Compliments of

Gilbert D. Harris.

PART V

GEOLOGY AND AGRICULTURE

A Preliminary Report

ON

THE GEOLOGY OF LOUISIANA

BY

GILBERT D. HARRIS, *Geologist-in-Charge*

AND

A. C. VEATCH, *Assistant Geologist*

MADE UNDER DIRECTION OF STATE EXPERIMENT STATION,
BATON ROUGE, LA.

WM. C. STUBBS, PH.D., *Director*

April 25, 1900.

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OFFICE OF EXPERIMENT STATIONS,
LOUISIANA STATE UNIVERSITY AND A. AND M. COLLEGE,
BATON ROUGE, LA., October, 1899.

To His Excellency MURPHY J. FOSTER, *Governor of Louisiana, and President of Board of Agriculture:*

Sir: Since our last report of the Geological and Agricultural Survey, a complete change has taken place in the personnel of the survey. Prof. W. W. Clendenin, who performed the duties of Professor of Mineralogy and Geology in the Louisiana State University and A. and M. College, and geologist for the stations, has severed his connections with both institutions by resignation, and taken charge of Blees' Military Academy, at Macon, Mo.

Upon his resignation arrangements were made with Prof. Gilbert D. Harris, Ph.B., of Cornell University, who is the recognized authority of this country in Tertiary geology, by which he was to conduct the survey under our direction and publish annually a report of his work. He gives considerable time to the actual field work and writes and superintends the publication of his reports. Mr. A. C. Veatch has been selected as his assistant and gives his entire time to the field and office work of the survey. Mr. Veatch is an acknowledged authority upon Quarternary geology, and with his assistance we feel satisfied that the entire State, which consists almost exclusively of tertiary and quarternary formations, will be correctly and fully reported. These two gentlemen have persistently followed their work through freezes and sunshine, over intolerable roads, impelled by an enthusiasm known only to lovers of science. How well they have accomplished their work, the present volume will testify.

Collections of typical soils have been made and are being analyzed both physically and chemically in the laboratories of the stations. Besides the above, in November next Prof. Milton Whitney will place in the field two or more soil physicists who will make an accurate soil survey of the State, and in his laboratory make the physical analyses of all these soils, giving the results to us for publication. It is hoped and believed that in this way a copious volume giving full information of the properties of all the soils of the State, with accurate soil maps, will ultimately be given to the public. Such a work will be of incalculable benefit to the agriculture of the State besides serving as a guide in giving directions to the various farmers and planters who seek daily knowledge relative to the capacity and requirements of their soils for growing various crops.

The within report covers the following subjects, viz.: Review of the Geological Work already done in the State, General Geology of the State, and Special Reports, including various topics of economic and scientific interest. (See Section III.)

It is found difficult to carry on so extensive and important a work as this upon the limited appropriation now received. To cover accurately an area of 45,000 square miles, giving the various geological horizons; the agricultural and forest resources; the mineral and underground resources, and the water supplies, both for drinking, irrigation and navigation, requires a large amount of time and the best scientific talent, and money is required for the successful accomplishment of such a huge task. In fact, a geological and agricultural survey can hardly ever be called completed. Increasing population, progress and enterprise are demanding the solution of problems constantly arising, and the State should always be ready to lend its assistance. With increased appropriations, the work on hand could be more rapidly prosecuted and the information gathered thereby the more speedily given to the thousands who are seeking homes in our State; to say nothing of the great value to the hundreds of thousands now residents in our borders.

I trust that sufficient funds will be appropriated to permit of a more rapid and extensive prosecution of the work under the able and enthusiastic men now employed in this survey.

Respectfully submitted.

WM. C. STUBBS, *Director.*

LETTER OF TRANSMISSION

DR. WM. C. STUBBS, DIRECTOR STATE EXPERIMENT
STATIONS, BATON ROUGE, LA.

Sir: I herewith present you a Preliminary Report on the Geology of Louisiana.

Mr. A. C. Veatch acting as assistant geologist, commenced field work November 1st, 1898, and studied the distribution of the soils of Caddo and Bossier parishes until my arrival in the State, December 23d. Thereafter we worked for the most part together in De Soto, Sabine, Natchitoches, Grant, Winn, Caldwell and Ouachita parishes.

After my departure from the State, the last of March, Mr. Veatch continued work in the northern tier of parishes between Ouachita river and Red river until requested by you to visit the Five Islands and the Sulphur region of the southwestern part of the State. This done, we worked on the report herewith transmitted from mid-summer to late autumn, when he again took the field and I saw to the completion of the report.

I gladly take this opportunity to inform you that Mr. Veatch has in all his connections with this survey, shown himself a most capable and energetic assistant; and it is to his untiring zeal, and your never failing and well directed support that such success as the survey has been able to attain is largely due.

Most respectfully submitted,

GILBERT D. HARRIS,
Geologist-in-Charge.

Cornell University, Ithaca, N. Y.,
Nov. 25, 1899

PREFATORY REMARKS

PLANS OF OPERATION

The prosecution of a well organized geological survey demands an expenditure of funds far in excess of those now at our command. This the reader is requested to constantly bear in mind. With much volunteer labor, however, we have been able to bring together, in this report such data as we believe will be of service to those who in the future shall investigate special problems relating to the geology of Louisiana. This remark applies more particularly to Section I and portions of Section II. They show what has already been accomplished, by whom, and where. They might well be styled a summary of geological reconnaissance work in Louisiana.

Part III contains the beginnings of some of the special lines of investigation that this Survey will, we hope, be able to take up and carry out. They include:

(1) The mapping geographically, topographically, and geologically, of certain areas that are of special interest either (a) on account of the large number of inhabitants they contain and to whom such maps would be of service, or (b) on account of some specially interesting geological phenemenon they exhibit, or (c) on account of their proximity to seats of learning where they will be of service to teachers who wish to teach geology from their own surroundings—the only true way. Detailed reports should accompany these sheets.

(2) The gathering of information for agricultural or soil maps, as has been explained in Dr. Stubb's letter heretofore affixed.

(3) The working out of the stratigraphic relations of the various deposits of Louisiana. This can be done by (a) studying with great care the fossil remains found in the various formations and hence identifying deposits by the fossils they contain, (b) by putting down test wells and observing the nature of the different beds passed through, (c) by studying the stratig-

raphy of natural sections, along rivers and smaller streams of water.

Until a thorough knowledge is obtained of the way the different deposits lie in the State, all questions relating to artesian waters, extent of mineral deposits, origin of soils, etc., are unanswerable.

(4) The determination of meridian lines and of the amount and direction of magnetic forces within the boundaries of the State—primarily for the assistance of land-surveyors.

(5) The investigation of the different mineral products of the State.

(6) The encouragement of road improvement.

So far as (1) is concerned, the earliest coöperation with the U. S. Geological Survey should be sought. The State would pay for but half of the field expense of topographic work, the general Government doing all the rest.

Coöperation has already been secured for work outlined under (2).

The Coast Survey is ready to coöperate as regards work under (4) and its aid should be early sought.

In case funds are not forthcoming for the prosecution of all these lines of work, then some will be discarded and such as seem most urgent will be continued. It rests with the people to say how much can be invested in work of this nature, and with the Geologist-in-Charge to see that due returns are made for the investment, be it great or small.

Section I

HISTORICAL REVIEW

BY

HARRIS AND VEATCH

HISTORICAL REVIEW

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PERIODS OF INVESTIGATIONS

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HISTORICAL REVIEW

PERIODS OF INVESTIGATION

First Period

From the Earliest Explorations to the Year 1867

Earliest explorers.—Few and desultory indeed are the contributions made to the geological literature of this State up to the middle of the present century. As might naturally be expected, it was the Mississippi, the great river, that first attracted and held the attention of the earliest explorers and naturalists in this region. Commerce dictated that its mouths should be explored and mapped at an early date, and in 1722 P. Charlevoix accomplished this task in a highly creditable manner.* He argued in a truly scientific spirit that "the quantity of shoals and little islands that have been seen to form in the various mouths of the river during the past twenty years" leave no doubt as to the manner and comparatively recent date of formation of the lower delta region.

Coxe.—If the reference of Coxe to the River Natchitock can be taken to mean the Red river, and it seems quite probable that they are the same, the salt springs in northern Louisiana were known and worked in the very early history of this country. He says, " Ten or twelve leagues higher on the west side," [of the Mississippi] "is the River *Natchitock*, which has a course of many hundred miles; and after it is ascended about one hundred, there are many springs, pitts, and lakes which afford most excellent common salt in great plenty, wherewith [the Indians] trade with neigboring nations for other commodities they want. Upon the river inhabit not only the Nachitocks, Naguteeres, Natsohocks but higher several other nations."† On the next

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* Thomassy, Géologie Pratique de la Louisiane accompagné de 6 planches, New Orleans and Paris, 4°, 263 pp., figs., 1860. See pp, 27–28.

† A description of the English province of Carolina, by the Spainards called Florida and by the French La Louisiane, and also of the great and famous River Meschacebe, or Missisipi, and the five vast navigable lakes

river above the river of the Natchitocks live the "Arkansas, a mighty nation."

*Bartram.**—In 1773 Wm. Bartram started on his journey of the Southern States "for the discovery of rare and useful productions of nature, chiefly in the vegetable kingdom."

He passed through Lake Pontchartrain and ascended the Mississippi as far as Point Coupé. The plains† near Port Hudson he described as showing "whitish clay or chalk, with veins of sea-shells, chiefly of those little clams called les coquelles [*Rangia*] interspersed with the white earth or clay, so tenaceous and hard as to render it quite sterile."

He described the Port Hudson‡ bluff as consisting of strata of various colors, white, red, blue, purple sand, marl and chalk. He observed the cypress stump stratum at the base of the cliff, and comments on the same as follows: "These stumps are sound, stand upright, and seem to be rotted off about two or three feet above the spread of the roots; their trunks, limbs, etc., lie in all directions about them. But when these swampy forests were growing, and by what cause they were cut off and overwhelmed by the various strata of earth, which now rise near one hundred feet above, at the brink of the cliff, and two or three times that height but a few hundred yards back, is a phenomenon not easily developed."

Dunbar.—In 1801 Wm. Dunbar, of Natchez, sent a letter to the president of the American Philosophical Society, extracts of which were published in the Transactions for that year (vol. vi,

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of fresh water and the parts adjacent. Together with an account of the commodities of the growth and production of the said province. And a preface containing some considerations of the consequences of the French making settlements there. By Daniel Coxe. Second edition. London 1726. See pp. 10–11.

*Travels through North and South Carolina, Georgia, east and west Florida, the Cherokee country, the extensive territories of the Muscogulges, or Creek Confederacy, and the country of the Choctaws; containing an account of the soil and natural productions of those regions, together with observations on the manners of the Indians Embellished with copper plates. By Wm. Bartram, Phila., 1791.

†Ibid. p. 431.

‡Ibid. p. 435.

pp. 40–42) recounting the discovery of fossil bones to the west of the Mississippi, supposed to resemble those of the big bone lick near the Ohio.

Two years later he forwarded to the same society (see vol. vi, pp. 55–58) a letter received from Martin Duralde from the "country of the Apelousas" relating to the occurrence of fossil remains, supposed to be elephant bones, in that region. Furthermore, "M. Duralde in sinking a well in his cow-yard found sound oyster shells, lying in a horizontal direction, near to each other, at a depth of 22 feet."

In 1804, Dunbar contributed an extended article to the same Transactions (pp. 165 *et seq.*) entitled "Description of the River Mississippi and its Delta, with that of the adjacent parts of Louisiana." This contains little of geological interest.

*Stoddard.**—In his Sketches of Louisiana, Maj. Stoddard comments as follows on the delta region†: "Nothing is more certain than that the delta has gradually risen out of the sea, or rather that it has been formed by alluvion substances, precipitated by the water from the upper regions. It is calculated that from 1720 to 1800, a period of eighty years, the land has advanced fifteen miles into the sea; and there are those who assert, that it has advanced three miles within the memory of middle aged men."

His notice of the Five Islands reads as follows: "There is an island of about three miles in circumference, situated in the gulf a few miles to the westward of the mouth of the Chafalia, elevated more than two hundred feet above the level of the sea and connected with the mainland by a sea marsh. Most of the islands along the shores of the Mexican gulf exhibit this proud pre-eminence, while the country for a great depth is most of the time covered with water. Some of them are impregnated with sulphur, and one of them has been known to be on fire for at least three months."

The production of the saline springs near Natchitoches is given

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*Sketches, Historical and Descriptive, of Louisiana. By Major Amos Stoddard. Phila. 1812.

†Ibid. p. 158.

as about two hundred and forty barrels of salt per month.* On page 186 the cause of the rapids at the site of Alexandria is ascribed to "two ledges of hard indurated clay, or soft rock which extend across the channel at about three-fourths of a mile from each other."

Lignite also receives notice in this work. He says: "Stone or pit-coal is an article of some importance. . . . . . It frequently makes its appearance on the Washita, the Sabine, and the Red river, particularly on the borders of a lake in the neighborhood of Nachitoches. This article is of use to smiths, even at this time, and its importance will increase as the country becomes more populous and the villages enlarge."†

Darby.‡§—Though Darby's works were of a general nature as the titles indicate he wove in many geological facts and observations quite in advance of anything that had preceded his works and in fact by no means equalled by many of his successors.

He calls attention to the salt deposits on the Saline (Drake's) (see Geog. La. pp. 29 and 211 and Emigrant's p. 89) on the land of Mr. Postlethwait.

He describes the occurrence of dead cypress trees in Lake

*Ibid. p. 400.

†Ibid. pp. 391–392.

‡A Geographical Description of the State of Louisiana: presenting a view of the Soil, Climate, Animal, Vegetable and Mineral Productions, Illustrative of its Natural Physiognomy, its Geographical Configuration, and Relative Situation: with an account of the Character and Manners of the Inhabitants. Being an Accompaniment to the Map of Louisiana. By William Darby. Phila., 1816.

§The Emigrant's Guide to the Western and Southwestern States and Territories; comprising a Geographical and Statistical Description of the States of Louisiana, Mississippi, Tennessee, Kentucky, and Ohio; the Territories of Alabama, Missouri, Illinois, and Michigan; and the western parts of Virginia, Pennsylvania and New York. With a complete List of the Road and River Routes west of the Alleghany Mountains, and the connecting roads from New York, Philadelphia, and Washington City to New Orleans, St. Louis and Pittsburg. The whole comprising a more comprehensive Account of the Soil, Productions, Climate, and present state of Improvement of the Regions described, than any Work hitherto published. Accompanied by a map of the United States, including Louisiana. Projected and Engraved expressly for this work. By William Darby, New York, 1818.

Bistineau (Geog. La. pp. 31–32) and attributes the origin of this and similarly located lakes to the choking up of small stream valleys by Red river sedimentation.

On pp. 45–46 the occurrence of rocks (now called Grand Gulf) on the Ouachita river on the western angle of Sicily island is noted and they are properly correlated with similar exposures on Red river at Alexandria. He mentions also rock exposures on the Sabine, p. 23, but does not correlate the same with the Sicily island beds.

He describes with care the river systems of the State and discusses at length the various prairies in the southwestern part of the State. He noticed marine shells in the banks of Red river, propably at the now well-known locality at Montgomery.*

His description of the Five Islands is much more complete and exact than Stoddard's, being based on a personal examination of Petite Anse. He noted the existence of a salt spring on Petite Anse from which salt had been manufactured.†

Nuttall.—In 1821 Thomas Nuttall mentions ferruginous conglomerate resembling the New Jersey conglomerate (afterwards referred to the Cretaceous by Morton) as extending for more than a thousand miles above Alexandria.‡ This seems to have been the first of the early erroneous references of Louisiana material to the Cretaceous.

Graham.§—The reports of the general land office for 1824 give the location by townships of two salt springs in the region north of Red river. "One in township No. 12 of range No. 5 West" (probably Drake's). "The other in township No. 13 of range No. 4 West" (Price's).

Delafield.‖—A good description of the topographical features of the mud-lumps of the passes of the Mississippi was given by

*Geographical Description of Louisiana, p. 48.

† Emigrant's Guide p. 68.

‡Jour. Phila. Acad. Sci., 1st series, vol. 2, p. 46.

§George Graham, Report of the Commisssioner of the general Land Office in Relation to Lead Mines and Salt Springs. 18th Cong. 1st Sess., House Ex. Doc., vol. 6, No. 128, 1824, pp. 14–15.

‖Report on the Survey of the Passes of the Mississippi, 21 Cong., 1st Sess., House Ex. Doc. No. 7, vol. 1, pp. 7–14, 1829. Reprint, 39th Cong. 1st. Sess., House Ex. Doc. No. 97, vol. 12, pp. 2–3, 1866.

Richard Delafield in 1829. Their life history is also fully described.

An examination in the early part of the same year by Bernard and Poussin resulted in a very brief description of the character of the material thrown out of the lumps.*

Harlan.—The first contribution to the systematic geology of the State may be regarded as Article XII in the Transactions of the American Philosophical Society, vol. 4, New Series, 1832, p. 397, *et seq.*, entitled "Notice of Fossil Bones found in the Tertiary Formation of the State of Louisiana. By Richard Harlan, M.D., etc. Read October 19, 1832."

Dr. Harlan here describes some of the large fossil bones sent him by Judge Bry "found on the Ouachita river in the state of Louisiana, at a distance (south) of about fifty miles by land, and one hundred and ten by water from the town of Monroe, in the parish of Ouachita, and in lat. 31° 46′ or 48′."

Judge Bry's comments on the geology of northern Louisiana are as follows: "The hills, beginning at Cataouta, extend north to the Arkansas river and west to Red river, whence they spread to the Sabine. Through that country are interspersed overflowed lands varying in extent according to the magnitude of the creeks, of which they form the bank at low water, and which flow over them at high water. In these hills very few ores are found except those of iron, which are abundant in two different places; but no measures have been taken to ascertain their value. The highest of the hills do not exceed eight hundred feet above high water mark; and in many places they dwindle into gently rolling ground. These hills appear to be of a much more ancient formation than the lower section of Louisiana. No rocks, however, enter into their composition; but a few sandy stones and pebbles, nearly all *siliceous*, are occasionally seen scattered on their summits, or in the beds of the numerous creeks fed by springs issuing from them.

"Sea shells are discovered in several places; I found them on the highest ridge which divides the waters running into the Red river from the tributary streams of the Ouachita. The tract, by far the richest in calcareous substances, is the one

*22d Cong. 1st Sess., House Ex. Doc., vol. 4, No. 185, 1832.

within the limits where the fossil bones have been found, extending about fifteen miles from north to south, and probably ten or twelve from east to west. Several years ago, while rambling among these hills, I met with a small creek, the banks of which are in some places thirty feet high, in which I found many different species of sea shells, among others, *pectenites*, *belemnites*, etc. At the same time, my attention was attracted by a large quantity of *cornua ammonis*, the largest of which did not exceed an inch and a half in diameter, while many were much smaller.

"The hill, in which the bones herewith presented were found, is within the limits above described, at a distance of not more than two hundred yards from the Ouachita river. About three years ago, after the occurrence of a long spell of rainy weather, a part of the hill slid down near the water's edge, and thereby exposed twenty-eight of these bones, which had been until then covered by an incumbent mass of earth about forty feet thick. They were embedded in a bank of sea marl, a specimen of which is added to the bones, as well as the calcareous spar and *talc* also found in the same hill. I followed the horizontal vein of this marl, five or six inches thick, which I traced to a distance of about forty feet, when it sinks into the valley under an angle of from twenty-five to thirty degrees. It appeared to have effloresced where it had been long exposed to the influence of the atmosphere.

"When these bones were first seen, they extended in a line, which, from what the person living near the place showed me, comprised a curve, measuring upwards of four hundred feet in length, with intervals which were vacant. The person referred to destroyed many of the bones by employing them instead of andirons in his fire place and I saved what remained from the same fate. I think, however, that a great many more bones belonging to the same animal are yet covered, and will gradually appear, as the soil and the marl shall be washed off by the rain."

Harlan was of the opinion that the bones under consideration were of a huge lizard-like reptile and proposed for the animal represented the name "*Basilosaurus*."

Morton.—The following year Morton concluded from the fossils mentioned in Dr. Bry's letter that the material represented was Cretaceous, and from a letter received from Dr. Pitcher states that the "ferruginous sand formation" (Cretaceous) outcrops between Alexandria and Natchitoches.* It is hardly necessary to remark that neither of these statements is supported by our present knowledge of that region.

Conrad.—In the Journal of the Philadelphia Academy of Natural Sciences, vol. 7, 1834, p. 120, T. A. Conrad refers to the shells found in connection with the *Basilosaurus* to the Eocene series, and states that the commonest fossil is *Corbula oniscus*, a common Claiborne fossil. He states that the bones were doubtless from a nearby Cretaceous stratum, not from the the Eocene as stated by Harlan.

In the Proceedings of the Philadelphia Academy of Natural Sciences for 1841, p. 33, Conrad describes one of the molluscan species found at the same locality. He names it *Cardium nicolleti* and gives its provenance as "Green clay, 50 feet high, right bank of the Washita river, Monroe County, La." The same fossil is described on p. 190, vol. 8, of the Journal of the same society.

Deméril.†—Harlan's description of the *Basilosaurus* soon attracted the attention of the French savants. M. Deméril in 1838 pointed out the true character of the animal. He says, "As to the *Basilosaurus* presented for comparison, it must be admitted that the vertebræ believed to have come from this fossil seem rather to be from a cetacean than a reptile."

Carpenter.—During the same period William Carpenter was gathering together information on the geology of the southern part of Louisiana. He records the finding of vertebrate remains in two localities. One on little Bayou Sara in the parish of West Feliciana where he found teeth and fragments of the jaw of a mastodon, and a tooth of an *Equus*, much larger than the modern horse. This he figures in the American Journal of Science, vol.

*Am. Jour. Sci., vol. 23, pp., 288, 1833. Also Synopsis of the Organic Remains of the Cretaceous Group of the United States, by Samuel George Morton. Phila., 1834.

†Compte Rendu des Séances de l'Academie des Sciences, Oct. 22, 1838, Paris.

34, p. 203, 1838. The other near Opelousas where mastodon bones were also found.* He described with considerable detail the Port Hudson section, and traced in the Florida parishes, the northern limit of what is now called the Port Hudson group.†

Owen.—Dr. Harlan had received later on some more perfect specimens of his *Basilosaurus* from Alabama and these he took with him to London in 1839, and submitted them to Richard Owen, who proved to the satisfaction of all that the huge monster was an aquatic mammal of dugong, or whale-like affinities. He gave the name *Zeuglodon cetoides* to the species. His studies and conclusions are given at length on pp. 69–79, Trans. Geol. Soc., Lond., vol. 6, 1842.

Talcott.—The subject of rendering the mouths of the Mississippi navigable to vessels of deep draught seems to have agitated the public mind from an early date. The report of Joseph G. Totten to the war department in 1839 contains a very accurate map of the mouths of this river, and drawings of two of the mud lumps by Captain Andrew Talcott.‡

Jones.—In the Journal of the Franklin Institute, 3d series, vol. 2, 1841, pp. 83, Engineer A. C. Jones gives a very accurate description of the physical characters of the mud-lumps at the mouths of the Mississippi.

Lyell.—The Athenæum Journal for Sept. 26, 1846, contains an article by Sir Charles Lyell "On the Delta and Alluvial Deposits of the Mississippi, and other points in the Geology of North America observed in the years 1845, 1846." This was republished in the Report of the British Association for the Advancement of Science for 1847, vol. 16, pp. 117–125. An abstract of the same occurs in the American Journal of Science, 2d series, vol. 3, 1847, pp. 34 and 118.

Herein the author states that he doubts whether the delta advances over one mile a century into the gulf. On p. 36 (A.J.S.) he states that the matter held in suspension by the waters of the Mississippi is about $\frac{1}{1245}$ the weight of the water itself. On p. 118 he changes the proportion to $\frac{1}{1700}$.

*Am, Jour. Sci., vol. 35, pp. 345–346, 1838.

†Am. Jour. Sci., vol. 36, pp. 118-124, 1839.

‡Senate Doc., No. 463, 26th Con., 1st Sess., vol. 7, 1840.

In volume 2 of his Second Visit to the United States, published (3d ed.) 1855, Lyell (p. 153) is greatly impressed with the stability of the general features of the mouths of the Mississippi, and concludes that "we must allow an enormous period of time" for the accumulation of the material constituting the whole delta. On p. 250 he estimates 67,000 years for the time required for the formation of the delta.

On pages 180–182 he describes the interesting bluff at Port Hudson after quoting largely from Bartram and Carpenter.

Natchez bluff is next described (p. 194) as follows: "The lower strata, laid open to view, consist of gravel and sand, destitute of organic remains, except some wood and silicified corals, and other fossils, which have been derived from older rocks; while the upper sixty feet are composed of yellow loam, presenting as it wastes away, a vertical face towards the river. From the surface of the clayey precipice are seen projecting in relief, the whitened and perfect shells of land snails of the genera *Helix*, *Helicina*, *Pupa*, *Cyclostoma*, *Achatina* and *Succinea*. These shells of which we collected twenty species, are all specifically identical with those now inhabiting the valley of the Mississippi.

"The resemblance of this loam to that fluviatile slit of the valley of the Rhine, between Cologne and Basle, which is generally called "lœss" and "lehm" in Alsace, is most perfect. In both countries the genera of shells are the same, and as, in the ancient alluvium of the Rhine, the loam sometimes passes into a lacustrine deposit containing shells of the genera *Lymnæa*, *Planorbis*, and *Cyclas*, so I found at Washington, about seven miles inland or eastward from Natchez a similar passage of the American loam into a deposit evidently formed in a pond or lake. It consisted of marl containing shells of *Lymnæa*, *Planorbis*, *Paludina*, *Physa* and *Cyclas*, specifically agreeing with testacea now inhabiting the United States." He records *Mastadon*, *Megalonyx*, horse, stag, etc., from these loams.

Dickeson and Brown.—At the first meeting of the American Association for the Advancement of Science held at Philadelphia in 1848, Dr. Dickeson read a joint paper on "The Sediment of the Mississippi," in which the statement is made that the delta of the Mississippi has been no less than 14,204 years in forming. (See p. 51, Proc. Am. Assoc. Adv. Sci., vol. 1.)

*Drake.**—In a volume entitled the "Principal Diseases of the Interior Valley of North America," Dr. Daniel Drake succeeded in weaving in many facts and statements of geological interest. His description of the mud lumps (pp. 91–94) is particularly good and deserves attention because he advances the gas theory for the formation of these objects. He gives (p. 71) a well section on Lake Pontchartrain and the section exposed in the gas tank excavation at New Orleans. On page 161 he states that the geological formation about Fort Jessup is Tertiary.

Ellet.—In 1853 appeared a somewhat extensive work on the lower Mississippi by Charles Ellet, C. E.† This book is severely criticised by Jones in the Journal of the Franklin Institute, vol. 26, 1853. (See pp. 60 and 162.)

Thomassy.‡ — In 1860, Reymond Thomassy published his "Géologie Pratique de la Louisiane," both in this country and in France (Paris).

Whatever may be said of the use of the word "pratique" in his title, Thomassy had access to and used to good advantage the earlier rare contributions to the cartography of Louisiana. His geology, was in the main limited to a discussion of the role the Mississippi river has played in the formation of the so-called delta region of the State. Particularly was he impressed with the multifold manifestations of water absorption all along the Mississippi and its consequent diminution in volume gulf-wards, and the appearance of lateral springs, lakes and terminal mud-lump volcanoes, all having their origin in the porosity of the grounds of southern Louisiana and the consequent subterranean flow of large quantities of water.

* A Systematic Treatise, Historical, Etiological, and Practical, on the Principal Diseases of the Interior Valley of North America, as they appear in the Caucasian, African, Indian and Esquimaux varieties of its population. By Daniel Drake, M.D., Cincinnati, 1850.

† The Mississippi and Ohio Rivers; containing plans for the protection against inundations and investigation of the Practicability and cost of improving the Navigation of the Ohio and other rivers by means of Reservoirs; with an appendix on the bars at the mouth of the Mississippi, 8°, 367 pp., 1853, Lippincott & Co., See Review in Jour. Franklin inst., 3d series, vol. 25, pp. 360.

‡ Géologie Pratique de la Louisiane par R. Thomassy. (Accompagné de 6 planches.) Chez l 'auteur à la Novella-Orléans, et à Paris, 1860.

Chapter VIII, he devotes to a discussion of the Five Islands, under this caption: "Intervention of Hydro-Thermal and Volcanic Forces in the Formation of Lower Louisiana." (See special discussion of this subject, special report No. 3.)

*Humphreys and Abbott.**—By far the most serious study of the lower Mississippi in all its bearings, is that by Humphreys and Abbott, first published in 1861 and afterwards with additions in 1876. The hydrography and geology of the whole Mississippi basin are taken into account in order to form just conclusions regarding the special subjects under consideration.

They hold that the river alluvium is a comparatively thin stratum underlaid by blue clay of wide geographical distribution and of Tertiary or even Cretaceous age. It is said to underlie the Vicksburg bluff, the whole Yazoo bottom, and to underlie New Orleans at a depth of not more than 40 feet. It forms the bar of tough clay across the efflux of the Atchafalaya 35 feet below the bank and 15 feet below Gulf level. An artesian well boring in the Atchafalaya upon Gen. Welles' plantation, 10 or 15 miles south of Alexandria shows that the alluvial soil there is 30 feet thick, the surface of the older formation being about 50 feet above tide.

For an extensive review of this work see Amer. Jour. Sci., vol. 33, 1862, p. 181; vol. 35, 1863, p. 223; vol. 36, 1863, pp. 16 and 147.

In the edition of 1876, pp. 465–466, it is stated that the "original mouth" of the Mississippi was near the efflux of the Plaquemine, 220 miles from the Gulf.

By comparing Talcott's maps, 1838, and the U. S. Coast Survey maps of 1851 it is found that the yearly advance of all the passes is 262 feet per annum. The total advance from the Plaquemine efflux has taken 4,400 years.

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* Report on the Physics and Hydraulics of the Mississippi River; upon the protection of the alluvial region against overflow and upon the deepening of the mouths. Based upon surveys and investigations (etc.) U. S. Army, Corps of Topographical Engineers, Professional papers, No. 4, xiii, 456, cxlvi pages, 20 plates, 4°, Philadelphia, 1861; also Washington, 1867. Again 214 pages, 1 plate, Washington, 1867. With additions, 691 pages, 25 plates (Professional papers, No. 13), Washington, 1876.

*Owen.**—Dr. Richard Owen of Indiana visited Petite Anse in the latter part of 1865. After a hasty examination he showed that the island was composed of sedimentary material and concluded that it was a wind and wave formed dune similar to those on the southern shore of Lake Michigan.

SECOND PERIOD

RECONNAISSANCE PERIOD, 1867–1892

Hilgard.—In 1867, Hilgard, under the direction of the Smithsonian Institution made a trip down the Mississippi and to the central three of the Five Islands. The preliminary report on this reconnaissance appeared in 1869.‡ At that time he regarded the rock salt as having been formed by evaporation in a lagoon or series of lagoons and as resting in a bed of marine clays of early Quaternary age. He considered the hills as simply the accidents of differential erosion.

The same year he published in the American Journal of Science the "Summary Results of a late Geological Reconnaissance of Louisiana." It was based on operations largely in the western part of the State and was made under the auspices of the New Orleans Academy of Sciences. Thirty days only were allowed for the field work. New Iberia, Bayou Chicot, Lake Charles, Sabinetown, Many, Mansfield, Coushatta Chute, Winnfield and Harrisonburg were passed through *en route*.

He reviews the various terranes of the State, commencing with the younger or "Port Hudson group" and notices in turn the other groups, viz.: the "Orange Sand formation," the "Grand Gulf group;" the "Vicksburg group;" the "Mansfield group;" and then takes up and discusses the salines of North Louisiana and the artesian wells of Calcasieu.

The Port Hudson group is said to be of considerable thickness, 600 feet or more beneath New Orleans and to extend up the

*On the Rock Salt at New Iberia, Louisiana by Prof. Richard Owen Trans. Acad. Sci., St. Louis, vol. 2, pp. 250–252, 1868. Abstract, Am. Jour. Sci., 2d Series, vol. 42, pp. 120–123, 1868.

‡Amer. Jour. Sci., 2d. ser., vol. 47, pp. 78–88, 1869; also Am. Assoc. Adv. Sci., Proc., vol. 17, pp. 327–340.

Mississippi as far as Memphis and the Red to Shreveport.

To account for the occurrence of the Orange Sand as seen in Louisiana the conclusion is reached that "in late Quaternary times the Gulf coast has suffered a depression to the extent of at least nine hundred feet (perhaps more), and during the Terrace epoch, a contrary motion of about half that amount."

"The features of the Grand Gulf group in Louisiana are almost absolutely identical with those prevailing in Mississippi." Hilgard still maintains the necessity of a "temporary cutting off of the Mexican Gulf from the Atlantic to account for the existence of the Grand Gulf strata." He calls attention to the building stone, potter's clay, and a "fine white and exceedingly refractory, semi-indurate white pipe-clay, occurring near the edge of the Vicksburg rocks in Catahoula parish." To the Vicksburg group, Hilgard refers practically all the marine Tertiary of the State. The only exception is the locality of the *Zeuglodon* on the Ouachita.

For the lignitiferous beds in northern Louisiana he proposes the name of Mansfield group and correlates them with the lower portions of the Vicksburg bluff.

In discussing the "Salines of Northern Louisiana" Hilgard refers to the method of obtaining brine by sinking shallow wells 15 or 20 feet deep, sometimes by drilling deeper wells, even 1100 feet and occasionally obtaining an artesian supply of brine. The records of these borings are unfortunately lost. "But in one case at least the pile of borings, in others tradition testifies that calcareous or gypseous materials were met with all the way down. This fact, coupled with the lithological character of the latter (which is foreign to all the Tertiary groups known to me) and the 'find' of several individuals of *Exogyra costata* and *Gryphœa pitcheri* in the rubbish of one pit, suggests that here we have not local Tertiary basins, but rather the peaks of a Cretaceous ridge, projecting through the lignitic Tertiary."

In this report, as stated above, Hilgard describes the artesian wells of Calcasieu. They "are located on two small islands in the (fresh water) marsh which forms the head of the bayou Choupique," a small tributary of the Calcasieu river.

At the time of Hilgard's visit the well being sunk by the

Kirkman's Well			Louisiana Oil Co.'s Well			Formations
Depth	Thickness	Materials	Depth	Thickness	Materials	
Ft.	Ft.		Ft.	Ft.		
	354	Blue and yellow clay some sand strata	160	160	Blue clay, sometimes with layers of sand soaked with petroleum	Port Hudson Group
	96	Sand, with clay, laminæ, 36 ft. Sand and gravel, 56 ft.	333	173	Loose sand and gravel, 138 to 153 ft. very pebbly; 153 to 173 ft. finer material	Orange Sand Group
450		Sandy pipe-clay, 4 ft.	343	10	Gray laminated clay ("soapstone")	Vicksburg Group
			383	40	Blue, sandy, nodular limestone, with marine shells Petroleum and gas	
			443	60	Soft, white, crystalline, crumbling limestone; tube driven through	Cretaceous Formation
			543	100	Pure crystalline sulphur	
			690	147	Sulphur and gypsum, alternating About ⅓ sulphur. 5ft. Sulphur bed at 650 ft. 10–15 ft. bed at 680 ft.	
				540	Pure gypsum Dense, granular and coarsely crystalline, grayish or white	

Louisiana Petroleum and Coal Oil Co. had reached a depth of 1,230 feet and Dr. Kirkman's well was 450 feet deep. Hilgard interprets and correlates the two as shown on p. 25.

Hilgard read before the Troy meeting of the American Association 1869, a paper "On the Geology of the Delta and the Mud-lumps of the Passes of the Mississippi.* Concerning the delta plain as a whole he believes that the river deposits cover it to but a "comparatively insignificant depth."† He has found the Orange sand beds in the Calcasieu well about 100 feet in thickness, lying below a 350 feet stratum of Port Hudson. The latter beds are found to resemble those in the New Orleans well, extending to a depth of 630 feet. Sir Charles Lyell's intimation that the beds were for the most part of a delta formation is again questioned and proven false by the microscopic and macroscopic fossils of marine origin found in them.

The alluvium about New Orleans varies usually from 31 to 56 feet in thickness beneath which or at the base of which is a stratum of mud in which combustible gas is frequently found. This is of indifferent quality as shown by analysis (p. 245). Accompanying this flow of gas are streams of water and mud making artificial mud-lumps of sometimes considerable dimensions (p. 368). The question of mud-lumps is taken up and figures illustrating their growth and decay are given (pp. 356–368). Their origin is discussed at length (pp. 425–435) and analyses of waters given.

In Hilgard's report on the material obtained from the New Orleans well (bored 1856) published in 1870,‡ he maintains that the distribution and kind of molluscan species identified show that at least the lower 510 feet of the well (630 feet deep) belongs to one and the same formation. It is not a delta deposit. It is the Port Hudson formation. A carefully drawn section of the well accompanies this report.

Before the American Association in 1871, Hilgard read a paper "On the Geological History of the Gulf of Mexico."* In this paper a Cretaceous "backbone" (p. 393) is said to pass through

*See Am. Jour. Sci., vol. 1, 1870, pp. 238–246, 356–368, 425–435.

† Ibid p. 239.

‡ Rept. Chief Eng., 1870, pp. 352–361.

*Am. Jour. Sci., vol. 2, 1871, pp. 391–404.

the State in a northerly and northwesterly direction and on either side there is a dipping of the strata away from the axis toward the Mississippi on the east side and westerly or southwesterly on the west side. The "Northern Lignitic" is correlated with the Buhrstone of the states east of the Mississippi (p. 394). He is led to make this mistake on account of supposing that the now well known Midway Eocene beds in west Tennesee lying immediately upon the Cretaceous, were of Lower Claiborne age. Hence the intervening Lignitic beds should probably be of the same age. The Cretaceous backbone is held responsible for causing the extremely lignitic character of the formations of north Louisiana (p. 396). The barrenness of the Grand Gulf beds is attributed to some exclusion of the waters in which they were being deposited from the sea (p. 348). The calcareous concretions found near the base of this formation may have been derived from organic remains. The Port Hudson beds underlie the Mississippi alluvium up as far as Memphis, and the Red river as far as Shreveport (p. 401).

The Smithsonian memoir by Hilgard on the "Geology of Lower Louisiana and the Rock salt of Petite Anse* published in 1872 is a more complete statement of the first article on the subject published in the American Journal of Science in 1869. He describes the Port Hudson section and gives a detailed description of each of the Five Islands. In this article he takes the view that the Five Islands are but the erosion-formed outliers of a Cretaceous ridge or backbone which traverses Louisiana from the northwest corner in the direction of Vermillion bay; the salt being of Cretaceous rather than early Quaternary age. He thinks that at the beginning of Tertiary time the existence of the axis of elevation was marked merely by a number of disconnected islands. In later geological time the lower five outcrops were buried under deposits of Orange Sand and Port Hudson material, as indeed was the whole Mississippi valley, and in the re-excavation of the valley by the Mississippi river the material covering the Cretaceous nuceli was not eroded so much as the surrounding country, thus forming the islands.

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*Smith. Contributions, vol. 23, No. 248, 32 pp.

HILGARD'S PROFILE OF BLUFF AT SABINETOWN, TEXAS

No.	Materials and Character	Feet	Formation
14	Ferruginous sandstone, and conglomerate of pebbles with fragments of silicified wood..	6	Drift
13	Ferruginous sand, of the usual Drift facies, with two or there ledges of ferruginous sandstone..........	18	
12	Yellow and variegated sand, with clay laminæ interspersed..........	6	Mansfield
11	Grey or brownish laminated clay with yellow (ochreous) cleavage planes, and a few sandy layers..........	25	Lignitic (Foot of Vicksburg Bluff)
10	Yellow and variegated sand, with clay bands at intervals of about twenty inches..........	30	
9	Grey laminated clay with Selenite, and ferruginous stratification lines at intervals of ten inches..........	12	
8	Greenish ferruginous sand with clay laminæ.	3	
7	Ferruginous, concretionary sandstone, porous, fossiliferous..........	3	
6	Solid blue sandy clay..........	3	Jackson
5	Brown laminated clay..........	1	(Marine)
4	Blue fossiliferous limestone, sandy, with *Rostellaria velata*..........	2	
3	Greenish sand, alternating with clay laminæ..	6	
2	Blue calcareous sandstone, fossiliferous......	2	
1	Greenish sand, as far as visible..........	2	

In 1873 Hilgard published a "Supplementary and Final Report of a Geological Reconnaissance of the State of Louisiana." It is a large octavo phamphlet of 44 pages, and may be regarded as the most complete statement of the geology of the State heretofore published. No brief review can give an adequate idea of the contents of this work. It should be consulted by any and all who care to become familiar with the geology of the State. It gives soil analyses, topographic, geologic, vegetation and other characteristics of the regions traversed *en route* as outlined in his previous report.

On the preceding page Hilgard's section at Sabinetown, Tex. is given.

"At the foot of the bluff, where at high stages of water it is difficult to find passage, it is lined with blocks of dark colored rock, tumbled from above. These are mostly derived from No. 7 of the section, a porous, concretionary, ferruginous sandstone, with casts of fossils, now unrecognizable. There are besides, blocks of hard, limy sandstone or sandy limestone derived from No's. 2 and 4. The former is generally poor in fossils, the latter in places very rich, and the fossils well preserved, but very difficult to detach from the rock. Among them, a small variety of *Rostellaria velata* is the only fossil usually characterizing the Jackson group. But this, at the time of my visit, I failed to identify, and was inclined to consider the fauna found here more nearly related to the Vicksburg than to the Jackson group. But at a subsequent visit Prof. Hopkins found on a tributary entering the Sabine just above the ferry, a bed of shells bearing most distinctly the Jackson character. While it is thus proven that the lower (marine) portion of this profile is of the latter age, the upper (lignitic) part is thereby parallelized to the lower division of the Vicksburg bluff, to which it bears a close lithological resemblnace. And if we define the area actually underlaid here by the Vicksburg marine rocks proper, we cannot assign to it, on an average, a width greater than about three miles in a northwest and southeast direction."

We are quite at a loss to know what shells Dr. Hopkins could have found here that would have a "most distinctly" Jackson character for they are purely upper Lignitic species as will be shown later on in this report. Moreover, Hilgard is still misled regarding the Vicksburg outcroppings by the little orbitolite specimens in the Lower Claiborne which he takes to be *Orbitoides mantelli*. The salt works in Northern Louisiana are well described, likewise the so-called marble and limestones. The Grand Gulf beds at Harrisonburg are well described. In the recapitulation he gives again the Calcasieu wells.

In 1874, Hilgard published a "Note on Lignite Beds and Their Under-Clays" in the American Journal of Science.* In the course of this note he says: "The cause of this complete obliteration of spongy roots or spongy parts of roots is doubtless to be sought in the oxidizing influence of ferruginous solutions percolating from above, and the subsequent action of pressure on the yielding mass." * * * "That another phase of the same agencies has been instrumental in obliterating the teeming fauna of the Port Hudson beds, whose character can now be studied only in a few limited localities, I have already shown (Smith. Contr. Knowl., No. 248, p. 12). And there can be little doubt that the absolute dearth of organic remains which has thus far frustrated all my attempts to gain a definite clue to the age of the Grand Gulf beds of the Gulf border, is largely due to the same cause, and not to the conversion of the Mexico Gulf into a dead sea during the Post-Eocene Tertiary period."

In arguing against the æolian origin of the Lœss, Hilgard states† that in Louisiana representative deposits are quite distinctly stratified.

In 1881, Hilgard contributed an article on "the Later Tertiary of the Gulf of Mexico" to the American Journal of Science.‡ This article is inspired by the recent publication of the Coast Survey chart "Soundings in the Gulf of Mexico" and the observations of Smith on the geology of Florida.

On his map the northern edge of the Grand Gulf formation is made to curve around in Alabama and "run out" into the Gulf of Mexico at about the western extremity of Florida. It thus seems to have some relationship to the abrupt descent in

*Vol. 7, pp. 208–210.

†Am. Jour. Sci., vol. 18, 1879, p. 107.

‡Vol. 22, pp. 58–65, map.

the bottom of the Gulf not far to the east and southeast of Pensacola.

The shelf along the northern coast of the Gulf, in case the bottom were raised 450 feet would be converted into a shallow water strip in which both fresh water and marine animals could have no safe footing. Add to this the partial closing of the Florida Straits and the Yucatan Channel and the whole Gulf would have become inhospitable for its marine denizens.

The first report on the Mineral Resources of the United States published in 1883 contains an article by Dr. Hilgard on the Salines of Louisiana.* It contains a complete restatement of the information regarding the northern salines published in his earlier articles and much additional data on the mining operations on Petite Anse.

In the Report on Cotton Production in the United States†, part 1, page iii, *et seq.*, Hilgard gives a brief summary of the geological features of the State, including however no new geological facts. The soils of the State are discussed with care, and many exhaustive analyses of the same are given.

In 1885 another article was contributed by Hilgard, entitled, "The Classification and Paleontology of the United States Tertiary Deposits."‡ This article was inspired by the peculiar stratigraphy of O. Meyer and the answer by Heilprin. Hilgard does not believe in Meyer's stratigraphy. On the other hand, he fully sympathizes with Meyer in considering many of Conrad's species as spurious or as varieties only; states he gave up sending Conrad material because the latter would describe all varieties as *species novæ*. Again and finally: "I doubt if there exists a finer opportunity for observing the evolution of marine species in Tertiary times than is presented by the minutely differentiated formations of Mississippi and Louisiana."

About simultaneously another article appeared from Hilgard's pen in the American Journal of Science, on The Old Tertiary of the Southwest."§ He disposes of Meyer's ridiculous stratigraphy in trans-Mississippi deposits, and adds: "But, outside of the

*Pp. 554–565.

†47th Cong. 2d Sess., House Mis. Doc., No. 42, part 5, 1884.

‡Science, vol. 6, p. 44.

§Am. Jour. Sci., vol. 30, pp. 266–269.

State of Mississippi, I can satisfy Dr. Meyer's postulate of 'seeing Vicksburg rocks actually superimposed upon the Jackson strata.' I have seen this in Louisiana on the Bayou Funne Louis, where I have stood on a ledge of Vicksburg limestone showing a southward dip and containing abundance of *Orbitoides*, *Arca mississippiensis* and *Pecten poulsoni*, looking down upon a level prairie country in which the bones of the *Zeuglodon* have been plowed up."

In 1887 Hilgard contributed to Science*, an article entitled, "The Equivalence in Time of American Marine and Intra-continental Terranes." Herein the following significant passage occurs: "The striking increase of the lignitiferous facies toward the northwestern border of the Gulf Tertiary area, culminating in the appearance of bands of fresh-water limestone at Mansfield and northwestward; the fan-like expanse in Arkansas and Louisiana of the older portion of the narrow bands formed by the marine stages in Mississippi and Alabama with a manifest northwestern trend of such deposits as are continuosly traceable in northwestern Louisiana, while the later stages are abruptly deflected to the southwest, all points to a rapidly progressing elevation of the axial Cretaceous trough that may or may not have completely separated the interior from the gulf waters before the beginning of the Tertiary period."

Hopkins.—In 1869 Dr. F. V. Hopkins made three geological trips in northern Louisiana and submitted his first annual report on the region covered late in the same year. In this report he reviewed the different geological formations occurring in the State from the oldest or Cretaceous to the most recent or alluvial formation.

His ideas of the stratigraphy of the State along a line "passing north through the Cretaceous outcrop in Winn and then turning a little southeast to intersect the St. Landry limestone, and the islands in the sea-marsh," is shown in the following figure:

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*Vol. 9, p. 535, 1887.

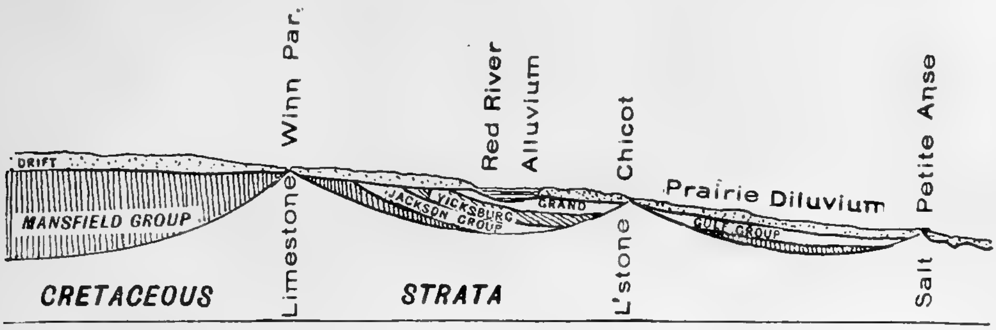

FIG. I.—*Transverse section of Louisiana. After Hopkins.*

The Cretaceous is said to rise to the surface in but few localities. One is on Dugdamona bayou, S. 35, 12 N., 3 W. Another is in St. Landry about seven miles west of Chicot. Other Cretaceous rocks have been met with in wells, around Drake's salt-works, King's salt-works, and in the sulphur well at Calcasieu.

The well section at Calcasieu he gives from information obtained from a Mr. Munn, as follows:

Prairie Diluvium.	1.	160 feet blue clay, layers of sand.
Drift............	2.	173 feet sand.
Grand Gulf......	3.	10 feet clay rock "soapstone."
Vicksburg.......	4.	40 feet blue anthraconitic, limestone, fissured.
Cretaceous	5.	60 feet gray limestone.
	6.	100 feet pure crystalline sulphur.
	7.	137 feet gypsum, with sulphur.
	8.	10 feet sulphur.
	9.	540 feet gypsum, grayish blue.

He is led to believe that: "The sulphur was formed by reducing the gypsum with vegetable matter. The carbonic acid, olefiant gas and the marsh gas produced by the process, have each left the proof its presence, *i. e.*, the limestone stratum No. 5 contains the former, the petroleum is made from the olefiant gas," and the small low mounds of that and other regions were formed by the escaping of these gases.

The Mansfield group is discussed lithologically, geographically and paleontologically. A hundred foot section is given near Columbia. Sections at Coal-bluff, on the Chickasaw creek, and at Grande Ecore, on Red river, are given in detail, with others.

At Spring Bank, in Arkansas, eight miles above the State line, a fine exposure occurs containing a sufficiently large amount of iron ore to "almost justify the establishment of a furnace." (p. 89.)

The Jackson group is next taken up and traced from Grandview, on the Ouachita, to Montgomery, on the Red. The latter locality, the most important Jackson deposit in the State, was brought to the attention of the scientific world by the transmission to the State Military Academy of a vertebra of *Zeuglodon* by Judge A. V. Ragan, the owner of the bluff and plantation. He notes (p. 94) the occurrence of *Orbitoides mantelli*, a typical Vicksburg species, in the Jackson beds at this locality. Many of the more important Lower Claiborne localities, as known to-day, were visited by Hopkins and referred to the Jackson period.

The "Vicksburg formation" he traces from "near the Ouachita to nineteen miles southwest of Natchitoches" including much that is now known to be Lower Claiborne.

The Grand Gulf is then taken up and its characters, extent, out-crops, etc., given. Sections are given at Harrisonburg, Chalk hills and Alexandria.

The deposits of the "Drift Period" are then discussed as regards geographical distribution. He makes the following general statements: "The country covered by the drift, i. e., the areas of the Grand Gulf, much of the Jackson and Vicksburg, and almost all of the Mansfield groups, comprises the upland region of the State. It is, in general, broken and hilly, the height of the hills depending principally on the underlying Tertiary strata. The highest are on the territory of the Mansfield group, between Shreveport and Monroe; but the Harrisonburg, Cloutierville and Kisatche hills are of Grand Gulf age, as we have seen already. The intervening region of the Jackson and Vicksburg are lower, and are often entirely bare of the drift, as is the case also with the marly regions of the Grand Gulf. Perhaps the presence of lime in the soil renders it more penetrable by water and therefore more subject to denudation, so that an oceanic current carrying detritus, would deposit it most heavily where there was the least lime. Whatever the explanation may be, this appears to have been the fact."

Hopkin's Second Annual Report of the Geological Survey of Louisiana was presented to the General Assembly late in 1870 and published in 1871. It is accompanied by a colored map of the State, the first and only geological state map thus far published. He correlates the "Mansfield group" with the marine Jackson, regarding their difference in appearance as due to local conditions in deposition instead of difference in time of deposit.

The Claiborne stage is still unidentified in the State; all localities now known to belong to the Lower Claiborne are here referred to the Jackson or Vicksburg stages. A long list of Jackson fossils is given, likewise a less exhaustive one of the Vicksburg.

This report cannot be regarded as more than a restatement of the more important facts of the first with some additions and corrections as noted above.

The third Annual Report of Dr. Hopkins is devoted almost entirely to a discussion of the newer formations from the "Drift," (now called the Lafayette) upwards. In this report he departs from the view which he has heretofore advocated of the comparatively slight thickness of the alluvium of the Mississippi valley. He says: "The professor [Hilgard] therein takes the view that the alluvium proper beneath New Orleans is but thirty-one feet thick, arguing that the marine deposits below are of the Port Hudson group. I followed him last year in this idea, and quoted his list of shells under the head of the Bluff formation. My observations this season oblige me to modify this conclusion somewhat. Wishing to ascertain as accurately as possible the actual depth of the alluvium, I instituted a series of experiments upon the water of wells dug in the Port Hudson formation and in the bottom lands, respectively. I have found (as indeed, Professor Hilgard had told me that he should expect) that the former contain a considerable proportion of sulphates and carbonates, while the latter show an excess of chlorides. This result is uniform, excepting where the wells happen to strike considerable beds of sand, when the waters are too pure to be distinguished. It is evident, therefore, that by testing the water of the deepest wells dug in the alluvium, it is possible to tell whether they pass through it into the underlying Port Hudson group or not. The patent wells that are made by simply driving a tube into the ground, offer great facilities for this research, as the water that they furnish comes necessarily from the bottom of the well only. On a trip that I made from Baton Rouge to the Arkansas line, I analyzed the water of various wells from seventy to one hundred feet in depth, and in not a single instance found any other than the alluvial characteristics."*

He discusses at length the Bluff formation under which he includes the Port Hudson, the lœss and the Yellow loam and gives the results of field work in East Baton Rouge, East and West Feliciana, Tensas, Madison, Carroll, Moorehouse, Ouachita, Richland, Franklin, Catahoula, Rapides, Avoyelles and Pointe Coupé parishes. He describes and gives sections in Bayou Macon hills, at Catahoula lake, in the Tunica hills, at St. Francisville, at Port Hudson and near Baton Rouge.

In the Tunica hills he records the unusual thickness of 150 feet for the lœss and on Red river connects the upland terraces with the Port Hudson material of the Mississippi valley. He gives an extensive list of Palæozoic fossils which have been identified from the "drift gravels," and is inclined to regard the gravels, as having been formed in Quaternary time by an arctic current flowing from Hudson bay.

To this discussion is appended a brief account of the formations exhibited on the geological map.

Edwards —In 1870 A. M. Edwards reported on the "Results of a Microscopical Examination of Specimens of Sand obtained from an Artesian Well at New Orleans." At the depth § of 32 feet he found sand, light grayish with fine specks of organic material. This is the gas bearing stratum. At 49 feet sharp sand consisting of clear transparent quartz with black organic specks and a few comminuted mollusks. At 52½ feet somewhat the same as above but darker. At 71 feet fine sea-bottom deposits with many sea-shells. The *Diatomaceæ* are the same species as those found living on the coast of Florida and South Carolina.

Hayes.—An analysis of lignite derived from a locality two miles below Shreveport was made in 1874 by S. Dana Hayes,‡

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* Third Annual Report Geol. Surv. of La., An. Rept. Supt. La. State Univ. for 1871, p. 168, 1872.

§ An. Lyc Nat Hist New York, vol. 9, pp. 329-33.

‡ Chemical News, vol. 30, pp. 153-154.

State Assayist of Massachusetts. This author adds: "This lignite has a specific gravity of 1.143, it is nearly black in color, and its lignitic structure is not so distinct as usual; but it dissolves completely in caustic soda solution."

Forshey.—In 1875 C. G. Forshey, Assistant Engineer, published a "Report of Survey and Borings Made at the Proposed Site of the Lake Borgne Outlet."* He finds that the banks of the Mississippi slope rapidly back towards the lake and reach the level of the swamp land at a distance of from 3,000 to 4,000 feet. He reports 14 soundings made by auger and casing pipe to depths of from 70 to 100 feet. The mollusks obtained from the wells were submitted to Prof. Carpenter of Montreal and found to belong to species now living in Florida waters. Violent eruptions of hydrogen gas sometimes brought up shells and mud from depths of 60 to 70 feet. The gas burns with a reddish flame. He notes the similarity of these phenomena to those seen at the mud-lumps of the Mississippi.

Gabb.—From his studies in the West Indies and Costa Rica Gabb concludes† that instead of being shut off from the sea in Miocene times, the Gulf of Mexico was less isolated than now since the marine Miocene deposits on these islands and shores prove the islands were then much below the present level.

Johnson.—In 1885, L. C. Johnson was directed by the U. S. Geological Survey to investigate the iron ores of Louisiana. In 1886 he was requested to extend his researches into the northeastern counties of Texas.

The results of these investigations are embodied in a report published in 1888, as House Ex. Doc. No. 195, 50th Cong. 1st Session and styled "The Iron Regions of Northern Louisiana and Eastern Texas."

He published a map showing the distribution of the ores and gave figures in the text illustrating characteristic or important exposures. In the matter of stratigraphy he followed Hilgard closely. He has nothing new to offer on the age of the Mansfield group. He did, however, collect fossils from several important

* 44th Cong. 1st Sess. Rept. Sec. War. Eng. Rept. vol. 2, pt. 1, pp. 622–629.

† Amer. Jour. Sci., vol. 9, 1875, p. 320.

localities, and Aldrich, who studied them, was enabled to correct some erroneous correlations made before Johnson's work ; the U. S. National Museum now has these considerable collections. He found several new localities for fossils.

His conclusions on the iron ore of the State will be found later on in this report.

"The Nita Crevasse" is the title of a brief article by Johnson in the Geol. Soc. Amer. Bulletin for 1891.* He states among other things that there was a period when the Mississippi embouched at Manchac. The Pontchartrain clays were then deposited. These extend up to the lœss and are the equivalents of the Port Hudson beds.

Knowlton.—The Proceedings of the U. S. National Museum, vol. 11,† contains a note by Knowlton describing two species of fossil wood from Rapides parish, La. They were collected by L. C. Johnson in 1886. Johnson called them Pliocene ; McGee says they are of Grand Gulf age ; Knowlton thinks the age very uncertain. They are Palms called *Palmoxylon quenstedti* and *P. cellulosum*.

Elsewhere in the same volume (p. 11 *et seq.*) Knowlton has prepared for publication some of Lesquereux's species from Campbell's quarry, Cross lake and from McLee's, two miles north of Mansfield. (See especially pp. 24–25.)

Leidy.—In 1884 Joseph Leidy made a short communication to the Academy of Natural Sciences of Philadelphia on Fossil bones received from Petite Anse.‡ This was followed by a detailed report published in the Transactions of the Wagner Free Institute of Science in 1889. In this he mentions *Mastodon americanus*, *Mylodon harlani* (?) Owen and *Equus major* DeKay as occuring at this locality.§

* Vol. 2, pp. 20–25, 1891.
† Pp. 89–91, pl. xxx, 1888.
‡ Proc. Acad. Nat. Sci. Phila., vol. 26, p. 22, 1884.
§ Trans. Wagner Free Inst. Sci., vol. 2, pp. 33–40, 1889.

THIRD PERIOD.

PERIOD OF WORK UNDER THE DIRECTION OF EXPERIMENT STATION.

Lerch.—Dr. Otto Lerch spent from March 1 to May 18, 1892, in the study of the geology of Northern Louisiana. His report, which appeared the same year, was entitled "A Preliminary Report upon the Hills of Louisiana, north of Vicksburg, Shreveport and Pacific Railroad." It consisted of 52 8vo. pages, and was illustrated by figures in the text.

The work of this brief period was mainly confined to localities along the line of the V. S. and P. R. R. He visited Rayburn's salt works, however, and was the first to note Cretaceous fossils at that locality. He gives a good description of the old works, including a figure showing his idea of the stratigraphy of the region.

A long section (opp. p. 22 of his report) shows his conception of the Eocene stratigraphy of N. Louisiana. Analyses of seven artesian wells and spring-waters are given. Ten soil analyses were made and published. Three specimens of iron ore and two of lignite were tested.

The "List of Fossils from the Green Sand Marl, two and one-half miles Northeast of Mt. Lebanon, La.," affords we believe, the first satisfactory published proof of the age of the large majority of the marly fossiliferous beds of northwest Louisiana.

Lerch continued field-work during July and August in northern Louisiana. The special field of investigation is indicated by the title of his second report published in 1893. It reads, "A Preliminary Report upon the Hills of Louisiana, South of the Vicksburg, Shreveport and Pacific Railroad, to Alexandria, La." His former publication being styled No. 1, this follows accordingly as No. 2.

After discussing the topography, drainage and lakes, he takes up "General Geology" and treats the various formations that underlie this portion of the State, beginning with the oldest, or Cretaceous.

"Drake's salt works are described, and represented in section; the Winnfield "Marble" is likewise described; and a list of all known or supposed Cretaceous outcrops is given. He refers to the N. W.—S. E. trend of these outcrops, as Hilgard and others had done before, and concludes "that at the close of the Mesozoic time enormous plutonic forces convulsed, fractured, faulted and folded the Cretaceous strata, throwing up mountain chains of vast extent and raising them far above the waters of the Gulf."

The lower Eocene beds of the State he styles "lower lignitic" in contradistinction to similar beds above the "marine Claiborne beds" termed "upper lignitic."

It should be borne in mind that the expression "lower lignitic," as here used is simply a descriptive term and in no way implies that the beds are equivalent to the lower Lignitic beds of the Alabama section.

To these lignitic beds he refers the outcrops seen along the T. and P. R. R., from 4 miles N. W. of Cypress station to Robeline. Other outcrops are mentioned about Mansfield and Shreveport.

"Marine Claiborne" outcrops are mentioned from S. 7, 17 N., 9 W.; S. 22, 18 N., 10 W.; Natchitoches; Capt. Plair's, 6 miles N. of Benton; well on S. 2, 20 N., 13 W.; S. 33, 16 N., 5 W.; White Oak creek, S. 14, 11 N., 5 W.; well on S. 10, 10 N., 5 W.

The lignitic beds in the eastern part of Northern Louisiana, he believes to be above the Claiborne and terms them "upper lignitic." They are typically exposed in the bluffs and R. R. cuts about Columbia.

The "Arcadia Clays" according to this author are bounded on the south "by the north boundary line of the calcareous marls and limestone of the overlying Jackson and Vicksburg groups of Hilgard, sub-parallel to the present coast line of the Gulf of Mexico. They cross the State from east to west, resting upon the deeply eroded surface of the lower lignitic, marine Claiborne and upper lignitic formations reaching northward into the State of Arkansas, westward into Texas, and are bounded in the east by the flood plain of the Mississippi river. Their dip is southwesterly, though on account of the erosion, they have sustained, the covering mantle of succeeding formations and slight disturbances in the deposits, it is frequently very "difficult to make it out."

"Jackson" beds are represented in a section "No. 13," as overlying "upper lignitic" beds and the latter in turn are shown to overlie the "Claiborne formation."

Unfortunately the "Jackson" localities given are ill-defined, or belong to the Lower Claiborne stage.

The "Vicksburg" sections given on p. 93. are Jackson (see "No. 15" and "No. 16").

The "Grand Gulf" rocks are described and illustrated on pp. 94–98.

The "Red Sandy Clays" of northern Louisiana are said to have been deposited at the close of the Tertiary.

Next, "The Sands and Gravel of the Drift" are described; and, finally, the "Alluvium" is discussed.

Under Economic Geology the waters examined are described.

Under "Useful Minerals" the analyses of 10 marls are given; and gypsum and limestones are discussed.

Under "Other Minerals of Economic Value" are placed Building stones, Gravels, Iron, Clay, Kaolin, Salt, Lignite; of the latter 4 analyses are given. "Soils of Northern Louisiana" are discussed and 45 analyses are given.

The "Botanical Notes" by Vaughan and Tracy are an important and interesting feature of the report.

Harris.—While engaged on the Tertiary of southern Arkansas, this author made a short visit to the Bossier and Claiborne parishes of this State to see what help in the classification of deposits in Arkansas might be derived from fossiliferous sections farther south. The results of this trip were embodied in one of the Arkansas Annual Reports.*

A detailed section at Roberta, and at the Pope Joy cut are given. Various fossiliferous localities are mentioned.

From the fossils collected by Johnson and deposited in the U. S. Nat. Museum this author was able to correlate the St. Maurice beds as Lower Claiborne.

A list of Jackson fossils from Montgomery follows; the chapter closes with a brief history of the *Zeuglodon* locality on Ouachita river.

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*Arkansas Geological Survey, Annual Report, 1892, vol. 2 (publ. 1894), by Gilbert D. Harris, 8vo. 207 pp., plates, map. See Chapter VIII.

Cope.—This author published in 1894* some notes "On Some Pleistocene Mammalia from Petite Anse, La."

He describes two new species of *Mylodon* and one of *Equus*, and mentions others. (See special report on Five Islands, under Petite Anse).

Vaughan.—By permission of the Director of the U. S. Geol. Surv., Mr. T. Wayland Vaughan published in 1895 an article entitled "The Stratigraphy of Northwestern Louisiana."†

This work represents the results of several visits to this portion of the State by the author dating from 1889, to the autumn of 1894.

Vaughan's treatment of the subject is chronologic, beginning with the lowest or oldest beds, the Cretaceous. He very properly doubts Hilgard's identification of *Gryphæa pitcheri* on the ground that this is a Comanche series fossil and not of the higher glauconitic horizon.

This author takes exception to Lerch's "disturbance in Louisiana succeeding the close of the Cretaceous deposition," and insists on an erosion period between the Cretaceous and Eocene. Furthermore he believes the Cretaceous strata to be undisturbed, or now quite horizontal.

By means of carefully noting the distribution of fossil remains in this portion of the State, Vaughan was able to correct some of the errors of Lerch as to the distribution of the Jackson stage.

Unfortunately he regarded Lerch's "lower lignitic," and Hilgard's "Mansfield group" as belonging to the Lower Claiborne.

He is doubtless right in referring Lerch's "Arcadia Clays" to the Lower Claiborne.

Some of Lerch's "upper lignitic" beds are proven to be Lower Claiborne, while others, as at Columbia, are referred to a newly named substage, the "Cocksfield Ferry beds."

Jackson and Vicksburg localities with lists of fossils are given. The Grand Gulf beds were discussed and a new group of strata is described under the name *Sparta Sands.*

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* Am. Phil. Soc. Proc., vol. 34, pp. 458–468.

† Amer. Geologist, vol. 15, p. 205–229.

"Covering the southern part of the Lower Claiborne area and all of the Jackson and Vicksburg, excepting small spots, and extending over the Grand Gulf, are deep quartz sands sometimes with gravel, which bear a growth of long-leaf pine. These sands rest unconformably on the lower terranes. The name *Sparta Sands* is proposed for them."

Vaughan published as Bulletin No. 142 of the U. S. Geol. Survey, 1896, practically the above notes plus a bibliography; list of fossils, with localities; and description of several new molluscan species, with figures.

Clendenin.—W. W. Clendenin in 1894 continued the work begun by Dr. Lerch. He was connected with both the University and the Experiment Stations. Six months were spent in the University and six months in the field. During the summer of 1894 and '95 he was engaged in an examination of the "Florida Parishes of East Louisiana and the Bluff, Prairie and Hill Lands of Southern Louisiana. His report on this area appeared in 1896, as part III of Geology and Agriculture. The general topographical features of the region are discussed and the terms Lafayette and Columbia substituted for Hilgard's old Orange Sand and Port Hudson.

On the Five Islands he worked out the fact that the islands were lifted, in part at least, during the period which followed the deposition of the Lafayette gravel. This idea was a marked improvement on Hilgard's early supposition that the islands were formed by the differential erosion of a Cretaceous ridge in pre-Tertiray times.

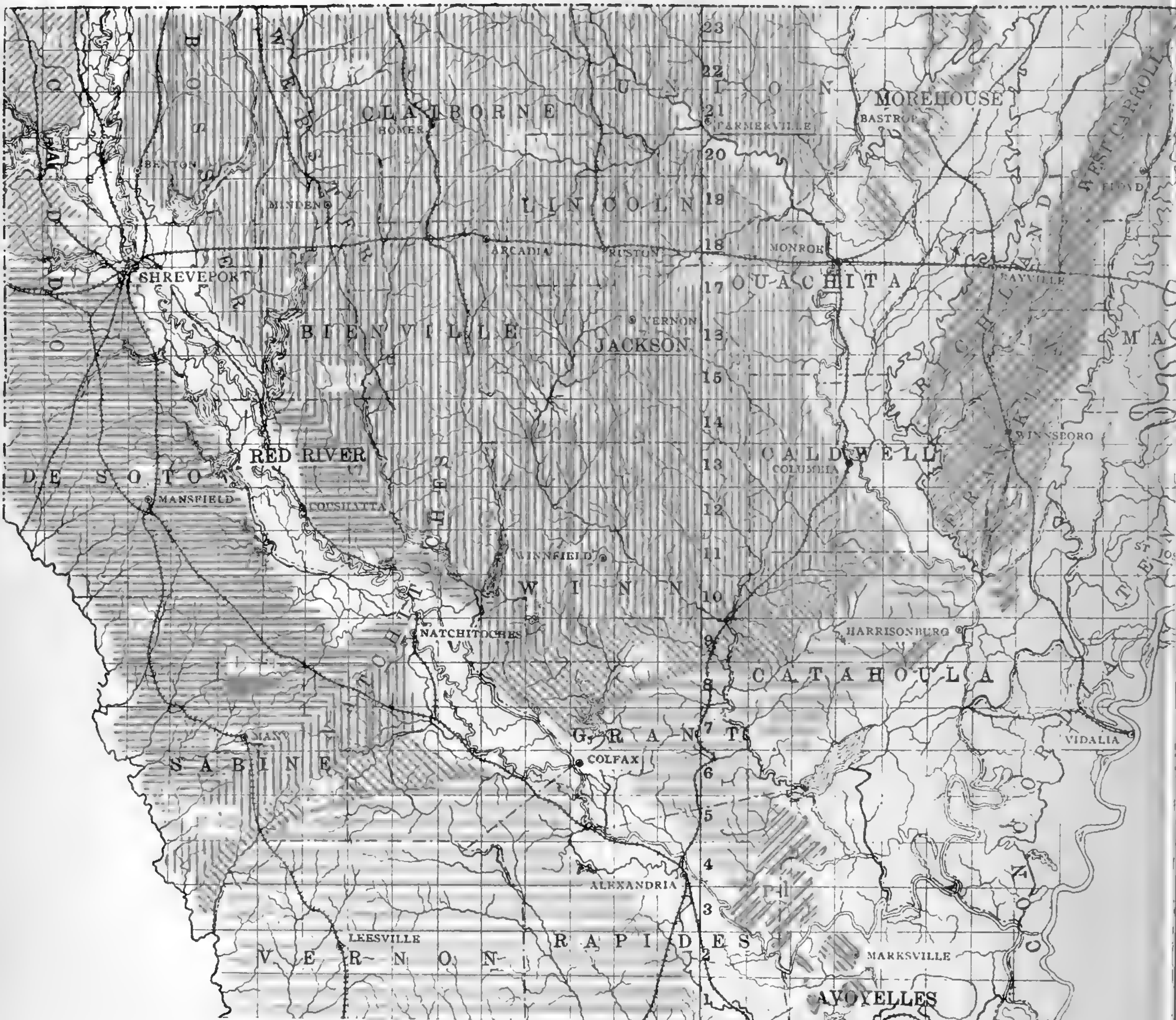
He also published several well sections in southern Louisiana which throw considerable light on the geology of the southwestern part of the State.

Part of the summer of 1895 was spent in the Bluff and Mississippi alluvial lands, and his report on this area appeared as Part IV of Geology and Agriculture. He gives a general discussion of the life and development of a river and shows how it applies to the Mississippi.

Johnson.—In 1899, an article appeared in the Philadelphia Academy's Proceedings entitled "New and Interesting species in the 'Isaac Lea Collection of Eocene Mollusca.'"

Proc. Acad. Nat. Sci. Phila., 1899, pp. 71–82, pl. 1–2.

Herein were described from the Jackson beds at Montgomery, La., *Mitra grantensis*, *Phos hilli*, *var. magnocostatus*, *Cypræa ludoviciana;* from the Lower Claiborne at St. Maurice, *Fusus ludoviciana;* from Hammett's branch, near Mt. Lebanon, *Cypræa vaughani*, *Ovula subtruncata*.



CLAIBORNE
HOMER
UNION
FARMERVILLE
MOREHOUSE
BASTROP
WEST CARROLL
FLOYD
BENTON
MINDEN
LINCOLN
ARCADIA
RUSTON
MONROE
SHREVEPORT
OUACHITA
RAYVILLE
VERNON
JACKSON
BIENVILLE
RED RIVER
CALDWELL
COLUMBIA
WINNSBORO
DE SOTO
MANSFIELD
COUSHATTA
WINNFIELD
WINN
NATCHITOCHES
HARRISONBURG
CATAHOULA
GRANT
COLFAX
VIDALIA
SABINE
ALEXANDRIA
LEESVILLE
VERNON
RAPIDES
MARKSVILLE
AVOYELLES

GEOLOGICAL MAP

OF

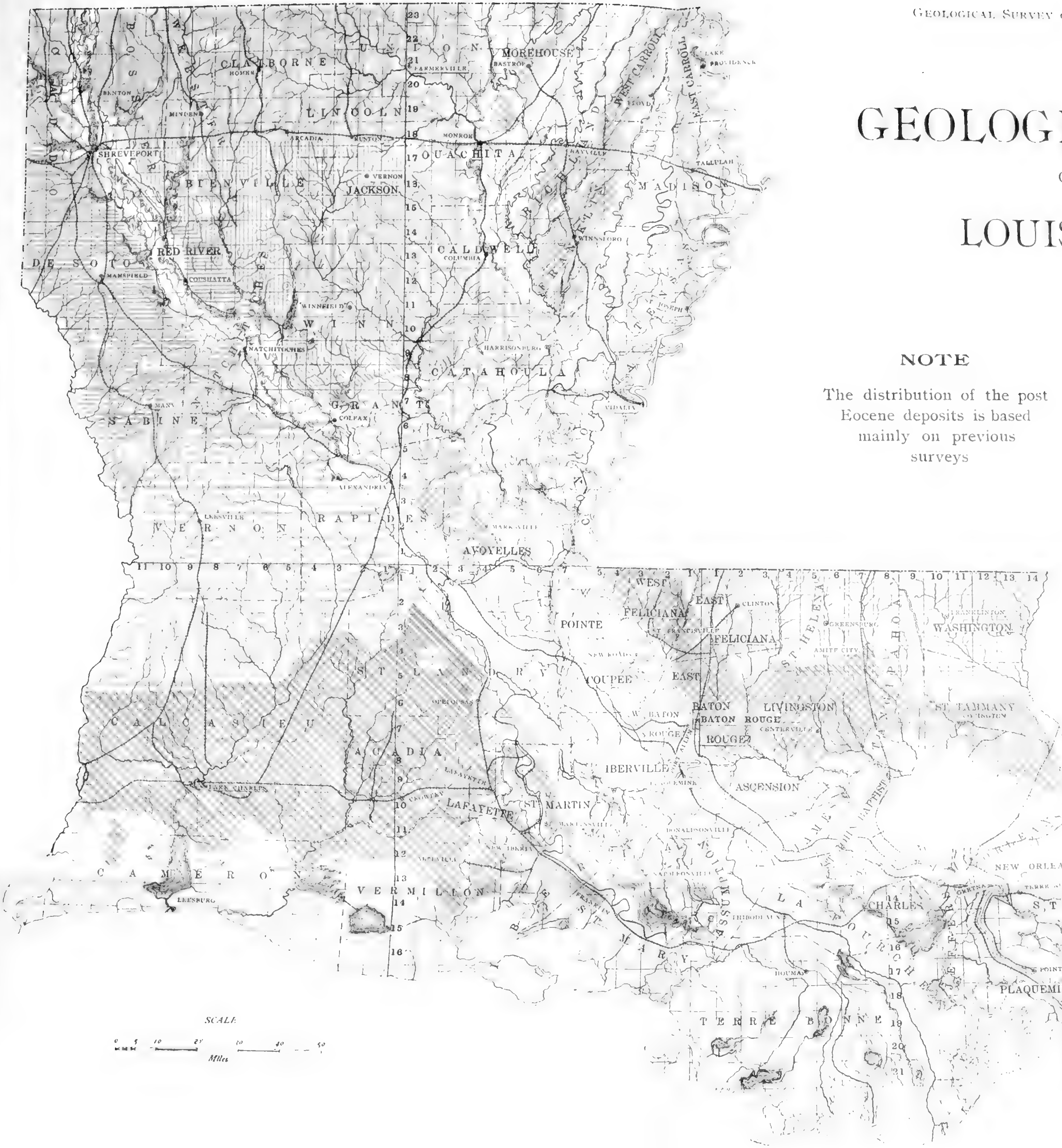
LOUISIANA

NOTE

The distribution of the post Eocene deposits is based mainly on previous surveys

- ◎ Cretaceous
- Eocene of doubtful horizon
- Midway Eocene
- Lignitic Eocene
- Lower Claiborne Eocene
- Jackson Eocene

GEOLOGICAL MAP OF LOUISIANA



NOTE

The distribution of the post Eocene deposits is based mainly on previous surveys

- Cretaceous
- Eocene of doubtful horizon
- Midway Eocene
- Lignitic Eocene
- Lower Claiborne Eocene
- Jackson Eocene
- Vicksburg Oligocene
- Grand Gulf Oligocene
- Port Hudson Pleistocene
- Lœss and Loam Pleistocene
- Alluvium and very recent deposits

SECTION II

GENERAL GEOLOGY

BY

HARRIS AND VEATCH

GENERAL GEOLOGY

DIVISION 1, STRATIGRAPHIC GEOLOGY

CRETACEOUS SERIES

Ripley Stage

Preliminary Remarks

Localities:

Conclusions

EOCENE SERIES

Midway Stage

Localities:

Lignitic Stage

Preliminary Remarks

Areal Distribution

Localities:

Quaternary Phenomena other than Erosion and Deposition

Local Crustal Movements

The Mud Lumps

DIVISION II. ECONOMIC GEOLOGY

Important Products

Salt

Sulphur

Clays

Sandstone

Limestones

Gravel

Unimportant Mineral Products

Iron Ores

Lignite

CRETACEOUS SERIES

Ripley Stage

Preliminary Remarks

In our historic review we have called attention to the fact that Judge Bry, early in this century mentioned the occurrence of Cretaceous fossils on the Ouachita river (see p. 16). Morton (see p. 17) soon followed with references to other localities of this formation in the State, namely between Alexandria and Natchitoches.

But there is every reason to believe that these early references were based on faulty evidence, the former on improper identifications of fossil remains, the latter on mere lithologic resemblances. Hilgard's references to two characteristic Cretaceous species found in dumps from salt wells in northern Louisiana have frequently been pointed to as the first satisfactory proofs of the Cretaceous series in Louisiana. But when it is seen by his Supplementary and Final Report (p. 28) that it is King's salt works that yielded these fossils and that the *Gryphæa pitcheri* is really *Ostrea pulaskensis* a characteristic Midway Eocene species; and the character of the material in which they are embedded is precisely that of the lower Eocene beds near Prairie bluff and Snow hill, Alabama, we are led to surmise that the *E. costata* was in reality something else or was brought up from some distance below the surface or from some altogether different locality.

We must therefore include King's salt works under the next stage, namely, the Midway Eocene.

Localities

Rayburn's salt works.—Mr. Lerch's report for 1892 (p. 13) this locality is described as in Section 24, 15 N., 5 W., about 10 miles southeast of Bienville. An ideal section of the rocks at this locality is given which, by the way is considerably at variance with Veatch's notes on the same region (see Fig. 2); but he mentions the occurrence here of well-preserved *Exogyra costata.*

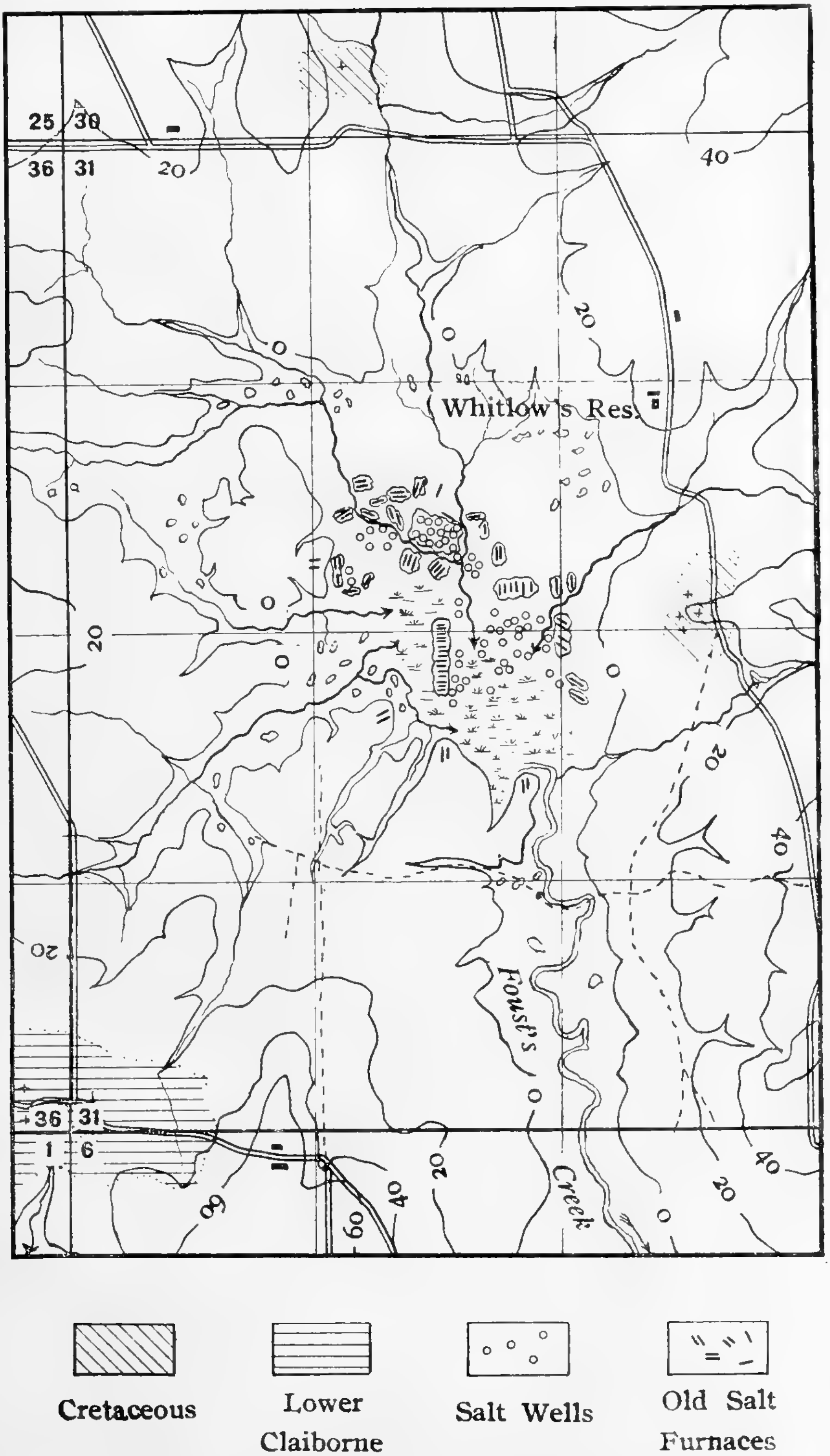


Fig. 2.—*Sketch Map of Rayburn's Salt Works*

The locality given by Hilgard and Lerch seems to be in error. The junior author has carefully gone over the deeds in the possession of Mr. Whitlow, the present owner of the place, in which the land is described as Sec. 31, 15 N., 5 W.

The old salt furnaces and wells cover about forty acres of a little circular valley which lies around and a little west of the center of that Section. The hills which surround the valley slope very gently down from an elevation of sixty feet, which they attain over a mile from the old works. The southern end of the valley is quite swampy, and during heavy rains is flooded to depth of two or three feet. The little outlet creek, Fousti creek, has its origin in the lower end of this swamp. Around the edge of the valley are numerous circular mounds about sixty feet in diameter and three to four feet high. They are of the same type as the little mounds which are so common in different parts of Louisiana.

The old dump heaps around the wells, the latter from fifteen to twenty feet deep, show large quantities of variously colored quartz and chert gravels. Fragments of dark gray and yellow fissured crystalline limestone, and of white or bluish white masses of gypsum, are quite abundant in some of the old dumps.

The hills surrounding the old lick are composed almost entirely of gray sand with small iron concretions. On the area mapped, but three places were seen which showed anything harder than sand. Just east of the wells, from five to eight feet above them, is a little patch of black prairie land covered with small hawthorn bushes. On the surface of the prairie numerous specimens of large *Gryphæa vesicularis* and a single valve of *Exogyra costata* were found.

It seems queer, from the abundance of the former species and the comparative scarcity of the latter, that the only large Ostrea-like shell mentioned by Lerch occurs at this locality in *Exogyra costata*. Immediately below the black soil is a layer of very soft white, chalk-like limestone. It is from this that the large shells have been derived. It is filled with finely preserved Cretaceous fossils. The following is a partial list of the species found here (mainly Stanton's identifications):

Exogyra costata,
Gryphæa vesicularis,
Ostrea plumosa,
Ostrea larva,
Pecten burlingtonensis,
Neithea quinquecosta,
Crassatella vadosa,
Inoceramus barabina?
Legumen planulatum,
Linearia metastriata,
Avellana bullata,
Baculites anceps,
Heteroceras,
Ptychoceras.

A second outcrop containing poor Cretaceous fossils was seen north of the old wells. Near the southwestern part of the area shown in the map the sandy land is replaced by stiff clay land, identical with the stiff Lower Claiborne land further north. The iron concretions which occur in places throughout the clay contain *Venericardia* and a few imperfectly preserved *Gastropoda.*

Section 32, 14 N., 7 W.—Found by recent investigation to belong to the Lower Claiborne stage, which see.

Head of Lake Bistineau.—The old works here, Hopkins has mapped as Cretaceous on account of the supposed connection between the salt beds and the Cretaceous series; covered, except at low stages of water. Recently proven Cretaceous by Vetach.

Price's lick.—This is listed by Hopkins and Lerch as a Cretaceous outcrop simply because of the presence here of strong saline springs. Location: S. 25, 13 N., 5 W.

"*Old salt works.*"—This is represented on Hopkins' map as being in S. 35, 13 N., 6 W. Nothing definite is known of these works.

Drake's salt works.—Section 21, 12 N., 5 W. The Licks, according to Hilgard, extend along Saline bayou for one and one-half miles. "At their northern end, on the east bank, a number of artesian wells have been bored; one, a thousand and eleven feet deep, and said to have been sunk in uniform limestone rock all the way, spouts a constant stream of from eighteen to twenty gallons of salt-water per minute." * * * * "Here, as elsewhere, many pits were dug during the war, fifteen to eigteen feet deep. All these struck the laminated clay, or "soapstone;" but in the rubbish of one I found large fragments of a very crystalline, yellowish limestone, horizontally banded with gray; evidently the same as that at King's and Drake's."

There can be no doubt that much of the limestone passed through in the deep well was of Cretaceous origin. Doubtless, too, some of the shallower wells reached the same formation ; but as yet, no positive proofs of the age of the various strata are at hand.

Winnfield limestone : SS. 19 and 30, 11 N., 3 W. (according to Lerch).—Perhaps there is no locality in northern Louisiana that can excel this in features of interest, for the geologist and layman alike. Nor is it a matter of wonder that great local interest should be manifest in this high mass of dislocated, faulted, folded rocks, showing here a mere confused mass of angular boulders, there a vertical cliff of 30 feet with rocks of all shapes and sizes piled up in a sloping talus at its base. The "Tower rock" or "Chimney" is well shown on Pl. 1. The rugged, fractured character of the cliff at this place is also well illustrated. Below the sloping talus, to the left of the picture is a small pond occupying a central or crater-like area of the upheaval that brought up these rocks from beneath the Tertiary strata.

The number, relative importance and positions of the various limestone outcrops of this region are shown on the accompanying topographic sketch, (Fig. 3) made by this survey early in the season.

On the western end of the high bluff in the center of the map the ledges seem to dip in a northerly direction. But farther east they dip eastward. Other outcrops to the left of the center of the map have a northerly or rather northwesterly dip of from 30° to 45.° The chimney seems to be composed of nearly horizontal layers.

The position of the other outcrops together with what dips have been ascertained seem to indicate that there is here an irregular anticlinal fold extending in a northeast and southwest direction ; that the greatest energy in the upheaving force took effect not far east of the "chimney," and about in the present Bayou channel ; that the axis there divided and the upheaval of the eastern outcrop was one result and the outcrops west of the Bayou to the north was another.

The general trend of the various outcrops is towards the Coochie brake west of Atlanta, discussed below.

Hilgard says briefly regarding the dislocations here shown :

CHIMNEY ROCK, QUARRY WEST OF WINNFIELD, LA.

CRETACEOUS LIMESTONE, COOCHIE BRAKE, LA.

"It evident that subsidences and consequent dislocations frequently occur in the mass; and large fragments frequently tumble down."

Hopkins' section (see p. 33 of this report) shows his idea of the relation of the Eocene and Cretaceous.

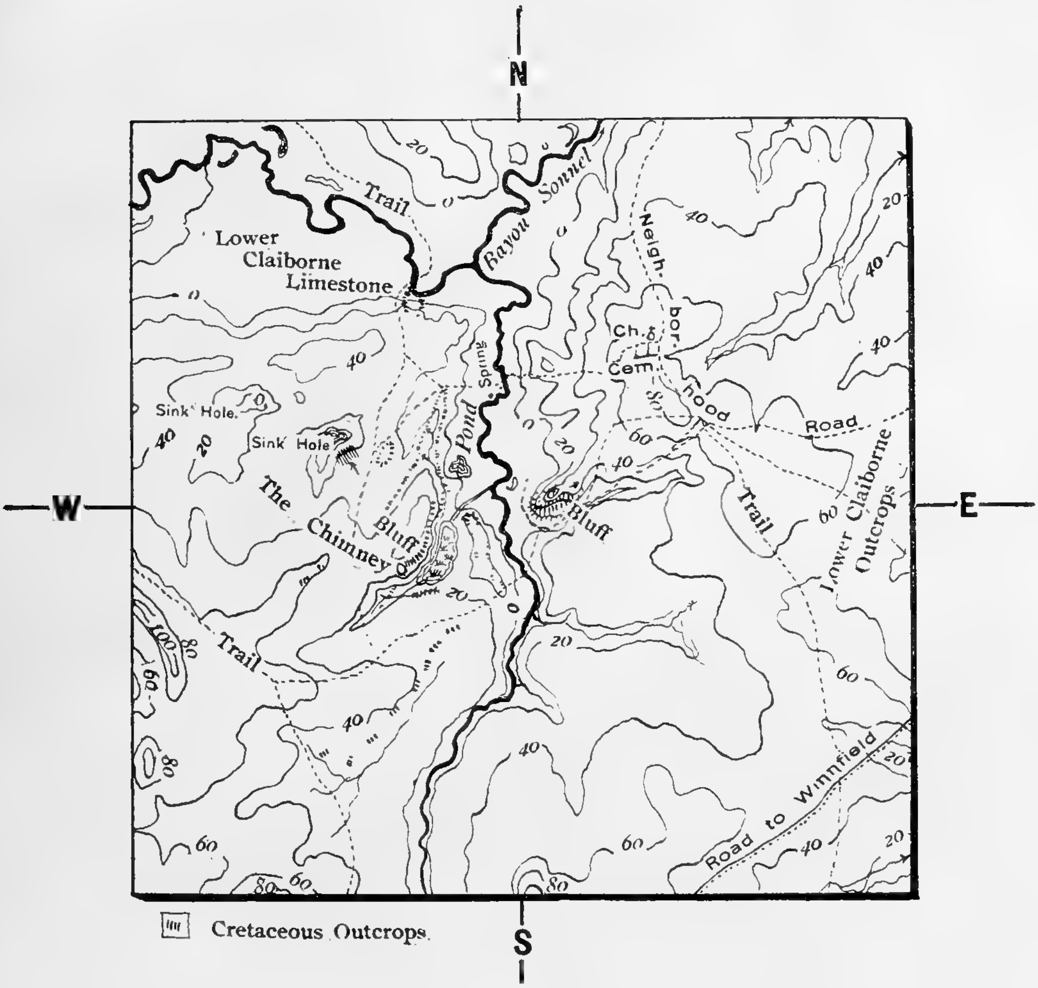


Fig. 3.—*Sketch of Winfield "marble" quarry and surroundings. This map embraces one square mile. Elevations are denoted by contour intervals of 20 feet, commencing with 0 at the base of the eastern Bluff.*

Johnson has indicated that the Cretaceous limestone, Tertiary limestone (which he improperly calls Jackson) and the Orange sands above, are each unconformable in their bedding to all the other layers.

Lerch (p. 72, 2d report), says definitely that "at the close of the Mesozoic time enormous plutonic forces convulsed, fractured, faulted and folded the Cretaceous strata, throwing up mountain chains of vast extent, and raising them far above the waters of the gulf." "If we could remove the covering mantle of Tertiary and drift, we would yet see the chains and peaks of limestone ranges formed at the close of the middle age of our planet, altered somewhat by later erosion and denudation." He believes there was no interval of a land period between the Cretaceous and Eocene in this State.

Vaughan * argues that there was a time interval between the close of the Cretaceous and the beginning of the Eocene, and adds: "Furthermore, the Cretaceous at the Winn parish marble quarry is almost horizontal, the limestone rising as a butte-like mass into the Eocene. If there had been a mountain chain, as Dr. Lerch maintains, with the Eocene deposited immediately thereafter, before erosion had degraded the limestone, the Cretaceous rock at the place under discussion should represent either a dome or anticline, but such is not the case. In the mind of the author the most logical explanation of the relation of the Cretaceous to the Eocene is that a land period followed the close of the deposition of the rocks belonging to the former series."

Vaughan is doubtless right so far as his last statement is concerned. Nowhere along the Atlantic or Gulf slope are we aware that the Eocene follows the Cretaceous without a marked stratigraphic break. But he is wrong in saying that domes and anticlines are not here represented. In fact both are splendidly exhibited. Nothing could be more apparent than the dome-like structure of the easternmost bluff whose western end shows a northern dip, which but a few yards eastward swings around eastward and finally becomes due east. To be sure it is only the N. E. ¼ of the dome that is represented by this bluff.

