ART. XIII.—*The Age of the Brandon Lignite and Flora;*
by EDWARD W. BERRY.

The small deposit of lignite near Brandon, Vermont, has excited an interest out of all proportion to its size ever since its discovery in 1848. This was due, in the first instance, to its uniqueness among New England deposits and to the diversity of strange fossil fruits which it contained. Its location makes it of very great importance in any broad consideration of the evolution and migration of the fossil floras of eastern North America, since except for a few scattered and small florules in New Jersey, Maryland and Virginia and these for the most part quite different in age, it is the sole relic of Tertiary vegetation north of Georgia, and it has also an important bearing on geological climates provided its age can be determined with reasonable accuracy.

I received recently from W. A. Nelson, the State Geologist of Tennessee, two fossil fruits from the clays of the western part of that state which prove to be unmistakably related to forms described from Brandon and not known from any other localities. This has led to a reawakening of my interest in the Brandon flora and to the present attempt to fix its age more definitely.

The late Edward Hitchcock was the first one to describe the Brandon locality and some of its fossil fruits, which he did in 1853,¹ subsequently reprinting what is substantially the same account in his *Geology of Vermont* eight years later.² The deposit lies at the western base of the Green Mountains about two miles northeast of the town of Brandon in a region of Cambrian quartzites, schists and dolomites, and is now entirely hidden by Pleistocene deposits. Associated with the lignite are clays and limonite, both formerly worked at different times for iron, paint and paper clay. Its interest may be indicated by the fact that there are no comparable Tertiary lignites within upwards of one thousand miles, that the contained flora is largely unique and is, except for Pleistocene, the only fossil flora thus far discovered in

¹ Hitchcock, E., Description of a Brown Coal Deposit in Brandon, Vermont, this Journal, (2) vol. 15, pp. 95-104, 1853.

² Hitchcock, E., *Geology of Vermont*, vol. 1, pp. 226-234, 1861.

Vermont, and also except for the Pleistocene, the only trace of post-Paleozoic deposits in that state.

Hitchcock submitted samples of the wood to Professor Bailey, who pronounced them to be exclusively dicotyledonous; and fruits to Lesquereux, who published an account of them in 1861³ and freely discussed their probable age. Fifty years later Knowlton published additional notes and announced the presence of coniferous wood.⁴ During the coal strike of 1902-1903 the old workings were reopened and G. H. Perkins, the State Geologist of Vermont, was thereby enabled to secure an unparalleled collection of the fruits, which he described and figured in several admirable papers published in 1905 and 1906,⁵ together with geological notes by Dale and Woodworth, and an account of the microscopic character of some of the lignites by Jeffrey & Chrysler.⁶

With this brief synopsis of the history of the investigations I turn briefly to a consideration of the views regarding the age of the deposits. Opinion has been almost unanimous from the first that the deposit was of Tertiary age, and this conclusion appears to me to be indisputable. Hitchcock stated with some slight reservation that the deposit was Pliocene or newer Tertiary, and made the rather bold assertion that it represented a marine Tertiary formation that extended from Canada to Alabama, the latter opinion being based upon the wide distribution of limonite or brown hematite, really of diverse origin and without bearing on the question.

Hitchcock was undoubtedly influenced in reaching an opinion regarding the age of the lignite by Lesquereux, who had identified five out of a total of twenty-three then known forms with European Miocene species, chiefly from Oeningen in Baden (Tortonian stage). At the same time, Lesquereux noted resemblances to plants from the "upper lignitic formation which extends on both sides of the Mississippi, and which I had opportunity to explore

³ Lesquereux, L., *Fossil Fruits from Lignites at Brandon, Vermont*, this Journal, (2) vol. 32, pp. 355-363, 1861; *Geology of Vermont*, vol. 2, pp. 712-713, 1861.

⁴ Knowlton, F. H., *Notes on the Fossil Fruits and Lignites at Brandon, Vermont*, Bull. Torrey Bot. Club, vol. 29, pp. 635-641, pl. 25, 1902.

⁵ Perkins, G. H., Rept. State Geol. 1903-1904, pp. 153-162, 174-212, t. f. 8, pls. 75-81: Idem for 1905-1906, pp. 188-194, 201-230, pls. 46-48, 52-58: Bull. Geol. Soc. Am., vol. 16, pp. 449-516, pls. 86, 87, 1905.

