

ART. XLV.—*The Matawan Formation of Maryland, Delaware, and New Jersey, and its relations to overlying and underlying Formations*; by WM. BULLOCK CLARK.

THE name Matawan was proposed by the author in an article published in the *Journal of Geology* in 1894 and was there described as equivalent in a general way to the term Clay Marls of Professor Cook. The chief characteristics of this series of strata had been briefly discussed, however, two years earlier in the *Annual Report of the State Geologist of New Jersey* for 1892. In this earlier publication the separation of the deposits into a lower clayey and an upper sandy member was indicated, although the names Crosswicks clays and Hazlet sands were not introduced until 1897 in an article published in the *Bulletin of the Geological Society of America*.

The work of the writer on the Cretaceous stratigraphy of the Middle Atlantic Coastal Plain has been conducted primarily for the U. S. Geological Survey, and was started in Monmouth County, New Jersey, beginning in 1891. The results of these early investigations, published the following year in the *Annual Report of the State Geologist of New Jersey* for 1892, which was accompanied by a "preliminary geological map," represent mainly the conclusions which were reached from a study of that local district. A wider extension of the studies after 1891, both in New Jersey and Maryland, led to the preparation of the fuller article published in the *Bulletin of the Geological Society of America* in 1897, in which certain modifications were made in earlier views. The practical completion of the detailed mapping of the Cretaceous formations in New Jersey and in Maryland the present season has now led, it is believed, to a fairly close approximation to a correct interpretation of the conditions represented in the entire province between the Potomac and the Raritan rivers. In the light of the Maryland work, the earliest maps prepared in New Jersey have been more or less modified in local details, although the general results remain the same.

In a discussion of the Coastal Plain formations of Maryland and New Jersey, it should be borne in mind that the entire series of Upper Cretaceous deposits amount to scarcely five hundred feet in total thickness, and that the beds, as far as known, are practically conformable throughout. Beginning with clays and sands slightly glauconitic, they pass over into greensand marls. Five formations have been defined and mapped, and several subdivisions of most of these formations described by the writer.

In order that the conclusions reached by the author and his associates may be clearly understood, the following discussion of the stratigraphic relations of the Matawan formation is

introduced. With the extension of the work southward from Monmouth County, and more particularly with the study of the stratigraphy in Maryland, we soon came to the conclusion that the reddish brown sands (Mt. Laurel sands, called Wenonah sand by the New Jersey Geological Survey) beneath the Lower Marl bed (Navesink marls) properly belonged with the Navesink marls and Redbank sands above rather than with the Matawan below. The Redbank sands were found to disappear in about the latitude of Philadelphia, bringing the Navesink marls in Camden, Gloucester, and Salem counties, New Jersey, into immediate contact with the Rancocas marls above, from which, however, they can be separated by their contained fossils and by their more or less distinctive materials. The Monmouth formation was established to embrace the three beds.* In Maryland; however, no such differentiation of the Monmouth is discernible, the only deposits found between the Matawan formation below and the Rancocas formation above being more or less homogeneous red sands, glauconitic from base to top. Earlier attempts to maintain the New Jersey subdivisions in Maryland have not proven satisfactory.† A proper division of the Cretaceous deposits would therefore call for a drawing of the line between the Matawan and Monmouth formations below rather than above the Mt. Laurel sands.

A lens of clays and interbedded sands lying beneath the typical Matawan at Cliffwood, New Jersey, on the shores of the Raritan Bay, and included by the writer in that formation in his "Preliminary Geological Map of portions of Monmouth and Middlesex counties, New Jersey," accompanying the report of the State Geologist for 1892, has been the subject of much discussion of late, although none of the views thus far advanced seem to afford an adequate explanation of the conditions there presented. The clays, which are more or less micaceous and at times sandy, possess many features in common with the typical Matawan deposits above, even to the occurrence now and then of patches of glauconite.‡ The interbedded sands, as well as the lack of continuity of the clay beds, suggest, on the other hand, conditions characteristic of the Raritan, although the deposits as a whole show quite marked differences from the typical

* Bull. Geol. Soc. Amer., vol. viii, pp. 315-358, 1897.

† The idea has been advanced that the Maryland Monmouth may perhaps represent the Mt. Laurel sands alone, and that the Navesink marls along with the Redbank sands have disappeared in Maryland, but the long distance between the last outcrop in New Jersey and the first occurrence on the west side of the Delaware Bay renders it unwise to draw such a conclusion from the data now at hand. The deposits have furnished, to be sure, specimens of *Belemnitella americana*, which is a distinctly lower Monmouth form farther north, but as they did not come from the higher beds of the Delaware-Maryland strata the evidence is not conclusive.

‡ Mr. E. W. Berry, on a recent visit to the locality, removed a small envelope full of glauconitic material from one of these patches below the debatable contact of the Matawan. The writer has also found glauconite in these beds, although the patches are very infrequent.

