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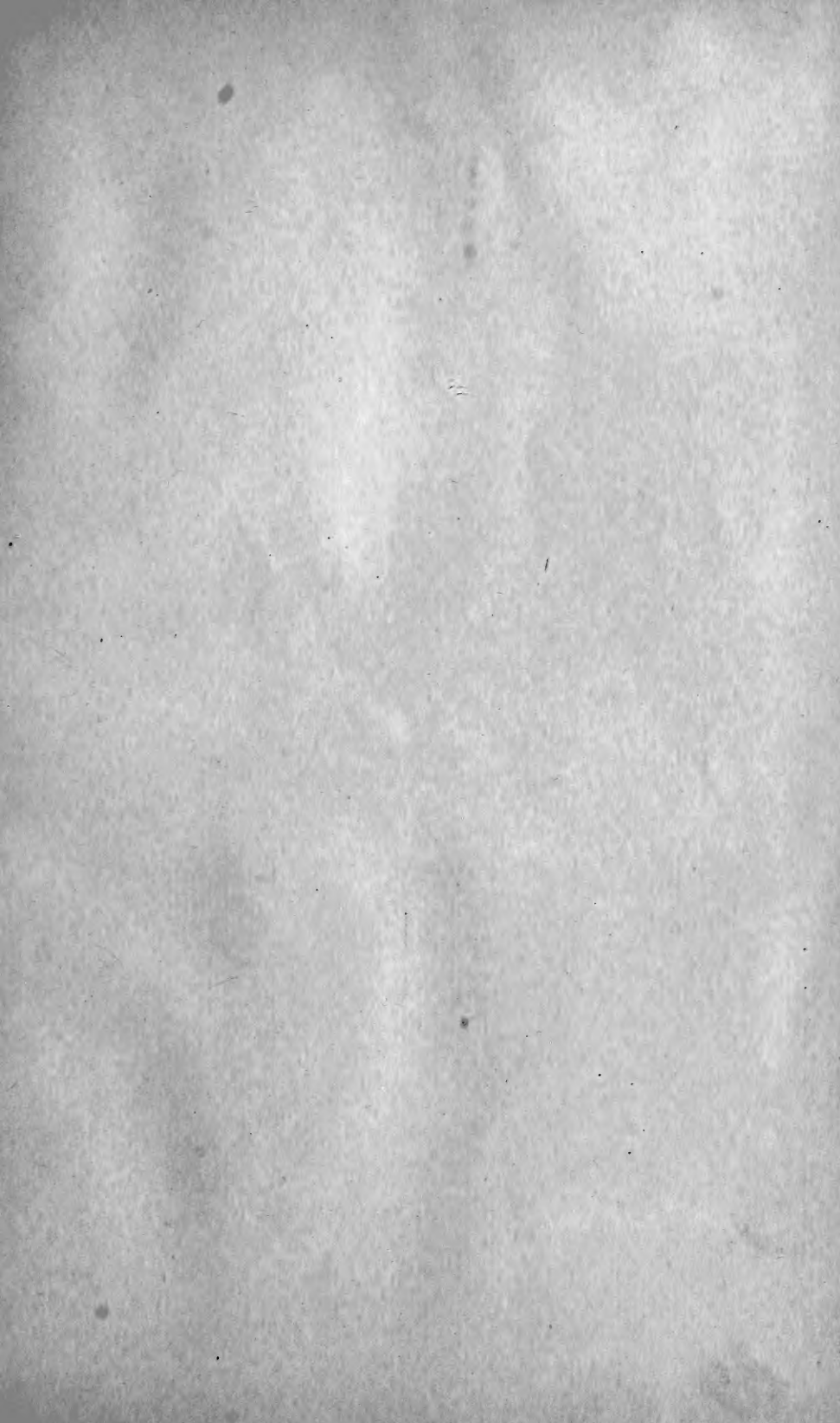
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SOUTH CAROLINA

PHOSPHATES









# SOUTH CAROLINA PHOSPHATES.

## A LECTURE

DELIVERED BEFORE

THE AGRICULTURAL SOCIETY OF SOUTH CAROLINA,

Charleston, S. C., December 12, 1879,

BY

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WITH

A MAP OF THE SOUTH CAROLINA PHOSPHATIC DEPOSITS.



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## SOUTH CAROLINA PHOSPHATES.

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*Ladies and Gentlemen*—It is with extreme diffidence that I appear before you to deliver an address on Carolina Phosphates. The subject is so familiar to Charlestonians, so thoroughly understood in its various branches by many whom I have the honor to recognize here, and yet so comprehensive in its scope—embracing both science and practice—that I am very naturally at a loss how to approach it, and to what aspects to confine myself.

It is because of this diversity of interest and information on the part of many present, and for the sake of our guests from the interior who may desire a general review of the entire subject, that I ask your kind attention while I briefly consider as many of the more important questions involved in our topic as the limited time permits, begging your indulgence if the matter presented savors too strongly of the chemical laboratory.

### THE GEOGRAPHICAL OCCURRENCE OF THE CAROLINA PHOSPHATES.

The coast of South Carolina presents few elevations of consequence, it being very nearly flat. In the region where the phosphates are found and worked, elevations of more than twenty feet are rare; while generally the level of the land is not more than ten feet above high water-mark. The coast line is formed by a number of projecting islands and peninsulas, separated by shallow, and sometimes broad, arms of the sea, from each other and the main land. The latter is intersected by innumerable and generally sluggish streams, whose water is either salt or brackish. The sources of these rivers are found in the middle Counties of the State, or in

extensive and frequently wooded swamps, which occupy a considerable part of the belt parallel to, and from ten to fifty miles distant from, the coast. The tide rises and falls in these streams for many miles from their mouths, their beds being exceedingly tortuous and almost level. The generally flat character of this section is conducive to the occurrence of low and wet "leads," i. e., depressions stretching up from the rivers and creeks, or from the marshes bordering the same, towards and around the higher tracts, which are generally sandy and covered with a growth of pines. These leads represent old water-courses and swamps. Their soil is deep and rich in organic matter. In places they have been drained naturally or artificially, are now dry, and have lost much of their old character; but are, nevertheless, easily distinguished from the sandy tracts. At a greater or less depth from their surface, but ordinarily within a few feet, occurs the phosphate rock. It is necessary to note, however, that the phosphate formation generally fails to occur in those deep rice-field soils which consist of recent alluvial deposits. If the rock is found under the higher sandy land, its position is deep.

The effect of such a configuration of the country upon the level of an easily movable deposit, as is that of the phosphatic nodules, can be readily understood. Where they have been long exposed to the force of running water or tides, the rounded masses have been gradually swept into the deeper levels, and have thus accumulated in the streams and bays, or they have been carried out into the ocean itself, whither these waters tend.

The geologists inform us that material changes have taken place in the elevation of this coast above the sea level; and abundant proof can be cited, that the shore lines have not always occupied their present position. Thus tidal action may have supplemented the force of river currents in moving about the nodules, or again, in changing subsequent formations, piling them up here or washing them away there, and in this manner burying or denuding the phosphatic deposit. Such superficial changes, if on a very lim-

ited scale, as compared with the vast modification of the earth's crust so often observed in other sections, have been sufficient to determine the accessibility of particular beds of rock. By "accessibility" we mean the possibility of profitable excavations so far as *depth* is concerned. This, under ordinary circumstances, would imply an average depth of not exceeding six feet of superincumbent earth for the land deposits, and for the marine or river beds not more than twenty feet of water, with an exposure of the phosphate rock on the bottom, or the supposition of only shallow sands and mud upon it.

That must, indeed, be a very level formation, and one which has exceptionally escaped subsequent disturbance, which, despite its nodular character, fails to exhibit over any considerable extent differences of level, greater than a few feet. Nevertheless, phosphatic beds are found underlying ten, twenty, or even hundreds of contiguous acres of land, over the whole of which mining is carried on at a depth not exceeding six feet, or forming the bottoms of broad and shallow water-stretches at a tolerably constant depth. But they constitute the exceptions; and naturally so, since the sinking of the level a foot or more in the case of the land deposits, or the accumulation to a like depth of mud or sand on the river beds, may put them either partially or wholly out of the category of accessible beds.

