MEMOIR

OF THE

GEOLOGICAL SURVEY

OF THE

STATE OF DELAWARE:

INCLUDING

THE APPLICATION OF THE GEOLOGICAL OBSERVATIONS

TO AGRICULTURE.

BY

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PREFACE.

THE following report of the geological survey of the state of Delaware, conducted in the years 1837 and 1838, embraces all the observations and examinations which were made during the continuance of the survey, including those contained in the first and second annual reports, already laid before the legislature. I have experienced no ordinary difficulties in the investigation of several sections of the state, more particularly in the two lower counties, chiefly in consequence of the less broken and comparatively level nature of the country, and consequently the fewer opportunities of viewing the strata subjacent to the soil; more minute examinations, however, would not have led to more satisfactory results in regard to the discovery of useful geological deposites in each hundred or in each county, simply from the fact that they do not exist in every situation. But as the act providing for the survey required that an equal portion of the appropriation should be expended in each county, it was evident that this could only be executed by passing an equal portion of my time in each county; to which view I have adhered as closely as possible. As soon, therefore, as I was convinced that few important geological inquiries would demand my attention in the lower counties, and more particularly in Sussex, I determined on traversing different parts of those counties, with the view of imparting such knowledge relative to agriculture as lay within the sphere of my information. For the same reason also, many sections of this memoir are devoted exclusively to agricultural essays, in which the subject is treated both practically and theoretically in order to its adaptation to all classes of the community.

When we observe the mode of action of our state legislatures and indeed of our national congress, it is to be feared that local prejudices and interests often exert too powerful an influence over their deliberations to the detriment of grand national undertakings. It appears to me, however, that the true interests of the citizen and the republic are more intimately blended together, and that what advances the reputation or monetary resources of an individual without interfering with those of another, elevates the standing and power of the nation. If this be true of one individual much more will it apply to a body of citizens—that benefits accruing to a district of country, other things being equal, must necessarily bear their influence on the whole country. Guided by these views I have sometimes devoted a larger share of time and observation to such formations as were deemed of greater importance in one part of a county than to those situated in other portions of the same county: thus the green sand region has been more thoroughly examined than any other part of New Castle county; the two tertiary belts in Kent, and the modern shell beds in Sussex were believed to be of more value than other deposites in those counties and were therefore more closely investigated. For the same reason, fewer examinations were conducted on the ridge and neck lands; for the true geological formations which were the primary object of the survey are more open to the observer in the intermediate region, while in the two former they are either wanting or so covered by more modern deposites as to forbid observation.

It has been a subject of deep regret to me that the formations possessing much practical value should be so few in number and limited in their extent; but as I believe that the wealth of a people, *cæteris paribus*, is in direct proportion to their capability of employing their own resources, I have devoted much of my time to the development of minor resources, of those which, however limited in extent, were deemed to be capable of useful application. Of this class are modern deposites of shells and decomposed organic matter, each of which will be found in their appropriate places in the following memoir. On the same account reference is made to the manufactures of glass and pottery, of iron, copperas, &c., no one of which will probably ever be carried to a great extent in Delaware, but as the raw material necessary for conducting them does exist in the state, it was incumbent on me to examine the deposites and point out their application.

A general view of the mineral deposites of the state is sufficient to convince every impartial and reflecting mind, that, however desirable it might be to advance the manufacturing interests, agriculture must be pursued and encouraged as the principal source of wealth, and that if manufactures arise, they must be mainly dependent on the productions of the soil; not exclusively indeed, for the water power of the north should receive a due proportion of encouragement. It does appear to me that in general the pursuit of agriculture is the basis of more solid capital and power than that of manufactures, and therefore more desirable, and it is chiefly on this ground that so large a portion of the present memoir is devoted to the soil and the modes of improving it, either by a change of its constituents or by the application of causes and sources of fertility. Besides, by far the larger portion of the state is benefitted by an attention to this subject, and a more equable distribution of the labors of the survey is attained, since the agricultural resources of the two lower counties are greater than those of New Castle, with the exception of the green sand region, and act as a compensation to the superior advantages of manufacture in the upper part of the state.

It may be asked why so much theoretic matter is introduced, when the work is designed to possess a practical character. To this I answer that in all probability the number of those who may peruse these pages is large, and their attainments of a varied nature, some being purely practical men, others again having made considerable attainments in literature and science; and hence it was deemed advisable to adapt the memoir to the various demands of the community. A few of the chemical views are offered as novel, others are barely known to a majority of men of science, while the greater part of them are well known and generally received in the scientific world. I am well aware of an opinion too generally prevalent among men devoted to practical pursuits, that an attention to theories is rather prejudicial than otherwise to the successful pursuit of business. Whatever grounds they may have for such views, they are not valid when applied in a general way to theoretic investigations, for independently of other proofs of the incorrectness of their conclusions, it may be shown that many valuable practical results have either originated with or were improved by theorists, by those who have experimented with the view of establishing, maintaining or refuting theories. Now in regard to agriculture, it may be observed that it had already made considerable advancement, when it began to assume a scientific form; but from that period to the present, by deriving assistance from other sciences and particularly from chemistry, its progress towards perfection has been constant and rapid. There is one part of the subject, however, which has been too much neglected, although it is of prime importance in the cultivation of the soil, the proper mode of preparing and applying manures. The discrepancies and opposite views and practices among agriculturists prove that this point is not well understood either in theory or practice, and yet it is a fact that the first impulse given to it latterly is due to chemical science. The discovery of humus and the humic acid, called also geine and geic acid, was the first step of advancement in our knowledge of the nature of manures, since which period the discovery of the crenic acids by Berzelius has tended to elucidate the subject still farther, and as their existence and nature is barely known or understood, I have introduced several articles bearing reference to their mode of preparation, their character and the theories of their action, the two former being derived from Berzelius' Chemistry and the theories being a statement of my own views.

The green sand being of great importance in agriculture, it was supposed that chemical analysis would lead to conclusions showing the relative value of the several deposites. My own impression from the first year of the survey has been that analysis would indeed reveal the proportions of the ingredients composing the green sand, without clearly pointing out the relative values of the several kinds, and this view has been confirmed by subsequent observation. That there are differences in their composition, that one contains more potassa or lime than another, is evident, but yet in their application to the soil, the difference in their effects is not precisely in accordance with their composition. Besides, it would be a point of great difficulty, if not of impossibility, to determine, whether the calcareous or cretaceous beds of the canal are superior or inferior to those containing pure green sand. In fact the differences between the several varieties in their effects on vegetation are too slight a basis on which to give a very positive opinion as to which is decidedly the best, and had I presumed to pass judgment on them during the progress of the survey it would have discouraged many from the use of the marl, when I already found it difficult to persuade them of its utility. From the several analyses of the non-calcareous or ordinary green sand, as well as from its striking effects when applied to land, I am inclined to believe that the "bluish green sand" on Drawyer's Creek is of rather superior quality to the other varieties. Whether its effects are more powerful than those of the calcareous varieties cannot be positively stated, but I think my observations lead to the conclusion that the bluish green sand takes the precedence of all others whether calcareous or otherwise. The greater part of the analyses contained in the memoir were conducted by myself, others by students and friends in my laboratory, and may be relied on for their accuracy excepting in regard to the exact proportion of potassa in the green sand, which, owing to the mode of its extraction, is probably rated a little too high.

Since then the differences existing between the several kinds of marl are slight and unimportant, it is to be hoped that the slowness with which the use of marl has gained ground in St. Georges hundred will soon receive an impulse from the accumulating evidence of its successful application, and that the old adage may not be maintained in Delaware, that the marl is "too near home to be of value." When the survey was commenced, only a small quantity of the calcareous marl had been employed near the canal, and a still smaller amount of the ordinary green sand on Drawyer's creek; but prior to its close, it is highly probable that not less than a half million of bushels had been extracted, and applied to the soil. Of the success attending its use I leave every candid observer to judge. My own observations prove that in nine-tenths of the instances, the results have been highly satisfactory, and have induced me to believe that the marl region is destined to become the most fertile portion of the state. In every section of an agricultural district there are always individuals who conduct experiments relative to the improvement of the soil by manures or otherwise, the results of which are rarely spread beyond their immediate vicinity, but should become known to the community at large. I would certainly advise the adoption of some general system, by which the experiments conducted in Delaware should be collected together, whether it be in the employment of green sand, lime, or organic manures; and it appears to me that one or more of the journals of the state are the most suitable medium of bringing these results before the public, and giving them a permanent form.

After the completion of the general geological survey of Massachusetts by its able conductor Professor Hitchcock, the legislature of that state ordered an agricultural survey in which some progress has been made, and reports of its results presented to the public. The great advantages of such a survey, lie in the collection of experimental results made by individual farmers, of the practices in manuring, rotation of crops, fencing and similar subjects of value to the agriculturist, which are pursued in various sections of the state, and presenting them in annual reports, in which a fair comparison of their useful results may be made, and those superior processes which are locally known may become generally diffused. In connection with the same, the analysis of soils has been attempted, but I am inclined to place little reliance on them, not from an impression of their inaccuracy, but from a conviction of their want of that unquestionable utility, generally ascribed to them, arising from the fact that the chemical nature of the organic constituents of soils, which is of the greatest importance, has not been sufficiently investigated to admit of very easy and accurate analysis. The presence of lime and of finely divided mineral matter may be readily detected, and their relative amounts ascertained and so far the analysis of soils would be of decided and signal benefit; farther than this, I am inclined to question their utility in the present state of chemical science. Beside collecting and digesting an account of the processes followed in certain districts, the agricultural surveyor might, on the close of his active duties, offer modes of improvement for the various parts of the state, derived from his observations, and from his adaptation of chemical and mechanical science to the subject. Impressed with the general advantages derivable from an agricultural survey, and more especially with those dependent on the personal communication of information by the surveyor, I do not hesitate to urge it upon the legislature to take the subject into consideration, and institute such a survey, under the direction of a competent individual. It appears to me that a moderate appropriation would be sufficient to defray all the expenses; nor would I advise its continuance for a less period than three or four years, in order that the whole state may be traversed, and time be allowed to digest the materials and perform the requisite chemical investigations. I am persuaded that the deteriorating one, two, and three field systems too generally adopted in many portions of the state will be finally eradicated, but at the same time I am inclined to believe that such a survey as the one proposed would bring about a more rapid change to a more productive and improving system of tillage.

A reference to the map, which accompanies the report, will give a clearer view of the position and extent of the several formations herein described, each peculiar geological deposite of sufficient extent and importance being designated by an appropriate color. For the construction of the map I am indebted to my friend Professor J. F. Frazer, who drew it from all the sources within our reach, basing it chiefly upon an old but excellent map of the state by Mr. Varley, and introducing such changes as my tours through the state suggested. The absence of a trigonometric survey necessarily excludes accuracy, but I think it in general sufficiently perfect for the object in view. Although it would be highly desirable to publish a map in connection with the report, containing the general geological features of the state, together with its roads, streams, towns, &c., as a useful guide to its own citizens and those of other states, yet the comparative paucity of the formations with the minute descriptions contained in the memoir render the publication less imperative. Besides, the accurate topographical survey of the coast ordered by Congress, and now in successful progress will afford a substantial basis on which to construct a more faithful representation of the state than could be given independently of a topographical survey, and at a far more diminished cost than would be requisite if such a survey were now undertaken. Agreeably to the suggestion of Prof. Ducatel, the geologist of Maryland, I submit to the legislature for their action the proposal of a combined map of Delaware, with the Eastern shore of Maryland and Virginia, merely remarking that from the contiguity and natural relations of the three states, I think it would prove highly desirable and mutually advantageous.

In conclusion, I cannot but congratulate myself on the successful termination of the survey, the advantages of which have not depended on the actual discovery of resources hitherto unknown, but on their fuller development and on giving greater publicity to their value. That the green sand would eventually have been discovered within the limits which have been assigned to it without my assistance, cannot admit of doubt; but I think no one will deny that the survey has in this respect anticipated the experience of years, that it has given certainty to its supposed value, and that it has mainly assisted even during its continuance in raising the value of land in St. Georges hundred and the adjacent country. That it will prove beneficial to the state will be farther seen in the course of a few years, when its fertilising effects shall be visible along the shores of the bay from Wilmington to Baltimore hundred. The employment of the smaller deposites of shells, of the blue and black soils of the river and marshes, may be almost said to have originated with the survey, when we remember how few had availed themselves of these riches prior to its commencement. Nor can I omit mentioning one prominent benefit which every where greeted me, in the rising spirit of inquiry among all who were devoted to the cultivation of the soil, as to the means and mode of rendering it productive, a spirit, which when once awakened, cannot cease its growth until the plains of Delaware teem with a busy population, and its garden-fields wave with luxuriant crops. The kindness and attention which every where awaited me throughout the state calls forth from me a sincere and warm expression of thanks, and only leaves the regret that it was out of my power to discover in every section of the state, some material of value as a return for what has become one of the characteristic features of the citizens of Delaware—hospitality.

JAMES C. BOOTH.

Philadelphia, May 4, 1841.

PART I.

GENERAL VIEW OF THE GEOLOGY OF THE STATE.

CHAPTER I.

PRIMARY FORMATIONS.

§ 1. The geological formations of the state of Delaware may be conveniently divided into four classes, according to their structure or the organic remains they may contain; but such an arrangement having no reference to superficial strata or soils may be regarded only as one of convenience in aid of description, and for the sake of identifying the locality of particular minerals comprised by the several formations. Were it required to view the state solely with regard to its agriculture, a different classification would become necessary, dependent on the character of the soil; but since the object of research has been to investigate the mineral deposites on or beneath the latter, with more especial reference to their application to agriculture, and since these are not necessarily connected with the soil in their character, the division of the state into four groups, consistent with received geological theories, may be regarded as most convenient and suitable to our purpose. When alluding therefore to the several formations, the soil must be kept wholly out of view, and those mineral substances understood, which are contained beneath it at variable depths.

§ 2. By an attentive examination of the surface from the northern, or curved boundary of the state, to a line crossing the state on and a little north of the Wilmington and Susquehanna Railroad, and in the same direction, we observe rocky masses protruding through the soil of a sufficiently marked character, to distinguish them from sandstones and slates. Where artificial excavations are

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made of sufficient depth, as for the construction of roads, in the digging of wells, &c., the same rocks are always met with, and no termination of the solid mass has hitherto been found. Therefore, independently of loose masses and fragments of stone detached from their adjacent beds, the whole of the district in question is underlaid by a continuous bed of rock. The term Primary has been applied to these rocks, indicative of the age sometimes attributed to them in geological theories, but this view may be demonstrated to be incorrect in the present more advanced stage of the science, as some of the rocks supposed to have been primarily formed may be found overlying those admitted to be of later origin. Since, however, a particular class of rocky formations is generally understood by the term Primary we shall adopt the same, and apply it to the region under consideration.

§ 3. The primary region of the state is characterised by the unevenness of its surface, by an apparently confused mass of beautifully moulded hills, with a bold and rounded outline, always elevated and often rising several hundred feet above tide water, and affords an outlet to the waters of rain, springs and creeks, through deeply cleft valleys, with rounded or abrupt rocky sides. The soil, though varying in particular localities, is generally uniform in its character, being argillaceous and mingled with a greater or less quantity of gravel, while an alluvial deposite of a similar character covers the rocks to the variable depth of from one to sixty feet, and perhaps still more. A cursory view might lead to the conclusion that the whole region contained one, or, at most, two kinds of rock; a more minute investigation, however, enables us to distinguish five different kinds, four of which are stratified: viz, Gneiss, Felspathean rock, Limestone, and Serpentine, and the remaining formation is of a veined and granitic character. The first and second of these constitute about ninety-nine-hundredths of the whole series. They are all characterised by their crystalline structure, and the variety of simple minerals with which they abound.

§ 4. I. *Gneiss.*—This rock, comprising about three-fourths of the primary region, may be observed in numberless places protruding through the soil in solid mass, while its fragments lie scattered over the surface of hill and valley, and the soil is highly charged with particles of mica. It is composed of quartz, felspar, and mica in varying proportions, the first named averaging a greater quantity than either of the two last, and these being in nearly equal proportions. The mica is not unfrequently wholly wanting, and sometimes, though rarely, replaced by scales of hornblende, which communicates to the rock a greater degree of hardness and toughness. To the mixture of these minerals, we must attribute the pervading gray color of gneiss, varying from a blackish to a very light gray, and at times deriving a reddish tinge from flesh-colored felspar. In some cases it may be easily impressed by a knife, and again the steel itself may be abraded, while in a majority of instances it presents a rock of a medium degree of hardness. Although composed of several distinct minerals, they are so firmly united, and one of them, the mica, so little frangible, that it has a decided character of toughness. Although quartz preponderates, yet we find at times the felspar in greater abundance, and when the latter is of a particular kind, the whole body of rock undergoes a disintegration from the decomposition of felspar, which then constitutes kaolin, and mingling with quartz, sand and mica, forms a very tenacious soil. This decomposition may be observed in many parts of the primary region near the surface of the ground, and often indeed of considerable thickness, exhibiting alternating layers of mica, and the two other minerals in the same position as in the solid rock, while the mass resembles clay in its softness.

§ 5. It requires only a superficial observation to discover that gneiss possesses a stratified structure, and that its micaceous particles usually lie in the plane of stratification, thus affording us an opportunity of determining its *bearing*, or the direction in which it traverses the country, and its *dip* or inclination to the horizon. The average bearing of the rock, deduced from numerous observations, is N. 47° E., and its dip 70° towards the N. W.; but these conditions are not constant, for we sometimes find it bearing N. and S., or E. and W., while its position is perfectly vertical. It is always distinctly stratified, and rarely so irregular as to prevent suitable instruments from giving the bearing and dip within an error of 2° to 5°, and hence the more striking deviations from the general direction of the strata are not to be attributed to local irregularities, but rather to those great causes of disturbance, which elevated the whole formation. We may also attribute to the same causes, those great natural joints, which traverse the gneiss in various directions, most frequently vertical, and nearly at right angles to the bearing.

§ 6. II. *Felspathean Rocks.*—These rocks occur chiefly along the shores of the Delaware from Naaman's creek to Wilmington, and from thence may be observed at intervals to the western state-line, being indicated by projecting masses of the solid bed, or by huge boulders, scarcely rounded by attrition or disintegration. Extending over one-fourth of the primary region, and with the preceding formation, embracing nearly the whole of the same area, they leave small spaces for the limestone, serpentine, and granite. The term Trappean, sometimes applied to them has been too frequently misapplied to other rocks, to admit of its employment in the present instance, and certainly, even if they had more decided trappean characters, there are good reasons why they cannot be so considered. The conformity of their bearing and dip with those of the gneiss, throughout their whole extent, and their gradual transition into the latter seem to place them in the same rank, although circumstances have modified their external characters. They form a confusedly crystalline mass of translucent smoky felspar and quartz, with occasional plates of black mica and more rarely veins abounding in hornblende. The first named of these minerals is the most abundant, sometimes constituting the entire rock, which in that case is coarse-grained and highly crystalline; but when mingled with quartz, the result is usually a fine-grained and harder material: and hence we may adopt a convenient and practical subdivision into coarse and fine-grained, or pure felspathic and quartzose. Being very compact in their texture, these rocks possess greater specific gravity than gneiss, and while their highly crystalline structure communicates to them much greater hardness, they have at the same time an increased degree of toughness. Their density, and the peculiar character of the felspar renders them less subject to disintegration, a circumstance more particularly characteristic of the fine-grained varieties, and hence, too, instead of finding the soil above them partaking of their constituents, it contains materials of gneiss, which is a much more decomposable rock. In many of the quarries opened in these rocks, it would appear as though it formed an irregular mass, incapable of stratification, but in a few instances by superficial and frequently by more accurate observation, its bearing and dip may be seen and measured. On the weathered surface of the rock, however, the lines of stratification are always well defined, and generally correspond with those of the gneiss. The hornblendic veins which sometimes traverse it are irregular, and appear to be incapable of measurement.

§ 7. III. *Limestone.*—Although occupying an unimportant extent of country in comparison with the two preceding formations, yet from its varied utility, the limestone holds pre-eminent rank among the mineral productions. It occurs in greater abundance at Jeanes' and Eastburn's, on Pike creek, and in smaller quantity at Klair's, 2 miles W. of Centreville, and at Bullock's, near the crossing of the state line by the Brandywine. It is a pure marble, essentially composed of lime, magnesia and carbonic acid, with a small amount of foreign matter. It is a coarse and fine-grained crystalline mass, with a white color of greater or less purity, presenting at times a bluish tinge from the presence of carbonaceous matter. It lies in heavy beds, generally disintegrated in its upper layers, and giving rise to a calcareous sand near the surface of the ground. It is regularly stratified, with an average bearing of N. 55° E., and with a dip at Jeanes' to S. E. At Klair's, it is interstratified with gneiss, and dips with it to the N. W. This variation in dip, gives strength to the conclusion, that, although the two localities fall nearly in the same line and have the same bearing, they are not connected, and that the rock does not necessarily exist in the intermediate space of country.

§ 8. IV. *Serpentine.*—A limited body of serpentine occurs about 6 miles N. W. of Wilmington. It is of various shades of green from a very dark to a light yellowish green;—is of different degrees of hardness, and exhibits, under the hammer, a moderate share of toughness. The influence of disturbing causes, probably arising from a heavy granitic vein which passes through it, has broken and shattered it to such an extent as to afford no opportunity of ascertaining the direction of its stratification or lamination with any degree of accuracy. As usual, it is accompanied by numerous veins of asbestos, talc, and other magnesian minerals. A smaller body of serpentine occurs near the state line in the immediate vicinity of Bullock's limestone quarry, § 40.

§ 9. V. *Granite.*—The principal vein of this rock has just been noticed as traversing the serpentine. It is characterised by its abundant content of a very pure and white felspar, unusually free from oxide of iron, a circumstance from which it derives its principal value. It also contains numerous minerals, and indeed the serpentine and granite together offer the finest mineral locality contained in the state of Delaware. Another granitic vein of considerable dimensions passes through the lime quarries on Pike creek, and is chiefly composed of felspar of less purity than the preceding; but beside these two, there are numberless smaller veins projected through the gneiss in various parts of the primary region.

CHAPTER II.

UPPER SECONDARY FORMATIONS.

§ 10. The preceding chapter exhibits a condensed view of the several formations comprised within the primary or rocky region of the state. From their lower limit to the southern boundary of Delaware, and indeed to the extremity of the peninsula, the general features of the country are widely different; for instead of a constant succession of irregular and boldly rounded hills, it presents a comparatively level country or table-land, gently sloping east and west towards either bay from an elevated strip of land several miles in breadth on which the streams flowing east and west take their rise in swamps and morasses, and scoop out their channels in the soft and yielding strata, which constitute the solid basis or geological formations of a very large portion of the state. Hence the name, water-shed or dividing-ridge, is frequently and not inaptly applied to this narrow tract, which extends through the peninsula. The deposites of the dividing ridge in the northern part of the state are argillaceous; towards the south, they are a mixture of the same with light sands, and have no connection with the subjacent geological strata. Similar clayey deposites constitute the greater portion of the neck-lands from Wilmington to Lewistown, likewise independent of the geological formations.

Approaching the surface in many situations, they communicate a well characterised tenacity to the soil both of the necks and ridge, which is only relieved towards the middle and southern portions of the state by the admixture of the there abounding light sands.

§ 11. From the lower limit of the primary, and nearly to the southern border of New Castle county, we find a series of clays, sands and gravel of a heterogeneous character when examined in detail, but nevertheless presenting certain general characters, sufficient to establish their unity as a formation, such as their position relative to each other, and their organic remains. As the former class was denominated primary, so this series bearing some analogy to another class, termed in Europe the Secondary, on the supposition of its being second in the order of formation, may receive the same appellation. Whether the term be correctly applied, may reasonably admit of doubt, but it is a matter of small moment to us, for from the general similarity of their organic remains to those of the upper portion of the secondary series of Europe, as well as to give a name generally understood, we shall designate them as the Upper Secondary Formation.

§ 12. This formation being composed of clays and sands, which are more or less loose in their texture, the surface of the country originally rather flat and level, has been scooped out by brooks, creeks, and rain-torrents into an undulating surface often presenting high hills and deep valleys, sometimes gently sloping, at others with abrupt declivities, where the formations offer a sufficient resistance to the agents of denudation. Were it not that such natural excavations penetrated and exposed the subjacent geological formations, this section of country would offer problems of very difficult investigation to the geological inquirer, and even with their assistance, the artificial excavations on the canal and roads, tend rather more to elucidate intricate points of importance. The soil of the region is decidedly argillaceous, varying from a sandy or gravelly loam, to a tenacious clay, and the varieties are mainly dependent on the rise of subjacent strata to the surface. Crossing the strata from the primary range southwardly, we find almost every natural and artificial section exhibiting a series of clays, in which a red color predominates, of so characteristic a shade, in this state, New Jersey, Maryland, and Virginia, that we may appropriate to them the name of the Red Clay Formation. Below this and as far as the Appoquinimink are a series of yellow and greenish sands, the former of which predominates, but the importance of the latter in agriculture, entitles the whole to the appellation of the Green Sand Formation.—The aggregate thickness of the formation is, probably, not less than 330 feet, including the red clay, and green, and yellow sands.

§ 13. *Red Clay Formation.*—The diluvial deposites of clay and gravel reposing on the red clay, communicate an argillaceous character to the soil, which is increased in tenacity, where they give place to the latter; and hence the hundreds of New Castle, Red Lion, and Pencader, possess a soil of a heavier nature than usual. In many instances, however, a stratum of sand in the underlying clays, or a large admixture of gravel relieves it of its extreme tenacity. The red clay formation may be examined advantageously, on the borders of the Christiana, where it forms precipitous hills rising to the height of 60—80 feet above tidewater. We there find it consisting mainly of a clay, varying from a light peach-blossom shade to an intense vermillion, and alternating with thin seams of light lead-colored, or yellow clays, with occasional beds of white and yellow sands. The red variety itself constituting by far the larger part of the whole stratum varies in different localities, for while we find it generally tenacious and plastic, yet again the presence of much arenaceous matter imparts to it a degree of friability. Although inconsiderable veins of a white, and highly plastic clay, are disseminated through the whole region, there is only one locality, where it exists in sufficient quantity to be wrought, on the Delaware shore below New Castle. The material obtained at this place is of a pure white color; remarkably free from ferruginous or siliceous matter. By adding the depth of a boring made at New Castle to the thickness of the stratum south of Wilmington, we may estimate the thickness of the red clay formation to be 250 feet.

§ 14. *Green Sand Formation.*—Towards the southern border of the preceding stratum, a deposite of yellow sand begins to appear in elevated situations, becoming gradually thicker as the red clay sinks below it, until we approach the canal, where it takes up, and includes in it another member of the series, the Green Sand or Marl. These two in combination occupy the whole of St. George's Hundred, the yellow usually preponderating over the other, sometimes presenting bluffs, 50 feet in height, while the green sand rarely exceeds 30 feet in thickness, There appear to be two principal deposites of green sand, the upper and lower, which rarely unite to form one stratum, and are often separated by 20 or 30 feet of yellow sand. The lower stratum is chiefly confined to the canal, while the upper, although visible at the Deep Cut, first assumes importance several miles to the southward. Both deposites derive their character from a green substance with which they abound, and which, being in the form of small grains, has received the name of green sand, but its granular form being the only property in common with ordinary siliceous sand, the two should not be confounded together; for while the latter contains principally one ingredient, silica or flint, the green sand is composed of five or six, among which are potassa and lime, two substances of the highest value in agriculture. The soil on the neck-lands and dividing ridge of the region in question is rather argillaceous and heavy, but throughout the rest of the hundred, the yellow sand rising to the surface, assumes the character of a loam, that can scarcely be excelled for the well-proportioned admixture of fine sand and clay, and proves itself capable of the highest degree of improvement.

§ 15. The lower stratum contains an admixture of carbonate of lime, in a finely divided chalky state, beside that comprised in its abundant shells, with a variable quantity of green sand; the upper is principally composed of the green particles, with a little siliceous or argillaceous matter. The southern border of the formation on the Appoquinimink, consists of a mixture of yellow and green sands, inclosing a compact bed of shells, which have in many instances undergone decomposition. In the same manner, the shelly strata on the western limit of the hundred have suffered the loss of a large proportion of their calcareous matter. Thus the peculiar features of the formation point a convenient classification of the several species, viz., the true green sand and the calcareous deposites—but they may be farther subdivided into 8 varieties; such distinctions, however, are not to be considered as scientific, but merely as an arrangement for convenience in describing the different parts of the formation, agreeably to their constitution, their external characters, their situation and fertilising effects.

Species of Green Sands.	Varieties of Green Sands.	Localities of the Varieties.
Calcareous.	Cretaceous or Cretoidal,	St. George's Creek.
	Decomposed & Indurated,	Head waters of the Bohemia.
	Shelly,	Appoquinimink.
Ordinary.	Bluish,	Silver Run and Drawyer's Creek.
	Yellowish,	Drawyer's Creek.
	Black externally,	Between Port Penn and Cannon's Mill-pond.
	Pyritiferous,	Heads of Bohemia and Dividing Ridge.
	Blue micaceous,	Deep-cut of the Canal.

CHAPTER III.

TERTIARY FORMATIONS.

§ 16. Between the lower limit of the green sand, and the lower part of Kent county exists a series of beds of clays and sands, comprising two narrow belts abounding in organic remains, which are different from those of the upper secondary. To these the appellation of Tertiary may be applied from their resemblance to certain formations of Europe, which have been similarly designated, although it may be doubted whether the correspondence between them is sufficiently exact. The land is generally less elevated and more level in this region than in the secondary, and the soil varies to a greater extent, sometimes presenting the extremes of sand and clay.

§ 17. In the northern part of Kent county, on Old Duck creek, and in Wales' mill-dam, may be observed a stony crust, topping a blue clay, containing abundant casts and impressions of shells. On the head waters of Murderkill, in the lower part of the same county, a heavier deposite with similar organic remains presents itself in the steep banks of the creek. The intermediate country offers no similar indications of its age, but consisting of yellowish clays surmounted by sands and gravel of a like character with those connected with the two tertiary belts, it may be included in the tertiary formation. The same remarks apply to the clays of Appoquinimink hundred. The greatest ascertained thickness of the several deposites taken in the aggregate amounts to 125 feet.

§ 18. *Northern Tertiary.*—The northern belt of tertiary offers difficulties of investigation from its presenting itself only in two localities, which are, however, well marked at Wales' Mill, § 17; and farther up Old Duck Creek at Cloak's mill, where it has been examined to the depth of 12 feet, and found to be uniform in its general features. It is a lead-blue arenaceous clay, containing impressions of shells, the upper portion of which at Wales' Mill has become indurated through the agency of oxide of iron, and the lime which it formerly contained has been wholly removed. In the same bearing, and in a southwest course from this locality we find the same blue clay at Smith's mill on the Choptank but without traces of organic remains. By adding the 12 feet of blue clay to the thickness of the superimposed yellow clay and gravel, the three deposites being always found together in the above localities, we may estimate the thickness of the formation as far as observation permits, to be 30 feet.

§ 19. *Southern Tertiary.*—The lowest stratum visible on the head-waters of Murderkill is a lead-blue clay, closely resembling that of the northern belt, § 18, but lying more open to successful investigation. It abounds in impressions of shells in a soft clayey state, and is separated from an overlying, white, sandy bed by a hard ferruginous crust, containing similar organic remains. The white arenaceous stratum is a semi-indurated mixture of sand and clay, and appears to consist almost wholly of shell-casts, but in no one of the places where it is exposed, has a trace of lime been detected, except in a solitary instance, when a shell was found unaltered. By adding the greatest observed thickness of the blue clay at Jester's mill, § 85, to that of the overlying sands &c., examined at Spring-mills, we obtain 25 feet for the greatest ascertained thickness of the Southern Tertiary.

§ 20. *Yellow clays of Appoquinimink Hundred.*—A careful examination of the lower limit of the green sand formation proves it to descend below a yellowish clay or loam, from which it is separated by a stratum of ferruginous sandstone, sometimes six feet in thickness. At these points the clay is not more than 10 to 15 feet thick, but farther south as near Blackbird, it constitutes hills some 30 feet in height, and occasionally alternates with deposites of a yellowish sand. It is a very soft and plastic clay, when wet, and contains a variable quantity of siliceous sand, generally too much to permit its being classed among valuable argillaceous deposites; and although its predominating color is a pale ochrey yellow, yet we sometimes find it lead-colored, and nearly black. Rising in many localities nearly or quite to the surface, it imparts to the soil of a large portion of the region, a considerable degree of tenacity, and consequent difficulty of working. The neck-lands, however, as well as the western part offer a soil of superior quality: indeed the latter, known as the Levels, has been long celebrated for its fertility.

§ 21. *Intermediate Yellow Clays and Sands.*—Wherever the strata subjacent to the soil can be examined over the large tract intervening between the two tertiary belts, § 18, 19, we find the lowest to consist of yellow, nearly white, and reddish clays, the yellow preponderating over the others, and the upper to be composed of gravel and sands, which graduate into the soil. They apparently overlie the tertiary on Old Duck Creek, and seem to be continuous with the yellow clay of Appoquinimink hundred, § 20, although the latter point may be doubted from the tendency of all the strata below the primary, to dip towards the southeast. For the same, and other reasons, § 88, it would appear to pass below the southern tertiary belt, and hence must be ranked with the tertiary formations, until it be shown that it is of more recent origin. If we include the sands and gravel in the same formation with the clays on which, they rest, we may assign 40 feet as its greatest ascertained thickness.

CHAPTER IV.

RECENT FORMATIONS.

§ 22. To the southward of the lower tertiary, and as far as the southern limit of the state, are deposites of clay, and sands with a preponderance of the former. Organic remains are rarely found in them, and as they contain none of those which characterise the tertiary, and resemble the shells which still exist in our waters, we may not go far astray in assigning to the whole formation a later origin, and terming it Recent. If this be true, the deposites on the neck-lands and on the dividing ridge are referrible to the same class. The surface of the country lying above the recent deposites of the lower part of Kent, and the whole of Sussex counties, is much more level than the preceding regions of secondary or tertiary date, and is less frequently scooped out into ravines. The soil is more variable than in any other portion of the state, offering the two extremes of stiff clays and blowing sands; but in several instances, as in Northwest Fork Hundred, and on the neck-lands, it is of medium texture, and endowed with superior fertility. The greatest ascertained thickness of the clays is 40 feet, § 90.

§ 23. The lowest stratum is a yellowish clay, at times of a light lead-color, alternating with thin seams of sand, and superimposed by yellowish and nearly white sands of very variable thickness, amounting at times to 20 feet. The Lower clays, Upper sands, and the more Modern deposites of the river constitute the recent formations of the state. The clay frequently rising to the surface forms a very heavy soil, while in a majority of instances the upper stratum forms a very light sandy soil, which has improperly imparted its character to the whole county. Organic remains are rarely discovered, among which may be instanced the deposite near Dagsborough, and others in Baltimore hundred, embedded in a blue clay, and those on the Nanticoke, contained in a yellow loam, which rests on a similar blue clay. On the head waters of some of the streams are deposites of iron ore, which have been wrought for years, and may still yield largely, unless the country be subjected to drainage.

§ 24. *Addenda.* Taking a general view of the state, by proceeding from the N. towards the S., we observe that the rolling country of the primary becomes less broken and more level—that the deposites of gravel diminish in extent and coarseness, graduating into fine sand—and that the amount of ferruginous matter decreases in the same ratio. To the latter assertion, the objection might be urged, that the deposites of iron ore in the south prove the contrary. It becomes evident, however, from an examination of the strata, that the iron in them does diminish in quantity, but that while it is carried away by streams from a more broken and hilly region, it is usually deposited at the place where chalybeates issue on the more level lands of Kent and Sussex. A glance at the map of Delaware shows the general bearing of the southern outline of the primary region to be nearly N. 50° E., and by a comparison of the respective limits of the other formations with similar strata in adjoining states, we find their general bearing to correspond with the same line, and all exhibit a parallelism to the great outline of the sea-coast. The irregularity of the primary will scarcely admit of determining its thickness, but the aggregate thickness of the upper secondary, tertiary, and recent formations will probably not fall short of 500 feet.

PART II.

SPECIAL GEOLOGY.

CHAPTER I.

PRIMARY ROCKS.

SECTION I.

Gneiss.

§ 25. Among the numberless places where this rock was examined, a few may be selected that may serve to establish its character as it has been described §§ 4–5, and at the same time show the variations to which it is subject. On the Lancaster turnpike, about one mile from Wilmington, the gneiss may be seen decomposed in its original bed, presenting light colored laminæ of quartz and kaolin (decomposed felspar), alternating with dark lines of black mica. It is very soft, easily cut with the knife, and yet so regularly disposed as to give the ordinary bearing and dip of the rock, § 5. Proceeding farther on the same road, it may be seen under similar circumstances in many exposures, but gradually gives way to a more solid rock. On the turnpike passing through Newport, and all the roads that cross the southern outline of the Primary region, this disintegration may be frequently observed, and is usually characterised by a deep red color from the large proportion of oxide of iron it contains. But the frequency of this occurrence is not more remarkable than its depth. 20 and 30 feet in thickness of disintegrated gneiss has been observed, and how much more may be found we cannot determine, although the probability is that the solid stone lies at no great distance below the depth just mentioned. From these facts, we are at liberty to draw conclusions relative to the great destructibility of the rock when exposed to the powerful decomposing agents of nature during lengthened periods of time; a conclusion, however, that is far from militating against its employment in the arts of construction, where it would be less influenced by those agents, and during a period of comparatively short duration. Its liability to change is farther shown by the total absence of angular fragments, and the rarity of rounded boulders, which have been found chiefly on the Lancaster pike between one and three miles from Wilmington, and near the point where the Brandywine enters the state. Even this last locality might furnish one proof of the point we aim to establish, from the unusual quantity of mica strewed over the soil, were it not that the dissemination of this substance through the soil of the whole region is abundant evidence in itself.

§ 26. Notwithstanding the variable quantities of the three principal ingredients of gneiss, § 4, it is rarely found very free from any one of them. One instance of this occurs near Phillips's mill in the vicinity of Brandywine springs, where a Trappean rock passes through gneiss composed in one part almost altogether of mica, and in another of felspar and quartz. The former of these varieties, if found in sufficient quantity, would answer a good purpose, as a hearth-stone for some furnaces, the latter as a building material, § 157. Since the absence of any one of the three minerals is of rare occurrence, when speaking of the rock, they must be supposed to be present nearly in the proportions stated, § 4.

§ 27. Beside the three constituents of gneiss, one other simple mineral is extensively diffused through it, the common red garnet, which communicates to it a peculiar tortuous appearance, and sometimes renders it a matter of no small difficulty to take accurate bearings. Thus about five and a half miles from Wilmington on the Concord turnpike is an irregularly stratified gneiss, chiefly composed of white felspar and quartz, with a few lines of black mica, and garnets disseminated through some portions, with veins of a pure white felspar; the same continues to the Pennsylvania line, where it assumes more regularity, and the garnets disappear. Passing from Smith's tavern (on an extension of the

Concord Pike), to Smith's bridge on the Brandywine, the same rock is observable, abounding in garnets to such an extent as to constitute a prominent constituent, and yet in some instances so regular as to admit of measurement of its direction, § 30. On the Kennet pike, about four and a half miles from Wilmington, the gneiss is regular and abounds in black mica, but a little farther onward, about five miles, it becomes more tortuous from the presence of garnets, and continues the same features for several miles. These few instances may serve to show the extensive diffusion of this simple mineral through the primary region.

§ 28. The quartz and felspar being generally white, the gray color of gneiss is chiefly due to its content of black mica, which is often in such abundance as to give its own hue to the rock, as in the locality mentioned in § 27—on the Kennet Pike, four and a half miles from Wilmington, and other places on the same road—on Red Clay creek, N. of the Lancaster pike—on Pike creek near the lime quarries, &c. But these micaceous scales are not unfrequently replaced by hornblende, (§ 4,) to distinguish between which often requires minute inspection. Thus, 100 yards on either side of Tucker's spar-quarries, they occur together, the hornblende communicating greater gravity, hardness, and toughness. At this place also, frequent natural joints (§ 5), intersecting the planes of stratification at similar angles, split the rocks into blocks so uniform as to resemble crystalline forms, a circumstance most frequently observed when hornblende is present. When hornblende occurs even in some quantity in the gneiss, it does not necessarily indicate the vicinity of a trappean rock, for there is no evidence of such an injection in the locality mentioned, nor in several others which were examined.

