ART. LX.—*Notes on the Geology of Florida: Two of the lesser but typical Phosphate Fields*;* by LAWRENCE C. JOHNSON, U. S. Geological Survey.

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A. *The Geology of the Gainesville Sheet—or the “Land-pebble” phosphates of Eastern Alachua County.*

COMMENCING with Lake Santa Fe, in the north, we find it, and Nunan Lake, to the southwest of it, both surrounded by a flat sandy country destitute of “sinks” and of rock exposures

* Before the Geological Society of America, Rochester, N. Y.. Aug., 1892.

of any kind. Some distance off, however, to the westward of the former and about four miles west of Waldo, is a small exposure known as the Preston Marl, near old Fort Harlee: and seven or eight miles still farther northwestward in Bradford County, is another large sink. Both these exhibit formations of Miocene age. The small streams also, which traverse these flat woods, including Santa Fe river and several of its affluents, and Lockloosa creek rising by several small branches from the eastern end of Lake Santa Fe, have in them or in their immediate valleys, driftlike sediments, containing casts of fossils similar to those of Waldo. These flatwoods are said to have a general elevation of about 150 feet above tide water.

It is well to acknowledge here in advance, the assistance derived from the topographical sheets of the Geological Survey.

Between Nunan Lake, and the great Alachua Sink or Lake, to the westward, are a number of exposures of clays, and phosphatic sandstones,—the latter being known as the Gainesville "Paving-rock." These may be regarded as alteration products of older Miocene beds. Fossils are rare; but traces exist of a *Venus*, a *Pecten*, and there is no scarcity of reptilian bones. Teeth of sharks and rays are quite numerous. In other parts of the region having this structure, and the *tufa*-like Gainesville Paving-rock, there are ferruginous marly sands with chalcified oyster shells not distinguishable from *O. Virginiana*, and there are also abundant patches of the large coral *Astrea Floridana* (or *bella*.) The contour lines of the Survey give the elevations of these deposits of the coral, and oysters and Gainesville rock at 70–100 feet.

At the great Alachua Sink, twenty feet lower than the lowest Gainesville rock of the adjoining hills, the formation is Eocene of the Vicksburg type.

For ten or twelve miles westward of this sink, and of Lake Nunan, the same relative position of the strata continues, with a constant gain to the Eocene rocks; until they reach the elevation of near 100 feet, and the Gainesville rock disappears, or becomes very thin and represented by its alternate clay. This probably signifies a small dip of the Eocene to the eastward; in which direction, it sinks under Miocene clays and marls.

The region south of Gainesville, a distance of ten miles, is one of apparent depression. Within it are contained Payne's Prairie—lately Lake Alachua*—the Kanapaha Prairie, and the Hogtown and Sugarfoot Prairies and Sinks. To the southeast of Payne's Prairie lie series of ponds and small cypress

* Alachua Lake was a *prairie* from the oldest record, till 1878, when after great rains it became a lake of 40 sq. miles. Again in June, 1891, after a series of four dry years, it suddenly dried off. Immense numbers of fish were taken or destroyed. And now, July, 1892, after a month of heavy rains, the water is reclaiming possession of the flats

swamps by which it is connected with Orange Lake. The elevated ridges of this section are, like the Flatwoods region of Lake Nunan, Miocene. The depressions usually expose Vicksburg rocks, silicified. These outcrop in many old sinks upon Payne's Prairie and about the various ponds. None however on the hills, and none at the northern end of Orange Lake and Lockloosa Lake, its northeastern extension. The southern end of Orange Lake, and Tuscawilla Lake—separated from it by hammock ridges 100 feet high—expose Eocene rocks.

Orange Lake—like so many others which have an Eocene bottom—has a subterranean outlet. And less than a mile north of this "sink," it has within its basin, a "rise"—one of the great springs, so common in the Vicksburg formation of Florida. The lake has its overland outlet also in time of high water, through Orange Creek into Oklawaha River. Over all the foregoing region it is evident that great denudations have taken place, and that from 40 to 100 feet of Miocene marls and later sands have been removed: a history only to be understood upon the Hilgard hypothesis of an elevation of 600 feet and over, in Post-Tertiary times.

