DEPARTMENT OF THE INTERIOR

BULLETIN

OF THE

UNITED STATES

GEOLOGICAL SURVEY

No. 151

WASHINGTON
GOVERNMENT PRINTING OFFICE
1898

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

THE LOWER CRETACEOUS GRYPHÆAS OF THE TEXAS REGION

BY

ROBERT THOMAS HILL

AND

THOMAS WAYLAND VAUGHAN

WASHINGTON

GOVERNMENT PRINTING OFFICE

1898

THE LOWER CRETACEOUS GRYPHÆAS OF THE TEXAS REGION.

BY

ROBERT THOMAS HILL and THOMAS WAYLAND VAUGHAN.

CONTENTS.

ILLUSTRATIONS.

LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C., January 13, 1897.

SIR: I transmit herewith, for publication, a paper entitled The Lower Cretaceous Gryphæas of the Texas Region, which has been prepared jointly by Mr. Thomas Wayland Vaughan, assistant geologist, and myself.

Very respectfully,

ROBT. T. HILL,
Geologist.

TO THE DIRECTOR,
United States Geological Survey.

THE LOWER CRETACEOUS GRYPHÆAS OF THE TEXAS REGION.

By Robert T. Hill and T. Wayland Vaughan.

INTRODUCTION.

The present paper treats of the specific classification, stratigraphic occurrence, and relationships of one particular group of the many kinds of fossil oysters occurring in the Lower Cretaceous formations of Texas. This group includes those forms which have generally been referred to *Gryphæa pitcheri* of Morton. Owing to the plentiful occurrence of the shells of these oysters in the formations mentioned, this group is of great importance from many standpoints, and a thorough knowledge of the forms composing it has the utmost economic value because of the assistance which they render in determining the stratigraphic position of various beds in the geologic sections. In two instances within the last year, by the aid of these fossils, brought up from great depths in diamond-drill cores, cities in Texas upon the point of abandoning the attempt to procure artesian water have been warranted in drilling a few feet farther, where the desired artesian flow was procured. Unfortunately, however, this group of fossils has not been properly understood or classified, owing to the inadequate manner in which they were originally described and published. These descriptions were often based upon single specimens or incomplete collections made in the hasty reconnoissances of early frontier expeditions and were unaccompanied by stratigraphic data. The species from the Texas region have usually been based upon one or two poor specimens, accidentally picked up without record of stratigraphic occurrence, and described by a paleontologist unacquainted with the stratigraphic relations of the rocks in which they were found. Other species have been made from variations of some previously described form. The forms have also become involved in a confusion of nomenclature and controversy, so that the student can not obtain from the literature a proper conception of their occurrence, distribution, and classification.

A controversy between Prof. Jules Marcou on the one hand and nearly all the eminent American paleontologists of the day on the other early arose concerning the species *Gryphœa pitcheri* and the formations in which it was found. Upon the finding at Tucumcari Mesa, New Mexico, of two fossil oysters which he termed *Gryphœa dilatata* var. *tucumcarii* and *Ostrea marshii* (Marcou, not Sowerby), Professor Marcou announced the existence there of rocks of the Jurassic age. He likewise asserted the existence of Lower Cretaceous strata at Comet Creek, on the head waters of the False Washita, a locality in what is now known as Oklahoma, basing this conclusion upon the existence of a single species of fossil oyster in strata of lumachelle limestone aggregating only a few feet in thickness.

Professor Marcou in his many papers has variously described these beds and their thickness, and has successively referred this species as follows: "*Exogyra ponderosa* Roemer" (provisionally), "*Ostrea aquili* or *couloni* (?)," "*Exogyra pitcheri*," "*Gryphœa pitcheri*," "*Gryphœa pitcheri* var. *navia*, Hall and Conrad," "*Gryphœa roemeri*," "*Gryphœa pitcheri*, and *Gryphœa roemeri* again. Inasmuch as much controversy has taken place concerning the thickness of the beds and the nomenclature of the fossil, we append the following extracts from his writings, giving the facts in full:

1855.—This limestone is only 5 feet thick; it is of a whitish gray color, containing an immense quantity of Ostracea, which I consider (provisionally) as the *Exogyra ponderosa* Roemer; having the closest analogy with the Exogyra of the Neocomien of the environs of Neufchâtel. [United States Pacific Railroad Explorations, 1853–54, Vol. IV, p. 43, H. Doc. 129. Washington, 1855.]

1858.—This limestone is only 5 feet thick; it is of a whitish gray color, containing an immense quantity of Ostracea, which I consider as identical with the *Exogyra* (*Gryphœa*) *pitcheri* Mort., having the closest analogy with the *Exogyra couloni* of the Neocomian of the environs of Neuchâtel (Switzerland). [Geology of North America, Zurich, 1858, p. 17. This passage purports to be a verbatim copy of the above paragraph and is from the chapter entitled "Extract from report of explorations for a railway route, near the thirty-fifth parallel of latitude, from the Mississippi River to the Pacific Ocean," etc., Washington, 1855, H. R. Doc. 129.]

1858.—In the literal copy and translation of Prof. Jules Marcou's field notes by W. P. Blake, page 131, Volume III, of the Pacific Railway reports, quarto edition of 1856, the Comet Creek locality, near camp 31, is described as composed of "three or four broken beds with crinoids disseminated here and there as if the ruins were formed of a lumachelle limestone of Neocomien age. This lumachelle is formed by the fragments of *Ostrea aquila* or *couloni* or a variety, for it is smaller. . . . . the four beds of lumachelle are 2 feet thick." Concerning these notes, however, Mr. Marcou later said: "I here declare that I know nothing of the publication of the edition in quarto of these reports, and that I decline all responsibility as to the use that may have been or may hereafter be made by others of my official notebooks," etc. (Geology of North America, etc., Zurich, 1858, p. 1.)

1858.—On page 27 of the Geology of North America, Mr. Marcou says, in discussing his Neocomian in America, of which this is the only locality recorded as seen by him, that "its thickness varies from 6 to 50 feet."

1862.—I have never seen Morton's original specimen. • • • I am led to believe that I did not meet with the true *G. pitcheri* of Morton in my explorations with Captain Whipple's party. Mr. Ferdinand Roemer having the opportunity of seeing in the company of the late Dr. Morton himself the original specimen at Philadelphia, I naturally followed his identification of *G. pitcheri;* and if Roemer has made a mistake I was misled by his description. • • • Thus we shall have three species of Gryphæa: 1, the *G. tucumcarii* of the Jurassic rocks of Pyramid Mount (New Mexico); 2, the false *G. pitcheri*, of Roemer and Marcou, or the false *G. pitcheri* var. *navia* of Conrad and Hall, of the Cretaceous rocks of the false Washita River (Texas), which may be called *G. roemeri* in honor of its first discoverer, Mr. F. Roemer; and 3, the true *G. pitcheri*, Morton, which I have never seen, and consequently on which I can not give any information as to its stratigraphical position and association with other fossils. [Proc. Boston Soc. Nat. Hist., Vol. VIII, p. 95, 1862.]

1889.—As to the *Gryphœa pitcheri* which Mr. Hall calls *var. navia*, it is the true *G. pitcheri* of Morton and Roemer, found by me at Comet Creek, near the false Washita River. [American Geologist, September, 1889, p. 163.]

1896.—The first strata of this Cretaceous system contain at Comet Creek, Fort Washita, etc., an immense number of *Gryphœa Roemeri* Marcou (formerly called *G. Pitcheri* by Roemer and Marcou). The *Gryphœa* are so numerous as to recall the "Limestone of the *Gryphœa arcuata* Lias of England, France, and Germany." These first beds, which may be called "Caprina and Gryphæa Roemeri limestone," are the bottom beds of the American Neocomian or Lower Cretaceous. [The Jura of Texas, by Jules Marcou, Proc. Boston Soc. Nat. Hist., vol. 27, p. 157, Boston, October, 1896.)

Prof. James Hall and Dr. B. F. Shumard, supported by Prof. James D. Dana, were the chief opponents of Professor Marcou's views. They correctly alleged that the species variously termed by him *G. tucumcari*, *G. dilatata*, etc., were identical with Morton's *G. pitcheri*, and correlated the Tucumcari beds with the Cretaceous instead of the Jurassic, to which age Professor Marcou referred them. This controversy,[1] carried on without knowledge of the stratigraphy, and primarily based upon the identity or nonidentity of Marcou's *G. tucumcari* with *G. pitcheri*, established the custom of referring nearly all the known gryphæas of the Southwest to the little-understood *G. pitcheri* of Morton. A cloud was also cast upon the value of the descriptions and figures of Cretaceous fossils which had been sent to Professor Marcou from Fort Washita, Indian Territory, and Texas by Captain Pope and Dr. G. G. Shumard, and described and figured by him in his Geology of North America. With the exception of Roemer's, those were the best illustrated figures of fossils from the Texas region, but unfortunately their exact stratigraphic position was unknown at that time. His now well-known species *Exogyra sinuata* var. *americana*, for instance, was strongly asserted to be iden-

[1] The substance of this controversy may be found in J. D. Dana's "Review of Marcou's Geology of North America," in the American Journal of Science, November, 1858, pp. 323-333; and in the same journal for January, 1859, pp. 137-141.

tical with *Exogyra ponderosa* Roemer,[1] and whatever of worth there may have been in his work was largely overlooked in the criticism of its errors, and confused by his own subsequent controversial discussions.

Of all who participated in the discussion, Professor Marcou and Dr. B. F. Shumard were the only ones who had seen or collected the fossils in situ; and neither of these had seen or understood the stratigraphic relations of the Cretaceous section in its entirety as it is now known. Dr. Shumard seems to have overlooked any varietal differences in the gryphæas. Professor Marcou later admitted[2] that the form which he called *G. pitcheri* might not be that species at all, and insisted that his *G. dilatata* var. *tucumcarii* was different from it. The others insisted that the form *G. dilatata* var. *tucumcari*, which Professor Marcou stoutly maintained was distinct, was the true *G. pitcheri*.

Professor Marcou, unfortunately, has never seen the Cretaceous formation in Texas or the main area of its occurrence in Indian Territory as at present constituted, his itinerary having taken him entirely to the north of the Ouachita range,[3] which separates the fragmentary, disconnected, and attenuated outlying areas of Kansas and Oklahoma from the true Texas region and its extension into the Chickasaw and Choctaw Nations. The "2," "4," or "5" feet of the Lower Cretaceous limestone which he saw at Comet Creek, Oklahoma, and the few feet of Cretaceous near Tucumcari, New Mexico, represent merely a horizon in a single one of the three divisions of the series. (See Pl. XXXIV.) His entire observation of the beds of both localities was not of a half day's duration.

Dr. Shumard's erroneous section[4] of the Texas Cretaceous completely obscured for the time being the sequence of the Cretaceous formations. Professor Marcou protested[5] upon theoretical grounds against the correctness of this section, but his objections carried little weight owing to the bitterness of the controversy in which he had become involved.

These misconceptions concerning the Cretaceous formations arose in the earlier days of American geology, before the Arkansas-Texas region had been explored. It was the general opinion at that time that there were no marine strata in the United States comparable to

[1] Am. Jour. Sci., 2d series, Vol. XXVI, 1858, p. 331.

[2] See extract from his writings, paragraph on p. 15 of this paper.

[3] At several times Professor Marcou in his writings has conveyed the impression that he had seen the Cretaceous at Fort Washita, Indian Territory, and in Texas. (See American Geologist, Aug., 1894, p. 100.) The various journals, itineraries, and maps of the Pacific Railway expedition, as published by himself and others, giving a minute record of the progress of the party day by day, show that it nowhere encountered these localities or any other south of the Ouachita Mountains. The fossils described by him in his Geology of North America and elsewhere, from Fort Washita, were collected and sent to him by Dr. G. G. Shumard, and those from the Cross Timbers of Texas by Captain Pope, of the Thirty-second Parallel Survey.

[4] Trans. Acad. Sci. St. Louis, Vol. I, 1860, p. 583.

[5] Boston Soc. Nat. Hist., Vol. VIII, 1862, p. 93.

the Lower Cretaceous strata of Europe, and that the Cretaceous formations of our country were conspicuously devoid of chalky deposits, and hence were exceptional by the absence of what is their most characteristic litho-paleontologic feature in other parts of the world and the one from which the name of the group is derived. These opinions were the logical result of what was then known of the American Cretaceous formations. Knowledge of this group was at first mostly confined to the strata of New Jersey, which, although devoid of any chalky material, are, as shown by their fossils, homotaxially equivalent to the Upper Chalks of Europe. The New Jersey deposits were also supposed to represent, stratigraphically and faunally, all of the American Cretaceous section, when in fact, as we now know, they are only the uppermost beds of the upper division of the American Cretaceous, and in no manner indicate the great development of the lower beds of the Southwestern States.

The Arkansas-Texas section shows the presence in America, as well as in Europe, of a most perfect sequence of Cretaceous deposits, from the Wealden (Trinity) beds to the equivalents of the Senonian, which embraces all Cretaceous time.

In the year 1886 it was shown[1] that current misconceptions of the Texas Cretaceous and its fossil species were largely due to the fact that underlying the hitherto supposed base of the beds of that period there was another lower and entirely distinct series of rocks, to which the name Comanche series was soon given, and that its fossils, collected at various times, had all been erroneously confused with the overlying Meek and Hayden section, which hitherto had been supposed to embrace the entire range of the North American Cretaceous. As a natural result of these misconceptions the stratigraphic occurrence of the Cretaceous Ostreidæ in general, although they are the best preserved and the most abundant of our fossils, was but little understood and has not been properly presented.

One of the first results of the separation of the Comanche series from the Upper Cretaceous was the discovery of the fact that the numerous forms of fossil Ostreidæ, then known by the name of *Gryphæa pitcheri*, *G. dilatata* var. *tucumcarii*, etc., were characteristic of and restricted in occurrence to this Lower Cretaceous series.

Mr. Stanton's[2] recent studies of Newberry and Schiel's *Gryphæa pitcheri* from the Upper Cretaceous of New Mexico and Utah show it to be a distinct species (*G. newberryi* Stanton) and removes the last vestige of *G. pitcheri* from the Upper Cretaceous.

The writers have visited every one of the historic type localities from which these forms were originally described and have studied

[1] The paper, with printed sections, was presented before the Philosophical Society of Washington in December, 1886, and published in the Am. Jour. Sci., 3d series, Vol. XXXIII, 1887, pp. 298-299.

[2] Bull. U. S. Geol. Survey No. 106, 1893, pp. 60-62.

minutely their stratigraphic occurrence, range, and association. Collections have been made, not of a few adults only, such as have usually been figured, but of specimens in every stage of growth and variation.

In the paper and section previously mentioned three distinct horizons of the several forms of so-called *Gryphæa pitcheri* were pointed out, one below the Comanche Peak fauna, associated with *Exogyra texana*, another at the base of the Washita division, above the "Hippurites" or Caprina (Edwards[1]) limestone, consisting of Dr. C. A. White's *E. forniculata* (*G. navia*, Hall); and another in the Washita division associated with *Ostrea carinata*. Still later it was discovered that another variety, Roemer's *G. pitcheri*, occurred only at the top of the Del Rio (*Exogyra arietina*) clays in a very persistent zone.

As studies of the Comanche series progressed, another important fact became apparent. The forms called *Gryphæa pitcheri* by Morton, Roemer, Marcou, and others each came from a different stratigraphic position in the Comanche series, and might or might not be distinct species, or varieties of the same species, which upon close study of abundant material could be defined so as to be of stratigraphic value.

At this time (1886) opinions of what constituted *G. pitcheri* Morton were formed largely from the accepted literature, and it was believed, with Roemer, White, and others, that the former's figures represented the type of the true *G. pitcheri*. As now shown in this work, this was an erroneous opinion, which has caused much trouble. Studies of the uppermost Comanche beds in the littoral regions of Denison, Texas; Tucumcari, New Mexico; and southern Kansas, which have since been published, had not been completed at that date. Later the senior author made special trips to Tucumcari mesa, where only a small portion of the entire Comanche series is revealed, in order to ascertain the facts as to Professor Marcou's locality. *Gryphæa tucumcarii* was found in abundance, and he was strongly impressed with the fact that this was a distinct species; but upon this trip its accompanying fauna of Washita fossils was not discovered, and he supposed that Marcou had ground for assigning these beds to the Jurassic, and for a short time was inclined to support Marcou's position.[2] Later, in 1889, he made a detailed study of the peculiar Denison (Texas) section,[3] which, as has been recently shown, has marked variation from the Comanche series in central Texas, and saw in them paleontologic evidence which led to the belief that the Tucumcari beds were equivalent in part thereto. On a second visit to Tucumcari an abundant fauna was found accompanying *G. tucum-*

[1] Geographic designations will hereafter be used for the various terranes of the Cretaceous group in Texas, instead of paleontologic denominations, in accordance with a system adopted by the Survey.

[2] Rept. Geol. Survey Arkansas for 1888, Vol. II, 1888, pp. 172-173.

[3] See Bull. Geol. Soc. America, Vol. V, 1894, pp. 297-338.

carii identical in species with those of the Denison beds of the top of the Comanche series, thereby fixing the stratigraphic position of Marcou's Tucumcari species.[1]

This extensive collection from Tucumcari, and those made by Hyatt, and later by the collectors of the Texas survey, all show that the variety *tucumcarii* of Marcou occurs in association with a characteristic and unmistakable fauna[2] of the Washita division (the uppermost division of the Comanche series), the same to which belongs his (Marcou's) *G. pitcheri* beds of Comet Creek,[3] Oklahoma, which he called Cretaceous. Furthermore, *G. corrugata* Say, of which Marcou's *G. tucumcarii* is but a variety, was later found in abundance in the Red River region of Texas and Indian Territory, southern Kansas, and Oklahoma, in association with an undoubted Washita fauna, including the species *Ammonites shumardi*, Marcou, described by him as a Cretaceous species, and which Professor Hyatt found in the Tucumcari beds. The exact horizon of this ammonite in Texas is at the top of the Kiamitia beds, which are principally composed of Marcou's Comet Creek Cretaceous *G. pitcheri* (*G. navia*, Hall), and are far above the base of the other fossiliferous beds of the Comanche Cretaceous.

Furthermore, while the two species of Gryphæa described by Professor Marcou from Comet Creek, Oklahoma, and Tucumcari, New Mexico, respectively (the former as Cretaceous and the latter as Jurassic), are both now known to occur in the Washita division of the Lower Cretaceous series, there is much stratigraphic evidence indicating that the alleged "Jurassic" form occupies a horizon slightly higher than that of the other species, which he called Cretaceous, although two forms are sometimes associated together.[4] The latter, in the main area of the Cretaceous where the section is complete, has a unique and persistent hemera in the Kiamitia beds at the base of the Washita division. The varieties of *G. corrugata* Say, called by Marcou *G. tucumcarii*, etc., found in the Tucumcari beds of New Mexico and in the outlying areas of the Comanche series in Oklahoma and southern Kansas, are associated with a molluscan fauna which belongs higher up in the Washita division.[5]

Reviewing the criticisms of Professor Marcou's work and species in the light of years of later observation, it is but justice to say that mistakes were made by both sides engaging in the discussion. Professor Marcou's assignment of the Tucumcari beds to the Jurassic was erroneous, and his antagonists' assignments of them to the Cre-

[1] Science, July 17, 1893. Also Am. Jour. Sci., 3d series, Vol. L, 1895, pp. 229-233.

[2] See outlying areas of the Comanche series: Am. Jour. Sci., 3d series, Vol. L, 1895, pp. 229-233.

[3] In November, 1896, Mr. Vaughan visited the region west of Arapaho, "G" County, Oklahoma, and endeavored to locate Professor Marcou's Comet Creek locality. The name Comet Creek is unknown to the present inhabitants, but beds were found which clearly conform to Professor Marcou's description. See Am. Jour. Sci., July, 1897, pp. 43-50.

[4] See Am. Jour. Sci., Sept., 1895, pp. 205-234, and July, 1897, p. 50.

[5] See Am. Jour. Sci., Sept., 1895, pp. 205-234.

taceous were correct, but erroneous in referring to the Upper or Meek and Hayden section of the Cretaceous. They are now known to be Lower Cretaceous, lying just midway between the horizons fixed by the parties to the controversy.

Professor Marcou's opponents correlated all of what is at present known as the Lower Cretaceous (Comanche series) with the Upper Cretaceous, and mixed the fossils from widely separated formations, now known never to occur together, such as *Gryphæa pitcheri* (of the Washita division) with *Ammonites texanus* (of the Niobrara), and *Inoceramus problematicus* (of the Benton) with *Holectypus planatus* (of the Fort Worth).[1] These were mistakes similar to those which Professor Marcou was supposed to have made.

The age of the Tucumcari beds has been determined to be Cretaceous in the light of more careful investigations made since Professor Marcou's hasty visit, upon the following evidence:

1. Professor Marcou, whose expedition permitted only a hasty examination, found but two species in the Tucumcari beds, and both of these were fossil oysters. More detailed recent investigations have shown, in addition to these, a large molluscan fauna of many species having greater value for correlation purposes.

2. The position of this fauna, from a fragmentary outlier of the Cretaceous, when compared with the complete section of the main body of the Cretaceous in Texas, has been shown to be that of the uppermost beds of the Lower Cretaceous of the Texas region. It has also been shown that, while Professor Marcou's Tucumcari fossils belong to the same stratigraphic division of the Cretaceous as do those of his Comet Creek beds, which he himself has termed Cretaceous, they come from a slightly higher horizon.

3. The Tucumcari fauna has been studied minutely by those paleontologists who are most familiar with the American Cretaceous formations and has been pronounced by them to be undoubtedly Cretaceous.

4. The Tucumcari beds contain fossils which Professor Marcou himself has described as Cretaceous species in other localities.

5. The Tucumcari fauna has been carefully collected and studied by Prof. Alpheus Hyatt, who is the chief American student of Jurassic invertebrate paleontology, and compared by him with known Jurassic species of other localities in this country and in Europe, and his verdict, as given in the following extract from one of his unpublished manuscripts in our possession on the age of the Tucumcari beds, is that he does not find a single Jurassic species in it:

> The following notes on the species found in the Tucumcari series of San Miguel County, N. Mex., are very imperfect. They are for the most part comparisons between the fossils found at Tucumcari and elsewhere with European Upper

[1] See observations on the Cretaceous strata of the United States with reference to the relative position of fossils collected by the Boundary Commission, by James Hall: Am. Jour. Sci., 3d series, Vol. XXIV, 1857, pp. 72–86.

Jurassic forms. My comparisons did not extend into the Cretaceous except in the case of the Trigonia, Ostrea, and Ammonites, which did not appear to have any close affinities in the Jura. If the work had not been interrupted by Congressional action in 1892, the comparisons would have been extended into the Cretaceous and also to those said to be the same by American authors. As the matter now stands, I have no opinion with regard to the age of these rocks further than what is expressed in this negative fact and in the positive results attained by the examinations of *Schloenbachia shumardi* and *Gryphæa tucumcarii*, both of which have the characteristics of Cretacic types.

It will be seen that I did not succeed in finding identical species in the European Jura. When the ostreas were being studied I found great confusion, and not having ample American materials, I determined to revise the whole group, and have added in Appendix A descriptions of the principal European and American species of the Jura and *vesicularis* of the Cretaceous. The object in point in this research was the finding of some characteristic which could be used to distinguish Cretacic from Jurassic species. This finally appeared in the peculiar crenulations on either side of the hinge line. These crenulations made by the border of the mantle have not yet been found, so far as I know, in any Jurassic species. The collections of this group are large in the Museum of Comparative Zoology, and both these and approximately all published figures by different authors were carefully examined. *Gryphæa tucumcarii* has these crenulations in common with all other American and European Cretacic species.

Having been requested to make an examination of the species of Ammonitidæ found at Tucumcari and compare it with *Ammonites shumardi* Marcou, I did this work carefully, and arrived at the conclusion that the two were identical. The young of *shumardi* have bifurcated costæ with huge tubercles on the umbilical shoulders and another row of smaller ones on the geniculæ. In well-preserved fossils an inner line of tubercles begins to make its appearance in some specimens, and these may possibly be distinct from some others in which they appear later in the life of the shell. The bifurcated costæ alternate with single costæ that do not usually reach internally to the umbilical shoulders, and these single costæ have only the outer row or rows of tubercles. The alternation of the costæ may be regular or irregular, but is evidently characteristic, being found in all well-preserved specimens from New Mexico and Texas that I have seen, and also appearing in Professor Marcou's figures of this species in his Geology of North America. In the next stage, the adult, which is reached in Marcou's specimen, according to his figure, only on the last quarter of the outer volution, the bifurcated costæ separate gradually into single costations. This separation, which makes an additional number of single costæ at this stage of growth, becomes quite perfect in some large specimens.

The keel is well preserved on casts, but is narrow, very prominent, and smooth, the outline of the exterior being entire and not crenulated or influenced in any way by the costæ. These last pass well up on the venter, and are very tumid and broad, and are either straight or very slightly bent, but invariably disappear at the base of the keel.

The old whorl of *shumardi* is not unlike *Ammonites leonensis* of Conrad;[1] and might be mistaken for it if a fragment of the cast of a senile volution were found which was not very well preserved and had lost the second row of tubercles, but in well-preserved specimens they are apparently easily separated. There are no species in the Jura, so far as I know, that approximate to *Ammonites shumardi*. It belongs to the well-characterized Cretacic division of the genus Schloenbachia, usually called the Inflatus group.

[1] Description of Cretaceous and Tertiary fossils: U. S. and Mex. Boundary Survey, Vol. I, Part II, p. 160, Pl. XVI, fig. 2*a*.

The misunderstandings that have surrounded the species have been augmented by misfortunes in the preservation of the original type specimens upon which it was founded. The types of Say's description are lost, although they may yet be rediscovered in the Philadelphia collections. That of Morton's was originally deposited in the collections of the Academy of Natural Science at Philadelphia, but was misplaced or lost, so that until the present day it has been inaccessible to all, with two exceptions, of those who have contributed to the literature concerning it. At the date of this publication it is in the collections of the University of Texas, Austin, Texas.

The first confusion arising from the inadequate preservation of this type specimen is seen in the writings of Dr. Ferdinand Roemer. In the year 1847 he visited Philadelphia to see the types of Morton's original species, in order to compare them with some forms he himself had found near New Braunfels and other points in Texas. Concerning these types he wrote:[1]

> I would never have recognized from Morton's insufficient figure, which represents a small form or a young specimen, that the large canoe-shaped, arched specimens from Texas belong to this species, if I had not seen in the Museum of the "Academy of Natural Sciences" in Philadelphia specimens determined by Morton himself which agree completely with those from Texas. Morton furthermore remarks[2] in the description of the species that he possessed specimens almost 3 inches in length.

Thus, by the erroneous impression given to Dr. Roemer, through the careless preservation of original type specimens, the first confusion of Morton's *G. pitcheri* with the other species of Gryphæa was started and the nucleus was created for an almost endless misrepresentation and confusion of forms, which has so permeated all the literature of the country that the task of correcting it has at times seemed almost impossible. Mr. W. M. Gabb, who was at one time curator of the Philadelphia collections, later clearly showed the lamentable confusion of these types and how in later years the original was rescued from oblivion. Concerning them he said:[3]

> One of the principal reasons for this is the fact that Dr. Morton described the species from a very small specimen and gave in his "Synopsis" but a single figure, which was not over characteristic. Dr. Roemer, after studying the fossils of Texas, visited the museum of the Philadelphia Academy to study Morton's types, but did not succeed in finding the original specimen of this species, it having been carelessly thrown aside in a drawer full of duplicates and worthless fragments, from which I had the good fortune to disinter it in 1860 or 1861, after years of concealment. Failing to obtain more reliable information than that furnished by Morton's short description and only passable figure, Dr. Roemer applied the name to a form very common in Texas, but which, as will be seen below, I believe to be distinct from the true *pitcheri*.

---

[1] Kreidebildungen von Texas, pp. 73–74; also noted in "Texas, mit besonderer Rücksicht," etc., p. 395, Bonn, 1849.

[2] Op. cit., p. 85.

[3] Palæontology of California, Vol. II, p. 272.

Professor Marcou has also noted that he has never seen the types of Morton's species,[1] and that his determination was based upon Dr. Roemer's figures.

In 1887 the senior author visited the Philadelphia Academy upon the same mission, and was shown a few specimens in a tray, including the form described by Dr. Roemer, mixed with others, but found nothing resembling Morton's figure, and departed with the same impression previously made on Roemer. Professor Heilprin, the curator, was absent during this visit, but a few days later a letter was received from his assistant stating that Morton's types had not been seen.

On the 21st day of July, 1894, the senior author once more visited the Philadelphia collections in order to see Morton's type of *G. pitcheri*, but was informed that it had been loaned to persons in Texas. More than a year later it was ascertained that Prof. F. W. Simonds, of the University of Texas, had been permitted to make some plaster casts thereof. Through his kindness we procured one of these casts, showing in exquisite perfection every detail of the original specimen, and thus for the first time an opportunity was obtained to form a correct conclusion as to its nature, and to present from these casts good and intelligible figures of the original *G. pitcheri* Morton. These figures are given in Plate VI, figs. 5 and 6, of this paper.

THE FOSSIL OYSTERS OF THE TEXAS REGION.

While this paper is devoted to the particular group of forms which have been referred to *Gryphæa pitcheri* Morton, it is necessary, before proceeding further, to make a few general remarks upon the fossil Ostreidæ of the Texas region.

The quantity and perfect preservation of the shells of fossil oysters in the Cretaceous formations of Texas excite the interest and curiosity of all who have visited that region. In places these shells weather out of the chalk or marly clay, representing the ancient sea sediments in which they were originally embedded, and lie strewn upon the surface in such great numbers that they are sometimes used for road material or collected and burned into lime. At other places extensive masses of indurated strata, the outcrop of which can be traced for many miles, are composed entirely of them. The pebble of every stream bed is made up largely of them, and they are even found as redeposits in later formations.

Catlin, the painter of Indian portraits, thus describes "a ridge of fossil shells" near old Fort Washita, Indian Territory, which is composed of one of the species commonly called *Gryphæa pitcheri*:

> One of the most curious places we met in all our route was a mountain ridge of fossil shells, from which a great number of the above-mentioned specimens were taken. During our second day's march from the mouth of the False Washita

[1] Proc. Boston Soc. Nat. His., Vol. VIII, 1852, p. 95.

we were astonished to find ourselves traveling over a bed of clam and oyster shells, which were all in a complete state of petrification. This ridge, which seemed to run from the northeast to southwest, was several hundred [?] feet high, and, varying from a quarter to half a mile in breadth, seemed to be composed of nothing but a concretion of shells, which, on the surface exposed to the weather for the depth of 8 or 10 inches, were entirely separated from the cementing material which had held them together, and were lying on the surface, sometimes for acres together, without a particle of soil or grass upon them, with the color, shapes, and appearance exactly of the natural shells lying loosely together, into which our horses' feet were sinking at every step above their fetlocks. These I consider the most extraordinary petrifactions I ever beheld. In any way they could be seen, individually or in a mass together, they seemed to be nothing but the pure shells themselves, both in color and in shape. . . . . . . This remarkable ridge is in some parts covered with grass, but generally with mere scattering bunches for miles together, partially covering this compact mass of shells, forming, in my opinion, one of the greatest geological curiosities now to be seen in this country, as it lies evidently some thousands of feet above the level of the ocean and 700 or 800 miles from the nearest point on the seacoast.[1]

The fossil oysters of the Texas region belong to many genera and species, embracing a great variety of size and form, from the minute *Exogyra arietina*, less than an inch in length, to the gigantic *Exogyra ponderosa*, individual shells of which weigh 5 pounds or more. They are found at various horizons throughout the 4,000 or more feet of rocks constituting the thickness of the Cretaceous strata of central Texas.

CLASSIFICATION OF THE OSTREIDÆ.

In undertaking the study of the Ostreidæ, one is soon confronted with the question, What constitutes species and genera in this group? The variation of species is much greater in the Ostreidæ than in other molluscan genera. No other group presents such unsatisfactory criteria for specific differentiation. These forms, judging from their stratigraphic occurrence as well as their habits, seem to adopt new variations of shape with every change in physical condition of habitat, as is illustrated in the variations of our living species. Changes similar to those occurring at the present time have occurred in the past, and no doubt many species have arisen by some of these local variations becoming fixed and persistent. Large suites of specimens often show that two species usually considered very distinct may grade into each other. The intergradations are of such a kind that frequently it can easily be shown that the two species have been derived from a common ancestor; in other cases one species is evidently derived from another occurring stratigraphically below it.

In the genus Ostrea proper it is a well-known fact that certain shapes recur in widely separated geologic horizons and are apparently missing in the intervening strata. Thus some of the normal ostreas of the Trinity and other beds of the Cretaceous and of the Eocene bear so

[1] From the Catlin Indian Gallery in the United States National Museum, by Thomas Donaldson: Smithsonian Report, 1886, p. 490.

great a resemblance in shape to forms of the living *O. virginiana* that one can only with great difficulty describe their difference, yet if a full suite of each species should be collected its ensemble would have an individuality that would be unmistakable.

Nearly all of the species of fossil oysters have been founded upon adult forms, without knowledge of the life history of the individual, so ably worked out in some cases by Ryder and Jackson. It is regrettable that full suites of specimens representing all the species hitherto described have not been studied after these modern methods, and in in this paper the endeavor will be made to point out the morphologic development of the particular species chosen for discussion.

Accepted authorities have stated that variation is so great in fossil oysters as to make specific differentiation difficult, thereby rendering them of little value as stratigraphic criteria. The observations of the writers of this paper have led to quite the opposite conclusion, namely, that certain forms of the Ostreidæ possess very distinct specific characters, have definite geologic horizons, and are of the greatest value in stratigraphic work.