In some instances the rocks are so faulted, fractured and fissured that no general dips can be ascertained; but we are strongly inclined to believe the huge masses of Lower Claiborne limestone indicated to the north—northwest of the Cretaceous escarpments are quite highly inclined to the north. It then follows that the time of upheavel of these limestone deposits was since the Lower Claiborne time.

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* Amer. Geol. Vol. 15, p. 208, 1895.

The character of the Cretaceous limestone here exposed is such as to render it almost useless as a building or ornamental stone, but it can be used to advantage for making lime. It is full of cracks, pockets and joints ; is highly crystalline and shows whitish and bluish bands of various shades of color. So far no fossils have been observed in these crystalline limestone ledges.

The Lower Claiborne limestone is of a yellowish or reddish white color, far less crystalline and very fossiliferous.

Limestone near Coochie brake.—The illustration herewith given,

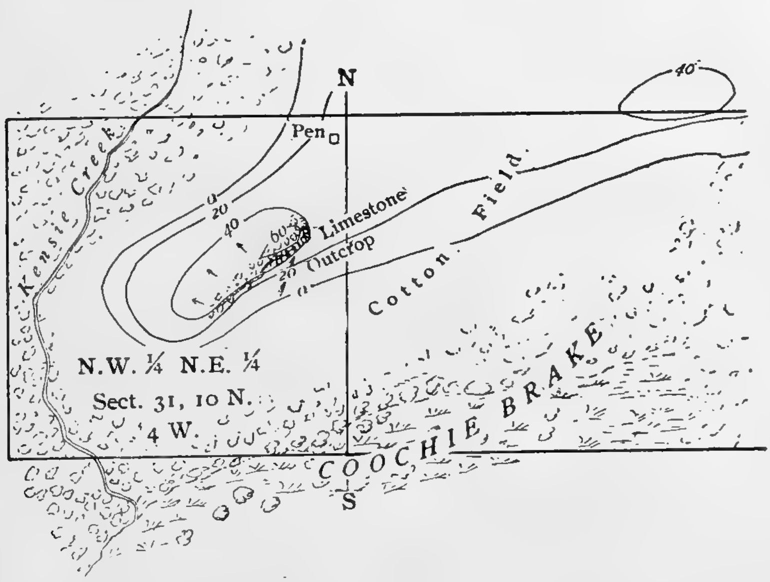

Fig. 4.—*Sketch map of vicinity of limestone outcrop near Coochie brake. The contour intervals are here 20 feet as usual. The little rise to the extreme right marked "40" is shown in a corresponding position on Pl. 2.*

Pl. 2, was taken just south of the limestone outcrop in the direction indicated by the large arrow (see Fig. 4).

Here there is a northwestern quarter of a dome-like upheaval well exposed. To the east is what appears to be a less marked, or lower structure of similar nature still hidden beneath the surface soil. Their location and general relations to each other are likewise shown on the sketch-map, Fig. 4.

This limestone is more arenaceous or sandy in appearance than that at Winnfield ; but is of a most excellent quality for building purposes. Its beauty as building material is, however, greatly marred by the nodules of pyrite scattered throughout its mass, causing streaks and blotches of iron oxide over its exposed surfaces. Its quantity is doubtless sufficient for any demand that is liable to be made on such material for many years to come.

The peculiarity of this limestone outcrop in the midst of Tertiary sands and clays has naturally aroused local curiosity. The glittering appearance of the freshly broken pyrite nodules has doubtless been at the bottom of the vast majority of statements made concerning the mineral wealth of this region. Vaughan* has made the following pointed statement regarding this exposure: "On sections 31 and 32, T. 10N., R. 4W., near Atlanta in Winn parish, there outcrops a hard, blue limestone, which is traversed by minute fissures. In these fissures a small amount of gold is found."

This must have been a near shore deposit, for it contains the impressions of dicotyledonous leaves, reminding one somewhat of the Dakota sandstone. The age of the limestone is not known to a certainty. As pointed out above it is quite different in lithological character from the Winnfield marble; but since the present position of the outcrop is due to a similar, if not the same orographic movement that brought up the Winnfield beds; in fact, both seem to be on the same line of weakness, N. E., S. W., we are led to regard all as of Cretaceous ages as elsewhere explained.

Coochie brake seemingly owes its origin to the same dislocation of the strata that brought up these limestone beds from below. It appears to rest upon the down-throw side of the fault-line that fractured these dome-like structures along their major axes. In case the weather were wet, a pond of water, very analogously located would be formed along the south side of the Winnfield outcrops, where in dry seasons only a stream is formed which has subterranean connections with Bayou Sonnel.

The origin of Coochie brake or Coochie lake as it is sometimes called, has little in common with the origin of the larger lakes found close along the Red river channel. This lake is but a few

* U. S. Geol. Survey, Bull. 142, p. 12, 1896.

feet in depth as proven by the cypress knees everywhere present, and by the fact that wading is possible well out to the middle. The author took the photograph shown as Plate 3, by wading out about 1/3 mile where the water was scarcely 3 feet deep.

The following detailed account of the timber contained in this brake has been kindly furnished by Mr. Ferguson, who personally surveyed the brake and made the estimates.

Brake contain somewhat over 700 acres; with
87,920,000 feet of cypress,
29,000,000 feet of gum,
14,000,000 feet of tupelo gum,
30,000 feet of long leaf pine.

Cedar lick.—Hilgard* says of this locality: "About seven miles southeast from this limestone hill [Winnfield marble], there is another salt lick called Cedar lick (from cedars growing there); it is several acres in extent, and there is on it a steadily flowing brine spring of pure taste and considerable strength. It can hardly be doubted that here, also, the Cretaceous rock underlies at a moderate depth."

Rapides Parish.—Johnson mentions a Cretaceous outcrop on N. E. 1/4 S. 26, 6 N., 4 W. in Rapides parish. We have not yet had time to investigate this locality.

Bayou Chicot limestone.—Two outcrops are included under this heading. They are located in S. 35, 3 S., 1 W., about eight miles southwest of Bayou Chicot P. O. They have been visited and favorably reported upon by Hopkins; unfavorably by Clendenin. One shows an exposure of eight feet high and fifty feet wide. This was made in procuring limestone for burning, and the ruined kilns can still be seen. The dip of the rocks is 22°, S. 70° W.

The second is exposed in the bottom of a pit about 350 yards southeast of the first mentioned outcrop; shows a dip of 33°, S. 65° W.

The limestone is here of a much darker color on an average than at the more northern outcrops. Some fragments, however,

* Sup. and Final Report Geol. Reconn., La., p. 32., 1873.
† House Ex. Doc. 50 Cong. 1st. Sess. No. 195, p. 23., 1888.

show a tendency to the white and blue banded structure so characteristic of the Winnfield layers.

Were it not for the excessive dip of these localities, carrying the beds below at a rapid rate, this limestone would doubtless be quarried extensively.

The Five Islands.—For information concerning the supposed Cretaceous layers in these islands, see special paper devoted to their geology.

Calcasieu Well Section.—As already shown on p. 25, the crystalline limestone, sulphur and gypsum beds in the Louisiana Oil Co.'s well on the west fork of Calcasieu river have been referred to the Cretaceous series. (See special topic Sulphur.)

CONCLUSIONS

Much has been said in geological reports on the State of Louisiana about the Cretaceous "backbone" which extends in a ridge northwest of the Five Islands to the Salines of Bienville parish.

This Cretaceous ridge was supposed to connect onto a fictitious southern deflection of the same series in Arkansas as laid down on Marcou's geological map of the United States.

Our observations go to show that whatever folding and faulting has been the cause of bringing the underlying Cretaceous strata to day, has been in the northeast-southwest direction, roughly parallel in fact to the northwestern shore line of the old Mississippi embayment in Eocene Tertiary time.

The shallow depth at which rocks supposed to be of this series have been struck in the Calcasieu wells (380 ft.); the salines at the mouth of Bayou Negreet and to the north; the Midway beds a few miles to the northeast of Many; the great depth of the Shreveport well (1,100 ft.) with no record of Midway or Cretaceous limestones though nearly in line with the so-called axis or "back-bone"; the various dips observed in the limestones at various exposures with but one exception—the St. Landry outcrops—all indicate northeast-southwest local folds parallel to old shore lines rather than a mountain chain at right angles to the same, or in a northwest-southeast direction.

EOCENE SERIES

MIDWAY STAGE

LOCALITIES

Rocky Spring church.—On the road from Marthaville to Many near Rocky Spring church (N. E. ¼ Sec. 24, 8 N., 11 W., on the Ranes' place) a very impure limestone is met with in the bed and left bank of a small stream. Impure as it is, this limestone is said to have been used for lime in the construction of Ft. Jessup.

To the westward, perhaps one-half mile on higher ground, a well is said to have passed through a bed containing shells in abundance. Another well to the north one-fourth mile, encountered the same stratum. Calcareous spots (black lands) are common in the near-by fields. One mile to the east a yellowish gray concretionary boulder was found in a bank by the roadside (Marthaville–Fort Jessup road), containing cross-sections of the shell of *Cardium tuomeyi* (?). Still further eastward, about one mile, ferruginous layers by the roadside show casts of Lignitic species.

This is doubtless the locality referred to by Hopkins in his second annual report (p. 10), as at Mr. Dillard's place, five miles north of Ft. Jessup. He says it consists almost entirely of the remains of *Ostrea georgiana*, an immense oyster found only in the latest Jackson beds. He was therefore quite mistaken as regards the species of oyster here represented as well as in horizon.

King's salt works.—We can scarcely doubt, from the statements of Hilgard, that here are to be found Cretaceous beds not far beneath the surface. As early as 1869* he reports the finding of *Gyphæa pitcheri* and *Exogyra costata* in some old well borings in the "Salines of North Louisiana," though no particular well or locality is mentioned. In his final report, however,

* Am. Journal Sci. vol 48, p. 342.

he definitely states that these characteristic fossils came from King's salt works, S. 35, 15 N., 8 W.

Vaughan* has recently shown that Hilgard was mistaken in his identification *G. pitcheri*, it being a Comanche stage fossil, while the deposits with *E. costata* must be Upper Cretaceous. Yet Vaughan did not suggest what Hilgard's *G. pitcheri* really was. We know now from the collections made at the place by Veatch that this species is no other than *O. pulaskensis*, Har., a typical Midway Eocene species.

Hilgard properly describes the rocks from which these shells were obtained as a soft gray, calcareous mass. In fact it is most strikingly similar to the basal Eocene beds around Prairie bluff, and Snow hill, Alabama.

He remarks: "A few hundred yards northward of the lick, there is a dug well 20 feet deep in which a similar rock was struck at 5 feet, which became harder as the depth increased, and had to be blasted. The rock now lying near the well is a rather hard, crystalline limestone, full of debris of shells; a great many perfect ones were found in digging; one described to me must have been a *Janira*. No salt water was obtained in this well."

Other localities.—That the above two were the only places in Louisiana where Midway or Lowest Eocene beds outcrop, seems very improbable. Black land areas reported from Mansfield westward may possibly owe their origin to the calcareousness of this stage. Another place that must be looked up shortly is on the Soda lake where Collins† reports "*Nautilus dekayi*" halfway between Albany and Henderson's mills.

LIGNITIC STAGE

PRELIMINARY REMARKS

The presence of this stage west of the Mississippi has been suspected ever since its differentiation, and its true relationships to the other Eocene stages was worked out along the river courses in Alabama.

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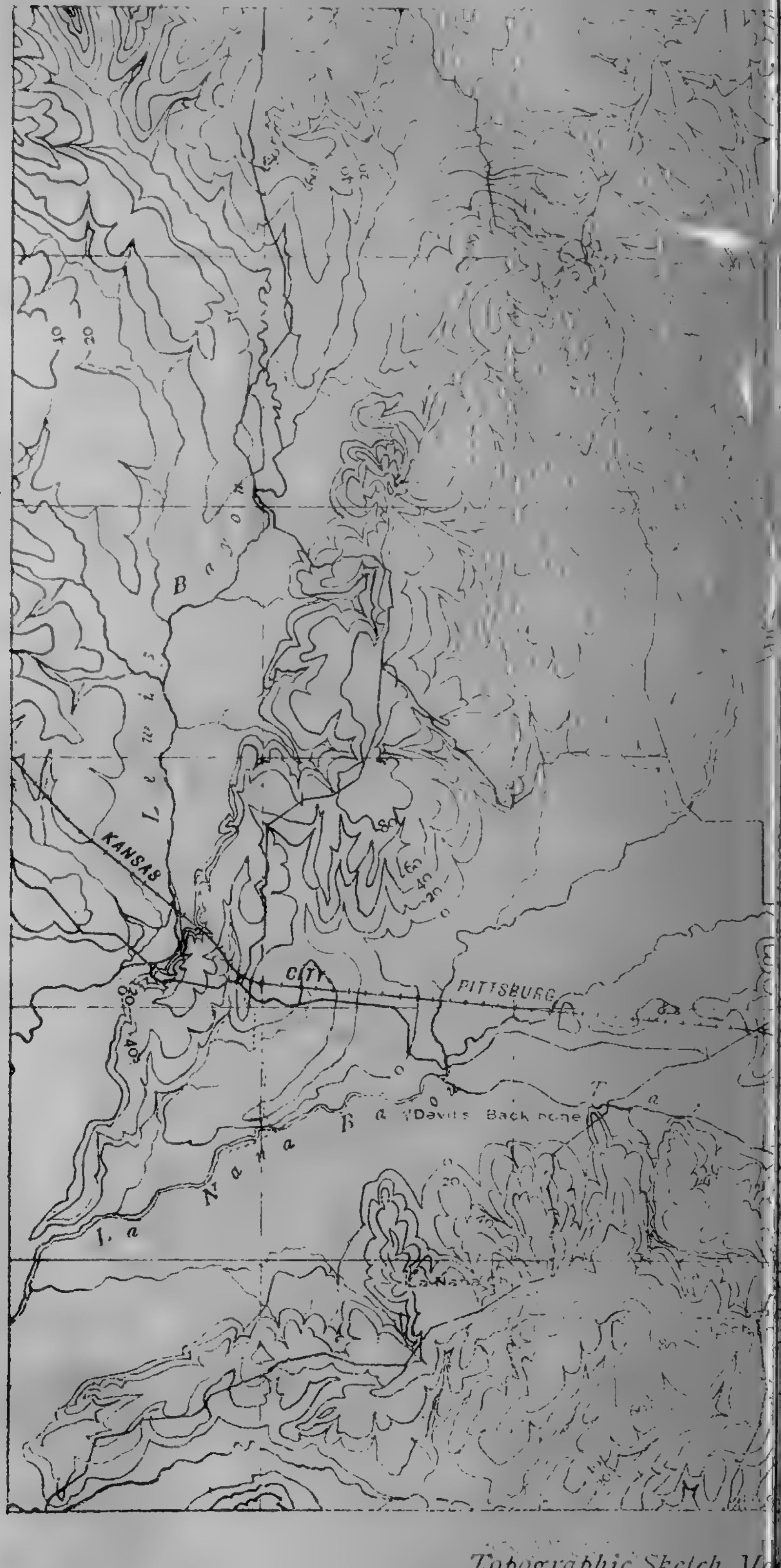
*Amer. Geol. vol. 15, p. 207.

†43d Con., 1st sess. Ho. Ex. Doc. vol. 2, pt. 2, p. 661, 1874.

TIMBER IN COOCHIE BRAKE, LA. PAGE 61



Topographic Sketch Ma

BY A. C.

A *Many Township*

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Topographic Sketch Map Many Township

BY A. C. VEATCH

Certain sandy and clayey layers containing more or less lignitic matter, but without animal fossil remains, lying geographically between the Midway and Lower Claiborne outcrops in Texas and Arkansas, have been provisionally referred to this stage. Lines of demarcation, however, between this and higher Eocene stages, have been difficult to locate insomuch as materials lithologically similar occur in this and many of the higher beds.

We have already seen how in Louisiana these beds have been given a special name, "the Mansfield Group," and correlated with the beds at the base of the Vicksburg bluff, then with the Jackson stage, and afterwards with some pre-Jackson horizon.

Definite proof of the position these beds occupy was first given in Bulletins of American Paleontology, vol. 2, p. 202, 1897. The locality there discussed,—Sabinetown, Tex.,—has been revisited by members of this survey and now can be discussed in detail.

AREAL DISTRIBUTION

The Map.—The area represented on the map as belonging to this stage may have its boundaries somewhat modified by subsequent investigation. But it certainly repsesents the truth with a fair degree of accuracy. To this survey belongs the credit of identifying or proving the existence of the Lower Lignitic, in this State by means of fossil remains, and being able to say positively that there is a southern peninsula-like extension of this stage in Louisiana between the Red and Sabine rivers.

LOCALITIES

Pendleton.—Along the Sabine river the best outcrops are seen on the Texas side. Yet since they throw such a vast amount of light on the geology of Louisiana,—for the same beds must occur east of the river though covered by detritus,—it seems highly desirable to insert them here in detail form.

The following section may be seen one-fourth mile above the ferry, just above the mouth of a small bayou.

9. Light gray to brownish laminated clay............. 7.5 ft.
8. Ledge of impure limestone concretions............. 2.5 ft.
7. Greenish brown and light blue clayey sand, with iron concretions and fossils........................ 4.5 ft.

6. Blue joint clay, fossiliferous..................... 2.5 ft.
5. Limestons boulders, fossiliferous, in dark gray sand. 1 ft.
4. Dark gray sand .... 2 ft.
3. Stratified lignitic clay........................... 1 ft.
2. Yellow and gray sand............................ 5 ft.
1. Wavy, alternate layers of blue sand and clay ...... 6 ft.
Water-level.

The dip is here to the westward about 1 to 50.

The main Pendleton bluff, just above the ferry, is about as follows:

5. Red sand................................ 15—20 ft.
4. Light gray and brown laminate clay .... 5—15 ft.
3. Ledge of limestone and sandstone boulders...... 2— 3 ft.
2. Light blue sandy clay, with fossils and iron concretions................................ 5 ft.
1. Wavy alternate layers of dark sand and clay.... 8 ft.

Fossils are numerous at each of these exposures, but are somewhat better preserved in the first mentioned section. They include (as may be seen by referring to the paleontology of the Lignitic Stage) such typical lower Eocene species as *Levifusus supraplanus*, *Buccinanops ellipticum*, *Turritella præcincta*, *Natica aperta*, *N. alabamiensis*, *Solarium bellense* and *Pleurotoma silicata*, leaving no doubt as to the horizon they represent in the Alabama section.

Stone coal bluff.—Down the river about half way from Pendleton to Sabinetown, but on the Louisiana side there is a 3 ft. ledge of lignite cropping out near water level. It is overlaid by gray sands of recent river origin. (See under Lignite, Economic Geology.)

Salt licks.—About ½ mile northeast of this lignite outcrop, are extensive salt licks where formerly large quantities of salt were made. (See further under Economic Geol.—Salt.)

Slaughter's creek lignite—This is located on S. W. ¼, S. 35, 6 N., 13 W. The beds associated with the lignite are as follows:

4. Reddish sandy surface loam.........................1 ft.
3. Alternate laminate of chocolate clay and gray sand....9 ft.
2. Lignite..4 ft.
1. Gray clay to water level...........................1 ft.

(See further under Econ. Geol.—Lignite.)

Sabinetown.—A short distance below the ferry on the Texas side of the Sabine there is a most interesting section, not only for the light that it sheds on the geology of west Louisiana, but also for the various horizons to which its beds have been referred. (See under Hilgard, Historic review.)

Putting aside the past, we proceed at once to a detailed description of this classic locality.

This bluff is from 115 to 120 feet high, counting from the surface of the river at a medium stage of water. It is located on a bend of the river where the latter pursues a nearly east-west direction. Though the dip is locally very considerable here as shown in little side gorges often $\frac{1}{50}$ south, it appears slight along the bluff as a whole, for the direction of the latter is nearly on the line of strike.

The main features of the various component strata are as follows:

8.	Sands and ferruginous conglomerates	9–16 ft.
7.	Ferruginous sandstone	1 ft.
6.	Lignitic clay	15 ft.
5.	Yellow sand	25 ft.
4.	More or less alternating shaly lignitic clay and sand. The latter weathering yellowish; the shaly clay sometimes light brown or pinkish	40 ft.
3.	More or less clayey sand, often greenish and fossiliferous in concretions; with a hard layer above	15 ft.
2.	Fossiliferous blue sand with concretions	6 ft.
1.	Brittle, shaly, drab clay	2 ft.

We have only to glance at the fossils to be impressed with the almost perfect likeness they bear to the Woods bluff beds in Alabama. Some have already been figures in Bulletins of American Paleontology and others may be found elsewhere in this report. (See Paleontology the Lignite stage.) The best fossils are found in the greenish sandy layer at the west end of bluff, just east of where a little stream empties into the river.

Low's creek.—One and one-half mile to the south of Sabinetown bluff in the bed of Low's creek at the ford, Lower Claiborne fossils are found. But beneath the same in what is presumably Lignitic material, a vast number of *Pectens cornuus* occur.

The beds at the water-mill are of this lower layer. They are replete with oölitic iron ore, greenish when freshly exposed, reddish when weathered.

Vicinity of Negreet P.O.—In stream beds about Negreet a bluish, sandy, lignitic clay is now and then to be seen. But the most prominent exposures, as at the church and cross-roads N. W. of the P.O., show beds of sand with ferruginous, shaly partings. Mr. Harvy Gandey's place shows in several localities the very sandy layers just mentioned, together with large ferruginous chunks, or rock fragments, reddish for the most part, but with pockets of yellowish limonite. In digging a well on his place some 20 years ago, Mr. G. found fossil shells in abundance. This fact should be borne in mind by residents of this community, for the very sandy series of the uplands could be improved by the application of the calcareous material obtained from these fossiliferous marly deposits.

It is to be regretted that the survey has not yet obtained the analyses of soils taken from the bottom lands of this place. They must be reserved for the next year's report. The peculiarity which they should show, however, is the nature of the saline efflorescence which oozes up from below, making in conjunction with the sand that accompanies them the regular low hillocks or mounds, that characterize many of the flat regions of this and other southern states.

On Mr. Henderson's place, 4 miles N. N. E. of Mr. Gandy's, on the Many-Sabinetown road, marine shells are said to have been found in considerable quantities.

Vicinity of Many.—The accompanying map shows the topography of the region well, viz.: broad, flat bottoms, and steeply sloping, much carved uplands. The valleys seem to owe their shape more to the filling up of a young V-shaped valley resulting from a change in the position of the base level than by the excavating action of the present streams. Along the stream beds, bluish or blackish sandy clays now and then appear; but the commoner beds exposed are clays and light colored sands. At one place, in the bank of Tar river at the Devil's backbone, a thin bed of lignite occurs. Here and there are light yellowish, concretionary calcareous boulders, containing sometimes leaves, as seen in those thrown out in the cuts of the R. R., perhaps 1½ miles southeast of Many, sometimes marine shells (generally *Venericardia planicosta*) as seen in the boulders near Tar river, south of Many and in others from near Ft. Jessup.

Lagoon and off-shore conditions evidently alternated geographically and stratigraphically during the deposition of these beds. Layers of lignite are reported from various places in this vicinity.

Casts of fossils are fairly abundant in the dark sandy micaceous clay on La Nana bayou, as it crosses the 29–30 section line. This material is strangely similar to the lower Eocene beds of Maryland and Virginia. The most characteristic fossil species are: *Turritella mortoni*, *Volutilithes petrosus*, *Pleurotoma siphus*, *Astarte smithvellensis*, var. *Venericardia planecosta*, *Pseudoliva*, sp. (See further under Paleontology, Lignitic Stage.)

In the little ravines or washouts near the Many school-house casts of several lignitic species of mollusca are found. They are embedded in indurate ferruginous, crust-like layers of argillaceous concretions. Similar beds were noticed for a mile or more to the southeast of this locality. Such casts are also abundant in the S. E, ¼ of the S. W, ¼ of Sec. 13 near Jerusalem Church. Just across the township line in Sec. 19, 7 N., 10 W. shells have been found in a well.

Ft. Jessup.—In this locality many yellowish concretionary boulders are to be seen. In fact the rocks that were used in constructing the Fort were of this character. We observed none containing plant remains. They were either barren or with traces of molluscan life. A fragment picked up at the old Fort contained a perfect mass of a small univalves. Another fragment found nearby contained many *Venericardia planicosta*.

Just to the east of the village Rocky creek sets in and extends nearly by the Williams place. Its banks are high and precipitous and afford the best view of the geology of the region yet seen. The characteristic or predominating material is dark clayey sand or sandy clay containing shining particles of mica and quartz.

On the Williams place perhaps one mile east of the Fort, several fossiliferous boulders were seen. In the banks of a stream, several imprints of marine fossils were found, including *Turritella humerosa*, and what seem to be fragments of *Volutilithes petrosus* and small fusoid forms.

Going eastward along the road to Robeline one sees several hill-slopes with light sands and clays, the latter apparently of a good grade for pottery, and ledges of rock (3½ miles from Robeline, on what is called Kirkam or Rock Chimney hill), remarkable for the size of the lenticular or irregular shape concretions they contain.

Robeline.—A good potters' clay has been worked 2½ miles east of Robeline on the Carter place. It is yellowish and quite sandy, but is very hard and tough to pick. Some 6,000 flower-pots and many jugs were made here a few years ago. There is a considerable difference in the amount of sandy material intermixed in the various clays seen outcropping in this vicinity and the so-called sassafras clays have been extensively used for bricks without the admixture of sands or clays from other strata. Mr. Ponder S. Carter has charge of this estate at present. He very kindly donated to the Survey a flower-pot and jug made from these clays.

Along the railroad track towards Victoria mills numerous cuts are seen exhibiting the Lignitic clays to good advantage. Lerch has given figures of two of these in his 2d report on the hills of N. Louisiana (p. 76). One shows two seams of Lignite. This Survey (1899), found numerous traces of marine mollusks in some of these layers. Near Victoria Mills the Lignitic strata pass beneath those of Lower Claiborne age.

Natchitoches.—The best display of Lignitic strata in this vicinity is at Grand Ecore. But beds of a similar character crop out on Cane river just north of the town. They are there overlaid by fossiliferous Claiborne deposits.

(For illustration of this bluff, see special report on Natchitoches area.)

The larger part of the upland of this township is underlaid by sandy and clayey deposits of the Lignitic stage. There appears to be far less calcareous matter in these deposits than was observed in those of the same age about Many. (See further under special article on Natchitoches area.)

Grand Ecore.—Hopkins visited this section as early as 1869 and published a section of its beds in his first annual, 1870, p. 86.

The beds with their estimated thicknesses as they appear just above the landing, or terminus of the R. R. track are as follows:

10. Sand with quartz pebbles........................10 ft.
9. Orange-colored sand, with white clay-ball concretions. 10 ft.
8. Yellow sand.. 2 ft.
7. Colored (greenish) clays........................... 3 ft.
6. Finely laminated, light, yellowish, clayey sand......18 ft.
5. Brown, black-banded, lignitic sand................. 9 ft.
4. Black and gray sand and sandy clay................. 6 ft.
3. Lignite..20 in.
2. Black clay shale................................... 2 ft.
1. Grayish sand or sandy clay......................... 5 ft.

Water level.

The face of the bluff farther upstream, as well as the top of the low bluffs below, show many large light yellowish concretions.

Cedar bluff.—Nearly east of Grand Ecore, on the Saline bayou, not far to the north of Congo, P. O., on the land of Mr. John Kieffer is an escarpment commonly known as Cedar bluff, which seems to show practically the same series of lignitic sands as have just been enumerated under Grand Ecore. The bed of lignite here, however, is below water level, except at extreme low stages. It has been dug in small quantities and used locally. It is evidently the same as the seam noted in the Grand Ecore bluff, but is of a decidedly better quality, remaining in large cuboidal masses or chunks after having been exposed to the air for months.

Cedar bluff is particularly rich in Indian relics. A walk of a few mimutes over any plowed field is sufficient for the collection of hands full of fragments of pottery.

About a mile to the south of the bluff on the St. Maurice road a Lower Claiborne prairie is struck, which shows the characteristic marine molluscan species and fragments of light yellowish limestone.

Marthaville.—A cut on the railroad at this place shows very large, hard, light yellowish calcareous boulders. They are characterized by a Lower Lignitic fauna including *Ostrea thirsæ* var., *Levifusus indentus*, and other species characteristic of this horizon.

Specimens from Sodus, from concretions presumably of the same horizon were scarcely identifiable.

One the north-east one-fourth of Section 2, 9 N., 12 W. Sabine parish, mineral water is obtained from Ferrell's well. Dr. J. E. Mumford collected several ferruginous, clay concretions near this well that show an interesting, though poorly preserved marine fauna. *Venericardia planicosta*, *Yoldia kindlei*, *Volutilithes petrosus*, *Calyptraphorus*, *Levifusus Pleurotoma silicata*, and other *Pleurotomæ*, seemingly of a lowest Lignitic or Midway aspect.

Mansfield.—This region was first described geologically by Hilgard in 1869 and much more fully by the same author in 1873. He called particular attention to the limestone, concretionary layers so often seen in this portion of the State, and concluded from the fact that they contain fossil leaves that they were of *fresh water* origin. This seemed such a departure from the ordinary run of lignitic Tertiary beds that he gave a new name to the group of sands and clays containing these concretions, calling them the Mansfield group. (See further under Historic review.)

The nature of the material that underlies the soils in this general region is well shown by the following section made from an outcrop in the gorge just west of the town.

5. Soil and red sand .... 5 ft.
4. Sand with iron streaks .... 10 ft.
3. Sand with a few light bluish clay streaks.......... 5 ft.
2. Very light, or yellowish calcareous concretions....... 2 ft.
1. Sandy, laminated, sands, with iron streaks above; light sands, medially; bluish laminated clays below.....30 ft.

As might be anticipated by the character of the rocks exposed in this section, the hill land about Mansfield is decidedly sandy. But there are broad bottom lands adjacent to stream courses, of a more clayey and loamy character, and very productive. To the southwest and west, calcareous black land prairies are reported.

At Logansport on the Sabine extensive deposits of lignite are

LOWER CLAIBORNE EXPOSURE, ST. MAURICE, LA.

described. Hilgard has noted similar beds in the Dolet hill. In fact, outcrops of this substance are of frequent occurrence in this part of the State, and we are prepared to reaffirm Hilgard's statement "that lignitic strata crop out on both sides of the dividing ridge from Pleasant hill to Mansfield, towards Shreveport.

Various estimates are given as to the thickness and character of these lignite beds. The whole subject must be taken up systematically and monographed in some future annual report.

Grand Cane.—Going north from Mansfield, numerous arenaceous deposits are seen along the roadside, some showing flow and plunge structure. Post-oak flats with mounds are here extensive. Red iron-stone concretions are here and there abundant. Yellowish concretionary limestone was noticed often near Grand Cane.

Stonewall.—Calcareous limestone boulders and lignite are noticed about Stonewall. The soil and topographic features are similar to those around Mansfield and Shreveport.

Shreveport.—(See special report on this area included in this report.)

LOWER CLAIBORNE STAGE

PRELIMINARY REMARKS

The beds that belong to this stage have been referred by the earlier writers on Louisiana geology to the "Vicksburg," "Jackson," "Mansfield," groups or stages, as it is stated in our Historical review (see Hilgard and Hopkins, Reconnaissance Period).

After a better understanding of the inter-relationship of the Eocene deposits east of the Mississippi was worked out, chiefly in Alabama by Smith and Aldrich, references were made to the "Claiborne" of Louisiana.*

To Hon. T. H. Aldrich of Birmingham, Alabama, science is mainly indebted for the recognition of this stage in Louisiana. It was he to whom many of the fossils collected by Johnson in 1885 were submitted.

With his aid, Johnson was able to state in his report on the

* Mineral Resources of the United States, 1883, p. 554.

iron ore of Louisiana and Texas, that it is the lower portion of the Claiborne group of strata that occurs in Louisiana and Texas. He properly refers a portion at least of the St. Maurice bluff to this horizon. Also the bluff at Natchitoches, and many localities in Bienville, Claiborne, Webster, and Bossier parishes were properly arranged under this stage.

It has remained for this survey to rectify the work of former reconnaissances west of Red river.

AREAL DISTRIBUTION

The map.—All along the northern tier of counties, from the Dorchite to the Onachita there may be uplifts of beds belonging to the Lignitic stage, for molluscan remains are generally wanting in these parts. The general trend of the various geological stages of this part of the State would indicate that all this territory is Lower Claiborne as mapped.

The doubtful area about Shreveport has been elsewhere discussed. (See Shreveport area.)

Otherwise the mapping of the Lower Claiborne may be regarded as approximately correct.

LOCALITIES

(Sabine parish)

Low's creek below Sabinetown, Tex.—This locality has already been referred to in connection with the Lignitic stage. At the ford perhaps one-fourth mile below the water mill on this creek, ledges of Lower Claiborne calcareous rock occur, characterized, among other fossils by *Ostrea falciformis.*

Lower Negreet.—Near the mouth of this bayou there is a cross bedded conglomerate, very ferruginous and rough in appearance with quartz pebbles and clayey and glauconitic nodules, containing fossils of this stage. A bed of white quartz sand 8 ft. thick lies above this conglomerate. Almost nothing of the salt-works that once were in operation a mile or so farther up stream could be found. It appears that some of the wells were in the bed of the bayou. One old shaft was seen on the left bank.

According to Mr. Dan'l Vandegaer the process of obtaining salt here was usually as follows: Hollow cypress logs were sunk vertically in the bayou over the places where the saline water seemed to rise; these were cut off at such a length as to be always above the surface of the water. The contents of the logs was pumped out and run off in kettles and evaporated to salt.

The light blue clayey beds around the shaft just mentioned and in a little rivulet close by, contained some very imperfectly preserved marine shells. Nothing was found to lead us to suppose that the deposits hereabouts were other than Lower Claiborne where the general stratigraphy of this region would place them. Quite a large tract, several acres, was noticed not far from the north bank of the bayou nearly devoid of vegetation.

Simpkin's place.—Mention has already been made of Lignitic strata occurring along streams to the southeast of Negreet P. O. The hill or ridges are often strewn with ferruginous sandstone chunk showing within limonite nodules. Near the northern border of the Simpkins' place a typical "black-land" soil is found, very calcareous, showing boulders of light yellow limestone and many marine fossils. Some collected are: *Ostrea falciformis*, *O. johnsoni*, an Orbitolite, *Pecten*, *Cypræa*, and *Turritella carinata*. Near Mr. Simpkins' house the fields are sometimes almost covered with red ferruginous chunks. Yet these fields are said to bear fine crops. The reason is very evident. These ferruginous rock fragments are before exposure, as when first obtained in digging a well, of a grayish greenish or bluish hue and are replete with marine organic remains. It is the leaching of this material, calcareous and glauconitic, that supplies the soil with the elements that it needs in plant production.

The red color is simply due to oxidation of the iron already in this material though in a different chemical combination and of a different color.

From the general lay of the land we assume that these excessively ferruginous layers are higher stratigraphically than the "black lands" with their limestone boulders mentioned above. Certain it is that above these ferruginous layers, come sandy beds some 30 feet or more in thickness, capped with large rough and micaceous sandstone chunks. The latter seem to be destitute of organic remains.

This particular calcareous and red land belt extends, with some few interruptions, from near the mouth of the Negreet to Natchitoches.

Leech neighborhood.—Going towards Many from Simpkins' place, one follows nearly the trend of the red lands. But they are often obscured by the overlying sandstone deposits mentioned above.

Near the Church and again in the Leech community some of the fields are of an astonishingly red color, and the red rock fragments seem to cover the fields. Likewise on toward the east, by Jas. Leech's, the red beds are very strongly developed. Perhaps one-fourth mile east of the last mentioned place fragments of slightly yellowish white limestone occur in a little depression that crosses the Many road. This is associated with a few feet of whitish marl, as at Natchitoches. About 7 miles from Many, or 2 miles N. E. of Jas. Leech's, the red lands cease abruptly on the Many road, and the Lignitic sands, with slight but constant slope to the south, furnish broad expanses on which flourishes the long-leaf pine. About the sole associate of the latter seems to be the hardy ill-formed black-jack oak.

There are occasional abrupt descents to the north where the edges of the southward dipping strata come near the surface. Some of these beds are clayey, wet and cold. They are characterized by the usual varieties of oak and short-leaved pine. Then another sand-covered gentle slope to the south occurs whereon luxuriates the long-peaf pine.

South of Many.—The railroad cuts south of Many are referred to in several places in this report.

For some distance they show nothing but sands and clays of the Lignitic period. But, perhaps 4 miles south of the station, the Lower Clairborne beds come in showing a marked unconformity with the Lignitic strata below.

Fossiliferous red lands were seen by Veatch two miles still farther south on the same railroad.

(Natchitoches Parish)

Victoria Mills.—Indurated calcareous beds crop out in the log tram-way back of these mills. From a soft layer below these beds a sack of marl was obtained for analysis, but has not yet been reported upon.

The hill back of the mills contains several ledges of *Ostrea falciformis* in impure limestone.

Provencal.—A very typical Lower Claiborne exposure occurs on the north side of the R. R. track about one-half mile west of Provencal.

Ostrea falciformis is in great abundance associated with a small Orbitolite, and imbedded in a light yellow clay marl. The region has the usual calcareous-land flora.

Other local beds of "red land" or "black land" were seen or heard of about Provencal. Railroad cuts were examined as far east as Robertsville, where an interesting and fossiliferous outcrop occurs. Ferruginous nodules about one-half to one inch in diameter contain *Lucinæ* and large numbers of *Arca rhomboidalis*. The light gray clays have scarlet red blotches as at several other places.

The residual soil is of a light gray, and a slightly reddish hue.

Two miles south of Provencal, on the Leesville road, the same phase of the Lower Claiborne is met as seen on the R. R. west of Provencal or at Natchitoches.

Another interesting locality, where marl and shells have been reported, is at a Mr. Stephen's house, half way between Robeline and Natchitoches. The locality was not visited by us, hence we are unable to say whether it belongs to the Lignitic or Lower Claiborne stage.

Natchitoches.—(See special report on this area.)

Black lake.—Small black land prairies covered with an abundance of oyster shells are very common in Natchitoches parish north of Black lake.

Section 4, 11 N., 16 W.—Near James Thompson's house, two and one-half miles north of Black lake, 1 mile west of Remy creek and south of the Saline-Weaver's ferry road is a small prairie covered with *Ostrea falciformis*, and *O. johnsoni*. It is on the very crest of the hill, 70 feet above the surrounding hollows and 90–120 feet above Black lake. Just south of the prairie and 6 feet below it is a bed of quartz and chert gravel. The creek west of the knoll shows the following sections:

1. Ostrea bed—top of hill........................... 3 ft.
2. Greenish gray to slate colored clayey marl, joining black soil. A few, poorly preserved shells occur in this layer. The best preserved was a strongly ribbed *Corbula*.................................50 ft.
3. Dark brown sand with plates of iron................ 8 ft.

In the creek east, layer 3 was not seen. In the creek bed are numerous very long limestone concretions. The sides of the hill are covered with gravel and furruginous pebble conglomerate and sandstone, but in no place did the gravel unquestionably pass under the marl.

Similar small prairies with the characteristic oysters, *Ostrea falciformis*, and *O. johnsoni* var., occur north of the locality at the following places: Sec. 5–8, Sec. 21–28, 12 N., 6 W. and at Black prairie hill N. E. ¼ Sec. 23, 13 N., 7 W.

(Winn Parish)

St. Maurice.—Here the Lower Claiborne beds are well exposed on the left bank of Saline bayou near its mouth. Plate 5 herewith given shows well the most important features of the bluff. The view is taken looking down-stream. The ledge in the bayou, showing a steep southerly local dip is composed of reddish clay ironstone. Then succeed 5 feet of bluish, blackish, or brownish barren clays. Above are blue clays, 5 feet with arenaceous ferruginous concretions. Shells are abundant in this layer. Still higher are 10 ft., of brown, brittle clays with yellow flakes. Finally, the upper 25 feet of the bluff are composed of brownish laminated sandy clays, becoming lighter in color and more sandy towards the top of the bluff.

The character of these underlying beds has less influence over the character of the soils in this region than might at first be supposed, for they are often concealed by Lafayette sands and gravels.

Concerning the paleontology of this locality see historical part of this report, p. 34 and especially next year's report.

Between this locality and Wheeling the country is somewhat hilly at first near the Red river, but becomes more rolling or level to the east.

Rather abrupt ascents and descents are frequently met with between St. Maurice and Congo P. O. In these regions the soil is sandy on the hills but more clayey in the bottoms. A mile or so north of Congo, Lower Claiborne beds are met with, characterized by white limy concretionary lumps, a light yellowish soil, very tenaceous when wet, boulders of light yellowish limestone, with fossils, and the usual scrubby growth of trees. Some beds have already been noted on p. 71 south of Mr. Kieffer's.

Couley.—The more ferruginous layers of the Lower Claiborne are well exposed on the hills near Couley, S. 10, 10 N. 5 W. In the stream beds, many exposures of bluish clayey marl were noticed and samples were collected for analysis.

Coochie brake.—East of Coochie brake the summits of the hills are in the neighborhood of 60–90 feet above the brake and show now and then great masses of red sandy iron ore concretions, or chunks ; but no fossils were observed in them. The region is generally sandy, and long-leaf pine is abundant.

Winnfield.—On approaching Winnfield from the Brake, after passing over long stretch of fairly level country, broken now and then in the vicinity of streams, a somewhat varied region is reached about 8 miles from Winnfield. It is not, however, until the 5 mile-board is nearly reached that the calcareous red beds crop out along the road. There are here veritable red lands, but of what extent it is not possible at present to state. Similar, though far less fossiliferous layers are found within four miles of Winnfield in the road, but the most abundantly fossiliferous layers are found to the northward towards the "Marble" quarry (see Fig. 3, p. 57).

About Winnfield no traces of red land were seen. Good brick clay, however, abounds, and the Court house stands as a witness of the good quality of the clay.

Lerch, notes the occurrence, of marl and "rotten shells" in the material thrown out in digging wells in this vicinity.

New Hope church.—About one-half mile northwest of this church (11 N., 4 W., near the house of John Neil), numerous ferruginous concretions are to be seen. They are replete with casts and impressions of a small gastropod (*Turritella*).

Sparta-Montgomery road, 24th mile-board.—On the Sparta-Montgomery road, about one-half mile south of 24th mile board ferruginous concretions are quite abundant at the road side. About a fourth of a mile north of this and at a slightly lower level there is a strip of black land exposing large yellow limestone boulders, in every way similar to limestone boulders which are so common on the little prairie spots in northern Natchitoches. Both the ferruginous and limestone concretions contain many casts of marine shells. This locality is just south of the house of Mr. James Jackson, about Sec. 12, 11 N., 5 W. Twin prairie is a little patch of black land of about 60 acres situated one-half mile southeast of Saunder's church (about Sec. 12, 11 N., 5 W.).

The ground is covered with very small limestone concretions and in some of the gulleys Lower Claiborne fossils are exposed: *Anomia*, *Plicatula filamentosa*, *Pseudolive vetusta*, and *Ostrea falciformis* were among the specimens collected.

Vasherie branch.—On this branch of White Oak Creek, about 10 miles northwest of Winnfield, Lerch and Vaughan record a Lower Claiborne exposure with a stratum of calcareous marl 20 feet thick.*

(Grant Parish)

Georgetown.—We were not able to find any traces of Tertiary deposits in the vicinity of this place. The mill, store, and station are surrounded on all sides by level alluvial lands. Vaughan cites Lower Claiborne fossils from this place.†

(Caldwell Parish)

Columbia.—The Lignitic sands and clays, belonging perhaps to the Lower Claiborne stage are exposed very advantageously for study around the station and for some distance to the south along the railway track.

Nowhere in this part of the State are there better outcrops.

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* See Lerch's 2d Report, etc., p. 89; and Vaughan, U. S. Geol.Sur., Bull. 142, p. 31.

†U. S. Geol. Sur. Bull. No. 142, p. 17.

CUT SOUTH OF STATION, COLUMBIA, LA.

Hopkins * and Lerch † have already given sections of several of these exposures. Hopkins most important section was taken "one mile back of Columbia" in the hills. It shows sands and clays of various colors and thin seams of "iron rock."

He noticed the abundance in certain layers of fossil leaves, and mentions a lignitized log "showing structure very prettily."

Lerch's best section was taken at the first important outcrop on the west side of the railroad going south from the station. We have several photographs of this interesting place, showing a non-conformity of the layers to the right and near the track with those to the left and above to the top of the bluff. One of these views is herewith reproduced. (Plate 6.)

Great trouble is experienced by the railroad officials in keeping the track from moving laterally or sinking in the mud in these deep cuts. This is due somewhat to the fact that layers of sand, approaching "quicksand" alternate with impervious clay layers. The water is held by the clay layers and this tends to make the sand very movable. The difficulty in this region, however, is not serious; it can be obviated very generally by widening the cut a few feet, and securing proper drainage for the track.

Lerch mentions a fine bed of lignite on Coal creek near this town. We did not visit the outcrop. Dicotyledinous leaves, however, are to be found in great abundance in the clayey layers of these various sections. Here, then, will be an excellent opportunity of determining the practical value of fossil leaves in determining the age, or horizon of the formations of this region. An endeavor will early be made to secure large quantities of these fossils.

Below the station on the hill slope towards the town, a layer of calcareous, light-colored sandstone is found, which has been quarried to a slight extent. It is but a thin stratum and can never be of any considerable economic importance.

On the west of the Ouachita the land is very hilly and broken, and most beautiful views are to be had from these high hills for

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* 1st Report, 1869, pp. 83–84.

† Lerch's 2d Report, p. 83.

miles up and down the river. To the east of the Ouachita stretch wide alluvial plains.

In general there would seem to be very little calcareous matter in the substrata of this region. Towards Olla, however, white calcareous concretions are found in wells.

Lone Grave bluff.—Hopkins gives a section at this locality. From the character of the various strata named (white sand, laminated lignitic clay *et al.*), it is evident the same condition of deposition obtained here as at Columbia, and the beds are doubtless of the same age.

(Ouachita Parish.)

Monroe.—This is a region very difficult to study geologically on account of the lack of good sections. Lerch reports Claiborne fossils, from the artesian well bored at this place under the supervision of W. A. Strong. Specimens supposed to be these have been sent us from Baton Rouge but they are almost certainly from Smithville, Tex., as determined by the character of the fauna and the very color of the embedding material. (See Lerch's 1st Report, p. 21.) They were from a depth of 185 feet, in a black clay stratum.

Calhoun.—The red sands and gray clays along the railroad from Monroe to Calhoun have already been described by Lerch in his first report pp. 21–22, 25.

(Jackson Parish.)

Our information regarding the geology of this parish is very meagre. Johnson * has mentioned a few iron ore deposits of apparently limited extents, and Vaughan † has given two localities of Lower Claiborne Eocene fossils on the Liberty hill, Vernon road. One 10 miles east of Liberty hill, the other 15 miles east of the same place.

(Lincoln Parish.)

Vining mills.—This parish has, as yet, received but little attention. Johnson mentions high hills capped with ferruginous

* Iron Ores of La. and Tex., p. 47.

† U. S. Geol. Sur. Bull. 142, p. 32.

sandstone in the vicinity of the Vining mills. Fossils were obtained from a greensand reached in a well sunk by Mr. Hudspeth in the bottom near this place.*

Vienna.—"In the vicinity of Vienna good limonite is abundant on the surface and it occurs widely scattered over the red lands which extend from Vienna to Mr. A. G. Reed's, Sec. 9, 19 N., 4 W., a distance of eight miles."—Johnson.

Redwine's spring.—Johnson gives a section at this place, and states that the greensand is 12 feet thick. In a foot-note he states that "tests of this greensand show it to contain potash and also to be highly phosphatic."

Lerch mentions the occurrence near here on Judge Graham's plantation of fossil casts in clay ironstone concretions. Vienna seems according to him, to be the center of a red-land area.†

The fine sections exposed along the V. S. and P. R. R., are illustrated by Lerch on a folding sheet placed opposite p. 26, of his first report.

Attention is called to the disturbances of these strata.

Nine miles west of Ruston.—Nine miles west of Ruston on the Arcadia-Ruston road a coarse iron sandstone containing many fossils crop out in the road-side. Hardly enough material was collected at this locality to render its identification beyond question, as the locality shows a tendency to combine Lower Claiborne and Lignitic forms. More material will probably prove it to be Lower Claiborne.

(Bienville Parish.)

Sec. 31, 14 N., 7 W.—About 200 yards east of the Campti Sparta road on the Lake village and Venon road is a typical *Ostrea*-strewn prairie. Above the *Ostrea* layer are numerous concretions, containing very indistinct casts. The common *Ostrea falciformis* and *O. johnsoni* were seen here. This is the locality which Lerch refers to in his first report as Cretaceous.‡

* Iron Ores of La. and Tex., p. 45.

† 1st Report, p. 26.

‡ Bull. La. Expt. Station, part 1, 1892, p. 14.

Sparta.—North of King's salt works on the Coushatta-Sparta road the hills rise very abruptly 120 feet. The material seems to be almost entirely a light colored, rather fine sand. Rapid erosion gives rise to some very interesting topographic forms; great, perfectly shaped ampitheaters are common near the heads of the valleys. On the whole it is a topography without sharp angles. In places natural land-locked ponds were seen, looking like great sink-holes.

About six miles from Sparta long-leaf pine takes the place of the short-leaf and continues to within a mile of the old town. At Sparta nothing is to be seen but fine, light-colored sand with coarse iron sandstone boulders. There seems to be no good reason for separating this sand from the adjacent Claiborne beds.

Liberty Hill.—Nearly all the hills in the vicinity of Liberty hill are covered with ferruginous concretions filled with casts of Lower Claiborne fossils. The best locality seen was above, 1¾ miles northeast of the village on the Ruston road. Near a graveyard, north of the stores, fossiliferous iron concretions were seen capping the hill. They were here underlaid by beds of coarse iron sandstone and by the gray Arcadia clays of Lerch. This would seem to show that the Arcadia clays are merely a subordinate bed of the Lower Claiborne.*

The fossiliferous Lower Claiborne material continues for about 10 miles north of Liberty hill on the Arcadia road.

Arcadia.—Dr. Givins, at Arcadia, has kindly furnished the following section of the well on his place:

1. Surface Soil—red and white sandy loam........... 3 ft.
2. Mottled red and white clay..................... 7–8 ft.
3. White clay with some red...................... 5 ft.
4. Dark brown or bluish black tenaceous clay, mottled with white and red, containing some sand and selenite crystals, shows traces of fossils and leaves. 10 ft.
5. Hard red iron concretions, containing fossils and some phosphate of iron........................ 1½ ft.
6. Pure white sand.............................. 2 ft.
7. Green sand with fossils.......................10 ft.
8. Hard rock not passed through.

*Also referred to by Vaughan, Bull., U. S. Geol. Surv., 1896, p. 21.

Water from above layer.

"5" is reported to be slightly sulphurous. Water for "7" is strongly impregnated with lime. In the base of the first cut west of Arcadia are about 3 feet of dark sandy clay with thin clay partings, and patches of greensand. Several shark's teeth and specimen of *Byssoarca*, *Cardium* and *Dentalium* were found here.

About three miles west of Arcadia is the "hog back" railroad cut. A rather soft layer, bearing greensand is here overlaid by harder clayey material. The cut was originally made through the upper clay, and a little way into the greensand. The weight of the top material squeezed the greensand up into the cut. The local section boss states that the railroad company has had to lower the track three times, each time about three feet. It is this sort of action that Hilgard regards as having formed the mud-lumps of the passes of the Mississippi. A few casts were found in the lower part of the greensand.

Gibbsland.—About two and one-half miles east of Gibbsland a light chocolate colored clay, about 8 feet up in the cut contains many casts of *Leda*, *Venericardia*, *Dentalium* and a small Echinoderm. At the base of Mt. Lebanon are easily identified Lower Claiborne fossils.

Hammett's branch.—This may be regarded as once of the classic Lower Claiborne localities of the State. It is situated in the S. W. one-fourth Sec. 30, 18 N., 6 W., about 2 miles northeast of Mt. Lebanon. The main exposure is in a little gully about a quarter of a mile from the road. As this section has been published by Johnson,* Lerch† and Vaughan,‡ it is hardly necessary to republish it here.

(Bossier Parish.)

Coushatta bluff.—This and a few other bluffs on Red river were examined by Hopkins and Johnson, and later by Veatch of this Survey. (See special report on Shreveport area.) Johnson points out how that from here southeasterly to Rocky mount

*50th Cong., 1st Sess., Hou. Ex. Doc., vol. 26, No, 195, 1888, p. 20.

†Bull. for Expt. Station: Geol. and Agr., part 1, 1892, p. 20.

‡Bull. U. S. Geol. Surv., No. 142, 1896, pl. 1, fig. 2.

and easterly to Red land there is an elevated expanse of ferruginous "red-lands."

Three miles east of these bluffs he records the occurrence of marine shells in shallow wells.

Red land area.—He reports iron ore in the N.W. ¼, S. E. ¼, S. 28, 22 N., 12 W. Again in N.W. ¼, S.W. ¼, Sec. 20, 23 N., 12 W., where casts of fossils occur. Sections 18, and 26, 22 N., 12 W., contain ores and fossils.

The Red land region was visited and reported upon by Harris* in the Arkansas Survey Report for 1892. The Pope Joy cut and that at Roberta, on the St. L. S. W. R. R, are described in a detailed manner. Fossils from the red land area are named.

Bellevue.—East of Lake Bodcaw other red lands appear. They are described by Johnson and Veatch. The former says: In southern Bossier is an island-like mass of hilly older Tertiary material entirely surrounded by comparatively level upland flats of probable Port Hudson age. Bellevue, Fillmore and Haughton are situated two miles from Bellevue; iron sandstone and iron concretions abound along the roads. A few poor fossils were collected here but hardly enough to prove the age of the bed. About Fillmore there are a few poor fossils in iron concretions.

Johnson's section, from a deep wash below the jail at Bellevue shows well the character of this region. It is as follows:

1. Reddish surface clay and sand with some fragments of geodes .... 30 ft.
2. White clay and sand .... 20 ft.
3. Stratum of sand .... 1 ft.
4. Dark lignitic sand .... 15 ft.
5. Blue greensand .... 2 ft.
6. "Soapstone," i. e., laminated smooth brown clay, of which there can be seen to main stream of branch, where there is an alluvial bed one mile from Lake Bodcaw, only .... 6 ft.

*Ann'l Report, Geol. Surv., Ark., 1892, vol. 2, pp. 179–180, Pub. 1894.

(Webster Parish.)

Minden.—On the west side of Crow creek in the Homer-Minden road, gravel appears on hillsides. The soil is generally a shade lighter and more yellow than on the red lands.

From eight miles northeast of Minden the gravel is quite common. The soil is red or yellowish-red and rather sandy. The relief is very small and the bottoms quite wide, in marked contrast to the red land topography about Homer.

Exposures of gray clay are common about Minden. Going north from Minden on the Minden-Sykes ferry road the most noticeable thing is the great abundance of gravel. The soil is a fine gray sand and occasionally gray loam. Red sandy soil is comparatively rare.

Northern part of parish.—One mile north of Mr. Sam. Mem's house (S. W. ¼, N. E. ¼, Sec. 19, 20 N., 8 W.) the road passes into what appears to be the bottom, but which turns out to be the second bottom. The bottom of Flat Lick creek is nearly, if not, a mile wide. On the Lewisville-Minden road at the 13 mile-board a very red sandy soil sets in.

This red sandy soil continues to the red-land hills, of which it forms an outlier. The red hills rise very abruptly above the surrounding country. They are covered with ferruginous concretions and sandstone. The summits of the hills are 210 feet above Black creek. North of the red hills, which are from a mile to two miles across, the land is reddish yellow sand or sandy clay with occasional patches of gray "dirt" land.

In a little branch one-half a mile northeast of Leton (Leton is a new post-office in the N.W. ¼, Sec. 36, 22 N., 9W.) in a small branch the following section is exposed:

1. Gray "dirt land," a sandy loam .... 2 ft.
2. Gravel and reddish rock .... 1 ft.
3. Iron sandstone .... 1 ft.
4. Green sand with little white spots of lime, no shells ... 1 ft.
5. Slate-colored clay to water level .... 1 ft.

A mottled gray and red clay, representing the Arcadia clays, is seen in nearly all the road gullies, about half-way up the sides of the hills. Gravel is seen here and there, and is quite common near Shongaloo.

About half a mile from Syke's ferry the road enters the level second bottom. Natural mounds are quite numerous. The soil varies from a gray clay to a pure gray sand.

The present bottom of Bayou Dauchite is about half a mile wide and at Syke's Ferry is on the west side of the Bayou. From Serepta to Cotton valley the relief is very small indeed. The prevailing soil is a pure gray sand.

Johnson describes briefly the iron ores of this parish, and determines their age as follows: From fossils collected in N. E. ¼ Sec. 16, 20 N., 9 W., and in S. 2, same township and range, and in S. 25, 21 N., 9 W., it appears that these red lands are the outcropping of *Claiborne* marls, rich in greensand, which were traced northward from Minden.

(Claiborne Parish)

Lisbon.—Around Lisbon is a red sandy clay soil, apparently of considerable agricultural value, for the country looks like a very thrifty prosperous strip of land. The larger creeks have great flat bottoms. Middle Fork bottom is in this region about a mile and a half wide. It is partly in cultivation. The hills on the southern portion of the bottoms have a height of about 100 feet. Some of the ironstone concretions which occur in this region, when broken open, contain a nucleus of gray phosphate of lime. Several of these concretions were picked up on the hills on the south side of Middle Fork bottoms and on McGarland's creek; and, Mr. Maurice Bird of the North Louisiana Experiment Station has shown that the concretions contain from 15 to 20 per cent of phosphoric acid. It is hoped that larger deposits of these may be found.

Haynesville.—Around Haynesville the topographic relief is not so great as farther east. Gray sands and clays occur in the road cuts, and gravel crops out on the hillsides.

Homer.—Six miles northwest of Homer on the Homer-Haynesville road the light gray sands of the Gordon region are replaced by red lands. These red lands occur with scarcely an interruption to Homer. At Homer the railroad cut shows 18 feet of light yellow to white strongly cross-bedded sands with

JACKSON EOCENE OUTCROP, MONTGOMERY, LA.

horizontal layers of white clay pebbles, and near the top, some iron concretions.

The red lands with very marked topographic relief continue for about 6 miles from Homer, on the Homer–Minden road. The iron concretions then commence to be conglomeritic, and about 8 miles from Homer large quartz pudding-stones are quite numerous. The first really noticeable alluvial valley is that of Crow creek which is about half a mile wide. Judging from the fields seen here it seems capable of producing good oats.

(Union Parish)

The northern part of Union parish is very heavily covered with sands in part belonging to the underlying Eocene strata and in part to the Lafayette gravels which are found over many of the hillsides. Very fine exposures of red and white sands are to be seen in the deep gullies around Walnut home and Wallace's store.

On the eastern side of the parish is a low strip of pine flats, presumably belonging to the Port Hudson period. These are well developed on the Ouachita city—Farmersville road from 3 to 8 miles west of Ouachita city and on the Alabama–Marion road to within 5½ miles from Marion.

D'Arbonne.—Along the D'Arbonne and its branches the country is very broken, a relief of about 150 being quite common. Mosley's bluff is an abruptly sloping hill 80 feet high. The soil is composed of sand with some iron sandstone. Near the top are layers of red sands separated by occasional thin layers of clay. Wherever the clay layers occur they give rise to a spring horizon. Around Farmersville high sandy hills covered with ferruginous sandstone and gravel, lie about in the northwestern part of the parish. Toward Junction city the relief is much less marked. The land is rather low and the soil a pure grained, silty sand.

Jackson Stage

Distribution

The map.—The general distribution of this terrane is shown on the accompanying geological map of the State. It is based wholly on the character of the fossil remains found at various localities throughout the entire extent of the belt. Our historic review shows how erroneously various deposits from Red river to the Sabine have been referred to the "Vicksburg," "Mansfield" and other horizons quite without regard to any study of the fossil remains they so well display. We have as yet found no trace of Vicksburg deposits west of Red river.

LOCALITIES

Bayou Toro.—On the east bank of Bayou Toro in the S. E. one-fourth of the N. W. one-fourth of Sec. 6, 3 N., 11 W., Vernon parish, is a small bluff about 20 feet high containing many Jackson fossils. The shells scattered through the clays are very much decayed and quite difficult to obtain. Scattered through the clay are large dark-colored limestone concretions. They are particularly abundant in the little stream which enters Toro just south of the bluff. It was from these limestone bowlders that most of the fossils were collected. Outcrops of typical Grand Gulf sandstone were seen in the hillside about 50 feet above this locality.

Hilgard in 1869* described a seam of shell limestone with "Vicksburg" fossils at the base of the Grand Gulf rocks on Bayou Toro. The location of this bed, corresponds very closely with the bed from which we collected fossils.

Rattan P. O.—The bed of Bluff branch on the place of Mr. J. L. Peace, near Rattan P. O. (N. W. one-fourth Sec. 8, 4 N., 11 W.) shows an outcrop about 8 feet high composed of a fine yellow sand containing many small shells. Several larger shells were obtained from a well sunk at Mr. Peace's house. These fossils indicate that the beds belong to the Jackson stage.

Material which is very strikingly similar to that just mentioned occurs on the Leesville-Provencal road between Middle and Sta Barba creeks about 10 miles south of Provencal. This is very nearly in line with the Jackson outcrops.

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*Am. Journ. Sci., 2d vol. 48, p. 339.

Montgomery.—This is already a classic locality in Louisiana geology. (See under Historic Review.) The accompanying illustration shows well the general appearance of the most important outcrop in this region.

The following beds are exposed:

8.	Orange sands	5–50 ft.
7.	The above grade downward into pebble beds	5 ft.
6.	Light sands	3 ft.
5.	Sands, slightly lignitic	5 ft.
4.	As 5, separated by clay layer	8 ft.
3.	Thin light sandy clay	
2.	Bluish marl, fossiliferous	5 ft.
1.	Lignitiferous clays	15 ft.

Large collections were made at this locality and will be reported upon next year.

Owing to a very heavy deposit of Lafayette material over these Jackson beds the influence of the latter upon the soils of the region is greatly diminished. Towards Wheeling, on the east side of Nantaches bayou, very extensive deposits of ferruginous sandstone and sands were observed. The hills are 50 to 150 feet in height above the Bayou. The ravines, although numerous, seem to show no traces of fossil remains. The soil of the hills is excessively sandy. Gravel layers are numerous, occurring above the heavy sandstone ledges, and below the gray sands of the hills.

Tancock's prairie.—Just south of Ben creek or the northern edge of Tancock's prairie many specimens of *Ostrea trigonalis* are scattered over the ground. The limestone concretions which accompany this outcrop contain in addition to other forms very large specimens of *Haminea grandis*. These with other specimens collected have proven the Jackson age of the locality. Hilgard refers this to the Vicksburg.*

Tullos.—This station is in a Jackson prairie. In light grayish sandy clay in the railroad cuts there are many calcareous concretions. In the bottom of some of the wash-outs by the side of the track a bluish clay appears.

*Am. Jour. Sci., 2d series, vol. 47, 1869, p. 340; Supl. and Final Report of a Geol. Record of La., p. 33.

A typical cut can be seen, along the track about one mile south of the station. *Zeuglodon* bones are fonnd here. A vertebra purchased of Mr. Porter shows an oyster grown upon it, proving that the *Zeuglodon* died and its flesh decayed before the oyster was attached.

In an old field about three-quarters of a mile north of the station, along numerous little washes in the field, many well-preserved fossils are obtained. Ligniferous clays appear in the branches to the north. A cut one mile north of the station shows southward dipping lignitic clays, superimposed by what seems to be Jackson marly clays.

There seems to be a slight nonconformity between the two classes of deposits.

Olla.—Going still farther northward from Tullos we saw no good exposures. Gray buckshot clays appear in shallow cuts. At Olla wells are said to penetrate marls with calcareous concretions.

Lerch reports fossils from the region in Sec. 34, 11 N., 2 E.*

Ouachita river.—The Jackson is exposed in numerous places along Ouachita river below Columbia. It was in this region that Judge Bry found in 1832 the bones of the *Zeuglodon* and the shells which caused Conrad to refer the region to the Eocene.†

In 1841 Conrad described a new species, *Cardium nicolletti*, from this region.‡

Hopkins visited Grandview bluff in 1869 and found several bones of *Zeuglodon* there. The presence of the little Orbitoline forms, which are common in the Jackson of this State, led him to confuse some of the beds northeast of the bluff with the Vicksburg.

In 1866 Aldrich described a new species of gastropod, *Haminea grandis*, from Bunker Hill bluff.

The first fossiliferous outcrops we saw on Ouachita river below Columbus were at Gibson's landing. In the bluff at this place is a layer of fossiliferous sandy clay about eight feet thick, and about fifty above water level. In a small branch about a mile

*Bull. La. Expt. Sta., part 1, p. 92.

†Jour. Phil. Acad. Nat. Sci., vol. 7, 1834, p. 120.

‡Proc. Phil. Acad. Nat. Sci. for 1841, p. 33.

north of this landing *Zeuglodon* vertebræ were found together with many shells.

Bunker Hill bluff exposes about eighty feet of bluish gray clay containing very large selenite crystals. Near the top is a layer of large *Venericardia planicosta* in reddish clay; at a height of sixty feet numerous casts of *Pinna* are in a yellow limestone concretion.

Some of these casts look very much like the teeth of some very large animal, and we are not surprised that Judge Bry mistook them for such.* The main fossiliferous stratum is at the very base of the bluff.

Grandview bluff, a mile above Bunker hill, shows about the same section.

At Danville landing, about 100 yards below the Caldwell and Catahoule parish line (marked Enterprise on Lockett's map) is a bluff about forty feet high composed of bluish yellow marl, very fossiliferous. The fossils have a slightly different appearance from the Bunker hill shells but are still decidedly Jackson in character.

Wyant's bluff, about four miles above Danville, is about twelve feet high and shows blue clay with a few impressions and occasional pockets of shells. They are the same as found at Danville.

OLIGOCENE

VICKSBURG

DISTRIBUTION

Rosefield.—The Vicksburg stage is only very slightly developed in Louisiana. It outcrops south of Rosefield and probably occurs along Bayou Funne Louis. West of the Little river it has not been seen.

Lerch has described a section along Shell creek, three miles south of Rosefield in Sec. 35, 11 S., 4 E., and Vaughan lists *Dentalium mississippiense*, *Ostrea vicksburgensis*, *Pecten poulsoni*, *Arca mississippiensis*, *Byssoarca lima*, *Pectunculus arctatus*, *Crassatella mississippiensis*, *Meretrix sobrina*, *Balanophyllia caulifera*, and *Orbitoides mantelli*, from this locality.

*Am. Phil. Soc., Trans., new series, vol. 4, pp. 400–401, 1832.

Shells were collected at several places between this locality and the Ouachita, but the specimens and notes were left with a gentleman at Rosefield to be forwarded, and have not yet been received.

On the Harrisonburg road near the branch to Danville about a mile and a half south of Rosefield, fossiliferous yellow limestone concretions outcrop in the road. They are seen again near Sone's store, a mile farther south. About three miles east of Sone's store fossils are common near the saw-mill. Near the center of Sec. 31, 11 N., there is a small prairie with shells. In bottoms below, beds of lignite, which have at different times attracted prospectors, are reported.

GRAND GULF

HISTORICAL

Origin of the term Grand Gulf.—This formation was first named by Wailes, then State geologist of Mississippi, from a typical exposure at Grand Gulf, Mississippi.* It was described at length by Hilgard in 1860 in his report on the Geology and Agriculture of Mississippi.†

The Pascagoula formation (Miocene).—In 1890, Mr. L. C. Johnson discovered near Vernal P. O., Miss., and at other localities on the Pascagoula river a series of marine beds in the upper part of Hilgard's Grand Gulf. These marine beds he named the Pascagoula formation. From the fossils collected at this locality, *Gnathodon johnsoni*, *Mactra lateralis* and a large oyster resembling *O. titan* of the west coast, Dall‡ has concluded that the beds are equivalents of the Chesapeaks Miocene.‖ It seems very probably that this formation is represented in Louisiana, in the southern part of what is now called Grand Gulf territory, but, thus far, it has not been recognized.

Study of the Louisiana beds of this period.—In 1816, William Darby recognized the northern edge of what is now called the

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* Report on the Agr. and Geol. of Miss., 1854, pp. 216–217.

† Pp. 147–154, 1860.

‡ Dall and Harris, Bull. U. S. Geol. Surv., No. 84, 1892, p. 164.

‖ Bull. Geol. Soc. Am. vol. 5, p. 157, 1894; 18th An. Rept. U. S. Geol. Surv., 1896–1897, part II, p. 339.

Grand Gulf, traced it from Sicily Island to the falls at Alexandria and correlated it with the bluffs on the east side of the Mississippi "above Natchez."* In 1869, Hilgard skirted the southern boundary of the formation, passed across the same in Calcasieu and Vernon parishes and examined the northern escarpment on Bayou Toro and between Little river and Harrisonburg. During 1869 and 70, Hopkins made several trips across the State seeing the Grand Gulf at several points. His descriptions of the Grand Gulf in Louisiana are the most complete that have yet been published.†

Johnson ‡ and Lerch ‖ have both examined portions of the northern boundary between Lena and Harrisonburg.

FEATURES OF THE FORMATION

Characteristics.—This formation, which unconformably overlies the Vicksburg,§ consists in the northern part of its territory, of a series of light colored sandstones and claystones of white, gray, or yellowish gray tints. The sandstone is generally rather soft, never over 20 feet in thickness usually only three or four. Beds of loose sand are unusual. The sand grains are commonly quite sharp. The hardness of the sandstone in a given layer varies very greatly and makes quarrying in this rock a rather uncertain business. Beds of sand will pass in a few feet horizontally into hard sandstones. The accompanying plate shows an exposure of Grand Gulf in a cut on the Texas and Pacific railroad, about three miles west of Lena. The lower sandstone bed in this exposure is rather uniform. The upper irregular one shows on a small scale the nodular masses in which the sandstone occurs. In some cases the amount of silicious cement is so great that the rock resembles a quartzite. Such is the typical Grand Gulf

* A Geog. Des. of the State of Louisiana by William Darby, 1816, pp. 45–46.

† 1st An. Rept. Geol. Surv. La., 1870, pp. 98–102; 2d An. Rept. Geol. Surv. La., 1871, pp. 18–26.

‡ 50th Cong. 1st Sess., House Ex. Doc., vol. 26, No. 195, pp. 13–14, 1888.

‖ Bull. La. Expt. Stations; Geol. and Agr., part II, 1893, pp. 93–98.

§ Hilgard.—The Later Tertiary of the Gulf of Mexico, Am. Jour. Sci., vol. 22, 1881, pp. 58-65.

sandstone as exposed at Grand Gulf Mississippi. Hilgard gives the following description of it: "The typical Grand Gulf sandstone consists of grains of pellucid quartz, constituting a rather coarse sand, imbeded in an opaque, white, enamel-like mass of silex, which forms quite half the bulk of the rock."

In the southern part of the territory occupied by this formation (possibly, in the part belonging to the Pascagoula formation) sandy clays and pure highly tenaceous massive clays of a gray, grayish-white, blue or green color are the rule. The color in the blue and green clays is often very intense, though on the surface they often appear yellow from oxidation. In some cases black lignitic clays are found in this deposit. Some of the beds are very calcareous and produce small black land prairies. In the northern part of the formation there are occasional beds of very fine white clay, locally called "chalk."

The sandstones have resisted erosion much better than the underlying Jackson and Vicksburg beds. This has given raise to a somewhat level Jackson plain bordered on the south by a high, rugged line of hills. This very abrupt northern declivity is in sharp contrast to the gradual southern slope which carries the formation down to the level of the southern prairies.

Distribution.—Large outcrops of Grand Gulf sandstone are to be seen at Harrisonburg and Sicily island. On the divide between the Ouachita and Little river the Grand Gulf extends well to the north, reaching a point near Rosefield. Along the edge of the formation "chalk" or fine white clay has been reported in a number of places. From Rosefield, according to Hopkins, the northern line of the Grand Gulf follows the Bayou Funne Louis to Centerville, then turns west and crosses Little river a little below Gilmore's ferry. On the Colfax-Winnfield road the high Grand Gulf hills are encountered just south of Saddle bayou. About two miles northwest of Colfax there is a very good outcrop of Grand Gulf sandstone in Rocky ford. The sandstone is quite abundant as far north as Sec. 19, 7 N., 3 W. Around Lena are large quarries in the Grand Gulf rocks. Hilgard reports these beds as capping the elevated ridges about Cloutierville on Red river.* The next notable exposure

*Am. Jour. Sci., 2d Series, vol. 48, 1869, p. 337.

GRAND GULF SANDSTONE, NEAR LENA, LA.

of Grand Gulf is in the Kisatchie hills. The road from Leesville to Provencal passes through a strip of black prairie land about four miles from Leesville called Anacaco prairie. Calcareous concretions are scattered over the ground in large numbers but no fossils were seen. Another small calcareous prairie of about four acres in extent occurs north of Hardshell. In about Sec. 5, 4 N., 8 W., a light colored ledge crops out in the road. Between Kisatchie bayou and Bellewood, sandstone becomes quite common, and calcareous prairies are still to be found. The northern limit of the sandstone is about Bellewood. On the divide between the headwaters of Kisatchie and Toro bayous the Grand Gulf probably extends well to the north, and it may be that the "Bad Hill* " mentioned by Hopkins as seven miles south of Many is in this region. If Bad Hill is seven miles due south of Many it is Lower Claiborne, for numerous fossils are found in this region and the distance to the first Grand Gulf outcrop due south of Many is about 18 miles. The writers have in no place seen the Grand Gulf north or west of Bayou Toro. The large quarries in 4 N., 11 W., which have been opened to obtain stone for crib work at Sabine Pass, Texas afford good opportunities for examining the formation in this region. The line of parting between the Grand Gulf and the Jackson lies from a mile to two miles east of Bayou Toro from the railroad bridge to its mouth, where the Grand Gulf crosses the Sabine river into Texas. In Sec. 9 and 17 3 N., 11 W., large quantities of stone are strewn over the hillsides. Great masses separated by erosion often occupy outlying hills and are locally supposed to be of volcanic origin. Of the southern boundary of the formation Hilgard says: "The line originally laid down by me, and adopted by Prof. Hopkins, in his Geological Map of the State, is based upon the connection of the outcrops near Chicotville, then near the mouth of Mill creek into Calcasieu river and the point on the Sabine (Salem) given as the limit between the Quaternary and Tertiary, by Prof. Buckley of Texas."§ In the bed of the Nez Piqué and Boggy bayous Hilgard found, what he

* 1st Annual Report. La. Geol. Surv., 1870, p. 99.

§ Supl. and Final Rept. of a Geol. Recon. of the State of Louisiana, 1873, p. 16.

considered, characteristic outcrops of the materials of the Grand Gulf group, viz.; solid greenish clays and jagged clay sandstones.

East of the Mississippi Hopkins has mapped as Grand Gulf almost all the hill-lands of the Florida parishes. The Grand Gulf is here deeply covered with deposits of Lafayette material, and exposures have been noted in but few places. Hilgard reports the Grand Gulf along the river front as far south as Tunica bend.* Two miles northeast of Laurel Hill McGee found an exposure of Grand Gulf in the west fork of Thompson's creek.† So far as we know these are the only exposures of Grand Gulf which have been reported, in Louisiana, east of the Mississippi; indeed, Clendenin states that the Mississippi is the only stream which has succeeded in cutting through the Lafayette and exposing the underlying Grand Gulf.

Thickness.—Hopkins calculates the thickness of the Grand Gulf in the vicinity of Harrisonburg at 182 feet and remarks that this is probably less than the true thickness of the deposit.‡ Some of the hills on Bayou Toro are barometrically from 250 to 300 feet high and hence we feel quite safe in assuming for the Grand Gulf a thickness of at least 300 feet.

Fossils—These beds have not yet yielded, in Louisiana, any trace of animal remains. Specimens of silicified wood have been found at a number of places,‖ and beds containing twigs and leaves have also been reported. Veatch has obtained very good impressions of leaves about two miles west of Hornbeck. Specimens of silicified palm-wood collected by Johnson in Rapides parish have been identified by Knowlton as *Palmoxylon quenstedti* and *P. cellulosum.* Johnson called them Pliocene; McGee says they are of Grand Gulf age; Knowlton thinks the age very uncertain.§

AGE OF THE GRAND GULF

Results of work in Alabama and Florida.—It thus appears that no clue to the age of the Grand Gulf is given by the Louisiana

* Am. Jour. Sci. 3d Series, vol. 1, 1871, p. 236.

† 12 An. Rept. U. S. Geol. Surv. part I, p. 432.

‡ 2d An. Rept. La. Geol. Surv., 1871, p. 19.

‖ Hopkins 1st An. Rept. La. Geol. Surv., 1870, p. 100.

§ Proc. U. S. Nat. Mus., vol. 11, pp. 89-91, pl. 30, 1888.

deposits. The material which has been lumped together, in Louisiana, as Grand Gulf lies between the Vicksburg (Lower Oligocene) and the upper Pliocene. It may therefore represent Upper Oligocene, Miocene or Pliocene. In Mississippi the conditions are a little more satisfactory. The collections of Johnson at Vernal P. O. demonstrated that the upper part of Hilgard's Grand Gulf, in that region, is Chesepeake Miocene. But the Alabama and Florida sections were needed to show the age of the Grand Gulf proper.* It has there been shown that the typical Grand Gulf passes under the Oak Grove beds, and hence is probably equivalent to the Chatahoochie or Upper Oligocene beds. The Grand Gulf beds above the typical Grand Gulf and below the Pascagoula clays pass into the Oak Grove sands, which are now regarded by Dall as transitional between the Oligocene and Miocene.†

LAFAYETTE‡

HISTORICAL

ORIGIN OF THE TERM LAFAYETTE

The attention of geologists engaged in work on the southern coastal plain was early attracted by beds of brightly colored sands and gravels extending over wide areas. The color of these deposits soon suggested a name; they were called "Orange Sand" by Safford in 1856 ‖. Hilgard adopted the term in his Mississippi report and gave the most complete description of the deposits that has been made up to the time of McGee's

* Smith, Geol. Surv. Ala., 1894, pp. 104–107; Dall and Stanley-Brown Bull. Geol. Soc. Am., vol. 5, p. 164, 1894.

† A Table of North American Tertiary Horizons, Correlated with One Another and with Those of the Western Europe, with Annotations by Wm. H. Dall, 18th An. Rept. U. S. Geol. Surv., 1896–97, Part II, p. 340, 1898.

‡ See article by W J McGee.—The Lafayette Formation, 12th Ann. Rept. U. S. Geol. Surv., 1891, pp. 347–521, which is by far the most complete account of the subject yet published.

‖ Geol. Recon. of Tenn. by J. M. Safford, 1856, pp. 148–162. Quoted by McGee.

report in the 12th Annual of the United States Geological Survey.

Safford referred the Orange Sand to the Cretaceous, to which only a portion of his deposits belonged, but later called it Tertiary and proposed a new name the "Bluff Gravel" for the portion which was of presumably Quarternary age*. Hilgard maintained that the deposit was of Quarternary age and was a southern equivalent of the northern drift. He supposed that the deposit originated in the great floods of water issuing from the ice front. This idea has given rise to the names "Drift," "southern Drift" and "Stratified Drift" which have been applied to this formation.

The uncertain meaning of the term Orange Sand caused the adoption in 1891 of the term Lafayette formation, from the typical locality in Lafayette county, Mississippi where Hilgard first studied and named the formation. The opinion now generally held is that the Lafayette is a littoral or coastal deposit of late Pliocene age and hence anterior to the glacial period. It has no connection whatever with the great sheets of true drift or till brought down by the glaciers.

FEATURES OF THE FORMATION IN LOUISIANA

DEFINITIVE FEATURES OF THE DEPOSITS

In Louisiana the only criterion for the determination of the beds of this formation seems to be the chert and quartz pebbles, often with casts of Paleozoic fossils, which portions of the beds contain. The lithological resemblance of the sands of this formation to the weathered sands of the underlying deposits is so close that it is impossible to differentiate them. This resemblance has led to many incorrect references of red sandy material to the Lafayette. Thus, Hopkins refers the iron bearing sandstone common around Rocky Mount and in all the higher hills of northern Bossier, Claiborne, Jackson and Union parishes to the Drift. Harris has collected Lower Claiborne fossils in the Rocky Mount material and is inclined to regard the fossils as being *in situ*. Veatch has obtained a series of very perfect

* Geol. of Tenn., 1869, pp. 432–433.

casts, preserving to an extreme degree all the fine surface sculpturing of the shells, from very coarse ferruginous sandstone about nine miles west of Ruston. Lerch seems to have made an error in his first report* where he refers the red sands and sandy clays, which form so large a part of the surface of northern Louisiana, to the Lafayette. Vaughan has shown, and the observations of the present survey support his conclusions, that the red sands are in part, at least, Lower Claiborne.†

DISTRIBUTION OF THE GRAVELS

The observations in the State have not yet been sufficient to show clearly the minor features of the distribution of gravels; but the main localities are known.

East of the Mississippi.—In the hill lands, east of the Mississippi river the gravel is very well developed. It there overlies the Grand Gulf beds and seems to pass under the Port Hudson. Regarding the distribution of the gravel in the Florida parishes Hopkins says: In "Washington Parish the pebbles are common. About five miles east of the Tangipahoa these have disappeared and the deposit is a yellow clay, with fragments of brown hematite and red ochre. On Beaver creek, and to the west of Tangipahoa, it has changed to a coherent sand of an intense red color. Red and yellow clay again, with a few quartz pebbles, are seen on the road to Greensburg, and red sand at that place. Violet and yellow clay with a peculiar chocolate shale, are found between this point and the Amite river. Then the pebbles recommence and are fossiliferous as usual. Clinton and Jackson are built upon them. They underlie the bluff to within a mile of the river at Bayou Sara.‡ The southernmost point on the Mississippi at which Lafayette gravels have been found is reported by McGee as in a road cut "seven or eight miles south-southeast of Bayou Sara, a mile west of Thompson's bayou, and midway between Fairview and Star Hill plantation.§

* Bull. La. State Expt. Stations: Geol. and Agr. part I, pp. 24–26, 1892.

† Bull. U. S. Geol. Surv. No. 142, 1896, pp. 20–22, 1896.

‡ Second Annual Report Geol. Surv., La., 1871, p. 22.

§ Twelfth Annual Report U. S. Geol. Surv. p. 430.

Along the northern and southern borders of the Grand Gulf.—West of the Mississippi the gravel is reported well developed on both the northern and southern borders of the Grand Gulf. Clendenin reports a very extensive gravel pit in the hills of southern Rapides, east of the Kansas City, Watkins and Gulf railroad where large quantities of gravel are obtained for railroad ballast.* According to Hopkins it is quite common between Cheneyville and the lime kiln near Bayou Chicot.† Gravel is extremely abundant along the Iron Mountain Railroad from Alexandria as far north as the northern boundary of the Grand Gulf, where it suddenly ceases. All along the northern line of the Grand Gulf, gravel seems to be quite abundant. It has been reported by Hopkins from the Harrisonburg hills.‡ It has been seen by the junior author on the northern edge of the Grand Gulf just south of Saddle bayou on the eastern road from Colfax to Winnfield; in the Kisatchie hills; and in the hills south of Toro bayou along the K. C. P. and G. R. R.

Around Many and Sabinetown.—North of the last locality referred to above is a great stretch of country covered with fossiliferous Jackson and Lower Claiborne. On the railroad, the first place where gravels are exposed north of the Grand Gulf territory is about two miles south of Many on about the line of parting between the Lower Claiborne and the Lignitic. Going west from Many no gravel is seen until the vicinity of Sabinetown is reached. The gravel caps the first big bluff on the east side of the river above Sabinetown and on the top of Sabinetown bluff is extremely well developed. The top of the bluff at Pendletown is covered with extremely red sand but no gravel was seen in it. At the mouth of Bayou Negreet Harris found a pebble conglomerate containing Lower Claiborne fossils. The fossils were poorly preserved and may have been redeposited.

The Black lake bayou gravel train.—In the northern part of the state the gravel is almost entirely confined to the two great gravel trains which were first pointed out by Lerch.

* Bull. La. State Exp. Sta; Geol. and Agr., part III, 1896, p. 214.

† 2d Ann. Rept. Geol. Surv. p. 22.

‡ First Annual Rept. La. Geol. Surv., 1870, pp. 99, 102.

The most important and continuous is the Black lake bayou and Dauchite bayou deposit. Between Shongaloo and Sykes ferry the gravel is quite abundant. At old Haynesville great quantities crop out in the hillsides. The territory between the two localities was not passed over, but it seems probable that the two deposits are connected. Going south the gravel ridge narrows. No northern gravels are found on the red lands in T. 21 N., R. 9 W. At Minden gravel was seen from about half a mile west of the Dauchite bridge to a little beyond Crow's bayou on the Homer road. On the large hill between Minden and the bridge it is common to a height of 65 feet above the bottoms. Between Minden and Sibley nearly all the hillsides show gravel. In the railroad cut at the latter place 17 feet of gravel and cross-bedded sands are exposed. Pebbles as large as a man's fist are seen here. This gravel was found as far east as Black lake bayou. The country between Sibley and King's salt works was not personally examined, but we are credibly informed that gravel is common. Pebble conglomerate is often seen on the hills around King's salt works, and on the Sparta-Campti road between Castor and Toby creeks. Just south of this exposure is a very fossiliferous Lower Claiborne prairie and no more gravel occurs between here and Lake village. On the west side of Black lake bayou, between Lake village and Coushatta, the gravel band is three or four miles wide. At Black lake the gravel again occurs on the eastern side of the bayou. Here it is in close proximity to fossiliferous Lower Claiborne prairies. The gravel occurs on the hillsides in Sec. 4, 11 N., 6 W. The very crest of the hill is covered with *Osterea falciformis* and *O. johnsoni*.

At Grand Ecore ten feet of white and yellow chert pebbles and sand cap the bluff. They extend scarcely an eighth of a mile from the river.

Saint Maurice and Montgomery.—At Saint Maurice large quartz boulders are found on the hillsides twenty to forty feet above the fossiliferous Lower Claiborne in the bed of Saline bayou.

From 3 to 4 miles northeast of Montgomery, on the east side of Bayou Nantaches, there are quite prominent escarpments of sandstone which in turn are overlaid by beds of white quartz gravel and conglomerate. Above the gravel are from 50 to 75 feet of yellow and white sands.

Ouachita river gravel train.—The gravel train along the Ouachita is not nearly so extensive. It is reported from about 12 miles south of Monroe. About three miles north, on Col. Jones' stock farm, there is a large gravel pit which is of great local importance. Gravel is seen along the railroad for two miles west of Monroe. A prolongation of the same deposit appears in force at the bluff about a mile above the mouth of the D'Arbonne and at Ouachita city. At Ouachita city the gravel band is about three miles wide.

In northern Union and Claiborne.—Gravel localities are sprinkled all over the northern part of Union and northern Claiborne. The following localities may be mentioned: near L'Outre bridge on the Spearsville-Ouachita city road; south of Cherry Ridge; around Farmersville and as far south as the D'Arbonne; on the hills west of Corney ferry, three or four miles from Farmersville; at the Corney bridge on the Junction city-Lisbon road; on the hills on the south side of Middle Fork bottoms near Colquett bridge; and between Colquett and Gordon in occasional patches.

Around the Cretaceous outcrops.—Besides these localities several of the so-called Cretaceous outcrops show gravel deposits, viz.: Rayburn's salt works and the Five Islands. For information on the gravel of the Five Islands see special report.

Localities where the gravels are found in wells.—Besides these surface outcrops wells have in several places revealed the presence of beds of sands and gravel which presumably belong to this formation. A bed of gravel from 20 to 40 feet thick seems to underlie the Red river valley in the vicinity of Shreveport at a depth of from 50 to 80 feet. Hopkins reports gravel under the Avoyelles prairie at a depth of 40 feet. In nearly all the Port Hudson territory deep wells reach the Lafayette gravels.

REGIONS WITH NO GRAVEL

Four principal regions in which no gravel has been observed may be thus outlined: (1) The alluvial lands; (2) the country overlaid by the Port Hudson; (3) an area centrally located between the Red, the Ouachita and the State line including Caldwell, the major part of Winn, Jackson, eastern Bienville, southeastern Claiborne, the major part of Lincoln and the western part of Ouachita parishes; (4) all the territory lying west of the Black lake gravel train and north of the Grand Gulf except the area about Many and Sabinetown.

THICKNESS OF THE DEPOSIT

In northern Louisiana exposures of a greater thickness than 10 or 20 feet seem to be rather rare. In the region of Minden the deposit is at least 60 or 70 feet thick. In southern Louisiana it shows a thickness in the Lake Charles wells of from 150 to over 200 feet. On Côte Carline, Grande Côte and Belle Isle the borings show that a thickness of 200 feet is by no means uncommon. Hole No. 7 on Côte Carline, which is for the most part in material of presumably Lafayette age, is 442 feet deep. On Belle Isle 400 feet of sand is recorded in hole No. 2.

CONCLUSIONS

There can be little question that these deposits were all formed in the same way and that they represent shore deposits. There does seem, however, to be room for a reasonable doubt that they were formed at the same time. It is seen in the beginning that the argument for the unity of a deposit which is differentiated from other deposits merely by the presence or absence of chert and quartz gravel is not very strong. Hilgard noticed the very peculiar irregularity of the distribution of the gravel in Mississippi and the same has since been found true in Alabama. In Alabama gravel occurs to a very limited extent or not at all (1) over the territory of the Rotten limestone, (2) over the Black bluff or basal Lignitic and (3) over parts of the Jackson or white Limestone.* In Mississippi it is found to a very limited extent (1) over the territory of the Jackson, being entirely absent in the prairies; (2) it is wanting in large portions of the territory occupied by the Rotten Limestone of the Cretaceous (3) in the Flatwoods region [Midway] of the northeastern part of the State †. This absence of the gravel from the most calcareous

*Geol. Surv. Ala., 1894, p. 68.

† Miss. Rept., 1860, p. 5.

deep sea deposits seems hardly well explained by the theory of the common time origin of these deposits. The Arkansas Orange Sand or Lafayette as identified by McGee seems capable of division. Harris found a portion of the pebble beds passing beneath the Midway Eocene in the vicinity of Little Rock. The Plateau Gravels of Hill contain Cretaceous fossils in Clark county, and Harris is inclined to regard the fossils as of the same age as the gravel.

Too little is known of the gravels of Louisiana to justify any very conclusive statements, and many years must elapse before the problem can be fully worked out, but the facts we know at present seem to suggest at least a working hypothesis. The band of pebbles which appears along the southern edge of the Grand Gulf seems to pass beneath the Port Hudson and to be the gravel which is struck in deep wells sunk in the Port Hudson territory. It is the time equivalent of the Lafayette of McGee. The band of gravel which follows the escarpment which marks the northern limit of the Grand Gulf does not extend, to any appreciable extent, over the adjacent lower territory of the Jackson.* The question then becomes, has the time since the deposition of the Lafayette been sufficient for the erosion of a strip of gravel several miles wide along a course which cuts the principal streams at right angles? The gravel train in the vicinity of Monroe lies in about the position and direction of the shore line in the Jackson period. The gravel at Many and Sabinetown is in about the position of the Claiborne shore-line. The Black lake bayou gravel train occupies a questionable position. Much of it lies along a line between the Lignitic and Lower Claiborne but seems too far east to represent the Claiborne shore-line. Indeed if the gravel in Sec. 4, 11 N., 6 W., be considered a part of it, it is younger than the Claiborne. We are hardly prepared to affirm that this is a true explanation of the deposition of the gravel as the facts at hand are entirely

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* Hopkins, 1st Annual Rept. La. Geol. Surv., p. 104, says: "The intervening region of the Jackson and Vicksburg is lower; and often entirely bare of drift as is the case with marly regions of the Grand Gulf." Whenever the northern edge of the Grand Gulf was passed by the present writers no gravel was observed even on the Jackson.

too meagre to justify such a statement. But it is felt that as the stratigraphy of the Southern states is more carefully worked out the positions of some of the gravel beds, which now seem very strange will become quite clear, and that parts of them will be found to be the true equivalents of adjoining fossiliferous beds.

QUATERNARY

CLASSIFICATION

HISTORICAL

The literature on the Quaternary deposits of Louisiana is quite voluminous. The great river and its delta have been studied and written about since the first settlement of the country. Commerce demanded it; and the scientific man found in the river and flood plain, problems of very great interest. Some of these problems are so large and the observed data so small that our present knowledge is by no means satisfactory. Their elucidation will require some years of very careful hard work.

Lyell.—Passing over the early observations of the U. S. Engineers engaged in work on the river and of the earlier unpublished part of the work of Forshey and Riddel we come to Sir Charles Lyell. The visit of this great geologist, and his subsequent publications may be considered the beginning of the present study of the river deposits. He conceived for the alluvial deposits a thickness of at least 500 feet and on this based his calculation of 67,000 years as the age of the delta. He recognized the lœss, and at Port Hudson saw deposits which he considered to be of alluvial formation.*

Hilgard.— In his Mississippi Report, 1860, Hilgard proposed the name Coast Pliocene for a series of recent, partly cypress swamp, partly marine beds with recent shells, occupying a strip along the Gulf Coast from 12 to 20 miles wide. This has its homologue along the whole southern coast of Louisiana. In the same report he recognized and named the Yellow Loam.†

* Second visit to the United States, 3d Ed., 1855, p. 250; also Principles of Geology, 11th Ed., p. 455.

† Report on the Geology and Agriculture of the State of Mississippi, 1860, p. 197.

After his examination of Port Hudson and his trip through southern Louisiana he recognized over the whole area the equivalents of his Coast Pilocene, and proposed for the whole the name Port Hudson group.* The layer of blue clay† which the labors of Humphreys and Abbott had revealed to be very widespread in the bottoms, and which they referred to a number of different geological horizons, from the Cretaceous up, Hilgard referred to the Port Hudson.‡ He came to the conclusion that the present deposits of the river are of inconsiderable thickness; a view which he has maintained in all his subsequent writings.

Johnson.—Investigations by Mr. L. C. Johnson in 1890, in southern Mississippi and in the region north of Lake Pontchartrain, in the coastal phase of the Port Hudson, led him to propose for it the name Pontchartrain clays.§ At the same time he proposed the name Biloxi sands for the more recent coastal formations. The difficulty in distinguishing between the two beds, which were formed under very similar conditions, led to the extension of the meaning of Biloxi sands to include the Pontchartrain clays.||

McGee.—In his correlation of the coastal deposits McGee includes all the Quaternary deposits in Louisiana, except the most recent alluvium, under the Columbia formation.¶ He restricts the Orange Sand, as used by Safford in 1888,†† to the basal portions of the Yellow Loam.