It is in the elevated region about Gainesville, the "Land-pebble" phosphates of Alachua occur. The derivation of these pebbles can hardly have been from beds of compact stone, whatever theory may obtain for other parts of the State. For several reasons:

First. The elevation assigned the pebble beds of this region is 150 feet above tide water. No known beds of compact hard rock occur above 75–100 feet.

Secondly. The pebbles are largely fossil casts or fragments of such casts; and it may well be assumed they had their origin in a fossiliferous marl, which by disintegration and removal of the calcium carbonates, left behind the less soluble phosphates. The aggregation of phosphatic matter in fossil forms contained in marls is well known. According to Dr. Eugene A. Smith, all the shell casts in Cretaceous rocks, as well as in those of Tertiary age, of Alabama and Mississippi, are phosphatic.

Third. Compact phosphate is not composed of fossils; nor are its beds especially fossiliferous; though phosphatic rock containing fossils may locally occur by metamorphosis of the original limestones upon which phosphate beds were deposited.

B. The "Plate-rock" Deposits of Eastern Marion County.

The term "plate-rock" is the mining term applied to fragmentary thin flat pieces of "Hard-rock" phosphates. It analyzes as high as any, namely: about 80 to 85 per cent tribasic calcium phosphate.

The area embracing these deposits lies some twenty miles eastward of the main belt of "hard-rock" phosphates, and extends from Citra on the southeastward bay of Orange Lake to the southwestern extension of Lake Wier, and to Wildwood in Sumter County, a distance of 40 miles, with an average width of $1\frac{1}{2}$ to 3 miles.

Within this region the first mining was done by the "Peninsula Phosphate Company," near Anthony, 10 miles north of Ocala, in 1890. Other works and mines have been since undertaken at Citra, Sparr, Montague, Welshon, Belleview and Summerfield—stations on the line of the "Florida Central and Peninsular," and "Florida Southern" Railroads. In only a few of these places, however, have excavations been sufficiently extensive to afford a complete insight into the nature extent and value of the deposits, yet in the smallest *prospect* hole, some facts of value are found.

The following figure may give a fair notion of the general mode of occurrence of this class of phosphates.

1.

Excavation in progress at "The Ohio Mining Co's" works, Sparr, Fla. This mine is selected from scores examined, on account of its exceeding regularity.

A. "Overburthen"—soil and sand—8 ft. in its greatest thickness.

B. Great mass of "Soft-phosphate," and matrix of the fragments of "Plate-rock," narrowing to 2 ft. at bottom—30 feet deep.

C, C'. The two buttresses or pinnacles of Vicksburg limestone--by the miners called "Lime-horses."

C is 33 feet high, C' 34 ft.

D, D'. Trial excavations just begun.

E, Calcite rock beneath; F. The drainage cavity.

This pit is 38 feet deep, from the top of sandy soil, to the cavity at the base. It is 28 feet across between the tops of the pinnacles, which are 2 feet apart at the base, where the cavity opens. The "plate-rock" is the thin layer next the limestone shoulder imbedded in the interior matrix of "soft-phosphate"—a little argillaceous. This

"Plate-rock" carries 79½ per cent tribasic phosphate of lime.
The soft phos. matrix " 69 " " " " " "

Attention is called in this section :

(1) To the "overburthen" of surface sand which, on the tops of the pinnacles of limestone, is approximately 4 feet, while in the center it is sunken and grades to 8 feet in depth.

(2) To the filling between the pinnacles, which is chiefly "soft-phosphate," a substance of clay-like appearance and consistency, of a creamy color. It is very variable in its phosphate of lime—often high in alumina and iron. In this instance it is a 69 per cent phosphate.

(3) To the comparatively small portions, 1-3 feet thick next the limestone sloping walls, containing the angular fragments of "plate-rock." This portion of the deposit alone is considered of commercial importance. In working the mine, the matrix, however rich in phosphoric acid, is washed away.

(4) To the opening at the bottom, between the base of the pinnacles, connected with a subterranean drainage. This is not universal in all the pits, but so general, as in those at Anthony, that it may be considered as a phenomenon of all the deposits in this elevated region. When the elevation is small, as at Welshton, no opening to take off the leachings has, as yet, been observed. However, mining there has progressed but little.

