ART. XI.—*Three Formations of the Middle Atlantic Slope;* by W. J. McGEE. With Plate II.

INTRODUCTION.

THE Middle Atlantic Slope may be described as that portion of Eastern United States which sheds its waters directly into the Atlantic Ocean and in which the principal rivers rise within the Appalachian mountain system. Thus defined, it extends from near the Mohawk and Hudson on the north to the Roanoke (called the Staunton in the middle part of its course) on the south, or from southern New York to northern North Carolina. Its principal rivers, in addition to those mentioned, are the Delaware, the Susquehanna (including its continuation, Chesapeake Bay), the Potomac, and the James; and its smaller but yet notable streams extending to tide water are the Raritan, the Schuylkill, the Brandywine, the Patapsco, the Patuxent, the Occoquan, the Mattaponi, the North Anna and South Anna (which unite to form the Pamunkey), the Appomattox, the Nottoway, and the Meherrin.

By geologic structure, by topographic configuration, by behavior of streams, and by the various cultural conditions resulting from these natural conditions, the Middle Atlantic Slope is separable into three distinct zones:—viz, the Appalachian zone, the Piedmont region, and the Coastal plain.

In the Appalachian zone the rocks are Paleozoic, and are characteristically corrugated by greatly elongated flexures; the predominant topographic characteristic of the region is long, parallel ridges separated by flat-bottomed valleys, the whole —save the sharpest ridges—diversified by a plexus of narrow stream-cut valleys and intervening minor hills; the great rivers wander meanderingly through the mountain ranges while the smaller streams and secondaries generally gather in elongated basins bounded by the ranges, and both large and small streams flow rapidly over the rocky bottoms of narrow, steep-sided ravines or gorges; and the civil boundaries and the routes of travel and traffic are generally determined by the parallel ridges and greater waterways, while the industries are determined largely by the resources of the rocks—anthracite and other coals, iron, building-stone, etc.,—the thin-soiled mountain slopes being unsuited for agriculture and allied pursuits.

The Piedmont region comprises an area of highly inclined crystalline rocks, abundantly diked, veined and faulted; its surface is a rather strongly undulating plain without conspicuous eminences, inclined seaward, and everywhere graven deeply by the larger and to proportionately less depths by the smaller waterways, which thus give origin to endless mazes of minor hills; its hydrography comprises the great rivers which meander irregularly through it, and a widely-branching dendritic system of secondary and tertiary drainage in which the individual members have no uniformity in direction, in which the basins are irregularly rounded or pyriform, and in which the divides are low and inconspicuous and constantly curving and recurving in labyrinthine convolutions; while, as in the Appalachian region, both the larger and smaller streams are unnavigable and rush rapidly over the rocky bottoms of sharply cut valleys, the declivity of the streams culminating at the seaward side of the zone, where all, river and rivulet alike, descend to tide level in cataracts and rapids. The civil boundaries of the region follow the waterways and transect the divides, the lines of traffic are either confined to the greater valleys or distributed over the surface, and the pursuits of the people are largely determined by the soil and its products.

In the southern part of the area, the Appalachian and Piedmont zones are sharply separated by the Blue Ridge—the easternmost member of the parallel Appalachian series; but in

Pennsylvania this mountain ridge looses its integrity and continuity and the boundary between the two zones is indefinite, while in northern New Jersey and southern New York the natural boundary fails and only an arbitrary demarkation can be drawn between the zones so sharply distinguished in Virginia and Maryland.

The Coastal plain extends from the line of cataracts and crystalline rocks to the ocean. Structurally, it consists of generally incoherent deposits of later Mesozoic and Cenozoic age, slightly inclined seaward but otherwise undisturbed; topographically, it is a plain, trenched by broad but shallow tidal estuaries and thus separable into smaller plains which sometimes undulate gently but irregularly, and again take the form of steeply-scarped terraces miles in extent, cut by steep-sided ravines and deeply scalloped along the greater waterways; the hydrography comprises the broad flat-bottomed estuaries into which the principal rivers are transformed on entering the plain, and local drainage systems of widely branching dendritic type in which the principals are also generally estuarine toward their mouths; the divides are but labyrinthine and crenulated remnants of an imperfectly drained plain only partially invaded by erosion; and throughout the region the water is slack except toward the heads of the adolescent drainage ways. The political boundaries and principal lines of traffic are determined by the great water avenues, while the civil boundaries and lesser lines of traffic are independent of the physiography, and the industries grow out of the products alike of sea and soil and out of the natural facilities for traffic and transportation.

The common boundary of the Piedmont region and the Coastal plain is one of the most strongly marked physiographic and cultural lines on the land surface of the globe: On the one hand there is a great series of crystalline rocks giving origin to a characteristic soil in which all streams, from the greatest rivers to the smallest brooks, flow through constricted gorges in a succession of cataracts or rapids; while on the other hand there is a series of incoherent and undisturbed deposits of clay, sand, and gravel through which the waters, gathering in the more elevated zones, move sluggishly in broad tidal estuaries. The boundary has long been known among students of manufacturing industries as the *fall-line;* yet it is even more noteworthy as a line of deflection in the rivers than as one of declivity. The great waterways of the Middle Atlantic Slope maintain their courses through Appalachian ranges and Piedmont highlands alike; but on reaching the low-lying Coastal plain they are turned aside, literally by a sand-bank little higher than their depth, and thence hug the hard

rock margin for scores of miles before finally finding their way into the open ocean. By this deflection of the rivers the northern half of the Coastal plain is nearly insulated; the isthmuses between the Raritan and the Delaware, between Claybank creek and Elk river, between the Patapsco and the Anacostia, and between Potomac creek and the Rappahannock, from tide-water to tide-water, are low, and but 20, 15, 25, and 5 miles in width respectively; measured directly along the fall-line, so that, the Hudson is barred from the Rappahannock by only about 60 miles of land and unnavigable water. The deflected portions of the rivers indeed occupy a great trough skirting and accentuating the Piedmont escarpment.* This remarkable physiography has materially affected the culture of the region: The pioneer settlers of the country ascended the tidal canals to the falls of the rivers where they found, sometimes within a mile, clear fresh water, the game of the hills and woodlands and the fish and fowl of the estuaries, and, as the population increased, abundant water-power and excellent mill sites, easy ferriage and practicable bridge sites; here the pioneer settlements and towns were located; and across the necks of the inter-estuarine peninsulas the pioneer routes of travel were extended from settlement to settlement until the entire Atlantic Slope was traversed by a grand social and commercial artery stretching from New England to the Gulf States. As the population grew and spread, the settlements, villages, and towns along this line of Nature's selection waxed, and many of them yet retain their early prestige—for Trenton, Philadelphia, Wilmington, Baltimore, Washington, Fredericksburg, Richmond, and Petersburg are among the survivors of the pioneer settlements; and the early stage route has become a great railway and telegraph line connecting North and South as they were connected of old in a more primitive fashion. The influence of natural conditions upon man and his institutions is nowhere else more strikingly exemplified.