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* Am. Jour. Sci., 2d series, vol. 48. p. 332, 1869.

† Hydraulics and Physics of the Mississippi River, p. 99.

‡ Am. Jour. Sci., 3d series, vol. 47, p. 79; also Am. Jour. Sci., 3d series, vol. 2, pp. 391–404; Am. Assoc. Adv. Sci., Proc., vol. 20, pp. 222–236.

§ Bull. Geol. Soc. Am., vol. 2, pp 20–25, 1890.

|| Geol. Surv. Ala., 1894, p. 41.

¶ The Lafayette formation by W J McGee, 12th Annual Report U. S. Geol. Surv., Part I, p. 392.

†† Agricultural and Geological Map of Tennessee (J. M. Safford, State Geologist), 1888.

TABLE OF LOUISIANA QUATERNARY FORMATIONS

River Development		Costal Development	
Alluvium		Coastal Marshes Biloxi Sands	
Yellow Loam Lœss Fluviatile Port Hudson or Old Alluvium Basal Gravel	Columbia (McGee)	Chocolate Colored Loam Yellow Loam Ponchartrain Clays or Marine Port Hûdson Coast Pliocene (Hilgard)	Biloxi Sands (Johnson)

DEVELOPMENT AND CHARACTERISTICS OF LOUISIANA QUATERNARY FORMATION

MANNER OF FORMATION

Natural periods in the Quaternary of Louisiana.—The history of the Louisiana Quaternary seems to be divisible into three parts: a long period of deposition, with varying conditions in altitude and consequent differences in the character of sediment deposited; a period of erosion; and the present, comparatively recent period of deposition.

First period of subsidence.—In the beginning of this period the land must have stood over 248 feet* higher in the northern part of Lousiana than it does to-day. In the valley where the stream was sufficiently rapid, portions of the Lafayette gravels were re-deposited or other gravel brought down by the river from the north. The deposition of gravel would naturally be greatest in the upper part of the valley while nearer the coast the material would be finer. Along the coast, deposits of clay and sand would be formed, which near the mouth of the river they would contain *Rangia* and other brackish water molluscs, while at a distance from the main outlet of the river the deposits would contain recent marine species. As the subsidence progressed the deposi-

* The depth of the Quaternary deposits at Lake Providence.—Hilgard and Hopkins, Report on Borings between Memphis and Vicksburg, 48th Cong., 1st Sess., House Ex. Doc., vol. 19, 1884, p. 481.

tion of sand and gravel in the main valley would cease and their place be taken by fine cypress swamp clays. In these cypress swamp clays local beds of sand and loam were formed along the sluggish streams which meander aimlessly through the valley.

In the Mississippi valley the irregular melting of the glaciers which occupied the whole region north of the Ohio and Missouri rivers caused great floods which brought with them large quantities of glacial rock meal. At times this flood may even have overflowed the bounding hills or bluffs of the old valley and formed on their summits great natural levees of silt even as the pigmy Mississippi does to-day. At any rate these periodical floods, caused by variations in temperature along the ice front, must have formed extensive mud flats, as wide as the river valley, and winds blowing over them would experience no difficulty in transporting this impalpable silt to the summits of the bordering hills.

Period of elevation.—At the close of this subsidence in which the land reached a level a hundred feet* lower than to-day, a period of elevation commenced. During this time an elevation slightly above the present was reached and the river cut out the deposits of the preceding period. The amount of this excavation can be judged by the height of the Port Hudson bluffs and the Opelousas, Carrencro and Cte Gelée hills. To this is to be added the very inconsiderable depth of the older material below the present alluvium. In the upper Red river valley this excavation amounted to about 60 feet.

Present period of subsidence.—At the close of this elevation the present period of subsidence commenced and with it the deposition of the alluvium. That a subsidence is going on is evidenced by a number of facts: (1) by the drowned condition of the mouths of the majority of coastal rivers; (2) by the

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*If the yellow loam and the lœss are not considered, a subsidence of this amount seems to be quite capable of producing the deposits observed in the Mississippi valley. The origin of the lœss is so little understood that an assumption that the subsidence was equal to the height of. the highest lœss above sea level seems hardly well founded. If the subsidence was so great, about 500 feet, as the estuarian theory of the origin of lœss demands, we should find well marked marine forms at Baton Rouge and Port Hudson.

burial of Indian shell heaps and mounds with recent material as at Belle Isle and in many mounds along the Mississippi coast;* (3) by the formation of numerous long dune-shaped islands just off the coast and along the seaward margin of the coastal marshes which are features of a subsiding coast;† (4) by the observations of Maj. Quinn, U. S. E., who reported the extraordinary subsidence of one foot between 1875 and 1894;‡ (5) from the almost stationary condition of the mouths of the Mississippi.

THE BASAL GRAVEL§

Characteristics and development.—The basal portions of the Quaternary which were formed by the redeposition of some of the preceding gravel have been definitely recognized in but two localities in the State because of the difficulty in separating them from the underlying Lafayette. In the Lake Providence borings there are certain beds which Hilgard is inclined to regard as basal Port Hudson.‖ McGee reports the basal gravel 7 or 8 miles south-southeast of Bayou Sara and in the region between Bayou Sara and the state line.** He also states that the basal gravel was found in the New Orleans well and below the Calcasieu prairie, a statement which seems to require further proof. The low level Red river gravels, which have been provisionally referred to the Lafayette, may belong to this period.

THE PORT HUDSON

Origin of Term.—In the American Journal of Science for November, 1869, Hilgard proposed the name Port Hudson for a group of swamp, estuarine, bayou and marine clays and sands covering parts of Louisiana and Mississippi. The formation

* Geol. Surv. Ala., 1894, pp. 45–46.

† Eastern Sea Coast Marshes by N. S. Shaler, 6th Ann. Rept. U. S. Geol. Sur., 1885, p. 360; also W J McGee, Gulf of Mexico as a Measure of Isostacy, Am. Jour. Sci., vol. 44. p. 187.

‡ Quoted in Annual Cyclopædia for 1895, Appleton and Co., p. 427. We have not been able to find this statement in the Annual Reports of the Chief of Engineers from which it seems to have been taken.

‖ 48th Cong. House Ex. Doc., vol. 19, 1884, p. 480.

§ McGee, 12th An. Rep. U. S. Geol. Sur., part 1, p. 499.

** 12th An. Rep. U. S. Geol. Sur., part 1, pp. 430–431.

was named from Port Hudson, Louisiana, where the typical exposure is found.

General characteristics.—This formation consists of beds of dark colored clays, commonly blue, black or green but sometimes gray and yellow, containing calcareous concretions and occasional beds of gray sand and slit. The blue clay which is probably the most distinctive bed commonly contains stumps and trunks of cypress and other lowland trees.

It shows two very distinct facies: a marine and fresh water. Along the gulf coast the littoral portion of the formation commonly contains marine and, near the old coast line, brackish water shells. The river portions contain cypress stumps, driftwood and occasional fresh water shells.

Synonymy.—This development of marine facies has given rise to two very different meanings for the term Port Hudson. In the river where the Port Hudson is strongly differentiated by physical characters from the lœss and yellow loam and separated from the very similar recent deposits by an erosion interval, the term Port Hudson is restricted to a fairly limited group of clays at the base of the Quaternary series. On the coast where deposition has been going on continuously and where the deposits of to-day are forming under the same conditions and contain the same marine forms as the earlier Quaternary beds, it is impossible to distinguish between them. This has led Hilgard to unconsciously use the term Port Hudson in the costal region to cover everything except the recent sea marsh deposits. That is, in the the costal region the Port Hudson not only includes the equivalents of the Port Hudson of the valley but the marine equivalents of the lœss, the yellow loam and in all probability a part of the alluvium.

The Port Hudson bluff, which is the typical exposure for the formation, represents only the fluviatile development. This led Johnson in 1890* to propose the name Pontchartrain clays for for the marine equivalents of the Port Hudson. The Pontchartrian clays consist of brownish or yellowish blue clay with sand partings, and contains a few stumps and marine shells. At the

* Bull. Geol. Soc. Am., vol. 2, pp. 20-25, and Am. Jour. Sci., vol. 40, pp. 332–333, 1890.

same time the term Biloxi sand was suggested for the recent costal formations, in general equivalent to the recent alluvium of the river. It was found impossible to differentiate them in the field and in 1894 the Pontchartrain clays and Biloxi sands were all included under one head, the Biloxi sands.*

The difficulty, nay impossibility, of distinguishing between the different parts of the Quaternary in the coastal region has given rise to a very interesting discussion on the thickness of the recent alluvium in the delta below New Orleans. This seems to be one of those points where a person can take either side and prove that he is right. If the period of the recent alluvium be said to begin at the time when the cutting out of the Port Hudson and lœss deposited in the valley commenced, then the delta formed of this material would be composed of redeposited Port Hudson material with marine shells and exactly the same difficulties will be experienced in differentiating the two deposits that are experienced both east and west of the delta region. If the period of the recent alluvium be defined as commencing when the period of degredation ceased, the same difficulties will be experienced. Off the delta to-day marine beds are forming which are the time equivalents of the recent alluvium, but which are in everyway similar to those which formed under similar conditions in the Port Hudson period proper. Indeed criteria for the separation of the Port Hudson proper from the more recent deposits in the lower delta region seem to be entirely lacking. All our present knowledge seems to justify, is to lump the whole together as has been done east of of the Mississippi in the Biloxi sands and west of the Mississippi in the Port Hudson.

Areal distribution and topographical features.—These vast beds of clay, which have not been exposed long enough for the development of drainage systems and which from their clayey nature prevent a perfect subterranean drainage, have had a very marked effect on the topography of part of Louisiana. East of the Mississippi they have given rise to the "Pine flats" or "Pine meadows" lying between the pine hills and the coastal marshes. West of the Mississippi they have produced another

* Geol. Surv. Ala., 1894, p. 41.

series of pine flats in Calcasieu parish and the whole prairie region of southern Louisiana (see geological map). The post oak or upland flats of Red river valley seem to belong to the same age also.

The Port Hudson seems to be distributed over the whole lower Mississippi valley at a slight depth below the modern river deposits. In places through the river valley the Port Hudson appears to be represented by butte-like masses which were not completely eroded during the degredation period that followed their deposition. The Moorehouse hills seem to represent one of these erosion-formed masses of Port Hudson material. The Bayou Macon hills represent hills of the same type which have received a coating of yellow loam. Further down the valley another one of these outliers is found in the Avoyelles prairie.

Thickness of the Port Hudson.—The deposition of the Port Hudson on the irregular and probably steeply inclined surface of the Lafayette gives to the Port Hudson a decidedly varying thickness. The wells about Lake Charles seem to indicate for the formation an average thickness of a little less than 200 feet. The great thickness, 354 feet, observed in the Kirkman well near Lake Charles appears to be rather abnormal. In the Mississippi valley at Lake Providence there are 205 feet of Port Hudson under 42 feet of recent alluvium.* East of the river the work of the Alabama survey has revealed the total thickness of the Quaternary to be from 200 to 250 feet.† Of this from 10 to 100 feet is supposed to be recent and the balance Port Hudson proper. The New Orleans well had not passed through the Quaternary deposits at a depth of 630 feet. In Red river valley in the vicinity of Shreveport the Port Hudson is about 100 feet thick. This would seem to allow for the Port Hudson a riverward development of from 100 to 200 feet, a normal coastal development of 200 feet and an extreme development immediately on the coast of over 600 feet.

Fossils.—The most common fossils are plants; leaves, trunks of trees and roots occuring in many parts of the formation. Vertebrate remains have been found in numerous parts of the

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*Hilgard 48th Cong. 1st Sess., House Ex. Doc., vol. 19, p. 493.

† Geol. Surv. Ala., 1894, p. 43.

State in deposits which are the time equivalents of the upper part of the Port Hudson or the lower part of the lœss. The early accounts of the geology of the State contain reports of finding mastodon remains near Opelousas. Carpenter reports the find of a mastodon jaw and teeth and the tooth of a large horse on Bayou Sara in the parish of West Feliciana.† The bone beds on the Mississippi just north of the line are extremely rich. On Petite Anse the remains of *Mastodon*, *Mylodon*, *Equus* and *Elephas* have been reported. Mastodon bones have been reported from Port Hudson bluff‡; from Cote Blanche §; from King's salt works; Price's salt works‖; Rayburn's salt works‖; Dunbar's creek, West Feliciana parish; and at Alsworth's, 6 miles above Baton Rouge ¶.

In the river exposures fresh water shells are occasionally found and Hilgard has reported imperfect specimens from Côte Blanche and Petite Anse**. Marine forms are found over nearly the whole of the area covered by the marine phase of the Port Hudson. They have been reported by locality from Bayou Sale, Belle Isle, Opelousas, Lake Charles, Bonnet Carre on the Mississippi river above New Orleans, New Orleans, the Lake Borgne borings and Pontchatoula.

THE LŒSS AND YELLOW LOAM

Origin of the term lœss.—The term lœss, applied to the very fine yellow calcareous silt of the Rhine valley, came into general use among European geologists early in this century. Lyell in 1846 recognized in certain deposits in the Mississippi valley the American counterpart of the European deposits.

Its great development along the bluffs bordering the Mississippi valley caused it to be called the "Bluff formation" by

* Dunbar, Am. Phil. Soc. Trans., vol. 6, pp. 40–41, 1801; Duralde, Am. Phil. Soc. Trans., vol. 6, pp. 55–58, 1802; Carpenter, Am. Jour. Sci., vol. 35, pp. 344–346, 1838.

† Am. Jour. Sci., vol. 34, pp. 201–203, 1838.

‡ Hilgard, Smith. Contr. No. 248, vol. 23, p. 5, 1872, and other places.

§ Ibid, p, 12.

‖ Hopkins, 2d An. Rep. Geol. Surv. La., 1871, p. 6.

¶ Hopkins, 3d An. Rep. Geol. Surv. La., 1872, p. 188.

** Smith. Contr. No. 248, vol. 23, pp. 12, 18, 1872.

Swallow in 1855.* This term has since been used by a number of southern geologists but with varying shades of meaning. Hilgard used the term as a synonym for the lœss proper. In his second annual report Hopkins used the term "Bluff Period" to cover the whole of the Quaternary except the most modern alluvium.

General characteristics of the lœss.—The lœss is a homogeneous, yellow or yellowish-buff, very fine grained, calcareous, silty, unstratified loam; commonly best developed along the hills bordering the river channels, and thinning out and becoming less characteristic as the distance from the stream channels increases. It often contains numerous land shells and occasionally fresh water shells. In its basal portions mastodon bones have been found and Lyell reports the finding of fish remains in the lœss at Vicksburg.† The calcareous matter forms very fantastically shaped concretions called lœss-kindchen. Probably the most distinctive feature of the lœss is its habit of weathering into perpendicular banks.

In the Mississippi valley it seems to be best developed along the eastern bluffs and to grade southward into a yellow loam or hardpan. Typical lœss is probably to be found in Louisiana only over a very limited area in the Florida parishes along the river immediately south of the Mississippi line and at Sicily island. The lœss, in its modified form, the yellow loam, however, covers a very considerable area in the State.

Origin of the lœss.—No satisfactory theory of the origin of the lœss has yet been advanced. Geologists are at present divided between two theories, the aqueous and the eölian. There are several modifications of the aqueous: the strictly fluviatile, the fluvio-lacustrine, the true lacustrine and the embayment.‡ All geologists agree that the lœss and the yellow loam are formed of glacial products.

The Yellow loam.—The studies of Hilgard in Mississippi, prior to 1860, indicated the presence of a stratum of unstratified, non-

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* Geol. Surv. of Missouri, 1st and 2d Annual Report, pp. 59–170, Jefferson City, 1855.

† Principles of Geology, 11th ed., vol. 1, p. 460.

‡ Chamberlin, Jour. Geol., vol. 5, 1897, p. 798.

calcareous yellow loam or brick clay often overlying the typical lœss and extending over a much larger territory. For this formation he proposed the name Yellow Loam.* He considered it genetically distinct from the lœss. More recent investigations have shown that it not only overlies the lœss but sometimes underlies and grades laterally into the lœss. They are now regarded as one and the same formation, the lœss representing a local development of the loam.

Distribution of the Yellow loam.—On the geological map of the State the thick deposits of lœss-like yellow loam on the Bayou Macon hills, on the Avoyelles prairie and on the uplands along the Teche have all been represented as belonging to this deposit. A thin layer of the yellow loam covers a much larger area. It extends over nearly the whole of the western Port Hudson, becoming in that region the chocolate colored loam of Clendenin. On the eastern side of the river it is found occasionally overlying the Grand Gulf and Lafayette, and in places over the Port Hudson. The mantle-like layer of yellow calcareous clay observed on the Five Islands seems to be a development of the yellow loam.

THE ALLUVIUM AND RECENT COASTAL FORMATIONS

Recent coastal formations.—Some of the difficulties experienced in differentiating these deposits and the Port Hudson proper have been discussed under the Port Hudson. The Quaternary coastal formations seem to be in all respects continuous, and it seems quite impossible to use the term Port Hudson in the coastal region without including in it some of the most recent formations. The blue clay stratum with stumps, which Hilgard reports around Petite Anse, and which he refers to the Port Hudson seems to belong to the subsidence now in progress. This conclusion is arrived at by the fact that in the immediate neighborhood of the stumps, and skirting the edge of the present sea-marsh is a cypress swamp. Thomassy describes on the seaward margin of the swamp a number of dead trees which clearly

* Mississippi Rept., 1860, p. 197.

owe their death and present position to a sinking of the land.* As a subsidence is now progressing in this region the relation between the partly live and partly dead cypress trees and the prostrate trunks and stumps in the adjacent marsh seems very clear.

The Alluvium.—In the valley, where a period of erosion has separated the old alluvium from the new, there is some hope of distinguishing between the two. But even here we are confronted by the fact that the local cypress swamp deposits of to-day and the cypress swamp deposits of the Port Hudson period must be very similar. As a result of work in the Yazoo bottoms, Dr. E. A. Smith came to the conclusion that the Port Hudson blue clay was characterized by calcareous concretions which are entirely lacking in the recent deposits.

The thickness of the material which may be unquestionably attributed to the deposits of the river during the present subsidence is very slight. In the Mississippi valley a deposit of over 20 feet of unquestionably recent river formation will rarely be seen, while a deposit of a few feet is most common.† The same thing holds true in the Red river valley.

QUATERNARY PHENOMENA OTHER THAN DEPOSITION AND EROSION

LOCAL CRUSTAL MOVEMENTS

The Five Islands.—The great deposits of sediment along this coast in Quaternary time have doubtless greatly aided other forces in distributing the equilibrium of the crust in this region. After the deposition of the Lafayette gravel and some of the basal Quaternary layers and before the deposition of the yellow loam a series of very peculiar dome-shaped folds and, to all appearances, a large fault were either formed or assumed their present position along the southern coast of Louisiana. These gave rise to those peculiar elevations along the coast known as the Five Islands. On two of these mammillæ-like protuberances, whose surfaces have been greatly ridged by erosion, enough borings have been made to reveal the fact that the underlying

* Geologie Pratique, 1860, pp. 82–83.

† Hilgard,—48 Cong. 1st Sess., House Ex. Doc., vol. 19, 1884, pp. 480–481.

salt mass is in the shape of an elongate dome. On Belle Isle fossiliferous surface beds show the same dip as the surface of the salt and where the apex of the dome was entered by the mine shaft the internal structure and bedding of the salt seems to show that the mass owes its shape not to erosion but folding. On Petite Anse the salt contains certain thin, black, slightly gypseous bands of salt which dip about 80° S. E. From this it is inferred that there is in this vicinity either a fault or a very steep anticline.

The date of the formation of the similar domes of Cretaceous material in northern Louisiana is yet an open question. There seems to be no evidence to prove or disprove that they were formed at the same time as the Five Islands. It is hard to believe that they were formed so recently. The disturbed condition and the dip of the Lower Claiborne beds on the northern part of the Winnfield anticline indicate that a part of the movement at least has occurred in post-Claiborne time.

THE MUD LUMPS

Description.—The peculiar upheavals in the channel and around the mouths of the Mississippi, early forced themselves on the notice of persons interested in the navigation of the river. Parts of the bottom of the river gradually elevate themselves until dome-shaped masses of blue clay project two or three feet above the surface of the water. Openings are formed in the summits of these cones, from which water and mud and gas issue. The mud is deposited about the orifice in successive layers and builds up a miniature, volcanic-like cone. This process continues until the elevation of the cones sometimes reaches ten or even twelve feet. The eruption then entirely ceases or an opening is made at a lower level. The extinct cones are finally destroyed by the waves.

Theories of origin.—Naturally many theories have been proposed to account for the origin of the sepeculiar eruptions but none has yet been advanced which has received the undivided support of scientists. The theories may be enumerated as follows :

1. Gas theory.
2. Superincumbent pressure theory.
3. Suppressed spring theory.
4. Hydraulic tube theory.
5. Tide and current theory.

One of the first theories advanced was that of the gas origin.* This theory attributes to gas the main part in the formation of the mounds. The decomposition of the vegetable and animal matter buried in the delta gives rise to gas. In its attempts to escape this gas will lift the upper clay to the surface of the water and then unable to lift it higher will break through, carrying with it water and fine mud.

The theory advanced by Lyell† and Hilgard‡ is that the weight of the material now being thorwn down at the delta on the fine semi-liquid mud deposited when the river was farther inland will tend to squeeze this fine mud from under the crest of the bar. This material finds vent where the pressure is least, giving rise to mud-lumps.

The other theories depend on water alone as a formative agent. In 1866 Beuregard advanced the following theory of the origin of the mud-lumps: "Now if a tube be supposed to pass from the inside of the bar, where the current is more or less strong, to the outside of it, where there is hardly any current, it is evident that the force of the current will fill this tube with that floating mud lying at the bottom of the river, and cause it to issue at its extremity to a higher or lower level, or not at all, according to the strength of the current acting at that time."§ As this can be proven to be contrary to physical laws it is hardly to be considered.

The suppressed spring theory holds that water originating at a much higher level finds vent here. Forshey supposed that for

* Sidell, Report to Capt. Talcott, 1839, in Humphreys and Abbott's Report on the Hydraulics and Physics of the Mississippi River, Appendix A, 1860; Drake, A Systematic Treatise on the Principal Diseases of the Interior Valley of North America, Con. 1850, pp. 93–94; Long, 35th Cong. 1st Sess., Ex. Doc. No. 139, p. 41; Hopkins, 1st An. Rep. Geol. Surv. La., p. 82, 1870.

† Prin. Geol., 10th ed., 1868, vol. 1, p. 449.

‡ Amer. Jour. Sci., 3d series, vol. 1, 1871, pp. 238–246, 356–368, 425–435.

§ 35th Cong., 1st Sess., House Ex. Doc., No. 97, vol. 12, pp. 6–7, 1866.

some reason the Lafayette sands come to an end near the present delta and that the water which has entered this stratum in the uplands north of New Orleans rise to the surface here.* Thomassy pictures a reservoir situated some where north of the delta but does not specify exactly where. The mud-lumps are also intimately connected with the subterranean channels which he pictures as honey-combing the delta.†

The theory of the tide and current origin was advanced by Montaigu in 1875. He supposed that in the eternal conflict between the river and the ocean currents, great pressure was at times exerted on the beds near the mouth of the Mississippi, which occasionally resulted in the formation of mud-lumps.‡

Of these theories the first seems to be best supported by the facts at hand at present.

DIVISION II—ECONOMIC GEOLOGY

MINERAL RESOURCES

IMPORTANT PRODUCTS

SALT

Drake's salt works.—This locality which is on the East side of Saline bayou in Sec. 21, 13 N., 5 W., seems to have been one of the first sites of salt making in Louisiana. This locality more nearly agrees with the descriptions of the position of the salt pits which Daniel Coxe§ described in 1726, from which the "Natchitock" Indians made salt with which to trade with the neighboring nations, than any other locality we know of.

In 1812, Maj. Amos Stoddard gave the following account of this locality: "The saline in the vicinity of Natchitoches, and on the navigable waters of Red river, promises to be productive. Three wells only have been sunk, they furnish water for thirty kettles, whose contents are six hundred and sixty gallons, and as the water is nearly saturated, these kettles attended by seven

* Am. Assoc. Adv. Sci. Proc., vol. 26, p. 154, 1878.

† Géologie Pratique de la Louisiane, 1860, Chap. VI.

‡ 43d Cong. House Ex. Doc., No. 1, vol. 3, p. 805, 1875; Ann. Rept. Chief of Eng. for 1874.

§ See p. 11.

laborers produce about two hundred and forty barrels of salt per month, at an expense of one hundred and forty dollars."*

To this statement Darby merely adds that the salt works are situated on the land of Mr. Postlethwait on Saline bayou about 25 miles by road from Natchitoches.†

The local demand so increased that in the early forties Mr. Drake attempted to obtain a stronger brine by a deep boring. A well a little over a thousand feet deep was bored in one of the licks and an artesian flow of salt water of from 18 to 20 gallons per minute obtained. The water was weaker in salt and more gypseous than that near the surface.‡

During the civil war, this locality was the scene of great activity. Since the war, the primitive methods employed at these works have been unable to produce salt, which could compete with the cheap salt made in large quantities in other localities by improved methods, and which improved facilities for transportation have put in easy reach of the people.

Rayburn's salt works.—(See Fig. 2, p. 53). Situated in Sec. 31, 15 N., 5 W., at a distance from the early settlements in Red river valley, it was not until 1840 that Mr. Foust commenced making salt at this locality for the immediate neighborhood. The work was continued on a very modest scale, until the breaking out of the Civil war, when the restrictions imposed on the importation of salt by the federal blockade, caused it to have a very greatly enhanced value. The fame of Rayburn's lick spread, and in 1862 men came from far and wide, bringing with them gangs of negroes. Hastily built shelters were put up, the valley was soon dotted with shallow wells from 15 to 20 feet deep, which were protected from the fresh waters of the occasional freshets by low levees. The natural mounds were utilized for furnace sites; and near the center of the valley, where these mounds were not found, artificial ones were made. Large iron sugar-kettles from four to six feet in diameter were mounted on rude foundations made of ferruginous sand-

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* Sketches, Historical and Descriptive of Louisiana by Maj. Amos Stoddard, Phila., 1812, p. 400.

† A Geog. Des. of the State of Louisiana by Wm. Darby, 1816, p. 29.

‡ Hopkins 2d Ann. Rept. Geol. Sur. La., pp. 4–5, 1871.

stone brought from the surrounding hills. Three or four kettles commonly constituted a " furnace." Large boilers were also obtained, split in half, wooden bulkheads inserted in the ends, and mounted on similar foundations of sandstone.

A rent of 2½ bits (37½ cents) per bushel was charged for the privilege of making the salt and for the wood consumed. The receipts by the owner of the land, at this rate, are said to have amounted to $375.00 per day. This would give a daily production of about 1,000 bushels. Each furnace is said to have averaged 30 bushels daily. As there are 66 old furnaces still well defined, at least three-fourths of which must have been in operation when the greatest receipts were realized, this latter estimate is probably a little too high.

Pumps were placed in the wells and platforms built around them so as to elevate the water to a sufficient height to conduct it in troughs to the furnaces. Every seventh day the kettles were "chipped," that is, the layer of limy matter which had formed a coating over the bottom and sides possibly an inch thick, was chipped or broken out.

King's salt works.—The history, the topographical surroundings and the extent of the old King's salt works are almost exactly the same as at Rayburn's. Mr. King commenced making salt for himself in " the forties." His salt well seems to have been about 150 feet deep. In the fall of the year, after the crops had been gathered, the negroes were taken to the salt house and the winter supply was made. Neighbors brought their negroes and availed themselves of the same opportunity. This salt work shared with the other localities a period of intense activity during the war. The lick was covered with shallow wells from 18 to 20 feet deep and rude furnaces of the same type as seen at Rayburn's were built on the edge of the bordering hills.

King's lick is situated on the side of Castor bayou very close to the line between Sec. 34 and 35, 15 N., 8 W. The whole lick occupies about 200 acres. The main lick where the old wells were sunk is a very flat, wet, palmetto meadow and occupies about 40 acres.

Price's salt works.—Price's old salt works are situated on Sec.

25, 13 S., 5 W. They were not visited by the writers. Hilgard, however, reports the brine stronger here than at either Rayburn's or King's.

Bistineau salt works.—We have not been able to obtain any very good description or idea of the works at this locality. They are situated on the shore of Lake Bistineau, just south of the V. S. & P. R. R., and are very often under water. None of the geologists who have written about the State, seem to have visited this locality. [Locality just visited by Veatch, Jan., 1900.]

Sabine parish salt works.—In 1812 Stoddard made the following general statement covering the salines of northern Louisiana: "The country about the Washita and Red rivers, affords many instances of salt, where a sufficient quantity of that article may be obtained to suppy a crowded population. Several salt springs have been discovered about the Sabine; and an excellent one is known to exist near Catahoula lake."* Salt has been made from several of the licks on the Sabine. Hilgard reports salt and "soda" made by Governor Allen in the Sabine flat about two miles below Myrick's ferry, in the northwestern corner of Sabine parish.†

Near Coal bluff on the Sabine, in Sec. 33, 6 N., 13 W., is a small salt flat containing several wells and traces of the old works. The operations here seem to have been on a much smaller scale than the licks farther east.

As stated under the heading, Lower Claiborne, there are numerous saline springs near the mouth of Negreet bayou, which at one time were utilized for the manufacture of salt. The method of obtaining the brine and manufacturing the salt was the primitive one of sinking hollow cypress logs vertically over the saline sources, and then pumping out the contents of the logs and running it into kettles along the banks where it was artificially evaporated. We have no accurate account of the daily product of this lick.

Other salt springs.—The salt springs on Lake Catahoula, mentioned by Stoddard (see this author above), have, so far as we

*Sketches of Louisiana, 1812, pp. 399–400.

†Suppl. and Final Rept. of a Geological Recon. of the State of Louisiana, New Orleans, 1873, p. 22.

know, never been worked. Hopkins, who examined the region in 1871, found numerous weak brine springs issuing from material of Port Hudson age. He was inclined to consider them of very doubtful economic importance. He reported a stratum of salt crystals five-eighth of an inch thick and 18 feet from the surface of the ground in Capt. L. D. Corley's well.*

About two miles southeast of Winnfield is a small lick, known as Cedar lick. Its waters have never been used to any considerable extent for making salt.

Five Islands.—By far the most important salt deposits of the State are on the Five Islands. Salt was made from brine springs on Petite Anse at intervals from 1791 to 1862 when a large deposit of very pure rock salt was discovered. This was mined extensively in 1862 and the early part of '63. Then there came a period of inactivity; but since 1879 when the mines were reopened the output has been very considerable. In the summer of 1895 salt was discovered on Côte Carline but, thus far, no use has been made of it. In December, 1896, salt was discovered on Belle Isle, and in the following summer, on Grand Côte. Companies were organized to mine the salt. At the time of the junior author's visit to the Islands (May, 1899), only the mine of the Avery Rock Salt Mining Company on Petite Anse was producing salt. On Belle Isle, the Gulf Company, and on Grand Côte, Myles and Company, were hastening their shafts toward completion. In addition to mining rock salt the Gulf Company proposes to make a fine grade of table salt by artificial evaporation. For a more complete account of these deposits see special report on the Five Islands.

Conclusions.—The great purity and extent of the rock salt deposits on the Five Islands has been discussed in a special report on the islands, and it only remains to mention the fact again here. The northern salt springs have only paid under the unusual conditions which existed during the war. It is believed, however, that with the opening of railroad communications these springs will again become of value. It is regarded as a very hopeful sign that the Arkansas, Louisiana and Southern Railroad, now building from Minden and Sibley southward,

*Hopkins 3d Annual, p. 178, 1872.

passes within half a mile of King's salt works. All the other licks are at present well removed from railroads. Rayburn's nearest railroad is at Bienville, eight miles away. Drake's, in addition to the railroad which is projected near it, and which it is hoped will be built, has the advantage of water transportation for a part of the year.

It is regretted that we are not able to present in this report views of the salt works and analyses of the brines. Those will appear in a following report.

SULPHUR

Sulphur City, Calcasieu parish.—About 1868 the Louisiana Oil Company was formed to exploit the oil and gas springs in the fresh water swamp at the head of Bayou Choupique, about 15 miles west of Lake Charles. The well which the company sunk was unsuccessful so far as the oil and gas was concerned, but revealed a very extensive deposit of sulphur, at a depth of 443 feet.

In 1869 and '70 numerous borings were made which showed that the sulphur bed had an average thickness of 100 feet, and occupied a position about 425 feet below the surface. The beds of water bearing sands, which overlaid the deposit, rendered the sinking of a shaft quite a difficult undertaking. A company was organized under Gen. Jules Brady. This company succeeded in forcing a large sectioned cast-iron shaft down to a depth of 110 feet, when it was abandoned because of the breaking of the lining.* After this attempt little was done at the sulphur deposits till 1895, when the invention of what is known as the Frasch process by Mr. Herman Frasch of Cleveland, Ohio, caused active work to be resumed at this locality. The process is briefly described by Mr. E. W. Parker, in the Mineral Resources of the United States for 1895, as follows: "The method consists of forcing superheated water through a 10-inch pipe and a 6-inch pipe within the other. The heated water melts the sulphur, which, being the heavier sinks to the bottom, and is pumped out through a 3-inch pipe inside the 6-inch one. The liquefied

* Mineral Resources of the U. S. for 1883-84, p. 864, 1885.

sulphur is drawn off into tanks about 65 feet long by 15 feet wide and 12 inches deep. After twenty-four hours of exposure to the atmosphere (the tanks being on the ground and uncovered) the sulphur solidifies and is broken out in lumps ready for shipment. The sulphur obtained is said to be 99.93 per cent. pure. The pumping was done as in oil wells, with sucker rods and working valve operating an aluminum working-barrel, alumnium not being affected by melted sulphur. All the trouble experienced in the execution of this novel smelting process has been caused by the working valve getting out of order, alumnium valves and zinc valves not being of sufficient strength to withstand the shock which the heavy column of the sulphur would cause at change of stroke." The principle of the "air-lift" pump was applied in 1896 and by this system the Union Sulphur Company was enabled to pump 265 tons of sulphur per day.

Plate 9 shows the melted sulphur pouring into the tank, in the central part of the picture; partly crystallized sulphur in the tank on the right, and on the left men engaged in picking out and wheeling away the finished product.

This process, while entirely successful so far as recovering the sulphur was concerned, did not prove to be entirely so from a financial point of view. As the size of the cavity about the foot of the pipe increased, the amount of heated water required to melt the sulphur became greater and greater and, in time, the size of the cavity became so large that the sulphur could not be economically removed.

The production of the mine in 1895 was about 800 tons, in 1896 about 4,200 tons and in 1897 a little over 1,000 tons. The mines are at present closed and there seems to be no prospect of their reopening in the near future.

CLAYS

General statement.—The clay wealth of Louisiana has been but imperfectly investigated and the attention of the survey will therefore be directed very particularly, during the ensuing year, to this one of our economic products.

Good brick clays are common in the alluvium and yellow loam and are also found in several places in the hill-lands. The clays of the Eocene in this region commonly lack pasticity, though some beds occur which will make a fair quality of earthenware.

At Robeline small earthenware objects have been made from Lignitic clays at Carter's pottery works. (See p. 70, and Dr. Ries' report under Special Reports, Section 3.)

The clays of the Grand Gulf hills seem to be more promising than any others in the State.

Catahoula parish.—In the north central part of this parish are numerous outcrops of a very pure white clay locally called "chalk." Near Spring Ridge church (about Sec. 17, 10 N., 5 E.) the following section was seen:

Section at Spring Ridge Church

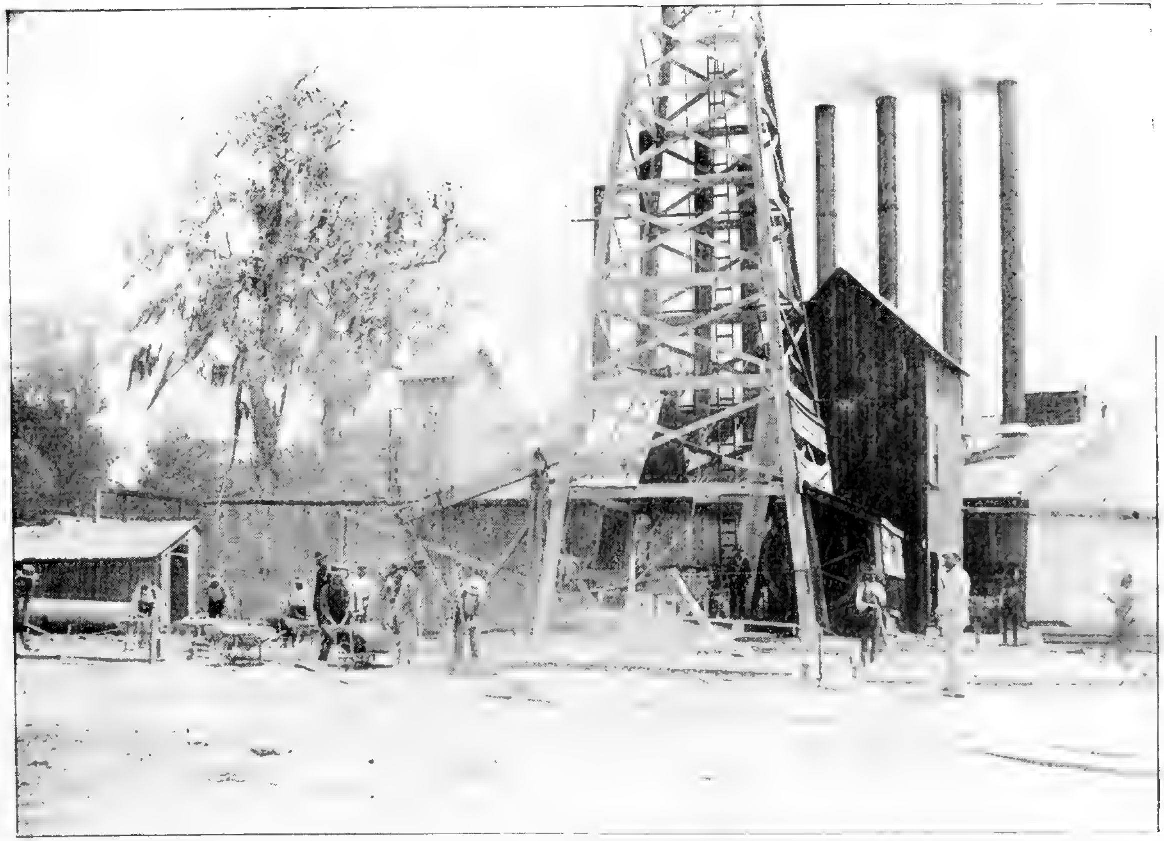
1. Sand to top of hill	20	feet.
2. Sandtone	2	"
3. "Chalk"—a very fine white clay	2–4	"
4. Dark gray clay with a few plant impressions	3	"
5. Sandstone to bed of branch	2	"

Layer 3 outcrops in Sec. 7, 8, 17 and 21, 10 N., 5 E. In the Chalk Hills (about Sec. 7, 10 N., 5 E.) it occupies the tops of hills, and the cost of obtaining it would consequently be small. The section here shown is:

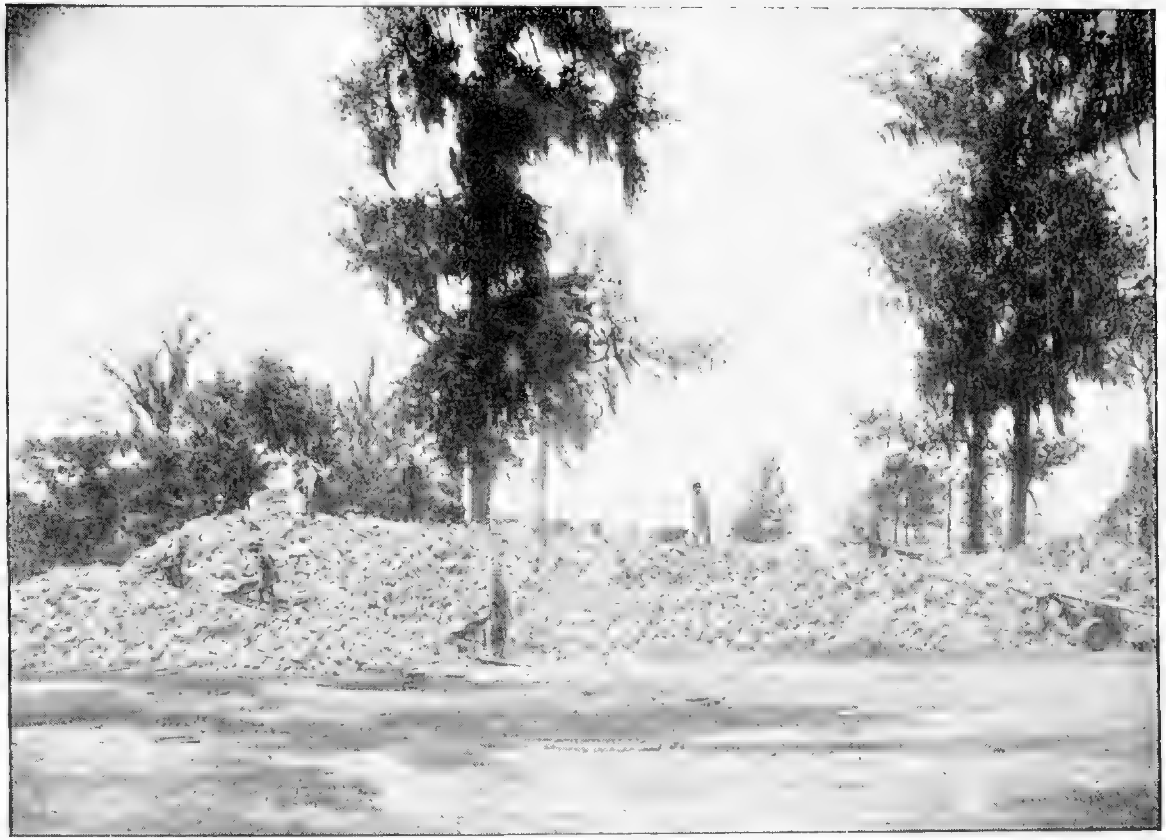
1. Sand	0–6	feet.
2. Soft, friable, fine gray sandstone	1½	"
3. "Chalk"—a fine white clay	8	"
4. Fine sandstone	1	foot.
5. Dark gray or drab indurate clay, with vegetable impressions	10–14	feet.
6. Hillside, no good exposures, covered with large sandstone bowlders, so evidently in place	50	"

A number of samples of this material were collected and left with a gentleman at Rosefield to be forwarded. The material has not yet been received, and we are, therefore, unable to present this year results of tests to determine their exact economic value. Samples of it are, however, reported to have been made into good stoneware at New Orleans.

Johnson reports a similar clay in the Grand Gulf rocks, near Lena, and it is also reported 10 miles southeast of Fort Jessup.



VIEW OF ONE OF THE WORKING HOLES, SULPHUR CITY, LA.



PILE OF SULPHUR, SULPHUR CITY, LA.

Vernon parish.—Attention was called to the large outcrops of Grand Gulf clays in Sec. 17, 3 N., 11 W., by Mr. Ira E. Moore. Samples Nos. 151 and 153 of Dr. Ries' report are from this locality. The bed from which No. 151 was taken is about 10 feet thick and as it is near the top of the hill the cost of obtaining it will not be great.

For tests of clay samples see report, of Dr. Ries.

SANDSTONE

Varieties.—The sandstone deposits of the State are of two classes, viz.: the ferruginous sandstones of the Eocene and Lafayette hills and the silicious sandstones of the Grand Gulf.

The first are of wide distribution and of only slight local importance. They occur over nearly all the hills of northern Louisiana, and sparingly in the hills of the Florida parishes. They are sometimes used for foundations and for chimneys. The foundations of the rude furnaces at Rayburn's salt works were built of this stone.

The silicious sandstones of the Grand Gulf is of greater importance. It is used for rip-rap and jetty work and for railroad ballast. It has been suggested that some of the harder quartzitic varieties might make good building stone but the irregular development of these beds makes it questionable whether large quantities of stones suitable for this purpose could be economically obtained.

Quarries have been opened on Bayou Toro, near the K. C. P. & G. R. R. in southern Sabine parish; near Boyce and Lena on the T. & P. R. R.; and at Harrisonburg.

Bayou Toro.—These quarries, known as Low's quarries, were opened to supply stone for the jetty and canal work about Sabine Pass and Port Arthur, Tex., the southern terminus of the Kansas City, Pittsburg and Gulf railroad. The first quarry was located in the S. W. one-fourth of the N. W. one-fourth of Sec. 28, 5 N., 10 W. Stone was obtained here until the cost of removing the top material became so great that a new site was chosen in Sec. 14. The work was continued there till the same difficulty was again experienced and in February of the present year, a third site was chosen three miles further up the bayou. The mine track, which is now nine miles long, connects with the K. C. P. & G. R. R. at Christie station. In February the company had a force of 60 men at the new quarry and was using 5 derricks and 4 steam drills.

Boyce.—Between Boyce and Lena the Texas and Pacific Railroad company has for several years past been quarrying the Grand Gulf sandstones for railroad ballast.

Harrisonburg.—Small quarries have been opened here to obtain stone for Government crib and dike work along the Ouachita river.

Petite Anse.—In Iron Mine Run on Petite Anse there is exposed a soft pink sandstone which may be of value for railroad ballast. The surface indications, however, seem to show that it is rather soft.

LIMESTONE

Limestone occurs in Louisiana in beds of limited extent, and also in the form of concretions.

Cretaceous limestones.—The beds of limestone seem to be almost entirely confined to the Cretaceous. Of the three outcrops which occur in the State, the Winnfield limestone is of very doubtful value as a building stone, but the Coochie Brake and Bayou Chicot deposit may be utilized for that purpose.

The Winnfield limestone is a highly crystalline blue and white banded stone. It is full of cracks and pockets and other flaws, which will render it useless as an ornamental or building stone. It can doubtless be used to advantage for making lime. The quantity of the stone in sight is large and it can be very economically quarried. Several kilns of lime have already been burned here for local use.

The purity of the stone is shown by the following analysis by W. F. Hillebrand:

*Analysis of Winnfield Limestone**

Insoluble	.65
H_2O	.13
CaO	55.01
MgO	.60
MnO	.10
CO_2	43.43
SO_3	.27

* Bull. U. S. Geol. Surv. No. 60, p. 160, 1890.

The Coochie Brake stone is a light yellow or bluish yellow coarse grained sandy limestome. It is of excellent quality for building purposes, but its value is somewhat impaired by the presence of small nodules of iron pyrites. These will restrict its use to situations where a good external appearance is not one of the qualities required of the stone. The pyrite, if the quantity prove to be large, may destroy its value altogether. The quantity of stone at this locality is large, and it is easily obtained.

The Bayou Chicot stone is the best for building that we have seen in the State. It is a fine grained, dark gray limestone. Only two very small outcrops of it were seen, and from these no very satisfactory ideas of the extent of the deposit could be gained. In the two outcrops the dip is great, and the cost of uncovering the stone would probably be large. Borings are needed to show the extent of this deposit. In the early history of the country lime was made at this place. The ruins of the old lime kilns are to be seen near the larger outcrop.

Tertiary limestone concretions.—The tertiary limestone concretions are often of large size and have been used locally for the foundations of houses. At Shreveport large calcareous concretions are crushed and used on the streets and in concrete work. Hopkins * reports a place five miles from Natchitoches, called the Kilns where large concretions have been burned for lime.

At Rocky Spring Church lime was burned from a little outcrop of Midway limestone for the masonry of Fort Jessup.

GRAVEL

For the location and distribution of the main gravel beds of the State, the reader is referred to the discussion of the Lafayette. Such deposits furnish material for the improvement of the roads and streets, and for railroad ballast. In the Florida parishes these gravels have been used in several places. McGee reports pits near Laurel Hill where the gravel is worked for road material.

Near Colfax the citizens have commenced improving the bad bottom roads with gravel from the hillsides east of the outlet of Lake Iatt.

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* 1st An. Rept., 1870, p. 95. See also the present Rept. under special Report No. I, S. W. cor. of township, p. 144.

At Monroe several of the streets of the city have been graveled from pits on the Traveler's Rest stock farm, three miles north of town on the west bank of Ouachita river. This gravel has also been used in the concrete work of the new bridge over the Ouachita. It is proposed to build a switch to this deposit from the V. S. & P. R. R.

The V. S. & P. railroad passes through a portion of this gravel deposit about three miles west of Monroe, and has removed some of it for ballast along the line. The Iron Mountain railroad has obtained a small quantity of gravel from the deposits in the northern part of the Grand Gulf, in Grant parish. In southern Rapides, according to Clendenin, the Kansas City, Watkins and Gulf railroad has obtained large quantities of gravel for road ballast.

On Belle Isle and Petite Anse the gravel beds have been utilized in making concrete. In southern Louisiana good sands are rarely found. Sands occur on Petite Anse and Grande Côte, in situations where they can be easily dug, and the sand-pits at these two places, especially the former because of its railraad connections, supply a large area of country.

UNIMPORTANT MINERAL PRODUCTS

IRON ORE

The latter part of 1885 and the early part of 1886 were spent by Mr. L. C. Johnson, of the U. S. Geological Survey, in northern Louisiana, in investigating the iron ores of that region. He found siderite and brown hemitite or limonite ores in the form of nodules or concretions and thin plates, occuring in nearly all of the beds of the old Tertiary, and occasionally in the Lafayette sands. These ores are scattered through beds of sands and clays, and it is believed that they can hardly be obtained in sufficient quantities to be of economic value. Selected specimens give very good results when submitted to analysis, as the following tables will show, but the quantity of ores of this quality seems to be quite limited.

ANALYSES OF IRON ORES.*—*By R. B. Riggs.*

	1	2	3	4	5	6	7	8	9
Ignition......	11.06	10.26	10.53	10.62	9.05	9.50	11.25	11.04	18.22
Silicious matt'r	27.85	6.37	21.77	10.97	23.20	28.12	18.72	21.70	39.95
Metallic iron..	39.65	50.32	43.17	52.18	44.54	39.26	45.72	43.76	22.22
Sulphur.......	.03	.10	.26	.03	.09	.03	.17	.03	.17
Manganese....	.126	.079	.01	.026	.006	.049	.007	.005	.157
Phosphorus....	.226	Trace	.382	.064	.859	.447	.247	.835	.072

* Bull. U. S. Geol. Surv. No. 42, 1887, pp. 144–145.

1. Bossier parish, one-half mile west of Bellevue.
2. Dr. Whitlaw's, four miles west of Greenwood, Caddo parish.
3. Simmon's bed, eight miles south of Homer, Claiborne parish.
4. Moreland's, nine miles southeast of Homer, Claiborne parish.
5. Vienna wire road, Lincoln parish.
6. Lincoln Reed's place, nine miles northwest of Vienna.
7. Webster parish, four miles northwest of Shongaloo.
8. Union parish, one and a half miles north of Downsville.
9. Moreland's, ten miles southwest of Arcadia, Bienville parish.

OTHER ANALYSES OF IRON ORES.

	1	2	3	4	5	6	7	8	9
Silicious matt'r	21.40	12.15	11.420						
Metallic iron..	38.35	49.97	43.170	36.517	47.565	52.005	51.94	33.16	35.56
Sulphur.......	.34	.08	.056	T	T				
Phosphorus...	.18	.62	1.650	0.689	0.919	0.727			

1. Miller's bluff, Bossier parish.*
2. Gilmer field, Phelp's lake, Bossier parish.*
3. H. L. Aubery, Claiborne parish.*
4. Location not given.†
5. Location not given.†
6. Location not given.†
7. Farmerville, Union parish.‡
8. Four miles northeast of Calhoun, Sec. 30, 18 N., 2 E.‡
9. Two miles west of Calhoun, Sec. 29, 18 N., 1 E.‡

Col. Samuel H. Lockett,§ of the State University, in his report of the topographical survey for 1870, makes the following statement, which seems to fully cover the case: "Many persons think that this parish (Bossier) will one day acquire great profit from the iron rocks found in such abundance on the hills of the red lands. This is hardly possible until the so much richer and more easily wrought and more accessible ores of iron found in every part of the United States are exhausted. It is true that Bossier and Claiborne and Jackson parishes might supply themselves with iron from their own hillsides, but, until they become completely isolated from the rest of the world, they will do well to seek their supply elsewhere. These iron rocks, though looking extremely rich in iron, are yet so largely composed of sand as to be appropriately named *ferruginous sand rocks*."

LIGNITE

The lignite beds of Louisiana have been known and looked upon as one of the resources of the country from its first settlement. Stoddard, in 1812, in his Sketches of Louisiana, p. 392, says of the Louisiana lignite: "Stone or pit-coal is an article of some importance. It frequently makes its appearance on the Washita, the Sabine, and the Red rivers, particularly on the

* Johnson, Iron Region of Louisiana and Texas, 50th Cong. 1st Ses. House Ex. Doc., vol. 26, p. 195.

† Min. Resources of the U. S. for 1887, p. 51. Analyses by Alfred F Brainerd.

‡ Lerch, Bull. La. Expt. Sta.: Geology and Agriculture, part I., p. 48 Analyses by Maurice F. Bird.

§ 2d Ann. Rept. of the Topog. Surv. of Louisiana for 1870, p. 49, 1871.

borders of a lake in the neighborhood of Natchitoches. This article is of use to smiths even at this time."

With the settlement of the country, beds of lignite were found in many places in the northwestern part of the State and fruitless attempts have from time to time been made to open lignite mines.

The best deposits either underlie the Lower Claiborne or occur in the territory shown on the map as Lignitic. A part of the Lower Claiborne deposits contain beds of lignite, but they are commonly small. Beds of lignite also occur between the Jackson and the Vicksburg stages.

Dolet hills.—The most promising deposits in the State are in the Dolet hills, in DeSoto parish. The reports of these deposits, which have reached us, seem to indicate that a very detailed and careful survey of this region should be made; and a report on it may, therefore, be expected in a future annual of this survey. None of the geologists who have worked on this region seem to have visited the main Dolet hill area. Hilgard skirted the edge of it and reported at Granning's ferry on Bayou Pierre, a bed of good lignite 3 or 4 feet thick. Analyses of the Dolet hills lignite, which have been made for interested parties at Mansfield, have shown that it is of very excellent quality.

Stone coal bluff, Sabine river.—The east bank of the Sabine river near the line between T. 5 and 6 N., shows at low water a platform of lignite about five feet thick and possibly a hundred yards long. The name bluff is a misnomer, for the bank here is little higher than the bottom-lands. Overlying the lignite is about twenty feet of gray sand and clay, evidently alluvial deposits. A barge load of lignite was mined here in the seventies, to be marketed on the lower river, but the barge is reported to have parted in the middle and sunk. Recently, gentlemen from Lake Charles have had a prospect hole drilled on the top of the bank about 200 yards from the river. The yielding nature of the overlying material will make the cost of mining the lignite very great in proportion to the value of the product.

About a mile from the river in the S. W. one-fourth of Sec. 3, 5 N., 13 W., the same bed is seen with a covering of Tertiary clays, which will make a much better roof than the material near the river. But even here the cost of timbering will be very great. (For the section at this point see page 66.)

Analyses of samples of lignite collected at this point have not yet been received, but it is doubted if this bed can ever be of more than local importance and that only after the great amount of good pine wood which covers the country is exhausted.

Many.—A small bed of lignite is exposed in Tar river, near the Sabinetown road, at the ridge known as the Devil's Backbone. (See map Pl. 4.) Specimens of this lignite have been tried by the Many blacksmiths in their forges with only partially satisfactory results. The lignite burns readily but, it is claimed, makes little heat.

Mansfield.—Lerch reports a deposit of lignite three and one-half feet thick nine miles southwest of Mansfield which has been used by local blacksmiths. For an analysis of this lignite see Lerch's second report, p. 128.

Shreveport.—A bed of lignite is exposed in many of the bluffs near Shreveport. At Arsenal hill this bed is about two feet thick. It is of fairly good quality and is reported to have been used as fuel in the Confederate Arsenal at this point.

S. Dana Hayes, State Assayist of Massachusetts, published an analysis of a sample of lignite "from the banks of the Red river about two miles below Shreveport, in Louisiana" in the Chemical News, vol. 30, 1874 page 153. The analysis was as follows:

Analysis of Lignite from Shreveport (by S. Dana Hayes)

Water	15.25
Volatile matter (bituminous)	41.30
Fixed carbon (coke)	37.55
Sulphur	Trace
Ash	5.89
	99.99

Underlying Bellevue is a thin bed of lignite.

Sec. 11, 18 N., 8 W.—This locality is interesting because the lignite is here of sufficiently good quality to have been used as fuel in a steam shovel working on the V. S. & P. R. R. when the railroad was first built through this section.

Outcrops of lignite are reported by Lerch at Cold Springs, six

Lerch First Report, p. 17.

GAS WELL BY NIGHT, THREE MILES WEST OF BREAUX BRIDGE, LA. PAGE 138

miles west of Homer and at several places between Gibbsland and Bienville.

In Catahoula parish, south of Rosefield, a small bed of poor lignite is found at the base of the Vicksburg beds. This locality is called the "coal mine." In Sec. 31, 11 N. 5 E., several pits have been dug in this bed.

LEAD AND ZINC ORES

For a discussion of the lead and zinc ores of the State, see Geology, Belle Isle, in special report on Five Islands.

MARL

The marls which have thus far been examined have been somewhat disappointing. The amount of phosphoric acid is very small and the general character of marls is such as to greatly restrict their use.

Several nodules of iron have been picked up in the vicinity of Homer and Lisbon, which contain nuceli of rich phosphate of lime. The extent of this deposit is still an open question, but it will be unwise to count too much on their value. That the calcareous material from a great many of the fossiliferous outcrops mentioned in this report will be of value in restoring impoverished sandy soils, cannot be questioned.

GYPSUM

Selenite crystals occur in many parts of northern Louisiana, and are especially abundant in the Jackson along the Ouachita river. In no place have they thus far proved of any agricultural value.

At Rayburn's salt works some gypsum is associated with the limestone, but according to analysis made by the stations some years ago the percentage of limestone accompanying it is very large.

The only deposit of any magnitude and purity yet found in the State accompanies the sulphur deposits near Lake Charles. The exploitation of this deposit must await the successful sinking of a shaft at this point.

PETROLEUM AND GAS

Lake Charles.—In 1839 Dr. William M. Carpenter states that "in the low lands bordering on the Calcasieu river there are numerous springs of petroleum."* These were the petroleum springs which finally led to the discovery of sulphur near Lake Charles. One of the wells at the Sulphur mine yields a small quantity of petroleum which, during the sulphur operations, was collected and barreled. A slight amount of gas was also found at this locality.

Belle Isle.—A spring formerly existed at the place now occupied by the saw-mill on Belle Isle, which furnished an oil that was highly esteemed in the neighborhood for its medicinal qualities. Capt. Lucas reported a slight amount of oil in several of the wells bored by him on this island. Inflammable gas was found in holes Nos. 4 and 10. In the latter, at a depth of 120 feet the amount of gas was sufficient to throw sand to the top of the derrick. It is now bubbling from the hole and can be easily collected and ignited.

Breaux Bridge.—About 2¼ miles from Breaux Bridge, in St. Martin's parish, gas is reported escaping from the "Natural Gas Spring" in considerable quantities. The gas is readily ignited and once lit continues to burn indefinitely. Mr. C. S. Babine, C. E., of Breaux Bridge has furnished us with the photograph from which the accompanying plate was made. The two pipes, shown in the plate, were simply pushed a few feet in the ground and the gas escaping from their top ignited. This is the largest flow of gas yet reported in the State. Capt. A. F. Lucas is at present engaged in boring near this locality, and we are watching for the results of his borings with interest.

Shreveport.—Salt water and gas were struck in the ice factory well at Shreveport at a depth of 961 ft. (See discussion of Ice Factory well in Shreveport Area article.) The gas is collected and used for lighting the office at the ice-factory.

Gas is reported from a well about 40 feet deep near Annanias club house, north of Ferry lake, in Sec. 9, 20 N., 16, W. This was from a local bed of vegetable matter, and the flow of gas soon ceased.

Negreet bayou.—A slight flow of gas accompanies the salt springs near the mouth of Bayou Negreet, in Sabine parish. An oil spring is reported in Sec. 16, 9 N. 12 W. So far as we know neither has been used.

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*Am. Jour. Sci., vol. 35, p. 345, 1839.

SECTION III

SPECIAL REPORTS

Including : *

No. 1. THE NATCHITOCHES AREA, by G. D. Harris.

No. 2. THE SHREVEPORT AREA, by A. C. Veatch.

No. 3. THE FIVE ISLANDS, by A. C. Veatch.

No. 4. A REPORT ON LOUISIANA CLAY SAMPLES, by H. Ries.

No. 5. A REPORT ON A COLLECTION OF FOSSIL PLANTS FROM NORTHWESTERN LOUISIANA, by Arthur Hollick.

No. 6. THE CRETACEOUS AND LOWER EOCENE FAUNAS OF LOUISIANA, by G. D. Harris.

No. 7. ESTABLISHMENT OF MERIDIAN LINES, by G. D. Harris.

No. 8 A FEW NOTES ON ROAD MAKING, by G. D. Harris.

No. 9. SOME WOOD-DESTROYING FUNGI, by George F. Atkinson.

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* A detailed table of contents is prefixed to each special report.

Special Report No. 1.

NATCHITOCHES AREA

BY

G. D. HARRIS

CONTENTS

NATCHITOCHES AREA

INTRODUCTION

Here is a classic spot both for the student of American history and American geology. It is geology alone, however, with which we are now concerned.

The detailed description of this area has been made such on account of the prevalence of general culture and the location here of the State Normal School of northern Louisiana.

As a preface to our remarks it may be said that geology is a subject learned mainly from a study of the Earth, not simply from a study of books. The latter, like a good teacher, may guide and stimulate, but cannot take the place of personal research on the part of the student. With this summary of the geology of Township 9 North and Range 7 West in hand, the earnest teacher and student of geology will quickly extend observations of similar character to adjoining townhips, and will soon be the means of causing the whole parish to be carefully mapped topographically and geologically. Great good will come of such local studies, both to the individual carrying on the work and to the community at large.

TOPOGRAPHY

HILL LANDS

West of Old river.—The southwest portion of this township rises up gradually going northward from the low-lands of Lake Jericho, here and there showing small abrupt slopes in the immediate vicinities of the larger streams, but in general, low and undulating. Between Texas road and the Lake, however, high ridges are prevalent, separated by V-shaped hills or ravines which bifurcate again and again on the flanks of the hills or ridges. To see this interesting type of topography, go over the "Dam" and cross Mill bayou and follow the trail indicated on the map to the westward.

Some outliers.—Hickory hill, and the triangular area west—southwest of Chapin's lake, are the only two elevated outliers left in this portion of the township east of Old river.

Natchitoches.—The abrupt topography which crosses the south central portion of this town is due to the considerable elevation which the general land surface has above the ordinary level of Cane river. This means that the little branches and creek which drain this portion of the corporation have highly inclined channels. This in turn means a large amount of wear, or erosion, continually undermining their various banks. Hence the maintenance of the abrupt topography.

North of the town, the steep escarpment or bluff is maintained by the continual undermining or wearing away of its base by the waters of Cane river.

It will be observed, by the map, that the curve of the river is such as to cause it to impinge upon its western bank with force at this place.

North of the Lake and west of Messi swamp.—North of the Lake, the land slopes gradually upward with no important steep declivities till after the first highway is passed. Strongly contrasting with this topography is the rugged, broken surface which appears on every hand along the Camp Salubrity road from the Iron springs northward.

Faithful to old customs the road winds along on the summits of ridges, securing at once fine drainage and fine views.

Between Camp Salubrity and the railroad there is a high elevation as shown on the map. The minor details, the many steep slopes of 10 to 20 feet, the many small ridges and V-shaped valleys, can of course not be duly represented on a map of this character. The old Lac à Poisson shown on the government survey plats, no longer exists in ordinary stages of water. It is represented by a clear stream which meanders to and fro across the old lake basin, fed by the many clear, cool springs that issue from near the bases of these hills.

The road and railway to Grand Ecore avail themselves of the gentler sloping uplands between Lac à Poisson and Messi swamp to avoid the wetness of the lowlands and the steep grades of the other highlands.

Sharp and abrupt is the slope from this last mentioned upland to the level of Messi swamp. Here is the western limit of the broad stretch of bottomland that reaches eastward to beyond the

Saline. Here is an old bluff, formed by the erosive agency of Red river many hundred years ago; but it has since been deserted by the river and the land where Messi swamp is now found was formed in the concave angle of the old river, and the latter has been continually pushed eastward and eastward.

LOW LANDS

Messi swamp.—This shows most beautifully the typical topography of the alluvial plains of Louisiana's rivers. *i. e.*, high and dry along the banks, low and wet a short distance back.

As soon as land increases somewhat in value, this so-called swamp will be drained and will disappear entirely from maps.

East of Cane river.—The same feature of elevated banks and lower grounds some distance in the rear as noted above are likewise well exhibited in this region.

The various bayous in the northeastern portion of this area once (prior to 1849) served to conduct the surplus water of the then Red river (now Cane river) from its channel to other channels farther eastward. But since the desertion of Cane channel by Red river these bayous have become functionless and their mouths have been stopped by levees or road embankments.

The observant student of nature will not fail to note the entire lack of streams entering Cane river from Natchitoches to the southeast corner of the township.

South of Chapin's lake and Cane river.—Chapin's lake is a portion of the "Old river" channel cut off from the rest by two artificial dams. It is a clear body of water, fed by springs, and using bayou Bulikano for the most part, for its overflow waters.

Old river is fed by the numerous springs about Sibley's lake or, more directly by Mill bayou.

Bayou Julien and other small channels are used principally or almost solely for flood-time waters.

The general adherence of the roads to the banks of the streams means here as elsewhere that the higher, better-drained stretches of land are in close proximity to water channels.

It is scarcely necessary perhaps to add that stream banks are more elevated than the back land, simply because in time of overflows the greater amount of sedimentation takes place not far from the river banks and hence tends in the course of a long period of time to elevate the strips of land immediately bordering the streams.

STRATIGRAPHY

EOCENE

That the reader may have a better conception of the stratigraphy of this township, an ideal section has been placed beneath the map, showing the way the various series of deposits lie along a line passing east and west through Natchitoches from the points W to E, as indicated on the map.

Beneath the whole region, at a depth of probably not over 800 or 1,000 feet, lie Cretaceous deposits. Some account of local outcrops of this series has already been given on p. 52., *et seq.*

Lignitic stage.—The oldest visible beds in this section are the lignitic sands and clays, appearing for the most part in the northwestern portion of the township though occurring elsewhere, as for example, in a branch or creek near the southwest corner of the township by the roadside. Here lignitic and ferruginous sands are to be seen in the south bank of the creek. But particularly abundant are the light yellowish calcerous concretions of various shapes and sizes. So abundant are they that they have been burned for lime.

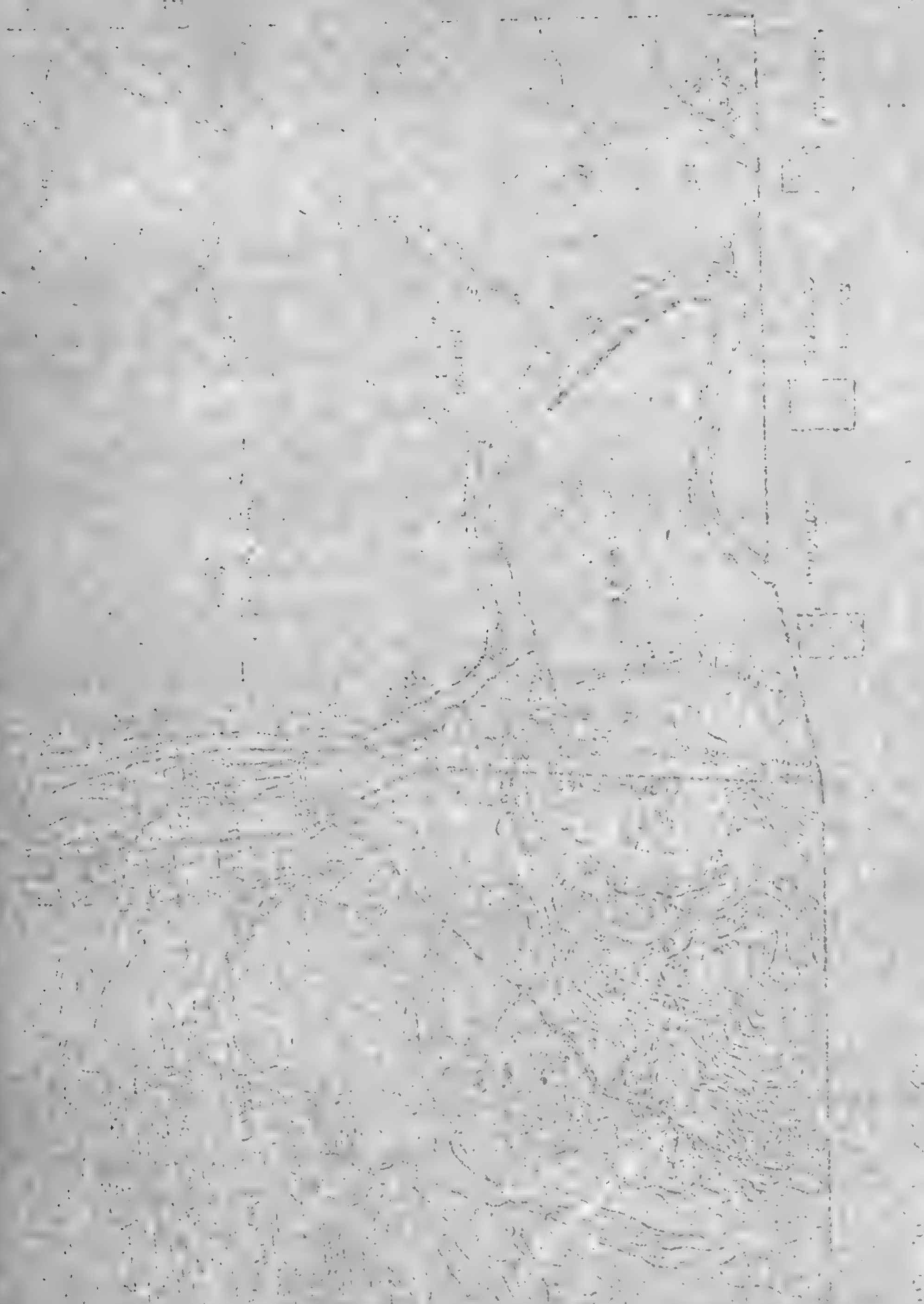
Probably all the sands and clays forming the hills west of Mill bayou are of this age. The same remark applies to hilly lands west of the railroad and north of Sibley's lake.

Three-fourths of a mile north of Natchitoches bridge the bluff as shown on Pl. 13, exhibits at base 20–25 feet of purplish clay with sand parting, all dipping southward.

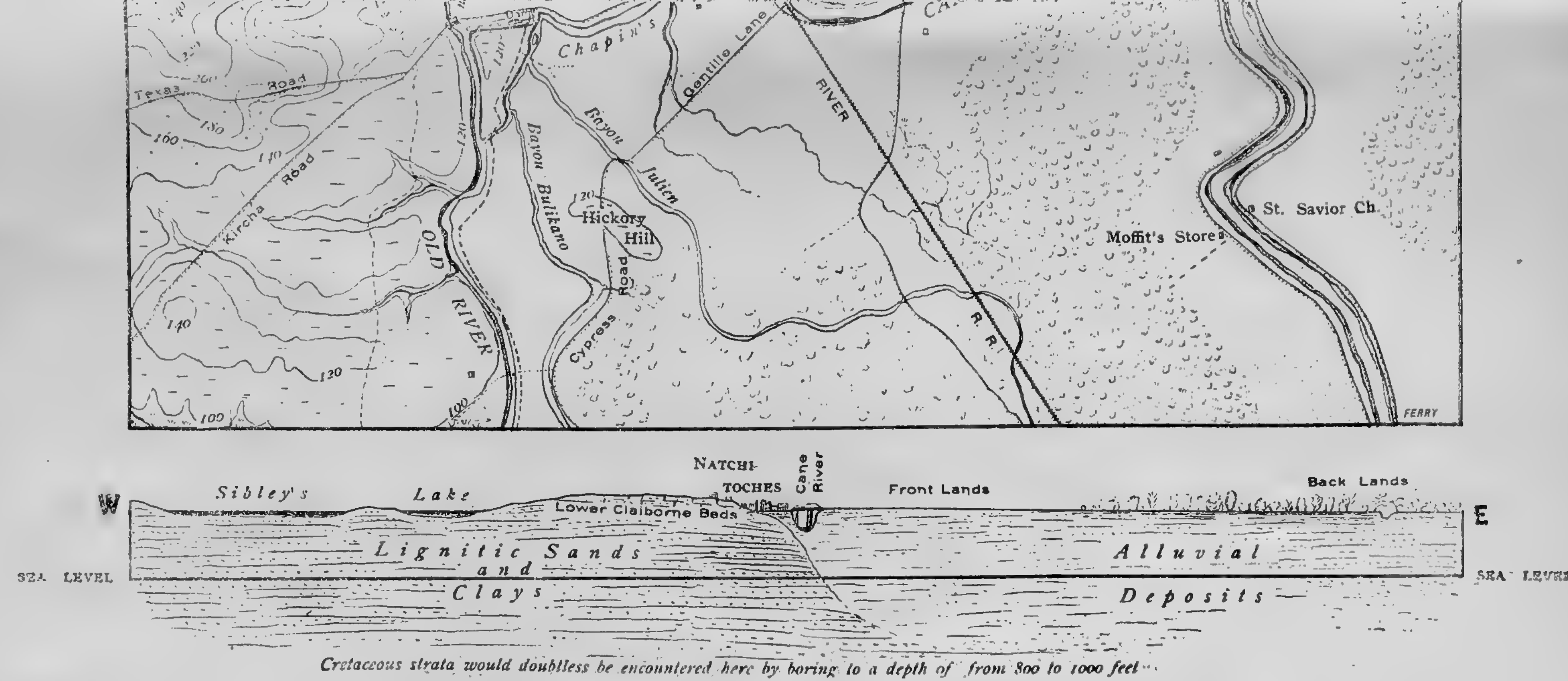
Slightly farther to the right, in a little ravine, a bed of light-colored, compact sand is exposed, showing at least a thickness of 15 feet. This bed is for the most part covered by the talus at the base of the bluff shown in the illustration.

It is however, at Grand Ecore, a place on Red river, a few miles north of Natchitoches that the Lignitic beds are best exposed. A section of the same has already been given on p. 71.

In the depths of little ravines in the northwestern part of this

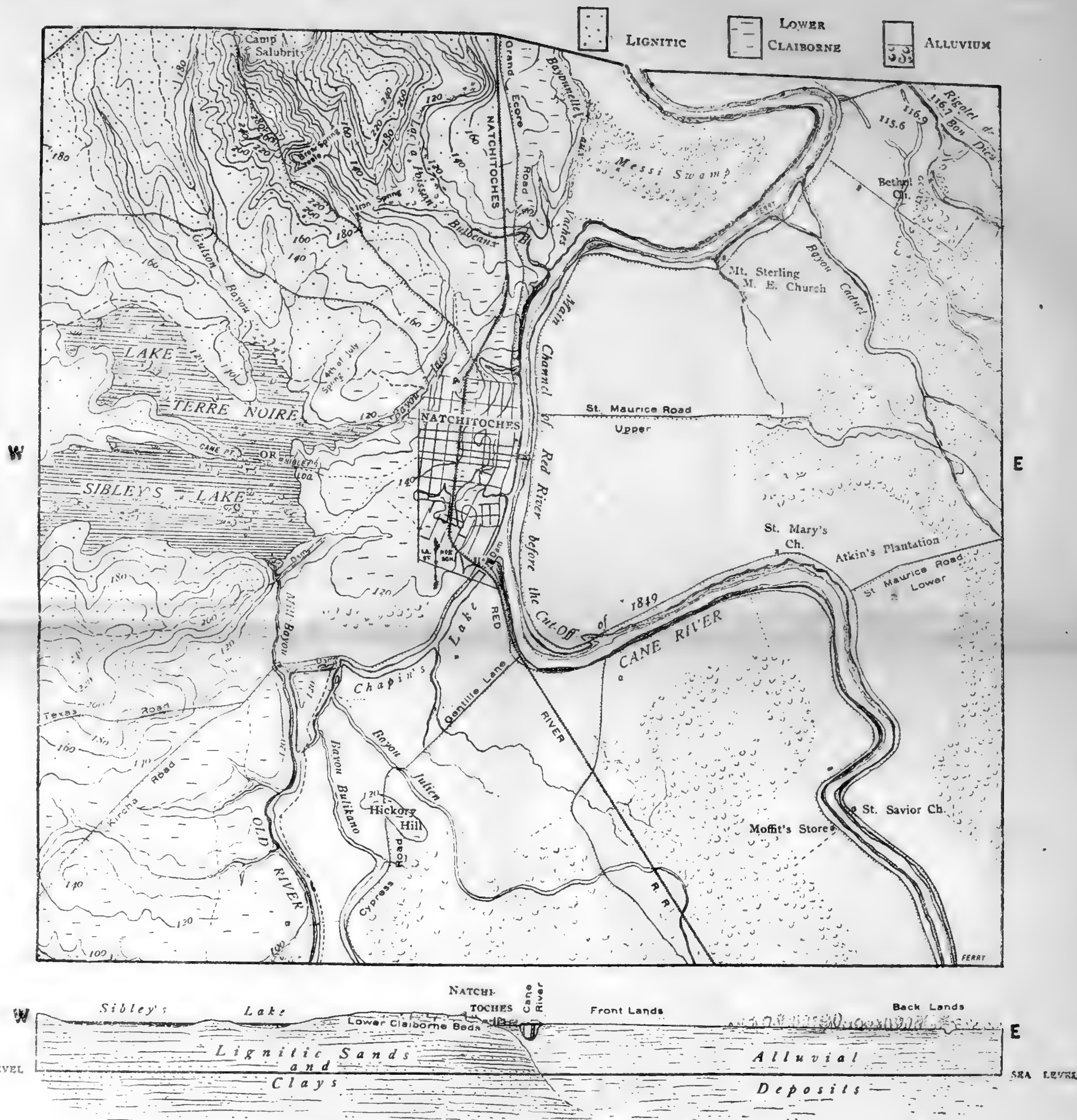



Lignitic
Lower Claiborne
Alluvium
W
E
Camp Salubrity
NATCHITOCHES
Grand Ecore Road
Bayounelle
Messi Swamp
Vaches
Main Channel of Red River before the
St. Maurice Road
Upper
Lac a Poisson
Iron Spring
Bulbeaux
Gutson Bayou
LAKE TERRE NOIRE
CANE R. OR SIBLEYS LOR
SIBLEYS LAKE
NATCHITOCHES
Rigolet
116.7
116.9
115.5
St. Mat
180
160
140
120
200
220
240
260
280



Sketch of Natchitoches Township

NOTE.—The general outlines of this map are based on the Land Office Surveys. The topography, geology, roads, and all minor details have been worked out in the field by the author of this article. No spirit level lines have been run. Heights have been determined mainly by barometic readings; distances, by pacing and checking up from known points; directions have been determined by a 4-inch compass. The map is intended to be sufficiently accurate for geological purposes and to show the general topographic and cultural features. For the plat of Natchitoches and valuable suggestions we are indebted to Harry Percy, of Natchitoches. The figures refer to elevation in feet above mean Gulf level.



Cretaceous strata would doubtless be encountered here by boring to a depth of from 800 to 1000 feet.

Sketch of Natchitoches Township

NOTE.—The general outlines of this map are based on the Land Office Surveys. The topography, geology, roads, and all minor details have been worked out in the field by the author of this article. No spirit level lines have been run. Heights have been determined mainly by barometic readings; distances, by pacing and checking up from known points; directions have been determined by a 4-inch compass. The map is intended to be sufficiently accurate for geological purposes and to show the general topographic and cultural features. For the plat of Natchitoches and valuable suggestions we are indebted to Harry Percy, of Natchitoches. The figures refer to elevation in feet above mean Gulf level.

BLUFF ON CANE RIVER ¾ MILE NORTH OF NATCHITOCHES, LA.

township, sands and clays of this stage are often exposed in the immediate vicinities of springs and rivulets.

Limestone boulders are abundant in the ravine west of Camp Salubrity. They are like those on the Kircha road in the S. W. portion of the township.

This is most decidedly a region of springs. They are cool and of a good quality of water, though often chalybeate. These various attributes are due to the stratigraphy and topography of the region. The uplands are very sandy, occasionally ferruginous. They absorb large amount of rain water. This leaches through the sandy layers until it strikes impervious clays and then is forced laterally by hydrostatic pressure and gravity to the surface.

The good character of the spring waters of this region is proof of the absence of any considerable marly material here in this series.

Lower Claiborne.—The town of Natchitoches is located on deposits of this age as is shown by the section at the base of the Natchitoches township map. The bluff three-fourths mile north of this bridge shows (see Pl. 13), above the Lignitic series, beds of about 50 feet in thickness, of yellow marly, or calcareous clay above, in the field; and glauconitic, fossiliferous sands from the brink of the bluff down to the Lignitic clays.

A description of the various marine fossils that occur in this vicinity will be given in our next report; this report, it will be remembered, gives the paleontology of the Cretaceous, Midway, and the Lignitic deposits. Next year the Lower Claiborne, Jackson and Vicksburg fossils will be similarly treated.

The attention of the reader is called to the way in which the shells in these marl beds decompose, and how their calcareous substance afterwards collects concretion-wise into white, irregular, lime nodules. In the cuts on the railroad just north of the corporation these nodules are very abundant.

Potable well water or spring water from deposits of this character is quite out of the question. By boring through these Lower Claiborne beds into the Lignitic clays there seems to be no reason why the pure water that supplies the springs in the Lignitic areas should not occasionally be encountered and utilized to great advantage.

Bad water would doubtless be met with if the drill penetrated to the underlying Cretaceous strata.

West of Old river and south of Texas road the surface material is mainly Lower Claiborne. This could be told, if by no other means, by the frightfully bad road bed from the forks of the Texas and Kircha roads for over a mile southwest along the latter road. But on the slopes on either side of the little branch which crosses the road just south of the word "Kircha" on the map there are thin ledges of limestone replete with *Ostrea falciformis* and a small discoid foraminifer. These are characteristic Lower Claiborne species.

Why the road is better for perhaps one-half mile south of this branch is because the Lower Claiborne marls are overlaid by porous sandy layers, into which the water can sink and drain off into side channels.

Hickory hill appears to be a Lower Claiborne island separated from the other deposits of this stage by the alluvial tract between Bayou Bulikano and Old river.

QUATERNARY

After the Eocene deposits just described had been laid down on the bottom of the sea, they were raised considerably higher above sea-level than they are to-day. This accelerated erosion, and the result was that the whole eastern half of this township was degraded, doubtless to present sea level or even below. This action went on until the land was once more depressed, and then the refilling of this deeply eroded area commenced. The section at the bottom of the map shows this old valley filled up to its present appearance by Quaternary sand and clay.

The low-lands about Mill bayou, and in fact Sibley's lake bottom, consist of Quaternary sands and clays that have likewise refilled an old post-Eocene valley.

SOILS

QUATERNARY

Front lands.—The fine reddish loams of Quaternary deposits along the borders of the larger streams in this township are rich and very productive. Corn and cotton are the staple products on these lands at present and very satisfactory are the results.

Back lands.—Passing along each lane or path that leads directly back from the large stream channels one observes that the soil becomes heavier, darker, and, when wet, very sticky. It is no longer cultivated, but allowed to become wooded with gum, hackberry, locust, sycamore, water oak, intertwined with bamboo and greenbrier. In the lower places a few scattering cypress are seen.

Even these lands are far above the normal level of the streams and by a comparatively small expense could be well drained.

Eocene

Calcareous soil.—Most of that portion of the township west of Old river and south of Texas road as indicated in the map shows a decided calcareous or limy soil. Occasionally the calcareous matter is overlaid by a few feet of sand. The same remarks apply to the uplands in the few square miles included between bayou Bulbeaux and Chapin's lake. Some of the best marly layers from the streets in Natchitoches are now in the hands of the chemists of the Experiment stations for analysis.

Light sandy soil.—By far the greater portion of the soil in the northwestern portion of this township is decidedly sandy. Several samples have already been collected for analysis. Short-leaf pine, oaks, hickory, dogwood, etc., abound on the ridges; magnolia, holley, etc., in the valleys.

As is usual with soils of this character they produce well for a few seasons after clearing but after a few years fail, unless properly cared for, to yield profitable returns for the labor expended on them. Many old cotton-rowed fields are overgrown now by forest trees of considerable dimensions. Especially is this the case in the northwestern-most part of the township.

Springs

Well-Known Springs

Fourth of July spring.—This is on a neighborhood road leading out from Natchitoches north of Sibley's lake. See map. It supplies an abundance of good water. Its name is derived from the fact that on hot mid-summer days its cool waters are sought by the many from Natchitoches.

Iron springs.—For location, see map, two thirds way from Natchitoches to Camp Salubrity. About five different sources of water are here found in a few yards square. The waters of each rise in sunken barrels or sections of large tile. They proceed from light Lignitic sand beds, and issue at a level of perhaps 25 feet above that of "Lac à Poisson." Their waters are chalybeate.

These springs are pleasantly located in a little ravine in the woods. Pine, oak (red, white), beech, black gum and maple are the commoner trees.

Chemical Analysis by Maurice Bird, B.S.

	(Parts per 100,000 of water)
" Silica	6.4
Iron and aluminum oxides	.8
Lime (CaO)	1 2
Magnesia	.93
Sulphuric acid (SO_3)	2.26
Potash	.6
Soda	3.0
Chlorine	1.9 "

"Water is colorless, but contains a little brown suspended matter; it is neutral to litmus paper and practically tasteless."

Breazeale spring.—This spring is still farther towards Camp Salubrity.

It is situated in a steep ravine 85 feet below the Breazeale summer house. It is large, stoned up with lignitic ferruginous sandstone.

Analysis according to Mr. Bird

	(Parts per 100,000 of water)
" Silica	5.5
Iron and aluminum oxides	.4
Lime (CaO)	.9
Magnesia	.57
Sulphuric acid (SO_3)	2.06
Potash	.4
Soda	2.2
Chlorine	1.74 "

"Water is clear and colorless, neutral to litmus paper and practically tasteless."*

* The Survey is under obligations to Prof. U. P. Breazeale of Natchitoches for obtaining and transmitting these waters to the Experiment Station at Calhoun.

Special Report No. 2.

THE SHREVEPORT AREA

BY

ARTHUR C. VEATCH

CONTENTS

Physiography of The Bottoms

Waterfalls and Rapids

Origin of Bottom Lakes

Notes on The Geology of The Hill-Lands

The Upland Flats

The Old Tertiary

Appendix

THE SHREVEPORT AREA

Introduction

The field work on which the present incomplete report is based was done in the latter part of November and December, 1898. The work was largely the preparation of a soil map of the bottoms; and as it has now been decided to turn over all soil work to a division devoted exclusively to that subject it has seemed best to publish the information collected.

Thanks are due to many Red river planters for their kindness and courtesy.

The valley region above Shreveport is possibly unique in the respect that changes, which usually occupy great periods of time, and whose full story can only be learned by deduction, have taken place here within a few years. Lakes have been formed and destroyed; stream beds formed and abandoned; waterfalls produced to destroy themselves; new streams formed out of parts of the beds of old ones; and temporary reversals of the drainage systems have been effected.

Present Topography and Drainage

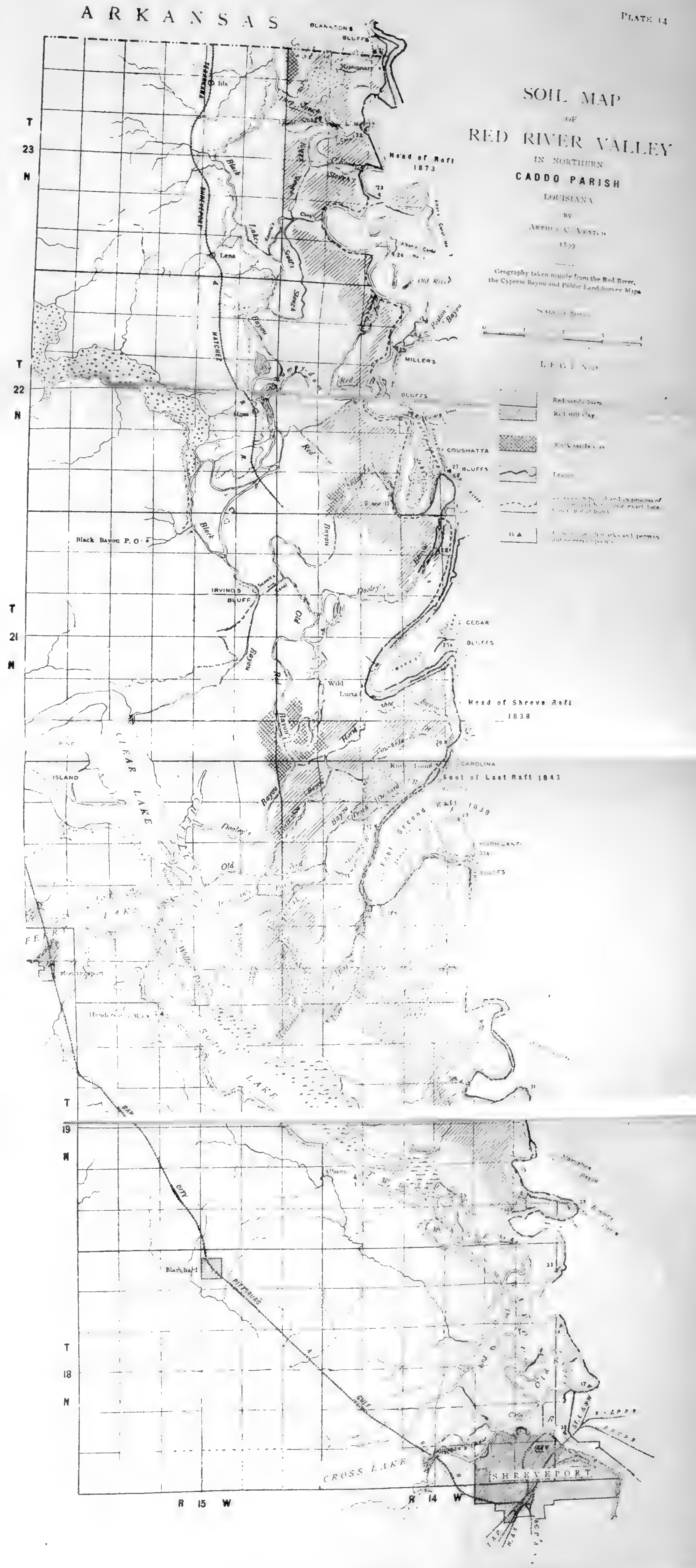
Red River

Location of area.—The main region under discussion is an irregular area lying in the Red river valley between Shreveport and the line between Louisiana and Arkansas. Red river valley in this region is from four and a half to eight miles wide.

Slope from the river.—As in other alluvial flood plains the greatest elevation is along the present banks of the river. From this line the plain slopes both ways to the bounding hills. The amount of this slope varies in different parts of the plain. The levels run by Lieut. E. A. Woodruff, U. S. Eng., in 1871–72, as plotted on a map in the archives of the War Department, show the following slopes:


SOIL MAP
OF
RED RIVER VALLEY
IN NORTHERN
CADDO PARISH
LOUISIANA
ARTHUR C. VEATCH
SCALE OF MIL
LEGEND
ARKANSAS
BLANKTON'S BLUFFS
Missionary
Head of Raft 1873
TEXARKANA
SHREVEPORT
NATCHEZ
Ida
Lena
Black
Lake
Scott's Slough
Bayou
Old River
Albon's Canal No. 1
MILLERS
T
23
N
T


T
18
N
R 15 W
R 14 W
Albany
Blanchard
CITY
PITTSBURG
GULF
CROSS LAKE.
SHREVEPORT
Starvation Bayou
Benoit's Bayou
The
Pass
Old River
Cross
Bayou
V. S. & P. R. R.
R. R. V. P. R.
ST. L. & S.W.
T. & P.
H. & S.
K. C. P. & G.


ARKANSAS
SOIL MAP
OF
RED RIVER VALLEY
IN NORTHERN
CADDO PARISH
LOUISIANA
BY
Arthur C. Veatch
1899
Geography taken mainly from the Red River, the Cypress Bayou and Public Land Survey Maps
Head of Raft 1873
Head of Shreve Raft 1838
Foot of Last Raft 1843
BLANTONS BLUFFS
MILLERS
BLUFFS
COUSHATTA
BLUFFS
CEDAR
BLUFFS
CAROLINA
Ida
Lena
Black Bayou P. O.
IRVINGS BLUFF
CLEAR LAKE
CROSS LAKE
ISLAND
Blanchard
SHREVEPORT
T 23 N
T 22 N
T 21 N
T 19 N
T 18 N
R 15 W
R 14 W

SLOPES OF LAND FROM RIVER BANK TO BORDERING HILLS

Between	Distance	Slope in feet	Slope per mile
Inlet to Red bayou and Black lake bayou..........	2.8	1.3	.46
Inlet to Irishman's bayou and mouth of Dooley's bayou on Shift-Tail lake..........	4.5	11.0	2.44
Inlet to Cottonwood bayou and mouth of Irishman's bayou..........	4.0	11.0	2.75
Inlet to Cottonwood bayou and Head of the Passes	5.0	11.0	2.20
Gold Point Bend to Albany..........	3.0	6.3	2.10
Pandora Bend to Twelve Mile bayou..........	.5	2.8	5.60

While the above table gives the average slope it gives no idea of the slope curve, it is much greater near the river bank and less near the distant hills. The slope for the first thousand feet from the river is generally at the rate of about 30 feet, although it is sometimes over 100 feet, to the mile.

Width of the channel.—The variation in the width of the channel of Red river, and its size in proportion to its tributaries from Shreveport to the State line must be a source of considerable surprise to a person not familiar with the history of the river.

The charts of the Red River Survey of 1886 gives the following stream widths in the vicinity of Shreveport:

Lower Red river..........	6–700 feet
Cross Lake bayou..........	400 "
Twelve Mile bayou..........	230 "
Upper Red river..........	225 "

From the mouth of Twelve mile bayou to the head of the old raft, with the exception of a stretch of 13 miles between Hervey's canal and Dooley's bayou, the river is very narrow, ranging from 130 to 250 feet in width. Above the head of the old raft it widens, reaching a width of 400 feet at the State line.