§ 29. Veins of quartz and felspar, are often seen traversing gneiss, forming waving lines, and yet in general following the planes of stratification, or its bearing; such are the localities on the Concord Pike five and a half miles from Wilmington, noticed in § 27, and on the Kennet Pike, a little beyond the fifth and sixth mile-stones, where the quartz has the appearance of having been injected in a fused or liquid state into the rock. In the neighborhood of Centreville are also to be seen true granitic veins of small extent in connection with the quartzose, from which, in all probability, the magnetic oxide of iron occasionally found

4

there has been derived. From the instances adduced in this and the preceding paragraphs, a false inference should not be drawn relative to the irregularity of the gneiss or the deviation from its ordinary features over the whole primary range, for these are merely exceptions to the general characters given in § 4—5.

§ 30. In a large majority of cases where the gneiss is exposed, we may apply the compass and levelling quadrant, to measure the bearing and dip with accuracy. Thus on an extension of the Concord turnpike near the state line, § 27, it bears N. 60° E., and dips at an angle of 80° to the S. E. contrary to its usual dip, which we may attribute to the vicinity of the serpentine, § 43, and its projection beyond a vertical position to the causes which upheaved it; for southwest of this place on the road from Smith's tavern to Smith's bridge it bears N. 60° E. with a dip of 60° to N. 30° W. and still farther to the S. W. at Blair's lime-quarry b. N. 55° E. dip to N. W. On the Kennet turnpike, four and a half miles from Wilmington, b. N. 40° E. d. steep to N. W.;—five miles from Wilmington, b. N. 40° E. d. 80° to N. W.; six and a quarter miles from Wilmington b. N. 35° E. nearly vertical; and on a road running W. from this turnpike at six miles from Wilmington b. N. 30° E. nearly vertical. These last bearings are probably affected by the granitic vein in the serpentine, lying to the southward, for around this injection the bearings vary from the ordinary direction, as on a small stream, emptying into Red Clay Creek, about one and a half miles S. by W. of the Spar Quarries the gneiss b. N. 20° E. and is nearly vertical, while on the Red Clay Creek it bears N. 50° E. To illustrate still farther this variation towards the east, may be adduced the bearing of interstratified gneiss and hornblende, E. of Jeanes' lime quarries, where they b. N. 5° to 10° E., dipping both east and west. If we take those localities where there have been fewer causes of disturbance, we find that the average bearing of the formation is N. 47° E., with a highly inclined dip to the N. W., and that its lower limit bears about N. 40° E., in which number it agrees with the trappean rocks, on its S. E. border.

SECTION II.

Felspathean Rocks.

§ 31. Beside the principal locality of this formation, mentioned in § 6, it is recognised by its boulders in various parts of the primary reigion, and in several instances *in situ*, as near Jeanes' lime quarries, and on Red Clay Creek, § 30. The boulders may be seen on the Concord, Kennet, and Lancaster turnpikes, within several miles of Wilmington, and on the Philadelphia turnpike as far as the state-line. Its usual composition, as stated § 6, is correct, but the deviations from this are so great, that it often appears to be a different rock. The formation has sometimes been termed the blue rock of the Delaware quarries; an appropriate term for one of its varieties, in which the quartz in addition to its smoky hue, reflects a shade of blue. The felspar contained in it is highly crystalline, and has likewise a smoky gray color. Being composed of these two minerals, the rock might be supposed to be always dark, but the latter mineral is at times less crystalline, and possesses a light color in common with the quartz, as on the banks of the Brandywine near Gilpin's mills, and where hornblende abounds, it is black.

§ 32. By examining the several quarries which have been opened, a better idea may be formed of the varied nature of the rock. At Churchman's quarry on the Christianna, the fine-grained variety is most abundant, and hence the fine blue color of the rock. Its predominant ingredient is quartz, veins of which free from felspar, traverse the quarry; and it is of that kind denominated greasy quartz, with a color nearly white passing on the edges of the vein into green, from the contact of hornblende. The veins sometimes contain a bronze-colored mineral which was supposed to be hypersthene or bronzite, but the small quantities which were obtained, do not permit of an accurate determination, whether they are bronzite or fractured plates of felspar. There is a decided tendency to stratification or lamination in this quarry, and the direction might have been measured had a weathered surface presented itself. Several irregular veins, however, traverse it which have not this tendency, and they are distinguished by their content of hornblende and consequent dark color, hardness, weight and toughness. Passing from these decidedly granular veins to that portion of the rock exhibiting lines, the hornblende decreases in quantity, and appears to be often replaced by black mica, until the gradation ceases in a true gneiss. Peculiar to the rock are also great joints intersecting each other at various angles, and as far as observed, without any degree of regularity; hence, in blasting, the fractures follow these lines rather than the planes of lamination.

§ 33. A rock in most respects similar to the preceding is comprised in Clyde's quarry, on the Brandywine, excepting that being much more extensively worked, it displays the formation to greater advantage, in regard to variety, to veins, joints, and structure. As in the preceding, so in this quarry, it is a fine-grained, blue rock, with a superior quantity of quartz, proportionably less felspar, but rather more black mica. Some few parts exhibit the coarse-grained variety, with more felspar, and generally in this, we find granular hornblendic veins, often containing large plates of hornblende and black mica. In one of these veins were well-defined crystals of sulphuret of iron. We have here a better opportunity of examining the great joints, only one series of which appears to conform in some measure to regularity, the remainder being so irregular as to prevent the possibility of forming a general law relative to their direction. The tendency to stratification is more clearly perceived, yet so obscure on the freshly fractured surfaces as to resist attempts at measurement. Although fragments might be mistaken for gneiss, yet there is no conclusive evidence in this quarry of a transition to that rock. A short distance N. E. of the Brandywine quarries, are Gordon's, presenting similar characters with less of the coarse-grained variety, and showing a more distinct lamination.

§ 34. Passing on still farther to the N. E., the rocks at Quarryville, on the W. of the turnpike, present us with the best examples of the coarse-grained variety. It is mainly composed of masses of crystalline felspar, of a smoky color, forming a solid bed, with a very small proportion of quartz, and occasional plates of black mica and hornblende. The felspar is very lustrous, cleaving into a regular form, and although closely resembling that found in Norway which often exhibits a beautiful play of colors, such specimens have hitherto eluded a search for them. No tendency whatever to stratification is perceptible, and the great joints or fissures are less frequent, and appear to follow no determinate law. Hence, in blasting, enormous masses of rock are frequently heaved from their solid bed, and are capable of being split by wedges in any required direction. The fine-grained and distinctly laminated rock adjoins the coarse-grained, and seems to bear the same relation to it that gneiss does to granite. The felspathic rock is more subject to disintegration than the fine-grained or quartzose, not from the abundance of its felspar, nor from local differences in the nature of this mineral, for we find it liable to change only in a few instances, where natural fissures admit of the percolation of water, and the felspar seems to be uniform in its character, but it would seem to arise from some cause which has escaped observation. At first sight, the presence of pyrites would point out the cause, but the sulphuret of iron proves, upon a closer inspection, to resolve itself into small scales of quartz and felspar, with a golden lustre. The decomposition having only been observed on pieces taken near the surface of the ground, we might rather attribute it to an incipient decomposition which took place before the rock was removed from its bed, in which case it becomes a matter of little moment. Where this felspar has suffered a partial change it is softer, of a lighter color, and resembles ordinary white felspar. On the east side of the road, we again meet with the fine-grained variety, with a well-marked lamination, and containing more black mica and hornblende than are usually found. As usual, it is distinguished by a greater degree of hardness and toughness, rendering it less manageable under the stone-chisel, but at the same time more durable.

§ 35. In the northeastern corner of the state are the quarries on Naaman's creek, which present excellent specimens of the fine-grained rock with an intermixture of the coarser kind, the former abounding in quartz, the latter in felspar. The same appearances are observable as has already been described under the preceding sections, with the exception of an increased quantity of hornblende, which being still in smaller proportion than the remainder does not materially affect its character for better or worse, in a practical point of view.

§ 36. The above are the most important quarries of the *blue* *rock* of Delaware, situated on, or near navigable waters. Far, however, from comprising all the localities whence a valuable material for purposes of construction might be derived, there are numerous other points which might be wrought to advantage along the Delaware shore, and farther in the interior, capable of yielding a stone of equally excellent properties, and more varied in appearance. To the N. E. of Wilmington on Shell-pot hill, the exposures of blue rock on the turnpike and other roads leading from it, and the openings made for stone around the neighborhood lead to the conclusion that the hill is wholly composed of this formation, but that its surface varies more than the outline of the hill is evident from the fact of its protruding through the soil in one place, and not far from this the diluvial deposite may be found of the depth of 60 feet. On the Concord turnpike, about two miles from Wilmington, the blue rock is traceable by numerous boulders, and in a few instances may be seen in place. It is distinctly stratified, as may be observed on all the weathered surfaces, even though the fracture exhibit no such appearance; but the latter sometimes shows a lamination composed of lines of light-colored quartz and felspar, alternating with those of smoky quartz, felspar and hornblende. It bears N. 40° E., and dips to the N. W. The same appearances are observable at intervals nearly to the fourth mile, where white felspar and quartz form regular laminæ, and a little beyond, the rock has precisely the same bearing and dip. Near the top of the hill skirting the west side of the Brandywine, at Gilpin's mills, the felspathean rock which is quarried out, is of so light a color as not to merit the name of blue, and closely resembles ordinary gneiss. Composed of a light-colored granular quartz, a light gray, nearly opake felspar, and light-colored mica lying in planes, it would be pronounced to be common gneiss, did it not gradually pass towards the bottom of the hill into the ordinary blue-rock. It is more distinctly stratified than the same rock of any other observed locality, b. N. 30° E., dipping at an angle of 60° to N. W.; indeed, this feature is so well impressed upon it, that it is quarried by splitting large blocks in the planes of stratification. Nearly the same bearing and dip are to be seen along the Brandywine as far as three miles from Wilmington. At the last place, the rock has a beautiful blue color, and contains veins with a reddish quartz, and apparently much pyrites. A more rigid examination, however, proves the latter to be fissured plates of quartz and felspar, refracting a golden lustre, similar to those met with at the quarries of Christianna, Brandywine, and Quarryville, § 34.

§ 37. From the instances noticed in the foregoing paragraphs, as well as from numerous observations which have not been detailed, we are safe in drawing the conclusion that the greater part of the trappean formation, possesses a clearly stratified structure, that the hornblendic and coarse felspathic veins do not, and that there appears to be a gradual transition from the former into an undoubted gneiss. An instance of the latter rock containing hornblende has been alluded to, § 28, but again we have examples of a hornblendic vein with the same structure, as a little to the eastward of Jeanes' lime quarries, § 30, and about one and a half miles N. by E. of the Buck tavern on the Kennet road. For a short distance beyond this tavern on the Kennet pike, the rock appears to be a medium between trap and gneiss, differing in few particulars from the latter, excepting in the replacement of mica by scales of hornblende. About one mile N. by W. of Springer's tavern, (on the Lancaster turnpike,) numerous boulders of stratified, and a few of unstratified trap, and true gneiss strew the hills and valleys. The instance alluded to (near Jeanes') shows a remarkable deviation from the ordinary direction of the formation. Leaving this anomaly out of the question, we obtain as the average bearing, N. 37° E., with a dip towards the N. W. The gradual passage of gneiss into felspathean rocks, rendering it impossible to define their relative limits with accuracy, the line drawn on the map throws the great mass of the latter on its eastern side, while it embraces at the same time, a few observed localities of gneiss.

SECTION III.

Limestone.

§ 39. The general features of the formation have been given, § 7. At Jeanes', it is composed of coarse, crystalline grains cemented together, which, having been subjected to the influence of atmospheric agents, in the upper portions of the quarry, have separated, and formed a calcareous sand and gravel, or are so little coherent as to crumble with a slight blow. Some of the veins have resisted disintegration, and still offer a hard and excellent stone, which is used for burning to quicklime. Descending from the surface to the lower portions of the quarry, the hard seams become larger, until in the lowest visible stratum, it forms one continuous mass of solid crystalline limestone, requiring the blast to dislodge it from its bed. Springs of water do not affect the upper portion, but when it becomes necessary to work the lower and more solid portions, drains and even machinery will probably be required to remove the water. Adjoining the granitic vein, § 9, in some other parts of the quarry, we find a mineral in considerable quantity, which though resembling limestone in appearance, differs from it in hardness, crystalline structure, and composition; it is tremolite, both fibrous and foliated, the former white, and the latter with a bluish shade. The bearing and dip of the limestone, § 9, nearly correspond with those of the gneiss. The strata being much shattered, and but few exposures of the rock offering themselves, it is impossible to determine with accuracy, its thickness; it cannot, however, fall short of 60 feet. Of far higher interest to us is the composition of this rock, which varies in its different layers. An experienced eye would say, judging in accordance with generally acknowledged characters, that it is a pure carbonate of lime, but analysis proves it otherwise, and although pieces might be selected, giving no evidence of magnesia, yet a careful analysis of an average specimen from Jeanes' quarry, conducted by Mr. James Blaney, of Newcastle, showed its composition to be—

Carbonate of lime, - - -	53·3
" of magnesia, - -	46·6
Alumina and a trace of oxide of iron,	0·6
Talcose residue, - - - -	0·3
	100·8

An examination of a dark colored seam by Mr. Wm. Baxter, gave as its constituents:—

Carbonate of lime,	78·5
" of magnesia,	9·0
Alumina and oxide of iron,	A trace.
Mica, sand, talc, &c.,	12·1
	99·6

§ 40. About two miles S. 80° W. from Centreville, Klair's quarry exhibits a limestone similar to the preceding in its general characters being coarsely granular and highly crystalline, and although wrought to a limited extent, it is sufficiently developed to afford an instance of the interstratification of gneiss and limestone, layers of the former intervening between the latter. The layers of the lime rock are several feet in thickness, one of them probably much thicker than the rest, but whether it can be wrought extensively, want of exposures of the rock and the absence of collateral evidence prevents our drawing a conclusion. That there is more than sufficient to supply the demand of the neighborhood, will scarcely admit of a doubt, and that its quality is equal to that of Jeanes', is shown by the following analysis performed by C. Morfit, of Washington:

Carbonate of lime,	54·4
Carbonate of magnesia,	45·2
Oxide of iron and alumina,	1·0
Talcose residue,	0·2
	100.8

Not far from where the Brandywine enters the state, and probably a short distance across the line, an excellent quality of limestone has been found, similar to both of the foregoing formations in the character of the stone, but differing in its connection with serpentine. Indeed, some hand specimens exhibit gneiss on one side, and limestone and serpentine on the other. Like the other quarries, this shows a stone disintegrated near the surface, displaying a coarse, calcareous sand, composed of rhombs; of its thickness we have still fewer means of judging. Each of the quarries described in this paragraph, are troubled with springs of water, which may be removed by long drains, through valleys with a gentle descent. The bearing of the former (Klair's), is N. 51° E., d. to N. W.; that of the latter (Bullock's), could not be measured, but it probably corresponds with gneiss in the immediate neighborhood, N. 60° E., with a dip of 60° to N. W., § 30.

§ 41. The two preceding paragraphs contain all that is of importance relative to the limestone formations of Delaware, as far as they have been investigated, but our inquiries should not cease here, for the great value of the stone, leads naturally to researches after other localities of the same. By a close examination of those already known, we find them to agree in the peculiar conformation of the valleys, their great depth, their abrupt flanks, in the calcareous sands of their upper parts of the formation, and in the calcareous waters issuing from them. Similarly situated valleys have been eagerly sought after, various waters have been tested, sands examined in the beds of brooks, and the bearings of existing quarries have been traced, but the search has thus far been fruitless. Nevertheless, the necessary brevity of such examinations, cannot throw reasonable doubts over the existence of other beds of limestone of equal value, and possibly of greater extent.

SECTION IV.

Serpentine.

§ 42. The largest body of serpentine in the state is that mentioned in § 8, which is irregularly traversed by a granitic vein, so rich in pure felspar, as to originate the "Spar quarries," in order to its employment in the manufacture of porcelain. The formation to the eastward of Tucker's spar-quarry consists of serpentine of different shades of green, with talc, asbestus, and other minerals, which are its ordinary accompaniments; the light green is softer, and abounds more in fibrous and foliated talc; the darker varieties are much more tough, harder, and more massive. A few yards west of Tucker's, another opening displays the serpentine with an abundant content of talc. West of the road passing by Dixon's quarry, several openings have been made in the serpentine, in which it presents the ordinary characters, except in the abundance of asbestus it contains, disseminated in numerous veins. As it crosses the road towards Dixon's, its talcose veins are more numerous, a feature which it possesses at these quarries, and which appears to increase in the most N. Easterly part of the serpentine ridge. At this last-mentioned place, (about one-third or half a mile N. E. of Dixon's,) the green rock rises abruptly from a meadow, and mainly consists of a fibrous mineral, with less of the unctuous feel, which is characteristic of talcose or magnesian minerals. It is traversed by veins of white talc and carbonate of magnesia. Serpentine often appears to be stratified, and its course can even be measured, but its exposures in this range being few in number, and chiefly in contact with the granite, it is impossible to make admeasurements of its bearing or dip that can be relied on. The greatest length of the ridge is about one mile, its extreme breadth one-third to half a mile. Serpentine rock containing a variety of minerals, cannot be expected to have an uniform composition, but a specimen of the precious serpentine, yielded Mosander and Lychnell, 44·3 silica + 42·7 magnesia + 13· water = 100; but it generally contains in addition to the above principal ingredients, protoxide of iron, alumina, lime, and bituminous matter; hence, in connection with it, we find a variety of minerals containing silica and magnesia, such as asbestus, anthophyllite, marmolite, and hydrate and carbonate of magnesia. Chromic iron, a mineral of some value, has not hitherto been detected in quantity in this range, in Delaware, although it was carefully sought after.

§ 43. There is another locality of serpentine near the state line, between Smith's tavern, and where the Brandywine enters the state, generally of a light green color, and containing hematitic iron ore of good quality. South of the principal exposure, it is associated with limestone, in Bullock's quarry, § 40, and bears a resemblance to the verd antique. Subject to a certain amount of disintegration, we find it converted into a talcose clay, in the brook flowing near the quarry, and from a granitic vein probably connected with it, as in that of Tucker and Dixon, arises a deposition of kaolin, with a little talcose matter. It is more irregular than the preceding formation and its dimensions within the state much smaller.

SECTION V.

Granite.

§ 44. The main body of one granitic vein seems to pass through the centre of the serpentine, § 42, but its ramifications extend through every part of that rock. It is mainly composed of a pure white felspar, which gave rise to the spar-quarries, and veins of quartz traversing it with a certain degree of regularity constitutes graphic granite, so called from the resemblance of its surface to written characters. Detached and imperfectly crystallised specimens of felspar are frequent at Tucker's; at Dixon's, it occurs at times more massive with large veins of quartz. That there is a difference between the felspars from different parts of the formation, is clearly shown by the partial decomposition of some portions of it in both quarries, while other portions, equally exposed to atmospheric agents are probably as firm as when first generated. The chief difference lies in the nature of the alkali, which is one of the characteristic constituents of felspar; for the ordinary mineral contains potassa, which, in the decomposable species is replaced by soda. The difference of their constitution is sufficient to establish another species, known to mineralogists as albite or soda-felspar, which is abundant in Tucker's quarry. The only other large vein which has been examined, passes through Jeanes' lime-quarry, and the limestone having been excavated on either side, it stands like a solid wall, with a bearing nearly E. and W. Although it does not appear to have affected the course of the limestone, yet it is possible we may look to it for the S. E. dip of the latter rock, in the same manner as gneiss has suffered in the vicinity of limestone and serpentine, with granitic injections, § 30, Pt. I. Like the preceding, it is mainly composed of felspar, but the presence of ferruginous matter, indicated by its yellowish color, deteriorates the quality of the mineral, rendering it almost useless in the manufacture of porcelain. Knowing the composition of felspar and limestone, we are at no loss to account for the masses of tremolite, § 39, on the sides of the granitic vein, for it contains nearly all the ingredients of the two minerals, and has evidently arisen from the injection of fused granite through the stratified limerock.

§ 45. There are numerous other veins of granite in the primary region, abounding in pure felspar, which might undoubtedly be wrought to advantage, but the demand for the material is at present too limited to permit an examination of their extent and value. When felspar undergoes decomposition, it forms a species of clay known under the name of kaolin, which possesses great value in the manufacture of china ware and porcelain, especially where it is free from oxide of iron. A few localities of this substance have been found, but being deposited by small brooks, they are too limited to demand attention. A larger deposite situated a short distance across the Pennsylvania line from Mill creek hundred yielded an excellent quality of kaolin, to the proprietors of the porcelain factory at Philadelphia, and were a minute search instituted by the farmer, many such localities might be discovered. When found in a moistened state, it resembles white clay, but is less plastic, crumbles when dry to a coarse or fine powder, is very white, may contain a few micaceous scales, between the teeth always shows the presence of siliceous particles, and hardens but slightly in an intense fire. Overlying, and in the vicinity of the granite in the serpentine, occur large blocks of a white granular quartz, apparently pure, which were used successfully in the fabrication of porcelain; no trace of its original bed was discovered, but the probability is that a vein of it traverses the granite.

§ 46. *Deposites over the Primary Rocks.*—Overlying the primary, is a diluvial deposite of clays, sands and gravel of various depths, arising from the uneven surface of the rocks, and amounting at times to at least 60 feet. On the southeastern edge of the region, it consists of a dark red clay, embodying in places a large proportion of gravel, as may be seen in cuttings on nearly all the roads, more strikingly in the neighborhood of Wilmington. The moment we descend from the primary to the succeeding formation, the gravel ceases to exist in quantity, and the red clay to increase without any visible interruption; whence it would appear that the diluvial deposite overlying the primary is one and the same with the red clay formation to be described. The great amount of clay in this deposite has necessarily its influence in rendering the soil of the upper hundreds tenacious and heavy, the more so as the gravelly beds sometimes, though rarely, approach the surface of the ground. On the Lancaster turnpike, about one mile from Wilmington, the trap is superimposed by a bluish clay, which is surmounted by the red gravel, the latter exhibiting itself at intervals for several miles on the same road. About three and a half miles in the same direction is a bed of white unctuous clay, resembling kaolin, in the bed of a small upland stream. Beyond this point, the argillaceous matter decreasing in quantity, the formation becomes a red gravel of diminished tenacity. Passing westerly, towards Mill creek, the gravel deposite gradually gives place to a yellowish loam on the upland, and a white clay in the valleys, the former being general, and the latter, local deposites. Proceeding in whatever direction towards the W. and N. W., from the S. E. border of the primary region, we find nearly the same order of deposites prevalent, showing the truth of the conclusions offered above relative to the continuity of the red clay formation over the lower part of the primary.

CHAPTER II.

UPPER SECONDARY DEPOSITES.

SECTION I.

Red Clay Formation.

§ 47. In the vicinity of New Castle, the soil is usually tenacious, loosened only in a few instances by the admixture of the yellow sands § 13, but where the basis of this region, the red clay crops out, it becomes rather too heavy to admit of superior culture unless the nature of the soil be altered by the free use of lime or the admixture of sands. About two miles N. by E. of the town, the mingled red and white clays rise to the height of some six feet above tide-water, and can be seen in only a few instances in the direction of Wilmington, in consequence of the superimposed heavy beds of sand and gravel, which may be best observed in the cuttings of the road. On the roads running S. W. and W. from the town, these last beds are so heavy, as to preclude the possibility of making any observations on the red clay, excepting a small exposure of it within the first mile, on the railroad. That it underlies the town itself, is proved by the borings made for water some years since, when it was struck near the Railroad wharf, at a short depth below the surface, and penetrated upwards of 70 feet, and another boring made on the green, extended to about 180 feet. It is to be regretted that an accurate account of these borings, together with specimens of the various deposites passed through were not retained, for all that we can ascertain is, that they perforated alternating beds of red, yellow and white clays, and white sands, to the termination of the boring, and that the light colored clays were the most abundant; from which we may draw an important inference relative to their extent, and diffusion.

§ 48. Proceeding from this place to the N. we find the formation on the hills sloping towards Wilmington rising some 30—40 feet above tide-water, and composed of mingled red and white clays, the former predominating, as is frequent on the hills skirting the Christianna farther to the W. Here, too, on a farm belonging to T. Stockton, the superincumbent sand assumes a degree of fineness which gives it value as an ingredient of mortar. No other localities have been seen in which the sand offered similar advantages, but there can be no reasonable doubt of their existence and discovery, and in order to induce a search for the same it may not be amiss to present its characters. It is very slightly coherent even in a moistened state, and when dry crumbles down to a uniformly fine-grained loose sand of a white color with a shade of yellow. Passing on towards the S. W. along this line of hills, the red clay is abundantly found with its overlying gravel and sand, which in many instances assume the characters of that overlying the lower portion of the primary, § 46, and sometimes, as in the vicinity of Newport, rise to the height of 40 feet. The neighborhood of Christianna offers the best opportunity of studying the red-clay formation, which presents excellent sections on the banks of the creek, and on the road-cuttings, the uppermost portion frequently lying 60–80 feet above tide-water.

The great preponderance of red clay communicates a peculiarly brilliant vermillion hue to the denuded acclivities of the banks bounding the creek on the N. A closer inspection, however, detects numerous subordinate beds of white, lead-colored and yellowish clays alternating with thin seams of sand, and shows the variable nature of the red variety; for although the last is usually very tenacious and plastic, throughout the whole region of which it constitutes the principal member, yet here we find some portions sandy and friable in a dry state, from the admixture of both sand and gravel;—other portions become so indurated as to pass into a clay-slate, both in reference to hardness and structure;—and its color varies in intensity and shade from a blood-red, to a delicate peach-blossom hue. In this, and many other respects, we find a strong analogy between it and the clay formation near South Amboy in New Jersey. Whether the light-colored varieties exist along the Christianna in sufficient quantity and purity, to be wrought extensively for the manufacture of pottery might be questioned from the great abundance of the red, the want of uniformity in the deposites, and the not unfrequent occurrence of arenaceous matter, and yet observation having shown the existence of many small beds of superior quality, the hopes of the citizens of this section of the country should not be damped nor their exertions to find such deposites intermitted.

§ 49. The great curve formed in the river, between New Castle and Delaware City, has been much enlarged by the increased force of currents during storm or spring-tides, in which the violent lashing of the waves undermines the banks and removes the detritus, while the effect of the ordinary currents of the river is to cover the clay-beach with a deposite of sand. This place affords us an opportunity of observing the red-clay formation under more interesting circumstances, for it may be seen in numberless places from New Castle for the distance of several miles to the southward. We have seen above that the red-clay predominates over every other kind, and that the white exists in many small irregular beds disseminated through it. At this place however, the latter assumes importance, from its abundance and purity, and indeed it has been wrought for manufacturing purposes for some 40 years. The two principal openings for white clay are on the farms of K. Johns and the Messrs. Nevins, in both of which the same general features are observable. The low banks exhibit a heavy argillaceous soil at the top, subjacent to which the red clay of an impure and arenaceous character lies in horizontal strata, and is irregularly traversed by veins of white and yellow clays, and ferruginous crusts. Between the bottom of the banks and beyond low-water, the white clay is more abundant, being contained in beds of many feet in extent, and sometimes wholly free from foreign admixture; other kinds are also found, as yellow and lead-colored clays of little or no value, and a ferruginous incrustation coating the exterior of the white beds. The irregularity of the formation precludes the possibility of giving any directions relative to the discovery and detection of beds of the white variety, the plan adopted by the workmen consisting in tracing and excavating a good deposite, when it is found, until exhausted, or as long as convenience permits. As the greater portion of it is obtained below high-water mark, it is found necessary to employ a small coffer-dam or large circular vat open at both ends, which is sunk in any convenient spot, the water removed from the interior, and the clay excavated by digging. When in its fresh and moistened state, it is of a light gray color, cuts with unusual smoothness, is very unctuous to the touch, soft and highly plastic, and capable of being moulded with accuracy into any required form; when dry, it is of a pure white color, of considerable hardness, may be polished on its surface by a hard and smooth substance, is remarkably free from ferruginous matter, and from grit or particles of sand, two most important conditions in determining its value. It is impossible to arrive at any definite conclusions relative to the extent of the deposite; several thousand tons have been extracted, and no reasonable doubt can be entertained that a sufficient quantity of superior quality can be obtained to supply a greatly increased demand. Possibly a greater demand inducing more rigid examinations of this locality will yet detect beds of comparatively unlimited extent.

§ 50. Beside the localities enumerated, the red clay may be observed in numerous places through New Castle, Pencader and Red Lion hundreds. Along Red Lion creek and its tributaries, it crops out on the sides of the hills and generally constitutes the bed of the streams, and exhibits all its characteristics on the roads in the vicinity of Red Lion Post Office; but there is nothing worthy of note in these exposures, excepting near the last mentioned place, where it forms the substratum of the yellow sands and gravel of unusual thickness. In these last, and but a short distance above the clay, is a sandy stratum of a greenish color, which might readily be mistaken for the green sand, until a closer examination shows the coloring matter to be a few particles of green sand disseminated through common siliceous sand. It has been found in excavations for wells in this neighborhood, on the farms of R. Rhodes, and A. Penington, and may be seen in the cuttings of the roads leading from the Red Lion to St. Georges and the Buck. Small masses of iron pyrites are abundantly contained in it which enables us from its very decomposable nature to account for the frequent occurrence of iron-stone, and ferruginous bands in this district. The transmutation of the pyrites (sulphuret of iron) into copperas (sulphate of iron) by exposure to the air points out at once the impropriety of employing this sand for fertilising the soil, for the quantity of green sand present is far too minute to overbalance the injurious effects of the former. It is evident that these deposites of sand and gravel are portions of the green sand formation overlapping the red clay.

§ 51. From Newark to the Buck on the dividing ridge, the soil is generally argillaceous from the presence of white and yellow clays, but where these are denuded, the gravel and sand below them, which rest on the red clay, improves the quality of the soil, forming a clayey loam with an interspersion of gravel. From the New-Castle and Frenchtown Railroad to the Buck, we find little else than gravel, and a soil assimilated to it. Certain portions of this district being at some distance from tide-water, and other places where mineral manures may be obtained, attention should be drawn to the black vegetable mould on the sources of the streams, which under proper management will be highly useful in improving the soil, Pt. III, § 151–156.

§ 52. There are several outlying spurs of considerable height in the vicinity of the head-waters of White Clay creek, of which Iron-hill is the most important. This elevation, rising abruptly from, and towering far above the plain, consists of clays, sand and gravel, and derives its name from the abundance of boulders of iron-stone and ferruginous quartz scattered over its flanks, the latter of which was probably at one time of good quality, but through exposure to atmospheric agents has been rendered valueless. An excavation has been made on the summit for the extraction of iron ore to the depth of 40 to 50 feet, which enables us to estimate the character of this singular hill. The mass of earth is a highly argillaceous loam, interspersed with large and frequent masses of yellow ochrey clay, some of which are remarkable for fineness of texture, not unlike lithomarge, and consist of white, yellow, red and dark-blue clays in detached spots communicating a peculiarly mottled appearance. This variegated clay is very free from grit, soft and plastic when moist, but on drying becomes very hard, and receives a polish from smooth steel. Nodules of iron-ore are abundantly distributed through the whole formation; it is of a chesnut-brown color, (sometimes bluish black from the presence of manganese), hard and tough; may be considered a moderately hard ore, being both siliceous and argillaceous; the nodules frequently enclose an ochrey clay, more rarely a black earth containing manganese. Large quantities of the ore have already been exported.

SECTION II.

Green Sand Formation.

§ 53. *Cretaceous or cretoidal green sand,* § 15, occurs chiefly along the ravines of the St. Georges creek, and is characterised by various shades of gray, in some cases passing into black, the lightness of color imperfectly indicating the proportion of carbonate of lime contained in it. The upper portion of the bed is usually of a lighter hue than the lower, but even the dark-colored on drying becomes gray. The carbonate of lime present is not contained in the shells alone with which the deposite abounds, but is in the form of white powder or a white pulverulent mass slightly cohering, and for this reason the beds are termed cretaceous or more properly cretoidal, the same features being characteristic of chalk. The formation is composed of carbonate of lime, green sand, and white siliceous sand, the proportions between the ingredients varying to such an extent, as to admit of no general deductions, excepting that when the amount of lime diminishes, it does not follow that the quantity of green sand increases—for the latter is sometimes partially replaced by a greenish micaceous sand, as will be shown to occur at the Deep-cut. The thickness of the stratum averages 20 feet, that of the upper yellow sand 40 feet; the substratum of the cretaceous green sand offers no data on which to ground any positive assertions relative to its thickness or its features.

§ 54. On the ravines opening into the canal west of the junction of the Dragon and St. Georges are several marl-pits, opened by Messrs A. Biddle, J. Higgins and P. Reybold, presenting the same general features as those described in the preceding § 53. In the two former it is lighter in color than in the latter, which passes into a black in the lower part of the pit when freshly excavated, but they all bear a strong resemblance to each other in the quantities of carbonate of lime, and green sand, as well as in the peculiar nature of the latter. It consists of very minute dark green grains, resembling the finest powder, and is rarely interspersed with a few micaceous particles. A specimen obtained from J. Higgins in 1838, previous to the opening of the pit, yielded upon analysis

Carbonate of lime - - - -	18·6
Green sand - - - - -	33
Siliceous sand - - - -	35
Clay - - - - - - .	14
	100·6

The specimen being obtained by boring, was somewhat contaminated by the superincumbent earth, and the marl is consequently several per cent richer in lime than is shown by analysis, for an examination of P. Reybold's of the same kind, furnished at an early period of the survey, have a greater content of lime. Thus a sample from the upper part of the bed, of a light gray color gave

Carbonate of lime - - -	24·7
Green sand - - - -	35
Siliceous sand - - - -	31
Clay - - - - - - -	9
	99·7

and one from below the same of a darker gray yielded

Carbonate of lime - - - -	20·13
Green sand - - - - -	38
Siliceous sand - - - - -	32
Clay - - - - - - -	10
	100·13

of the carbonate. A. Biddle's marl is of the same quality, and offers convenient access for its extraction. The average quantity of lime in the state of a carbonate may be estimated at 22 per cent. The marl forms a gray pulverulent mass, cohering when dry, although still somewhat friable. In a majority of cases, these beds are unusually destitute of shells, the carbonate of lime being in the form of a fine powder, not unlike friable chalk, § 53, a circumstance imparting additional value to it as a manure. The most abundant shells are Exogyra costata of large size, and Gryphæa convexa. The quantity of lime diminishing in the lower part of the bed, and yielding in the same measure, to an increase of fine green sand, these portions are not inferior in quality to the upper, and the whole must be viewed as a marl of great value. In the immediate vicinity of the pits, there are few opportunities of observing the beds resting on the marls, but artificial sections made on the canal at a short distance from them exhibit 30–40 feet deposite of yellow sand, the upper part passing into diluvial clay and gravel, which sometimes forms the soil; the greater part of the soil of this section, being formed of the yellow sand, is a good loam.—Nearer to St. Georges, and within sight of the town, the same kind of marl is wrought by Mr. Sutton, and that obtained in the lock of the canal at the same place presents no distinctive features from those above described, excepting in the greater abundance of shells, among which are Ostræa falcata, and abundant casts of Turritella. At the last-named position, as well as on the hills to the N. of St. Georges, the yellow sand swells to the height of some 40 feet. The marl of all these pits being compact, springs issuing from near the upper level of the stratum render it necessary to employ pumps for removing the water, notwithstanding the elevation of the top of the marl to the height of several feet above the canal level, but the expense attending this operation may be diminished by extracting the marl as rapidly as possible after opening one pit, and proceeding with another in the same manner, leaving a partition or wall of marl between them.

§ 55. On the same side of the canal, about two miles W. of St. Georges, Messrs. Price and Reybold have opened a large pit in a ravine, exposing the heavy deposite of marl similar in its general features to the foregoing, for the quantity of carbonate of lime varying in different parts of the same, averages the same per centage; the green and siliceous sands are nearly in the same proportion, but the former is in coarser grains. Shells are also much more abundant, and among them we find Gryphæa convexa and vomer, Exogyra costata, Ostræa falcata, Turritella, and other voluted univalves, a few belemnites. Some time since, Mr. Hurlick obtained a few saurian bones in a perfect state, the greater part having been unfortunately broken by the workmen under the impression that they were stones. Shark's teeth are also among the organic remains of this opening. The breadth of the ravine, and the gradual slope of its sides, together with the considerable elevation of the stratum above the level of the canal, afford great advantages for obtaining the marl, for it will not be requisite for a long time to remove a large amount of superincumbent earth, and facilities are afforded for drainage. The yellow sand at this place attains a much greater thickness than usual, rising in some cases 50 feet or more, and as in other situations approaching the Ridge, is covered on the summits of the hills by gravel and clay. When we therefore observe the height of the land, the deep gorges and ravines exposing the different strata, and their commingling by frequent denuding action, we might be prepared to find a variety of soil in this vicinity; but it is less observable than might be imagined from the uniform mixture of the strata over the undulating surface. In general, the summits of the hills and the valleys are more argillaceous, while their flanks constitute a good loam. The openings into the marl, enumerated in § 54 and 55, are those most extensively developed on the north side of the canal; but there can be no doubt that it might be conveniently extracted from many other localities in the same range, and it only remains for those interested in the land to examine closely for it in the low bottoms bordering on the canal. But some precautions on this head may be given. The meadow-lands of the creek being detritus from the surrounding upland frequently attaining great depth, it should not be looked for there, but it is advisable to commence the search in ravines and washes where the bottom of the hill meets the lowland.

§ 56. On the south side of the canal, W. of St. Georges, L. McWhorter, J. Wilson, J. Hudson, and E. Lore have opened pits in the cretaceous marl, which presents characters similar to those described in §§ 53–55, the carbonate of lime, green and siliceous sands being nearly in the same proportions, the green being rather more coarse-grained. Shells are rather more abundant in this locality, as they also are in Price and Reybold's, on the opposite side of the canal. L. McWhorter's marl-pits lie about one and a half miles W. of St. Georges, at the foot of a broad ravine. The marl is of a light gray color, and is remarkable for the abundance of a delicate, very brittle shell, the Anomia tellinoides; but beside this there are many casts of Turritella vertebroides, and a few of the genera Trigonia and Ostræa, the species of which could not be recognised. About half a mile farther W., are the pits of J. Wilson, the first that were opened on the canal while in the progress of its construction. The marl has been penetrated 14 feet, with but little variation in its features from the upper to the lower surface of the pit, and being a compact mass, the springs issue from the upper level; but since it is elevated many feet above the canal, it offers facilities for drainage. The most abundant shells besides those usually accompanying the stratum, §§ 54 and 55, are Belemnites Americana, Ostrea falcata, Turritella vertebroides, Pecten quinquecostatus (a few), a species of Ammonites, either the placenta or Delawarensis. The overlying yellow sand is some 30 to 40 feet thick, and immediately above the marl is cemented into a hard ferruginous crust; its uppermost portion is overlaid by an argillaceous deposite with disseminated gravel, and hence the soil varies in character. J. Hudson's pits, which are about two and a quarter miles W. of St. George's, although presenting the general characters of the cretaceous green sand, are distinguished by an unusual amount of organic remains, among which are Gryphæa convexa and vomer, Ostræa falcata and panda, Pecten quinquecostatus, Cucullæa vulgaris, Turritella, Rostellaria and Natica. E. Lore's pits are in a deep ravine, and do not differ materially from those described, if we except the lower level of the upper portion of the marl. The small shell Ostrea falcata is frequently found with both valves perfect; besides this and ordinary shells, there are a few casts of Trigonia, Cucullæa, Pectunculus, Rostellaria, and Natica. The yellow sand rises at this place some 50–60 feet, being capped by clay and gravel, and exhibits its planes of deposition, dipping at an angle of 10° to 30° to the S. and S. E.