#### THE ACCESSIBLE PHOSPHATIC DEPOSITS.

Hence it follows that the outlines of any accessible bed of rock, when accurately traced on paper, must present great irregularity of contour; so also the attempt to delineate all the deposits of our section is a task involving a great expenditure of labor and time.

Whether a given bed of phosphate can be profitably mined depends upon a number of conditions, natural and artificial, as, for instance, in the case of the land deposits on—

1. The location of the tract as to the point of shipment or consumption.

2. The facilities for removing the rock.
3. The supply of water, wood and labor.
4. The quality of the rock.
5. The extent, depth to and yield of the stratum.
6. The difficulties to be encountered on excavation; i. e., the character of the overlying earth, drainage, trees, &c.

In river beds on—

1. The location, both as regards commerce and health.
2. Depth of the water and liability to storms.
3. Thickness and character of the rock-bed.
4. The possible occurrence with the rock of troublesome concomitants, in the shape of marl, oyster shells, &c.
5. Quality of rock, &c., &c.

With a view of better presenting the outlines of the regions where the Carolina Phosphate occurs *at an accessible depth*, a map has been constructed under my directions by Messrs. Simons & Howe, based on Mills' Atlas of this State and the Coast Survey's charts. Copies of this chart may be found in the State Capitol at Columbia, and in the Museum of the College of Charleston. It embraces the results of much field work; and constitutes, so far, the only attempt of the kind.

In calling your attention to this enlarged and simpler copy, (one adapted to the purposes of a lecture,) it may not be amiss to repeat the caution that the space colored light red designates those regions in which phosphate beds occur at an accessible depth. By which is to be distinctly understood, that it is only here and there in the colored portions that accessible deposits are found. You will notice that some parts of the rivers are traced in deep red. This is to signify that in those water-stretches, the rock-beds lie very favorably for utilization. To the question, "Why have not the several deposits been fully defined?" it may be replied, that complete surveys of the various mining properties have been executed in but few instances, and that where made, the owners are often averse to the publication of the results,

The territory colored red on the map represents approximately two hundred and forty thousand acres, whereas we roughly estimate the extent of the accessible deposits at about ten thousand acres.

A cursory examination of the map shows that, the phosphatic deposits extend from the head-waters of the Wando River and the Eastern branch of the Cooper, more or less parallel to the coast line, and at a distance from it of say ten to forty miles to the head-waters of Broad River. Although this section embraces the territory of active operations, whether of "prospecting" or economical development, it by no means contains the entire formation, which certainly extends into North Carolina on the North, and probably as far South as Florida; and has been observed in a few instances in the interior, sixty miles and more from the coast.

Beginning at the Northeast, you perceive the Wando River deposit, which has produced many thousand tons of small nodular rock, dark in color, dense in structure, of a high grade, and having mixed with it more fossil bones than have been elsewhere found. This nodular layer has proved eminently adapted for the use of tongs, while its thinness has prevented the remunerative employment of dredging machines. Farther inland, occurs the phosphate bed of the Eastern branch of the Cooper. This deposit contains a considerable quantity of rock, richer towards the "T" (the junction of the Eastern and Western branches,) and poorer, i. e., mixed with more sand, towards its head-waters. The extension of this bed towards the Wando River is considerable in surface, but thin. Owing to various causes, especially however, to the difficulty of access, little has been accomplished in this region.

Beginning on Back River, and stretching to the South and West across the Ashley to the Stono River and Rantowle's Creek, is the largest of all the various Carolina deposits. Land beds occur here and there throughout its wide extent, many of them of very considerable size and of excellent quality, and some of them even now under successful operation. It is especially in the region between the



Ashley and Stono Rivers that the deposit occurs over immense tracts at a remarkably uniform depth—a circumstance extremely favorable for mining operations.

The Stono River bed has been long regarded as a most successful field for phosphate workers. Here we have a favorable depth of water, whether for dredging or “tonging,” a convenient proximity to this City, an excellent nodular stratum readily worked, a quality of rock easily ground and mixing kindly with acid. All these advantages have combined to render the locality popular.

The Edisto deposits occur both in that river and on its banks. As a rule the quality is fine, but the depth lacks uniformity. Stretching across from the Edisto to the Ashpoo is a tract of country containing several more or less isolated, but extremely rich beds.

At the head of St. Helena Sound, extending up Bull and Coosaw Rivers, and underlying Chisolm’s Island between them, is a body of rock which has contributed a large share of the total yield of Carolina Phosphates. In this section, especially, we witness the results of excellent management and the abundant use of capital, superadded also to favorable natural advantages. Here has been no dearth of phosphates to be raised, nor can complaint be urged against their quality. Nevertheless any one knowing the obstacles overcome by the companies operating in this region will admit, that their success has been well deserved.

About and below Beaufort occur a number of remarkably heavy beds of phosphate; but unfortunately they are generally of an inferior grade, and must await, for utilization, better times and the exhaustion of richer deposits.

The other beds, whether represented on this map or not, do not deserve special mention in this enumeration, which is only intended to direct your attention to the prominent divisions of the deposit at large.

#### PHYSICAL PROPERTIES.

The most prominent characteristic of the Carolina Phosphate is its nodular form. Even where the deposit occurs

as an apparently smooth and compact floor, or in large flat cakes, it is nevertheless composed of irregular nodules, partially cemented or tightly compacted together. The shape of the nodules is egg or kidney-form. The exterior is rough and indented, often perforated or even honey-combed by round or irregular holes and cavities, or it is smooth and compact. The surface is occasionally shiny and coated, as it were, with an enamel. The masses are wholly devoid of crystalline structure or cleavage, exhibiting occasionally, however, an imperfect lamination. Well preserved casts of Eocene shells occur throughout the phosphate rock; and fossil fish-bones and teeth are not unfrequently found embedded in them. The nodules vary in size from a fraction of an inch to several feet in diameter; in weight from almost a ton downwards. The specific gravity of the dry and clear rock varies from 2.2 to 2.5, the average being about 2.4. The color of the land rock is generally lighter than that found under water or marsh-mud; the former having a yellowish or grayish-white color, the latter a gray or bluish black. The hardness of the average rock varies from 3.5 to 4. The masses are easily broken and readily ground to a fine powder, whose color is light yellow or gray; and whose fineness may allow of its floating in air (the so-called "dust"). The structure of the rock is so porous, that when previously hot-air dried, it can absorb from five to fifteen per cent. of water. Carolina Phosphate gives on friction of its fresh surfaces, a peculiar fetid odor, termed by some naphthous. This property is, as a rule, the more decided the denser the structure, and the higher the content of organic matter.

#### CHEMICAL ANALYSIS.

The phosphate rock of our section can hardly be termed a mineral species, lacking that essential claim to such consideration—uniformity of composition. Not only do the several beds differ in this respect, but even in the same locality, it is easy to distinguish by the eye marked variations of color and structure; and when the separate masses

are subjected to chemical examination, the difference is still more apparent. But viewing the subject from a commercial stand-point, equally important factors must enter into the question. We are obliged to regard in any body of rock its cleanness, i. e., how thoroughly it has been washed free from the sand, clay or mud in which it occurred; and its dryness, i. e., how much water or moisture has been permitted to remain in its cavities.

Since we are unable to present a typical composition for the South Carolina Rock, we must content ourselves with a general statement of the average amount of each of its more important constituents, premising of course, that we are considering clean and dry samples of what may be regarded as fair to excellent qualities. As the result of many hundred analyses, the following percentages may be given :

	Per ct.	Per ct.
Phosphoric acid (1).....	25	to 28
Carbonic acid (2).....	2½	to 5
Sulphuric acid.....	½	to 2
Lime.....	35	to 42
Magnesia.....	traces	to 2
Alumina.....	do.	to 2
Sesqui-oxide of iron.....	1	to 4
Fluorine.....	1	to 2
Sand and silica.....	4	to 12
Organic matter and combined water.....	2	to 6
Moisture.....	½	to 4

(1) Equivalent to bone phosphate of lime 55 to 61 per cent.