River bottom-basins—The river after striking the western hills at Blankton's Bluffs, near the State line, meanders diagonally across the valley to Miller's bluffs. It makes a series of great loops along the bluffs on the east side and again strikes the western hills just below Shreveport. The land on the west side of the river has the shape of a great basin; the hills forming the rim of the basin on three sides, and the elevated river ridge on the other. The outlet of such a basin must necessarily be at its lower end, just above the place where the river again strikes the bordering hills. Such bottom-basins are common in all alluvial plains. In Red river valley below Shreveport is the basin of Bayou Pierre, extending from Shreveport to Grande Ecore and having its outlet just above the lower bluff. Above Shreveport is the basin of Poston's bayou having its lower limit at Miller's bluffs. In the Mississippi valley, probably the best example, is the Yazoo bottom extending from Memphis to Vicksburg.

Slope of the river.—Varying as it does in different stages and dependent as it is on many factors the slope of the river between Shreveport and the State line can hardly be stated exactly. Of the three methods of determining the average slope by a comparison of high water records, bank levels and by simultaneous observations on the water surface, the first two are to be preferred.

The average fall in the banks from Missionary to Shreveport is .57 feet per mile. The high water slopes* vary from .41 in the flood of 1855 to .60 in the flood of 1879. The slope of the flood of 1892, .55 feet or 6½ inches per mile, probably represents about the mean.

SMALLER STREAMS OF THE VALLEY†

Nearly all the streams formerly leading out of Red river have now been closed by levee improvements. Their position is however well marked by old channels, now mere rain-water drains. The streams in the back-lands, not receiving their usual compliment of Red river waters, have shrunk to a mere fraction of their former size. The intricate network of bayous and

* Tables of high water marks on Red river. Capt. J. H. Willard. Annual Report Chief of Eng., for 1893, vol. 2.

† The nomenclature of these streams is hopelessly confused. I have endeavored, in describing the different bayous to give the names which have appeared for these bayous in different works and maps and to retain the old name if it is not greatly in variance from the common name of to-day.

canals makes a description of the drainage somewhat difficult and a reference to the map (Plate 16) will probably aid greatly in understanding their peculiarities.

Black bayou.—Entering the State near its extreme northwestern corner, Black bayou flows southeast through a cypress brake and enters the river valley a little above Irving's bluff. At Irving's bluff it turns southwest, along the line of bordering hills, and empties into the old bed of Clear lake. Just below the entrance of Sewell's canal the bayou has a depth of from 35 to 45 feet.

Black lake bayou.—Just above Irving's bluff Black bayou receives a tributary from the north. This bayou has had a number of names; from the Arkansas line to a point opposite the inlet to Red bayou at Miller's bluffs it has been called Kelley's bayou, Peace's bayou and Black Lake bayou. At this point an old channel turns eastward and connects with Red bayou. This old channel has received, in addition to the above mentioned names, the name Stumpy-dam bayou. This channel now carries very little water, the main body continuing southward through a new channel known as Hackedy or Haggarty's slough.

Red and Old Red bayous.—A reference to the map of the bottoms in 1839 will show a bayou leaving Red river opposite the lower part of Miller's bluffs and running southward through the middle of the valley. Sewell's canal, an artificial channel, connects this bayou with Black bayou at Irving's bluff. The effect of cutting this channel was to discharge practically all the water of Red bayou into Black bayou. Hence that part of the bayou above Sewell's canal alone retains the name Red bayou; that below is known as Old Red bayou. Old Red bayou finally turns westward and enters Cheftel's lake. Red bayou has an old well developed channel.

Elmer's bayou.—Elmer's * or New bayou after a short westward course from Elmer's Landing or Roswell P. O. empties into Red bayou.

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* It seems probable that Long's New bayou mentioned in Senate Doc. No. 64, pp. 5, 27th Cong. 1st Sess., vol. 1, 1841, refers to Elmer's bayou.

*Dooley's bayou.**—Just below the old Elmer's bayou outlet and about opposite Coushatta bluffs is the head of Dooley's bayou. It is a young channel much divided by islands and in several places crossed by beds of hard resisting clay which, just above the channel of Old Red bayou and a little below the ancient Dooley's lake, has formed a little water-fall. The bayou appropriates about a mile of the Old Red bayou channel, reverses the ancient flow of a portion of it and, leaving it, continues its course southwest into Cheftel's lake.

Cow-hide and Horseshoe bayous.—The old outlet to these bayous is just above Carolina bluffs. A short distance from the river the two channels separates. Horseshoe describes a course to the northward almost as far as Wild Lucia and finally reaches Old Red bayou at a point almost due west of its source. It follows the channel of Old Red bayou for half a mile and then turns southwest and empties into Dooley's bayou and Old Red bayou near Cheftel's lake. Cowhide bayou enters Old Red bayou about a mile below Horseshoe.

Peach Orchard bayou.—Another common name for this bayou is Shift-tail bayou, which seems to be a corruption of Cheftel's bayou. On the early land office maps it is called Coshatta Chute. It is the next old outlet below Cow-hide bayou and after a short course southwest it joins Old Red bayou.

Sterling and Irishman's bayous.—Following the course of the river the next bayou to start westward is Sterling bayou. After a course of about two miles it changes its name to Irishman's bayou. It follows a course about parallel to Old Red bayou and empties near the foot of Cheftel's lake.

Cottonwood bayou.—The first considerable old outlet channel on the west bank above Shreveport is Cottonwood bayou. It left the river just above Hurricane bluffs and empties into Sodo lake above Albany.

Trinity bayou.—Connecting Cottonwood and Irishman's bayous and in the general line of Old Red bayou, this has also been called Red bayou.

Twelve Mile bayou.—In ordinary stages of water this is the most considerable tributary stream which Red river receives in

* Spelt Dooky's and Dooly's on the early Land office township sheets.

the region under discussion. It is the outlet of the Cypress bayou and Black bayou drainage systems as well as all the back-lands between Shreveport and the State line. Before the closing of the outlet bayous in upper Red river the discharge of this channel was greater than the river proper. It has also been called Caddo and Sodo bayou. It formerly emptied into Red river a little over two miles above Shreveport but by a cut off of the main river its mouth has now advanced to within a mile of the city.

Cross bayou.—The outlet of Cross lake, in its upper part called Bowman's Chute, empties into Red river at Shreveport. Its normal drainage area is small, being a very limited region about Cross lake. In flood times it receives a very large amount of water from the upper valley through "The Pass." It has thus been able to discharge at times, and indeed under the old raft régimé normally, more water than either Twelve Mile bayou or Upper Red river.

Old outlets on the east bank.—On the east side there are several old outlet channels below Hurricane bluffs. The principal ones are: Benoit's bayou, Starvation or William's bayou and Willow Chute.

Poston's bayou.—The spelling of this name has varied quite a little. Originally Poston's, it became Posten and Postern. It drains the back land above Miller's bluffs.

ARTIFICIAL CHANNELS

During the raft period navigation between upper and lower Red river was possible only by devious channels through the bayous and lakes of the back-land. In an attempt to improve these channels and to render navigation possible a number of artificial cuts were made. These were greatly enlarged by the water flowing through them.

Sewell's canal.—The earliest and probably the most important of these artificial channels was Sewell's canal. This was cut in 1839 by Lieut. Sewell, U. S. A., from Black bayou near Irving's bluff to Red bayou and diverted the waters of the later bayou to Black bayou.

Hervey's canal.—When the raft closed the mouth of Red bayou a canal was cut about 1859 by Col. C. M. Hervey from the river four miles above the Red bayou outlet into what was then Simpson's lake.

Other canals.—As the raft advanced other canals were cut: on the west side—Kountz's canal and Sale and Murphy's canal; on the east side, Alban's three canals.

LAKES

Cross lake.—About a mile west of Shreveport is the foot of what is left of old Cross lake. It is extremely irregular and is now possibly seven or eight miles long.

It was formed by the filling of an old flat-bottomed stream valley with water. This is the reason for its very irregular shape. On a small scale, a similar result is obtained when an artificial dam is thrown across a little valley to form a pond; water fills the space behind the dam and extends itself not only up the main valley but a little way into each side valley. An examination of the map, Plate 16, will show old Cross lake to have the shape of this type; the main lake occupies the main stream valley and in the place of each little side stream there is a little sharp re-entrant bay.

As seen in last December the Bowman's chute outlet exhibited a rather peculiar phenomena. The head of the bayou shows a complete delta (see map and plate 15) and the water instead o flowing from the delta was flowing toward it. That is, there is here a delta with the current reversed.

Sodo lake.—Whatever the origin and meaning of this name its spelling has undergone several changes in the present century; originally Sheodo,* Sodor,† or Soder‡ it bacame Sodo or Soda. It has also, with Ferry lake, been called Caddo lake, after the Caddo Indians. The lake now occupies a narrow strip along the base of the hills, four or five miles long and half a mile wide.

*Bowman, 25th Cong. 2d Sess. Senate Doc., vol. 1, No. 1, p. 353, 1838.

†Map of T. 19 N., R. 15 W., La. Meridian. Land office maps.

‡Map of Red river, by Capt. H. M. Shreve, 23 Cong. 1st Sess., House Ex. Doc., vol. 3, No. 98, p. 13, 1834.

Ferry lake.—Connected with Sodo lake by Big Willow pass is Ferry or Fairy lake. It differs from Sodo in having hills on both sides ;. being exactly the same type as Cross lake, a lake occupying an old stream valley. Ferry lake is quite shallow with a narrow line of deeper water winding irregularly through it. This lake is rendered particularly interesting by the large number of cypress and oak stumps standing upright in it, even in the deepest water.

Near the Texas line a large valley partially filled with water enters Ferry lake from the north. This long arm of the lake is known as Coushatta Jim's bayou or as simply James bayou.

Clear lake.—Just north of Big Willow pass and connected with the lower end of Ferry lake by stumpy bayou is the bed of the most peculiarly shaped lake in the bottoms. It is kite-shaped with the larger end toward the north. The larger end is almost entirely occupied by a triangular elevated island called Pine island, which seems to be the same as the adjacent upland flats. As seen early in December the lake bed showed a mass of cockle-burs, a few cypress trees and a narrow band of water in the central portions about 200 yards wide.

Cheftel's lake.—The common name Shift-tail seems to be a corruption of Cheftel. It is a very narrow, shallow lake lying east of the lower end of Clear lake.

Smaller lakes.—The river after reaching the eastern hills at Miller's bluffs makes three great loops along their coral margins. Several small bottom-basins are thus formed. The southernmost of these formed by the loop between Carolina and Hurricane bluffs is occupied by Adjer's lake.

In the next bend are two small lakes, remnants of a much larger one, both of which retain the name of the original one, Mark's lake.

Dutch John's lake in the bend between Coushatta and Miller's bluffs, in ordinary water-stages consists of three parts. These are the remnants of the larger Dutch John's lake of the raft period. Silver lake occupies an old stream valley between Cedar and Coushatta bluffs. In the outlet of Silver lake is a little waterfall about ten feet high.

THE GREAT RAFT

ORIGIN AND ORIGINAL EXTENT

Original extent.—There seems to be little doubt that the raft once extended far below the place where Shreve commenced work on the 11th of April, 1833. The early Spanish and French accounts speak of the raft beginning near Natchitoches. Dr. Joseph Paxton in a very able letter (*l. c.*) written in 1828 says:* "The time is yet within the memory of some of the oldest inhabitants in and near Natchitoches, when the lower end of the raft was still below that place; and the Governor ordered out the troops in command, to break down and cause to float off, all the parts then below."

Dr. John Sibley, writing from personal observation, in 1805, says: "At the upper house (of this Campti settlement) the great raft or jam of timber begins. This raft chokes the main channel for upwards of one hundred miles by the course of the river; not one entire jam from the beginning to the end of it, but only at points with places of several leagues that are clear."†

Between Natchitoches and the mouth of Red river trunks of trees growing only on upper Red river, such as cedar and bois d' arc, have been seen in the banks in several places. These, in themselves, do not prove that the raft once extended this far down the river, since local masses of drift-wood might have accumulated before the raft period; but in the light of the recorded recession of the raft from Natchitoches and Campti to Loggy bayou it would seem quite reasonable to look upon them as indicating the former prolongation of the foot of the raft well down toward the mouth of the river.

It is possible that the rapids at Alexandria were formed by the choking of the original channel by raft and the consequent enforced passage of the river over a low outlying spur of the Grand Gulf rocks.

Origin of the Raft.—Before the clearing of the banks of Red river for cultivation the amount of timber caving into the river

* 20th Cong. 2d Sess., Senate Doc. vol. 1, No. 78, p. 5, 1829.

† Chief of Eng. Report for 1873, p. 640; also, 43d Cong. 1st Sess., House Ex. Doc. No. 1, vol. 2, part 2, p. 640, 1873.

after each flood must have been very considerable. Trees thus thrown into the river catch on the bars ; are exposed to the sun and thoroughly dried, the branches are broken off ; and after a time, in a high flood, they find their way into the Mississippi and finally into the sea. If at any time the amount of timber brought down should be unusually large it may become jammed in a short narrow bend, or accumulate about a series of snags or "planters" and start a "raft."

Dr. Paxton describes at certain stages of high water in the Mississippi an eddy near the mouth of Red river which ascends or descends according to the difference between the stages of the two rivers. Timber floating down the river would tend to collect in this eddy, and, as Paxton suggests, it is possible for the conditions to be such that this mass of timber should become jammed in the river.

Whether this be the true explanation or not, it is certain that the narrowness, crookedness and, before any improvements were made, the great number of "planters" in Red river would in themselves be quite sufficient to produce a log-jam. A jam once solidly formed collects all other material floating down the river. Some of the logs become soaked with water and gradually sink to the bottom or are forced there by the weight of other logs and the small spaces between the logs are soon filled with leaves and silt.

Formation of Outlet Bayous.—The level of the water above is raised by this obstruction and the river continues to rise until it flows over its banks. More water will flow over the lower places and there, aided by the great velocity given it by the great slope between the front and back lands, will soon erode a very considerable channel. This channel will then become for the time the main river channel.

This water goes to the extreme edge of the valley and follows the edge of the hills till it enters the river again at the lower end of the bottom-basin it happens to have entered.

GROWTH AND DECAY OF THE RAFT

Manner of growth.—Between the head of the raft and the outlet bayou will be a space of water with little or no current, and timber floating down the river will stop at the upper end of this slack water or will be drawn toward the narrow outlet channel. The timber will soon obstruct this channel and the raft thus started will extend across and up the river. This raft will become more and more compact with the accumulation of other timber, as well as silt and leaves, another outlet will be made above and the process repeated until the river is obstructed for many miles.

It will be seen that the great resultant raft is not a single prolonged raft, as has been supposed by those who have not studied the river, but a series of larger and smaller rafts with open spaces between. The timber portion of the raft occupied from a third to a half of the whole space.*

Rate of advance of the head of the raft.—In this manner the head of the raft moves up stream at a rate varying (1) directly with the amount of timber brought down; (2) with the amount of space left between the parts of the raft; and (3) inversely with the width and depth of the river. For a short space of time the growth may even be negative. Thus: if a raft, formed above an inter-raft space, happens to give way during very high water, when water is flowing over the raft below, it will be carried down till stopped by the lower raft. Thus the head of the raft will actually move down stream. This is, however, but a temporary interruption.

The greatest annual raft accumulation recorded is five miles. In a letter dated Jan. 16, 1836, Capt. Shreve says: "Raft has accumulated five miles since last May. Unusually high freshets having brought down three times the usual amount of material."† The same thing occurred again in April, 1879, when a single freshet formed a jam whose aggregate length was five miles.‡ These two instances are, however, very much above the average rate of formation.

The average movement of the raft up stream from 1820 to 1872 was a trifle over four-fifths of a mile per annum; as shown by the records of the U. S. Engineers who made examinations

* 23d Cong., 1st Sess., House Ex. Doc. No. 98, vol. 3, p. 9.

† 24th Cong., 1st Sess., Senate Doc., vol. 3, No. 197, p. 2, 1836.

‡ 46th Cong., 2d Sess., House Ex. Doc. No. 1, vol. 2, part 2, p. 95, 1879. Also, Annual Rept. Chief of Eng. for 1879, vol. 2, p. 952.

of the river. The following table gives the accumulation in the different periods:

From 1820 to 1838.........	16	miles (Lieut. Col. Long*).
1839 to 1857.........	14	miles (Lieut. Col. Long†).
1857 to 1872.........	13.5	miles (Lieut. Woodruff‡).

Of this space only from a third to a half was occupied by timber.

Formation of lakes.—As the head of the raft moves up the valley it will obstruct the outlets of the bottom basins and tributary stream valleys and by preventing the discharge of the streams convert them into lakes. The size of these lakes will be further increased in two ways: (1) the checking of the river current in the raft region will result in the deposition of great amounts of sediment. This will build up the bed and banks of the river and so increase the height of the dam at the mouth of the lake; (2) as the raft continues its movement up stream outlet bayous will be formed and a porton of the river current deflected into these lakes.

Retreat of the foot of the raft.—For a number of years after its formation and until enough logs decay in the lower end to allow the remaining logs to be floated off in high water the foot of the raft will remain stationary. The rate of retreat will be even more irregular than the advance of the head of the raft because a snag or two of very resisting wood may be able to keep back a large amount of decayed raft for many years and even after their decay several years may elapse before a sufficiently large flood will occur to occasion enough current at the foot of the raft to float the fragments away.

The information bearing on the rate of decay of the foot of the raft is not so full or satisfactory as that bearing on the rate of advance of the head. According to the letter of Dr. John Sibley, quoted above, in 1805 the foot of the raft was at the Campti settlement. At the beginning of Shreve's work in 1833 the foot was just above Loggy bayou, a distance of about 59 miles by the charts of the Red River Survey. This would give an average annual rate of decay of about $2\frac{1}{9}$ miles.

* 27th Cong., 1st Sess., Senate Ex. Doc., vol. 1, No. 64, p. 10, 1841.

† 35th Cong., 2d Sess., Senate Ex. Doc., vol. 3, p. 1053, 1859.

‡ 43d Cong., 1st Sess., House Ex. Doc., vol. 2, part 2, p. 648.

Assuming 60 or 70 years for the time since the oldest inhabitants at Natchitoches saw the raft at that place, Paxton concludes that the rate of retreat was about equal to the advance, that is, about a mile a year.*

It seems probable that the rate of retreat between 1805 and 1833 was abnormally great. If it be the true rate of retreat the original raft 160 miles long would have destroyed itself in less than 62 years. This is manifestly an impossibility.

Growth of vegetation on the surface of the raft.—The decay of the logs and the accumulation of silt on the surface of the raft will afford a place for the growth of plants. In summer the weeds, vines, small cottonwoods and willows which spring up on the surface of the raft may entirely cover the raft with foliage; giving to the raft a false appearance of solidity.

In speaking of the surface of the raft Lieut. Woodruff says:† "No trees grow upon floating raft except a few small cottonwoods and willows which have taken root in some decaying log; but the whole surface of all the rafts, except the newest formation, is covered in summer with a dense growth of weeds, vines and small willows. It must not be supposed, however, that the surface of the most compact raft affords at ordinary stages secure footing."

EARLY ATTEMPTS AT REMOVING THE RAFT

Period: 1829–1830.—In the beginning of this century when the attention of the government was first turned to internal improvements, the continued efforts of the congressmen from the State of Louisiana and the Territory of Arkansas, as well as the difficulties experienced in transporting supplies to Fort Townson, caused the government to undertake the improvement of Red river.

The first appropriation, $25,000, made May 23, 1828, was almost entirely consumed before 1833 in preliminary examinations and in making the passage around ths raft safer. No attempt was made to remove the raft.

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* 20th Cong., 2d Sess. Senate Doc., vol. 1, No. 78, 1829.

† Report. Chief of Eng. for 1873, also 43 Cong. 1st Sess., House Ex. Doc., vol. 2, part 2, p. 642, 1873.

The steamboat route around the raft is given in a letter* written in 1825 by George Izard as passing through parts of the following lakes and bayous: "Coshattee Shute," "Lake Bistino," Swan lake, "Badcaw" bayou and lake, Bee bayou, Mud lake, Stump-lake and Willow bayou.

Shreve's work: 1833–1838.—When Shreve commenced the work of removing the raft the foot was a little above Loggy bayou† and the head near Hurricane bluffs.

The first year the work progressed very rapidly in the decayed portions of the raft, 71 miles of river being cleared.‡ As the more solid portions of the raft were reached the removal progressed much slower. The amount of raft removed the fourth year of the work (1837) was only 12¾ miles.§

On March 7, 1838 Shreve reached the head of the raft, which was then midway between Cowhide bayou and Cedar bluffs,|| and the first steamboat passed through.

Period: 1839–1871.—In July, 1838, almost immediately after the close of Shreve's work, a new raft 2,300 feet long formed three miles below the head of the old raft, very near the Sterling bayou outlet** and as this was not removed every freshet added to it.

It was then that the Red bayou route around the raft was first utilized. Colonel Sewell of the U. S. Army in 1839†† finding the river blocked left the river just above Shreveport and passing through Twelve Mile bayou, Sodo lake, Stumpy bayou, Clear lake and Black bayou reached Irving's (then McNeil's) bluff. Here he cut a canal into Red bayou and passing through Red bayou entered the river again opposite Miller's bluffs. This

* 19th Cong. 2d Sess., House Report, vol. 2, No. 96, pp. 4–5, 1827.

† See "Rough Sketch of that part of Red river in which the Great raft is situated, and the Bayous, Lakes, Swamps, etc. belonging to or in its vicinity." By Capt. Henry M. Shreve, 23d Cong., 1st Sess., House Ex. Doc., vol. 3, No. 98, 1834.

‡ 23d Cong. 1st Sess., House Ex. Doc., vol. 3, No. 98, p. 10, 1834.

§ 25th Cong. 2d Sess., Senate Doc., vol. 1, No. 1, p. 351.

|| Long, 27th Cong. 1st Sess., Sen. Doc., vol. 1, No. 64, p. 9.

** 26th Cong., 1st Sess. Sen. Doc., vol. 1, No. 1, pp. 205–209, 1840. Also 26th Cong., 1st Sess., House Ex. Doc., vol. 1, No. 2, pp. 205–209.

†† Collins, 43d Cong., 1st Sess., House Ex. Doc., vol. 2, part 2, p. 658, 1874.

route was destined to be the main steamboat passage for the next thirty years.

The raft of 1838, which had its origin near Sterling bayou was partially if not altogether removed by Capt. Thomas Williamson in 1841–2–3.

In the latter part of 1843 a new raft formed at Carolina bluffs, midway between Peach Orchard and Cow-hide bayous, and at the time of the Fuller survey in 1854 had prolonged itself a distance of 13 miles to a point 2 miles above the head of Dooley's bayou. Fuller in 1856 removed the portion above the head of Dooley's bayou and the following year undertook the improvement of Dooley's bayou; hoping to form a steamboat route around the raft through Dooley's bayou, Cheftel's lake, Stumpy bayou, Big Willow pass, Sodo lake and Twelve Mile bayou.

The large accumulations of drift in 1856–7 filled the bend below Elmer's bayou. To avoid this, Fuller cut two canals into Dutch John's lake, which are known as Fuller's Inlet and Outlet. The early formation of the raft above the Inlet very soon effectually stopped this route. Capt. C. M. Hervey says, in a letter to Lieut. Woodruff in 1872, that no steamboat ever succeeded in passing through the Dooley's bayou route.

In 1859 the raft reached and blocked the mouth of Red bayou; thus closing the only practiceable route between upper and lower Red river. The first of the upper canals, Hervey's canal, was then cut. When this was closed other canals were cut higher up the river. affording very dangerous temporary routes around the raft.

FINAL REMOVAL OF THE RAFT

Woodruff's work.—On December 1, 1872* Lieut. E. A. Woodruff, U. S. A., commenced the removal of the raft which originated at Carolina Bluffs in 1843. The work was made much easier than early work by the use of nitro-glycerin; and the work progressed so much more rapidly that the head of the raft, which was about three-quarters of a mile above O'Roukes' slough, was reached in November 1873.†

* 43d Cong, 1st Sess., House Ex. Doc., vol. 2, part 2, p. 64, 1874; also An. Rept. Chief of Eng., for 1874.

† 43d Cong. 2d Sess., House Ex. Doc., vol. 3, p. 702, 1874.

Present work: 1873–1899.—Although the raft was removed the conditions for raft formation were everywhere present along the river for 60 miles. The channel was very narrow and filled with silt, snags and fragments of the old raft; the amount of water passing along the main channel was only a portion of the whole discharge of the river, the balance passing out the numerous enlarged outlet channels. Log jams immediately formed only to be broken up by the government boats. Now, after 25 years work, by removing all the snags and by closing the outlet bayous thus forcing all the water to flow in the main channel, the river has so enlarged itself that it is capable of carrying its timber with only the possibility of forming jams.

EFFECTS OF THE RAFT

CHANGES DUE TO THE FORMATION OF THE RAFT

Condition of upper Caddo bottoms before the formation of the raft.—The great changes which have taken place in Caddo bottoms in recent times are due (1) to the formation of the raft, (2) to its removal. The condition of the bottoms before the formation of the raft can be approximated quite closely. Red river occupied very nearly its present position. The banks of the river were probably on an average from 5 to 10 feet lower than they are to-day. It is doubtful whether the river has even now finished cutting out the sediment deposited in the main channel of the river during the raft period and hence it may be that the river has not yet reached its former base level.

A sluggish stream, the ancestor of Black lake and Red bayous entered the northern Caddo bottom basin at the present state line and made its devious way through the middle of the bottoms. At what time connection was established between this bayou and the river no man can tell. It may be that the bayou occupies parts of old channels left by the river in its journey across the bottoms and has been connected with the river since the beginning of the present period. The shape of Red bayou for its first mile and a half from the river is however peculiar and it may be that, in the constant changing of the great bends of the river, one has approached the bayou channel very closely and during some period of high water a channel was cut between the two. Shortly after this time the river cut across the narrow neck of the great bend, leaving a great half-moon shaped connection with the old bayou.

A second stream, occupying a fairly deep cypress-fringed channel in the middle of a level bottom similar to those which accompany all streams of even moderate size over all northern Louisiana,* entered the river bottoms above Irving's bluff. It followed somewhat closely the western hills; passed through the eastern part of what is now Clear lake and at the lower end of what is now Stumpy bayou emptied into a large bayou coming from the west.

This large stream was the ancestor of Cypress and Twelve Mile bayous. It was a fairly rapid cypress-fringed stream with a slope of possibly a foot to the mile. It meandered through a fairly level valley covered with over-cup oak and a few scattering pine trees and after its entrance to the river valley, where it received the waters of the ancient Black bayou, it meandered through the river bottoms, now near, now bending far out from the Albany line of hills. Somewhere near Albany it probably received the waters of the old Black lake and Red bayou drainage system. From there its course to the river was along the line of the present Twelve Mile bayou.

At Shreveport another little creek valley with its crooked little stream opened into the river valley.

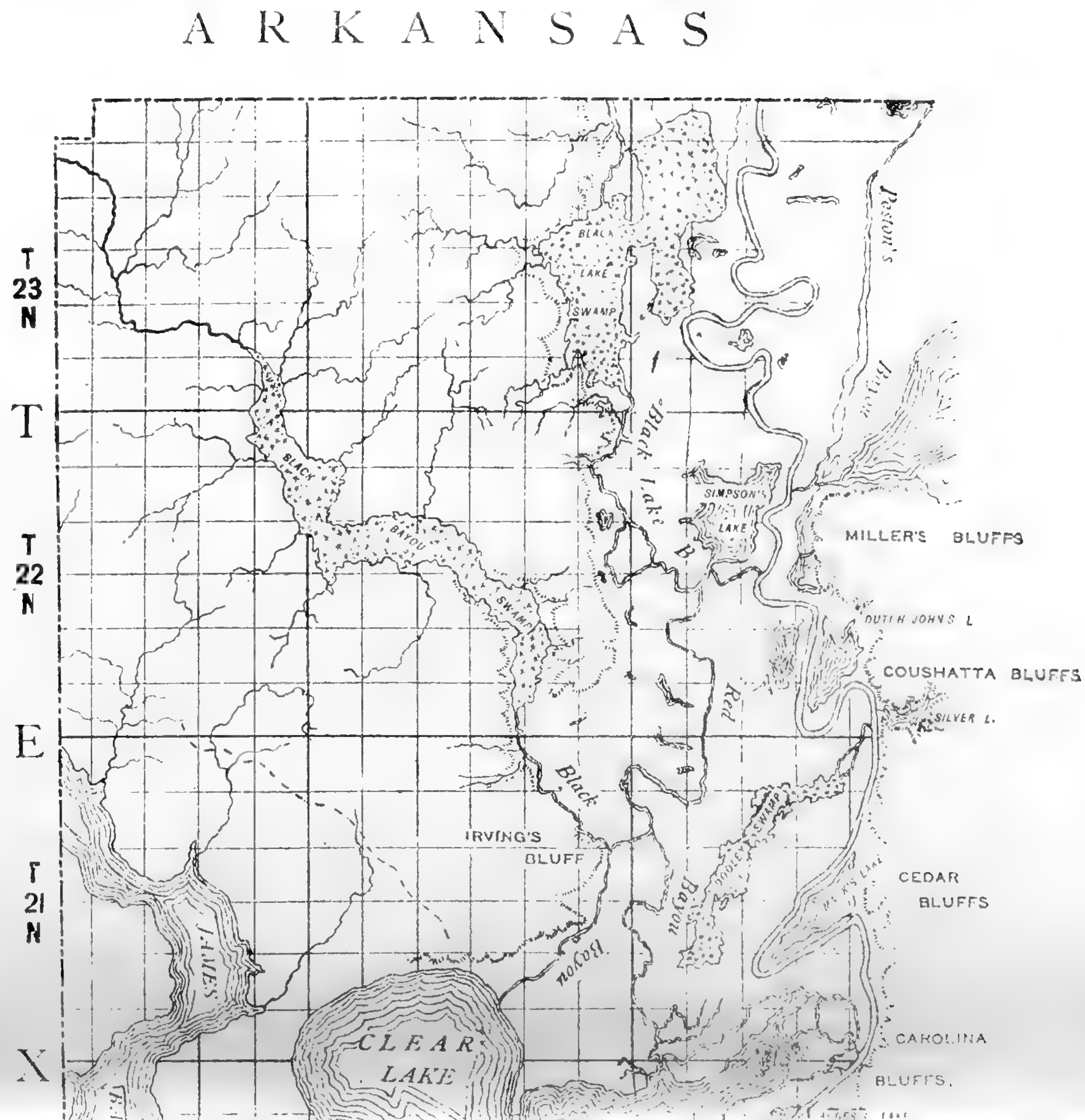
The formation of Cross, Caddo and Ferry lakes.—When the raft in its progress up the river approached the mouth of the little creek which drained Cross lake valley, the water was backed up into the valley. As the distance between the mouth of the little stream and the raft diminished the level of the water in the valley was raised and when the raft reached the mouth of the creek the water in the valley reached a level equal to the banks of the river.

When the mouth of Twelve Mile bayou was reached the lower part of the Shreveport-Blankton's bluffs bottom-basin was filled with water forming Sodo lake. The water was also backed up into the Ferry lake valley.

The flooding of Ferry lake valley killed all the trees. After

* For a discussion of similar creek bottoms see article on page 68.

DELTA, FOOT OF CROSS LAKE, NEAR SHREVEPORT


ARKANSAS
T 23 N
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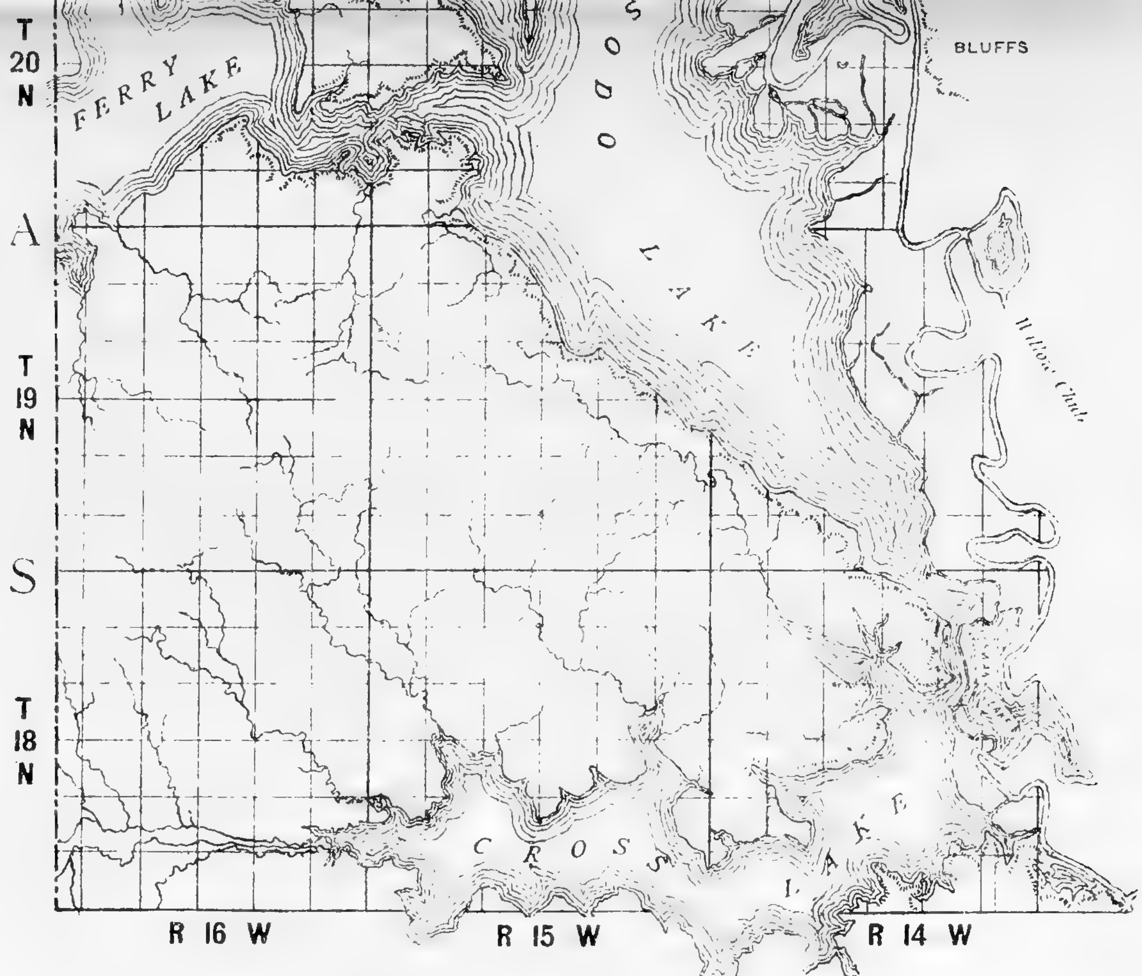
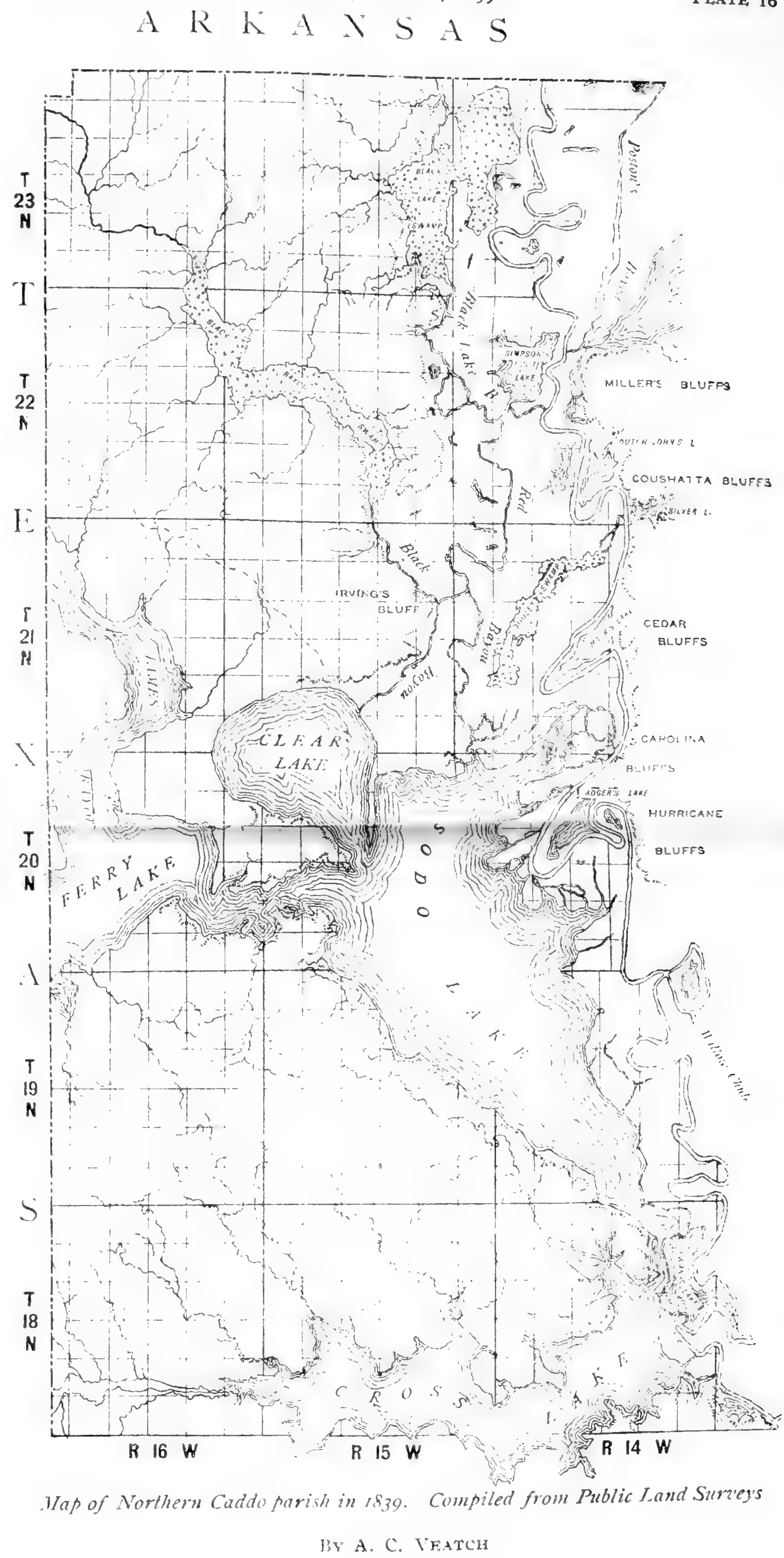
T 21 N
TEX
Poston's Bayou
Black Lake Swamp
Black Lake B.
Simpson's Lake
Black Bayou Swamp
Red
Black
Bayou
Dooley Swamp
Irving's Bluff
Miller's Bluffs
Coushatta Bluffs
Silver L.
Cedar Bluffs
Carolina Bluffs.
James
Clear Lake



Map of Northern Caddo parish in 1839. Compiled from Public Land Surveys

BY A. C. VEATCH



Map of Northern Caddo parish in 1839. Compiled from Public Land Surveys

By A. C. Veatch

a time the tops of the dead trees were broken off by the winds, leaving the unsightly stumps as silent witnesses of the great catastrophe.

A peculiar ox-bow shaped depression, being below the level of the banks of the river at the mouth of Twelve Mile bayou was filled with water at the same time forming Clear lake.

Origin of Black bayou swamp.—The Black bayou stream valley being higher than the Cypress bayou stream valley was not so deeply inundated by the daming of Twelve Mile bayou. Still it was low enough * to receive a little water. Cypress trees, being fitted by their peculiar knees to grow in such a situation, soon converted the land into a cypress swamp.

Formation of Silver lake and Poston's lake.—Silver lake and Poston's lake were formed in the same way, the first in a stream valley the second in a bottom-basin, but at a later date. Poston's lake is shown on the land office charts made in 1839, when the raft was far below its outlet, as a bayou. On Woodruff's map of 1872 it is a large lake offering a good steamboat passage. It is now a bayou. Thus in fifty years a lake large enough for the passage of large steamboats has been formed and destroyed.

Outlet bayous—The formation of the outlet bayous, both artificial and natural, has already been discussed. It only remains to call attention to the development of the drainage systems by outlet bayous. A reference to the two maps accompanying this report will show something of this development.

It will be noticed that in the lower part of Old Red bayou the outlet channels, Dooley's, Cowhide and Horseshoe, have deliberately cut across the old channel. Indeed the map seems to indicate that Trinity bayou and the lower part of Cottonwood bayou represent the true continuation of Old Red bayou, and that the portion of Old Red bayou, so called which flows west, is really a continuation of the Peach Orchard outlet.

* The average elevation of the river banks about Shreveport is about 170 feet above Gulf level. The bottom of Black bayou where crossed by the Kansas City, Pittsburg and the Gulf Railroad is, according to the railroad companies corrected levels 173 feet. Thus the lower part of the valley would probably receive a few inches of water and even if the water did not back up into the valley the current would be so checked that the lower part of the valley would be very imperfectly drained.

Most of the outlets were made before any of the land surveys, and we have a record of the formation of one of them only. In 1841 Lieut. Col. Long says: "Commencing at the southern boundary of Arkansas and proceeding downwards, we have in succession the following considerable outlets from the main river, communicating more or less directly with Caddo, or Sodo lake, situated on the southwest or right side of the valley, viz.: Red bayou, which is the uppermost of all the bayous within the district just mentioned; New bayou, Dooly's bayou, and Cheftel's bayou, besides several others of inferior size. The three bayous first mentioned are situated above the head of the raft; while the last passes from the river at a point about midway of the new or present raft. One of these outlets, viz.: New bayou, has been formed during the existence of the present raft."*

Sedimentation.—One of the most important changes wrought by the raft was the building up of the land by sedimentation. The checking of the current by the raft, the large stretches of almost dead water both in the river and the lakes afforded conditions for the rapid deposition of sediment that are seldom excelled.

The result was that, in the stream channel over fifteen feet of sediment was deposited. Along the banks the deposition ranged from a very thin layer on the higher portions to ten or even more feet at lower levels. Lieut. Woodruff says in regard to the average rate of deposition: "I think that the average increase of elevation of the immediate banks of the river and principal bayous from near Carolina bluffs to the present head of the raft, during the past thirty years, is about 3 feet. Mr. James Marks, an intelligent and observant resident near Carolina bluffs, estimates this deposit at five feet."† In the lakes the deposition was much more irregular and generally slower. There seems to be no way of determining even approximately the deposition in the lakes. In the region of the Indian mounds in Sec. 5, 19 N., 14 W., which was all under water during the raft period, there is a layer of stiff red clay from 6 inches to a foot thick overlying a black sandy clay similar to that on the Caddo prairie.

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*27th Cong. 1st Sess. Senate Doc., vol 1, No. 64, pp. 3–4.

†43d Cong; 1st Sess. House Ex. Doc. vol. 2 part 2, p. 642, 1873.

The deposition near the main bayou mouths was undoubtedly much greater. Parts of the old Cypress bayou channel, in the region of Albany, was filled to the level and above the banks of the old stream by the material brought down by Red bayou.

After the cutting of Sewell's canal with the resultant diversion of the waters of Red bayou, a great deal of sediment was deposited in the lower part of Ferry lake. H. C. Collins gives an interesting account, in 1872, of the passage of the water of Stumpy bayou into Ferry lake. He says: "Most of the water follows the bluff, and passes into Ferry lake on its north side, the current running west up the north side of the lake about a mile, and depositing in it a large amount of its mud. At times of rapid rise of the river there is a strong current up the lake to the west, so that sometimes Red river water is seen beyond the Texas line."*

CHANGES DUE TO THE REMOVAL OF THE RAFT

Deepening of the river channel.—After the removal of the raft the current immediately commenced removing the sediment deposited during the raft period. Attention was first drawn forcibly to the erosion of the channel by a peculiar obstruction in the river about 15 miles above Shreveport, known as the "Dawn Stumps."

There were several hundred of these standing upright in the bed of the river and when the raft was first removed, boats passed over them without difficulty. In 1886 they pojected six feet above the surface at low water and those in the middle of the channel were cut off as near the water surface as possible. The following year, at the same stage, the stumps, that had been cut, projected four or five feet above the surface of the water.† They were finally entirely removed with high explosives.

Maj. J. H. Willard, U. S. E. about 1892, succeeded in recovering some of the benches of the Woodruff survey and so determined the exact amount of the erosion since the removal of

*Ibid, pp. 657-658.

†J. H. Willard. Preliminary Examination of the Lakes connected with Red river, etc. 50th Cong. 1st Sess., House Ex. Doc., vol. 4, p. 1490, 1887. Also, An. Rept. Chief of Eng. for 1887, vol. 2, p. 1490, 1887.

the raft. He says: "Having recovered some of the benches of Maj. Howell's and Lieut. Woodruff's surveys, and reduced the levels to Cairo datum, it is found that the water line has fallen more than 15 feet at the head of the raft, diminishing to about 3 feet, at Shreveport, while a similar reduction has been going on in the river below."* Thus the river is tending to return to the conditions which existed before the raft period.

Drainage of the lakes.—In the lake region the irregular deposition of sediment has rendered the return of that region to pre-raft slower than in the main channel. Certain of the old channels have been more than filled with sediment and the streams which have been forced by this filling to flow over older, harder beds have not yet succeeded in cutting channels in them to a depth equal to the depth of the old channels. The reduction in the size of the lakes, though hindered in this way, has nevertheless been very marked. Sodo lake is a very noticeable instance of this reduction in size. (Compare plates 14 and 16.)

Poston's lake has returned to very nearly it former condition. This is because the raft had not been above the mouth of Poston's bayou long enough to fill its old channel, and hence this lake experienced none of the difficulties of the lower lakes.

At Silver Lake† the former outlet has been entirely filled and the water is engaged in cutting a new channel through the older clays on which it has been forced.

Simpson's lake, a lake which formerly existed just above Elmer's bayou, and Dooley's lake, have been almost entirely obliterated. During the raft period they were almost completely filled with sediment and after the removal of the raft the lowering of the river channel by erosion completed the drainage.

The cutting out of the river channel has resulted also in the partial drainage of the small lakes in the bends on the east side of the river. Marks' lake has shrunk to two small lakes, and the encroachment of the river on Adger's lake threatens to completely destroy it. Dutch John's lake has shrunk to about one-

*An. Rept. Chief of Eng. for 1893, pp. 1909–1910, 1893.

† This Silver Lake which occupied a valley in Coushatta bluffs, should not be confused with the now dry Silver lake near Shreveport, which has entirely drained since the removal of the raft.

third of its former size. Near Shreveport, Swan lake is completely destroyed.

Cross bayou discharge.—After the removal of the raft and the formation of the second raft, which forced nearly the whole of the river current to flow through the lakes, the water seeking the shortest channel through the bottoms cut the channel known as "The Pass" between Sodo and Ferry lakes; and nearly all the water returned to the river through Cross bayou. Before the closing of the outlet bayous, even after the removal of the raft, the discharge of Cross bayou in medium and high stages of water was always greater than either Twelve Mile bayou or Upper Red river.

CHANGES RESULTING FROM A COMBINATION OF CAUSES

Reversal of drainage systems.—The great discharge through Cross bayou, while the river about Hurricane bluff was clogged with raft material, resulted in an upstream current at times as high as Benoit's bayou*. Fuller states that the upstream current ran as far as "half the distance between Shreveport and Red bayou," or as far as Willow chute. Woodruff questions this.†

Linnard's early account, however, agrees with Fuller. He says: "During the freshets the greater part (of this water) sweeps directly across the channel of the river, and continues eastward to the Bodcau lake; a portion ascends the channel to Benoit's, or Williams' bayou, or the Willow chute and the remainder passes down the channel.‡

The cutting of Sewell's canal has resulted in the reversal of the drainage for about a mile down the bayou. A new channel was made across the old Henderson fields between 1864 and 1871 and water flowed from Dooley's lake through it and Old Red bayou to Sewell's canal.§

A number of the bayous and canals which were outlets during the raft periods have, since the removal of the raft, became inlets. This is true of Alban's canals and Poston's bayou.

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* Long. 27th Cong., 1st Sess., Senate Doc., vol. 1, No. 64, pp. 9–10.

† 33d Cong., 2d Sess., Senate Ex. Doc., vol. 7, No. 62.

‡ 28th Cong., 2d Sess., Senate Doc., vol. 1, No. 1, p. 289, 1845.

§ An. Rep. Chief of Eng. for 1873, p. 658.

Formation of the delta at the foot of Cross lake.—The peculiar delta at the foot of Cross lake has already been described under Cross lake, and the peculiar fact noticed that, at present, in ordinary stages of water the water flows from the delta instead of into it.

Under the old raft regime the great amount of water sweeping through the pass from Sodo lake into Cross lake must have carried with it a great deal of sediment and thus silted up the lower end of Cross lake valley. The ancient stream channel was entirely filled and the present outlet was thus forced to flow over projecting points of the older, harder Eocene material. The delta at the head of Bowman's chute is one of the incidents of the silting up of the foot of Cross lake.*

Formation of irregular ridges in the bottoms.—Along the river front and the banks of bayous, where the sandy front land is well developed, the surface is often very irregular as if a great volume of water had rushed through in time of flood, cutting a multitude of little gullys and leaving little irregularly shaped knolls one to two feet high.

They are markedly different from the natural mounds of the post-oak or upland flat region ; they are not so uniform in shape, so symmetrical, being irregularly oblong rather than circular, and, a minor difference, they are not so high. The ridges are well developed in Sec. 33, 20 N., 14 W.

The theory of the current origin of the upland flat topography hardly seems probable when these unquestionably current-formed mounds are seen.

Old shore line at Cross lake bridge.—Extending along the base of the hills and about 15 feet above the present water level is a little wave formed bluff ranging from a few feet to 12 feet in height. It represents the old water level of the lake. As the interval between the formation of this lake and the removal of the raft was about 60 years, this bluff represents the effects of 50 years' wave work. It is best developed just east of the south end of the railroad bridge. (Plate 17.)

*On plate 15 a delta is shown only at the head of Bowman's chute. This was the only portion of the foot of the lake carefully examined. The other channels should show the same peculiarity.

GEOLOGY OF THE BOTTOMS.

FORMATIONS REPRESENTED.

Recent beds.—The recent Red river deposits cover the greater part of the area and consist of all gradations from a light red sandy loam to a stiff, dark red clay. In places it exists as a mere veneer over the presumably older deposits; in others it covers it to great depths.

Older beds.—Outcropping here and there through the bottoms and exhibited in places along the river banks are beds of blue clay markedly different from the river deposits formed under the present regime. Its altitude varies greatly, indicating considerable erosion.

The blue clay outcrops in several places at Dooley's bayou, in the bottom of Willow pass and Albany flats. At the last two places, the blue clay seems to be simply a weathered continuation of the dark gray Eocene clays of the adjoining bank.

On the west bank of the river in the S. W. ¼ of the N. E. ¼ of Sec. 3, 19 N., 14 W., there is a limited exposure of the older clays. On the opposite side of the river only the recent reddish sandy loam was seen; about 200 yards above the point where the section was taken only the most recent deposition filled with logs of the raft, occurs.

The section here exposed is:

Section, Red River Bank, James Eric Place (Sec. 3, 19 N., 14 W).

3. Light reddish yellow sandy loam containing numerous specimens of *Helix;* grading above into surface loam, 10 ft.
2. Dark bluish black, crumbly clay grading below into red sandy clay . . . . 6 ft.
1. Jointed clay containing numerous irregularly shaped calcareous concretions. Blue above, mottled with red below . . . . 7½ ft.

The two lower strata seem to be in part represented in the Caddo prairie section, though that section contains more sand. In the southern part of Caddo prairie the older beds are represented by beds of poor yellow and red clayey sand, very different from the sandy front lands of the river but similar to the sands of the adjoining hill lands. The upper part of the red sands grades into a very fertile black sandy loam showing in places numerous specimens of *Unionidæ*. Caddo prairie occupies the highest part of the back bottom lands.

This layer of black sandy loam with *Unios* appears in the sides of the bayous in several places in the bottoms, commonly overlying the same poor sands.

Age of the beds.—The exact age of these beds can only be a matter of conjecture. The blue clay suggests the Port Hudson beds of Hilgard and the spirited discussion of the age of the blue clay of the Mississippi bottoms. In this region some of the blue clay is clearly part of the adjoining Eocene formations, as at the rapids at Albany flats and Big Willow pass.

The poor red sands may represent outliers of the Eocene hill lands or may belong to the same age as the upland flat deposits. Examples of unquestionably erosion-formed outliers are to be seen in several places in the bottoms. Just above the mouth of Black Lake bayou are two mounds which are merely detached portions of the hill-lands. Pine island in Clear lake seems to be of the same class. The data at hand are, however, at present a little too meagre to admit of drawing any very definite conclusions on the exact age of the sands.

Shells from the front land.—Some of the light yellowish-red loam which occupies the immediate banks of the river is extremely lœss-like in texture and appearance. The resemblance is greatly strengthened by the presence of numerous land shells. Mr. C. T. Simpson, of the U. S. National Museum, has identified the following species from Sec. 14, 19 N., 14 W.:

Pyramidula alternata,
Polygyra thyroides.
Polygyra clausa.
Polygyra inflecta.
Polygyra palliata.?
Omphalina friabilis.
Helicina orbiculata.

To this list of species Mr. Simpson has added: "We do not have any of the *Omphalina friabilis* quite so flat as the species you send, and one or two others are a little different from the ordinary manifestations of the same species. *P. thyroides* as sent by you has a closed umbicilicus and in our shells it is open."

WAVE-FORMED BLUFF. PAGE 174

A comparison of specimens shows the following species from layer three of the James Eric section :

SOILS*

Varieties.—The partially complete soil map accompanying this report shows but three soils, viz.:

1. Red sandy loam. (Front land.)
2. Stiff red clay. (Back land.)
3. Black sandy clay. (Prairie.)

These are the principal types, but by the mixing of different proportions of the three kinds an almost indefinite number of varieties are produced. Number one grades into number two, making it quite difficult to say just where one begins and the other ends. The line between the second and third is generally well marked if the land has not been plowed. The red, stiff land thins out to a feather edge on the edge of the prairie land ; when the land is plowed the two are thoroughly mixed, forming a complete series of soils from one to the other.†

It often happens that a thin veneer of stiff red clay will overlie a layer of sandy loam. In plowing these are thoroughly mixed, forming what is locally called "dough-faced land." A mixture of back-land and prairie-land produces "black stiff land."

Peculiarities and distribution.—The red, sandy loam occupies the highest portions of the bottoms along the immediate banks of the river and the old outlet bayous. The predominant tree is

* No satisfactory account of the soils can be written until they have been analyzed. Such analyses of the samples collected in this region are now being made under the direction of Dr. Stubbs. Reports of these analyses will be published in Dr. Stubb's work on the soils of the State. The notes here offered are rather on their general aspect and location than on their agricultural value.

† On the map an attempt has been made to show only the predominate soil. Thus, if an area is mapped "front land" it does not mean that the land is always typical red, sandy loam, but that the red, sandy loam is the principal constituent of that soil. The overlapping of one material on the others makes satisfactory soil mapping quite difficult. The surface may be typical stiff red land and an inch or more below, black land. The depth of the lower layer varies greatly over even a small area.

the cottonwood; but ash, hickory, red oak and sweet gum also occur.

As the distance from the river and bayous increases the amount of sand in the soil decreases and at a short distance from the stream channels the sandy front land has changed into stiff clay back land. This ranges in color from a dirty cherry-red to a rich dark mahogany. Here the cypress and hackberry find congenial homes.

The surface aspect of the little spots of prairie land scattered through the bottom is markedly different from that of the surrounding heavily wooded country. There are a few scattered cottonwoods, numerous scrub thorns (hawthorn and honey-locust) and grass; altogether a sort of forbidding looking place, but when cleared yielding excellent crops. If the soil is in any way washed off, leaving the underlying red and yellow clayey sand, the fertility of the field is a thing of the past.

Origin.—It is easy to see the manner in which the front and back land have been formed. Indeed it has been so often stated and is so well understood that a very brief statement will suffice here. When the water flows over the banks in time of high water its velocity is greatly checked and it deposits its heavier sandy material on the immediate banks of the stream; thus forming the sandy front land. The waters which now contains only the finest sediment passes into the lower parts of the bottoms, forming great temporary lakes. Having little or no velocity, the water is unable to keep even this very fine sediment in suspension. This is gradually deposited, forming a stiff clay.

In times of high floods the sedimentation is very large. Large areas of stiff back sand are often sanded. Thus, in the flood of 1892 Cottonwood bayou covered a large area of stiff land lying along its banks with sandy material. It is stated that in places this deposit amounted to two or three feet.

The formation of the prairie land can only be a matter of conjecture. The Eocene Tertiary of northern Louisiana abounds in little bare spots caused by the outcropping of unusually calcareous beds. It may be that certain layers of the older beds in the bottoms contain a large amount of calcareous matter and are responsible for the formation of these spots. The section given above (p. 175) shows quite a calcareous layer.

There is, however, a very widespread black calcareous layer through the bottoms, which contains numerous mussel shells (*Unionidæ*).

It may be after the partial erosion of the valley, in which island-like outliers of the hill land were left above the surrounding bottoms, that a period of marsh or swamp conditions ensued, in which the water plants formed a peat-like deposit over the sandy clay. A slight deepening of the water and a deposition of sediment on the top of the vegetable matter would make a cozy home for the *Unios.* Here they lived and died in great numbers. On the re-elevation of the ground and the decomposition of the vegetable matter the result would be a very black sandy clay with *Unios.*

WATER SUPPLY

Sources of water.—Water can generally be obtained in the front lands at a depth of from 35 to 85 feet. The common method employed is to point a pipe and drive until water is reached. Water obtained from this layer is generelly not very wholesome, containing as it does quite an amount of mineral matter. When used in boilers it "scales" badly and on Mr. John Sentell's place "eats out" the boiler tubes. He has succeeded in obtaining partial relief by pumping the water into a tank and exposing it to the atmosphere for from 36 to 48 hours.

Mr. A. L. Pullin, a well driller at Shreveport, states that he has succeeded in getting very pure water from a soft red sandstone at depths ranging from 160 to 300 feet.

General section of Red river wells below Shreveport.—Mr. Pullin has kindly furnished the following general section:

General Section of Red River Wells below Shreveport.

1.	Red soil, sandy loam	4–10 ft.
2.	Red clay and sand. Water bearing. This stratum is clayey above and becomes more sandy below. The lower 5–10 feet is a quicksand. This layer is the source of the highly mineral water which is obtained in the driven wells...............	45–60 ft.
3.	Gravel and sand. Quite firmly bedded, so much so that it is impossible to drive a well into it.	

The gravel sometimes reaches the size of a goose egg. White chert and quartz pebbles are common. The gravel is largest at the top and gradually grows finer until at the base of the strata it grades into a fine white sand........ 20–40 ft.

4. Soft gray sandy clay containing vegetable remains and occasional shells........................ 8–16 ft.

5. Fine white sand.............................. 0–40 ft.

6. Hard tenaceous blue clay, called "rubber clay" containing scattered iron concretions about the size of a pea .... 40–132 ft.

7. Indurate red sand, water bearing. Furnishes an abundance of soft water..
Water from this stratum generally rises to within ten feet of the surface.

None of these deep wells were personally examined nor was I able to obtain any shells from layer 4. It can hardly be doubted, from the general character of the material, that the water is from the older Tertiary strata. The presence of large gravel beds in the river valley is also to be specially noticed for no gravels of northern origin have yet been found on the hills west of the Black bayou and Bayou Dauchite gravel trains.

Well at Lotus Landing, Robson P. O.—At the time of the writer's visit Mr. Pullin had just finished a well on the place of Capt. Robson at Lotus Landing, in 16 N., 12 W. from which he had a large suite of gravel specimens.

Well Section on Capt. Robson's Plantation (16 N. 12 W.).

No.	Depth		Thickness
1.	0– 4	Red sandy loam..................	4 ft. 0 in.
2.	4– 79	Fine red clay with sand............	75 ft. 0 in.
3.	79– 82	Red sand, water bearing	3 ft. 0 in.
4.	82–106	Gravel and sand, same as 3 in foregoing section..................	24 ft. 0 in.
5.	106–118	Organic clay with shells...	12 ft. 0 in.
6.	118–121	Brown lignite.....................	3 ft. 0 in.
7.	121–123	Good black lignite	2 ft. 0 in.
8.	123–130	"Soapstone," soft white friable clay.	7 ft. 0 in.
9.	130–131	Very hard blue limestone	0 ft. 8 in.

10.	131–135	Hard black lignite	4 ft. 3 in.
11.	135–225	Blue clay	90 ft. 0 in.
12.	225–	Water in sand, not passed through.	

Any separation of this section in beds of different ages must be necessarily a mere guess. It will be quite necessary to have good samples from each of the different layers in order to arrive at even a partially satisfactory conclusion. The section is, however, quite suggestive. Layers 2 and 3 may represent the Port Hudson of Hilgard. Layer 4 suggests the Lafayette or Orange sand, whatever that name may really mean, and the lowest part seems to be older Eocene Tertiary.

PHYSIOGRAPHY OF THE BOTTOMS

WATERFALLS AND RAPIDS

Description.—It is a decidedly interesting thing to find in the midst of an old, well developed, river flood-plain, waterfalls and rapids. Several were seen in upper Caddo bottoms and there are doubtless others in localities which have not been examined.

The most perfect waterfall seen was at the outlet of Silver lake just below Coushatta bluffs. The waterfall is about ten feet high and is at the head of a little gorge probably 300 yards from the river. The crest of the waterfall is composed of hard bluish-gray and red sandy clays.

Collins describes a waterfall formed by the water flowing over a hard clay layer underlaid by sand, in a channel accross the old Hamilton fields from Dooley's bayou to Old Red bayou.* There are also rapids in the main Dooley's bayou channel, about a mile above its entrance to Old Red bayou where the water flows over a layer of hard clay. This is sometimes called "Dooley's Falls."

We have before spoken of the rapid current at Big Willow pass and the rapids and small waterfall at Albany flats. These are, of course, not noticeable in very high water when the inequality is not enough to effect the large volume of water greatly but in moderate stages they are very marked.

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*43d Cong. 1st Sess., House Ex. Doc., vol. 2, part 2, p. 658.

There are very marked rapids in Bowman's chute, just above where it joins Middle bayou and the "Ditch" forming Cross bayou.

Formation of waterfalls and rapids.—During the raft period many of the old stream channels were covered by lakes. The sediment deposited in these lakes often more than filled parts of the old channels so that after the removal of the raft and the partial drainage of the lakes the streams were forced to cut new channels. It would sometimes happen that a stream thus forced out of its channel would find itself superimposed on the older blue clays or on projecting points of the adjoining Eocene clays. Such a stream may, in its course, find its way back into a portion of the old stream bed which has not been filled. The fall thus developed on the bank of the former stream will wear rapidly back through the alluvium till the face of the blue clay is reached. At this point, if there is a layer of harder clay underlaid by softer material, the waterfall will maintain itself and gradually wear back until the lake formed by the daming of the old stream channel is reached. If the clay is a uniform mass the face of the falls will be worn off and rapids produced.

In this region the same result could be produced without the formation of a waterfall by the tumbling of the stream over the old stream bank. If the old channel has been completely filled the water will flow in the lowest part of the adjacent land; part of its bed being of alluvial material and part possibly of the older clays. As the river erodes its channel the side streams would tend to do likewise and would soon cut ample channels through the alluvium lying between the older clays and the river, leaving the less easily eroded clays to form rapids and waterfalls in the channel.

In the case of the rapids at Albany flats the ancient channel was evidently to the north of the present channel. This old channel was filled with sediment brought down by the outlet bayous. When the raft was removed the stream occupied the lowest land, which, since the greater part of the filling was on the northern side of Sodo lake, was along the base of the hills. Here the stream found hard blue Eocene clays. The rapid erosion of the alluvial material between these clays and the river left them to form rapids in the channel. The rapids are gradually wearing backward and the day is not far distant when Caddo parish will be the richer by a number of acres of good land where there is now a lake.

It is believed that the ancient channel at Big Willow pass is also to the north and that the blue clay will finally, after the Albany rapids have worn out and drained Sodo lake, wear back and drain Ferry lake.

The rapids on Bowman's chute are of exactly the same type, were formed in the same way and will have same life history.

The falls at Dooley's bayou are slightly different from those just described. It seems that as the raft advanced up the river the little ditch which drained the old Dooley's swamp offered a good outlet channel; water rushed through it and tumbled over the bank of Old Red bayou. The falls thus formed wore back until the blue clay was reached when a rapids was produced. A portion of the water turned over the old Hamilton fields and fell into Old Red bayou. Here there was a layer of hard clay underlaid by softer clay, the exact conditions for a typical waterfall, and as the under sand washed out portions of the clay strata broke off, thus maintaining a perpendicular fall.

At Silver lake the old channel was to the south of the present outlet. The filling of this resulted in the tumbling of the water over the bank at a place occupied by a projecting point of the Eocene clays. A waterfall resulted whose height has been increased by the deepening of the main channel of the river. The fall is wearing back by the removal of the lower layers by the water and the caving off of the upper strata and will soon reach and destroy Silver lake.

ORIGIN OF BOTTOM LAKES

Classes.—With reference to origin, there seems to be three types of lakes in the bottoms, viz.:

1. Cut-off lakes.
2. Lakes of enclosure.
3. Raft lakes.

Cut-off or Horseshoe lakes.—Lakes of this type are not well developed in this part of the valley, not nearly so well as they are in the lower Red river valley. The most perfect example is Moon lake or Old River lake, east of Oven bayou, on the line between 19 N. and 20 N. A river in an alluvial flood plain is constantly cutting the banks on the outside and filling on the inside of the bends. When two parts of a great bend approach near each other the intervening neck will be cut through in a freshet, forming a cut-off. The connections between the river and the portions of the river cut-off will gradually become filled with sand-bars and in time entirely separated from the river. As the river travels across the valley the lake thus formed may be left several miles from the river. Several such cut-offs have been formed in this region, with a little help from man, in the last fifty years. Near Hurricane bluffs is the Shreve cut-off of 1837. Benjamin's cut-off near Willow chute, and the Hotchkiss cut-off above Shreveport, have been formed in this way.

Lakes of inclosure.—The second type of lakes is quite common. They owe their origin to the formation of natural levees by the river. Along the east bank of the river this is well exemplified, where the river strikes the hills and then makes three great loops far out into the bottoms. In these loops, miniature bottom basins are formed; the hills forming one side and the elevated land along the banks of the river the others. In these basins water collects forming little lakes. To this type belong Adger's lake, Marks' lake, Dutch John's lake and a little lake on Black Lake bayou in Sec. 12 and 13, 22 N., 15 W.

A similar little lake may be formed entirely by the river without the aid of the bounding hills. In a great ox-bow bend where there is in one place only a very narrow neck of land between two parts of the river the elevated land which forms the banks of the river will extend entirely across the neck, forming in the interior of the bend a complete basin. Water accumulates in these depressions forming lakes. On plate 14, lakes of this type are shown in the center of the bend at Hurricane bluffs and in the old bend at the Willow chute outlet. A similar lake of inclosure is found near Blake Lake bayou in Sec. 14, 22 N., 15 W.

There is still another way in which a lake may be formed by inclosure. Not only has the river built its banks up higher than the surrounding land but each little bayou has done likewise. Thus a basin is formed in the inter-bayou space. The old Dooley bayou swamp and the now filled Simpson's lake probably occupied such depressions. Old Swan lake just above Shreveport, between Twelve Mile bayou and the river was of this type.

Raft lakes.—The origin of lakes of this type has already been discussed under the headings "Growth of the Raft" and "Changes due to the Formation of the Raft" and Ferry, Sodo and Cross lakes were referred to this type. It remains, however, to call attention to the similarity in position and origin of these lakes to the other large lakes of Red River valley ; to give the traditions and historical data we possess regarding them and to give some other theories which have been advanced to account for them.

A reference to a good map of the State of Louisiana will show lakes which are the exact counterpart of Cross lake and Sodo lake all along the river valley below the Arkansas line. Those which have been clearly formed by the drowning of old stream valleys and which belong to the same type as Cross and Ferry lakes are: Lake Bodcau, Wallace lake, Lake Bistineau, Black lake, Saline lake, Spanish lake, Lake Terre Noir, Lake Nantaches and Lake Iatt. There are also several which have been formed in bottom basins like Sodo lake. The two most pronounced of these are, Lake Cannisnia and the lower part of Bayou Pierre lake. They are so alike in their general features and occupy such analogous positions that any theory accounting for the origin of one must, in general, cover the origin of all.

Of the recent origin of the lakes in the upper part of the valley there can be little question. A number of planters of Red river bottoms have repeated to me the old Caddo Indian tradition that about one hundred and fifty years ago the land now occupied by Sodo lake was an oak ridge, that all the water flowed in a narrow cypress-fringed bayou in the center and that the filling of the valley was sudden, as if by an earthquake.

Collins evidently heard much the same story, which he states in this way: "Mr. Josey, living at Swanson's landing, who is probably the most intelligent man in the vicinity, thinks there was a general subsidence of a very large tract, including the bluffs as well as the bottoms, and that it took place since the removal of the Caddo Indians. He says, that a few years ago, when a few of the Caddo Indians came back to visit the country they told him that they used to cultivate cornfields on land adjoining these oak and pine stumps, and now covered with water to the same depth, and that the entire country was above overflow.''* The statement of the Indians is in part substantiated by a group of mounds in Sec. 5, 19 N., 14 W. A comparison of the two maps accompanying this report will show that the site of these mounds was covered by Sodo lake during the raft period.

Dr. Joseph Paxton, in a letter written in 1828, gives a similar account of Bodcau lake. He says: "Bodcaw prairie is represented to have been exceedingly beautiful, and thirty years since was the resort of immense herds of buffaloes. It is now a stagnant lake."† These statements, together with very positive evidence furnished by the only partially decayed trees in Ferry lake shows a very sudden and recent origin of these lakes.

The most common theory of the origin of these lakes is that they were formed by the sudden lowering of a portion of land by earthquakes; in a similar way and at the same time as the Sunk lands of the St. Francis basin and Reelfoot lake near New Madrid, Mo., which were formed by the earthquake of 1811–12. Lyell, in his Principles of Geology, 11th edition, vol. 1, page 452, after quoting Darby's statement that the lakes have been formed by the damming of the mouths of the tributary stream valleys with the Red river alluvium, suggests that they owe their origin in part to earthquake action. Lyell had just visited the sunk region about New Madrid, and was greatly impressed with the phenomena there shown.

There are several reasons for believing that the lakes do not owe their origin to earthquakes. Probably the most satisfactory are the results obtained in the borings made by the Cypress bayou survey in 1892 under the direction of Capt. Willard. Of

* 43d Cong. 1st Sess. House Ex. Doc., vol. 2, part 2, pp. 658–659, 1873; An. Rept. Chief Eng. for 1873, pp. 658–659.

† 20th Cong. 2d Sess. Senate Doc., vol. 1, No. 78. p. 10, 1829.

the results of these borings Capt. Willard says: "The borings also disprove the notion that these lakes were formed by the same convulsion that made those at New Madrid, the strata plainly being water deposits without contortions that the upheaval or sinking would produce, and the oak stumps as well as the cypress are everywhere found vertical."* The second reason is that a theory of origin similar to the New Madrid lakes will hardly account for the peculiar positions of these lakes. Lakes of the type of Sodo lake and lake Cannisnia might be produced by the sinking of an area of land in the bottoms by earthquake action, but it must be confessed that it would be a most peculiar earthquake or series of earthquakes which would drop the bottom out of *every* large valley entering Red river valley, or which would raise the land at just the points where these valleys enter the river valley. This drives us to the supposition that the subsidence was not local but extended over the whole valley; effecting the hills and bottoms alike. Such a movement is different from the local subsidences in the bottoms produced by the earthquake at New Madrid. A general movement of this kind over a large area is more likely to be produced by slow crustal movements than by an earthquake.

A general subsidence of this kind is capable of producing such lakes. As the subsidences progresses, the river will commence building up its channel and banks in an effort to regain its base-level. If this movement is rapid, Red river with it great amount of sediment will build up its bed much faster than the less muddy tributaries. This will result in the elevation of the river above the tributary streams and the consequent ponding of the water in their valleys.

The fact that there is abundant evidence that the southern part of the United States is sinking † seems to corroborate this theory, but other facts, at hand, do not sustain it. If such a

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* An. Rep. Chief of Eng. for 1893, p. 2069, 1893.

† This evidence consists in the estuary character of the mouths of the majority of Gulf rivers; the great depths of some of the costal rivers; the observations of Maj. J. B. Quinn of the U. S. Engineers, and the buried shell heaps on the coast. See Five Island article and Geol. Surv. of Ala., 1894, pp. 45–47.

subsidence is going on it does not seem probable that the line of maximum depression should follow the Red river valley, and if it extends over a large area all the streams of that area should be affected alike. That is, we would look for lakes of the same type along the valleys of the Brazos, the Trinity, the Sabine and the Ouachita and especially along the Arkansas, which in point of size and amount of sediment it carries, fully equals the Red. Lakes should also be found in Red river valley above the region effected by the raft. No lakes like Ferry, Cross or Bistineau lakes are found.

This seems to leave only the theory of the raft formation of these lakes. This theory is greatly strengthened by the known formation of a large lake similar to Sodo lake just below Miller's bluffs by the closing of the outlet bayou by the raft. Then there is the simi-historical account of the formation of Sodo lake proven as it is by the old tree stumps and the Indian mounds. This theory, however, requires that the lakes be drained on the removal of the raft. This has not been fully accomplished, although a large part of the lake area has been drained. There are several possible reasons why the drainage has not been completed at the present time: (1) the river may not as yet have succeeded in cutting out all the material deposited in the channel during the raft period, (2) many of the streams have been superimposed on older clays by the filling of their old channels and have not yet had time to cut new channels to as low a level as the old channels.

If, as now seems probable, the lakes owe their formation to the raft, it is possible to approximate the date of the formation of Cross and Ferry lakes. The distance, counting the old stream detours, from Cross lake outlet to the head of the Shreve raft in 1838, is 49 miles. If four-fifths of a mile represents the normal rate of advance of the raft, about 61 years had elapsed in 1838, since the closing of Cross lake bayou by the raft. This would make the date of the formation of these lakes about 1777.

NOTES ON THE GEOLOGY OF THE HILL-LANDS *

THE UPLAND FLATS †

General characters.—The point of land between Ferry lake, Clear lake, James bayou and the dotted line on plate 16 shows a marked topographical difference from the land north of it and from the land on the south side of Ferry lake. The country in the last two mentioned localities is hilly and has fairly mature stream valleys. The area under discussion, although from 30 to 40 feet above the adjacent drainage systems, has no well developed stream valleys. The water finding no outlet forms little swamps between the little mounds or hillocks with which the country is covered. These mounds are nearly circular and range from 20 to 80 feet in diameter and are from 2 to 6 feet in height. The composition of these mounds is quite different from that of the intermound spaces, being a moderately fertile sandy loam, while that between them is a poor stiff gray or yellowish gray clay, commonly called "post-oak clay." The intermound spaces are filled with water, forming little puddles and supporting a growth of swamp or pin-oak and post-oak. The mounds are covered with post-oak and short leaved pine. Under the "post-oak clay" at depths varying from a few inches to several feet, is a hard red clay. This is exposed only in the occasional gullies.

The distribution of these upland flats is quite extensive in this part of Louisiana. They are well developed just north of Wallace lake. In Bossier parish they occupy a strip of land between Carolina bluffs and Bodcau lake and east of bayou Bodcau they extend almost to Fillmore. The great level land between bayou Bodcau and bayou Dauchite in northern Webster, may belong to the same class. There seems to be a great piece of very flat uplands, younger than the Eocene, lying between bayou Bodcau and Red river in northern Louisiana and southern Arkansas. In this upland flat there are two island-like masses of Lower

* As the main part of the work was in the bottoms, only occasional opportunities presented themselves for examining the hill-lands.

† Lerch, Bull. La. State Exp. Stations, Geology and Agr., Part 2, 1893, p. 106.

Claiborne Eocene; one occupies an area south of lake Bodcau and includes Bellevue, Fillmore and Haughton; the other is represented by the red lands of the northern Bossier.

Well sections.—Only very shallow wells have been sunk in the upland flats and of these we have only very incomplete records. They, however, agree in finding occasional fresh water mussels (*Unionidæ*). The well diggers are quite positive that they were exactly like the shells now living in the adjoining lakes. A well in the S. W. ¼ of the N. E. ¼ of Sec. 1, 20 N., 16 W., gave the following section:

Well Section S. W. ¼ of N. E. ¼, Sec. 1, 20 N., 16 W.

1.	0– 4	Fine loamy sand	4 ft.
2.	4–11	Yellow and gray mottled clay, post-oak clay	7 ft.
3.	11–29	Red clay with calcareous concretions in lower part	18 ft.
4.	29–46	Blue mud with vegetable matter and mussel shells	17 ft.
5.	46–55	Fine blue sand, not passed through	9 ft.

A well digger living just north of Wallace lake reported that in a strip of country about two miles wide, just north of the lake, he had found "mussel shells" at depths from 18 to 30 feet in all but two wells. Shells were very abundant in a well on the Patterson place in the N. E. ¼ of N. W. ¼ Sec. 34, 16 N., 13 W. The well was sunk on an outlying hill 45 feet above the level of of Wallace lake. The shells were found at a depth of 20 feet. In a well sunk on the Little place a great many shells were found between 25 and 30 feet. The old dump heap at the Patterson place was examined and a few fragments of *Unios* found. As it was possible for these to have been scattered there since the digging of the well they can not be considered conclusive.

Colored sands and clays.—Where large sections of these beds are to be seen along the water courses very heavy beds of brilliantly colored sands and clays with calcareous concretions are to be seen. This is especially noticeable near Red Chute bridge in Bossier parish. On the road, which is about 50 feet above the bottoms, from Bellevue to the bridge, about three miles from the bridge deep red clay filled with lime concretions outcrop in the hillsides. This clay is markedly different from the red clays of the Tertiary to the east. The concretions are in themselves very distinctive; these light red, smooth, rounded claystone masses are entirely distinct from the red ironstone concretions of the old Tertiary. For about a half a mile east of the bridge the clay is overlaid by thick beds of red silty sand. Red Chute hill, where the road descends from the uplands to the bottoms is about 50 feet high and the washed road cut shows good exposures. It is composed entirely of fine grained red sand and loam with a little red clay.

An exposure of these sands was seen at Carolina and Hurricane bluffs. Carolina bluffs are composed of about 60 feet of light red with some white and yellow, cross bedded-sands. Lenticular masses of red clay are scattered through the sands. In the upper portion of the hill a thick bed of red clay is overlaid, for a short distance, by a bed of gray clay two feet thick.

The red concretionary clay outcrops in numerous places along the north side of Ferry lake, where the waves have washed out the concretions and formed numerous little pebble beaches. It is also well developed along the north shore of Cross lake, while the southern shore shows the entirely different old Tertiary strata.

The first cut north of the trestle over Lake Wallace exposes irregularly bedded white and red sands and red concretionary clays. Weathered surfaces show a red glaze over the whole mass, even over the white sands. Little or no clay was seen in the part of the cut immediately adjacent to the lake, here light colored stratified sands, not effected by dilute hydrochloric acid, are covered by massive brick red sand about four feet thick. Toward the northern end of the cut the calcareous clays and fine sands with very large calcareous concretions become very prominent.

The first cut south of the trestle (on the other side of the lake) consists of finely laminated gray clay with sand partings, overlaid by grayish yellow sands which contain lense-shaped masses of clay which have evidently been derived from the underlying clays. This sand contains numerous specimens of silicified wood.

Age of the upland flats.—The facts at hand indicate that these beds should be separated from the adjacent older Tertiary beds. We have a fresh water deposit resembling more nearly the recent Red river deposit than anything else in the region, but evidently formed under different conditions and occupying a level from 20 to 50 feet above the present bottoms. So far as the stratigraphy of the State is known these beds seem to be most nearly represented by the Port Hudson deposits.

This conclusion is greatly strengthened by the observations of Hopkins in lower Red river valley. He says: "On Dunbar's creek the equivalents of this clay (the Port Hudson) form the terraces upon Red river, if the calcareous nodules are a sure guide. These beds partake of the ferruginous aspect of this whole region, and are so intense red that it was not until they were traced laterally into the Mississippi deposits that they were recognized as belonging to this group. Examples are seen on the road from Avoyelles to Pineville, at the falls above Alexandria, on the west bank of Cane river in Natchitoches parish, and at Grapp's bluff, above Campté.*

Origin of the mounds.—The mounds, which have been noticed as covering the Upland Flats are by no means confined to them. They cover large portions of the Tertiary and Quaternary deposits of Arkansas, Louisiana and Texas. In Louisiana they are very markedly developed in the region under discussion, around Lake Charles and in the Moorhouse hills. They are not confined to any deposit or to any hypsometric level. Entirely absent in one locality they are quite abundant in another.

The popular interest in the origin of these mounds is very great and theories of their origin are common. An old darkey offered the following explanation: when the "Great Massa" made this earth he made it with a sieve and when he finished the sifting there were a number of lumps left in the sieve. These were thrown out forming the mounds. Another explanation, of a similar kind, is reported to have been given by the Caddo Indians. Their legend ran that many, many years ago the country was inhabited by a race of giants. For some reason, which the legend did not state, the giants were carrying dirt in

* Third Annual Report Louisiana Geol. Surv. An. Rept. Supt. La. State University for 1871, 1872, p. 187.

their aprons; when the dinner horn sounded they dropped the dirt where they stood and hurried away to a dinner from which they never returned.

Some of the theories which have been advanced by more cultured people are but a step removed from these. Others show considerable thought. The following theories have been advanced by scientists:

1. Ant-hill theory.
2. Wind theory.
3. Water volcano theory.
4. Pressure theory.
5. Gas theory.
6. Indian garden-mound theory.
7. Current theory.
8. Slow erosion theory.

The ant-hill theory was suggested by Hilgard in his Supplementary and Final Report of a Geological Reconnaissance of the State of Louisiana p. 11; it holds that the mounds were made by a large species of ant, which for some reason was entirely destroyed after the formation of the mounds. This theory seems to greatly tax the ants' abilities. A similar theory sometimes heard among the people of the country, is that the mounds were made by some burrowing animal.

Clendenin suggests * that the wind theory was suggested by emigrants from the prairie regions of the northwest, who had seen little mounds of sand or dust form behind little obstructions during a wind storm.

Thomassy conceived the idea that these mounds were formed by springs or "aqueous volcanoes." †

So far as we know, the pressure theory, which was advanced ‡ to account for mud lumps, has not been directly applied to the similar phenomena, the mounds. It holds that over a semifluid layer of quicksand there has been deposited a thick layer of tenaceous clay. The weight of the upper clay in places bulges

* Bull. La. State Expt. Stations: Geol. and Agr. part III, p. 180.

† Geologie Pratique de la Louisiane, Chap. VIII, New Orleans, 1860.

‡ Lyell. Principles of Geology, 10th ed., 1868, vol. 1, p. 449. Hilgard. A. J. S. 3d series, vol. 1, 1871, p. 425.

the surface of the ground and forces out some of the underlying mud. The objection to this theory lies in the great range of these mounds in altitude and over beds of different ages.

Scattered through all the beds of Louisiana, from the lowest Tertiary to the most recent, there are large amounts of vegetable matter mixed with beds of sands and clays. The decomposition of this vegetable matter forms gas and if this gas in its passage to the surface passes through a bed of sand it will probably carry to the surface some of the sand and so form a little mound. Such cones are now forming near the sulphur well at Lake Charles and formation of the mudlumps seems to be very analogous. This theory was first originated for the mud-lumps by Siddell * and and applied to the mounds by Hopkins.† Clendenin supplements this explanation with a hypothetical formation of the gas vents by earthquakes. The theory of the gas origin of the mounds seems to be more nearly supported by the observed facts than any other theory yet advanced. But the exact relation between the water and the gas, which issue from the mounds now forming, has never been fully worked out. It may be that the gas merely accompanies the water instead of the water accompanying the gas.

The Indian garden-mound theory is probably one of the most hypothetical yet advanced. Nadaillac in his Prehistoric America, p. 182, says: "Between Red river and the Wichita they (the Indian garden-beds) can be counted by thousands. According to Forshey, who described them to the New Orleans Academy of Sciences, these embankments cannot have served as the foundations for homes of men. He remarks that none of the known burrowing animals execute such works, whilst hurricanes could not have accumulated materials with such regularity. He added that in his opinion it was impossible to say anything definite with regard to their origin, which seemed to be inexplicable. Other archæologists are more positive; they consider that these

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* Report to Capt. Talcott, 1839, in Humphrey's and Abbott's Report, Appendix A.

† First Annual Report of the La. State Geol. Survey in An. Rept. Board of Supervisors of the La. State Seminary for Learning and Military Academy for 1869, p. 82, 1870.

embankments were used for nothing but cultivation, and that they are intended to counteract the humidity of the soil, still the greatest obstacle with which the tillers of the soil of the plains of the Mississippi valley have to contend.

The last two theories account for the origin of the mounds by erosion; the first by a rapid rush of waters; the second by differential erosion.* Neither seems to be at all sustained by the facts.

THE OLDER TERTIARY

Previous work.—A number of geologists have done work on parts of the older Tertiary which border the bottom lands discussed in this paper. By far the most careful and detailed observations on the bordering hills were made by Mr. H. C. Collins, one of Lieut. Woodruff's assistants on the Red River Raft Survey of 1871–1872.† Although not a professional geologist or a man who had had much geological training, his observations have great value as being a concise statement of what he saw. This report was not known to the writer while he was in the field so no investigation was made of Collins' reported find of the Cretaceous fossil, "*Nautilus dekayi* and another fossil" in the bluff at the Cypress brake between Henderson's Mills and Albany, and at Irving's bluff. Prof. Harris has suggested that he has in all probability mistaken *Nautilus dekayi* Mort., for *Enclimatoceras ulrichi* White, and that the beds are probably Midway Eocene.

Besides Collins, Hopkins,‡ Johnson,§ Lerch ‖ and Clendenin¶

* Brief statements of this latter theory are given by David Dale Owen, Second Report of a Geol. Reconnaissance of part of the State of Arkansas, Phila., 1860, p. 144, and Otto Lerch, Bull. La. State Expt. Sta., Geol. and Agri., part II, 1893, p. 106.

† Geologic Notes of Assistant H. C. Collins. An. Rept., Chief of Eng., for 1873, vol. 1, pp. 651–664, 1873; also 43d Cong., 1st Sess., vol. 2, part 2, pp. 651–664, 1873.

‡ Second An. Rept. of the Geol. Surv. of La. by F. V. Hopkins, 1871, pp. 9, 22. Also First Annual Report of the Geol. Survey of La., by F. V Hopkins, pp. 86, 89, 1870.

§ The Iron Regions of Northern Louisiana and Eastern Texas by L. C. Johnston. 50th Cong., 1st Sess., House Ex. Doc., No. 195, vol. 26, pp. 17–19, 22, 34–37, 1888.

‖ A Preliminary Report Upon the Hills of Louisiana, North of the Vicksburg, Shreveport and Pacific Railroad, by Otto Lerch. Bull. La. State Ex. Sta.; Geol. and Agr., part 1, 1892, pp. 18–19.

¶ W. W. Clendenin spent two seasons working on the Geology of Caddo parish but published no report.

have touched this region but, with the exception of the latter, the work was of an extremely hasty reconnaissance character and our knowledge of the country is very meagre. Vaughan has republished Johnson's Slaughter Pen Bluff section but does not seem to have visited the locality.* It is with a hope of adding something to this meagre information that the facts on the old Tertiary which the writer was incidentally able to collect, while working on the bottoms, are published. What is needed is a very careful examination of the northern Caddo hill-lands; it has been a guessing ground for quite a number of years.

Slaughter Pen bluff section.—This section, which is on Cross bayou just above the water-works, has been examined by both Johnson and Lerch and as has been stated above, Johnson's section has been republished by Vaughan. Johnson considered it a part of Hilgard's Mansfield series, the major part of which is now known to be Lignitie Eocene; Lerch referred it to his lower Lignitic, which is in part equivalent to the Lignitic and in part to the Lower Claiborne. Vaughan suggests that it is probably Lignitic.

The discovery of a small *Mactra* in the upper part of the bluff and the general resemblance of this species and the lithological character of the material to Buhrstone outcrops in Alabama on the Alabama river has led Prof. Harris to suspect that it may be eventually classed as Lower Claiborne. The section here exposed is:

Section at Slaughter Pen Bluff, Shreveport.
(Plate 18.)

9. Yellow clay with plates of calcareous matter grading above into red soil .... 6 ft.
8. Gray calcareous concretions .... 2 ft.
7. Grayish and yellow sandy clay with leaves and shells .. 5 ft.
6. Fine lamellæ of brown clay and yellowish gray sand with reddish iron nodules .... 5 ft.
5. Same as No 6 but without iron nodules. Contains large log of silicified wood .... 6 ft.
4. Dark drab clay .... 2 ft.

*Am. Geol., vol. 15, 1895, p. 205; also Bull. U. S. Geol. Surv., No. 142, 1896.

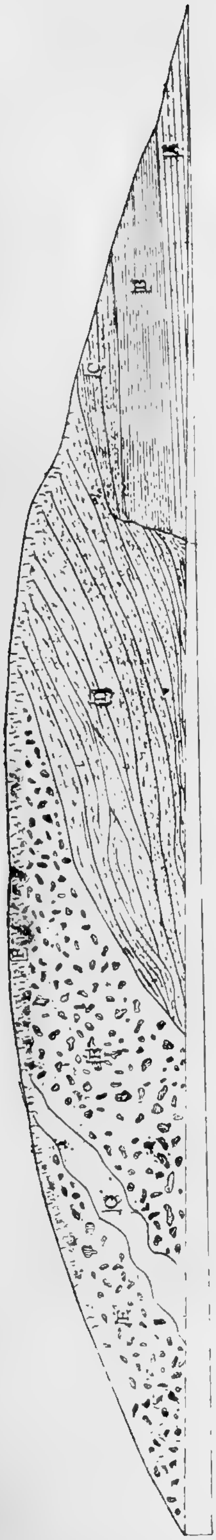


Fig. 5.—*Section of cut half way between Cross Lake bridge and K. C. P. & G. R. R. shops. Length of section 800 feet. Extreme height 58 feet.*

A. Gray, orange, yellow and brown sands with chocolate and lavender clay partings.
B. Black and brown lignitic clay.
C. Thin bedded gray clays with layers of brownish sands.
D. Reddish and grayish brown sands with blue clay layers.
E. Gray and reddish brown sand with blue clay boulders.
F. Red sandy clay formed by weathering.

3. Lignite .... 2 ft.
2. Gray and yellow sand with fine blue clay layers. Leaves.. 3 ft.
1. Gray and yellow, more and less laminated sand with thin lamellæ of blue clay to water level ....13 ft.

In a gully about one-fourth of a mile south of the Slaughter Pen bluff twenty feet of gray or bluish gray laminated clays overlaid by 15 feet of stratified yellow clays are exposed. The gray clays, like the yellow clays at the top of the Slaughter Pen bluff section, contain thin plates of calcareous matter. The lower clays show several streaks of dark lignitic clay two to eight inches thick. This seems to represent the upper part of Johnson's section.

About two hundred yards south of the section shown in the photograph there is a small but extremely distinct fault in the lignite layer. It is probably due to local earth shocks. The fault shows one rather peculiar feature, the downward displacement of a portion of the lower lignite along the fault line. Normally this should turn up instead of down. Its present shape could be produced by a double movement along the fault line, that is a movement downward and then a movement upward. If the fault at its formation gaped open slightly the layers in the overhanging portion would gradually settle down producing the appearance shown in the figure.

Kansas City, Pittsburg and Gulf Railroad cut south of Cross Lake bridge.—The large cut on the Kansas City, Pittsburg and Gulf Railroad about midway between the Cross lake bridge and the railroad shops shows a very peculiar collection of great rolled clay boulders in a gray and brown sand. Near the northern end of the cut are about eight feet of interstratified orange, yellow, gray and brown sands and chocolate colored clays. The clay strata are quite thin not over two inches thick in any case (layer A, fig. 5). The layer just above this, B, is a very black lignitic clay. As this approaches the fault line it becomes lighter and grades into a brown sand.

This fault only extends half way to the surface. The disturbance along the fault line increases toward the bottom where the layers are much crumpled and broken up. Layer D is made up entirely of grayish yellow sand with thin pastings of blue clay. In this are the large concretionary masses of calcareous sandstone which are so well developed in the first cut to the south and indeed in all the region about Shreveport.

The southern end of the cut is composed of blue clay boulders scattered through a gray and brown sand. These masses of blue clay are rounded and the stratification lines lie in every direction. Some are of large size several measuring 25 by 15 inches. The outer portions of this clay show a rim of yellow clay an inch thick, which has been produced by oxidation. Many of the clay pebbles have coats of iron oxide. Through the mass are often beds of sand, one very noticeable one, G, extends diagonally from the top to the bottom of the cut. Through it are scattered very small clay pebbles.

These blue clay gravels are shown also in some of the cuts between this cut and the lake. They are also exposed in the road side a little east of Jewella.

It is diffcult to conceive the exact conditions under which these large clay bowlder were fashioned out and transported to this place. Vaughan describes an almost identical exposure containing large clay bowlders at Port Caddo, Texas, and concludes that it represents a local unconformity of Eocene age.* If the beds at Slaughter Pen bluff are of Lower Claiborne age the uncon-

* Am. Geol., vol. 16, 1895, pp. 304–308.

formity was formed in the early part of the Lower Claiborne stage. This conclusion is strengthened by a greatly disarranged exposure seen in a railroad cut about four miles south of Many. Here the disturbed material, which contains Lower Claiborne fossils, lies between undisturbed fossiliferous Lower Clairborne beds and fossiliferous Lignitic beds.

Sands.—There are few facts bearing on the age of the upper yellow and red sands about Shreveport and in the absence of the same there seems to be no reason for considering them separate from the lower Tertiary beds. The sand beds are well developed on the Spring tract east of the City park. In the street car cut they are seen underlying horizontally stratified gray clays containing good leaf impressions. Very similar sands are exposed in the Union depot cuts under lignite and gray clay. These sands contain numerous pieces of silicified wood. No gravel of northern origin was seen in any place over the hills.

The ice factory well.—The following letter has been received from Mr. F. J. Lukins of the American Well Works who had charge of the drilling of the deep ice factory well: "I had charge of the deep well that was sunk at Shreveport, but it has been so long ago that we have no record here now as to the different formations. You can perhaps get from local well drillers, the nature of the formation to 450 feet. At that depth we passed through a sand rock formation. It was very fine and not very hard, and contained considerable water. We made a well at the Shreveport Junction in this formation, and got a good supply from that stratum. The sandstone formation was about 50 feet thick. From there to 971 feet, it was a sort of blue clay formation with occasional very hard streaks of thin shelly rock. This rock itself was very thin, perhaps one-half to one inch in thickness, but there would be several layers together, which would make up a thickness of from 6 to 12 in. At one point, I think about 600 feet, we passed through a stratum of pyrites of iron, which was about 14 in. in thickness. We could not tell whether this formation was solid, or whether it was a collection of small pieces packed together. However, I procured one specimen which was spherical in shape, and about one-half inch in diameter, and it appeared from it, that it must be a collection of small pieces that made up the 14 in. stratum. At 961 ft., we penetrated a stratum that contained water. This stratum was 10 ft. in thickness. We could not tell what the formation of this was, as we took out none of the drillings. The water flowed over the top of the well at this point. There was also a discharge of gas from the well that would burn. The water was very strong with salt. I believe this same well was sunk deeper by some other parties after, but what was found below, we do not know."

