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ORIGIN AND DISTRIBUTION OF THE MORRISON FORMATION [1]

BY CHARLES C. MOOK

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INTRODUCTION

The age of the Morrison formation is necessarily bound up with the question of its origin and the physiographic conditions under which it was deposited. The present paper is a study in this direction. The writer was sent into the field in the summers of 1913 and 1914 by Prof. H. F. Osborn to study the Morrison formation in connection with his forthcoming monograph on the sauropod dinosaurs. Considerable time has been spent in the winter of 1913-1914 and in the past fall in assembling the results of this field study, together with a thorough study of the literature of the subject. Some of the conclusions from these studies are given in the present communication. The Morrison formation is one of those series of beds which have been the subject of considerable controversy. By the workers on the Hayden and other early surveys they were known as "variegated beds," Jurassic beds, Dakota beds, Lower Dakota beds, Atlantosaurus beds, and in part Flaming Gorge formation. Later they have been known locally as the Beulah shales, Como beds, McElmo beds, and Gunnison formation. These local names

[1] Contribution to the symposium held at the Philadelphia meeting of the Society December 30, 1914.

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are all given to parts of the same formation, and it is best to drop them, in a general discussion, in favor of the name Morrison.

Distribution and Thickness of the Morrison

The Morrison, in the broad sense, is widely distributed. At the type locality in Colorado it is poorly exposed. It occurs in the hog-backs along the eastern border of the Rocky Mountain front range, from the Laramie Mountains south to the central parts of New Mexico; in the Grand River Valley and tributaries in western Colorado and Utah; in the canyons of streams tributary to the San Juan River in southwestern Colorado; south of the Uinta Mountains and in the Grand Hog-back in

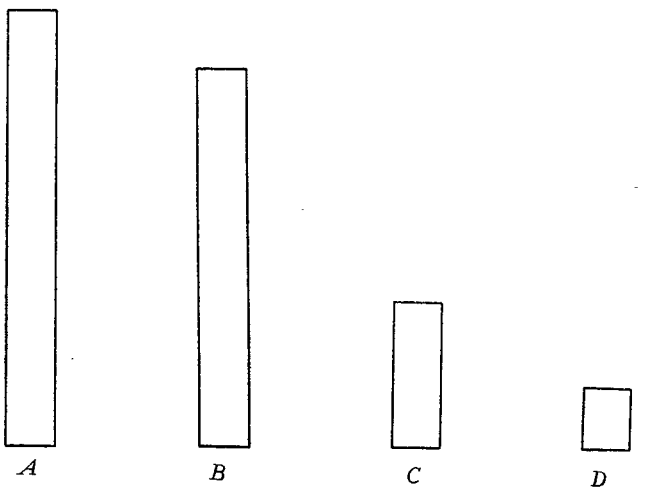

Figure 1.—*Diagrammatic Representation of the Thickness of the Morrison Formation in various Areas from South to North*

A, maximum thickness in the Telluride quadrangle, Colorado; B, thickness near Mack, Colorado; C, thickness near Tensleep, Wyoming; D, thickness near Belt Creek, Montana. Scale, 400 feet to 1 inch.

western Colorado and eastern Utah; in a few isolated areas in Montana, around the flanks of the Bighorn, Owl Creek, and Wind River Mountains; in local uplifts and faulted blocks in eastern and central Wyoming, and around most of the rim of the Black Hills.

In the southwestern areas the Morrison, or McElmo, has a considerable thickness; near Green River, Utah, it is over 1,000 feet thick, according to Lupton; in the Telluride quadrangle it is reported by Cross to be 900 feet thick; near Grand Junction and Mack, in the Grand River Valley, it is about 700 feet thick; south of the Uinta Mountains it is about 650

feet thick; in the Owl Creek and Bighorn Mountains it is about 200 to 250 feet thick, and in central Montana it is less than 100 feet thick. From this it is seen to thin out toward the north. It is possible, however, that the Kootenie may in part be equivalent to the Morrison. This would reduce this northward thinning.

Eastward from the Telluride area, the formation is about 450 feet thick in the Crested Butte quadrangle, 350 feet (possibly a little more) near Cañon City, and 200 feet or less in the canyons in eastern Colorado. There is thus a decided thinning toward the east.

Toward the northeast, the formation is about 400 feet thick in the Encampment district, in southern Wyoming, 200 to 250 feet in the

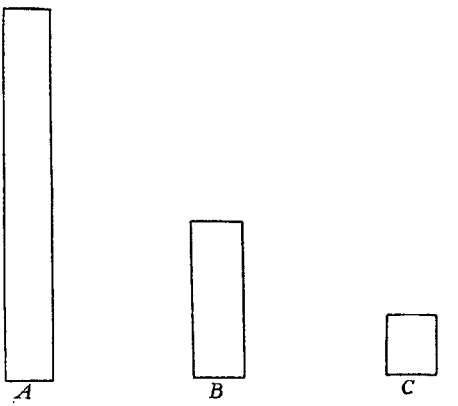

FIGURE 2.—*Diagrammatic Representation of the Thickness of the Morrison Formation in various Areas from West to East*

A, thickness near Mack, Colorado; B, thickness at Garden Park, near Cañon City, Colorado; C, thickness at Red Rocks Canyon, in eastern Colorado. Scale, 400 feet to 1 inch.

vicinity of Rawlins and Como Bluff, and 100 feet or less around the Black Hills. There is also, according to this, a decided thinning toward the northeast.