(2) Equivalent to carbonate of lime 5 to 11 per cent.

In addition to the ingredients mentioned, sodium, chlorine and occasionally other elements occur in small quantities. Iron-pyrites, rarely found beyond one per cent., is included under the estimate of sulphuric acid and sesqui-oxide of iron. The organic matter is nitrogenous, containing occasionally as high as a quarter per cent. nitrogen.

## THICKNESS AND YIELD OF THE PHOSPHATIC STRATUM.

The thickness of the nodular stratum varies from a few to almost thirty inches—the latter depth being very rarely observed. Ordinarily it is from six to fifteen inches, and averages about eight. Where the deposit exceeds fifteen inches in thickness, the depth rarely extends beyond a limited area, and is generally due to a local accumulation, or it is the result of the accidental superposition of a few large nodules. The yield per acre of clean and dry rock varies from three hundred to twelve hundred tons. Instances have been noted of a greater yield, but these were probably in every case quite limited and exceptional. Under ordinary circumstances of occurrence and quality, deposits of less than five hundred tons to the acre do not prove remunerative. The average yield of land-beds now worked is seven to eight hundred tons to the acre.

The yield per acre stands in a certain ratio to the thickness of the stratum; but not invariably so, as the compactness of the phosphatic seam plays an important part in determining the amount of production.

The remarks made in explanation of the map indicate how uncertain must be the attempt to estimate, even approximately, the quantity of phosphate rock in South Carolina, which, at the average price in the past, might be profitably raised.

When an accurate and comprehensive survey of the entire region has established the extent of the beds, their yield per acre, their quality and the cost of excavation and delivery on ship-board or alongside the factory, *then* will it be possible to answer this question.

Nevertheless, since others have not hesitated to express their individual estimates of this quantity, it may be proper for one who has given no little time to explorations in the field to record his opinion also.

As to the result of my field-work, and the calculations based thereon, I should say that the total yield of all the known phosphatic deposits of South Carolina, of merchant-

able quality and accessible position, would not exceed five million tons.

#### THE EXCAVATION OF THE LAND-DEPOSITS.

Pick and shovel suffice for the working of the land-beds. The usual procedure is the following :

A trench is dug across or on the side of the tract to be mined—the natural drainage of the field being kept in view. This is carried below the nodular stratum, and serves as the starting point of operations. The superincumbent soil and earth is thrown behind the laborers, the rock-bearing seam in front on the undisturbed soil, whence it is put in cars or carts to be dragged by steam or mules, usually over an iron road, to the “washers.” The manual labor is performed by blacks, under the supervision of whites; and if at times unreliable, is with proper management, quite satisfactory. The blacks are usually employed on “task” work; and under ordinary circumstances, produce half a ton of rock to the man, per diem.

When trees or stumps are encountered, they are usually undermined; and then pulled over upon the excavated side of the trench. Owing to the level character of the country, it frequently occurs that ordinary ditching is inadequate for maintaining the trenches in a condition sufficiently dry for uninterrupted work; and consequently steam-pumps have been of late introduced to overcome this difficulty.

The separation of the rock from the accompanying earth, and its thorough cleansing from adhering matter, is effected by subjecting it to a preliminary washing in an inclined, perforated iron cylinder or trough (a step rarely resorted to), and a coarse crushing, either under the blows of a sledge or by machinery which regulates the size of the fragments with but little pulverization. It is then treated to a thorough cleansing in long “washers,” constructed of wood or iron, in whose axis revolves a shaft armed with projecting steel teeth, which slowly move the nodules up the inclined bed of the

trough, and against a copious (descending) stream of water. Or a "cylindrical washer" is employed, consisting of a rotary cylinder, to whose sides are attached spiral flanges of iron, and through whose axis runs a perforated pipe, distributing a powerful stream of water. The flanges keep the rock rolling, and all the while slowly ascending the inclined tube.

These arrangements permit the rock, as it becomes free from adhering matter, to be brought in contact with fresh portions of water. From the upper end of the washer the clean rock falls out upon an iron grating, which separates the masses of a proper size from the finer stuff (the so-called "tailings," frequently containing coarse gravel). The clean rock is transported in cars or barrows to the receiving or drying sheds. The capacity of a washing machine is fifty tons or more per diem of ten hours, according to its size and the character of the seam of rock being mined.

#### HOW THE RIVER BEDS ARE WORKED.

The phosphatic deposits situated in the river beds, or on the bottoms of the extensive and shallow arms of the sea so frequently met with on this coast, are covered by only a few feet of water, or they may lie at greater depths, and occasionally under layers of sand and mud. The manner of their excavation depends on the depth of water and the nature of the deposit.

#### HAND PICKING.

When the depth of water is not too great—some deposits running dry at low water—the rock is loosened by crowbar and pick, and then thrown into flat-bottomed scows, capable of carrying a few tons. There being no superincumbent stratum to be removed, it is sometimes possible for a gang of three or four laborers to obtain a boat-load in two tides, by commencing operations a couple of hours before low water, when the water is waist deep, and continuing their work for a like period after the turning of the tide. The

localities favorable for this description of mining are few, and are best worked during the summer months; but they have yielded an immense quantity of rock at a moderate cost.

The boat-loads are discharged either at the shore or alongside large lighters; and the rock is subsequently crushed and washed in the usual manner. The oyster shells and other foreign matter, which are occasionally found in these shallow beds, are carefully thrown aside.

Other deposits lie too deep to allow of their being worked after this fashion; but are within the reach of oyster-tongs, which grasp and raise the nodules if they are loose.

Or, again, it is not unusual to observe the laborers diving into water six to ten feet in depth, and bringing in their hands to the surface masses of rock of such size as to require the strength of two men to place them in the flats.

It was an exciting spectacle some years since, to witness the hundred phosphate-flats moored closely together, near the confluence of the North and South Wimbee Creeks, teeming with blacks, naked and vociferating, brandishing their tongs and poles, or swimming about in the surrounding water. The low, marshy banks, dotted with palmetto clumps, formed the background to a picture that suggested some of Stanley's African experiences.

#### DREDGING.

A very considerable part of the Carolina Phosphate is excavated by dredging boats from deeper waters, where it lies bare on the bottom, or sometimes covered with several feet of sand and mud. These powerful machines work best in about twelve feet of water, but have been employed in double that depth. Their strength is adequate to tear up the thickest and hardest phosphate beds. Under favorable circumstances, they can daily raise one hundred tons of rock. The "dipper" of the dredging machine empties its load of rock, marl, mud and sand on a grating, or into a preliminary conical "washer," where it is subjected to a heavy stream of



water, which carries off the greater part of the mud and sand, thereby enabling the operatives to detect any pieces of marl, sandstone or oyster shells that may be mixed with the rock. These are picked out and cast aside. The partially cleaned rock then falls, or is cast by machinery, into a "crusher," and thence into the second "washer," where the fragments are thoroughly cleansed from remaining impurities. The washing apparatus employed in the preparation of the river rock consists of either upright and cauldron-shaped, or the "shaft" washers previously described. They discharge the washed rock upon lighters for transportation to the drying sheds, where it is heaped upon and around a system of perforated iron pipes, which conduct hot air (driven from an oven by a fan) through every part. A few days' continuous drying is sufficient to expel all the moisture from the originally saturated rock.

*Hot-air-dried* cargoes constitute more than half of the rock now delivered in South Carolina; and the fact that the local fertilizer factories are supplied with the means of drying their purchases of phosphate has alone prevented the yet more general adoption of this practice. Where these appliances do not exist, resort is had to sun-drying, i. e., exposure to the hot sun and subsequent storing under sheds—a method limited in its applicability and unreliable.

A simple heaping up, though it be under cover, does not suffice to expel all the absorbed water, not even when the rock is allowed to remain in pile for a long period. The whole mass may contain several percentum of moisture, notwithstanding the surface of the heap appears quite dry.