The preceding §§ 53–56, includes the main part of the observations made on the cretaceous green sand, lying on and near the canal. Many new localities have been discovered since the commencement of the survey, among which are seven of those enumerated in the foregoing pages, and it is certain that many more will be developed, as soon as the true value of the marl is recognised.

§ 57. *Decomposed and indurated Green Sand,* § 15.—Passing in a S. W. course from this northern line of the marl stratum to the W. line of the state, we find a calcareous marl, differing in many respects from the cretaceous variety. In a majority of cases it abounds in shells and their casts, but the greater part have suffered decomposition, and seem to have injured the green sand itself, notwithstanding its moderate resistance to atmospheric agents. The marl-pits of W. Polk, about three miles W. of Middletown, on one of the sources of the Bohemia river, present us with the characters of the marl in its integral state or rather perhaps in its incipient stage of decomposition. At the first view, it would seem to be wholly composed of shells cemented into a hard mass requiring the aid of a pick to remove it from its solid bed; a more rigid examination, however, detects a mixture of shells, green sand, siliceous sand and calcareous matter cementing the whole into a stony mass, thus forming an instructive example of the origin of rock formations. It is essentially different from the cretaceous deposites on the canal, §§ 53–56, the pulverulent chalky carbonate of lime being wholly wanting, and the pure white siliceous sand forming coarse grains often one quarter of an inch in diameter. The carbonate of lime of the shells being frequently wanting around the abundant casts, instead of being carried away, has merely been transferred to other portions of the bed on which it has acted by cementation. These remarks apply rather to the upper portion, for towards the lower part of the excavation, the solidifying action decreases, and the beds become sandy. In a practical point of view, excepting the difficulties of excavating the more solid portions, the whole may be shown to possess great value, for it crumbles to powder soon after its exposure to the atmosphere, and its effects on vegetation may be seen at the present time after an application of 20 years. The yellow sand rises on the abrupt hill-sides to the height of 50–60 feet, and contains several bands of a highly ferruginous conglomerate. The soil of the upland is in general a sandy loam, and has been exhausted by excessive tillage. On the same branch are two other openings into green sand, which being nearly destitute of shells, and varying in several other important particulars, will be described § 72, under another division of the subject. The large number of shells and their casts, constituting nearly the whole of the bed, serve as marks of distinction from all others, and were it desired to enrich a cabinet of fossils, no locality in the green sand region affords equal advantages, whether for beauty, variety, or solidity of the specimens. Single pieces of Ammonites placenta and Baculites ovatus were found; turritella, and a variety of other single-celled univalves are abundant, and equally so are the bivalves, among which were found Gryphæa convexa and vomer, Ostræa falcata and vesicularis, Cucullæa vulgaris, Crassatella vadosa, Anomia tellinoides, Plicatula urticosa, and a species of Plagiostoma. The upper and lower strata together, are not less than 20 feet in thickness, but not having been penetrated farther than this, we cannot rely upon a higher estimate. The difficulty of excavating to the bottom, arises from the water of the stream which flows over and near the beds. The pits of J. Driver, situated on another of the head streams of the Bohemia, although containing shells, will be more particularly described under the dark colored green sand of the dividing ridge.

§ 58. In the vicinity of Murphy's mill-pond at the head of tide-water on the Bohemia, the green-sand formation assumes a novel and unwonted character. That it appertains to the calcareous variety, is abundantly proved by the organic remains distributed through the whole bed, but analysis showing the absence or deficiency of lime, contradicts the assumption of its presence from the appearance of organic remains, and from the whiteness of the strata. It comprises several substrata, those composed of casts of

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shells with variable quantities of green grains, and those containing a mixture of white siliceous and dark colored green sands. The greater part being elevated above tide-water, and unincumbered with springs, has undergone a material change from the percolation of water through it at some former period of time, by which the lime has been removed, a part of the green sand decomposed, the oxide of iron taken up and redeposited in various parts of the strata. The reddish brown color of the whole deposite may be attributed to the last-mentioned circumstance. The disseminated milk-white clay and sand, probably owe their origin to decomposed green particles, as they are essentially different from the small rounded grains of siliceous sand which are found both here and elsewhere in the marl district. At J. Smith's, the deposite may be observed in the ravines and washes. Below the soil of the upland, occurs the yellow sand and gravel, varying in thickness according to the height of the land, and beneath it we find a partially compact bed of dark-colored sand from one to three feet in thickness, containing green particles profusely disseminated in a light-colored clay; this is separated by a two to three inch crust of iron ore from an indurated bed of shells. Wherever the beds lie above the water and springs have ceased to percolate through it, induration has taken place, and it is much more the case where shell-casts are abundant. In some instances a trace of lime is found, but in no instance has an undecomposed shell been detected; for its place is usually occupied by a crust of oxide of iron. The mass or cast of the shell, not inaptly compared to old mortar, is composed of a white, earthy, and friable substance, (siliceous and argillaceous), enclosing granules of the green and very coarse siliceous sand. Some of these casts and the mass around them have become so hard as to require fracture by the hammer, and since both lime and oxide of iron are frequently wanting, the inference is that silica assists in the cementation of the heterogeneous compound. The shells being altogether in the state of casts, and these being imperfect, it is difficult to name them; a good cast of cucullea and cardium were found, but all that remains of the belemnites are casts of the interior cone in the lower part of this curious remnant of organic life.

§ 59. In the immediate vicinity of the mill, and on the S. E. banks of the stream, the steep banks exhibit the same beds, § 58, but the dark sand at the top having a darker shade of color appear upon a close inspection to be the grains of decomposed green sand, their green protoxide being converted into brownish black peroxide of iron. In the subjacent shell-beds, oxide of iron plays a prominent part by communicating to the whole mass a brownish tinge. A few hundred yards S. of this point the high bluffs offer a section of the formation to the height of 30 to 40 feet, the quantity of ferruginous matter being greatly increased by a total decomposition of shells, casts, and green sand, and consequently it is in a state of induration approaching that of a loose red sandstone. It appears then from an attentive examination of §§ 57–8–9, which present the principal exposures of this marl, that it has undergone, and is still suffering, decomposition; that in every place where it is laid dry and unaffected by springs, it is altered by the removal of lime, potassa, and oxide of iron, and that the latter is deposited in other portions of the beds, acting by cementation; that where it is in its incipient state of disintegration, the small quantity of lime abstracted from the shells has been deposited again in the same bed which it cements into a hard and stony mass; and lastly, that no deposition of carbonate of lime occurring in a pulverulent form, this decomposed and indurated green sand is sufficiently distinct from the cretaceous variety on the canal.

§ 60. *Shelly Green Sand,* § 15.—From the high land under Cantwell's bridge on the north side of the Appoquinimink, and along the southern border of the same stream to the fork at the head of the Noxentown mill-pond, we find another and well characterised variety of the green sand formation, constituting its extreme southern limit. At the fork of the mill-pond, are the openings of J. Townsend, which fairly expose the deposites to view. It consists of two substrata, rising about fifteen feet above the pond, the lower abounding in small unaltered shells, the upper consisting of yellow sand, in which green particles are sparsely distributed. The lower stratum rises, on an average, six feet above the level of the pond, to which height it consists of small friable shells, firmly imbedded in horizontal, somewhat tortuous layers in a mixture of yellow and green sands, the former of which predominates. Above this unaltered marl, the shells are much thinner, and are coated on their inner and outer surfaces by oxide of iron, and still higher we find the main body of brownish sand abounding in ferruginous impressions and casts of the same species of shells which constitute the lower stratum. The upper line dividing the unaltered from the decomposed strata, presents a very jagged outline, rising in some cases four, and at other times 10 feet above the water-level, but sufficient quantities for spreading on the soil may be obtained with facility. Among the shells composing the marl, may be recognised abundant specimens of the Gryphæa vomer, Gryphæa mutabilis and convexa, which T. Conrad views as the same, Terebratula fragilis, a triangular Serpula, resembling a species found in Alabama, spines of echini, and a single specimen of the claw of a crab; but all of them are friable, and the abundance of minute fragments, together with a few per cent. of green sand, give the marl some claim to our attention as a source of fertility. Interesting in a theoretic point is the gradual replacement of shells by oxide of iron, and the interstratification of the yellow sand with the calcareous beds. The same formation may be seen to advantage at the excavation made by S. Naudain on the N. side of the same pond, and not far from the locality just described. The unaltered shell deposite rises some twelve feet above the water, and presents the same jagged outline formed by currents, but differs in being filled up with a detritus of gravel and clay, or a clayey loam. The central stratum has a greenish hue from its abundant content of green sand particles. The shells, of which Gryphæa vomer, mutabilis and convexa appear to constitute nearly the whole mass, are much shattered, but they are not unfrequently cemented firmly together by calcareous matter. Below the water-level, the shells decrease in quantity and even cease, but give place to a deposite containing a large proportion of green granules. J. Whitby's marl lies on the S. side of the Appoquinimink about a mile S. or S. by W. of Cantwell's Bridge, and has been found on a small branch of the creek in many places. Presenting no distinctive features from the openings of J. Townsend, the remarks made on the latter are applicable to those of J. Whitby, with the exception of the diminished thickness of the stratum, as far as it has been investigated. Its upper level rising but a few feet above high-water mark, is at least 20 feet lower than the highest point on the Noxentown mill-pond, thus showing a rise of the strata towards the W. According to an analysis of an average specimen from the latter locality crushed to a coarse powder, it contains

Carbonate of lime,	58·6
Green sand,	6·
Common siliceous sand and undecomposed shells,	35·4
	100·0

Which may be viewed as the average composition of the undecomposed shell-beds.

§ 61. The same formation underlies the town of Cantwell's Bridge, and forms the high bluffs bordering the creek. It may be described as a brownish yellow sand, traversed by irregular and thin veins of iron stone, having in general a horizontal direction. Some portions have a decidedly greenish tinge from the presence of green sand, others again are whitened by the removal of oxide of iron, while the uppermost layer below the soil is cemented by ferruginous matter, into a sandstone of varying friability. Beds containing casts of the same shells, § 60, wholly replaced by oxide of iron, are found both in the upper and lower parts of the bluffs, and as it is continuous with the yellow sand overlying the marl at a short distance N. of the Bridge, we may safely rely upon their identity, and on its membership in the green sand series. Rising the hill from the causeway towards Blackbird, the same formation is seen, differing only in the absence of organic remains. The formation of a sandstone and conglomerate in the upper layers of this deposite is deserving some attention, for we find it in place on nearly every abrupt descent to the creek on its southern side, and in a few instances on its northern banks. Not far from the marl of J. Whitby, it attains the thickness of four to five feet, and boulders of the same are sometimes found weighing more than a ton. Being often extremely hard and tough, and capable of resisting atmospheric agents, it ought to derive importance as a buildingstone, where it can be discovered in sufficient quantity. Taking a general survey of the shelly variety of green sand, as described, it will be perceived that the several deposites lying in the same geological line of N. E. and S. W., are one continuous stratum, that this stratum is essentially distinct from the two preceding varieties in its position, its mineral and its organic contents, that by far the larger portion of it has undergone a decomposition which diminishes its value as a marl, but that the lower part of it is well adapted to agricultural purposes. Farther, when we observe its southern position relative to the remainder of the green sand region, its peculiar organic contents, and the amount of lime which it contains, we may view it as a continuation of the yellow limestone noticed in the survey of New Jersey, with which it lies in the same geological bearing.

§ 62. *Bluish Green Sand.*—What precedes comprises the extent of observations made in the several calcareous deposites § 53–61 situated on the Northern, Western, and Southern limits of St. Georges hundred. We now pass to the more numerous excavations made into the second division of the green sand formation, embraced within the above limits, and underlying nearly the whole of the hundred, which has been divided, § 15, into several classes for convenience in description. The first of these, the bluish variety, occurs on Drawyer's creek and Silver run, chiefly to the eastward of the main state road, and is so named from the color which it assumes in the few localities where it has been found. It is more perfectly developed at S. Townsend's on Silver run, where it has been excavated to the depth of 16 feet from the top of the stratum, and bored 7 feet deeper through the same material, but a portion of the bed being below the level of Silver run, the entrance of water obstructs the operations of the workmen. The greatest observed thickness therefore is 23 feet. It is a bluish green sand, very uniform throughout the whole bed, excepting two or three feet near the surface, of the size of grains of gunpowder, containing too small a proportion of argillaceous matter to cause it to adhere even when wet, and but a small quantity of arenaceous matter. It is therefore a very pure material, which in addition to its large per centage of potassa stamps its character as among the best marls of the region. The particles are soft, readily crushed by the nail, and as their powder exhibits the same color as the exterior, they have evidently not suffered from decomposition. According to the first analysis, the quantity of potassa appearing too large, it was submitted to a second and third examination with the following average results, as obtained by Dr. H. Seybert, J. S. McCulloh and J. C. B.

Silica - - -	55·775
Potassa - - -	9·00
Lime and magnesia -	2·30
Protoxide of iron -	21·70
Alumina - - -	3·12
Water - - -	8·50
	100·395

It is accompanied by no traces of shells, the only articles of curiosity being a few sharks' teeth. Adjoining S. Townsend, and nearer to the state road, J. Vandegrift has discovered marl of nearly equal quality, and when more extensive examinations are made, it will probably prove of equal quality in every respect. Still nearer the same road, Z. Glazier's pits show a change in the quality of the material, the upper part being more argillaceous and of a more decided greenish shade, and the lower more sandy and containing casts in which the shell is replaced by oxide of iron. The upper stratum, which is 3 to 4 feet in thickness, has been chiefly employed, but is subject to the disadvantage of becoming compact, by drying. The lower stratum is nevertheless inferior to it in quality, from its having undergone partial decomposition, abounding in siliceous sand and presenting some difficulties of drainage. It would not be unadvisable to search for the bluish green sand on the same premises.

§ 63. The beds of G. Karsner on Silver run about three quarters of a mile E. of the Trap, derive additional interest from the fact that they were the first excavations made into the true green sand in the state, on the supposition that it was marl. It belongs to the bluish green variety throughout, the greater part of the pits having been found uniform to the depth of 25 feet. The uppermost layers are rather argillaceous, and one of them in particular resembles a green clay in all its external characters, so that upon *washing over*, nothing is left but a white siliceous sand with a few green particles; notwithstanding which it presents to chemical analysis the same composition as ordinary green sand, and must therefore be considered as a pulverulent and not granulated variety of that material. Now the same substance is usually removed by washing over in the ordinary processes of analysis, and hence it follows that an estimate of the amount of potassa in the marl deduced from an analysis of the selected green grains falls short of that which is actually contained in the marl.—An analysis of the average sand of the bed, taken at the depth of 8 to 10 feet from the surface, yielded:

Silica	56·70
Potassa	8·50
Protoxide of iron	22·21
Alumina	5·00
Lime	a trace
Water	9·30
	101·71

Sharks' teeth are frequently met with in the marl, and occasionally fragments of bone, but the latter are too far disintegrated to determine their character. The upper surface being at no great elevation above the run and being moreover argillaceous, acts as a water-shed for springs and requires, as at Townsend's, rapid excavation, and the use of a pump to keep it free from water. Proceeding down Vance's Neck to the eastward of Townsend's, we might anticipate the existence of the same marl nearer to the bay, but up to the date of the close of the survey, it had eluded observation. There is every reason to believe, however, that researches for it will be crowned with success, notwithstanding the eroding action of the bay, and the replacement of the more ancient strata by the argillaceous and gravelly deposites of the Delaware. To the latter circumstance is to be attributed the heavy nature of the soil on the neck-lands on either side of Silver run. The same variety of marl is found on Drawyer's creek near the state road in the pits of Mrs. L. Sims, and J. Rogers. In the former, the upper part is dark colored and somewhat argillaceous, below which the main body is sandy, and has the characteristic bluish shade. The upper surface being elevated some 15 feet above the creek, it is not improbable that the bottom of the deposite may be reached in this pit, and being nearly dry, will afford facilities for extracting it to the whole depth. In J. Rogers' excavation on the W. side of the state road, the lower part adjoining the road contains the bluish green sand and appears to be the western termination of this valuable variety. Farther examinations are required to discover it in many of the ravines bordering Drawyer's creek from the bridge to its mouth. It would appear then from the preceding enumeration of localities, §§ 62 and 63, that the bluish green sand is not an extensive deposite, being most largely developed at Townsend's and Karsner's, and attaining the thickness of 25 feet; that it is unusually free from foreign matter, incloses few traces of organic life, and that it contains a very large per centage of potassa, with traces of calcareous matter.

§ 64. *Yellowish Green Sand.*—The principal part of the green sand formation on Drawyer's creek, has a yellowish or grayish tinge in its dry state, arising from the intermixture of much white sand, and a little clay. More or less extensive openings have been made into it to the W. of the state road by Mc Lane, Rogers, Croft, Polk, Uhler and Pennington. The pit of J. Rogers offers a complete section of the formation. Its color is generally bright green and sandy, traversed by a few argillaceous veins, and passing into the bluish green, § 63. The uppermost layers have suffered partial decomposition by the removal of silicate of potassa, and the diffusion of peroxide of iron, which communicates a brownish tinge to the marl, and cements it at times to a brown sand-stone. A peculiar white pulverulent substance which constitutes the substratum, is a sandy clay containing variable quantities of carbonate of lime, rarely so much as to effervesce with acids. The lower surface rising several feet above the level of the creek, and the upper some 30 feet, the thickness of the bed may be estimated at 20 to 25 feet. Notwithstanding its general sandy nature, it is so compact as to require the use of the pick to displace it, and yet it is sufficiently porous to permit the percolation of water, which generally issues in springs below the marl. Its freedom from argillaceous matter may be inferred from the last mentioned fact, and is further proved by its readily crumbling upon exposure to the atmosphere. A few sharks' teeth and fragments of bone have been found, but the latter were too friable to admit of transportation.

An average sample of the bright green sandy marl proved upon analysis to consist of:

Silica, - - - - - - -	56·35
Potassa, - - - - - - -	8·418
Protoxide of iron, - - - - -	22·25
Alumina, - - - - - - -	6·00
Water, - - - - - - - -	7·11
	100·128

Rising from Drawyer's bridge to the N. on the state road, the green sand has been observed for fifty years, and has given rise to a variety of conjectures as to its nature and origin, to mention which would be irrelevant to the subject. It undoubtedly extends westward on the lands of L. McLane, and in all probability does not diminish in quality, even if it decrease in thickness; for the absence of sufficient excavations admits of positive assertions relative only to its nature, which is that of the yellowish green sand. Thorough search after it will be amply compensated by the discovery of marl of good quality, and easy of access.

§ 65. E. Croft and W. Polk, have opened pits in the same formation in a ravine which commences near the N. W. end of Cantwell's Bridge, and runs to Drawyer's creek. It is still more elevated than that of Rogers and appears to be of the same thickness. It has a light green color in the pits, passing in a dry state into a grayish or yellowish green, in consequence of particles of siliceous sand which are transparent when wet, and yellowish when dry. The dryness of the bed is remarkable, since it is so compact, although free from clay, that the necessary use of a pick increases the expense of its extraction. The same marks of decomposition in the upper and lower portions of the bed are observable as were noticed in Rogers, but cannot be considered as characteristic of these beds, since the extent of alteration varies materially in the same locality. That of Croft is lighter colored, and more compact than any of the marls now being described, but it is not on that account inferior, for it crumbles soon after exposure to the air. The yellow sand constituting the uppermost stratum, rises from 5 to 15 feet above the marl, and produces a fine loamy soil. A few hundred yards W. of this point are the marl banks of W. Polk and Dr. Uhler adjoining each other immediately on the abrupt banks of the creek. The lower part of Uhler's pit is about 10 feet above the meadow. The marl is about 12 feet thick, has 15 feet of earth on the top, and a two feet white clayey stratum at the bottom, § 64, is partially decomposed near their upper surface, and only differs in the absence of some of the siliceous sand, and consequently darker shade of color. A carefully conducted analysis of Uhler's by J. F. Frazer gave the following results:

Silica, - - - - - - -	52·60
Potassa, - - - - - - -	5·37
Protoxide of iron, - - - -	27·02
Alumina, - - - - - - -	7·70
Water, - - - - - - -	7·40
	100·09

The quantity of potassa being smaller than is usually given in the preceding and following analyses should not give rise to the belief that this marl is of inferior quality, for it was observed in the preface that it is generally estimated too high. A pit excavated by W. Polk in a ravine near this locality offers one point of interest to the geologist, at the same time proving that the marl is not inexhaustible. The substratum of the green sand is exposed to view, and proves to be a coarse yellow sand, wholly destitute of the green particles, and reposing on an argillaceous bed as may be inferred from the springs issuing from it. Still farther west on the same stream, Mr. Pennington has commenced operations for extracting marl, and although the stratum was not laid sufficiently open for a more accurate description, yet enough was observed to justify the conclusion that it is the same kind of marl, and probably of the same extent, differing only in its liability to become charged with water. But even this may be obviated by opening a pit on the flank of a hill, instead of in the bottom of a ravine. During the first eighteen months of the survey, green sand had not been found on the N. side of Drawyer's creek, but impressed with the belief that it did not fine out, although circumstances seemed to strengthen the assumption, the banks of the creek and its ravines, were closely investigated several times without success. Since that period it has been accidentally discovered in the race-way of Tatman's mill, on the southern branch of Drawyer's, closely resembling the marl found lower down the same stream, but it has not been farther investigated. The detection of the marl in this place, points out the advantages of instituting farther researches for it on the N. branch of Drawyer's as far as Cannon's mill-pond, since it is also found on the head-waters of this branch. One difficulty attends the extraction of marl on the lower part of the two branches of Drawyer's, in the unusual thickness of the superincumbent yellow sand, a difficulty only to be obviated by finding it in ravines, and near small water courses.

§ 66. A few miles W. by S. of Cantwell's Bridge the Appoquinimink is formed by the union of two branches, the one of which abounds in shelly green sand on the Noxentown mill-pond, § 60, and on the other we find the same as is described in the preceding paragraphs. It may be seen in the banks of the stream from the fork of the two branches as far as Murphy's mill, where the formation may be better studied. The upper portion is partially disintegrated, and colored brown by the oxide of iron, below which the main body of the sand is dark green when wet, grayish green when dry, and is free from argillaceous matter. While digging for settling the foundation of the saw-mill, the marl was penetrated 14 feet, to which if we add five feet for the height of it above the road, we have about 20 feet for its greatest observed thickness. Near the lowest point of the digging, the workmen struck a bed of shells, not a specimen of which could be obtained; and it is to be regretted since they might have determined the question more satisfactorily, whether the green overlies or is subjacent to the shelly sand on the Noxentown branch, § 60, or passes into that deposite. The stratum rises 12–15 feet above tide-water, and is overlaid by 10 to 20 feet of yellow sand, the upper part of which is converted into a sand-stone, § 61. The lower part of the green sand submitted to analysis gave,

Silica, - - - - - - -	58·10
Potassa, - - - - - - -	7·54
Protoxide of iron, - - - - -	22·13
Alumina, - - - - - - -	5·14
Lime, - - - - - - -	a trace
Water, - - - - - - -	8·22
	101·13

Many fruitless attempts have been made to discover the same stratum on the N. side of this branch both above and below the mill, and the probability is that it does exist, but so covered with detritus as to elude superficial research.

§ 67. Reviewing the preceding §§ 64–5–6, it may be gathered that the yellowish green sand is characterised by its elevation above tide-water, so that the lower surface may be reached in some instances, that it attains the thickness of 20–25 feet, that it is remarkably dry and compact, that it is rarely argillaceous, and abounds rather in siliceous sand, whence its yellowish and grayish green color; that it contains on an average more than 7 per cent. potassa, and is, therefore, an excellent material for fertilising the soil; that its uppermost layer is usually decomposed, the protoxide being converted into peroxide of iron; and lastly, that it is surmounted by 5 to 20 feet of yellow sand, capped by a mingled clay and gravel, on which reposes a fine yellow loam. The elevation, dryness, and sandy nature of the marl, offer facilities for its extraction and employment on the soil not ordinarily met with in St. Georges hundred. The planes of deposition, so obvious in many localities where the yellow sand is freshly excavated may be observed to advantage near Tatman's mill on the southern branch of Drawyer's.

§ 68. *Black colored Green Sand.*—Between Silver run and the canal to the E. of the state road, we find the largest number of excavations into the marl, embraced in a district three miles in length by one half in breadth, and disclosing a distinctly granular sand, usually of a very dark shade passing into black, and remarkable for its hardness. It is not presumed that the marl exists in greater abundance in this district than in other parts of the hundred, but the land gradually sloping to the bay, exposes in numberless places the outcropping of the green sand, and renders it generally more easy of access. The undulating surface on the land of S. Higgins, exhibits the marl on the flanks of the hills communicating a greenish color to the soil, and by the argillaceous character of its upper layers renders these spots heavy in moist, and hard in dry weather. It is to be regretted that notwithstanding the readiness of access to the marl, it has been wrought to a very limited extent, not sufficient to determine its character with accuracy. It has a dark green color, contains an admixture of siliceous sand, its upper surface is elevated many feet above tide-water, the bed is generally dry in summer, and it may be obtained in many places without difficulty. In addition to these circumstances, its good quality should entitle it to credit as a fertilizer. Specimens of amber have been found in the deposites on the canal, but the green sand of S. H. is the only noncalcareous variety, in which a well characterised piece of that curious remnant of ancient forests has been hitherto detected.— At J. Jefferson's, adjoining the former, it lies in a similar position, being often ploughed up in the fields, but not being extensively wrought, the features of its better qualities cannot be given, excepting so far as to state its resemblance in every respect to that of S. H. In a ravine between J. Jefferson and J. Dale, the latter after persevering research has succeeded in discovering green sand of the same character, but the formation being uncovered to some depth, offers a better means of examining its features. It has a dark shade of green, is evenly granulated, nearly uniform to the bottom of the opening, slightly decomposed and mingled with foreign matter near its upper surface, and contains a little arenaceous and still less argillaceous matter. The larger part of it lying above the water and not materially affected by springs, offers no impediment to its being extensively worked, as far as its thickness has been ascertained, which in all probability does not fall short of 20 feet. The above openings lie on the S. side of the road leading to Augustine landing; and to the N. of the same road are several others bordering on the streams which flow into Augustine creek. J. Walraven's marl has no distinctive features, the upper layers being light green and argillaceous, the lower darker and more sandy: when examined, it had not been deeply penetrated. J. McConaughey's pit has a stratum of bright, bluish green clay at the top, under the yellow sand, and beneath it the marl consists chiefly of black grains, intermixed with green. It is partially decomposed where exposed to view, but when it shall have been more fully developed, it will prove to be of good quality, and springing water will throw fewer obstacles in the way of its extraction. Viewing all the above openings into the green sand on either side of the road, we observe that the marl where sufficiently wrought, is of good quality, and promises the same in all cases; that it is sandy in its nature, and therefore convenient for spreading on the soil; that it is elevated above tidewater, and not incommoded by springs, and therefore in its employment offers great facilities. From the proximity of the Delaware, we might anticipate the fact of the prevalent argillaceous character of the soil, which, however, may be demonstrated to admit of profitable culture.

§ 69. All that land lying between Silver run and Augustine creek near the bay, shows a deposition of a light colored clay, imbedding gravel, to such a depth as to preclude the discovery of green sand without close investigation: it is probably an ancient deposite of the bay, when the land was relatively at a lower level than at present, and has replaced a portion of the marl which has been removed. That the latter has not been wholly removed, is proved by the deposite opened by J. Dale, and still more conclusively in those nearer Port Penn, which immediately underlie the clay without the intervention of the regular deposite of yellow sand. There are several places from which marl is obtained on that neck of land lying between Augustine and St. Georges creeks, at the extremity of which Port Penn is situated, and this appears to be its nearest point of approach to the bay. A light green, argillaceous marl from the upper part of the bed opened by W. Kennedy was analysed by C. Morfit and found to consist of:—

Silica,	55·9
Potassa,	8·0
Protoxide of iron,	18·1
Alumina,	4·9
Water,	12·1
	99·0

The same kind of green sand was found at J. Carpenter's, a short distance below the surface, and was probably the upper layer of the formation. It was not excavated below the clay, and cannot therefore be described with more minuteness. W. Cleaver has discovered the same variety within view of Port Penn, which was examined chemically, and found to contain agreeably to two analyses performed by R. McCulloh, and J. V. Blaney:—

Silica,	58·42
Potassa,	7·51
Protoxide of iron,	17.45
Alumina,	7.13
Water,	8·57
	99·08

The upper part of the stratum has likewise been discovered on J. Dilworth's land not more than a foot below the surface, presenting the same argillaceous features and lightness of color, which characterise the preceding. The land being higher at J. Cleaver's, the same formation crops out on the flanks of the hills, and having been excavated several feet in depth, affords us the means of describing its character. The upper part is bluish green, argillaceous, and contains small disseminated masses of iron-stone. Below this the main body of the marl is black when moist, and dark gray when dry, contains a trace of argillaceous matter, a little siliceous sand, and the green granules which vary in size are remarkably hard. The latter property in connection with their color, indicating a change in their composition, the marl was subjected to analysis, and proved to be of good quality, as may be practically shown by crushing the grains in a white surface, when their characteristic green color is developed. The black color is, therefore, nothing more than a decomposition on the surface of the granules not detracting from their value. The following are the results of analysis, as obtained by C. Lea:—

Silica, - - - - - - -	49.93
Potassa, - - - - - - - -	7·80
Protoxide of iron, - - - - -	23·41
Alumina, - - - - - -	6·90
Water, - - - - - - -	10·95
	98·99

The land in the vicinity of Port Penn rises from 5 to 20 feet above high water, and the marl being usually elevated, affords great facilities for its extraction, notwithstanding the probable inconvenience of water. In this district, the main part of the marl is black and sandy, and is overlaid by a light green argillaceous stratum rather inferior to the former: above the latter, we generally find a thin seam of iron ore, and the whole is capped by a mingled white and yellow clay, with imbedded gravel, an undoubted deposite of the bay. That ferruginous springs have been in action is shown by the stratum of iron ore, which is best observed at J. Carpenter's, where it rests on marsh mud. The springs still exist, but their chalybeate nature has ceased.

§ 70. The marl exhibits its outcrop on the road from Port Penn to the state road, and is found on the lands on either side of the road. On the S. side it has been excavated by T. Stockton and L. Vandegrift, particularly on the lands of the former, where its constant outcropping on the flanks of the low hills proves it to underlie the whole farm. T. S., having searched for it in many places, and excavated it to some extent, has shown that it is variable in its character near the surface, being at times argillaceous, and of a light green color, at others, sandy, yellowish, and gray. After the upper and adulterated portions have been removed, the principal body of the marl appears of a very dark brown or black color, in grains of variable size, generally very coarse and hard, mingled with a little white siliceous sand, and rarely with a little clay. In nearly all the exposures, its sandy nature is evinced by the dryness of the bed, the water-bearing stratum lying below it; but as the ordinary consequence of this dryness, we find the upper portions of the sandy marl partially decomposed and the bed traversed by veins of the same nature. It is unnecessary to allude to the manner of its decomposition, which has been frequently alluded to in the preceding pages. This green sand was one of the first subjected to analysis, and at that time the ordinary method adopted of selecting the green granules from the rough marl, and submitting them to chemical examination; according to the analysis, the green particles alone contained:—

Silica,	47.84
Potassa,	10·30
Protoxide of iron,	24·29
Alumina,	7·38
Water,	10·19
	100.00

By a comparison of these results with a similar marl from J. Mansfield, § 74, and observing the amounts in the unselected marl of the latter, we have the means of ascertaining the per centage of potassa in the rough marl of T. Stockton. But that portion submitted to analysis was obtained from the surface, and the main part of the marl has undoubtedly the same composition as that of J. Cleaver, § 69, to which it bears the closest resemblance. On the opposite side of Augustine creek, the deep ravines with steep flanks show the marl at a higher elevation under the same general features, and L. Vandegrift has not been inattentive to these developments, having made several openings with the view of testing its qualities. It is nearly black in color, loosely granulated, and is characterised by the abundance of a white earthy material, which often forms thick layers in the marl in a horizontal position. This peculiar substance found under J. Rogers' marl pit, § 64, and in small quantities in several other places, consists of white clay, green and siliceous sands, partially cemented by silicate of potassa (?) into small irregular nodules from half an ounce to several pounds in weight, sometimes forming casts of shells, and containing, (but rarely,) a sufficient quantity of carbonate of lime to effervesce with acids. These layers also embrace pieces of bone in a very friable state. The quantity of lime being small, the beds containing the nodules cannot equal the pure green sand in value. On the N. side of the road, C. Vandegrift has obtained the black colored marl, described in the preceding, in several places in the vicinity of his house, and will undoubtedly find it in many other situations on the farm, where it is easy of access and not incommoded by water. It appears to have undergone more change than any of the preceding, and is probably not of the same thickness; for on the farm of W. Bennet, a short distance to the N. of C. V., the stratum may be seen in the washes of hill-sides only a few feet in thickness, much decomposed and mingled with the over and underlying yellow sand. At W. Bennet's, a large proportion of the green sand is converted into iron-stone, and has suffered such an alteration throughout, that it is questionable whether it can be profitably employed on the soil. Passing a little farther to the N., the green sand disappears and fines out in the yellow sand, for the hills bordering Scott's run are composed of the latter with green grains sparsely distributed through it, to the height of 40 to 60 feet. At the extreme northern point where it is observed, (Bennet's), it lies at a considerable elevation above tide-water, and could certainly be found on Scott's run if it existed there, but an examination made on that stream failed to detect the least trace of it to the E. of the main state-road. At the mill, a short distance W. of the road, it is said that shell-marl was found in digging for the foundations of the dam or race-way, and it is probable that it was the cretaceous green sand of the canal. The difference of elevation between this deposite and the above black colored green sand, point to two different strata of this formation included between the yellow sands.

§ 71. Reviewing the preceding details relative to the darker variety of green sand, § 68–9–70, we observe that at its southern limit, it attains the thickness of 20–25 feet, is dark green, and uniform throughout, that to the westward of Port Penn, it is 15–20 feet thick, externally black from a partial disintegration, and is overlaid by a light green argillaceous sand—that still farther to the N. it is three to five feet thick, much decomposed, a large proportion being black internally, and that eventually it fines out, passing into the yellow sand, which is the heaviest deposite in the green sand series. We farther observe that its upper surface near the bay lies but a few feet above tide-water, and rises towards the W. and S. W., so that the bottom of the stratum may be reached above the level of tide—that the land rises in the same direction more rapidly; and that, therefore, the denuding action of the bay in former periods of time has merely removed the yellow sand, and been resisted by the superior tenacity of the green-sand stratum. As a consequence of the last conclusion, we find an argillaceous and gravelly deposite near the bay shore, producing a heavy soil, and as it gives way to the yellow sand on the more elevated country forming a good loam, characteristic of the middle portion of St. Georges hundred.

§ 72. *Pyritiferous Green Sand of the Dividing Ridge, and the Head Waters of the Bohemia*, § 15.—Passing across the state to the S. W. corner of the Hundred, and resting on one of the head streams of the Bohemia, we find a dark green, nearly black marl in the vicinity of the calcareous beds, § 57, and although resembling the bluish green sand, §§ 62, 63, in its general composition, yet materially differing from all others in its content of phosphoric acid, it deserves a separate notice. It has been sought for and extracted by W. Polk with praiseworthy enterprise. It is very uniform in color, and granulation, and contains few traces of organic life and few impurities. Situated at the base of the steep flanks of the hills skirting this branch of the Bohemia, and its upper surface being slightly argillaceous and semi-indurated by the deposition of peroxide of iron, it becomes a water bearing stratum, which incommodes its ready excavation, and prevents us from ascertaining its thickness; it exceeds 25 feet, and if we may judge from the adjacent decomposed beds, § 59, its thickness is over 30 feet. That of the yellow sand above it is upwards of 40 feet. While workmen were employed in the excavation, they observed it sparkle in the sun's light with the brilliancy of polished silver, which they attributed of course to the presence of that metal in the form of small spangles. A closer inspection proved them to be small crystals, with a brilliant, nearly adamantine lustre, perfectly limpid when first obtained, but rapidly changing to blue by exposure to the air; and chemical analysis showed their constitution to be phosphoric acid, protoxide of iron, and water. They are the same as those found some years since at Mullica Hill in N. Jersey, and termed Mullicite by Dr. Thomson of Glasgow, who analysed them. This marl is farther characterised by a white efflorescence which coats the grains on drying, and often forms no inconsiderable proportion of the mass. The efflorescence submitted to examination was found to contain sulphate of lime, rarely a little copperas, and although not detected, it undoubtedly contains phosphate of lime. The formation of the copperas, which would be detrimental to vegetation, is obviated in a great measure by the presence of carbonate of lime, which explains the efflorescence of sulphate of lime (plaster). A specimen of that obtained prior to the opening of the pits, effervesced slightly with acid (from the carbonate of lime), but contained lime in addition to that in the carbonate. The following is the result of the analysis of a portion destitute of phosphate of iron:

Silica,	48·30
Potassa,	8·63
Lime,	1·50
Protoxide of iron,	26·46
Alumina,	4·80
Water,	10·79
	100·48

C. Polk has opened pits in a similar marl a few hundred yards lower down the same stream. It differs from the former in containing exogyras and a few other shells in its upper part, in the presence of a little more siliceous sand and the absence of a quantity of the phosphate of iron. Its thickness, not yet accurately ascertained, is over 20 feet. In a southwesterly direction from these openings is a third across the state line, deviating in no important particulars, and as it lies without the limit of the survey will not be described. Above the marl, an unusually heavy deposite of yellow sand rises to the land level, and constitutes a soil of superior quality, which, however, having been exhausted by excessive tillage, requires the employment of this excellent marl, to restore it to fertility.

§ 73. A short distance to N. E. of the preceding localities and N. of the road leading from Middletown to the Bohemia River, lie the marl pits of J. Driver, on one of the branches of that river. It is a dark colored sand, very uniform in texture, containing a little argillaceous, and arenaceous matter, and frequent shells or their casts; among which we notice, Exogyra costata, Gryphæa convexa, Ostrea falcata, and Belemnites americana, many casts of Turritella and other univalves, and small pieces of Baculites and Ammonites. Being sufficiently sandy to permit the percolation of water and sufficiently elevated above the bed of the stream comparatively few difficulties will be experienced from the entrance of water into the excavations. Its thickness, not yet ascertained, will probably exceed 20 feet, and as it may be found in many places on the branch much more may be obtained than is sufficient to meet the demand. It is said not to have been found on the N. W. side of the stream, although but a few yards distant; the presumption is, however, that it does exist there, and remains to crown the labors of some enterprising individual. About two miles N. by E. from J. Driver's, we again meet the marl on another of the sources of the Bohemia, where it has been opened by J. Clayton. It is remarkable for its elevation above tide-water, its upper surface approaching within some 20 feet of the top of the dividing ridge. It is a very fine-grained black sand, containing much siliceous matter in its upper layers, which diminishes in descending, and gives the first evidence of sulphuret of iron, so abundant in the deep-cut of the canal. Small nodules of the sulphuret may be found, and after the marl has been exposed a short time to the atmosphere, its surface becomes covered by an efflorescence of sulphate of lime (plaster), and sulphate of iron (copperas), the quantity of lime being too small to decompose the whole of the latter salt. Organic remains are not abundant, the principal species observed being the Belemnite, casts of Turritella, and a few small bi-valves. The thickness has not been ascertained, nor is it necessary to do so, since it may be conveniently opened at many points. Hitherto the excavations have been made adjoining or in the branch, but since the sandy character of the marl lends no authority to its being a water-bearing stratum, it may be presumed that it will be detected in some equally convenient spot, and less incommoded by water.

