized by means of marine invertebrates as far north as Salina, Kansas, where it rests directly on the Permian and beneath the Dakota. Its occurrence at several points in Oklahoma, and eastern New Mexico, especially at Mesa Tucumcari, has long been known, but until recently there was no evidence that Comanche sediments with their marine fauna approached the dinosaur-bearing Morrison formation more closely than several hundred miles.

In 1901 Lee announced the discovery of the Morrison formation[1] in southeastern Colorado on the Purgatoire River, and its probable occurrence as far south as the Cimarron in New Mexico. It had previously not been known east of the Rocky Mountain foothills. The following year Lee continued[2] his explorations south and east and found the Morrison on Canadian River[3] in New Mexico, as well as on the Cimarron. He also suggested its correlation with the Comanche series in the following words:

> In Mr. Hill's folio of the *Texas region* he gives a section showing the geology of the Texas region. This region embraces the exposures which I studied along the Canadian, and extends to within a few miles of the Rio Cimarron. According to Mr. Hill's section the Lower Cretaceous, consisting of the Trinity, Fredericksburg, and Washita, lies between the Red Beds and the Dakota. If Mr. Hill's section represents correctly the age of the formations in the Canadian valley, then the shales and possibly the Exeter sandstone, must be of Lower Cretaceous age. But the shales, as I have already shown, are probably the same as the dinosaur-bearing shales of the Purgatory. There is some probability, therefore, that the Morrison formation may be identical with some part of the Lower Cretaceous of the Texan region.

This suggestion and the argument supporting it would have force if Hill's generalized Texas section were applicable to the Canadian valley, and if sedimentation had been continuous from the Red Beds to the Dakota inclusive. Several years earlier Hill suggested the possible equivalence of the Atlantosaurus beds with the basal or Trinity group of the Comanche series.

[1] *Journal of Geology*, Vol. IX, pp. 343–52.

[2] *Journal of Geology*, Vol. X, pp. 36–58. [3] Pp. 56, 57.

The next step in the attempted correlation of the Morrison formation with the Comanche series was the announcement by Lee, at the Washington meeting of the Geological Society of America in 1902, that he had discovered *Gryphaea corrugata* Say, a characteristic Comanche fossil, in the Morrison shales on the Cimarron near Garrett, Oklahoma. Only brief abstracts of his paper, entitled "Age of the Atlantosaurus Beds," have been published.[1] His conclusion was that the non-marine Morrison formation is traceable laterally into marine shales of the Comanche series containing fossils that indicate a horizon within the Washita group, and that therefore the Morrison is of that age. Darton stated that he had observed similar relations on Butte Creek, southeastern Colorado, and he accepted Lee's interpretation. As Darton's current field-work covers the entire area from the Missouri River to the Wasatch Mountains, the immediate effect of the new correlation on the mapping and classification was far-reaching. In two published folios[2] of the *Geologic Atlas of the United States*, and in *Professional Paper No. 32*, "Geology and Underground Water Resources of the Central Great Plains,"[3] the Morrison formation is classified as Cretaceous and the chief reason assigned in every case is essentially that it "appears to be equivalent to a portion of the Comanche series in northwestern Oklahoma and southeastern Colorado."

Last June, through the courtesy of Mr. Darton, I was enabled to join Mr. Lee in the field and visit with him the exposures on the Purgatoire, the Cimarron, and the Canadian that he had previously studied. We were accompanied by Mr. C. W. Gilmore, of the U. S. National Museum, who is familiar with the dinosaurs of the Morrison. We also visited Mr. Darton's locality on Butte Creek, and later extended our observations as far south as Tucumcari, New Mexico.

[1] *Science*, New Series, Vol. XVII (1903), pp. 292, 293; Geological Society of America, *Bulletin*, Vol. XIV (1904), pp. 531, 532. *Science* gives a very brief account of the discussion that followed the reading of the paper but the reporter completely missed the point of Stanton's argument in opposition.

[2] "New Castle (Wyoming-South Dakota)," and "Edgemont (South Dakota-Nebraska)."

[3] See pp. 34, 96, 102, 141, and 164.

