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The benefits of education and of useful knowledge, generally diffused through a community, are essential to the preservation of a free government.

Sam Houston

Cultivated mind is the guardian genius of democracy. . . . It is the only dictator that freemen acknowledge and the only security that freemen desire.

Mirabeau B. Lamar

ON A NEW EXOGYRA FROM THE DEL RIO CLAY AND SOME OBSERVATIONS ON THE EVOLUTION OF EXOGYRA IN THE TEXAS CRETACEOUS[1]

By Emil Bose

Nearly twenty years ago attempts were made to subdivide the Texas Cretaceous, basing stratigraphical zones on the occurrence of oysters, especially Gryphaeas and Exogyras. That such a subdivision must be doomed to failure will be evident to any paleontologist on account of the extreme variability of oysters, Exogyra included. But these attempts are interesting, in so far as they showed that Exogyras occur in most of the Cretaceous beds of Texas and that all these may be related to each other. Exogyras occur practically from the lowest stratum of the Trinity formation, which corresponds to the Aptian, to the highest Cretaceous, the Navarro beds; which in their upper part, the higher Escondido beds, certainly represent the Maestrichtian.

In order to show the evolution of Exogyra in the Texas Cretaceous a thorough collection of specimens of this genus in the different beds and a redescription of the known species would be absolutely necessary; first, because many forms are still undescribed; and second, because in most of the described species the development from the smallest to the mature individuals has not been sufficiently taken into account. The very small specimens are often the most important ones, because their ornamentation is frequently quite different from that of the full grown individuals and demonstrates from which forms in lower beds the species has branched off. Often the ornamentation on the very first part of the beak of mature specimens shows also this original ornamentation, but generally the beak has been corroded by the movement of the shell in the water or by the grinding effect of sand in currents. In these cases the beak will appear smooth, although the younger specimens show a decided ornamentation. In Exogyra the evolution

[1]The manuscript for this paper was submitted in June, 1919; the bulletin was issued in September, 1919. (Ed.)

of the beak is of an importance similar to that of the suture and the smaller whorls in the ammonites.

More than twelve years ago, when I described the fauna of the Cerro de Muleros near Ciudad Juarez, Chihuahua, Mexico, I felt convinced that most of the Texas Exogyras had developed from a common tribe, but at that time I did not have enough material and there seemed to exist serious gaps which in part have been filled since that date. One of them especially was between the Vraconnian and the highest Cenomanian; or, using local terms, between the uppermost Edwards limestone and the Buda limestone. This latter one has been recently filled through a discovery made by Mr. W. R. Cartledge, who found a new Exogyra in the upper part of the Del Rio beds in the region near the quicksilver deposits of the Terlingua district; a species which will be described farther on.

I do not propose to prove that the evolution of the Texan Exogyras was entirely continuous, because my material is still very incomplete; but I wish to open a road for somebody else who may want to demonstrate in what manner Exogyra developed in Texas during the Cretaceous. It will probably be found that such an evolution existed and was at least partly parallel to the development of this genus in southern Europe and northern Africa; possibly in the later stages also in Asia.

Thus the content of the following paper will be merely a sketch, but it may point out a way for a monographical description of the Cretaceous species of Exogyra in Texas.

The oldest species of Exogyra in the Texas Cretaceous seemingly occurs in the lower part of the Trinity formation, the Basement sands or Travis Peak formation of Travis County. This species has been described, although not figured, by Cragin[1] as *Exogyra Hilli*. He asserts that it has also been found in Arkansas, where it was described by R. T. Hill.[2] It is a small form somewhat similar in out-

[1]F. W. Cragin, A contribution to the invert. Paleontol. of the Texas Cretaceous. 4th An. Rep. Geol. Surv. Texas, 1893, p. 186.

[2]R. T. Hill. The Mesozoic geology of southwestern Arkansas. An. Rep. Geol. Surv. Arkansas, 1888. vol. 11, p. 131 (under the name of *Ostrea Franklini*), pl. 5, fig. 1-10 (not pl. 5, fig. 11-18; pl. 6, fig. 19-27; pl. 7, fig. 28-30).

line to immature specimens of *Ex. texana*, with 5 to 8 radial folds on the anterior slope, a distinct umbonal ridge, and a steep anterior slope. The upper valve is practically smooth. This form seems to be intimately related to *Exogyra Boussingaulti* d' Orb.[1] which occurs approximately in the corresponding horizon of Europe. A similar form has been found in the Aptian of San Juan Raya, Puebla, Mexico.