While some species of the genus Ostrea proper may be of little value in stratigraphic determination, species of other genera appear and disappear in relation to the sequence or beds with great certainty. For instance, in the Texas region there are no more positive or persistent criteria of exact stratigraphic position than such forms as *E. arietina*, *O. lugubris*, *O. quadriplicata*, *O. carinata*, *and O. diluviana*, while other forms, such as *E. costata* and *G. vesicularis* have their hemeræ coincident with certain divisions or groups of beds. No other fossil mollusks are so numerous or so favorably preserved for study. Some have considerable vertical range and variation, while others, like *Exogyra arietina* Roemer, appear by millions in a single definite stratigraphic horizon only. The stratigraphic occurrence of all the species, so far as known, is shown on Pl. XXXIV.

The majority of paleontologists are agreed that four broad divisions of the Ostreidæ may be recognized, to wit: Ostrea, Alectryonia, Exogyra, and Gryphæa. A considerable number of other generic or subgeneric names have been proposed, as Amphidonta, Liogryphæa, Pycnodonta, and Gryphæostrea. Bayle has gone further than any other student of these forms and has used[1] the names Actinostreon, Ceratostreon, Rhyncostreon, and Aetostreon, for specimens figured, but has never published any descriptions.

In our opinion no one of the proposed classifications is entirely satisfactory. Probably none can be proposed until the whole group, both the fossil and the recent Ostreidæ, has been the subject of thorough investigation from a phylogenetic and morphologic standpoint, according to the lines of research followed out by Hyatt in the cephalopods, Jackson in the pelecypods, Beecher and Schuchert in the brachiopods,

---

[1] Carte géologique de la France, IV, Atlas, 1878.

and Von Koch in the stony corals. It is very evident that some of the groups are in no sense natural—Alectryonia, for instance, in which are forms that have entirely different phylogenetic histories. Some forms, such as the *Ostrea quadriplicata* of Shumard and the *O. crenulimargo* of Roemer, will not adapt themselves to any of the proposed classifications.

While not proposing new generic terms of classification in the list of Texas species herewith given, the various forms may be provisionally classified into certain groups, as follows:

Genus OSTREA Linnæus, 1758.

a. Ostrea s. s. Type, *O. edulis* Linné. Represented by the ordinary recent oysters.

b. Alectryonia, 1807. Type, *O. crista-galli*, Linn. The type has both valves radiately plicate and sends out from the lower valves processes that aid in its attachment. The generic names Lopha of Bolten, Dendrostrea of Swainson, and Actinostreon of Bayle are synonyms of Alectryonia. The radiately plicate forms have the plications in some species confined to the lower valve; in others, both valves are plicate.

b. 1. The above-described types grade into the forms represented by *Alectryonia carinata* Lam., *A. larva* Goldfuss, *A. frons* Parkinson, etc., in which the plication diverges from a medium carina.

b. 2. Quadriplicate forms. Plicated forms tending toward extreme unilateral expansion, producing a lateral elongation at right angles to the antero-postero axis of the shell, contrary to the general rule, whereby most of the oysters have their greatest length parallel to this axis. Example, *Ostrea quadriplicata* Shumard.

Genus EXOGYRA Say, 1820.

a. Exogyra s. s. Type, *E. costata* Say. Obese or craniate forms, in which the valves are rounded and are excessively thick in the region near the beak, which often has a tendency to coil perpendicularly to the shell and free from it. Examples: *E. costata* Say, *E. ponderosa* Roemer, *E. læviuscula* Roemer, *E. arietina* Roemer; and probably *E. plexa* Cragin should be included in the same category.

b. Ceratostreon Bayle, 1878. Types, *E. flabellata* and *E. matheroni*. Auriculate or flattened forms, in which the upper valves have very flat or concave surfaces; usually there is a rather sharp angle or carina near the convex margin of the shell; the umbones are relatively small, compressed, flattened against the shell and attached thereto. Example, *E. texana* Roemer and its various varieties, *E. americana* Marcou.[1]

---

[1] *E. sinuata* var. *americana* Marcou.

Bayle has used two other names: Rhyncostreon, to include those forms like *E. columba* Lam.; and Aetostreon for those like *O. latissima* Lam. and *O. couloni* Defrance. No forms belonging to the Aetostreon division have been found in Texas.

Genus GRYPHÆA Lamarck, 1801.

a. Paul Fischer defines Gryphæa s. s. as follows: "Bord des valves ondulé; surface plissée plus ou moins."[1] Lamarck described the genus Gryphæa in his Histoire Naturelle des Animaux sans Vertèbres (2d ed.), Vol. VII, 1836 (original date 1801), p. 201, as follows: "Coquille libre, inéquivalve; la valve inférieure grande, courbée, concave, terminée par un crochet saillant, courbé en spirale involute; la valve supérieure petite plane et operculiforme.

"Charnière sans dents; une fossette cardinale; oblongue, arquée. Une seule impression musculaire sur chaque valve.

"Animal inconnu."

He mentions as examples on succeeding pages *G. angulata*, *G. cymbium*, *G. arcuata*, *G. secunda*, *G. lituola*, *G. latissima*, *G. plicata*, etc., thirty-four in all. There are included in the list both what we now understand by Gryphæa and by Exogyra. The first species mentioned, *G. angulata*, after an examination of specimens in the United States National Museum, appears to the authors to be a radiately plicate true oyster. Lamarck specified no species as a type. De Blainville, in his Manual de Conchyliologie, Strasbourg, 1825, page 522, appears to be the first to fix the type. His description is as follows:

Animal entièrement inconnu.

Coquille plus finement lamelleuse que celles des huîtres, libre ou peu adhérente subéquilatérale très-inequivalve; la valve inférieure très-concave, à sommet plus ou moins recourbé en crochet; la supérieure operculiforme, et beaucoup plus petite; charnière édentule; ligament inséré dans une fossette alongée et arquée; une seule impression musculaire, comme dans les huîtres.

A. Espèces dont le sommet de la valve est subvoluté.

Ex. La Gryphée gondole, *Gryphæa cymbium*, E. m., pl. 189, fig. 1-2, la *G. arquée*, *G. arcuata*, Pl. LIX, fig. 3 [should be 4].

B. Espèces dont le sommet de la valve inférieure n'est pas voluté.

Ex. La G. podopsidée, *G. podopsidea*.

Observ. On ne connoît encore qu'un espèce vivant dans la première division de ce genre. M. Defrance en compte vingt espèces fossiles et paroît beaucoup douter de l'existence de l'espèce vivante. . . .

Here we have a figured type, *G. arcuata*, and this, in the writer's opinion, must be the type of the genus Gryphæa. Examples: *G. marcoui*, *G. corrugata*, *G. navia*, *G. mucronata*. *G. arcuata* is also the type of Paul Fischer's section Liogryphæa, 1886: Manuel de conchyliologie, p. 927.

[1] Man. de Conchyliologie, 1887, p. 927.

b. Pycnodonta, Fischer von Waldheim: Bull. Soc. imp. des naturalistes de Moscou, Vol. VIII, 1835, p. 118.

The date is sometimes given as 1834, sometimes as 1835. The original description is in a letter from Fischer von Waldheim to Férussac, dated December 12, 1834, but published in 1835 in the journal already mentioned.

This name was proposed for *Gryphæa vesicularis.* The form is hemispherate; the apical or beak is proportionately less conspicuous and the shell thinner than in the Gryphæa s. s.

Examples: *G. vesicularis,* the type, and *G. washitænsis* Hill.

Genus GRYPHÆOSTREA Conrad.[1]

We copy the following from Meek's Invertebrate Cretaceous and Tertiary Fossils of the Upper Missouri Country.[2]

Shell thin, elongate, straight narrow; lower valve rather deep and smooth; upper valve flat or slightly concave, and ornamented with distant, regular, thin, concentric laminæ: beak of lower valve contorted, or turned to one side; cartilage-pit narrow, oblique. *Gryphæa vomer* Morton (sp.).

In a footnote appended to the foregoing Meek says:

Mr. Conrad did not publish a diagnosis of this type, but merely gave the name in a list of fossils. At my request, however, he gave me in manuscript the above diagnosis and mentioned the above type. I would add that in perfectly preserved specimens the typical species presents the singular peculiarity of throwing out long, slender, auricular appendages (one on each side) from the lower valve near the beak. These, being very fragile, are nearly always broken away, as the specimens are found; but I observed several with more or less of them preserved in the New Jersey beds, and one I found growing in the inside of a *Gryphæa vesicularis* with them perfectly preserved and apparently attached to the Gryphæa by their extremities. This type or section might with almost equal propriety be placed as a subgenus of Exogyra.

ACCEPTED SPECIES.

Following is a list of all the known described species of fossil oysters from the Cretaceous formations of Texas, and such data concerning their geologic horizons and geographic distribution as the authors have been able to acquire from many years' experience in observing these forms.

Ostrea, Normal forms.
- O. bella Con.
- O. camelina Cragin.
- O. carica Cragin.
- O. congesta Con.
- O. cortex Con.
- O. franklini Coq.
- O. franklini Cragin.
- O. franklini var. ragsdalei Hill.

[1] Am. Jour. Conchol., Vol. I, 1865, p. 15.
[2] Rept. U. S. Geol. and Geog. Surv. Terr., Vol. IX, 1876, p. 11.

Ostrea, Normal forms—Continued.
- O. lyoni Shum.
- O. owenana Shum.
- O. perversa Cragin.
- O. planovata Shum.
- O. plumosa Mort.
- O. pseudo-franklini Coq.
- O. soleniscus Meek.
- O. subspatulata Forbes.
- O. vellicata Con.

Alectryonia.
- O. alifera Cragin.
- O. alifera var. pediformis, Cragin.
- O. alternans Cragin.
- O. diluviana Lamck. White.
- O. lugubris Conrad.
- O. panda Morton.
- O. subovata Shum.
- O. ?munsoni Hill.
- O. quadriplicata Shum.
- O. crenulimargo Roemer.
- O. crenulimargo stonewallensis Cragin.
- O. larva.
- O. carinata.

Exogyra.

Exogyra s. s.
- E. arietina Roemer.
- E. colombella Meek.
- E. plexa Cragin.
- E. costata Say.
- E. drakei Cragin.
- E. ferox Cragin.
- E. læviuscula Roemer.
- E. ponderosa Roemer.
- E. n. sp., Shoal Creek.
- E. n. sp., from El Paso, Texas.

Ceratostreon, Bayle.
- E. americana Marcou.
- E. Americana var. quitmanensis Cragin.
- E. hilli Cragin.
- E. texana Roemer.
- E. texana var. fragosa Conrad.
- E. weatherfordensis Cragin.
- E. texana var. hilli.

Rhyncostreon Bayle.
- E. columbella Meek.

Gryphæa.

Pycnodonta.
- G. vesicularis Lamck.
- G. aucella Roemer.
- G. newberryi Stanton.
- G. washitaensis Hill.
- G. gibberosa Cragin.

Gryphæa—Continued.
  Liogryphæa.
    G. mucronata Gabb.
    G. corrugata Say.
    G. corrugata var. belviderensis Cragin.
    G. hilli Cragin.
    G. navia Hall.
    G. marcoui H. and V.
    G. wardi H. and V.
  Gryphæostrea.
    G. vomer Morton.

INDEFINITE AND ABANDONED SPECIES.

The following species have also been reported, but are for the present considered invalid, owing to the fact that they are too poorly described to be recognized:

Ostrea roanokensis Cragin.
Exogyra fimbriata Con.
Exogyra paupercula Cragin.

The following names are abandoned:

Ostrea anomiæformis Roemer, belongs to the genus Anomia.
Ostrea blacki White, O. alifera Cragin, O. alifera var. pediformis Cragin, and O. belliplicata Shum. = O. lugubris Con.
Ostrea camelina Cragin = O. franklini Coq.
O. franklini Cragin (not Coq.) = undescribed species.
O. franklini var. ragsdalei Hill = O. ragsdalei Hill.
Exogyra sinuata Cragin.
Exogyra walkeri White = E. americana Marcou.
Exogyra weatherfordensis Cragin = E. texana var. weatherfordensis.
Exogyra hilli Cragin = E. texana var.
Exogyra caprina Con. = E. arietina Roemer.
Exogyra fragosa Con. = E. texana var.
Ostrea marshi Marcou (not Sowerby) = O. subovata Shumard.
Gryphæa pitcheri of Morton, Hall, Shumard, Roemer, White, et al = G. corrugata, Say.
Exogyra forniculata White = G. navia Hall.
G. gibberosa Cragin = G. washitaensis Hill.
G. tucumcarii Marcou = G. corrugata Say.
G. hilli Cragin is reduced to varietal rank as G. corrugata var. hilli.

Each of these different species occupies a definite horizon or range (hemera), so that they become valuable landmarks in determining the exact geologic position of the beds in which they occur in the general series of rocks, thus giving important data for estimating the depth of certain water-bearing strata in the artesian areas of Texas. The geologic position and range of the various species are shown in the accompanying table (p. 31) and plate (Pl. XXIV).

	Lower Cretaceous.								Upper Cretaceous.					
	Trinity.	Glen Rose.	Paluxy.	Walnut.	Comanche Peak-Edwards.	Preston.	Forth Worth.	Denison.	Lower Cross Timbers.	Eagle Ford.	Austin.	Taylor.	Uppermost division.	Horzion unknown.
NORMAL OSTREA.														
O. bella Con														×
O. cortex Con													×	
O. vellicata Con													×	
O. subspatulata Con														×
O. owenana Shum													×	
O. planovata Shum												×	×	
O. congesta Con										×				
O. carica Crag									×					
O. lyoni Shum									×					
O. soleniscus Meek									×					
O. perversa Crag								×						
O. pseudo-franklini Coq						×								
O. franklini Coq	×	×												
O. franklini var. camelinas Crag		×												
O. franklini var. hilli Crag		×												
O. ragsdalei Hill		×												
ALECTRYONIA.														
O. diluviana Lamck. White												×		
O. lugubris Con										×				
O. subovata Shum					?		×	?						
O. ? munsoni Hill					×									
O. panda												×		
O. quadriplicata Shum								×						
O. crenulimargo Roemer			×											
O. larva Goldfuss													×	
O. carinata Lamck								×						
GRYPHÆA.														
G. vesicularis Lamck												×	×	
G. vomer Morton													×	
G. aucella Roemer											×			
G. newberryi Stanton											×			
G. washitaensis Hill						×	×	×						
G. corrugata Say						×								
G. navia Hall						×								
G. marcoui H. & V				×	×									
G. wardi H. & V		×												
EXOGYRA.														
E. arietina Roemer								×						
E. plexa Cragin						×								
E. costata Say													×	
E. ponderosa Roemer											×	×		
E. laeviscula Roemer											×			
E. columbella Meek										×				
E. ferox Cragin									×					
E. drakei Cragin								×						
E. arietina Roemer								×						
E. plexa Cragin						×								
E. americana Marcou						×	×	×						
E. texana Roemer		×		×	×	×								
E. texana var. fragosa Con						×								
E. texana var. weatherfordensis Crag		×												
E. texana var. hillii Crag		×												

In examining the foregoing table and Pl. XXXV, one is impressed with the hemeras or ranges of the various groups. The genus Ostrea, which had its origin before the Cretaceous, probably in Carboniferous time, continues with local and horizontal variations through the Cretaceous.

The alectryoniate oysters likewise have an extensive range, and are no doubt descended from Jurassic forms. The *O. carinata* type, however, appears in one horizon of the Lower Cretaceous (Upper Comanche), and is not present again until *O. larva* occurs in the uppermost Cretaceous.

The particular *O. quadriplicata* group has only a limited range, the two species *O. quadriplicata* Shumard and *O. crenulimargo* being confined to the Comanche series, and no intermediate forms occur indicating its ancestry.

Among the gryphæas those of the Lower Cretaceous, with one exception (*G. washitaensis*), are confined to the thick-shelled species of the *G. corrugata* type, and there is no doubt that these are differentiated from some common ancestral form of the Jurassic, probably closely related to *G. calceola* var. *nebrascensis*. The thin-shelled (Pycnodonta) type has a faint representation in the upper part of the Lower Cretaceous, in *G. washitaensis*, but occurs in greatest abundance as the type of Gryphæa in the Upper Cretaceous, from which the thick-shelled species are missing.

The Gryphæostrea is not represented in the Lower Cretaceous, so far as we know.

In the exogyras the hemera of the flat-ear-shaped (Ceratostreon) group of the *E. texana* type is confined to the Lower Cretaceous. *E. texana* is a highly differentiated form, and must have had an ancestry as yet unknown. It is interesting to note that the two well-marked groups of Exogyra have different and succeeding hemeras. The flattened exogyras are succeeded in the Middle and Upper Cretaceous by the deeply arched, long-beaked, thick-shelled species of the *E. ponderosa* type, of which *E. plexa* and *E. arietina* are the ancestral forms.

It would be impossible from the American Cretaceous forms alone to construct a family tree showing the evolution of all species. In the first place, we have in this country no Jurassic fossils of the antecedent Atlantic sedimentation, and inasmuch as the prototypes from which much of the differentiation proceeded must have existed in that period, our record is incomplete.[1]

Again, some of the forms, like *Gryphæa vesicularis*, *Ostrea carinata*, and many others, have trans-Atlantic occurrences, and there is no reason to assume that they originated in the Texas region. They may or may not be immigrants from distant loci of origin and descendants of ancestral forms not represented in the Texas sediments.

[1] Since this paper was written Jurassic sediments with fossil Ostreidæ have been discovered in Trans-Pecos Texas, on the western or interior side of the Codilleran front. Further studies may give important light on the points discussed.

HISTORICAL STATEMENT OF THE DISCOVERY IN THE TEXAS REGION OF THE FORMS REFERRED TO GRYPHÆA PITCHERI MORTON.

GRYPHÆA CORRUGATA Say, 1823.

The first description from the Texas-Indian Territory region of any of the group of gryphæate oysters, now commonly but erroneously referred to *G. pitcheri* Morton was based upon material collected in southern Indian Territory by Mr. Thomas Nuttall, described by Say, and published in James's account of Major Long' expedition.[1]

The specimens described were found by Nuttall, the botanist, on the prairie bordering the Kiamitia River, near its confluence with Red River. From the writings of that traveler we learn that in 1819 he also traversed the narrow area of Texas-like prairie lands adjacent to the Kiamitia River, lying south of the Ouachita Mountains and north of Red River, in southern Choctaw Nation, a region concerning the stratigraphy of which little further has been known until the senior author's studies and explorations of recent years.[2]

Although it is not clear from the records that Major Long collected any fossils from the region, he was the first, in 1817, to explore the Kiamitia River from its source to its mouth, and first noted the extensive prairies on the lower part of that stream, "some of which," he says, "command delightful views of the country." He continues, "before you lies the great valley of Red River, exhibiting a pleasing variety of forests and lawn; beyond are the summits of the Ozark Mountains, imprinting their broad outline upon the margin of the sky." Then he describes the area where the characteristic prairies of the Texas region, underlain by the Cretaceous formations, abut against the Paleozoic rocks, the latter projecting above them as the mountains of Indian Territory.

Nuttall traversed the same region in 1819 and described it more minutely.[3] From his description (and the senior author has visited nearly every locality he describes in his report) one is impressed with the acuteness and accuracy of his observations.

Nuttall thus describes the prairie of the Kiamitia, from which these fossils were collected:[4]

The surface of these woodless expanses was gently undulated and thickly covered with grass knee-high, even to the summits of the hills, offering an almost

[1] Account of an expedition from Pittsburg to the Rocky Mountains, performed in the years 1819-20, under the command of Maj. Stephen H. Long, compiled by Edwin James, Philadelphia, 1823, Vol. II, pp. 410-411.

[2] Neozoic geology of Southwest Arkansas: Ann. Rept. Geol. Survey Arkansas, Vol. II, Little Rock, 1888. The Comanche series of the Texas-Arkansas region: Bull. Geol. Soc. America, Vol. II, 1891, pp. 503-528. Geology of portions of Texas and Indian Territory adjacent to Red River: Bull. Geol. Soc. America, Vol. V, 1894, pp. 297-338. Outlying areas of the Comanche series: Am. Jour. Sci., 3d series, Vol. L, 1895, pp. 205-234.

[3] Travels into the Arkansa Territory during the Year 1819, Philadelphia, 1821. Although Nuttall's explorations were made after Major Long's, the report of his expedition was published two years earlier than the latter's.

[4] Ibid., pp. 156-157.

inexhaustible range to cattle. The flowers, which beautify them at this season of nature's vigor, communicated all the appearance of a magnificent garden fantastically decked with innumerable flowers of the most splendid hues. The soil appears to be universally calcareous, with the limestone nearly white and full of shells, among which there was abundance of a small species of gryphite, and in the more compact beds some species of terebratulites.[1] This calcareous rock, different from the Mountain limestone, often contains uncemented or loose shells immersed in beds of friable clay, and is more analogous to that of South Carolina and Georgia than that of St. Louis and the Ohio.

The small species of "gryphite" above mentioned was no doubt the same that Say later described, under the name *Gryphæa corrugata*, as having been collected by Nuttall. Say's original description is given in full on page 54 of this paper.

If the type of this specimen has been preserved, its existence is unknown, but the description, insufficient as it is, when supplemented by the reference to Sowerby's plate, enables one to identify the species. It is a remarkable fact, however, that this original description and specific name were soon forgotten, and from the day of their publication until the present have been overlooked. It is through the kindness of Mr. T. W. Stanton that the writer's attention has been called to this description of Say's. Within eleven years after it had been written the same species from the same general locality was redescribed under the name *Gryphæa pitcheri*, by Dr. S. G. Morton, and this name was accepted and used by most subsequent writers until the present time.

GRYPHÆA PITCHERI Morton, 1834.

Soon after the acquirement of the territory of Louisiana by the United States, and long before observations had been made on the stratigraphic geology of the Texas region, a military post was established at Fort Towson, in the southwest corner of what is now the Choctaw Nation, and in the region which had previously been reconnoitered by Long and Nuttall. Among other officers sent to this post was an army surgeon, Dr. Z. Pitcher, who, in 1833, gathered some fossil shells[2] from the vicinity and sent them to Philadelphia, where, in 1834, they were described and figured by Dr. S. G. Morton.[3]

Dr. Morton's description of the species was brief, and his illustration, an exact copy of which is reproduced on Pl. VI, fig. 7, based on the limited material which he possessed, was very poor.[4] Carefully prepared copies of the original type specimen are also reproduced on Pl. VI, figs. 5 and 6.

---

[1] Kingena.

[2] For Pitcher's personal account of the collection of these shells see his letter to Captain Whipple, printed by Prof. Jules Marcou in his "Lettres sur les roches du Jura," etc., Paris 1860, pp. 291-292.

[3] Synopsis of the Organic Remains of the Cretaceous Group of the United States, Philadelphia, 1834, p. 55, Pl. XV, fig. 9.

[4] "Morton's figure of Gryphæa pitcheri (Morton), I understand, was made by Conrad."—James D. Dana, American Journal of Science, January, 1859, p. 139.

Following is an exact copy of this description:

4. *G. pitcheri* (S. G. M.), Pl. XV, fig. 9.

Specific character.—Shell thick, expanded, distinctly lobed; lower valve very convex; upper valve thick and sub-convex; beak distinctly incurved.

Length, one inch; but I possess less perfect specimens nearly three inches long. I received the fossil, together with some others of great interest, from my friend, Z. Pitcher, M. D., of the U. States Army, who obtained it from the plains of the Kiamesha, in Arkansas. I have seen others from the falls of Verdigris River, in the same territory.

There is no doubt, as will be shown later in this paper, that the *Graphæa pitcheri* of Morton is the same species, from the same locality, as the *Gryphæa corrugata* of Say, and hence, in the final classification, the name *Gryphæa pitcheri* is abandoned.

ROEMER'S GRYPHÆA PITCHERI, 1849.

Some fifteen years after Morton's description appeared Dr. Ferdinand Roemer made the first original paleontologic field studies in the Texas region, the scene of his investigation being near New Braunfels, some 350 miles southwest of Fort Towson. He described[1] (1849) and figured[2] (1852) from the Waco Indian camp near the Guadalupe River, 8 miles above New Braunfels, and other localities, with his customary accuracy, a beautiful gryphæa, a fossil entirely distinct from Dr. Morton's both in appearance and, as has since been discovered, in geologic occurrence.

Copies of Dr. Roemer's figures are given in Pl. XXVI, figs. 1, 2, 3. On previous pages, in the discussion concerning the preservation of the types of Morton's species, the reasons are given why Dr. Roemer correlated this form with Morton's species.

MARCOU'S GRYPHÆA PITCHERI, 1853.

In 1853 Prof. Jules Marcou, en route from Fort Smith, Arkansas, to Albuquerque, New Mexico, crossed Indian Territory along the line of the Arkansas and Canadian rivers through a region separated from the main body of the Cretaceous of Texas and southern Indian Territory by the great topographic feature of the east-west mountain ranges known as the Ouachita system. On this journey he noted two small outcrops of what are now known to be the rocks of the Comanche series, and near Comet Creek, a locality in western Oklahoma now known as "G" County,[3] where one of the outlying areas of the Comanche series occurs, he collected a form of Gryphæa (*G. navia* of Hall) to which he applied the name *G. pitcheri*. He also

[1] Texas, mit besonderer Rücksicht auf deutsche Auswanderung, etc., Bonn, 1849.

[2] Die Kreidebildungen von Texas und ihre organische Einschlusse, Bonn, 1852.

[3] See Outlying areas of the Comanche series in Kansas, Oklahoma, and New Mexico, by R. T. Hill: Am. Jour. Sci., 3d series, Vol. L, 1895, pp. 205-234.

pointed out the occurrence of this form at Fort Washita, Indian Territory, and near Preston, Texas, from which places he had seen collections made by Dr. G. G. Shumard. This form he figured most excellently, so that it can not be mistaken. The grounds upon which he called this form *G. pitcheri* Morton were later set forth fully in another place.[1] He likewise correlated it with both Morton's and Roemer's forms, but later suggested that the latter might be a distinct species.[2] The completeness and the stratigraphic details of the Cretaceous section of the Southwest not being known at this time, naturally the horizon or true place of this form in the Texas section was not known.

In 1854 Dr. Benj. F. Shumard described and figured[3] from the Cretaceous clays of Fort Washita, Indian Territory, and at "Cross Timbers, Texas," a form which is probably the same as that described by Professor Marcou.

BLAKE'S GRYPHÆA PITCHERI, 1855.

In 1855 Mr. W. P. Blake[4] described still another form of Gryphæa from Texas under the name of *Gryphæa pitcheri*. This is an important form, which was overlooked in the subsequent discussions, and which will be here alluded to as Blake's *Gryphæa pitcheri*. The type locality of this species was the Big Springs of the Colorado, and Blake's figure is the first clear illustration of the form herein designated *G. marcoui* (sp. nov.), as will be seen by a comparison of figures and by the abundant collections made from his type locality.

SCHIEL'S GRYPHÆA PITCHERI, 1855.

In the same report,[5] the same year (1855), Schiel described still another *Gryphæa pitcheri* from what is known to be the Upper Cretaceous system in New Mexico. This form has also been figured as *G. pitcheri* by White (1876).[6]

HALL'S GRYPHÆA PITCHERI, 1856 (=G. DILATATA VAR. TUCUMCARII Marcou).

Professor Marcou's collections, through official action,[7] were given to Prof. James Hall to study, and in 1856 the latter author published[8] this form as *Gryphæa pitcheri* Morton, saying: "It has clearly the typical form and characters of the species, as will be seen by referring to Dr. Morton's figure of a small individual."

---

[1] Extracts of Professor Marcou's writings bearing upon this species are given on pp. 14 and 15 of this paper.

[2] Proc. Boston Soc. Nat. Hist., Vol. VIII, 1861, pp. 86-97. See quotation on p. 40.

[3] Marcy's Exploration of Red River, Washington, 1854, p. 179, Pl. VI, fig. 5.

[4] Pacific Railroad Reports, Vol. II, 1855, Pope's report on route near 32d par., The geology of the route, p. 39.

[5] Beckwith's rept. on route along 41st par., Vol. II, Chap. X, Geology, p. 108.

[6] U. S. Geog. Surv. west of One hundredth Mer., Vol. IV, 1877, p. 171, Pl. XVII, figs. 1a-1f.

[7] Geology of North America, etc., by Jules Marcou, Zurich, 1858, pp. 1-8.

[8] Pacific Railroad Reports, Vol. III, 1856, p. 100.

Professor Hall does not say that he had seen Morton's poor type specimen, a copy of the original figure of which is herein reproduced on Pl. XVI, figs. 6 and 7. Later Professor Hall, in an extended review,[1] expressed two important opinions: (1) That the specimens presented "no features, either in form, character, condition of preservation, or otherwise, which can serve to distinguish them from *Gryphæa pitcheri*" of Morton; and (2) that the beds from which these specimens came were of Cretaceous age and not Jurassic.

Professor Marcou, on his journey from Fort Smith to Alburquerque, discovered at and near Pyramid Mountain, New Mexico, 300 miles west of the locality of his *G. pitcheri*, the now famous *G. dilatata* var. *tucumcarii*, which he later figured beautifully and accurately, and which, upon grounds then apparently justifiable, he placed in the Jurassic.[2]

Professor Marcou mentioned this species several times before it was figured by himself in 1855, by Hall in 1856, and again by himself in 1858. In the first[3] of these papers he provisionally gives the form the name *Gryphæa tucumcarii.* Later he called the form *G. dilatata* var. *tucumcarii*, believing the species to be a variety of the *G. dilatata* of the European Jurassic. In 1861 he again used the name *G. tucumcarii.*

HEILPRIN'S GRYPHÆA PITCHERI, 1890.

In the years between 1886 and 1890 the senior author observed, in the Lower Cretaceous of Texas, numerous specimens of a Gryphæa (see Pls. XX–XXIII) which presented marked external difference from the forms described by previous authors. With Roemer's positive assertion in mind that his excellent figures represented the true *Gryphæa pitcheri* (as, in common with most others, he had seen the so-called type in Philadelphia), the senior author early formed the conception that if this was true the forms of *Gryphæa pitcheri* associated with *O. carinata* and with *E. arietina*, respectively, were two entirely different species.

The name *Gryphæa washitaensis* was proposed for the former, and specimens were sent to various museums, including the Philadelphia Academy of Sciences. No word was returned intimating that the determination was wrong, but within a short time Professor Heilprin published the following remarks:[4]

> *Gryphea washitaensis*, specimens of which Professor Hill has kindly sent to me, is true *G. pitcheri*, corresponding almost absolutely with the type specimen of that species (Morton's) which is contained in the collections of the Academy of Natural Sciences.

Later it will be shown that Professor Heilprin was mistaken in his identification.

---

[1] Am. Jour. Sci., 2d series, Vol. XXIV, 1857, p. 85.

[2] Geology of North America, 1858, Pl. IV, figs. 1, 1a, 1b, and 3. Reproduced on Pl. XVI, this work.

[3] Résumé of a geological reconnaissance extending from Napoleon, at the junction of the Arkansas with the Mississippi, etc.: Rept. Expl. Railway Route near 35th Par., by Lieut. Whipple, pp. 40–48; Thirty-third Congress, 2d session (?), H. Doc. 129, 1855.

[4] Proc. Acad. Nat. Sci. Phila. for 1890, p. 452.

GRYPHÆA PITCHERI VAR. HILLI[1] Cragin, 1891.

Professor Cragin has reported three forms of Gryphæa from the Comanche strata of southern Kansas.[2] One of these, which he identified as *Exogyra forniculata* White, must hereafter be called *G. navia* Hall. Another well-developed species is the *G. tucumcarii* of Marcou, which has an extraordinary development.

The small specimens of *G. corrugata* found in the basal fossiliferous beds of the Belvidere, Kansas, section he has called by the name of *G. pitcheri* var. *hilli*,[3] the "hilli phase"[4] and *G. hilli*.[5] This he has alleged to be identical with the Texas form found west of Weatherford, which we herein describe as *Gryphæa marcoui* sp. nov. We have collected abundantly from both localities, and can not agree with Professor Cragin that the species are the same. Our studies show that the Belvidere specimen is merely a small varietal form of *G. corrugata* Say.

DIFFERENTIATION.

The more important facts concerning the early discovery and descriptions of forms referred to *Gryphæa pitcheri* have been briefly given.

During the decade of 1850–1860 governmental exploration of the southwestern border States and Territories was vigorously prosecuted. During this epoch occurred the extended controversy already sketched concerning the species under discussion.

Prof. James Hall made the first published intimation that the forms which had been called *G. pitcheri* were subdivisible into varieties. In his report of 1856,[6] based on Professor Marcou's collections from Indian Territory, he first suggested differentiation of the forms called *G. pitcheri* by proposing that the name "variety *navia*" be substituted for the form called *Gryphæa pitcheri* by Professor Marcou. Thus a good varietal differentiation was made, and a great advance would have been made had not Professor Hall immediately and erroneously added that this variety "is well represented in the figures of Dr. Roemer." This explains why the variety name "*navia*" in the subsequent confusion of literature became attached to Roemer's species instead of Marcou's, to which it was originally applied.

In 1857, one year later, Volume I of the United States and Mexican Boundary Report appeared, the "General Geology" of which is by Prof. James Hall, the "Tertiary and Cretaceous Paleontology" by T. A.

---

[1] Am. Geologist, Vol. XIV, 1894, p. 6.

[2] See Bull. Washburn College, Vol. I, No. 9, Topeka, Kansas, January, 1889, pp. 33–36, and Vol. II, No. 11.

[3] Am. Geologist, March, 1891, Vol. VII, p. 184; 1894, Vol. XIV, p. 10.

[4] Ibid., 1894, p. 6.