Finally the rock may be "screened," i. e., rolled over a sieve, before its shipment. This step in the preparation—unfortunately seldom carried out—separates a considerable quantity of finely broken material.

#### THE PRICE AND PROFIT.

The price of South Carolina Phosphate naturally varies according to the usual conditions of supply and demand;

but it has been also unnecessarily and unfortunately affected by a lack of concert on the part of the wealthier corporations engaged in mining the rock, and by the exigencies of the needy, who have been forced to sell their product as fast as raised, in consequence of an inability to hold it for better times.

The price has ranged of late years from five to eight dollars—averaging about six dollars per ton. The foreign purchases are based almost wholly on the content of bone phosphate of lime, as reckoned from the percentum of phosphoric acid, at a stipulated price per unit, or at a guaranteed percentum, usually fifty-five per cent. of bone phosphate. The domestic transactions are, on the contrary, very lax, being frequently free from all conditions as to cleanliness and moisture—a round sum per ton constituting the trade. With advancing experience in the business, and a closer attention to economy, the American buyers must discover that it is suicidal to disregard the chemical composition of the *basis* of their products, which are sold on the percentage of an ingredient derived from it.

Contrary to expectation, it has been found that few engaged in raising our rock have reaped any profit; and, it may be added, that many have met only with loss and failure. There were many lessons to be learned and much costly experience to be gained. An entire ignorance of the mining operations, the difficulties of a new system of labor (the industry having been established during the troublous Reconstruction period), an inadequate appreciation of the commercial and chemical requirements, a lack of capital, and high prices for freights and materials—all these and yet other drawbacks, told against the pioneers.

Next possibly to the generally unexpected decline in the English consumption, the greatest obstacle of late years to a thrifty condition of the phosphatic industry has been the vacillating legislation on this subject by the General Assembly of the State. Unfortunate as this has been in its direct results, there is no question that a fear of what form such adverse action might assume has restricted the investment of capital in lands and mining operations.

As a rule, it has cost less to mine the river beds; but, as the more accessible ones approach exhaustion, the advantage will probably favor the land deposits. Hitherto the companies operating in the rivers have especially enjoyed the popular reputation of success; but, owing to great expenses and competition at home and abroad, it is to be feared that the profits have been small in all but a very few instances, whether on land or water. If we were able to ascertain the total amount of money that has been invested in lands, machinery and working capital during the prosecution of mining operations, and then that of the actual dividends and profits earned, it is to be apprehended that the exhibit would be far from encouraging.

A year ago, when the annual production exceeded two hundred thousand tons, and the demand was excellent, it seemed possible for both the land and river mining companies to clear a reasonable, not to say handsome, profit. Unhappily, as all know, this state of affairs was of short duration.

No one, however, will question the advantages that have accrued to the State from the large payments in royalty, nor those enjoyed by thousands who have found in this industry a profitable employment or support. The total royalty of one dollar per ton, received by the State on the production from the river beds (as kindly communicated by the Comptroller-General), amounted on the 1st of September, 1879, to \$546,965.75.

The total production to date of all the Carolina deposits may be safely estimated at almost one million five hundred thousand tons, which, valued at six dollars per ton, would represent \$9,000,000 received and generally retained, in this State.

There are rich and poor in phosphate mining as in other things. Some of the companies have expended from one-half to a million of dollars in the purchase of lands and the equipment of their "plants." Their works, when in full operation, give employment to several hundred hands each; and are models of order and adaptation. There are also not a few operating on the river beds, under the new license law,

who bring little else to the work than their own energy, and, perhaps, the outfit of a small phosphate craft. All have been equally rich in expectations.

Among the advantages possessed by the South Carolina Phosphates are :

1. That most of the phosphate beds have convenient points of shipment for whole cargoes, or the rock may be forwarded from Charleston, Port Royal, or Savannah, at a lower rate, in ballast under cotton. Some of these ports have sufficient water for ships of two thousand tons burden, while the rest are generally situated on streams navigable for schooners and other light draft vessels. A few miners use the railroads crossing the phosphate belt for the transportation of their product to deep water.

2. The proximity of the beds to the field of greatest consumption on this continent, viz: The Southeastern States, which annually consume over two hundred thousand tons of commercial fertilizers. As competition reduces the profit on the manufactured articles, it will be found necessary to manipulate the crude rock here, thus avoiding the expense of two freights on the phosphate.

3. Commercial phosphatic manures consist very generally of superphosphates (i. e., ground phosphates treated with sulphuric acid), containing from ten to thirteen per cent. soluble phosphoric acid, to which may be added ammoniacal matter and potash salts.

For the manufacture of such articles the South Carolina Phosphate Rock excels, and for the following reasons: It is cheap. It is remarkably free from gangue rock and other impurities. It is readily ground to that impalpable fineness which is indispensable for its complete decomposition by sulphuric acid. It contains little flouride of calcium, and consequently yields on its treatment with acid, less noxious fumes than is the case with apatitic phosphates. The superphosphate made from it dries readily, and is light in color and weight. It may be easily made to contain the amount of soluble phosphoric acid required in commerce, and this in-

gradient is subject to less reversion than takes place in most of its competitors.

4. Its physical structure and chemical composition favor its resolution (without the intervention of sulphuric acid) by the natural solvents of the soil; and consequently the assimilation of its constituents by plants takes place more rapidly and effectually than occurs with most other mineral phosphates.

#### THE POSITION OF THE ACCESSIBLE BEDS, AND THEIR RELATION TO THE UNDERLYING STRATA.

The ordinary occurrence of the superficial beds of phosphate—those now worked—may be thus stated:

##### A—*Land Deposits.*

I. *Soil and Subsoil*—A few inches to a foot in depth.

II. *A Light-colored Siliceous Clay*, iron stained in places, and containing much fine transparent sand and minute scales of silvery mica, with little calcareous matter—One foot or more in thickness.

III. (Wanting in the more superficial beds)—*A Blue Argillaceous (clayey) Marl*, probably altered marsh mud. It does not adhere to the tongue or give an argillaceous odor. Fragments of recent shells occur in this deposit—Its depth is about two feet.

IV. *A Thin Layer of Coarse Sand*—One to three inches in depth.

V. *The Phosphate Nodules*, in either a loose siliceous or a tenaceous, bluish or rich buff colored argillaceous marl, frequently accompanied with abundant fossil bones and teeth. The upper nodules are often harder, the lower softer, and at some land localities exhibit a gradual transition, by loss of cohesion and decrease of phosphatic content, into

VI. *A Marl*, highly phosphatic towards the rock-bed,

and occasionally containing twenty to thirty per centum of phosphates, but at the depth of a few inches containing only ten to twenty per centum of those constituents.

VII. *Argillaceous or Arenaceous (sandy) Marls*, containing seven to ten percentum of phosphates.

B—*River Deposits.*

Beneath the river deposits occur either

I. *A Gray Marl*—Sometimes in nodules resembling phosphate, with five per centum of phosphates, underlaid by

II. A white hard marl, enclosing phosphatic grains, and containing three to five per centum of phosphates (Wando River); or

I. *A Green Sand*—With some clay, and rich in black phosphatic grains, occurring with and beneath the phosphatic rock containing fifteen per centum of phosphates.

II. *Soft and Hard Marls*—Several feet in thickness, and containing ten to fifteen per centum of phosphates (Stono River); or

I. *Hard Marls*—Poor in phosphates, (one-half to one per centum) unless their tops be coated with phosphate rock. (Coosaw River.)

#### DEPTH OF OCCURRENCE OF THE UPPER DEPOSIT OF PHOSPHATES.

The depths at which the upper nodular phosphatic stratum occurs are variable. In some places the bed crops out in the top soil; in others it is found at ten to twenty feet, and even greater distances (under this City at sixty to seventy feet) from the surface. Whether the nodules underlie the whole of the region between the various known beds can be determined only by an extensive and costly system of borings, as yet not attempted, and probably never will be,

unless at the expense of the State government. Hitherto whatever information has been gained in regard to this remarkable deposit, so full of interest to the people of this State, and to Science, is due to private enterprise. Thus far not a single investigation towards the solution of the scientific questions involved, has been instituted at the expense of the State.