The temperature of the water is 83 ° F. The gas which Mr. Lukins mentions, is collected and used for lighting the office at the ice factory.

Coushatta bluffs.—The faint casts of *Leda*, *Lucina*, *Nucula*, *and Venericardia* which were found at this bluff, while proving the Eocene age of the material, are not distinctive enough to show exactly the division to which it belongs. The *Ledas* are however nearer the Lower Claiborne forms than either the Midway or Lignitic forms. The section here shown is :

Section, Coushatta bluffs

6. Orange, red, yellow, gray and white sand, stratification generally horizontal, but in places showing cross-bedding. It contains numerous gray clay gravel and a few thin clay layers. Changing above to surface soil .... 20 ft.
5. Black clay with thin gray sand partings below becoming light brown above. Layer about eight inches thick and two feet from the base contains faint casts of *Leda*, *Nucula*, *Lucina and Venericardia* .... 10 ft.
4. Very dark brown laminated clay filled with large iron concretions. The concretions are arranged along three principal lines ; at the base, a double layer about 14 feet from the base and a layer at the top . . 20 ft.
3. Black laminated clay, with crystals of gypsum .... 6 ft.
2. Dark brown sand containing a few thin layers of black clay .... 3 ft.
1. Black laminated sandy clay, showing clay partings and numerous crystals of gypsum, to water level ...... 3 ft.

SLAUGHTER PEN BLUFF, NEAR SHREVEPORT. PAGE 196

Conclusions.—The possible occurrence of Lower Claiborne at Shreveport and of Midway at Albany flats makes the stratigraphy about Shreveport appear much more complicated than had been supposed and it is greatly to be regretted that suits of the samples of the borings of the deep wells in the river bottoms and the deep well at the ice factory have not been saved. It furnishes a flow of warm, artesian water. From this fact it has been supposed that the well has reached the upper part of the Cretaceous.* But it must be confessed that the correlation with the Cretaceous on the basis of salt water furnished is very doubtful. One of the brine springs of Sabine parish, whatever its ultimate source may be, flows from the lower Claiborne strata; the other from presumably Lignitic. It is to be hoped that samples will be saved from future wells.

APPENDIX

A CATALOGUE OF ABORIGINAL WORKS ON CADDO BOTTOMS

N. W. ¼ of S. W. ¼, Sec. 4, 20 N., 14 W.—A small, rudely rectangular platform mound about 25 by 30 feet and 10 feet high. On the north side there is an irregular raised platform two to three feet high. The mound has been opened, with a hole about five feet in diameter, by negroes searching for treasure.

Sec. 5, 19 N., 14 W.—Group of three mounds. They are rudely rectangular, truncated pyramid mounds. The largest is known as "Treasure mound." It is almost square, measuring about 75 feet each way, and is about 16 feet high. It is composed of black, sandy loam like that beneath the veneer of red clay on the surrounding land. An excavation about six feet square has been made on the eastern side and a pot is reported to have been discovered. A small excavation was started on the west side but was abandoned before anything was discovered. About 150 feet south of the mound is a "water-hole." This probably represents the excavation from which the material was obtained for the mound. The top of the mound is covered with

* Lerch. Bull. La. State Expt. Sta.; Geol. and Agr., part II, pp. 117, 1893. The engineer at the ice factory reports that it maintains a constant temperature of 83° the year round. A slight flow of gas accompanies the water which is collected and used for lighting the ice factory.

a growth of white locust and is said to be the only place in the region where it is found. The mound although surrounded by the waters of Sodo lake during the raft period, was not covered. It was used as a place of refuge during the war by persons desirous of escaping the conscription officers.

"Arick's mound," the second of the series, is rudely rectangular, measuring 40 by 50 feet on top, and is 12 feet high.

"Youngblood mound" is 6 feet high and about the same dimensions on top as "Arick's mound."

A fourth elevation, known as "Trezevent mound," is found in the same group. It is very irregular and appears to be simply a natural elevation.

Sec. 21, 22 N., 14 W.—Small conical mound on Red bayou; reported to have been opened.

Sec. 15, 18 N., 14 W.—Mound between the Pass and Twelve Mile bayou. This mound was not visited but is shown on sheet No. 17 of the Red river survey, 1886.

Sec. 2, 21 N., 15 W.—Two mounds, 200 feet in diameter and 15 feet high on Black bayou, reported by Collins to be natural.*

Hale's wood yard.—Artificial mound on top of lower bluff at Hale's wood yard, 100 feet in diameter and seven feet high; reported by Collins.†

Stormy point, Ferry lake.—A cellar dug near the end of Stormy point by Col. S. D. Pitts in 1885, disclosed quite an amount of pottery at a depth of from four and one-half to five feet. One large pot, when found, was full of living ants, evidently attracted there by something the pot contained. A smaller pot was filled with children's bones. An iron tomahawk, two iron rifle barrels and an iron knife about eight inches long were also found.

About 1870 high water washed out the bluff on the southwestern corner of the point and exposed a skeleton. The forehead was covered with a thin highly ornamented piece of silver bent to fit the skull. On the back of the head was a circular piece of silver. These pieces are said to have been analyzed by a local jeweler and pronounced virgin silver. On the shoulders were thin crescent shaped pieces of metal. They were described as

* 43d Cong. 1st Sess., House Ex. Doc., vol. 2, part 2, p. 654.

† *Ibid*, p. 653.

having been coated with green, and are hence inferred to have been copper.

The son-in-law of Larking Edwards, the interpreter and friend of the Caddoes, "Old James Shemick," from whom the place was bought, stated several years before the skeleton was found that the last chief of the Caddoes was buried somewhere in that vicinity.

This point was a favorite place for the collecting of the Caddo Indians when they desired to start for Shreveport. They crossed the lake at Newport point and their trail from there to Shreveport is said to have been quite visible as late as 1860.

A Dictionary of Altitudes in Northern Caddo Parish and Adjacent Portions of Bossier

Introduction.—The most important lines of levels which have been run in this region are those which were made in connection with the Red river and Cypress bayou surveys by the U. S. Engineers under direction of Maj. J. H. Willard. The closure of the line of precise levels, run by the Red River Survey from Coast and Geodetic Survey P. B. M. No. 215 at Delta, La. by way of Shreveport to Coast and Geodetic Survey P. B. M. No. XLV at Smithland, within 22 millimeters* leaves little doubt of the extreme accuracy of the work.

The altitudes given in the following tables and credited to the U. S. E. have been reduced to mean Gulf level from the tables published in the Annual Report of Capt. J. H. Willard for 1893.† A few marked R. R. S. M., have been taken from the maps of the Red River Survey.

The reduction of the altitudes on the profiles of the various railroads centering at Shreveport to Gulf level has been made possible by a connection of the U. S. E. gauge with the city bench mark at the corner of Crockett and Commerce streets by Mr. Cain, city engineer, Nov. 22, 1898. This showed city elevation 7.18 feet equal to zero U. S. E. gauge. Hence zero city elevation equals 132.83 feet mean tide.

* An. Rept. Chief of Eng. for 1893, pp. 1944, 1956.

† An. Rept. Chief of Eng. for 1893, Appendix V. pp. 1953, 1956–57, 1973–74, 1982, 2064, 2080–81, 1893.

A connection of the city levels with the levels of the Kansas City, Pittsburg and Gulf Railroad levels made by Mr. H. DeW. Smith, the company's division engineer, and Mr. Cain showed zero city levels=221.9 feet K. C. P. & G. R. R. levels. Hence zero K. C., P. & G. R. R. levels is 89.07 feet below Gulf level.

ABBREVIATIONS

K. C. P. & G. R. R.—Kansas City, Pittsburg and Gulf Railroad.

R. R. S. M.—Red River Survey Maps.

T. S. & N. R. R.—Texarkana, Shreveport and Natchez Railroad.

T. & P. R. R.—Texas and Pacific Railroad.

U. S. E.—United States Engineers.

Locality	Authority	Elevation
Albany, U. S. E. bench mark	U. S. E.	226.0
Ananias station	K. C. P. & G. R. R.	201.
Arkansas-Louisiana line	K. C. P. & G. R. R.	224.
Bargetown slough, high water 1892	U. S. E.	212.0
Beazley's Landing, bench mark, No. 10.	U. S. E.	190.0
Beckham's branch, K. C. P. & G. R. R. bridge	K. C. P. & G. R. R.	217.
Do bed of branch	K. C. P. & G. R. R.	196.
Black bayou, K. C., P. & G. R. R. bridge	K. C. P. & G. R. R.	201.
Do bed of branch	K. C. P. & G. R. R.	173.
Blanchard	K. C. P. & G. R. R.	226.
Blankton's bluffs: U. S. E. permanent reference point No. 21	U. S. E.	215.0
Blankton's, top of bluff on La.-Ark. line	Barometer	335.
Bossier City, P. R. P., No. 35, yard of Mrs. D. C. Caine	U. S. E.	173.8
Corner plantation, high water 1892	U. S. E.	188 8
Do U. S. E. bench mark, No. 11	U. S. E.	185.4
Coushatta bluffs, P. R P., No, 27	U. S. E.	240.9
Cross lake, south end K. C. P & G. R. R. bridge	K. C. P. & G. R. R.	181.
Cross lake, center K. C. P. & G. R. R. bridge	K. C. P. & G. R. R.	180.
Cross lake, bed of outlet channel	K. C. P. & G. R. R.	152.
Do high water, 1892	K. C. P. & G. R. R.	177.
Elmer's bayou, high water 1892	U. S. E.	203.0
Eric's plantation, bench mark, No. 13.	U. S. E.	183.7
Ferry lake, K. C. P. & G. R. R. bridge.	K. C. P. & G. R. R.	197.
Do K. C. P. & G. R. R., bed of lake	K. C. P. & G. R. R.	155.
Ferry lake, K. C. P. & G. R. R., high water 1892	K. C. P. & G. R. R.	187.
Gilmer landing, bench mark, No. 8	U. S. E.	225.3
Gold Point plantation, bench mark, No. 14	U. S. E.	181.3
Hackedy slough (Sec. 36, T. 22, N., R. 15 W.) *	T. S. &. N. R. R.	174.
Henderson's Mills, bench mark, No. 2.	U. S. E.	251.5
Herndon's landing, bench mark, No. 17.	U. S. E.	177.7
Herndon plantation, per. ref. point, No. 34	U. S. E.	177.9
Highest point on the K. C. P. & G. R. R., between Shreveport and the State line, center N. E. ¼, S. 20, T. 19, N. R. 15 W	K. C. P. & G. R. R.	323.
Holmes bayou, K. C. P. & G. R. R. bridge	K. C. P. & G. R. R.	201.

*This elevation is only a rough approximation. Hackedy's slough in the company's levels is 60 feet: where the survey crossed the road a little west of U. S. E. B. M., No. 10, near Rocky Point, the elevation was 76 feet. This gives an approximate correction of 114 feet (190-76).

Locality	Authority	Elevation
Holmes bayou, bed of bayou	K. C. P. & G. R. R.	186.
Hoss*	T. S. & N. R. R.	249.
Howard bayou, K. C. P. & G. R. R. bridge	K. C. P. & G. R. R.	192.
Howard bayou, bed of bayou	K. C. P. & G. R. R.	182.
Hurricane bluffs, base per. ref. point, No. 29	U. S. E.	194.7
Hurricane bluffs, top per. ref point, No. 30a	U. S. E.	224.8
Irving's bluff, base †	Woodruff survey	184.
Do top of hill south of ferry	Barometer	330.
Jeter landing, bench mark	U. S. E.	200.3
Kountz's canal, high water, 1892	U. S. E.	210.5
Lake Home plantation, per. ref. point, No. 28a	U. S. E.	192.6
Line creek, K. C. P. & G. R. R. bridge	K. C. P. & G. R. R.	202.
Do bed of creek	K. C. P. & G. R. R.	177.
Louisiana-Arkansas line	K. C. P. & G. R. R.	224.
McLaughlin's branch, K. C. P. & G. R. R. bridge	K. C. P. & G. R. R.	216.
McLaughlin's branch, bed of branch	K. C. P. & G. R. R.	192.
Missionary place, high water, 1892	U. S. E.	212.7
Missionary P. O	R. R. S. M.	208.
Mooringsport, bench mark	U. S. E.	186.2
Do K. C. P. & G. R.R. station	K. C. P. & G. R. R.	196.
Do highest point in, on K. C. P. & G. R. R. track	K. C. P. & G. R. R.	202.
Myrtis station	K. C. P. & G. R. R.	209.
Pandora planta. bench mark, No. 15	U. S. E.	184.2
Peru plantation, per. ref. Point, No. 28	U. S. E.	198.5
Poston's bayou, high water, 1892	U. S. E.	208.5
Rodessa	K. C. P. & G. R. R.	227.
Roswell	R. R. S. M.	200.
Rush Point	R. R. S. M.	193.
Do high water, 1892	U. S. E.	194.3
Shreveport, bench mark in Post-Office yard	U. S. E.	198.81
Shreveport, corner Murphey and Texas ave	City engineer	261.0
Shreveport, high water, May 28, 1892	U. S. E.	175.7
Do low water, Nov. 20 1893	U. S. E.	142.6
Do low water, Dec. 1, 1894	U. S. E.	145.4
Do south end of V. S. & P. bridge	City engineer	188.34
Do Texas street and K. C. P. & G. R. R. crossing	K. C. P. & G. R. R.	242.
Do top of corporation stone near K. C. P. & G. R. R. shops	K. C. P. & G. R. R.	247.

* See note under Hackedy's slough.

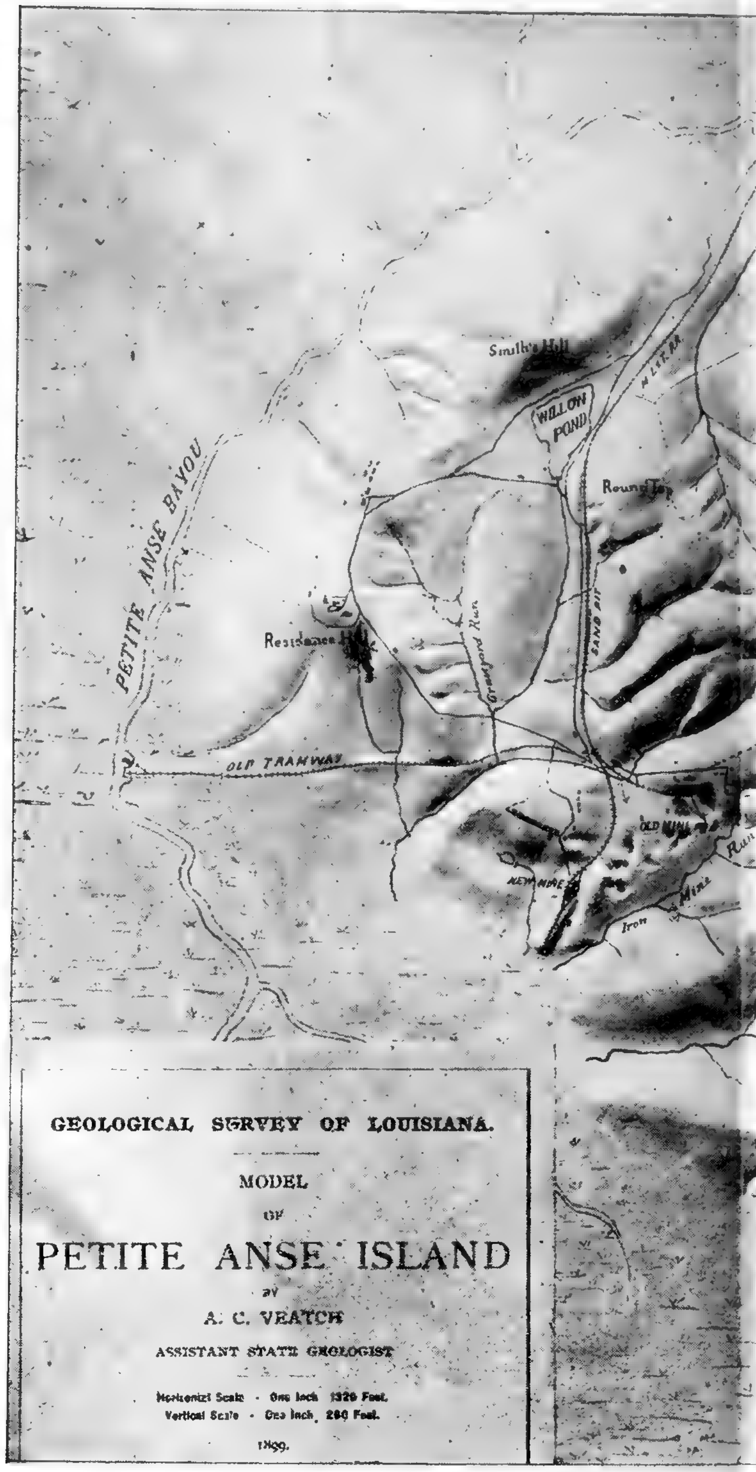
† Obtained by comparison of data shown on Woodruff survey map with Red River survey charts. It therefore represents only an approximation.

Locality	Authority	Elevation
Shreveport V. S. & P. R. R., and K. C. P. & G. R. R. crossing....	K. C. P. & G. R. R.	235.1
Shreveport water-work standpipe, base	City Engineer	266.9
Do zero U. S. E. gauge........	U. S. E.	140.01
Shreveport Junction, T. & P. R. R. bench mark......	T. & P. R. R.	230.28
Slaughter's bayou, K. C. P. & G. R. R. bridge.........................	K. C. P. & G. R. R.	221.
Slaughter's bayou, bed of bayou......	K. C. P. & G. R. R.	199.
Soda Fount plantation, bench mark, No. 12...........	U. S. E.	183.6
Southside plantation, bench mark, No. 16......................	U. S. E.	179.6
Surry P. O..........................	K. C. P. & G. R. R.	205.
Tiger branch, K. C. P. & G. R. R. bridge	K. C. P. & G. R. R.	190.
Tiger branch, bed of branch..........	K. C. P. & G. R. R.	163.
Do high water............	K. C. P. & G. R. R.	188.
Vance's plantation, per. ref. point, No. 31............................	U. S. E.	180.3
Vivian.........	K. C. P. & G. R. R.	249.
Wild Lucia P. O....................	R. R. S. M	195.
Do high water, 1892...... ...	U. S. E.	198.0
Willow Bend place, high water, 1892...	U. S. E.	186.6

U. S. E. BENCH MARKS AND PERMANENT REFERENCE POINTS SHOWN ON SOIL MAP OF UPPER RED RIVER VALLEY.

(The elevations here given are taken from the report of Capt. J. H. Willard for 1893, An. Rept. Chief of Eng. for 1893, Appendix V. The elevations have been reduced to mean Gulf level and are the elevations of the boss of the pipe cap over the bench mark.)

			Feet
P. B.M.	No. 1	Albany Point	226.0
	" 2	Henderson's Mills	251.5
	" 3	Mooringsport	186.2
	" 4	Jeter Landing	200.3
B. M.	" 8	Gilmer's Landing, near Dr. Vance's residence.	225.3
	" 9	Between Cowhide and Horseshoe bayous	193.0
	" 10	Uni Plantation near Irving's bluff road	190.0
	" 11	Corner place on west side of road running south	185.4
	" 12	On back levee north end of Soda Fount Plantation	183.6
	" 13	James Eric place	183.7
	" 14	S. W. corner Gold Point plantation	181.3
	" 15	Levee, Pandora plantation	184.2
	" 16	Back levee between South Side and Cuba plantations	179.6
	" 16a	Cuba plantation between Twelve Mile bayou and the river	178.2
	" 17	Herndon's landing	177.7
P. R. P.	" 21	Blankton's bluffs, 500 feet north of Louisiana-Arkansas line	215.0
	" 22	West bank, 90 feet south of Bargetown slough.	207.9
	" 23	East bank, head of Boom bend	206.6
	" 24	East bank, south side of Alban's canal No. 1 450 feet from the river	204.0
	" 25	East bank, just below Poston's bayou	200.8
	" 26	East bank, between Red river and Dutch John's lake	200.4
	" 27	Top of Coushatta bluff	240.9
	" 28	Back levee between Peru plantation and Dooley's bayou	198.5
	" 28a	Back levee, Lake Home plantation	192 6
	" 29	Hurricane bluffs, upper end	194.7
	" 30a	Top Hurricane bluffs	224.8
	" 31	Vance's plantation, near wind-mill	180.3
	" 32	North side Benoit's bayou	184.7
	" 33	West bank, just above Barr's ferry	175.6
	" 34	Herndon plantation	177.9
	" 35	Bossier City, yard of Mrs. D. C. Caine	173.8
B. M.	" 45	Shreveport, postoffice yard	198.81



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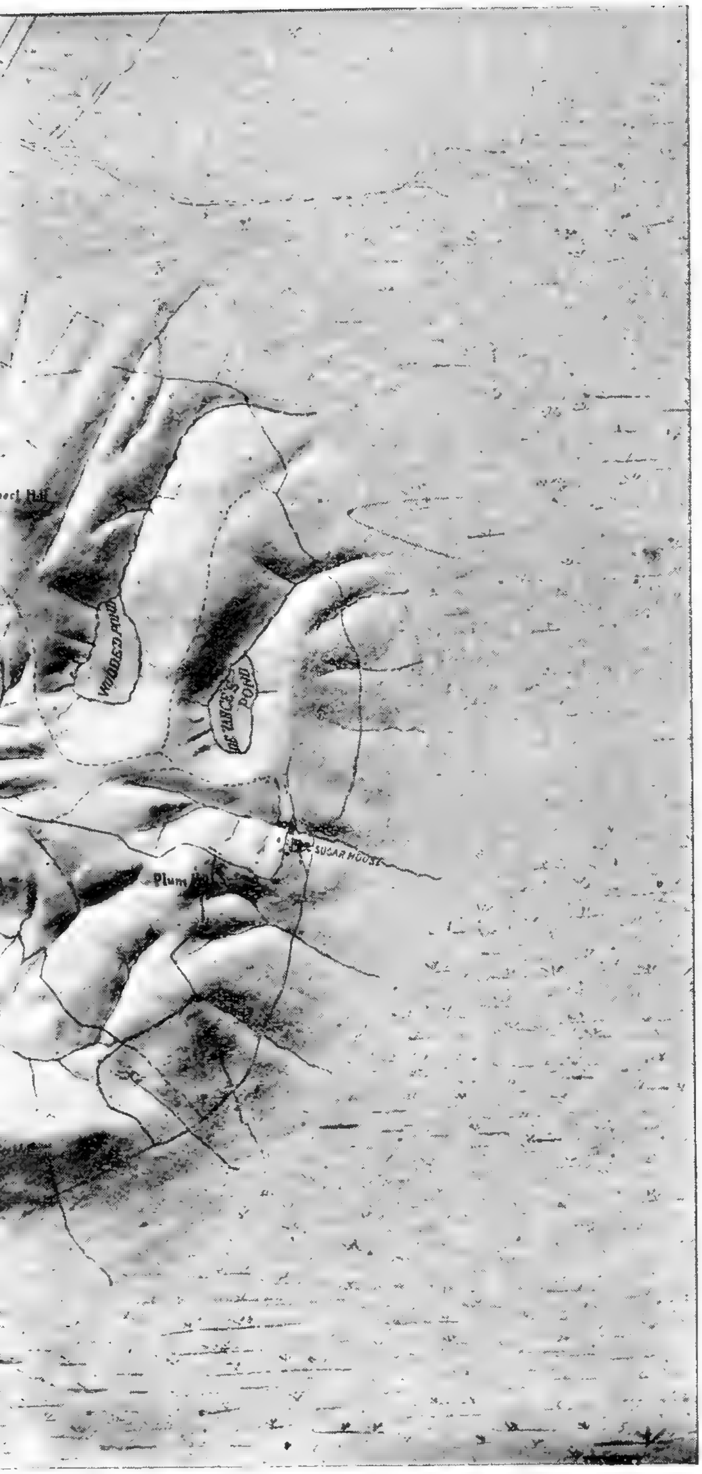
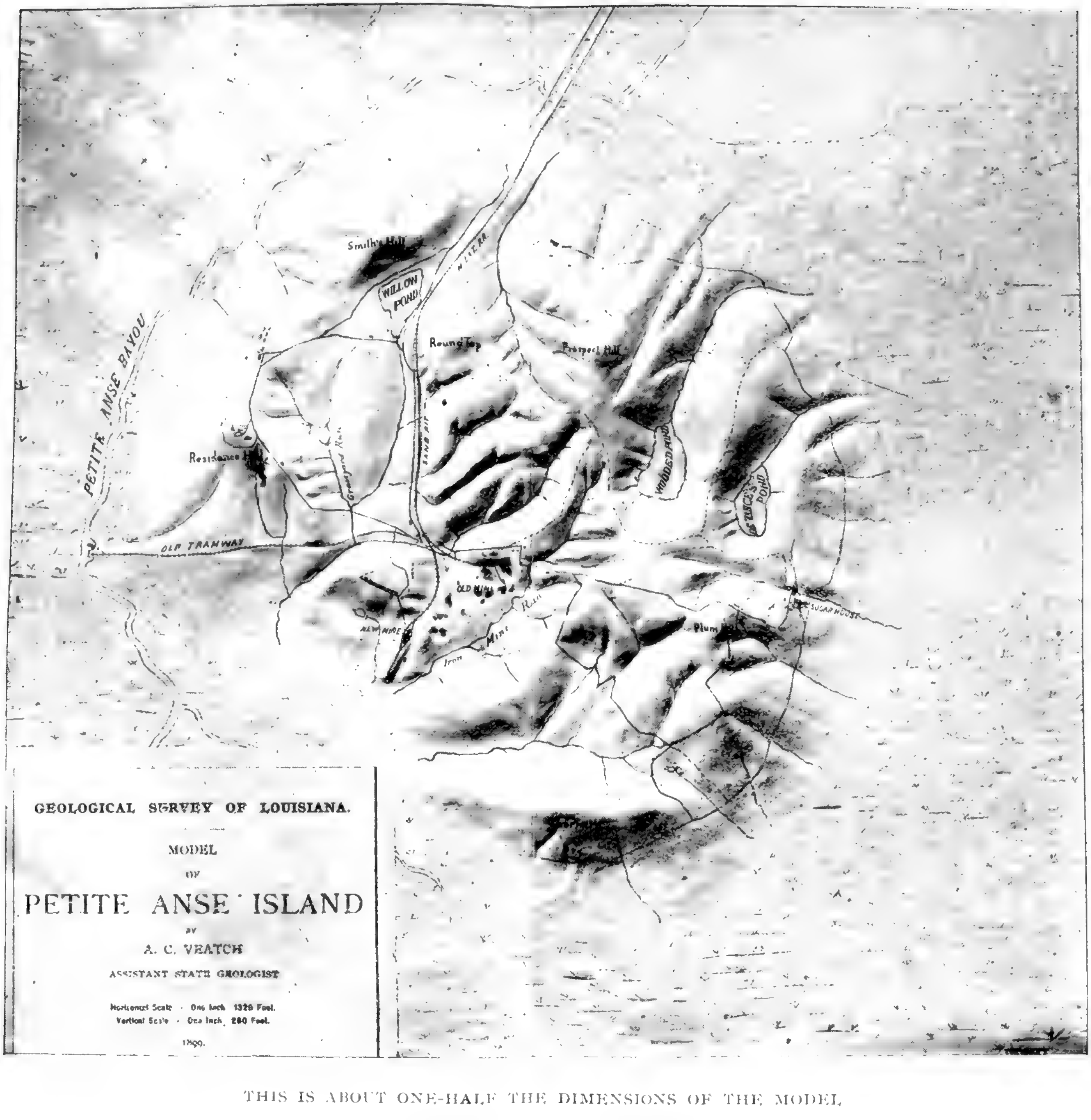


MENSIONS OF THE MODEL



THIS IS ABOUT ONE-HALF THE DIMENSIONS OF THE MODEL

Special Report No. 3

THE FIVE ISLANDS

BY

ARTHUR C. VEATCH

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INTRODUCTION

The writer's visit to the islands.—In view of the recent developments, the writer was directed during the spring of the present year to leave work in northern Louisiana and make an examination of the Five Islands in Iberia and St. Mary parishes.

Mapping of the Islands.—The lack of accurate maps of the islands was immediately noticed and he at once began making a twenty-foot contour map of Petite Anse island. During the work on Grande Côte, in locating the different prospect holes and in determining their elevation above tide, enough facts were collected to make a sketch topographic map of that island. Belle Isle was also mapped. It is regretted that there was no one on Côte Carline (or Jefferson island) who could give information regarding the prospect holes there. It accordingly seemed advisable to postpone the mapping of this island, for its general features are shown on the maps of the other islands, till such data could be obtained.

HISTORY OF THE STUDY OF THE ISLANDS

PERIOD BEFORE THE DISCOVERY OF ROCK SALT

Probably no portion of Louisiana has received more attention from geologists than the central costal region and especially Petite Anse island. The phenomena there shown are of such a character as to attract attention at once.

Stoddard.—Although Maj. Stoddard evidently did not visit any of the islands, their existence was known to him. He speaks of the elevated islands along the coast; "some of which" he assures us, "contain sulphur and one has been known to be on fire for at least three months." To stories of this nature is doubtless to be traced the origin of the name "Fire islands" applied to this group.* He describes Belle Isle as about three miles in

Sketches of Louisiana by Maj. Stoddard, Phila., 1812, pp. 179–180, 184.

*Geology of Lower Louisiana, by E. W. Hilgard, Am. Jour. Sci., 2d Series, vol. 47, p. 86.

circumference, 240 feet high, and situated a few miles west of the mouth of the "Chafalia" river.

Darby.—During or about 1817 William Darby visited Petite Anse. This is, to the best of our knowledge, the first visit of a man of scientific attainments to any of the islands. He was a man of keen insight and may justly be regarded as the first to make geological observations of importance in Louisiana. Darby noticed the marked difference between the flora of the island and that of the surrounding marshes and prairie. The flora he regarded as the same as that on the Opelousas hills and the hills further north. He pointed out the likeness of the salt spring, discovered several years before his visit, to the salt springs of Louisiana north of Red river.* This point was not again noticed until Hilgard's third Louisiana article.† He attributes the islands to a source other than the "revolution affected by alluvion." ‡

Thomassy's first visit.—Thomassy's first visit to Petite Anse was made in 1857.§ Between that time and 1859 he visited all the islands but Belle Isle. He speaks of the salt springs on Petite Anse and traces their origin to masses of rock salt "scattered through the strata." He regards the Five islands and the hills along the Bayou Teche, Bœuf and beyond the Red river as the products of sort of mud, water and gas volcanoes; in a word they are gigantic mud-lumps. They are not of the same age, Côte Blanche being the oldest and the Côte Gelee, Opelousas and Avoylles hills the most recent. They have probably been forming since the middle of the Quaternary.||

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* The Emigrant's Guide to the Western and Southern States of Louisiana, Mississippi, Tennessee, Kentucky, Ohio, etc. With map. By Wm. Darby; New York, 1818, p. 86.

† Summary of Results of a Late Geological Reconnaissance of Louisiana, by E. W. Hilgard. Am. Jour. Sci., 2d Ser., vol. 48, p. 342, 1869.

‡ A Geographical Description of Louisiana by William Darby, 1816, p. 48.

§ Supplement à la Géologie Pratique de la Louisiana. Ile Petite Anse. Geol. Soc. France, Bull., 2d Series, vol. 20, 1863, p. 542.

|| Géologie Pratique de la Louisiana par R. Thomassy. New Orleans, 1860, Chapter VIII, pp. 72–86.

PERIOD SINCE THE DISCOVERY OF ROCK SALT

Thomassy's second visit.—Shortly after the discovery of rock salt (1862) on Petite Anse he again visited the island, and made a more thorough examination of it. On this visit he found besides the original "crater of elevation," which he mentions in his earlier report, three others. His report * on this visit entitles him to the credit of having been the first to bring the discovery of rock salt before the scientific world and of having prepared the first and most accurate sketch map of the topography of the island.

Owen.—The next scientific observer, and the one to whom the credit of having been the first to make a scientific investigation of the island is generally given,† Dr. Richard Owen, visited the island in November, 1865. After a hasty examination he showed that the island is not of volcanic origin; but consists entirely of sedimentary material.‡ The island he considers a dune-like formation made by the combined action of the wind and waves.

Goessmann.—Under the auspices of the American Bureau of Mines, in November, 1866, Dr. Chas. Goessmann, in company with Mr. C. E. Buck, made a careful economic examination of the island and prepared a sketch hacheur map. Goessmann supposes that the rock salt deposit was formed from salt springs rather than sea water, and is of Tertiary origin.§

Hilgard.—The following year Prof. Eugene W. Hilgard, under the direction of the Smithsonian Institution, visited the

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*Supplement à la Géologie Pratique de la Louisiane. Ile Petite Anse: par M. R. Thomassy. Carte. Soc. Géol. de France, Bull., 2d serie, tome 20, pp. 542–544, 1863.

† On the Geology of Lower Louisiana and the Rock Salt Deposit of Petite Anse (abs.). Am. Jour. Sci., 2d series, vol. 47, p. 77, 1869, by E. W. Hilgard.

Ibid.—Smithsonian Contr., vol. 23, separate No. 248, p. 1, 1872.

‡ On the Rock Salt at New Iberia, Louisiana by Prof. Richard Owen, Trans. Acad. Sci., St. Louis, vol. 2, pp. 250–252, 1868.

Ibid.—Am. Jour. Sci., 2d series, vol. 42, pp. 120–123, 1868.

§ On the Rock Salt Deposit of the Petite Anse, Louisiana, Salt Company. Report of American Bureau of Mines by Chas. Goessmann, New York, 1867.

three central islands. The results of his investigations are embodied in a number of articles.*

Before his reconnaissance of western and northwestern Louisiana in May and June, 1869, he considered the rock salt as having been formed by evaporation in a lagoon or series of lagoons and as resting in a bed of marine clay similar to that found at New Orleans and Bayou Sale (since correlated with the Port Hudson) and of similar early Quaternary age, anterior to the Orange Sand. During the Orange Sand and Port Hudson deposition the western part of the Mississippi valley was filled to a height equal to if not exceeding that of the highest hills of the islands and in the subsequent erosion of the valley by the Mississippi river these islands were formed by the accidents of differential erosion.‡

In November, 1869, Hilgard first advanced the theory of the "back-bone" of Louisiana. This theory he re-affirms in his

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* Preliminary Report of a Geological Reconnaissance of Louisiana New Orleans, 1869.

—— De Bow's Review, vol. 37–38, pp. 754–768.

Geology of Lower Louisiana and the Rock Salt Deposits of Petite

—— Anse. Am. Jour. Sci., 2d series, vol. 47, pp. 77–88, 1869.

—— Am. Assn. Adv. Sci., Proc., vol. 17, pp. 327–340, 1869.

—— Abstract, Neues Jahrbuch, 1873, pp. 553–554, 1874.

On the Geological History of the Gulf of Mexico.

—— Am. Jour. Sci., 3d series, vol. 2, p. 393, 1871.

—— Am. Assn. Adv. Sci., Proc., vol. 20, 1871.

—— La. State Univ., Report of Supt. for 1871, pp. 207–222, New Orleans, 1872.

—— Am. Nat., vol. 5, pp. 514–518, 1871.

(Remarks on the Age of the Rock Salt of Petite Anse.)
Am. Nat., vol. 5, pp. 523–524, 1871.

On the Geology of Lower Louisiana and the Rock Salt Deposits of Petite Anse Island.
Smith. Contr., vol. 23, separate No. 248, Washington, 1872.

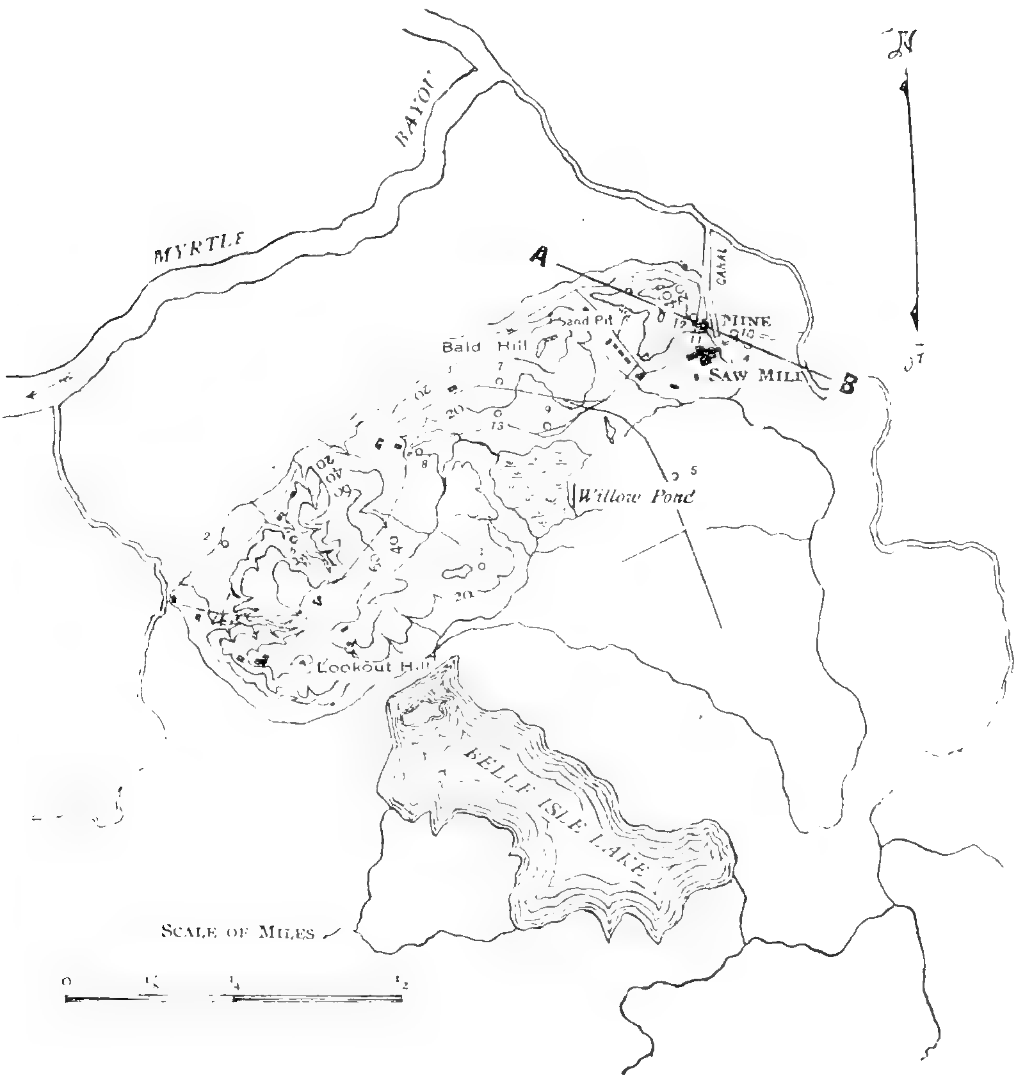
The Salines of Louisiana.
Mineral Resources of the U. S. for 1882, pp. 558–565, Wash., 1883.

Physico-geographical and agricultural features of the State of Louisiana.
Tenth Census U. S., vol. 5, p. 112.

† On the Geology of Lower Louisiana and the Rock Salt of Petite Anse by Eugene W. Hilgard, Am. Jour. Sci., 2d series, vol. 47, p. 84, 1869.

‡ Ibid, p. 88.

JOHN MARSH AVERY, DISCOVERER OF ROCK SALT



Topographic Map of Belle Isle

By A. C. Veatch

later articles. According to this, the Five Islands are but the erosion-formed outliers of a Cretaceous ridge or backbone which traverses Louisiana from its northwest corner in the direction of Vermillion bay; the salt being of Cretaceous rather than early Quaternary age. He thinks that at the beginning of Tertiary time the existence of the axis of elevation was marked merely by a number of disconnected islands.* In later geological times the five outcrops were buried under deposits of Orange Sand and Port Hudson material, as indeed was the whole Mississippi valley, and in the re-excavation of the valley by the Mississippi the material covering the Cretaceous nuclei was not eroded so much as that of the surrounding country, thus forming the islands.†

Closely following Hilgard came Lockett of the Louisiana State University.

Lockett.—Col. Lockett visited the islands in 1870. He considered them as merely a prolongation of the Côte Gelée, Carencro, Grande Coteau and Opelousas hills; the whole at one time forming a great natural levee along the shore of a vast estuary occupying the present Mississippi valley. During a great flood a series of mighty crevasses were made in this levee, thus forming the islands.‡

Hopkins.—So far as we are aware Hopkins did not visit the Five Islands, certainly not during the time spent in collecting material for his first three reports. His idea of the structure and relations of the islands to the surrounding terranes is shown in his cross-section of the State republished in the general discussion of the Cretaceous (p. 33).

Rapley.—In 1884, in the preparation of an article on the "Soils and Products of Southwestern Louisiana" for the U. S. Department of Agriculture Mr. E. E. Rapley visited Petite Anse

* Geological History of the Gulf of Mexico by E. W. Hilgard, Am. Jour. Sci., 3d Series, vol. 2, pp. 393, 871.

† Ibid, p. 404.

‡ Second Annual Report of the Topographical Survey of Louisiana, by Samuel H. Lockett. Louisiana State University, Report of Supt. for 1870, pp. 16-26, New Orleans, 1871.

and Côte Blanche. He gives a short account of the mining methods on Petite Anse.*

Pomeroy.—Pomeroy's report on the islands is confined to a discussion of the methods of mining salt on Petite Anse.†

Bolton.—Early in 1888 Dr. H. Carrington Bolton read a paper before the New York Academy of Science on the "Great Salt Deposits of Petite Anse." He mentions the occurrence of lignite and sandstone north of the shaft in Iron Mine run and concludes from the direction (S. E.) of the dip that it must pass beneath the salt. The black bands in the salt, he states, contain about seven per cent. of insoluble matter chiefly gypsum and form well marked folds, from which he concludes that at some time the salt has been submitted to lateral pressure.‡

Joor.—The discovery of numerous vertebrate remains on Petite Anse in an attempt to sink a shaft in 1890 was the occasion of a visit to the island by Dr. Joseph F. Joor of New Orleans.§

Lerch and Vaughan.—Although neither Lerch nor Vaughan visited the Five Islands their diametrically opposite views on the origin of the various Cretaceous outcrops in the State, based on observations in northern Louisiana early in the present decade, are of interest here. Lerch holds || that they represent the peaks

* Bull. U. S. Dept. Agr. The Soils and Products of Southwestern Louisiana, including the parishes of Saint Landry, LaFayette, Vermillion, Saint Martin's, Iberia and Saint Mary's (by E. E. Rapley) Washington, Government Printing Office, 1884, pp. 36-40.

† The Petite Anse Salt Mine, by Richard A. Pomeroy. Eng. and Mining Journal, vol. 46, pp. 280-281, 1888.

Sci. Amer. Suppl., vol. 26, pp. 10719-10720, No. 671, 1888.

Am. Inst. Mining Eng., Trans., vol. 17, pp. 107-113, 1889.

‡ The Great Salt Deposits of Petite Anse by H. Carrington Bolton, New York Acad. Sci., Trans., vol. 7, pp. 122-127, 1888. The Great Salt Deposits of Petite Anse, Louisiana, by H Carrington Bolton.

New York Acad. Sci. Trans., vol. 7, pp. 122-127, 1888.

Sci. Am., Supp. vol. 26, pp. 10475-10476, No. 656, 1888.

Am. Nat. vol. 20, p. 1074, 1886.

§ Notes on a Collection of Archeological and Geological Specimens Collected in a Trip to Avery's Island (Petite Anse), Feb. 1st, 1890, by Joseph F. Joor, M. D., Am. Nat., vol. 29, pp. 394-398, 1895.

|| A Preliminary Report of the Hills of Louisiana South of the V. S. & P. R. R. to Alexandria, La., by Otto Lerch. Bull. State Expt. Station, La., Part II, p. 72, Baton Rouge, 1892.

of the great mountain chain made of fractured, faulted and folded strata; while Vaughan thinks that they owe their origin entirely to erosion in pre-Eocene time.*

Clendenin.—W. W. Clendenin, formerly geologist to the State Experiment Station, visited all the islands during 1895. He concludes that the foundation of these islands is Cretaceous and that the Cretaceous ridge, of which the islands are remnants, owes its origin to differential elevation in pre-Lafayette time; which differential elevation was continued in the later part of the Lafayette; but that the present aspect of the islands is due to the interruption of this ridge by erosion, which began immediately after the initial elevation and was most active during the early part of the Columbia period.†

Lucas.—The latest published observation on the islands are by Capt. A. F. Lucas, at one time superintendent and manager of the Avery Mine and in charge of most of the borings on Côte Carline, Côte Blanche and Belle Isle. He gives abstracts of the Côte Carline Island borings ‡ and records the discovery of salt on Grande Côte and Belle Island.§ He states that the salt is of Tertiary age but gives no reasons for believing it such.

GEOGRAPHICAL POSITION AND GENERAL TOPOGRAPHICAL FEATURES OF THE ISLANDS

GEOGRAPHICAL POSITION

Location.—Reference to the geological map of the State will show five elevations along a line bearing S. 49° E. and running from Lake Peigneur, half way between New Iberia and Abbeville, to the mouth of the Atchafalya river. Only one, the second,

*A Brief Contribution to the Geology and Paleontology of Northwestern Louisiana by T. Wayland Vaughan, U. S. Geol. Survey, Bull. No. 142, p. 15, 1896.

† A Preliminary Report on the Florida Parishes of East Louisiana and the Bluff, Prairie and Hill Lands of Southwest Louisiana by W. W. Clendenin, La., State Expt. Station Bull. Geology and Agriculture Part III, pp. 239-240, 1896.

‡ The Avery Salt Mine and the Joseph Jefferson Salt Deposit, Louisiana, by A. F. Lucas, Eng. and Mining Jour., vol. 62, pp. 463-464, 1896.

§ Louisiana Salt Resources by A. F. Lucas. Am. Manuf., vol. 63, pp. 910-911, 1898.

is on the sea-coast. The others range from an eighth of a mile, in the case of the central elevation, to at least eight miles in the case of the one at the extreme northwest end of the series. All face on one side at least, the waters of a bayou or lake.

Surrounding country.—The lower four are entirely surrounded by a great sea marsh, much of which during extremely high tides, occasioned by strong south winds, is covered with water. The upper one rises abruptly from a very level prairie. In order, from the most southeastern, they are Belle Isle, Côte Blanche, Grand Côte, Petite Anse and Côte Carline.

GENERAL TOPOGRAPHY

Island-like character of the hills.—It will be readily seen that in the ordinary sense these are not islands, but there is very little difficulty in seeing why the lower four were called such. The isolated, island-like character of these groups of hills ; their separation from the main land by impassible sea marsh and cypress swamp ; the fact that they offer to man a place for houses and fields and the surrounding land does not ; all tend to make the resemblance of these isolated clusters of hills to ordinary islands very marked indeed. The term would then naturally attach itself to the analogous group of hills, Côte Carline, rising abruptly out of the prairie.

Area.—The largest island, Grande Côte, is an irregular circle a trifle over two miles in diameter ; the longest, Petite Anse, has an extreme length of about two and three-eighths miles. The former has an area of a little less than 2,000 acres ; Côte Carline, the smallest, has only about 300 acres.*

Elevation.—While an elevation of 75 feet, the elevation of the highest hill on Côte Carline, or even twice as much, the elevation of Prospect hill Petite Anse, in some regions would be a very insignificant feature indeed, hills of this size rising abruptly out of the perfectly flat sea marsh attract attention at once.†

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* Lucas. Am. Manuf., vol. 63, p. 910. 1898.

† Both the areas and the altitudes have been the subjects of a great variety of statements, by different authors. Many are merely estimates. Some, in the case of land areas, are based upon deeds which describe land situated not only on the island but in the surrounding marshes. Thus the area of

BELLE ISLE

LOCATION

Geographical surroundings.—Near the mouth of Myrtle bayou, one of the distributaries of the Atchafalya and about eight miles from the mouth of that river, surrounded by a network of bayous and impassible sea marsh is Belle Isle.

Myrtle bayou is a quarter of a mile from the islands but two little deep bayous pass along the island, one on the eastern and one on the western side. On the south is a small shallow lake, Belle Isle lake, about half a mile long and a quarter as broad, with a tiny little marshy island near the northern end; and a mile over the marshes is the shore of Atchafalaya bay, an arm of the Gulf. (See plate 21.)

TOPOGRAPHY

Shape and area.—The general shape and immediate surroundings of Belle Isle are shown on the topographical map of the island (Pl. 21). The island, that is, the portion above the sea marsh, has an area of 360 acres, barely half of which is now in cultivation.

Position of the hills.—The island is a rudely triangular area with a single range of hills along its north-west side. This range shows four peaks. The highest, "Lookout hill," on the

Côte Carline is given in one place as 300 acres and in another 9,000 acres. Most of the elevations are based on barometric readings, though some are merely guesses. Belle Isle is given as more than 200 feet high by Maj. Stoddard (Sketches of Louisiana, Phila. 1812, p. 179); 85 feet by Hilgard (Mineral Resources of the U. S. for 1882, p. 558); and 125 by Clendenin (Bull. La. State Expt. Stations, 1896. On the Florida Parishes, etc., p.240). It is regretted that on account of lack of time and instruments it was impossible to do exact leveling this year, but it is believed that the results obtained in altitudes are accurate to within five feet. Leveling was done with a Locke's hand level, all levels being run at least twice from different points on the nearest bayou, and repeated if the results showed a discrepancy greater than five feet. Locations were made with a 3½ inch, open sight, Keuffel & Esser compass. While great precision is impossible with these instruments, it is believed that the results will advance our knowledge at least one step toward a satisfactory degree of refinement.

westernmost point of the island is 80 feet high. It derives its name from the U. S. Coast and Geodetic triangulation platform on its summit. The second, "Green Tree hill," is merely a spur of Lookout hill. Near the giant live oak on one side of its summit is a bit of crumbling masonry which is pointed out as the ruins of the chimney of the house of Lafitte, the pirate. Around it many holes have been dug in a fruitless search for hidden treasure. "Bald hill," 67 feet high, and the Shaft hill, 51 feet high near the northeastern point of the island complete the range. The rest of the island is a gently sloping, slightly elevated ridge which extends south-east from the hills. Willow pond, almost in the center of the island is a shallow, wooded, fresh water pond.

HISTORY OF MINING OPERATIONS

Discovery of salt.—The accidental discovery of rock salt in an artesian boring on Côte Carline, and the ever increasing difficulty of mining salt on Petite Anse, due to water in the mine, caused systematic explorations for salt to be begun on the other islands.

In November, 1896, Capt. A. F. Lucas undertook, at his own expense, to find salt on Belle Isle. In December he discovered salt in hole No. 1 at a depth of 373 feet.* In 1897 and 1898 the Gulf company bored additional holes and in August started a shaft on the site of hole No. 11 where the salt was found within 103 feet of the surface.

Present work.—With the beginning of work on the shaft the Gulf company put up a large saw-mill plant and has with it cut all the timber for its buildings. To the saw mill has been added a small machine-shop and a barrel-factory. To facilitate transportation a short canal has been dug from Myrtle bayou along the eastern side of the island. At the time of the writer's visit, it had reached the southern end of the shaft building and it was proposed to extend it past the saw-mill to the site of the evaporating plant and storehouse.

Wax and Doctor's bayous give deep water communication with the Atchafalya and the Atchafalya afford a fair depth of water both to the Mississippi and to the Gulf.

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* Letter from Capt. A. F. Lucas.

It is proposed besides mining the rock salt to make a fine grade of table salt by artificial evaporation and to that end a large plant is to be erected south of the saw-mill.

The company has purchased a tug and two steamboats and with the construction of the floating elevators it proposes to build, will soon become a very active factor in the salt market

GEOLOGY

Surface geology.—With the exception of a little area on the eastern side of Shaft hill the whole island is covered with grayish yellow to yellowish brown clay. The clay is particularly well developed on the western part of the island. Southeast of Willow pond quite a number of springs ooze out of the ground. This patch of ground though well elevated above the sea marsh is covered with salt grasses. A spring which was situated south of the Shaft house, where the saw-mill now stands was regarded with high faver by the inhabitants on account of a medicinal oil which it produced.

On the eastern slope of Shaft hill are small outcrops of a gray, iron stained, rather soft, broken, barytic limestone, which occasionally shows galena and chalcopyrite. This is doubtless the crumbled or shattered limestone which Thomassy mentions* and which Hilgard correlated with the Côte Blanche concretions.† It is evidently quite different from the concretions. This limestone is well exposed in a number of pits dug several years ago by the U. S. Engineers in an attempt to find stone suitable for jetty work. Near by, sand and gravel come to the surface. The gravel has been dug for concrete work around the works.

The sand pit fossils.—About 150 yards from this outcrop a sand pit shows a very interesting section, with fossils. The material dips about 23°, north 15° west.

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* Géologie Pratique, p. 80.

† Am. Jour. Sci., 2d Series, vol. 47, p. 85, 1869; Smith. Contr., vol. 23, separate No. 248, p. 20, 1892.

Sand Pit Section.

(Elevation of top of section 22 feet A. T.)

		Feet	In
1.	Surface soil. Dark humus stained clay	0	6
2.	Mottled gray to yellowish brown clay	2	6
3.	Mottled gray and brown clay grading below into finely laminated gray clay	4–7	0
4.	Massive dark gray clay	1	0
5.	Black clay with iron pyrite	1–3	0
6.	Black shell conglomerate	0	8
7.	Irregular bedded brown to white sand with clay pockets and traces of sulphur	2–5	0

The fossils in layer 6 are very poorly preserved but so far as they can be identified indicate a cold water fauna different from the warm water fauna of the Pliocene. All species seem to be represented on the Gulf coast to-day and we are inclined to regard it as Pleistocene although it approaches some phases of the Chesapeake Miocene rather closely. The following is a list of species:

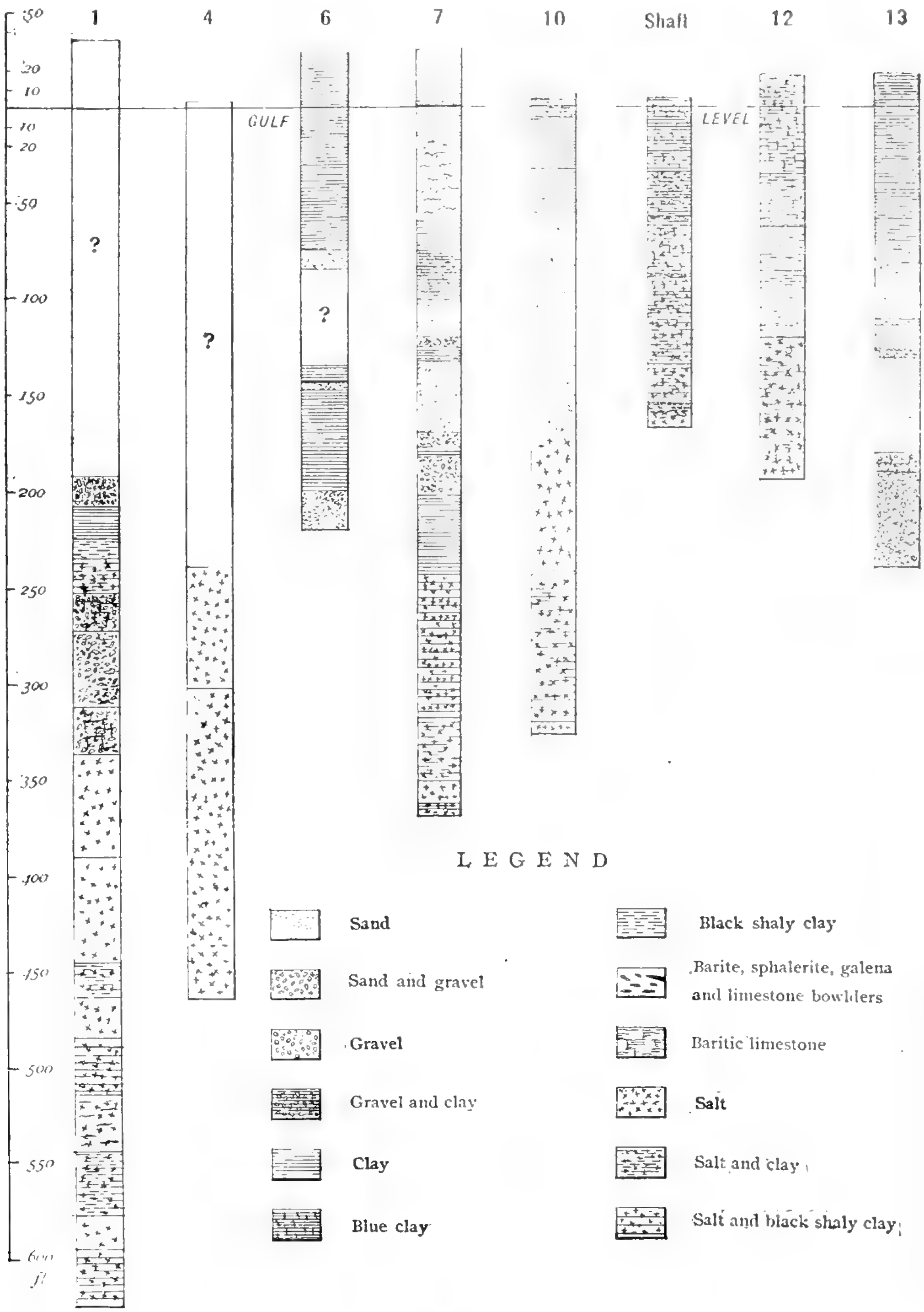
Ostrea virginica,
Lithopaga, cf. *caudigera*,
Scapharca transversa,
Gnathodon cuneatus,
Dosinia sp.
Cardium muricatum,
Corbula sp.
Mactra sp.
Lucina sp.
Venus cancellata,
Semele truncata,
Fulgur canaliculatum.

The wells.—A fairly complete idea of the substructure of the island may be gained from the records of the thirteen holes drilled on the island. Eight of these are given on the adjoining (Plate 22).* In hole number 10 gas was struck at a depth of

*All the facts we possess regarding the other five holes are as follows:

2. Quicksand 400 feet.
3. Salt at a depth of 276 feet.
5. 200 feet deep. No salt.
8. Sand 175 feet. No salt.
9. 0–248. No record 248 feet.
   248–500. Salt 252 feet.
   500–748. Salt crystals 248 feet.

The records of all the sections shown on Plate 22 and also hole No. 9 were obtained from Mr. C. B. Weiser of the Gulf company. The others are from Capt. A. F. Lucas, who supterintended the drilling.



Belle Isle Well Sections

GALENA
(Belle Isle)

CRYSTALLINE SALT
(Petite Anse)

SPHALERITE
(Belle Isle)

ROCK SALT
(Belle Isle)

IMPURE ROCK SALT
(Belle Isle)

120 feet in sufficient quantities to throw sand all over the derrick. It is now bubbling out the hole where it can be easily collected and ignited. A small amount of gas and oil was struck in hole number four. The last three are probably of greater interest than the others.

Section at the shaft.—The shaft was sunk on the site of hole 11 so we can feel quite sure of the material there.

Shaft

(Elevation above tide 7 feet)

No.	Depths		Feet	In.
1.	0– 4	Clay	4	0
2.	4– 13	Hard sand	9	0
3.	13– 30	Blue clay	17	0
4.	30– 40	Blue clay and sand	10	0
5.	40– 63	Hard clay and gravel	23	0
6.	63– 68	Blue clay with crystalline masses, from the size of marble to a man's head, of baryte, galena, sphalerite, pyrite and chalcopyrite	5	0
7.	68– 95	Blue clay and shells	27	0
8.	95– 96½	Rock. Impure black limestone and baryte	1	6
9.	96½–103	Blue clay with masses of baryte near the base	6	6
10.	103–116	Dark colored clay with large salt crystals	14	0
11.	116–117	Dark colored clay with oil	1	0
12.	117–142	Salt with dark colored clay	25	0
13.	142–162	Discolored salt	35	0
14.	162–163	White limestone	0	8
15.	163–175*	Dirty salt becoming white	12	0

Galena from shaft.—The occurrence of galena and associated minerals here is even more surprising than the occurrence of rock salt. It adds another locality to the lead deposits of the Mississippi valley. The crystals are all sharp and show no signs of

*This was the depth of the shaft at the time of the writer's departure, May 19, 1899.

erosion. (See Plate 23.) Numerous pieces were scattered over the dump at the time of the writer's visit.

Dr. A. C. Gill, of Cornell University, who has very kindly examined and identified the specimens collected, states that the galena shows no silver, which is common in vein deposits, and that it therefore seems more probable that this represents a deposition from sea water by chemical action. The manner of occurrence, scattered through a bed of blue clay, strongly emphasizes this conclusion.

Numerous finds of galena are reported from different parts of the State especially in the northern parishes. These when looked into, have always shown that the lead was not *in situ* but had, without a reasonable doubt, been carried there by the Indians. Such an explanation will not apply to this deposit.

Salt.—The salt occurs in several forms; large transparent crystals one to eight or more inches long, either in masses, where interference has prevented the formation of perfect crystals or scattered through dark colored clay, as in the upper part of the salt mass; smaller crystals in masses having the appearance of rather coarse crushed ice or inclosing pieces of dark colored clay which gives the salt a dirty earth-like appearance. Occasionally the large salt crystals show crystals of gypsum.

Unlike any of the other islands the salt when first struck on Belle Isle is very impure; its purity seeming to increase with the depth. The black material which is abundant enough in the upper part of the salt to color the whole mass and which shows some traces of oil, brings to mind the thin black bands in the Petite Anse salt. The resemblance is further heightened by the fact that the black salt on Petite Anse shows about seven per cent. of insoluble matter, part of which is gypsum* and the Belle Isle black salt shows about the same amount of insoluble matter, part of which, although a much smaller part, is gypsum.

Analyses of salt.—Two samples of salt from Belle Isle have been analyzed under direction of Mr. R. E. Blouin of the Experiment Stations. To these records we have added for the purpose of comparison three analyses of salt produced by evaporation of sea water.

*Notes on the Great Salt Deposit of Petite Anse, Louisiana (Abstract) by Dr. H. C. Bolton. New York Acad. Sci. Trans., vol. 6, p. 125, 1888.

Analyses of Salt.

	Black salt Belle Isle Layer 12 (120 ft.)	White salt Belle Isle (175 ft.)	Setubal or St. Ubes, Portugal (Henry).	Turk's Island, West Indies (Cook).	Martha's Vineyard, Mass. (Goessmann).
Sodium chloride	92.750	96.405	96.00	96.76	94.71
Calcium sulphate	——	3.051	2.35	1.56	1.42
Magnesium chloride	——	.074	.30	.14	.24
Magnesium sulphate	——	——	.45	.64	.19
Magnesium carbonate	.201	——	——	——	——
Sodium carbonate	.067	——	——	——	——
Sodium sulphate	.837	——	——	——	——
Calcium carbonate	1.804	——	——	——	——
Calcium chloride	——	.226	——	——	——
Ferric and Aluminic Oxides (Fe_2O_3 and Al_2O_3)	.500	.025	——	——	——
Water	——	——	——	.90	3.24
Insoluble matter	3.325	.059	.90	——	——

These analyses show a marked difference between the black and white salt of Belle Isle and a close similarity between the white salt and salt obtained from sea water by evaporation.

Limestone in salt.—The white chalk-like limestone, eight inches thick struck 74 feet below the top of the salt shows no traces of organic remains. It is composed of extremely small globular grains, like an oölite, only the grains are much smaller. The presence of a limestone of this type in the midst of a salt deposit possibly indicates a continental movement of considerable magnitude during the deposition of the salt.

Section of hole No. 12. About 150 yards northwest of the shaft and near the old U. S. Engineers pits in hole 12. It is ten feet higher than the shaft.

Hole No. 12.

No.	Depths		Feet
1.	0– 12	Clay and sandy barytic limestone	12
2.	12– 21	Blue clay	9
3.	21– 53	Blue clay with indurate dark colored clay	32
4.	53– 80	Dark colored clay	27
5.	80–103	Dark colored clay with hard bands	33
6.	103–130	Dark colored clay	21
7.	130–131	Hard bowlder (probably similar to 6 of the shaft section)	1
8.	131–138	Dark colored clay	7
9.	138–213	Salt with dark colored clay	75

Section of hole No. 13.—Fossils were found in two layers of hole No. 13 which was sunk a short distance north of Willow pond.

Section of Hole No. 13.

No.	Depths		Feet
1.	0–100	Clay	100
2.	100–130	Sand	30
3.	130–135	Clay and shells	5
4.	135–145	Sand	10
5.	145–150	Hard clay and shells	5
6.	150–200	Sand	50
7.	200–216	Very hard gravel	16
8.	216–260	Hard sand and gravel	54

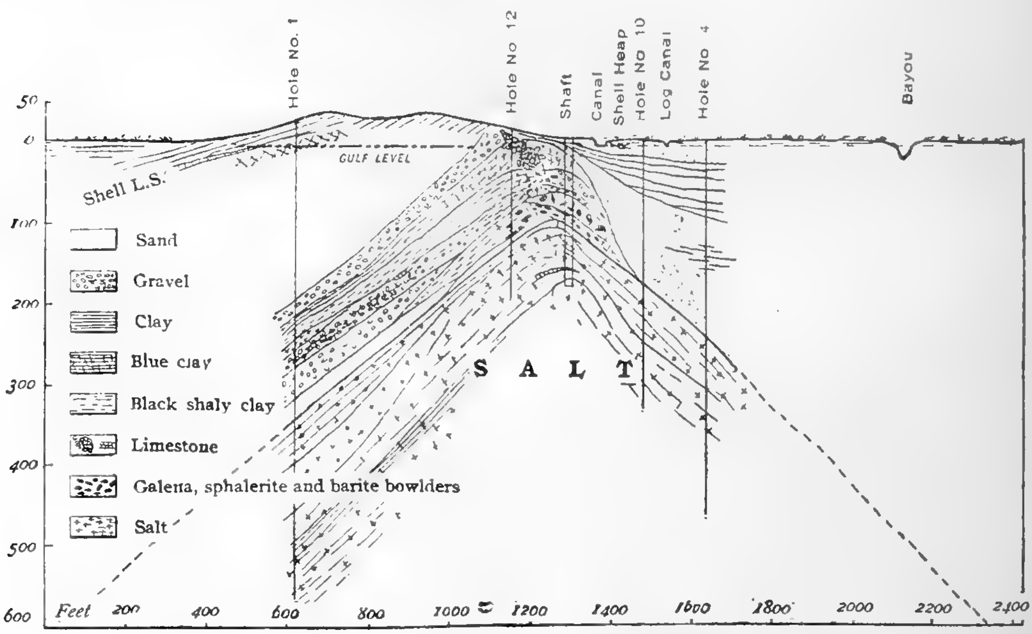


FIG. 6—*Section cross Belle Isle, along line A-B, pl. 20.*

Conclusions.—All the data collected, while throwing little or no light on the age of the salt deposit and further complicating the questions involved by the introduction of a deposit of galena, baryte and sphalerite have afforded rather satisfactory evidence on the manner of the formation of Belle Isle. A map showing the contour of the salt, constructed on data furnished by the drill holes, shows an oblong dome-shaped mass, longest along its northeast and southwest axis, having just the same trend as the hills; but differing from the hills in the fact that the dome of the salt is situated on the northeast of the island. (See plate 24.)

The shaft shows clearly that this dome shape is due to uplift and not erosion. When the salt was first struck in the shaft it was in the form of a distinct anticline and although the shaft has not followed the dome of the anticline exactly, it being now on one side of the shaft and now on the other, its presence was always clearly indicated. A cross-section of the island from A-B, Plate 21, made by connecting the data furnished by the shaft, the different wells along the line of the section, and the surface outcrops show a very distinct anticline, or better, elongated dome (Fig. 6). It is interesting to note the similarity of the dip of the shell layer and that of the salt. This would seem to fix the time of uplift. The shells are all species now living in the Gulf. They may be regarded as representing the marine facies of the Port Hudson of Hilgard. This would indicate that in very recent time the Gulf coast has been the scene of crustal movements.

ARCHEOLOGY

Shell heap.—Excavations for a canal near the shaft on the northeastern corner of the island, have revealed just in the edge of the present sea-marsh and covered by from one to three feet of its deposits a kitchen-midden or kitchen refuse heap composed of shells of *Gnathodon cuneatus*, *Ostrea virginica*, an occasional representative of the *Unionidæ* and vertebrate remains. As exposed along the side of the canal the heap is 150 to 200 feet long and three feet thick. A human skeleton was taken out near the northern end.

The most interesting feature of the shell heap are the numerous little baked clay objects found scattered through it. Fragments of pottery are relatively scarce. These little objects average about two inches in diameter. A common form has the shape of two cones placed base to base. This pattern is varied by making four indentations around its equator. Others are irregular spheres with four elongated indentations about them medially. The way they fit in the hand and their shape would suggest that they were used in playing some game.

The location of the mound on the edge of the marsh and not on the island or the edge of some bayou and its being covered with marsh deposits, would seem to indicate that the subsidence which has been progressing on the Gulf coast for the last period is still going on at a fairly rapid rate.

CÔTE BLANCHE

LOCATION AND TOPOGRAPHY

Location.—Although not the central island, Côte Blanche, or "Cap Blanche" of the early Spanish cartographers, occupies the geographical center of the Five Islands. It is near the center of the north shore of Côte Blanche bay in township 15 south, range 5 east. Access is had to the island by means of a raised dirt-way leading through the marsh from the land of Cypremort point.

Topography.—Côte Blanche is nearly circular and in point of size is the third of the islands, having an area of 1400 acres. On one side the waves of Côte Blanche bay have formed a bluff about fifty feet high. To this wave-formed bluff is probably due the early appearance of this island on the Spanish maps. It is much less rugged than either Petite Anse or Grande Côte. The deep V-shaped hollows of the centers of those two islands are entirely wanting here. On the south side, east of the bluff, a long arm of sea-marsh runs up into the island. Rising abruptly from this is Oak hill the highest hill on the island.* North of Oak hill is a shallow depression in the tops of the hills which was pointed out as the bed of Clear lake. Time was when this was a small pond something like 300 feet in diameter and 3 feet deep. This is the only trace of a natural pond on Côte Blanche.

GEOLOGY

Salt investigations.—The recent salt excitement which has caused the deposits of the islands to be investigated has not yet had its effect on Côte Blanche. A recent letter from Mr. F. F. Myles reports that he intends to prospect the island in the near future.

Immediately after the discovery of salt on Petite Anse in 1862 numerous shallow pits were sunk on the island in a vain search for salt. There can hardly be any doubt that the salt is there. All that is required is deep wells.

Surface geology.—The lack of rugose topography and well sections renders the exact information on the geology of the island

* No altitude determinations were made here, but at the time the writers estimated it as about 100 feet. Hilgard (Smith Contr. No. 248 p. 10) gives it as 180 feet on authority of the coast survey.

not quite so full as could be desired. There are but two sources of such information; the sea-cliff and an artesian well near the sugar house. The surface is composed almost entirely of brownish yellow loamy clay. At one point near the northeast end of the island a gully exposes a little rather clayey sand with some gravel scattered through it.

The sea-cliff section.—The sea-cliff section has changed since Hilgard's visit in 1869 as one would naturally expect; the constant encroachment of the waves on the land would exhibit different portions of the same beds and in such irregularly bedded material a fairly marked change may be looked for.

Section at Sea-cliff

		Feet.
1.	Light yellow surface clay, contains some lime........	11
2.	Green or blush-green clay..........................	1
3.	Reddish, greasy looking joint clay with many limestone concretions..................................	7–8
4.	Very fine light red silt with thin clay partings about every six inches. Looks like successive flood deposits as seen on the banks of Red river	11
5.	Same as above but with more clay..................	15
6.	Grayish yellow clay eroded in irregular forms by the waves to water level..........................	2

No trace of fresh water shells could be found. Particles of vegetable matter could be seen in several layers, particularly in the lower part of layer six. Quite a number of the calcareous concretions which cover the beach were broken open in a search for fossils. Off the southwest corner of the bluff numerous stumps and trunks of trees are seen, ranging all the way from the tree which has just fallen in from a recent cave of the bank to the old remnants which have been battling with the waves for many years.

Unfortunately the data from the Sugar house well are not accessible at present.

GRANDE CÔTE

LOCATION

Methods of communication with the main land.—Until the early sixties the only way to reach Grande Côte or (Weeks' Island) from the main land was by a canoe through Week's bayou from Prairie Au Large below New Iberia. All the products of the island were shipped by light-draught schooners which could enter the bay. Finally, at a very considerable expense, Mr. Weeks connected the island with the main land of Cypremort Point by a raised dirt-way. This rendered access to the island much easier.

Surrounding country.—The island overlooks, on its western side, an arm of Vermillion bay called Weeks' bay. Two bayous approach the island near enough to furnish convenient landing places. Near the southwestern corner of the island, Garrett's bayou is within a hundred yards of the timber. The largest bayou and the one which affords the best landing place is Weeks' bayou near the northwest corner of the island. It is probably more than three hundred feet across and quite deep. Were it not for the shallowness of Vermillion bay, which prevents the passage of vessels of even moderate draught, water transportation of the salt would be quite feasible. Here is the remains of an old pier, a relic of the days when water transportation was the only thing possible. This bayou skirts the island for a little over a quarter of a mile then turns northwestern and finally southwestward into Vermillion bay. On three sides of the island is a trembling sea marsh; on the eastern side is a swamp which without the "causeway" would be utterly impassible.

TOPOGRAPHY

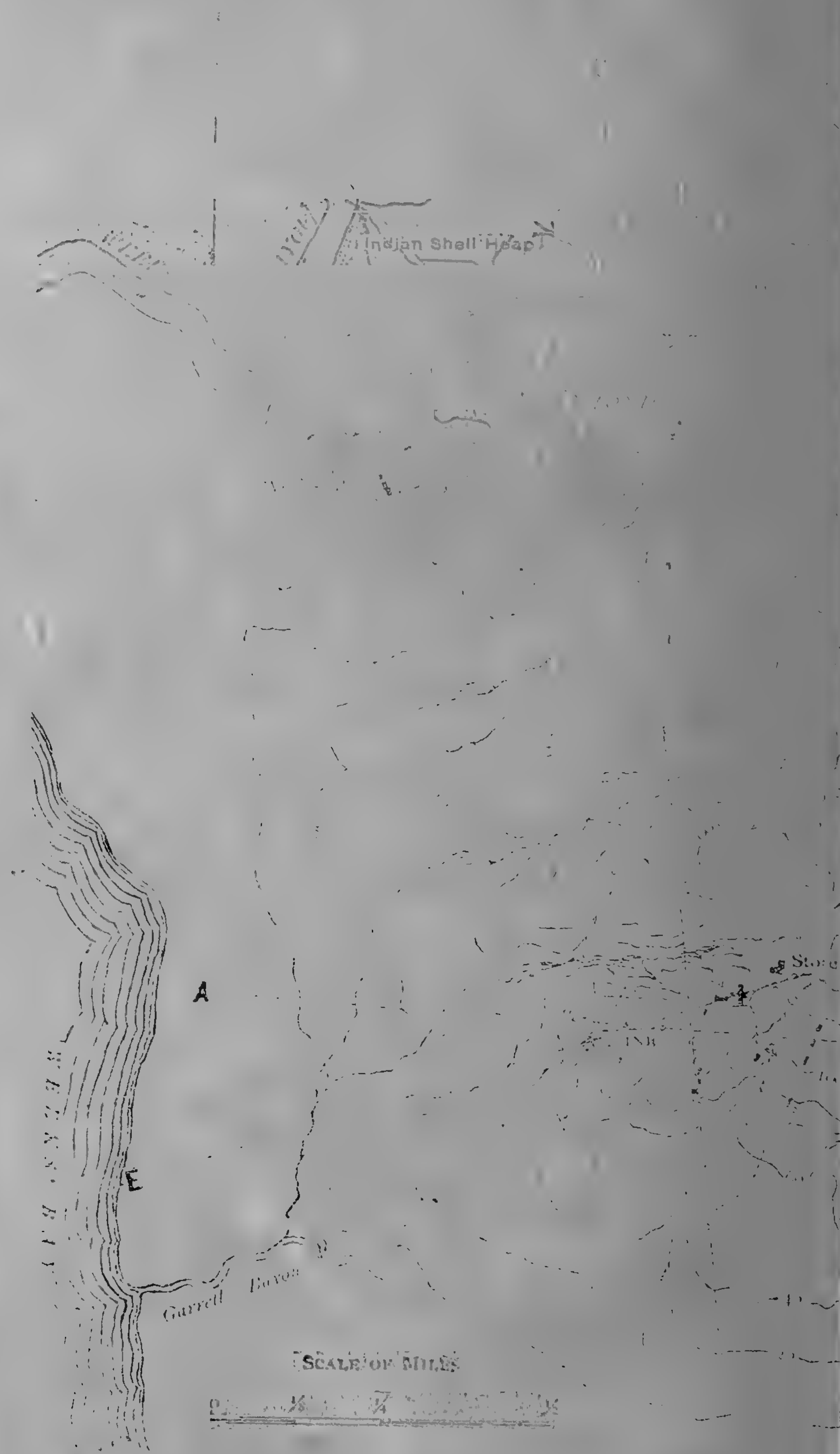
Shape and area.—Grande Côte is almost circular with an indentation in the shore line on either side a little above the center. The area as shown by the land office records is 1907.69 acres. It is the largest of the islands.

Central ridge.—The "Devil's Backbone," the principle topographical feature, extends north from the mine store to near boring No. 2, thus occupying the central part of the island and having a general trend a little east of north. The slopes of the gullies on either side of this dividing ridge are almost perpendicular and from 20 to 60 feet in height. Occasionally the divide is no wider than a wagon bed and near the northern end is almost severed in two or three places. This ridge is from 100 to 135 feet high and contains the highest point on the island. From the mine store it turns eastward and then northward giving the whole ridge the shape of a fishhook (Plate 25).

The lakes.—In the space thus inclosed by steep hills is Lake

Contour Map of the Salt Deposit on Belle Isle. Elevation given in feet below Gulf Level

BY A. C. VEATCH



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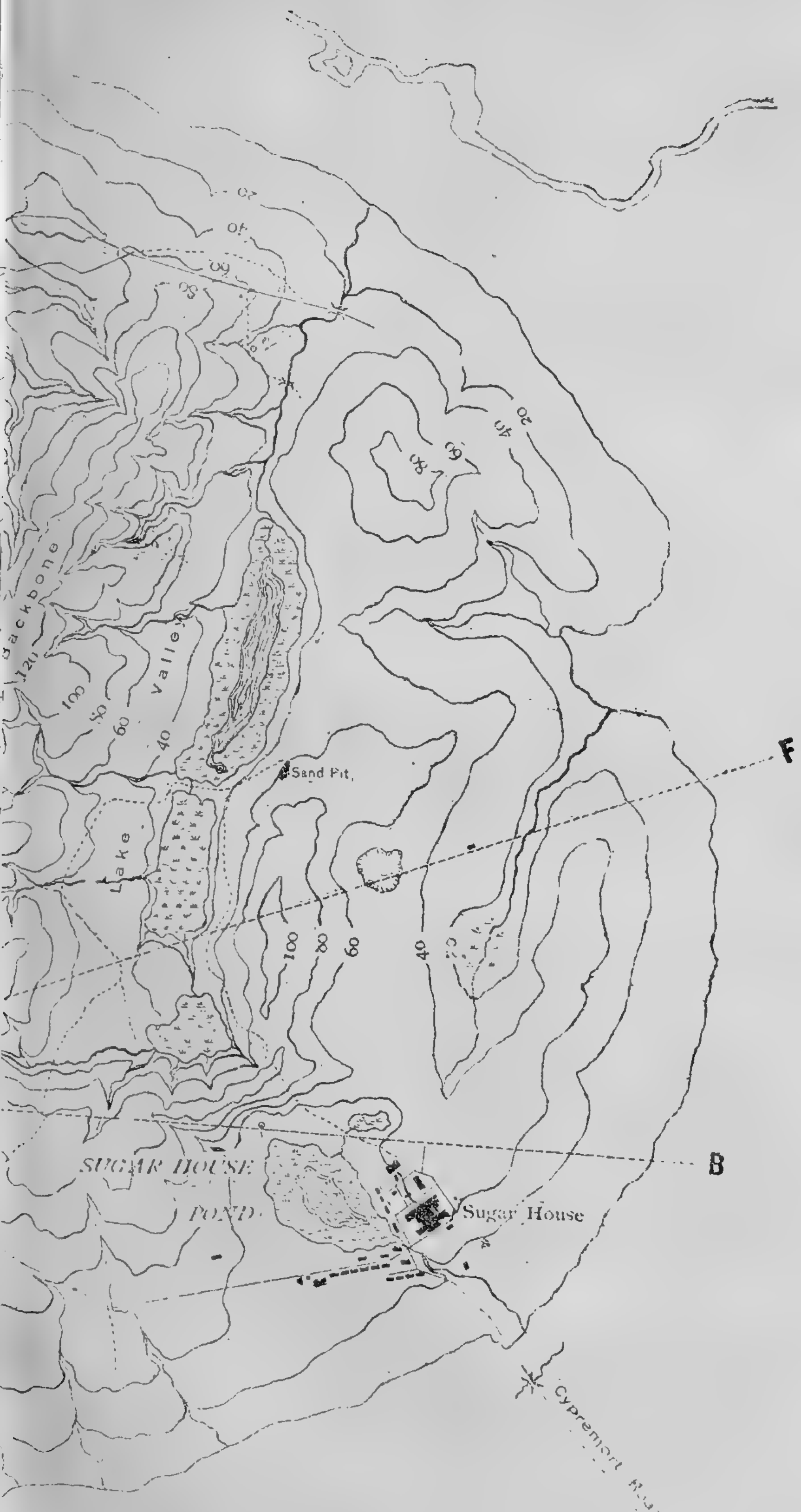
Topographic Sketch

BY A. C.



f Grande Côte

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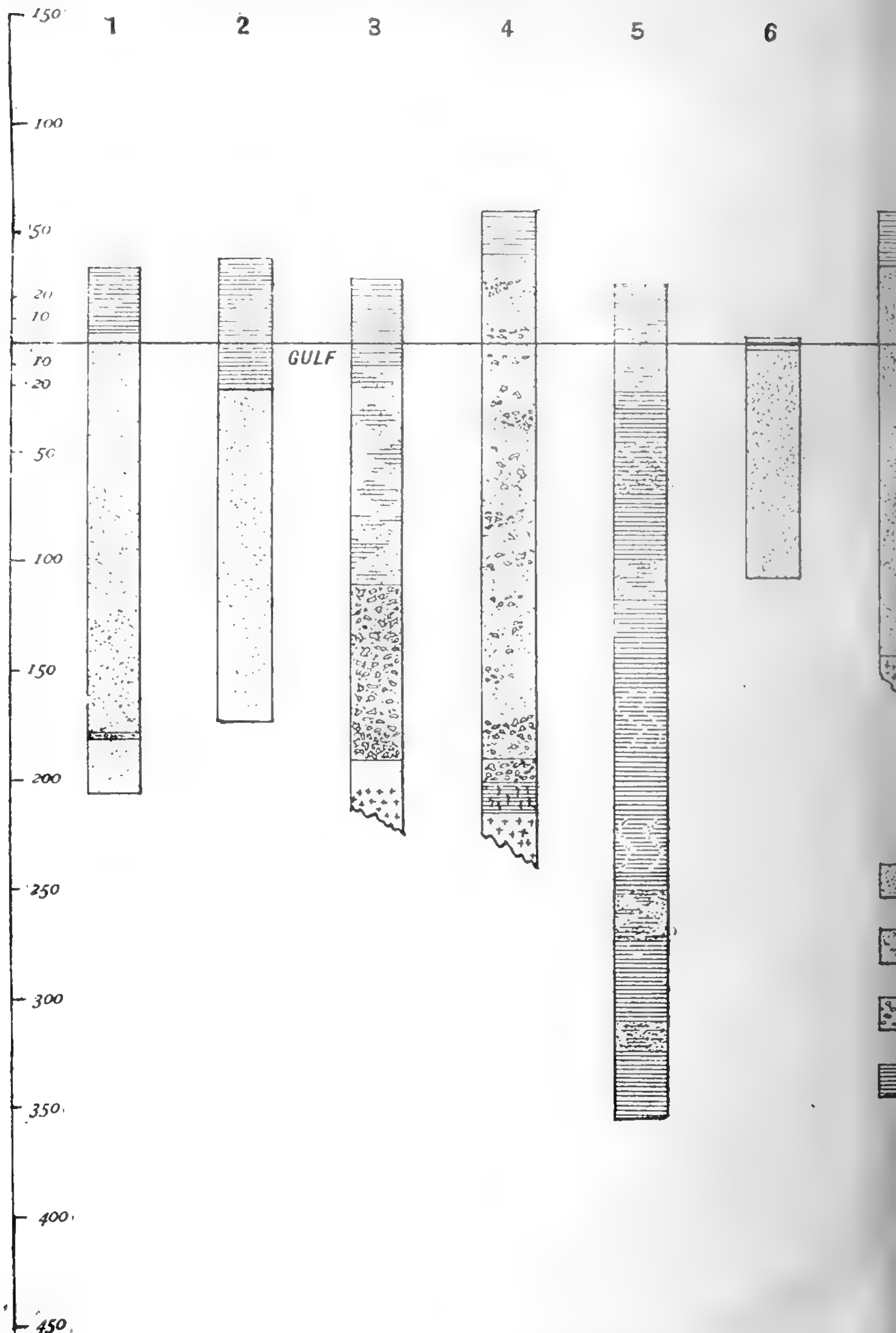
Topographic Sketch Map of Grande Côte

BY A. C. VEATCH

SALT SHAFT, GRAND CÔTE, APR., 1899. LARGE SECTIONED IRON PIPE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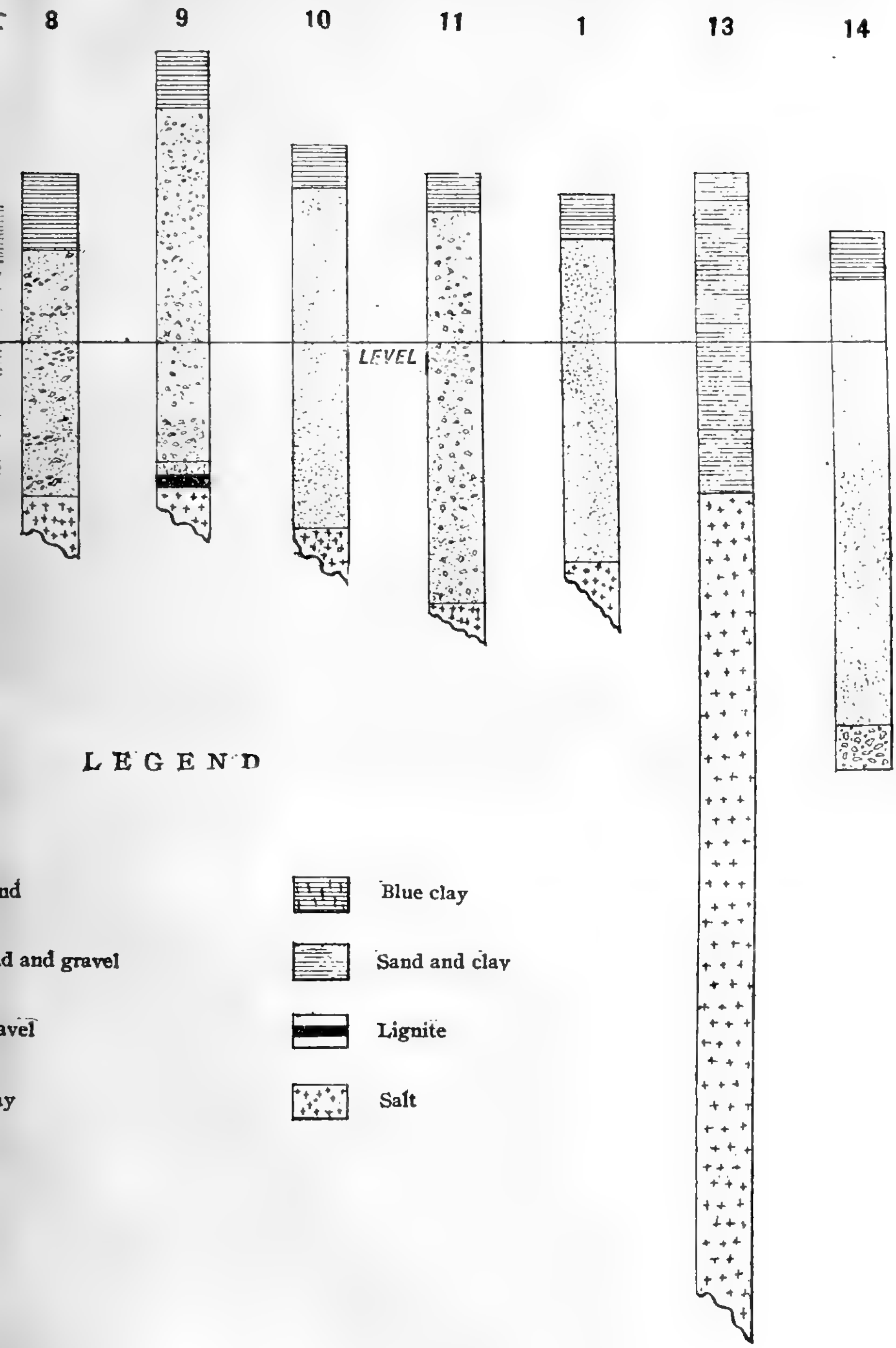
Grande C

PLATE 27



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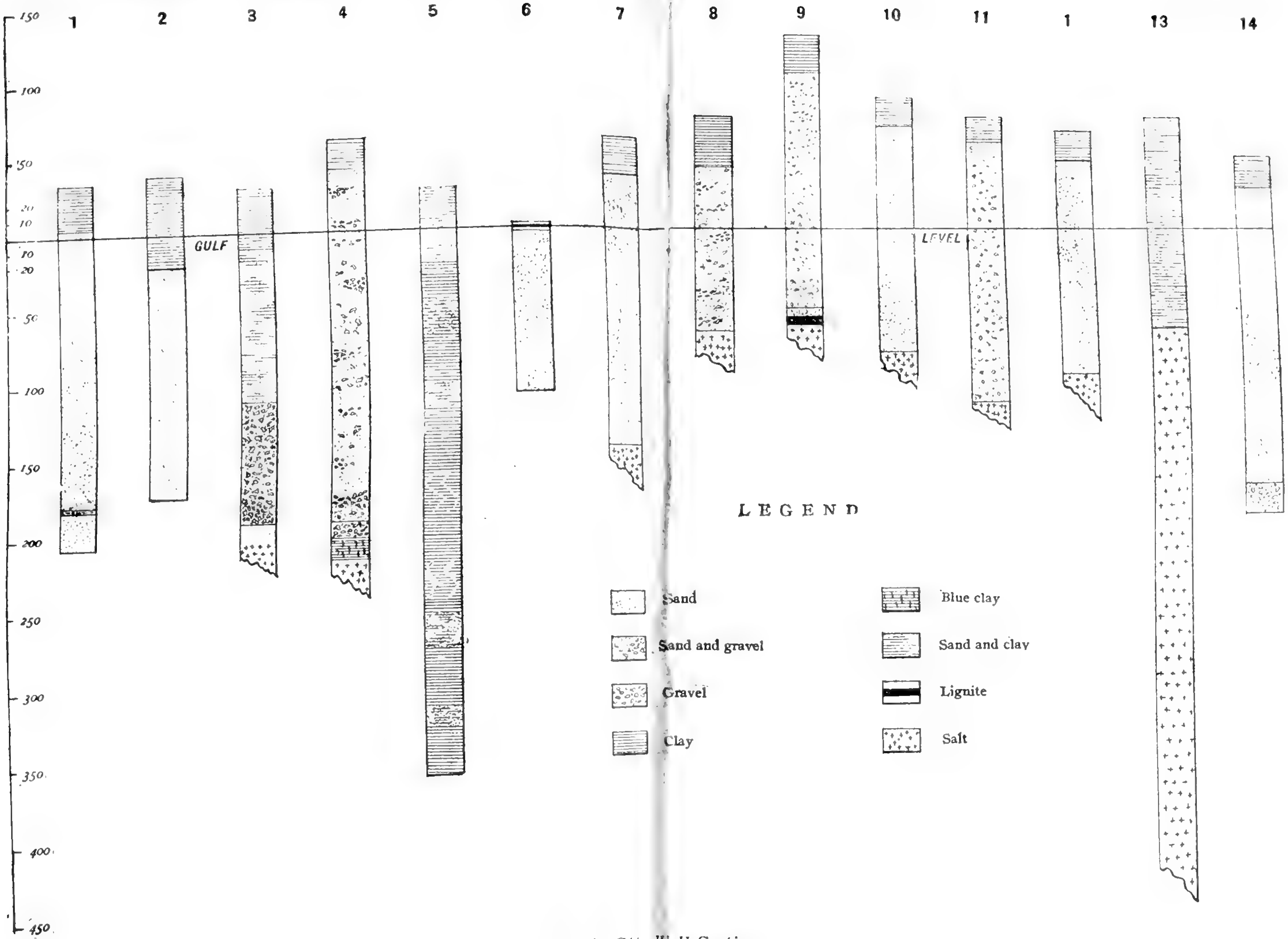

Grande Côte Well Sections

valley. This is a small, comparatively level plain about 35 feet above tide. It now contains three wooded lakes, remnants of a much larger one which has been partially destroyed by the down-cutting of the outlet. The most northern of these little lakes is 660 yards long and a fourth as broad. It was reported to be bottomless but careful soundings showed a very gently sloping bottom nowhere more than eight feet deep. The edge is fringed with reeds and trees but the center is open.

There are two other natural ponds on the island: one near the sugar house, Sugar House pond, has had its level raised about two feet by a dam. Its depth is about the same as the larger one in Lake valley. It is situated in the pit of a great amphitheatre. The other, Lily pond, is near the Weeks residence and like the others occupies the pit of an amphitheatre of rather low hills.

HISTORY OF MINING OPERATIONS

Early work.—Sharing with the other islands the excitement produced by the discovery of rock-salt on Petite Anse in 1862 and further stimulated by the high price of salt at that time a few wells were dug in search of salt, but without success.