[5] Ibid., Dec., 1895, Vol. XVI, pp. 368, 369, 371.

[6] Pacific Railroad Reports, Vol. III, 1856, p. 100, and Pl. I, figs. 7–10.

Conrad, and the illustrations by F. B. Meek. Conrad's descriptions[1] and references to plates and figures are not accurate, and only Meek's excellent figures and the preservation of the type specimens in the United States National Museum rescue the contribution from confusion. In a geologic discussion of this report Professor Hall again presented his views of the identity of *G. pitcheri* Morton and *G. dilatata*[2] Marcou, which, as shown above, he amplified later. The five lines of description of *G. pitcheri* which Conrad gives do not furnish one of the criteria by which any of the gryphæas can be differentiated, but is so generic that it will fit any one of them.

Mr. Conrad, like Professor Hall, recognized the fact that possibly more than one variety, if not species, had been confused under the general name of *G. pitcheri* Morton. He speaks of "one resembling *G. vesicularis*, and which is the type of the species as figured and described by Morton, and the other truncated anteriorly with a narrow, elongated, boat-shaped umbone, var. *navia*, Pl. VII, fig. 3, *c*, *d*."[3]

Fig. 3*d*, the type of Conrad's var. *navia*, is a poor specimen, which can not be placed satisfactorily. The type of this figure is either an abnormal specimen of *G. corrugata* (Marcou's *G. tucumcarii*, Morton's *G. pitcheri*) or a noncarinated specimen of Marcou's *G. pitcheri*, which Hall described as var. *navia* in the preceding year, and which Gabb later elevated into the species of *G. navia*.[4]

Let it now be noted that two, and possibly three, forms have been called var. *navia*, to wit: Two by Professor Hall (Marcou's *G. pitcheri* and Roemer's *G. pitcheri*) and one by Conrad, which is an indefinite form, possibly different from either of the above, although probably a variety of Marcou's *G. pitcheri*.

Gabb was the first to attempt a differentiation into distinct species of the forms called *Gryphæa pitcheri*. In a communication read before the Academy of Natural Sciences of Philadelphia on February 12, 1861, he said:[5]

Through the kindness of my friend, Dr. Janeway, I have obtained some specimens of *Gryphæa Pitcherii* from the Indian Territory, near the Choctaw Mission, and I believe I now have the means of proving the identity of the true *G. pitcherii* with the form called by Prof. Marcou *G. dilatata* var. *tucumcarii*.

With the aid of Professor Marcou's figures, 1 to 3, pl. 4, on one hand, and Dr. Morton's types on the other, I have an unbroken series of gradation from one form to the other. I have exhibited the suite to a number of the best naturalists in Philadelphia, and no one has been able to show a break in the series. Mr. Conrad, after a careful examination, pronounced them to be a regular gradation from one variety to another of the same species.

Dr. Morton's original specimens, now lying on the table, as well as the last sentence of his descriptions, show that the beak is "distinctly incurved." Professor Marcou refers a form to this species in which the beak is strongly deflected. This

[1] U. S. and Mexican Boundary Survey, Vol. 1, 1857, p. 155.

[2] Am. Jour. Sci., 2d series, Vol. XXIV, 1857, pp. 84-85.

[3] The last should read only fig. 3d, for fig. 3c is clearly a side view of the form figured as 3a, 3b, and now in the United States National Museum.

[4] Proc. Acad. Nat. Sci. Phila. for 1861, p. 22. Gabb called the species *navis*.

[5] Ibid., p. 22.

form, unknown to Dr. Morton, is, I have no doubt, distinct. I have recently gone over the whole subject carefully, with the following results: The oblique, carinated form is a distinct species, and must be called *Gryphæa navis*. The species described by Morton is *the same* as the one called *tucumcarii* by Marcou. The small specimen figured by Morton is said by Marcou to be "incomplete and without the superior valve." This is not so. The specimen is a young one, but is *very perfect*. Dr. Roemer did not see it, because it was lost some time before his visit to Philadelphia, and afterwards discovered by me among some rubbish. The beak and umbone are round, there is no carination, and the figure in the Synopsis will convey a very correct idea of its form. It is as distinctly lobed as the fig. 1, pl. 4, of Geology of N. A.

The large specimen spoken of by Dr. Morton, from the plains of Kiamesha, is more nearly of the form of fig. 3 of the same plate. There is every form between the two varieties, viz: The one figured by Morton in his Synopsis, pl. 15, fig. 9, and the pl. 4, figs. 1 and 2.

I do not wonder that Professor Marcou should have maintained the difference between *G. pitcherii* and *G. tucumcarii*, as he understood them, but the key to the difficulty is this: *G. tucumcarii* is the typical form of *G. pitcherii*, while *G. pitcherii* Marcou is *G. navis*. This can be proven to any person who will take the trouble of investigating the subject.

The authors' studies have substantiated the opinions expressed by Gabb in the foregoing.

In a paper in the Proceedings of the Boston Society of Natural History,[1] dated May, 1861, Professor Marcou makes the following remarks in a footnote:

I have never seen Morton's original specimen. If the figure in his *Synopsis of the Cretaceous Group of the United States*, Pl. XV, fig. 9, is correct, it differs in its general outline and in the details of both valves from the young specimen of *G. tucumcarii* published in my *Geology of North America*, Pl. IV, fig. 2, and as it differs even more from the young specimen of *G. Pitcheri*, fig. 6, on the same plate, I am led to believe that I did not meet with the true *G. Pitcheri* of Morton in my explorations with Captain Whipple's party. Mr. Ferdinand Roemer having the opportunity of seeing in the company of the late Dr. Morton himself the original specimen at Philadelphia, I naturally followed his identification of *G. Pitcheri*, and if Roemer has made a mistake, I was misled by his description in Die Kreidebildungen von Texas. Thus we shall have three species of Gryphæa: 1, the *G. Tucumcarii* of the Jurassic rocks of Pyramid Mount (New Mexico); 2, the false *G. Pitcheri* of Roemer and Marcou, or the false *G. Pitcheri* var. *navia* of Conrad and Hall of the cretaceous rocks of the false Washita River (Texas), which may be called *G. Roemeri*, in honor of its first discoverer, Mr. F. Roemer; and 3, the true *G. Pitcheri* Morton, which I have never seen, and, consequently, on which I can not give any information as to its stratigraphical position and association with other fossils.

Professor Marcou was mistaken in considering his *G. tucumcarii* distinct from Morton's *G. pitcheri*, and in considering his own *G. pitcheri*, for which he proposes the name *G. roemeri*, the same as Roemer's *G. pitcheri*, later described by Gabb as *G. mucronata*.[2]

The magnificent specimens illustrated on Pl. XXI of the Mexican Boundary Report have a strikingly different aspect from the other forms illustrated therein as *G. pitcheri*, and anyone who has col-

[1] Vol. VIII, 1862, p. 95.

[2] Geol. Survey California, Palæontology, Vol. II, 1869, pp. 274–275.

lected in the Tucumcari region would be very apt to consider them the *G. tucumcarii* of Marcou, as Marcou himself asserted them to be. Mr. Conrad later, in 1861, in a letter to Professor Marcou, confessed his doubts as to the identity of these forms with *G. pitcheri*, as follows:[1]

When I drew up the Report in Emory's Survey, I was shown by Professor Hall a series of *Gryphæa*, some of which were undoubtedly your *G. tucumcarii*, as figured on Pl. XXI. Professor Hall thought they graduated into *G. Pitcheri*, and I thought so at the time. The name of your species ought not to have been placed as a synonym to Pl. VII, fig. 3, for it is undoubtedly *G. Pitcheri*.

But the figures on the Pl. XXI represent a species and specimen the locality of which is *unknown* to me, and were engraved *after* I had sent in my report and descriptions. So that I can now say that I do not know whether *G. Pitcheri* is identical with your species or not.

The types of these specimens in the National Museum are labeled from Leon Springs, a point in Trans-Pecos Texas, in the western peripheral region of the Comanche series, almost due south of Tucumcari, and as they are *G. tucumcarii* Marcou, as Marcou himself alleges, this specific name is of no value, for, as we shall show later, they possess all the critical features by which *G. pitcheri* Morton could be distinguished from Marcou's species.

Gabb, in the second volume of the Palæontology of California,[2] made another contribution to the differentiation of these species. He repeated the conclusions previously announced,[3] and redescribed Roemer's *G. pitcheri*, giving it the name *G. mucronata*. Thus three species of the *G. pitcheri* group were clearly defined, viz: *G. pitcheri* Morton (=*G. tucumcarii* Marcou), *G. navia* (=*G. pitcheri* of Marcou and *G. roemeri* of the same author), and *G. mucronata* (=*G. pitcheri* of Roemer).

Still further specific differentiation of the forms called *G. pitcheri* was later made by Hill, Stanton, and Cragin, as follows:

Gryphæa washitaensis Hill.—During the years 1885, 1886, and 1887 the senior author initiated field studies of the various forms which had been called *G. pitcheri* Morton. He found the form (later described in this paper on pp. 59–62, and figured on Pls. XX–XXIII) for which he proposed the specific name *G. washitaensis*.[4]

Gryphæa newberryi Stanton.—In 1893 Mr. T. W. Stanton further cleared up the confused synonymy by redescribing under the specific name of *Gryphæa newberryi*[5] the forms called *G. pitcheri* by Schiel and Newberry, and thus removing them from the *G. pitcheri* group entirely.

---

[1] Proc. Boston Soc. Nat. Hist., Vol. VIII, 1861, pp. 96-97. The letter is dated January 25, 1861, a date previous to Gabb's contribution read before the Philadelphia Academy February 12, 1861, and already alluded to.

[2] 1869, pp. 272-275.

[3] Proc. Acad. Nat. Sci. Phila. for 1861, p. 22, 1862.

[4] University of Texas, School of Geology, Check-List of the Invertebrate Fossils from the Cretaceous formations of Texas, Austin, 1889, p. 11; also Prelim. Check-List of the Cretaceous, Invertebrate Fossils of Texas, Bull. 1, Geol. Survey Texas, p. 4, Austin, 1889.

[5] The Colorado formation and its invertebrate fauna: Bull. U. S. Survey No. 106, 1893, pp. 60-62.

Gryphæa gibberosa Cragin.—In 1893 Professor Cragin proposed the name *gibberosa* for a large old-age form of Gryphæa which occurs in the same beds at Austin with the species for which the senior author[1] proposed the name *Gryphæa washitaensis.*

Professor Cragin, as shown on page 30, has also proposed the name *G. pitcheri*[2] var. *hilli* for a form from the base of the Kiowa shales of Kansas.

As a result of this differentiation of the forms which had once been called *Gryphaea pitcheri* Morton, the following specific and varietal names, indicating a differentiation of the species, have been used in the literature of the subject:

G. pitcheri Morton.
G. tucumcarii Marcou (also G. dilatata var. tucumcarii Marcou).
G. pitcheri var. navia Hall.
G. pitcheri var. Navia Conrad.
G. navia Hall Gabb (assigned by Gabb to Conrad).
G. washitaensis Hill.
G. gibberosa Cragin.
G. newberryi Stanton.
G. pitcheri var. hilli Cragin.
Exogyra forniculata White.

According to the law of priority, only the following names for the forms called *G. pitcheri* in the list above given can survive, and these, with certain others to be introduced, will hereafter be used in this paper:

G. corrugata Say. In accordance with the laws of priority, this has precedence over *G. pitcheri* Morton, *G. tucumcarii* Marcou, *G. dilatata* var. *tucumcarii* Marcou, *G. pitcheri* var. *hilli* Cragin, and *G. hilli* Cragin.

G. navia Hall. The synonyms *G. roemeri* Marcou and *Exogyra forniculata* White must be abandoned.

G. mucronata Gabb, 1861, must supersede *G. pitcheri* var. *navia* in part as applied to Roemer's *G. pitcheri.*

G. washitaensis Hill, of which *G. gibberosa* Cragin is a very old form.

G. newberryi Stanton.

In the succeeding chapter, which deals with the systematic classification of the species, this list will be still further modified by the introduction of two new specific names, so that the list of all the above forms will be as follows:

Gryphæa wardi sp. nov.
Gryphæa marcoui sp. nov.
Gryphæa corrugata Say.
    G. corrugata var. tucumcarii var. nov.
    G. corrugata var. hilli Cragin.
    G. corrugata var. belviderensis var. nov.
G. navia Hall.
G. washitaensis Hill.
G. mucronata Gabb.

[1] Contributions to the invertebrate paleontology of the Texas Cretaceous: Fourth Ann. Rept. Geol. Survey Texas, pp. 189-190, Austin, June, 1893, p. 189, Pl. XXX, figs. 1 and 2.
[2] Am. Geologist, March, 1891, Vol. VII, No. 3, p. 181.

GEOGRAPHIC AND STRATIGRAPHIC DISTRIBUTION OF THE LOWER CRETACEOUS GRYPHÆAS.

Although originally described from the plains of the Kiamitia, in the Choctaw Nation of Indian Territory, and "from the falls of the Verdigris,"[1] the various species referred to *Gryphæa pitcheri* Morton have been reported by various writers from as far north as Kansas and to the westward in New Mexico and Utah. It has also been reported from New Jersey, Alabama, Mississippi, Louisiana, and Mexico, and has even been correlated with species from Europe, Africa, and the Andean regions of South America. In the opinion of the authors the geographic distribution of these species, so far as definitely known, is restricted to the present known areal extent of the Comanche series in southern Kansas, Indian Territory, Texas, New Mexico, and northern Mexico, and owing to the uncertainty surrounding the identity of the species and the correctness of the correlations, assertions of its occurrence in other regions should be carefully examined before acceptance.

Inasmuch as in their studies the writers have never yet found in the Upper Cretaceous any form belonging to the so-called types of *Gryphæa pitcheri* group, the reference to *G. pitcheri* by Schiel, Newberry, and White of a certain form found in the Upper Cretaceous of New Mexico and Utah has often caused much perplexity. Mr. T. W. Stanton, however, has recently shown that this is an entirely different species from the *pitcheri* group, and has removed it from the controversy by giving it the name *G. newberryi*. In view of this fact, this form need not be further considered in the present paper.

Mr. Conrad was the first to assert that *G. pitcheri* occurs in the Upper Cretaceous in New Jersey.[2] No proof of the statement is given, nor has a single specimen which can now be identified with this species ever been found east of Arkansas or in the Upper Cretaceous of North America. Mr. Conrad's erroneous conclusion concerning the existence of the species in New Jersey was probably the authority for its frequent appearance in subsequent literature.

In Dr. C. A. White's paper on Fossil Ostreidæ, published in 1884, *Gryphæa pitcheri* Morton is not only reported as occurring in New Jersey, but that locality is given as the place of its original discovery. Dr. White says:

> This is perhaps one of the most widely distributed and most variable species among the Ostreidæ of North America. It was originally discovered in the Cretaceous strata of New Jersey, and published by Dr. Morton in his synopsis of the Cretaceous formation of the United States.

---

[1] This species does not occur in situ at the falls of the Verdigris, a locality a few miles north of Muscogee, Indian Territory, as reported by Morton. The falls are over Carboniferous rocks and no Cretaceous outcrops occur within 100 miles of the locality.

[2] Rept. Mex. Bound. Survey, Vol. I, 1857, Pt. II, p. 141.

We have shown that the species was originally described from what was then Arkansas and is now the Indian Territory, and that the several species here called one are not widely distributed; as we shall show, each is confined to a definite and limited geologic and geographic zone.

Whitfield is the only writer who actually records[1] the finding of this species in New Jersey at various localities, but references to his figures and plates show that the form is not a member of the *Gryphœa pitcheri* group, but is an ally of *Gryphœa vesicularis*.

Hilgard has mentioned[2] *Gryphœa pitcheri* as occurring in what is now known to be the uppermost division of the Cretaceous in Louisiana. Lerch has repeated[3] this identification, but, as shown by the junior author,[4] these identifications are erroneous.

The senior author has already said:[5]

> Varieties of the *G. vesicularis* and *E. costata* in Alabama, Mississippi, and Texas have frequently been confusingly termed *G. pitcheri*, but after most painstaking endeavors and study of the faunas of those regions I have failed to authenticate a single reference of *G. pitcheri* in the Upper Cretaceous.

The first correlation of this species with forms from South America that the writers have found is that given by Roemer,[6] as follows:

> Finally, Mr. Leopold von Buch has brought to my attention the agreement of the Texas specimens with the specimens in his collection, which were collected by Mr. J. Domeyko in the vicinity of the volcano of Aconcagua, in Chile, 30° S., and were designated *G. arcuata*. Probably, also, at least a part of the forms which Coquand and Bayle have described from the same region under the name of *Ostrea cymbium* Desh. are identical with them. Therefore the species possessed a wide distribution on the American continent.

Marcou also[7] speaks of his form of *G. pitcheri* as "having more resemblance to the *G. couloni* (of Europe) than any other species," and says that this resemblance led him to consider the strata from which they came "as the equivalent of the Neocomian of Europe."

De Loriol, in a personal letter, has called the senior author's attention to a certain gryphæate oyster (*O. szajnochai* Choffat) from Benguelaland, West Africa, which had a suggestive resemblance to the forms called *Gryphœa pitcheri* of the Texas region by Coquand. It is impossible, however, to see in the forms figured[8] more than a general resemblance to the genuine *G. pitcheri* (*G. corrugata* Say).

In view of what has already been stated, and anticipating the conclusions to be presented in the later pages, it can only be said at this place that these comparisons have been founded on insufficient data,

---

[1] Mon. U. S. Geol. Survey, Vol. IX, 1885, p. 38.
[2] Preliminary Report of a Geological Survey of Louisiana, 1869, p. 11.
[3] First Ann. Rept. Geol. Survey Louisiana, 1870, p. 78.
[4] The stratigraphy of northwestern Louisiana: Am. Geologist, April, 1895, p. 207.
[5] Neozoic geology of southwest Arkansas: Rept. Geol. Survey Arkansas for 1888, Vol. II, p. 169.
[6] Kreidebildungen von Texas, p. 74.
[7] Geology of North America, pp. 38-39.
[8] Matériaux pour l'étude stratigraphique et paléontologique de la Province d'Angola, par Paul Choffat et P. de Loriol, Genève, 1888, pp. 92-93, Pl. V., fig. 18.

and that satisfactory extraterritorial correlation for the present would best be eliminated and deferred to more careful studies of the future.

In the accompanying table we have endeavored to show the position of occurrence in the different beds of the various species of Gryphæa, together with their synonymy. The vertical position of these species is also shown in the columnar sections of figs. 1, 2, 3, and 4.

Tabular exhibit of forms which have been called Gryphæa pitcheri.

Species.	Synonymy.	Geologic position.	Geographic distribution.
G. vesicularis Lam., 1806.	G. pitcheri Conrad (in part), 1857. G. pitcheri Hilgard, 1869. G. pitcheri White (in part), 1884. G. pitcheri Whitfield, 1885. G. pitcheri Lerch, 1892.	Upper division of Upper Cretaceous.	New Jersey and Atlantic coastal plain, westward to the Rio Grande; Colombia, S. A.; Europe.
G. newberryi Stanton, 1893.	G. pitcheri Schiel, 1855. G. pitcheri Newberry, 1861. G. pitcheri White (in part), 1876.	Benton, Niobrara.	New Mexico, Colorado, Utah.
G. mucronata Gabb, 1869.	G. pitcheri Roemer, 1849. G. navia Hall (in part), 1856. G. navia Conrad (in part), 1857. G. navia White, 1884.	Washita division; Del Rio clays and Grayson marls.	Cerro Gordo, Arkansas, west to Fort Washita, Indian Territory; Denison, Denton, Handley, Round Rock, Austin, west of New Braunfels, Del Rio, and intermediate points. El Paso and Trans-Pecos Texas.
G. washitaensis Hill, 1889.	G. pitcheri var. dilatata Hill, 1887. G. pitcheri Heilprin, 1890. G. gibberosa Cragin, 1893.	Washita division; Fort Worth and Lower Denison beds.	Denison to Rio Grande via Fort Worth, Belton, Salado, Georgetown, Austin, El Paso.
G. navia Hall, 1856	G. pitcheri Marcou, 1855. G. pitcheri var. navia Hall (in part), 1856. G. navia Gabb, 1861. G. roemeri Marcou, 1861. G. navia Gabb, 1869. Exogyra forniculata White, 1880.	Washita division; Preston Kiamitia.	Goodland, Indian Territory, west to Marietta, south to Belton, Texas. Bexar County.

Tabular exhibit of forms which have been called Gryphæa pitcheri—Continued.

Species.	Synonymy.	Geologic position.	Geographic distribution.
G. corrugata Say, 1823.	G. pitcheri Morton, 1834. G. tucumcarii Marcou, 1851. G. dilatata var. tucumcarii, 1853. G. pitcheri Hall, 1856. G. pitcheri Conrad, 1857. G. pitcheri Gabb, 1861. G. pitcheri Dana, 1880.	Washita division: Preston beds.	Pyramid Mountain, Tucumcari, northeast New Mexico; Kent, Leon Springs, El Paso, Texas; southern Kansas; also at Goodland, Indian Territory, and south side of Canadian Valley, Oklahoma.
G. marcoui sp. nov., 1897.	G. pitcheri Blake, 1855.	Fredericksburg division; Walnut clays and Comanche Peak.	Wise, Parker, Hood, Erath, Comanche, Brown, Lampasas, Hamilton, Coryell, Williamson, Burnet, and Mitchell counties, Texas; and many other localities.
G. wardi sp. nov., 1897.	....	Glen Rose beds.	Travis County, Texas.

SPECIFIC CLASSIFICATION AND EVOLUTION OF THE LOWER CRETACEOUS GRYPHÆAS.

Under the above heading it is proposed (1) to specifically define the various species which have been called *G. pitcheri*; (2) to discover as many data as possible concerning the development and methods of growth of the Lower Cretaceous gryphæas of the Texas region; and (3) to attempt to show their phylogeny.

The work of various paleontologists, most notable among whom are Hyatt, Jackson, and Beecher, has shown the value of the study of the development of the individual as an index to the history of its ancestral forms. The principle involved is one that is almost universally recognized among students of zoology, whether it be the zoology of recent or that of fossil animals, and may be briefly stated in the following words: The successive stages in the development of an individual usually represent adult stages of its ancestors. The appearance of the adult ancestral characters in embryonic or youthful stages is due to acceleration of development. In some cases it is known that certain modifying conditions have induced changes in the development of forms, such as the intercalation of the larval and pupal stages in higher insects. Therefore, in studying development with a view to constructing phylogenetic trees, care must be used to avoid considering these intercalated or modified larval forms as indicating the history of the group.

As the terms employed by previous writers to indicate the stages of development will be applied in this paper to the forms here considered, the following explanation of these terms is presented as given by Jackson:[1]

Protembryo.—The ovum and stages of segmentation of the egg preceding the formation of the blastula cavity.

Mesembryo.—The hollow blastula stage comparable to the condition found in the adults of Volvox and Eudorina types of the Mesozoa.

Metembryo.—The gastrula, comparable to the lower Porifera, in which three cell layers exist, as in the lowest Hydrozoa.

Neoembryo.—The trochosphere. Stages not yet possessing the essential diagnostic characters of the Mollusca; comparable to the embryos of Chætopod worms and Cœlomata.

Typembryo.—The period at which an essential molluscan feature, the shell gland, and plate-like beginning of the shell are discoverable, and yet the embryo is not referable to the class to which it properly belongs.

Phylembryo.—Early veliger stages in which the characters of the class subdivision are indicated and the structure of the shell and other features render the embryo referable to the group of Mollusca to which it belongs.

Completed protoconch and prodissoconch.—The completed first-formed shell of molluscs, the ovisac, fry shell, embryonic shell and larval shell of authors. It finds its representative in the globular, cup-shaped, or spirally coiled protoconch of cephalopods.

Nepionic period.—The period of the first formation of the true shell which succeeds the embryonic shell and is normally retained throughout the rest of life. The period is commonly characterized by marked stages.

Nealogic period.—The period succeeding the nepionic and preceding that period which may properly be considered as the adult. It is frequently characterized by marked stages, being a period in which the growing animal often differs widely from the adult, and as it is of considerable size, the differences and stage are easily recognized. Example, *Hinnites cortesi* has a pecteniform nealogic stage sharply marked off from the Ostreaform adult condition.

Ephebolic period.—That period best characterized by saying that in it the adult characters find fullest expression; it is often separable by marked stages from the earlier nealogic period, and also from the later or senile period.

Geratologic period.—The period of decline of the individual, often marked by distinct stages. The geratologic period is subdivided by Professor Hyatt into the clinologic and nostologic periods, signifying the early and later periods of decline of the individual.

Since the publication of Dr. Jackson's memoir, from which the above is quoted, some changes in the nomenclature of stages have been made.[2] We give these changes for those stages succeeding the nepionic:

Neanic = Nealogic.
Ephebic = Ephebolic.
Gerontic = Geratologic.

[1] Phylogeny of the Pelecypoda: Mem. Boston Soc. Nat. Hist., Vol. IV, No. 8, 1890, p. 290 et seq.

[2] Hyatt, Bioplastology and the related branches of biologic research: Proc. Boston Soc. Nat. Hist., April, 1893, Vol. XXVI, 1895, p. 94.

It has been shown by various investigators that in the prodissoconch stage of the oyster the umbones are directed posteriorly. At this early stage the young oyster has an anterior and a posterior adductor muscle. Of these two muscles the anterior arises first. At this age the young oyster has a rather straight hinge line. In the adult stage we know that only one muscle is present, and on account of this fact the oyster has been placed in that division of the Pelecypoda known as the Monomyarians. The muscle which remains is the posterior adductor, the first muscle to arise atrophying and disappearing. On account of the disappearance of the anterior adductor muscle, great changes take place in the axes of the animal. The antero-postero axis of the adult, instead of being parallel to the antero-postero axis of the prodissoconch, makes an angle of about 45° with it, the posterior adductor muscle having revolved through an angle of 45°. The development of *Ostrea virginiana*, beginning with the prodissoconch stage and extending to that of the adult, has been worked out in very great detail by Dr. Jackson in his memoir[1] from which the above data concerning the development of the oyster are taken. The writers have, however, been able to verify a good many of his observations from an examination of material which he has prepared. Dr. Jackson has described in a most admirable manner the revolution of the axes of various mollusks due to the diminution or disappearance of the anterior adductor muscle, and for the details of these changes his paper should be consulted.

In only two species were prodissoconchs seen that were well enough preserved to enable the writers to discover the form of the shell in that stage. These species were *Gryphœa marcoui* and *Gryphœa washitaensis*, Pl. II, figs. 1 and 2, and Pl. XX, figs. 1 and 2. In no essential features do these prodissoconchs differ from those of recent *Ostrea virginica* Gmel. The prodissoconch is more or less oval, with the umbones directed posteriorly.

The nepionic, when the specimens are well preserved, is in all cases distinctly marked off from the preceding prodissoconch and the succeeding neanic. This stage has usually the same form in all the species. It is generally elliptical in outline and smooth.

[1] Phylogeny of the Pelecypoda, the Aviculidæ and their allies, loc. cit., p. 47.

DESCRIPTION OF SPECIES.

GRYPHÆA.

GRYPHÆA WARDI, sp. nov.

Pl. I, figs. 1–16.

Upper valve.—The shape of the valve is irregular in outline. Two different areas can be recognized. First, one in which it is convex, the lines of growth being fine and the surface rather smooth. In this stage there are small ridges running approximately at right angles from the hinge margin. These raised lines when seen in profile present gently rounded upper surfaces with depressions between them. Second, succeeding this stage is one in which the outer margins of the valves turn upward somewhat abruptly. The length of one of the larger specimens is 19 mm., the breadth 18 mm. The margins are milled on the anterior portion. The muscular impression is deeply excavated on the anterior side, but not at all excavated on the posterior. The young of this species is broader than is usually the case in the other gryphæas herein considered; but it resembles those specimens of *G. marcoui* that have a large area of attachment for the lower valve. The sculpture, however, is different. Attention has been called to the fact that the markings running away from the hinge line in the species under consideration present a rounded upper surface. In those specimens of *G. marcoui* which have similarly shaped upper valves the markings are narrow ridges with wide flat areas between them. Whether this difference is of any importance we can not at present say, but probably it is not. No prodissoconch could be discovered; therefore we can not describe that early stage.

Lower valve.—The shape of the lower valve is extremely variable, its chief variation consisting in the amount and mode of attachment. The shells are thin and always small, the largest that we have seen being only 25.5 mm. long. The attached area may vary from 6 to 12 mm., or may be even more across, showing that in proportion to the size of the shell this area is very large. Sometimes the valve is attached to a gasteropod shell, and is correspondingly elongated parallel to the greatest length of the object to which it is attached. The surface may be plain, but is usually ornamented with rather strong folds parallel to the direction of elongation of the shell. The lines of growth are very regular; the margin is sharp and undoubtedly projected beyond that of the upper valve. A short distance within—in one specimen measured to be 2 mm.—are raised lines or crenulations corresponding to those of the upper valve. The direction of the cartilage pit is variable in both the upper and the lower valves, as it depends upon the amount and mode of attachment of the lower valve.

Upon first examining this species it is difficult to decide what its natural affinities with other oysters are, and it is only by comparison with other species that this could be discovered with certainty. The resemblance of the upper valve to that of certain specimens of *G. marcoui* has been pointed out. The forms of the species under discussion with small areas of attachment can not be distinguished from young specimens of *G. marcoui* with a rather large area of attachment. So far as we know, this species does not grow to the normal size of the Comanche Peak form.

The stratigraphic position of this gryphæa is in the Glen Rose beds of the Trinity division.

Specimens have been collected from the roadside between Bee Creek and Pedernalis River, Travis County, Texas, in the Blanco quadrangle on the road leading from Beecaves to Corwin; they have also been collected north of Onion Creek, near Driftwood post-office, Hays County, and Lohmann's Crossing of the Colorado River, Travis County.

As this species occurs not far below *Gryphæa marcoui* of the Comanche Peak formation, and as the two undoubtedly grade into each other, we must regard it as the immediate and undoubted ancestor of the latter.

GRYPHÆA MARCOUI, sp. nov.

Pls. II, III, IV, V.

Gryphæa pitcheri Blake (not Morton). Reports of Explorations and Surveys to ascertain the Most Practicable and Economical Route for a Railroad from the Mississippi River to the Pacific Ocean, Vol. II, 1855, Pope's Rept. on Route near 32d Par., The Geology of the Route, p. 39.

The following is the description of what may be considered a typical adult upper valve. The usual outline of the valve is oval, with the end which corresponds to the hinge margin truncated. The length of a valve of an ordinary size is 28 mm.; its greatest breadth is 20 mm.; the breadth at the hinge line is 8 mm. The surface for all stages succeeding the nepionic is rough; the cartilage pit, on account of the sharp incurving of the beak of the lower valve, is on the upper surface, and is wide in the specimen described. From the beak to the anterior margin of the cartilage pit is 4 mm. The sides of the valve in the anterior portion are sinuous but not especially thickened. The dorsal margin of the shell is sharply reflexed toward the right; the margins are milled through a variable extent; muscular impression is excavated on the anterior but not on the posterior side; in outline it is oval.

The adult lower valve normally has a strongly incurved narrow beak with a small area of attachment, slight ridges radiating from the beak, and a distinct dorsal sinus. The lines of growth are coarse.

The narrow beak is caused by the mantle spreading out but little in the stages extending from the neanic to the ephebic, including both. In the gerontic it spreads out considerably to the dorsal. It is the narrow incurved beak with a small area of attachment and the occurrence in the gerontic stage of an extremely deep dorsal sinus with a high dorsal wing that characterizes this species.

DEVELOPMENT OF THE UPPER VALVE.

Prodissoconch.—Among the upper valves of this species that we have we did not discover perfect prodissoconchs, but they were sufficiently well preserved to permit one to make out the chief features of the stage.

The form is suboval, with the more pointed end directed anteriorly and the umbones directed posteriorly. The stage is sharply marked off from the succeeding nepionic.

The nepionic.—The relationship that the nepionic growth bears to the prodissoconch is interesting. It should be stated here that the anterior margin of the prodissoconch is directed toward the ventral margin of the adult oyster, and the posterior margin of the prodissoconch is by necessity directed toward the dorsal margin of the adult oyster. The lines of growth of the nepionic extend around the anterior side of the prodissoconch in gentle curves, ceasing near the position of the umbones. The later growth on the ventral side of the nepionic continues in gentle curves. On the posterior side of the prodissoconch the nepionic lines of growth at first extend around in gentle curves, but after a very short time do not extend around it, and build a slight shoulder. The growth at this early stage is of such a character as to form a slight dorsal wing, and there are indications of the dorsal sinus. The surface of the shell in the nepionic stage is smooth, the lines of growth being indistinct. Usually the form is that of an elongate ellipse, the longer axis of the ellipse being parallel to the longer axis of the individual, but in some cases the form is subcircular instead of being elliptical. This variation in form is due to attachment of the lower valve. If the lower valve has a large area of attachment, its method of growth would necessarily be somewhat circular or of an irregular shape, and as the upper valve must conform to the outlines of the lower, we should see a variation of the upper valve corresponding to the varying form of the lower. We have called attention already to the close resemblance of the upper valves in some specimens of *G. marcoui* to those found in the preceding species. The size of the nepionic is about 6 mm. long and 5 mm. wide. In another specimen it is 7.5 mm. long and 5 mm. wide. The figures illustrate the variations well.

An interesting abnormality in this species is shown in one of the upper valves. Instead of adopting the ordinary gryphæate method of growth, by which the increase in growth is approximately the same on each side of a plane bisecting the two valves longitudinally, this specimen has assumed an exogyrate method of growth, the ventral margin growing very rapidly, whereas the dorsal margin has grown but slowly, in this way indicating that should the specimen have reached maturity it would have been forced into a spiral such as is characteristic of Exogyra.