No discussion of the phenomena of the Atlantic slope is intelligible without clear comprehension of the great physiographic divisions into which it is naturally separated. These divisions are represented graphically in the accompanying stereogram, which also exhibits the essential continuity of the Coastal plain to the great submarine escarpment off the Atlantic coast; the submarine profiles being based on soundings by the Coast Survey, the Fish Commission, etc., while the indicated sub-marine structure is hypothetic.

* It is shown elsewhere (7th Annual Report, U. S. Geol. Survey) that this trough is due to a post-Tertiary displacement along which movement is now in progress, probably at a rate as high as in the well-known recent faults of the Wasatch or the Sierras.

Four years ago the writer undertook to ascertain the origin and relations of certain conspicuous deposits in the District of Columbia, under the direction and auspices of the U. S. Geological Survey. It was soon found that while certain formations of the region—especially those containing fossils,—had received more or less study, while the various formations had been classified by means of the fossils contained in a few of them, and while the entire region had even been repeatedly mapped geologically, nothing was accurately known of the exact relations of the different fossiliferous and unfossiliferous deposits forming the portion of the Coastal Plain within and contiguous to the District of Columbia; it was soon found, moreover, that the formations in question are not only generally unfossiliferous in the district, but that the deposits themselves are destitute of constant and definite petrographic and structural characters whereby the stratigraphy might be ascertained; and thus it was early found difficult, if not impossible, either to correlate the different local exposures and deposits among themselves, or to establish their relations to formations already classified elsewhere by commonly employed methods. Accordingly, the investigation was commenced *de novo;* and in default of fossils or definite structural characters, locally applicable methods, standards, and criteria were developed as the work progressed: Conditions of deposition were inferred from deposits, and continent-movement was in turn inferred from evident conditions of deposition superinduced thereby; conditions of degradation in unsubmerged areas were inferred from the topographic forms thereby developed, and, since degradation is preëminently dependent on base-level, another means of inferring continent-movement was thus evolved; the record of events interpreted from earth-forms fashioned in accordance with determinate principles on the one hand was compared with the record interpreted from correlative deposits on the other hand, and history was thus deduced from independent but consistent and cumulative testimony; and final correlations were made through deposits regarded not only as rocks but also as indices of continent movement, and at the same time through the correlative topographic forms. In short, the methods, standards, and criteria have been of necessity physiographic rather than paleontologic or petrographic.

Certain preliminary results of the work appear of sufficient moment to merit a place in the standard medium of American students of science. They are summarized in the following pages.

In the present sensitive if not revolutionary condition of geologic terminology, it may be wise to define, without spe-

cially defending, the term "formation" as employed in this article. It is applied to a naturally defined series of deposits, evidently formed by a definite set of agencies within a determinate area during a definitely limited period—an easily recognizable structural, chronologic, and taxonomic unit.

The formations described are: (1) the *Potomac*, consisting of irregularly bedded and heterogeneous sand, clay, arkose, gravel, etc., of Mesozoic age and forming the base of the series of unaltered deposits of the Coastal plain, named from the river on which it is best developed; (2) the *Appomattox*, a series of predominently orange-colored sands and clays of later Tertiary age, also named from the river on which it is typically exposed; and (3) the *Columbia*, a series of delta and associated littoral deposits formed during a brief period of submergence in early Quaternary time, named from the district in which it is typically developed and in which it is first systematically studied. Certain deposits of each of the formations have already been investigated by different geologists, but they have not hitherto been correlated and systematically combined. The Potomac formation has already found place in geologic literature and taxonomy; the Columbia has been defined and briefly described in print;* but the Appomattox is here defined and named for the first time.

Professor William M. Fontaine began his elaborate investigations of the later Mesozoic formation and its flora in Virginia some time before the study of the contemporaneous deposits of the District of Columbia was taken up by the writer; but a meeting was soon arranged, notes were compared and exchanged, and a detailed examination of the principal exposures in Virginia, in the District, and in Maryland south of Baltimore, in which Mr. Lester F. Ward participated, was undertaken in the summer of 1885; during this joint study the characters of the Potomac formation were worked out and its name (previously proposed by the writer) adopted, the Appomattox formation was discriminated, and many features of the Columbia formation were brought to light; and it is a pleasure not only to acknowledge indebtedness to these gentlemen, and especially the former, for the greater share of our knowledge of the Potomac and Appomattox formations, but to record their substantial concurrence in the following statements and inferences concerning them. It is an equal pleasure to add that the phenomena of the Columbia formation have been more or less carefully examined in the vicinity of Washington by the same gentlemen and several other geolo-

* Rep. Health Officer of the District of Columbia, 1884–85 (1886), 20; this Journal, III, xxxi, 1886, 473; Proc. A. A. A. S., xxxvi, 1888, 221; etc.

gists, that acknowledgments are due to them for pertinent and valuable suggestions, and that all coincide in the essential conclusions as to its genesis and age set forth in subsequent pages.

The Potomac Formation.

Character and Distribution.—The southernmost observed occurrence of the formation is at Weldon, N. C., where a bed of obscurely stratified arkose, interspersed with well rounded quartzite pebbles, appears in the north bank of the Roanoke beneath the railway bridge. The deposit rests on an unequally eroded surface of gneiss, is not over a foot thick, and is unfossiliferous; but its composition and structure are characteristic, and there is little doubt as to its identity.

Better exposures occur on the Nottoway river just below Bolling's bridge. An irregularly and obscurely stratified arkose, unquestionably belonging to this formation, here rises four or five feet above low water, and is unconformably overlain by three or four feet of stratified greenish-blue clay containing Eocene fossils; and exposures of similar character occasionally occur in the river channel within the next five miles up stream. In all of these outcrops the deposit exhibits a typical and easily recognizable aspect: it is a nearly homogeneous, granular, loosely aggregated, almost mealy mass of quartz grains (generally angular but sometimes rounded), flakes and grains of kaolin (sometimes so little decomposed as to retain the form of the parent crystals of feldspar), and scales of mica, with an unimportant admixture of loamy particles, and now and then a rounded or irregular pellet of white plastic clay. The fresh surface is commonly light gray in color, but is frequently flecked with white and stained with brown in curiously curved lines. In structure it is either massive or obscurely stratified and cross-laminated; but even where the bedding is most distinct it is rarely consistent and continuous for more than a few feet vertically or a few yards horizontally. Except for its obscure structure planes, its pellets and lenticular pockets of clay, and the slight admixture of loamy matter, the mass could hardly be distinguished from decomposed granite or gneiss *in situ*. Some of these deposits on the Nottoway river were observed and referred to the "secondary class of rocks" by W. B. Rogers in 1839;* but *a propos* to the interesting question of geographic changes during the historic period, it is significant that Rogers failed to find the formation where it is now best exposed but found it "nearly on a level with the water" at a point "about 4 miles above Bolling's bridge" where it now rises fully 8 feet above the river; the

* Geology of the Virginias, 1884, 261.

indications being that the river has here deepened its channel several feet since 1839.