It may be added that it seems probable, even where in this region the customary prospecting has failed to reveal the existence of the phosphate deposit at easily obtainable depths, deeper explorations might lead to their discovery, excepting, however, those sections where moving water has removed the nodules.

#### UNEQUAL CONTENT OF PHOSPHORIC ACID IN DIFFERENT PARTS OF THE SAME NODULE OR MASS.

A marked difference in the content of phosphoric acid between the upper and lower surfaces of the same flat mass, or between the rind and core of the same phosphate rock, is frequently to be observed. There occur in company with the ordinary commercial phosphate, especially in the Coosaw and Bull Rivers, large masses of marl, several inches to a foot in thickness, presenting the same fossils as the phosphate rock and the underlying marl, whose top is covered with a coating of phosphate, and whose inferior side is chemically almost identical with the ordinary marl. Between the physical and chemical characteristics of the two sides there is a gradual transition.

At some localities—as in the Ashepoo region—where flat cakes of rock lie so compactly together as to form an almost unbroken floor, the dissimilarity between the top and bottom of the bed is very striking. The former, which is the richer of the two in phosphoric acid, is smooth and “enamed;” the latter granular, jagged and honey-combed with cavities that penetrate almost to the top of the deposit.

Again, certain nodules, of not unfrequent occurrence, exhibit a noticeable difference as regards the content of phos-



phoric acid in the superficial layers and the core. Actual investigation has demonstrated that the shiny enamel-like rind contains several per centum more of phosphates than the centre. This difference is more marked in those nodules whose internal portion is less compact than the external. In these cases there is far more carbonate of lime within, occasionally approximating it to the marl itself.

#### THE CHEMICAL COMPOSITION OF THE STRATA UNDERLYING THE PHOSPHATIC LAYERS PREVIOUSLY DESCRIBED.

Several opportunities have been afforded during the past ten years for securing specimens of the deeper lying formations, in consequence of the boring of a number of Artesian Wells in this City and neighborhood.

The samples thus collected have been carefully examined and analyzed; the most important contribution to our knowledge being the discovery of the existence of several deeper layers of phosphate rock occurring to the depth of three hundred feet from the surface, and in the form of isolated pebbles to a much greater distance. These lower deposits are probably not thicker than a few inches, and consequently they lack all but scientific interest.

#### THE SOURCE OF THE PHOSPHORIC ACID CONTAINED IN THE UPPER BED OF CAROLINA PHOSPHATES.

It is clearly beyond the scope of this lecture to enter into a discussion of the many interesting theories that have been advanced by different scientific men concerning the geology of the South Carolina nodular phosphatic deposit. Various suppositions have been propounded in regard to its origin.

At this moment, with the additional light shed by recent observations, I am inclined to accept the opinion advanced by that enthusiastic student, Professor Francis S. Holmes; for a fuller account of whose views I must refer you to his pamphlet published in 1870. (*The Phosphate Rocks of South Carolina; their History and Development*, Francis S. Holmes, Holmes' Book-House, Charleston, 1870.)

Professor Holmes regarded the nodular phosphates as detached masses of Eocene marl, torn off by the action of waves from the great mass of this formation, and swept inland over the sand bars, which (as also the great marl bed) were covered by the waters of the ocean, to be deposited in those shallow bays and salt water lakes that are now the phosphatic region of South Carolina. I will not dwell on his fundamental argument, viz: that the internal structure of the marl and the phosphate is identical, containing (as they do) the same casts of fossil shells and the same remains of marine vertebrates embedded in them, but proceed to the consideration of his views concerning the phosphatization of these masses.

Professor Holmes advanced the theory that, on the elevation of the shore of this continent, these salt water bays or lakes became lagoons frequented by land animals, whose fæces and remains, augmented by those of others transported by various streams into the same receptacle, were the cause of the conversion of the carbonate of lime, constituting the marl masses, into the highly phosphatic character of the nodular rock which we mine.

We find occurring with the phosphatic stratum, *but never imbedded in the nodules*, the teeth and bones of a number of species of land animals, some of them now extinct, viz: those of the mastodon, elephant, horse, deer, megatherium, rhinoceros, tapir and others. Frequent are the osseous remains and coprolites of many extinct marine animals, some of them of great size, viz: those of several species of saurians, sharks and whales, whose deposition must date back to the period when comparatively deep salt water covered this region.

If we regard the beds of phosphate from a chemical standpoint, we may find additional proof in support of these opinions.

The decomposition of a mass of animal remains superimposed upon the marl-nodules, would cause the production of carbonic acid and the solution of the phosphates originally contained in the animal matter, in water percolating through

the layer. As this solution penetrated into the carbonate of lime of the marl masses below, the phosphoric acid would be detained there, and the carbonic acid, whether of the original solution or of the marl, would be carried off. Under such circumstances we should expect to find the greatest phosphatization at the point of contact; and such is the case, it having been remarked that the top of the stratum—especially when it formed a floor and has been but slightly disturbed—is the richest in phosphoric acid, and where the marl occurred in nodular masses the rind is richer than the core.

Again, this theory explains the gradual transition from hard phosphate rock, through soft rock to the feebly phosphatized marl, which is itself much richer in phosphates than the parent Eocene marl occurring at greater depths below. This phosphatization was accompanied by a hardening of the previously softer marl masses, which became denser in proportion to the completeness of the change; it cemented together contiguous masses, giving rise to the more or less continuous phosphatic floor before alluded to, and penetrating below produced curious projections on the rock-bed, by the chemical conversion of accumulations of marl which had filled up irregularities in the top of the underlying stratum.

#### THE DEEPER PHOSPHATIC DEPOSITS.

The occurrence of other nodular phosphatic layers at greater depths has been mentioned, and we are forced to seek some other explanation for their production.

In the case of these deeper strata we have unquestionably to do with a concentration, by chemical agencies, of the phosphates contained in the surrounding marls, into more or less isolated masses or layers. Similar concretionary processes have been observed in the production of flint pebbles and nodules in the chalk of England. In fact, phosphoric acid exhibits a special proneness to concentrate whatever it is sparsely distributed through a formation per-

mitting such interpenetration. The vehicle most favorable for the exercise of this tendency is carbonic acid, either simply dissolved in water or contained in an aqueous solution of alkaline and alkaline earthy salts.

Repeated analyses, executed in my laboratory, of the waters of the deep strata beneath our feet, have demonstrated the presence of this medium, as also of phosphoric acid in the waters of certain levels.

These facts would appear as sufficient grounds for the opinion that :

*The deeper strata of phosphatic masses are the result of a concentration by carbonic acid of the phosphates sparsely distributed through the overlying marls.*

In this connection I will mention an observation made at Sineath's Station in the case of the deeply occurring phosphatic nodules and pebbles, viz: that they lie beneath layers of argillaceous marl. The inference is that these last were muddy bottoms, receiving (phosphatic) animal matter from shore and sea, and that they subsequently underwent a lixivation into the underlying stratum, similar to that before described as occurring in the great upper deposit, which converted the Eocene nodules into phosphate rock.

Where the phosphatic masses are a fine sand or pebbles, presenting every appearance of having been subjected to rolling and attrition, there seems no other explanation than that they were once lying at the bottom or sloping shore of the ocean, and were afterwards covered by subsequent formations.

#### THE HISTORY OF THE DISCOVERY.

Neither is it my intention to dwell on the history of the discovery and utilization of the South Carolina phosphatic deposits, more than to direct your attention anew to the fact, already noted in the literature on the subject, that their value was surmised even before the war, and that their

manipulation was prevented before and immediately after that struggle, only by fortuitous circumstances.

Interesting as the topic is, its due treatment would necessarily tax your patients, and any cursory review of the claims advanced in favor of the several gentlemen who are credited with having first discovered the existence and value of these beds would be eminently improper on such an occasion. The subject has frequently appeared on the pages of various papers and pamphlets, and to them I would direct you for your instruction and judgment.