The neanic.—This stage is introduced usually by the lines of growth becoming very distinct, the surface rough, and the postero-dorsal sinus more distinctly marked. In some specimens, in a stage which seems to correspond to the neanic, there are radiating impressed lines, but in the particular specimens to which we allude the surface is not rough, but rather smooth, and it may be that we are mistaken in considering this stage as neanic, though it seems to be such.

The ephebic.—The neanic stage passes imperceptibly into the adult or ephebic stage. The latter stage is indicated by a considerable bending to the right of the dorsal margin of the valve, thus marking very clearly the position of the dorsal sinus.

DEVELOPMENT OF THE LOWER VALVE.

On account of the attachment of the lower valve we were not able to discover the character of the prodissoconch, but the nepionic stage is well indicated. In forms which show small areas of attachment this stage is smooth, rather flat, curving but little, and is usually sharply marked off from the succeeding neanic. In other specimens with large areas of attachment the nepionic stage can not be so easily recognized. The form, at least in the later period of the stage, presents an elongate elliptical outline.

The neanic.—At the close of the nepionic stage the method of growth changes. Instead of being smooth and flat, curvature and very distinct lines of growth are initiated. This curvature seems to be caused by two combined principles. The first is that the lines of growth on the posterior part of the shell are much farther apart than on the anterior portion. This fact in itself would not give curvature unless the calcareous deposit of the mantle in the posterior part were much thicker than in the anterior portion. We know from the study of sections that the deposit of the mantle is thicker in the anterior than in the posterior portion; so this would tend to counteract the curvature. Each succeeding plate laid down by the mantle is at an angle to the preceding plate. The angle between the last plate and the preceding one is less than 180° on the interior of the shell and more than 180° on the exterior; so the chief mechanical principle involved in the curvature is due to the varying angles of these successive plates. It is aided, however, by the growth being more rapid in the posterior than in the anterior portion of the shell.

The ephebic.—The neanic stage is not distinctly marked off from the ephebic. The posterior dorsal sinus in the latter begins to show its characters in the nepionic, and does not increase until what is apparently the gerontic stage is reached.

The gerontic.—At the close of the ephebic stage the sinus becomes very deep and a high dorsal wing is protruded. Although some of the young forms show rather large areas of attachment in the very large suites of specimens we have examined, it does not seem that these specimens ever reach maturity.

In one specimen which we possess an interesting variation is seen. In this specimen, although we have the narrow beak which is one of the characteristics of the species, the margins dilate rather gradually and the shell is very much thicker in the anterior portion, so as to present characters almost identical with those of some forms of *G. mucronata.* In the gradual dilation of the sides also, and in the small curvature of the old-age or gerontic stage, a method of growth very similar to that of *G. corrugata* is assumed.

Geologic position.—In the Walnut clays, the base of the Comanche Peak beds, and occasionally in the Edwards limestone.

This species constitutes the horizon of *G. pitcheri* with *Exogyra texana* as given[1] in Hill's original section, and now known as the Walnut beds of the base of the Fredericksburg division.

Geographic distribution.—Parker, Bosque, Hamilton, Coleman, Coryell, Brown, and Hood counties of north-central Texas, constituting great masses of shell agglomerate, reaching in places 10 feet in thickness. Southward, in Travis, Burnet, and other counties, it is still abundant, but not so gregarious as in north and central Texas.

It is the form figured by Blake,[2] from Big Springs on the Colorado River, and called *Gryphæa pitcheri* by him.

In Edwards County, Texas, we collected the species in the Caprina limestone.

GRYPHÆA CORRUGATA Say.

Pls. V–XV, XVIII and XIX.

Gryphæa corrugata n. s. Say. Account of Exped. Pittsburg to Rocky Mountains, Vol. II, Phila., 1823, pp. 410–411.

Gryphæa pitcheri n. s. Morton. Synop. Org. Rem. Cret. Gr. U. S., Phila., 1834, p. 55, Pl. XV, fig. 9.

Gryphæa tucumcarii n. s. Marcou. Résumé of a géol. recon., etc.; Rept. Expl. R R. Route from Miss. River to Pacific: Whipple, House Doc. 129, Washington, 1851, pp. 44–48.

Gryphæa dilatata var. *tucumcarii* Marcou. Bull. Soc. géol. France, 2d series, Vol. XII, 1855, p. 880, Pl. XXI, figs. 1, 1a, 1b, 2, and 3.

Gryphæa pitcheri (Morton) Conrad. Rept. U. S. and Mex. Bound. Survey, Vol. I, 1857, Pt. II, p. 155, pl. 7, figs. 3a, 3b, and 3c (3d on this plate is probably a variety intermediate between *G. corrugata* and *G. navia* Hall, being more closely related to the latter species); pl. 10, fig. 2; and pl. 21, fig. 3a, b, c.

---

[1] Am. Jour. Sci., 3d series, Vol. XXXIII, 1887, pp. 298-299.

[2] Pacific Railroad Reports, Vol. II, 1855; Pope's rept. on route near 32d par., The geology of the route, p. 39.

Gryphœa pitcheri (Morton) Hall. Rept. Expl. and Surv. R. R. from Miss. River to Pacific, Vol. III, Washington, 1856, Pt. IV, pp. 99–100, Pl. I, figs. 1–6.

Gryphœa dilatata var. *tucumcarii* n. var. Marcou. Geology of North America, Zurich, 1858, pp. 43–44, Pl. IV, figs. 1, 1a, 1b, 2, and 3.

Gryphœa pitcheri (Morton) Gabb. Proc. Acad. Nat. Sci. Phila., Vol. XIII, 1861–1862, p. 22.

Gryphœa pitcheri (Morton) Gabb. Geol. Survey California, Paleontology, Vol. II, Phila., 1869, pp. 272–273.

Gryphœa pitcheri (Morton) Dana. Manual of Geology, 3d ed., 1880, p. 461, fig. 836.

Gryphœa pitcheri (Morton) var. *hilli.* n. var. Cragin. Am. Geologist, March, 1891, Vol. VII, p. 181.

Gryphœa pitcheri var. "*hilli* phase" Cragin. Am. Geologist, July, 1894, Vol. XIV, p. 6.

Gryphœa pitcheri var. *hilli* Cragin. Am. Geologist, July, 1894, Vol. XIV, p. 10.

Gryphœa pitcheri (Morton) Dana. Manual of Geology, 4th ed., 1895, p. 835, fig. 1359.

Gryphœa hilli Cragin. Am. Geologist, Dec., 1895, Vol. XVI, pp. 368, 369, and 371.

The following is Say's original description:[1]

Among the shells found about Red river, is one which approaches nearest to the variety of the *Gryphœa dilatata* of Sowerby, p. 149, fig. 2, but the lobe is far less distinct, and the shell is far more narrowed toward the hinge, and is somewhat less dilated, and much more like an ostrea. It may be called *G. corrugata;* small valve flat, and very much wrinkled, and like the other, narrowed near the hinge; the beak is short, and curved upwards and laterally, and the sulcus is very distinct. Length and greatest breadth of the small valve nearly equal, from 1½ inches to 2 inches; found by Mr. Nuttall on Red river. It is in a very perfect state of preservation.

The adult upper valve is subtriangular in outline, the greatest length in a typical specimen being 67 mm., its greatest width about the same; the width at the hinge line is about 22 mm. The margins are slightly crenulated; the shell is thick, being in a typical adult specimen about 11 mm.; the muscular impressions are well marked, slightly impressed anteriorly, and posteriorly there is a raised rim. In the anterior portion the shell is thickened on the sides considerably. These various features are shown in the figures.

Lower valve.—The adult specimen usually shows gradually widening margins with an incurved beak; the shell is boat-shaped and thick. The ligamental pit is large, the lines of growth are coarse, the dorsal sinus is distinct, and there is a considerable wing posterior to it. The beak is usually though not always slightly twisted toward the dorsal margin. The following are the measurements of what may be considered a normal adult: Length, 94 mm.; width, 67 mm.; length of cartilage pit, 14 mm.; greatest width of cartilage pit, 14 mm. An attempt has been made in the accompanying plates to show the variations of the species. The variation in the character of the beak

[1] Major Long's manuscript journal: Account of Long expedition, by Edwin James, Vol. II, Philadelphia, 1823, pp. 410–411.

and the reason of it will be stated later. As a usual thing, in the lower valve there is no carina, the region ventral to the dorsal sinus being gently rounded. In some forms, however, which have the beak slightly twisted, although there is no distinct carina, the portion of the shell below the dorsal sinus becomes much constricted. The constriction of this region of the shell is a very important fact and must be borne in mind in comparing it with *G. navia.* There is a great variation also in amount of dilation of the wings, and this variation must be borne in mind in considering the *G. washitaensis.*

In a collection from Duck Creek, near Denison, Texas, coming from the upper part of the Kiamitia clays, where they grade into the overlying Duck Creek beds, there are forms which can be recognized as belonging to the following species: *Gryphæa corrugata*, *Gryphæa navia*, and *Gryphæa washitaensis.* The *G. navia* approaches *G. corrugata* very closely, and *G. corrugata* apparently grades into *G. washitaensis*, though *G. washitaensis* and *G. navia* have great differences within themselves which would probably prevent their confusion.

Development of the upper valve.—Although we have large suites of this species, we were not able to discover any specimens with well-preserved prodissoconchs. As the prodissoconch is most probably the same for all species of oysters, the failure to discover it in this species is not a matter of very great moment. The nepionic stage was very well preserved and resembles in general characters that of *Gryphæa marcoui* rather closely, except that it is somewhat broader. This stage is characterized by a rather smooth method of growth. Its size is about 11 mm. long and 9 or 10 mm. wide.

Succeeding the nepionic stage the valves widen rather rapidly, with very coarse lines of growth, and a slight ridge near the dorsal margin indicates the position of the dorsal sinus.

Development of the lower valve.—This valve is usually attached during the early periods of growth, and we did not discover the prodissoconch. The stages succeeding this one can be made out with moderate distinctness. In very young specimens two types of development may be recognized. The first is one in which the area of attachment is quite small, or can not be seen, and the nepionic growth is elongate elliptical, the elliptical outline of the growth continuing through a considerable portion of the neanic stage. The second type is one in which the method of growth is not so elongately elliptical or may be subcircular. In one specimen which we studied, the nepionic growth in very early stages was elongate elliptical, and suddenly becomes more nearly subcircular. In some of those specimens which show considerable areas of attachment, we can not discuss the early stages with much satisfaction. The two methods of growth above described lead to two types of adults. The first method of growth leads to an adult with a rather narrow-pointed, sharply incurved beak. The second method leads to an adult with a blunt, slightly incurved beak. As we saw that the early stages of the two different types of growth were practically the same, it seems that the form with the elongate elliptical method of growth was one in which the embryonic characters persisted for a longer time. The neanic stage is marked off from the nepionic, as in the previously described species, by the introduction of a rapid curving of the valve. Some specimens show in this stage slight radiating folds. With the introduction of the neanic stage the dorsal sinus becomes much more distinctly marked, and a dorsal wing is present.

Varieties of Gryphæa corrugata.—This species shows several distinct varietal forms, as follows: (1) *G. corrugata* var. *hilli* Cragin. This occurs in great numbers near the base of the Kiowa shales of the Belvidere beds of Kansas, stratigraphically below the *G. navia.* and the larger varietal forms of *G. corrugata* to be mentioned later. This form, called *Gryphæa hilli* by Cragin, is beyond doubt a small ancestral form of *G. corrugata*, and shows comprehensive characters of the three forms *G. marcoui*, *G. corrugata*, and *G. navia.* The figures of var. *hilli* are given on Pl. VIII, figs. 8, 9, 11, 13, 14, and can be compared with the young individuals of *G. corrugata* from Goodland, Indian Territory, Pl. VI, figs. 1–4, and the figures of the cast of Morton's type of *G. pitcheri*, Pl. VI, figs. 5, 6, 7; (2) *G. corrugata* var. *tucumcarii.* The larger forms of *G. corrugata*, such as were figured by Marcou and called by him *Gryphæa dilatata* var. *tucumcarii*, good specimens of which are shown on Pls. XIII, XIV, and XVI, constitute a recognizable variety of *G. corrugata*, and come from a slightly higher horizon of the Washita division; (3) *G. corrugata* var. *belviderensis.* In the Belvidere beds of Kansas the larger specimens of *G. corrugata* (Pls. IX and X) also come from a higher horizon than the smaller forms mentioned and tend to assume a more triangular and flattened outline than the allied synchronous forms called var. *tucumcarii* (see Pl. XIV, figs. 1, 2; XVI, figs. 1, 2, 3; and XVII, fig. 5).

Geological occurrence.—The typical *G. corrugata* Say (*G. pitcheri* Morton) occurs in the upper portion of the Kiamitia beds of the Washita division, near their contact with the Duck Creek chalk, in the Red River portion of the main Cretaceous area. At Denison, Texas, this form appears in a bed in the Duck Creek chalk, which contains the last of the lower-ranging *G. navia* of Hall and the first of the upward-ranging *G. washitaensis* Hill. In the outlying areas *G. corrugata* var. *hilli* is the earliest to appear, and this is succeeded in ascending series by *G. navia*, and then by *G. corrugata* vars. *tucumcarii* and *belviderensis.*

Geographic distribution.—The normal type has its typical development in the main Texas area, in southern Indian Territory from the Arkansas line to Fort Washita, and in Cooke and Grayson counties, Texas. The southernmost localities reported are in the vicinity of Georgetown and Round Rock, Williamson County, and in the northern part of Travis County. The same conditions which have produced known differences in sedimentation between the outlying and main areas of the Cretaceous series seem to have facilitated varietal differences in the forms *G. corrugata*, which may explain the fact that the large forms which we have called vars. *tucumcarii* and *belviderensis* occur only in these outlying areas in Barber, Comanche, Kiowa, and other counties in southern Kansas and along the eastern breaks of the plains; thence southward through Oklahoma to the head of the Washita River; in the Tucumcari region of New Mexico, and near the base of the Rio Grande section west of El Paso, Kent, and other places in Trans-Pecos Texas.

From Nuttall's writings we learn that the exact locality of his original collection was on the plains of the Kiamitia, about 14 miles northwest of the mouth of that stream. The present town of Goodland, Choctaw Nation, is as near the locality as can be identified, and from this place the senior author collected several hundred shells of this species, which are now deposited with his collection in the State capitol of Texas. Later the junior author made a second collection from the same locality, which is now in the United States National Museum.

Phylogeny of Gryphæa corrugata.—In discussing the young forms of this species the two types of growth have been described. Of the two types described, the one with the narrow beak is the one in which it is probable that the embryonic method of growth has persisted for the longest time. This, as we have shown, gives rise to a narrow, elongate beak. We also have noticed in the early stages the presence of narrow radiating folds. Reasoning a priori, we should expect the ancestor of this species to be a form with a narrow beak, and one which possessed radiating folds. In searching for a form which could probably have given rise to this, our attention is directed to *G. marcoui*, which possesses both the narrow incurved beak and the radiating folds. There is stronger reason than this, however, for associating these two species phylogenetically. It was shown in discussing *G. marcoui* that sometimes it assumes a variation which is very similar to the type of growth of *G. corrugata.* Putting together all the facts that we have regarding the development and variations of *G. corrugata*, its stratigraphic occurrence, and those facts that we have concerning the development and variation of *G. marcoui*, the conclusion seems justifiable that the former is descended from the latter or from some closely allied form.

GRYPHÆA NAVIA Hall.

Pls. XVII, XVIII.

Gryphæa pitcheri Marcou (not Morton). Bull. Soc. Geol. France, 2d series, Vol. XII, 1855, p. 883, Pl. XXI, figs. 5, 5a-b and 6.

Gryphæa pitcheri var. *navia* Hall n. var. Rept. Expl. and Surv. R. R. from Miss. River to Pacific, Vol. III, Washington, 1856, Pt. IV, p. 100, Pl. I, figs. 7-10.

Gryphæa pitcheri var. *navia* Conrad (in part). Rept. U. S. and Mex. Bound. Survey, Vol. I, Washington, 1857, Pt. II, p. 155, pl. 7, fig. 3d. (The specimen figured in the place here referred to is a form somewhat intermediate between *G. corrugata* and *G. navia*, but is more closely related to the latter species.)

Gryphæa pitcheri Marcou (not Morton). Geology of North America, Zurich, 1858, pp. 38–40, pl. 4, figs. 5, 5a, b, c, and 6.

Gryphæa roemeri Marcou. Proc. Boston Soc. Nat. Hist., Vol. VIII, 1862, p. 95.

Gryphæa navia Gabb. Proc. Acad. Nat. Sci., Phila. for 1861, 1862, p. 22.

Gryphæa navia (Conrad) Gabb. Geol. Survey California, Paleontology, Vol. II, Phila., 1869, pp. 273–274.

Ostrea pitcheri Coquand (in part). Mon. du genre Ostrea, Terr. Crétacé, 1869, p. 40, Pl. XII, figs. 5 and 6.

Exogyra forniculata n. s. White. Proc. U. S. Nat. Mus., Vol. II (1879), Washington, 1880, Pt. II, pp. 293–294, pl. 4, figs. 3 and 4. Smithsonian Miscell. Coll., Vol. XIX, Washington, 1880, pp. 293–294.

Exogyra forniculata White. Twelfth Ann. Rept. U. S. Geol. and Geog. Surv. Terr., Washington, 1883, pp. 13 and 14, Pt. I, pl. 14, figs. 2a and 2b.

Exogyra forniculata White. Fourth Ann. Rept. U. S. Geol. Surv., Washington, 1884, p. 305, Pl. LII, figs. 1 and 2.

Gryphæa pitcheri Brown (not Morton). Proc. Acad. Nat. Sci., Phila., for 1894, p. 65.

Upper valve.—General form ovate, the posterior dorsal portion reflexed toward the right. The cartilage pit descends somewhat from the apex ventrad. Dorsal margin of the valve considerably thickened; ventral margin of the valve very much thickened. Both the dorsal and ventral margins marked by minute transverse striæ, which are especially distinct on the latter. Posterior margin of the valve not especially thickened. Lines of growth coarse; the plates constituting the shell structure are thick. The nepionic stage distinctly marked off from the succeeding growth. Its size is 12 mm. long by 8 mm. wide. The figures on Pl. XVIII illustrate the characters above described.

Lower valve.—The nepionic and early neanic stages of this valve are practically the same as those individuals of *G. corrugata* which possess a prolonged beak. In the later neanic stage, however, a carina begins to be developed and the mantle spreads out dorsally, thus producing a dorsal wing. On the lower side the valve is sharply incurved, so that a carina is produced. Between the wing to the dorsal of the sinus and the carina there is a depressed area which is frequently marked by slight ridges running from the beak. This species is very easily characterized by the possession of the carina, the depressed area extending from the carina to the dorsal sinus, the bending toward the dorsal margin, and the strong incurving of the beaks. It has already been noted that the features in the young stages of this species are possessed in their entirety by some varieties of *G. corrugata*, and there seems to be no doubt, in spite of the usual great distinctness of the adult of *G. corrugata* and *G. navia*, that they are both derived from an ancestral form of the typical *G. corrugata*.

This conclusion, however, is not based merely on the studying of the development, but the specimens from the Kiamitia clays of Duck Creek, near Denison, connect the two species very closely; in fact, so closely that it is with considerable difficulty that some specimens can be referred to either one or the other.

Geologic and geographic distribution.—In the main Texas area this form is found in the Kiamitia clays at the base of the Washita division, from the Arkansas State line in Indian Territory westward through the prairies of the Kiamitia to near Marietta, and thence southward through Texas to the Colorado, always in the same geological horizon. It is the chief species found on the plains of the Kiamitia, in northern Texas and in Indian Territory, where it occurs by millions. The form is especially abundant at old Fort Washita, Indian Territory, where the buildings are constructed of flags formed almost entirely of these shells. The high prairie surmounting Red River Valley south of old Preston is also marked by this species. In Grayson County, Texas, at the top of the Kiamitia clays, near their contact with the overlying Duck Creek chalk, *G. navia* is mixed with *G. washitaensis* Hill, *G. corrugata* Say, and *Exogyra plexa* Cragin. In the "outlying areas of the Comanche series" the species occurs abundantly in the southern counties of Kansas, Kiowa and Comanche; near old Camp Supply, 10 miles west of north from Taloga, 18 miles north of Arapahoe, 10 miles south of west from Arapahoe, and, according to Mr. G. T. Dulaney, 21 miles north of west from Arapahoe, in the bluffs of Panther Creek, in Oklahoma. Marcou's original localities are between the South Fork of the Canadian and the Washita River, west of Arapahoe. It is very abundant in the Pass of the Rio Grande, 3 miles west of El Paso, Texas.

It is a singular fact that this form does not occur abundantly, if at all, south of the Colorado River, but is apparently confined to the northern provinces of the areal outcrop of the Comanche series.

GRYPHÆA WASHITAENSIS Hill.

Pls. XIX, XX, XXI, XXII, XXIII.

Gryphœa pitcheri Morton, var. *dilatata* Hill. Am. Jour. Sci., 3d series, Vol. XXXIV, 1887, p. 303.

Gryphœa washitaensis Hill sp. nov. Check List of the Invertebrate Fossils from the Cretaceous Formations of Texas, 1st ed., 1889, p. 11.

Gryphœa washitaensis Hill, sp. nov. A Preliminary Annotated Check List of the Cretaceous Invertebrate Fossils of Texas: Bull. Geol. Survey Texas, No. 4, 1889, p. 4.

Gryphœa pitcheri Heilprin (not Morton). Proc. Acad. Nat. Sci., Phila., 1890, p. 452.

Gryphœa gibberosa Cragin. A Contribution to the Paleontology of the Texas Cretaceous: Ann. Rept. Geol. Survey Texas, Austin, June, 1893, pp. 189–190, Pl. XXX, figs. 1 and 2.

The outline of the adult upper valve is elliptical, with a wing protruding on the dorsal side and truncated anteriorly at the hinge line. It is rather deeply concave. The nepionic stage is usually very distinctly marked on the adult valve. The surface in the stages succeeding the nepionic is rather rough, but the lines of growth are delicate. The valve is thin; the dorsal sinus is well marked. The size of a normal adult is: length, 31 mm.; width, 25 mm.; width of cartilage pit, 8 mm.; length of cartilage pit, 4 mm. The cartilage pit is slightly inclined posteriorly—that is, a line running from the base of the cartilage pit to the apex, or where the prodissoconch should be, would have its upper portion inclined toward the posterior margin of the shell. The margins in the posterior part are rather sharp and turned up abruptly; in the anterior portion they are considerably thickened, the thickening being much greater on the ventral than on the dorsal side. The muscular impression is faint.

The lower valve of this species usually has a strongly developed dorsal wing and a considerably developed ventral wing. On account of the strong development of the wings in this species, Mr. Hill has been inclined to class it differently from the others of our Lower Cretaceous Gryphæas. The shell is deeply excavated; the lines of growth are usually rather fine, and the shell is thin. The beak is strongly incurved and the cartilage pit rather deep. The muscular impression is only moderately distinct, being slightly impressed on the anterior side and not impressed on the posterior side. The upper valve sits in the lower valve for a considerable distance. The size and general types of variation of this species are shown in the figures.

DEVELOPMENT OF THE UPPER VALVE.

Prodissoconch.—Of this species most excellent material was obtained. In fact, the specimens are so well preserved that the development of the shell can be made out quite as well as if special pains had been taken to grow the young forms on glass plates, as Jackson did in his study of oysters. The prodissoconch is subcircular, very slightly wider anteriorly than posteriorly; the beak is directed posteriorly and is situated near the posterior margin. It is about 5 mm. in diameter.

The nepionic.—The prodissoconch is followed by the nepionic stage, from which it is sharply marked off. The nepionic growth on the anterior side continues parallel to the margin of the prodissoconch for a considerable time. On the posterior side it at first makes a slight shoulder against the prodissoconch. Ultimately there is a spreading out dorsally, that is, posteriorly to the prodissoconch, so as to form a slight wing. In the early part of the nepionic stage the lines of growth are subcircular or semicircular; as the shell grows older they assume a more elliptical outline. The completed nepionic is elliptical, being truncated on the anterior margin. Its size is about 9 mm. long by 7 mm. wide. The surface is smooth. In the older part of the stage the valve begins to be concave externally. The nepionic stage is marked off from the neanic by the concavity increasing rapidly. The dorsal side of the valve is bent more than the ventral. A dorsal sinus is very slightly indicated and the surface becomes rather rough from the failure of each succeeding layer of growth to cover to the margin the preceding one. The layers of growth turn up a little at the close of their secretion. As each succeeding layer of growth grows in a general way parallel to the valve, these little margins are left standing up.

THE LOWER VALVE.

Prodissoconch.—It is rather phenomenal to find the prodissoconch of the lower valve of a fossil oyster well enough preserved to be studied. In the species under consideration, although the prodissoconch was not well preserved, enough was left to make out its chief features, which coincide with what is known of all other species of oysters; that is, it is subelliptical or suboval, with the umbones directed posteriorly and sharply marked off from the succeeding nepionic.

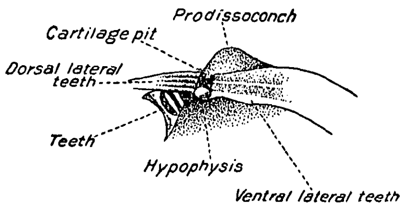


FIG. 1.—Hinge of lower valve of *G. washitaensis*, nepionic stage.

The nepionic.—The nepionic stage is characterized in this species, as in the others, by having a rather flat method of growth. Its surface is smooth; the lines of growth at first are subcircular in form, being truncated along the hinge margin, and gradually become more elliptical. On the ventral side the margin is gently curved, whereas on the dorsal side, even at this early stage, a slight wing is developed. The margins in the anterior portion are crenulated. The posterior portion is flat, rather wide; the muscular impression is rather distinct and has an irregularly quadrangular shape, being somewhat square on the interior ventral side, rounded on the anterior dorsal side, with a short truncation on the posterior side. Along the hinge line ventral to the cartilage pit are apparently two lateral teeth. Dorsal to the cartilage pit are four very narrow lateral teeth; in the posterior portion of the cartilage pit is a small hypophysis. Just interior to the dorsal lateral teeth and subparallel to the margin of the shell are crenulations.

Neanic stage.—Succeeding the nepionic stage the curvature of the valve becomes abrupt and the neanic growth is almost at right angles to the nepionic. For a considerable time after the close of the nepionic stage there are no lateral wings developed, and we should define the neanic stage as that included between the close of the nepionic and that when the dorsal wing begins to be developed to such a large extent.

The adult or ephebic stage was described before discussing the development.

Gerontic stage.—In this stage the shell is gibbous, very thick, and has lost its lateral wings. To a form representing this stage Professor Cragin has given the name *G. gibberosa.*

Phylogeny.—This species presents an enormous amount of variation. In some the lateral wings are very much developed; in other specimens they are but slightly developed, and we have noticed the peculiar type of the neanic growth. This neanic stage corresponds almost precisely to the characters of the adult *G. corrugata.* In the collections from Duck Creek, near Denison, it is almost impossible to separate *G. washitaensis* from *G. corrugata*, and it seems that the two species there grade into each other. From the intergradation of the two species and from the neanic stage of *G. washitaensis*, representing the adult of *G. corrugata,* there seems to be no doubt that *G. washitaensis* is a direct descendant of *G. corrugata.*

The hemera of *G. washitaensis* is from the top of the Kiamitia clays, through the Duck Creek and Fort Worth into the base of the Denison beds, reaching its greatest development in the agglomerates near the base of the latter. It is a fossil which in its greatest development occupies a stratigraphic position above the horizon of *G. corrugata,* and *G. corrugata* reaches its greatest development in beds stratigraphically below *G. washitaensis.* From these facts it seems that *G. washitaensis* of the middle and upper portion of the Washita of Texas is a direct descendant of *G. corrugata,* which became extinct in the lower Washita.

Geologic occurrence and geographic distribution.—*Gryphæa washitaensis* is characteristic of the medial portion of the Washita division, making its first appearance at the contact of the Kiamitia and Duck Creek beds, where it is relatively sparsely represented, and attaining its maximum numerical development in the great sheets of Gryphæa near the contact of the Fort Worth and Denison beds, in the basal portion of the latter. These agglomerates of *Gryphæa washitaensis* can be traced from Denison, on Red River, to Austin, a distance of nearly 300 miles, constituting a unique formation. They are usually, if not always, closely associated with *Ostrea* (*Alectryonia*) *carinata* Lam. The latter does not occur in large numbers, however. This bed is well exposed in the northern suburbs of Denison, near the cemetery, in the railway cuts in the suburbs of Fort Worth, and in the railway cuts of West Austin. *G. washitaensis* is also very abundant in the pass of the Rio Grande west of El Paso.

GRYPHÆA MUCRONATA Gabb.

Pls. XXIV, XXV, XXVI, XXVII, XXVIII, XXIX, and XXX.

Gryphæa pitcheri Roemer (not Morton). Texas mit besonderer Rücksicht, etc., Bonn, 1849, pp. 394-395.
Gryphæa pitcheri Roemer. Die Kreidebild. von Texas und ihre organ. Einchl., Bonn, 1852, pp. 73-74, Pl. IX, fig. 1a, b, c.
Gryphæa pitcheri var. *navia* (in part) Hall. Rept. Expl. and Surv. R. R. from Miss. River to Pacific, Vol. III, 1856, Pt. IV, p. 100.
Gryphæa pitcheri var. *navia*, Conrad (in part). Rept. Mex. Bound. Survey, Pt. II, 1857, p. 155.
Gryphæa pitcheri Owen (not Morton). Second Rept. Geol. Surv. Arkansas, Phila., 1860, pl. 7, fig. 6.
Gryphæa mucronata Gabb sp. nov. Geol. Surv. California, Paleontology, vol. 2, Philadelphia, 1869, pp. 274-275.
Ostrea pitcheri Coquand (in part). Mon. du Genre Ostrea Terr. Crétacé, 1869, p. 40, Pl. IX, figs. 9-12.
Gryphæa navia (Conrad in part). White, Fourth Ann. Rept. U. S. Geol. Survey, 1884, p. 302, Pl. XLIX, figs. 3, 4, 5, and 6.

Upper valve.—Form usually elongate oval, generally thick, frequently much thickened along the margins in the anterior portion, especially on the ventral side. Size indicated on plate.

Lower valve.—Owing to the varying size of the attached area the form of the shell is very variable. The typical form is naviate, with a sharp, constricted, much incurved beak. The shell is massive, very much thickened in the anterior portion, and the lines of growth are very coarse. The dorsal sinus is distinctly marked.

The general characters of this species and its development correspond very closely with *Gryphæa marcoui.* It can be distinguished by the following characters: In the first place, it is a larger shell than *Gryphæa marcoui.* In the second place, the region of the beak is not quite so much constricted; the dorsal sinus is indicated at a considerably earlier stage. The lines of growth are much coarser and the shell is more ponderous. Another distinction is the great variability of this species, which the figured specimens show.

In a species which presents such enormous variations as the one under consideration, it is necessary to try to discover some characters which will enable us to recognize it. The method that we have used is to get a large suite of specimens, and by careful comparison show the intergradation of the forms; but it seems that some characters can be discovered which are common to the whole series. One of these is, in a general way, the width of the adult valves, which is approximately the same. Another is in the texture of the shell. The lines of growth are very coarse, and the successive layers which compose the shell are very thick. Although these characters will appear as extremely meager, yet of all the specimens of Gryphæa which have passed under our notice none present the exact duplicates of what are seen in *Gryphæa mucronata.* We have given figures illustrating the principal types of variation found in this species, and it is to be hoped that from these one may be able to recognize the form.

Development of the upper valve.—The great variation of this species depends to a large extent upon the variation in the size of the attached area. Some of the specimens are attached only by a very small area, whereas in others the area of attachment is one-fourth to one-third of the whole outer surface of the upper valve. This variation in the amount of attachment has induced a corresponding variation in the shape and method of growth of the upper valve. One specimen showed faint indications of the presence of the prodissoconch, but these were so faint that an accurate description of the prodissoconch is impossible. It can be discovered, however, that the umbones were directed posteriorly. The nepionic stage is not very well marked off from the succeeding neanic, but in the typical valve—that is, one in which the area of attachment is small—the method of growth is elongately elliptical. The lines of growth are not very well marked, but with the introduction of the neanic they become much more distinct. The neanic can not be separated from the succeeding ephebic. The dorsal sinus does not become very distinct until the shell has attained considerable size, and even then sometimes its position can be made out only with difficulty. In searching for similar development in other species, we find that it more closely resembles what is discovered in *G. marcoui*, the form being much more like that of the latter species than that of *corrugata.*

The development of the lower valve.—In specimens with a wide area of attachment not a great deal can be said as to the development. In specimens of small areas of attachment the nepionic stage is quite distinctly marked, it being rather flat, with very slight indications of a dorsal wing. The form is rather elongate elliptical, depending in shape to a considerable degree upon the extent of the attached area. In the specimens with the small areas of attachment the nepionic growth is somewhat marked off from the succeeding growth. In a general way the nepionic method of growth is continued far into the later life of the mollusk; that is, the elongate-elliptical outline of the lines of growth continues, but at the close of the nepionic stage the curvature of the shell begins. We have also in this species, as was noticed in *Gryphæa marcoui*, the frequent occurrence of slight ridges, which radiate from the beak. The dorsal sinus in the adult is also distinctly marked. In the adult shell, which has a small area of attachment, we have a rather narrow and strongly incurved beak, always showing at its tip an indication of the point of fixation.