The next exposures of the formation occur on the Appomattox between Petersburg and its mouth at City Point; the most conspicuous being Point of Rocks (some four miles above the mouth) where the larger part of the material is an arkose similar to that on Nottoway river, interspersed with well rounded quartz and quartzite pebbles and rounded or irregular masses of plastic clay, interstratified with laminated clay beds, and the whole so firmly lithified that the solid quartzite pebbles fracture as readily as the matrix. The deposit here forms a prominent bluff 50 or 60 feet high, the material of which has been largely quarried as a building stone.

On James river the formation is notably exposed between Richmond and Deep Bottom, a few miles above the mouth of the Appomattox. Perhaps the most abundant constituent is arkose, such as occurs on the Nottoway, generally friable but sometimes lithified; but the arkose beds are frequently intercalated with beds of massive or laminated clay and heterogeneous sand or gravel, sometimes forming the greater part of the mass. Where laminated, and especially in the lenticular bands intercalated between beds of arkose, the clay frequently contains well preserved impressions of leaves; and silicified wood is common in the sandy and gravelly portions, as are lignitized trunks and branches of trees in the beds of clay. One of the most conspicuous elements in the deposits exposed on James river is its large pebbles and bowlders, reaching three or four feet in diameter, sometimes of Piedmont gneiss (which crops out in the river channel within a few miles of Dutch Gap), but more frequently of quartzite sometimes containing *Scolithus* borings and casts of brachiopods identifying it with the axial quartzites of the Blue Ridge. It is noteworthy that W. B. Rogers recognized the materials of this formation in borings from an artesian well at Fort Monroe at a depth of 835–907 feet.*

Interesting exposures of the formation occur on the South Anna river (where, as at Point of Rocks, it is in part a firmly lithified arkose containing well rounded pebbles of quartz and flakes and pellets of plastic clay) as well as on the Little river, the North Anna, the Mat, the Taponi and its tributaries, on Massaponax creek, and indeed in nearly every considerable valley or deep ravine, and occasionally on the surface, between the South Anna and the Rappahannock. It is generally overlain by the orange sands and clays of the Appomattox formation; and in the neighborhood of Hanover Junction it reposes unconformably upon the petrographically similar, but disturbed

* Ibid., 733–5.

and diked, Rhætic beds. Here too, the quartzite pebbles, so abundant on the James and Appomattox, disappear.

About Fredericksburg the formation is well exposed and exhibits some noteworthy characters: it consists predominantly of locally lithified arkose with abundant pebbles either irregularly disseminated or arranged in bands and beds, and numerous bowlders of gneiss and vein-quartz (quartzite being altogether absent) up to two feet or more in diameter, together with heterogeneous sand containing a considerable element of finely divided diffused clay; while lenticular beds of clay are frequently intercalated in both arkose and sand, and in some exposures constitute the major part of the mass. As on the James, the clay is massive, obscurely bedded, or finely laminated, and sometimes contains abundant leaf impressions; and here, as elsewhere, silicified and lignitized wood are common in the sand and clay respectively.

Thus, south of the Rappahannock the formation consists of an indivisible mass of arkose, sand, clay and gravel, generally overlapped by the Tertiaries, and exposed only along waterways and over a limited area between the two Anna rivers.

North of the Rappahannock the formation increases in volume and in diversity, and forms the surface over a zone several miles in width between the Eocene margin and the Piedmont crystallines. Near the mouth of Acquia creek it has an observed thickness of 180 feet, mainly of lithified arkose (long known as a fairly valuable building stone and extensively used in old structures in Washington, Alexandria, and Fredericksburg), intercalated with plant-bearing clay beds. Midway between Fredericksburg and Acquia creek the characteristic phases of the formation as developed in the south are found to be overlain by a bed of clay of obscure or inconstant structure, containing occasional intercalations of arkose or beds of pebbles; and this clay deposit, which lies beneath the Eocene and is generally unfossiliferous, increases in thickness northward. At the same time, isolated patches of gravel identical with that of the body of the formation, and evidently outliers insulated by erosion, begin to appear along the marginal portion of the Piedmont zone, generally capping eminences of circumdenudation. These outliers are sometimes 25 or 30 miles within the fall-line.

Between Acquia creek and Washington the formation continues to form the surface over a considerable zone; its lower part maintains the characters exhibited farther southward, as shown by excellent outcrops at many points on the Potomac river, and in ravines and railway cuttings to the westward; and the superjacent clays progressively increase in thickness without material change in character. On Occoquan river quartzite

pebbles, which are absent southward nearly to the James, again appear, and at Pohick creek become an important element in the formation; while the leaf impressions so abundant to the southward disappear.

About Washington the formation comprises two members sometimes discriminated with difficulty but apparently unconformable, the lower consisting of friable arkose or more heterogeneous sandstone, with lenticular partings and intercalated beds of clay and notable accumulations of quarzite pebbles (which in the westernmost outcrops become respectable bowlders), and the upper consisting of irregularly and discontinuously bedded clays, with occasional intercalated beds of sand and pebbles. The clays comprising the greater part of the upper member, like those intercalated within the lower, are of obscure or inconstant structure, variable in composition, and diverse in color: they are sometimes massive and again finely laminated, now silty and unctuous, again made up of flakes and pellets of kaolin, and elsewhere intermingled with sand and grit; they are commonly gray, whitish, or lead-colored, but again pure white, blue, black, pink, red, brown, purple, or mottled with part or all these colors, generally in soft and delicate tints. Silicified and lignitized wood and even lignitized stumps *in situ* occur in both members; but identifiable plant remains are not here found. Both members are locally stained and cemented by ferruginous infiltrations. Isolated outliers, made up principally of well-rounded quartzite and vein-quartz pebbles up to six or eight inches in diameter, crown eminences on both sides of the Potomac river, some of those on the south occurring fully twenty miles west of the continuous formation boundary. In this latitude the formation generally constitutes the surface over a belt fully fifteen miles in with, from the Piedmont gneiss on the west to the overlapping Eocene beds on the east; but the eastern boundary cannot be accurately drawn by reason of the puzzling graduation into newer deposits, sometimes filling ravines and sometimes covering considerable areas, made up of redeposited Potomac materials. Attention was called to the deposits of the formation at Washington by W. B. Rogers in 1875.*

Between Washington and Baltimore the upper division of the formation (the "Iron Ore Clays" of Tyson†) forms the surface generally and is extensively exposed in the cuttings on both railways and in the numerous workings from which disseminated nodules of carbonate of iron are extracted, and has recently yielded abundant dinosaurian remains; and at Balti-

* Proc. Bost. Soc. Nat. Hist., vol. xviii, 1875.

† 1st Rep. State Agricultural Chemist of Md., 1860, 30, 42.

more, as well as on the Patuxent and Patapsco rivers and their tributaries, the lower division is exposed and occasionally yields plant remains closely allied to those found in Virginia.