§ 74. Reference was made to the probable continuity of the yellowish green sand, § 65, on the main stream of Drawyer's, with that on the head waters of its Northern branch, the nearest points of approach being Tatman's mill, and J. Mansfield. This branch, on which Cannon's mill is situated, is formed by the confluence of two streams, on each of which marl is found at some distance from their junction. On the more southerly of these brooks it has been found on H. Templeman's land of the same kind as those about to be described, but not sufficiently investigated for more accurate information. It lies at a lower level and but a short depth below the meadow. The openings made by C. Haughey, J. Mansfield and J. Rogers lying near together, exhibit the same kind of marl. Those of J. Mansfield, were among the first made prior to the commencement of the survey, and having been since more thoroughly investigated, we may describe this marl as the type of all the others. Its upper surface struck a little below the water-level presents a foot or more of green clay or argillaceous green sand, below which the main body of marl is a uniform dark green or black sand, with little argillaceous, and more siliceous matter of unknown depth, having been penetrated less than 10 feet. Like that of J. Clayton on the western side of the ridge and at about the same elevation, it is characterised by the presence of a little sulphuret of iron and lime, and hence when exposed to the air in heaps a white efflorescence appears on the surface of a slightly aluminous and styptic taste, composed of the sulphates of iron, alumina and lime, the last mentioned ingredient preponderating, and the two former being in too small quantity to be detrimental to vegetation. Specimens of J. Mansfield's and J. Rogers', yielded upon an analysis of the unselected marl:

	J. Mansfield.	J. Rogers.
Silica, - - -	70·20	70·31
Potassa, - - -	6·10	6·51
Protoxide of iron, -	15·25	15·16
Alumina, - - -	3·14	2·63
Water, - - -	6·22	6·26
	100·91	100·87

The latter analysis, performed by T. Elder, proved the uniformity of composition of the two marls. The former was also subjected to analysis after selecting the pure green grains from it, which were found to be composed of:

Silica, - - - - - -	47·30
Potassa, - - - - - -	9·16
Protoxide of iron, - - - -	24·46
Alumina, - - - - - -	7·82
Water, - - - - - -	11·26
	100·00

Farther west on the same stream, and still nearer the elevated table land of the dividing ridge, it has been found by A. Lewis, at about the water level of the branch, offering no distinctive features from those described, and it is highly probable that were proper investigations made, it might be discovered in many localities on the summit-level itself.

§ 75. By proceeding northwardly from the last named opening to the other branch of the mill-pond, where it rises in the heavy soil of the ridge, we find the same kind of marl near the surface of the ground, constituting the bed of the brook. Several pits were there opened by Mr. Haughey, and the heaps of marl thus exposed to the air were more thickly coated by the white efflorescence of a strong, styptic taste, and even small pieces of sulphuret of iron were detected. It is, therefore, of inferior quality to the preceding, although still a valuable marl, and its astringent quality may be wholly obviated by the conjoint application of a little lime. While the presence of more or less sulphuret of iron may be considered as characteristic of the ridge marl, from this point to the deep cut, observation nevertheless shows that it is more abundant in the upper layers of all the pits just described. Lower down the same branch H. Templeman's principal marl opening is made in the steep banks of the run, where it rises about

8 feet above the water level, is very dry, compact and argillaceous, of a bright green color, and seems to have lost all traces of sulphuret of iron. Its character, and convenient position offer strong inducements for its employment on the adjoining land. Nothing certain can be asserted relative to its thickness, but from its rise above the water, and its being found in the stream, it undoubtedly exceeds 10 feet. One hundred yards below T's a singular bed has been struck, and slightly opened by G. Houston on the edge of the branch. It abounds in shells, such as Exogyra costata, Gryphæa convexa, Belemnites americana and others, of large size, and closely resembles the cretaceous green sand of the canal excepting in the absence of much cretaceous matter and green sand, which are replaced by siliceous sand. The bed has not been thoroughly explored, but should these characters continue the same, it will not prove a superior marl. Of a better quality will that be, when sufficiently excavated, which crops out in the adjoining field north of the branch, where it is constantly turned up by the plough, and produces sterility from its excess. It is probably a pure green sand destitute of organic remains.

§ 76. Reviewing the localities just described, §§ 74, 75, it appears to be a uniform black sand (internally green) containing a little siliceous sand, traces of sulphuret of iron and lime, and overlaid by a clayey green sand—that it constitutes the bed on which the streams flow from the ridge nearly to their confluence, therefore, that the formation rises towards their sources on the ridge. The latter point may be farther shown by a comparison of the heights of the formation on the main stream of Drawyer's, as at Polk's, Rogers', &c., with that at Houston's lying nearly on the same level. Where the yellow sand overlies the marl, as it does at some distance from the ridge, we find a good medium soil capable of high cultivation by the use of marl and other fertilisers, but the nearer we approach the summit-level, the heavier, and less productive does the soil appear, and the more necessitous of improvement. Still the presence of the marl in exhaustless quantities should encourage the proprietors of that land to employ it, and redeem the soil from comparative sterility. By a comparison of the height and nature of this marl, with that of J. Clayton on the western slope of the ridge, and with the upper stratum in the deep cut about to be described, we might anticipate the existence of the same bed under the whole ridge, at no great depth below the surface, but with the exception of one opening on Scott's run, it still remains to be discovered. The opening alluded to was made by Mr. Jamieson on the upper part of Scott's run, and contained a marl similar to the foregoing, but appeared to have undergone partial decomposition. Its thickness and other circumstances cannot be stated with precision, having been newly and not extensively excavated; but sufficient is known both of its quality and quantity, to recommend its employment. Fruitless examinations have been made to discover it lower down the same stream, and the promises held out by it are too fair not to advise continued and persevering search until it be detected. At the mill near the state road on the same stream, the cretaceous marl is said to have been found, § 70, and we know that at a short distance S. E. of it, the green sand fines out at a considerable elevation above tide-water, § 70. It would appear therefore, that there are two principal beds of green sand, to the upper of which that described in the present § belongs, and if so, there is every probability for supposing that the stratum of Mr. Jamieson also fines out lower down Scott's run.

§ 77. *Blue Micaceous and Tenacious Sand*, § 15.—The deep-cut of the canal presents a view of the various strata constituting the green-sand formation as they repose in their native beds, such as could not possibly be attained without a similar artificial section in any other portion of the region. Passing directly through the dividing ridge in an easterly and westerly direction, and descending to a depth not far above tide-water, it exhibits below the soil several distinct layers of green sand with undulating upper and lower surfaces, of varying thicknesses, sometimes approximating and uniting into one, again separating to the distance of 20 feet, and interposed by the yellow sand. The following sections are extracted from Dr. S. G. Morton's synopsis of organic remains, to whom they were given by Mr. A. A. Dexter, one of the engineers on the canal. The first section was made at or near the summit-bridge, to the depth of 82½ feet, the second about one quarter of a mile west of it, to the depth of 62½ feet, and both beginning at the top or soil. "1. A series of white, yellow, and brown sands and gravel, traversed by iron crusts, and containing large masses of primitive rocks, 35½ feet thick. 2.

Argillo-micaceous sand of a dark blue color; organic remains few and indeterminate, 28½ feet thick. 3. Argillo-ferruginous sand of a greenish color, abounding in Ammonites, Baculites, Pholadomyæ, lignite, succinite, &c., four feet in depth. 4. Coarse gray sand with similar organic products, as No. 3. Depth, seven feet. This stratum forms the bottom of the canal, but the excavation was made six feet deeper for experimental purposes. 5. Argillaceous sand of a dull green color, which it imparts to water; organic remains same as in the last beds. Depth three feet. 6. Coarse gray sand, which was penetrated about three feet, but no fossils were observed." The second section contained:—"1. Ferruginous gravel and sand. Diluvial. Depth nine feet. 2. Black tenacious clay. Depth seven feet. 3. Ferruginous brown sand and clay containing a profusion of Ammonites and Baculites with Scaphites, lignite, succinite, and casts of various simple univalve and bivalve shells. Depth 23 feet. 4. Blue micaceous sand and clay with similar fossils to No. 3. 5. Ferruginous sand and clay, of a dull green color, abounding in multilocular and other shells. Depth six and a half feet. 6. A white siliceous sand, which, about 200 yards farther west, rises 12 or 15 feet above its level at this point, and contains lignite in vast quantity; sometimes even the trunks of trees 20–30 feet long, and a foot in diameter. No other organic remains were observed in it." A comparison of the sections is sufficient to show the varying quality and quantity of the several beds, and that they belong to the green sand series, but they are not given with sufficient precision. The following section made during the survey, was commenced about 200 yards west of the summit bridge on the tow path, and continued upwards in an oblique direction towards the bridge.—1. Blue micaceous and argillaceous sand, very uniform in its appearance, and of a fine grain, most remarkable for the abundance of small colorless micaceous scales. Height nine feet, above which it gradually intermingles with a yellow sand, and contains less mica, till at length it forms—2. a partially indurated bed of yellow ferruginous sand, embodying a few layers of the blue, containing a few grains of green sand, and a greater number of micaceous particles. Its thickness is eight feet. 3. Another stratum of blue sand, containing a few green granules, one and a half feet thick, and capped by six inches of an iron stone, enclosing white sand. 4. A bright yellow siliceous sand, eight and a half feet thick, the upper foot of which alone contains green sand. 5. A dark green compact stratum, six feet thick, the first three and a half sandy, the upper two and a half feet argillaceous and lighter colored. It is a pure green sand stratum containing a little clay and siliceous sand, and is topped by iron-stone and yellow sand containing pebbles about two feet thick. 6. A bed of yellow sand similar to 4th, 11½ feet thick. 7. A compact bed of white siliceous pebbles, one and a half feet, above which they are distributed in a white and yellow clay of five feet thickness to the surface or soil. The irregularities of the strata within short distances did not require mathematical accuracy in their admeasurement, but great care was exercised in examining the nature of the deposites. An analysis of the fifth stratum (dark green sand) of the preceding section, made by J. V. Blaney, gave the following results:—

Silica,	80·73
Potassa,	4·46
Protoxide of iron,	8·37
Alumina,	2·12
Water,	4·84
	100.52

From which it appears to be an ordinary green sand, containing a larger proportion of siliceous sand. The following diagram exhibits the three sections, the first on the right being made at the bridge, the second on the left, about one quarter of a mile W. of it, and the middle taken intermediate between the two during the geological survey.

W. → E.

Soil.	Soil.	Soil.
Ferruginous gravel and sand, 9 feet.	White and yellow clay with pebbles and gravel, 5 ft.	White, yellow and brown sands and gravel with iron-crusts, 35½ ft.
Black tenacious clay, 7 ft.	White siliceous pebbles, 1½ ft.	Dark blue argillaceous and micaceous sand, with few organic remains, 28½ ft.
Ferruginous brown sand and clay, abounding in ammonites, and baculites, lignite and amber, 23 ft.	Yellow siliceous sand, 11½ ft.	Tow-path.
Blue micaceous sand and clay, with same organic remains as above, 11 ft.	Sand and pebbles, 2 ft.	Argillo-ferruginous sand, greenish color, 4 ft.
Tow-path.	Argilla. green sand, Granular green sand, } 6 ft.	Coarse gray sand, abundant organic remains in this and above, 7 ft.
Ferrug. sand and clay of a dull green color, many shells, 6½ ft.	Yellow siliceous sand, a little green sand, in the upper part, 8½ ft.	Argilla. sand, green, same organic remains, 3 ft.
White siliceous sand, Lignite abundant, 5 ft.	Blue argillaceous sand, 1½ ft.	
	Yellow ferruginous sand, mica, a little green sand, 8 ft.	
	Blue argillaceous and micaceous sand, 9 ft.	
	Tow-path.	
	Bottom of the canal.	
	Coarse gray sand.	

By comparing the right and left sections, we find the coarse gray sand below the water level of the canal sinking slightly towards the west, but still farther west it rises 12 to 15 feet higher. It therefore rises on the whole, and lends strength to the position, that the red-clay formation dips below the green sand. The blue argillaceous deposite which is 28½ feet thick at the summit bridge, becomes 18½ feet in the middle, including a bed of yellow sand, and diminishes to 11 feet one quarter of a mile W. of the summit.—As it does not dip below the coarse gray sand, it therefore only diminishes in thickness, and probably passes into a greenish sand, § 50, which is above the red clay. The yellow and brown sands and gravel of the right-hand section have not been accurately observed, for the six feet bed of green sand noticed in the middle section may be seen of varying thickness on either side of the bridge nearly at the same height above the water, and passes into the black tenacious clay of the western section, which is in fact a dark-colored argillaceous green sand. The whole bed of yellow sand including the green is 35½ feet thick on the right, 35 in the middle, and 39 on the left; without diminishing in thickness therefore, it apparently sinks towards the west, but this is only apparent, for it gradually replaces the blue argillaceous clay, and the two together do certainly rise, and repose on the coarse gray sand. To the irregularity of the strata, which are thus revealed by the deep-cut, may be ascribed many otherwise unaccountable phenomena observed in the green-sand region, such as the varying thickness and elevation of beds within limited spaces, as well as their varying qualities.

§ 78. The blue sand stratum being sufficiently tenacious to constitute the water-bearing stratum of the region, numerous springs issue at various heights above the canal, transporting fine clay, sand and mica in great quantity, the former of which communicates a greenish color to the water, and the two last are constantly tending to lessen the depth of the canal. Several of the strata also at various heights holding a small quantity of water, renders the whole mass liable to slips or slides of earth in the present steepness of the sides, several formidable instances of which have occurred, and more may be anticipated unless efficient means are adopted for obviating them. One obvious method would be to remove such a quantity of the earth, as to give a gentle slope to the sides of the canal, and to transport it to such a distance that its weight would not force out the softer subjacent strata. Without resorting to such an expensive process, others might be adopted. Short stakes driven into the heavier beds at various heights, will not be sufficient security against slides, since they include such masses of earth as would carry the stakes with them. Long and heavy piles driven down in rows, and at several points of elevation, would in a great measure obviate the difficulty, and wholly so, if combined with a partial removal of the earth. The silting up of the canal from springs can scarcely be prevented, and although their operation is too slow to offer a formidable obstacle, it will nevertheless in all probability require the frequent employment of a dredging machine to maintain sufficient depth of water. Independently of the matter mechanically suspended in the spring-water, a considerable quantity of sulphate of iron (copperas), in solution is thrown into the canal, which is so highly charged with it as to destroy fish and other aquatic animals, such as the barnacles adhering to the bottom of sea-vessels. Nearly all the springs in the deep-cut, give evidence of copperas in their taste, and in the ferruginous deposite they form at their point of issue, and we might hence conclude, that the formations abounded in sulphuret of iron (iron-pyrites), if we had not stronger evidence of it in masses of that mineral abundantly diffused through the sands and clays. We have seen that the green sand of the ridge generally contains pyrites, but it is minute in quantity compared with that found in the deep-cut, where it often constitutes a very material part of the strata. The question arises, whether it could be applied to the manufacture of copperas? Probably not; for it would require much labor and time to discover localities where it would be sufficiently abundant to work profitably; and such is the irregularity of the formations, that the extent and continuity of these beds could not be depended on. The same efflorescence of sulphate of iron may be anticipated in nearly all the openings for marl, which will be made in the N. Western part of St. Georges hundred, as has proved to be the case, in the excavation of Mr. Ellisson in that section of the green sand region. Existing in small quantity in the uppermost strata, it is probable that no injurious effects will flow from the employment of this green sand on the soil, or if it should do so, means of obviating them will be pointed out in the third Part of the memoir.

§ 79. Reviewing all the descriptions of the green sand formation from § 53 to § 78 inclusive, we find that there are two deposites, the upper and lower, which sometimes unite and again are separated by interposed yellow sand, that the lower appears on the canal and western border of the state, and the upper embraces the remainder of the region. Practically speaking, there are two principal kinds of green sand, that containing lime as an essential ingredient, and that consisting chiefly of green particles. The former contains variable quantities of carbonate of lime, the highest limit yet observed, being 25 per cent. The average composition of the latter in its natural state and selected may be thus expressed:—

	Unselected.	*Selected.*
Silica, - - - -	58	50
Potassa, - - - -	7	10
Protoxide of iron, - -	22	$22\frac{1}{2}$
Alumina, - - - -	5	7
Water, - - - -	8	$10\frac{1}{2}$
	100	100

The first is either *cretaceous*, containing finely divided carbonate of lime not formed by comminuted shells, and occurring on the canal, § 53 to § 56; or *decomposed calcareous*, on the western limit of the state, from which the calcareous matter has been wholly or partially removed, although abounding in casts of shells, § 57 to 59;—or *shelly green sand*, on the southern line of St. Georges hundred, in which there is no fine calcareous matter but that of comminuted shells; § 60 to § 61. The second contains mere traces of lime, and consists of green sand particles, with variable quantities of clay and common sand, and is either ***bluish green***, and of the finest quality, as found on Drawyer's and Silver run, § 62 to § 63;—or *yellowish green*, containing white siliceous sand, as on Drawyer's and the Appoquinimink, § 64 to § 67;—or *black-colored*, decomposed externally, rarely internally, and containing both white sand and argillaceous matter, from Silver run to Scott's run, § 68 to § 71;—or *dark-colored*, and containing pyrites, as from the S. W. corner of St. Georges hundred, and along the ridge to the Deep-cut, § 72 to § 76;—or lastly, the *blue micaceous sand* of the Deep-cut rarely containing particles of green sand, although abounding with casts and impressions of shells characteristic of the green sand formation, § 77 to § 79. We have seen that the yellow sand is the principal member of the series, both over and underlying the green sand, that it is characterised by its uniformity of grain and color, and rising to the surface constitutes the chief and most valuable soil of the region. We farther observe that the green sand stratum is undulating, and varies in its depth, the average thickness being 21 feet, from which we may form a rough estimate of the amount contained in the whole district. It is seven miles long, and nearly six and a third broad, and therefore embraces about 44 square miles. Deducting from this one quarter for the place where it fines out, and for streams, ravines, &c., we have 33 square miles underlaid by green sand. There are then 102,220,800 square yards, which multiplied by seven yards, the average thickness, gives 715,545,600 cubic yards of green sand in Delaware. Supposing then that the one-hundredth part of it is accessible, we have more than seven million cubic yards which may be made available. In a majority of cases, the flowing of water into the pits presents a source of inconvenience that may be remedied without great difficulty, and with a trifling expense compared with the value of the material; but whatever the disadvantages in particular localities, it is within the reach of every individual in the district, and no reasonable doubt can exist that the fertility of St. Georges and the neighboring hundreds will be limited only by the enterprise, industry, and intelligence of the inhabitants.

CHAPTER III.

TERTIARY FORMATIONS.

SECTION I.

Northern Tertiary.

§ 80. On Old Duck Creek and its branches, about four miles below Smyrna, we find the tertiary formation only recognisable by its characteristic shells in a few localities, the best of which is at Wales' mill-dam, § 18. Its features will be clearly seen by the adjoining section. From below the water-level is a very tenacious bluish clay, containing a little white sand and scales of mica, the greatest observed thickness of which at Cloak's mill was 12 feet. Above it reposes a 6–10 feet bed of reddish yellow sand, passing at times into a similarly colored clay, and its uppermost gravelly layer cemented into a conglomerate by oxide of iron, while the whole is capped by a light-yellow, loamy soil. These strata in the same order of superposition may be observed at Layton's mill, where Old Duck Creek crosses the state road, at Wales' about one mile W. of it, at Cloak's still farther west, and on several branches of the same stream. At Wales' mill-dam, the blue clay is visible at the water-level, and constitutes the bed of the creek. Its upper surface has been converted into a ferruginous sandstone of moderate coherence, averaging a foot in thickness, and abounding in numerous casts of shells of the same character as those found on Murderkill, and evidently belonging to those characteristic of the tertiary period. Among these we notice a species of Mactra probably new, Balanus, Serpula and Cardium, the specific characters of which are difficult of determination; farther Venus alveata,

Venus inoceroides, Nucula lævis, and Myoconcha, probably the incurva lately described by T. Conrad. The Mactra, Venus inoceroides and Nucula lævis are the most abundant. Immediately below the stony crust lies the blue clay, which preserves great uniformity in its mineralogical characters wherever it has been observed. It consists of a bluish clay and white sand in such proportions as to crumble without difficulty, on becoming dry, to a lead gray pulverulent mass; that there is a small amount of pyrites may also be safely inferred from a white efflorescence with a styptic taste, which appears on its surface after exposure to the air, although the clay when freshly obtained gives no traces of copperas. The hardening of the upper layer may be attributed to the decomposition of pyrites and formation of peroxide of iron which cements the remaining mass. By carefully taking up the blue-clay, impressions of the same shells as in the stony crust are observable, and often indeed one half of a large shell-cast is soft and tenacious, while the remainder is converted into stone; from which it is evident that the formation has decomposed *in situ*. Notwithstanding the abundant indications of the former existence of shells in the formation, it now gives no trace of lime, and is therefore worthless as a material for enriching the soil. Passing westward on the same stream, we find few indications of the blue clay until we reach Cloak's mill-dam, below which it is observed under its ordinary features, excepting in the absence of organic remains, but one specimen of a large Pecten having been detected. It rises several feet above its level at Wales' mill, and at the head of Cloak's mill-pond on H. Ridgely's land appears to be still higher, whence the conclusion that it rises towards the dividing ridge, like the green sand. A boring to the depth of 10 feet from the top of the stratum at Cloak's mill gave no indication of a change in the nature of the clay at that depth, excepting that it became more arenaceous. As in the lower tertiary on Murderkill we here find chalybeate springs issuing from the blue clay, which, by depositing their oxide of iron, form a ferruginous conglomerate, an instance of which may be seen on W. Nelson's farm about half a mile N. E. of Wales' mill-dam. In the several localities noticed, the overlying formation is a yellowish clay, loam or sand, capped by gravel, and hence the varying nature of the soil in this section of country, according as it is based upon one of those formations. Crossing the dividing ridge in a S. Westerly direction to the head of the Choptank, there is a blue clay found at Smith's mill, rising a few feet above tide-water, differing in no respect from that on Old Duck Creek excepting in the absence of shell-impressions. It is in like manner overlaid by a yellow sand and loam with bands of yellow clay and capped by gravel. The quantity of copperas efflorescing from the blue deposite after exposure to the atmosphere, induced the proprietor to send samples to Baltimore to ascertain whether it could be employed in the manufacture of that salt; the operation would probably not prove advantageous. Now since this blue clay appears to be continuous with that belonging to the tertiary lower down the Choptank, we may suppose it also to be a continuation of that on Old Duck Creek, in which case it would form a belt, falling in with the tertiary shell-marl on Stow Creek in New Jersey, and parallel to the usual N. E. and S. Western bearing of the green sand and other strata.

§ 81. Near that branch of Duck Creek lying immediately south of Smyrna, are found large masses of siliceous rock, which from its extreme hardness and toughness, could scarcely be supposed to have had its birth in this region of soft clays and light sands, had it not been found in place in one locality. So numerous and so large were the blocks on a farm of Messrs. Cloak lying on the state road on the south side of the branch, that it was found necessary to sink them in order to the better cultivation of the land. They consist of coarse sand and gravel cemented by siliceous matter containing frequent casts of shells, and what is still more interesting, the shells themselves are often converted into a pure translucent siliceous substance, which may be called flint or more properly chalcedony. Large blocks of the same are to be seen on a farm of Judge Davis, about one mile S. W. of Smyrna, and are so hard and tough that small pieces cannot be broken off without great difficulty. Small fragments are frequently found in the neighborhood, but the rock is not seen in place. Many such hand specimens would remind the geologist of the Buhrstone of Georgia and Florida. About five miles S. W. of Smyrna on the road to Kenton, a small branch crosses the road and empties into Cloak's mill-pond. Rising the hill on the south side of it we again light upon the silicified shells which appear to be in place. Being much more abundant and the mass less coherent, by striking them a little, the greater part of the adhering pebble falls off, leaving a shell wholly composed of silex, excepting its white surface, which may contain a trace of lime, very similar to nodules of flint found in the chalk of Europe. Detached specimens of petrified wood were found in this locality, which closely resemble those already described, § 80, and point out the probability of the identity of the two deposites. There is no reason why the large masses above described may not be near their original localities, but the elevation of this bed above tide-water (some 30–40 feet), countenances the belief that the fragments strewed over the surface of the country for many miles are derived from this or similarly elevated points. It is exceedingly difficult to recognise the siliceous fossils, the most prominent being a Mactra similar to that found at Wales' mill, § 80, and an Ostrea, both of which will probably prove to be new species. The above, §§ 80, 81, are the chief localities of the deposite which have been developed, but there is every probability that others will be discovered, and it will be interesting to know their extent and character, not merely in a scientific but also in a practical point of view, for if they could be found of sufficient extent, they will prove a valuable material for the purposes of construction. Relative to their age it may be remarked that the blue clay appears from its fossil contents to belong to the older pliocene period, and that the siliceous deposite appertains to the same era, resting upon the former. If this last observation prove correct, then the loam, clay and sand in which the silicified shells are imbedded, connects the yellow clay of Appoquinimink hundred, §§ 85, 86, with that occupying a position intermediate between the two belts of Tertiary, and they consequently belong to the same epoch.

§ 82. Examinations made on the other branches of Duck creek and on the head-waters of Chester river led to no useful results relative to the continuation of the tertiary strata, the main deposites being yellowish sands and clays with overlying gravel, similar to those described as resting on the tertiary. It is difficult to say whether they belong to that formation, or are of more recent origin, nor is it matter of sufficient moment to determine. We cannot leave the subject without referring to a local deposite, which gained some reputation for a short time, in consequence of its external resemblance to green sand. It has been found in several of the small branches within a short distance of Layton's mill about three miles S. of Smyrna, and was more particularly examined on the farms of Messrs. Williams and Register. Below the black soil of the branch lies a 2–4 feet bed of a green, and bluish-green sand, very similar in color and size of the grains to some varieties of green marl; but here the resemblance ceases; for by crushing it on a smooth surface, it abrades hard iron, showing its siliceous nature, and by heating it becomes yellowish, and then white, proving the coloring matter to be of vegetable origin. It is therefore nothing more than a white sand colored externally by vegetable matter, for below the influence of the latter, the same sand is colorless, and if applied to land might produce the same effect as earth removed from one field to another.——Although the soils of the northern part of Kent county are very variable, yet we may distinguish three kinds, which are most prevalent, viz: those on the neck-lands of a heavy character, but supposed to be the most fertile in the state; those of the dividing ridge, consisting of very heavy bottoms, not always productive, with occasional light sand hills—and lastly those intermediate between them in position, and occupying a much greater space; they are light loams, easy of culture, and although reduced by excessive tillage, are capable of receiving the highest degree of improvement.

SECTION II.

Southern Tertiary.

§ 83. Crossing the middle section of Kent county, we again find the tertiary formation more fully developed on the confluent streams of Murder kill. There being some confusion relative to the names of the numerous branches of this creek, it may not be amiss to describe them. At the town of Frederica it divides into two parts, the smaller coming from the N. W. on which Bonwell's mill is situated, the main branch again dividing about two miles S. W. of Frederica, at the Fork landing. On the most southerly of the two latter, which comes from the S. W. and is called Brown's branch, is Short's mill; while on the other are located Spring mills, and farther W. Jester's mill, its branches being named Fork and Spring branches. The clearest indications of tertiary strata are observable at Spring-mills, where the following occur in a descending order. The uppermost stratum is a loose sand, below which is a ferruginous conglomerate of sands and pebbles, 1–2 feet thick; next a brownish yellow sand, containing a large proportion of oxide of iron, 3 feet, at the bottom of which is a thin layer of gravel; still lower a light gray, somewhat argillaceous sand, partially indurated, and abounding with casts of shells, from which the carbonate of lime has been wholly removed and sometimes replaced by a thin coating of brown oxide of iron, excepting in one instance in which a part of a single shell remained; its thickness from 3 to 6 feet; below it is a stratum of hard iron stone, 1 foot; and the lowest stratum visible is a blue clay similar in every respect to that of the Northern Tertiary, § 80, consisting of more or less white sand imbedded in a highly tenacious blue clay, and abounding in impressions of the same shells as characterise the upper white sand. The hardest shell casts are found in the iron-stone, and among these we recognise a large scolloped shell, probably the Pecten Madisonius. A boring made to the depth of 5 feet below tide-water, offered no variation in the nature of the blue stratum. At the upper end of the mill-pond, where Spring branch enters it, the cold spring, a chalybeate of excellent quality, issues from the upper part of the blue clay, in which no traces of shells were found by boring. Above it lies a yellow sand, and the whole is capped by a yellow clay and heavy loam, from which numerous springs pour out large quanties of pure water, and indicate a rise towards the N. of the water-bearing stratum.——At Jester's mill on Fork branch, the blue clay rises a foot or more above the water-level below the dam or 11 feet above tide-water, and as usual, is topped by iron-stone. It contains a few impressions of the shells found at Spring mills. The Northern banks are more sloping, and their deposites more argillaceous than the southern, which at this place attain an elevation of some 30 feet, are steep, and chiefly arenaceous. The following strata in a descending series are observable at Short's mill on Brown's branch: a loose sand, and a thin band of iron-stone subjacent to it; a brownish yellow sand, sufficiently fine and even in grain to make a good moulding sand for bricks, 2–4 feet; a light yellow ochrey clay, from below which issue several springs of pure water. One spring rising still lower is chalybeate, with decided traces of sulphuretted hydrogen, and probably originates in the blue clay, although the latter was not discovered. No traces of the tertiary were detected at Smithers' mill, farther to the S. W. on the same branch, the main deposite at that place being light colored sand, rising steeply to the height of some 30 feet on the southern banks. That branch which empties into the main stream at Frederica, is again divided into two branches a short distance N. W. of the town, one coming in from the N., and the other from the W. by N. An examination on the latter near Bonwell's mill exhibited the following strata in descending from the soil; a yellowish sandy loam, 5–8 feet thick; a light lead-colored and yellowish clay, free from sand and compact, but splitting even in its moistened state into small rectangular fragments, 3–4 feet thick; a white and yellow compact argillaceous sand, 5–8 feet. Similar strata are found on this branch for several miles along the steep banks of the southern border, the northern being too sloping to admit of accurate observation.

§ 84. From the data presented in the preceding, we conclude that this belt of Tertiary is about two miles in width; that the lowest accessible stratum is a blue sandy clay which abounds in impressions of shells, and has been decomposed *in situ*; that the stratum above it, a white, slightly argillaceous sand, abounding with the same organic remains, has suffered the same loss of calcareous matter, which renders them both of no value to agriculture; that the upper stratum, a yellow sand and clay resting uniformly on the preceding, and shading into it, belongs to the same formation, and is situated in the same relative position to it, as it is to the northern belt; and that the loose sand with included bands of clay presenting little uniformity relative to the above strata, is probably of more recent origin. The abundance of organic remains and their peculiar character prove that these deposites are of the same nature with the shell-marls of N. Jersey and Maryland, but that causes which were not as extensively in operation in those states, have obliterated the calcareous features of the tertiary deposites of Delaware. We farther observe that the numerous chalybeate springs of this region issue from the blue clay, and that the latter deposite, ordinarily impervious to water, must be broken in some localities to admit the passage of water through it, which sometimes flows copiously from below its upper level, as seen at Spring mills, or that the clays and sands about to be described in the fourth section pass under it.——There is a blue clay found at various depths below the surface, between E. and S. E. from Frederica. About 1½ E. by S. from the town, it was observed in digging a well, and by boring at two or three points in the vicinity, the same stratum was struck, its nearest approach to the surface being within 7 feet. It contains an 8 or 10 inch stratum of thin shells, (the ordinary oyster of the creeks,) imbedded in a blue clay distinguishable in none of its external characters from the blue deposite of the tertiary, although it probably does not belong to that period. The same formation has been found about 2½ miles in the same direction from Frederica, about 3 feet thick, and at the depth of 16 feet from the surface. Offering no superficial indications of its existence, this deposite presents unusual difficulties of investigation, which could not be surmounted in the short space of time allotted to the survey, but those interested in the lands of that vicinity, as well as of the whole tertiary region, should not cease making examinations for shell-marl, wherever opportunities of instituting them without much expense are offered; for although observations have shown the absence of lime in that which certainly was at one time a marl, yet it cannot be safely asserted that the whole of it has undergone a similar decomposition.—From a short distance N. of the tertiary to the lower part of the county we find the soils of the high or ridge land generally light and sandy with occasional clay-bottoms; farther east they are usually light loams, and as we approach the bay become more tenacious, and finally very heavy.

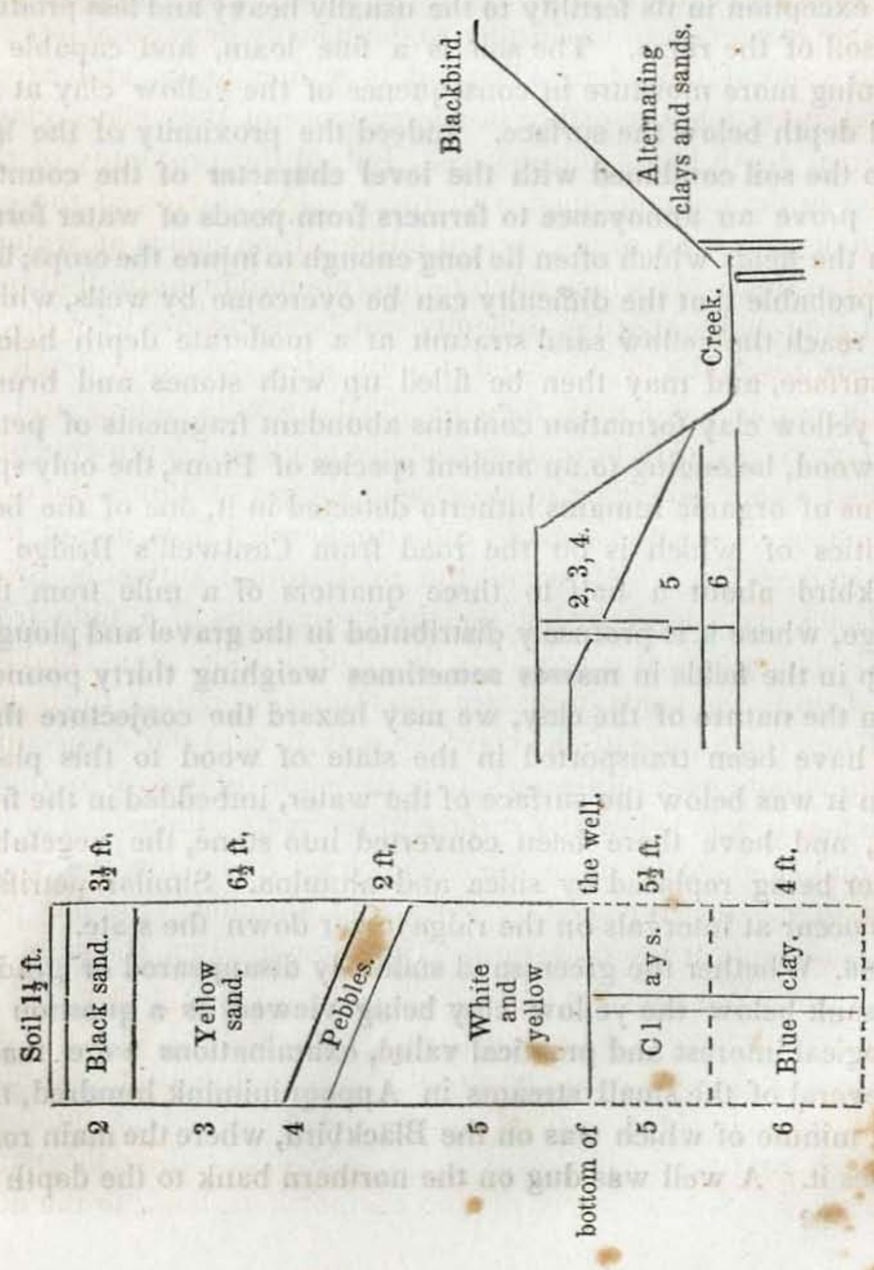
SECTION III.

Yellow Clay Formation of Appoquiniminnk Hundred.

§ 85. The Yellow clay formation lying in Appoquinimink hundred, § 29, being of a uniform character, and containing but few points of interest, will not require lengthened description. It was observed § 61, that the southernmost deposite of the green sand passes under the clay, from which it is separated by a 6 feet bed of sand-stone; and the same holds good of many other exposures of the sand-stone on the southern banks of the creek to the E. and W. of the state road from Cantwell's Bridge. On the road from Middletown to Blackbird and near the head waters of the Noxentown mill-pond, the overlying yellow clay is distinctly observable, becoming thicker on the southernmost branch. It consists of alternating bluish, white and yellow clays, the latter of which is most abundant, and encloses a large amount of coarse gravel. The beautiful tract of land, to the W. and N. W. of this place, appropriately called the *Levels*, is the dividing line of the waters which flow towards the E. and W., and forms a remarkable exception in its fertility to the usually heavy and less productive soil of the ridge. The soil is a fine loam, and capable of retaining more moisture in consequence of the yellow clay at no great depth below the surface. Indeed the proximity of the latter to the soil combined with the level character of the country may prove an annoyance to farmers from ponds of water formed in the fields which often lie long enough to injure the crops; but it is probable that the difficulty can be overcome by wells, which may reach the yellow sand stratum at a moderate depth below the surface, and may then be filled up with stones and brush. The yellow clay formation contains abundant fragments of petrified wood, belonging to an ancient species of Pinus, the only specimens of organic remains hitherto detected in it, one of the best localities of which is on the road from Cantwell's Bridge to Blackbird about a half to three quarters of a mile from the Bridge, where it is profusely distributed in the gravel and ploughed up in the fields in masses sometimes weighing thirty pounds. From the nature of the clay, we may hazard the conjecture that they have been transported in the state of wood to this place when it was below the surface of the water, imbedded in the fine mud, and have there been converted into stone, the vegetable matter being replaced by silica and alumina. Similar petrifactions occur at intervals on the ridge lower down the state.

§ 86. Whether the green sand suddenly disappeared or gradually sank below the yellow clay being viewed as a question of geological interest and practical value, examinations were made on several of the small streams in Appoquinimink hundred, the most minute of which was on the Blackbird, where the main road crosses it. A well was dug on the northern bank to the depth of

15 feet, a boring made 7 feet deeper, in which the following strata appeared, beginning at the surface. 1. Vegetable soil half a foot. 2. White siliceous sand containing much black sand, 3½ feet. 3. Coarse yellow sand containing a few particles of green sand, 3½ feet on the upper, and 6½ feet thick on the lower side, declining towards the creek. 4. The same stratum containing pebbles and green particles, 1½ on the upper, and 2 feet on the lower side. 5. White and yellow clays, the former predominating 9 feet on the upper, and 5¼ on the lower side. 6. Bluish and greenish blue fat clay, 4 feet thick. The following sections represent the formations:



From which it would seem as if the overlying yellow sand were derived from the green sand formation, and had been deposited on the clay, which is newer than the marl. The report in common circulation that shells were found in digging wells near the place where the above examination was made induced the investigation, which resulted unsuccessfully relative to the marl. Deposites have been examined on the neck-lands, one of which lies on the lower part of Thoroughfare neck, where the main body of it is a yellowish clay varying from 10 to 20 feet in depth, below which a blue clay contains shells of the common oyster and clam, and from 1 to 3 feet in thickness. They are too deep, and not sufficiently charged with lime to become useful to the farmer, nor is there a probability of their forming large and continuous beds, as they are of recent origin. In some of the upland branches were observed conglomerated masses of gravel cemented by oxide of iron, which, however rich they may have been prior to the drainage of the land, are now valueless.——The soil of Appoquinimink hundred is of good quality in the Western and Eastern borders, being rather heavier than a medium soil, but fertile; intermediate between which, it is generally a heavy clay of less fertility. In the lower part of the hundred we meet at times with the lighter loam and sands of Kent county.

SECTION IV.

Intermediate Clays and Sands.