CRITERIA FOR DETERMINING THE ORIGIN OF THE FORMATION

The formation is made up essentially of fine-grained massive materials, often referred to as "joint-clays," of sandstone, shale, a very little medium-grained conglomerate, and some limestone in thin beds. Many of the sandstones are arkosic, especially those near the base of the formation. Many of the sandstones and some of the so-called clays are extremely calcareous, so that it is difficult to decide, in some cases, whether

a certain specimen should be called calcareous shale or argillaceous limestone. Many of the "joint-clays," when examined with the microscope, are seen to be exceedingly fine-grained sandstones, sometimes with a matrix of hematite, and not clay at all. True kaolinic clays do, however, occur in some abundance. The colors of the formation vary to a great degree, giving rise to the term variegated beds, often applied to the formation. The clays are, in places, brick red or chocolate colored, due to the presence of large amounts of hematite; at other places they are gray, white, purple, or nearly black. The sandstones are usually yellow or white, but may be reddish. They are often made up largely of angular or rounded quartz, as the case may be, with replaced feldspars, calcite, and minor amounts of volcanic matters and other material. The lime-

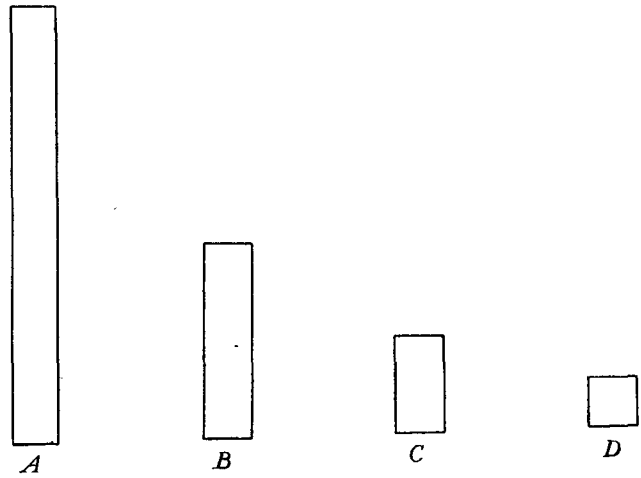

FIGURE 3.—*Diagrammatic Representation of the Thickness of the Morrison Formation in various Areas from Southwest to Northeast*

A, maximum thickness in the Telluride quadrangle, Colorado; B, thickness in the Encampment district, southern Wyoming; C, thickness at Como Bluff, Wyoming; D, thickness near Devils Tower, Wyoming. Scale, 400 feet to 1 inch.

stones are usually thin, are often fine grained, and generally argillaceous.

Perhaps the most characteristic features of the Morrison are the variegated colors of most of the outcrops, the "uniformly variable" character of the succession of beds, and the presence of distinct channeling, with sandstone lenses occupying depressions in the underlying clays.

The origin of the Morrison formation has been the subject of a number of discussions in the past. Some workers have held that the beds were deposited in the sea; others, such as C. A. White, have held that the formation was deposited in a great lake. Riggs has advanced the theory

that deposition took place in a number of small lakes, with deltas on the borders, and possibly by rivers as well. Hatcher maintained that the deposits were laid down in a series of floodplains, with alternating deposition and erosion at successive levels.

In discussing this subject several considerations are of prime importance, other factors being accessory. The important facts to be considered are these: 1, the formation was laid down on a comparatively level surface; 2, the fauna is exclusively of the continental type, either land or fresh water; 3, the nature of the sediments is such as to imply deposition in or by quiet water at times, and again in more agitated waters; 4, the thickness of the formation is much greater in the west, and especially the southwest, than in any of the other Morrison areas, gradually thinning out toward the east and northeast; 5, internal structures, such as channeling; 6, the "uniformly variable" character of the succession of beds. Other factors to be considered are: the presence and kind of cross-bedding, the condition of preservation of the fauna and flora, the variegated colors, etc.

Conclusions

From these facts as starting-points we may infer that the Morrison was deposited on a wide-spread plain of low relief, and probably of low altitude. It is the result of alternating deposition and erosion, there being no place, probably, where deposition went on continuously from the time when the first beds were laid down until the uppermost beds were deposited. The source of the material was to the west, and especially the southwest, of the present area of its outcrops.