Both members of the formation appear in the precipitous shores of the head of Chesapeake bay, the sandstone only on the north, but the white, blue, purple and varigated clays on both east and west; and along Sassafras river these clays are unconformably overlain by the pyritous clays and greensands of the Maryland Cretaceous. Identifiable fossils have not been found in the sandstone member at this locality; but a few plant remains were found in the clays. The magnificent exposures of both the Potomac and Columbia formations here are described in detail and fully illustrated elsewhere.*

Extensive outliers of gravel occur on both sides of the Susquehanna several miles from the body of the formation, notably at Webster on the south and Woodlawn (or Battle Swamp) on the north of the river.

In extreme northeastern Maryland and in northern Delaware the sandstone member of the formation is not exposed as a continuous body, though it is represented by occasional isolated outliers of gravel upon the marginal Piedmont hills; but the superjacent clays appear in a number of localities, and form the subterrane over a considerable zone parallel with the Piedmont escarpment. They have been studied by Chester, who designates them "Plastic Clays," and refers them to the "Lower Cretaceous (Wealdon?)."†

So between the Rappahannock and the Brandywine the formation is a continuous terrane, consisting of a series of clays reposing perhaps unconformably upon a series of sands and gravels, while outliers of the inferior division crown the crests of the Piedmont plateau many miles from the main body; but northward it contracts and is again represented only by isolated remnants and exposures.

In southeastern Pennsylvania both members of the formation have been recognized by different geologists and have been variously classed. Clays apparently representing the upper member occur in the northeastern part of Philadelphia county where they have been referred to the Wealden;‡ the gravelly outliers representing the lower member in the vicinity of Philadelphia have been designated the "Bryn Mawr Gravel" (from a locality of typical outcrop) and referred to the Tertiary by Lewis;§ and similar exposures in Delaware county have been

* "Notes on the Geology of the Head of the Chesapeake Bay," 7th Ann. Rep. U. S. Geol. Survey (in press).

† Proc. Acad. Nat. Sci., 1884, 250–1.

‡ 2nd Geol. Surv. Pa., Report X, Hand Atlas of Pa., J. P. Lesley, 1885, Plate 46.

§ Proc. Acad. Nat. Sci. Phil., xxxii, 180, 269, 272; Ibid. 296, *et seq.;* Journ. Franklin Inst., xcv, 1803, 371–73; and elsewhere.

mapped by C. E. Hall, who designated the deposit "Ferruginous Conglomerate," and followed Lewis in referring it to the Tertiary.* The low-lying clays in the valley of the Delaware are not well exposed, have yielded no fossils, are not known to be connected with the plastic clays of Delaware, and cannot be certainly correlated with the upper member of the formation; but the gravelly outliers belong to a series traced from the Rappahannock river northward, everywhere sustaining identical relations to the underlying rocks and to the topography, and everywhere petrographically similar to a characteristic phase of the formation as typically developed in Maryland and Virginia, and may be confidently correlated with the lower member. Indeed, in the exposure in Media the most abundant materials are characteristic kaolinic arkose and more heterogeneous brown ferruginous sands such as occur about the head of Chesapeake bay, coarse gravel being but a subordinate element.† In the vicinity of the Susquehanna the gravel of the outliers is generally coarse and abundant; over the plateau between that river and the Schuylkill it is finer and less abundant: and toward the latter stream it again grows coarse and the outliers become more conspicuous.

North of the Schuylkill the lower member is typically developed at several localities in Rose valley, in the northwestern part of the village of the same name. The deposit is an obscurely bedded arkose, generally friable but sometimes lithified, containing well worn quartz and quartzite pebbles both disseminated irregularly and in lines, together with pellets and flakes of clay, the whole similar to the deposits found in Virginia; and silicified wood occurs in small quantities, but neither leaf-impressions nor the bands of clay in which they are commonly preserved were found. The mass is irregularly stratified and evidently undisturbed, and rests directly upon tilted Triassic sandstone. Again, three or four miles north of Conshohocken, extensive deposits of white, pink, and mottled plastic clay, petrographically indistinguishable from the upper member of the formation where typically developed, are found overlying gravelly arkose. The clay beds are largely worked for pottery, while the subjacent arkose is excavated and screened for building sand and road metal—indeed there is a considerable area north of Conshohocken and Norristown in which the proximity of the Potomac is proved by the presence of its materials in roadways and foot-paths, and in the mortar of houses and barns. Still farther northward outliers of gravel generally finer than that found in the vicinity of the Schuylkill occur,

* 2nd Geol. Surv. Pa., Report C5, 1885, 10–13, and map.

† C. E. Hall notes pebbles 6 inches in diameter at this point; but so large pebbles are probably rare, and were not found by the writer.

as in the neighborhood of Broad Axe, near Three Tuns, three miles northeast of Hatboro, and indeed generally on the subordinate divides and eminences northwest of Chestnut Hill and Edge Hill. The gravel in these outliers is fine (seldom over an inch in diameter), well rounded, generally of quartzite, and commonly imbedded in a scant matrix of arkose. A compact pinkish quartzite is abundant and gives distinction to the gravel.

The substantial continuity of the formation as represented by outliers is here broken, no exposures being known between the east-flowing tributaries of Neshamin creek (near Churchville) and the Delaware river, a distance of nearly twenty miles; but two miles above Trenton on the New Jersey side of the Delaware there is a distinctive deposit locally known as the "Yellow Rocks," made up of arkose, sometimes lithified but generally friable, containing abundant well rounded (but frequently disintegrated) quartzite pebbles, disseminated, arranged in lines, or accumulated in pockets, together with pellets and flakes of white plastic clay. The deposit is irregularly stratified and inclines northwestward, but at a considerably less angle than the immediately subjacent Triassic strata. No fossils were found in the beds, but they are petrographically similar to those everywhere characteristic of the lower division of the Potomac formation, totally unlike those of the Triassic sandstones in structure, composition, and attitude, equally unlike the Raritan clays found in the vicinity, and quite distinct from the gravels and loams of the Columbia formation by which they are overlain; and on the whole it seems evident that the deposit represents the sandstone member of the Potomac formation. Somewhat similar and probably contemporaneous deposits of stratified sand occur two miles below Trenton beneath the Raritan clays.

Midway between Princeton and New Brunswick, N. J., an anomalous and hitherto unclassified deposit of friable ferruginous sandstone crowns the southernmost of the Triassic trap ridges, and is locally known as the "Sand Hills."* It consists of massive or irregularly stratified and sometimes cross laminated brown sands, occasionally cemented by ferruginous infiltration, with a few intercalated lines of white or pinkish plastic clay, and is strikingly similar to the non-kaolinic sands of the Media outlier and of the body of the formation as exposed north of the head of Chesapeake Bay. This outlier is completely isolated and unfossiliferous; but it is distinct from the Triassic sandstone on both sides of the ridge in all diagnostic features, and is, moreover, manifestly newer than the trap dike, which was itself formed after the sandstone was de-

*Geology of N. J., 1868, 227, 342.

posited. At the same time it is too unlike the well defined Cretaceous and Tertiary formations found a few miles to the southeast to warrant correlation with, and is therefore evidently older than, any of these formations. In short, it appears to be a remnant of a formation largely removed by erosion before the later Cretaceous submergence, just as are the Potomac outliers in Virginia and Maryland; and on this indirect evidence of its chronology together with that of its petrography it may be provisionally referred to the lower member of the Potomac, although nearly twenty miles from its nearest supposed, and thirty-five miles from its nearest known, homologue.