Gryphæa mucronata occurs in greatest abundance in the upper portion of the Del Rio (*Exogyra arietina*) beds and in the base of the overlying Shoal Creek limestone from the Brazos southward to the

Guadalupe. It is well shown in Shoal and Barton creeks, near Austin. North of the Colorado it occurs abundantly in the Grayson beds overlying the Main street limestone, as near Handley, a few miles east of Fort Worth, and northward toward Red River at Denison. It also occurs in the Trans-Pecos region and as far west as Sonora, according to Gabb.

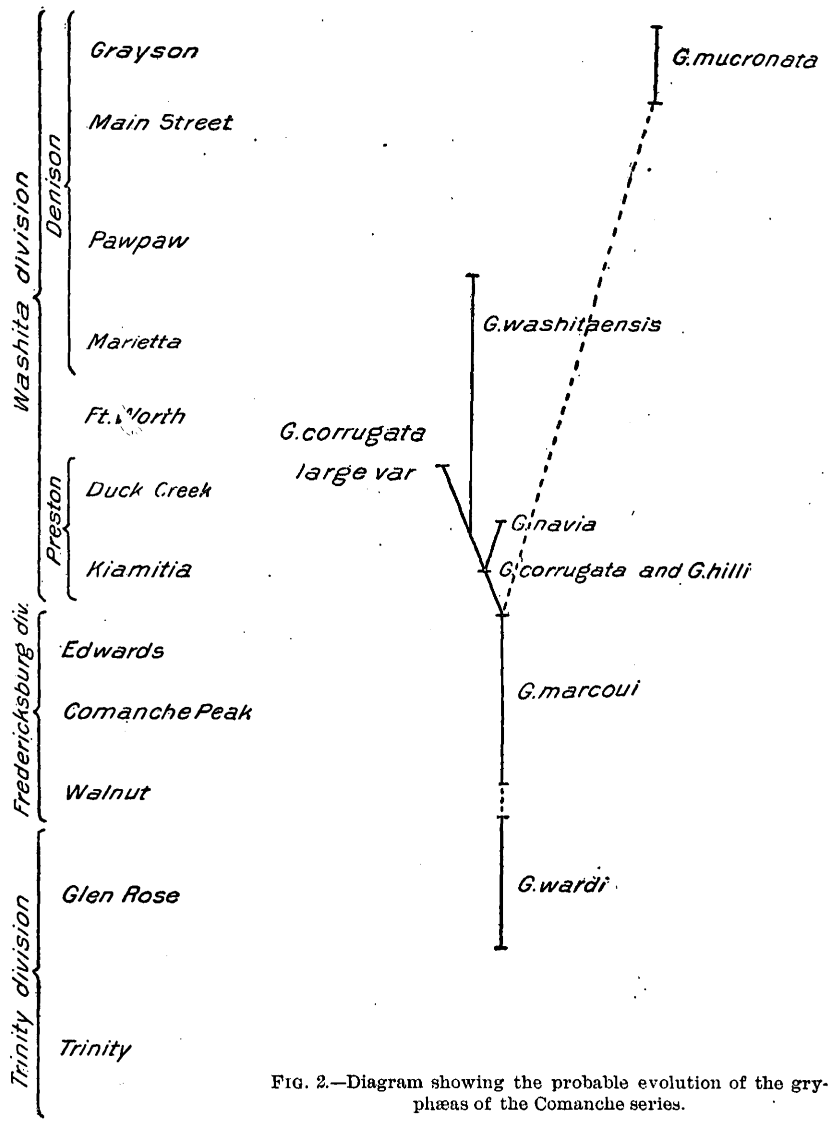


FIG. 2.—Diagram showing the probable evolution of the gryphæas of the Comanche series.

RELATIONSHIP AND EVOLUTION OF THE GRYPHÆAS.

From the foregoing study of the development, variation, and stratigraphic distribution of the gryphæas, it seems probable that the résumé of their genetic relationships shown in fig. 2 is correct.

The earliest form found is *Gryphæa wardi* of the Glen Rose beds of the Trinity division. From it the *G. marcoui* of the Walnut clays, Comanche Peak limestone, and Edwards limestone was derived by direct descent. The beds intervening between the Comanche Peak limestone (of the Fredericksburg division) and the Kiamitia clays (at the base of the Washita division) have yielded but few specimens of Gryphæa, so we have not been able to discover as definite intermediate examples between the species occurring in the two beds above mentioned as we desired.

The next Gryphæa to occur after the *G. marcoui* is the variety of *G. corrugata* called by Cragin *G. hilli*, found in the Champion shell bed of Cragin at the base of the Kiowa shales, and immediately overlying the Cheyenne sandstone, near Belvidere, Kansas. This variety, though referable to *G. corrugata*, presents many synthetic characters connecting the Gryphæas of the Washita division with the *G. marcoui* of the Fredericksburg. From this variety as a lateral offshoot, the *G. navia* of the Kiamitia clays has originated on one hand; on the other, and usually occurring above the *G. navia*, the large varieties of *G. corrugata*, *tucumcarii*, and *belviderensis* have arisen. From the larger forms of *G. corrugata*, as can be shown by the direct intergradation of the species, *G. washitaensis* was derived in the latter part of the time of the deposition of the Kiamitia clays. *G. corrugata* does not range above the Duck Creek chalk, while *G. washitaensis* continues through the Fort Worth limestone into the base of the Marietta beds.

In the upper marly layers of the Denison beds at the top of the Comanche series *G. mucronata* appears. This form, although in general a more robust species, in some of its varieties is almost a reappearance of *G. marcoui*, and there seems no doubt that it is a descendant of the latter form, furnishing an interesting example of how a similar or only slightly modified form may reappear after a long interval of time, when similar physical conditions recur.

PLATES.

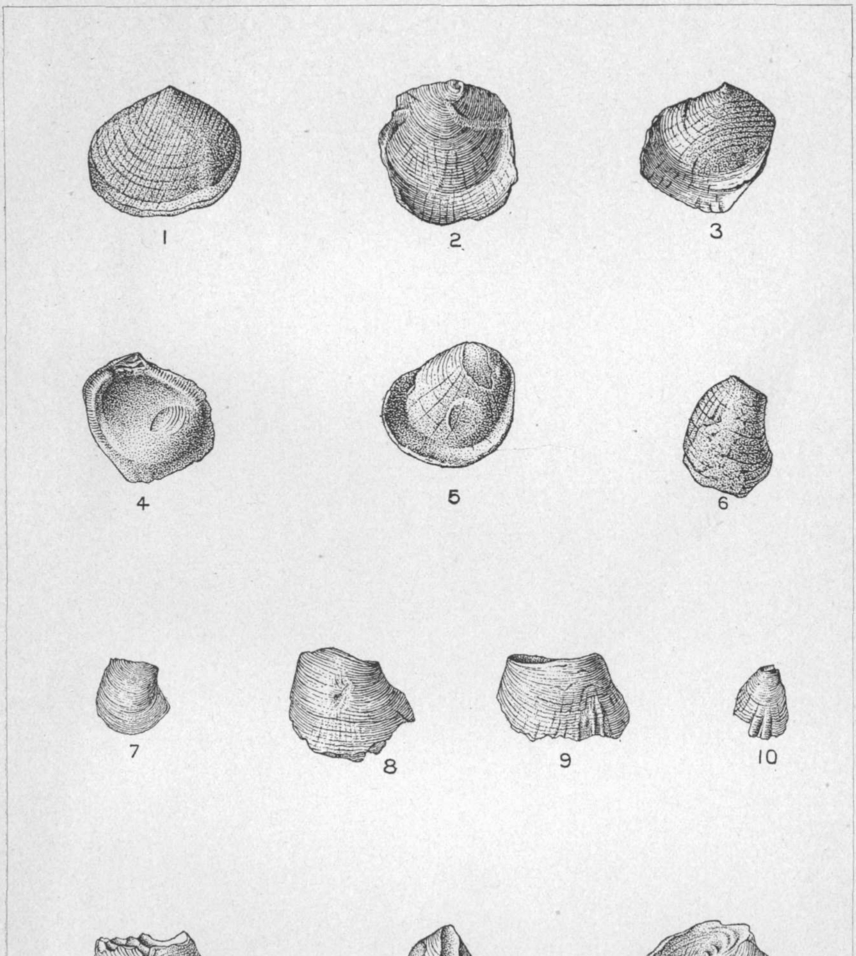
PLATE I.

PLATE I.

Gryphæa wardi sp. nov. (pp. 49–50).

Figs. 1–5. Upper valves. Fig. 1 enlarged twice; others natural size.

6–16. Lower valves. All natural size.



GRYPHÆA WARDI.

PLATE II.

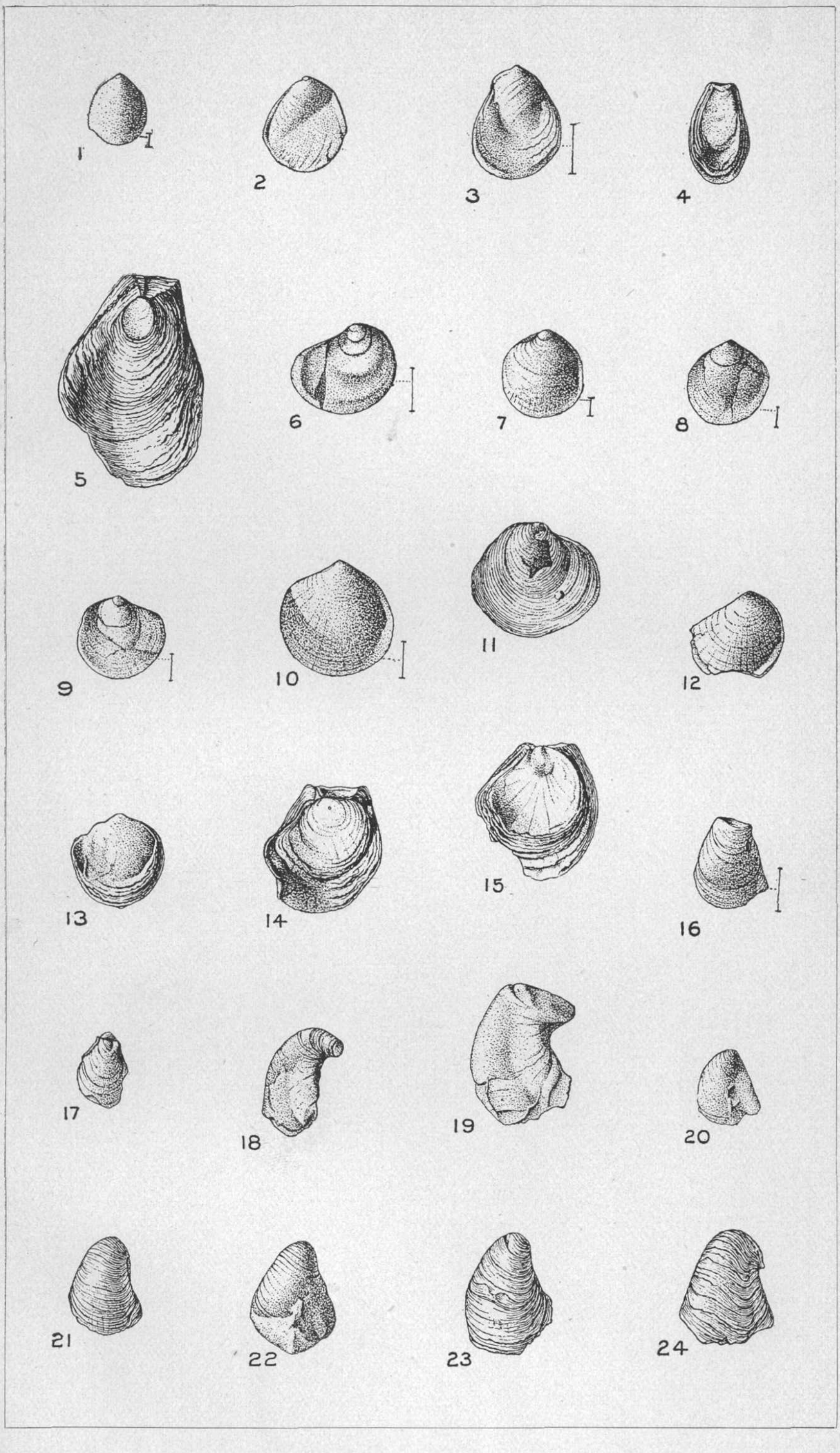
PLATE II.

GRYPHÆA MARCOUI sp. nov. (pp. 50–53).

Figs. 1–15. Series of upper valves, showing the development of the elliptical type of valve. Figs. 1 and 2 show small prodissoconchs. Note the smooth nepionic stage, succeeding the prodissoconch stage. Fig. 6 is a young upper valve (p. 51) of the nepionic stage that shows a tendency toward an exogyrate growth. Figs. 7–15 show development of the broader type of valve. Figs. 7–11, valves in the nepionic stage. Figs. 7–9 have parts of the prodissoconchs still attached, and the outline thereof is preserved in fig. 7, although the apex is worn off.

Figs. 16–24. Young stages of lower valve. Figs. 16, 17, and 20 are the nepionic stage. Figs. 18 and 19 show the sharp curvature at the close of the nepionic and beginning of the neanic stage.

All figures natural size except where otherwise indicated on plate.



GRYPHÆA MARCOUI.

PLATE III.

PLATE III.

GRYPHÆA MARCOUI sp. nov., lower valves (pp. 50–53).

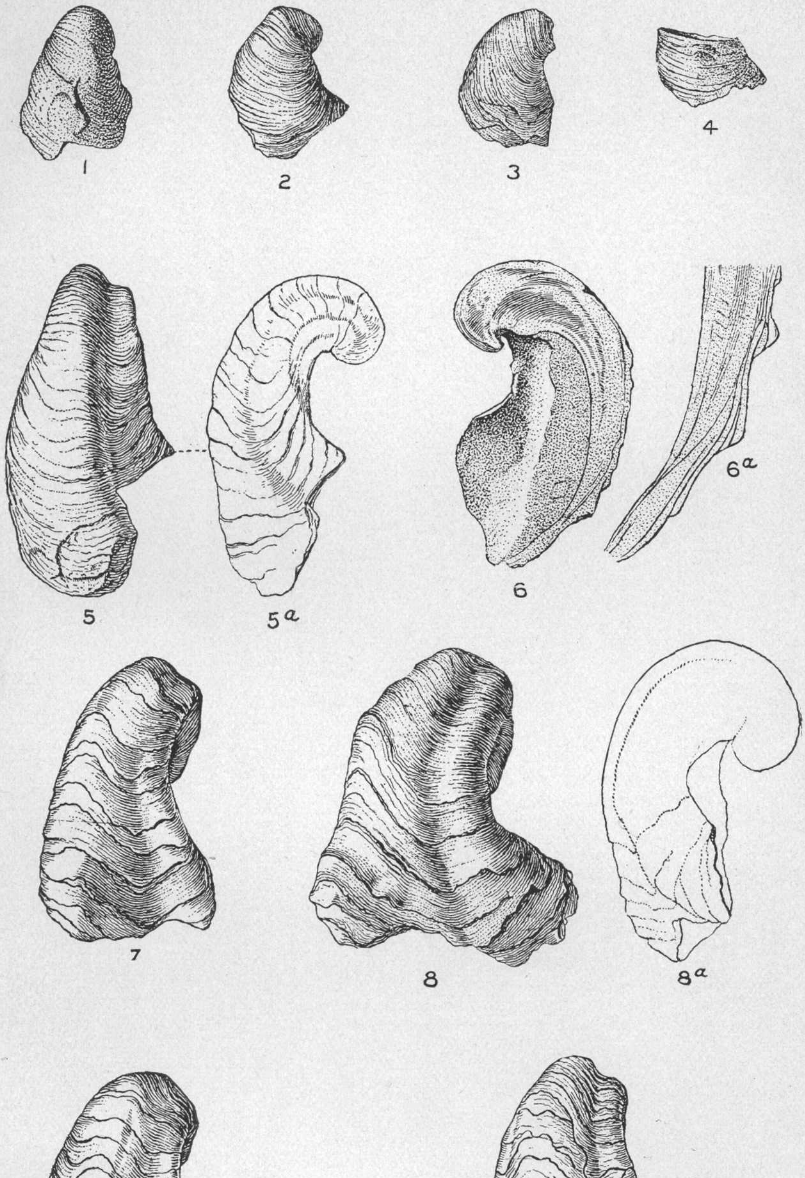
Figs. 1–4. Types of young valves.

5 and 7–10. Variations of the valves of adults (further shown in figs. 1–4 of Plate IV).

8. Specimens passing into gerontic stage. (See also fig. 1, Pl. IV.)

6, 6*a*. Section of a valve. Fig. 6*a* enlarged to show method of overlapping of the successive plates.

All natural size.



GRYPHÆA MARCOUI.

PLATE IV.

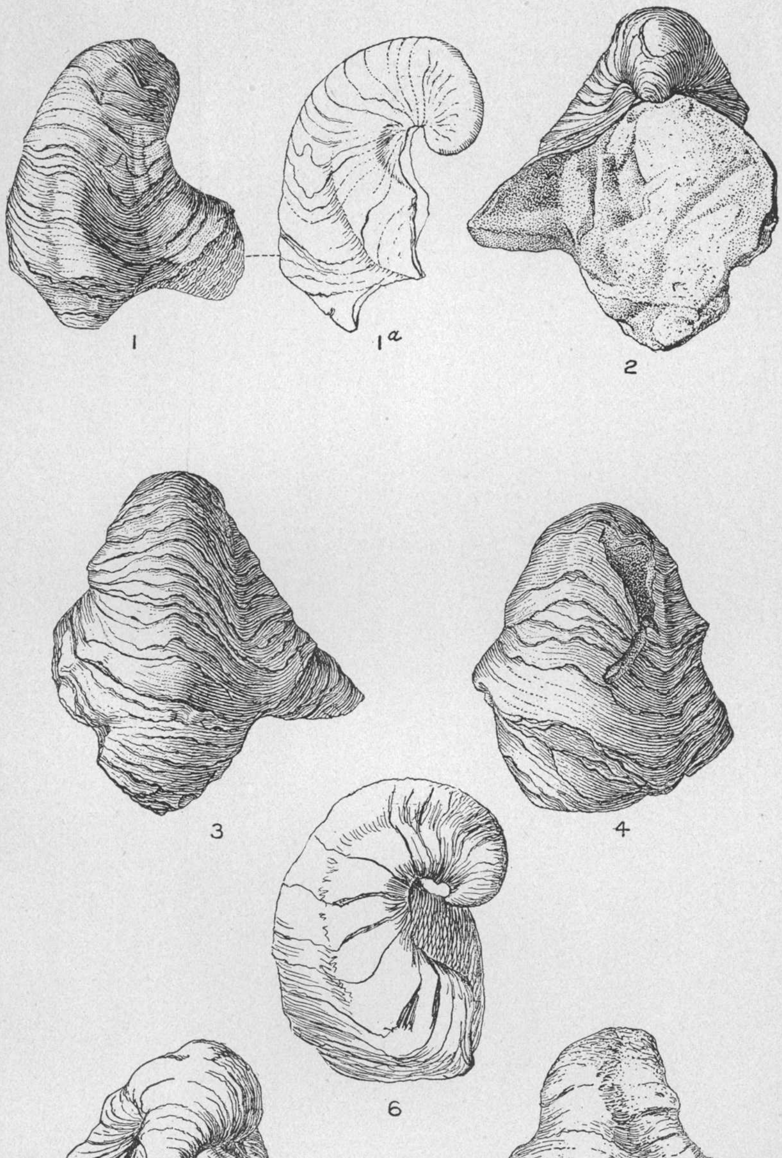
PLATE IV.

GRYPHÆA MARCOUI sp. nov., adult forms (pp. 50–53).

Figs. 1–3. Specimens showing passage into gerontic stage. Figs. 2 and 3 are reverse views of same specimen.

1, 1a, 3–7. Lower valves. Figs. 5–7. Views of same specimen.

All figures natural size.



GRYPHÆA MARCOUI.

PLATE V.

PLATE V.

GRYPHÆA MARCOUI sp. nov., adult forms (pp. 50–53).

Figs. 1, 2. Different views of a single specimen.

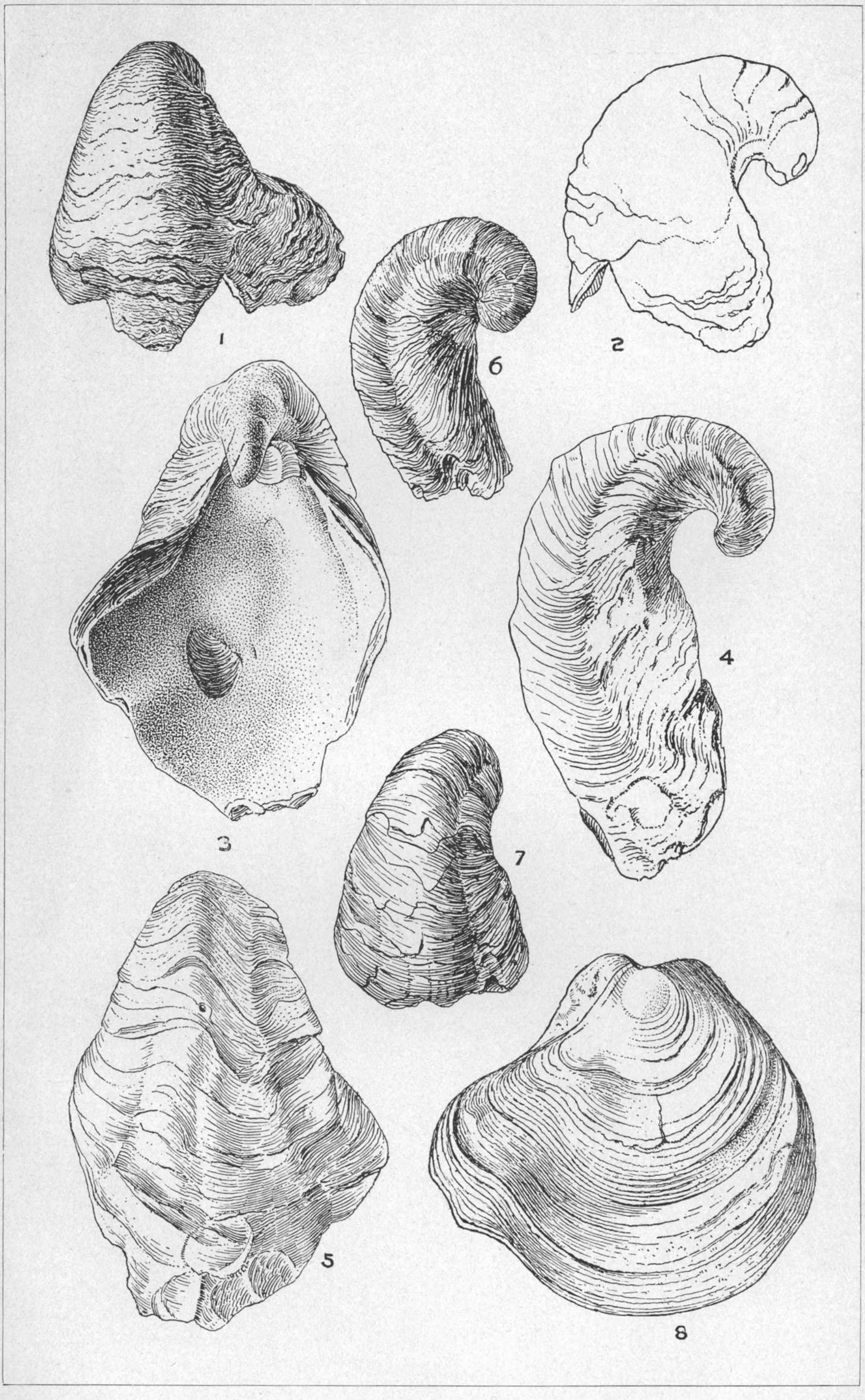
Figs. 3, 4, 5. A specimen which in its later growth gently flared out, assuming a method of growth similar to *G. corrugata* Say (see pp. 53–57).

Figs. 6, 7. Different views of a specimen from the Edwards limestone.

GRYPHÆA CORRUGATA Say (pp. 53–57).

Fig. 8. Upper valve. Note the early stages of growth.

All figures natural size.



GRYPHÆA MARCOUI and G. CORRUGATA.

PLATE VI.

PLATE VI.

GRYPHÆA CORRUGATA Say (pp. 53-57).

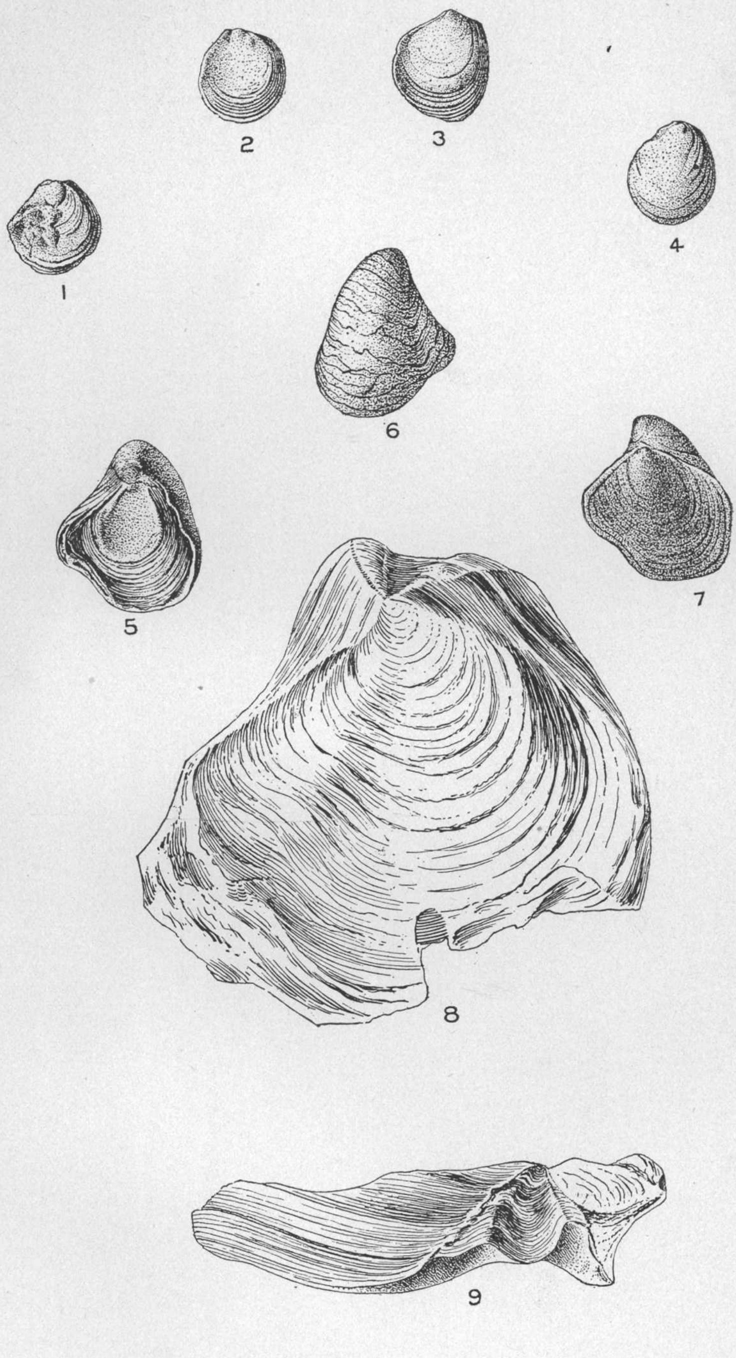
Figs. 1-4. Young valves. showing the smooth nepionic stage.

Figs. 5-6. Drawings of casts of Morton's original types of *Gryphæa pitcheri*. The casts were very kindly furnished us by Prof. F. W. Simonds, of the University of Texas.

Fig. 7. A copy of Morton's original figure of *Gryphæa pitcheri.*

Figs. 8, 9. Two views of same valve.

All figures natural size.



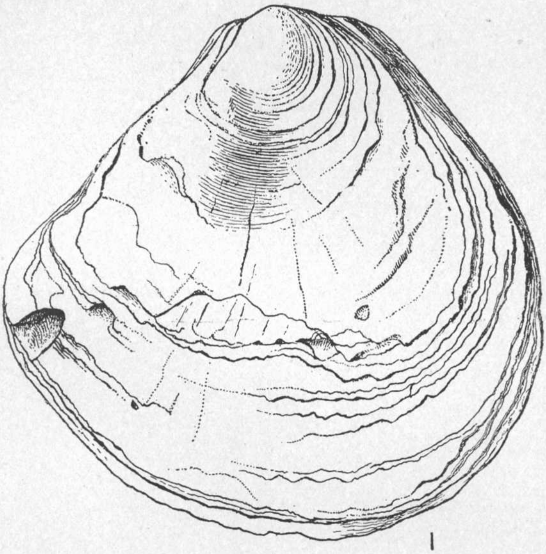
GRYPHÆA CORRUGATA Say.

PLATE VII.

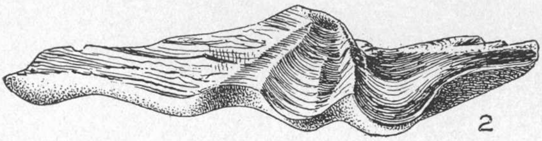
PLATE VII.

GRYPHÆA CORRUGATA Say (pp. 53–57).

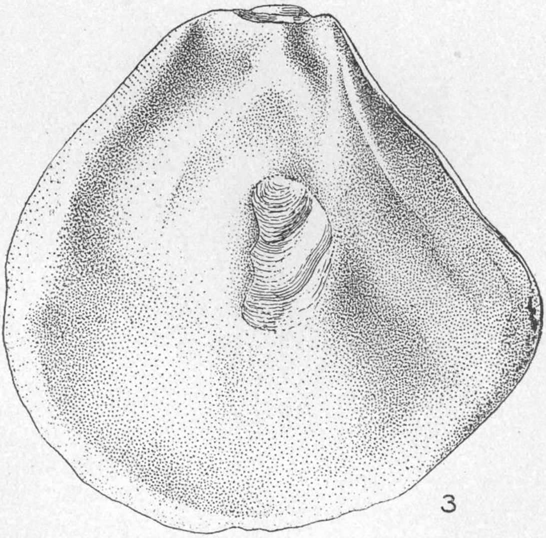
Figs. 1–3. Upper valves; natural size.



1



2



3

GRYPHÆA CORRUGATA Say.

PLATE VIII.

PLATE VIII.

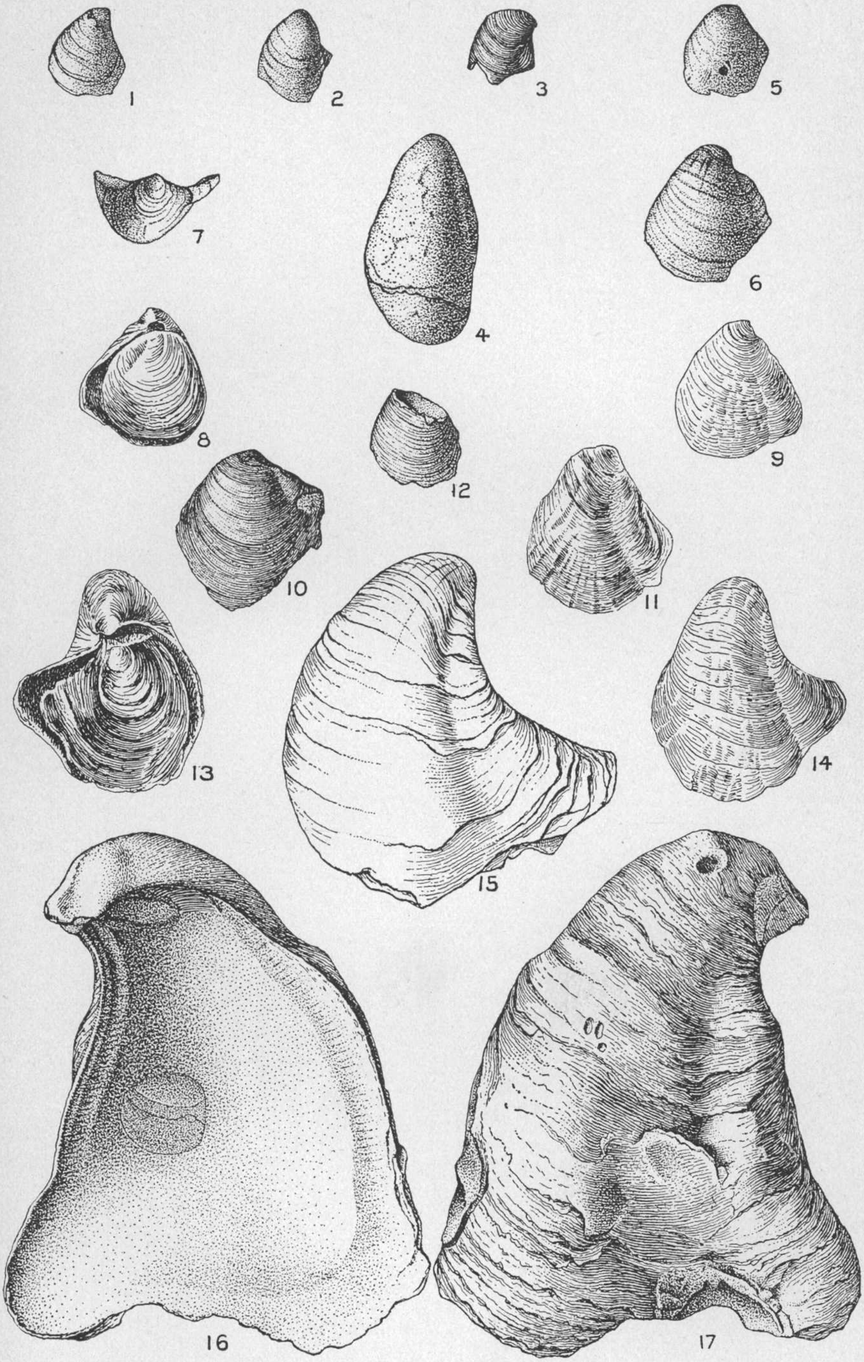
GRYPHÆA CORRUGATA Say (pp. 55–57).