This species seems to have branched off into several forms in the next higher division of the Trinity formation, some of which have been described and very imperfectly figured by Cragin as *Ex. paupercula*[2] and *Ex. weatherfordensis*.[3]

These species are quite frequent in the Alternating beds (Glenrose), the middle and upper part of the Trinity formation. Both seem to be related to *Ex. Hilli* and *Ex. Boussingaulti*, although the distinguishing feature in *Ex. paupercula* is that the beak becomes free from the rest of the shell as in *Ex. arietina*. *Ex. paupercula* has only 2 to 4 irregularly-topped, angular, radial folds on the lower valve, while the upper valve seems to be smooth. I have not been able to see the original specimens.

Much more similar to the *Ex. Boussingaulti* group is the *Ex. weatherfordensis* (pl. 1, fig. 1, 2) with a strong umbonal ridge, 6 to 12 oblique plications on the anterior slope, and a greater number of narrow, subradiate, or curved plications on the posterior slope. The upper valve is smooth, but the margin is often scalloped corresponding to the ending of the ribs on the lower valve.

This is, at least, what I take to be *Ex. weatherfordensis*, a species which has not been very well figured. In the collection of the University of Texas exists a number of specimens collected by Taff at one quarter of a mile west of Weatherford, labeled *E. Boussingaulti* d'Orb. This species certainly is very similar to the French form and a near relative of it, and at the same time also of *Ex. Hilli*. It does

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[1]A.d' Orbigny, Voy. dans l'Amérique mérid. t. 111, 4me part, Pal., p. 91, pl. 18, fig. 20; pl. 20, fig. 8, 9.

Idem, Paléont. franç., Terr. Crét. t. 111, p. 702, pl. 468.

[2]Cragin, loc. cit., p. 186, pl. 30, fig. 7, 8.

[3]Idem, ibidem, p. 188, pl. 45, fig. 7-10.

not seem possible to prove that it is the type of *Ex. weatherfordensis* but it appears at least to be very similar to the specimens described and figured by Cragin; and it certainly proves that a very near relative of *Ex. Boussingaulti* lived in the Texas sea at about the epoch of the European species. The specimens from a place four miles west of Montell, also cited by Cragin, may belong to the same species, but they are mainly upper valves, and not very characteristic.

These last two species seem to grow larger than *Ex. Hilli* and to a certain degree lead over to *Ex. texana* and *Ex. arietina*. The first of these two species is found well developed in the Walnut clays, the base of the Fredericksburg formation. This species has been described and figured by several authors, first by Roemer,[1] then by Conrad, Gabb, Coquand, White, Hill and Vaughan, and by myself.[2] The species is nearly related to *Ex. flabellata* Goldfuss of the Cenomanian of Europe, but it is in general broader, the ribs are more numerous, and the ridge is nearer to the anterior side; the European species is generally a little younger than *Ex. texana*, although this latter passes through quite a number of horizons. In the Walnut clay it is associated with *Engonoceras, Schloenbachia* group of *Sch. Belknapi*, and *Schloenbachia* group of *Sch. acutocarinata*, and these beds probably represent the Vraconnian or the Albian. It is found also in the Comanche Peak limestone and the Edwards limestone; both still belonging to the Vraconnian or Albian. At the Cerro Muleros it occurs throughout the whole Vraconnian.

It should not be overlooked that the Comanche Peak limestone seemingly contains another species of *Exogyra*, directly derived from the main tribe and exceedingly similar to *Ex. Boussingaulti;* it is distinguished from *Ex. texana* by its smooth upper valve, is not very frequent, and I have not seen more than a very few specimens.

Ex. texana is certainly derived from the tribe of *Ex. Boussingaulti* represented by *Ex. weatherfordensis*, but the younger species grows much broader, the umbonal ridge

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[1]Roemer, Kreidebild. v. Texas, 1852, p. 69, pl. 10, fig. 1a-1e.