It should be noted that the Raritan clays, which are perhaps equivalent to the superior member of the Potomac, and almost certainly newer than the sands and gravels of the two exposures just mentioned, are tentatively regarded as Jurassic by Whitfield.*

Briefly, the Potomac formation consists of two perhaps unconformable members, of which the upper is an inconstantly bedded and protean clay of variegated colors, either clean or sandy and pebbly, and the lower a generally friable sandstone, arkose, or gravel of irregular and inconstant structure. The upper member extends from the Rappahannock at least to the Delaware and probably to the mouth of the Hudson, either forming or closely approaching the surface over a somewhat sinuous zone 275 miles long and only ten miles or less in maximum width, overlooked throughout by the Piedmont escarpment. As a continuous terrane the lower member forms a still narrower zone flanking the Piedmont escarpment from the Appomattox to beyond the Susquehanna, and reappears in isolated exposures southward to the Roanoke and northward to beyond Delaware, over a total length of 300 miles; while as a series of insulated remnants crowning the hills of circumdenudation toward the coastward margin of the Piedmont region it occurs occasionally from near the James certainly to the Delaware and probably to the Raritan, over a zone from five to forty miles in width. The tenuity of these zones of outcrop is but an accident of degradation and deposition. Studies about the head of Chesapeake Bay led to the conclusion that the former westward extension of the formation can be reliably inferred from the topographic configuration of the Piedmont region, the western part of which has a drainage evidently determined by lateral heterogeneity of the vertically-bedded terrane and a characteristic topography resulting therefrom, while the eastern

* Brachiopoda and Lamellibrachiata of the Raritan Clays and Greensand Marls of N. J., Monog. U. S. Geol. Surv., ix, 1885 (Mem. Geol. Surv. N. J., 1885), 23.

part has a drainage independent of the varying obduracy of the terrane and therefore evidently superimposed by a formation (which could only have been the Potomac) now generally removed by erosion; this conclusion has since been verified by the discovery of isolated remnants of the Potomac formation on many parts of the area of supposed superimposed drainage; and it may be confidently inferred from the configuration of the Piedmont plain that about half of its area north of the James River (but not much more than half) was submerged beneath the Potomac sea and at one time covered by its deposits. A great extension of the formation eastward may also be inferred from the Fort Monroe boring, fifty miles from the nearest outcrops, in which undoubted Potomac deposits were found in considerable volume. The thickness of the formation, either original or present, has not been accurately ascertained; the upper member must approach 350 feet and the lower 250 feet near Baltimore and Acquia creek respectively, from which points both attenuate gradually, giving an aggregate (the maxima being nearly 100 miles apart) of perhaps 500 feet; and while the loss by erosion at the localities of maximum thickness has not been great, it cannot be readily evaluated.

Stratigraphic Relations.—South of the James river, the Potomac deposits rest upon an irregularly eroded and sometimes deeply ravined surface of highly inclined crystalline rocks, the inequality in altitude of the base within a mile on the same meridian (the formation and its subsurface having a considerable eastward inclination) reaching 100 feet or more. On that river the formation rests upon the irregular surface of the Richmond granite at the "fall-line," and upon the truncated edges of highly tilted gneisses and schists down the river for 20 or 30 miles; while to the westward outlying gravel patches repose unconformably on the tilted and faulted Rhætic* beds forming the Richmond coal field. Near Hanover Junction, the upturned Piedmont crystallines and the faulted, tilted, and diked strata of the Rhætic are alike overlain by the Potomac arkose which fills deep ravines in, and conceals irregularities of, the subjacent surface; and thence northward to the river from which they take their name, the Potomac sandstones repose unconformably upon irregularly eroded surfaces of gneiss, except at Drainesville (25 miles west of Washington), where a gravelly outlier rests on the planed edges of tilted Triassic sandstones. At Washington the inequality in altitude of the base of the formation, which evidently filled the valley of the Mesozoic progenitor of the Po-

* Fontaine, "Older Mesozoic Flora of Virginia," Monog. U. S. Geol. Surv., VI, 1883, 2, 96, 128.

tomac river, is fully 200 feet within a mile and a half. North of the Potomac river, the deposits, both in the main body and in the outliers, generally repose upon the eroded surface of the Piedmont crystallines, the depth of local ravining reaching some 250 feet about the mouth of the Susquehanna and proportionately less depths on the smaller streams; but the great outlier north of the Schuylkill in Pennsylvania, which exhibits all of the characteristics of the main body of the formation, rests in part upon crystallines, in part upon folded Silurian limestones, shales, and quartzites, and in part upon degraded Triassic sandstones and shales. On the Delaware the "Yellow Rocks," believed to represent the formation, rest upon a planed surface of tilted Triassic sandstone and highly inclined gneiss; and the still more doubtfully identified outlier forming the "Sand Hills" near the Raritan, rests upon an apparently eroded Triassic trap dike. In short, the formation everywhere reposes on a deeply degraded surface of upturned Piedmont crystallines, folded Silurian strata, tilted, faulted, and diked Triassic sandstones, and diked and displaced Rhætic beds; and it is significant that this surface is a generally uniform plain, inclined seaward and deeply incised by great waterways, coinciding closely with those of the present.

South of the Rappahannock the Potomac formation is overlain by the Appomattox formation, the fossiliferous Miocene, and the Eocene; between the Rappahannock and the Patapsco it is overlain by the Eocene; north of the Patapsco it is overlain so far as known by the upper Cretaceous; and in the abscence of these, and up to certain altitudes indicated later, it is overlain by the Columbia formation; the relation generally, but not invariably, being one of visible unconformity. The unconformity between the Columbia and the Potomac is well exhibited in representative sections at Fredericksburg, Washington, Baltimore, and the head of Chesapeake bay, but over the interfluvial plains and on certain slopes about Washington the formations, though widely diverse in age, intergraduate so imperceptibly that it is impossible to demark them; there is notable unconformity between the Appomattox and Potomac formations on the Roanoke and in some sections on the Appomattox and James rivers, but in other sections on the last named rivers (at Fredericksburg and elsewhere), there are deposits of composite character certainly belonging to one or both of these formations which cannot be discriminated even in the same section; the Miocene rests on the Potomac in the local absence of the Eocene at Petersburg and Richmond, but no noteworthy unconformities have been observed; the Eocene is unconformable to the Potomac on the Nottoway and generally about Richmond, and notably in a railway cutting near Brooke

(where two deep ravines in the Potomac are filled with fossiliferous Eocene deposits), though in some sections at Richmond the two cannot be discriminated, and at Good Hope Hill, near Washington, Eocene fossils occur in deposits made up of Potomac materials supposed to be *in situ* before the discovery of the fossils; and on Sassafras river there is a marked unconformity between the pyritous clays and greensands of the upper Cretaceous and the subjacent Potomac clays, while in the best section about the head of Chesapeake bay (Maulden's Mountain) the sequence from massive Cretaceous greensand above to iron-bearing Potomac clay below is unbroken save by arbitrary lines. In short, it is evident that the Potomac terrane has ever lain near sea-level, and has alternately suffered less by denudation and accretion by sedimentation during oft-repeated oscillations, has been deeply ravined during one epoch only to have the ravines filled largely with its own materials but with some foreign matter and more recent fossils during the next, and has contributed material to each newer formation of the Coastal plain. Its characteristic pebbles have indeed been successively transferred to the newer Mesozoic beds, to several of the Cenozoics, and finally incorporated in the Quaternary.