Figs. 1–14 represent young specimens.

8–9 (the same specimen), 11, and 13–14 (the same specimen) are of the form from Belvidere, Kansas, to which Cragin applied the nam *Gryphœa hilli*. Compare figures 13–14 of this form with the figu of Morton's type, Pl. VI, figs. 5, 6, and 7.

16–17 represent an abnormal adult individual.

All figures natural size.

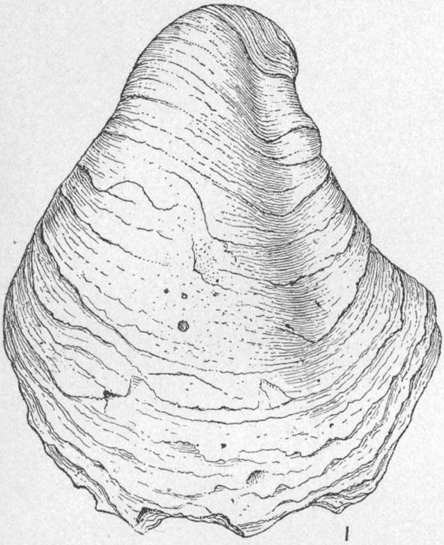


GRYPHÆA CORRUGATA Say.

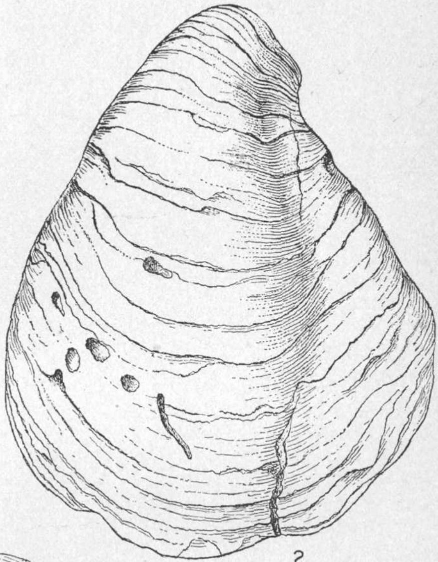
PLATE IX.

PLATE IX.

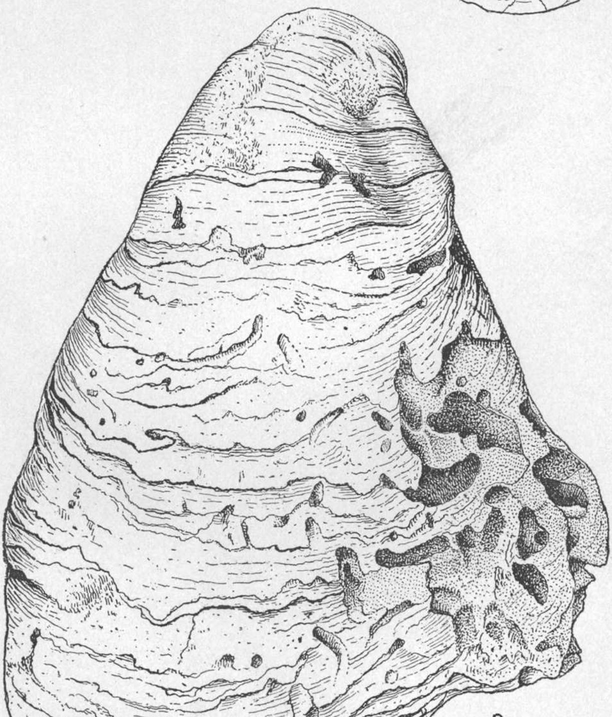
GRYPHÆA CORRUGATA Say, var. BELVIDERENSIS (p. 56).
Figs. 1–3. Adult lower valves from near Belvidere, Kansas.
Natural size.



1



2



3

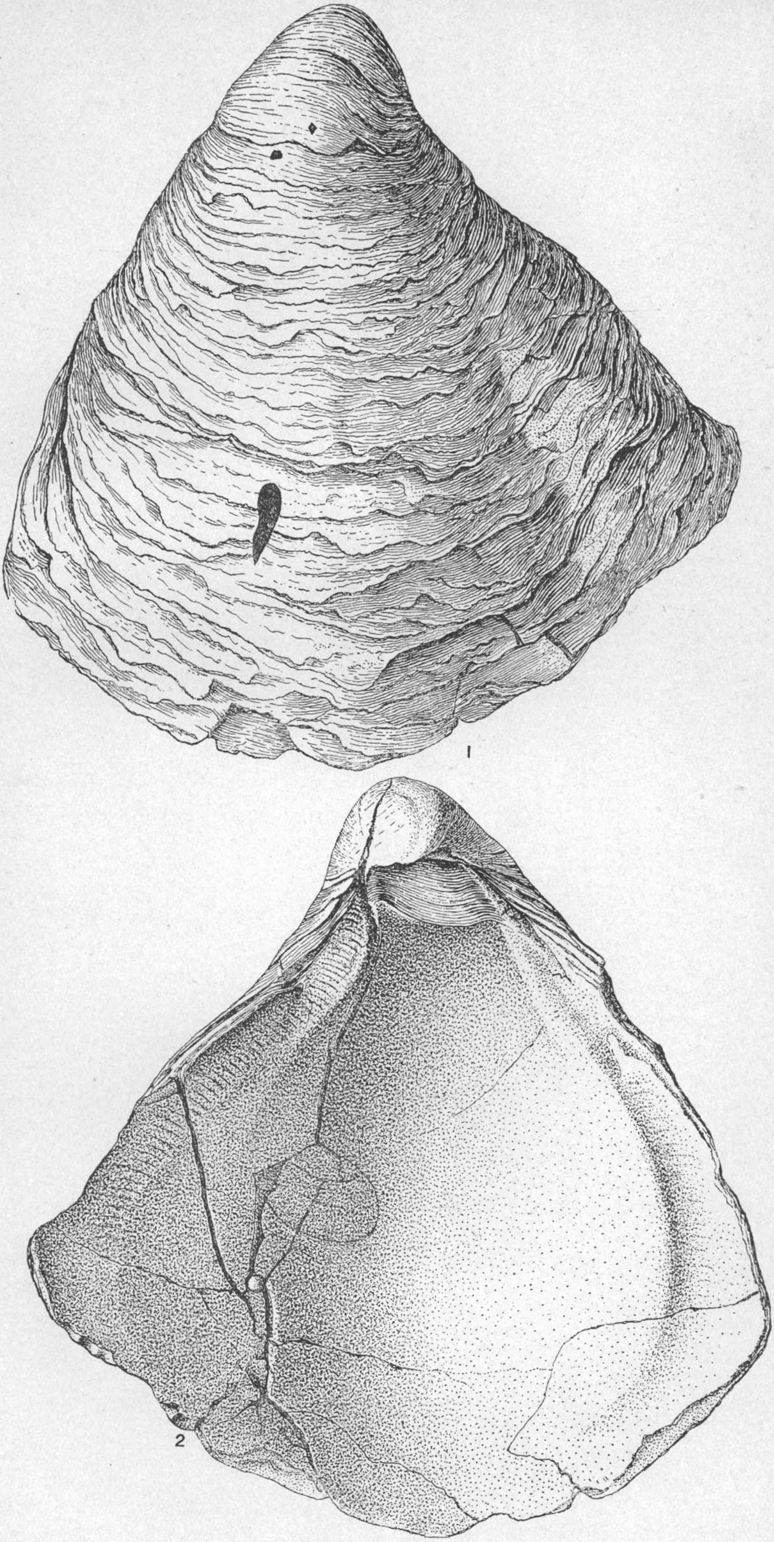
GRYPHÆA CORRUGATA Say var. BELVIDERENSIS.

PLATE X.

PLATE X.

GRYPHÆA CORRUGATA Say, var. BELVIDERENSIS, maximum size (p. 56).

Figs. 1 and 2. Adult lower valve, two views of the same specimen. Natural size.



GRYPHÆA CORRUGATA Say var. BELVIDERENSIS.

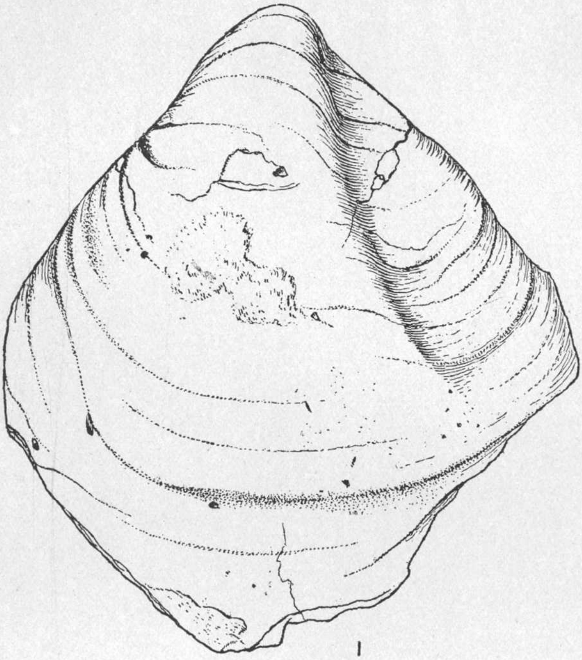
PLATE XI.

89

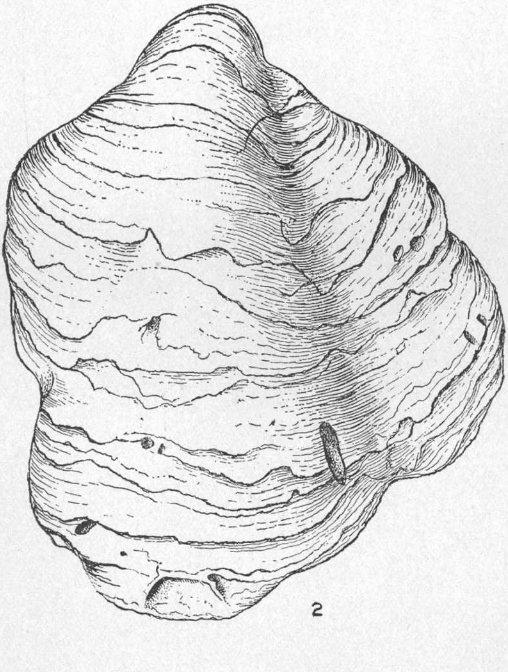
PLATE XI.

GRYPHÆA CORRUGATA Say (p. 56).

Figs. 1, 2. Adult lower valves from Belvidere, Kansas, showing variation. Natural size.



1



2

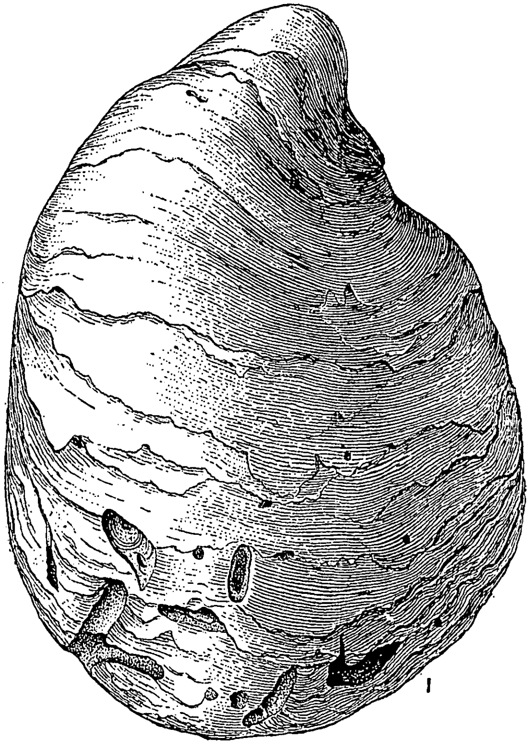
GRYPHÆA CORRUGATA Say.

PLATE XII.

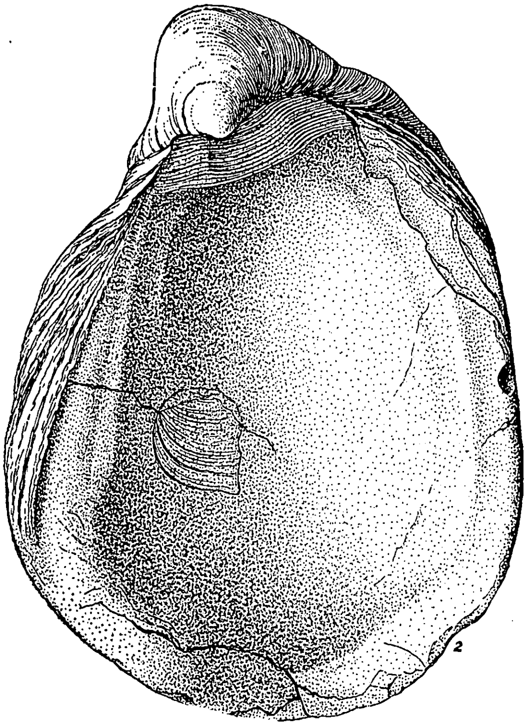
PLATE XII.

GRYPHÆA CORRUGATA Say (pp. 53–57).

Figs. 1, 2. Adult lower valves from Belvidere, Kansas, showing variation. Natural size.



1



2

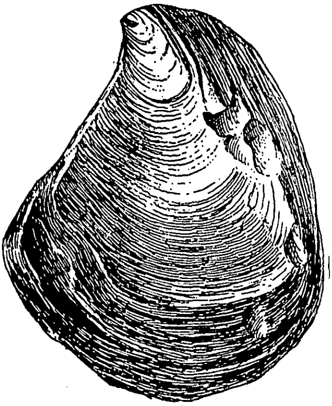
GRYPHÆA CORRUGATA Say.

PLATE XIII.

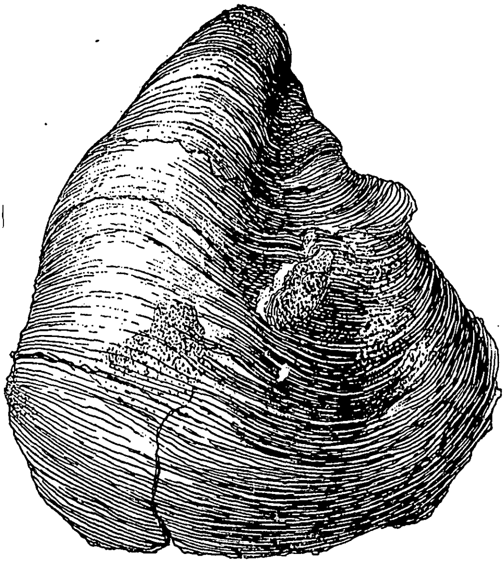
PLATE XIII.

GRYPHÆA CORRUGATA Say, var. TUCUMCARII (p. 56).

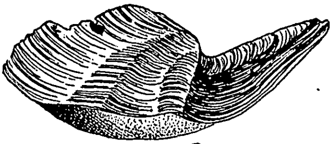
Figs. 1–5. Specimens from Tucumcari, New Mexico. Collected by Prof. Alpheus Hyatt. Natural size.



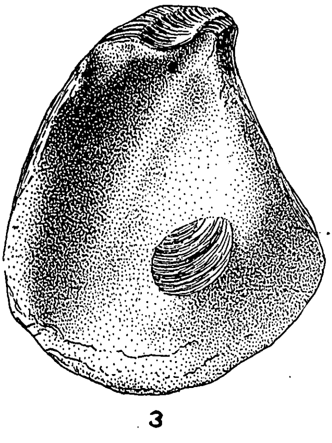
1



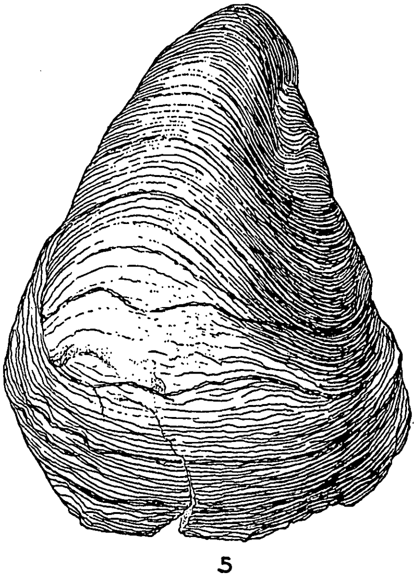
4



2



3



5

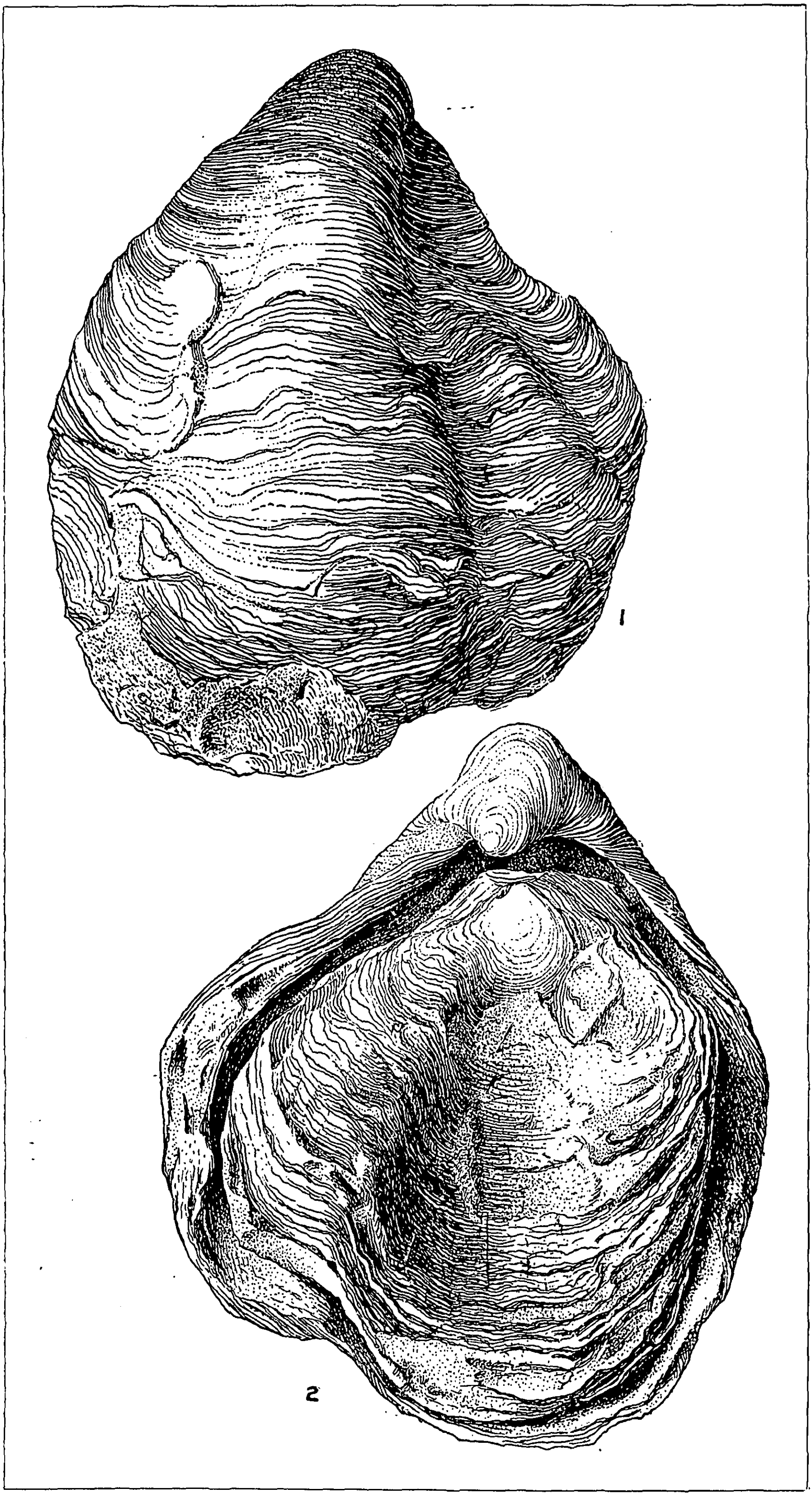
GRYPHÆA CORRUGATA Say var. TUCUMCARII.

PLATE XIV.

PLATE XIV.

GRYPHÆA CORRUGATA Say, var. TUCUMCARII (p. 56).

Figs. 1, 2. From Tucumcari Mesa, New Mexico. Maximum size. Collected by Prof. Alpheus Hyatt. Natural size.



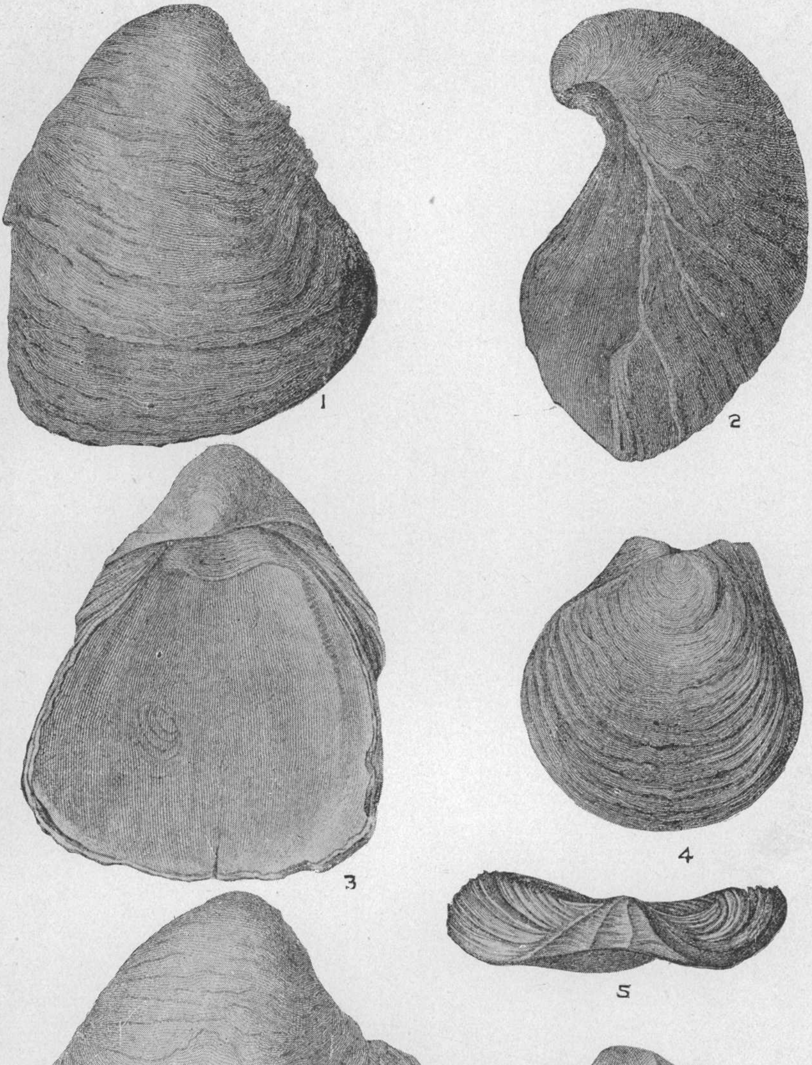
GRYPHÆA CORRUGATA Say var TUCUMCARII.

PLATE XV.

PLATE XV.

GRYPHÆA CORRUGATA Say (pp. 53–57).

Figs. 1–7. Reproduced from figures by Prof. James Hall, described as *G. pitcheri* Morton, in United States Explorations and Surveys for a Railroad Route from the Mississippi River to the Pacific Ocean, Senate Ex. Doc. 78, Vol. III, Pt. IV, Geology, Plate I, Washington, 1856. Figures natural size.



GRYPHÆA CORRUGATA Say.

PLATE XVI.

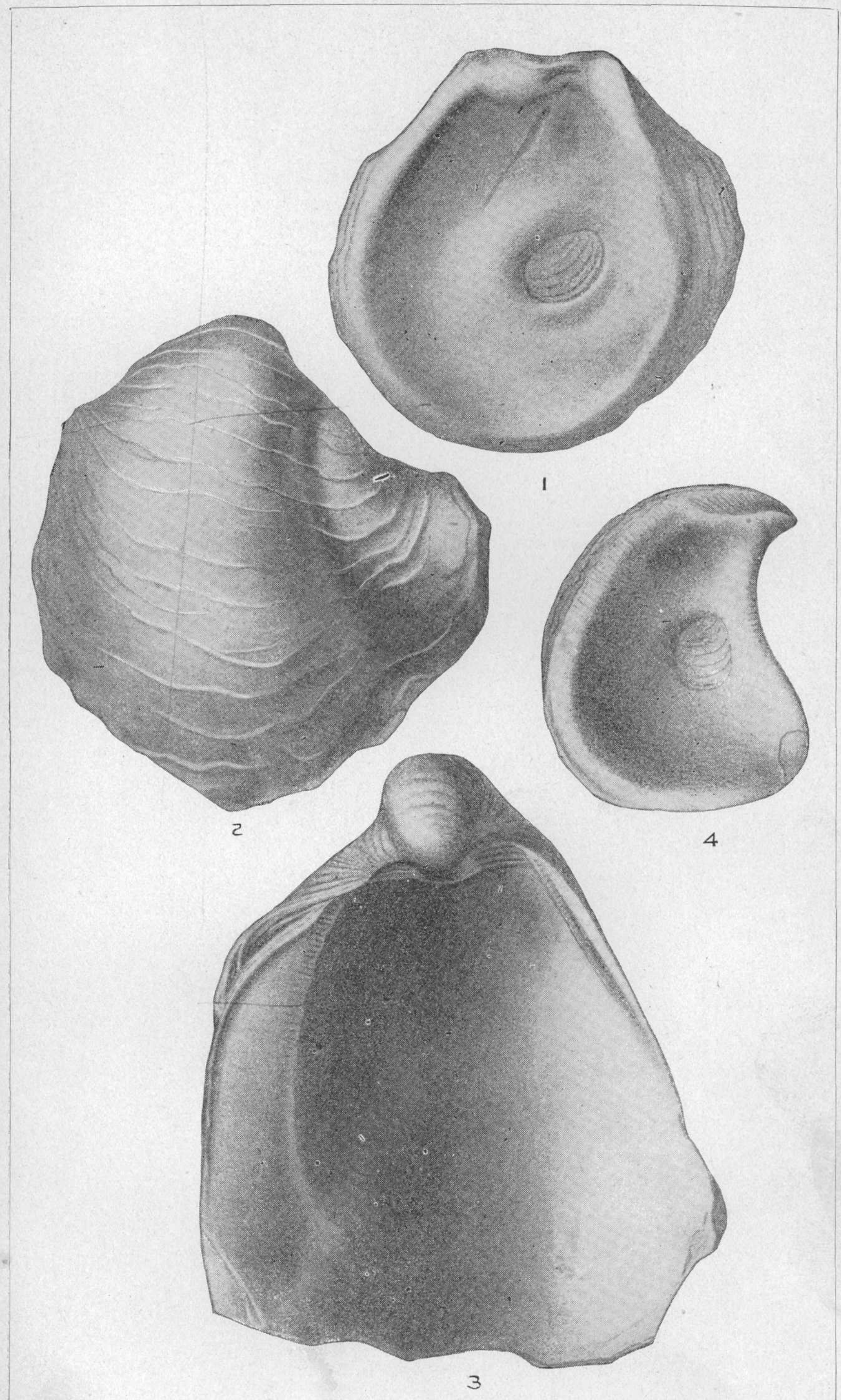
PLATE XVI.

GRYPHÆA CORRUGATA Say (pp. 53–57).

Figs. 1, 2, 3. Copies of specimens figured by Prof. Jules Marcou under name of *Gryphœa dilatata* Sow. (Geology of North America, Zurich, 1858, Plate IV, figs. 1, 1*a*, and 3.)

Fig. 4. Copy of figure of *Gryphœa pitcheri* of Marcou = *G. navia* Hall. From same plate as above.

Figures natural size.



GRYPHÆA CORRUGATA Say = GRYPHÆA PITCHERI Marcou.

PLATE XVII.

PLATE XVII.

GRYPHÆA NAVIA Hall (pp. 57–59).

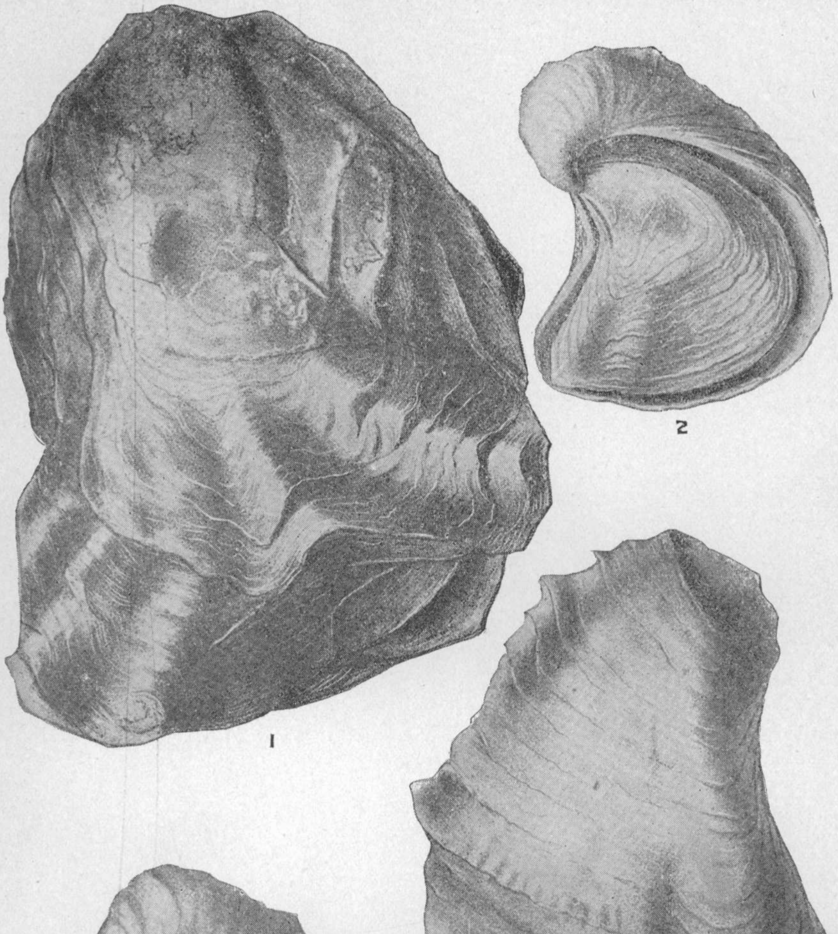
Fig. 1 is a copy of Professor Marcou's *Ostrea marshii* (= *O. subovata* Shumard). Found in association with *G. corrugata* Say in New Mexico, Kansas, and Texas.

Figs. 2–4. *Gryphœa pitcheri* Marcou = *G. navia* Hall.

Fig. 5. *Gryphœa dilatata*, var *tucumcarii* Marcou.

Copied from figures by Prof. Jules Marcou, Geology of North America, Zurich, 1858, Plate IV.

Figures natural size.



GRYPHÆA NAVIA Hall and O. SUBOVATA Shumard.

PLATE XVIII.

PLATE XVIII.

GRYPHÆA CORRUGATA Say (pp. 53–57).

Figs. 1–2. A young specimen of *G. corrugata* Say, for comparison with figures of *G. navia* Hall.

Fig. 3. A specimen from near Belvidere, Kansas. It appears to be intermediate between *G. corrugata* and *G. navia*. Note the slightly developed keel.

