ART. XIV.—*A Dicotyledonous Flora in the Type Section of the Morrison Formation*;^{*} by F. H. KNOWLTON.

There has been renewed discussion within the past few years regarding the age of the Morrison formation, that is, as to whether it should be placed in the upper part of the Jurassic or in the overlying Cretaceous. The divergence of opinion on this point among stratigraphers and paleontologists was well brought out in a symposium on "The close of Jurassic and opening of Cretaceous time in North America," given before the Paleontological Society in 1914, though the majority opinion among those who participated in the discussion appeared to favor placing it in the Cretaceous. The object of the present paper is to present some recently acquired paleobotanical evidence, that, if correctly interpreted, seems to refer the upper part of the Morrison formation of the type locality definitely to the Cretaceous, and, further, to place it much higher in the Cretaceous than has been thought possible.

The dicotyledonous plants to be considered in this paper were collected in 1916 by W. T. Lee, of the United States Geological Survey. They came from the type section of the Morrison formation at Morrison, Colorado, occurring about 15 feet below the top of the formation in the north wall of the so-called gap at this place. The matrix bearing the plants is a hard, shaly, somewhat carbonaceous sandstone.

In view of the fact that the plants here described are of a type not before known to occur in the Morrison formation, it is naturally of the utmost importance to fix their position definitely with reference to the limits of the type section of this formation. Mr. Lee was fortunate in having with him on the occasion of his visit to Morrison, Mr. George L. Cannon, of Denver, who not only assisted in excavating many of the dinosaurs described by Marsh from these beds, but who also assisted in measuring the section and preparing the data on which the Morrison formation was established. He pointed out to Mr. Lee the top of the beds as originally included within the formation, and there can, therefore, be no doubt as to the position of the plant-bearing layer,

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which, as already stated, is about 15 feet below the upper limit of the formation. A fuller discussion of this type section of the Morrison, and a recommendation for redefinition, will be found in the paper by Mr. Lee which accompanies this paper.

The material studied consists of about 20 pieces of matrix and has afforded the following forms:

Salix sp., cf. *Salix proteæfolia* Lesquereux.

? *Ficus daphnogenoides* (Heer) Berry.

Ficus magnoliæfolia Lesquereux.

Cf. *Eucalyptus dakotensis* Lesquereux.

Phyllites sp.

Phyllites sp.

This small flora is thus seen to comprise six distinct forms, of which one species is positively, and three are provisionally identified.

Ficus magnoliæfolia, the form positively determined, was first described from the supposed Dakota at Morrison, Colorado, and was later reported by Lesquereux as present in the Dakota sandstone of Kansas.

Ficus daphnogenoides was established on material from the Dakota sandstone of Nebraska, and has since been found in the Woodbine formation at Arthur's Bluff, Texas, the Cheyenne formation at Chatman Creek, Kansas, the Magothy formation of New Jersey, Delaware, Maryland, and elsewhere, the Raritan formation of New Jersey, the Bladen formation of North Carolina, and the Tuscaloosa formation of Alabama.

Eucalyptus dakotensis has the Dakota sandstone of Kansas as the type and only previously known locality. It may be only a very narrow leaf of *Salix proteæfolia*.

The leaves described by Lesquereux under the name of *Salix proteæfolia* came originally from the Dakota sandstone of Nebraska, and were subsequently found at many localities in the Dakota of Kansas, and are present in the supposed "Dakota" of Colorado.

The above comparisons show very clearly that the affinity of this Morrison flora is undoubtedly with the flora of Dakota sandstone, or perhaps it would be better to say, with the plant-bearing beds possibly in the upper part of the Lower Cretaceous, or the lower part of the Upper Cretaceous which the term Dakota is now made to cover. It is perhaps safe to say that without the knowledge that this flora came from beds hitherto re-

ferred without question to the Morrison formation, it might have been identified as a Dakota flora, or rather with that from the so-called Colorado "Dakota." These plants have special significance because they came from the type Morrison; because they are biologically higher forms than have heretofore been found in this formation; and because practically only two localities were heretofore known to have afforded Morrison plant remains, these being the Freezeout Hills, Carbon County, Wyoming, and the eastern part of the Bighorn Basin, Wyoming.

The plants from the Freezeout Hills comprise 23 species, two of which are based on coniferous wood and the others on silicified trunks of cycads. To the latter Ward gave the name *Cycadella*, but according to Wieland this is not sufficiently distinct from the older genus *Cycadeoidea*.

The plants known from the Bighorn Basin embrace six forms, three of which are ferns, one an equisetum, and two are cycads based on foliage.

No dicotyledons have been found in either locality, and there is ordinarily no hesitation in referring both the Freezeout Hills and Bighorn Basin floras to the Lower Cretaceous. This matter will be referred to on a later page.