The general features of the whole region traversed have been well described by Lee[1] and the description need not be repeated except to say that it is a portion of the Great Plains region through which the principal streams have cut canyons several hundred feet deep, thus exposing good sections of the nearly horizontal strata. The Dakota sandstone always forms prominent cliffs near the top of the canyon walls and in some part of the course of each large stream the cutting extends as low as the Red Beds. The conditions are thus especially favorable for studying the strata immediately below the Dakota, as the Dakota itself, and many of the other hard beds are often continuously exposed for many miles, and furnish convenient, easily-recognized reference planes.

Purgatoire River.—Our first examinations were made on Purgatoire River at Higbee Plaza, about twenty miles south of La Junta, Colorado, where some marine invertebrate fossils, seen in the talus by Mr. Lee, gave us an important clue to the solution of our chief stratigraphic problem. At the top of the canyon wall is a cliff-forming gray and brown, mostly massive, cross-bedded sandstone, here fifty feet thick, but the upper part has been removed by modern erosion. Back from the river, where it passes under the Benton shales, its total thickness is not far from one hundred feet. This is unquestionably Dakota, as is attested by its stratigraphic position, its lithologic character and its flora, of which a few specimens, collected here and at other localities in the region, have been identified by Dr. Knowlton. Separated from this upper sandstone by about fifty feet of dark shales and thin-bedded sandstones, usually in large part covered by talus, is another lithologically similar coarse gray sandstone, varying in thickness from fifteen feet, or less, to sixty feet. This has also been referred to the Dakota by Lee, and probably by every geologist who has worked in southern Colorado, the intermediate more shaly portion being correlated with the "fire-clay band" of the earlier reports.

It was soon found that this intermediate shaly portion of the "Dakota" was the source of the fossils found in the talus below, and the fossils themselves were recognized as belonging to the

[1] *Journal of Geology*, Vol. IX, pp. 343–52; Vol. X, pp. 36–58; *Journal of Geography*, Vol. I, pp. 357–70; Vol. II, pp. 63–82.

Comanche fauna, although some of them belong to unnamed species and others are not well enough preserved to justify positive specific determination. Among those collected at this locality are:

Inoceramus comancheanus Cragin
Trigonia emoryi Conrad?
Cardium kansasense Meek
Cyprimeria sp.
Pholadomya sancti-sabae Roemer?

Farther up the Purgatoire, in the neighborhood of Chaquaqua Creek, where the underlying formations are better exposed, this fossiliferous horizon was easily recognized and fossils were collected from it in Browns Canyon, on the ridge east of Chaquaqua Creek, and in Iron Canyon. These localities added to the list of species *Protocardia texana* Conrad, *Leptosolen conradi* Meek and an unnamed species of *Tapes* (?) which also occurs in the Kiowa shales of Kansas. No specimens of *Gryphaea corrugata* were found on the Purgatoire, but the forms listed are elsewhere associates of that species and there is no doubt that the horizon is the equivalent of some part of the Washita group, and should be directly correlated with the Kiowa shales of southern Kansas. It must certainly be removed from the Dakota. The underlying sandstone, which has been called Lower Dakota, probably goes with the shales in the Comanche series, though the evidence on this point is not conclusive. Its variation in thickness and its absence from some sections would suggest a possible erosion interval after its deposition.

The variegated shales and the sandstones and limestones, of the Morrison with an average thickness of about 200 feet are partly exposed in the neighborhood of Higbee, but they may be better seen farther up the river especially near Chaquaqua Creek, about fifteen miles southwest of Higbee.

Here Mr. Lee had previously announced the occurrence of large dinosaurs, and Mr. Gilmore was able to recognize Brontosaurus and other dinosaur genera of the Morrison fauna. At the locality where the bones were seen in the greatest abundance, near the southeast corner of the Timpas quadrangle, the dinosaur horizon is about 200 feet below the marine Comanche fossils.

Beneath the Morrison formation, or possibly forming a member

of it, there are gypsiferous shales and gypsum varying greatly in thickness in different exposures, the maximum observed being 125 feet.