There is an apparent unconformity between the two members of the Potomac, marked by beds and pockets of gravel superimposed upon erosion planes, as in a noteworthy section three miles southeast of Washington; but since local unconformities, including both erosion planes and accumulations of gravel and bowlders, occur at various horizons in each member, there is some doubt as to the importance of this apparent unconformity.

Fossils.—Until recently animal remains were believed to be exceedingly rare in the formation: fragments of a rib of a cetacean and part of the teeth and bones of a reptile supposed to be related to the Iguanodon are recorded by Tyson from the upper member in Maryland,* the latter being the *Astrodon Johnstonii* of Leidy;† six undescribed species of the fresh water genera *Unio* and *Anodonta* and several "ctenoid fish scales" associated with "leaves of dicotyledonous trees" are noted from the upper member in western New Jersey, and identical *Unios* "from the banks of the Potomac" by Cope;‡ Conrad described from the plastic clays of New Jersey (which are either equivalent to or newer than the upper division of the Potomac formation, but which he regarded as Triassic), two lamellibranchiates, *Astarte veta*, and *A. annosa*;§ and

* First Report Maryland Agricultural Chemist, 1860, 42; cf. Uhler, Johns Hopkins University Circulars, vol. ii, No. 21, 1883, 53.

† Cretaceous Reptiles of the U. S., Smithsonian Contributions to Knowledge. vol. xiv, 1865, 102.

‡ Proc. Acad. Nat. Sci., xx. 1868, 157. § Am. Jour. Conch., iv, 1868, 279.

Whitfield has more recently recognized from the same clays (which he, too, is disposed to refer to the Triassic) five lamellibranchiates—*Astarte veta*, *Ambonicardia Cookii*, *Corbicula emacerata*, *Corbicula annosa* (Conrad's *Astarte annosa*), and *Gnathodon tenuides*.* In the course of an examination of the formation extending over some years, Fontaine has found but a single animal fossil, viz: the posterior portion of a homocercal fish about the size of a salmon from the lower member on James river. Careful search during the past three months has led to the discovery of moderately abundant dinosaurian remains of upper Jurassic type and the upper member between Washington and Baltimore, some of which have already been described by Marsh.†

At several points on the Appomattox and James rivers, on both Anna rivers, about Fredericksburg, on Acquia creek, at Baltimore, and at a number of other localities the laminated beds of clay intercalated within the lower member yield abundant and well preserved leaf impressions; and throughout the whole extent of the formation both members abound in silicified and lignitized wood. Fontaine has collected and investigated the plant remains, and has just sent to press a monograph containing descriptions of over 370 species, of which more than 300 are new. Extensive collections of silicified and lignitized wood have also been made from both members and have been investigated by Knowlton; and eight new species belonging to two new genera have been discriminated and are described and illustrated in a memoir now in press.‡

Viewed as a whole, the Potomac flora is unique. It is, moreover, of special interest in that it records a stage in the development of plant life not known to be represented elsewhere on the globe. The plant history of the earth falls naturally into two eons, instead of the three represented by animal life, during the first of which the various non-dicotyledonous forms (the cryptogams, cycads, conifers, and monocotyledons) of archaic type prevailed, while throughout the second dicotyledonous forms of modern type have greatly predominated,—the transition from the archaic to the modern type being sudden, and the bipartite division being consequently stronger and more trenchant than the tripartite division based chiefly on animal remains. Now the exact period of transition from the archaic flora to the modern one (hitherto placed about the middle of the Cretaceous)§ appears to be represented in the Potomac flora; there is a commingling of primitive and recent types in nearly every plant bearing clay bed; the types

* Monog. U. S. Geol. Surv., vol. ix, 1886, 23–27.
† This Journal, xxxv, 1888, 89–94.
‡ Bulletin U. S. Geol. Surv. (in press).
§ Ward, 5th Ann. Rep. U. S. Geol. Survey, 1885, Plate lvi.

are about equally represented in the entire section; and the transition is recorded not only in the commingling of types but in a measure by the assumption of modern external forms while the plants yet retained the archaic internal structure.

It is significant that well preserved leaf impressions are not found in the formation about Washington, in the lower member at the head of Chesapeake bay, in the deposits near the Schuylkill, in the "Yellow Rocks" at Trenton, nor in the immediate vicinity of Richmond—the plant-bearing localities on the James being several miles from the fall-line,—i. e., about the mouths of the Mesozoic prototypes of the great rivers of the region.

Taxonomy.—The general facies of the wonderfully rich flora most closely approaches that of the middle and lower Neocomian of Greenland and Europe, and Fontaine is disposed to refer the formation to the lower Cretaceous on this evidence; but since the flora is manifestly too nearly unique to permit precise correlation, and since Marsh finds the vertebrate remains to be distinctly upper Jurassic, the formation must be at least provisionally assigned to the latter period.

The Tuscaloosa formation of Alabama appears to be the precise equivalent of the Potomac;* and Hill has recently collected data indicating that the Trinity formation (Dinosaur Sand)† of Texas and Arkansas is coeval with the Potomac and Tuscaloosa.‡

Sources of Materials.—Roughly classified, the materials of the Potomac formation are (1) quartzite pebbles, (2) quartz pebbles, (3) arkose, (4) quartzose sand, (5) plastic clay, and (6) various combinations of these.

1. The distribution of the quartzite pebbles is significant: They are abundant and large on James river but diminish rapidly both in abundance and size about to the Appomattox on the south and the South Anna on the north, where they finally disappear—none occurring on the Nottoway or Roanoke, nor on the North Anna, the Rappahannock, or the intermediate smaller streams. They reappear near the Occoquan, and increase rapidly in abundance and size to the Potomac, where they form a predominant element in parts of the formation; but they again diminish in size and abundance northward, becoming inconspicuous north of Baltimore, to once more increase in size and number about the Susquehanna, where the outliers consist almost exclusively of well rounded quartzite pebbles and bowlders. North of the Susquehanna like relations obtain, so far as size is concerned, the pebbles gradually diminishing in size over the Susquehanna-Schuylkill divide, enlarging

* Bulletin U. S. Geol. Survey, No. 43.
† American Naturalist, vol. xxi, 1887, 172. ‡ Science, vol. xi, 1888.

again about the Schuylkill, once more decreasing in size in the outliers lodged behind Chestnut hill and Edge hill, and again assuming considerable dimensions on the Delaware; but in this part of the area of the formation the quartzite pebbles occur on the smaller streams and over the divides as well as on the great rivers. Finally, in the Sand Hills quartzite is nearly or entirely absent. In short, the quartzite pebbles occur only in the vicinity of those rivers which flow through the quartzites of the Appalachian and upper Piedmont regions, and their abundance and size vary with the dimensions of the rivers and the proximity of the ridges.