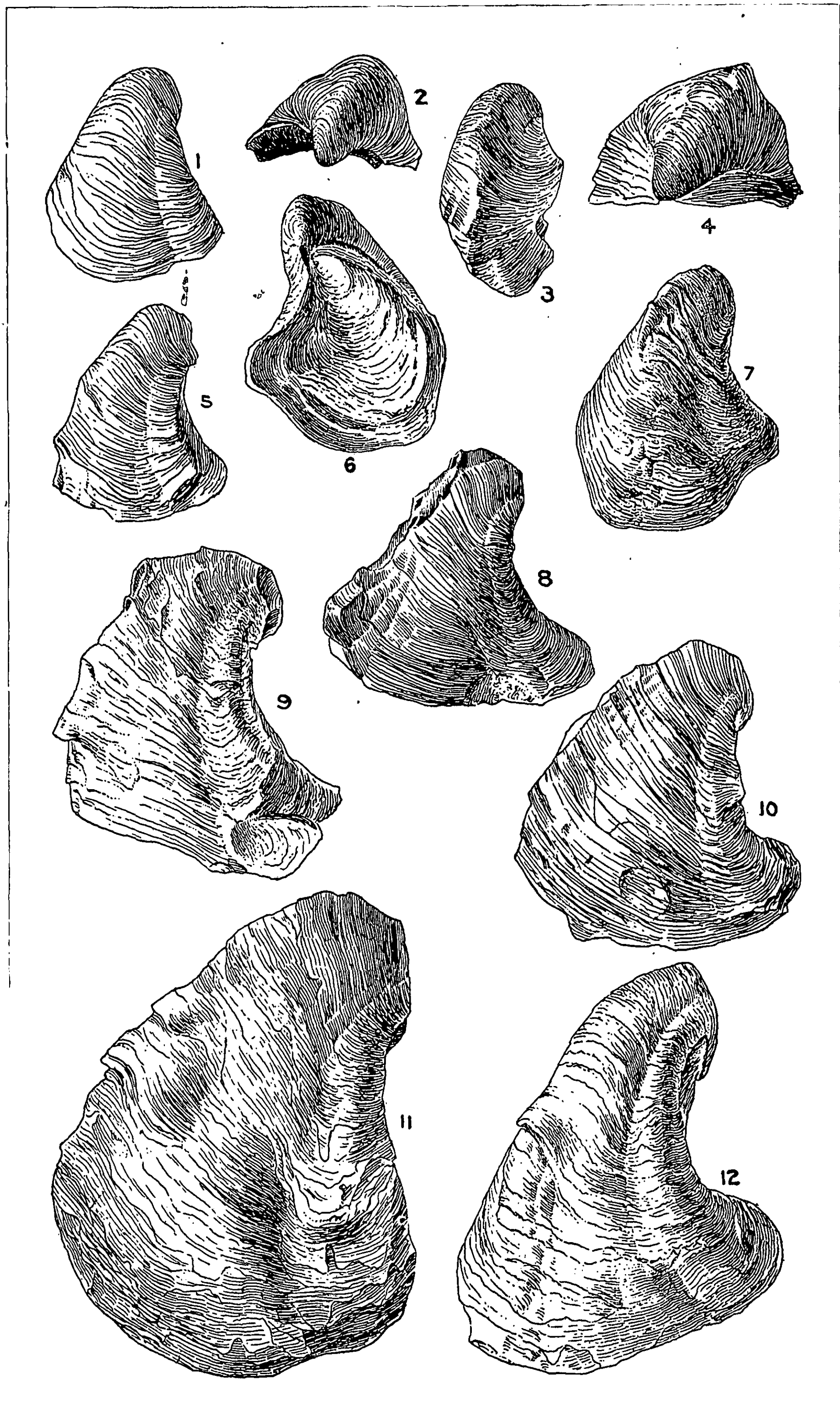
GRYPHÆA NAVIA Hall (pp. 57–58).

4. *Gryphœa navia* Hall, seen from above, to show that the young is like that of *G. corrugata*.

Figs. 5–11. Other specimens of *G. navia* Hall.

Fig. 12. A specimen from near Denison, Texas, that probably should be referred to *G. navia*.

All figures natural size.



GRYPHÆA NAVIA Hall.

PLATE XIX.

PLATE XIX.

GRYPHÆA CORRUGATA Say (pp. 55–57).

Figs. 1–2. Figures of *Gryphæa corrugata* Say, for comparison with the figures of *G. washitaensis* Hill.

GRYPHÆA WASHITAENSIS Hill (pp. 59–62).

Figs. 3–19. *Gryphæa washitaensis* Hill. The specimens represented in figs. 3 and 5 have very little lateral expansion. These specimens come from the Duck Creek chalk north of Denison.

Fig. 4. *Gryphæa washitaensis* Hill, ordinary adult lower valve.

6. Prodissoconch and a little of the succeeding nepionic growth of *Ostrea virginica* Gmel., enlarged (after Jackson).

Figs. 7–9. Young upper valves of *Gryphæa washitaensis*, showing the prodissoconchs.

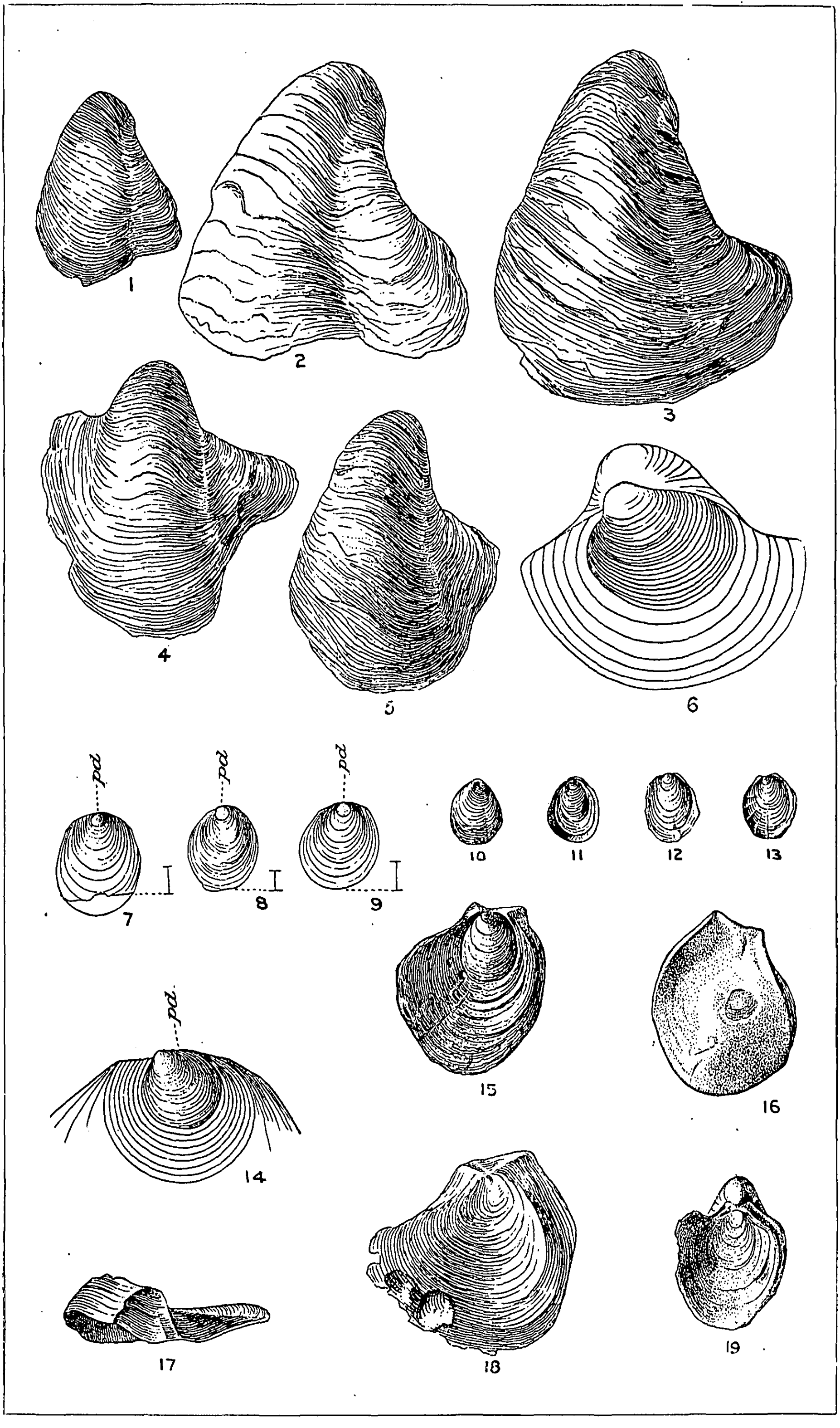
10–13. Illustrating the nepionic stage of the upper valves of *G. washitaensis.*

Fig. 14. The prodissoconch and a part of the nepionic growth of the same specimen represented in fig. 9, much enlarged.

Figs. 15–18. Upper valves of *G. washitaensis.* Note the distinctness with which the nepionic stage is marked off from the later growth. Fig. 16 is a reverse view of the specimen represented in fig. 15. Figs. 17–18 are two views of the same valve. Note the thickening on the ventral side in the anterior portion.

Fig. 19. *Gryphæa washitaensis.* The upper valve is still attached to the lower.

All figures are natural size except when otherwise indicated on plate.



GRYPHÆA CORRUGATA Say and G WASHITAENSIS Hill

PLATE XX.

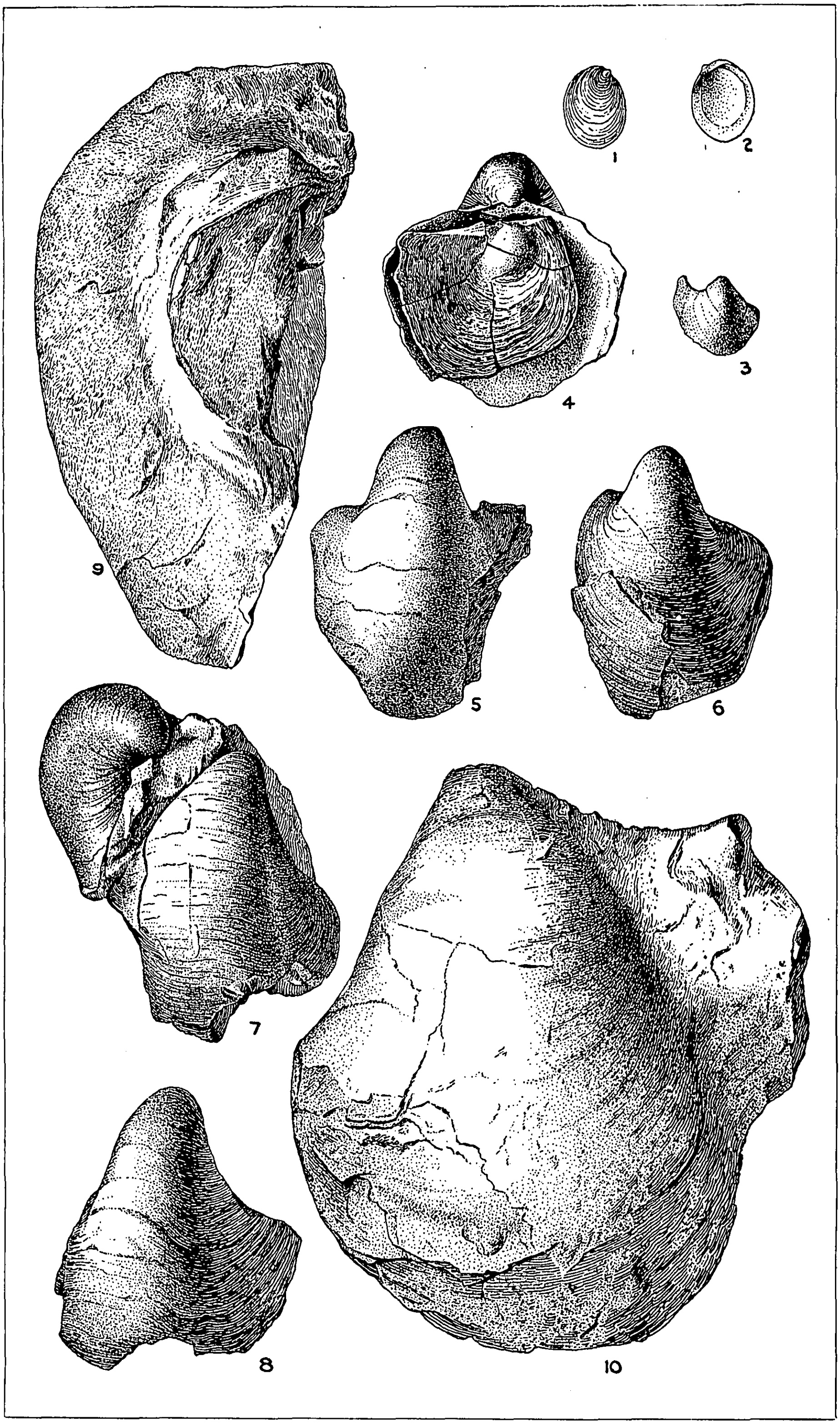
PLATE XX.

Gryphæa washitaensis Hill, lower valves (pp. 59–62).

Figs. 1–2. Two views of a young valve, showing the prodissoconch still attached. Note the presence of a few taxodont teeth on the dorsal side of the ligamental fossa in fig. 2.

3–8. Usual varieties.

9–10. Old forms, passing into the gerontic stage.



GRYPHÆA WASHITAENSIS Hill.

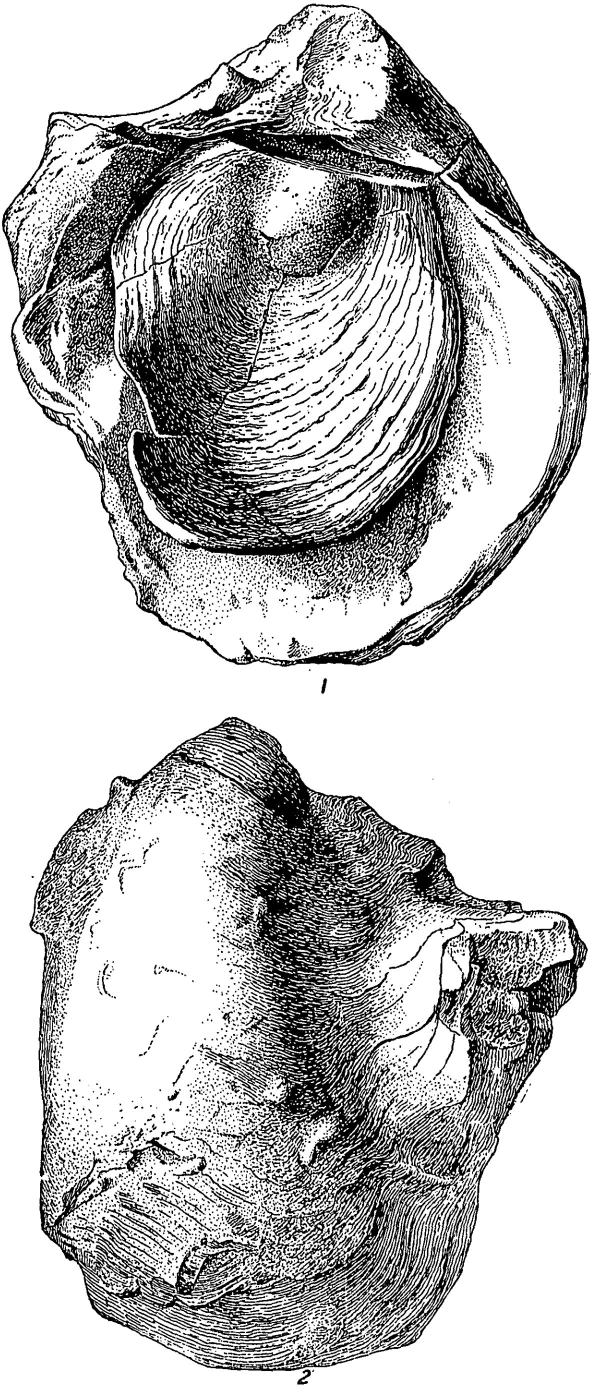
PLATE XXI.

PLATE XXI.

GRYPHÆA WASHITAENSIS Hill (pp 59–62).

Old form showing maximum development; natural size.

110



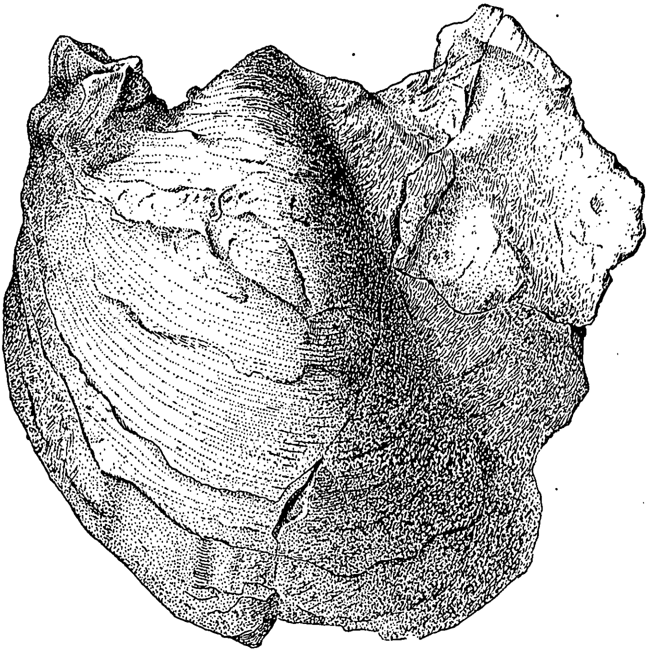
GRYPHÆA WASHITAENSIS Hill.

PLATE XXII.

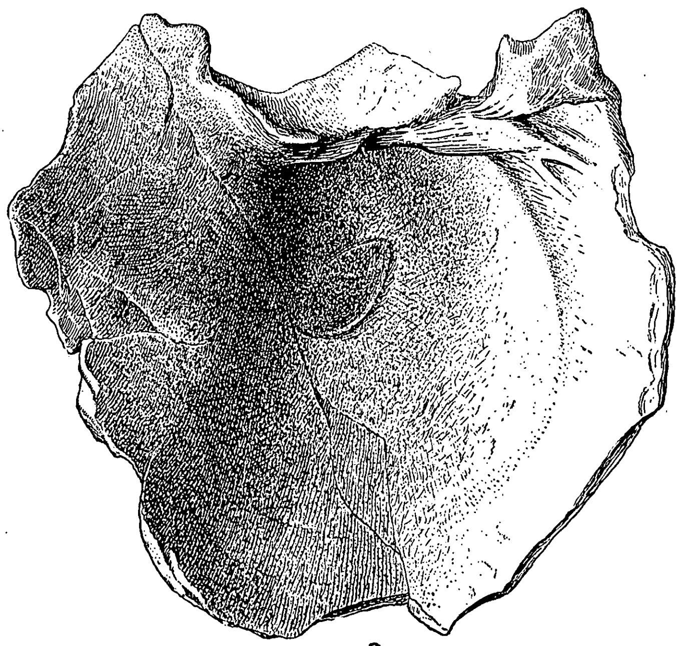
PLATE XXII.

GRYPHÆA WASHITAENSIS Hill (pp. 59-62).

An old form, showing maximum development; two views of the same valve. Natural size.



1



2

GRYPHÆA WASHITAENSIS Hill.

PLATE XXIII.

PLATE XXIII.

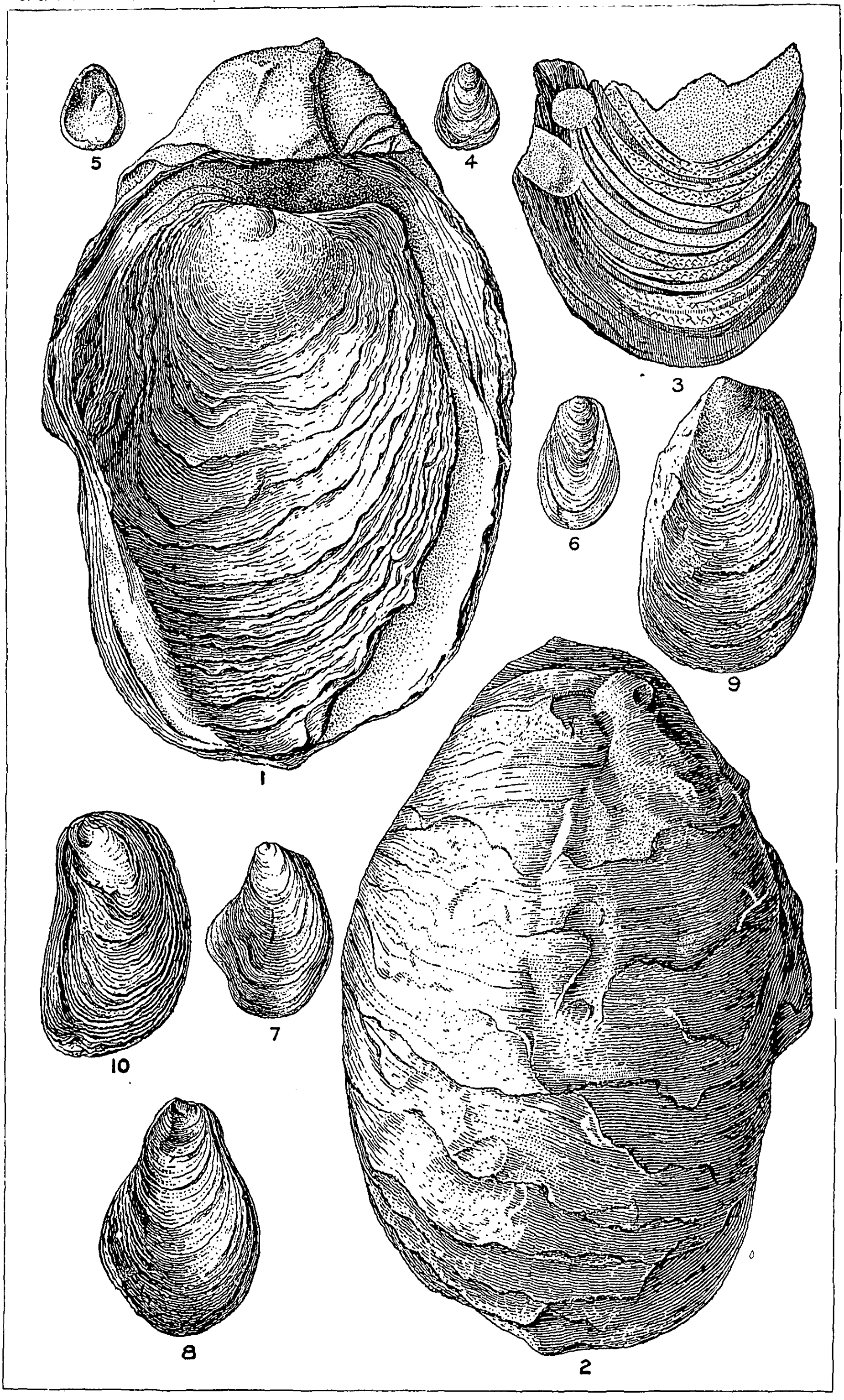
GRYPHÆA WASHITAENSIS Hill (pp. 59–62).

Figs. 1–2. A very old specimen of *Gryphæa washitaensis*, Hill; illustrates the extreme of the gerontic stage. This is the form called *Gryphæa gibberosa* by Cragin.

3. Section through a very old specimen of *G. washitaensis.*

GRYPHÆA MUCRONATA Gabb (pp. 63–65).

Figs. 4–10. Upper valves of *G. mucronata* Gabb. Note the nepionic stage in figs. 4, 6, and 7.



GRYPHÆA WASHITAENSIS Hill and G. MUCRONATA Gabb.

PLATE XXIV.

PLATE XXIV.

Gryphæa mucronata Gabb, stages of development (pp. 63-65).

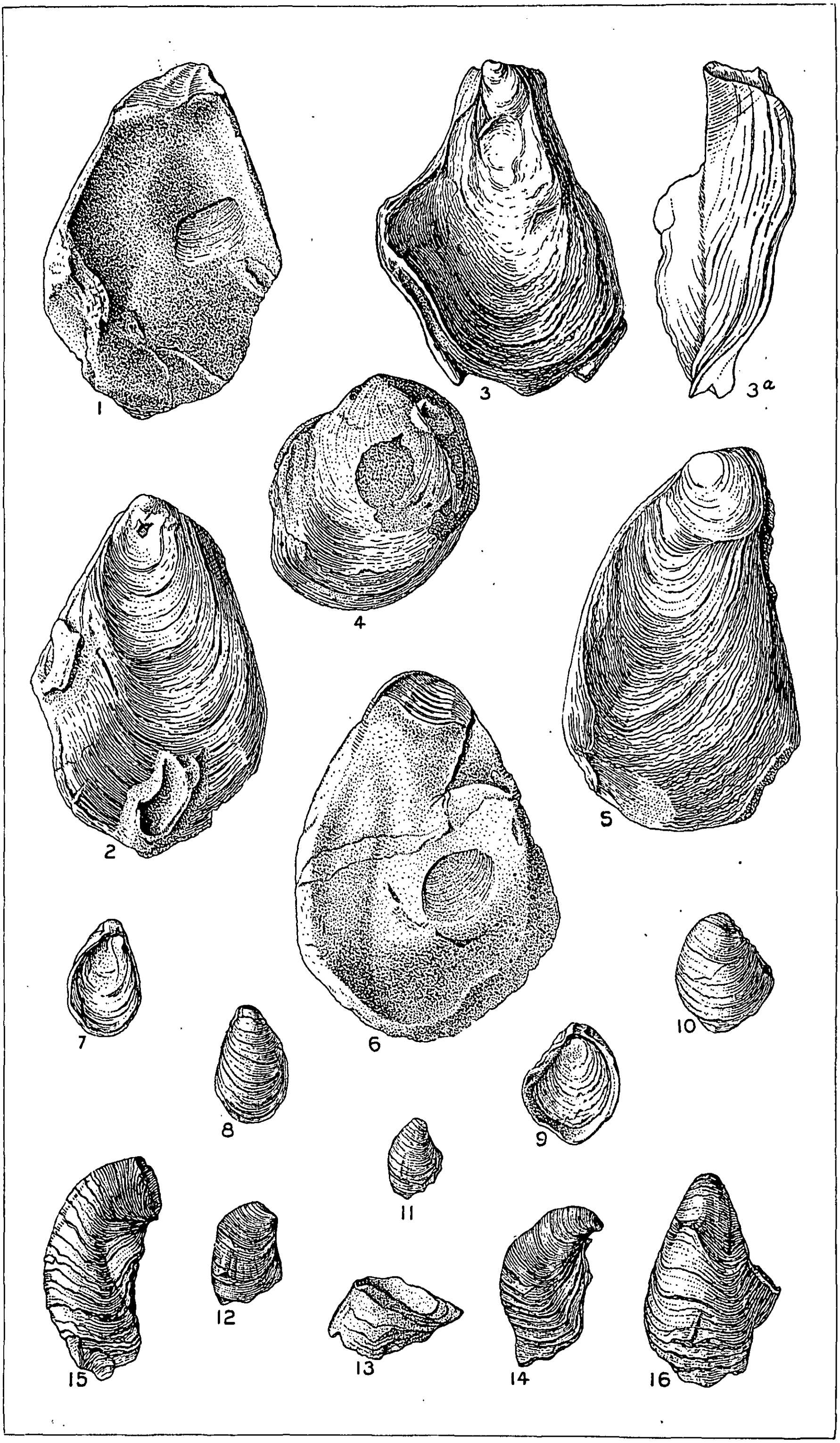
Figs. 1-6. Adult upper valves. Note the great thickening along the ventral margin in fig. 6*a*.

7-8. Two views of the same specimen (young).

9-10. Two views of the same specimen (young).

11-16. Young lower valves.

All figures natural size.

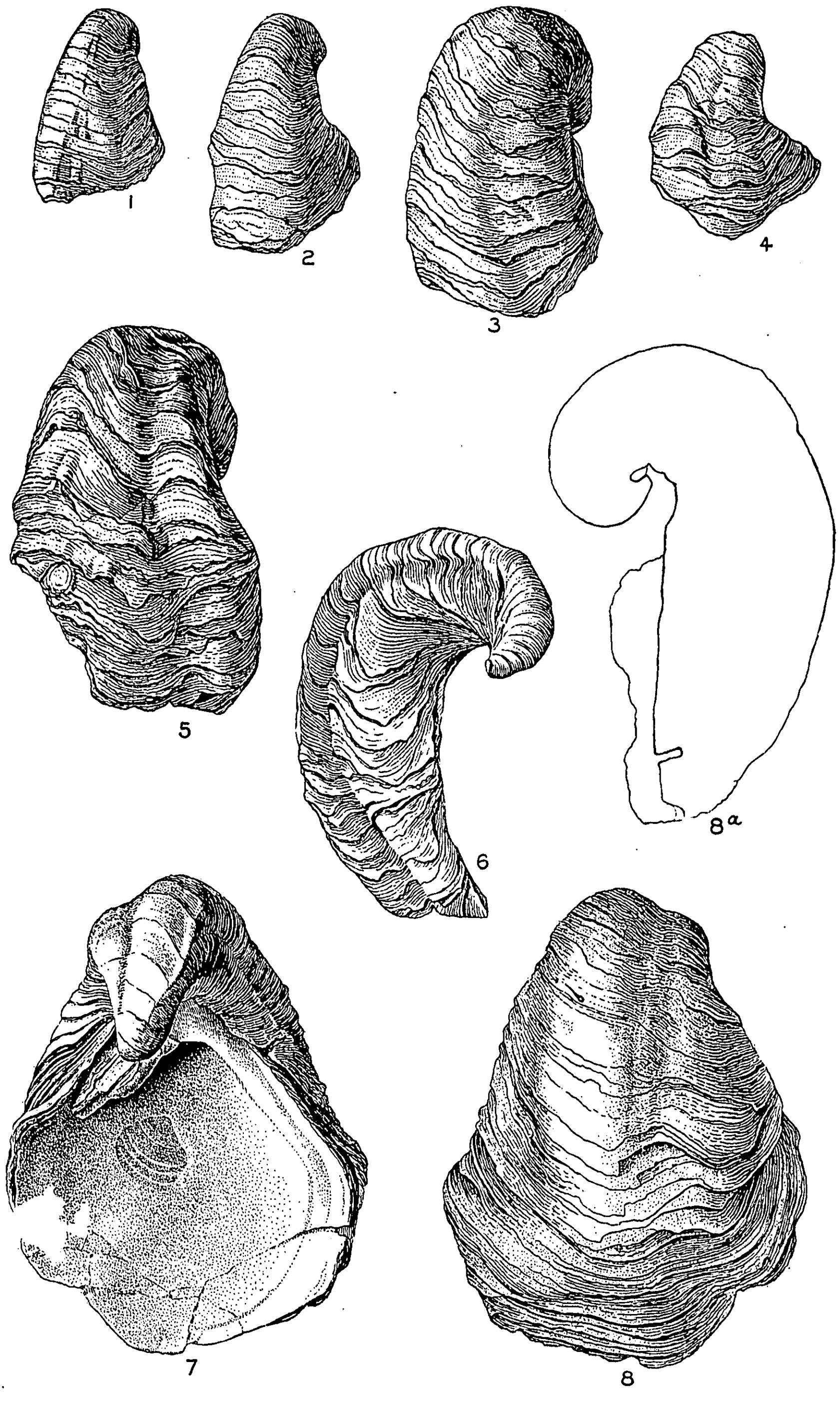


GRYPHÆA MUCRONATA Gabb.

PLATE XXV.

PLATE XXV.

Gryphæa mucronata Gabb, lower valves (pp. 63–65); natural size.



GRYPHÆA MUCRONATA Gabb.

PLATE XXVI.

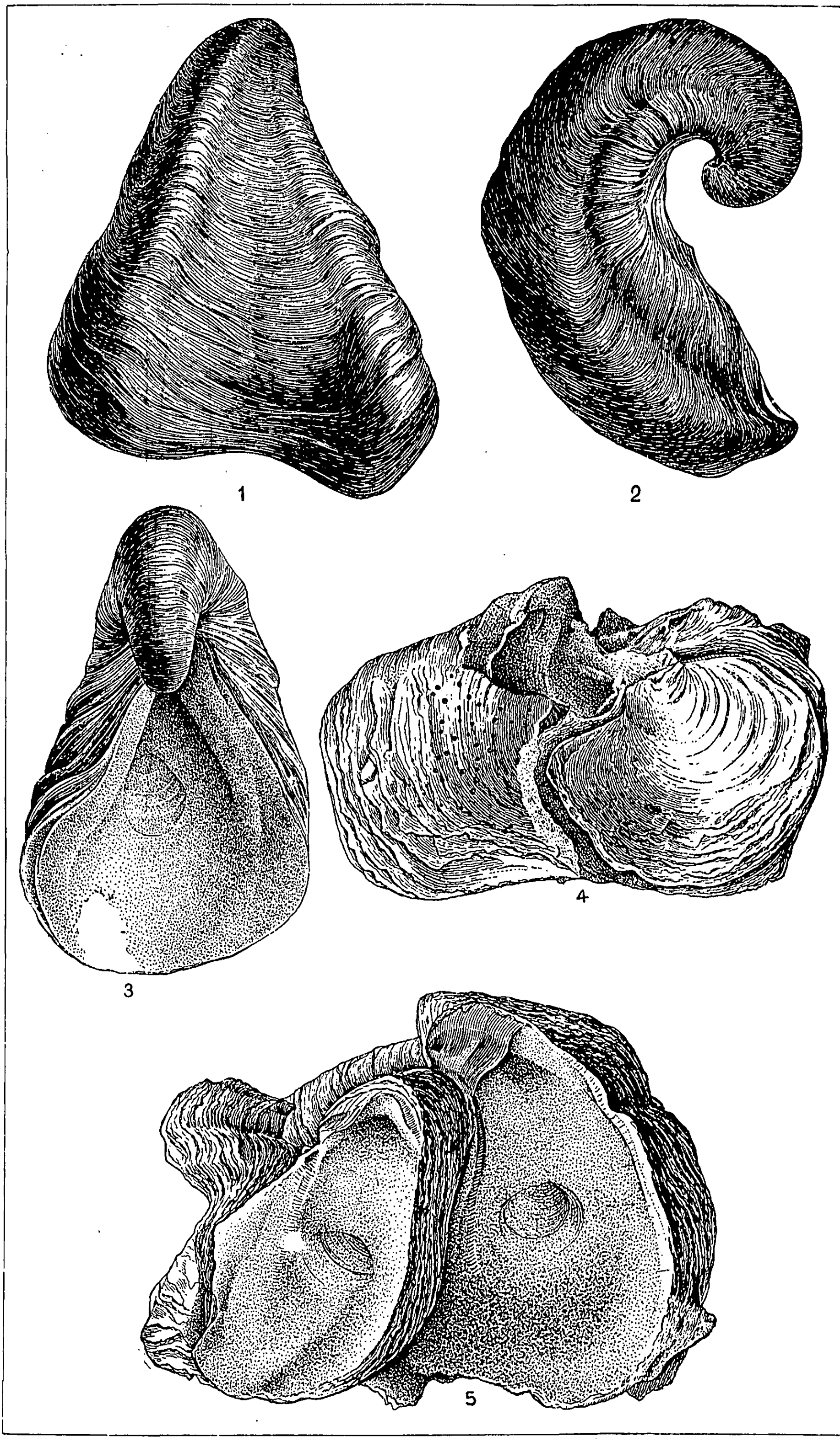
PLATE XXVI.