Later work.—Following the discovery of salt on Côte Carline in 1895 and on Belle Isle in 1896, Mr. F. F. Myles undertook the exploration of Grande Côte as a private enterprise. In March 1897 with Mr. N. Conrad in charge of the drilling he started the first hole near the sugar house. Conrad drilled five holes, reporting salt in the fourth at a depth of 276 feet, June 25, 1897. In July, the same year, Capt. A. F. Lucas who oversaw the work on Côte Carline and Belle Isle was put in charge. He struck salt in well No. 7 at a depth of 205 feet late in August. In all, fourteen holes were drilled in this preliminary examination. In March 1898 the Myles Salt company was organized and fourteen additional holes were drilled under the direction of Mr. Geo. Cowie, to determine the best location for a shaft. In July 1898, it was started on the site of hole No. 24 where the salt approached nearest the surface.

After a great deal of trouble with quicksand and by employing a portion of the large, sectioned tubing made to penetrate the quicksand overlying the sulphur deposit of Calcasieu the shaft had, at the time of the writer's visit, reached the salt. The difficulty then, on account of the dissoluble nature of the salt, was to make a water tight joint between the tubing and the salt.

As soon as this is accomplished the intention is to erect the shaft house and build a switch from the Cypremort branch of the Southern Pacific.

GEOLOGY

Surface geology.—Like Côte Blanche nearly the whole of the island is covered with a brownish yellow soil. In places, notably in the deep gorges along the Devil's Backbone and indeed in nearly all hollows going into Lake valley the upper stratum of clay has been cut through exposing the underlying sands, and sometimes gravel. East of the larger lake is a sandpit which furnishes sand for the surrounding country. Springs are common on the Northern slopes of the island.

The wells.—The twenty-eight well sections (shown on Plates 27 and 28) show very little variety in the subterranean structure of the island. There is commonly a surface layer of clay from a few inches to 30 or 40 feet thick and then sand and gravel down to the salt. In two wells No. 9 and No. 17 layers of lignite, five feet thick in the first and three feet in the second, were struck just above the salt. In many of the wells the hydrostatic pressure is sufficient to force the water almost to the surface and in well No. 6 it is sufficient to lift the water above the top of the pipe and form a flowing well.

The shape and position of the salt mass.—The salt on Grande Côte forms an elongate dome, longest along its north and south diameter (Plate 29). It occupies the western side of the island and appears to extend a little west of the main ridge. No borings have been made along the ridge so that we can not positively say that the salt does not extend in that direction. Well No. 2 did not find salt at 212 feet but no borings have been made between it and No. 9. Whether the dome shape of the salt, well shown by Plate 29 and the cross-sections of the island Plate 30, really indicate a dome or whether its present shape is due to the erosion of the edge of an upturned fault block or to the erosion undisturbed material, could not be determined in any direct manner. All data collected would however tend to disprove the last supposition. The shaft, at the time of the writer's visit, had not entered the salt far enough to determine the direction and intensity of the dip.

Origin of the lakes.—Thomassy in his visit to the island noticed the upland lakes. Sugar House pond he considered the "orifice where the hydrothermal forces made their principal eruption;" the others are craters of depression similar to those which have given rise to the numerous little lakes of southern Louisiana.* In the light of our present knowledge of the islands this explanation can hardly be accepted, for the phenomena shown here cannot be confounded with that exhibited by the mud-volcanoes of the passes of the Mississippi. The similarity in all these lake basins point to a common origin.

The observed facts would point to four different ways in which the lakes might have been formed: (1) by faulting or landslips produced by orographic movements, (2) by faulting or landslips produced by the removal of the salt by subterranean waters, (3) by the formation of sink holes like those of limestone regions and the subsequent stopping of the basal outlet, (4) by the irregular filling of antecedent drainage channels by Columbia loam.

Landslips in the sands and clays occasioned by the folding or faulting of the salt bed, even with the aid of subsequent erosion, would hardly be likely to produce the rounded amphitheatre-shaped lake valleys.

Many of the local faults, anticlines and sink holes in northern New York have been formed in the second way by the removal of the soluble matter from the beds of the Onondaga salt and waterlime groups by subterranean waters coming from a distance. It is possible, though hardly probable, that the lake valleys on the islands have been formed in the same way. The lack of continuous layers of impervious strata to confine and conduct the underground waters would strongly oppose this theory.

The third necessitates the assumption of a very marked subsidence in the region in very recent times, an assumption which is supported by the partially drowned stream channels of the coastal regions. If the salt mass was elevated well above the sea, say 200 to 500 feet above its present level, water percolating down from the surface of the island would dissolve the salt and

*Géologie Pratique de la Louisiana, p. 82, 1860.

emerge in the form of salt springs at or near sea-level. The removal of the salt by water would form caverns. Dirt and sand would naturally be carried by the water into these caverns in the salt and finally a large funnel-shaped opening would be produced on the surface. Such sink holes are common in limestone regions and quite a number have been very recently produced artificially on Petite Anse. The galleries and rooms hollowed out by man in mining the salt correspond to the caverns which would have been produced by water if the salt were elevated enough to give the water an outlet above sea-level. Water running into these chambers through natural crevices in the salt would soon enlarge them to good sized holes when the dirt and sand and gravel would follow giving rise to a great funnel-shaped opening which would tend to enlarge with every succeeding rain. As the water is kept pumped out of the mine the effect is the same as if the salt stood 90 or 100 feet higher.

Now, if a subsidence should occur, the chambers and caverns would become clogged with sand and gravel and clay because of the diminished velocity of the waters. The material washed down from the steep sides of the sink hole would tend to fill it and if there was a considerable amount of clay in the material the subterranean outlet would become effectually stopped. Water would accumulate in the depression till it reached the lowest point in the surrounding rim of hills, flow over and begin to destroy itself by cutting down the outlet. This second stage is shown in only one of the holes near the mine on Petite Anse. This one, which is northeast of the shaft, has become clogged with clay even though the subterranean channels are still open and a little pond has formed in its bottom.

Lakes formed outside of the glacial limits by the irregular filling of a valley by lœss, where the latter seemed to collect in the form of a great levee across the mouth of a valley, have been noticed by the writer in southern Indiana.* No trace of such a structure was observed here, and further the lakes have neither the shape nor appearance of a dammed valley, the upper end being commonly larger than the lower.

* Notes on the Ohio Valley in Southern Indiana. Jour. of Geol. vol. 6, p. 262, 1898.

Conclusions.—Grande Côte shows the same mantle of loamy clay that appears on Côte Blanche although erosion has progressed a little further on the former, due to the formation of sink-holes and the increased gradients thus given the side streams. The lakes seem to represent old sink-holes formed at a time when the land stood higher than now and whose clogging is the result of the subsidence now progressing on the Gulf coast.

From what little salt has been taken out of the shaft and from the drill holes, the top layer of impure salt found on Belle Isle seems to be lacking on Grand Côte. This is a point to be taken into consideration in any theory explaining the origin of the dome-shape of the salt mass.

ARCHEOLOGY

Shell heap.—The most interesting archeological feature of the island is the shell heap on Weeks' bayou near the landing place just at the edge of the island. This was first noticed by Thomassy.* It is 600 feet long between 30 and 60 feet broad and 10 feet high. The southern end has the shape of a truncated pyramid from which a narrow ridge, gradually increasing in width, extends to the northern end of the mound, which is almost as wide as the southern. The heap is composed almost entirely of the common coast *Gnathodon*. A few animal bones, oysters and pot-shreds are found scattered through the mass. Near the northern end numerous skeletons have been found.

PETITE ANSE

LOCATION

Geographical position.—Petite Anse island, Thomas' island,† Marsh's island, Salt island or Avery's island, as it has been called in succession, is situated in township 13 south, range 5 and 6 east of the Louisiana prime meridian. It is about ten miles south-southwest of New Iberia in Iberia parish and three miles from the shores of Vermillion bay.

Surrounding Country.—Like all the islands we have thus far

* Géologie Pratique de la Louisiane p. 82.

† The History and Geography of the Mississippi Valley, to which is appended a Condensed Physical Geography of the Atlantic United States and the whole of the American Continent, 2d Edition by Timothy Flint vol. 1, p. 253, 1832.

discussed, Petite Anse is entirely surrounded by marsh and swamp land. On the east and southeast, is a large cypress swamp; a continuation of the Cypremort swamp. The level sea marsh gives an unobstructed view of the prairies on the main land and on clear days, of the Gulf waters.

The western side of the island is skirted by the Bayou Petite Anse. Here is the landing, the boat-house and the old piers used for shipping sugar and salt; for Petite Anse was important first as a sugar plantation. Branches of Petite Anse bayou run along the northern and southern sides of the island and finally lose themselves in the marsh.

Communication with the main land.—Communication between Petite Anse and the main land was established early in the present century by the building, from the northernmost point of the island, of a raised dirt way or causeway through the swamp.* Communication with the outer world by water was greatly hindered by the bar at the mouth of Petite Anse bayou. This was partially overcome in 1880 by the digging of a canal from the lower part of the bayou across the marshes to the Gulf. In 1886 a branch of the Southern Pacific was completed from New Iberia to the island.

TOPOGRAPHY

Shape and area.—Calculations from the land office maps give the area of Petite Anse as 1,640 acres or about 300 acres less than Grande Côte. The island is somewhat oval, longest along its northwest and southeast diameter and has a marked indentation in the southwestern part. (See Plate 19.) Its greatest length is two and three-eighths miles and the narrowest place is barely a mile and a half.

The hills.—The general relief of the island is well shown by the topographical map (Plate 31) and the model of the island (Plate 19). From them it will be seen that, while the island has no main central line of hills from which everything slopes, there is a principal hill cluster with minor ones about it. The main hill cluster extends from southeast to northwest, beginning with Plum hill, the second highest on the island, and extending to

*The Emigrant's Guide to the Western and Southwestern States of Louisiana, Mississippi, Tennessee, Kentucky, Ohio, etc. by William Darby, with map. New York, 1818, p. 68.

Prospect hill and Round Top, which occupy separate spurs on the northern end. This dividing ridge does not fall below 80 feet and in the case of Prospect hill reaches a height of 152 feet. Its eastern slope contains two deep pit-like depressions which are occupied by wooded ponds. A third upland lake or pond, Willow pond, separates Round Top from Smith's hill. From Smith's hill a chain of hills follow the shore line southwest to the beautiful residence of the Avery family where it turns and extends a little way southeast. A fourth pond valley, now almost entirely drained, separates Plum hill from Cherry hill which with its outliers occupies the southernmost point of the island. The whole group assumes on the map the appearance of a great, rude capital E near the middle of which is Salt mine valley.

The lakes.—The three upland lakes are essentially the same as those seen on Grand Côte. Willow pond is reported to be 15 feet deep and is the principal "crater of elevation" of Thomassy. Wooded pond and DeVance's pond show remarkably well the rounded sink-hole shape of these valleys. The water level in the lake is between 35 and 40 feet above that of the Gulf. This would show the lakes to be of comparatively recent origin for the streams have not yet, even with this gradient, succeeded in cutting down their outlets.

Near the old mine are numerous great funnel shaped openings whose origin has been fully explained in the discussion of the origin of the lakes on Grande Côte. Their depth ranges from 20 to 60 feet below the surface. To prevent water from running into these holes and thus into the mine a ditch has been dug to conduct the waters of the stream, which flows north of the office, into Willow pond branch. It originally emptied into Iron Mine run.

HISTORY OF MINING OPERATIONS

Early period: Prior to 1862.—The existence of brine springs and possibly rock salt on Petite Anse was known to the aboriginal inhabitants of this country long before it was known to white man. A great deposit of potshreds and ashes in places three feet thick and extending over an area of possibly five acres testify to the extent of salt operations here in prehistoric times. The occurrence of a piece of basket work lying directly on the salt has given rise to the supposition that the existence of rock-salt was also know to the Indians.

The springs were rediscovered in 1791 by John Hayes while hunting. In that day of slow transportation salt was not so readily obtained as now and an attempt was soon made to use the waters of these springs for making salt. This was three years after the first attempt was made to make salt from the brine springs of New York.* At the time of William Darby's visit (about 1817) the springs had been in active operation for a number of years and had supplied, to a large extent, the demands of the settlements of Attakapas and Opelousas.† This activity was due to the demand and increased value of salt caused by the war of 1812. The operations were conducted by John C. Marsh then owner of the island.

War period: 1862–1863.—Following the opening of the Civil war, salt became very scarce and John Marsh Avery, the 18 year old son of Judge D. D. Avery, built up the old salt works established by his grandfather John C. Marsh in 1812. The demand soon overtaxed the capacity of the springs and Mr. Avery directed his negroes to clean and deepen the salt wells. The negro engaged in work on one of the wells when he had reached a depth of 16 feet cried up to "Massa John" that he had struck a hard log. Mr. Avery descended into the well and found the log to be a bed of rock salt. To Mr. Avery therefore belongs the honor of being the first to discover an important rock salt deposit in North America, and, considering the size and magnitude of the deposit, this is no small honor. This discovery, May 6, 1862, had been partially foreseen by Thomassy. In 1860, in speaking of the brine springs on Petite Anse he states that they are formed by the dissolution of rock salt by rain water. At the time of Thomassy's second visit the production was about 40 baskets of rock salt per

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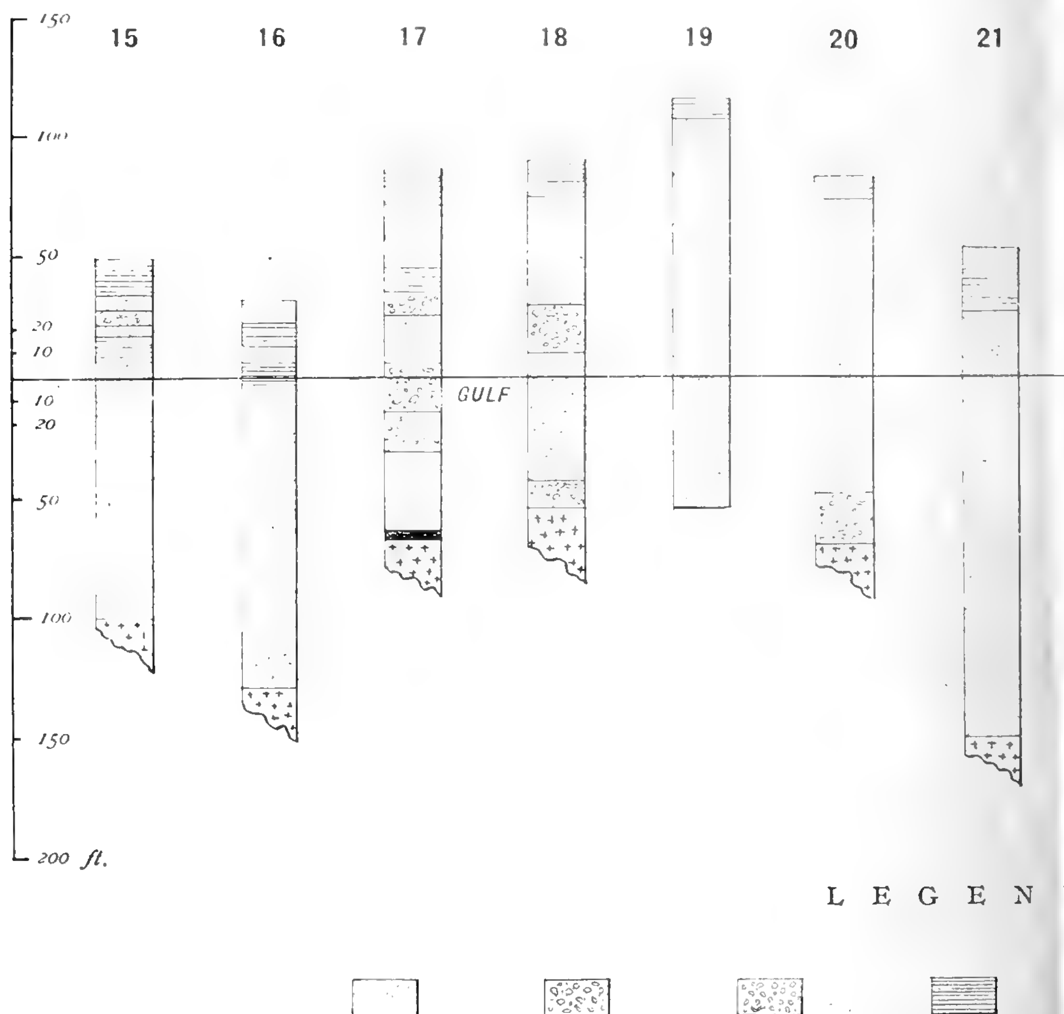
* Mineral Resources of the United States for 1896. Non-metallic Products Except Coal. Salt by E. W. Parker. 18th An. Rept. U. S. Geol. Sur. 1896–1897, Part V (con.) p. 1289.

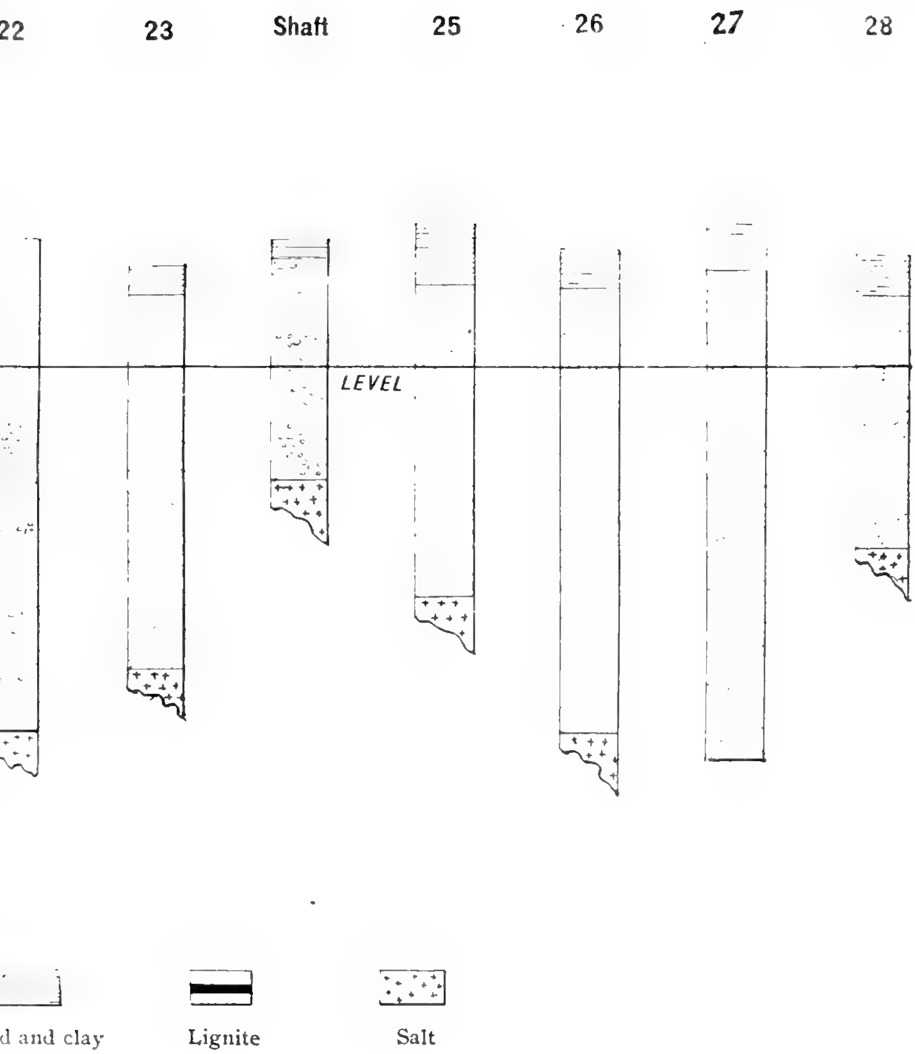
† The Emigrants Guide etc. by Wm. Darby, New York 1818 p. 68.

‡ Geologie Pratique p. 78, 1860.



Grande Côte We

PLATE 28



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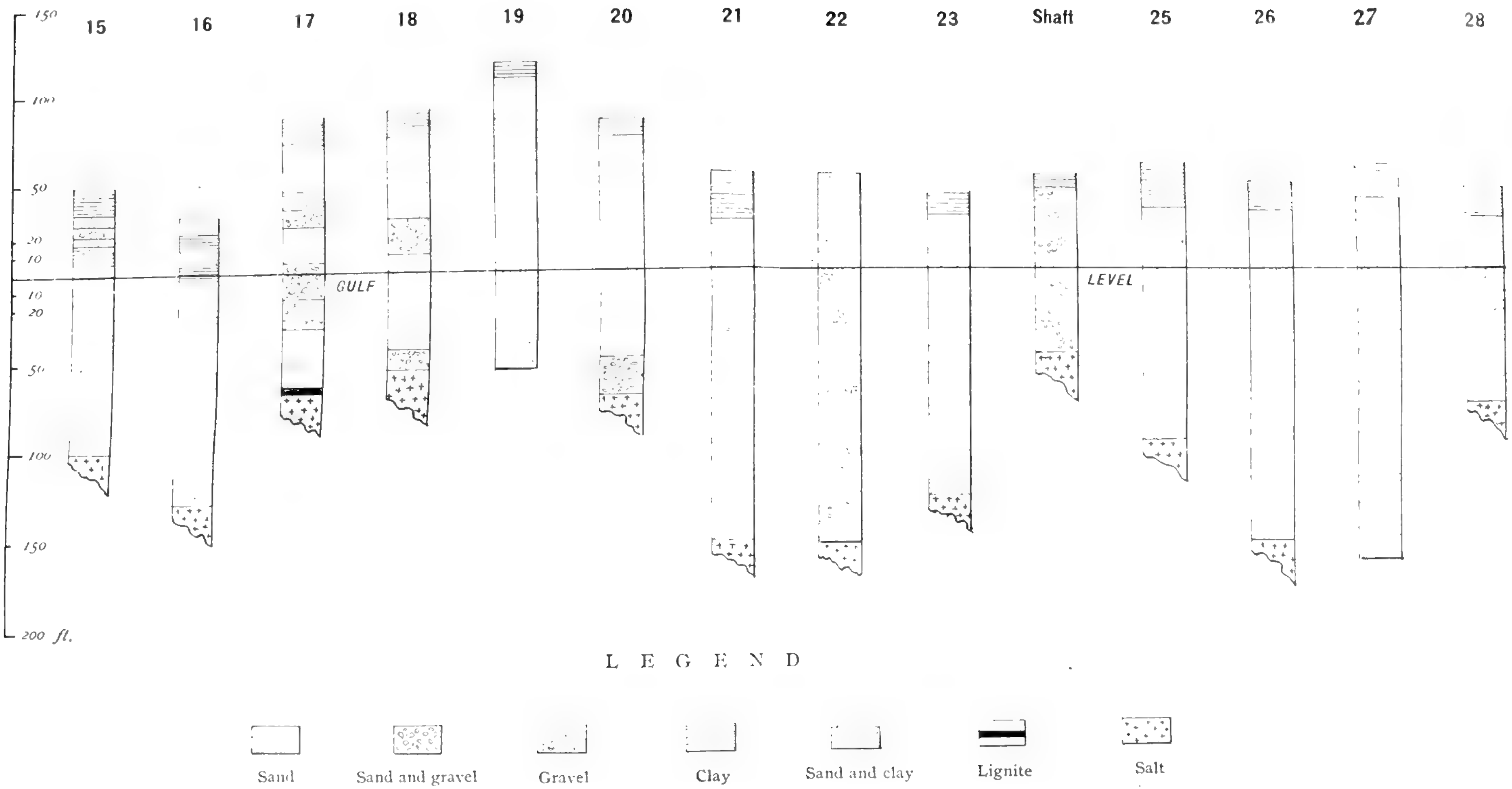
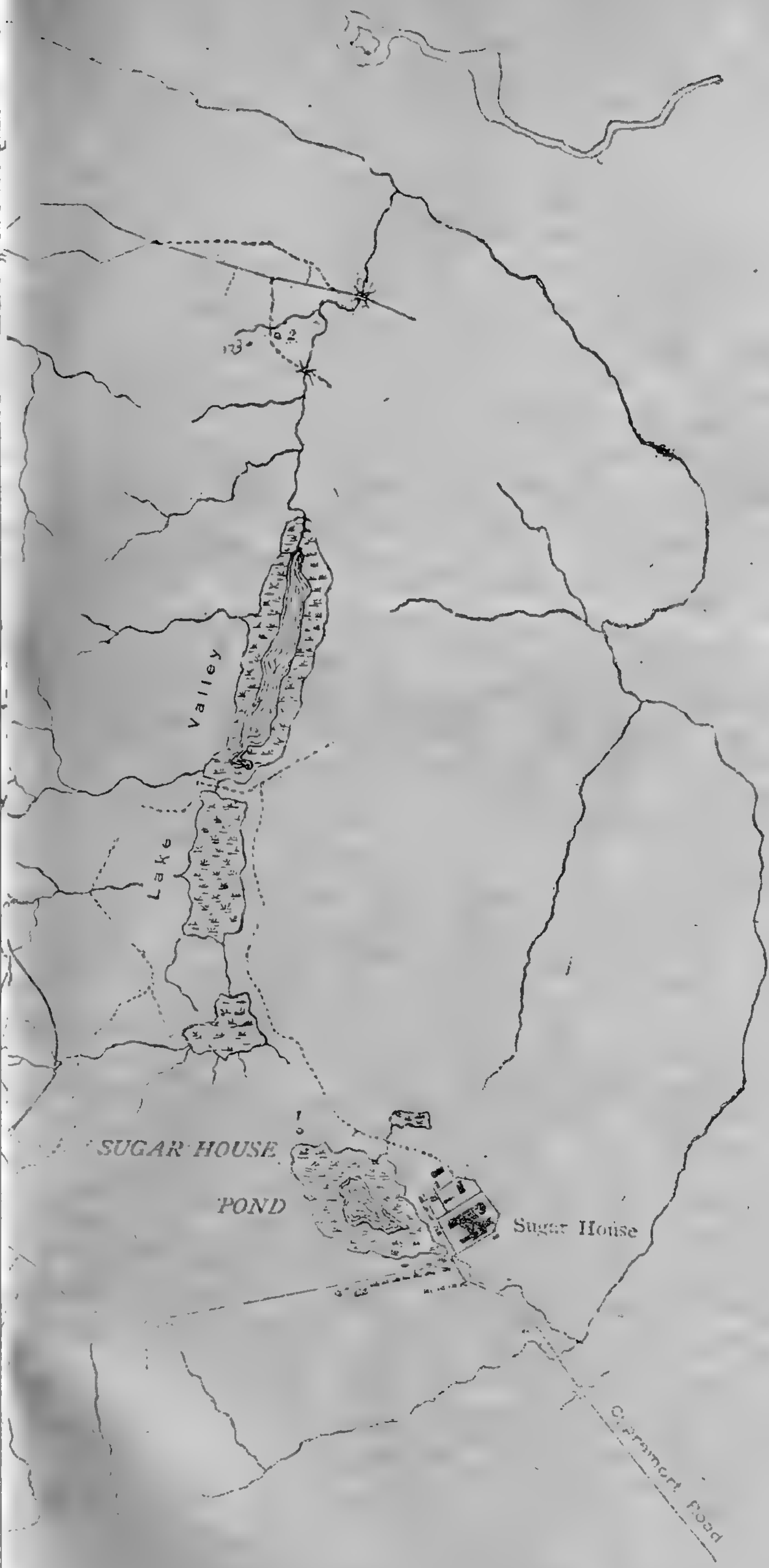


Grande Côte Well Sections

Contour Map of the Salt Deposit of Grande Cote.

BY A. C. V



Elevation given in feet below Gulf Level

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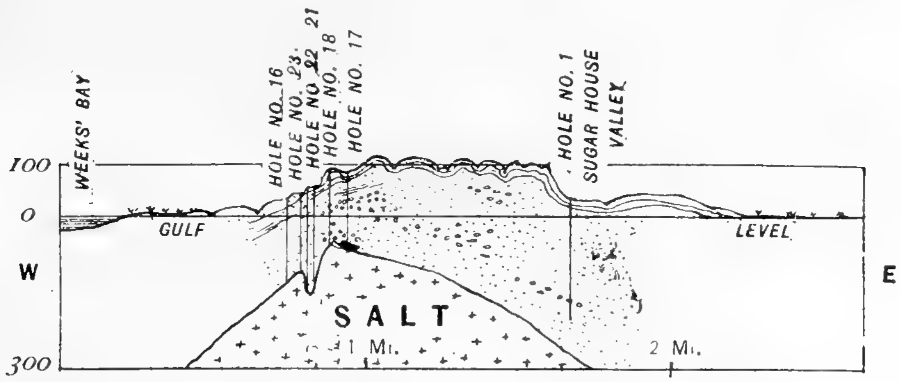
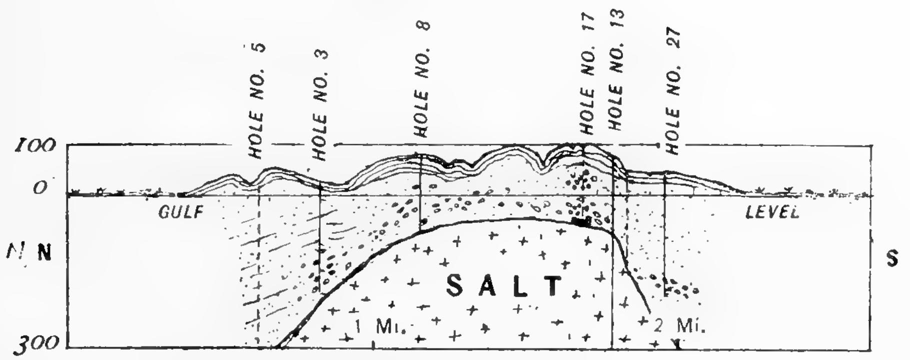
Contour Map of the Salt Deposit of Grande Côte. Elevation given in feet below Gulf Level

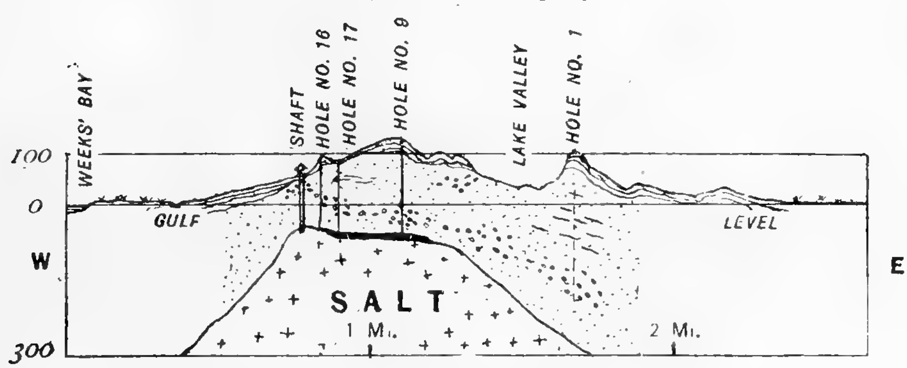
By A. C. Veatch



Section A-B



Section C-D



Section E-F

Cross Section of Grande Côte

day.* The salt was quarried from a number of large open pits. This was a scene of great activity until the destruction of the works by the Federal forces under General Banks, April 17, 1863.† The amount of salt taken out is estimated between 10,000 and 30,000 tons.

Present period: 1867-1899.—After this, little or no work was done in mining the salt till 1867 when Chouteau and Price sunk the first shaft 8x8 feet and 83 feet deep; a depth which was afterwards increased to 90 feet. Of this, 58 feet were in solid salt. At the time of Hilgard's visit (Nov. 1867), galleries eight to ten feet high and 25 feet wide had been driven east and west to a distance of 150 feet each way. Work was finally abandoned by Mr. Chouteau in 1870 upon the death of Mr. Price.

In 1879 the mines were leased to the Galveston company and in 1880 were transferred to the American Salt company. The American Salt company occupied Chouteau's 90 foot shaft and fitted up a mill at the mouth of the shaft for crushing the salt. In order to secure transportation, a canal was cut across the marshes from near the mouth of Petite Anse bayou to the Gulf.

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*Supplement à la Géologie Pratique de la Louisiane. Ile Petite Anse. Bull. Geol. Soc. France, 2d series, vol. 20, 1863, p. 543.

† This date of occupation is taken from extracts of the New Orleans Era of April 19, 1863 published in the New York *Times* April 27. This is quite interesting as giving a very early newspaper discription of the island and as showing something of the extent of the mining operations at that time. "For the last two months it" (the Steamer Cornie) "has been constantly employed in carrying salt from the mines, seven miles southwest of New Iberia, to the junction of the Teche and Cahawba Bayous. From this point the salt has been transported to Alexandria, and by way of Red River, to Vicksburg, Port Hudson and other places occupied by the rebels." * * * * * "Seven miles west of New Iberia and near Vermillion bay, in the middle of a mud lake, thick grown with flag and cane, rises a ledge of solid rock, the surface and depth of which have not yet been discovered. From this mine thousands of dollars' worth of the best salt has been daily sent away for the use of the rebel army. Negroes were employed to blast and break it up, some being ground at the mine. It is reported that the rebels paid four and a half cents per pound for what they took away. When our troops reached Iberia" (April 17) "a regiment was sent to destroy all tools and machinery there."

See also Annual Cyclopædia, 1863. Appleton and Co. New York p. 70, 1867.

P

A tramway was built from the mine and a short embankment made across the marsh to Petite Anse bayou where a number of slips were dug. The salt was loaded in lighters and carried down the bayou to Vermillion bay where it was transferred to schooners. This did not prove very satisfactory because of the cost of transfers and accidents to the lighters and schooners due to mud-flats and bars.

The salt was mined by chambers and cross-headings averaging about 40 feet wide and 25 or more feet high, pillars 40 feet in diameter being left to support the roof.

In 1886 the American Salt company was succeeded by the New Iberia Salt company which made arrangements with the Southern Pacific railroad for a switch from New Iberia. This was completed in 1886 and solved the question of transportation.

The extreme irregularity of the surface of the salt was not fully appreciated by the companies first engaged its mining. The surface of the salt changes in one case from 20 feet below the ground to 100 feet in a distance of less than 200 yards. The galleries on the 90 foot level were driven under the false idea that there was 40 or 50 feet of salt above them and soon approached the outer limit of the salt. Then water commenced to come in the mine through the crevices. After the water had started, it did not take long for it to dissolve the salt and change the crevices into holes. Thus the first sink-hole was formed as early as 1883.

Others followed and the sand and water and debris carried into the mine through the sink-holes very greatly interfered with the mining operations. First the eastern and then the western side of the mine was abandoned and it was decided (1885) to sink the shaft 70 feet deeper. This additional depth, with the eight feet required for the pump, made the total depth of the working shaft 168 feet. Work was prosecuted on the 160 foot level by driving galleries and crossways 80 feet wide and 40 feet high and leaving supporting pillars 60 feet in diameter.

July 1, 1893, Myles and company of New Orleans, obtained a sublease of the property. The water which entered the upper levels through the sink-holes finally effected an entrance to the lower levels and caused that part of the mine to be abandoned in

July, 1895. Operations were continued in the upper level till 1896 when the mines reverted to the Avery family by default of contract.

Appreciating that the life of the present mine is limited, in 1898 a new company was formed under the name of the Avery Rock Salt Mining company, to carry on operations in the old mine and to sink a new shaft. Borings were made and a site was selected southwest of the old mine and beyond the limits of the old workings. After considerable trouble with water bearing sands and gravels, salt was entered at a depth of 54 feet. The shaft at the time of the writer's visit had reached a depth of 125 feet and some trouble was still being experienced from water coming in between the salt and the timbers of the shaft.

GEOLOGY

Surface Geology. — While showing commonly a brownish lowyel loamy soil, this island differs from the others in the numerous surface exposures of gravel. The gravel and sand outcrops seem to be confined entirely to the southern extremity. Sand and gravel are particularly abundant to the southeast on Cherry hill and at the shaft. Some gravel is exposed in the sandpit on the railroad track and in the sandpit between the house and the store. The sand and gravel obtained from the pits is used quite extensively along the line of the Southern Pacific. While the bank sand is of fairly good quality the best is obtained near the mouths of the ravines where the water has washed out the little clay it contains.

On the northern part of the island there are numerous outcrops of a variegated chocolate, yellow or green jointed clay. The notable ones are on the northwest slope of Prospect hill, on the western slope of Smith's hill, in the cut north of Avery's station and on both the eastern and western slopes of Residence hill. On the eastern slope of Residence hill, Hilgard reports finding besides imperfect vegetable remains, shells of *Paludina*, several species of *Unio* and a *Cyclas*. The writer was unable to find any specimens which could be identified. The false bedding and cross-bedding of these strata render dip determinations practically impossible.

Lignite.—One of the gullies at the head of Iron Mine Run hollow exposes part of a bed of lignite, 65 feet above tide. An attempt was made to mine this for local consumption but it was soon given up. A shaft 30 feet deep was sunk exposing the following section :

No.		
1.	Yellow clay	12 ft.
2.	Lignite	18 ft.
3.	Clay not passed through.	

Something of the thickness of this underclay is shown by a boring 85 feet deep made about 100 yards, a little north of west from the lignite shaft, which passed through nothing but clay.

The lignite as exposed in an excavation in one side of the gully shows a dip of 44°, S. 69° E. If this is the dip shown in the mine the real thickness of the lignite is about 12 feet. This dip led Bolton to surmise that the lignite and sandstone, shown further down the same ravine, dipped beneath the salt.

Section at deep boring.—That this idea is incorrect is shown quite conclusively by a deep boring about 220 yards from the lignite in the direction of the shaft.

Section of Deep Boring
(Elevation 48 feet above tide)

No.	Depths		
1.	0– 4.	Fine sandy clay soil	4 ft.
2.	4– 160.	Very fine grained, soft pink and drab or purple sandstone	156 ft.
3.	160– 166.	Hard, coarse grained, chocolate colored sandstone	6 ft.
4.	166–1005.	White rock salt not passed through	839 ft.

This section clearly shows the sandstone on top of the salt and indicates an unconformity between the salt and the overlying beds. A dip of slightly more than 44°, S. 69° E., would be quite sufficient to account for the absence of lignite in this section. The absence of gravel is quite conspicuous.

Sandstone of Iron Mine run.—The sandstone, 3, of the above section, is exposed all along the sides of the ravine from the deep boring almost to the bridge near the shaft. As exposed it is a very fine grained pink sandstone with here and there pieces of specular iron ore. It is to these bits of iron that the branch owes its high sounding name. The sandstone outcrops along a line running northeastward in the direction of Willow pond but no fragments or outcrops were seen beyond this pond. It has been suggested that this stone might be used for railroad ballast and concrete work but no careful tests have yet been made.

Section northeast of the mine.—The large sink hole northeast of the mine reaches a depth of 63 feet below the level of the top of the shaft. It thus affords an excellent exposure. It shows little besides white and orange sands with occasional gravel, and masses of clayey sand. On account of crossbedding, falsebedding and landslips, the stratification could not be satisfactorily determined.

Vertebrate remains.—The most interesting sections to be seen are in the sink holes which occupy the region between the old and the new shafts. Here are the bone and pottery beds which have been cited as evidence that man and mastodon were cotemporaneous.

The first notice of vertebrate remains on the island, so far as we are aware, was given by Prof. Joseph Henry in a paper before the Chicago Academy of Sciences on the verbal statement of Mr. T. F. Cleu, who contributed a specimen of basket work to the Smithsonian Institution.* Owen mentions the occurrence of pottery, but says nothing about fossil vertebrates. In 1883 Mr. William Crooks, of the American Salt company, presented to the Smithsonian Institution a collection of bones obtained in sinking an air shaft. These were turned over to Prof. Joseph Leidy for examination. He made them the subject of a brief communication to the Philadelphia Academy of Sciences in 1884 † and of a detailed report published in the Transactions of the Wagner Free Institute of Science in 1889.‡ In this he lists:

Mastodon americanus.	*Mylodon harlani* Owen.
Mylodon sp. (cf. *robustus* Owen).	*Equus major* De Kay.

* Trans. Chicago Acad. Sci., vol. 1, part II.

† (Notes on Fossil Bones from Petite Anse, Louisiana) by Joseph Leidy, Proc. Acad. Nat. Sci. Phila., vol. 36, p. 22, 1884.

‡ Notice of Some Mammalian Remains from the Salt Mines of Petite Anse, Louisiana. Trans. Wagner Free Inst. Sci., vol. 2, pp. 33–40, 1889.

Late in the "eighties" General Dudley A. Avery sent several other bones to the Smithsonian Institution; one of which was identified as the claw of a *Megalonyx*.

Probably the largest collection which has yet been made at this locality was by Dr. Joseph F. Joor, of New Orleans, for Tulane University, in 1890.* These were submitted to Prof. E. D. Cope. In his report he figures and describes two new species of *Mylodon* and considers that the teeth identified by Leidy as *Equus major* DeKay really represent a new species†. The species determened by him are:

Mastodon sp.
Mylodon harlanii Owen.
Mylodon renidens Cope.
Mylodon sulcidens Cope.
Equus intermedius Cope.

To this list Dr. Joor adds doubtfully the remains of an *Elephas*. The bone bed is a fairly rich one and may be expected to yield some good material to the careful worker.

The section shown on the north side of the sink hole near the old air-shaft is:

Section Near Air Shaft

1.	Gray sandy loam with numerous pebbles	7 ft. 0 in.
2.	Broken pottery and ashes	1 ft. 0 in.
3.	Dark gray silt; looks like hill-wash	5 ft. 6 in.
4.	Finely laminated black loam containing many grass roots	1 ft. 6 in.
5.	Medium coarse white sand grading above into gravel about the size of a pigeon's egg	2 ft. 5 in.
6.	Black or dark brown, very hard, gravelly sand containing fragments of vegetable matter and *Mastodon Mylodon* and *Equus* bones. Exposed surface shows greenish yellow with sulphur efflorescence	2 ft. 0 in.
7.	Salt. Exposed	10 ft. 0 in.

On the south side of the same hole layer 6 becomes much thicker and grades into a dark tenacious clay.

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*Notes on a Collection of Archeological and Geological Specimens, etc. Am. Nat., vol. 29, pp. 394–398.

† On Some Pleistocene Mammalia from Petite Anse, Louisiana, by E. D. Cope, Am. Phil. Soc. Proc., vol. 34, pp. 458–468, 3 plates, 1895.

Leidy remarks that none of the bones examined by him showed any trace of erosion; a statement which is confirmed by all the specimens collected by the writer. Just south of the new shaft in grading for the railroad embankment what appears to have been a fairly complete skeleton of a mastodon was unearthed and before it was seen by any one who realized its value it was buried in the embankment. A few bones which had rolled down to the foot of the embankment were picked up by General Avery and led to the disclosure of the above facts. About three feet of a tusk was afterwards found by one of the workmen in the side of the embankment.

A few stray bones have been found in Iron mine run above the bridge. These are the only two localities where bones have been found outside of the lowest part of Salt mine valley.

New shaft section.—Just west of the last section the new shaft shows very little in common with the bone-bed section.

Section at New Shaft

1.	Surface soil	4 ft.
1.	Yellow sand	12 ft.
3.	Sand clay and gravel. Water line	8 ft.
4.	Sand and gravel	30 ft.
5.	Salt	

The salt.—The salt is white, hard, dry, crystalline, commonly composed of many small crystsls from an eighth to a quarter of inch in diameter which are very irregular because of interference. Occasionally masses are found which are composed of very large crystals as shown on Plate 23. The salt here shows nothing of the upper dirty salt found on Belle Isle but is quite white so far as penetrated, with the exception of parallel bands of dark salt from two to six inches thick. These are best shown on a freshly blasted face. Analysis of this black salt by Mr. McCalla, at one time resident engineer and chemist, shows that the black bands contain seven per cent of insoluble matter, chiefly gypsum.

Access could be had to only a very small portion of the mine, at the time of the writer's visit but Mr. John Avery, Assistant Superintendent, states that the extravagant dip shown on the present working face is the same both in intensity and direction throughout the mine. The dip shown there is southeast. That is, if these really represent, as they seem to, lines of stratification, the salt is almost vertical. Pomeroy states however that a close examination reveals the fact that the salt is folded, the upper level showing three distinct anticlines.

Analyses of the salt.—The remarkable purity of the salt and the absence of the usual impurities found in other rock salt deposits has been the subject of quite a good deal of comment and is one of the hardest points to meet in a rational explanation of its origin. Quite a number of analyses have been made, of which the following are the most important.

ANALYSIS OF SALT

Chemist.	Sodium chloride.	Calcium sulphate.	Calcium chloride.	Magnesium chloride.	Magnesium sulphate.	Other matter.	Not determined.
Jules Lafort ‖—1863	97.920						2.08
E. W. Hilgard * †—1863	99.880	.126	t.				
Peter Collier †	98.900	.838	.146	.022		.080	.014
Dr. Riddle †	98.880	.76	.13	.23			
C. A. Goessman †	98.880	.79	t.	t.		.33	
C. A. Goessman ‡ §	98.88	.782	.400	.003		.33	
Joseph Jones †	99.617	.318			.062	.003	
F. W. Taylor 1882 * †	98.71	1.192	t.	.013		.030	
Dr. Doremus †	99.097	.7293			.1584	.0389	
Gustavus Bode †	99.252	.694	.042	.012			

Yearly production of salt.—From the following table of the yearly production of salt at Petite Anse it will be seen that the output reached its maximum shortly after the completion of railroad connections and that after the discovery of rock-salt in Kansas in 1888–1889 it suffered a heavy decline. Although the

The Petite Anse Salt Mine, by Richard A. Pomeroy. Trans. Am. Inst. Min. Eng., vol. 17, pp. 107-113, 1888.

‖ Supplement à la Géologie Pratique. Ile Petite Anse. Comp. Ren. Géol. Soc. France, 2d series, vol. 20, 1863, p. 543.

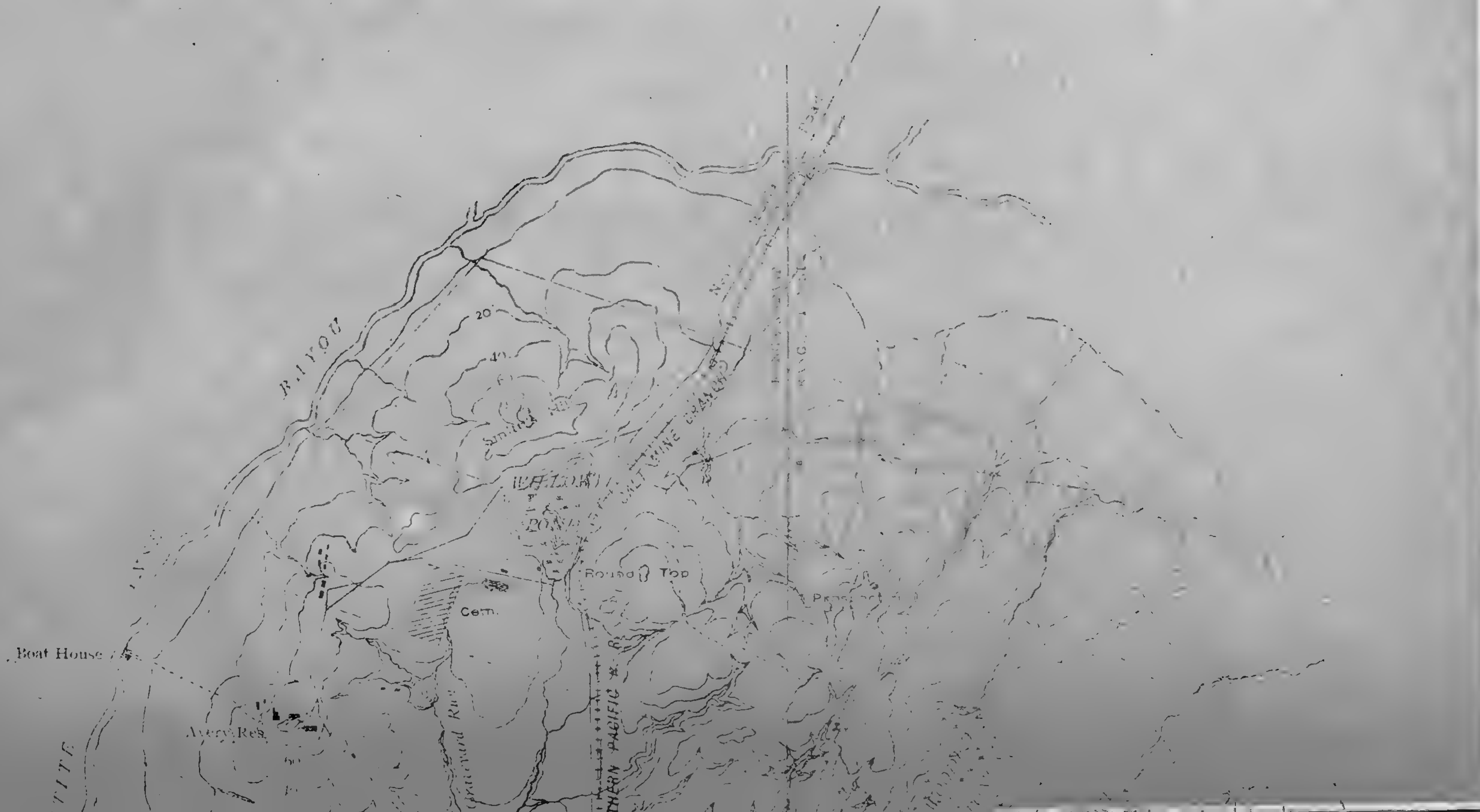
* Mineral Resources of the United States for 1882, Salines of Louisiana, by E. W. Hilgard. p. 564, 1883.

† Mineral Resources of the United States for 1883–1884, p. 841, 1885.

‡ Salt by C. A. Goessman, Johnson's Universal Cyclopædia, New York, 1895, vol. 7, p. 274.

§ American Cyclopædia. Salt. New York, 1881. vol. 14, p. 572

Buck, C. E., and Goessman, C. A. On the rock-salt deposits of the Petite Anse, La. Salt Company, Report of American Bureau of Mines, New York, 1867.


BAYOU
20
40
SALT MINE BRANCH
Round Top
Cem.
Boat House
Avery Res.
PACIFIC R. R.

Topographic Map of Petite Anse.

BY A. C. VEATCH

Topographic Map of Petite Anse.

BY A. C. VEATCH

quality of the Kansas salt is inferior to that of Petite Anse, its nearness to the great packing houses largely offsets the difference.

PRODUCTION OF SALT ON PETITE ANSE.*

Year.	Short tons.	Year.	Short tons.
1812–1861	?	1888	25,214
1861–1862	200– 500	1889	45,588
1862–1863	10,000–30,000	1890	39,978
1868–1880	5,000	1891	24,320
1881	15,000	1892	28,000
1882	25,550	1893	26,800
1883	37,130	1894	26,047
1884	31,355	1895	22,368
1885	41,898	1896	24,236
1886	41,957		
1887	47,750		

* 1881 to 1896 from mineral resources of the U. S.

The Lakes: a zoölogical problem.—The lakes on the island are of the same origin as those on Grand Côte. These fresh water lakes, three on Petite Anse, five on Grand Côte and one on Belle Isle, offer material for a very interesting scientific investigation. Isolated as they are from other bodies of fresh water and separated from the main land by sea marshes we would naturally look for some faunal peculiarities. Although the age of the lakes is not very considerable they would probably show some interesting things on variation.

Marsh fires.—Few nights passed during my stay on the island that great parts of the horizon were not an angry red from distant marsh fires. During the day columns of smoke told of their existence, and sometimes they approached sufficiently near to be seen and heard. In dry seasons or after a very severe winter the reeds are easily ignited, and once started the fire spreads with great rapidity, often covering many hundred acres. To these marsh fires is probably to be traced the early idea that these hills were blazing volcanoes. They have given rise to the name "Fire Islands" mentioned by Hilgard and to Stoddard's story that "one of the islands has been known to be on fire for at least three months."

The cypress stump stratum.—It is believed that the cypress stump stratum which Hilgard found in the marshes surrounding the island and which he represents in his cross-section as extending under the island,* represents a stratum much younger than that seen at Port Hudson bluff. On the eastern side of Petite Anse is a living cypress swamp which extends eastward along the coast on a line between the prairie and the marshes. Taking the present rate of subsidence on the Gulf coast (1 foot in 20 years according to the observations of Maj. Quinn†) it hasn't been a very great while since the prairie occupied the land now claimed by the cypress swamp and it in turn occupied that which is now sea-marsh. The islands antedate this time. Further there is no evidence of the stump stratum in any of the borings yet made on the islands. The lignite has in every case been found in or below the gravel.

Conclusions.—The data thus far collected seem to show that the salt mass on Petite Anse represents the edge of an upturned fault block. The dip together with the absence of the impure salt bed seen on the top of the Belle Isle anticline would seem to indicate this. Whether this be due to orographic movements or to faults produced by the dissolution of vast amounts of the underlying salt cannot be positively stated, but the evidence at hand rather favors the former. The dip of the lignite bed, the only surface bed whose dip could be determined, taken in connection with the data furnished by the holes drilled near it indicates that this bed rests unconformably on the salt. Two separate movements of the strata are then indicated: an initial movement of about 38°, with an interval during which the clay and lignite and the pink sand bed were deposited around the

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* See section of island. Hilgard, Smith. Contr. vol. 23, separate No. 248, 1872.

Copied by Pomeroy, Eng. and Min. Jour., vol. 46, pp. 280–281, 1888. Sci. Am., Suppl., vol. 26, pp. 10719–10720, No. 671, 1888; Am. Inst. Mining Eng. Trans., vol. 17, pp. 107–113, 1889.

In this connection it is well to call attention to the difference between this section and the facts as they now present themselves.

† An. Rept. U. S. Engineer 1895. Quoted in Appleton's Annual Cyclopædia, 1895, New York 1896.

protruding salt mass and a second greater movement which resulted in the tipping of the lignite at an angle of 44°.

The stratigraphical position of the gravel seems to be above the lignite and its position on the southern end of the island would thus be readily explained. Although the position of the gravel could be almost as well accounted for by the supposition of a deposition prior to the first movement. Of the clay beds, part are undoubtedly older than the lignite, indeed the direction of the dip would make the bulk of the under clays on the northern end of the island older.

There are some facts bearing on the date of the last movement. The vertebrate remains found in mine valley show no trace of erosion, so they can hardly be regarded as having been transported by the same agent that brought the gravel. The animals, which the bones represent, in all probability ventured into the valley for salt and became mired in the mud which surrounded the lick or spring. Such deposits in the mire about salt springs are not at all uncommon. The bone bed was formed after the elevation of the island and the bones represent Pleistocene mammalia.

ARCHÆOLOGY

Remains in salt mine valley.—The potshreds and other remains which have been mentioned above as indicating the former use of the salt by the Indians, seem to have been first seen in the excavations made during the war. Owen on his visit to the island (1865) found fragments of pottery scattered over the old dump heaps.

About that time Prof. Joseph Henry figured and described in the Transactions of the Chicago Academy of Sciences a fragment of cane basket work from Petite Anse received from Mr. T. F. Cleu with the statement that it had been found directly on the salt two feet beneath elephant remains.*

This has formed the basis of the statement by Foster† and

* Trans. Chicago Acad. Sci., vol. 1, part II. Quoted by Foster.

† Prehistoric Races of the United States of America by John Wells Foster, Chicago, 1881, p. 56.

Nadaillac* that man and the mastodon lived at the same time on Petite Anse.

Hilgard and Fontaine examined the deposit during their visit to the island. Dr. Hilgard makes no positive statement but seems to feel rather doubtful, on account of the detrital nature of the material, that the reported position of the bones above a part of the human relics really represents their true order of deposition. Dr. Fontaine, though writing an article to disprove the high antiquity of man, states positively that "they are so mingled that we can only infer that the men and animals were coeval."†

The formation of the sink holes around the mine made it possible to examine these deposits more carefully than before. Bolton states that pottery and other relics are found mingled with the mastodon bones.‡ Dr. Joor does not mention any relics from the bone bed or below. All those seen by him he considers of comparatively recent origin; four or five hundred years being ample to account for their present position.§

The writer carefully searched in the bone bed for objects which could be unquestionally attributed to man but was unable to discover any. Numerous pieces of cane were found in this layer and some had a peculiar split appearance which was first thought to be artificial but turned out to be due to unequal weathering. If a piece of cane was found partially embedded in clay the exposed end almost always had the split appearance while the part enclosed in the bank was perfectly solid. Pieces of wood showed a tendency to behave in the same way.

A section about 50 yards northwest of the section given above from the old air shaft shows the greatest thickness of the pottery bed yet observed.

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* Prehistoric American by Marquis de Nadaillac. Trans. by N. D'Anvers New York, 1895, p. 36.

† E. W. Fontaine. How the World Came to Be Peopled.

‡ Trans. New York Acad. Sci., vol. 7, p. 125, 1888.

§ Notes on a Collection of Archeological and Geological Specimens, etc., Am. Nat. vol., 29, 1895, p. 396.

Section Northwest of Old Air Shaft

No.		Feet	Ins.
1.	Surface loam, a brown sandy clay	6–10	0
2.	Potshreds and ashes with a few specimens of *Gnathodon cuneatus* and recent animal bones	2–3	6
3.	Dark gray loam with iron pyrite and iron tubes	3	6
4.	Gravel, light colored	1	0
5.	Finely laminated gray silt	1	0
6.	Hard dark sandy clay, filled with black gravel about the size of a hen's egg. Fragments of reed cane, twigs and small branches are numerous. Contains bones of *Mastodon*, *Elephas* (?), *Mylodon*, *Equus*. Weathered surface shows sulphur efflorescence	4	
7.	Salt		

So far as our present knowledge goes the evidence of the contemporaneity of man and the mastodon on Petite Anse consists of a single fragment of basket work found in contact with the salt. While it is not at all impossible that man did live in the same period as the mastodon yet for this locality to prove that such was the case it must first be shown, as Mr. H. C. Mercer suggests,* that the Indians or their predecessors did not carry on mining operations here. If pits were dug to the surface of the salt then the position of the basket work beneath the fossil bones can be readily accounted for.

Other remains.—On the summit of Prospect hill is a little tumulus scarcely five feet high and forty feet in diameter which has all the appearance of an artificial mound. It may be one of the so-called lookout or signal mounds which cap the highest hills along many of the northern rivers. It shows traces of an excavation in the center, which I suppose was made by Dr. Fontaine as he reports the mound to be regularly statified.†

On the point of the ridge between Wooded pond and DeVance's pond are numerous specimens of *Gnathodon cuneatus* and potshreds, indicating a camp site.

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*The Antiquity of Man on Petite Anse (Avery's Island) Louisiana, Am. Nat. vol. 29, pp. 393-394, 1895.

† Fontaine's conclusions are mentioned by Hilgard in his article in Smith. Con. vol. 23, separate No. 248, p. 19, 1872.

CÔTE CARLINE *

LOCATION AND TOPOGRAPHY

Geographical position.—Like Petite Anse, this island has had a great variety of names: Côte Carline, Depuy's island, Miller's island, Orange island and Jefferson's island. As the winter home of Joseph Jefferson, the famous actor, it is now better known by the latter name. It is situated very near the line between Vermillion and Iberia Parishes in the southwestern part of township 12 south, range 5 east. It is about nine miles west of New Iberia and but a short distance from the Abbeville branch of the Southern Pacific railroad.

Surrounding country.—Unlike the other islands Côte Carline rises out of a prairie, the sea marsh being two miles and the Gulf nine miles away. Touching the island on the northwestern side is Lake Peigneur, a beautiful little stretch of water about two miles long. The fishermen say that sometimes during very high prolonged south winds the tide of the ocean is felt in the lake. The depth of this lake has been variously stated, estimates ranging from 15 to 32 feet. Surrounding the island are flat prairie lands used for the cultivation of rice.

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* This seems to have been the first name for this island which appeared in literature, having been used by Darby in 1818 in his Emigrant's Guide to the Western and Southwestern States of Louisiana, Mississippi, etc.

Flint, in his History and Geography of the Mississippi Valley, 2d edition, vol. 1, p. 53, says the principal islands along the gulf shore of Louisiana west of the mouth of the Mississippi are Barataria, the noted resort of Lafitte's piratical squadron, Thomas, La Croix and Ascension Islands. It is difficult to place these names exactly. They are referred to as elevated islands rising to a height of from 30 to 100 feet above the sea marsh and hence we suppose refer to the Five Islands. Thomas' is probably Petite Anse for it is spoken of as being connected with the main land by a causeway and, so far as we know, Petite Anse was the only one so connected at that time. Barataria may refer to either Belle Isle or Côte Carline, more probably the former; for while Côte Carline has a number of old tombs which are attributed to the early pirates most of Lafitte's operations seem to have been conducted from Belle Isle on account of its nearness to the sea. It may however refer to one of the low lying islands in Barataria bay or bayou. No clue has yet been found by which the other two names may be placed.

Topography.—The area of this circular protuberance in the prairie is about 300 acres. It is very regular with a maximum diameter of about a mile. Facing the lake is a little wave-formed bluff about thirty feet high. With this exception the slope from the highest point, which has an elevation of 75 feet above the lake just back of the Jefferson residence, is very gradual. The hollows are very insignificant.

GEOLOGY

Surface geology.—It is this little bluff which Thomassy mentions in his description of the island and Lake Peigneur is the "ancient crater" from which he supposed the material forming Côte Carline was thrown out. Hilgard did not visit the island and was unable to locate the "central crater" from descriptions received because he was evidently looking for a small lake on the island itself like those on Petite Anse and Grande Côte. Although Thomassy's conclusions were a little distorted his observations were in the main very correct.

Bluff section.—The bluff sections which he describes shows:

		Feet
1.	Surface soil	2
2.	Light yellow buckshot clay with limestone concretions.	26
3.	Gravel to water level	2

The surface of the island is uniformly covered with a humus-stained yellow loam containing limestone concretions. The only exposure of gravel is along the shore of the lake at the base of the cliff. Numerous springs issue from the gravel bed.

Salt explorations.—In 1894 Mr. Jefferson let a contract for drilling a well near his home, this resulted in the discovery of rock salt at a depth of 334 feet early in the summer of 1895. Mr. A. F. Lucas was then put in charge of the drilling and with a diamond drill sunk the hole to a depth of 2,090 feet. The drill was still in salt when work ceased. The section exposed there was:

Section of Hole No. 1

(Elevation above lake 65 feet=72 feet A. T.?)

			Feet
1.	0– 265	Unknown	265
2.	265– 334	Coarse gravel and sand	69
3.	334–2090	White rock salt without noticeable impurities	1756

Section of Hole No. 8.—Altogether eight holes were drilled to locate the contour of the salt. Only four of these reached the salt. They all show a surface layer of clay from 33 to 110 feet thick beneath which are irregular layers of sand and gravel with one or more layers of blue clay, and in one case a thin layer of lignite. The nearest the salt approaches the surface is 91 feet, in hole No. 8 which showed the following section:

Section of Hole No. 8

No.	Depths		Feet
1.	0– 33	Clay	33
2.	33– 91	Sand and clay	58
3.	91–112	Rock salt, not passed through	21

Blue clay and zinc.—In hole No. 7, a depth of 442 feet was reached without finding salt. This shows fairly well the usual arrangement of the beds on the island.

Section of Hole No. 7

No.	Depths		Feet
1.	0– 80	Clay	80
2.	80–187	Sand	107
3.	187–195	Sand and blue clay	8
4.	195–260	Sand	65
5.	260–278	Sand and gravel	18
6.	278–303	Coarse gravel	25
7.	303–363	Sand and gravel	60
8.	363–396	Blue clay and zinc sand	33
9.	396–428	Sand	32
10.	428–442	Cemented sand and blue clay *	16

In layer 2, at a depth of between 130 and 160 feet, a fragment of pottery 2x3 inches was pumped out of the pipe. It is positively stated that it could not have fallen in from above. Layer 8 records the blue galena and zinc clay of Belle Isle.

Shape of Salt Mass.—At the time of the writer's visit there was no one on the island who could give the exact location or order of the holes. It was therefore impossible to determine their relative position and elevation. This leaves us decidedly in the dark as to the exact shape of the salt mass. All that we know is that there is a point of maximum elevation.

* To this Mr. Lucas adds "Salt is probably not very far from this point."

Conclusions.—The regularity of the surface layer of clay and the underlying gravel beds is very similar to Grande Côte and Côte Blanche, so far as we know it. In three of these wells there is a single layer of clay which might show something about the dip, the relative elevation and position of the holes was known. The island shows no evidence whatever of having been thrown out of Lake Peigneur by an explosion or eruption of any kind. Nor was Lake Peigneur necessarily formed at the same time.

ATTAKAPAS PRAIRIE

WELL SECTIONS

Hilgard's supposition.—The boring of numerous artesian wells in Attakapas prairie has thrown much light on the stratigraphy of this part of the country. Hilgard, from a superficial examination of the country around the islands states that nearly all the material above the Port Hudson stump stratum has been eroded; indeed, he believed that the present relief of the islands was to a very great extent produced by the removal, by erosion of the Port Hudson material from the country surrounding the islands. These sections rather disprove this idea as they show material of very considerable thickness which Hilgard would undoubtedly have regarded as Port Hudson.

Jeannerette well sections.—The data collected by Clendenin give a set of four wells extending from Jeannerette in the direction of Grande Côte; two of which we have taken the liberty of reproducing.

Ice Factory Well Jeannerette

	Depth		Feet
1.	0– 15	Red clay	15
2.	15– 95	Mottled clay and sand	80
3.	95–105	Organic bed, leaves, twigs, etc.	10
4.	105–175	Sand and gravel. Water bearing	70
5.	175–350	Yellow clay, not passed through	175

A second well much nearer Grande Côte shows a greater thickness of the beds overlying the gravel.

*Artesian Well 3¼ Miles Southwest of Jeannerette**

	Depth		Feet
1.	0–140	Soil and gray mottled clay	140
2.	140–142	Shell bed	2
3.	142–152	Organic bed	10
4.	152–217	Sand and gravel	65

Two other wells in the same region give about the same sections.

Glencoe well section.—A deep well at Glencoe although quite near the line of the islands shows an increased thickness of the upper beds.

*Artesian Well Glencoe**

	Depth		Feet
1.	0– 1	Soil	1
2.	1– 12	Yellow clay	12
3.	12– 24	Quicksand	12
4.	24–224	Blue clay	200
5.	224– ?	Shale and clay	?
6.	?–625	Coarse sand and gravel. Water	?

Although this section is quite incomplete the depth below the top of the sand and gravel strata at which water is usually found would lead us to suppose that the depth of the sand and gravel here is at least 500 feet.

Thomassy's section.—On his way from New Iberia to Grande Côte, Thomassy passed by a Mr. Zenon Oliver's plantation. This was probably in the southern part of Prairie Au Large. Here he obtained the following section :

Section of well at Prairie Au Large †

1.	Yellow to chocolate clay	2 to 3 ft.
2.	Yellow sand	5 to 6 ft.
3.	Red sand containing flint pebbles and gravel which are entirely foreign to the alluvium of the Mississippi. Not passed through	25 ft.

* A Preliminary Report upon the Florida Parishes of East Louisiana and the Bluff, Prairie and Hill Land of Southwest Louisiana by W. W. Clendenin. Part III, Bull. La. State Expt. Stations, 1896.

† Géologie Pratique de la Louisiane, p. 82.

This section is quite different from the other sections. The uncertainty of its location makes it difficult to frame any conclusions regarding it. It may represent a local gravel bed in the Port Hudson or a slight uplift connected with the insular uplifts. If the latter be the case a deep well will probably reach salt.

GENERAL CONSIDERATIONS

THE ORIGIN OF THE ISLANDS

Method and date of formation.—Only two of the islands furnish definite data on the method and date of their formation. Belle Isle shows a very distinct dome-shaped fold. Petite Anse seems to represent a fault block.

They cannot be regarded as a portion of a great anticlinal ridge or backbone, as Hilgard supposed, extending from northwest to southeast. On Petite Anse the line of strike of the lignite, sandstone and salt is at right angles to the line of the islands, *i. e.*, across the supposed fold rather than with it. On Belle Isle the main line of hills and the salt mass lie northeast and southwest instead of northwest and southeast. On Grande Côte the main line of hills and the salt mass extend almost north and south.

No evidence of the two movements indicated on Petite Anse has been seen on the other islands and it may be that the phenomenon there shown is the result of complex faulting. If we suppose the Five Islands were made at the same time, the time of this crustal movement can be approximated very closely. The principal folding or faulting occurred after the deposition of the shell bed on Belle Isle and before the bone bed on Petite Anse. Both of these are Pleistocene.

The upper clay beds spread mantlewise over the gravel beds, on Grande Côte, Côte Blanche and Côte Carline, seem to have been deposited after the formation of the islands; very probably at the same time and in the same manner as the lœss beds of the eastern escarpment of the Mississippi valley.

It would seem then that the formation of the islands began with a possible initial movement (evidences of which have thus far been seen only on Petite Anse) in probably late Tertiary time. The main folding and faulting which occurred in the Pleistocene was followed by the depression of the whole costal region and the deposition of the upper yellow clays. During the succeeding high level period the deep channels of the costal rivers were excavated and the lake valleys formed on the islands. The subsidence which followed has continued to the present day.

That the immediate shore of the Gulf should have been the scene of orographic movements in Pleistocene time may at first appear a little startling but there is no reason why it should not be so and every reason why it should. The great sedimentary deposits which have been forming along the Gulf shore in recent time would tend to disturb its equilibrium. The extent of these recent deposits is shown in the Galveston well section which at a depth of 2,920 feet had not penetrated the Upper Miocene. 1,500 feet of this material is above strata known to be Upper Tertiary.*

Age of the salt deposit.—No data bearing directly on the age of the salt deposit have yet been obtained. No fossils older than Pleistocene have been found *in situ* in the neighborhood of the salt. The gravel beds which overlie the salt are of decidedly uncertain date. If we accept the generally received opinion of the age of the southern gravel beds they are Lafayette or late Pleiocene. This would make the salt bed pre-Pleistocene.

The only other data we have bearing on the age of this deposit are the salines of northern Louisiana. Darby first called attention to the similarity between the salt springs on Petite Anse and those north of Red River.† Hilgard noticed the same resemblance is his reconnaissance of Louisiana in 1869 and conceived the idea of a Cretaceous ridge or backbone with several peaks now represented by outcrops. These salines are in many cases associated with hard crystalline limestone showing,

*Preliminary Report on the Organic Remains Obtained from the Deep Well at Galveston together with Conclusions Respecting the Age of the Various Formations; Penetrated by G. D. Harris, 4th An. Rept. Texas Geol. Surv., pp. 117–119, 1893.

†The Emigrant's Guide to the western and southwestern States, etc., New York, 1818, p. 86. He says, "From its proximity, this spring, has been considered as merely a drain of the sea, but on inspection, it has all the common features of the salt springs found north of Red River."

wherever the outcrop is large enough to see the stratigraphy, a marked dome. The salt springs apparently emerge from this gypseous limestone, which Hilgard, on two fossils found at King's salt works, pronounced Cretaceous. Vaughan on very slender evidence guessed it to be upper Cretaceous.* This was proven this year beyond question by a large suite of fossils collected at Rayburn's salt works.

The salt springs of northern Louisiana are then known to emerge from upper Cretaceous outcrops. No salt springs are known in the Tertiary of this region; therefore Hilgard concluded the salt to be Cretaceous. So far as our evidence goes this seems the most probable though it can hardly be said to be proven.

Comparison of the Louisiana rock salt deposit to the great deposits of the world.—In thickness and purity the Louisiana salt deposit easily outranks any other yet known in this country. In Europe the famous Strassfurt deposits of Permian age show only 685 feet of pure rock salt.† But it is outranked by the salt wells in strata of the same age at Sperenberg near Berlin, which passes through 3,769 feet of rock salt.‡ Geikie gives to the famous Wieliczka deposits of Gallacia, Austria, which are now believed to be Tertiary, § possibly Miocene, or even later,‖ an aggregate thickness of 4,600 feet. But this does not represent the thickness of a single mass of salt as is the case in the Côte Carline deposit. The saliferous formations of Wieliczka consist of layers and

* A Brief Contribution to the Geology and Paleontology of Northwestern Louisiana by T. Wayland Vâughan. Bull. U. S. Geol. Surv. No. 142, 1896, pp. 12–13.

† Text Book of Geology by Archibald Geikie, 3d ed., London, 1893, p. 148.

‡ Geology, Chemical, Physical and Stratigraphical, by Joseph Prestwich, Oxford, 1884, vol. 1, p. 116, vol. 2, p. 140.

Nature, vol. 15, p. 240, 1877.

Hand Book of Geology by A. Geikie, 3d ed., London, 1893, p. 148.

Elements of Geology by Joseph LeConte, 4th ed., New York, 1897, p. 439.

§ A System of Mineralogy by E. S. Dana, 6th ed., New York, 1892, p, 155.

Address by Andrew Crombie Ramsey. Report of Brit. Assn. Adv. Sci., 1880, p. 13.

masses of salt separated by beds of clay, marl and anhydrite.* The rock salt of the salt range of India, the only other deposit which can compare with the Louisiana beds in thickness, is associated with beds of clay; the aggregate thickness of the whole averaging 300 to 700 feet and not exceeding 1,200.†

It would seem that according to thickness and purity the Louisiana salt beds rank third and possibly second in the great salt deposits of the world.

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* Elements of Chemical and Physical Geology by Gustav Bischof, London 1854, vol. 1, p. 383. Quotes Zeuchner in Jahrbuch für Mineralogie, etc., 1844, p. 527.

* Earthy and Other Minerals and Mining by D. C. Davies, London, 1888, p 86.

† Memoirs of Geol. Surv. of India, vol. 2. "The Trans-Indus Salt Region," by A. B. Wynne. Quoted by Davies in Earthy Minerals and Mining, p. 93.

Special Report No. 4

A REPORT ON LOUISIANA CLAY SAMPLES

BY

HEINRICH RIES

A REPORT ON LOUISIANA CLAY SAMPLES.

PRELIMINARY REMARKS

LOCALITIES

The samples examined were from the following localities :

Harris No. 53. Alluvial clay, R. R. track just S. of Little R.
40. Grand Gulf clay, 1 mile west of Lena.
62. Carter's pottery works, Robelien, La.
X. Sec. 17, 3 N., 11 W.
St. Joe brick clay.
Shale, Sec. 17, 3 N., 11 W.

EXPLANATION OF TESTS

Before giving the results of the tests and presenting my conclusions concerning the possible uses of the material investigated, it may be well to explain the tests which were carried out on the sample, and their practical bearing.

Two kinds of tests.—In the testing of clays, two different lines of work may be followed, the one chemical and the other physical. The former gives results that are of practical value only in certain cases; the latter is of practical importance in every case, and yields information concerning the material that can be appreciated and used by the intelligent clay worker. It is the physical testing that has been done on the samples submitted.

Plasticity.—Clay is a very common substance in nature, and yet nothwithstanding its abundance, it is one of the mineral products whose properties are least understood. The most striking property that clay possesses is plasticity, and it is one of the two properties that make it of such enormous value to mankind. Plasticity in brief is the property by virtue of which the clay when mixed with water can be molded into any desired shape, which form it retains when dry. The second great property is brought out when the clay is subjected to a degree of heat above low redness, it becoming converted into a hard rock-like mass, which for durability and strength is exceeded by few building stones.

ORIGIN OF CLAYS

Residual.—Clay is a secondary substance ; that is it is formed by the decay of other rocks, especially those containing the mineral feldspar. When feldspar decays it yields the mineral kaolinite, which is a hydrated silicate of alumina. A mass of kaolinite would be called kaolin, and this latter is the purest form of clay known, but thus far no absolutely pure clay has been found in nature. The feldspar often occurs in the forms of veins, and its decomposition gives rise to veins of kaolin. As a rule the feldspar is associated with other minerals, especially quartz and mica, so that the kaolin thus formed is a mixture of kaolinite, quartz, mica and even some undecomposed feldspar. A deposit of clay formed under these conditions and containing only the minerals mentioned would be pure white, and would also be called a residual clay, because it represents the residuum of rock decay and is found at the locality where it was formed. Very often the feldspar is intermixed with minerals which contain iron in some form, and in the decay of such feldspathic rocks the iron is set free in the form of iron oxide and colors the clay red. Residual clays of this type are very common all through the south in those regions which are underlaid by gneisses and other crystaline rocks, and they form the great brick-making material of many of the Southern states.

Sedimentary.—As the land surface is gradually worn down by weathering, the particles of residual material are washed down into the lakes or seas and there spread out over the bottom in the form of sediment. Beds of clay formed in this manner are known as sedimentary clays.

STRUCTURE

Two types.—The structure of these two types of clay deposit is very different. In residual clays we find that there is a gradual passage from the fine grained clay at the surface into that which contains a mixture of fine particles and angular fragments, and this in turn passes by stages into the undecomposed rock beneath. Indeed the structure of the parent rock is often observable for several feet up into the clay mass, as in the process of rock decay there is often very little movement of the mineral fragments. Sedimentary clays on the other hand show no relation to the underlying parent rock. They are usually distinctly stratified, and there may be a number of distinctly similar, or markedly different layers one on top of the other.

COMPOSITION

Either residual or sedimentary clays may be composed entirely of very fine grains of clay substance as it is called, or they may be made up of a mixture of both coarse and fine ones.

The relative amount of these present exercises an important effect on the behavior of the clay as will be explained later.

In nature it is possible to find all grades of clay varying from the nearly pure ones to those which are most impure.

A clay which is nearly pure such as the higher grades of kaolin would have only silica, alumina and combined water in its composition, while the impure clays would have not only the above mentioned ingredients, but in addition lime, magnesia, iron oxide and alkalies, and the less pure the clay the greater the quantity of these substances which are found in it. The most important effect of these impurities as a whole is to alter the fusibility of the clay, and the greater the percentage of them that the clay contains the more easily will it melt.

A second effect of these impurities, especially the iron, is their influence on the color of the clay in burning.

PHYSICAL PROPERTIES OF CLAY

The physical properties of clays are extremely important, and on them depend many possibilities. The most important of these properties are plasticity, tensile strength, fusibility, color on burning, shrinkage, and slaking.

Plasticity.—This property has already been explained as that by virtue of which the clay can be molded into any desired shape, which shape it retains when dry. The plasticity of a clay depends almost entirely on its physical condition, that is on the size and shape of the clay grains, and stands in absolutely no direct relation to the amount of kaolinite which the clay contains, although this fact is often erroneously stated in many books. The cause of plasticity being thus partly understood it is easily conceivable that clays will vary widely in the degree of plasticity which they exhibit. Very plastic clays are called "fat" while those which are low in plasticity are called "lean." One of the important effects of plasticity is that it permits the clay to be molded more readily, and obviates the danger of its cracking while it is being formed.

Plasticity is developed by mixing the clay with water, and the plasticity of any clay increases with the amount of water added up to a certain point, while the addition of more water causes the clay to soften and turn into a condition of mud. In sedimentary clays, especially the very plastic ones an appreciable amount of water can be added to the clay after the point of maximum plasticity has been reached without destroying the cohesiveness of the clay, but with residual clays the addition of a very slight excess of water in mixing is often very noticeable as the material softens to the mud like condition very rapidly.

Very plastic clays may require as much as 35 or 40 per cent of water by weight to develop their greatest plasticity, while the lean ones may not need over 15 or even 20 per cent to accomplish the same result.

Shrinkage.—If a mass of clay is set aside after being molded and allowed to dry, because of the evaporation of the water, the particles begin to draw together and the mass shrinks. This is known as the *air shrinkage.* Clays, which are very plastic and contain a large quantity of fine particles in their mass tend to shrink the most, while the very lean clays as a rule shrink the least. The more water that is added to the clay in molding, the greater will be the air shrinkage. It is in this stage that the effects of dry-pressing make themselves beneficially felt, that is when the clay is molded in the form of a dry, or nearly dry powder there is little or no water to escape and consequently the air shrinkage is very low. The air shrinkage of lean, sandy clays may be as low as two per cent, while for very fat plastic clays it may be as high as 12 per cent. There are certain dangers which attend the high shrinkage in the air drying, i. e. that the clay does not tend to dry equally fast throughout the mass unless the operation is carried on very slowly, and consequently there is danger of cracking in the ware, or twisting of the form. (If the particles of the clay interlock in an intimate manner, and resistance very strongly the tendency to be pulled apart, then there is less danger of cracking.) This resistance of the particles to tearing is spoken of as the tensile strength and is expressed in pounds per square inch. It is measured by forming the clay into the form of briquettes of the same shape and size as those used in the testing of cement. When dry these are placed in a cement testing machine and the number of pounds per square inch, which is required to pull them apart, is measured. This is a variable quantity, and may run from 10 or 15 lbs., to 400. The tensile strength shown by the various types of clay in their *air dried* condition, is

Kaolins....................	10– 25	lbs. per sq. in.
Brick clays................	60– 75	"
Pottery clays..............	100–150	"
Paving brick clays..........	75–150	"

Fire shrinkage.—If after a clay has been air dried it is put in a furnace or kiln and subjected to a slowly rising temperature, it begins to shrink more, beginning at a low temperature and continuing upwards. This second shrinkage is known as the fire shrinkage and may be just as variable as the air shrinkage. It is due partly to the loss of chemically combined water which the clay contains, and also to the presence of other volatile materials such as organic matter in the clay. It is just as important that the fire shrinkage should proceed slowly in order to prevent cracking and warping of the ware. Fine grained clays usually shrink more in burning than coarse, sandy ones, and it is on this account that sand is sometimes added to the clay in the process of mixing and molding.

Effect of heat on clay.—In addition to the fire shrinkage which has just been mentioned, there are certain other changes which take place during the burning of a clay and these depend on the temperature and also on the clay, whether pure or impure. If the clay is heated to a certain point, which will be the higher, the purer the clay, a softening of the particles takes place, or fusion begins. If the clay is not heated further than this point, it will on cooling be of a hard, rock-like nature, but will still be porous. This is known as the condition of incipient fusion. A further heating to a temperature of from 75 to 200 degrees Fahr.

causes the particles to soften still more under the action of the heat, so that they pack together in a smaller space, leaving no interstices. At this point the maximum shrinkage of the clay has been reached and the mass will also be impervious or very nearly so. It is what is known as the condition of vitrification. This is the state to which stoneware, paving brick and sewer pipe should be burned. But all clays do not yield the best results if burned to this point.

If the clay is heated still higher it begins to soften still more and at a certain point becomes viscous or flows. This is therefore spoken of as the point of viscosity. In clays which are to be burned to the condition of vitrification the points of vitrification and viscosity should be at least 150 degrees Fahr. apart and preferably 200 degrees. In limy clays the points of incipient fusion and viscosity are very close together and consequently it is not possible to burn a kiln full of ware to vitrification without danger of running it beyond to the point of viscosity. In some fireclays the differcence between the points of incipient fusion and viscosity may be as much as 600 degrees Fahr.

In very impure clays incipient fusion may begin at as low a temperature as 1,700 degrees Fahr., while in fireclays this same point may not be attained below 2,700 degrees, and indeed it really should not in order to permit calling the clay refractory.

Another effect of heating is the change of color that is brought about, especially by iron, for this is the great coloring agent of clay in both the burned and unburned condition. With a given percentage of iron, the clay when lightly burned will be light red, but as the temperature of the firing increases the color deepens, passing into deep red and finally, when the clay fuses, into bluish black. Again, the greater the quantity of iron oxide in a clay the deeper will be the color produced at any given temperature. This production of the red color assumes that the condition of the kiln fires is oxydizing, that is that there is a supply of air. If there is an insufficient supply of the latter the the fire will act reducing and the color of the burned clay will be bluish instead of red.

There are certain ingredients which tend to destroy the reddening power of iron, and these are lime and alumina. It has been found that if the clay contains a large percentage of alumina, that the coloration produced by the iron will be much fainter than if the percentage of alumina were smaller. Lime, however, is far more powerful in this respect than alumina, for if the lime percentage is only one and one-half times greater than that of the iron it begins to exert a bleaching action on the color of the clay in burning, and if the ratio of lime to iron is as three to one the brick instead of burning red will burn buff. This explains the cream color of many cream colored bricks. It should be added, however, that a small percentage of iron in a clay will produce the same shade, but the limy clay will not stand much heat whereas the one low in iron will, and furthermore if they are overburned, the limy one will turn greenish yellow, and the other will tend to pass into a deep buff or deep red.

An important question with clay workers is the regulation of the temperature, and the production of similar results during a number of successive burnings. It, therefore, becomes necessary to have some means of judging the temperature of the kiln. One method consists in using a testpiece of clay, which shows certain effects when the burning has reached the proper point. Another method, which is a modification of the one just mentioned, is to use what are known as Segers cones. These are little pyramid pieces of clays with other substances of a fluxing nature added. They are so compounded that there shall be a constant difference between their fusing points. These cones are numbered from .022 to 33. The theory of these pyramids or cones is that the cone bends over as the temperature approaches its fusing point, and when this is reached the tip touches the base.

In actual use they are placed in the kiln at a point where they can be watched through a peephole, but at the same time will not receive the direct touch of the flame from the fuel, and it is always well to put two or more in the kiln so thas warning can be had of the approach of the desired temperature, as well as of the rapidity with which the temperature is rising.

In order to determine the temperature of the kiln several cones are put in, as for example, Nos. .07, 1 and 5. Suppose that .07 is bent over in burning but 5 is not affected. Then the temperature of the kiln was between 3 and 5. The next time 2, 3 and 4 are put in, and 2 and 3 may be fused but 4 remain unaffected, indicating that the temperature reached the fusing point of three. If this is the temperature at which the burning of the kiln is completed then in future burnings it is only necessary to put cone three in the kiln and raise the fire until this bends over. These cones can be obtained for the sum of one cent each from Prof. E. Orton, Jr., of Columbus, O. In the testing of the samples of the Louisiana clays these cones were used, and the fusibility of the clay is expressed in terms of them. For the temperature of the fusing points of these cones reference can be made to the following list which gives the fusion points in degrees Fahrenheit.

Number of cone	Fusing point degr's Fahr.	Number of cone	Fusing point degrees Fahr.	Number of cone	Fusing point degrees Fahr.
.022	1094	.02	2030	18	2714
.021	1148	.01	2066	19	2750
.020	1202	1	2102	20	2786
.019	1256	2	2138	21	2822
.018	1310	3	2174	22	2858
.017	1364	4	2210	23	2894
.016	1418	5	2246	24	2930
.015	1472	6	2282	25	2966
.014	1526	7	2318	26	3002
.013	1580	8	2354	27	3038
.012	1634	9	2390	28	3074
.011	1688	10	2426	29	3110
.010	1742	11	2462	30	3146
.09	1778	12	2498	31	3182
.08	1814	13	2534	32	3218
.07	1850	14	2570	33	3254
.06	1886	15	2606	34	3290
.05	1922	16	2642	35	3226
.04	1958	17	2678	36	3362
.03	1994				

Slaking.—When a lump, or mass of clay is thrown into water it falls to pieces. This is called slaking. Some clays slake very rapidly, while in the case of others it proceeds so slowly as to be almost imperceptible. Sandy clays tend to slake more rapidly, than fine grained or dense ones, and shales will at times not slake at all, although on grinding and mixing with water they show the same degree of plasticity as clay, for a shale is nothing more than a clay which has become consolidated by simple pressure of the overlying sediments that cover it. The practical bearing of slaking is twofold. It comes into play when the clay is being mixed with water before molding, when it is desired that the clay shall permit the tempering water to enter all of its pores both thoroughly and quickly. It also comes into play when clays are being washed in order to free them from any coarse particles of sand that they may contain, in which case if the clay slakes rapidly, the operation of washing can be carried on with greater speed and at the same time the result will be more complete.

PHYSICAL TESTS OF LOUISIANA SAMPLES

148. (Survey No. 53.) Alluvial clay R. R. track just S. of Little R.

This was a somewhat gritty clay, and slaked easily when thrown into water. On working it up it developed very good plasticity, and required only 20 per cent. of water to mix it, which is low. The tensile strength of air dried briquettes made from this mass is 55 lbs.

The ratio of fine to coarse particles is shown by the mechanical analysis which gave

Clay and fine silt	73 per cent.
Fine sand	27 "

The bricklets made from the clay had an air shrinkage of 6 per cent.

At cone 3 the total shrinkage was 7½ per cent., and incipient fusion had begun. At this temperature the clay burned to a good red color. It contains small specks of pyrite which produce little fused spots when the clay is burned.

At cone 5 the shrinkage is the same and vitrifaction began at 9.

The clay is not to be classed as a fire clay for it is thoroughly viscous at cone 26.

It would no doubt work for the manufacture of a good grade of brick, and would perhaps lend itself to the molding of pressed brick by the dry-press process.

149. (Survey No. 40.)

This is also coarse grained sandy clay and at the same time one that slakes very rapidly.

It took 21 per cent. of water to work it up and the air shrinkge of the bricklets made from this mass was 10 per cent.

The mechanical composition is very similar to the preceding one and is:

Clay and fine silt	73.50	per cent
Very fine sand	26.30	"
	99.80	

The tensile strength was 45 lbs. per sq. in. which is sufficient for a brick clay, but really should be greater.

At cone 3 the clay burns light red and shows signs of incipient fusion.

At cone 5 the total shrinkage was 13 per cent. and the color of the bricklet had changed to a deep red, while the iron oxide mixed in with the clay substance had caused the latter to sinter, but the brick was by no means vitrified.

In burning it would be best not to raise the temperature above cone 3, for it destroys the color and also the texture of the body.

The clay contained but a trace of soluble salts and therefore there would be but little danger of its becoming covered with a coating unless it were from the mortar after being set in the wall.

150. (Survey No. 62.) Carter's pottery works, 2½ mi. E. of Robeline, La.

This is quite a plastic clay and one of the best of the lot submitted. As the tensile strength often stands in more or less direct relation to the plasticity, it may be remarked that the latter is 75 lbs. per sq. in.

The mechanical analysis also indicates that the clay has mostly plastic particles, for it gave

Fine sand	None	
Fine silt	80.75	per cent
Clay	20.20	"
	100.95	

At cone 1 the clay burns hard and dense with a total shrinkage of 13 per cent.

At cone 3 the shrinkage was the same, but vitrification had begun.

At cone 5 the clay began to get viscous.

This would bar it out from being a fireclay. It burns however to a very dense hard body, and could perhaps be used for paving brick.

The percentage of soluble salts amounted to a mere trace. It would work for common earthenware articles of small size, but for stoneware it would probably be found more desirable to mix it with a more plastic clay.

151. (Survey 10.) Sec. 17, T. 3 N., R. 11 W.

This clay is very plastic and while it contains little coarse grit it has much very fine sand. It took 31 per cent of water to work it up, and the tensile strength of the air dried briquettes was 75 lbs. per sq. in.

The mechanical analysis gave:

Clay and fine silt	42.10	per cent
Very fine sand	57.25	"
	99.35	

The air shrinkage was 11 per cent.

At cone 3 the clay burned light red and the total shrinkage was 12 per cent.

At cone 6 the total shrinkage was 14 per cent and the color of the brick brownish red, while incipient fusion had begun.

If burned to this temperature the clay would no doubt make a good grade of face brick. It is not a fire clay for at cone 26 it became thoroughly viscous.

The clay contained but one-tenth per cent. of soluble salts.

Like the preceding it would do for making earthenware, and good pressed brick as well.

152. St. Joe Brick Clay, St. Tammany Parish, La.

A sandy mottled clay that slakes very fast. It took 21 per cent of water to work it up and gave a plastic but slightly gritty mass, which for practical purposes does no harm. The tensile strength of the air dried briquette was 60 lbs. per sq. in.

The mechanical analysis yielded,

Fine sand	63.00	per cent
Clay and fine silt	36.50	"
	99.50	

The air shrinkage was only 4 per cent which is due to the high sand percentage shown by the mechanical analysis.

At cone 3 the clay burns bright brick red and shows specks of fused pyrite.

At cone 5 the color was still red and the shrinkage was 8 per cent, while incipient fusion had begun.

At cone 26 the clay was completely vitrified.

It is to be regarded as a semi-refractory clay, but not good for fire-brick.

There was only a trace of soluble salts.

153. Sec. 17, T. 3 N., R. 11 W.

This is a soft gritty shale with flakes of mica and much organic matter. It took 35 per cent. of water to work it up but did not give a very plastic mass.

The air dried briquettes had a tensile strength of only 30 lbs. per sq. in.

The air shrinkage amounted to 9½ per cent.

At cone 1 incipient fusion occurred and the color of the brick was red. The total shrinkage up to this point was 12 per cent.

At cone 5 vitrification began and the shrinkage was 13 per cent.

The soluble salts amounted to three-tenths of one per cent, which is not excessive, but enough to yield a coating.

While the clay burns dense at a comparatively low temperature, viz., cone 5, at the same time it lacks in plasticity, and if it is desired to use it for paving brick or stoneware it should be mixed with a more plastic clay.

In conclusion it may be said that all of the clays submitted would, when used alone work for pressed brick, one for paving brick and two for earthenware.

Attention should be called to the fact that the points of incipient fusion of all lie somewhat higher than they do in most brick clays, and therefore the best results will be obtained by burning them in permanent walled kilns.

There is a great tendency among Southern brickmakers to not only underburn their bricks, but also to mix sand with the clay, when there is already enough sand in it.

Special Report No. 5

A REPORT ON A COLLECTION OF FOSSIL PLANTS FROM NORTHWESTERN LOUISIANA

BY

ARTHUR HOLLICK

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A REPORT ON A COLLECTION OF FOSSIL PLANTS FROM NORTHWESTERN LOUISIANA

LETTER OF TRANSMITTAL

COLUMBIA UNIVERSITY, NEW YORK, N. Y.
Sept. 23, 1899.

PROFESSOR G. D. HARRIS,
Cornell University, Ithaca, N. Y.:

Dear Sir: I transmit with this a report upon the collection of fossil plants from the vicinity of Shreveport, La., which you sent to me for examination some months since. The collection numbers about 175 specimens, the majority of which are beautifully preserved. The larger number, and best specimens, are in a fine reddish sandstone *; a few are in gray sandstone † and the remainder in clay ‡ or clay concretions ‖.

About 50 species are represented. Of these I have been able to identify 30 either positively or provisionally. Six others I have described as new species.

They are all dicotyledonous angiosperms, with the exception of two monocotyledons and one fern, and they indicate a Lower Tertiary horizon.

Very truly yours,
ARTHUR HOLLICK.

* ¼ mile above Coushatta, La.

† K. C. P. & G. R. R. cut, 1 mile west of Shreveport, La.

‡ Slaughter-Pen bluff, Shreveport, La.

‖ Vineyard bluff, Cross bayou (½ m. above Slaughter-Pen bluff), Shreveport, La.

Cryptogamia

Pteridophyta

POLYPODIACEÆ

Pteris pseudopennæformis, Plate 32, fig. 1.

Pteris pseudopennæformis Lesq., Tert. Fl. p. 52, pl. 4, figs. 3, 4.