§ 87. Between the Northern and Southern belts of Tertiary, a distance of about 20 miles, are a series of beds of clays and sands, the lowest of which is clay observable on nearly all the streams, varying in its color and texture in the same locality, but generally of a yellowish shade and of medium fatness or richness, and the upper consisting of ferruginous sands and gravel. The planes of deposition observable only in the sands are to the S. and S. E. dipping at an angle of from 10° to 30° to the horizon. At Layton's mill on Old Duck Creek, it is either continuous with the tertiary blue clay or rests upon it; it is somewhat difficult to say which is the case, although the presumption is in favor of the latter conclusion; it has a bluish white color, with streaks of yellow, and is topped by 6–8 feet yellow loam, terminating in gravel at its upper surface. The same order of superposition may be seen on the branches of Little Creek. At Dover the sandy nature of the upper beds and the upper level of the clay are indicated by the numerous springs of excellent water, which issue at the foot of nearly every declivity. On Jones' river E. of the State-house, we find the clay rising a little above the water-level of its prevailing yellow color, with a few white seams occasionally varying its appearance; above which is a reddish gravelly loam about 8–10 feet thick, and still higher a yellowish sandy loam 4–6 feet in thickness. The numerous springs between this part of Jones' river, and Tydbury branch would sufficiently prove a depression in the upper surface of the clay, if other evidence were wanting; but the gradual dip of the bed observable towards Dover from the head streams of Little Creek, and its rise again towards Tydbury branch are conclusive. Its western rise may be also shown by an examination on Isaac's branch. We are, therefore, at no loss to account for the large amount of water thrown off in springs, which, draining an extensive surface of country, give rise to several branches of limpid water, like Puncheon run. Below the entrance of Tydbury branch into Jones' river, at the Forest landing, the clay and overlying loams can at all times be observed, the former rising some 10 feet above tide-water. The greatest observed thickness of the clay is 15 feet, as ascertained by boring at this point, where a stratum of yellow sand was attained; the latter may, however, be merely a subordinate bed in the clay. Where Isaac's branch is crossed by the lower road to Frederica, we find the clay rising several feet above tide-water, and resting on it a heavy bed of gravel rising some 20 feet. To the ferruginous character of the gravels and sandy loams are due numerous crusts of iron-stone, which have sometimes given rise to a fruitless search after iron ore; for although there is a sufficient amount of ferruginous matter in these formations to constitute good beds of ore, yet their elevated position, causing the rapid drainage of water, prevents the deposition of oxide of iron. The effect of a sluggish flowing of springs through such formations may be observed about one mile N. of Rash's cross-roads on one of the head-streams of Jones' river, where such deposites of bog-ore are found at intervals to the extent of nearly a mile along the branch. Yellow sandy loam composes the adjacent formation, through which the water slowly percolating, dissolves a quantity of oxide of iron, which it again deposites in the form of ore, where it oozes out from the ground, and remains on it for a short time. The aluminous earth resting upon the ore to the thickness of a foot is highly charged with peroxide of iron, and contains numerous small pieces of grain ore. The bed of solid ore below it is from 4–10 inches in thickness; it is brown, glistening with a resinous lustre, compact and tough.——The same tendency to form bog-ore is perceptible on many, indeed on nearly all the branches which take their rise on the level land of the ridge, and prove that formations similar to the above are loamy and ferruginous.

§ 88. As we experienced some difficulty in determining whether the clay is continuous with, or rests upon the tertiary blue clay on Old Duck Creek, so do we meet with the same obstructions in investigating its position where it adjoins the southern tertiary. The general dip of the strata south of the primary rocks towards the S. E. would seem to show that it passes under the lower belt, and this might be farther confirmed by the more numerous issue of springs on the N. side of the streams where this tertiary exists. On the other hand there is a gradual rise of the strata from near Dover southerly to the northern branches of Murder-kill, and we have clays and sands resting over the tertiary blue clay, § 85–86, on other branches of the same stream, similar in every respect to those just described. The most probable conclusion is that the clay of Appoquinimink hundred is continuous with the intermediate clays of Kent, and that the latter pass under the southern tertiary belt. From the similarity of soils throughout a great part of Kent county in the same relative situation, we may readily class them as was done with those of New Castle county. With the exception of the marshes bordering on the bay, all that low land known as the neck-lands is of a heavy argillaceous character and remarkably fertile, a character which some of them still retain, notwithstanding the excessive tillage to which they have been subjected for nearly a century. As we rise the country to the westward and meet the tertiary deposites, the soil becomes more loamy, corresponding with the subjacent deposites, and as these become covered by loose sand towards the ridge, the surface necessarily partakes of the same character. Proceeding from N. to S. through this middle section, the amount of loose sand increases in depth and breadth, so that much of the land in the lower part of the county has a loose sandy soil. On the ridge we find the same alternations of light sand hills and heavy clay bottoms, which was noticed in New Castle county, but which in Kent are more strongly contrasted; in addition to these however, there is a vegetable soil too remarkable to be passed over by a simple notice, a rich, deep and black vegetable mould situated on the marsh lands of the west, which will be particularly described in Pt. III, § 151.

CHAPTER IV.

RECENT FORMATIONS.

SECTION I.

Lower Clays.

§ 89. From the lower limit of the Southern Tertiary, that is from Murder-kill and its branches, to the extreme southern border of the state, embracing part of Kent and the whole of Sussex counties, are a series of deposites of clay and sand, to which we can assign no date excepting in a few instances, in consequence of the absence of organic remains, and the impossibility of drawing any conclusions relative to their age from their mineral characters. Thus the lower tertiary blue clay on Murder-kill could not be distinguished from a similar clay on the shores of the bay, which is quite recent in its origin, except by comparing the ordinary bay-shells in the latter with tertiary shells in the former. In the few cases where shell-beds have been found there are no indications of tertiary fossils, the shells being referrible only to the same genera and species which now inhabit the waters of the bay. We may therefore view the whole country alluded to as of recent origin (after-tertiary), until future investigations may show the incorrectness of the position. The lowest formation visible and the deposites along the shores of the Delaware are usually tough clays, the superficial strata light sands or loams. On Mispillion creek in the vicinity of Milford and to the west of it, the uppermost stratum is a loose sand with an occasional argillaceous bed, below which is a heavy bed of clay extending below the water-level. It is more or less ferruginous in its upper part, lower down white and lead-colored, extending many feet below tide-water. Its texture is that of a very plastic, fat clay, and free from grit, but whether it could be adapted to the manufacture of earthenware, to which its external characters give it some claim, can only be determined by subjecting it to the action of a strong fire. On Mill branch, about a mile S. E. of Milford, and near P. F. Causey's mill, the uppermost stratum is a loose yellowish sand, resting on a clayey loam, which is underlaid by and interstratified with a white clay, and the lower part of the latter has a lead color to the water-line; below this again is a fat yellow loam, reposing on white sand. The whole thickness of the loam and clay is about 15 feet. On Cedar Creek the clay lies at a much lower elevation, while the superimposed sand is of considerable thickness. From the springs which issue copiously near Milford, we might conclude that the formation rises towards the south, a supposition which is confirmed by as many observations as the nature of the unbroken surface of the country admits. There are occasional deposites of gravel above the clays, which appear to belong to the same formations rather than to the superficial sands, for the loam constituting the upper member of the argillaceous deposites graduates into the gravel, while there is a marked line between the latter and the overlying sand. From the abundant superficial loose sand, the soil of the region under notice derives its character; but where this has been partially removed, we have basins with a substratum of clay, which being impervious to water, constitutes ponds that are sometimes a convenience, but oftener an annoyance to the farmer.

§ 90. The clay beds are again visible on Prime-Hook creek, where they have usually a yellowish color, but at Ponder's mill it becomes nearly white, is very plastic and contains but a small amount of arenaceous matter. At Milton, the clay rises to the height of some 40 feet above tide-water, and from its undulating surface often appears through the superficial sand. It is of a light yellowish color, very compact, lies in horizontal undulating strata, interrupted occasionally by beds of sand, and breaks into small angular pieces resembling slates. On the S. side of the stream, there are wells over 40 feet in depth passing through clay nearly to their full depth; others are excavated only to thin seams of sand in which the supply of water is less abundant than in the lower stratum, from which it would appear that the argillaceous deposite is extensive. To the W. and E. of Milton, the same stratum may be traced by exposures on the creek and its feeders, generally offering the same features as at the town, excepting that lower down Broad Creek it becomes more ferruginous; for on a farm belonging to P. S. Parker, a short distance E. of Milton, bricks of good quality are made from the same formation. The surface-coating of sand communicates its own light character to the soil of this section, excepting in a few instances where the clay being uncovered constitutes a heavy bottom. Proceeding in a S. Western course from Milton to Lewistown, we find the same beds of clay presenting themselves on Cool Spring and several small streams, offering the same features as have been already described, the yellowish and light-colored clays every where predominating. Numerous and large springs indicate a rise in the clay stratum towards the N. and W. One of these on Black Oak Gut has been deservedly held in high estimation from its size, coldness, clearness, and delightful taste, but its medicinal virtues have been probably over-rated. The numerous springs issuing out of the banks of Lewes Creek from the upper surface of the clay prove that the formation rises towards the west, but it is not of great thickness, scarcely exceeding six feet, below which is a stratum of sand. There are a few large springs, however, which evidently rising from below this sand, prove the existence of another and deeper layer of clay, and that it also rises towards the west. Thus it appears that what was remarked of the secondary and tertiary formations relative to the rise of strata towards the west, holds good of the recent deposites, and farther that like them the latter are independent of the general rise of the surface of the land.

§ 91. The same clay which is to be seen in many places below Lewes, crops out on the beach about 3 miles S. of Cape Henlopen, where it is uncovered by the gradual encroachment of the ocean on the looser loams and sands resting upon it. The upper portion is yellow, the lower lead-colored, very plastic, and of a superior quality. We farther observe the deposite in question skirting the higher banks of Rehoboth bay, under the same features as before. It is also met with on the streams which flow into Indian river, and is more clearly developed on those, which constitute the head of that stream. It is visible near Dagsborough, and to the S. and S. W. of the town, but in all these localities the yellow clay appears to predominate. About two miles N. of Dagsborough, a deposite of recent shells has been opened, which are contained in a blue clay below a yellowish argillaceous stratum, constituting the soil. The shells are in a shattered condition, and being intimately mingled with the clay, will prove serviceable to poor and sandy soils. An average specimen pulverised, yielded upon analysis:

Carbonate of lime, - - - - - - -	23·65
Siliceous sand, - - - - - - -	48·00
Clay, - - - - - - - - -	28·00
	99·65

The upper surface of the bed lies some 15 feet above tide-water, being several feet below the soil, is about 8 feet in thickness, including layers of clay destitute of shells, and is probably several acres in extent. Two other deposites in every respect similar to the foregoing excepting in extent have been partially investigated in Baltimore hundred, on the lands of Johnson and E. Walters, and there can be little doubt that many more will eventually be discovered. The Ostrea virginiana constitutes the main part of the organic contents of these beds, beside which we have Venus mercenaria, and occasional fragments of the Fulgur canaliculata. The argillaceous deposite resting upon the shell-beds appears to be of a different nature from that which we term the Lower clays, and to be the same as that which constitutes the heavy soil of the neck lands throughout the greater portion of the state, so that it is difficult to determine whether the blue clays and shells belong to the lower clays or are mere nests on their surface, as seems to be the case on the Nanticoke. The beds appear to lie in depressions on or near the sources of streams; and it is more likely that these have followed such natural courses in which they have subsequently worn their present channels, than that they were small streams in which the shells were originally deposited. It is from such deposites and their accompanying circumstances that we deduce conclusions relative to the gradual emergence of our coast from the ocean. Over the greater part of the surface we have passed from below Lewes to the southern border of the state on the S. and nearly to the dividing ridge on the W. the soil is a light sand, excepting where the lower clays are exposed, when we may have the extremes of light and heavy land in the same field; and excepting on the necks, where the river-deposite forms a heavy soil of good quality.

§ 92. Although we do not find many traces of the lower clay on the heads of Cypress swamp, yet there is every probability that it underlies the whole country between Indian river and the Nanticoke, constituting the basis of the swamp, for we observe it well developed in the vicinity of Laurel, closely resembling that on Indian river, and it may be seen on nearly all the branches of the Nanticoke River rising from 5 to 20 feet above tide-water, composed of yellow and lead-colored clays. Under the town of Laurel, it is observable in the steep banks of the creek consisting of yellowish clays of an arenaceous character, alternating with thin seams of sand reaching nearly to the soil, and were it not for the covering of loose sand it might be seen in nearly every ravine. Indeed it is in consequence of the ease with which the sand is transported by the wind, that so few exposures of the strata offer themselves to our examination and that the investigations cannot always be relied on for perfect accuracy. We are not, however, destitute of sufficient data on which to base satisfactory views of the region, which is peculiar to itself, and different from the remainder of the county. A considerable quantity of iron-ore has been removed from Little Creek about two miles S. of Laurel, where it is still wrought; the hard, and loam ores are chiefly obtained, and together with a medium ore are converted into wrought iron of good quality at Chipman's Forge, situated on Broad Creek about two miles E. by S. from Laurel.

§ 93. Between one and two miles S. W. of the same town is a series of small beds or rather nests of shells, chiefly the Ostrea virginiana, embedded in a yellow clayey loam, the nests being generally 2–4 feet broad, and 1 to 2 feet deep. In a majority of cases the shells are whole, both valves being present, but are so friable as to crumble readily to a coarse powder after exposure to the air or on being excavated by the spade. The S. Eastern banks of the Nanticoke between Seaford and Concord, exhibit similar shell-deposites more clearly in their position relative to the other formation. From the water-line to the height of 5 to 15 feet is a nearly vertical section of a blue clay, very tough and impervious to water, and containing a small quantity of arenaceous matter; above which are some 5 to 10 feet of yellow loam or clay, graduating into the soil. The shells lie in clusters or nests, as in the preceding case, between the blue and yellow clays, being evidently contained in the latter, but forming at the same time excavations in the blue; for they are always coated with the yellow loam, and never with the latter. The upper line of the blue is level excepting where the shells occur, and then it is excavated as if for their reception. The dimensions of the nests vary, containing from a peck to many bushels, and they are met with at short intervals for the distance of several hundred yards along the stream. Under the town of Seaford, we have an opportunity of examining the formation overlying the blue clay. It consists of a series of clays with yellow and white colors, containing very different proportions of arenaceous matter and occasional seams of sand, with intervening crusts of iron-stone, the whole rising from 15 to 20 feet to the sandy soil, but no traces of shells were found either at this place or nearer Concord; nor are there indications of them lower down the river, until we reach Cannon's ferry, where they were formerly met with in digging wells, but were again sought for by boring without success. They occur, however, a short distance below the ferry on the land of John Goslin, imbedded in a yellow sandy loam, similar to the beds above Seaford, and still lower down near the state line on the land of the Messrs. Wright. At the last mentioned place the shells are generally whole, the two valves enclosing a yellow, very sandy loam, the same in which the deposites are enveloped. The amount of shells appears to be greater than usual, and if more extensive deposites could be found their crumbling nature would render them useful for application to the soil. The same formation occurs on the N. W. Fork, and apparently under similar circumstances, but as it lay without the limits of the state, it was not farther investigated. There are few localities in N. W. Fork hundred, where the lower clays are seen, excepting on branches of the Nanticoke, and these presenting no novel features, it is unnecessary to describe them. Of a more interesting nature are the overlying sands to which we shall presently proceed. Reviewing the localities above described, it appears to be a deposite of modern shells imbedded in the same earth in which they lived when it was a soft loamy bottom, (otherwise we should sometimes find the shells detached and fragmentary;)—that it is in the lower stratum of the lower clays, and rests upon an older blue clay—that the different deposites at distances of 15 miles apart are of the same geological age, as proved by the constant uniformity of circumstances under which they occur—and that they are not extensive, as shown by the smallness of the nests, wherever found, and their absence in nearly every place where the same clay exists. The age of the underlying blue clay is a problem of difficult solution; but it would appear to be connected with a similar clay on the N. W. Fork river, which probably belongs to the tertiary. The few data, however, which the formation offers in Delaware cannot be considered a sufficient basis on which to ground positive assertions, nor is it of practical moment to determine the point, until it is found to contain beds of good calcareous marl.

§ 94. There are a few other localities of the lower yellow clays on the various branches of the Nanticoke, in N. W. Fork hundred, but their features are so similar to those which have been given that it would be mere repetition to describe them. The soil in the S. Western part of the state exhibits the same extremes as in the S. E., according as it is formed by the lower clays or overlying loose sands. In N. W. Fork hundred, there is one section of country remarkable for the good quality of its soil, which may be designated as a medium loam; although it does not form a large district by its continuity, yet since many smaller patches of the same quality of land exist in that hundred, the amount of surface covered by a good loam places it as an agricultural district in the first rank among the lower hundreds of the state.

SECTION II.

Upper Sands.

§ 95. To the traveller, who for the first time passes through Sussex county, the formations would undoubtedly appear to consist almost wholly of loose white and yellow sands, but a more thorough investigation shows the fallacy of such a conclusion, proves that in reference to geological deposites, the argillaceous greatly predominates over the sandy, forming the substratum of the whole county, but that the latter overlying and capping the clays over a large proportion of the surface, communicates the well-known sandy character to the soil. These upper sands probably cover one half or two thirds of the county, are of very variable thickness, sometimes yellowish and more tenacious, at others nearly white, and so loose, as to be readily transported by the winds. We have had occasion to notice them casually, while describing the lower clays, from Milford through the eastern and southwestern portions of the county. Along the eastern border they are generally of inconsiderable thickness, from six inches to several feet, and the lower clays may often be thrown up by the plough. Towards the S. E., the sand is unusually white, and may probably be found of sufficient purity for the manufacture of glass. If this formation be examined in the vicinity of the coast, its very undulating surface must strike the observer. A surface we would suppose to be more level from its position, we there find to consist of a series of hillocks apparently following no law relative to form, size, or situation, consisting wholly of light sand sometimes bare, but generally covered with herbage. The sand is so slightly coherent that often, where the sod has been removed in an exposed situation, the action of the wind roots it out to the depth of several feet, distributing it over the surrounding soil or heaping it against a bush, fence or other obstruction. The formation of *dunes* along the coast at Cape Henlopen is due to the same cause. As the fine sand thrown up by the waves of the ocean becomes dried, it is raised by the wind, and deposited on the sides of the present dunes, which were first formed by its lodging on the outer edge of a pine-forest. They stretch along the shore for some distance, enclosing one of the Light-houses, and imburying many of the trees, some of which were about 40 feet in height, and yet their tops only appear on the dunes like small bushes. These dunes are evidently of very recent origin, and still in the act of forming, as is proved by the moderate age of the trees, and the want of herbage on their surface. The whole forest against which they have lodged appears from the very undulating surface of the ground, to have sprung out of the remains of more ancient dunes. Similar appearances are observable near the coast in Baltimore hundred, and may be traced for several miles inland, until the undulating surface gradually becomes more even, and forms the ordinary superficial stratum of light sand.

§ 96. That the superficial stratum of sand is due to the destruction of sand dunes is more clearly seen in the western portion of the county, where the arenaceous stratum is much heavier, often attaining the thickness of 20–30 feet, and many of the ridges of loose sand are nothing more than dunes which have resisted the destroying influence of the wind, and may be traced from the lower hundreds to the sources of the Nanticoke in the southern part of Kent county. Indeed in whatever direction we approach the Nanticoke from its source to the point of its crossing the state line a range of sand hills strike the observer from their frequency—often from their continuity, their steepness, and the lightness of the sand composing them, circumstances which would at once induce him to refer them to the same origin as dunes. The sand is of so loose a nature, that where the sod is removed, it is very liable to removal by the wind, to the great annoyance of agriculturists. While alluding to the forest lands of the upper counties, we have incidentally noticed the existence of sand hills, which increasing in number and extent as we approach Sussex, and gradually passing into the sand dunes, must be attributed to the same origin. But although we meet with the sand in great abundance in the form of detached and connected hills, the greater portion of it constitutes a nearly level covering to the subjacent clays, varying in thickness from 1 to 20 feet, and covering a large amount of surface in the southwestern part of the county. In N. W. Fork hundred, the greater part of it is in the form of hills, and there is a comparatively small amount on the dividing ridge, where the soil is usually more or less argillaceous. This formation of light sand should not be confounded with several ranges of gravel hills in the county, which have a totally distinct character, although they are partially covered with the sand. The most striking of these ranges is one lying to the south of Milton, and between Georgetown and Lewes. It is a ridge of variable breadth, not more than 50 feet in height, extending for several miles apparently in a N. W. and S. E. direction, composed of fine gravel and sand with a sufficient admixture of clay to render it compact. Its isolated situation in a region composed of such different materials has attracted the notice of the inhabitants, and given rise to a variety of conjectures relative to its origin. It is undoubtedly to be referred to the same causes, formerly in action when the land was beneath the water, which are now operating in the bay to form shoals and bars, and which, if the whole bottom of the bay were elevated, would present the similar elevations composed of sand and gravel.

§ 97. Reviewing what has been said relative to the sand in the two preceding §§ 95, 96, we find that it is a stratum covering one half or two thirds of the county of Sussex, and extending partly into Kent, composed of a light colored sand of a fine and even grain, containing scarcely a trace of argillaceous matter, excepting on its surface, and so loosely deposited as to be liable to shifting from the action of the wind, that the greater part is distributed as a loose covering over the surface, from 1 to 30 feet, but probably averaging 5 feet in thickness;—that it is frequently drifted into the form of hills, closely resembling the sand dunes still forming on the coast near Cape Henlopen, and may be referred to the same origin.

§ 98. The ores of iron found in various parts of Sussex in considerable quantity and particularly on the dividing ridge, claim attention as having yielded, and still introducing some revenue into the state. The most remarkable are those situated a few miles N. W. of Georgetown, near the sources of several streams flowing westerly, which being on elevated and level land, spread themselves in broad and shallow basins covered with a stratum of black, argillaceous mould. The ore found below this black soil is of various kinds, hard or solid, gravelly and loam ore. The hard variety which exists in great abundance, forms a solid substratum to the mould from 6 to 18 inches or more in thickness; it is hard, moderately tough, of a rich brown color, and resinous lustre, with an uneven, conchoidal fracture; sometimes compact, oftener cellular in structure, composed essentially of peroxide of iron and water. An analysis of this variety of ore from the Clowes bed, performed by E. Mayer, yielded:

Peroxide of iron, - - - - - -	80
Water, - - - - - - - -	15
Silica, - - - - - - - -	5
Alumina, - - - - - -	a trace
	100

which may be viewed as the average composition of the same kind found in other localities. The amount of metallic iron in the above is 55½ per cent., but when subjected to roasting, the remaining ore will yield nearly 66 per cent. The gravelly ore consists of irregular masses of a similar ore of the size of a nut and smaller, disseminated in a yellow ferruginous loam, but containing rather more argillaceous matter, is softer and more readily worked. The loam-ore, which is still softer than the preceding, is a yellow ochre or clay highly charged with hydrated peroxide of iron. For working in the furnace the several kinds are mingled together, which not only facilitates the reduction and fluxing, but results in the production of a better quality of iron. Various names have been given to the ores in Sussex, more dependent on differences in their external form and other characters, than on chemical composition; thus the honey-comb ore varies only in its extreme cellular structure. There is probably another point of difference, which is not discerned in the external characters of the ore, and first renders itself perceptible in the metal; it is that matter which forms a cold short metal and in all probability is a compound of phosphorus or arsenic, but analysis has not hitherto detected their presence in the ore. The hard or solid variety is very apt to produce such a metal, but by mixing with the softer kinds, the result is a good malleable iron when worked in a forge.

§ 99. Collins' ore bed, the lowest on one of these streams, called the Green-meadow branch of Deep Creek, consists chiefly of a solid loam ore, which is principally wrought at Collins' forge of a hard compact ore, very rich in iron, but said to yield a cold short metal, and of a small quantity of sandy ore. There are many other deposites of ore in various parts of Sussex, such as that on Green branch about 10 miles W. of Millsborough, the best of which is in balls or nodules and yields good metal—that on Burton's branch one mile W. of the same town, making a cold short iron—that on Little Creek near Laurel, § 92, and others in which the characters are referrible to those given above. There are numberless localities in which smaller deposites of iron have been made, and are yet being formed from the visible action of springs, such chalybeate waters being every where abundant, some of them of excellent quality, and scarcely a mill-pond can be examined, but gives traces of such a ferruginous water recognisable by its yellowish and reddish yellow deposite. These appearances are however, far from being evidences of beds of ore, as is frequently conjectured, and merely indicate the presence of a considerable quantity of iron in the formations whence the water flows. Under favorable circumstances, they might generate ore beds, but being so situated that the water flows off freely, of course the greater part of the oxide of iron is carried away by the stream. Adjoining the town of Dagsborough on a meadow belonging to W. D. Waples, good evidence is presented to us that these deposites arise from ferruginous springs, for such chalybeates are still in action, and the effects of others are visible in small mounds of ore, through which the springs originally flowed. The process of deposition was more particularly described in the latter part of § 87. If we examine the formation adjacent to the ore beds, we shall generally find it to consist of a yellow ferruginous loam, both sandy and clayey, giving visible evidence of a considerable amount of peroxide of iron, but the quantity being apparently insufficient to account for the size of some of the beds, we must suppose that the springs flow from a greater distance, or that the formation has been more heavily charged, and is now partially exhausted. The *raising* of ore in quantity was commenced about 1814, since which time, nearly 200,000 tons have been raised, about 190,000 of which were exported, introducing not less than 600,000 dollars of capital into the state.

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SECTION III.

River Deposites.

§ 100. The Delaware has been for ages engaged in transporting gravel, sand and clay from the Northward, by means of which the sand-banks and shoals of the bay have been raised, and the heavy soils on the Neck lands deposited. A large number of the shoals are in all probability remnants of the land which once united Delaware and N. Jersey prior to the wearing away of its channel by the river, but they have undoubtedly been increased, and many of them entirely formed by the detritus brought down by the river. A boring made on the island on which Fort Delaware is situated, proves it to have been wholly formed by the river deposite; for the formations on either side of the river are red and white clays, and green and yellow sands, whereas in the boring they passed through river-sand with occasional beds of blue mud for the depth of 100 feet and more. Farther confirmation of deposition is given by the increase of some of the banks, as for example, the point separating the mouth of Lewes creek from the main land, which promises to unite it with Broad creek at no distant period of time. Although a portion of these deposites lower down the bay are due to the tributary streams of the Delaware from above tide-water, yet a large proportion is more immediately derived from the destroying effects of waves during spring tides on the shores of the bay.

§ 101. As interesting as the more minute investigation of the deposition of sand and gravel might be in a geological light, yet the deposition of argillaceous matter, is of greater practical importance. It is generally known by the name of *blue mud* along the Delaware shores, from its peculiar lead-colored hue when in a partially dried state. When land which is ordinarily under water is embanked, and afterwards thrown open to the influx and efflux of the tide, this argillaceous deposite gradually accumulates on the surface of the marsh, forming a solid stratum, when the embankment is renovated, that is remarkable for its fertility. On Bottle neck on the northern side of Duck creek, S. Spearman was engaged in 1837, in reclaiming a portion of meadow land by embanking it, when the deposite of blue mud was observed to be from 6 to 18 inches in thickness, formed in the lapse of 15 to 20 years, previous to which, the same tract had been enclosed. The old top was found under the blue mud in a decomposed state and mingled with earthy matter, below which the same black mould abounding in vegetable matter lay to the depth of several feet, sometimes containing much vegetable fibre or being wholly composed of it, at others being entirely deficient in the same. The whole was based upon a white sand.—The same observations will apply to a majority of the marshes, with the exception of the thicknesses given, for it is probable that the depth of the black mud sometimes attains nearly 50 feet, as at the confluence of the St. Georges and Dragon creeks. In all of them we find the black mud below crowned by the blue, where the latter exists. A close examination of them from the mouths of the creeks inland leads to the conclusion that the blue is wholly produced by the river, and that the black is the result of the combined action of the river and creeks, and a luxuriant vegetation.

§ 102. It has been a frequent subject of remark that soil of the neck-lands, or those tracts bordering on the Delaware from New Castle to Sussex are always argillaceous, §§ 69, 81, 84, 86, 88. The St. Georges, Augustine, and other marshes reclaimed from the river, belong rather to those described in the preceding, § 101, but also offer an explanation of the origin of the neck-soils, for having been laid dry for a length of time, we may compare the nature of the marsh-soil with that of the adjacent upland. They appear to be identically the same, or if different, the variation is only such as might be anticipated from the action of time with its accompanying and altering effects. On the neck between Silver run and Augustine creek there is a lead-colored and yellow clay with occasional beds of gravel, the yellowish variety constituting the soil, but by proceeding southwardly, the gravel is less frequently observed, and the same argillaceous soil is characteristic of the necks, modified in color by its content of decomposed vegetable matter. The yellow clay was mentioned as occurring on Thoroughfare neck to the depth of 20 feet, § 81, and that beds of bay-shells were found in it. It is also of considerable thickness on Little Creek and Jones' necks. The shells found in a blue clay, S. E. of Frederica, § 84, seem to place it in the same class, as the argillaceous strata lying above it, which is of the usual nature of neck-lands. On the bay-shore in Sussex, the same formation meets our observation, but less frequently in consequence of the abundance of loose Upper sand, and even on the coast in Baltimore hundred, the soil is of a similar nature, excepting that the blue clay is rather more abundant. It appears, therefore, to be a uniform deposite of argillaceous matter lying upon or within a short distance of the river and bay, indiscriminately covering older geological formations, such as the Upper secondary, Tertiary, and the more recent strata of Sussex; and from its similarity to the present deposites of the river under like circumstances to have resulted in like manner from the matter brought down by the river when it had a relatively higher water-level. The fertility of these neck-lands is proverbial, and shows another point of resemblance to the blue-mud now depositing by the Delaware, § 101; among them may be mentioned Raymond's neck, supposed by many to contain the best land in the state—Little creek, studded with excellent farms—Prime Hook and Slaughter necks, remarkable for the superior quality of their soils, although much exhausted by excessive tillage. It is highly probable that the noblest forest in the state exists on Prime Hook neck, consisting of Tulip-poplar, black walnut and black oak, remarkable for their enormous size and flourishing condition. Those enumerated are but a few of the fertile lands fringing the Delaware, which are deservedly held in the highest estimation. In conclusion, it appears that the river has been largely depositing gravel, sands and clays throughout a lengthened period of time, and that its operations are still in activity with the production of useful results.

PART III.

ECONOMICAL GEOLOGY.

CHAPTER I.

AGRICULTURE.

SECTION I.

On Soils.

§ 103. Soils are under all circumstances difficult of classification, in consequence of the variety of mineral and organic substances composing them, as well as of their different states of disintegration, and although many have attempted a scientific arrangement with partial success, yet until such systems attain greater perfection we may content ourselves in the present work with a nomenclature commonly received among the farmers of Delaware, applying the term *sandy* or arenaceous to many of the soils of Sussex and Kent; *clayey* or argillaceous to those in N. Castle county N. of the canal, to those on the ridge and neck-lands; *loam* to a medium soil or proper mixture of clay and sand, such as the middle portions of St. Georges hundred, and many in Kent and Sussex; and a *vegetable mould* to such as contain a large proportion of decomposed vegetable matter, like Marshy Hope, Tappahanna and other marsh-lands. The substances constituting soils are silica, alumina, oxide of iron, lime, magnesia, alkaline, earthy or a few metallic salts, and animal and vegetable matter in various stages of decomposition. On the proportion in which these are combined together, and on their fineness depends fertility. Thus a soil consisting in a large proportion of gravel must be sterile, and even 90–95 per cent. of siliceous sand cannot be productive; nor can it be more profitable, on the other hand, where the matter is almost wholly a finely divided clay: there is, therefore, a medium between these extremes which is requisite for fertility. Again, supposing the materials to be in a due state of fineness, their relative proportions are of the highest importance, for plants will not grow thriftily in any one of the above-named substances, and it is found that the most fertile soils contain a majority of them. Of these silica is the most abundant and may be viewed as the basis of all, and with alumina and oxide of iron, acting with reference to the other substances, as nitrogen to oxygen in the atmosphere, moderating and equalising their action. These then, in a state of fine division, give coherence to the soil, particularly where alumina is present, and the same effect is produced by decomposed organic matter. Gravels are commonly termed *hungry* from the quantity of manure required to render them productive, the reason of which will be evident from a knowledge of the fact that chemical action takes place more readily when substances are in the finest comminuted state, and hence little or no combination taking place on the surface of gravel, the richest portions of the manure are liable to destruction from atmospheric agents, or to be carried away by water previous to the action of plants upon them. The same reasoning will apply to pure sands, although in a diminished ratio. Again, where the quantity of fine matter is very great the manure will be held a greater length of time, and in this case there is another difficulty, which is chiefly mechanical in its nature, where the aluminous or argillaceous earth is in such quantity as to constitute a fat clay; it is then more difficult to work, bakes hard in the sun, does not absorb a sufficient amount of moisture from the atmosphere, and parts with it with difficulty. To correct the stiffness of clays, such as occur in the Upper hundreds of New Castle, north of the canal and in Appoquinimink, in some portions of Sussex, and on the neck-lands of all three counties, it is only necessary to add sand or better a sandy soil; while the lighter sands of Sussex and portions of Kent will be greatly benefitted by the application of clay or a heavy soil.

§ 104. The advantages of a good medium soil are not only the greater facility of working and increased power of retaining manure, but also the greater power of absorbing moisture from the atmosphere. The utility and absolute necessity of water for promoting the growth of plants is too generally acknowledged to require farther notice, but the manner of its operation is not generally understood. It is in fact the medium of chemical action in vegetable organisation; for the food, whether mineral or organic, is not taken up by them in a solid state, but by solution in water; and hence the power of absorbing and retaining moisture in soils is a matter of great moment, essentially connected with their fertility. The more finely divided the constituents of the soil are, the greater its absorbent power, the same substances being present, but it is found that different materials possess it in differing relations; for stiff clays and loose sands absorb far less than a medium soil composed of a mixture of the two, and an ordinary loam less than one containing organic matter. Absorption takes place in the night, and when succeeded by a hot sun, the moisture is readily evaporated from a sandy soil, much less so from loam; but the action of the sun on clay is such as to render its surface compact, so that its porosity being diminished its absorbent power is decreased.

§ 105. It has been often observed that white clay soils are much less productive than the yellow, and the former are termed *cold, unkindly*, an observation that deserves some notice, as it is true and can be satisfactorily accounted for. The theory of the absorption and radiation of heat might be brought to bear upon it, but it is more to our purpose to view the subject practically. It has been observed that dark colored soils will absorb more heat from the sun than those of a lighter color: and hence one abounding in decomposed vegetable matter possesses this power in a high degree, and a yellow clayey bottom containing oxide of iron excels one composed chiefly of white clay: farther, the presence of ferruginous matter renders a clay less cohesive, more porous, and consequently more capable of receiving and retaining moisture. We may therefore attribute the different productive powers of white and yellow clay soils in a measure to their relative capabilities of receiving both heat and moisture, for there can be no doubt that the heat of the vernal sun tends to accelerate vegetation when the season is usually more moist, while the dry sun of summer evaporates the moisture of very stiff land, and by rendering it more compact diminishes its faculty of re-absorption. We see in these circumstances in part the cause of the fertility of the upper hundreds of New Castle county, of St. Georges hundred, of the neck lands, particularly in Kent and Sussex, and of a portion of North West Fork, in all which the soil is decidedly clayey but is relieved by the presence of oxide of iron and organic matter. In parts of Red Lion, in Pencader, and frequently on the ridge throughout the state, we find a white clayey soil, not remarkable for its fertility, but it is fortunate for those holding such cold soils that either sands or loams are to be found in the vicinity, by which their sterility may be ameliorated. Another cause of the greater productive power of yellow clayey soils will be pointed out in § 115.

§ 106. The necessity of finely divided matter to fertility was long since discovered, and so striking was the result which the earlier experimenters obtained, that they believed it to be the chief or sole cause of fertility, an error which may readily be excused when we examine the mode of its operation and its vital importance. Now the constituents of plants are organic and mineral matter, the latter of which obtained in the form of ashes consists chiefly of alkaline and earthy salts, and it is remarkable that most plants contain very small quantities of oxide of iron and silica and scarcely a trace of alumina, a circumstance giving strength to our position, § 103, that they serve as a basis for the action of other inorganic and for organic compounds. But since chemical effects or the vital action of plants take place only on the surface, and since the more minute the division, the greater the extent of surface, then, when the latter condition is fulfilled in a high degree, the alkaline, earthy and organic matters forming the requisite food of vegetable organisation will be more comminuted and mingled with the soil, and a greater amount of chemical action ensuing, the more luxuriant will be the vegetation. Let not the conclusion be drawn from this that the fattest clays, composed of exceedingly fine matter, comprise all these conditions, for independently of the mechanical difficulties which such soils present, their chemical constitution is a strong hindrance to their fertility. They contain silica, alumina, and a little oxide of iron, not one of which is received in quantity by wood, and the silica only exists in abundance in grasses, grain and other plants—whereas we require potassa, lime, magnesia, manganese, and the phosphoric, sulphuric and muriatic acids, all of which are found in the ashes of plants, and the two first named in considerable quantity. The chemical constitution of the soil must therefore go hand in hand with minute division to produce fertility.

§ 107. From what has been said, we conclude that a state of minute division of the materials composing soils is necessary to fertility from its greater capability of retaining manures, of absorbing and retaining moisture from the atmosphere, of absorbing heat, and of promoting chemical action; but that too much fine matter, particularly aluminous, hinders fertility by its becoming too compact in the heat of the sun and its diminished absorbent power for water, and generally by the absence of a sufficient variety of the mineral constituents of plants. The following analyses of soils calculated from Sir H. Davy's Agricultural Chemistry, may serve to show the difference in their constitution. The finely divided matter was ascertained by washing the soil with water, and collecting the lighter portion that gradually subsided from the fluid; while the remainder was regarded as sand

1. A poor heath-sand, destitute of herbage, contained less than 5 per cent. ($\frac{1}{20}$) of fine matter, and after heating to redness, it consisted of:

Coarse siliceous sand,	95
Fine " "	2·25
Finely divided matter,	2·75
	100·00

The fine matter consisted of ferruginous clay and carbonate of lime.

2. A moderately good sandy soil contained $\frac{8}{9}$ siliceous sand.

Siliceous sand,	88·88
Fine matter,	11·12
	100·00

The fine matter consisted of

Alumina,	1·22
Silica,	1·67
Carbonate of lime,	7·01
Oxide of iron,	0·33
Vegetable and saline matter,	0·56
Moisture,	0·33
	11.12

3. A good soil containing $\frac{5}{6}$ of fine siliceous sand, or,

Sand,	83·33
Fine matter,	16·67
	100·00

which consisted of:

Alumina,	6·84
Silica,	7·00
Carbonate of lime,	0·67
Oxide of iron,	0·83
Vegetable, animal and saline matter,	1·33
	16·67

4. A good wheat soil containing $\frac{3}{5}$ of sand, or,

Siliceous sand,	60·
Fine matter,	40·
	100·

which 40 per cent. contained

Alumina,	11·6
Silica,	12·8
Carbonate of lime,	11.2
Animal and vegetable matter and moisture,	4·4
	40·0

5. A rich soil containing $\frac{3}{5}$ fine siliceous sand and 40 per cent. fine matter, which yielded

Alumina,	14·0
Silica,	16·4
Carbonate of lime,	5·6
Oxide of iron,	1·2
Vegetable, animal and saline matter,	2·8
	40·0

6. A very productive alluvial soil containing $\frac{1}{8}$ sand and 87½ per cent. fine matter, which gave by analysis

Alumina,	5·06
Silica,	4·05
Carbonate of lime,	72·92
Oxide of iron,	1.62
Vegetable, animal and saline matter,	3·85
	87·50

7. An excellent soil for pasture contained $\frac{1}{11}$ of coarse sand, or

Coarse sand, - - - - - -	9·09
Finely divided matter, - - - - -	90·91
	100·00

The 90·91 per cent. fine matter consisted of

Alumina, - - - - - -	6·36
Silica, - - - - - - -	12·73
Carbonate of lime, - - - - -	57·27
Oxide of iron, - - - - - -	1·82
Vegetable, animal and saline matter, - -	12·73
	90·91

§ 108. To apply the principles and observations laid down, we may remark that the heavy soils of Pencader and other hundreds in New Castle county may be improved by a yellow gravelly sand and loam which is found in abundance in those districts; the clayey soil of the ridge generally by the application of a yellow sand found in quantity in its vicinity throughout the state; the middle section of Kent containing a sandy loam is sufficiently tenacious to yield profitably, and may be best improved by a judicious, not exhausting system of tillage; the light sandy soil of Sussex and the lower part of Kent should be rendered more coherent by the application of yellow clay or even a sandy loam, or where these are not convenient even by light colored clay, and then a course of improvement by proper tillage will amply reward the outlay of capital; the stiff, clayey bottoms of Sussex will be benefitted by applying sand or a sandy loam, which are every where abundant. There are however certain bluish colored clays both in Kent and Sussex, §§ 82, 86, 89, 91, which by exposure to the air become coated with an efflorescence of copperas (recognised by its styptic taste), in such quantity as to be injurious to land; even these may be employed in default of better provided lime be used at the same time, for the copperas will then be decomposed and the lime converted into plaster. It may be urged that the moderate value of land in the lower part of the state will not warrant such an expenditure. This is undoubtedly true if it were advised to cover a large tract immediately, but it may be done by slow degrees, commencing with a small lot of ground, and if the result be favorable, the system may be gradually extended according to the means of the individual. Nor should it be forgotten that the improvement here recommended will prove more permanent than all others and will be the foundation on which they can rest with the greater certainty; for all are aware that organic manures have an immediate but transient action, whereas a soil of the proper texture may be viewed as permanently fertile, capable of producing more abundantly with the least expenditure.