The type section of the original Morrison formation has a thickness of about 300 feet and is separated from the overlying beds by carbonaceous material which has the appearance of being a fossil soil. These overlying beds are about 75 feet thick and otherwise have been interpreted as identical with beds at Colorado Springs and Castle Rock, Colorado, that have been referred to the Purgatoire formation. Above the so-called Purgatoire formation is the Dakota sandstone of the region.

Lee made a small collection of plants in the presumed Purgatoire formation at Morrison about 25 feet above its base. The only species recognizable is *Sapindus morrisoni* Lesquereux, a form well known in the Dakota flora of the Denver Basin. The presence of plants in this so-called Purgatoire formation naturally suggests a review of what has long been known as the Dakota flora of the Denver Basin, especially since, according to Mr. Cannon, most if not all of the known "Dakota flora" of the Denver Basin came from the presumed Purgatoire formation and not from the Dakota as now recognized.

In the complete paper, of which the present is an abstract, I have given a revision of this "Dakota flora" of the Denver Basin. It includes 21 species, all but 3 of which came from the beds of Morrison. It further develops that only 6 of the 18 species are confined to the beds at Morrison, the others being widely distributed in the Dakota, Cheyenne, Woodbine, Raritan, Magothy, Bladen, Eutaw, Black Creek, Tuscaloosa, etc.

In attempting to interpret the relation of the "Dakota" of the Denver Basin to the Dakota in the type area as well as other areas where it has been identified, it appears that several views are possible. The type area for the Dakota is northeastern Nebraska. Here the Dakota has not been subdivided and is followed immediately by the Benton. In southern Kansas the leaf-bearing Dakota rests on the marine Kiowa shale, and this in turn on the Cheyenne sandstone, which contains a flora that certainly has much in common with the overlying Dakota. At Morrison the section appears to be similar to the Kansas section, that is, the Dakota as now delimited rests on the shale of the upper part of the Purgatoire formation, which in turn is underlain by the sandstone of the Purgatoire—the so-called lower Dakota which contains the "Dakota flora" of the Morrison region.

Are the strata at Morrison which contain similar plant forms to be referred to separate series? Are they to be correlated with the ordinary leaf-bearing Dakota of the Kansas section or with the Cheyenne, or are they to be considered as a group with the three units (Dakota, Kiowa, and Cheyenne) as formations? The data available are perhaps not sufficient to permit a definite answer to these questions, though it may be pointed out that certain observed facts of stratigraphy and physiography would be harmonized or rationalized by considering the Dakota as a group within the Upper Cretaceous and embracing the several units as formations. This, of course, involves the age assignment of the Cheyenne sandstone. As already pointed out, this forms a part of the Washita division of the Comanche series that has usually been placed by American geologists at the top of the Lower Cretaceous. But, as Berry¹ has recently pointed out, foreign paleontologists long ago indicated

¹ Berry, E. W., Maryland Geol. Survey, Upper Cretaceous, text, p. 222, 1916.

their belief that it is of Cenomanian age. Berry places it without qualification in the Upper Cretaceous. A very large Cheyenne flora is known, and although it has not been thoroughly studied, Berry and I have looked it over with some care and agree perfectly that its affinity is undoubtedly with the Upper Cretaceous. Whatever may be ultimately decided as to the relation between the Cheyenne and the type Dakota or with the so-called Dakota of the Denver Basin, I do not think there is any doubt about the "Morrison" plants being in the Upper Cretaceous flora.

A further word may be said on the interpretation to be given the stratigraphic position of the plant-bearing strata of the type Morrison. The floras previously known from beds regarded as of Morrison age, or in the approximate position of the Morrison, are without dicotyledons and there is no hesitation in referring them to the Lower Cretaceous. It is difficult to reconcile these floras with the dicotyledonous flora from the type sections of the Morrison. Is it not within the limits of possibility that certain beds that have been identified elsewhere as of Morrison age may not be the same age as the Morrison in its type section?

A hasty review of the Dinosaur fauna of the type Morrison, which includes some five or six species, shows that several of the species have been reported elsewhere, but according to C. W. Gilmore, of the U. S. National Museum, not a single one of these species has with certainty been identified outside the type area.

Conclusion.

The conclusion is reached that the dicotyledonous flora discussed in this paper from the type section of the Morrison formation, finds its closest affinity with the so-called Dakota flora of the Denver Basin, a flora that is known to come in whole or in part from what is classed as the Purgatoire formation, and not from the Dakota as at present delimited. Under the classification which places the Purgatoire formation,—the so-called lower Dakota at Morrison—in the Lower Cretaceous series, the "Morrison flora" occurs below the base of this series. The suggested classification makes Purgatoire include the plant-bearing part of the original Morrison,

and makes it all basal Upper Cretaceous. Further, Lee's interpretation of the physiographic history of the region, indicating a relatively short time interval between the type Morrison and the sandstone formerly called lower Dakota, and making the main stratigraphic break at the base of the Saurian conglomerate the line of separation between Lower Cretaceous and Upper Cretaceous, undoubtedly finds support in this flora.