⁶ Jeffrey & Chrysler in Perkins, Rept. State Geol. for 1905-1906, pp. 195-201, pls. 49-51.

in Arkansas.” The latter refers to formations now known to be exclusively of Eocene age (Wilcox, Claiborne and Jackson groups), which Lesquereux also regarded as of Miocene age, both views being also those of Newberry.

Notwithstanding the opinion of Lesquereux, Dana, in the first and subsequent additions of his *Manual*, shrewdly placed the Brandon lignite in the Eocene, because of the stratigraphic relations of the Gulf deposits, Knowlton (op. cit.) appears to have been of the opinion that the Brandon deposit was of Miocene age, and Woodworth concurred in this view, stating that the earlier Tertiary was a time of erosion in New England. The current opinion founded on this tradition appears to definitely place the deposits in the Miocene, Chamberlin & Salisbury’s *Text* going so far as to label them the Brandon formation and stating, quite without basis, their occurrence in Vermont, Pennsylvania and Georgia.⁷ In the study of the Eocene floras of the Gulf states I became so far convinced that the Brandon flora was not Miocene that I stated in the introduction to my work on the lower Eocene flora that the Brandon flora was pre-Miocene.⁸

The cumulative evidence for this opinion will now be given. The flora of Brandon as made known through the researches of Perkins, and to a less extent by the work of the other authors previously mentioned, comprises about 150 species of fruits and seeds and two or three additional forms based upon wood structure. None of these have in late years been regarded as identical with previously described forms from deposits of known age, and this conclusion appears to be fairly well-founded for the great majority of the Brandon species. Although I would be inclined to depreciate the multiplicity of species described by Perkins this in no wise affects the question of age.

The botanical character of the Brandon flora is difficult to evaluate owing to our lack of knowledge of the precise botanical relationship of the majority of the fruits. Nevertheless the greater proportion of the forms are such as would be incapable of existence in New England under existing climatic conditions, and of genera present in the lignite that are found in the existing flora of New England, namely *Juglans*, *Hicoria*, *Nyssa*, *Pinus*, etc., *Jug-*

⁷ *Manual*, vol. III, p. 261.

⁸ U. S. Geol. Surv. Prof. Paper 91, p. 6, 1916.

lans and *Hicoria* come from a warm climate ancestry and the center of distribution of existing *Nyssas* is in the South Atlantic states. In addition to these more definitely determined forms the Brandon flora contains a variety of so-called species, some of which to be sure are illy understood, that suggest relationship with existing tropical and sub-tropical *Menispermaceæ*, *Sapotaceæ*, *Rubiaceæ*, *Tiliaceæ*, *Malvaceæ*, *Cucurbitaceæ*, *Sapindaceæ*, and *Lauraceæ*. According to Jeffrey the bulk of the lignite studied microscopically belongs to the *Lauraceæ*, and both Lesquereux and Perkins have identified the genus *Cinnamomum* in this flora. The latter reaches its present northern limits in Florida (cultivated) and in the rain-forests of Formosa and southern Japan.

The Brandon flora could not have existed except in a humid warm climate. The question then is: Could this flora fit into the Miocene environment of Vermont? An affirmative answer was most natural when, following Heer's wonderful discoveries in the Arctic region, it was believed that the circumpolar floras extending to within a few degrees of the pole itself, were of Miocene age. This supposition has now been definitely disproved and the maximum northward spread of the Tertiary forests is known to have been much earlier, certainly in the Eocene as opposed to the Neogene portion of the Tertiary, and probably at a time corresponding to the time of the greatest northward extent of tropical floras in our Gulf states, which was in the late Eocene (Jackson) and earliest Oligocene (Vicksburg).