§ 109. A view of the mineral constituents of plants, as developed by analyses of their ashes will show how varied should be the nature of the substances in soils The following analyses of ashes are extracted from Berthier's chemistry, and their accuracy may not be questioned.

1. *Ashes of Oak Wood.*

Alcaline Salts.	
Carbonic acid, - - - - - -	28·4
Sulphuric " - - - - - -	5·9
Muriatic " - - - - - -	4·0
Silica, - - - - - - -	1·0
Potassa, - - - - - - -	} 60·7
Soda, - - - - - - -	
	100·0
Insoluble substances.	
Carbonic acid, - - - - - -	30·1
Phosphoric, " - - - - - -	7·0
Silica, - - - - - - -	1·7
Lime, - - - - - - -	44·7
Magnesia, - - - - - - -	7·9
Oxide of iron, - - - - - -	0·1
" manganese, - - - - -	2·9
Carbon, &c. - - - - - -	4·5
	98·9

2. *Ashes of Straw.*

Sulphate of potassa, - - - - -	0·4
Muriate " - - - - - -	3·2
Carbonate " - - - - - -	trace
Silicate " - - - - - -	13·0
Silica, - - - - - - -	71·5
Carbonate of Lime, - - - - -	9·6
Phosphate, " - - - - - -	2·3
	100·0

The following analysis of a good siliceous sandy soil is taken from the work referred to § 107.

Gravel, - - - - - - -	13·25
Fine sand, - - - - - -	53·
Undecomposed vegetable fibre, - -	3·50
Water of absorption, - - - -	4·75
Finely divided matter, - - - -	20·25
Loss of analysis, (chiefly water,) -	5·25
	100·

The 20.25 per cent. of finely divided matter consisted of:

Alumina, - - - - - - -	3·25
Silica, - - - - - - -	5·25
Carbonate of lime, - - - -	4·75
Carbonate of magnesia, - - - -	·75
Sulphate of lime (gypsum,) - -	·50
Oxide of iron, - - - - -	1·25
Matter, chiefly vegetable, (insoluble) -	3·75
Soluble matter, chiefly common salt and vegetable extract - - - - -	·75
	20·25

There was no potassa apparently found unless a small quantity were contained in the three-quarters of one per cent. of soluble matter, and yet there is no doubt that plants grown in that soil would yield an abundance of that alcali in their ashes, which they must have obtained from the soil. We perceive from the above analysis the difficulty of detecting potassa in small quantity, and from the two former, the necessity or propriety of introducing a larger amount of it into the ground in order to insure more abundant fertility. Now all good farmers are agreed that of mineral manures, ashes is one of the best, whether leached or unleached; and it has been shown above that it contains potassa and lime in the greatest quantity; even when leached, it still retains no inconsiderable amount of potassa, and a larger quantity of lime, when the latter is employed for running off lye, as is usually the case. What better materials indeed do we need for yielding the fixed constituents of plants, than the same obtained from plants? From the large proportion of lime and potassa in the ashes of plants, and their great fertilising powers when applied to land, we might suppose that a soil should be made replete with them; it is, however, contrary to experience, for an excess will produce equal sterility with a deficiency, and hence the assertion § 103, that silica, alumina, and oxide of iron act as diluents to the other constituents. The muriatic acid is not uncommon in the heavier soils of Delaware, but this acid with the sulphuric and phosphoric are chiefly supplied from organic manures. In conclusion, then, silica and alumina should constitute a very large proportion of the mineral basis of a soil, the former in the state of sand preventing the too adhesive properties of the latter, an effect often produced by oxide of iron, § 105; potassa and lime should next follow in their ratios, magnesia in small quantity and the above mentioned acids also in small proportion. It has been stated, § 108, how soils might be improved in texture; and in order to communicate the other constituents, we should employ mineral substances, such as green sand, ashes, lime (which generally contains magnesia) &c., and organic manures. Some exception might be made to the necessity of this rule in all cases, and particularly in rocky regions, where the soil often partakes of the nature of the subjacent rock. Thus in the upper hundreds of New Castle county, the detritus of gneiss forms a large proportion of the soil, and introduces substances containing a variety of ingredients, for felspar and mica contain potassa, and while the former is often subject to decomposition, §§ 25, and 157 the latter under peculiar circumstances § 157, is also affected, and their separated constituents enter into the soil.

§ 110. But even supposing that a soil is properly constituted, there are methods of increasing fertility to which some attention should be given. The light, drifting sands of the lower part of the state might be advantageously compressed by rolling when wet, and after drying. Nearly all soils, however, are apt to become too compact, and should be rendered looser by ploughing, harrowing, &c., the advantages of which are that the rootlets or fine fibres of roots, can ramify with greater freedom and even increase in number, by which a larger proportion of food may be received; that atmospheric air, and moisture will be absorbed in greater abundance; that it diffuses the food of plants more uniformly; and that the temperature of the soil may be increased. It is partly with this view that naked fallowing was introduced, but as the utility of this process is at least doubtful, it will not be insisted on. Irrigation is of great utility, not merely in consequence of its supplying moisture, the medium for conveying food, but materials of fertility also, which are usually suspended in water. There is one species of irrigation practised to some extent in Delaware, on the marsh lands bordering on the river, by flooding, or suffering the ingress and egress of the tide on land, which has been embanked, by means of which a large portion of valuable matter suspended in the water is deposited, and gradually raises the surface of the marsh, § 101. A system of irrigation might be advantageously adopted on the numberless upland meadows throughout the state, by leading the waters of brooks in channels along the side of the meadows, and suffering it to flow over them through small lateral openings in the channels.

SECTION II.

Organic Manures or those of animal and vegetable origin.

§ 111. Both animal and vegetable substances in their ordinary mixed state undergo a remarkable change by the influence of air, heat and moisture, giving rise to a process which is called the putrefactive fermentation. That these changes are of a purely chemical nature, governed by the ordinary laws of affinity, experiments have fully demonstrated, but at the same time it is much to be regretted that few chemists have investigated them to the extent they deserve, since their results would undoubtedly prove of the highest utility to the noblest and most useful of all pursuits, the science and practice of agriculture. A rich garden-mould, that is, a soil containing much decomposed organic matter has been found to contain, as the result of organic decomposition, a black or brownish black substance resembling charcoal, to which the name of Humus-coal is applied, another brown substance with acid properties which is termed the Humic acid, and a third similar to the preceding in appearance, but possessing neither an alkaline nor an acid character, termed Humin. Berzelius applied the terms gëine and gëic acid to humin and the humic acid, but he has since laid them aside, giving preference to the names which are adopted in this memoir. By examining the mineral spring of Porla in Sweden, in his usual thorough and accurate manner, he discovered the existence of two other substances which he calls the crenic and apocrenic acids (acids of a spring), which he has since found to be products of putrefactive fermentation, and to be contained in some quantity in productive soils. These five substances then constitute the amount of our theoretic knowledge of organic compounds formed in manures of animal and vegetable origin, but a broad and most useful field has been opened for chemical research, on the results of which the use of manures will eventually be based. A concise description of these substances, may not be amiss, as tending to elucidate a very important, but intricate subject.

§ 112. If a rich vegetable soil be extracted with water, we obtain a yellow solution, which by evaporation in a water-bath, leaves a yellow extract. By dissolving in a little water, a large portion remains containing humic acid; but the extract contains also crenic acid. If the earth after being extracted by water be treated with dilute muriatic acid, lime and magnesia with a little alumina and oxide of iron are dissolved, and then alcali takes up a large amount of humic acid, which was combined with those bases in the soil. After the action of alcali, a blackish substance still remains, humus-coal, which is probably the same as humin. Humin appears to exist under two forms, one of which is converted into humic acid by the action of bases, as potassa and lime, the other retains its indifferent properties. Humic acid as it occurs in the earth has neither alcaline nor acid properties, but if it be dissolved in alcali, then precipitated by an acid and washed with water, it becomes aqueous humic acid and possesses decidedly acid properties. It has a sour and astringent taste, and when evaporated to dryness is no longer soluble in water. It forms soluble neutral salts with potassa, soda and ammonia, being readily dissolved by them in a caustic, and sometimes in a carbonated state. With the alcaline earths, it gives powdery compounds, difficultly soluble in water; the humate of lime requiring 2000, that of magnesia 160 parts of water for solution; but after perfect drying they are insoluble. To the greater solubility of the magnesian salt we may attribute the injurious effects of magnesian limestone on soils containing much humic acid. Humate of alumina while moist is soluble in 4200 parts of water, but is very soluble in carbonated alkalies. A solution of ness *in vacuo*, treated with alcohol, which dissolves crenic acid and crenate of magnesia, and this solution also evaporated *in vacuo.* It is dissolved again in water, and treated with acetate of lead until a portion of the precipitate dissolves, leaving a brown residue of apocrenate of lead. The filtered solution is next thrown down by basic acetate of lead, producing insoluble crenate of lead, which mixed with water, and treated by sulphuretted hydrogen and filtered, gives a solution of pure crenic acid. By evaporating the solution to dryness *in vacuo*, we obtain a transparent mass colorless in thin, and pale yellow in thicker layers, but after perfect dryness it is a hard fissured body, opake, and of a yellow color. This is crenic acid as pure as Berzelius has yet obtained it. According to an analysis of Hermann, it consists of—

	By experiment.	*Atoms.*	*By calculation.*
Carbon	40·24	7	40·43
Hydrogen	7.69	16	7·54
Nitrogen	7·50	1	6·69
Oxygen	44.57	6	45·34

On which Berzelius remarks that the content of nitrogen appears to be too small.

§ 114. The importance of this acid to chemists, particularly to those who are interested in the application of science to the arts, and the deficiency of some of our chemical works in many of the later discoveries in the science induced the publication of the preceding method for obtaining the pure acid, and will be a sufficient apology for devoting a few moments to its compounds. It is decidedly acid, not only reddening vegetable blue colors, but communicating a sour taste in a solid state or in solution. It combines with silicic acid (flint), so that alcali cannot wholly decompose the compound. It forms very soluble salts with the alcalies; those of the earths are less so, and with the metallic oxides, its compounds are very difficultly soluble, but by continued washing with water, they dissolve in a greater or less degree. Crenate of lime precipitates from a solution containing another salt, although it is somewhat soluble in pure water; the bicrenate of lime is very soluble. Crenate of magnesia is more soluble, and its bi-salt still more so. Bicrenate of alumina is soluble, but there is also a neutral crenate of alumina and ammonia perfectly soluble in water.

Crenate of protoxide of manganese is partially and the bi-salt perfectly soluble in water. Crenic acid will attack iron with difficulty so far as to form a very soluble bi-salt. Neutral proto-crenate of iron is also soluble, and may be directly obtained by diffusing yellow ochre in water, and passing sulphuretted hydrogen through it, but it is difficult to prevent its passing into a peroxide-salt. To apply these observations as far as our limited knowledge of the subject will permit, we observe that crenic acid combines with silica, and it would be interesting to know the extent of its solubility either alone or with such substances as may be met with in soils, as it might unfold the manner in which silica is received into plants. From the degree of solubility of the salts of the alcalies, earths, and the two metallic oxides mentioned, it is evident that this acid may play a more important part in the fertility of soils than the humic acid. Allusion was made, § 105, to the greater fertility of yellow clay over white clay soils, and the mechanical causes of the difference pointed out; but the chief reason is of a chemical character, and refers evidently to the content of the crenic acids in the yellow ochrey matter which imparts its characteristic color to the land.

§ 115. If moist crenic acid be exposed to the action of the air, it is converted into the apocrenic. After acidifying the first alcaline solution obtained from the bog-ore, and precipitating by acetate of copper, § 113, it was observed that apocrenate of copper remained. The precipitate should be mixed with water, sulphuretted hydrogen passed through it, and the whole filtered. By evaporating the filtered liquid to dryness and treating with warm absolute alcohol, the pure apocrenic acid dissolves. Another portion, however, remains on the filter with the sulphuret of copper, from which it may be extracted by a solution of acetate of potassa; and by evaporating the last to dryness, and treating the residue with alcohol of 0·86, the apocrenate of potassa remains undissolved. It is dissolved in water, and precipitated by muriatic acid. When dry, apocrenic acid is blackish brown, full of fissures and gives a dark red powder; reddens vegetable blues, and has an astringent, but not an acid taste. The salts of apocrenic acid resemble the crenates, § 114, excepting that the former are blackish brown, and those of difficult solubility are still more so than the corresponding crenates. According to Hermann this acid contains—

	By experiment.	*Atoms.*	*By calculation.*
Carbon	62·57	14	62·11
Hydrogen	4·50	14	5·07
Nitrogen	15·00	3	15·41
Oxygen	17·63	3	17·47

The apocrenated alcalies are very soluble; those of the earths, as lime, are blackish precipitates, which by continual edulcoration gradually dissolve with a yellow color, but if the bases be in excess they are insoluble. It has so strong an affinity for alumina, that if hydrate of alumina be digested with apocrenate of potassa in solution, the whole of the acid is precipitated, and leaves a trace of crenic acid with the potassa, but a portion of the alcali has fallen down, so that an insoluble double salt is formed. Berzelius was unable to separate it from alumina by any process short of decomposition. Protapocrenate of iron is soluble and by exposure to the air forms a basic persalt. There is also a basic protapocrenate, which becomes brown in the air, and closely resembles the ochre deposited from the Porla spring. Although it is an exceedingly difficult matter to solve complex questions on the action of organic manures in the present imperfect state of our knowledge relative to these acids, yet on the assumption strengthened by observation that they play an important part in the vegetable economy, we are enabled to explain the mode of certain operations in agriculture. Thus, for example, if a soil contains an excess of earthy bases in comparison with the amount of organic matter, insoluble basic salts with the organic acids will result, constituting a soil of diminished fertility. The large quantity of manure requisite to render a clayey soil productive may be explained by the well-grounded supposition that much of the organic matter is rendered temporarily inert by its difficultly soluble combination with alumina and other earthy bases, while the very slow and gradual solution of its salts explains in part the fact that such soils yield for a greater length of time.

§ 116. The valuable series of experiments conducted by Berzelius did not terminate with the examination of these acids as obtained from the spring of Porla or ferruginous ores, for he was led to examine for their presence in putrefied vegetable matter, and as usual with all his operations with useful results. He procured the blackish brown pulverulent residue of an oak stem, which had putrefied in marshy ground, from which by a series of operations similar to those described above, § 113, 115 he obtained crenic and apocrenic acids, the latter differing in a few points from the same acid described in § 115, and in such a manner as led him to view it rather as a combination of that acid with the humic. He farther examined the action of nitric acid on charcoal and found the greater part of it converted into a yellow substance (not examined), and two acids which resembled the crenic and apocrenic, but the apocrenic thus obtained differed in its atomic weight and power of saturation from the acid obtained from ochres, or that from putrefied vegetable matter. The experiments therefore, although not giving results perfectly conclusive to the theorist or practical man, offer nevertheless the first insight we have obtained into a series of phenomena of the most complicated nature, but at the same time promising the most useful results. Hænle examined a chalybeate, and found it an organic acid very similar to the crenic, which he called *puteanic acid*, (puteum, a well) and Brandes discovered one in another mineral spring; from all which it would seem as if there were a class or genus of such organic acids, differing more or less from each other and yet possessing certain properties in common, which entitle them to be placed in the same rank.

§ 117. It was shown in § 109, how varied the mineral contents of a soil should be in order to its fertility, but even if these constituents are mingled together in due proportion, there is one point of the greatest importance, the commixture of organic matter, without which no soil can be productive. If we examine the constituents of wood, we find that Pine contains less than one per cent. of ashes or earthy matter, Birch about one per cent. Hazel 1½, Oak branches—2½, the remainder (90–99 per cent.) being organic matter. The chief constituents of the organic matter are Carbon, Oxygen and Hydrogen, the minor but not less essential are Nitrogen, Sulphur, Phosphorus, &c., of which a large proportion of the first four may be obtained from water and atmospheric air, but undoubtedly the greater part of all these constituents is derived from organic matter in the soil;

for although plants will vegetate simply from the presence of air and moisture, yet their feeble and sickly state compared with those growing luxuriantly in a good soil, under similar circumstances, and other things being equal, fertility being in direct proportion to the amount of organic matter, is abundant evidence of its utility and necessity. Growing plants, particularly when inflorescence commences, take up large quantities of organic matter, and if successive crops be removed from the soil, constantly diminish the amount of such matter so that the earth however fertile, would at length cease to be so. This must therefore be replaced by organic manures, or the residues of animal and vegetable matter, which are gradually converted into humin, and the humic, crenic and apocrenic acids. The experiments of De Saussure on mould seem to prove that by the alternate action of air and moisture, a portion of insoluble humin is changed into soluble humic acid, and that the contact of air with a solution of the latter, reconverts it into humin. Humus-coal, § 111, generates a portion of carbonic acid with the oxygen of the air, and then becomes humin and humic acid, and indeed on this principle alone we may account for the utility of naked fallowing or frequently by turning up a soil which contains much humus-coal for it loosens the earth and permits the free entrance of the atmosphere.

§ 118. It is to be regretted that few practical experiments have been instituted since the valuable discoveries of Berzelius relative to the crenic acids, but the following analyses made by Hermann of a very fertile soil, which covers a large portion of southern Russia and Siberia and stretches into Hungary, will serve to show the influence of culture on those acids, and the advantages that must flow from their closer investigation. This mould is ordinarily from one to two feet deep, but sometimes attains a thickness of several fathoms, and may not inaptly be compared to our prairie or bottom-lands of the West. *A* is a soil, which has never been under culture; *B* has been long cultivated but never manured, and *C* from the same locality below the former, from a depth not penetrable by the plough.

		A	B	C
Sand,		51·84	53·38	52·77
Clay or finely divided matter.	Silica,	17·80	17·76	18·65
	Alumina,	8·90	8·40	8·85
	Oxide of iron,	5.47	5·66	5·33
	Lime,	0·87	0·93	1·13
	Magnesia,	0·00	0·77	0·67
	Water,	4·08	3·75	4 04
Acids, which were combined with oxide of iron and alumina (and other bases?)	Phosphoric acid,	0·46	0·46	0·46
	Crenic "	2·12	1·67	2·56
	Apocrenic "	1·77	2·34	1·87
	Humic "	1·77	0·78	1·87
Humic extract,		3·10	2·20	0·00
Humin and vegetable fibre,		1·66	1·66	1·66
		99·84	99·76	99·86

From an examination of the first column, we find that the soil contains 20½ per cent. organic matter, four of water, and 85½ of earthy material; a comparison of it with the second and third columns shows that the humus extract is produced on the surface and is probably thrown off by vegetation; a comparison of the second and third proves that by cultivation the humic acid is diminished by more than one per cent. of the whole soil, the crenic seven-eighths, and that the apocrenic has increased by nearly one half per cent.; that, therefore, the crenic and humic acids have partly been converted into the apocrenic, and partly received into the growing plants.

§ 119. It is not uncommon to divide soils into fertile or neutral and acid, a correct distinction, but not according to the ordinary views of the subject, for it is not a rare conclusion that a soil is acid because it grows certain weeds, such as the sheep-sorrel. The truth is, that acid soils are very rare, either producing nothing or at best a little moss, and are only found in marshy ground; and farther, the acid existing in sorrel, is very different from those in an acid soil, and is not taken up by the plant, but actually generated and secreted by it. They have nearly the same composition as ordinary soils, excepting that instead of the humic acid being combined with lime, it is united according to Einhof with acetic and phosphoric acids, and according to V. Pontin with the same and also malic acid. Such soils may be rendered fruitful by the application of lime which neutralises the acids, producing large quantities of humate and the crenate of lime. Ashes will produce a similar result. The acidity of a soil may be conveniently tested by litmus paper or an aqueous infusion of a vegetable blue color, which the smallest quantity of free acid will change to a red.

§ 120. The power of a well comminuted and well proportioned soil to absorb moisture was shown, § 104, but in proportion as it contains organic matter, this power is greatly increased, so that a good soil may contain three-fourths of its weight of water without appearing to be wet. It is in fact the mould or humus in it to which it is indebted for this valuable property, for it is one of the most powerful of hygroscopic substances. Such decomposed vegetable matter may absorb double its weight of water and yet appear dry, and even after being dried it will take up in the course of 24 hours 80–100 per cent. of its weight of moisture. Like charcoal it is mainly indebted for this property to its porosity, which it loses when converted into humin, by becoming more dense and solid. From this fact we are enabled to account for the continued moisture of a mouldy soil, even in a drought, for it requires a great amount of heat to expel the greater part of the water. Farther, it has the property in a high degree of absorbing the rays of the sun, and by parting rapidly with its acquired heat in the evening, it condenses the dew more readily, which is therefore in contact with it a greater length of time. It is then evident from what has been said relative to soils in the preceding, §§ 111 to 120, that their fertility depends in a higher degree upon the amount of organic matter they contain than on any other condition, and that it is a matter of some moment in what state of decomposition it is found, for if too large an amount of the organic acids be present, the action on vegetation would be too rapid and transient, whereas, if much humin or humus-coal is contained in a soil, the action will be gradual and commensurate with the increasing wants of the plants.

§ 121. Having shown the theory of the operation of organic manures as far as it has been investigated, we will in the next place notice the various kinds which are or may be employed in agriculture in Delaware. All kinds of vegetable matter constitute manure, but as it is composed of various substances, such as gum, sugar, albumen, gluten, oils, fibre, &c., which are variously subject to decomposition, it is necessary that different kinds of plants or the same plants at different seasons should receive a different treatment prior to their application. All green succulent plants are very liable to fermentation and it becomes a question whether it is necessary to suffer them to ferment above the soil. The rich juices they contain render them liable to a rapid change, and they should, therefore, be immediately applied, which may be performed by ploughing them into a shallow depth, so that fermentation may take place slowly in the soil. Hence the acknowledged utility of turning in grass-land, in which the decay of the vegetable matter during the time it lay in grass, and of that which is freshly turned under, consisting of roots, stems and leaves, affords, by a gradual decomposition, much nutriment to the future crop. Indeed, this principle is now so well understood and generally received, that it is not an unfrequent practice to sow crops with the view of turning them under the surface; and in many parts of Delaware particularly in the middle and southern portions of the state, this method of improvement cannot be too strongly recommended, for the chief deficiency of those soils lies mainly in organic matter. In order to derive the greatest benefit from growing plants as a manure, they should be ploughed in during inflorescence, as it is believed they then contain the largest amount of nutritive matter. Along the bay-shore and sea-beach are to be found large quantities of sea-weed, soft-reed and other plants, both in a green and dry state, which should unquestionably be applied, perhaps not immediately to the land, but to the barn-yard heaps, which they will increase in quantity without detracting from their value.

§ 122. Dried vegetable matter, such as straw, hay and stubble, whether of weeds or of useful plants, affords abundant nutriment. It has been a constant practice, until within a few years, to ferment vegetable substances thoroughly, under the impression that such a process was necessary before they could become nutritive; of late years, however, the plan generally adopted and most approved of by skilful farmers, has been to suffer them to enter an incipient stage of fermentation. This view was based upon the experimental deductions of Sir H. Davy, and the subject should not be passed over without drawing the attention of farmers to the fact that this important change in the application of manures was first induced by theoretic experiments made in the laboratory, and ought alone, if other proof were wanting, to satisfy them that

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what is technically termed book-farming is not without its benefits in the practice of agriculture. There is no doubt that fermentation destroys a large portion of nutritive substance, and that in proportion to the extent of decomposition, but at the same time it is also objectionable to plough in long straw, "from the difficulty of burying it, and from its rendering the husbandry foul," but by a partial fermentation, seeds are more or less rendered incapable of germination, and the manure is more manageable, while there is not an important loss of nutritive matter. The chief reason why a partial fermentation should have taken place, lies in the very difficult decomposability of fibre, which constitutes an essential and large portion of dried vegetable matter. Hence also the chief objection to the use of tanner's spent bark, which being divested of its soluble and more decomposable materials, consists principally of fibre. But even this substance may be fermented by the lapse of time, and will then constitute a manure of considerable fertilising power. It has been employed with success in a few instances in Delaware, where the slow fermentation of several years has rendered it soft and perfectly rotten. To hasten its fermentation, stable-manure should be occasionally added to it; but it is not advisable to throw it on the barn-yard heaps, since it would not be sufficiently decomposed when it is required to haul out the latter manure. Saw-dust and wood-shavings may probably be fermented in a shorter time than spent-bark, as they still contain soluble matter.

§ 123. Even charcoal has been employed as a fertiliser, and Sir H. Davy proved by direct experiment that it absorbed oxygen from the air and formed carbonic acid, from which he deduced its efficacy. It probably acts beneficially from two other causes, 1. From the great absorption of gaseous matters and water, and 2. From the changes which some of them undergo. We have just seen that carbonic acid is generated by the absorption of oxygen, but nitrogen is also absorbed, and it is not improbable that nitric acid may be generated particularly where a base is present to receive it. According to experiment the nitrogen is not changed, but then these experiments were conducted in a short space of time, and no account taken of the changes which nature would produce by length of time or the presence of moisture and bases. If nitric acid be formed, we would be at no loss to account for the utility of charcoal, since we might refer its action to the phenomena examined by Berzelius, § 116, in which substances are formed resembling the crenic and apocrenic acids. It would therefore be both interesting and useful to ascertain whether nitric acid can be generated by the absorption of atmospheric air. It is not, however, necessary to resort to its formation in charcoal, for small quantities of this acid are brought down by rain, and it may have in its diluted state by lapse of time, the same action as more concentrated acid would exhibit in a shorter period. Or since carbonic acid is generated, may not charcoal act in a manner similar to humus-coal, and become more easily convertible into humin and humic acid, as was mentioned in § 117. The subject is certainly deserving farther investigation, and experiments may be performed by impregnating fresh charcoal with a weak solution of potash, exposing to sun and air or under the soil for a year, and then examining for the presence of saltpetre, to ascertain whether nitric acid is generated, or with and without potash to ascertain whether it has become more easily convertible into humin.

§ 124. All kinds of animal matter constitute a powerful manure, whether excrementitious or not, and being much more subject to decomposition, their fermentation so far from being attempted should be checked. Flesh, fat, hair and feathers may all be employed with little or no preparation. The common practice of burying a dead animal should be discarded, since it is actually throwing away a quantity of matter possessed of the highest fertilising powers. They should be covered plentifully by soil with a very little lime, suffered to remain some months, and upon removing them mixed with fresh lime to destroy the effluvia; both the animal residue and the superincumbent soil may be applied to land. Fish are employed with great success, both in Britain, on the coast of New England, and on the shores of the Chesapeake, but their effects are so powerful, that it is advisable to mingle them with a poor soil. It is probable that there are places in Delaware where fish could be obtained in sufficient quantity to be employed as manure, and in the event of their application, the following points should be attended to, viz:—to mingle them with poor earth—to apply them quickly to the soil—to turn them under immediately, and at a considerable depth, for if near the surface they would ferment too rapidly, and dissipate much valuable matter. The refuse of the tanning processes, containing much animal matter and lime, ought to be viewed as a very valuable manure, and fortunately there are many such establishments in Delaware, which may avail themselves of this refuse. Horn and bones constitute a superior manure, the value of which in Delaware is not practically known, for heaps of bones may be sometimes seen filling up holes under fence rows, or whitening in a field, that is *thrown out* after having been impoverished by tillage. After the fatty matter has been removed, they consist chiefly of gelatine and phosphate of lime, both of which are useful in promoting fertility. To attain the greatest amount of benefit from them, they should be reduced to the finest powder, and spread lightly over the soil.

§ 125. Excrementitious animal substances form manures of superior quality, which have been employed from the earliest times, and yet the nature of their operation is far from being satisfactorily understood. Urine having been examined chemically is found to consist of a large number of alkaline and earthy salts, gelatine, albumen, urea, uric acid, lactic acid, &c., in a state of solution, and is very subject to fermentation chiefly in consequence of the presence of albumen and gelatine, which being destroyed by the operation, render it less valuable as a manure. It should therefore be applied immediately to the soil, being previously diluted with water or earth, in consequence of its excessive richness. Containing all the ingredients necessary for the luxuriant growth of vegetables, and these in a state of solution, it is easy to understand its value as a manure. Dung of every kind is a valuable source of fertility, and although universally acknowledged as such, the best method of its application is far from being generally known. That of birds and domestic fowl ranks among the most powerful, but being very subject to fermentation, if it can be obtained in quantity should be immediately employed. The excrements of cattle, horses and sheep, although less subject to fermentation than the preceding, is sufficiently so, to admit of its immediate application with advantage. A better method of employing it is to apply its fermentative qualities to straw, hay and other refuse vegetable matter of a farm, towards which it acts as yeast to flour, causing the whole to ferment.——

One of the most powerful manures, easily obtained and in considerable quantity, and yet remarkable enough, one which is frequently if not generally thrown aside in Delaware, is night soil or human excrementitious matter, every particle of which should possess the highest value in the eyes of an agriculturist. It is valuable whether employed in a moist, dry or fermented state, but as with other similar substances, fermentation lessens its value. ——As a large amount of animal and vegetable matter collects in process of time on roads and along fence-rows, it should be taken up together with the subjacent soil, and applied to land either alone or mingled with lime.

§ 126. When we have more or less of the above materials in the barn-yard, it is far from being an immaterial point as to the state in which they should be employed. If applied prior to fermentation, a good effect will result although less so than if fermentation had commenced, but if fermentation be carried to its utmost, a very large proportion of nutritious matter is destroyed; but where the proper medium lies, what is that point at which the greatest benefit results, neither practice nor theory have determined with precision. Two experiments of Sir H. Davy are worth introducing here, although they have been often recorded. He filled a retort with hot fermenting dung, and in three days obtained a liquid containing chiefly ammoniacal salts and gaseous matter containing 21 cubic inches of carbonic acid gas. Finding such matter to result which was generally believed to be nutritive, he applied the beak of a retort filled in the same manner to the roots of grass in a garden, and in less than a week, he observed the grass to grow much more luxuriantly than in any other part of the garden. It follows, therefore, that much valuable matter is lost during the process of fermentation; and so conclusive were the arguments deduced from practise and theory, that Sir H. Davy thought it worth the experiment to ascertain whether straw chopped fine would not be a more economical manure than if employed after fermentation; and yet in another place he observes that "a slight incipient fermentation is undoubtedly of use," in order to decompose woody fibre, which "is always in great excess in the refuse of the farm." The latter observation is the more correct of the two, viz. that fermentation should be commenced in the farm-yard. Independently of numerous practical experiments which prove the superior advantages of only a partial decomposition, the following reasons are conclusive in themselves; fermentation destroys or dissipates in proportion to time and violence, much organic matter, which would have been a source of fertility to growing plants; it farther occasions a loss of that heat which would be generated by a fermentation in the soil; substances in their nascent state, that is, at the instant of their formation, are much more disposed to enter into new combinations, and hence fermentation in contact with the rootlets of plants will be more likely to excite a more vigorous action; where fermentation has taken place out of the soil, the action of the manure will be more rapid and vigorous for a short time, but where it occurs in the soil, it will be more gradual and salutary in its operation, and the amount of benefit will be greater in the aggregate.

§ 127. Since it is, therefore, a matter of importance that manure should be applied in a partially fermented state, and as it is only applied once or twice during the year, the quantity will necessarily accumulate, and being composed of fermentable materials, we must resort to some method of checking its progressive decomposition. Air, heat and moisture being the active agents in producing the change, they must be excluded or their influence diminished. Watering the dung-hill has been proposed and employed for the purpose of cooling it, but the effect is only temporary, and when the water becomes warmed, the action will be more violent. The contrary course of spreading it out to dry is undoubtedly preferable, nor need we fear that much valuable matter is lost by evaporation, as seems to be apprehended by many agriculturists, for if preserved from moisture, but little danger is to be feared from heat. Covering the heap with a stiff clay is of advantage in keeping off the ready access of air, which is essential to fermentation and may be readily practised in many parts of Delaware. We have, however, more efficient means of obviating the difficulty by resorting to compost or composite manure, which has the additional advantage of increasing the quantity without materially diminishing the intensity of stable manure. As manure is formed and removed to the farm-yard, it should be levelled and not heaped as is usually the case, then covered over by a layer of undecomposed vegetable matter, as straw, hay, weeds, &c., and topped by black soil from marshes, creeks, ponds, &c. The same series may be repeated until the compost has acquired the depth of several feet. The black soil alluded to which abounds in the state, is composed of vegetable matter in various stages of decomposition mingled with variable quantities of earth, but the larger portion of it is peaty and not sufficiently altered to be immediately applied to land in the state in which it is found, so that a partial fermentation adds to its fertilising effects. Hence its application in the way proposed not only improves itself, but prevents the fermenting manure from farther injury by excessive fermentation. To assert that the addition of lime to manure would check its decomposition might appear to a majority of persons heterodoxical, were it not that there are many facts to show that such is the result. Among other proofs the desiccation of night soil, § 125, may be adduced. Being very subject to fermentation, its value would be materially lessened if suffered to remain exposed to the air in a moist condition, and therefore the Chinese mix it with one-third of its weight of fat marl (calcareous), make it into cakes, and dry them in the sun, in which state it forms an important article of internal commerce. The *poudrette* of the French, and *desiccated night soil* of the English, is a similar article, excepting that it is prepared with quicklime. The fermentation of the night soil in these instances is prevented not merely by the drying nature of the materials with which it is mingled, but chiefly by the chemical action of lime.

§ 128. What has been said above relative to fermenting manures referred more particularly to their solid portions. There is however, always formed in the dung-hill a liquid, which in many instances is suffered to drain away, as if it were actually detrimental; but who, that has observed the astonishing fertility that marks the course of such a stream from the barn yard, has not been convinced of its fertilising powers? In truth it often contains the richest portions of the manure, where fermentation has been carried to excess, and in every case it should be preserved. This may be conveniently effected by composing the manure with dry materials which will absorb a portion of the liquid, and exercising care in the location of the yard, so that we may have a solid basis impervious to water, such as clay or stone; a floor of the former may be conveniently constructed in any part of the state, and may be so modified, if required, as to conduct the liquid in a shallow cistern, from which it may be removed when wanted, and applied to the garden or other small patch as it is more convenient for this purpose than solid manure. Whatever system be adopted, the method too commonly pursued in Delaware, of suffering the barn-yard to become nearly fluid, or at least, very muddy, cannot be too much deprecated nor too soon abandoned.

§ 129. The subject of organic manures has received in the present section such attention as is not inconsistent with the nature of the memoir, when we consider that the main resources of the state are confined to agriculture, but so far from having exhausted the subject, we may safely say that it is a mere outline containing general views, and descending only to particulars where it is thought to be applicable to the wants of the people. We have shown that the constituents of a fertile soil beside earthy matter, are humus coal, humin and the humic, crenic and apocrenic acids, and that these substances evidently play an important part in vegetation §§ 111—120: that the different kinds of animal and vegetable matter form manures which replace those substances extracted from the soil, §§ 121—125; that animal substances should be directly applied without previous chemical preparation, §§ 124–125, and that vegetable substances should have been partially fermented prior to their application, § 126, that therefore the fermentation of the latter should be retarded rather than accelerated, § 127; and lastly, § 128, that the liquid as well as solid parts of manure are endowed with fertilising powers.——Although chemists have done much to unravel the intricate nature of organic manures, yet it must be acknowledged that the theory of their application is as little understood as the practice, and until the former is placed upon a more certain foundation the latter cannot make that progress which is so desirable, and which will one day place agriculture on a footing with more exact sciences. We must however be rejoiced to perceive that many of the best chemists of the day are applying their theoretic knowledge to the advancement of the arts, and that organic chemistry is at length receiving its due share of attention.

SECTION III.

On Calcareous Manure.

§ 130. Limestone when pure is composed of 56¾ per cent. of lime, and 43¼ of carbonic acid or fixed air. When chalk or powdered limestone is dropped into vinegar, a strong effervescence ensues with the disengagement of the carbonic acid while the lime is dissolved, and hence the use of vinegar or other acids for testing shell-marl which is chiefly valued for the carbonate of lime it contains. By heating also, the fixed air is driven off and quick-lime remains, which is the ordinary process by which lime is obtained in a caustic state. If the quick-lime thus obtained be moistened with a certain quantity of water, it soon becomes heated, throws off a portion of the water in the form of steam, and falls to a very fine white powder which is a hydrate of lime, always containing 24 per cent. water; if, however, more water be added, the same hydrate is formed, but the excess of water agglutinates the powder into lumps or masses which will eventually become hard, and resemble stone. Still more water dissolves it, and forms lime-water. If quick-lime be exposed to the air, it also falls to a coarser powder by absorbing 12 per cent. of water and 24 per cent. of carbonic acid from the air, constituting a mingled carbonate and hydrate of lime. The same change occurs with that which has been slacked by water and is exposed to the air, the carbonic acid of the atmosphere replacing the water of the hydrate. The carbonate of lime such as exists in chalk, limestone, &c., is scarcely soluble in pure water, but if the latter contain carbonic acid, as rain water usually does when in contact with the soil, the limestone enters into solution. Magnesia combined with carbonic acid is a common ingredient in limestones, and is rendered caustic in the same manner as lime, but as its attraction for that acid is less powerful than that of lime, when the two are mingled together, the latter will become carbonated before the magnesia begins to attract the same acid from the air. What has been said relative to the two earths will be found sufficient to explain their mode of operation, when employed for promoting fertility.

§ 131. The ground from which we start in order to ascertain the effect of lime is unfortunately but little understood, for few direct and decisive experiments have been made to ascertain its precise effects on animal or vegetable substances. Much has been written and said relative to its preservative and destructive effects on organic manures from which we learn that it operates both ways according to its chemical state. If employed as quicklime, and placed in contact with organic matter, its alkaline properties would lead us to infer a decomposing influence, which is confirmed by experience; but the effect is of short duration, and is succeeded by the reverse operation, that of preserving such matter from farther decomposition. The truth is, if we could insure a continuance of its caustic state, we might be equally sure of its constant decomposing power, but by this action, it generates carbonic acid from the organic matter uniting with it and forming a neutral carbonate, which either acts like other salts in preventing decomposition by its *presence* or *catalytic* influence, or being formed and hardened in the interior of the organised material, protects it from farther decay. For this reason it was mentioned § 127, that it might be used to prevent excessive fermentation in the dung-hill; and to the same properties we may in part ascribe its utility in the soil, viz. that of permitting the slow and gradual decay of organic matter in quantities suited to the demands of vegetation. It has been supposed that the chief value of lime as a manure lay in its caustic or destructive effects, but that this position is untenable is proved by the successful application of marls and even powdered limestone, which are robbed of their caustic properties. Sir H. Davy and others who have written on the subject of agriculture refer the utility of lime to its causticity, and state that "chalk, marl or carbonate of lime will only improve the texture of the soil or its relation to absorption; it acts merely as one of the earthy ingredients." This view is unquestionably incorrect, for it has been known to produce astonishing effects on peaty soils when applied in the form of carbonate and not caustic lime, and powdered limestone as well as marl have been successfully used on ordinary soils. Besides, if "the formation of soluble matter from insoluble organic materials" be the chief effect of lime, this effect should take place immediately while the lime is in its caustic state, but it appears § 130, that it soon becomes carbonated in the soil, or by exposure to the air, and yet its useful effects are more perceptible a considerable time after its application, and may be perceived for many years. Whence it appears that its action on organic matter in the soil is continued (probably not increased) in the soil after carbonation.