The composition of the pebbles is equally significant: Those found about Washington and Richmond sometimes exhibit *Scolithus* borings and casts of brachiopods, etc., identical with those found *in situ* in the axial quartzites of the Blue Ridge and adjacent Appalachian ranges in their less metamorphosed portions; the pink quartzite of the pebbles found over the Schuylkill-Delaware divide is in all respects similar to that of certain exceptionally obdurate ledges in the quartzitic axes of the low ranges here encroaching upon the Piedmont region; and the distinctive pebbles are in both these as well as in other cases confined either to the vicinity of the distinctive ledges or to the lower reaches of the rivers transecting them.

So by distribution and composition, the quartzite pebbles of the Potomac formation may be traced to their parent ledges in the Appalachians; and their distribution indicates at the same time the ancient river-courses and the shore lines along which they were transported.

2. The quartz of the second class of pebbles (which sometimes assume the dimensions of respectable bowlders) is petrographically identical with the vein quartz everywhere intersecting the Piedmont crystallines; the pebbles, like those of quartzite, are generally largest in the greater valleys and toward the western margin of the formation, though considerable bowlders occasionally occur in all parts of it; they are most abundant where the quartz veins are large and numerous; and local peculiarities in the vein quartz are reflected in the leeward pebbles. It is evident, in short, that the pebbles are derived from adjacent veins. Indeed in a section in the northwestern part of Washington a train of fragments of a quartz vein intersecting the Archean gneiss and projecting into the superjacent Potomac gravels, is traceable in the gravels for some distance before the fragments so far lose their angles as to become undistinguishable from the neighboring erratic pebbles.

3. The arkose is made up of angular grains of quartz, crystals of feldspar or flakes of kaolin, scales of mica, etc., the

whole sometimes so similar to disintegrated granite or gneiss as to be distinguished only with difficulty. It reaches its best development toward the base of the formation, and especially in the smaller valleys and ravines or on the subjacent gneissic surface; and it is not found in perfection along the lines of the larger rivers. Its petrography and distribution alike justify the inference that it is granitic debris, not far transported.

4. By far the larger part of the quartzose sand, whether in homogeneous beds or intermingled with other constituents of the formation, consists of rounded quartz grains of doubtful origin, but evidently worn by transportation; a smaller part consists of angular quartz grains and flakes such as might be produced by impact of masses during transportation; a yet smaller part is made up of rudely crystalline grains such as result from the disintegration of vein quartz; and the least important element in volume, though it is locally conspicuous and significant, consists of more or less perfect crystals of quartz such as might form the residue of disintegrated granite after the solution and removal of the less obdurate constituents. All of these sources are doubtless represented in the sands of the Potomac.

5. The clay occurs in minute flakes (sometimes of crystalline form) in the arkose, in rounded and irregular pellets and balls up to an inch or more in diameter in the arkose and sand beds, in lenticular or sometimes continuous bands intercalated with sand, and again in considerable beds exhibiting more or less definite structure planes; but whenever pure it is clean, plastic, kaolin-like, and evidently derived from a common source, and the smaller flakes retain the shapes of feldspar crystals undistinguishable from those of the adjacent Piedmont gneisses. The clay in the larger masses it is true appears to be thoroughly triturated, and was evidently deposited in finely divided condition; and the pellets and balls appear to have been washed from such beds and redeposited in conjunction with other materials; but the structural differences between the pseudo-crystalline and the water-laid phases of the clay are no greater than would inevitably result from the trituration and assortment accompanying the breaking up of gneiss or arkose and the separation of the materials of unlike specific gravity and solubility.

6. The heterogeneous and ever varying accumulations of composite character which constitute the larger part of the formation are, qualitatively, just such as would be formed by the assortment and deposition of the different materials by powerful currents; but the quantity of coarse materials in the Potomac formation is greater than would result from simple admixture of the disintegrated gneiss of the Piedmont zone and such

proportion of Blue Ridge quartzite, vein quartz, etc., as appear to be mingled with it, suggesting that the portions of the formation now exposed were littoral, and that the finer materials were swept into deeper off-shore waters.

The History recorded in the Formation.—The conditions of deposition of the lower member of the Potomac formation may be inferred from its structure and composition: the coarseness of the predominant materials is proof of the prevalence of powerful currents or violent waves; the local accumulations of arkose and of finely laminated clay are indicative of quiescent periods, of slack-water eddies, or of sheltered spots on a stormy coast; the frequent alternation of coarse and fine deposits, the broken up and re-deposited clay beds, and the local unconformities, all suggest repeated alternations of slack water and strong currents throughout the area of deposition; the distribution of the quartzite pebbles proves that this material was brought down from the easternmost Appalachian mountains by rivers coincident with the great rivers of to-day, and the unequal altitude of the base of the formation along the rivers and the prevalent coarseness and inconstant structure of the deposits there indicate that the ancient rivers embouched into deep turbulent estuaries, while the interosculation of some of the estuarine deltas and the coarseness of the deposit connecting others prove violent wave action along the intermediate shore; the dearth of remains of marine and estuarine animals is suggestive of turbulent waters; and the peculiar distribution and preservation of the plant remains suggests encroachment of the Potomac ocean upon lands covered with a luxuriant flora. The conditions of deposition of the upper member appear to have been similar but quieter.