Immediately underlying the gypsum and forming the lowest exposures of the region are the Red Beds of which 200 or 300 feet are exposed over a considerable area, where the overlying formations have been removed from a broad, domelike uplift. They consist mainly of coarse, dark-red sandstones with some red and purplish shales and a few thin bands of white calcareous sandstone, which are conspicuous where they form the surface of low mesas. In the upper layers of the Red Beds, below the mouth of Chaquaqua Creek, Mr. Darton has collected a bone that has been identified as Belodon, indicating Triassic age.

The Purgatoire section may be summarized as follows:

1.	Benton shales, thickness probably not more than . . .	200	feet
2.	Dakota sandstone	100	"
3.	Dark shales and shaly sandstones with Comanche fauna .	50 to 100	"
4.	Coarse gray, cross-bedded sandstone	15 to 60	"
5.	Variegated shales, marls, sandstones and limestones of the Morrison formation, with Brontosaurus, etc.	200	"
6.	Gypsum and gypsiferous shales	70 to 125	"
7.	Red Beds with Belodon near top, exposed	200 to 300	"

With some variations in thickness and, in a few cases, the disappearance of one or more members, this section is essentially repeated throughout the area we examined in Oklahoma and New Mexico as far south as Tucumcari.

Two Buttes uplift.—On the way south from Lamar, Colorado, to the Cimarron in Oklahoma, the exposures were examined near Two Buttes, where Mr. Darton[1] had found the Comanche *Gryphaea corrugata*. Here the so-called Lower Dakota, beneath the fossiliferous Comanche shales and sandstones, appears to rest directly on the eroded surface of the Red Beds. Several additional Comanche species were collected, including *Pachydiscus brazoensis* (Shumard), and incidentally it was determined that the oyster bed reported by Darton as occurring in the Dakota of this region is probably beneath the true Dakota and in the Comanche.

[1] *Science*, New Series Vol. XXII, July 28, 1905, p. 120.

Rio Cimarron.—East of Garrett P. O. on the Cimarron in western Oklahoma, the Red Beds are exposed with a slight westerly dip which carries them below the surface near Garrett, and in that neighborhood the section extends up to the top of the Dakota.

The section generalized from observations covering a few square miles is as follows:

1.	Massive, coarse, cross-bedded gray and brown sandstone of the Dakota	150 feet
2.	Dark shales with layers of brown flaggy sandstone and bands of somewhat calcareous yellow sandstone with Comanche fauna	50 to 60 "
3.	Coarse, brown or gray cross-bedded sandstone with irregular bands of pebbles, apparently unconformable on the underlying stratum	4 to 15 "
4.	Variegated shales, gray sandstones and bands of siliceous limestone, referred to the Morrison, not well exposed. Thickness probably less than	100 "
5.	Red Beds.	

The Comanche horizon has yielded a varied fauna which is clearly the same as the Washita fauna that has long been known at Mesa Tucumcari, New Mexico, in northern Texas, and in the Kiowa shales of southern Kansas. The following species have been identified:

Gryphaea corrugata Say
Ostrea subovata Shumard
Ostrea quadriplicata Shumard
Plicatula incongrua Conrad
Inoceramus comancheanus Cragin
Gervilliopsis invaginata White
Trigonia emoryi Conrad
Protocardia multilineata Shumard
Pholadomya sancti-sabae Roemer?
Anchura kiowana Cragin?
Turritella seriatim-granulata Roemer
Hamites fremonti Marcou?
Pachydiscus brazoensis (Shumard).

This horizon was traced with practical continuity westward up the Cimarron to Folsom, New Mexico, a distance of about seventy-five miles across the strike. Its lithologic features show little variation and its thickness is never less than fifty feet nor more than one hundred

feet. Fossils gradually become less abundant in both species and individuals toward the west, until near Folsom only a small mactroid shell was found in considerable numbers. The most western point at which *Gryphaea corrugata* was collected is about thirty miles east of Folsom.