§ 132. Much of the vagueness in descriptions relative to the use of lime has arisen from an imperfect knowledge of the organic constituents of soils, which have latterly been partially developed, and a description of which has been given §§ 111—119. Authors have divided the organic matter into soluble and insoluble, by the former of which we understand the humic, crenic, and apocrenic acids, and by the latter humin, humus-coal and vegetable fibre; and they state that lime is injurious where there is much soluble matter in the soil as it forms insoluble combinations. The truth is, the humate of lime is partially soluble § 112, the crenate somewhat so, and the bi-crenate very soluble, § 114. Now by admitting these acids as active ingredients in soils, we are at no loss to account for the utility of carbonate of lime, for the weak affinity of the carbonic acid is overcome by their superior attraction, and more soluble salts are formed which may then be received into the rootlets of plants. There can be no doubt however that caustic lime is of greater benefit where a soil contains humin and vegetable fibre, as it promotes their incipient decomposition. The utility of lime, therefore, is threefold; first, that of decomposing organic matter, and rendering it a suitable nourishment for plants, § 112; secondly, that of combining with organic matter and rendering it capable of being received into the vessels of vegetable organization for promoting vegetation; and lastly, that of lengthening the time of decomposition of organic matter, which, therefore, yields nutrition in proportion to the demands of a plant in the progress of its growth.

§ 133. It has been supposed by many to be necessary that lime should be caustic as it is only then soluble, but it should not be forgotten that the carbonate is also soluble in water containing carbonic acid, § 130, and farther, it is not necessary that either the carbonate or quicklime alone should be dissolved in order to explain its influence in vegetation, for moisture, the medium of chemical action, is always present in the soil, and assists in its soluble combination with the organic acids. There is, however, another action of lime with reference to the soil itself, which is of importance, viz., that it renders clayey lands looser, and sandy soils more tenacious. The latter of these contrary effects is of a chemical character, and there is little doubt that lime acts like mortar by combining the particles of sand together. The former is partly mechanical, the mingling of less cohesive earthy matter with the clay, and partly chemical, in which the lime dissolved by rains is washed into the crevices and cracks of the clay, where, becoming carbonated, it prevents their farther adhesion. To effect these results most powerfully it is evident that the lime should be employed in a caustic or water-slacked state. According to these views, therefore, it is a matter of less moment on what kind of land lime should be spread as it tends to ameliorate its condition or texture, and is the medium of conveyance of nutrition to vegetable life.

§ 134. It was stated, § 130, that magnesia usually enters into the composition of lime, and § 39, that a part of that in Jeanes' quarry contains nearly one half of carbonate of magnesia. In fact nearly all the limestone employed in Delaware, for spreading on the soil is magnesian, and it is therefore worth investigating how far the magnesia may be injurious. One of the first limestones employed for this purpose in Pennsylvania, from which lime derived much of its reputation as a manure in this section of country, and which has not lost its character to the present time is nearly of the same composition with Jeanes' stone; a very fair proof that such a content of magnesia is not injurious under certain circumstances. Sir H. Davy's view of the subject appears to be correct, that magnesia in a caustic state is injurious, but that when carbonated it is beneficial. It was stated § 130, that it remains caustic for a long time exposed to the air, and particularly when mingled with lime; therefore, in employing a magnesian limestone if there is little vegetable matter in the soil it will be apt to injure the crops, but this effect may be obviated by mingling it with fermenting manure which will rapidly carbonate it. There is another view of the subject which has never been broached, viz., the influence of the organic acids in the soil. If much humic acid be present it will form humate of magnesia soluble in 160 parts of water, while humate of lime requires 2000, § 112, so that it will be taken up in greater quantity than lime. But by referring to the quantity required by plants as shown by an analysis of their ashes, we find § 109, that oak requires about 5½ times as much lime as magnesia, and that ashes of straw yield nearly 12 per cent. of carbonate and phosphate of lime and no magnesia, from which it would seem that the latter is injurious to plants from its excess where humic acid is abundant. But if the soil contain much humin, and other insoluble organic matter, its action in a caustic state would be beneficial like that of lime § 132. We have, therefore, in Delaware abundant means of rendering magnesian lime useful, by employing it in conjunction with peaty matter, the black soil of marshes, creeks, &c.

§ 135. To point out the advantages of the use of lime on the soil would be useless as it is too generally acknowledged; nor is it necessary to enter upon a discussion whether it may be viewed in the light of a nutritive substance itself, for it is undoubtedly as necessary to vegetable as to animal life, and probably plays the same part by assisting in the formation of the skeleton or bony part of vegetables. It will be more advantageous to consider what preparation it should undergo prior to its application. What is the object we have in view in its application? It is to obtain it in the finest possible powder, so that it may be diffused more equally in the soil, and may present the greatest amount of surface to the organic matter on which it is destined to act. It is a general law, and one without exception, that the more finely divided a substance is, the more rapid and intense will be its chemical action; in other words, the action will be energetic in proportion to the surface exposed. Now it must be evident that if a solid mass of lime be laid on or in the soil, its effects will be trifling, since its surface is small; and if it be broken into two parts, we have not only the original surface of the whole mass, but the additional fractured surfaces, and by pursuing our division into very small pieces, that is, to powder, the increase of surface is almost beyond calculation. The chief object in slacking lime, is to obtain this extended surface. It would be most injudicious to pour an indefinite quantity of water upon quicklime for the reason stated § 130, that to form a hydrate an exact quantity is required amounting to 24 per cent. But as there is usually a large proportion of magnesia present which takes up a little more water, more than one-fourth as much water as there is lime should be added to convert the whole into a hydrate. And since the heat developed by the slacking process evaporates a large amount of moisture, still more water should be added so that for a good quality of stone, about one third as much water as there is lime may be safely employed to convert it into finely powdered slacked lime. Where the lime is known to be of inferior quality, less water will be required, and indeed it is always advisable to add too little, since more may be used to supply the deficit which shows itself after slacking. If too small a quantity be employed, the whole of the lime will not fall to a fine powder, and this state may be recognised by its grittiness and coarseness; if too much § 130, the powder which is formed adheres together forming a more or less pasty mass. In either case the value of the lime is lessened, but while the former deficiency may be remedied as pointed out above, the latter can only be obviated by recommending it to the kiln. The more common fault in the use of lime is adding too much water, and it is practised to such an extent that one-half if not two-thirds of the lime employed in agriculture is lost to all good effects in the soil. So important is this point, that it would be worth the expense to every farmer to slack his lime under cover, lest the addition of an excess of water from rain might diminish its value. There appears to be a want of union among agriculturists on the question whether it is better to employ it water or air-slacked; but it appears that the air unaccompanied by rain does not bring it to as fine a powder as water alone, and if the rain is permitted to fall on it, we may have an excess of water, since we cannot regulate the quantity; so that under all circumstances it appears to be more advisable to slack it artificially with water alone.

§ 136. The quantity of lime which should be applied to land varies very much with the nature of the soil, and no precise rules on this head can be given. The practice in this section of Pennsylvania, is to apply from 30 to 80 bushels per acre to light soils, and from 100 to 300 bushels to clayey lands, but in England they consider 150 as a good dressing for lighter and as high as 500 have been spread on an acre of heavier lands. Two chief reasons why so little definite is known on the subject are, that sufficient attention has not been given to slacking lime with the proper quantity of water, and that the quantity and nature of the organic matter in the soil has been too much neglected. It might seem incredible to assert that often not more than one-fifth of that which is applied proves serviceable, and yet from the ordinary careless mode of slacking it, the proportion lies within the truth. The lighter soils of Sussex and Kent, containing but small amounts of organic matter, would be as much benefitted by 20 bushels in fine powder, spread evenly over the surface as by 60, as ordinarily employed. In the same manner 100 of fine lime on heavy soils would produce as striking results as 2 or 300 of a half pulverised lime. One point cannot be too strongly insisted on under all circumstances, that of never turning in lime too deep, or otherwise by its sinking much of it becomes valueless.

§ 137. Much diversity of opinion exists relative to the time when lime should be spread. The season is probably of less importance, excepting where much undecomposed matter exists in the soil, in which case lime in its caustic state should be applied during the summer season, when the heat will promote chemical action. Much has been said and written on its application to different crops and every mode found successful by some individuals because they can scarcely fail in deriving benefit sooner or later; the more preferable method seems to be to spread it on a fresh grass or clover sod and suffer it to lie quietly upon the surface, until the sod is turned under, which should not be done to a great depth. If a green crop alone be ploughed under, its decomposition will probably be too rapid, and all or nearly all the gaseous matter will escape, whereas by the action of caustic lime, a more rapid decomposition ensues, until in a short time the carbonic acid thus generated being absorbed by the lime, farther decomposition is rendered more gradual. By spreading lime as here advised on the sod, and permitting it to remain, a portion of it will be dissolved by water while in the caustic state, and diffused through the soil, and when the residue is fully carbonated, the rain becoming charged with carbonic acid on the surface of the land, becomes capable of taking it up in small quantities and carries it to the rootlets of the plants. A more luxuriant vegetation should therefore occur, which is indeed agreeable to observation; and hence, when the sod is ploughed up, the remaining lime (which is possibly $\frac{9}{10}$ of that employed) is brought to act in a slow and salutary manner on the decomposing organic matter with the production of humate and crenate of lime. It is thought inadvisable by good farmers to put it on the heap of stable manure, and the reason given for this advice is, that it renders nutritious matter insoluble. That the difficultly soluble humate of lime would be formed cannot be doubted, particularly where it is employed in a caustic state, but it is not improbable that if a light layer of slacked lime were applied, which had been exposed for some time to the air, it would prove advantageous by decreasing the fermentation. It seems as if they had been alarmed by this formation of insoluble compounds, whereas they are in truth partially soluble, and to this slow solubility we must partly attribute the value of lime; and besides, the same compounds will be formed when organic manure and lime are separately spread over the same soil. Where there is a mass of unfermented organic matter, the application of freshly slacked lime will be decidedly beneficial by promoting its incipient decomposition.

§ 138. Beside the lime obtained from the Schuylkill and Jeanes' Quarry, there is one other source which has not received its due share of attention, and which applies more particularly to the lower section of the state, where some other kinds of manure are not very accessible. It is to be found in numberless shell-beds of various dimensions, scattered along the shores of the bay from the middle of Kent to the lower part of Sussex. There are both natural and artificial deposites, and although many of them are strictly subjects of geological inquiry, they were omitted in Pt. II, because of their want of continuity and extent, but the two kinds may now be noticed together with reference to their application to agriculture. Some of them, as that mentioned § 81, are too deeply covered to be made available, but generally speaking they lie upon the surface in beds of from six inches to two feet in thickness, imbedded in a dark and even black soil; they consist chiefly of the common species of oyster which now inhabit the bay and creeks, and are in various stages of decomposition, usually crumbling to fine scales with a slight force, but sometimes as hard as fresh shells. There are a few small beds, evidently the production of the Indians, in Little creek and Jones' necks, but between Jones' river and Murderkill, they are not only more numerous but far more extensive. On the land of G. Emerson in

Little creek, a small bed varying from six inches to two feet in thickness, and situated on the banks of a small stream, is evidently an Indian deposite, for the shells are imbedded in the same clay which constitutes the subsoil. On Jones' neck there is another deposite on a farm belonging to Messrs. Sipple and Penniwell, where the shells are imbedded in a black soil precisely similar to that of the adjoining marsh, but very unlike the yellow clayey subsoil. The bed appears to pass into the marsh and indeed from all circumstances connected with it, it seems to have been a natural deposite. Many similar deposites exist on small branches of Murderkill, but the quantity of shells in them is small when compared with those both natural and artificial, which literally cover the point of land between the mouths of Jones' and Murderkill.

§ 139. On Mispillion neck, and indeed on both sides of the creek, the quantity of shells would entitle them to the appellation of a good calcareous marl, were the beds continuous, but even as they are now situated they may be advantageously employed. On Slaughter and Prime-hook necks these deposites appear to be chiefly of Indian origin, but on Broadkill neck, they are both natural and artificial, and as far as the wants of the neighborhood are concerned, there is sufficient to supply the demand. Although there are such deposites between Broadkill and Lewestown, they are neither numerous nor extensive; below Lewes, however, they again increase in quantity. One of the latter on marsh land belonging to H. F. Hall, is decidedly a natural deposite, the shells belonging to various species of oyster, clam, &c., being so broken and comminuted that scarcely a whole specimen is to be found. Another about three miles S. of Lewes on a high bank is an unusually extensive Indian deposit, the utility of which has been attested, although applied to the land in the same unbroken state in which it is found.——The marly deposite near Dagsborough, and the two in Baltimore hundred, § 91, are of a different character from those under description, and evidently lay claim to a much greater antiquity; there are, however, others in Baltimore hundred, of the same nature as those above described of artificial and natural origin, which should not be neglected by the citizens of that section of country.———The western border of the state crosses the rivers and creeks too far inland to admit of the examination of similar deposites within the state; it is known, however, that there are extensive beds of ancient and very modern shells, of which advantage may be taken by those residing in the western part of Delaware.

§ 140. The sources of shell lime for manure in Delaware may be arranged under four groups. 1. Those from which the oyster has been latterly procured for food, large quantities of which are brought from the bay and creeks, and the trifling importance attached to them is proved by the facts, that in a majority of instances they are thrown aside, or when sold, it is at the price of two or three cents per bushel. This source presents the advantage of continuance.—2. Shells drifted on the beach in layers of six inches to two feet, and sometimes nearly free from gravel and sand. They are chiefly the thin-shelled oyster, inhabiting the creeks, from which they are carried out during storm-tides, and driven on the open beach. A deposite of considerable extent existed in 1838, on Thorn Point, S. side of Mispillion, and small mounds of the same of a more ancient date were visible in many places on the marsh lands. 3. Deposites on the marshes, coast, creeks and their branches, usually embedded in a black marshy soil, which extends into the adjoining water or cripple. On Bowers' beach at the mouth of Murderkill, they extend below high, and some below low water mark, and are united into a compact mass by a black clayey soil and sea-weeds. Exposed to the action of air only on the surface, and probably not for a great length of time, they are less decomposed and friable than those farther inland. From all the circumstances connected with them, they appear to have been natural shell-beds, the accumulation of a long period of time, which have been undisturbed since their formation, and have been elevated with the general level of the land until many of them are now above high-water mark. 4. Deposites on the banks of creeks, inlets, &c. They differ from the preceding in being contained in an earth similar to the subsoil, for although it may be sometimes black, yet it is decidedly different from the marshy soil which encloses the third group. That they are Indian deposites is shown from their situation on the dry banks of streams navigable at least for canoes, from the accompanying earth which is not marshy; from the nature and size of the shells, which are such as can be used for food; and from the occasional presence of Indian works of art.

§ 141. These various scattered deposites taken in the aggregate contain in all probability a sufficient amount of lime to supply the neighborhood in which they occur for all purposes for which they may be required, and we ought to avail ourselves of every means, however small, of enriching land from its own productions, whether presented by nature or by art. Two methods may be followed to prepare shells for application to the soil, the first of which, to burn them, is ordinarily adopted. The usual mode of burning is sufficient for making a good lime, unless wood has been sparingly used; it consists in erecting a hollow square pile of logs which is filled up by alternate layers of wood and shells, and the whole mass fired. In consequence of the too frequent want of fuel a large proportion of the shells falls into scales by slacking, instead of forming a fine powder, a defect which may easily be remedied by the plentiful use of wood. The process of burning should only be applied to the first and second groups, but even in such a case, how much valuable animal matter is destroyed, which if it could be obtained would render the shells far more efficient as a manure! Whoever has watched the burning of shells, must have observed that they soon become dark and even black, continuing the same color for some time. This arises from the combustion of animal matter, and proves what quantity is present. In order to obviate this loss, the geologist during his tour through the state, has advised the crushing or grinding the shells to powder, from whatever source they may be derived, for although such a process might seem too laborious and expensive at first view, yet it may be shown that it may be done in a very simple and convenient manner without the outlay of much capital. An ordinary horse bark-mill may be employed for grinding the hardest fresh shells, although the operation is imperfectly conducted on a wooden floor, but it may be used with impunity for shells of the second and third groups. The best form of construction would be to arrange an old worn out mill-stone like the stone of a bark mill, and to make a floor of rammed clay and shells, or better of brick or stone by which arrangement from one to 500 bushels might be ground to a fine powder in a day. Passing them between two cast iron cylinders would undoubtedly be a preferable arrangement, for speed and perfect crushing; but the advantages would scarcely be justified by the expense attending it. The fresh shells of groups one and two, would undoubtedly tend more to fertilise the soil than if reduced to powder by burning, in consequence of the superior fertilising power of animal over mineral matter; much more would those of the third and fourth groups prove beneficial if used in the same manner, for the black or dark soil in which the latter are imbedded contains a large amount of both animal and vegetable matter, the whole of which together with that in the shells would be destroyed by burning. They should, therefore, together with the accompanying soil be ground as fine as possible, and without any other preparation be applied to the soil. Even where they have in a few instances been drawn out from their beds and scattered over the land in their unbroken state, increased fertility has been the result; and if applied in the manner proposed, they deserve to be viewed as a fertilising source of the first order.

SECTION IV.

Green Sand.

§ 142. The average composition of the green sand was stated, § 79, and the experience of nearly half a century in New Jersey and of a few years in Delaware having proved its efficacy in imparting fertility to the soil, we may now inquire in what manner it operates. The quantity of lime contained in the pure varieties being usually very small and having treated of this substance at some length in the preceding section, we may neglect it altogether and regard the other constituents. When it is decomposed by the ordinary processes of the laboratory, only a small quantity of silica and all the other constituents being dissolved, we may regard the oxide of iron, potassa and alumina as performing the principal functions, assisted by the presence of water. The useful action of potash or of ashes in the soil has been long acknowledged, and hence, as soon as it was known that the green sand contained potassa, its utility was immediately referred to that alcali; latterly, however, the opinion has gained ground that the protoxide of iron plays an important part by acting with the organic matter in the soil, in a manner resembling the saponification of oil by potash. This view is correct as far as it goes, but it can scarcely be deemed admissible to make such a practical generalisation as to call all decomposed organic matter in the soil geine, in the present more advanced condition of the subject, when we know that humic acid (geic acid) is formed from humus (insoluble geine), and that two other acids, the crenic and apocrenic, are also constituents of soils, as well as of organic manures. The iron in the green sand being in the state of protoxide, amounting to upwards of 20 per cent., and the potassa averaging 7 per cent., both strong bases, we can readily explain their mode of action by assisting in the formation of humic acid at least, § 112, and it is highly probable that farther experiments will show a similar generation of the crenic acids. It is also farther probable that where these bases are present, their catalytic influence causes the atmosphere to convert humus into the organic acids with greater rapidity. The humic and crenic acids being present combine with such free bases and even decompose their feeble compounds, forming salts of different solubilities, the protohumate and crenate of iron being very soluble but rapidly convertible into per-salts, the salts with potassa being very soluble and those of alumina and lime difficultly soluble. §§ 112 and 114. The addition of much unleached ashes to a soil determines the formation of salts of potassa, which being very soluble are taken up in excess by growing plants, and produce such luxuriant vegetation as to cause it, technically speaking, to *burn up*. The same operation would probably occur with protoxide of iron were its salts not soon converted into more insoluble humate and crenate of the peroxide. We may farther suppose that the protocrenate of iron is received into the vessels of organisation, a portion of the crenic acid yielded up as food, and a basic perapocrenate secreted and ejected by the rootlets of the plants. To the difficult solubility of the humate and crenate of lime may in some measure be referred the utility of that earth, and therefore if we suppose the frequent formation of soluble super-salts, as is sometimes done, they would tend to induce excessive luxuriance. § 132.

§ 143. It might be objected by many that green sand being decomposed with difficulty by the powerful acids of the laboratory, there is little probability that it can be resolved into its constituents by the feeble action of humic or atmospheric agents. Independently however of the proof of its decomposition by its inducing increased fertility, and of the mode by which nature, operating with feeble agents during a lengthened period of time, produces great results, it may be shown that it is more readily decomposed than is generally admitted. Wm. M. Uhler, in conjunction with the author of this memoir, has lately been engaged in making a series of experiments on this subject, which, although incomplete, nevertheless afford sufficient grounds for drawing a few conclusions. Dilute acetic acid decomposed green sand after the lapse of a week or more; oxalic acid produced the same result in a few days and in the course of two weeks nearly all the green sand had disappeared and the yellow oxalate of iron precipitated. But the most surprising effects were produced by the action of carbonic acid, one of the feeblest known to the chemist, the use of which for this purpose was first proposed by Mr. Charles Roberts, of Philadelphia. By a well charged solution of this acid a large portion of the sand was decomposed in a few days and a weak solution induced the same effects in the course of a few weeks. Although few experiments were made to determine quantitatively the relative amounts of the constituents taken up by the acids, yet the qualitative tests were sufficient to show that all the ingredients were separated from each other and that the green sand might be analysed even by the feeble operation of carbonic acid. At the time of publishing the present memoir, experiments are being instituted to determine approximatively the effects of the crenic and humic acids on green sand, but from their known power, no doubts can remain relative to their efficacy in promoting its decomposition. If this series of investigations be carried out not only with the above acids in a separate, but also in a combined state, as in organic manures and rich vegetable mould, they may prove of considerable value to agriculture, in developing the mode of operation practised by nature in her extensive laboratory.

§ 144. As the present state of our knowledge of these subjects is limited when compared with that advanced stage which we firmly believe chemistry will produce in process of time, it would be presumption to make unhesitating assertions relative to the modus operandi of organic and inorganic manures; we may nevertheless, and indeed we ought to draw such inferences as is consistent with our present knowledge of facts. The potassa of the green sand appears to act on organic matter in the soil by catalysis forming soluble salts of potassa; the protoxide of iron acts in a similar manner, but is itself changed to a less soluble compound; and the alumina probably has a similar action proportional to its feeble affinity. To the question that, since potassa acts in this manner, why does not a large quantity of green sand produce excessive luxuriance? it may be answered, that it does where the quantity is very large, but that its action is modified and extenuated by the difficulty with which the marl is decomposed and by the presence of other bases beside potassa. When green sand is decomposed by nature or in the laboratory a small quantity of silica is taken up, and even this substance by forming a salt with crenic acid, § 114, may assist in increasing fertility, as it is an essential constituent of plants. The action of lime and magnesia has already been noticed. There are two points touching the theory of the operation of green sand, which remain to be noticed, the first of which is that when its decomposition has commenced it advances in an increasing ratio; and the second, that the constituents of green sand in their nascent state, that is, at the moment of their disengagement from the compound, act with much greater energy. Thus it would appear then that all the constituents of the marl exercise an influence in promoting vegetation, and this action must take place in proportion to their respective affinities, potassa being the most powerful, followed by lime, magnesia, protoxide of iron, alumina and silica; that the four first assist in the generation of organic acids, with which they and a small portion of alumina and silica combine to form salts of different degrees, but generally of difficult solubility, which nourish and invigorate nascent vegetation; that by the presence of a large portion of bases which will form salts of difficult solubility a more prolonged and healthy action is insured.

§ 145. The above remarks relative to the mode of operation of marl apply equally to the several varieties, § 18, as far as relates to the content of green grains, but the calcareous species owe their action partly to lime in proportion as its carbonate exists in the marl. When phosphate of iron occurs in quantity, § 72, some notice must be taken of its probable influence, for in regard to it, we can only reason from theory, since it has never been applied directly to land with the view of ascertaining its effects on vegetation. It appears from the analyses of Berthier, that both phosphate of lime and of iron exist in appreciable quantity in the ashes of plants, for in the composition of oak ashes, given § 109, he divides the 7 per cent. of phosphoric acid between lime and iron in such a manner as to form nearly 14 per cent. of phosphate of lime and $\frac{1}{3}$ per cent. of phosphate of iron, and in other cases he gives the amount of the salt of iron as high as 9 per cent.; and we believe from experience that the utility of bone manure is largely due to its phosphate of lime; and hence we may infer that the marl alluded to may be serviceable or even very valuable from its phosphate of iron, and that if it were mingled with a little lime, where it is wanting in the marl, the atmospheric and *humic* agents, if the expression be allowed, will cause such a transmutation of the constituents as to bring both phosphates to exert their influence in advancing the growth of plants. But it would appear unnecessary to add lime in the present instance, as there is already a small quantity in the marl, § 72, were it not that there is still another substance mentioned as occurring chiefly in the marl of the dividing ridge and deep cut, § 73 to § 78. This substance, the sulphuret of iron, is not, it is true, observed in the pits mentioned, § 72, but its presence is shown by the large amount of white efflorescence with which it becomes coated after exposure to the air, precisely similar to those pits where it is observed in pieces of considerable size. After the marl described in § 74 has been exposed to the air for a short time, a whitish efflorescence forms on its surface, which has a strong styptic taste and is the sulphate of iron, formed from the sulphuret, but in the pits alluded to above, § 72, the snow white efflorescence is chiefly sulphate of lime or plaster. Now the latter marl contains lime, and the former does not, and hence this operation of nature in the formation of plaster from sulphuret of iron points out to us the manner of attaining the same result, viz., by mixing with marl, which exhibits an efflorescence after exposure to the air, a quantity of lime sufficient to convert all the sulphuret of iron into sulphate of lime; for if this be not done, the sulphate of iron or copperas will be formed, which is known to be prejudicial to vegetation. The quantity required for this purpose will vary with the amount of sulphuret of iron; where the efflorescence is light, one bushel of lime to 100 of marl will be amply sufficient, and where it is abundant, it may be necessary to use two, three, or four to the 100 of marl. If the green sand contain already a portion of lime, a smaller quantity will be required. The best method of applying it will be to remove the marl from the pit to any convenient, adjoining spot, to form a stratum not more than two feet thick, and after it has been exposed to the air for two weeks or a month, to cover it over with slacked lime. After exposure to one or two rains, it may then be most thoroughly mixed by passing a plough through it, or digging it down with the spade.

§ 146. In what manner and in what quantity should the green sand be applied? All varieties of the marl are more or less compact, when freshly extracted from the pit, and if applied in such a state would be unequally distributed over the soil, and hence the first precaution is to suffer it to be exposed to the air for a few days, according to its compactness or tenacity, in order that it may crumble to powder if possible, for the finer the pulverisation, as shown of lime § 135, the greater will be the immediate benefit. There is another advantage attending this delay, that we may then observe the efflorescence, § 145, and obviate its ill effects by lime. Indeed, in a majority of cases, the addition of lime in small quantity will prove serviceable, since it is generally wanting in the pure green varieties, and yet it is an important requisite in the fixed constituents of vegetables. The most economical method of applying the marl as above proposed, will be to cart it from the pits immediately into the fields, to which it is to be applied, to throw it into heaps at convenient distances for spreading, and then to put a small quantity of lime on each heap, excepting in the case of those noticed, § 145, which should remain exposed to the air for a longer time. In regard to the quantity to be applied, a variety of opinions exist, and hence from 50 to 1000 bushels per acre have been tried, with and without success. A little attention to the theory of its operation, § 142–4, will enable us to approximate to the true proportion. Its strong bases appear to act on the organic matter in the soil, and to combine with it, hence it would be useless to apply a large quantity to a poor and light soil, for which 60 to 100 bushels would suffice, but a clayey soil would be rendered looser by it, and as there is usually more organic matter present in such a case, from 100 to 200 may be employed with advantage. Where the land is already of good quality from 200 to 500 may be used, according to its richness and tenacity. Many persons believe that because one kind of marl is inferior to another, a much larger quantity will be required, but the truth is, that the differences, although important, are less so than is generally believed, and should not lead to the employment of quantities greater than have just been enumerated. Notwithstanding the effects of marl will be shown to be striking on ordinary, and even on very poor land, yet it is essential that the soil should contain a fair proportion of organic matter in order to reap the highest benefit from it. Hence the failure of some experiments made with the green sand, for although it stands superior to lime in requiring the presence or addition of less organic manure, still the views offered to explain its mode of action show the necessity of some organic materials on which to operate, and this conclusion is strengthened by experience.

§ 147. The difficulty of overcoming prejudice is clearly exemplified in the progressive employment of green sand in Delaware. One of the first experiments made with it in St. Georges hundred may probably be dated as far back as the year 1826, when a small quantity was drawn out from the site of the canal. One spot of ground where this was applied was observed in 1837 on the farm of James Wilson, 11 years after its application, and although that soil had received no other assistance, a luxuriant growth of corn clearly pointed out the limit to which it had been spread. Notwithstanding the satisfactory results of this and other experiments on this calcareous marl, how short a time has elapsed since enterprise opened an inexhaustible source of fertility from near the Deep-cut on the canal to within a short distance of Delaware City. When the survey was commenced, although many persons were well satisfied that the calcareous marl of the canal would prove beneficial to the soil, yet proof is not wanting to show that there were not ten persons who placed confidence in the effects of the pure green sand, and not four who relied upon its efficacy with such a faith as to induce them to apply it to their soil. The labors of the geologist were chiefly directed to pointing out every inducement to its application by personal intercourse with the inhabitants of that section of country where it is found, rather than to a devotion of his time towards its discovery in new localities, or its farther examination where an opening had been already made. He pointed to its increasing employment, and estimation in New Jersey, proved its value from chemical reasoning on its composition, determined in a general way its boundaries, and urging all to search for it, exhibited or explained the manner in which research should be undertaken. The result was as had been anticipated; men of enterprise taking the lead, it was searched after, found in numberless places, applied to the soil, and its effects forced conviction in the minds of many. Others withheld their assent to its utility, and some even endeavored to dissuade their friends from its application, but the writer, aware that the strongest prejudice must eventually give way, pursued his undeviating course by still urging experiment as the surest means of ascertaining its effects. Notwithstanding the proofs of its utility drawn from Jersey, and from its limited use in Delaware—although many of its former opponents are now its firmest advocates—while land has been evidently benefitted by its use, and has increased from 50 to 100 per cent. in value—it will scarcely be credited that there are still a large number of individuals in St. Georges hundred who either believe that it is not endowed with fertilising powers, or are persuaded that it is absolutely detrimental to the crops. To such may be pointed out the results obtained by their fellow-farmers, as exhibited in § 148 to § 152, we might say, look around you and observe what your neighbors are doing—try one, two or more experiments—and if you are not then satisfied, all that can be said is, desist and let your fellow-citizens grow more wealthy by the employment of marl, and resting in your antiquated systems, do you remain at a still-stand until you shall regret your delay.

§ 148. It may be deemed improper to withhold all the information which has been acquired relative to the effects of marl in various parts of St. Georges hundred, and yet as giving it in all its detail would swell the present memoir to a large volume, we must be content with a cursory notice of a few of the results obtained with the several kinds. The cretaceous green sand on the canal § 53 to § 56 has been longer known and tried, than any other, excepting in one instance on the Bohemia, but as all appear to be well satisfied of its good effects, we will dwell on it no longer than to refer to the enterprising and skilful farmers of its vicinity, who are rapidly restoring fertility and beauty to a soil that had been impoverished by the injudicious systems of their predecessors. The decomposed and indurated marl on the Bohemia §§ 57–59, is very variable in its character, and consequently produces different effects. A portion of that described § 57, which is indurated, but scarcely decomposed, was taken from a pit shortly after the close of the last war, and applied to a small square of ground on the land of H. Freeman, adjoining the road to Murphy's mill, on the Bohemia, and although it has lain on the soil for upwards of 20 years, and been cultivated with the rest of the field, the quality of the crops in 1839 afforded a test of the quality and durability of the marl, so remarkable and satisfactory, that by tracing the outline of the square by the luxuriance of its vegetable productions, this was found to be the limit of the marl, as proved by the broken shells on the surface of the ground. Wm. Polk made use of the same marl in 1837 on a soil then not worthy of cultivation, and in 1839, the clover crop on it was unusually large and thrifty. That portion of the marl lying on or near the Mill-pond would at first sight appear to be too far decomposed to be useful had not J. Smith proved that it still contains sufficient green sand and calcareous matter to benefit his crops. The shelly variety of the calcareous marl, § 60, has been successfully tried. J. Whitby spread 400 bushels per acre, and the effect on oats was nearly equal to stable manure, on corn very striking, less so on grass. As remarked, § 144, these calcareous marls owe their effects both to lime and to green sand, and hence the less yellow sand they contain, the greater their value, but whether their effects are due more to the lime or to the green particles will not now be decided.

§ 149. The most striking effects have resulted from the use of the bluish green sand, §§ 62–63. Z. Glazier marled on wheat and rye, the latter of which was better than ever raised before. A field had been limed; a large portion of it was manured, and the remainder marled with 300 bushels per acre, excepting a single land between the two parts, which was only limed. The manured proved best, the marled but little inferior to it, and the intervening strip which had been limed, did not appear to produce more than one half as much. J. Vandegrift's marled wheat appeared as well as the manured by more than doubling the crop. S. Townsend spread 300 to 500 bushels per acre; where the latter quantity, the crop was stronger; he manured in the same field and there it was generally, but not always better than the marled, but where marl and manure were together, the growth was very heavy; the effects of the marl and manure separately, were such that it was difficult to say where the one passed into the other, but where neither was placed, the crop fell off to less than half; in one part, the marled, and that without any kind of manure exhibited an estimated difference of 20 to 8 bushels of wheat; the effects were also striking on other crops. On the farm of Mrs. Sims the effects were equally remarkable, for according to the estimate of several individuals the produce of corn was doubled and the extent of its application might be defined to a line from the increased luxuriance of the crop. The marl of G. Karsner has had the test of more lengthened experience than any other of the varieties of non-calcareous green sands, and the results of some of his experiments are detailed in the Farmer's Register for 1838. In 1839 the effect on oats was little if at all inferior to manure, and the superior growth of the crop might be seen at some distance. It was observed that the stalks had a yellowish color, which G. K. remarked was usually the case, and alarmed at such a result the first time, he measured the grain from a given piece of land and found it greater in bulk, and that it had five pounds more in weight to the bushel. The effect on wheat was nearly equal to that produced by manure.

§ 150. The yellowish green sand has been well tested, and so well convinced were the enterprising holders of the land where it is found of its great value, that they had extracted up to the close of the survey more than had been employed in all the remainder of the hundred. The effect of J. Rogers' marl on oats was so striking, that the land not marled adjoining that which had received its covering of marl, was aptly compared to a road passing through the field. Indeed from all his experiments, he is so well satisfied of the benefits accruing from the employment of marl, that he has caused to be spread not less than 100,000 bushels. E. Croft was not satisfied of the result of his experiments for 18 months after the marl was spread, but finally became convinced that it had materially benefitted the soil. Wm. Polk had extracted largely, and covered his land in the vicinity of the pit, but with a success inadequate to his expectations, a circumstance which may be attributed to the already superior quality of the land attained by the use of other manures; for where it is improved, the increase of produce is far from being in direct proportion to the quantity or quality of manure applied to it, and even where the best materials are employed, the difference in the crops may not be perceptible to the eye, and only becomes evident by measuring the product of equal extents of land of similar quality, manured and unmanured. Dr. Uhler spread marl over poor land at the rate of 350 bushels per acre; one acre was left unmarled, and a stye or pen had been located in another part of the field. It was put in corn, and he estimated the marled corn at four times the amount of that unmarled on equal surfaces of soil, while no difference was observable between that portion where the pen had been, and the adjoining marled soil. Others have experimented with the marl in the vicinity of the bridge, some successfully, and others less so, but all will probably be soon convinced by the results daily observable around them.

§ 151. The opinions of those who have tested the black-colored sand, § 68, are more discordant than the preceding. S. Higgins had not obtained confidence in his own marl, although he believed that of G. Karsner did produce some benefit. Where the stratum crops out in his field, it has often been remarked that the crops were there most rapid in their growth early in the season, but that after the summer's heats began to be felt by vegetation they usually "burned up." What better proof can be required of the value of the marl, than that an excess of it, after producing luxuriance, should eventually destroy vegetable life?—J. Jefferson has made experiments on his land, and although successful, the result has fallen short of his expectations. J. Dale's experiments on different crops and applied in various ways, have proved eminently successful. The effects upon the corn might be traced to the exact limit of its application, and compared with that which had received a good dressing of stable manure evinced a trifling inferiority. On an impoverished sedge field it produced a good growth of white clover.——To the W. of Port Penn,

J. Cleaver, § 69, has tried a few experiments with varying success, but on the whole, he was not satisfied of the value of the marl.———T. Stockton's marl, § 70, applied in various ways proved decidedly beneficial, for where put on buckwheat in 1838 the difference between that marled, and that manured would strike an ordinary observer, and in 1839, on oats, it evidenced equal service. The trials made by L. Vandegrift were sufficiently decisive to induce its extensive application.———C. Vandegrift was not satisfied in 1838, with the results he obtained by employing marl.—W. Bennet also drew unfavorable conclusions relative to its use, but the causes of this were pointed out in § 70.

§ 152. Experiments with the marl of § 72, are too recent to admit of their being detailed. J. Driver § 73, has tried the marl with success, and attributed the unusual productiveness of his garden in 1839, to a very heavy dressing of marl which he had given to it the preceding year. J. Clayton has made numerous and well-directed experiments on marl by comparing it in its effects with other species of manure. Its effects on oats were not striking, while on the corn, it would be difficult to decide whether it does not equal the best manure in one experiment, and in another it is decidedly superior to manure from the stye (pen manure.) These and other trials, which it might be interesting to enumerate, if time and space allowed, were carefully conducted by J. Clayton, on ground of uniform quality, and to such an extent as to admit of observing the results at some distance. J. Mansfield's green sand submitted several years since to experiment, was found to be of utility and in some cases little inferior to ashes, but the result of later trials is not known. C. Haughey found some benefit on several crops, but the want of more striking effects must be attributed to the presence or formation of copperas, which will be determined by the result of two years application, when the operation of the latter, having ceased, the action of the marl will be more distinctly observed. The results of trials made by J. Rogers and A. Lewis, were not witnessed but are said to be favorable. H. Templeman's employment of the same marl on oats sufficiently proved its efficiency. It would be advisable to mingle a little lime with the marls noticed in the present paragraph for the reasons stated § 145. The *green* marl of H. Templeman also proved to be a useful source of fertility to the crops. J Jones, not possessing an accessible bed of marl on his farm, has with highly creditable enterprise procured specimens from eight different marl pits, which he submitted to comparative experiment on adjacent squares in a field, and although the results were different from what might have been anticipated yet they were sufficiently favorable to induce him to commence the marling of his farm with activity, and at a considerable expense, being obliged to haul it from a distance of three miles.— In consequence of the large proportion of sulphuret of iron in the "blue tenacious sand" of the Deep cut, it is not likely to be employed as a fertiliser, even if it could be procured with facility, but should it be employed, it will be necessary to adopt the precautions pointed out, § 145, and make free use of lime.