Our specimen is the best one of this species thus far figured and gives a clear idea of the difference between it and *P. pennæformis* Heer, Fl. Tert. Helvet., vol. 1, p. 38, pl. 1, fig. 1, with which it was originally confused by Lesquereux. In addition to the fragments figured by Lesquereux another by Newberry may be found in his Later Extinct Floras, etc., Monog. U. S. Geol. Surv., vol. 35, pl. 48, fig. 5.

In hard clay concretions, Vineyard bluff, Cross bayou (½ m. above Slaughter-Pen bluff), Shreveport, La.

Phanerogamia

Angiospermæ-Monocotyledonæ

GRAMINEÆ

Poacites, sp. Plate 32, fig. 2.

This is evidently a portion of a leaf blade of some monocotyledon, apparently a grass, and may be compared with similar fragments described under the genus *Poacites*, such as *P. lævis* Al.Br., depicted by Heer in Fl.Tert. Helvet., vol. 1, pl. 25, fig. 10, *P. firmus* Heer, *ibid.*, fig. 11, etc.

In soft clay, Slaughter-Pen bluff, Shreveport, La.

CYPERACEÆ

Cyperites, sp. Plate 32, figs. 3, 4.

These specimens are evidently fragments of monocotyledons, which may be placed in the genus *Cyperites* for convenience, although they might equally well be considered as belonging to the Palms.

In soft clay, Slaughter-Pen bluff, Shreveport, La.

ANGIOSPERMÆ-DICOTYLEDONÆ

JUGLANDACEÆ

Juglans rugosa, Plate 35, figs. 1, 2.

Juglans rugosa Lesq., Am. Journ. Sci., vol. 45 (1868), p. 206; Tert. Fl., p. 286, pl. 54, figs. 5, 14; pl. 55, figs. 1–9; pl. 56, figs. 1, 2.

In red sandstone, ¼ m. above Coushatta, La.

Juglans schimperi, Plates 32, fig. 5; 33, figs. 1, 2; 35, fig. 3.

Juglans schimperi Lesq., Ann. Rep. U. S. Geol. and Geog. Surv. Terr., 1871(1872), Suppl., p. 8; Tert. Fl., p. 287, pl. 56, fig. 5–10.

Although these specimens vary considerably amongst themselves they occur in such close proximity in the rock that I have thought it advisable to include them all under the one species. In regard to our fig. 2, pl. 33, there can be no doubt, when compared with Lesquereux' fig. 5, pl. 56, above quoted, but the others might be more or less successfully compared with *J. dubia* Ludw., Palæontog., vol. 8, pl. 59, figs. 1, 2, or with *J. occidentalis* Newb., Later Ext. Fl., Monog. U. S. Geol. Surv., vol. 35, pl. 65, fig. 1; pl. 66, figs. 1–4.

In red sandstone, ¼ m. above Coushatta, La.

FAGACEÆ

Quercus microdentata, *n. sp.*, Plate 34.

Leaf elliptical in outline, about 8½ in. long by 3½ in. broad in the middle; finely dentate-serrate from below the center to the apex, entire and wavy margined below; secondary nervation fine, sub-parallel, leaving the midrib at an angle of about 45 degrees, curving upward near the margin, each nerve ending in one of the teeth, or the lower ones extending close to and upward along the margin.

In red sandstone, ¼ m. above Coushatta, La.

ULMACEÆ

Ulmus tenuinervis, Plate 32, fig. 6.

Ulmus tenuinervis Lesq., Ann. Rept. U. S. Geol. and Geog. Surv. Terr., 1873, (1874), p. 412; Tert. Fl., p. 188, pl. 26 figs. 1-3.

In red sandstone, ¼ m. above Coushatta, La.

MORACEÆ

Artocarpus dubia, *n. sp.*, Plate 38, fig. 3.

Leaf irregularly three-lobed, lower lobes short, obtuse, ascending, middle lobe broadest near the middle and tapering to a pointed apex, base wedge-shaped; secondary nervation pinnate throughout and camptodrome.

It is possible that this may be merely a young or small leaf of *A. lessigiana* (Lesq.) Kn., but it appears to be so distinct and is so well defined that I have thought it best to describe it as a new species.

In red sandstone, ¼ m. above Coushatta, La.

Artocarpus lessigiana, Plate 37.

Artocarpus lessigiana (Lesq.) Kn., Science, vol. 21, (1893), p. 24; *Myrica ? lessigiana* Lesq., Ann. Rept. U. S. Geol. and Geog. Surv. Terr., 1874, (1876), p. 312; *Myrica ? lessigii* Lesq., Tert. Fl., p. 136, pl. 64, fig. 1.

In hard clay concretions, Vineyard bluff, Cross bayou, (½ m. above Slaughter-Pen bluff) Shreveport, La.

Artocarpus pungens, Plate 38, figs. 1, 2.

Aralia pungens Lesq., Cret. and Tert. Fl., p. 123, pl. 19, figs. 3, 4.

In red sandstone, ¼ m. above Coushatta, La.

Ficus artocarpoides, ? Plate 35, fig. 4.

Ficus artocarpoides Lesq., Cret. and Tert. Fl., p. 227, pl. 47, figs. 1-5.

Our specimen is too imperfect for satisfactory identification and I have therefore only referred it provisionally to this species. It agrees very closely with Lesquereux, fig. 3, above quoted.

In red sandstone, ¼ m. above Coushatta, La.

Ficus harrisiana, *n. sp.*, Plate 46, fig, 2.

Leaf about 3½ in. long by 3½ in. broad across the middle; constricted to a blunt (?) apex and wedge-shaped at the base; margin entire and wavy; three-nerved from the base and with two pairs of prominent sub-opposite secondaries above; midrib strongest, basal nerves branched from the lower side; all nervation finally thinning out and inosculating near the margin, tertiary nervation mainly at right angles to the primaries, secondaries, and sub-secondaries, but broken in places by finer cross reticulations.

It is with hesitation that I have finally decided to place this leaf in the genus *Ficus*. In some respects it suggests *Aralia*, and in others *Hedera* and in general appearance is not unlike

H. auriculata Heer, Fl. Foss. Arct., vol. 2., Fl. Foss. Alask., p. 36, pl. 9, fig. 6, but it is a much larger leaf and I have not been able to compare it satisfactorily with any described species in either genus.

The specific name is given for Prof. G. D. Harris, through whose efforts the collection containing the specimen was brought to my attention.

In clay concretions. Vineyard bluff, Cross bayou, (½ mile above Slaughter-Pen bluff) Shreveport, La.

Ficus planicostata, Plate 36.

Ficus planicostata Lesq., Ann. Rept. U. S. Geol. and Geog. Surv. Terr., 1872, (1873), p. 393; Tert. Fl., p. 201 pl. 31, figs. 1–8, 10–12.

Our specimen is larger than any of those figured by Lesquereux, but otherwise it agrees too closely with the species to warrant a separation.

In soft clay, Slaughter-Pen bluff, Shreveport, La.

Toxylon longipetiolatum, *n. sp.* Plate 48.

Leaf, exclusive of the petiole, about 5¾ in. long, slightly inequilateral, broadest in the middle, rounded and curving in a bow to the base, somewhat constricted to a short point at the apex; margin entire; petiole about 3 in. long, curved; midrib curved; secondaries simple, sub-parallel, curving upward and approaching each other near the margin, all but the lower two pairs alternately arranged.

In red sandstone, ¼ m. above Coushatta, La.

MAGNOLIACEÆ

Magnolia hilgardiana, Plate 39.

Magnolia hilgardiana Lesq., 2d Rept. Geol. Recon. Ark., p, 319, pl. 6, fig. 1.

In red sandstone, ¼ m. above Coushatta, La.

Magnolia lanceolata, Plate 40.

Magnolia lanceolata Lesq., Mem. Mus. Comp. Zoöl., vol. 6, (1878), No. 2, p. 24, pl. 6, fig. 4.

Our specimen appears to be merely a more robust one of this species. It is also comparable perhaps with *M. longipetiolata* Etts., as figured in Foss. Fl. Bilin, pl. 41, figs. 8, 9.

In red sandstone, ¼ m. above Coushatta, La.

LAURACEÆ.

Cinnamomum buchi, Plate 43, fig. 1.

Cinnamomum buchi Heer, Fl. Tert. Helvet., vol. 2, p. 90, pl. 95, figs. 1–8.

Our specimen appears undoubtedly to be a large one of this species although it also closely resembles the allied species *C. polymorphum* (Al. Br.) Heer, as figured in the above quoted work, on plates 93 and 94, and *C. spectabile* Heer, *ibid.*, pl. 96.

In red sandstone, ¼ m. above Coushatta, La.

Cinnamomum scheuchzeri, (?) Plate 41, fig. 4.

Cinnamomum schuchzeri Heer, Fl. Tert, Helvet., vol 2, p. 85, pl. 91, figs. 4–22; pl. 92, figs. 1–10b; pl. 93, figs. 1, 5.

The reference of this specimen to the above species is made provisional on account of its imperfect condition; there is but little doubt, however, that it is correct.

In soft clay, Slaughter-Pen bluff, Shreveport, La.

Cinnamomum sezannense, Plate 42, fig. 2.

Cinnamomum sezannense Wat., Pl. Foss. Bass. Paris, p. 175, pl. 50, fig. 2; *C. dubium* Wat., *ibid.*, p. 176, pl. 50, fig. 4; *Daphnogene pedunculata* Wat., *ibid.*, p. 178, pl. 50, figs. 6–10; *D. longiqua* Sap. and Mar., Essai Vég. Marnes Heers. Gelind., p. 48, pl. 4, fig. 7; *D. sezannensis* Sap., Fl. Foss. Sezanne., p. 369 [81], pl. 29 [8] fig. 5, etc.

There is but little doubt that most, if not all the leaves described under the above names are referable to one species, to which our specimen belongs. In addition to the above references comparisons even more satisfactory may be made with figs. 5 and 6, pl. 6, Essai Vég. Marnes Heers. Gelind and with figs. 2 and 5, pl. 9, Rév. Fl. Heers. Gelind., of Saporta and Marion.

In hard clay concretions, Vineyard bluff, Cross bayou (½ m. above Slaughter-Pen bluff) Shreveport, La.

Cryptocarya eolignitica, *n. sp.*, Plate 42, fig. 1.

Leaf about 6 in. long (including a petiole of about ½ in. in length), by about 2¼ in. maximum width at the middle, oblong-ovate in outline, slightly inequilateral, entire and wavy margined, tapering to the apex, abruptly curved at the base and extending a short distance down the petiole; sub-three-nerved by the lower pair of sub-opposite secondaries, which start from a point about ½ in. above the base and curve strongly upward ; upper secondaries irregularly disposed, curving upward and all finally thinning out close to the margin ; tertiary nervation fine, forming a series of loops between the margin and the outer sides of the lower secondaries.

This beautiful leaf appears to be entirely distinct from any heretofore described. It almost certainly belongs in the *Lauraceæ* and after a number of comparisons with living species in the genera *Phoebe*, *Oreodaphne*, *Litsæa*, etc. I have decided to place it as given above.

In red sandstone, ¼ m. above Coushatta, La.

Daphnogene kanii, (?) Plate 41, fig. 3.

Daphnogene kanii Heer, Fl. Foss. Arct., vol. 1., p. 112, pl. 14, figs. 1–5 ; pl. 16, fig. 1.

If our specimen were in a better state of preservation it would probably not be necessary to question the reference to the above species, of which it seems to be a small form. I have thought it best to so refer it however, rather than to attempt a description of a new species founded upon fragmentary material.

In hard clay concretion, Vineyard bluff, Cross bayou (½ m. above Slaughter-Pen bluff) Shreveport, La.

Laurus primigenia, Plate 41, figs. 1, 2.

Laurus primigenia Ung., Gen. et Sp. Pl. Foss., p. 423.

I have included our specimens under this protean species largely for the reason that they may be satisfactorily compared with figures of specimens referred by other authors to the same species, notably by Heer, in Fl. Foss. Arct., vol. 7, pl. 77, figs. 8–13, and pl 78, figs. 1–11.

In red sandstone, ¼ m. above Coushatta, La.

Persea speciosa, Plate 41, fig. 5.

Persea speciosa Heer, Fl. Tert. Helvet., vol. 2, p. 81, pl. 90, figs 11, 12 ; pl. 100, fig. 18.

In red sandstone, ¼ m. above Coushatta, La.

Tetranthera præcursoria, Plate 44, figs. 3, 4.

Tetranthera præcursoria Lesq., Cret. and Tert. Fl., p. 228, pl 48, fig. 2.

In red sandstone, ¼ m. above Coushatta, La.

AQUIFOLIACEÆ

Ilex? affinis (?), Plate 44, fig. 2.

Ilex? affinis Lesq., Ann. Rept. U. S. Geol. and Geog. Surv. Terr., Suppl. 1871, (1872), p. 8; Tert. Fl., p. 270, pl. 50, figs. 2, 3.

Our specimen is too imperfect for accurate comparison, but it appears to be an *Ilex* and is sufficiently near to Lesquereux' species for at least provisional reference.

In red sandstone, ¼ m. above Coushatta, La.

Ilex, sp., Plate 43, figs. 2, 3.

The two fragments figured apparently represent a leaf related to the genus *Ilex* or perhaps to *Celastrus*, but they are too indefinite either for satisfactory comparison or as a basis for the description of a new species. Figures more or less closely resembling ours may be seen under *I. longifolia* Heer., Fl. Foss. Arct., vol. i., pl. 48, figs. 3–6 and *I. hibschi* Engelh., Sitzb. Isis, Jahrg. 1891, pl. 1, fig. 1.

In soft clay, Slaughter-Pen bluff, Shreveport, La.

CELASTRACEÆ

Celastrus taurinensis (?) Plate 46, fig. 1.

Celastrus taurinensis Ward, Types Laram. Fl., Bull. U. S. Geol. Surv. No. 37, p. 79, pl. 34, figs. 5, 6.

This specimen is placed provisionally under the above name as it is too imperfect for accurate identification. That it belongs in the genus *Celastrus* there can be but little doubt as may be seen by comparison with the figures above quoted and also with the closely allied species, *C. alnifolius* Ward, *ibid.*, p. 80, pl. 35, figs 1, 2, and *C. borealis* Heer, Fl. Foss. Arct., vol. 2, Fl. Foss. Alask., p. 37, pl. 10, fig. 4. In fineness of serration it more nearly resembles the latter two species while in its nervation it is more like the species to which it is provisionally referred, especially as indicated in fig. 5 above quoted.

In red sandstone, ¼ m. above Coushatta, La.

Celastrus veatchi, *n. sp.*, Plate 43, figs. 4, 5.

Leaf about 3 in. long by 1⅜ in. broad in the middle, elliptical in outline, tapering about equally to base and apex, obtusely or crenately toothed or the lower portion merely wavy, with a blunt tip at the apex; midrib strong and straight; secondary nervation well defined, curving upward, becoming brochidodrome or sub-camptodrome through the tertiary nervation, with fine nervilles extending to the teeth and margin.

These leaves closely resembles those of *Elæocarpus europæus* Etts., Foss. Fl. Bilin, Part III., p. 16, pl. 43, figs. 6–10, but ours almost certainly belong in the genus *Celastrus* and I have thought it best to consider them as a distinct species.

The name is given for Mr. A. C. Veatch, the collector.

In red sandstone, ¼ m. above Coushatta, La.

SAPINDACEÆ

Sapindus angustifolius, Plate 35, fig. 5.

Sapindus angustifolius Lesq. Ann. Rept. U. S. Geol. and Geog. Surv. Terr., 1873 (1874), p. 415; Tert. Fl., p. 265, pl. 49, figs. 2–7.

This little leaf appears undoubtedly to belong to the above species, although it might almost equally well be compared with the leaf figured as *Quercus elæna* Ung. by Lesquereux in Cret. and Tert. Fl., pl. 28, fig. 11. Its identity with the genus *Sapindus*, however, is much closer than with *Quercus*.

In gray sandstone, 1 m. west of Shreveport, La. (K. C. P. & G. R. R. cut).

RHAMNACEÆ

Rhamnus cleburni, Plate 47, fig. 1.

Rhamnus cleburni Lesq., Ann. Rept. U. S. Geol. and Geog. Surv., Terr., 1872, (1873), p. 381; Tert. Fl., p. 280, pl. 53, figs. 1–3.

In red sandstone, ¼ m. above Coushatta, La.

CORNACEÆ

Cornus studeri (?) Plate 45, fig. 2.

Cornus studeri Heer, Fl. Tert. Helvet., vol. 3, p. 27, pl. 105, fig. 18–21.

In referring our specimen provisionally to this species I have followed the example of Lesquereux, who also questioned the reference of his specimens to the species. There can be but little doubt, however, that ours is identical with the one figured by Lesquereux in Tert. Fl., pl. 42, fig. 5.

In red sandstone, ¼ m. above Coushatta, La.

ERICACEÆ

Andromeda delicatula, Plate 45, fig. 1.

Andromeda delicatula Lesq., Cret. and Tert. Fl., p. 175, pl. 34, figs. 10, 11.

Our leaf appears undoubtedly to belong to this species, although considerably larger than either of those figured by Lesquereux.

In red sandstone, ¼ m. above Coushatta, La.

Andromeda eolignitica, n. *sp.*. Plate 47, fig. 2.

Leaf lanceolate in outline, entire, about 6 in. long by 1¼ in. wide at the middle, tapering gradually to the base and somewhat more abruptly to the apex, which is constricted and narrowed into a point; midrib strong and conspicuous; secondary nervation not visible.

This leaf was probably of thick leathery texture, in which the finer nervation was hidden. In outline it closely resembles the leaves figured by Lesquereux as *Ficus lanceolata* Heer, in Tert. Fl. pl. 28, fig. 1–5, and also some of those figured by Heer as *Salix longa* Al. Br., in Fl. Foss. Arct., vol. 3, Nachtr. Mioc. Fl. Grönl., pl. 4, figs. 7–10; but inasmuch as the secondary nervation in ours is lacking, I have thought it best to give it a new name.

In red sandstone, ¼ m. above Coushatta, La.

SAPOTACEÆ

Sapotacites americanus, Plate 42, fig. 3.

Sapotacites americanus Lesq., in Safford's Geol. Tenn., p. 428, pl. 7 [K], fig. 8.

In red sandstone, ¼ m. above Coushatta, La.

OLEACEÆ.

Fraxinus johnstrupi (?) Plate 44, fig. 1.

Fraxinus johnstrupi Heer, Fl. Foss. Arct., vol. 7, p. 113, pl. 80, figs 1, 2.

In comparing this leaf with figures of described species I found it almost impossible to decide between the one above quoted and *Quercus juglandina* Heer, *ibid.*, p. 89, pl. 71, fig. 19;

pl. 74, figs. 4–7; pl. 76, fig. 12, and pl. 102, fig. 9a, especially in regard to fig. 7, pl. 74. It also has some resemblance to *Ilex grandifolia* Lesq., Cret. and Tert. Fl., p, 187, pl. 38, fig. 1, but Lesquereux' specimen is too fragmentary for accurate comparison.

In red sandstone, ¼ m. above Coushatta, La

APOCYNACEÆ.

Apocynophyllum sapindifolium, *n. sp.*, Plate 46, fig. 3.

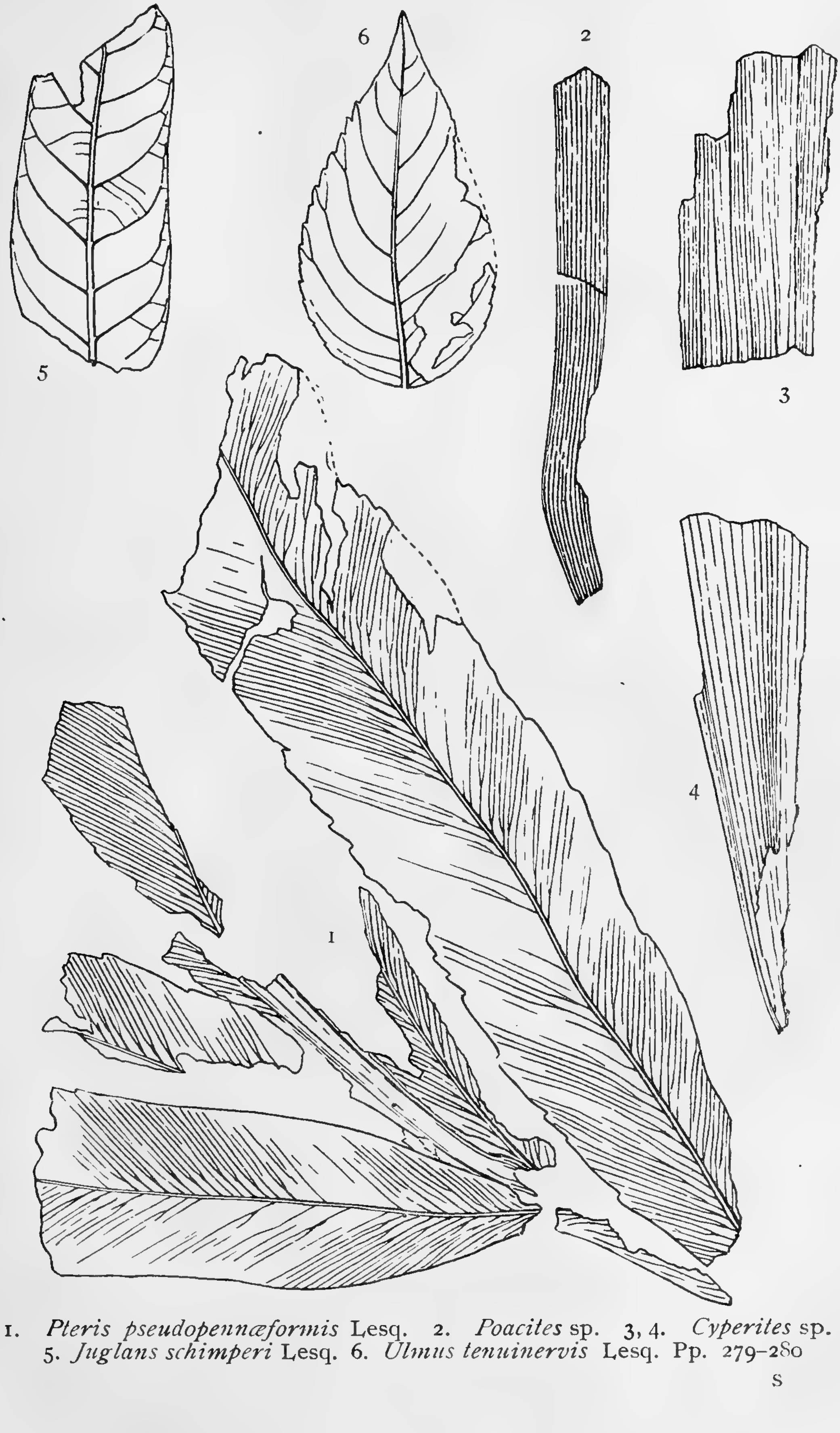
Leaf lanceolate, entire, slightly inequilateral, narrowed and decurrent for a short distance at the base; midrib strong; secondaries thin and regular, leaving the midrib at an acute angle near the base, at a slightly more obtuse angle upward, running parallel to each other for a short distance, and approaching each other close to the margin, where they curve upward; tertiary nervation straight, sub-parallel and essentially at right angles to the secondaries.

This leaf might be provisionally referred to several described species under the genera *Ficus* and *Laurus*, but some slight difference in each instance has led me to think that it represents a new species. Interesting comparisons may however be made with *Ficus lanceolata* (Heer), Web., as figured by Lesquereux in Tert. Fl., pl. 28, figs. 1–5; *Laurus princeps* Heer, by the same author, in Cret. and Tert. Fl. pl. 58, fig. 2 and *L. primigenia* Ung., as figured by Velenovsky in Tert. Fl. Laun, pl. 5, figs. 1–5.

In red sandstone, ¼ m. above Coushatta, La.

NOTE.—After page proof of this report had been set up my attention was called to a paper by Professor H. Engelhardt, entitled "Ueber Tertiärpflanzen von Chile," (Abh, Senckenb. Naturf. Gesellsch. vol. 16 (1891), pp. 629-692, pls. 1–14) in which are described and figured a number of species identical with ours but under different names. Of special interest is his *Goeppertia spectabilis*, which is undoubtedly identical with my *Cryptocarya eolignitica*, in which case Engelhardt's name has precedence.

A. H.



1. *Pteris pseudopennæformis* Lesq. 2. *Poacites* sp. 3, 4. *Cyperites* sp. 5. *Juglans schimperi* Lesq. 6. *Ulmus tenuinervis* Lesq. Pp. 279–280

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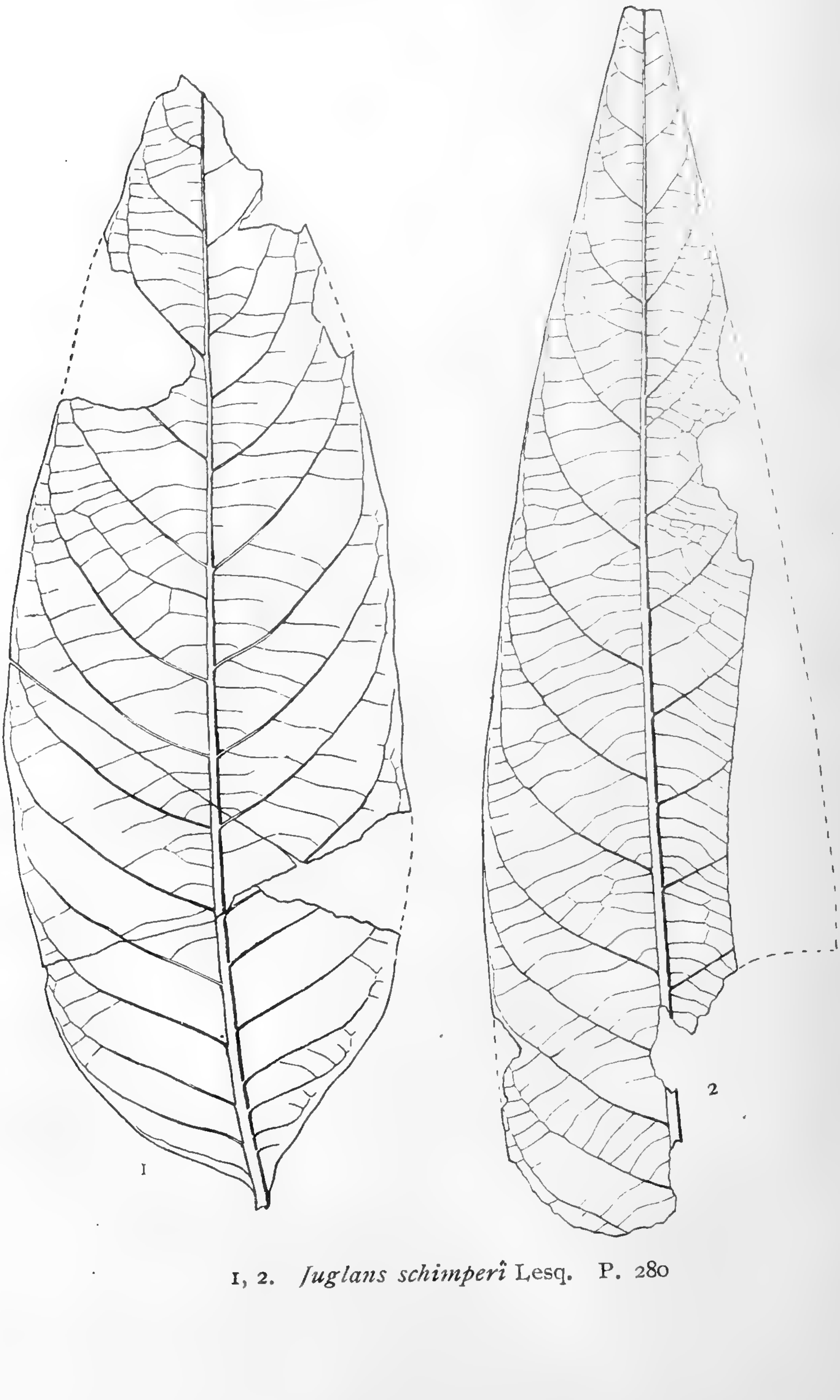
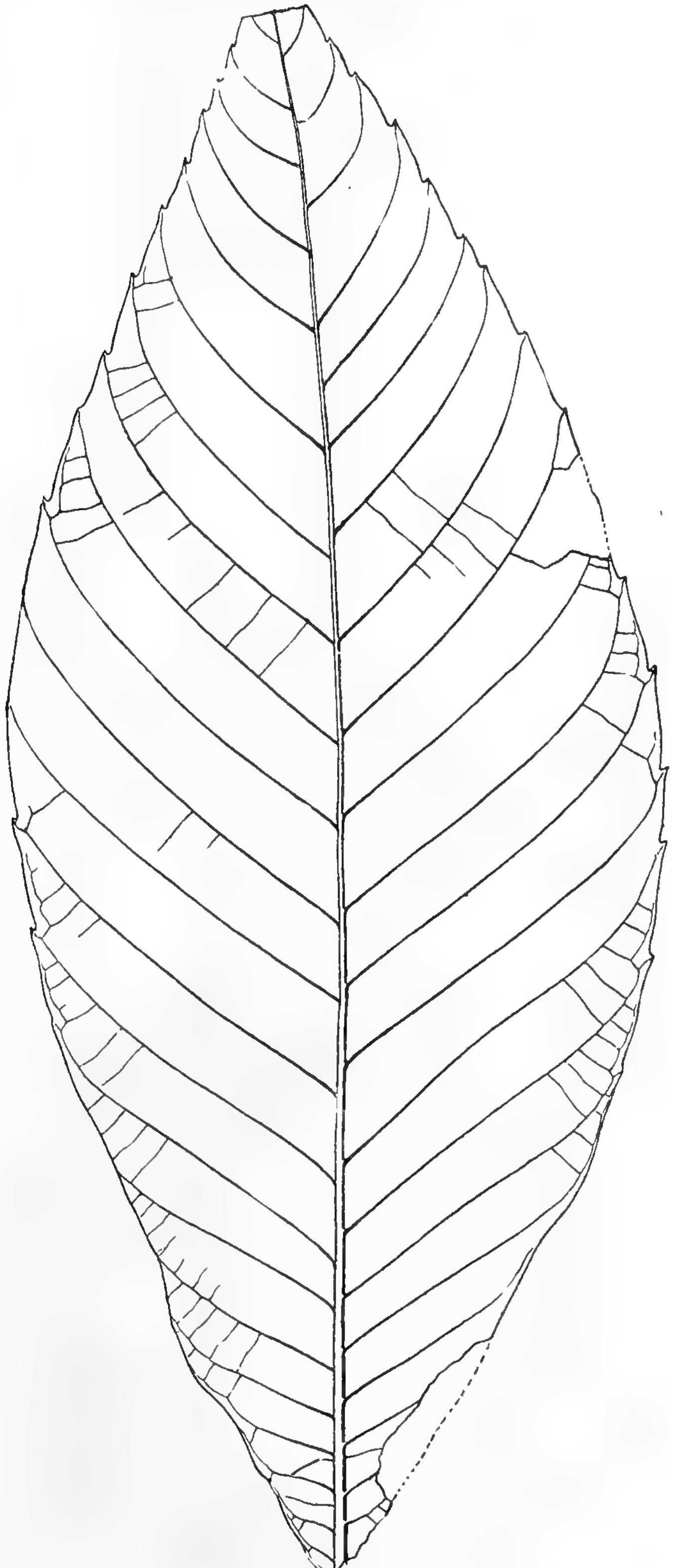
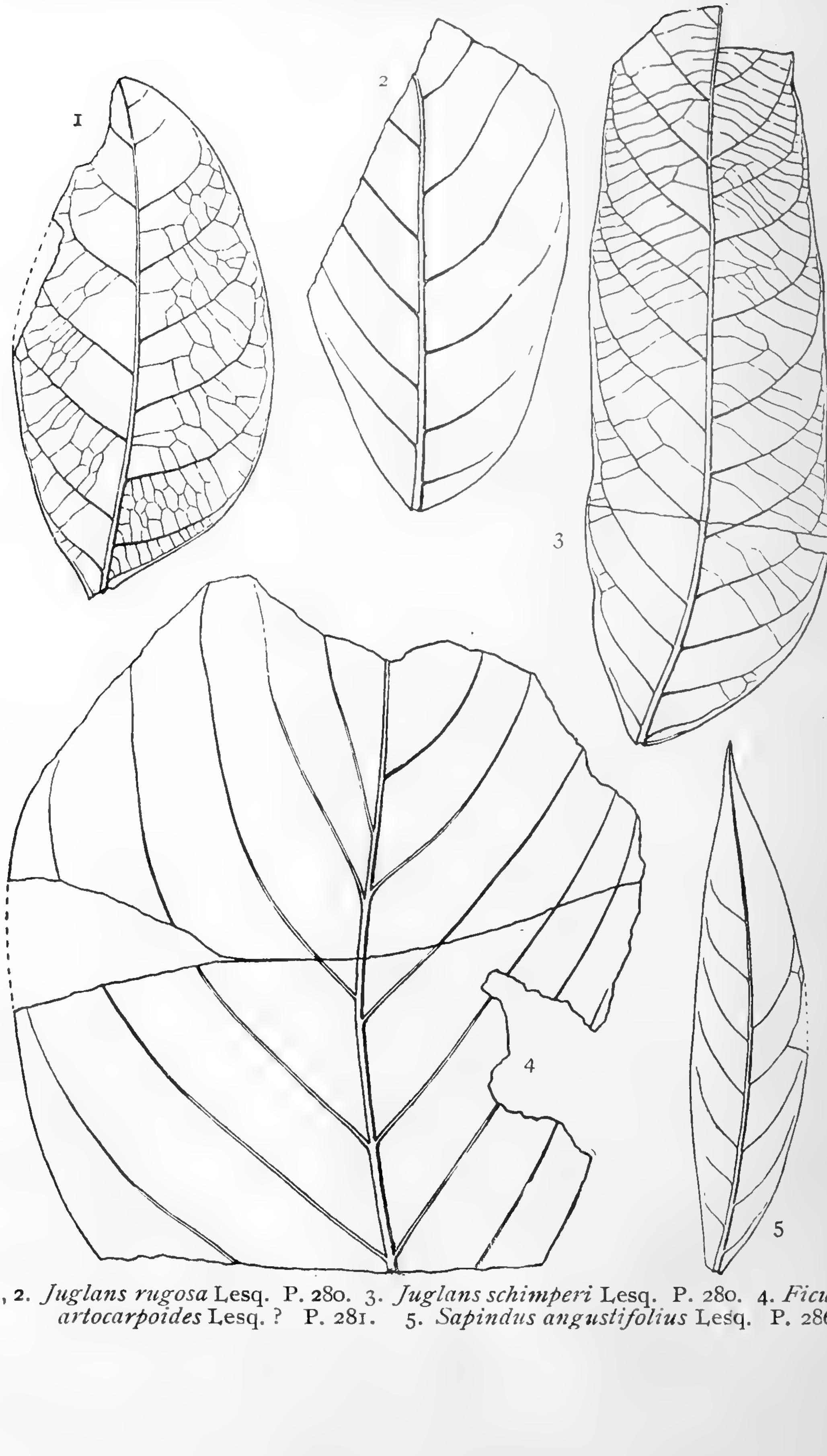


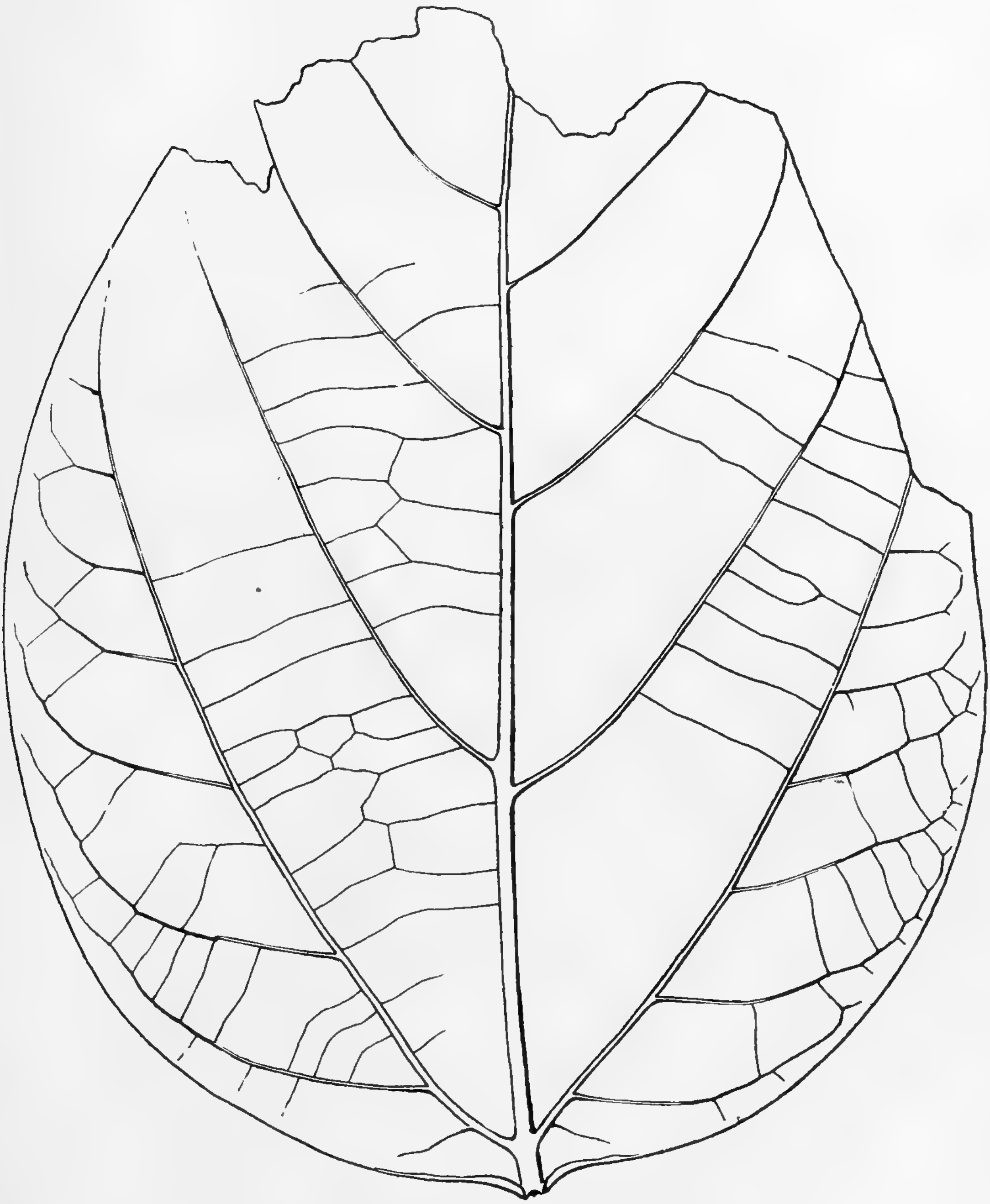
1, 2. *Juglans schimperi* Lesq. P. 280



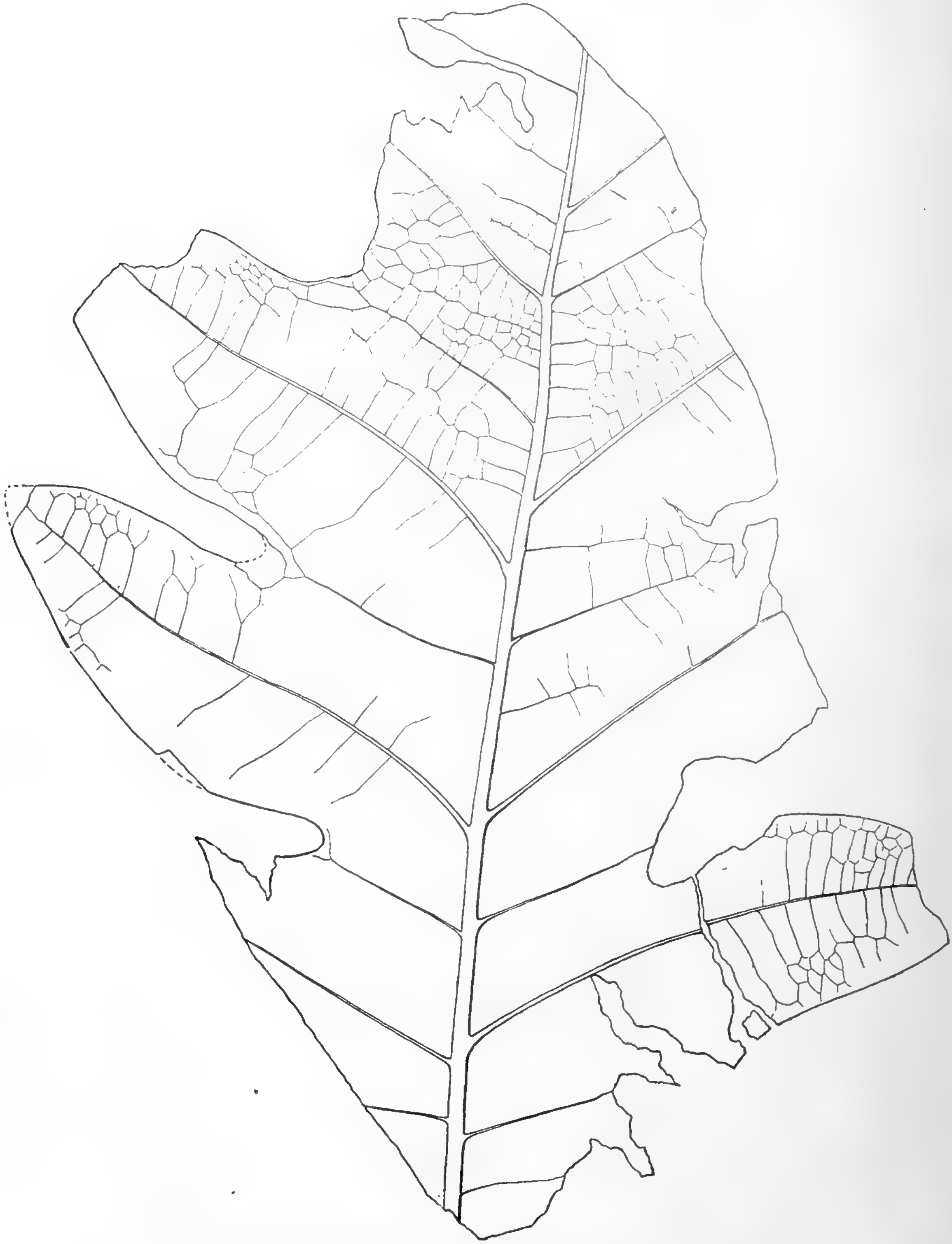
Quercus microdentata, n. sp. x ¾. P. 280



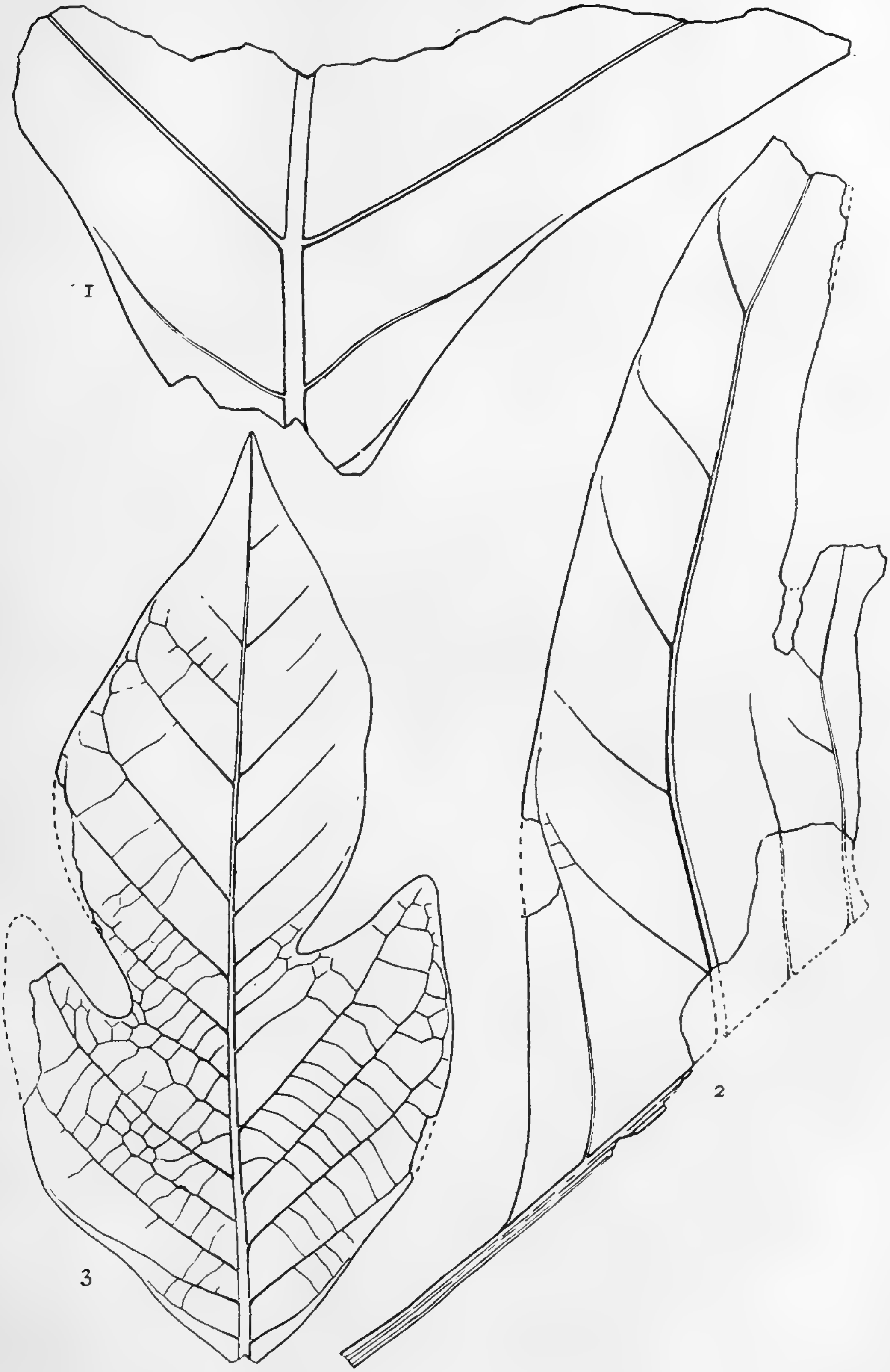
1, 2. *Juglans rugosa* Lesq. P. 280. 3. *Juglans schimperi* Lesq. P. 280. 4. *Ficus artocarpoides* Lesq. ? P. 281. 5. *Sapindus angustifolius* Lesq. P. 286.



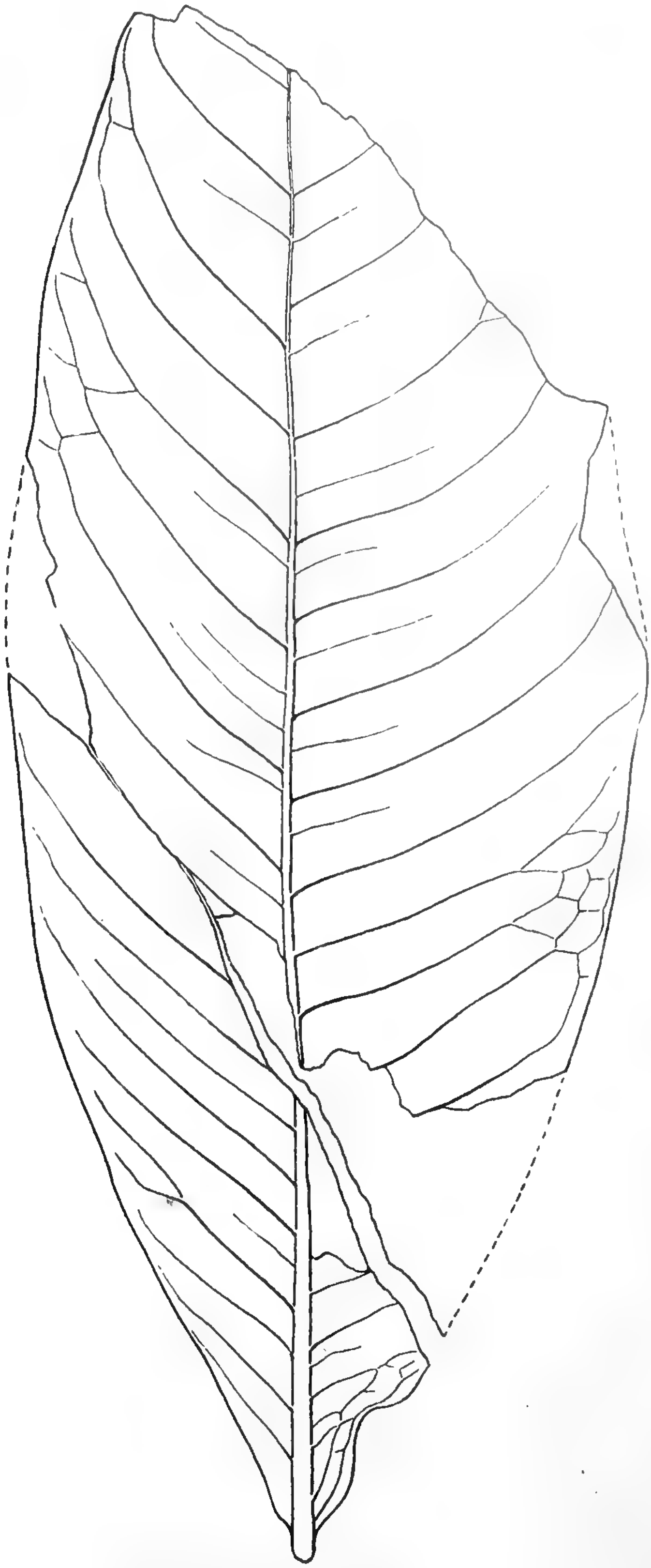
Ficus planicostata Lesq. P. 282.



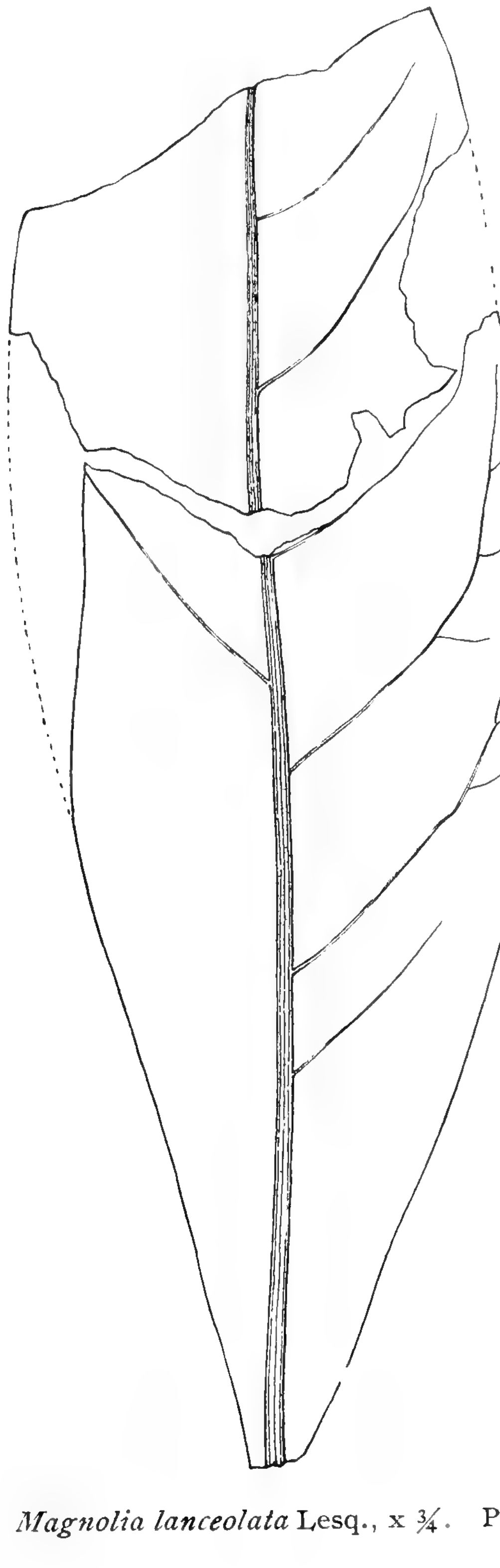
Artocarpus lessigiana (Lesq.) Kn. $\frac{7}{10}$ nat. size. P. 281



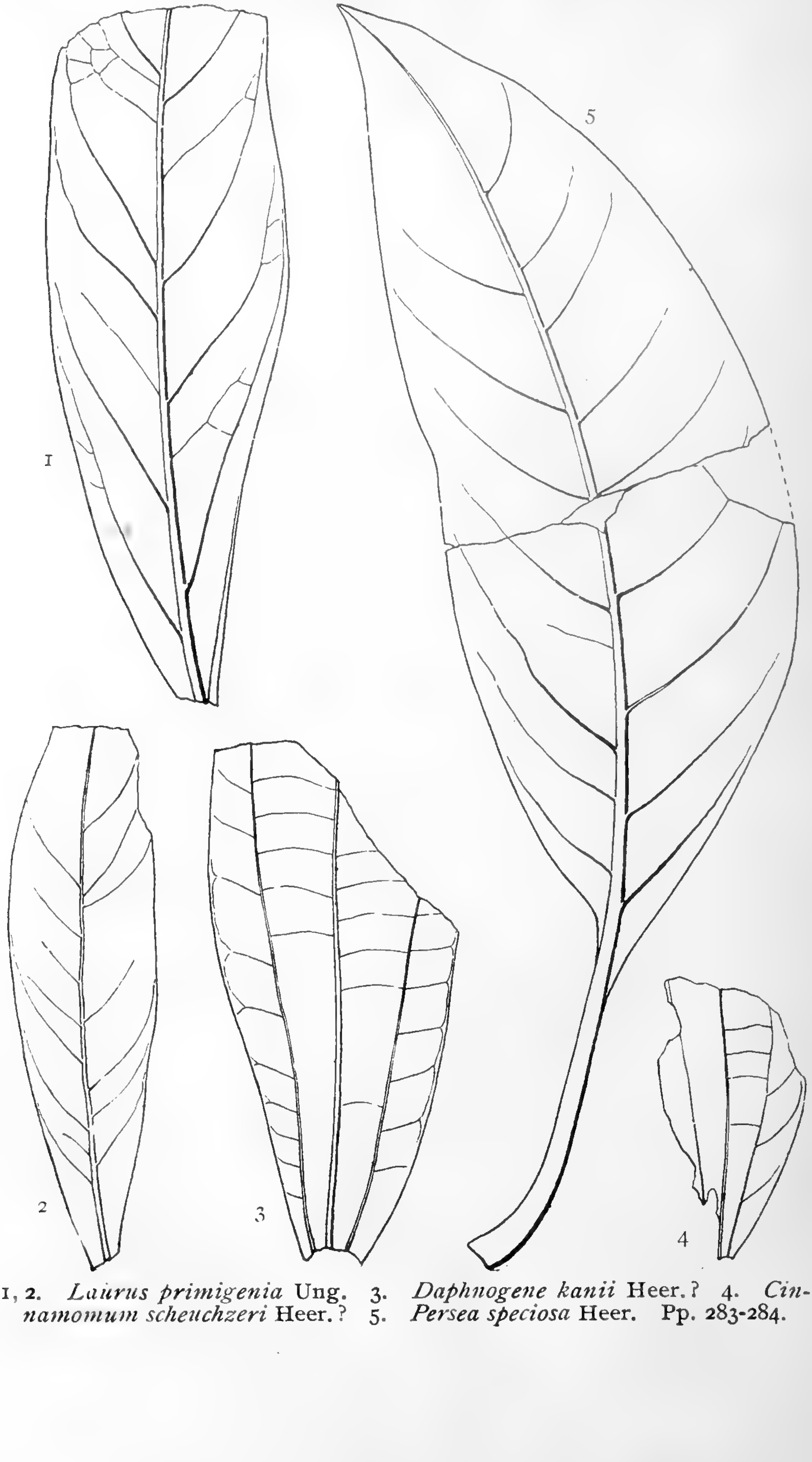
1, 2. *Artocarpus pungens* (Lesq). 3. *Artocarpus dubia, n. sp.* P. 281



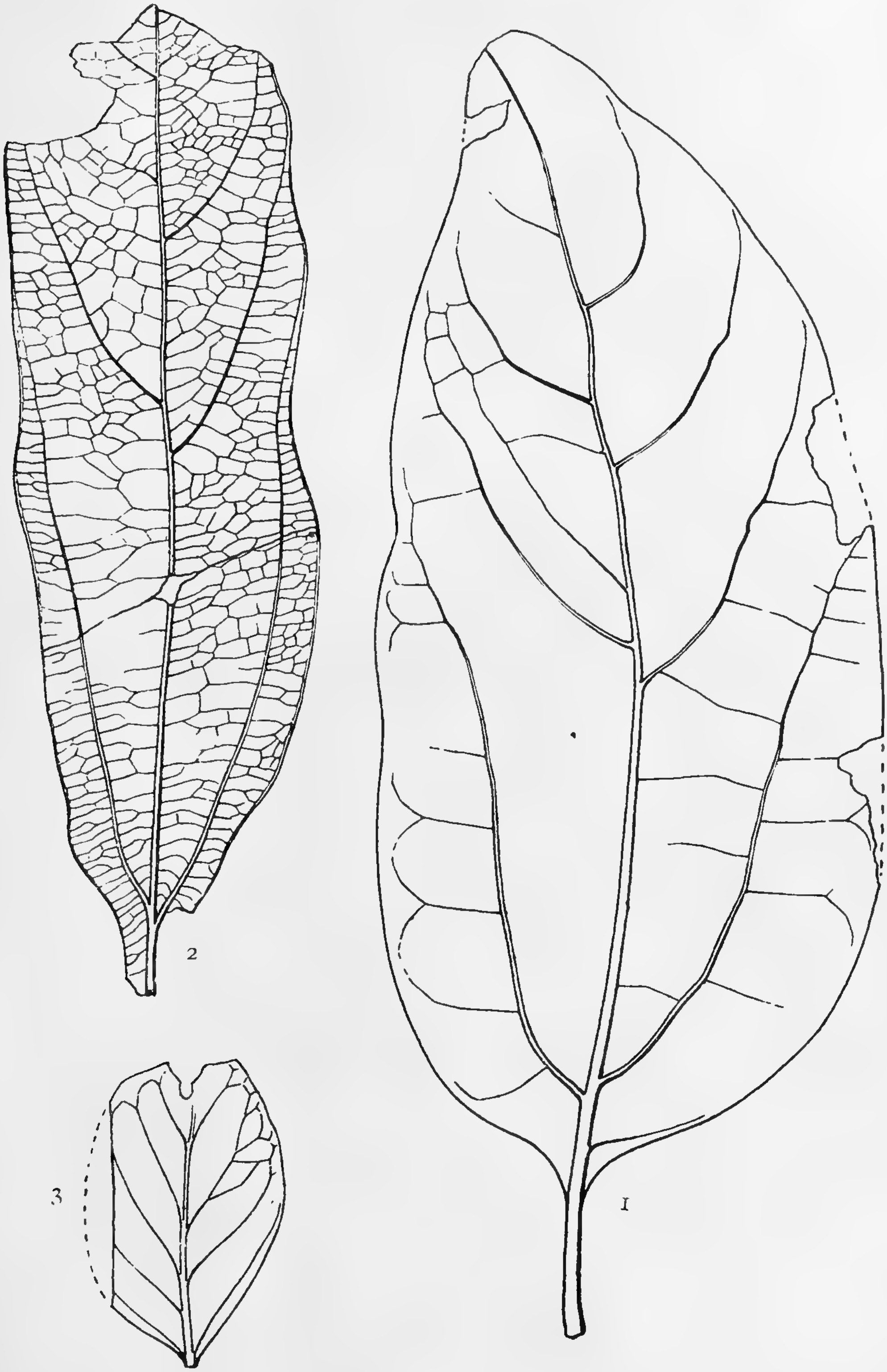
Magnolia hilgardiana Lesq. P. 282



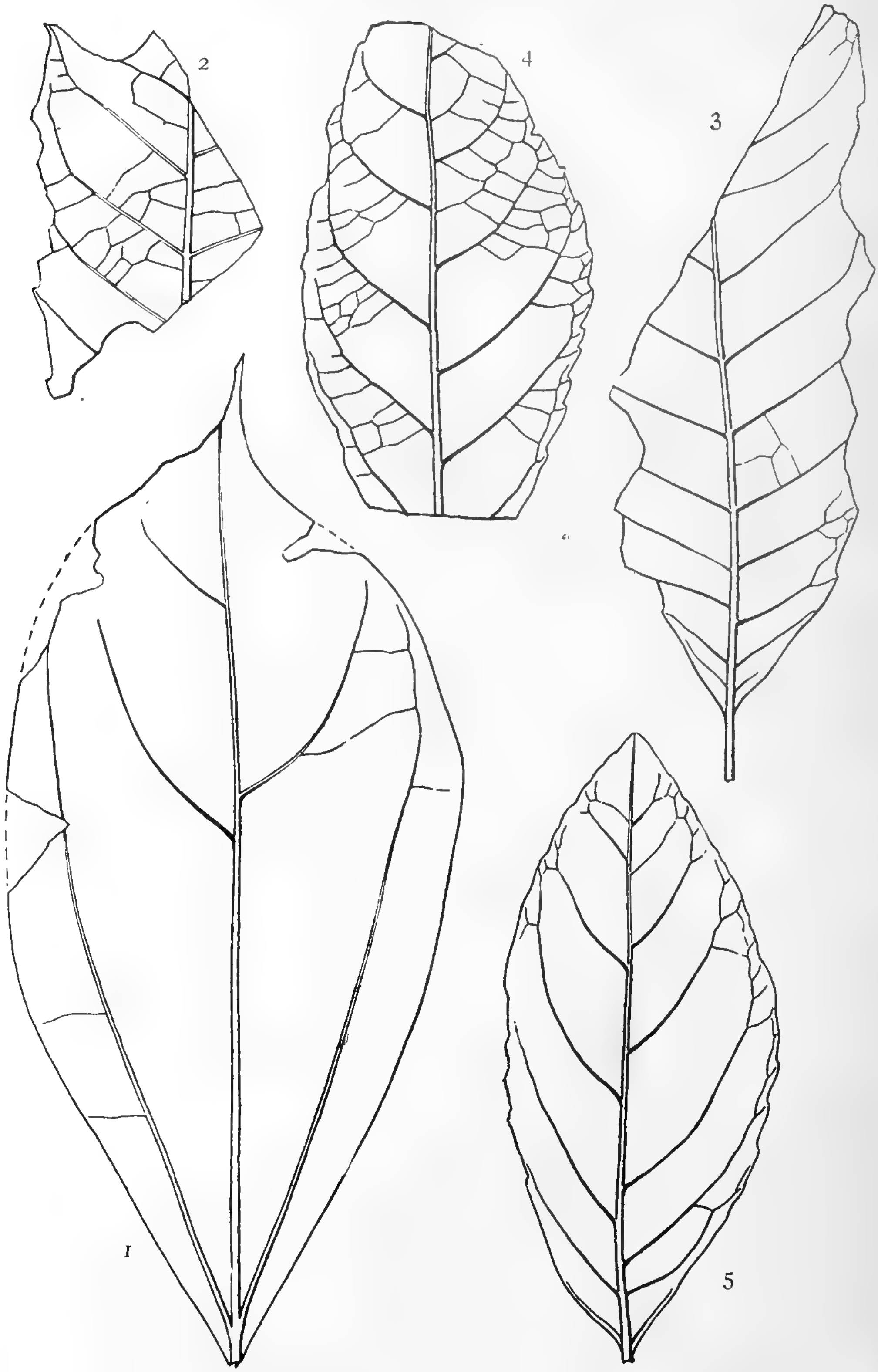
Magnolia lanceolata Lesq., x ¾. P. 282



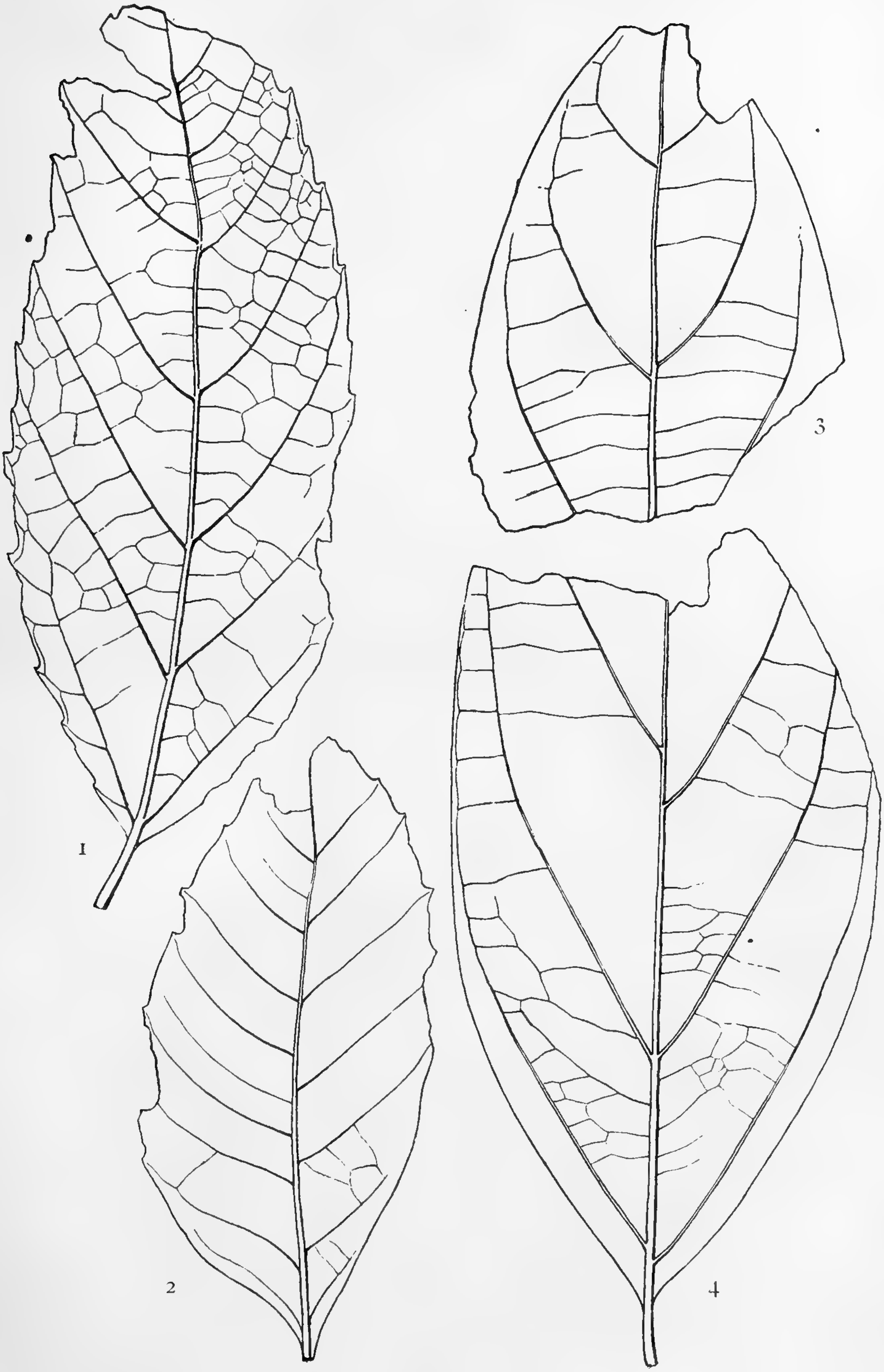
1, 2. *Laurus primigenia* Ung. 3. *Daphnogene kanii* Heer.? 4. *Cinnamomum scheuchzeri* Heer.? 5. *Persea speciosa* Heer. Pp. 283-284.



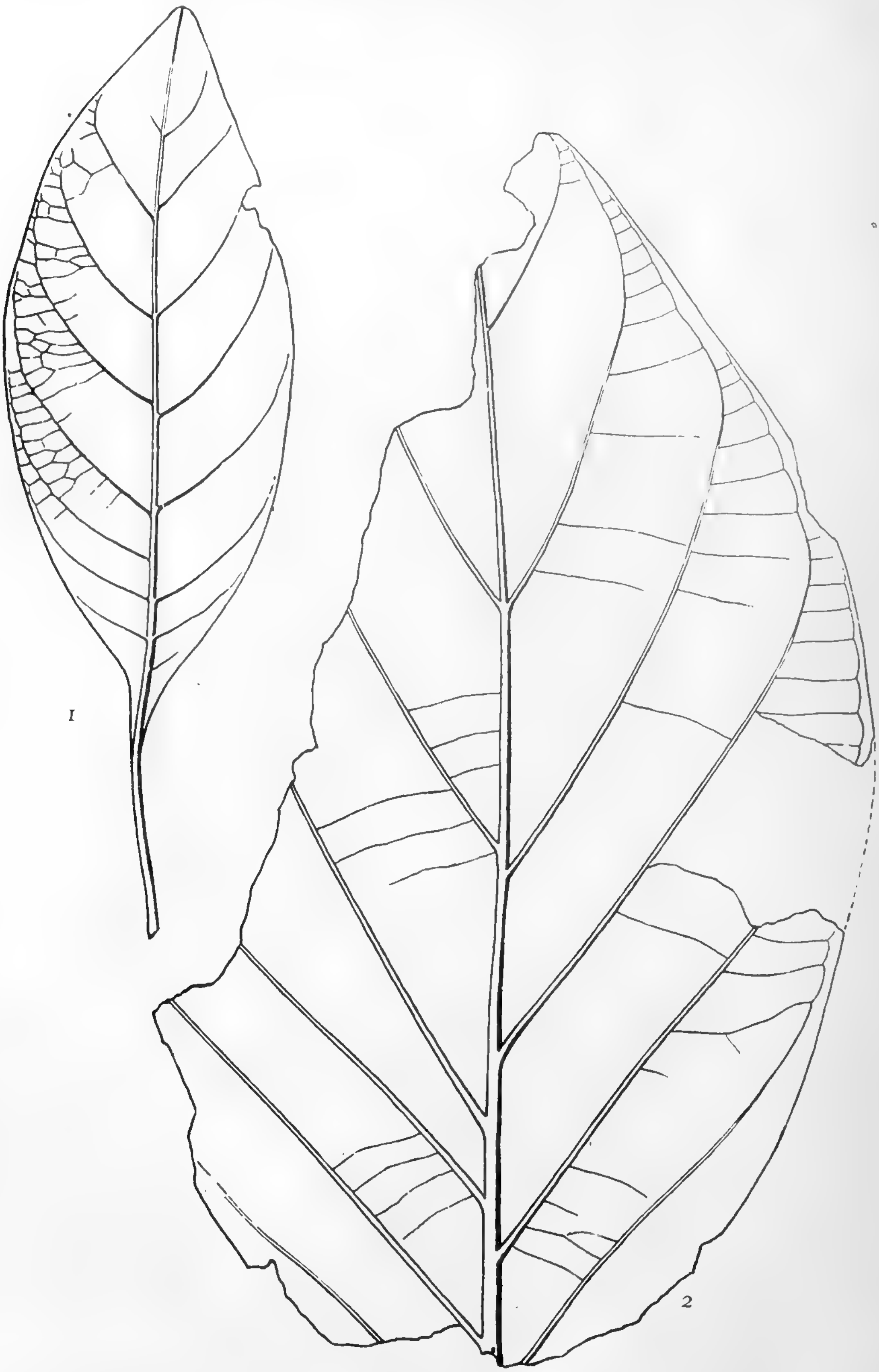
1. *Cryptocarya eolignitica*, *n.* sp. 2. *Cinnamomum sezannense* Wat. P. 283. 3 *Sapotacites americanus* Lesq. P. 287



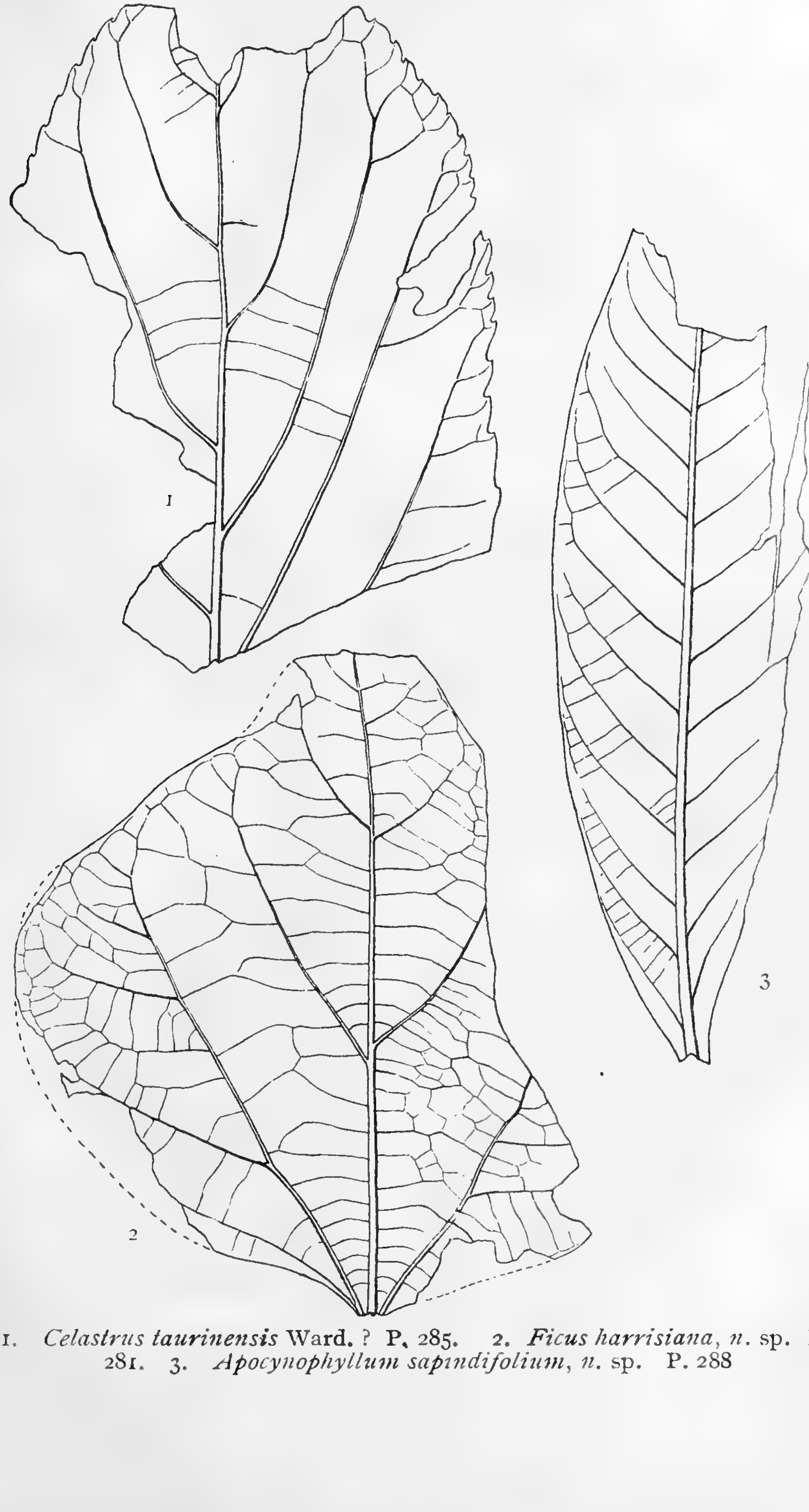
1. *Cinnamomum buchi* Heer. P. 283. 2, 3. *Ilex* sp.
4, 5. *Celastrus veatchi*, *n*. sp. P. 285.



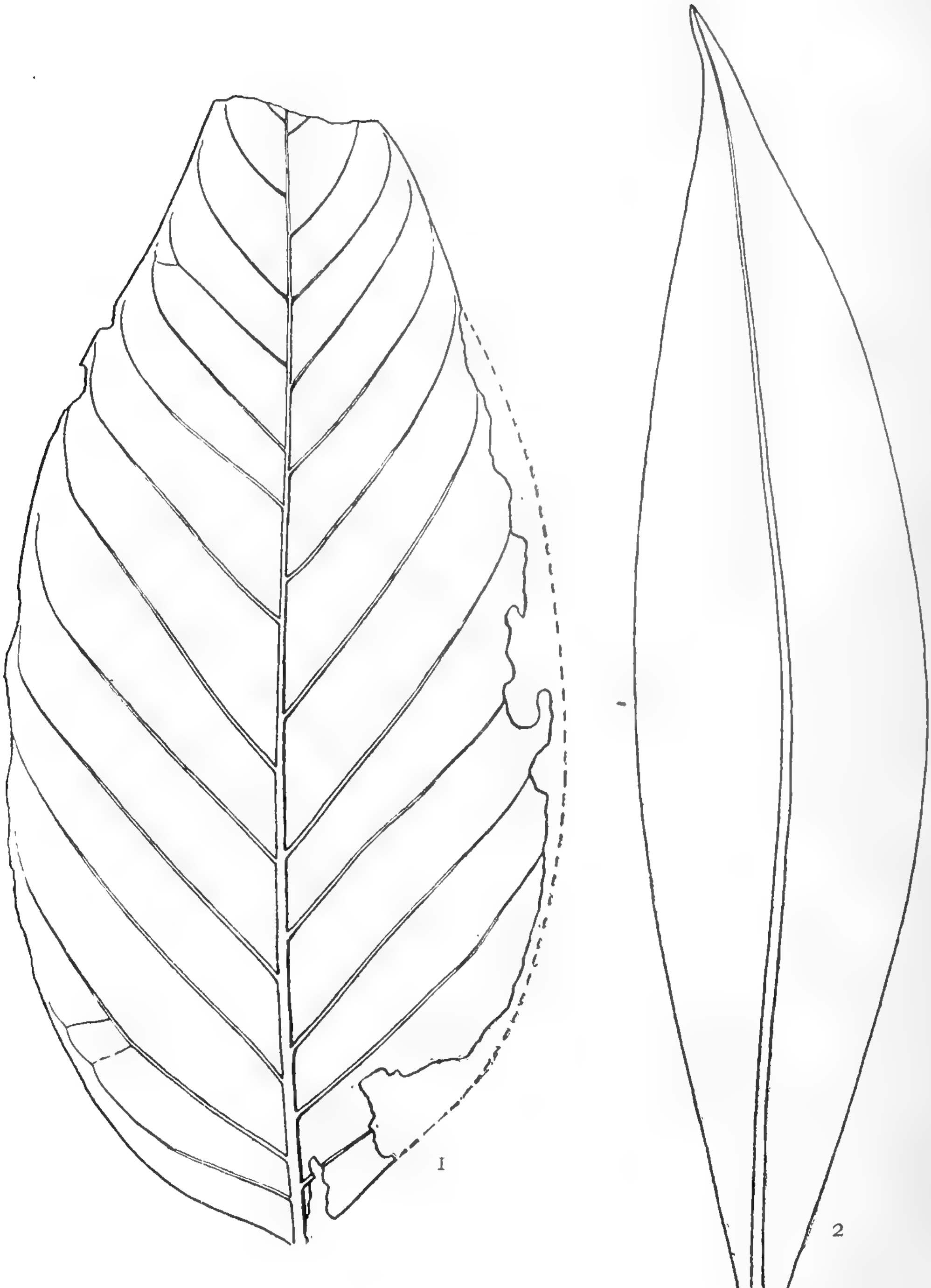
1. *Fraxinus johnstrupi* Heer.? P. 287. 2. *Ilex*? *affinis* Lesq.? P. 285.
3, 4. *Tetranthera præcursoria* Lesq. P. 284.



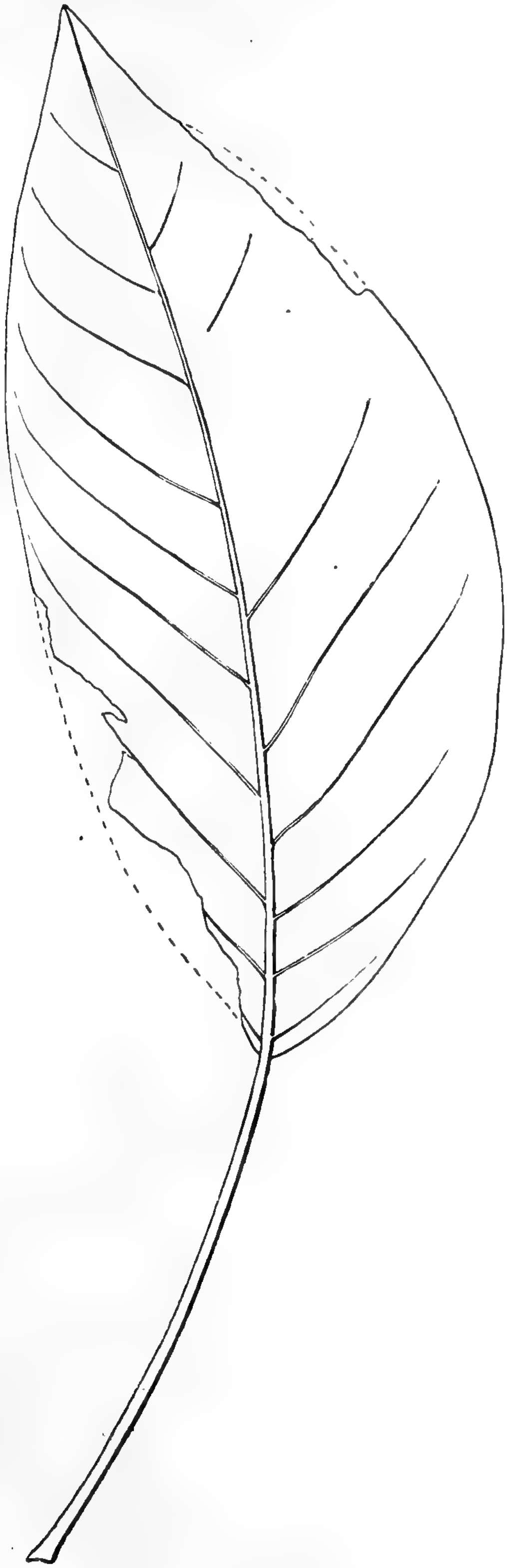
1. *Andromeda delicatula* Lesq. P. 287. 2. *Cornus studeri* Heer. ? P. 286



1. *Celastrus taurinensis* Ward. ? P. 285. 2. *Ficus harrisiana*, *n*. sp. P. 281. 3. *Apocynophyllum sapindifolium*, *n*. sp. P. 288



1. *Rhamnus cleburni* Lesq. P. 286. 2. *Andromeda eolignitica*, *n.* sp. P. 287



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T

Special Report No. 6

THE CRETACEOUS AND LOWER EOCENE FAUNAS OF LOUISIANA

BY

G. D. HARRIS

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CRETACEOUS

EXPLANATORY REMARKS

We have seen how, early in the century, several fictitious Cretaceous localities and fossils were mentioned from eastern Louissana and how Hilgard, Hopkins, Learch and others have since mentioned *Exogyra costata* and *Gryphæa pitcheri* from the salt licks of northern Louisiana. The latter fossil having been proven by Vaughan to have been improperly identified, *Exogyra costata* has remained the only well authenticated Cretaceous species in Louisiana. It is owing to Mr. Veatch's energy that we have now a fairly good representation of the Cretaceous fauna of this State.

Mr. T. W. Stanton of the U. S. Geological Survey has kindly looked over and labeled the majority of the more perfect specimens; and hence the names which follow may be regarded as his identifications.

PELECYPODA

Exogyra costata, Plate 49, fig. 1.

Syn.—*E. costata* Say, Jour. Acad. Nat. Sci. Phila., vol. 2, p. 43, 1820.

E. costata White, U. S. G. S., 4th Ann. Rept., p. 304, pls. 56–57, figs. 1 and 2, 1884.

E. costata Whitfield, U. S. G. S., Mon. 9, p. 39, pl. 6, figs. 1 and 2, 1885.

E. costata Say, Bull. Am. Pal., vol. 1, p. 291, 1896.

This is one of the most abundant and characteristic molluscan species in the Cretaceous of the Atlantic and Gulf States. The smaller or operculated valve only is herewith figured since our collections have not as yet furnished any of the larger valves.

Localities.—Rayburn's salt work, Bienville parish, La.—Veatch (specimen figured). King's salt work.—Hilgard.

Gryphæa vesicularis, Plate 49, fig. 2; Pl. 50, figs. 1 and 2.

Syn.—*O. vesicularis* Lam., Am. du Mus. vol. 8, p. 160, pl. 22, fig. 3, 1808.

Gryphæa convexa Morton, Jour. Acad. Nat. Sci. Phila., vol. 6, pp. 79–80, pl. 4, figs. 1, 2, 1828–31.

G. mutabilis Morton, *ibid.*, pp. 81–83, pl. 4, fig. 3.
G. convexa Morton, Synopsis, etc., 1834, p.53, pl. 4, figs. 1 and 2.
G. mutabilis Morton, *ibid.*, fig. 3.
G. vesicularis White, 4th Ann. Rept. U. S. G. S., p. 303, pl. 48, figs. 1–5.
"*G vesicularis* Lam?" Whitf., U. S. G. S., Mon., 9, p. 36, pl. 3, figs. 15 and 13, pl. 4, figs. 1–3, pl. 5, 1885.

This species is widely distributed in the Cretaceous of the Atlantic and Gulf States. It also occurs in beds of like horizon in Europe. The Arkansas and Texas form of this species is the same as the one herewith figured.

Locality.—Rayburn's salt work, Bienville parish, La.

Ostrea larva, Plate 49, fig. 3.

Syn.—*O. larva* Lam., An. sans Vert., vol. 6, p. 216, 1819.
O. falcata Morton, Jr. Acad. Nat. Sci. Phila., vol. 6, pl. 1, fig. 2.
O. falcata Morton, Synop. Org. Rem. Cret. Group, U. S., 1834, p.50, pl. 3, fig. 5, pl. 9, figs. 6, 7.
O. (*Alectryonia*) *larva* White, U. S. Geol. Surv., 4th Ann. Rep., 1884, p. 296, pl. 42, figs. 2–9.

This is a very common species from the Upper Cretaceous of the Atlantic sea border and Gulf States. It occurs also in beds of similar age in Europe and southern Asia.

Locality.—Rayburn's salt work, Bienville parish, La.

Ostrea plumosa, Plate 49, fig. 4.

Syn.—*O. plumosa* Mort., Synopsis Organic Remains, Cretaceous Group, U. S., p. 51, pl. 3, fig. 9, 1834.
O. plumosa Whitf., U. S. Geol. Surv., Mon. 9, p. 31, pl. 3, figs. 12, 13, 1885.

Our specimens do not show such coarse radii as Morton's figure indicates, nor do they show the undulations indicated by Whitfield's figures. Yet we feel little hesitation in assigning them to this species.

Originally described from Arneytown, N. J.

Locality.—Rayburn's salt works, La.

Neithea quinquecostata? Plate 49, fig. 6, 7.

Syn.—*Pecten quinquecostata* (Sowerby) Morton, Am. Jour. Sci., vol. 18, pl. 3, fig. 6, 1830. Synop. Org. Rem., p. 57, pl. 19, fig. 1, 1834.

Neithea quinquecostata Whitf., U. S. Geol. Surv., Mon. 9, p. 56, pl. 8, figs. 12–14, 1885.

Our specimens are all small and cannot be identified with this species beyond doubt.

This is one of those forms showing an almost universal distribution.

Locality.—Rayburn's salt works.

Camptonectes burlingtonensis, Plate 50, fig. 3.

Syn.—*Pecten burlingtonensis* Gabb, Acad. Nat. Sci. Phil., Jr., vol. 4, p. 304, pl. 48, fig. 25, 1860.

Camptonectes (*Amusium*) *burlingtonensis* Whitf., U. S. Geol. Surv., Mon. 9, p. 53, pl. 8, figs. 3–9, 1885.

The specimen figured is very finely and beautifully marked. There are concentric broad undulations about the beak; over the whole surface are concentric lines averaging perhaps one-twentieth or thirtieth inch apart; between these extend radially very fine and sharply defined lines, the characteristic markings of *Camptonectes*.

Described originally from Burlington County, N. J.

Locality.—Rayburn's salt works, La.

Lima pelagica, Plate 49, fig. 5.

Syn.—*Plagiostoma pelagica* Morton, Amer. Jr. Sci., vol. 23, p. 293, pl. 5, fig. 2, 1833.

P. pelagicum Morton, Synop. Org. Rem., p. 61, pl. 5, fig. 2, 1833.

Radula pelagica Whitf., U. S. Geol. Surv., Mon. 9, p. 61, pl. 9, figs. 3–5, 1885.

Described originally from the Lower Greensand marls of New Jersey.

Locality.—Rayburn's salt works.

Cardium alabamense, Plate 50, fig. 4.

Stanton has so labeled several imperfectly preserved specimens in our collections.

Locality.—Rayburn's salt works.

Inoceramus barabini, Plate 51, fig. 2.

Syn.—Probably the same as *I. barabini* Mort., Synop. Org. Rem., p. 62, pl. 17, fig. 3 and pl. 13, fig. 11, 1834.

Also probably the same as *I. barabini* Whitf., U. S. Geol. Surv., Mon., p. 75, pl. 15, figs. 3–5, 1885.

Originally described from the Cretaceous of Green Co., Ala., and named in honor of Joseph Barabino of New Orleans.

Locality.—Rayburn's salt works.

Veniella sp., Plate 50, fig. 8.

Syn.—Cf. *V. rhomboidea* Con., Acad. Nat. Sci. Phila., Jr., vol. 2, p. 275, pl. 24, fig. 7, 1853.

There can be little doubt about the generic affinities of these imperfect specimens, but specifically they are unidentifiable.

Locality.—Rayburn's salt works.

Crassatella vadosa, Plate 50, fig. 5.

Syn.—*C. vadosa* Morton, Synop. Org. Rem , p. 66, pl. 13, fig. 12, 1834. *C. vadosa* Whtf., U. S. Geol. Surv., Mon. 9, p. 117, pl. 17, figs. 12–15.

Our specimens are all small, but they seem to agree well with the general character of this species, so far as can be judged.

Locality.—Rayburn's salt works.

Thetis sp., Plate 50, fig. 6.

This little specimen is very well preserved exteriorly but both valves are together, closed, so that the interior of the shell cannot be studied without damaging the specimen.

Locality.—Rayburn's salt works.

Trigonia eufaulensis, Plate 50, fig. 9.

Syn.—*T. eufaulensis* Gabb, Acad. Nat. Sci. Phila., Jr., vol. 4, p. 396, pl. 68, fig. 32, 1860.

T. eufaulensis Whitf., U. S. Geol. Surv., Mon. 9, p. 113, pl. 14, figs. 1-4.

These specimens like the typical forms at Eufaula, Alabama are rather small.

Locality.—Rayburn's salt works.

Linearia metastriata, Plate 50, fig. 7.

Syn.—*L. metastriata* Con., Acad. Nat. Sci. Jr., vol. 4, p. 279, pl. 46, fig. 7, 1860.

L. metastriata Whitf., U. S. Geol. Surv., Mon. 9, p. 165, pl. 23, figs. 6-7, 1885.

This is a beautiful little species preserving not only all the delicate surface markings, but also some of the original color of the shell.

Originally described from Eufaula, Ala.

Locality.—Rayburn's salt works.

Legumen planulatum, Plate 51, fig. 1.

Syn.—*Solemya planulata* Con., Acad. Nat. Sci. Phila., Jr., vol. 2, p. 274, pl. 24, fig. 11. *Legumen planulatum* Con., Acad. etc., Jr. vol. 4, p. 277.

Legumen planulatum Whitf., U. S. Geol. Surv., Mon. 9, p. 184, pl. 25, figs. 3-4.

Specimens all imperfect, yet showing well their characteristic flattened form

Locality.—Rayburn's salt works.

GASTROPODA

Avellana bullata,

Syn.—"*Tomitella? bullata*" Morton, Synop. Org. Rem., p. 48, pl. 5, fig. 3, 1834.

Avellana bullata Whitfield, U. S. Geol. Surv., Mon. 18, p. 163, pl. 20, figs. 1-4, 1892.

Though we possess but a small fragment of this species, it is sufficient to show the characteristic labrum and surface markings of the species.

Locality.—Rayburn's salt works.

Laxispira lumbricalis, Plate 51, fig. 3.

Syn.—*L. lumbricalis* is Gabb. Ac. Nat. Sci. Phila., Proc., 1876, p. 301, pl. 17, fig. 7.

L. lumbricalis Whitfield, U. S. Geol. Surv., Mon. 18, p. 148, pl. 18, fig. 25.

The figures represent but small portions of perfect specimens of this species. They show, however, the characteristic spiral markings.

Locality.—Rayburn's salt works.

CEPHALOPODA

Ptychoceras, near **crassum,** Plate 51, fig. 5.

See Rept. Geol. Black Hills of Dakota, by Whitfield, p. 459, plate 16, figs. 3-5, 1880. See also Meek's report U. S. Geol. Surv. Terr., vol. 9, p. 412, plate 20, figs. 4a-d, –*P. mortoni*.

Locality.– Rayburn's salt works.

Heteroceras sp., Plate 51, fig. 4.

See *Turrilites pauper* Witf., U. S. Geol. Surv., Mon. 18, p. 268, plate 45, figs 1–4.

We do not feel quite satisfied that *Heteroceras* is the name that will finally be applied to sinistral cephalopoda of this type. However, this is a very interesting specimen and deserves to be figured in this place.

Locality.–Rayburn's salt works.

Baculites anceps, Plate 51, fig. 6.

Syn.—This species Stanton has regarded as *anceps* of Lamarck, and probably regarded it as synonymous with *B. asper* Morton.

Only small fragments have been so far found. They show the low undulations of *asper* as figured by Morton, though the suture line is not determinable.

Locality.–Rayburn's salt works.

BRACHIOPODA

Terebratulina sp., Plate 51, fig. 7.

We have not seen any species figured that looks just like this. Whitfield's figures of *Terebratella vanuxemi* and *T. plicata* from N. J. have much coarser costæ. The same is true of *T. sayi* Morton.

Locality.–Rayburn's salt works.

EOCENE

MIDWAY STAGE

PELECYPODA

Ostrea crenulimarginata, Plate 52, figs. 1. a.

Syn. *O. crenulimarginata* Gabb, Jr. Acad. Nat. Sci., Phila., 2d ser., vol. 4, p. 398, plate 68, figs. 40, 41, 1860.

For general synonymy and description, see Bull. Am. Pal., vol. 1, p. 159, 1896.