[2]Böse, Cerro de Muleros, Bol. Inst. geol. de Mexico, 25. P. 112, pl. 20, fig. 14-16; pl. 21, fig. 1-11; pl. 22, fig. 1-9.

moves nearer to the anterior margin, which becomes exceedingly steep, while the posterior slope becomes flattened or even concave. The upper valve develops a great number of somewhat irregular radial ribs, the umbonal ridge becomes very pronounced and the anterior slope quite steep. A conscientious study of the forms from different horizons may show that even within the species a certain development takes place, in so far as the umbonal ridge is nearer to the anterior margin in the older specimens than in the younger ones, and that the ribs grow coarser in the individuals found in the higher horizons.

Ex. texana nearly always occurs in great numbers and with it begins the rich development and subdivision of the principal tribe.

Before we go any farther we shall have to mention another form developed during the Albian or the Vraconnian and apparently the ancestor of several younger species. This is the form described by Cragin[1] as *Ex. plexa*. Under this name Cragin seems to have united at least two different species; I refer his name to one of these which looks entirely like an enlarged juvenile specimen of *Ex. arietina* (compare the description of this species given below). The exact types could not be found, but there is sufficient material from the original localities. (Compare pl. 1, figs. 3, 4.) I regard as the type the specimen figured by Cragin in his figures 3, 5, 6 (not 4). It is entirely covered with fine radial ribs which cross the prominent umbonal ridge obliquely as in the juvenile specimens of *Ex. arietina*. The specimens occur in the bed of *Ex. texana* below the Kiamitia clays on the Texas and Pacific railroad, three miles west of Benbrook. The whole shell is spirally curved similar to the young *Ex. arietina* although the size is much larger. The beak is still pressed down against the body of the shell, but a further spiral development would detach the beak from the rest of the valve.

This species has probably developed from the group of *Ex. Boussingaulti* (*Ex. weatherfordensis*) losing the thick

[1]Cragin, loc. cit., p. 187, pl. 30, fig. 3-6.

folds and developing fine ribs, but retaining the high umbonal ridge.

In the same strata we find another species, of which a specimen not very characteristic has been illustrated by Cragin in his fig. 4. The upper part (about 15 mm. in height) is practically of the same form and ornamentation as *Ex. plexa* typ. but from there on it begins to develop on the anterior side four to five strong radial folds beginning near the umbonal ridge and going down obliquely with the ridge to the antero-inferior margin. They are much stronger and sharper than shown in Cragin's figure and are covered by fine radial ribs. They are fainter on the mould and there appear smooth. As our material is not sufficient to allow a complete description we shall designate the species as *Ex.* nov. sp. aff. *plexa.* (Pl. 1, fig. 5).

Ex. plexa seems to lose the fine ribs on the lower margin in larger specimens, as is shown by an individual from the original locality. This feature is still more evident in larger specimens found at the base of the Fort Worth limestone in Duck Creek, Grayson County. This is evidently a younger form of the same group, but possibly a different species or variety. It grows much larger than the type, shows approximately the same ornamentation on the umbonal region, but becomes entirely smooth on the inferior margin.

Another form from the Kiamitia clays found on little Mineral Creek, north of Pottsboro, Grayson County, shows an ornamentation very similar to that of *Ex. plexa* on the umbonal region, but develops a rather deep furrow along the umbonal ridge on the posterior side and several obtuse folds covered with fine radial ribs on the anterior side near the antero-inferior margin. It is most probably a descendant of *Ex.* nov. sp. aff. *plexa,* mentioned above (Pl. 1, fig. 6.)

About the development of *Exogyra* in the Georgetown formation, i. e., the lower and middle part of the Cenomanian, little is known.

There is a large species frequently found in this formation and it has generally been called *Ex. americana* or *Ex. Walkeri.* It was originally described by Marcou as *Gryphaea sinuata* var. *americana,* and Cragin cites it as *Ex.*

americana Marcou. Unfortunately, only very large specimens are described and figured, but the individual illustrated by Marcou shows that the younger specimens must have strong, fold-like, radial ribs in the umbonal region. Therefore I presume that this broad and flat species with its obtuse ridge near the anterior margin developed from a broad, coarsely-ribbed group, probably one derived from *Ex. texana.*

Exogyra becomes exceedingly frequent on top of the Georgetown formation in the Del Rio clay which represents part of the upper Cenomanian.

The principal species is *Ex. arietina* Roem. which we have redescribed farther on. It is evidently a descendent of *Ex. plexa;* it retains the ornamentation of this species and its form on the umbonal region and in the very young individuals, but later on becomes entirely smooth and its beak becomes detached because the whole valve coils spirally.