Along this line the coarse sandstone beneath the Comanche fossils is from fifteen to forty feet in thickness, and the variegated shales, sandstones, etc., of the Morrison increase to about 200 feet. Lithologically and stratigraphically this is identical with the Morrison beds seen on the Purgatoire where characteristic dinosaurs were collected. Fragmentary, undetermined, dinosaur remains were seen in it on the Cimarron near Exter, New Mexico.

Beneath the recognized Morrison some localities show forty to fifty feet of gypsum and gypsiferous shales resting on a massive white or pinkish sandstone which Mr. Lee has described as the Exter sandstone. It varies greatly in thickness, the maximum observed being eighty feet. The Exter is separated from the Red Beds by a striking angular unconformity, wherever the Red Beds are folded in local uplifts. The Red Beds show the usual character and at Tod's ranch, fifteen miles east of Folsom, they yielded fragmentary Triassic vertebrates.

From Folsom we traveled by rail to Tucumcari and from that place by wagon to Las Vegas.

Tucumcari region.—At Mesa Tucumcari the Dakota sandstone, eighty feet in thickness is underlain by sixty feet of fossiliferous Comanche shales and yellowish sandstones containing the same fauna as at Garrett, Oklahoma, with a few additions. The Morrison formation was not recognized but its place in the section is occupied by a talus slope with no exposures. The lower part of the section is composed of Red Beds of the ordinary character, overlain by friable, light-colored sandstone that is suggestive of the Exter.

At Mesa Redondo, a few miles south of Tucumcari, the space between the Comanche zone and the Red Beds is filled by 300 feet of heavy bedded gray and buff sandstones with intercalated thinner beds of red shales.

About ten miles northwest of Tucumcari station the section shows

[1] *Journal of Geology*, Vol. X (1902), p. 45.

considerable change. The Comanche fossiliferous zone, here only twenty-five feet thick, rests on 100 feet of coarse gray cross-bedded sandstone which in turn is underlain by 300 feet of variegated shales and sandstones very similar to those of the Morrison on the Cimarron and the Purgatoire. Fragmentary bones of large dinosaurs are common in these shales but none of these collected was sufficiently characteristic to be identified.

On the north side of Canadian River, fifteen miles northwest of Tucumcari, a similar section is exposed with only twenty feet of fossiliferous Comanche, and this is the last point in this direction at which Comanche fossils were found in place. Farther north and west in the neighborhood of Sanchez and on the upper course of the Rio Concha, the stratigraphic place of the Comanche is occupied by an inconspicuous shaly band in which no fossils were found. The other members of the section remain practically unchanged.

An occurrence of Unio previously discovered by Mr. Lee about 500 feet below the top of the Red Beds on Rio Concha is worthy of mention as indicating the post-Paleozoic age of that much of the Red Beds.

Canyon City.—At the end of the field season I visited the well-known Morrison locality in Garden Park, eight or nine miles north of Canyon City, Colorado. On Oil Creek, below Garden Park and about a mile south of the "Marsh quarry," which has yielded so many dinosaurs, the Dakota sandstone and associated strata are well exposed with a dip of 17° S. E. Guided by the experience gained on the Purgatoire and the Cimarron a brief search in the shaly strata beneath the upper cliff of Dakota sandstone was rewarded by the discovery of plentiful marine fossils that belong to the Comanche fauna. Those collected include *Pholadomya sancti-sabae* Roemer, a *Tapes* (?), a *Lingula* and a small mactroid shell, all of which occur in the Kiowa shales of Kansas. The cliffs at this point show the following section:

1.	Rather massive gray Dakota sandstone overlain by Benton shale	100 feet
2.	Dark gray shales alternating with thin-bedded sandstones. Marine Comanche fossils at 35 feet from top	85 "
3.	Massive gray sandstone with bands of fine conglomerate near top	35 "

4. Chocolate, reddish, and variegated shales and variable sandstones of the Morrison. Only upper part here exposed. Total thickness probably . . . . . 300 or 400 "

The general section of the region includes the entire Upper Cretaceous and a considerable thickness of Red Beds and Paleozoic.