(5) The "pinnacles" are evidently upward projections of the bed-rock Eocene limestone of the country. They are seen in these excavations (and in all of them except one great pit of the Pen. Phos. Co. northward of Sparr) without definite order or arrangement and of all sizes and shapes. The walls are often sloping as in the figure, often vertical and eroded into hollows and into deep round wells or pot-holes, washed out by the waves of a restless sea.

It would be tedious to enumerate all the mines in this region, and comment on the peculiarities of each, and it would serve no general purpose. Suffice it to say, the variations are principally in the phenomena of erosion, both before and subsequent to the deposition of the phosphates. Of these the general facts are about the same.

Reference has been made to the occurrence of fossils within the workable deposits. There are none, with only one excep-

tion as yet observed—at Belleview on the Florida Central and Peninsula railroad, 12 miles south of Ocala. The remains are chalcedonized oyster shells. As related by the manager of the mine they are associated with the "plate-rock" next the shoulders of Eocene limestone. As observed by the writer in an abandoned pit, where it was said they had been numerous, the shells of *Ostrea Virginiana* were still adhering to the rock, evidently undisturbed since the day they attached themselves, and grew there.

B. *Genesis of the Plate-Rock Deposits.*

The problems presented by the foregoing facts are: (a) To account for compact phosphate; (b) To account for the "soft-phosphate" phase; (c) To account for the presence therein of "plate-rock."

Peninsular Florida first appeared above water in early Miocene times, in the form of numerous small islands of Eocene limestone, stretched along what would later be the Gulf coast—corresponding in position to parts of the present counties—Suwanee, Columbia, Lafayette, Levy, Hernando, Citrus, Pasco, Sumter, and the western parts of Marion and Alachua. Twenty miles eastward of this main line facing the Gulf, was this smaller cluster of islets we have under consideration, then braving the Atlantic. Denudation of these islands by the sea imparted to them at many points the water-worn low bluffs with pinnacles, such as are visible on any part of the present coast composed of rocks like these. Notably may be instanced, St. Mark's Bay, and Deadman's Bay, of the Gulf side. Upon shores of this nature were laid down the deposits described in the foregoing pages.

The varieties of this class of phosphates in Marion County alone, comprise in mining language "hard rock," "laminated-rock," "plate-rock" and "soft-phosphate."

The explanation offered herewith of the *genesis* of these phosphates, is based upon the hypothesis of the original deposition of *guano*.

In a rainless region the deposits would have remained in form similar to those of the Chincha islands. In the present case in a region of much rain and great moisture, the guano beds became converted into the phosphates here encountered. The arrangement of land and sea in the Miocene age rendered the deposition of immense deposits of *guano* quite possible. Only upon such secure island homes, away from the predatory animals of the continent, could the sea-birds have successfully maintained their breeding grounds. The waters of such an archipelago at that age teemed with life, which with the rich vegetation of warm shallow seas afforded ample food.

Having the material deposited, adequate to furnishing a supply of phosphoric acid, the process of change to the present forms followed as a natural consequence, from the attendant circumstances in due course of *law*. The guano beds after the leaching out of their carbonates and other soluble materials, became very compact, yet not entirely impervious to water. It is probable that some waste of material by solution is continued in degree to the present day.

Cavities are found in the most compact beds of the "hardest rock." Small cavities in close contiguity became finally separated by mere plates, and in this condition are called "*laminated-rock*."

By further disintegration such laminated rock is broken up into fragments greater or less, and is then "plate-rock"—such as is found mixed up with more finely comminuted material in the deposits of Anthony and Sparr and Fairview clinging to the walls of the pinnacles of Eocene limestone.

Still further progress of the disintegrating process results in the masses of "soft-phosphate"—the impurity of the final material depending in part upon the amount of clay originally contained in the immense deposits of the original rock, and partly upon the amount of extraneous matter washed in.

That the fragments of "plate-rock" should cling to the walls of the pits is the natural result of drainage being more energetic in the center of the hopper than at the sides; at the same time the middle portions become dissolved or reduced more quickly and more completely than the exterior.