A second species is *Ex. Cartledgei* nov. sp., described below. It certainly was derived from *Ex.* nov. sp. aff. *plexa,* developing the strong radial ribs still more, while the beak became somewhat detached from the rest of the shell by the coiling of the valve. The strong umbonal ridge is still in existence, but the fine ribs on the beak were lost; or at least are not preserved on the specimens I have in hand. This species grows much larger than either *Ex.* nov. sp. aff. *plexa* or *Ex. arietina.*

Cragin[1] described another species from the Del Rio clay which he called *Ex. Drakei.* Unfortunately his figures are very deficient, but his originals show that the species is entirely different from *Ex. Cartledgei.* It is covered with irregular but strong ribs on the lower valve, not really coiled, but rather bent over to one side, as shown in Cragin's figure 11. The upper valve is very similar to that of *Ex. arietina* and *Ex. Cartledgei.*

In the next higher horizon, the Buda limestone and the corresponding strata of the Cerro de Muleros, which, according to the echinoid fauna described by Whitney, and

[1]Cragin, loc. cit., p. 184, pl. 29, fig. 8-11.

the ammonites, represents the very uppermost part of the Cenomanian, several Exogyras occur which are larger than most of those in beds below, with only the possible exception of *Ex. americana.*

The species found in the Buda limestone is *Ex. Clarki* Shatt.,[1] but the specimens figured by Shattuck represent only medium-sized individuals and the species should be redescribed and figured. It is a very broad and not very thick species very similar to *Ex. americana;* the medium-sized specimens show rather strong radial ribs, while the mature specimens are almost smooth. Very juvenile specimens do not seem to have been found. The species evidently is a direct descendent of the older *Ex. americana.*

In the corresponding strata of the Cerro de Muleros an *Exogyra* is found in great numbers, which I took formerly to be identical with *Ex. Clarki* and which on account of its great similarity with *Ex. ponderosa* I described as *Ex. ponderosa* var. *Clarki.*[2] The medium-sized specimens of this species really are extremely similar to *Ex. Clarki* while the full grown individuals are entirely different. I therefore rename the species from the Cerro de Muleros and call it *Exogyra Whitneyi* in honor of Prof. F. L. Whitney, whose beautiful studies about the echinoid and mollusk fauna of the Buda limestone have given us the first idea of its rich fauna and its real age.

I have figured especially the juvenile and medium-sized specimens of *Ex. Whitneyi* in the work cited above. If we compare figs. 5, 6, 7, 11 on plate 26 with specimens of *Ex. plexa,* we can find nearly no difference. Comparing figs. 4, 8, 10, 12 on the same plate with *Ex. Cartledgei* and *Ex. Drakei* we see at once that the similarity is extremely great, although the beak is not quite as much coiled spirally as in *Ex. Cartledgei.* The upper valve figured in fig. 9 of the same plate is very similar to that of *Ex. Cartledgei.* The mature forms are entirely different from the younger

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[1]Shattuck, Buda Limestone, Bull. U. S. Geol. Surv. no. 205. 1903. p. 22. pl. 10, 11.

[2]E. Böse, Cerro de Muleros, p. 115, pl. 23, fig. 17; pl. 24, fig. 6; pl. 25, fig. 8; pl. 26, fig. 4-11.

ones; the ribs mostly are destroyed by erosion and the shell becomes entirely smooth, the beak detached from the body. It brings to mind at once the elongate varieties of *Ex. ponderosa* but notwithstanding the great similarity between the two species I have become convinced that they should be separated specifically on account of the somewhat different form of the younger specimens, the generally broader shape of the mature *Ex. ponderosa*, and the extremely different age of the beds in which both species occur.

Those small individuals from Cerro de Muleros which I have taken to be juvenile forms of *Ex. Whitneyi* show an astounding similarity to a small *Exogyra* extremely frequent in the Mainstreet limestone of Denison. This form has been frequently cited under the name of *Exogyra arietina*, but is easily distinguished from it by its rather strong ribs and the form of the beak pressed against the body of the shell. The real *Ex. arietina* occurs in a somewhat higher horizon of the same locality; that is to say, in the Grayson Marls. The similarity between the small *Exogyra* of the Mainstreet limestone and the small individuals from the red sandstone of Cerro Muleros is so great that I have become somewhat doubtful if these latter forms are really the juvenile forms of *Ex. Whitneyi* and not perhaps a different species identical with or very similar to the small *Exogyra* in the Mainstreet limestone, although they certainly occur together with *Ex. Whitneyi* in the red sandstone of Cerro Muleros. It is of course possible that the small *Exogyra* of the Mainstreet limestone is at the same time a predecessor of *Ex. Whitneyi* and of *Ex. arietina*.