§ 153. Since both favorable and adverse results have been adduced, unfairness cannot be attributed to the statements given above, and from these we discover, that out of 29 who have tried it, and the results of whose trials were witnessed by the geologist, 14 have produced very favorable results, 11 simply favorable, two doubtful, and two individuals believed their experiments decidedly unfavorable. Let every one draw his own conclusions with fairness, and form his opinions accordingly, and we shall soon see every doubt vanish before conviction. It is difficult to state the precise amount of marl already extracted, (1839,) but from all the estimates we can gather, the amount does not fall short of one million of bushels. Now supposing this amount correct, and that a bushel is about equal to a cubic foot, for a cubic foot of the compact marl will make nearly double that bulk when taken out of the pit, then the above amount already used is equal to one million of cubic feet. But the seven millions of cubic yards supposed to be accessible in Delaware, § 79, are equal to one hundred and eighty-nine millions of cubic feet, so that there has been used the $\frac{1}{189}$ part of the green marl, and the amount remaining will satisfy every one that there is a sufficient quantity for the consumption of the district in which it occurs and for exportation. In conclusion, it might be supposed that something should be said relative to the methods of searching for, and extracting the marl, or constructing and draining the pits, but as experience has already facilitated these operations more than could be done by advice, it is not deemed sufficiently important to demand a place in the present work.

SECTION V.

Marshy Soils.

§ 154. The richness of the marsh lands in the Western and Southern parts of Kent and on the ridge in Sussex has been a theme of admiration to all who have visited them. They are situated on the branches of the several streams, which having their sources in Delaware usually flow towards the Chesapeake, and which originating from rains and springs in the midst of extensive forests on a broad and very flat surface with an argillaceous substratum impervious to water, and becoming clogged and dammed up by fallen trees, leaves and brushwood, naturally expand into broad basins, termed marshes. The luxuriant growth of trees, shrubs, and smaller plants, and their constant dilapidation and decay, in the shallow waters of the sluggish streams during the lapse of ages has generated a black vegetable mould, averaging three feet in depth, being rarely less than six inches and sometimes exceeding six feet composed throughout of the same materials. It was not until the close of the past or within the present century that effectual means were resorted to for recovering this land from almost constant inundation, since which time nearly all the great marshes have been drained by the excavation of ditches or more properly canals in the natural bed of the stream, and a large amount of the most fertile soil in the state brought under cultivation. One of these great drains increases from 12 to 24 feet in width from its source to its mouth, a distance of nine miles, and throws off a sufficient quantity of water in spring freshets to float a moderately sized vessel. The Colberth, Cow, Herrington and Tappehanna marshes in the West of Kent county are the main feeders of the Choptank, and Marshy Hope in the South forms a main source of the North West Fork River. The principal and several minor branches of the Nanticoke have been also subjected to drainage, beside many smaller streams in Sussex. When all the water-courses shall have been confined in a similar manner within their proper channels, a very large amount of an inexhaustibly fertile soil will be brought under the plough, and the noxious exhalations of marshy lands will cease to produce diseases to which their inundated state renders them subject.

§ 155. When we examine the soil thus wrested from the waters, an unusual uniformity of composition appears to prevail in it; it is black, very unctuous to the touch in its moistened state, rarely so light and spongy as not to admit of grain after a little cultivation, becoming sufficiently compact on drying and consisting of decayed organic matter and argillaceous earth. The organic matter chiefly humus-coal, and humin, § 111, a little of the humic and crenic acids, §§ 112, 113; and that it does not contain uncombined acids, such as the malic, acetic or phosphoric in quantity, is shown by its productiveness immediately after clearing § 119. The fertility of these soils is shown from the fact that some fields have been tilled in corn for 40 years in succession, without an apparent diminution of their productiveness; but nevertheless the idea, which seems to have become deeply rooted in the minds of the people of our western states, that such land can never be exhausted, cannot be too soon refuted and exploded in Delaware. No soil, however rich, can withstand excessive tillage, except it receive an adequate return of its richness; an assertion to which the experience of ages will bear witness, and which will be confirmed by the experience of the West, ere 50 years shall have elapsed. The quantity of organic matter in some of the marshes is so great that during a dry season, the soil which was accidentally fired, continued to burn like coal, and could only be extintinguished by rain. The remains of such fires have been observed in several instances, where the carbonaceous matter having been burned out, left the earthy constituents converted into a substance resembling brick by the heat of the fire. It is said that lime applied to this land has sometimes been found injurious. It may admit of a doubt whether the experiments were judiciously made, but supposing that to be the case, it must arise from the existence of too much humin, or the organic acids, which the addition of lime would bring into a too rapid action. The proper course to pursue with it would be to give a very light dressing of lime, which has been exposed to air for some time in order to its combination with carbonic acid, in which state it guarantees a gradual decomposition of insoluble vegetable matter, as shown §§ 131, 132. There is one important use which these soils may receive and it is only surprising that so little attention has been paid to it; the adjoining lands, sometimes argillaceous, are usually light sands, and if a portion of the black marsh soil were spread upon them, it would render them both more productive and cohesive, and surely there is in nearly every place where it occurs a superfluity which should not be suffered to lie unproductive.

§ 156. Similarly formed to the marshy soils and arising in part from them, are those black deposites in the creeks and branches, existing in all parts of the state, but abounding in Sussex and Kent. They are largely composed of organic matter, but contain more earthy constituents than the preceding, and appear to be better elaborated, and prepared for use. In a majority of cases they may be directly applied to land without mixture, and will prove a very valuable substitute for manure of the organic kind, but if extracted where the tide flows, it will often be requisite to expose them to frost, or mingle them with lime, or submit them to both, prior to their employment. It is not merely in larger streams we are to look for this material, but in small branches, brooks and even in the courses of springs; it may be found on nearly every tract of land in the state, and more especially to the south. It is a source of fertility within the grasp, and certainly within the means of every citizen, and it only needs to be tried, fairly tried to gain it a lasting reputation as natural organic manure. Experiments have been made with it to a very limited extent, and although successful, it is surprising that its use has not extended; for in some instances, applied alone it has doubled a crop of corn in the first season, and exhibited good effects for many years; with lime it has produced similar results which will stand the test of a longer time. This vegetable soil is not always uniform in its composition, for although in creeks it is usually black, and earthy, yet in some small upland ponds or swamps it is brown, light and spongy. In the latter case in particular it should be employed in connection with lime in the caustic state, i. e. freshly slacked, to promote incipient decomposition, and to correct acidity, and even in all instances of its application, lime will benefit it and insure greater durability of action. Many farmers in Delaware, really desirous of improvement, know not where or how to commence, since they cannot raise one-fourth the quantity of manure requisite for restoring productiveness, and their farms are extensive. Here is a material, with which to make the first attempt; let them use it alone, and if it prove good, continue until means are obtained to employ lime in addition to it; if the result be not favorable alone, let it be carried to the barn-yard, to form a layer of it there, and when its surface has been covered by manure, let them bring in another layer, and in such a manner, the quantity of manure may be increased many fold, without deteriorating its quality.

§ 157. From the upper part of the state to its southern boundary the Delaware river and bay, and the sea-coast are skirted by flat lands of varying breadth sometimes exceeding a mile, subject at times to inundation, consisting of a flat, and dark colored vegetable mould, clothed with a luxuriant growth of reeds and grasses. Supposing them to average a mile and a half in width through the whole length of the state, we would have about 100,000 acres of Delaware marshes, a large extent of land, which if it were brought under cultivation, would prove to be the richest land in the state. Its depth and richness of soil, and the ready means of restoring it when exhausted, are ample proofs of the assertion, but it may be reasonably doubted whether so great an undertaking as reclaiming this land at the present time would meet with an adequate return, when we consider its expense, the comparative paucity of population, and the imperfect system of agriculture pursued in the state. The successful execution of a small portion of the task in the upper county is ample evidence that the work is practicable, and the experience, which Holland has attained on this subject during ages, could be wielded in Delaware. But since it is not at all likely to be brought into execution for a long period of time, why may we not derive some benefit from these lands at the present time? Independently of the embankment of small tracts along the shore, and without reference to the grazing of cattle on these natural grass lands, the soil of the marshes may, and should be applied extensively as a manure on the upland. The embankment of ditches where they are not otherwise required, may be employed; or the marsh may be dug expressly with the view of employing the soil as a fertiliser, and it is such a vegetable mould which is chiefly required in Delaware to render it more fertile. The marshy deposite to which allusion was made, § 101, is variously composed, or more properly speaking, it is in different states of decomposition; being sometimes a black, unctuous matter, both vegetable and mineral, containing no traces of vegetable fibre, again a similar soil with fibre, and lastly a formation consisting chiefly of fibre or the undecayed roots and leaves of plants. The first of these, is the most valuable, and may sometimes be directly applied to land without admixture, but it is advisable to adopt a uniform method of using it which may be done in two ways, by mingling it with lime, better after exposure to the air for some time, or by drawing it into the barn-yard to bring it into an incipient fermentation by contact with stable manure. In either case it will more than repay its expense, and if lime be employed on the land at the same time, a more powerful and durable influence will be derived from it. There is one kind of material bearing some connection with the preceding, a species of sea-weed, observed along the shore of the bay, but more remarkably constituted on the beach a few miles below Lewes, which will prove of great excellence, when brought to an incipient fermentation, as it contains much blue mud, and is penetrated, and inhabited by numberless shell-fish. It would become more useful if drawn into the barnyard, and suffered to ferment in a slight degree, for the decomposing animal matter, will bring the weed rapidly into a similar state.

§ 158. There remains yet one other substance, which is easily obtained, and will repay the expense of its application to the soil. It is the "blue mud," § 101, which is constantly depositing from the river and bay, on the marsh lands under the circumstances pointed out in the paragraph referred to. The fertility of those lands of which it forms the upper surface, and its beneficial effects in the few instances in which it has been employed on the upland are a warrant of its fertilising powers, but it is a matter of some doubt to what substances its effects are mainly to be attributed. Its basis is a fat clay, both lead-colored and yellowish, with a quantity of organic matter, which appears to be chiefly in the state of crenic and apocrenic acids combined with the oxide of iron. There is no doubt that it would be advantageous if applied directly to the soil, but its tenacity is an objection to such a mode of using it, and hence it is more advisable either to draw it into the barn-yard, where it will be broken down and mingled with manure, or to mix it with lime, and expose it for some time to the air, adding at the same time, the black marsh soil, which is generally to be obtained in its vicinity.

§ 159. In the present section our attention has been devoted to a fertilising ingredient of a high order, which we have denominated "*Marshy Soil*" in order to embrace the several varieties under one head; in agricultural works it might be termed a *peaty* soil, but the term would not include all those which have been described, for the "blue mud" is wholly unlike a peaty soil, but being deposited on the river-marshes, it soon becomes a marshy soil, and many of the creek and western marsh deposites are far from being peaty, although they contain much organic matter. From a careful perusal of the section, it will be observed that this source of fertility is every where abundant, and in the two lower counties may be said to lie within the grasp of every farmer; let it not, therefore, as is too often the case, be disregarded or undervalued, for its abundance and convenience, but applied judiciously, frequently, and profusely. Its value rests not on a mere theoretic assertion, but it has received the test and sanction of experience, and such experience both in Delaware and elsewhere, as may not be contradicted. As it would be a matter of nicety to discriminate between such varieties as are not sufficiently decomoposed, and require some preparation prior to their application, and those which might be directly employed, it would be better to adopt a general rule relative to the mode of using it, viz., either to draw it into the barn-yard, or to form a compost with lime, or with ashes. In either case it will form an excellent manure, and with lime or ashes a durable one. It is indeed a fortunate circumstance that this valuable material is diffused in such abundance over the state, and not less gratifying that it is more widely distributed in Sussex and Kent counties, where the soil chiefly requires the addition of organic matter to restore it to its former fertility or even to excel it, and where it is of such a peculiarly light character as to require the use of precisely such a substance to render it more compact and tenacious, and more capable of repaying the expenditure of time, labor and materials, liberally bestowed upon it by the hand of industry and enterprise.

CHAPTER II.

ARTS OF CONSTRUCTION.

SECTION I.

Architecture.

160. *Gneiss*, §§ 25 to 30, being more abundant than any other rock in the northern part of the state, and of ready aecess, is more generally employed in ordinary architecture, not often it is true in the construction of entire buildings without the assistance of other materials; but in laying the foundations, its indestructibility under ordinary circumstances renders it an almost indispensable material. Its regular stratification and the readiness with which it yields to force applied in the direction of its planes, together with the varying thickness of its laminæ afford great facilities in quarrying, nor are these advantages appreciably diminished by the presence of garnets § 27, nor by the quartzose and felspathic veins, § 29, which render the plane of stratification somewhat tortuous, for this effect is local, and limited to slight deviations, while the general direction of the planes remains the same, § 30. The slightly roughened surface of the rock offers another point of utility, by which it is enabled to hold mortar with greater firmness. Being softer in texture compared with the felspathean rocks, it is more readily bored for blasting, and very susceptible of receiving any required form under the chisel. The advantages of its employment, therefore, are its abundance and ease of access, of blasting, quarrying, and forming, and its firm retention of mortar. What are its disadvantages? The principal one lies in its destructibility, as shown § 25, but even this disappears upon closer inspection, for in the cases alluded to, it has been exposed to decomposing influences for an incalculable length of time, in-

finitely beyond that which can possibly be required for any architectural purposes, § 25; and farther, although there are places in which it has lain imbedded in walls for more than 100 years, it still presents no evidence of decay. That constituent most subject to decay is evidently the felspar which forms kaolin or china-clay, where it is sufficiently abundant, and undoubtedly assists in imparting richness to the soil. We have sufficient evidence of the great durability of mica from its diffusion in the soil, while other ingredients of rocks disappear, and from its constituting a part of secondary formations, but there are circumstances under which even this substance is subject to change, for the Danish chemist Forchammer has observed that if particles of mica be suspended in water, and sulphuretted hydrogen passed through the liquid, the mineral then becomes soluble in acids. On the other hand a highly micaceous gneiss is so little affected by fire, that it is often employed in the construction of furnaces. Considering then the circumstances under which gneiss is applied in architecture, it must be viewed as a very convenient, substantial, and therefore highly valuable species of rock. All its varieties however, are not equally good, for in some of them the felspar has already undergone a partial decomposition and become soft and friable, § 25, an observation that applies more particularly to the surface of the formation. Hence in searching for a good material for building, it will be advisable in nearly every instance to remove the surface, perhaps several feet in depth, before obtaining the rock in its undecomposed state, in which condition alone it should be employed in fine and ordinary architecture. It is not probable that rough or dressed blocks of this rock can ever constitute an article of export from Delaware, since the river is bordered by the *blue rock*, but altered gneiss, or the felspathic rocks which will be presently noticed, may hereafter constitute a source of revenue to the state.

§ 161. The situation of the felspathic rocks, § 31–37, on or near navigable waters, leads us naturally to inquire how far they may admit of application to the arts of construction. Both the fine and coarse-grained varieties possess hardness and toughness, which are important characters for the purposes designated, but at the same time may often prove a draw-back on their utility from the increased difficulty of quarrying and dressing them.

There is, however, a difference between them, for the coarse-grained, containing a large proportion of felspar, and relatively less quartz is softer and more yielding to steel, and hence one chief reason why it has been extensively employed for railroads, and is now being used for supports in the lower stories of large stores in Philadelphia. Its employment in the latter instance shows also that, notwithstanding its hardness, it may be chiseled and sculptured into ornamental forms. It possesses another advantage in being destitute of lamination, for which reason it may be split by wedging in any direction. This method of splitting consists in drilling holes in any given line, straight or curved, filling them with wooden wedges, and forcing iron wedges into the wood, until the block is severed from the mass. The fine-grained variety containing more quartz, is harder and more difficult of drilling, and although often laminated, is so compact that it may be split at any required angle to the laminæ. The cause of that remarkable tendency to disintegration in certain parts of the coarse-grained rock must be left unexplained, but the fact does not interfere in the least with its general character nor with its value, for such parts are easily known, and are very small relatively to the mass of the formation.

§ 162. Much of the blue rock of Delaware has been employed in the construction of a great national work, the Break-water at the mouth of Delaware bay, and a question of no easy solution offered itself some years since, in regard to the relative values of gneiss and blue rock for this work. The importance of the undertaking considered in a national light, should certainly banish all attempts at state or local feelings or influences. The opinions of the author on the subject were embraced in part in a report of the Franklin Institute, nor hasa closer observation since that period changed his views. As the question stood, "which rock was better adapted to the purpose," the answer was clearly pointed out in the superior gravity, hardness and toughness of the blue rock, which were conceived to be important characters. But it was urged that this rock was liable to decomposition, which is shown to be true of the coarse-grained variety in only a few instances observed at the quarry, § 34, and as may be seen at the Break-water. The gneiss could, however, be obtained at a lower rate, from the greater ease with which it is wrought, and this circumstance was evidently greatly in its favor, where enormous quantities of stone have been, and will still be employed. There was another view which was adopted by the writer contrary to the opinions of those who favored the blue rock, that although that formation was superior to gneiss in point of hardness, toughness and gravity, yet that the latter can be, and is quarried out, possessing those characters to a sufficient extent to justify its employment. He deems it his duty to present this concise statement of views, since his appointment to the survey of Delaware, necessarily called for an expression of his opinions, and before leaving the subject, he would point out the necessity of a strict inspection of the materials employed at the Breakwater, from whatever sources they may be derived, as inferior qualities of stone may be obtained at the quarries of blue rock in Delaware, as well as those of gneiss in Pennsylvania.

§ 163. The blue rock has been wrought for many years on the shores of the Delaware, and from its well ascertained characters, the unlimited supply which the formation can afford, and its proximity to tide water, it is highly probable that its consumption will continue to increase. If durable monuments be required in commemoration of events or individuals, this rock is well adapted to the purpose, while its color would equally suit the heavy gothic arch, or the ponderous Egyptian pile. It is not, however, confined to the shores of the river, for we find it holding a firm situation several miles up the Brandywine, and appearing at distant intervals in the midst of the gneiss, which it usually assimilates more or less to itself. This altered gneiss is better developed on the Brandywine near Gilpin's mills, § 36, and displays a light gray rock of a texture, hardness and toughness, intermediate between gneiss and the felspathic rocks, from which, and from its cleavage in the planes of stratification, it deserves a high rank among the formations of the northern part of the state. The extension of quarries in the blue rock, consequent upon a presumed increasing demand, will in all probability discover new varieties, which may even possess advantages superior to those described, by combining all the desiderata of materials for architecture.

§ 164. Limestone has ever been regarded as a valuable building material, and as it occurs presenting a variety of colors and of other external characters, is justly viewed as one of great beauty. In Delaware we have chiefly the white and gray, both of a crystalline structure, and in the lower part of Jeanes' quarry beyond the influence of atmospheric agents, it is massive and heavy bedded, and may be obtained in blocks of large dimensions, § 39: as the formation is limited, § 39–41, there is no probability that it will ever be extensively employed in architecture, particularly where the gneiss and blue rock are so abundant and easy of access.——Serpentine has been employed with success in building, as witnessed by specimens in, and near Westchester, Pa., and its shade of green unquestionably produces a novel and pleasing effect. It may be similarly applied in Delaware, but its small extent § 42–43, limits its utility. Although detached granitic veins are frequent, yet they are too small to admit of their application to architecture.

§ 165. The upper hundreds of New Castle county abounding in rock formations, may be conveniently distinguished from the remainder of the state by the appellation of the rocky region. It is not, however, exclusively so; for there are two other instances of rock formations among the sands and clays farther south. One of these noticed, § 61, may even now receive a partial application in building, and may be more extensively used when heavier beds of it are discovered. The other described in § 83, is a valuable material as far as regards its durability, hardness and toughness, but like the preceding requires extent to permit its classification with useful building stone.——The large number of small ferruginous springs throughout the lower part of the state, and the abundance of oxide of iron in the sandy strata, are the frequent cause of the partial induration of the formations, as exhibited in numberless ferruginous crusts, or iron-stone, in which sand and pebbles are cemented by oxide of iron, but they are too unimportant to require more than a passing notice. Beside these formations lying in their natural beds, there are numerous boulders, or erratic blocks sparsely strewed over the surface, derived from the more northern rocky regions, and transported to their present isolated situations by currents of water, when the whole surface of the land was at a relatively lower level than it is at the present period of time.

§ 166. It might appear a useless proposition to offer clay as a material adapted to architecture, were it not that it has met with successful application in other countries, and received the stamp of success from the lapse of centuries. In Germany and other parts of Europe it has long been a custom among the less wealthy classes of society to employ clay largely in filling up the interstices of the frame work of their houses, which had been latticed by rough brushwood, and branches of trees, and it is worthy of observation that when the weather surface is properly washed with lime, it becomes so hard in process of time as to resist atmospheric agents, and even tends to preserve the wood-work of the building. In some of the departments of France, and in parts of South America they construct dwellings wholly of clay which becomes sufficiently hardened to stand alone as a durable wall. Dr. R. M. Bird first suggested to the author the practicability of making such constructions in Delaware, and although it appeared at the first view impracticable, yet a more mature consideration of the mode of operating with the clay, and the evidence offered by its employment abroad, led to the conclusion that it is deserving of especial notice among the materials used in the arts of construction. It is applied in a state approaching to dryness, the blocks of clay being rammed tightly into a form of wood which is raised in proportion as the wall advances in height. The conveniences of such a construction in Delaware arise from the abundance, diffusion, and qualities of the clay-deposites from the northern to the southern limit of the state, while its general advantages lie in the simplicity of the means by which any given design may be accomplished, and consequent economy of the operation. A coating of lime on the exterior is sufficient to protect it against the destructive influences of rain, frost, and heat, and appears to act chemically by combining with the constituents of the clay, and forming a hard mineral compound. Dr. Bird ascertained during the course of numerous experiments, that ordinary linseed oil mingled with a small quantity of drying oil, and applied by a brush, formed a superior coating for clay-walls rendering the surface harder and more compact, capable of withstanding atmospheric agents, and adapting it to the reception of ordinary pigments. A building well constructed after this method might vie with the proudest mansions in the beauty and durability of its architecture.

SECTION II.

Construction of Roads.

§ 167. While the citizens of the United States are intently pursuing a course of public improvements in the construction of railroads and canals, they have been misled by their advantages in suitable locations to neglect the improvement of ordinary roads. Where the former are intended to bring distant places into a closer proximity, or to render the means of conveying large amounts of natural or artificial productions more convenient, expeditious and economical, our common roads, designed as the medium of intercourse for comparatively short distances and of conveying smaller bulks of products, are equally deserving of our attention. Although the increasing wealth and populousness of Britain originated those excellent roads which cover the United Kingdom like a net-work, their number and excellence undoubtedly reacted by developing and diffusing the resources of the interior, and consequently by raising its wealth to a still more elevated point. Like causes must produce like effects in a nation derived from and similarly constituted to Britain; for which reason more care should be exercised in the improvement of our common roads. It is not presumed that every unimportant road should be converted into a turnpike, for the absence of a dense population forbids it, but the principal thoroughfares can and should be bettered by the application of such materials to them, as are found in their vicinity. Roads which are in constant use should receive a covering of a hard and durable material, such as broken stone and gravel, but those less frequented may be amended by the less expensive application of clay, sand or loam, according to the nature of the substratum or soil.

§ 168. The macadamized road is unquestionably that form which combines the greatest number of advantages, examples of which are the five turnpikes leading from Wilmington. But these are far from being good specimens of this kind of road, for the principles of their construction have not been adhered to, the principal objection to them being the large size of the pieces of stone, which will ever prevent the attainment of an even surface;

another is the practice of covering the stone over with a layer of earth. Stone-pikes are sometimes carefully and properly constructed at first, but when they become rut-worn are often repaired by throwing heedlessly on them mingled earth and stone, dug at the side of the road or at the nearest possible point for convenience. The national road is a well-constructed macadamized road, in many places of perfectly even surface, but instances have been seen where, to obviate the destructive effects of a heavy rain, earth and stones of large size have been thrown on it, which rendered it about equal to a common turnpike road. There is an abundance of stone in the upper part of New Castle county of superior quality, possessing the desirable properties of extreme hardness and toughness, and breaking into sharp angular fragments. The best rock for the purpose is the blue rock of every variety; the hard gneiss, although a good material, being rather inferior to it. An objection urged to felspathic rocks is the greater difficulty and expense of breaking them, but the coarse-grained formation at Quarryville offers a material admirably adapted to roads, as it decomposes in some portions, § 34, crumbling into small angular pieces, which will become compacted and solid. The same kind of road may be constructed nearly as far south as the upper part of Kent county by employing erratic blocks and pebbles, which when fractured afford a superior and very durable material. Nearly all the fine roads in the northern part of Prussia, within fifty miles of the Baltic, are thus constructed, on a level country not unlike the two lower counties of Delaware.

§ 169. Instances of gravel roads are met with in the central parts of New Castle county, which are nearly equal in value to those constructed of broken stone, exhibiting an inferiority only in long-continued wet weather or during the thawing of the winter's frosts. Their superiority to ordinary roads should point out the propriety of transporting gravel to the latter, for although the expense of their construction may be greater at the first, yet their greater durability reduces the actual outlay nearly to the same amount. Gravel is found abundantly in the upper and middle sections of New Castle county, §§ 46, 50, 51, 52, in sufficient quantity in the lower part of the same, §§ 55, 56, 67, 69, 80, and in Kent, §§ 82, 84, and exists in several places in Sussex, § 89. Some attention should be paid to the character of the substratum, for if it be a light sand, the gravel will not produce a material improvement, while on clay or better on an argillaceous sand, it will become compact and durable. The remarks just made, §§ 167, 168, refer more particularly to the leading thoroughfares of the state, which should evidently be rendered more suitable for transportation and travel through as much of the year as is practicable. The advantages of such improvements would not merely affect the inhabitants of that particular section where they are made, but a large portion of the state.

§ 170. The local advantages derivable from the improvement of less frequented and smaller roads might be shown to be fully commensurate with the outlay which they ought to receive; nor will the expenses attending it be much greater than at present. The principle on which this improvement depends is founded on a change of the soil; when it is clay, sand should be added to it; when sandy, clay should be added, in order to attain a mixture of the two in which sand should predominate. Now by the usual method of digging down or ploughing up the side of the road and throwing the earth on the centre the same kind of soil is added, and a sandy road only benefitted for a short time by the little clay which fresh soil contains, whereas if a little more expense were devoted to searching for clay or sand, in proportion as either is required, and applying it, a good medium will be attained, which after short use, will become hard and compact. A light sandy road is very good in the winter season, and moderately good after rain, which renders it more compact, but at other times it is very objectionable;—a clayey road is worn into deep ruts during the winter, which becoming frozen, renders it exceedingly uneven, while after heavy rains and when not frozen in winter it is almost impassable. A suitably mingled sand and clay is in better condition during the summer than sand and during the winter than a road composed of clay alone; is not as easily rutted by rains and becomes sooner smooth after rain. In short, it is superior either to sand or clay by being useful through a much larger portion of the year. Where gravel can be obtained it ought to be employed in preference to sand. It is a fortunate circumstance in the deposition of the various strata, that both sand and clay accompany each other throughout the state and are accessible in almost every place where a road is located; nor ought their application to be limited to ordinary roads, for they may be employed for improving the principal thoroughfares in the lower part of the state, in the absence of more valuable materials, stone and gravel.

CHAPTER III.

CHEMICAL ARTS.

SECTION I.

Manufacture of Pottery and Glass.

§ **171.** The manufactures of pottery and glass, and particularly the former, are deserving our attention, since allusion has been made in the preceding pages to frequent localities of materials which are employed in them. The simplest, but not the least important of these is the making of brick; the simplest, because it requires very little previous preparation of the materials, and is not attended by difficult processes in the progress of the manufacture; and important, because it obviates the necessity of drawing materials for ordinary and finer architecture from abroad. Happy is it therefore for the state that it possesses an abundant supply of these materials so extensively diffused, that a small district can scarcely be found destitute of them, and so conveniently situated, that a building may often be erected over the same spot from which was derived the substance employed in its construction. The substances used in making brick are clay and sand, mingled in due proportion. A very fat clay will not answer the purpose alone, as the contraction of the clay in drying produces fissures, nor will one containing a large proportion of sand, for in this case the brick is too soft and crumbling. A due proportion of sand and clay is therefore essential, which is best attained, where practicable, by mingling together fat and poor clays, or white and lead colored with yellowish and loamy clays. The former may or may not contain sand, the latter always fine sand, while their yellowish color is derived from oxide of iron. The presence of the last named substance is essential, as it acts by cementing the clay and sand or alumina and silica. Hence the white clay, containing but little oxide of iron, can never form a strong brick, while the yellow alone containing too much ferruginous matter, is apt to enter into semi-fusion and become glazed. These effects can be ascertained practically by the *ring* of a brick; for if it produces very little sound on being struck, it is either not burned sufficiently or there is too little iron in its composition; if it produces a very sharp and quick tone, it is burned too much or there is an excess of oxide of iron in the clay. It follows from what has been said that the excess or deficiency of iron may be remedied by adding more white or yellow clay. Where the two clays are not found in juxtaposition or conveniently near together, if we have white or lead colored, a yellow loam is added; if a yellow clay alone, we add sand and use a less intense heat in the kiln. It is frequently advisable to try the mixtures on a small scale, preparatory to burning a kiln, on a smith's hearth or other convenient place, for even those skilled in the art cannot always judge of the fitness of a clay by its external characters. Of the geological formations many have been and are employed in this manufacture; the red clay of New Castle county, §§ 47, 52, and the yellow clay of Appoquinimink hundred, §§ 80, 81, the intermediate clays of Kent, §§ 87, 88, the lower clays of Sussex, §§ 89, 94, as at Causey's, § 89, and Parker's, § 90, the more recent argillaceous deposites near tide-water throughout the state, the clay of the ridge, as at Georgetown in Sussex, and numerous local clayey beds or loams scattered through the three counties. In all of these localities bricks are made of sufficiently good properties, in many of them of superior quality. The greatest difficulty in this manufacture is obtaining a good moulding sand, no localities of which have been found, excepting perhaps the stratum mentioned, § 85, which is probably too coarse for a fine quality of brick.

§ 172. There are deposites of clay in many parts of the state affording a sufficiently fine material for the manufacture of earthen ware, stone-ware, and even fine pottery or English ware. For the former, several of those deposites now employed in the making of brick would be well adapted, if other purer clays were mingled with them; and indeed they may be employed alone, if previously and carefully subjected to the process of *washing over*, by which the coarser and finer portions are separated from each other, and the latter alone employed. As it is believed that this manufacture may be prosecuted in many parts of the state, the method of preparing clay for the purpose should be described. If clay be stirred up in water, and allowed to settle for a few moments, the gravel, sand and coarser matter will subside, and if the muddy liquid be poured off, the finest parts will finally settle down and may be obtained by pouring off the clear water, and partially drying the remainder. Carrying out the same operation on a large scale, we obtain a fine clay adapted to earthen ware. By the old *blunging* process the clay was broken by picks, and worked up with water in a pit or tank by hand-paddles, suffered to settle, and run off through sieves into the drying tank. A far better, but somewhat more expensive method is the following. A cast iron cylinder of three feet diameter, more or less, with wrought iron spokes attached to the interior sides at different distances, and projecting one-third towards the centre is placed in a horizontal position; a shaft passes through the cylinder with similar spokes attached to it in such a position that when it revolves they will not interfere with those attached to the cylinder; the lower half of each end of the cylinder is closed by iron plates, cast at the same time. Clay is introduced at one end of the cylinder through the open upper half, and the shaft turned while the stream of water enters at the same opening. The clay and water are thus thoroughly mixed, and pass out of the opening at the other end of the cylinder, which is slightly inclined, into the first trough, in the centre of which is a deep and narrow wooden vessel, to receive the gravel and coarse sand. The muddy fluid still passes on to a sieve, through which it empties itself into a second trough—it passes through a second, and sometimes a third sieve, each one being finer than the preceding, into the slip-reservoir. When the water becomes clear in the slip tank, it is drawn off by opening pegs on one side, and the slip collected for use. The same operation is equally well adapted to stone as to earthen ware. For the finer pottery, (queen's ware &c.,) the operation of blunging is best performed by throwing fine clay into a vertical cylinder or cone having knives attached to its inner surface and at right angles to it. An upright shaft has knives attached to it in such a manner that their edges pass close to those of the cylinder knives, in revolving, and cut or slice the clay between them, while by their blades lying in a spiral around the shaft, they force the clay downwards towards the bottom where it passes out at an opening. It is then put into the *large blunger*, where it is mingled with water by a vertical shaft with arms, and when the vat is full the liquid is allowed to stand for the coarser matter to subside, and then run off into the slip-reservoir. The former process for common earthen-ware, is successfully practised in Germany; the latter in England.—For earthen and stone-ware, we have resources in the red clay, of New Castle; the intermediate of Kent and the lower clay of Sussex. For fine pottery we might have recourse to the white clay on the Delaware below New Castle, and to the same wherever it may be found in the red clay formation of warrantable extent. Although this white clay is a source of revenue at present, from its exportation, yet were it to form the basis of finer clay manufactures within the state to which its quality adapts it, its benefit to individuals, and to the state would be increased an hundred fold. The mode of obtaining clay in a very fine state for earthen-ware has been more minutely described as the process appears preferable to those ordinarily adopted, and as that manufacture is more likely to be established than any of the others. But for this and other parts of the manufacture, reference is made to establishments already in successful operation.

§ 173. Allied to the manufacture of fine pottery is that of porcelain or china-ware, one of the most useful and beautiful of the arts, for the establishment of which materials are presented by formations within and near the state. The necessary ingredients of porcelain are Kaolin, Quartz, and Felspar, the latter of which is furnished in abundance, and of good quality by the spar quarries, § 44–45, and was used by the porcelain manufactory at Philadelphia, when that valuable establishment was in successful operation. The blocks of quartz from the same vein, § 45, were also employed, and should more be required, a fine quality is found, and may be obtained in large quantity near Columbia on the Susquehanna. Although beds of kaolin are frequent in Delaware, yet being too small in extent or too impure, it may be obtained a little beyond the state line near Mill creek hundred, which was the source of that employed in the Philadelphia manufactory. For making the seggurs in which porcelain is burned, and which is an important item in this manufacture, we may rely upon the red clay formation, the white variety and other parts of which are admirably suited to the purpose. Thus it appears that all the materials requisite for the manufacture of porcelain lie within the grasp of the upper part of the state, and should its establishment be attempted, it will prove a valuable acquisition not merely to Delaware, but to the artificial productions of the United States.

§ 174. The white clay below the town of New Castle, § 49, has been exported to various parts of the United States with a view to its employment in the manufacture of glass-pots, or crucibles in which glass is melted. It belongs to that variety of infusible clay, known as *plastic* or *pipe-clay*, being infusible in a powerful heat, merely caking together and becoming hard. Specimens of it are found nearly equal to the best German pipe-clay from Gross-almerode in Hessia, although in its general characters as a deposite, it yields place to the Hessian. Its unusual freedom from iron renders it of great value in the manufacture of glass pots, for where the oxide of that metal is present, it communicates color to the glass, injures the texture of the pot, and renders that part liable to fusion; hence where these particles of iron are found, they are removed at the beds or more carefully at the glass works. Its freedom from siliceous sand or grit is another property of importance, as it enables the workmen to give a smoother surface to the interior of the pots, and gives the latter greater compactness. This white clay then possesses properties which adapt it to the manufacture of fine pottery, porcelain, pipes and crucibles, for the latter of which objects it has been excavated for more than 40 years. There is no reason why it cannot be equally well employed in the others, nor why the manufacture of glass may not be established within the state; for although good beds of a sufficiently pure white sand were not observed during the survey, they possibly and probably exist in Sussex, and even if they should not be found, a glass house on tide-water could draw from the deposite in New Jersey. Enterprise and skill would certainly render such an attempt successful.

SECTION II.

Minor Chemical Arts.

§ 175. Although the manufactures of iron are the most numerous, varied and important, of all others, yet as we are only contemplating those which draw upon the natural resources of the state, and since the comparative paucity of the deposites of iron-ore in Delaware will ever be a drawback on the extension of iron manufactories, the nature of this memoir restricts us to a few words on the subject. The several deposites alluded to in §§ 87, 92, 98, 99, have been principally wrought for exportation, the remainder having been reduced to the metallic state in Delaware either by forges or a blast furnace. The latter yielded a good metal, at Millsborough in Sussex, but is now out of blast. The forges are conducted in a very simple and ancient style, by mingling the ores and charcoal together on an open forge-hearth and urging the fire by a bellows, and as the fire decreases, by adding more until a sufficient body is obtained to form a bloom, which is then wrought under the tilt-hammer into bars of the required dimensions. From the absence of flux, oxide of iron must supply its place, and hence the loss of a large amount of iron in the cinders; the quality of the bar iron obtained is nevertheless superior. The quantity of ore raised in the state may be estimated at 200,000 tons, which have introduced more than half a million of dollars revenue into Delaware, but had this large amount been converted into metal within the state, the revenue would have amounted to several millions for the metal alone, independently of other arts originating from the employment of iron, which would in all probability have arisen and been successfully conducted. As a subject of interest might be mentioned the employment of green sand as a partial flux for iron ores. Limestone is the flux ordinarily employed, but as the green sand contains potassa, it would be a matter of deep interest to ascertain how far it may be substituted for lime, while at the same time its frequently large percentage of iron would assist in an increase of the metal. It is well known that potassa will form a more fluid glass with silica than lime, and as one object of the iron-smelter is to obtain a fluid slag through which the melted particles of metal may readily pass to reunite at the bottom, it is highly probable that this material might render important assistance in his operations. The quantity of silica in the green sand is, perhaps, too great, to admit of its application alone as a fluxing medium, but it may be united profitably with lime, or in order to employ a single substance, the calcareous varieties §§ 53–56, and particularly the cretoidal might be used alone with advantage. It would also be a matter of some interest to ascertain what quantity of iron could be obtained from the pure green sand without the assistance of either ore or fluxing material.

§ 176. Sulphuret of iron occurs in numerous localities in the state, but in no place of sufficient extent to demand attention, excepting in that portion of the green sand formation traversed by the Deep cut; and even there, although masses of the sulphuret of considerable size are abundantly disseminated through the blue tenacious sand, §§ 77, 78, yet no one locality has yet been observed, which might be worked to advantage. By exposure to air and moisture, we have already seen §§ 73 to 75, and § 78, that the sulphuret is decomposed and converted into sulphate of iron or copperas, which sometimes detracts from the value of the green sand, § 143. A similar method pursued with the masses of sulphuret carelessly selected from the clay might be adopted on a large scale to convert it into copperas, and the indications of the mineral in quantity are such as should induce those residing in the neighborhood to search for superior localities.

§ 177. Having devoted some attention to the construction of buildings from sources within the state, a *few* words should necessarily follow relative to the means of cementing building materials. More ample and satisfactory information on the subject of mortar may be attained by referring to a series of French essays, translated by Col. Totten, U. S. A., which appeared in the Journal of the Franklin Institute for 1839. The limestone found in the upper part of the state, yields an excellent mortar, when well burned and freshly slacked; and with proper care, one bushel of burnt lime will more than double its bulk. Beside the convenient proximity of the greater part of the state to navigable water, whence lime may be obtained from abroad, there are sources of the same valuable material in some of the strata of deposition. Thus, the large shells, chiefly Exogyra costata, and Gryphæa convexa and vomer in the cretaceous green sand, § 53, 56, in the indurated marl, § 57, 59, the smaller shells in the shelly green sand, § 60, may be profitably burned for lime, where stone-lime is not convenient. The indurated marl falls to pieces after a short exposure to the air, § 57, and this and the shelly varieties may be most economically used by sifting them in the same manner as gravel and sand are separated by a standing and inclined sieve, and then burning the coarser portions, which will contain as large a proportion of lime as many good limestones. Still farther south, advantage should be taken of the natural and artificial accumulation of shells which are often found of sufficient extent to justify their being collected for burning, and may be separated from the adhering earth in the manner just described, § 138, 139, 140. In the construction and burning of field-kilns, which are ordinarily employed for shell-lime, no important improvement can be suggested, except it be the plentiful use of wood, in order that the shells may be thoroughly burned, for otherwise the lime will be of inferior quality. Even if it is intended for liming land, it should be brought to the finest possible powder, for reasons stated, § 135, which can only be done by a thorough burning and careful slacking. This caution is the more necessary, as some individuals are of opinion that a par-burning is decidedly preferable to one in which the lime becomes thoroughly pulverised.

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THE END.