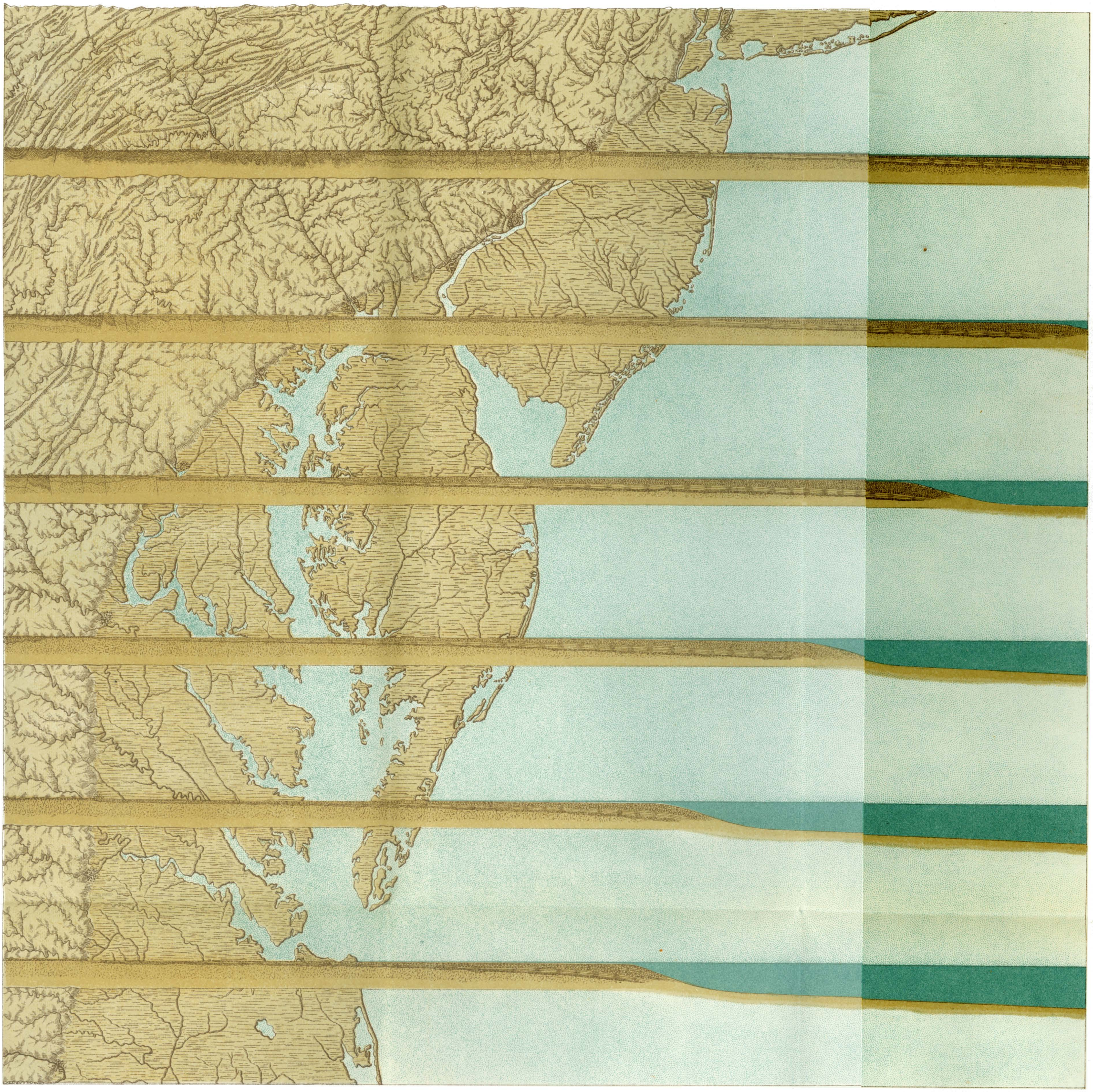
From the relations of the formation to the foundation upon which it rests, from structure and composition and indirectly from the conditions of deposition indicated thereby, the physiographic conditions attending the deposition of the Potomac formation may be inferred: The surface upon which the deposits rest is formed of dislocated strata of Archean, Cambrian, Silurian, Triassic and Rhætic age, all degraded to a plain as uniform as the Piedmont zone of to-day—a plain destitute of noteworthy eminences despite the great heterogeneity of the rocks, and one which accordingly must have been reduced to base level; yet the unequal altitude of the deposits about the waterways indicate that this plain was ravined as deeply as is the present Piedmont plain; and the slight sinuosity of the shore line, despite the depth of the ravines, is proof of pronounced seaward inclination of the surface.

Thus the structure, composition, and stratigraphic relations of

the Potomac formation, when freely interpreted, give the outlines of an intelligible and harmonious picture of the Atlantic slope during and for some time antecedent to the Potomac period: Before the initiation of Potomac deposition, but subsequent to the accumulation of the Triassic and Rhætic deposits and to the displacement and diking by which they are affected, there was an eon of degradation during which a grand mountain system was obliterated and its base reduced to a plain which, as its topography tells us, was slightly inclined seaward and little elevated above tide—the Piedmont zone alike of the later Mesozoic and the present; and over this plain meandered the prototypes of the Delaware, the Susquehanna, the Potomac, the James, and the Roanoke, within a few miles at most of their present courses and but a few hundred feet above their present channels, flowing slack and in shallow valleys because at base level. There followed a slight elevation of the land, when the rivers attacked their beds and excavated valleys as deep as those to-day intersecting the Piedmont plain; but whether or not there was concomitant tilting of the land, the phenomena thus far fail to indicate. Then came the movement by which the deposition of the Potomac formation was initiated—the deeply ravined base level plain was at the same time submerged and tilted oceanward; its waterways became deep but short estuaries; deep oceanic waters extended quite to the intermediate shores; the declivity and transporting power of the rivers was increased; and the accumulation of coarse delta and littoral deposits progressed rapidly. With continued deposition the sea gradually shoaled, the declivity of the land decreased, the materials became finer and finer; there was probably temporary emergence of the land about the middle of the Potomac period, followed by renewed submergence without seaward tilting during which the clays of the upper member were laid down; and the period was finally closed by an emergence represented by the unconformity between the upper Potomac and the glauconitic deposits of the Maryland Cretaceous.

There is a great hiatus in the geologic history of the Atlantic slope: The history is fairly legible up to the termination of the Paleozoic deposition, and it is even more clearly legible from mid-Cretaceous time to the present; but the hiatus includes the most interesting period in the evolution of the eastern portion of the continent. The transfer of sea and land: the elevation and corrugation of the Appalachians, and the profound displacement and metamorphism of the Piedmont rocks; the degradation of thousands of feet if not miles of strata and the transportation of the materials whither no man

knows; the deposition of the Triassic and Rhætic rocks under conditions which no geologist has ever clearly pictured in imagination—at least to the satisfaction of his fellow geologists; the Triassic displacements and diking; the post-Triassic degradation of thousands of feet of strata and the removal of the debris to other regions—these and many other remarkable episodes have been completely blotted out of the geologic record as commonly interpreted. But the Potomac formation narrows the hiatus: the formation itself carries the record back from mid-Cretaceous time to the earliest dawn of the Cretaceous or the closing episodes of the Jurassic; and the post-Rhætic and pre-Potomac degradation will tell the story of the Jurassic as eloquently, when men have come to read geologic history in erosion as well as in deposition, as if the deposits of the period were exposed to observation instead of lying beneath the thousands of feet of newer strata forming the Atlantic bottom. So while the hiatus is not yet closed it is reduced by a fifth, a fourth, or perhaps a third of its length.



Drawn by J.H.Klemroth.

STEREOGRAM OF THE MIDDLE ATLANTIC SLOPE.

By W.J.McGee, Geologist.

Horizontal Scale 1: 2,,230,000 = 35mi. :1in.

Vertical Scale 1: 425,000 = 35,000 ft. :1in.

T. Sinclair & Son, lith Phila