#### THE PRESENT DEPRESSION.

But, on the other hand, it seems quite appropriate to call your attention to the present depressed condition of the phosphatic industry; and to consider the possibility of its recovery, as also what measures would appear to conduce to that desired end.

The cause of the general depression in South Carolina Phosphates was unquestionably *over-production*. The immediate occasion was a decline in the English consumption, the result of agricultural disasters in that country. It is well known that the condition of the English farmer has been rapidly passing from bad to worse during the past few years. To hard times, high rents, increased taxation, the extensive importation of American agricultural products and their sale at a price which defied competition, were added unpropitious seasons and scanty crops. The farmers became dispirited, and shrank from outlays for commercial fertilizers that previously had been regarded as essential; and the dealers were disinclined any more to put out their wares on the customary long credit.

This condition had been gradually developing for some time; but it was a most disastrous harvest that created the panic and brought matters to a crisis. Manufacturers of fertilizers became alarmed; they seriously questioned the ability of the farmers to pay for what they had received, and doubted the safety of maintaining their production. They

were disposed to ask the cessation or reduction of existing contracts for crude phosphates, much less were they willing to assume new ones. A stagnation in the phosphate market followed of course, with a tumble of prices. Phosphates less popular than the Carolina went begging in vain for a purchaser at any price, while our own severely felt the shock. A few high grade articles would appear to have suffered only a reduction of price, not of quantity. Foreign shipments fell off, and phosphate rock was thrown in large quantities on the American market at its worst season. Some richer or more favorably situated companies have continued their mining operations, although generally on a reduced scale. But the production, on the whole, was suddenly and very materially checked; and it has been found desirable to entirely stop several works.

The prices now obtained cannot cover the average cost of production and the interest on money invested; and it would be simply a question of capital, how long many of the miners could stand the trial. The objection may be urged that parties are to-day willing to raise rock from the river beds of the State for sale at the current rates. This fact cannot be denied; but, while they are attempting an experiment which is likely to prove calamitous to themselves, they are inflicting an incalculable injury on the entire phosphatic industry of the State, by maintaining the existing depressed price, and at the same time, in most instances, by lowering the reputation of our rock, in consequence of their inability to properly prepare it,

Let us not delude ourselves with the belief that Carolina Phosphates encounter no serious competition in the markets of Great Britain, or even of our own country. Under the favorable conditions obtaining but a few months ago, there seemed to be room for all similar materials. But now, when the demand has shrunk to very limited dimensions, we must necessarily feel the pressure of high grade articles which naturally take precedence over ours, and to the extent of their production, occupy the market. Never was the importance so manifest of not only maintaining whatever re-

putation for grade we may have earned, but of increasing it by the utmost attention to the quality and preparation of our rock. In the early days of this industry, incalculable damage was done by the shipment of dirty cargoes, from which it has cost years of effort to recover. It is true that outside opinions as to the success (or the lack of it) of business ventures are apt to be fallacious; but the statement may be risked, that in no case has prosperity favored any company or individual engaged in large sales of improperly prepared rock.

An unusually abundant harvest and the sensible retreat of hard-times in the country at large, promise an increased home demand for phosphates. Their consumption is spreading rapidly not only throughout the Southern, but also the Eastern and Central States, wherever long continued tillage has told on the natural fertility of the soil. In a few years we may expect a domestic demand for commercial manures not inferior to that which heretofore obtained in Great Britain.

Greater attention to agricultural interests, the realization of promised reforms in rent, and the wider appreciation of the necessity of the continued phosphatic enrichment of the soil must, perhaps slowly, but nevertheless surely, restore the English market to its former state. Meanwhile other competitors are either suffering in common with ourselves, or, in the case of the few preferred ones, are gradually exhausting their supply.

Let us avoid too large an accumulation of mined phosphate, which puts us at the mercy of the buyer, by limiting the supply to the demand. Let us devote greater attention to quality and preparation, thereby retaining our old customers and gaining new ones; and finally, let us live in the hope that an enlightened policy on the part of the State government may seek to support a struggling industry, rather than, by the imposition of new burdens, repel the introduction of fresh capital and crush out what vitality remains.

It is indeed a mine of wealth—this great phosphatic deposit; not only to every farmer who makes judicious use of



its products, but also to the State (if properly guarded); and to those who will apply to its development the experience of other mining industries. It is, however, no treasure heap, into which all may plunge with the certainty of gain. It is, and will continue to be, the field for the prudent capitalist, and the industrious laborer. Others had better not tempt the fate that surely follows a misconception of the difficulty of dealing with so close a margin of profit.

In conclusion, I thank you for the courteous attention with which you have listened to my remarks; and will only express the hope that the development of the phosphate beds may contribute alike to Science and the continued prosperity of the State.

## NOTES TO THE MAP.

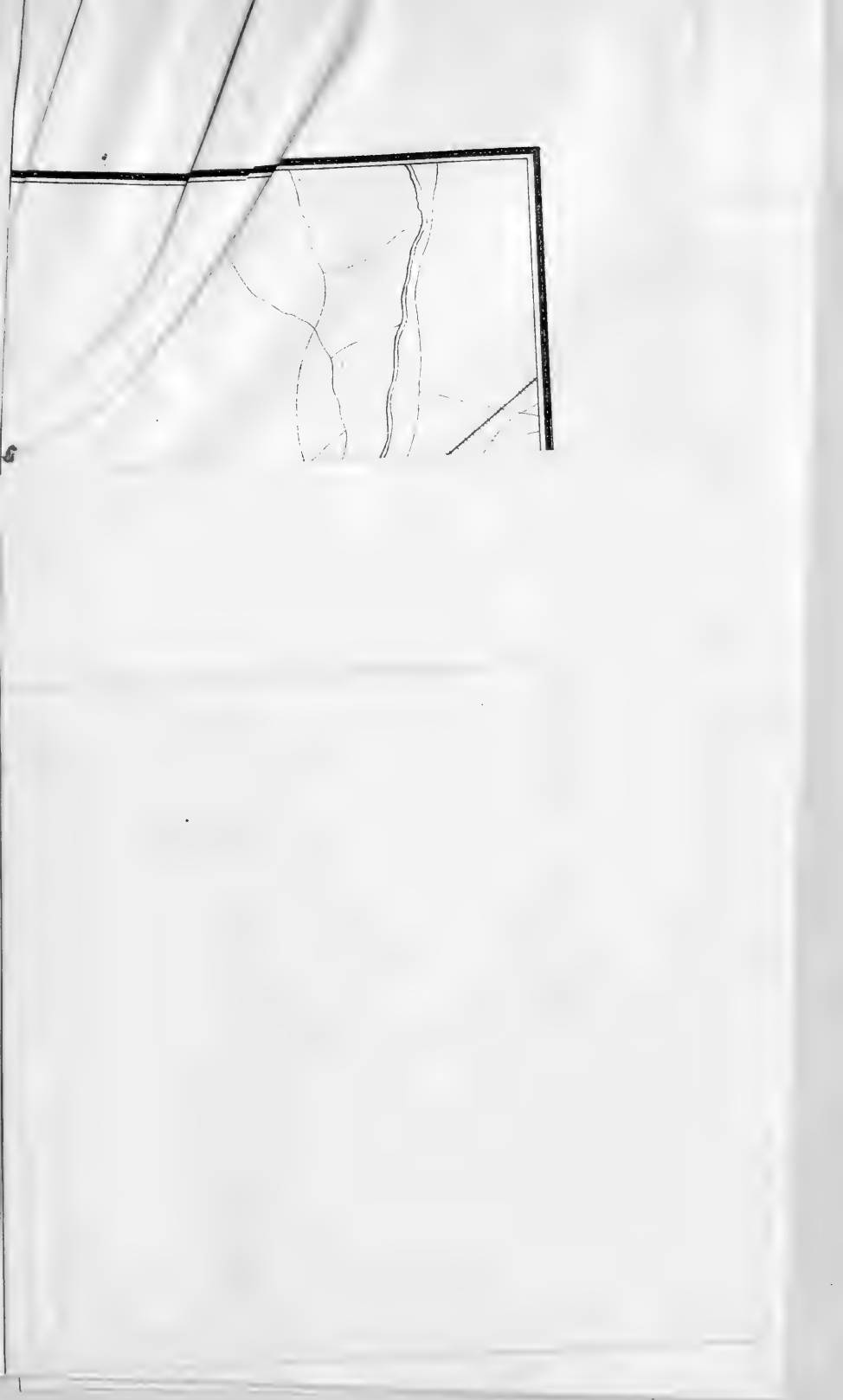
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The *red-lined* spaces designate the regions in which phosphate beds occur at an accessible depth.