Raritan beds. The most important feature connected with this occurrence is the presence of a typical Cretaceous marine fauna,* part of the species being similar to the overlying Matawan, and a flora* containing many representatives of genera more recent than those in the Raritan below. Mr. E. W. Berry,† who has recently studied this flora, finds that only 37 per cent of the forms occur in the Raritan and among these the oldest and most characteristic types are lacking. In an earlier communication I referred to the lack of a clear line of separation between these beds and the typical Matawan above. At the time of my first and only study of the occurrence, thirteen years ago, the sections were much less distinctly exposed than at present, slips obscuring the upper beds. I felt in much doubt at the time as to whether the beds belonged to the Matawan above or to the Raritan below, and although I at first regarded them as Raritan and so mapped them, I finally decided to refer them to the Matawan and changed my lines accordingly before publication. On a recent visit to the locality I found the line of contact clearly shown, and it is evident that the Cliffwood clays represent an older horizon than the basal Matawan elsewhere exposed. Messrs. Kummel and Knapp in the recent Clay Report of the New Jersey Survey, have referred these beds to the Raritan, but from their structural relations, lithologic character, and contained fossils it is apparent that it is equally impossible to refer them to that formation. All of these features indicate that these deposits constitute a transitional zone between the Raritan below and the Matawan above, and that they should be given independent rank as a formation.

A study of the basal contact of the Matawan formation from the Potomac to the Raritan rivers shows that the Matawan rests on successively later deposits northward, thus indicating a gradual transgression of the Matawan over the Potomac formations southward. Near the Potomac river the Matawan overlies the Patapsco formation, but farther north the Raritan soon appears. In approaching the Severn river and on the Eastern Shore of Maryland, deposits that suggest the Cliffwood beds occur between the typical Raritan and Matawan. In Delaware and also in southern New Jersey similar deposits have been found by the author and his associates, marine fossils occurring in the beds at Bordentown. Characteristic concretions of iron carbonate, frequently fossiliferous, have been found all the way from the shores of the Chesapeake to Cliffwood on the Raritan, although marine fossils have not been observed south of Bordentown. These deposits are significant in furnishing the earliest known Coastal Plain marine fauna, a fauna which apparently contained the first strictly marine types of life to migrate into the

* Hollick, A., *The Cretaceous Clay Marl Exposure near Cliffwood, N. J.*, *Trans. N. Y. Acad. Sci.*, vol. xvi, pp. 124-136, pls. xi-xiv, 1897.

† *Bull. N. Y. Bot. Garden*, vol. iii, No. 9, pp. 45-103, pls. 43-57, 1903; *Amer. Geol.*, vol. xxxiv, pp. 253-260, pl. xv, 1904.

basin of Potomac sedimentation. It is possible that the Island Series of Professor Ward farther north may also prove to be the equivalent of these beds, although the exact stratigraphic limits of the former are not quite clear.

Uhler* in 1892 described what he termed the "Alternate Clay Sands" overlying his Alburpean (in part Raritan) formation in Maryland, and Darton† in 1893. proposed the name Magothy formation for these deposits, stating that they constituted a well-defined stratigraphic unit between the Potomac formation below and the marine Cretaceous deposits (Matawan, etc.) above. He, as well as Shattuck,‡ regarded certain of the clays, which unquestionably underlie the true Matawan formation, as part of the Matawan, and the similarity of the materials would often suggest this reference. Recent work by the writer and his associates both in Maryland and in New Jersey, as well as along the Delaware and Chesapeake Canal§ in Delaware, shows that a series of deposits, lying between the Matawan above and typical Raritan below and consisting of alternating beds of dark clays and light sands, the latter frequently brown in color, or of one or the other, as the case may be, and having a thickness of from 10 to 100 feet or more, can be traced almost continuously from the western shores of the Chesapeake Bay in Maryland to the Raritan Bay in New Jersey. Darton was evidently the first to name this formation should it be ultimately shown to represent a single stratigraphic unit. In the absence of satisfactory exposures in Maryland a critical study of the plant remains is demanded before final judgment can be passed. It is highly probable, however, that the Maryland strata represent a somewhat lower horizon than the fossiliferous beds at Cliffwood, and may be the equivalent, in part at least, of the "laminated sands" which underlie the lignitic beds at Cliffwood. The base of Darton's Magothy may thus prove to be the base of the "laminated sands" and may necessitate the transfer everywhere of certain upper sands hitherto regarded as Raritan to the Magothy-Cliffwood series.

The Matawan formation in New Jersey, as previously stated, has been divided by the author into the Crosswicks clays and Hazlet sands, the former corresponding to the Merchantville clay and the Woodbury clay and the latter to the Columbus

* Uhler, P. R., *Trans. Md. Acad. Sci.*, vol. i, pp. 200, 201, 1892.