Although Miocene floras for comparison with the Brandon flora are practically nonexistent along the Atlantic coast of North America, traces of such floras as are recorded from Maryland and Virginia⁹ are of a decidedly more temperate facies than that of Brandon despite their much more southern and lower location. The largely undescribed flora from southern New Jersey (Bridgeton) which is of newer Tertiary age (late Miocene or early Pliocene) is also quite different from that of Brandon and indicative of less warm climatic conditions. More weighty perhaps in any consideration of Miocene climate is the evidence of the much more abundant marine faunas of the Atlantic Coastal Plain Miocene. These clearly

⁹ Berry, E. W., U. S. Geol. Surv. Prof. Paper 98 F, 1916.

indicate temperate oceanic waters and a marked, if not quantitatively great, lowering of temperatures in the Miocene, during which the marine life of the middle Atlantic coast penetrated southward to Florida and replaced the sub-tropical faunas of the upper Oligocene. The paleobotanical evidence of this change of climate is seen in the south in the presence of temperate forest trees such as the elm in the Aquitanian or Burdigalian Alum Bluff formation of Florida. I conclude from the foregoing considerations, which might be amplified with much greater detail, that the Brandon flora can not be of Miocene age.

More direct evidence of the age of the Brandon flora, largely unpublished, may now be summarized. I have already alluded to Lesquereux's discovery of a resemblance between the Brandon flora and that of the Eocene of the Mississippi embayment. This rests to some extent upon general facies and is not as conclusive as could be wished since in the one case we are dealing with coastal floras largely represented by leaf impressions, while in the other case we are dealing with an inland flora represented by fruits and seeds gathered by streams and deposited in a single limited basin, the two separated by over 1000 miles, mostly latitudinal in direction. In spite of these difficulties the peculiar Brandon genus *Monocarpellites*, whether an identical species or not I hesitate to say, is found in the Wilcox, as are several *Nyssa* stones. The genera *Juglans*, *Hicoria*, *Cinnamomum*, *Aristolochia* and *Sapindus* are present in both. An undescribed *Laurinoxylon* from the Wilcox is very close to the one so abundant at Brandon. *Nyssa* stones of large size and closely allied to, if not identical with, a Brandon type, occur in both the Claiborne and Jackson of the Gulf states.

The genus *Tricarpellites* to which Perkins refers twenty species of fruits from Brandon, is a genus founded by Bowerbank and known elsewhere from only the Ypresian stage of the Eocene of Sheppey. Moreover other of the Brandon fossils suggest comparisons with, and some are very close to, other Sheppey forms, the latter representing an early Eocene accumulation of fruits by a river system located in what is now the Thames basin. For example the genus *Monocarpellites*, so abundant at Brandon and present in the Wilcox, appears to be congeneric with Bowerbank's genus *Hightea*, which is a common

fossil at Sheppey. The most striking difference in the English flora is the abundance of the palms, and its more decidedly tropical character. Another fact bearing on the age of Brandon is that the coniferous wood described by Knowlton is so nearly related to a species described by Schmalhausen from the Eocene of southwestern Russia that the Brandon form is made a variety of the latter. Furthermore two fruits found in the Eocene of Maryland (Nanjemoy formation) and described as *Carpolithus* by Hollick¹⁰ are not only strictly comparable with fruits from Brandon which are referred variously to *Apeibopsis* and *Cucumites*, but both are likewise comparable with the genus *Wetherellia* founded by Bowerbank upon Ypresian forms from the London Clay of Sheppey.

Summarizing the foregoing statements they are seen to comprise, 1. general considerations of unsuitable climatic environment during the Miocene and an unlikeness between the Brandon flora and such Miocene floras as are known from the Atlantic coast of North America; 2. the presence of closely related, if not identical, species in the Eocene of Maryland, of the Mississippi embayment region, of southern England and of southwestern Russia.

These all point in the one direction and are sufficiently weighty to justify considering the Brandon lignite and its contained flora as of Eocene instead of Neogene age. Much as I dislike these terms I hesitate to attempt a closer correlation, since Eocene floras in North America are much more extensive and better known than Oligocene floras, and the possibilities of the Oligocene age of the Brandon deposit cannot be lost sight of, although the evidence derived from the extensive European Oligocene floras and the resemblance to American and other Eocene floras leads me to regard the Eocene age of the Brandon flora as the most probable of the two possible assumptions.

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¹⁰ Hollick, A., Md. Geol. Surv., Eocene, p. 258, pl. 64, figs. 11, 12, 1901.