The *full-red shading* in the river courses indicates the position of favorably situated river deposits.

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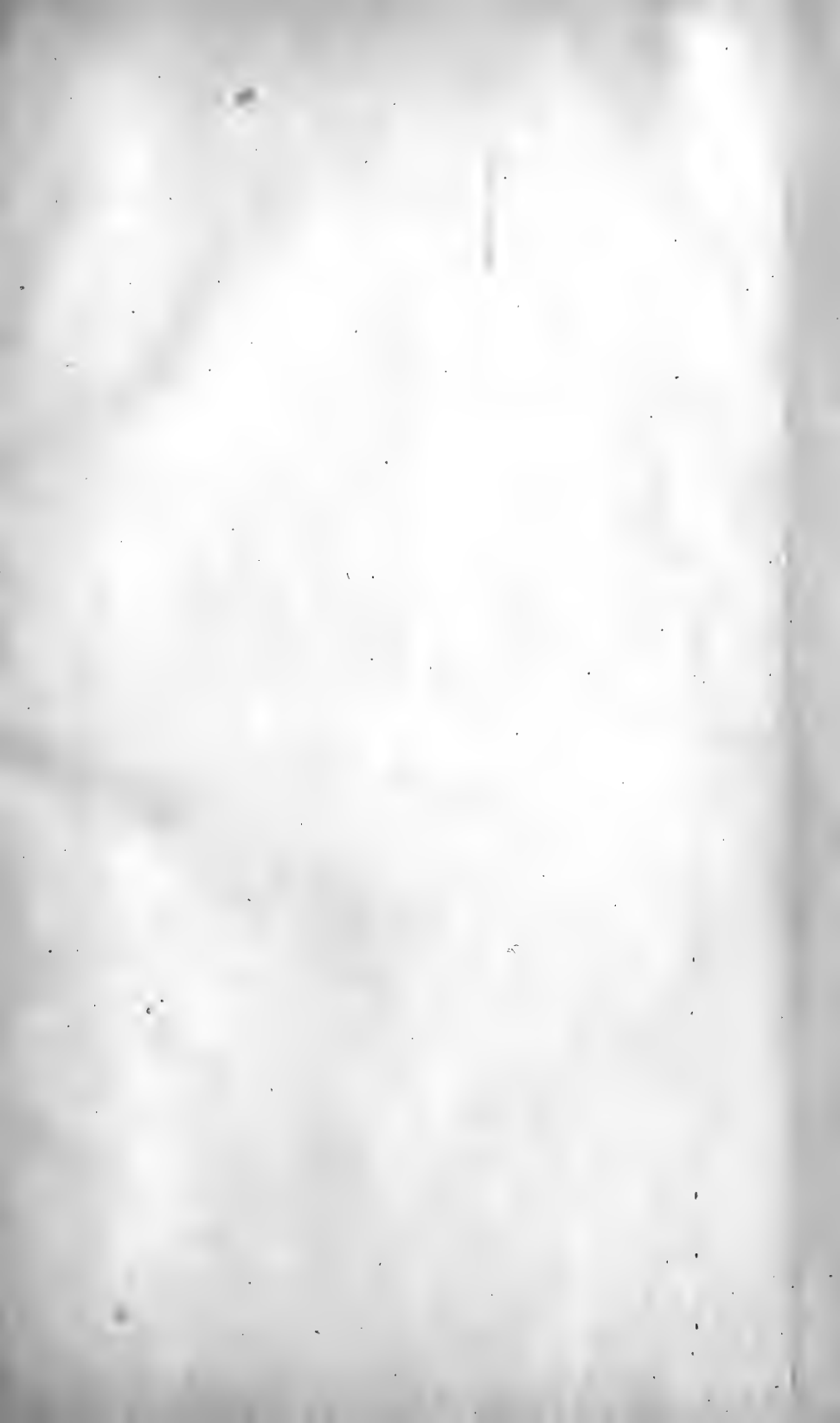
Grateful acknowledgment is herewith made for valuable assistance by Mr. George M. Wells and the late Mr. Wm. Hume Simons, during the construction of this map.