† Darton, N. H., *this Journal*, ser. iii, vol. xiv, pp. 407-419, 1893.

‡ Shattuck, G. B., *Md. Geol. Survey, Cecil County Report*, pp. 158, 159, 1902.

§ The section in the Deep Cut of the Delaware and Chesapeake Canal is one of the best in the Coastal Plain and shows the Matawan resting on the clays and sands of the Magothy formation, which at this point are in places highly lignitic. The Matawan formation consists at the base of chocolate-colored marls 15 to 20 feet in thickness overlain by black micaceous sandy clays 10 to 12 feet in thickness, which together apparently represent the Crosswicks clays. Above these beds is a more sandy member distinctly glauconitic that may perhaps represent the Hazlet sands farther north. At the eastern end of the Deep Cut the red sands of the Monmouth occur with fossils characteristic of the lower Monmouth in New Jersey.

sand and the Marshalltown sand and clay of the New Jersey Geological Survey.*

The Matawan formation gradually thins from about 220 feet on the shores of the Raritan Bay to less than 20 feet along the Potomac, where the formation finally disappears. The country throughout much of this distance of nearly 200 miles is more or less thickly covered with deposits of Pleistocene age which make it impossible to trace the beds continuously, although the numerous well-borings have greatly aided in the interpretation of the deposits. For cartographic purposes, on the scales adopted by the U. S. Geological Survey and the Maryland Geological Survey, it has not been thought desirable to attempt the mapping of the subsidiary divisions of the Matawan, although this is reported to have been successfully accomplished for the State Geological Survey of New Jersey by Mr. G. N. Knapp, who has recognized four members in the Matawan, known from below upward as the Merchantville clay bed, the Woodbury clay bed, the Columbus sand bed, and the Marshalltown sand and clay bed,† which he has extended practically across the State of New Jersey, although the Columbus sand bed 100 feet thick in Monmouth County is represented as reduced to 20 feet at Swedesboro and “farther southwest it seems to pinch out.” These beds, because of the different physical conditions attending their formation, are reported by the State Geologist of New Jersey to show minor differences in their faunas, these faunules being recognized wherever the deposits appear. These subdivisions cannot, however, be satisfactorily recognized in Maryland, where the Matawan possesses greater homogeneity, being throughout predominantly a micaceous sandy clay.‡ Similar faunal differences commonly appear with lithologic variations, and in Maryland many such occurrences have been recognized and described in the Paleozoic and Tertiary formations, although from their size it has not seemed wise to cartographically represent them.

Many attempts have been made to correlate the Atlantic Coast Cretaceous deposits with other American and with European formations. In an earlier paper the author referred to the Senonian and Danian affinities of the higher Cretaceous formations in New Jersey, while the paleobotanists have regarded the lower Cretaceous formations to be the equivalent

* See description of these beds in vol. vi, Final Rept. of the State Geologist of New Jersey, pp. 155-161.

† These names first appeared in print in the Annual Report of the State Geologist for 1898 published in 1899, although the field work was started some years earlier.

‡ The more sandy character of the upper Matawan is still recognized in Cecil County but becomes largely lost in Kent County where the black micaceous sandy clay increases, and is found in the upper as well as the lower beds. Farther south no differentiation in the formation appears possible and the deposits become mainly black micaceous sandy clays throughout, although the few feet of the lower and often slightly darker beds of the undifferentiated red sands above may possibly represent the upper Matawan farther north.

of the Neocomian and Gault of Europe. The Cliffwood clays are considered by Professor Hollick and Mr. Berry to show Cenomanian characteristics in the flora, and a study of the fauna will doubtless throw much important new light upon this division of the Cretaceous.

It is evident, therefore, that the Atlantic Coast Cretaceous formations represent a considerable part of the European series, although the data at hand are insufficient as yet for complete correlation of the several horizons.

In the following table an approximate correlation of the Atlantic Coast Cretaceous formations is suggested.

AGE.		FORMATIONS.	MEMBERS.		
Eocene		Sharkriver 10-15 ft.			
Cretaceous	Upper	Danian	Manasquan 30-50 ft.		
			Rancocas 30-125 ft.	Vincentown Limesands Sewell Marls	Marl
			Monmouth 30-200 ft.	Redbank Sands	and
				Navesink Marls	
				Mt. Laurel Sands (Wenonah Sand of N. J. Geol. Survey)	Clay Marl
		Matawan 20-220 ft.	Hazlet Sands Marshalltown Sand and Clay bed Columbus Sand bed	Series	
			Crosswicks Clays Woodbury Clay bed Merchantville Clay bed		
	Lower	Cenomanian	Magothy and Cliffwood beds 10-100 ft.		Transi- tional deposits
		Albian-	Raritan 200-400 ft.		
		Neocomian	Patapsco 150-240 ft.		Potomac Group
Jurassic (?)		Arundel 0-125 ft.			
		Patuxent 50-100 ft.			