Under the guidance of Mr. Edward Felch, who has had personal knowledge of all the vertebrate collecting that has been done in the neighborhood, I visited the various quarries that were worked by Marsh, Cope, and Hatcher, and determined that they are all on horizons below the Comanche fossiliferous bed and below the sandstone immediately underlying it. It is evident therefore that the Morrison formation is no more closely related to the Dakota near Canyon City than it is at other localities.

Extent of the Comanche Sea.—It has now been shown that the Comanche sea extended as far northwest as Canyon City, Colorado, and that its sediments overlie the Morrison in an area more than 100 miles wide. How much farther it extended in that direction is not known, as no special search for paleontologic evidence has yet been made, though the recent discovery by Prof. S. W. Williston[1] of Comanche species of fish teeth in the "upper part of the Atlantosaurus beds" near Lander, Wyoming, suggests the possibility of much greater extension.

This leads to the question whether the Fuson and Lakota formations, which have been differentiated from the Dakota in the Black Hills, should be identified respectively with the Comanche shaly beds and the underlying sandstone which hold the same stratigraphic positions in southern Colorado and New Mexico. Such an identification is plausible, and yet it seems to me that it is not warranted by the evidence now in hand. The Fuson formation is apparently non-marine, and, judging from the descriptions, its lithologic character is different from that of the Comanche shales and sandstones. It contains a flora which is comparable with that of the lower Potomac, and has nothing in common with the Dakota flora, which is of much later type. On the other hand, the Comanche[2] of Colorado

[1] *Journal of Geology*, Vol. XIII (1905), p. 347.

[2] The term Comanche throughout this paper is used as a general term of correlation—not as a formation name.

and New Mexico is the equivalent, in part at least, of the Kiowa and Mentor beds of Kansas which are very intimately connected with the Dakota, as Gould[1] has pointed out. This connection is shown by the flora as well as by apparent stratigraphic continuity. The Cheyenne sandstone which underlies the Kiowa in southern Kansas contains a flora not yet fully studied which is of the same type as the Dakota flora and includes some identical species.

In the neighborhood of Marquette, central Kansas, there are sandstone bands with Dakota species of plants intercalated in the marine beds with characteristic Comanche fauna. The paleobotanic evidence therefore tends to place the Fuson formation considerably lower in the general geologic column than the shaly Comanche beds beneath the Dakota in Colorado and Kansas.

Age of the Morrison.—The question whether the Morrison formation is Jurassic or Cretaceous is still to be answered, and if a satisfactory answer is ever received it will doubtless be from vertebrate paleontology, aided by careful stratigraphic methods. If the Morrison is Cretaceous, the proof that it is so will not be by tracing it directly into marine Cretaceous strata. It has been shown that the beds supposed to be thus connected with it overlie it for more than 100 miles across the strike. But these overlying beds are by no means the earliest Cretaceous, and there is still room for the Morrison within that system if the fauna requires such a reference. On the other hand, there is ample space for it in the Jurassic[2] not otherwise represented in the region by sediments, and before the final decision is made the character of the flora in the Fuson formation of the Black Hills and in the Kootanie of Montana should be given due weight, and these formations should be closely studied and searched for other evidence.

In this connection I may quote from the late Clarence King who, in speaking of paleontologists as "these scientific autocrats," says:[3]

[1] *American Journal of Science*, 4th series, Vol. V (1898), pp. 169–75; *American Geologist*, Vol. XXV, pp. 10–40.

[2] The marine Jurassic Sundance formation, characterized by *Cardioceras cordiforme* M & H, etc., on which the Morrison rests in the northern area, does not represent the latest Jurassic according to European standards

[3] *Report Chief of Engineers*, U. S. Army, 1875, p. 919.

It is the misfortune of geology to be more or less dependent on this branch of specialists. Without their specific determinations the geological maps, even, cannot receive their ultimate color designations, nor can reports, which, like ours, involve a wide range of stratigraphy, be safely written.

It may seem autocratic, but in these days the paleontologist insists, not only that his specific determinations must be used, but that he must be consulted as to the interpretation that is placed upon his lists, and especially he insists that the geologist must know what horizon yielded the fossils under discussion before he uses them in stratigraphy and correlation.