These conditions may have been satisfied by such a history as the following: In Jurassic time there was a crustal disturbance and slight upheaval in the present Rocky Mountain area. This disturbance is shown in the undulating character of the Red Beds noticed by Lee in northern New Mexico. Following this upheaval, erosion progressed steadily until much of the Rocky Mountain area was reduced to a fairly level plain. At the end of the interval, when the mountains to the west were fairly well reduced in height and extent, the Rocky Mountain plain, if it may be so called, was low and flat and the site of numerous lakes and swamps. Erosion in the plain itself was no longer possible to any considerable extent. Erosion of the mountainous areas to the west was still possible, however, and went forward steadily. It is the products of this later erosion which now comprise the Morrison formation. A few large streams, flowing eastward or northeastward from the old mountains,

flowed across the swampy plains and deposited silt over broad floodplains. Lakes were probably present and were the seat of deposition of many of the fine-banded clays and sandstones. Deltas into these lakes, as suggested by Riggs, probably account for some of the coarser local sandstone bodies. Some of the streams from the old mountains were much larger than others and carried a greater load. From streams of varying size and with different loads the deposits formed could not be uniform throughout the whole area of deposition. Further than this, streams of low gradient, such as those postulated, would deposit much of their material before reaching a great distance from the original source. According to the evidence from the fauna and flora, the depositional area was not an arid one, certainly not through its entire extent. Rainfall was probably fairly abundant, throughout much of the area at least, and new systems of streams were produced on the plain itself. The basal beds of formation were derived to a certain extent from the strata of the formations underlying, as well as from the mountain areas. These streams consequent upon the deposition plain would also carry a considerable load, and in this way the formation would be built out from itself. Material at the outer fringe of the area would therefore be much younger than material deposited at the same distance above the base nearer the source of supply. Shifting of channels would also result in erosion of material already deposited. In this way a series of deposits might be formed over a wide area, comparatively thin, with very great lateral and vertical variation, and yet present the same kind of characters over the whole area. Most of the formation being fine grained, the streams were probably mostly sluggish. Occasional coarse beds, with cross-bedding of the stream type, testify, however, to a considerable amount of carrying power and a fairly swift current at times.

The whole area probably remained nearly level throughout the whole depositional interval, though there were probably slight irregularities. The difference in thickness between the beds at the southwest and those at the northeast, providing the base rested on a level surface, is not enough to contradict this statement. The southwestern areas, near the sources of the material, probably were, at times, slightly higher than the northern and eastern areas. The sediments in the southwestern areas contain a larger proportion of coarse material and may have been built up above the level of the larger part of the plain. It is also possible that depression took place in the southwestern part of the area in the later part of Morrison time, allowing fine silts to be deposited farther southwest. It is noticeable that the fine clays in the southwestern area are confined largely to the upper half or third of the formation.

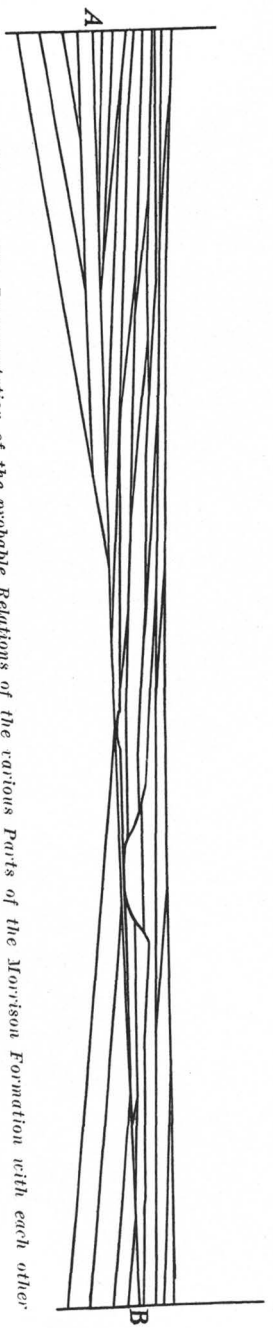

FIGURE 4.—*Diagrammatic Representation of the probable Relations of the various Parts of the Morrison Formation with each other before Burial*

A–B, peneplaned surface upon which the Morrison rests

Such a history as outlined above will fit the conditions observed in the Morrison formation, and it is probable that its history was something of that nature.

It is important to observe that a given thickness of beds deposited under the conditions of alternate deposition indicated would require a much longer time for its formation than beds deposited under conditions of continuous deposition. It is perfectly in accordance with the above outlined history for parts of the formation to be Upper Jurassic in age and for other parts to be distinctly later than the Jurassic, perhaps well up in the Comanchian. It could even be that practically all the beds represented in a single outcrop of the formation might be Jurassic, and that in another area, not a great distance off, be made up largely of beds of Comanchian age. The accompanying diagram is an attempt to show, in a very schematic way, the kind of cross-section the formation would have immediately after deposition and before being covered or disturbed.

If the above interpretation be correct, great care must be taken in judging the age of the formation as a whole, from a fauna or flora of definite age, in any one locality or level. *It will only be possible to decide definitely the age of the various parts of the formation when extensive collections have been made from a number of levels in many localities.*