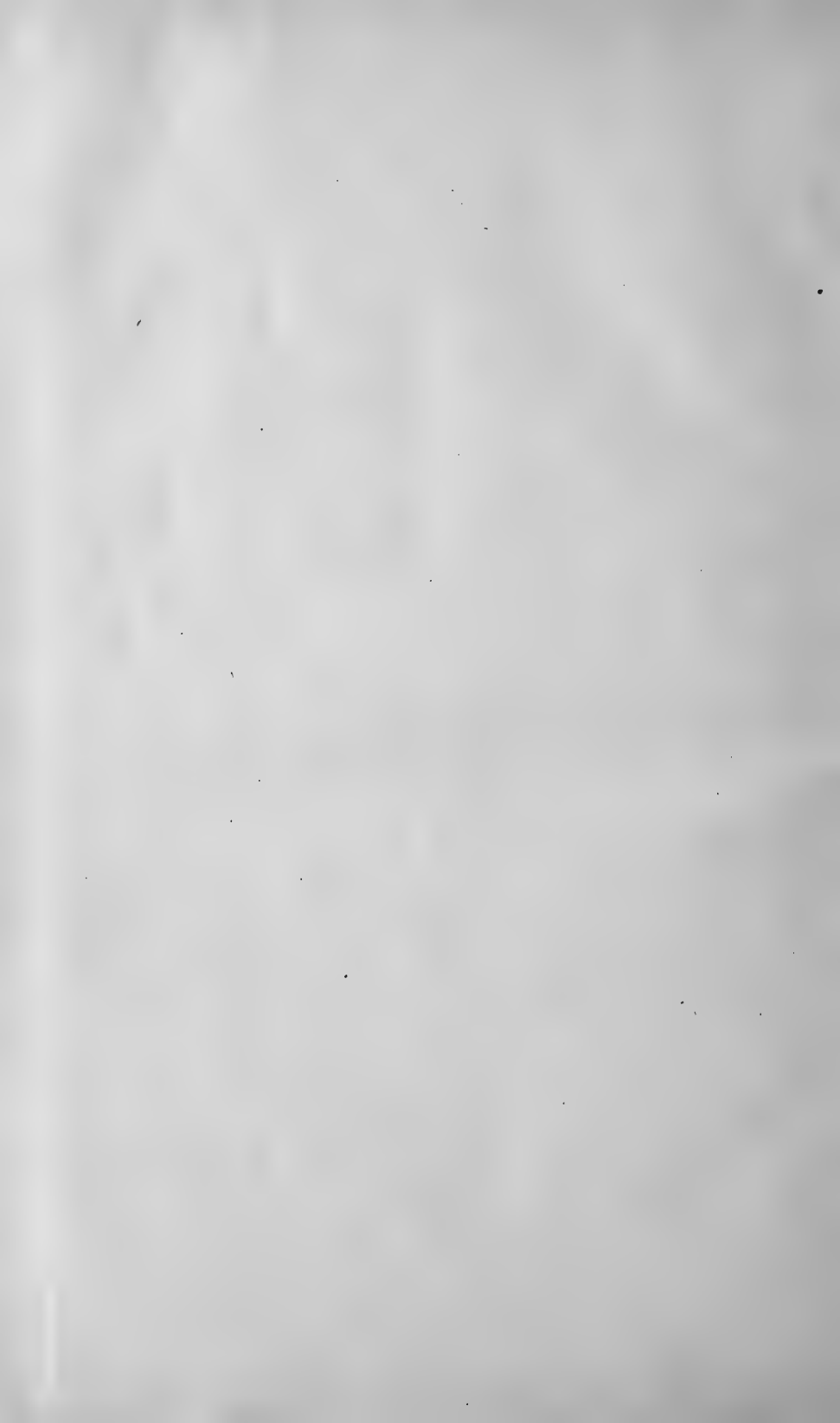




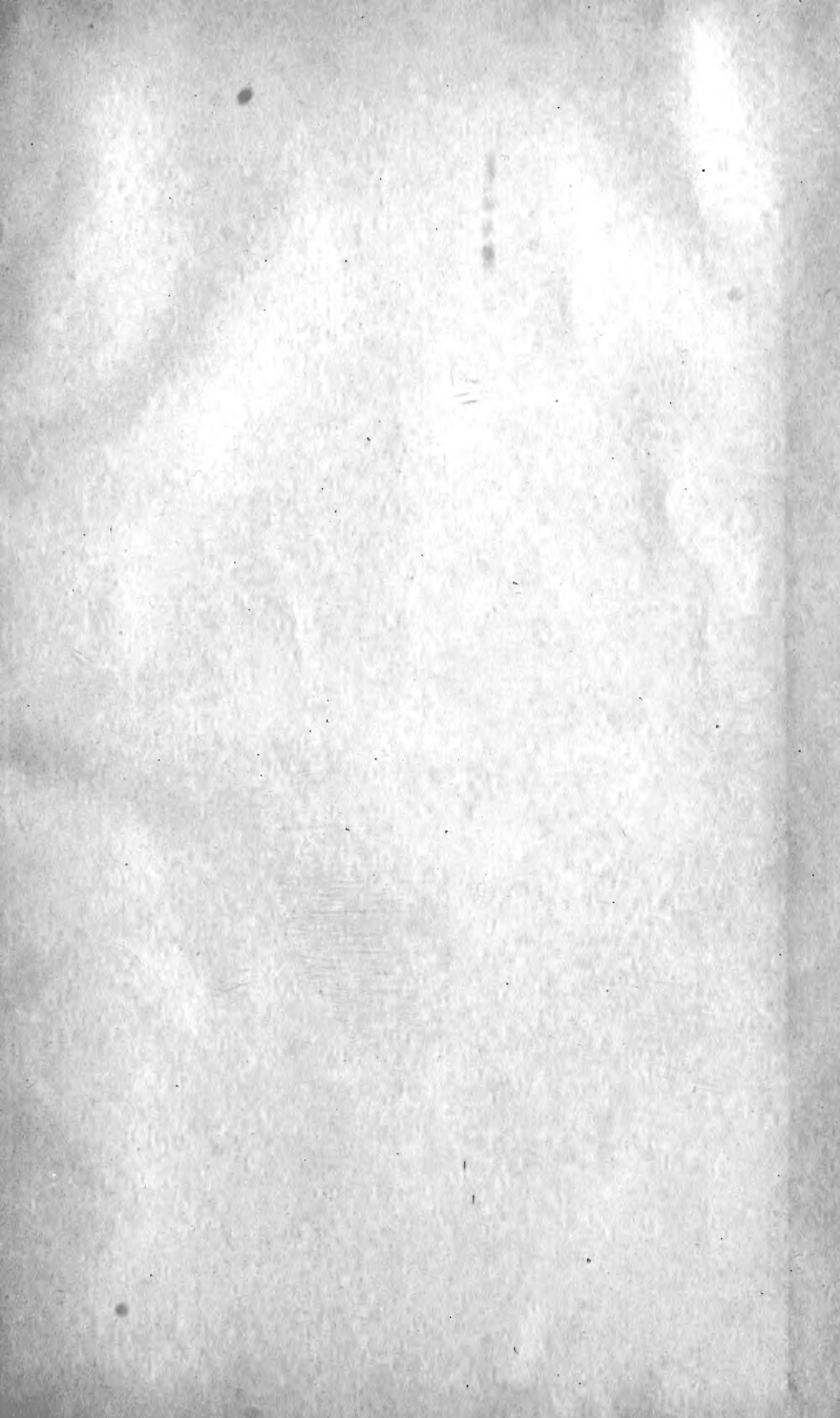




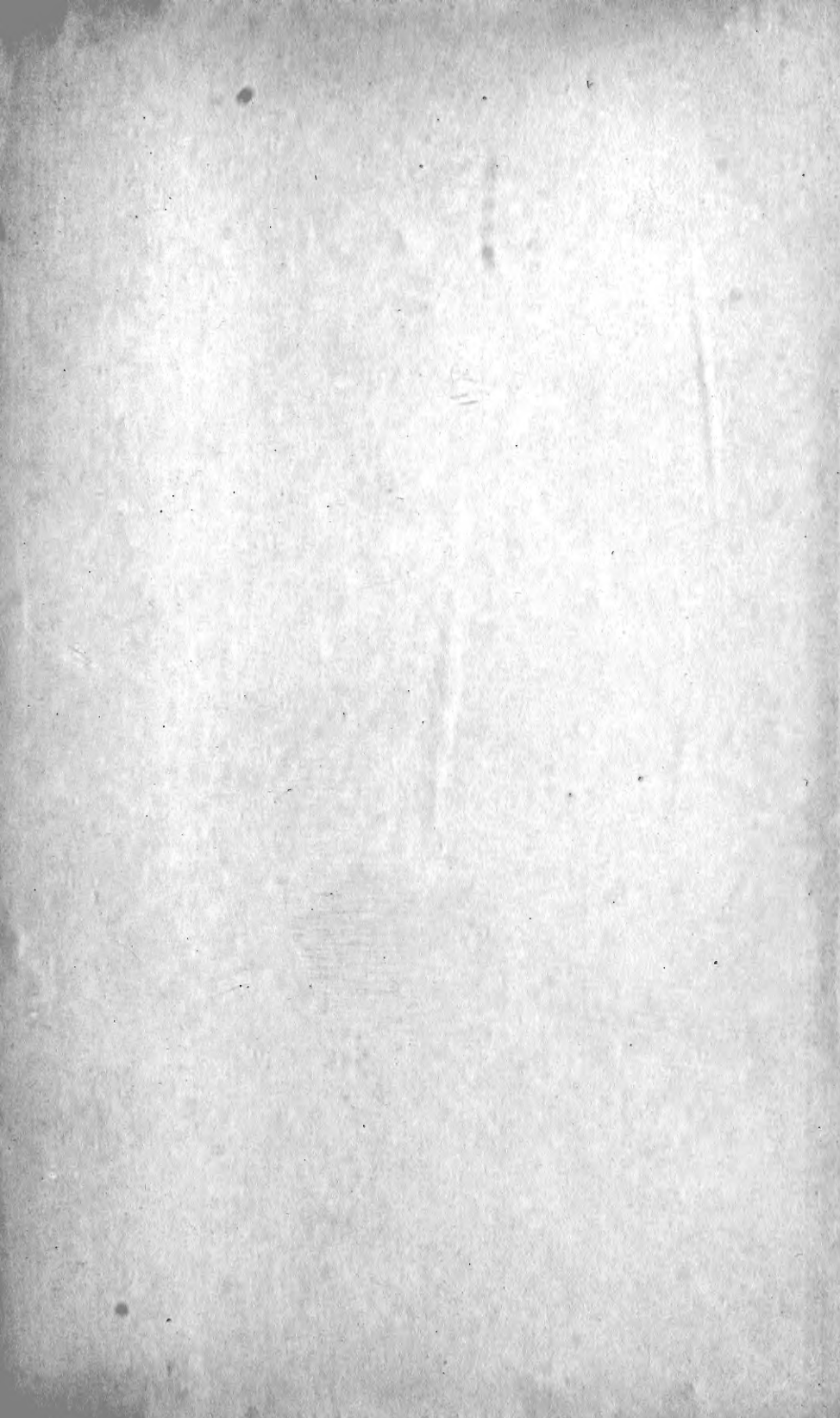












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