The state of preservation of this species in Lousiana is not the best. Specimens are firmly imbedded in the rock and fragments only can usually be obtained. In the bed of the brook however, there were a few loose, fairly well preserved specimens. It is these oyster shells that gave the rock in which they they are imbedded its limy character.

Locality—Raines' place, near Rocky Spring church, about six miles W. S. W. of Marthaville, Sabine Parish. The writer has personally collected this species also near the Cretaceous-Eocene border line in Texas, Arkansas, Tennessee, Mississippi, Alabama and Georgia.

Ostrea pulaskensis, Plate 52, fig. 2, 3, 4.

Syn.—*O. pulaskensis* Har., see Bull. Am. Pal., vol. 1, p. 160.

This is the *Gryphæ pitcheri* Hilgard (Geol. Recon., Final Rept. 1869, p. 29) without doubt.

Mr. Veatch found a large number of these oysters lying on some of the old dumps at King's salt works; and it was probably here that Hilgard found his specimens.

Vaughan has already called attention (Am. Geol., vol. 15, p. 297, 1895 and elsewhere) to the fact that "*G. pitcheri* is a Comanche series fossil and does not occur in the upper Cretaceous," but he failed to state what the Louisiana specimens really should be called.

Modiola stubbsi n. sp., Plate 52, figs. 5, 6.

The general appearance and dimensions of this species are shown by the figures. It is specially characterized by the prominent angulation on the posterio-dorsal margin, and by the coarseness of the plications between this angulation and the most posterior point on the shell. The shell matter is thin and its various layers show a beautiful mother-of-pearl appearance, All specimens are broken and crumpled to a considerable extent. This species seems to have been the most common associate of the large oyster described above.

Locality.—Raines' place, about six miles W. S. W. of Marthaville.

Turritella mortoni, Plate 52, fig. 9.

Syn.—*T. mortoni* Con., Acad. Nat. Sci., Phila., Jour. vol. 6, p. 221, pl. 10, fig. 2, 1830. See Bull. Am. Pal., vol. 1, p. 224, ; vol. 3, p. 74.

The fragments of this species are sufficiently well preserved to prove the existence of this species in association with the large oyster and the few other species found at the exposure given below.

Locality.—Raines' place, near Rocky Spring church, about six miles W. S. W. of Marthaville.

Fusus harrisi, Plate 52, fig. 7.

Syn.—*F. harrisi* Ald., Bull. Am. Pal., vol. 1, p. 64, pl. 5, figs. 2 and 8, 1895. See also vol. 3, p. 43, 1899.

The only specimen we have of this species is by no means perfect as could be desired, but there seems to be no reasonable doubt regarding its identification. It has hitherto been known only from the lower Lignitic at Gregg's landing and Yellow bluff on the Alabama river.

Locality.—Raines' place, near Rocky Spring Church, about six miles W. S. W. of Marthaville.

Leiostoma (?) ludoviciana, n. sp., Plate 52, fig. 8.

We have a number of fragments of this *Caricella*-shaped species but none show its generic affinities beyond question. When broken off anteriorly the shell has very much the shape and appearance of some varieties of *Pseudoliva vetusta*, but no trace of the characteristic furrow of that genus has been found. The anterior canal was shorter and more twisted than in *Caricella*. More material is needed for a satisfactory diagnosis of the species. It is here included on account of its strange appearance and association.

Locality.—Raines' place, about six miles W. S. W. of Marthaville, near Rocky Spring church, Sabine parish.

LIGNITIC

The fossiliferous localities of Sabinetown and Pendleton on the Texas side of the Sabine have already been described in this report, pp. 65–67. Though they are not on Louisiana soil, the horizons to which they belong are certainly to be found east of the Sabine, though generally not well exposed.

Had these localities and their fossils been described in the Texas Survey reports or elsewhere a mere reference to them would have sufficed here. But since the Sabinetown fauna has long been misinterpreted and that at Pendleton has been unknown to previous writers, we have no hesitation in devoting some time to their study and space to their elucidation.

PELECYPODA

Ostrea thirsæ, Plate 53, fig. 1.

Syn.—*Gryphæa thirsæ* Gabb, Acad. Nat. Sci., Phila., Proc. 1861, p. 329.

Ostrea thirsæ Heilp., U. S. Geol. Surv., 3d Annual, p. 311, pl. 63, figs. 4, 5, 6.

O. thirsæ Har., Bull. Amer. Pal., vol. 2, p. 40, pl. 12, figs. 5, 6.

This species was originally described from Nanafalia, Ala., where it is found in great numbers.

These specimens have in some instances the true *thirsæ* appearance, but often they grade towards what we have believed to be the young of a variety of *O. trigonalis* at Woods bluff. See pl. 12, Bull. Amer. Pal., vol. 2.

Localities.—Marthaville R. R. cut; well, S. W. ¼ S. W. ¼ S. 18, 7 N. 10 W.

Horizon.—Lower Lignitic.

Ostrea, sp.

There are numerous fragments of large oysters found at Pendleton and elsewhere; but so far we have not found sufficiently perfect specimens to warrant specific identification.

Modiola alabamensis, Plate 53, fig. 2.

Syn.—*M. alabamensis* Ald., Bull. Amer. Paleont., vol. 1, p. 68, pl. 6, fig. 13, 1895.

The specimens found are from Pendleton, Texas. It will doubtless be found in Sabine and other parishes of La., where the Lower Lignitic rocks crop out.

Pinna sp.

No special importance is attached to the finding of fragments of specimens of this genus in rocks from Cretaceous or Tertiary deposits. However, the silvery, scaly character of the semi-disintegrated shell is rather noticeable and is apt to attract attention and arouse wonderment as to the nature of the animal that produced it. It is a distant relative of the pearl oyster.

Localities—La Nana bayou, near Many; S. E. of Sodus, limestone concretions.

Horizon—Lower Lignitic.

Barbatia cuculloides, var. Plate 53, fig. 3.

Syn.—*Arca cuculloides* Con., Foss. Shells, Tert. Form., p. 37, 1833.
B. cuculloides Har., Bull. Amer. Pal., vol. 2, p. 239, pl. 14, fig. 1, 1897.

The members of this division of the Arcas are somewhat variable in form and surface markings, and we have been unable to satisfactorily differentiate the Eocene species. In fact the Oligocene forms from Vicksburg, are perhaps of one and the same species with the Eocene.

Localities.—Pendleton, Tex., S. W. ¼, S. W. ¼, S. 18, 7 N., 10 W. Marthaville.

Horizon.—Lower Lignitic.

Leda aldrichiana, var., Plate 53, fig. 5.

Syn.—*Yoldia aldrichiana* Har., Bull. Amer. Pal., vol. 2, p. 245, pl. 14, fig. 15, June, 1897.
Leda acala Dall., Tr. Wag. Free Inst. Sci., vol. 3, 586, pl. 32, fig. 3, Oct. 1898.

The Sabinetown specimens when compared with those from the type locality, Woods bluff, will be found to be somewhat broader posteriorly or comparatively less ventricose anteriorly than those from the last mentioned locality. Yet the distance between the localities is doubtless sufficent to account for a considerable amount of variation. It would certainly be unwise to propose a new specific name for these western specimens when the differences are confined to general outlines of the shells.

Locality.—Sabinetown, Texas.

Horizon.—Upper Lignitic.

Leda corpulentoides, var.

Syn.—*Yoldia corpulentoides* Ald., Bull. Amer. Pal., vol. 1, p. 70, pl 6, fig. 9, 9a, 1895.

See also Bull. Amer. Pal. vol. 2, p. 243.

We must be in possession of better specimens from the type locality before we can say just what *L. corpulentoides* is. See remarks on p. 343, vol. 2, Bull. Amer. Pal. It would seem, however, that this is a variety of the species.

Locality.—Pendleton, Texas.

Horizon.—Lower Lignitic.

Venericardia planicosta, Plate 53, fig. 6.

Syn.—See Bull. Amer. Pal., vol. 1. p. 172, vol. 2, p. 246.

The specimens so far found in Louisiana are rather smaller than the average, but still are well formed.

This is the most typical and important species of the Eocene series.

Lignitic localities.—Sabinetown; 1 mi. E. of Ft. Jessup; Wms. farm; well, S. W. ¼ S. W. ¼ Sect. 18 7 N. 10 W.; La Nana bayou.

Astarte smithvillensis, Plate 53, fig. 7.

Syn.—See Bull. Amer. Pal., vol. 2, p. 248.

This species seems to be very poorly represented in the Lignitic of Louisiana. Only one specimen, an exterior impression has thus far been found. It is from La Nana bayou near Many. See p. 69 of this report.

Crassatella sp.

Casts of what seem to be short, rugose *Crassatellæ* have been found at several places, but they are too fragmentary for specific determination.

They remind one of *C. gabbi* from the Midway of Tennessee.

Localties.—Marthaville; La Nana bayou.

Kellia prima, Plate 53, fig. 11.

Syn.—*Kellia prima* Aldrich, Bull. Amer. Paleont., vol. 2, p. 181, pl. 6, figs. 3, 3a.

See also vol. 2, p. 202 and 250.

We have already recorded this species from Sabinetown in the Bulletins of American Paleontology, p. 202 as given above. The specimens were in the Lea Memorial collection of the Philadelphia Academy, and were collected by C. W. Johnson, of the

Wagner Free Institute of Science. So far as known this species is confined to the Upper Lignitic or Woods bluff horizon.

Cardium tuomeyi. Plate 53, fig. 9, 10.

Syn.— *C. tuomeyi* Ald., Geol. Surv. Ala., Bull. 1, p. 40, pl. 4, figs. 13, 13a, 1886.

See also Bull. Am. Pal., vol. 2, p. 252.

The specimens we have in hand are of the same species as those of the Lower Lignitic of Alabama. They often show, however, a somewhat coarser costation than the type specimen of *tuomeyi* does; but so do many specimens from Nanafalia, the type locality. We have come to think the gap between *toumeyi* and *hatchetigbeense* not so very wide. *C. hatchetigbeense* is supposed to have fewer ribs and to have sharp large spines on the anterior and posterior slope. Many of these show this feature clearly.

Locality.—Pendleton, Texas; Marthaville, La.; La Nana bayou, near Many, La.

Horizon.—Lower Lignitic.

Mactra bistriata, Plate 53, fig. 4.

Syn.—*M. prætenuis* var. *bistriata* Har., Bull. Amer. Pal., vol. 2, p. 258, pl. 19, fig. 10, 1897.

With better specimens in hand it is safe to say that this is distinct from *M. prætenuis*, Con.

Locality.—Sabinetown, Tex.

Horizon.—Upper Lignitic.

Corbula alabamensis, var.

Syn.—See Bull. Amer. Paleont., vol. 2, p. 260.

Here is the same small varietal section of this species as noted in the above-mentioned Bulletin from various Lignitic localities in Alabama. It has no strongly marked characteristics by which to differentiate it from other members of this section.

Locality.—Sabinetown, Tex.

Lucina ozarkana.

Syn.—*L. ozarkana* Har., Bull. Amer. Pal., vol. 2, p. 264, 1897.

These fragmentary specimens from Sabinetown seem to belong to the same species found in Woods bluff beds at Ozark, Ala.

Ceronia.

We cannot presume to identify or name specifically the fragmentary specimens in hand. Suffice to say they seem to be quite common, and can easily be told by the silvery character of the shell matter.

Locality.—Sabinetown and Pendleton, Tex.

Pholas alatoideus, Plate 53, fig. 12.

Syn.—See Bull. Amer. Pal., vol. 2, p. 261.

We have little doubt as to the specific identity of this imperfect cast with the Alabama Lignitic specimens. It will be observed, however, that in Alabama the species comes from the Lower Lignitic, while this is from Sabinetown, and Upper Lignitic horizon.

GASTROPODA

Pleurotoma huppertzi var.

Syn.—*P. huppertzi* var *penrosei* Har., Acad.Nat.Sci. Phila., 1895, p. 58, pl. 4, fig. 10.

P. servatoidea Ald., Bull. Amer. Pal., vol. 1, p. 59, pl. 5, fig. 5, 1895.

The beds at Smithville, Texas, have a number of species with Lignitic affinities. This is very evident so far as the *Pleurotomæ* are concerned. The *servatoidea* as Aldrich has styled it in Alabama, is common to the Upper and Lower Lignitic, but so far as we are aware, has not yet been recorded from the Lower Claiborne. The specimen in hand is a typical Alabama Lignite form.

Locality.—Sabinetown, Tex. Here in the Upper Lignitic.

Pleurotoma silicata, Plate 54, fig. 1.

Syn.—*P. silicata* Ald., Bull. Amer. Pal., vol. 1, p. 60, pl. 4, fig. 3, 1895. See also, vol. 3, p. 21, pl. 2, fig. 13, 1899.

There are quite a number of specimens of this species in our collection from Pendleton. In Alabama thus far the form is known only from Gregg's landing. This then goes to show, along with others, the close equivalence of these two localities on opposite sides of the Mississippi, so distant from each other.

Locality.—Pendleton, Tex.

Pleurotomella veatchi, *n. sp.*, Plate 54, fig. 2.

Specific characterization.—Size and form as figured; spiral whorls about six; somewhat angular centrally, especially the larger ones, crossed by twenty or more fairly well marked ribs with directions as follows: commencing just below a well-marked suture they pass downward and to the right to the middle of the whorl, where they are deflected perpendicularly to the suture below; over each whorl pass raised spiral lines, often slightly larger and farther apart on the central part of the whorl; body whorl showing ribs above, which die out below; spiral striation over whole volution; besides the humeral angle a pronounced though not sharply carinated angle appears on the body whorl about twice as far below the humeral angle as the latter is below the suture; mouth parts and columella *Levifusus*-like.

Localities.—Pendleton, Texas; Marthaville, La. Named in honor of the finder, Mr. A. C. Veatch of this survey.

Cancellaria quercollis var. **greggi.** Plate 54, fig. 3.

Syn.—See Bull. Amer. Pal., vol. 3, p. 26, pl. 3, fig. 6, 1889.

We have but a small, fragmentary specimen of this species from Pendleton, Texas, but its markings are so peculiar that its identification is simple and certain.

Buccinanops ellipticum. Plate 54, figs. 4, 5.

Syn.—See Bull. Amer. Pal., vol. 3, p. 30, pl. 3, figs. 14, 15, 1899.

The specimens before us are small but seem to belong to this species.

Localities.—Pendleton, and Sabintown, Texas.

Pseudoliva vetusta var., Plate 54, figs. 6, 7.

Syn.—Bull. Am. Pal., vol. 1, p. 213; vol. 3, p. 31, pl. 3, fig 16.

Two varieties of this species are present in the Lignitic of Louisiana. One, the form figured, is rather characteristic of the Lower Lignitic and Midway; another with much callosity about the upper portions of the volutions is not uncommon in the form of casts.

Localities—Pendleton, Tex.; Marthaville, La.; La Nana bayou.

Volutilithes petrosus vars.,

Syn.—See Bull. Amer. Pal., vol. 3, p. 33, pl. 4, fig. 1, 1899.

West of the Mississippi it seems to be the Upper Lignitic

Sabinetown specimens only that show the peculiar callosity which often characterizes the Lignitic specimens in Alabama.

Localities—Sabinetown and Pendleton, Tex.; La Nana bayou; N. E. of Sodus; S. 2, 9 N., 12 W. The last mentioned locality may be Midway.

Levifusus indentus, Plate 54, fig. 8.

Syn.—*L. indentus* Har., Bull. Amer. Pal. vol. 3, p. 52, pl. 7, fig. 1, 1899.

This species is locally common in the Lignitic of Louisiana and is in fact of great assistance in correlation. So far as known it belongs exclusively to the Lower Lignitic.

Localities—Pendleton, Tex.; Marthaville.

Levifusus supraplanus, Plate 54, fig. 9.

Syn.—*L. supraplanus* Har., Bull. Amer. Pal., vol. 3, p. 50, pl. 6, fig. 1, 1899.

The one specimen from Pendleton is sufficient to show the existence of this rare species in the Lower Lignitic west of the Mississippi.

Levifusus pagoda, Plate 54, fig. 10.

Syn.—See Bull. Amer. Pal., vol. 3, p. 51, pl. 6, fig. 10, 1899.

Represented by several specimens though not very complete from Pendleton, Texas.

Levifusus trabeatus var.?

Syn.—See Bull. Amer. Pal., vol. 3, p. 50, 1899.

The form here referred to is precisely that which we formerly described from the Lower Claiborne of Texas under the name of *L .trabeatoides.*

Rare at Pendleton and Sabinetown.

Mazzalina plena, Plate 54, fig. 12.

See Bull. Amer. Pal., p. 54, 1899.

We had one excellent specimen of this species from Pendleton, Tex.; but it air-slaked and crumbled badly before a figured could be made of it. Hence the necessity of using our Alabama specimen for the purpose.

Tritonidea pachecoi, n. sp., Plate 54, fig. 11.

Specific characterization.—For form and general characters see figure; size sometimes larger than indicated by the figure; whorls about seven, slightly rounding, smooth; suture distinct; body whorl with traces of spiral striation medially becoming more apparent anteriorly; outer lip crenate at margin and occasionally within at places of former stops in growth of shell; inner lip slightly crenate or striate in places; columella hollow as viewed from below.

Locality—Pendleton, Texas. Lower Lignitic Eocene. This may be the species which is seen in such large masses in fragments of concretionary limestone used in the construction of some portions of Ft. Jessup.

Nassa exilis, Plate 55, fig. 1.

Syn.—See Bull. Amer. Pal., vol. 3, p. 57, pl. 7, fig. 9, 1899.

Locality.—Sabinetown and Pendleton, Texas.

Calyptraphorus trinodiferus,

Syn.—See Bull. Amer. Pal., vol. 3, p. 70, pl. 9, figs. 2, 2a, 1899.

The Sabinetown bluff specimens show the trinodate character of the shell finely, likewise the specimens at Pendleton. But some specimens from a well in N. E. ¼ Sect. 2, 9 N., 12 W. Sabine parish, have, so far as observed, not shown any indications of a knob upon the reverse side of the body whorl. This locality, as stated before may belong to a Midway horizon.

Cassidaria brevidentata var.

Syn.—See Bull. Amer. Pal., vol. 3, p. 67.

We shall not be surprised when sufficient material shall have been collected from the Lower Lignitic if this varietal form proves to be different enough from the original "Red bluff" type to warrant a new specific name. Our present specimens though numerous are all too fragmentary to use as types.

Locality.—Pendleton, Texas.

Fusoficula juvenis, Plate 55, fig. 2, 3.

Syn.—See Bull. Amer. Pal., vol. 3, p. 66, 1899.

This is a characteristic Lignitic Eocene species. It occurs in abundance at Woods bluff and lower localities in Alabama. I have already recorded (see above reference) it from Sabinetown, Texas. We have obtained more material from the same locality.

Turritella mortoni, Plate 55, fig. 4.

Syn.—See Bull. Amer. Pal., vol. 3, p. 74, pl. 10, figs. 3 and 4.

This is one of the most common and widely distributed species in the Lower Eocene of the east and southern States.

Many of the Louisiana specimens are rather diminutive in size.

Localities.—Pendleton, Tex.; well on S. W. ¼, S. W. ¼, Sect. 18, 7 N., 10 W., near Ft. Jessup; Marthaville; La Nana bayou near Many.

Turritella humerosa, Plate 55, fig. 5.

Syn.—See Bull. Amer. Pal., vol. 3, p. 75, pl. 10, figs. 5–7, 1899.

Also a widely distributed lower Eocene species; but very difficult to obtain in perfect form.

Localities.—La Nana bayou; Williams place, 1 mi. E. of Ft. Jessup, La.

Turritella præcincta, Plate 55, fig. 6.

Syn.—See Bull. Amer. Pal., vol. 3, p. 76, pl. 10, fig. 8, 1899.

This is a rare companion of the two preceding species in the Lower Lignitic beds.

Locality.—Pendleton, Texas.

Natica eminula, Plate 55, fig. 7.

Syn.—See Bull. Amer. Pal., vol. 3, p. 88, pl. 11, fig. 22, 1899.

This is a very common Eocene form and may be found from the Jackson to the Midway beds.

Localities.—Pendleton and Sabinetown, Texas.

Natica aperta, Plate 55, fig. 8.

Syn.—See Bull. Amer. Pal., vol. 3, p. 90, pl. 11, fig. 27, 1899.

This is a common and characteristic Lower Lignitic species.

Locality.—Pendleton, Texas.

Natica alabamiensis, Plate 55, fig. 9.

Syn.—See Bull. Amer. Pal., vol. 3, p. 91, etc.

This is found in the Lower Lignitic and Upper Midway beds of Alabama.

Locality.—Pendleton, Texas.

Sigaretus declivus, Plate 55, fig. 10.

Syn.—See Bull. Amer. Pal., vol. 3, p. 93, pl. 11, fig. 30, 1899.

Found in the various horizons between the Jackson and Midway in Alabama though not abundantly.

Locality.—Sabinetown, Texas.

Solarium bellense, Plate 55, fig. 11.

Syn.—*S. bellense* Har., Bull. Amer. Pal., vol. 3, p. 82, pl. 11, fig. 7, 1899.

Described originally from the Lower Lignitic of Alabama. One fragmentary specimen is from Pendleton, Texas.

EXPLANATION OF PLATE 49

EXPLANATION OF PLATE 50

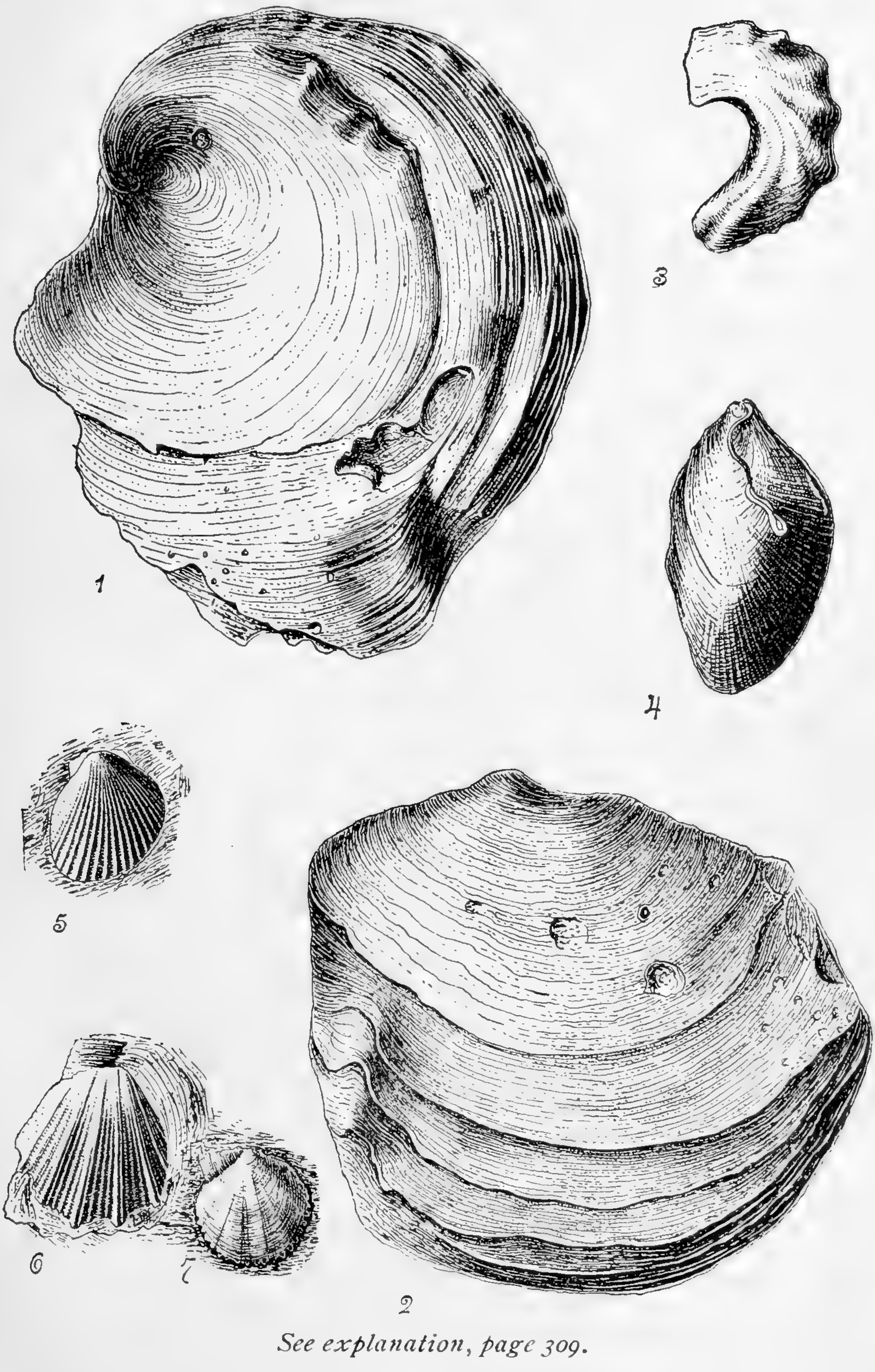
EXPLANATION OF PLATE 51

EXPLANATION OF PLATE 52

EXPLANATION OF PLATE 53

EXPLANATION OF PLATE 54

EXPLANATION OF PLATE 55



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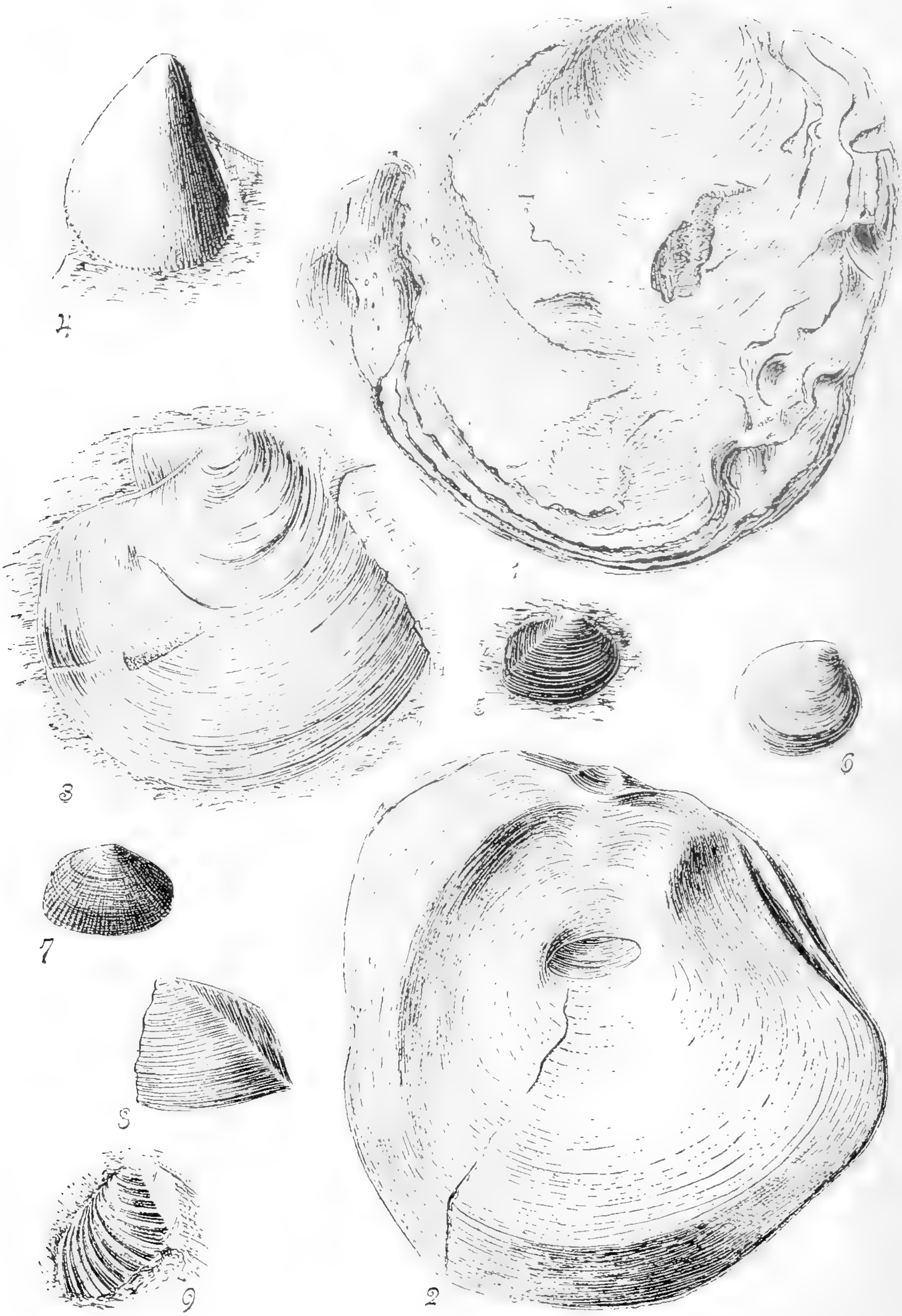

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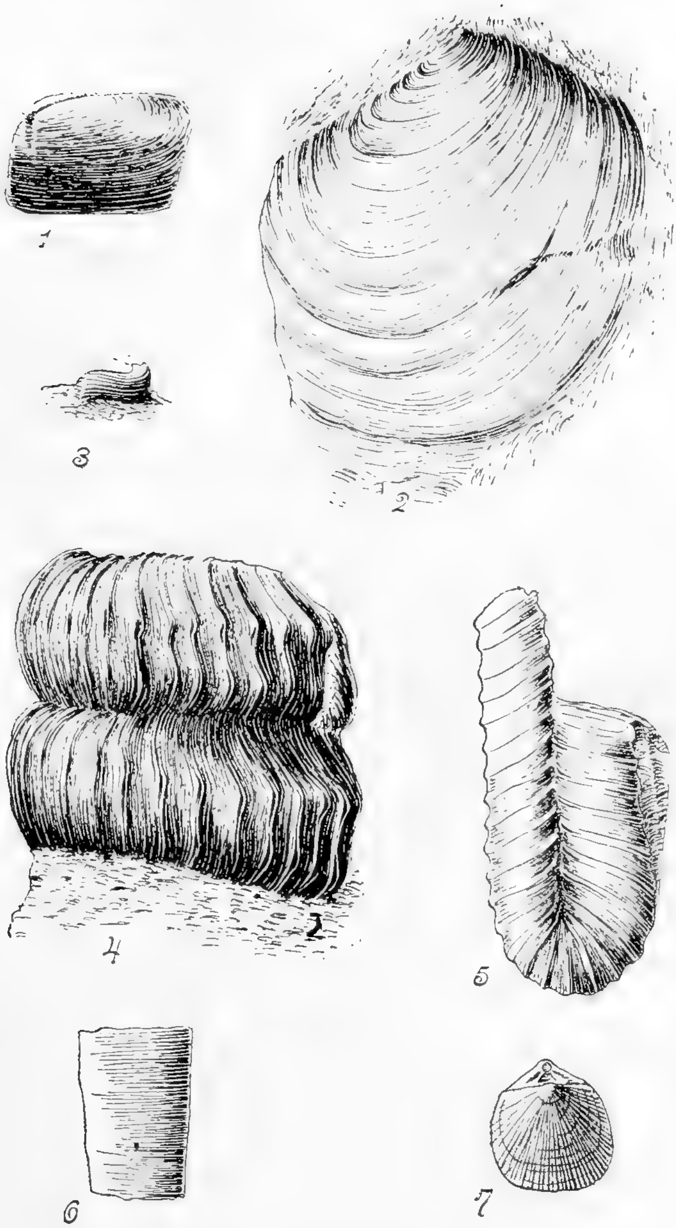

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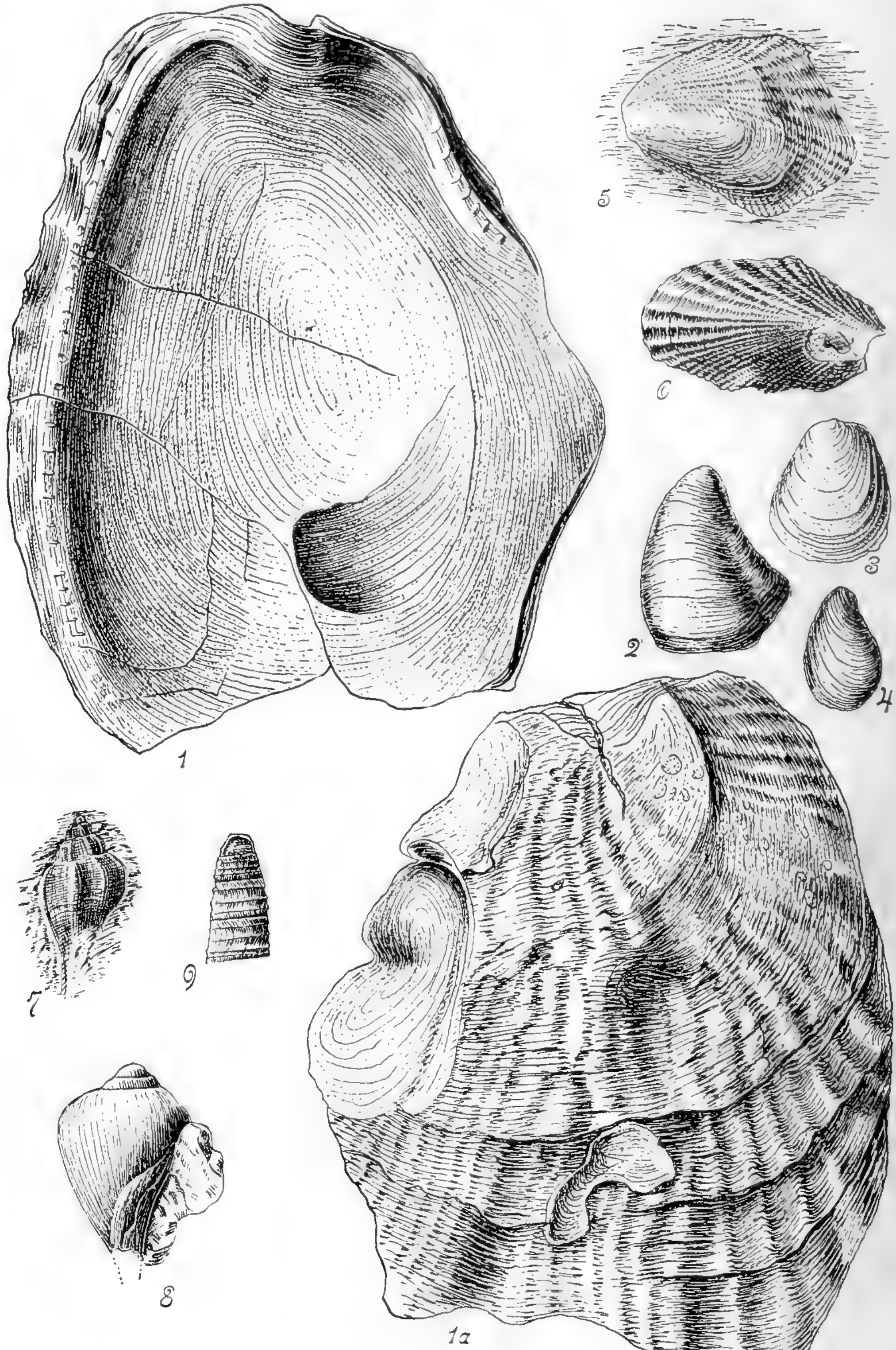

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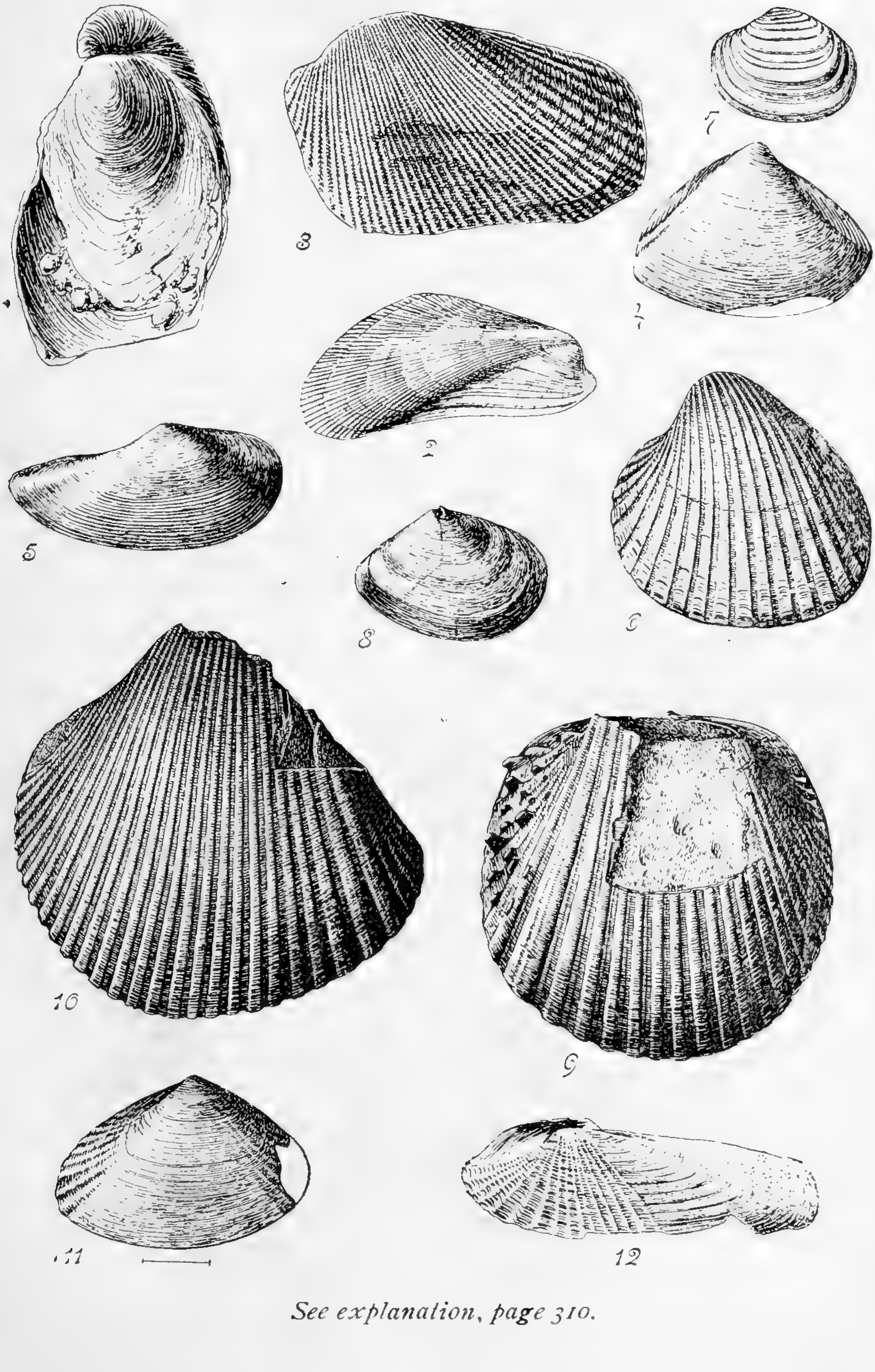

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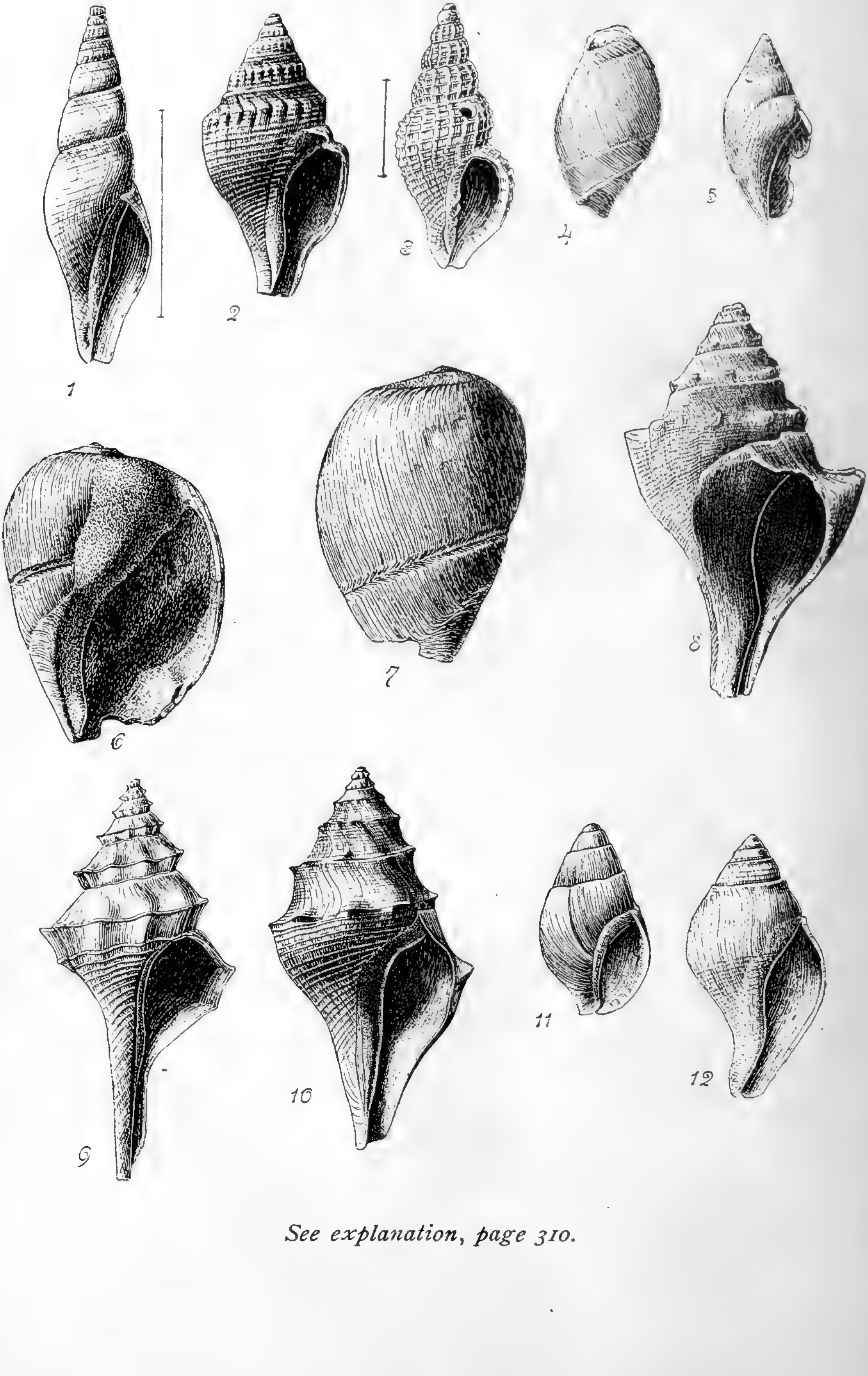

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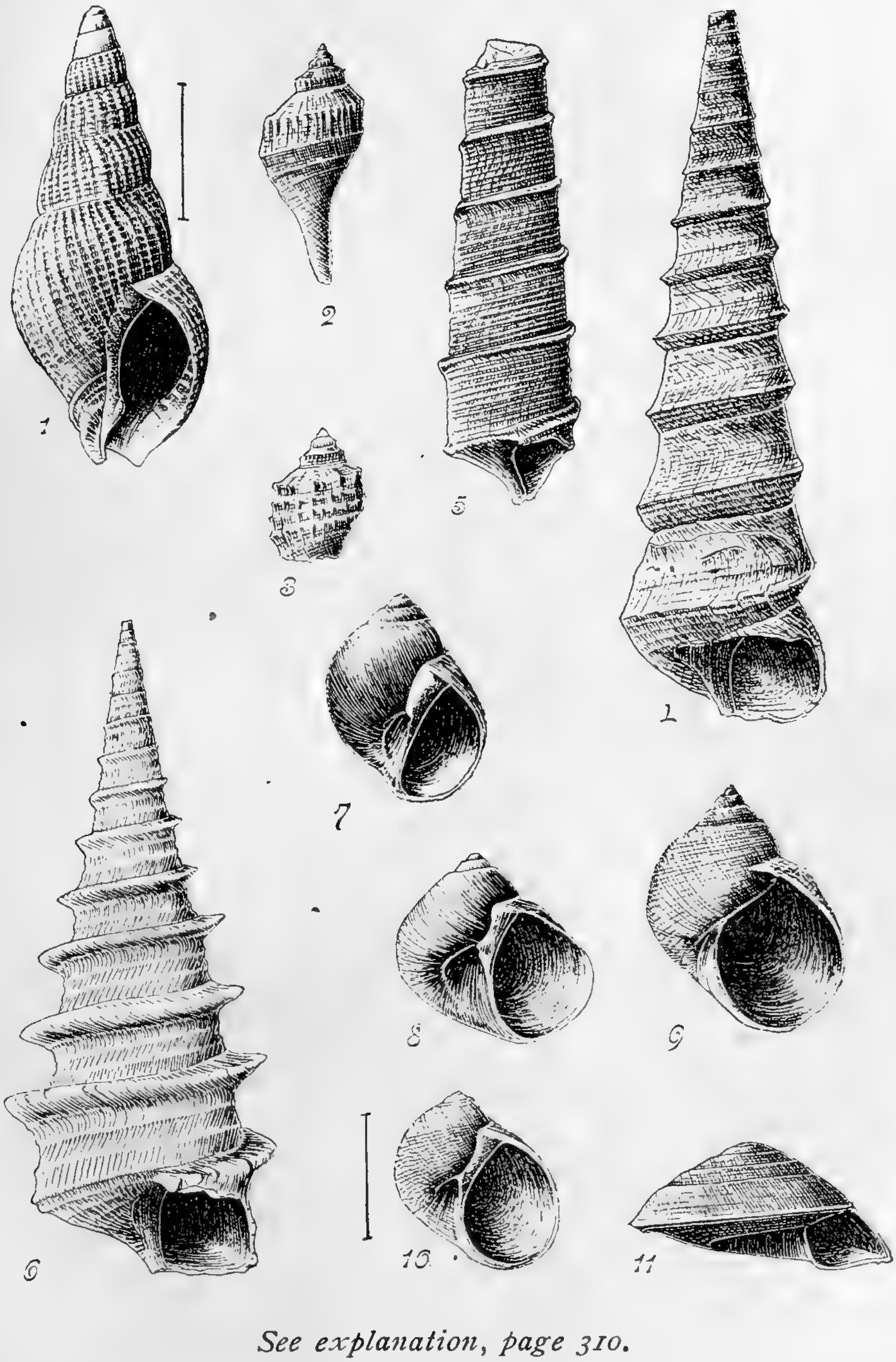

See explanation, page 310.

Special Report No. 7

THE ESTABLISHMENT OF MERIDIAN LINES

BY

G. D. HARRIS

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THE ESTABLISHMENT OF MERIDIAN LINES

PRELIMINARY REMARKS

The Compass Needle

Variations and imperfections.—The propriety of using a magnetic needle for determining direction in ordinary land surveying is indeed questionable. When we know that so called "variation of the compass needle" is changing from year to year (secular variation); when we remember that there is an annual variation, or change from season to season, and a diurnal or daily change; when we observe the sensitiveness of the needle to extreme changes in temperature, its deflection by local attraction and magnetic storms, or its sluggishness from a worn center or loss of magnetism; when finally we know that no non-reversing needle ever does indicate the exact magnetic meridian because its physical axis is never exactly the same as its magnetic axis; then we must admit that even though the instrument is in perfect adjustment, the chances of laying off two coincident lines from any given starting point, at different intervals of time with one and the same compass are indeed slight. Different men with different instruments at different times, have naturally, as we all know, come to very different conclusions regarding the location of many corners and boundary lines.

Without going into details regarding the troubles thus brought about, it is more to the point to make inquiries as to how the present methods of determining direction can be improved upon.

The Transit, With or Without Solar Attachment

Its use.—No one who has ever become familiar with an engineer's or surveyor's transit can go back to compass surveying with any degree of satisfaction except in mere preliminary or reconnaissance work. Again, the ordinary transit is equipped with a needle, so that whatever merit may be in such a mechanism, is possessed by the transit as well as the plain compass. But the possession by a transit of a horizontal limb provided with verniers for laying off or reading angles directly to within a minute or less of an arc, gives it a superiority over the plain compass that no surveyor can fail to acknowledge at once.

As time goes on and the price of land increases, there in a tendency to lay less and less emphasis on the actual direction the boundary lines of land bear to true north and south or east and west lines. Descriptions are based more and more upon cultural features the more such features increase. Points are fixed by their distances from other fixed points, the angle that two intersecting lines make is measured with the transit, and such angles are recorded, while the true bearing of either line with the meridian is neither sought nor given.

If, however, there is need of knowing accurately (say to 1′ of arc) the bearing of a line, it can be determined in the day-time by the same transit instrument provided it possesses a vertical circle with proper graduations and verniers. This is done by alt-azimuth observations on the sun. The solar attachment greatly lessens the amount of calculating involved, though it means more adjustments to care for.

Cost.—The ordinary compass can be bought for from $25 to $50. A good transit costs at least $200; it cannot be carried in saddle-bags, nor can a limb or rail splinter be used as a temporary yet admittedly efficient support. Obviously, then, there is here a question of more money, time, care and attention at stake, points not readily and willingly overlooked by employer or surveyor.

Yet, if the parish owned the instrument, and this it could well afford to do, and the surveyors were selected by civil service examination and given a small salary in addition to their fees for each piece of work, there can be no doubt that in the long run thousands upon thousands of dollars would be saved and many life-long troubles averted.

IMPROVEMENT OF COMPASS SURVEYING

Magnetic declination and secular change.—Every surveyor knows that to follow certain lines established by one surveyor, say in

1820, he must run on one variation, and to follow another in the same region but established by a different surveyor with a different compass at a different time he must run on a different variation. In other words, putting aside occasional outright poor work, the lack of a definite knowledge of magnetic declination and its secular variation on the part of the previous surveyors has often been the source of a vast amount of trouble, mental and financial. Unfortunately, even to-day, the surveyor with an ordinary compass has no ready means of determining the amount of this variation; for to determine the number of degrees and minutes that the axis of his needle makes with a true meridian line means that the latter is already established or known. But such a known line does not exist in his parish, nor has he the means of establishing one.

Need of meridian lines.—The above statements are sufficient to show that if compass surveying be continued, it is quite time that some systematic records be kept of what each surveyor means by "due north" or any other direction he gives, basing his statement on the direction assumed by his unclamped compass needle.

A well kept needle will usually settle twice within 5′ of the same place. With proper care, it can be read to 5′ of arc. Poor needles may mislead to the extent of 30′ or more. A line then that is within 1′ of the true meridian of the place is sufficiently accurate for all compass work. Any higher degree of refinement, however desirable and satisfactory on general principles, is wholly unappreciated in compass surveying.

How established.—But as before stated, such a line can be established by day whenever the sun is shining; or by night whenever the circumpolar stars are visible, to a still greater degree of accuracy by a rather unpretentious engineer's transit.

Instructions for this operation have been so frequently published in works and reports relating to surveying and surveys that it seems quite unnecessary to repeat them here. However we cannot refrain from suggesting that in place of the usual paragraph of instruction in night work which reads somewhat as follow: "Let an assistant place a light corresponding in brightness to that of the stars at a point seemingly exactly beneath Polaris at its elongation, or let him hold the fine point of an illuminated pencil on a wooden plug or board fixed to the ground;" we would suggest placing an illuminating scale (see Fig. 7) at 600 to 1000 feet from the transit some little time before the elongation and then watch the star move in azimuth from 1, 2, to say 8 and return.

A fairly good scale can be improvised as follows: Take a new piece of tin about 6x14 inches and cut slits at intervals of from .05 to .10 ft. according to the power of the telescope and the distance available.

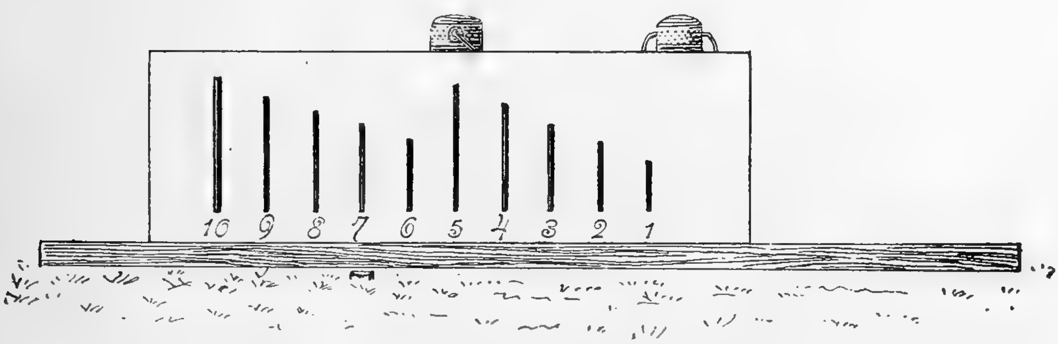

Fig. 7.—*Illuminated scale for night work.*

Fractional parts of interspaces can be estimated to the nearest $\frac{1}{10}$ *i. e.*, 0.01 ft., if the instrument has no micrometer attachment.

When the scale is placed at such a distance as to cause one space to represent about 20″, it follows that readings are made to about 2″ of arc. If when the various readings have all been reduced to the elongation and there is no serious discordance shown, it is safe to conclude that the average is a close approximation to the true elongation.

Other circumpolar stars giving an opposite elongation the same night can also be observed with the scale reversed. The true elongation of each can be computed from the several observations on the same, and all can be used in the final location of the meridian line.

The position of the scale on the subjacent board should be accurately marked, and in the morning a fine, straight steel pin can be placed where the mean of the elongation readings was on the previous night and the azimuth of the stars at elongation laid off in order to establish the true north and south line. The position for Polaris and several other circumpolar stars is conveniently given for each day of the year in the American Ephemeris and Nautical Almanac. The latitude of the place can be determined with sufficient accuracy by an inspection of any good state map. Then

$$\text{Sin. Az. at Elong.} = \frac{\text{Sin. Polar Distance}}{\text{Cosine Latitude.}}$$

The surveyor will find it greatly to his advantage to establish his meridian line in the day-time before his night work by equal altitudes, or ordinary alt-azimuth observations on the sun to within 1′ of arc. He will thus be able to have the monuments placed, but not cemented in, and will also have his scale placed already for illumination at night. The final lining up of the monuments is but a short task for the next morning. Where monuments are small and of local construction, there should always be four placed in line so that any disturbance in one can be detected by the rest.

OUR OUTFIT AND EXPERIENCES

We have only to add that our outfit for the past year consisted of a good Heller & Brightly engineer's transit, of high magnifying power, but with verniers reading directly to minutes only. Great interest seemed everywhere to be manifest in the work and we are glad to say that during the coming year this work will be greatly facilitated by the use of an instrument of a much superior order of construction and refinement.

With our present small staff, no considerable amount of time can be spent on work of this nature. It is for this reason we have suggested and urged cö-operation with the U. S. Coast and Geodetic Survey. See Introduction.

As will be seen below, we have been favored by Maj. Willard with careful descriptions of many of the Reference and Azimuth Points of several of the river surveys.

MERIDIAN LINES ESTABLISHED

MANSFIELD

General location.—Across (midway) west yard of Mansfield Female College grounds and ¼ mile to south, in Mrs. Williams' field.

Marks or monuments.—Three Lignitic, calcareous, concretionary boulders. N, at northern side of the college grounds, N′, at the south side, and S, 1800 feet south of N, in Mrs. Williams' lot.

MANY

General location.—In Mr. E. C. Dillon's lot west of residence. For detailed information call on either Mr. Dillon, or Dan'l Vandegaer, Esq., parish surveyor.

Marks—Calcareous, Lignitic boulders. Only three in number. S, near a pine tree in Dillon's yard, west of house; S′, by the fence just north of stream, perhaps 300 ft. north of S; N, in edge of field, 897 ft. north of S.

NATCHITOCHES

General location.—Through Normal school grounds west of the buildings about 150 feet.

Marks.—Calcareous Claiborne boulders; exact meridian marked by drilled holes filled with lead plugs. The northern most, N, is within perhaps five feet of the northern line fence; N′ is south of N about 30 feet, S′ is just south of the walk or road leading westward to the woods and S is within 3 feet of the southern line fence of the school grounds.

COLFAX

General location.—Court house yard, east of Court house. See Mr. R. E. Mc Knight, Colfax, La.

Marks.—Grand Gulf sandstone boulders; all four within court yard limits. Definite marks consist of sunken lead plugs in sandstone. N and S are very close to north and south limits of the yard.

Colfax Base Line Established by U. S. Engineers *

" *Colfax base line*, tertiary triangulation of Red river, was in Grant Parish, La., near Colfax, but was marked permanently only at one end; the triangulation stations adjacent to south base at Colfax were permanently marked.

" *South base* is marked by the point of a nail set in cement within the end of a vitrified sewer pipe. The pipe is 12 centimeters in diameter and 75 centimeters long. The top of the pipe projects about 1 decimeter above ground and stands in a meadow just above Colfax. It is about 100 meters northwest of the row of cabins on C. H. Teal's place and about 110 meters northeast of the fence enclosing a small lot.

" Elevation, 35.92 meters, [Cairo Datum.]

" Latitude, 31° 29′ 50″.

" Triangulation stations are marked in a manner similar to South base.

"Azimuth, South base to Sta. 260, 77° 07′. Distance 801 meters.
South base to Sta. 260a, 16° 55′. Distance 1093.6 meters.
South base to Sta. 261, 333° 40′. Distance 1160.6 meters."

WINNFIELD

General location.—Court house yard, east of Court house.

Marks.—Four limestone boulders from the " Marble Quarry." Exact mark consist of lead plugs, as elsewhere. N. and S. are near the north and south limits of the court yard. In case of doubt see Messrs. Dunn, Bailey, Wallace or any other citizen.

COLUMBIA

General location.—Diagonally across Court house yard passing but a few feet west of the corner of the same.

Marks.—Calcareous boulders. All four within the court yard limits. Line defined by sunken plugs. In case of doubt as to location drop a card to A. J. Daniel, Parish Surveyor, Kelly, La.

* The information here and elsewhere credited to the U. S. Engineers was very kindly furnished by Maj. J. H. Willard, Vicksburg, Miss.

Line, Monuments, Etc., U. S. Engineers (Ouachita River Survey).

"*Permanent reference line, Columbia*, Ouachita River survey, is in Franklin parish, La., on the left bank of the river opposite the town of Columbia. Both ends of the line are marked alike by a 4 centimeter gas pipe about 1.6 meters long, with a cap on top, and a circular flange attached near the lower end by lock nuts. The pipe is bedded in cement and projects above ground about 1 decimeter.

"*Permanent reference point* is about 2.4 kilometers below Columbia, near the bank of Bridger Bayou. It is about 7 meters north of the front fence of the Ivy Davis plantation. Witnessed by three trees with triangular blazes, as follows:

"Double China berry, 0.4 meter in diameter, 29 meters, 77° 00′.
China-berry 0.4 meter in diameter, 19 meters, 131° 45′.
China-berry 0.3 meter in diameter, 16 meters, 143° 55′.
Northeast corner of a cabin, 24.5 meters, 126° 45′.
Elevation of cap, 27.01 meters," [Cairo Datum.]

"*Permanent azimuth point* is on the main top bank of the river opposite Columbia, near where the road from the ferry comes out of the woods, and joins the main road. It is north of the plantation fence and about 7.5 meters from the main road. It is about 30 meters east of a cabin and about 260 meters west of St. Peter's church. Witness trees blazed with triangular blazes as follows:

" Sweet Gum, 0.5 meter diameter, 19.5 meters, 356° 45′.
Locust, 0.3 meter diameter, 6.8 meters, 310° 00′.
Locust, 0.3 meter diameter, 6.4 meters, 109° 05′.
S. W. Corner St. Peter's Church, 291° 29′.
Azimuth, P. R. P.—P. A. P., 94° 49′."

Harrisonburg

General location.—Main line on Mr. E. D. Spann's property passing just east of his house.

Marks.—Grand Gulf sandstone boulders, with lead plugs. N′, in front of Mr. Spann's house, 5 feet south of the north yard fence; N′ by fence at N. E. corner of house; S and S′ are near the edge of the field on either side of a little branch, about 360 to 380 feet south of N′. Two boulders in the school house yard one by the fence E. of the school house yard, one by the fence south of the same building mark an east and west line. The westerly side of the new brick jail has a bearing of N. 14° 32.7′E.

Line and Monuments Established by U. S. Engineers Near Harrisonburg

"*Permanent referenee line*, *Bushley*, Ouachita River survey, is in Catahoula parish, La., on the right bank of the river, about two kilometers below the town of Harrisonburg. The line is marked by a gas pipe in a manner similar to P. R. L., Columbia.

Permanent reference point is about 200 meters south of the mouth of Bushley bayou, at edge of wood-line, and about 325 meters back from right bank of river. Witness trees blazed with triangular blazes, as follows:

Maple, 0.4 meter diameter, 18 meters, 320° 30′.
Pecan, 0.3 meter diameter, 21 meters, 14° 00′.
Cypress, 1.0 meter diameter, 6 meters, 265° 45′.
Elevation, 24.20 meters, [Cairo Datum.]

"*Permanent azimuth point* is about midway of old Scott plantation, on large mound (first near river above Bushley bayou), about 140 meters back from right bank of river. Witness trees, blazed with triangular blazes, as follows:

Honey Locust, 0.2 meter diameter, 8 meters, 340° 45′.
Sweet Gum, 0.2 meter diameter, 13 meters, 110° 20′.
Sweet Gum, 0.4 meter diameter, 19 meters, 240° 05′.
Azimuth, P. R. P. to P. A. P., 155° 43′."

Other Localities Where Azimuth Lines are Established by the U. S. Engineers

Shreveport base line, tertiary triangulations of Red river, is in Bossier parish, La., on the left bank of Red river, opposite the town of Shreveport. Both ends of the base are marked alike with an underground stone slab and iron pipe rising above ground. The underground mark is a piece of limestone 46 centimeters square, and 15 centimeters thick, marked U.S. o Δ with a spherical headed copper bolt leaded in the center of the upper face. The pipe is cast iron, 12 centimeters in diameter, and 1.2

meters long and stands on top of the stone. The pipe is covered by a cap which is fastened on by a bolt and nut. There is a small boss on top of the cap, with a hole in the center.

Northwest base is now buried under the front slope of the levee, about 20 meters from where the levee crosses the embankment of the V. S. & P. Ry., about 300 meters from the northeast end of the bridge across Red river. A wooden post stands on top of the pipe, and projects above the surface to mark the location.

Southeast base is on the field side of a fence on the north side of a lane running down the river near the left bank, and it is about 200 meters east of the turn in the lane and 150 meters west of the house of C. M. Dougherty.

Length of base, 704.34 meters,

Azimuth, N. W. B.–S. E. B. 296° 45′.

Latitude of N. W. B., 32° 31′ 38″.

Elevation of bolt in stone marking N. W. B., 58.37 meters.

Elevation top of cap N. W. B., 59.61 meters, [Cairo Datum.]

Elevation top of cap S. E. B., 59.83 meters, [Cairo Datum.]

"*Permanent reference line, Monroe*, is in ouachita Parish, La., on the left bank of the river and lies along De Siard street in the town of Monroe. Both ends are marked alike by a piece of "T" rail set in the ground with the top buried about 0.03 meter below the surface. The head of the rail has a cross on it, marking the point.

"*Permanent reference point* is near the west end of De Siard street, and about 28 meters from the river bank. It is on line between a cross cut on Merchants' & Farmers' Bank and one cut on the Block building. It is 3.84 meters from the first and 8.7 meters from the last. The cross on the bank building is 9.36 meters from the angle in the wall beside the door; that on the Block building is 14.32 meters from the front line on Grand street.

Elevation, 30.83 meters," [Cairo Datum.]

"*Permanent azimuth point* is 5.6 meters from the iron fence around the Monroe cemetery and 30.5 meters from the corner at the gate. Witnessed as follows:

Spire (Col'd) Methodist church, 225° 01′.

Spire (Col'd) First Baptist church, 121° 56′.

Index finger on monument to Margaret J. Henderson, 9° 32′.

Azimuth, P. R. P. to P. A. P. 232° 52′ 47″.

Alexandria base line, tertiary triangulation of Red river, is in Rapides Parish, La., on the right bank of Red river and behind the town of Alexandria. Both ends of the base are marked alike with stone and pipe similar to the Shreveport base line.

"*Northeast base* is in a meadow about 50 meters southeast of a barn.

"*Southwest base* is in open field on a low levee about 50 meters east of fence.

Length of Base, 955.676 meters.

Azimuth, N. E. B., to S. W. B., 81° 48′.

Latitude, N. E. B., 31° 17′ 47″.

Elevation top of cap N. E. B., 30.21 meters, [Cairo Datum.]

Elevation top of cap S. W. B., 31.58 meters, [Cairo Datum.]

"*Permanent reference line, Floyd*, Bayou Macon survey, is in West Carroll Parish, La., on the right bank of the Bayou in and below the town of Floyd.

"*Permanent reference point* is marked by a 4 centimeter gas pipe with a sleeve on the upper end, driven in the ground about 400 meters below Floyd on Mrs. Emma White's place. It is about 150 meters west of bayou bank, about 10 meters west of edge of hills, about 200 meters southeast of dwelling, 44 meters south of cabin and 27 meters north of fence.

"*Permanent azimuth point* is the cupola of the Court House in Floyd.

Azimuth, P. R. P. to P. A. P., 161° 46′.

MAGNETIC DECLINATION

Amount of "variation" determined by one compass not applicable to work done with another.—There are in all compasses and transits strong probabilities of a certain error in their readings of magnetic bearings owing to the fact 1st, that the line of sights is not exactly in line with the zero marks on the compass box and 2d, that the magnetic axis of the needle does not exactly co-incide with its physical axis.

Though we made a number of readings at various parish seats and elsewhere and though we took the precaution to determine the amount of index error of the transit used, yet we feel that such readings are scarcely worthy of publication, and for the following reasons: The results though correct would not be directly serviceable to local surveyors using their own instruments, and, to be of service in purely scientific work, the amount of declination should be determined by a magnetometer specially constructed for such work. And again, the dip and intensity or total magnetic force should be determined in order to advance the cause of the science of terrestial magnetism.

A fine field for magnetic work.—The complicated geologic structure of Louisiana is just beginning to be realized. Generalities based on trans-Mississippi investigations, and smooth, straight lines separating the different series and stages will soon be relegated to the past. It is mainly through invertebrate paleontology that the relationships of the various formations represented in the State are and have been determined. Yet if we mistake not, paleobotany will soon be able to lend a hand in this work. Possibly too magnetic investigations may throw some light on stratigraphy. Be that as it may, it is certain that the smooth agonic lines heretofore drawn through Louisiana will be crumpled and curved in a marked fashion when they have been platted from a large number of field observations.

Witness: At Many decl. about 7°; Natchitoches, 6° 40′; St. Maurice, 6° 35′; Couley, 6° 40′; Winnfield, 6° 45°; Columbia, 6° 10′. January and February, 1899.

Have the results of orographic movements so manifest about Winnfield anything to do with the irregular declination there shown?

In Louisiana, as well as other States laid out in rectangular townships, sections, etc., the question of latitude, so essential in rapid and accurate magnetic survey work is often quickly determined with sufficient accuracy by asking any resident what section he is in, or by inspecting his deeds or tax receipts, and having him point out the locations of the various "quarter quarters" called for. Yet there are places occasionally where there are no inhabitants for 15 or 20 miles along the main roads.

Here the road maps mentioned in our next article would serve an excellent purpose, enabling one to locate himself at any time with accuracy.

A magnetic survey of a state should include at least one observation in every township. The greater the facility with which trustworthy observations can be made, so much the less expensive and more accurate will be the results.

Special Report No. 8.

A FEW NOTES ON ROAD MAKING

BY

G. D. HARRIS

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A FEW NOTES ON ROAD MAKING

LITERATURE

Office of road inquiry.—Fortunately for those interested in the construction of good roads, the Department of Agriculture at Washington, D. C., has instituted an "Office of Road Inquiry" under the able direction of Gen'l Roy Stone.

This office has collected a large amount of valuable information and published it as bulletins and circulars, and has distributed copies of the same, free to those interested in the subject.

The titles alone are sufficient to show the scope and importance of this "inquiry." Note the following:

Bulletin No. 1.—State laws relating to the management of roads, enacted 1888–1893.

Bulletin No. 18.—(Supplement.) State laws relating to the management of roads, enacted 1894–1895.

Bulletin No. 17—Historical and technical papers on road building in the United States.

Bulletin No. 12.—Wide tires. Laws of certain States relating to their use, and other pertinent information.

Bulletin No. 9.—State aid to road building in New Jersey.

Bulletin No. 16.—Notes on the employment of convicts in connection with road building.

It seems entirely unnecessary here to give even an abstract of these and other important papers since they are so readily obtained, by addressing the Office of Road Inquiry at Washington.

Practical instruction.—The easiest, quickest and most satisfactory way of learning the art of good road making is to watch those who understand and are actually engaged in making roads.

It was hoped and even announced that Mr. Harrison of the Washington bureau would oversee the construction of a model road from the North Louisiana Experiment Station to Calhoun Station soon after the meeting of the Agricultural Society at Shreveport. Circumstances were such, however, that Mr. Harrison could not then leave Washington to take charge of the work and the matter was postponed.

LOCATION OF ROADS

No surveys yet made.—The vast majority of Louisiana roads seems never to have been properly located. They represent enlarged trails. They are, within certain broad limits, wherever each season the traveling public sees fit to go. Observe the broad band of land on either side of most any old or well recognized road and count the different road beds of tens or scores of years ago now recognizable as narrow long ditches and frequently overgrown by forest trees. Look again at the several lines of log roads ("causeways") that can be seen running along parallel to each other across marshy stretches.

Is there any real incentive to do thorough and lasting work on a stretch of road that may soon be paralleled by a new one, simply because the old one somewhere had one impassable spot?

Right here we believe is the place to begin. We have urged each parish surveyor and all others who manifest an interest in the subject to see at once that at least the "first class" roads are located. This should be done by giving the distance from the nearest section corner at which the road enters each section and the traverse through the section. This information would, of course, be recorded at the parish seat.

Monuments.—Stone or iron posts could well be used at the road-sides to indicate the crossing of section lines, and certainly permanent monuments should be carefully located on either side of the road at each angle.

Other objects of a road survey.—I believe the benefits to be derived from a road survey can scarcely be overestimated. It would establish a network of known points and distances throughout each parish that would be a most welcome guide to all travelers, be they geologists, botanists, timber men, commercial travelers, pleasure seekers, produce shippers or home seekers. It is no exaggeration to say that a geological survey could be prosecuted with double the despatch and double the accuracy if the roads were only located and mapped. Other public and private works would be likewise benefited by the mere location of roads. Add to this, the increased facilities of a road bed well made and well maintained, and the annual benefit, direct to the traveling public, indirect, though far greater to the resident would be almost beyond calculation.

We have already noted the fact that as time goes on cultural features are used more and more for reference points and lines in the description of real estate. Here then is another reason why roads should be well located. For the future will see many of these very roads used as boundary lines between subdivided estates.

ROAD MATERIALS

The common country roads through Louisiana will naturally be for some time to come "dirt roads." There are however, favored localities where shell and gravel can be freely used for ballast.. In section II of this report under "Lafayette" (pp. 100–104) numerous localites are given where quartz pebbles occur. In some few cases they are sufficiently abundant to be easily obtained in quantity, and will doubtless be shipped to a considerable distance for road-making in the near future.

So far as dirt roads are concerned their construction and maintenance has been greatly simplified of late by the introduction of road machinery, and we close with the following paragraphs from circular No. 31 of the Office of Road Inquiry. If they have already been read, they certainly will bear reading again.

ROADS AND ROAD MACHINERY

The first thing to be observed in building country roads is to afford protection against water. A dirt or gravel road properly built and maintained can be made to shed water like a roof, and if the use of narrow tires and the wearing of ruts could be prevented, our country roads might be excellent. Water always runs down hill, and this should be taken advantage of in road building. If the road be properly crowned, that is, if its middle be properly raised above the sides, the rain and melted snow will naturally run off into the ditches. On the other hand, if the middle be worn down by travel, the water collecting there will soon form a puddle, and ruin the road. In the same way, ruts formed by narrow tires afford a trough for the collection of water, and contribute to its destruction.

Labor as they might, American farmers have long been unable to build their roads so as to shed water. But the solution has been found in the road grader. The American farmer is quick to realize the value of machinery, and the rapid growth in the use of the reaper, the binder, the separator, is an eloquent tribute to the practical genius of American agriculture. The growth of the use of road graders has been wonderful during the last few years, and indicates that the farmer has discovered a practical solution of the problem how to build his local dirt roads.

The peculiar feature of a road grader is that it cuts away the dirt at the side of the road, and draws it up into the middle, thus producing a ditch at each side and a slope in each direction from the center. At the same time it will cut away the dirt to just the proper depth, and no deeper. In this particular, its work differs from that accomplished by the use of plows, shovels or hand scrapers. The road grader leaves a smooth, regular surface, giving the road the proper contour. A dirt or gravel road can be put into excellent shape by running the grader repeatedly over it. Care should be taken first to remove brush and rubbish from the side of the road, that the grader may not carry it into the traveled roadway.

To properly finish a dirt road made with the use of the grader, it should be thoroughly rolled and hardened. It is not sufficient that it be crowned, but it should be made hard and smooth. The same thing is true of gravel roads. This can be best accomplished with the use of rollers. Horse rollers weighing from five to eight tons are most frequently used for the purpose. All loose stones should be removed from the road surface before rolling, as well as sods, turf, leaves, sticks or any other matter that will tend to soften the road bed. A road that is thoroughly and repeatedly rolled is well fitted to stand the wear of travel, and can be made into a perfect watershed.

The difficulty about the use of road machinery in many localities is to be found in its cost. It is frequently thought wrong that farmers should be obliged to tax themselves for the purchase of road graders and road rollers, in addition to having to stand the regular road tax. There is much justice in this position, for the average farmer pays his full share of taxes, and these should not be added to or increased without some very excellent reason. But the farmers of the United States are badly in want of good roads, and the clamor for their construction is growing from year to year. Quite a number of towns have solved the road machinery problem by voting to pay their taxes in cash instead of working them out, and using a parts of this fund for the purchase of machines, which avoids the necessity of levying an extra tax for the purpose. This plan has been adopted in New York and Wisconsin, and probably elsewhere. The town of North Salem, Westchester Co., N.Y., adopted it as far back as 1881. The town of Canaan, Columbia Co., N. Y., adopted it in 1887. In Wisconsin, C. H. Everett, until recently the president of the Wisconsin Dairymen's Association, says on this subject in a recent letter: "The town of Turtle, Rock County, where I reside, was among the first to adopt the cash system, and has two improved road graders. I do not think that our people could ever be induced to go back to the old system. We know that we have spent enough money in road taxes during the past forty years to have macadamized every road, and until we began to pay our road taxes in cash and use machinery, there had been little or no improvement in our highways."

The proposition to pay road taxes in cash met with little favor in the beginning. Farmers were unwilling, as might reasonably be expected, to pay their road taxes in cash instead of in work. But sentiment is now largely the other way among intelligent farmers, since experience has shown that more can be accomplished with one dollar of tax paid in cash, than two dollars or even three dollars of tax worked out on the highway. Where the system has been fairly tried, farmers have found it by no means the burden expected, since they may still be hired by the road officers to run the machinery used. Two cases in Wisconsin are instructive on these points. Martin J. O'Malley, chairman of the town of Westport, Dane county, writes: "We adopted the money system in the town of Westport two years ago. We purchased a good road grader, and we levied a 2-mill road tax instead of the 4-mill tax that we had been paying working the old way. The people are allowed to vote on the question at every election, and they are fully convinced that the cash system is the only true way of getting good roads. There has been more work done on our roads during the past two years than in twenty years before."

The same experiment was tried in the town of Middleton in the same county, and with the greatest success. In 1894, under the new law passed the year before, the town paid its road taxes in cash, and used part of the money for the purchase of two road graders. Wm. F. Pierstorff, chairman of the town, told of their experience in an address delivered at Watertown, in the spring of 1896. "Under the old laws," says Mr. Pierstorff, "we always levied a road tax of 4 to 6 mills. In 1890, a tax of $2,297.80 was levied; in 1891, $3,346.70; in 1892, $2,326 77, and in 1893, $2,471.93. In 1894, the first year under the new law, we levied 2 mills, amounting to $1,051.58, and bought two road graders. We gave the farmers a chance in handling graders to work at three dollars per day with team, they giving us ten hours for a day's work. In 1895 we levied 2 mills as before, and expended $1,231.56 for our regular work on the highway. You will see that for the last two years we expended for general highway purposes an average of $1,141.57 a year, while the average for the preceding four years was $2,827.28. It is admitted by all that there was more work done in the last two years than the town has ever done before. You can do more work with three teams and one grader in a day than with three teams and a small scraper in a week. Our people are well satisfied with the new system, and they will never vote to go back to the old method of working the highway."

For the most recent exhaustive treatise on roads, road-making and road materials, see Rept. Geol. Surv. Md., Vol. III.

Special Report No. 9

SOME WOOD-DESTROYING FUNGI

BY

PROF. GEO. F. ATKINSON

CONTENTS

SOME WOOD-DESTROYING FUNGI

STUDY OF FUNGI IN GENERAL

Fungi on Garden Vegetables

During the past ten years or so a great deal of attention has been given to those low forms of plant life known as fungi, which cause diseases of farm and garden crops. These investigations have made us familiar with the history of many of these enemies of the farmer and horticulturist, and have taught us how in many instances to successfully combat them. This has resulted in the prevention of great loss, and taking the country over, thousands of dollars each year are now saved by the practical application of the knowledge gained by studies of the fungi.

Fungi on Forest Trees

Very little attention, however, has been given to the study of those forms of fungi which attack forest and timber trees, although the National Government for a number of years has been engaged in propagating information along certain lines of forestry work, and in an endeavor to arouse general interest in the question of the preservation of forests, as well as in the establishment of a rational method of timber cutting, which shall protect the young growth and provide for future crops of timber.

The number of fungi which occur on living and dead trees in the forest is very large, and the damage which is caused by them in producing the decay of fallen timber, of cuttings, and especially in causing heart rot of many valuable standing timber trees is very considerable. When one begins to observe these wood destroying fungi in the forest, one is impressed with the great variety of form which they possess, indicating that there are many species or kinds.

They stand out as brackets or shelves from the trunks of trees, from the sides of fallen logs, from old stumps, or even from the ground where they are growing from some decaying wood in the soil, or perhaps from some diseased root. Some of these plants are fleshy and soft in consistency, so that they soon disappear. Others are more or less tough, and dry up considerably during dry weather but expand again during rains. Still others are of quite a woody or corky texture, often very hard. Many of these latter ones live from year to year so that they are perennial.

This article is written for the purpose of calling the attention of those who frequent the forest, either from a professional or from a pleasure point of view, to these enemies of the forest. There are many problems of interest and importance presented by the relation of these plants to the timber trees. A few of these problems are suggested by the description of several of these plants.

Polyporus borealis Plate 56

Occurrence and distribution.—The first one of these plants to which attention is called here is very active in causing one kind of heart rot of coniferous trees, especially the spruces, pines, balsams, hemlocks, etc. It is known as the *Polyporus borealis*. It has a very wide distribution not only in Europe and in America, but probably in other countries as well. A photograph of this fungus attached to a living hemlock tree is shown in Plate 56. This tree occurred in one or the deep wooded ravines at Ithaca, N. Y., along one side of the Campus of Cornell University.

Characters.—The fungus is white and is of the bracket kind. As can be seen, there are several brackets growing very closely together overlapping each other. The bracket is the "fruit body." While these plants have no fruit in the sense that the higher plants do, yet they produce countless tiny bodies, called spores, so minute that we cannot see them except with the aid of a microscope, or unless there are a large number of them massed together. These spores are capable of starting a new growth of the fungus. They are borne on the under side of the fungus, in minute pores or tubes which are so numerous that the under surface of the bracket reminds one of a honey-comb structure. The upper side is hairy with coarse strands which bristle all over the surface. It is rather soft and spongy.

How nourished.—It will be of interest to know how such a fungus attached to a living tree obtains its food from the tree, and also how it is enabled to cause the decay of the heart wood. In the first place the fungus is growing from quite a large wound in the side of the tree. The tree has been trying to heal over the wound for years but it has not been successful, for the wound is a large one. The healing process, however, advanced quite far as can be seen by the new growth all around the edge of the wound.

How the tree is killed.—Two years ago when I first observed this tree though it was still alive, a number of the top limbs were dead. This suggested that the rot caused by the fungus extended entirely through the tree. To determine this question, and also to see the relation of the fungus to the decay, as well as to determine the structural peculiarities produced in the wood by this species, during its disintegrating action on the wood, the tree was felled and sawed up into short sections. These sections were then split and a large number of them were preserved for examination.

Several of the blocks of heart wood split from the tree were photographed, and one of these is shown natural size in Plate 57. The white strands which extend horizontally in the wood are the strands of mycelium which is the vegetative part of this fungus. It corresponds to the so-called "spawn" of the mushroom, which is characteristic of all the members of the fungi belonging to the mushroom group, though there are variations in its nature and extent. These strands of the mycelium are composed of numerous delicate, slender fungus threads all woven together. They extend throughout the length of the tree in the heart wood. They grow through the cell walls of the wood and cause the disintegration of the latter, first by opening minute holes along the line of their advance, which is in a longitudinal, radial, and tangential direction. This tends to divide up the wood into small cubical areas which are more pronounced later as the fungus threads disappear and the wood by advanced stages of decay tends to collapse. The fungus threads have the property of excreting a kind of ferment which dissolves the woody and cellulose walls, thus disintegrating the wood and opening a way for the advance of the fungus.

Starting of the fungus germ.—By this thorough examination of the felled tree it is possible to make out the history of this fungus. The photograph in Plate 56 tells a great deal of the story of how the fungus was able to get inside of the tree and then to grow out again in the form of the bracket fruit bodies. The *Polyporus borealis* is not a parsitic fungus. It cannot make its way unaided through the sound living part of the tree which lies just beneath the bark. The heart wood of the tree is dead, so that the fungus when it once gets in there can perform its destructive work. The living wood, just underneath the bark, when it remains unbroken or unharmed forms an impassible barrier to the entrance of the fungus.

How then did the fungus first get into the heart wood of the tree? The photograph tells us something of that. There is an old decaying log lying at the foot of the hemlock tree. Twenty-five or thirty years ago this log was a standing tree. It fell, and in its descent it struck the projecting base of the hemlock and knocked off the bark and living wood from quite a large area, two to three feet in length and a foot or more in breadth. The wound was so large that it could not heal in time to prevent the entrance of the wood destroying organisms. Furthermore, the bruised tissues would afford a secure lodgment for these germs. So here was formed a most favorable infection court, or area. During damp weather bacteria and fungus germs, the chief producers of the decay of organic matter, lodging here were enabled to get a foothold and start the disintegration of the wood. Among them were the spores of this *Polyporus borealis*. These spores produced the delicate mycelial threads, and by the ferment action of their products these threads gained access to the heart wood, where there was an abundance of moisture for growth during the entire season. From this point mycelium spread upward and outward as it advanced through the tree.

Fruitage.—After a number of years, when the decay had extended far up in the tree and a large quantity of the spawn or mycelium strands had formed, reaching a large feeding area, there was a sufficient amount of food within reach to form the bracket fruit bodies which can only be formed in the open air. This same wound then provided a place of exit for the fruiting stage. The spores formed over the honey-combed area are scattered by the wind, and are ready to infect other trees when an opportunity comes.

Hydnum septentrionale. Plate 58

Character and distribution.—In Plate 58 is illustrated another fungus growing on a living sugar maple tree. This is also one of the bracket or shelving fungi. Its natural size is about eight times larger than appears in the picture. While it is one of the bracket fungi it differs from the *Polyporus* in that the fruiting under surface is not in the form of a honey-comb, but is covered with spinous, or awl-shaped processes. This fungus grows in the heart wood also, and the interior portion of the tree was so badly decayed that the fungus was enabled to push its way out through a long crack which occurred through the living area. This tree was one of a grove of trees in Elysium Park, Cortland, N. Y., and was so weakened by the action of the fungus that it was blown down during a severe southeastern gale which swept over this area during the autumn of 1897. This fungus also occurs in other parts of the United States, and is widely distributed in Europe, where it also occurs on the maple.

Fomes fomentarius. Plate 59

Character and distribution.—During the same gale a large number of trees weakened by the attacks of the wood destroying fungi were blown down in this region. Plate 59 represents a beech tree weakened by wood destroying fungi near McLean, N. Y., which was broken over at this time. Upon the trunk can be seen several of the brackets of one of the species, the *Fomes fomentarius*. Its fruiting under surface is honey-combed, but it is very different in habit, texture, form, and color from the *Polyporus borealis*. The brackets are scattered and usually occur singly, so that several do not overlap. The plant is shaped more or less like the hoof of a horse, small where it is attached to the tree, and then enlarged outward and downward. The under surface is more or less concave, with the thick margin projecting somewhat like the edge of a horse's hoof. Furthermore, the surface is marked by a number of concentric ridges, and furrows, marking off the age of the bracket in years. The plant is perennial, and each year a new layer is added on below, which is broader than the layer of the previous year. The outer surface is light brown or grayish in color and thus harmonizes with the color of the beech bark, while the under surface is rich brown in color. The plant is quite hard and woody, especially the outer portion, while the inner portion is more spongy and fibrous and dark brown in color. The inner fibrous portion in years gone by was used as a tinder in some parts of Europe.

The plant is widely distributed on both Continents, and occurs also on the birch, maple, and other deciduous trees.

Trametes pini Plate 60

Character and distribution.—Another wood destroying fungus shaped something like a horse's hoof, but much more irregular, is the *Trametes pini* shown in plate 60. This photograph is taken from a specimen on a pine log collected by Professor Harris near Mansfield, Louisiana, during the winter of 1898–99. The fruiting surface here is also honey-combed, but there are other characters which place it in the genus *Trametes*, instead of in *Polyporus* or *Fomes*. This plant is also perennial and each consecutive ring represents a yearly layer added by growth, the lowermost layer being that of the last year's growth. This fungus occurs on pines in Europe, and also in the southern and southwestern United States. In Europe it is known to produce a characteristic and serious disease of the timber pines.

Dædalea ambigua Plates 61 and 62

Characters.—Another very interesting fungus is that shown in Plates 61 and 62. It is the *Dædalea ambigua*, also sometimes called the *Trametes ambigua*. The honey-combed fruiting surface here is very irregular, sometimes the tubes or pores are cylindrical with rounded mouths, and again they represent elongated or sinuous passages, the round ones illustrating *Trametes* while the elongated or sinuous ones illustrate *Dædalea*. Since the plant in this character varies from one to the other, it is rather "ambiguous" as to which genus it appertains, and so it was named *Dædalea ambigua*. This plant was also collected by Professor Harris in Louisiana.

It is whitish in color, of a very beautiful appearance, grows on several different deciduous trees, and forms a true single shelf. An individual illustrated in Plate 61, is an abnormal form and shows to us one very interesting peculiarity of all these plants. The figure to the left represents the position in which the fungus grew when the tree to which it was attached was standing. At this time the broad single shelf was formed so that the shelf was horizontal, or parallel with the surface of the earth. This is a peculiarity of all the bracket fungi, and of the mushrooms as well. The fruiting surface being the under surface generally, the plane of the cap or pileus is parallel with the surface of the earth, so that the spores of the fungus can fall easily out of the tubes, or from between the awl-shaped processes, or from between the gills or lamellæ, as the case may be.

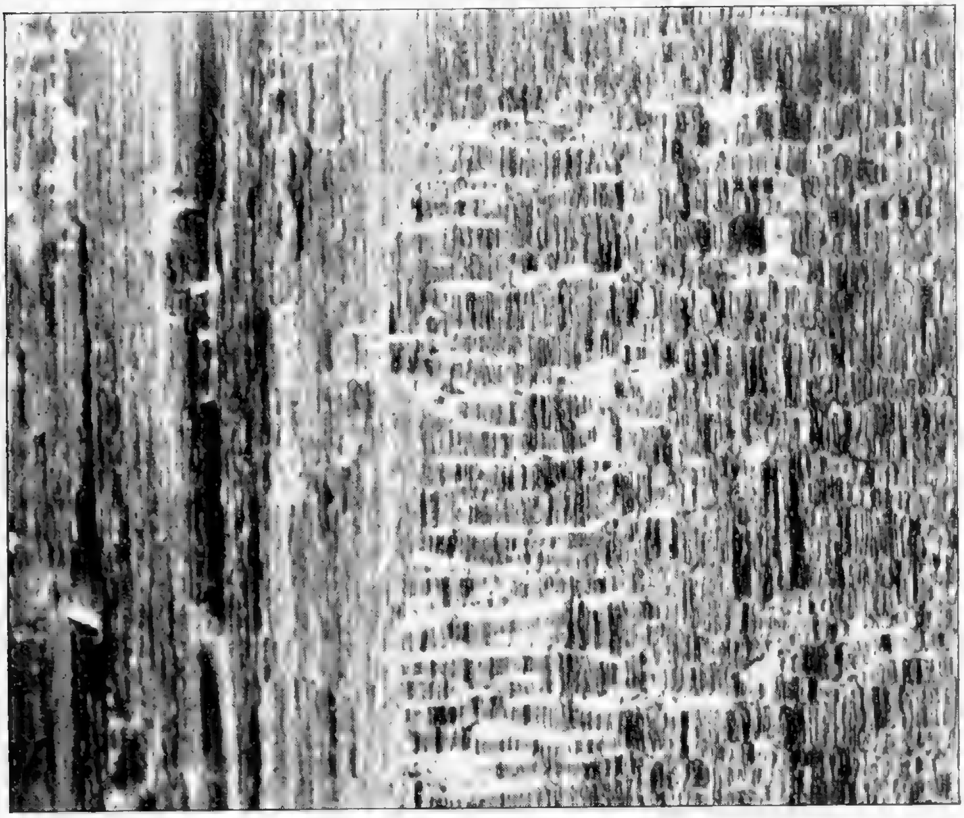
Accidents in growth.—Now, if by any chance the bracket, or cap, becomes turned in another direction before the fungus has completed its growth, it will either change back, as in the case of the mushrooms, or new growths will start out from the edge of the bracket in the tough or woody forms. Now, if we examine Plate 62 of this *Dædalea*, we shall see the position of the plant after the tree fell. Since the entire edge of the large bracket was still in a growing condition there are established a large number of growing points, each of which develops a new bracket parallel with the surface of the earth, forming a series of steps up one side and down the other.

IMPORTANCE OF A STUDY OF THESE FUNGI

From a few of the observations here presented it will be seen how some of these fungi work serious injuries to forest and timber interests. The trees which are attacked may live on for years or even for a century or more, but each year the injury to the timber in the tree is greater, until within a few years it is worthless. A careful study of the conditions of attack by these enemies of the forest, as well as of their life histories, and the characteristic injuries to the trees would do much to teach us how to prevent such injuries and loss in the forest. The wonderful variety of form and kind among these plants make them objects of great importance to those who are interested in nature. There is here a great field for new observations on the part of those whose professional work leads them to the forest. When such persons become interested enough in these questions to prepare themselves for making accurate observations, by some training in the study of fungi, they can do great good in bringing to light a fuller knowledge of the habits and distribution of these plants, and careful study by trained observers must precede any successful attempts toward a rational treatment designed to lessen the losses now sustained from these sources.

POLYPORUS BOREALIS

(Growing on hemlock.)



HEARTWOOD SHOWING MYCELIUM

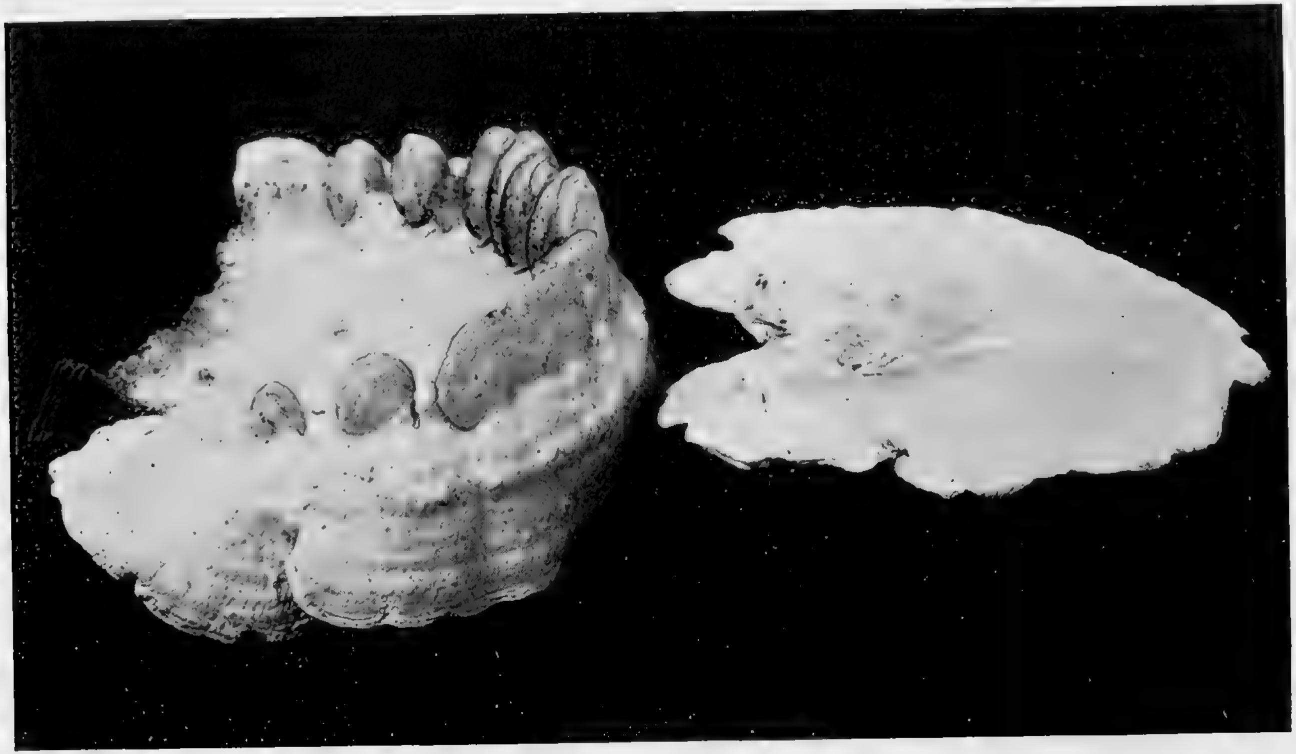
HYDNUM SEPTENTRIONALE

(Growing on sugar maple.)

FOMES FOMENTARIUS

(On beech.)

TRAMETES PINI



DÆDALEA AMBIGUA

DÆDALEA AMBIGUA

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