GRYPHÆA MUCRONATA Gabb (pp. 63–65).

Figs. 1–3. Copies of Roemer's original figures of what he called *G. pitcheri*.

4–5. Clusters; the shells much distorted by their fixed condition of growth.

Figures natural size.



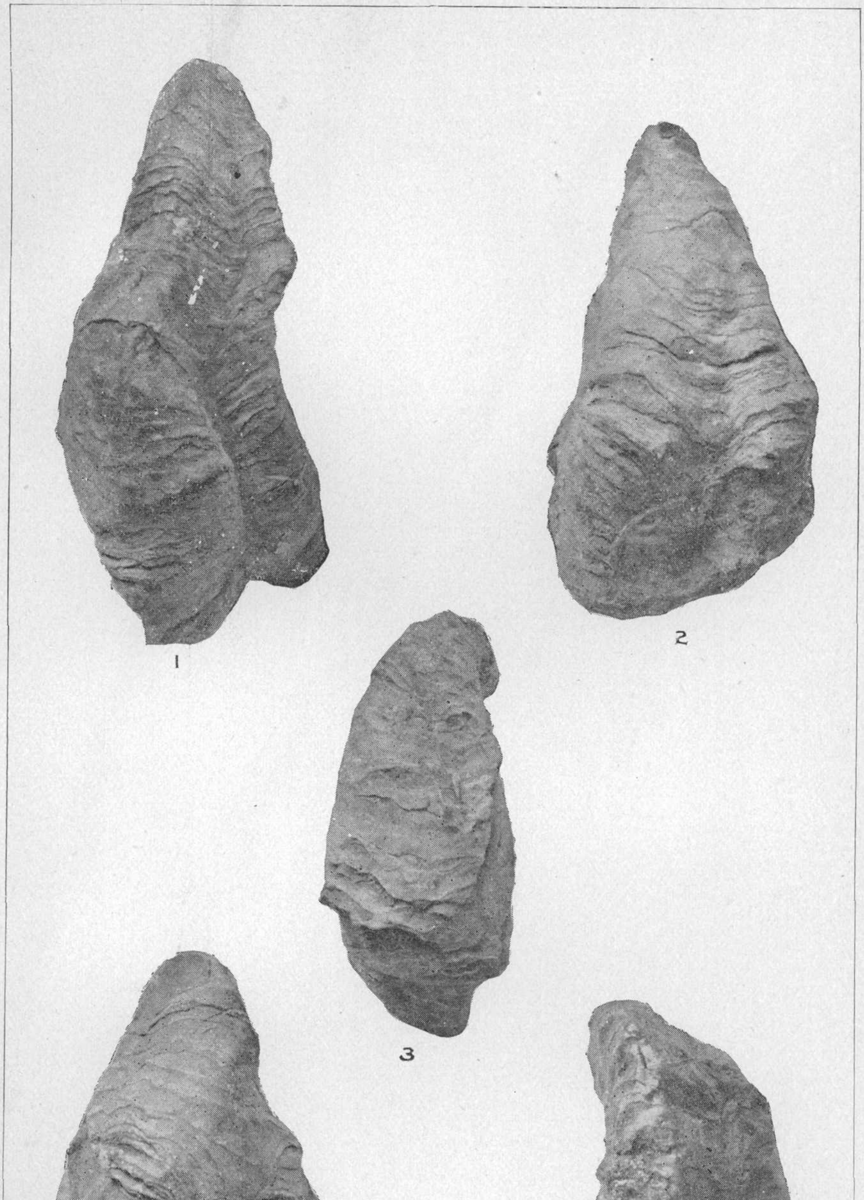
GRYPHÆA MUCRONATA Gabb.

PLATE XXVII.

PLATE XXVII.

GRYPHÆA MUCRONATA Gabb. Elongate forms.

Figs. 1-5, together with all figures on Plates XXVIII-XXX, are intended to show the great variation in this species. All specimens from a single locality in the bluffs of Shoal Creek at Austin, Texas. Figures natural size.



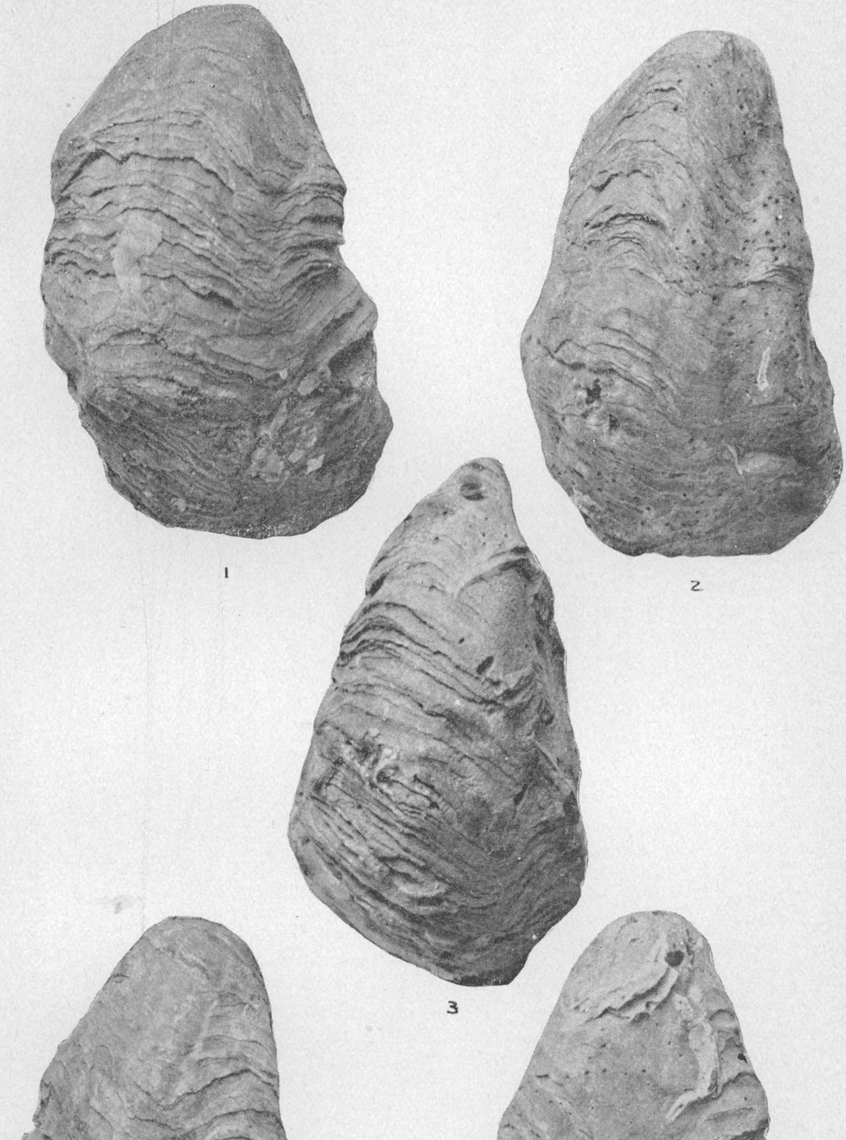
GRYPHÆA MUCRONATA Gabb.

PLATE XXVIII.

PLATE XXVIII.

GRYPHÆA MUCRONATA Gabb (pp. 63–65).

Figs. 1–5. Normal forms; natural size.



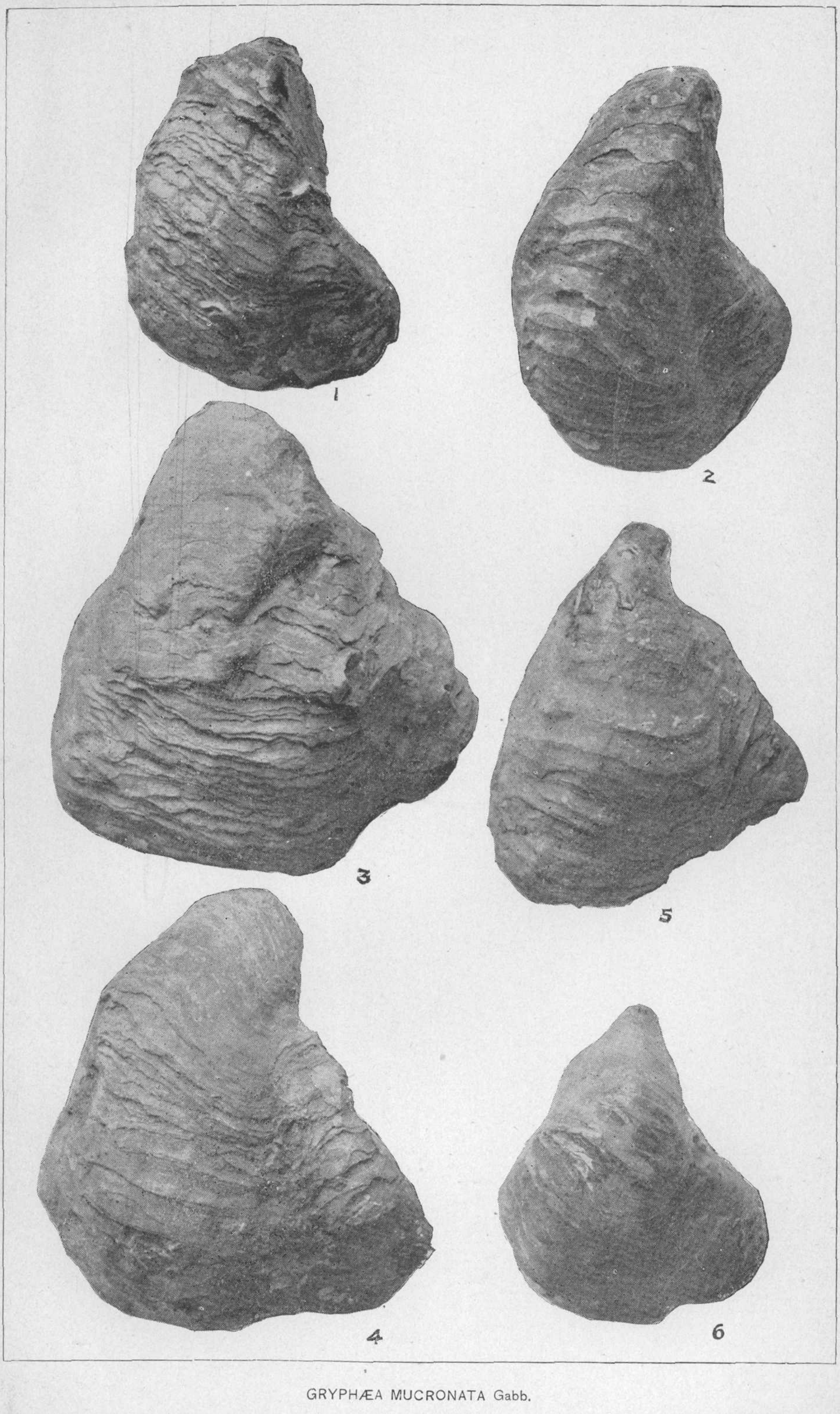
GRYPHÆA MUCRONATA Gabb.

PLATE XXIX.

PLATE XXIX.

GRYPHÆA MUCRONATA Gabb (pp. 63–65).

Figs. 1–6. Triangular forms; natural size.



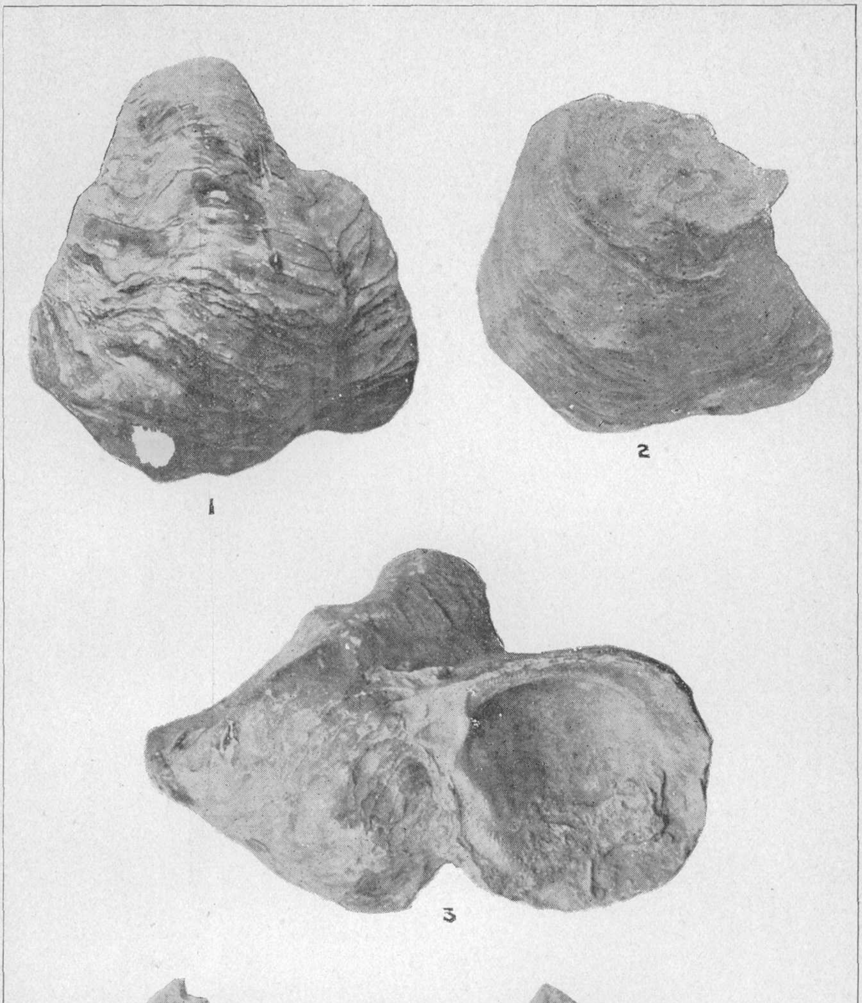
GRYPHÆA MUCRONATA Gabb.

PLATE XXX.

PLATE XXX

GRYPHÆA MUCRONATA Gabb (pp. 63-65).

Figs. 1-5. Attached forms; natural size.

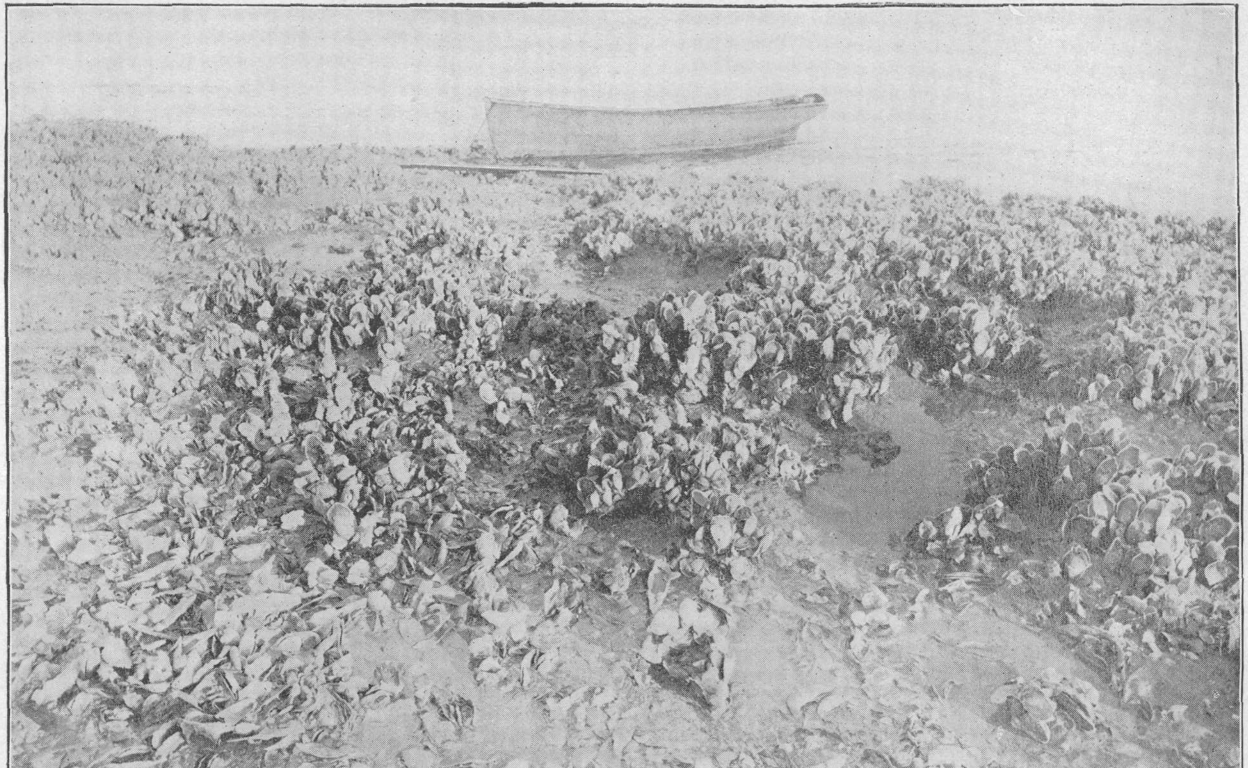


GRYPHÆA MUCRONATA Gabb.

PLATE XXXI.

PLATE XXXI.

View of a bed of living oysters 5 miles below Brunswick, Georgia; from a photograph by C. D. Walcott.

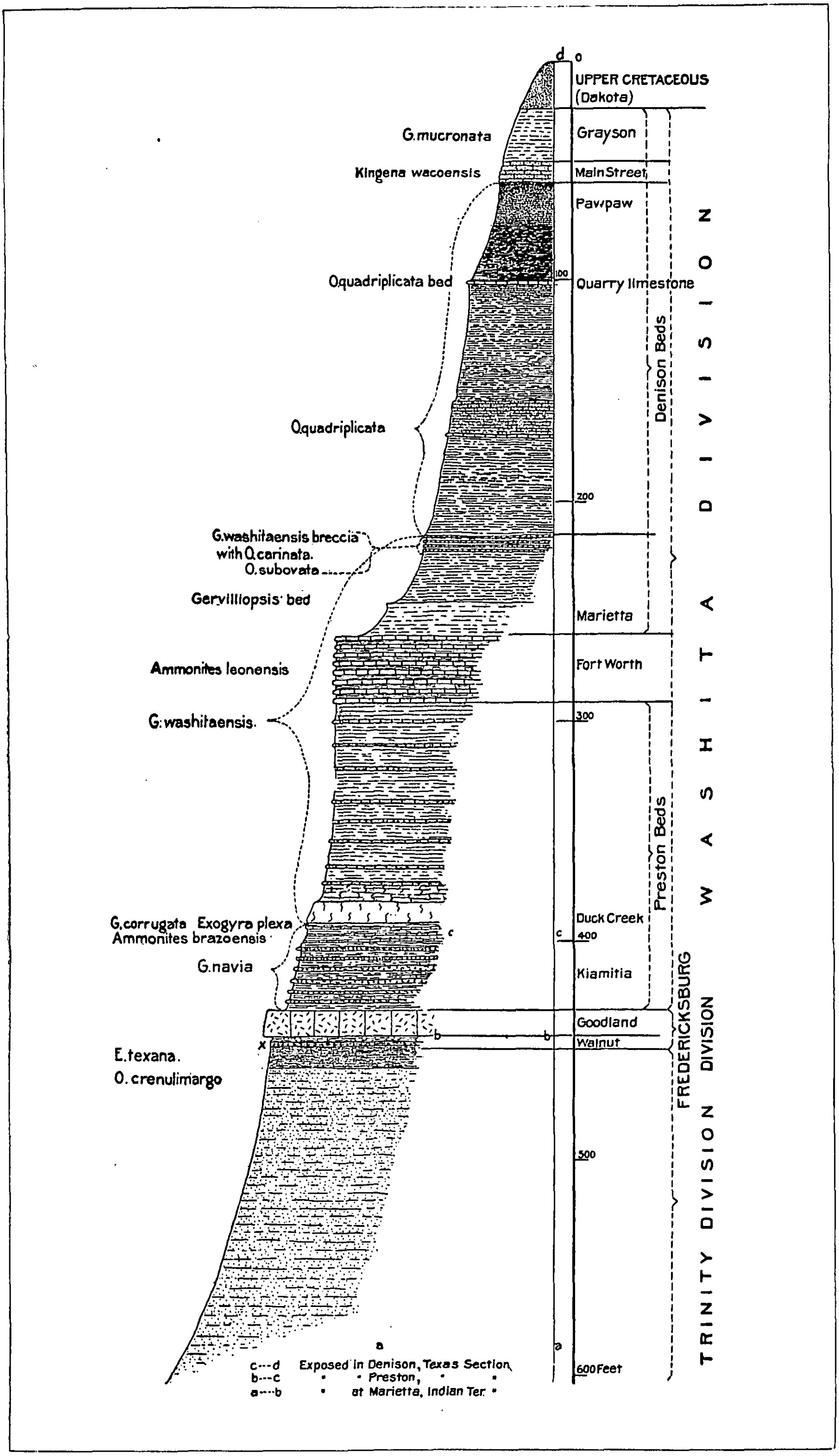


BED OF OYSTERS (OSTREA VIRGINICA).

PLATE XXXII.

PLATE XXXII.

Columnar section near Denison, Texas, showing stratigraphic occurrence of the fossil Ostreidæ in the Comanche series.

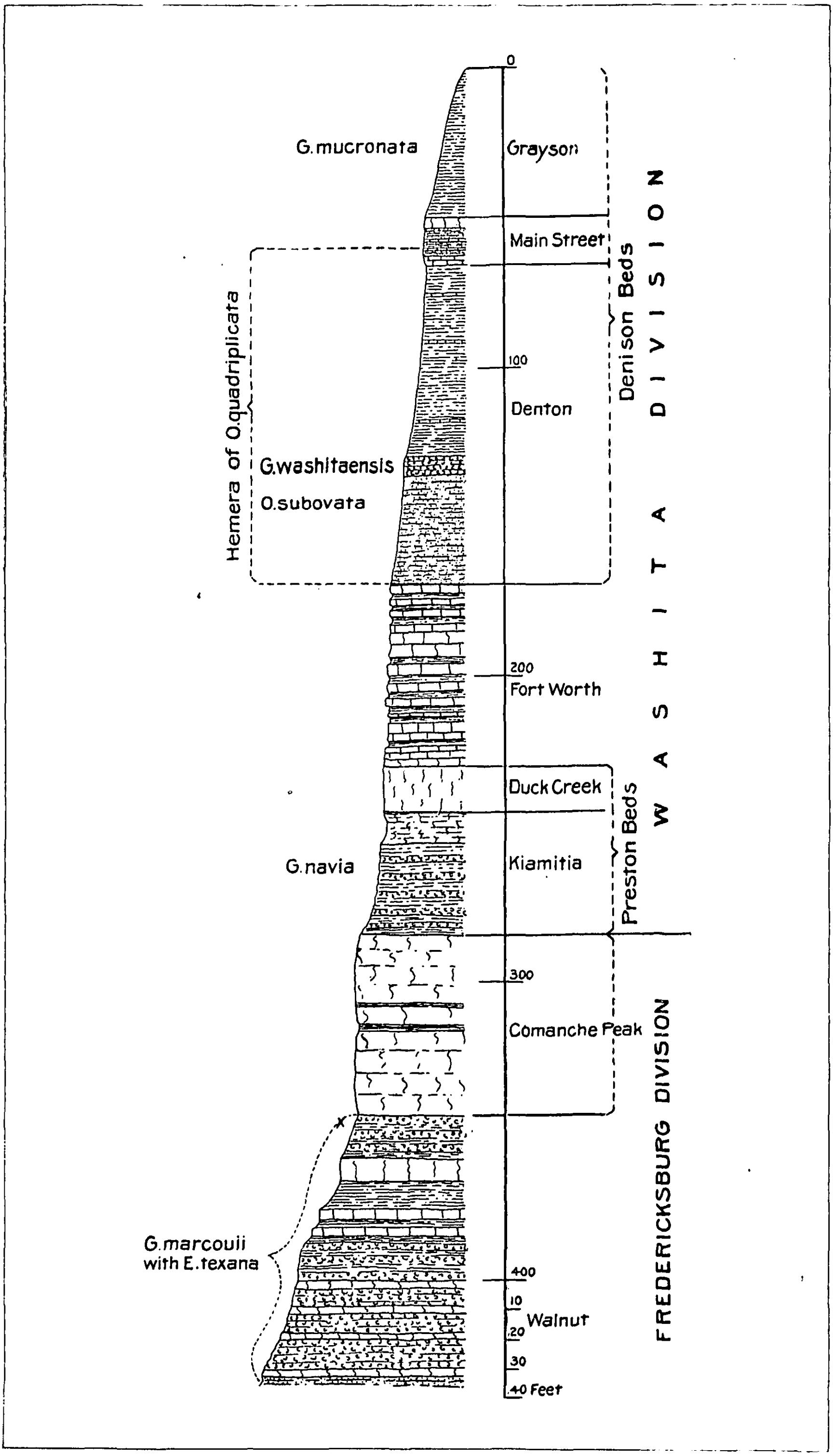


COLUMNAR SECTION NEAR DENISON, TEXAS.

PLATE XXXIII.

PLATE XXXIII.

Columnar section near Fort Worth, Texas, showing stratigraphic occurrence of fossil Ostreidæ in the Comanche series.

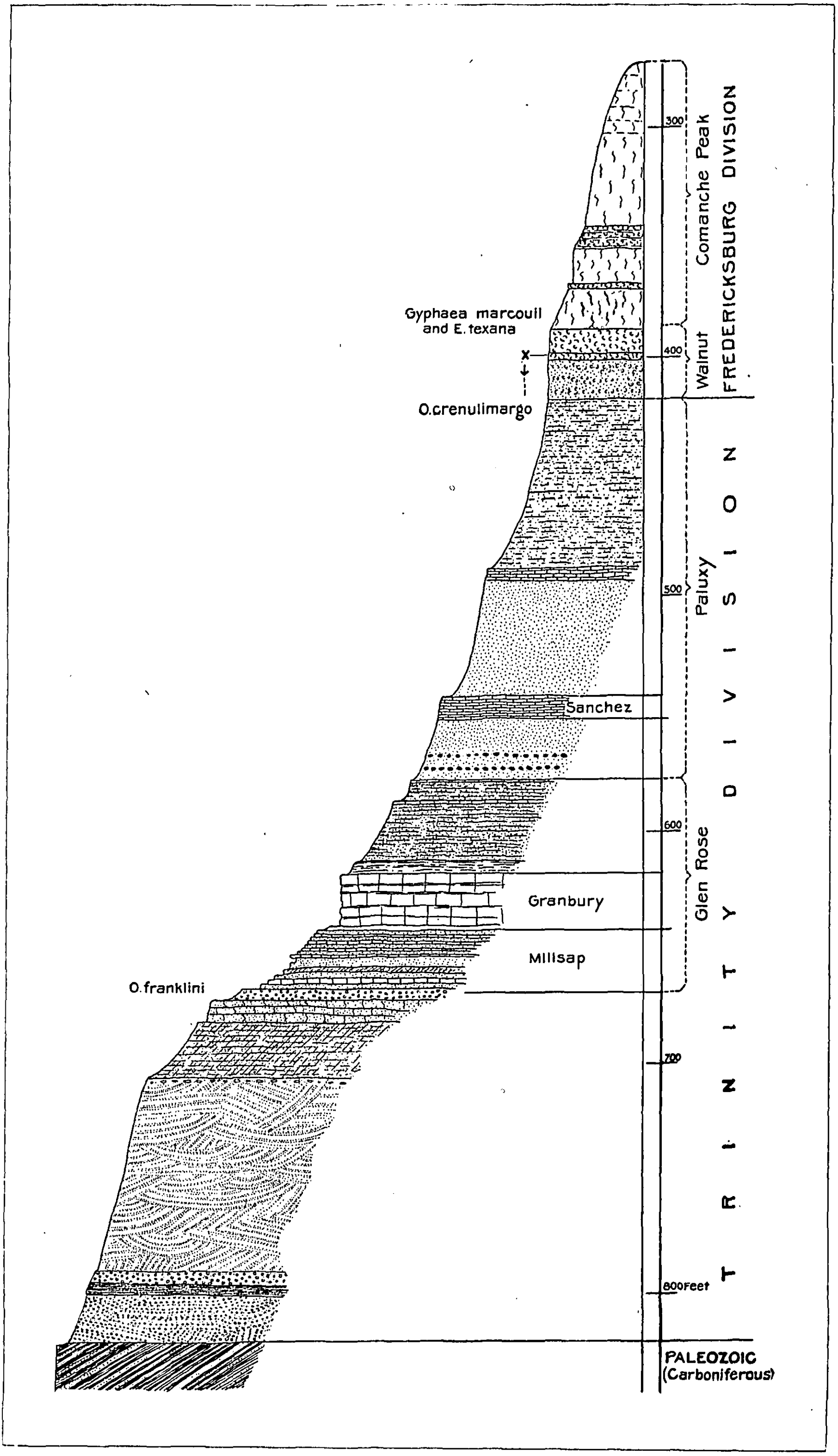


COLUMNAR SECTION NEAR FORT WORTH, TEXAS.

PLATE XXXIV.

PLATE XXXIV.

Columnar section near Weatherford, Texas, showing occurrence of fossil Ostreidæ. This is the downward continuation of the section shown on Plate XXXIII.



COLUMNAR SECTION NEAR WEATHERFORD, TEXAS.

PLATE XXXV.

PLATE XXXV.

Table of columnar sections across the State of Texas and in New Mexico and Kansas, showing the vertical range and position of the Cretaceous Ostreidæ. Scale: 1 inch = 400 feet.

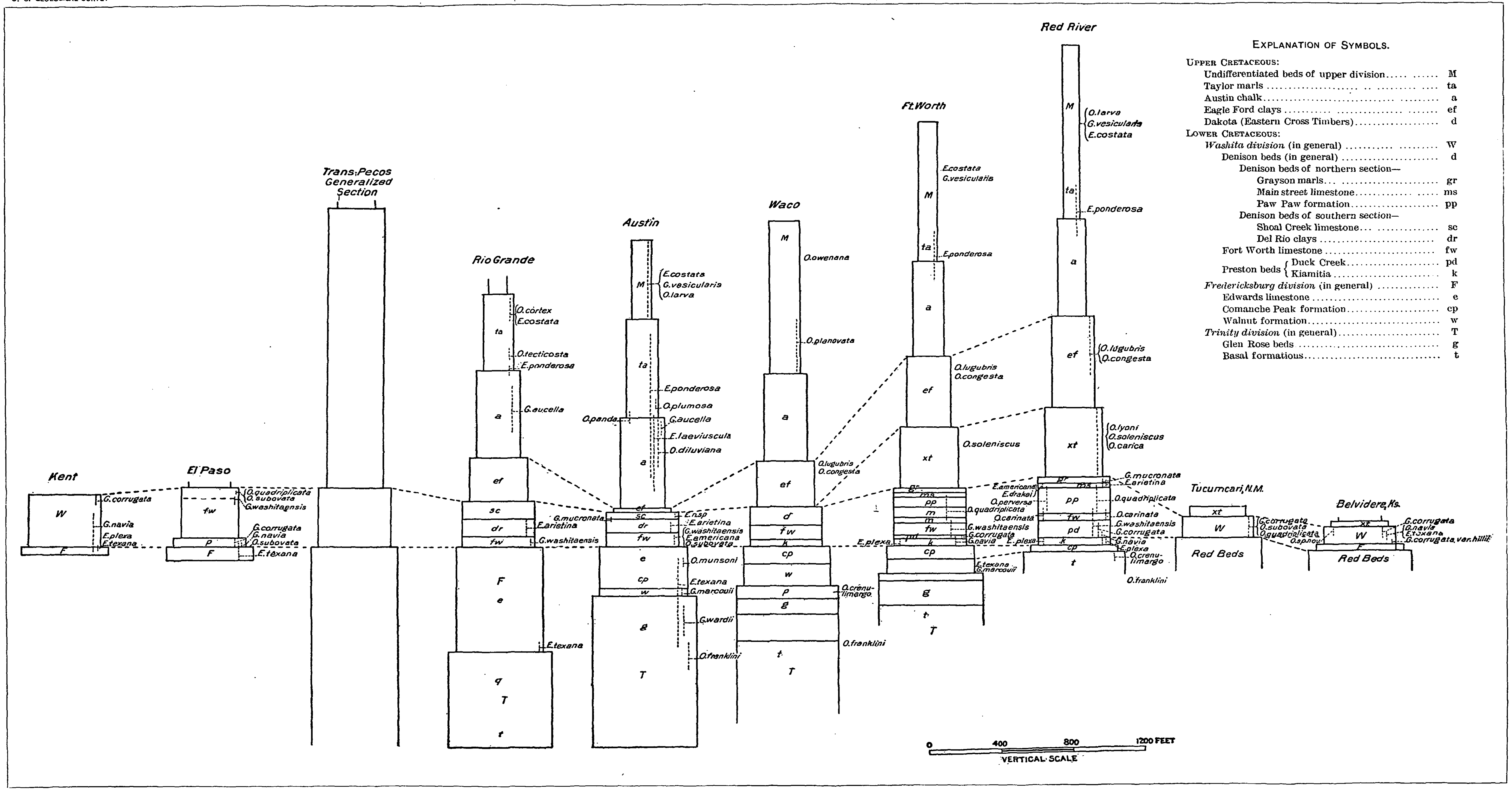


TABLE OF COLUMNAR SECTIONS SHOWING VERTICAL RANGE AND POSITION OF THE CRETACEOUS OSTREIDÆ.

INDEX.