A species very nearly related to *Ex. Whitneyi* is *Ex. ferox*, if it is not only a variety. *Ex. ferox* was described by Cragin[1]; unfortunately his figures are so deficient that one cannot get an adequate idea of the shape, and the upper valve of the original has been lost. The lower valve is very similar to that of the mature *Ex. Whitneyi*, but is still more elongate; no closer comparison can be made before the ju-

[1]Cragin, loc. cit., p. 185, pl. 32, fig. 1; pl. 33, fig. 5; pl. 34, fig. 1; pl. 36, fig. 6.

venile stages of *Ex. ferox* have been found and described. The species was found in the so-called lower Cross Timber (Woodbine) sands, which correspond in age probably to the Buda limestone; at least, they also belong in their lower part to the upper Cenomanian.

It is difficult to say to what group belongs the form cited by Cragin[1] as *Ex. columbella* Meek. It certainly has nothing to do with the type of that species. The specimen which came from the lower Cross Timber sands of Timber Creek, two miles below the Dallas-Lewisville Road, Denton County, is so much corroded that the surface appears nearly smooth, but on close inspection one can easily see that it had been covered by thick, rounded, rather strong ribs. It might be a very young individual belonging to the group of *Ex. Clarki.*

From the next higher beds, the Eagle Ford shales, which correspond to the Turonian, very few fossils have been described in Texas, and among these only one *Exogyra* is cited under the name of *Ex. columbella* Meek. This is a rather small form with thin shell and covered by small, quite regular, radial ribs, which bifurcate at the umbonal ridge. It seems to be very possible that this species is a branch of the *Ex. Clarki* group, if it is not directly derived from *Ex. arietina* through the so-called *Ex. columbella* Cragin. This may only be decided when larger collections in the Eagle Ford shales or the upper part of the Woodbine sands shall have been made. In Colorado a large species, *Ex. suborbiculata* Lam., occurs, which as Stanton justly remarks, is intimately related to the European group of *Ex. columba*, but this larger form has not yet been found in Texas.

Also in the next higher formation, the Austin Chalk, very few *Exogyras* are known, although they can be found in great numbers in it. The Austin Chalk corresponds in its lower part to the Emscherian, in its middle to the lower Santonian, and in its upper part to the middle Santonian. I have not seen any *Exogyra* in the lower part, but it is

[1]Cragin, loc. cit., p. 184.

possible that *Ex. lacriuscula* Roemer or a related form occurs there, as it certainly does in the middle portion. This very characteristic form is entirely smooth, but if the younger specimen figured by Roemer in Pl. 9, fig. 3c, really belongs to this species, we might suppose that it is derived from *Ex.* nov. sp. aff. *plexa* through *Ex. Cartledgei* and *Ex. columbella* Cragin (not Meek) having lost entirely the finer ribs.

An undescribed and unstudied small *Exogyra* is very frequent in the middle part of the Austin Chalk (zone of *Mortoniceras texanum*) on the Rio Grande.

In the upper part of the Austin Chalk near Austin we find a great number of a large *Exogyra* which commonly has been called *Ex. ponderosa,* although it is specifically quite different. It has a broad and not very convex lower valve, with a rounded ridge and an extremely steep slope on the anterior margin, and is very similar to the large specimens of *Ex. Clarki* and to a certain degree to *Ex. americana.* These species with very low right valves probably form an independent branch and are derived from *Ex. texana.* I have not seen any of this tribe in higher strata of Texas, but a near relative, *Ex. tamulica* Stol., appears in the higher Senonian of India.

The *Exogyras* of the higher strata of Texas, the Taylor marls (upper Santonian), Navarro beds (Campanian) and the higher Escondido beds (Maestrichtian) are very little known, practically only two species having been described: *Ex. ponderosa* Roem. from the Taylor marls and *Ex. costata* Say from the Navarro beds, which seems to continue into the base of the higher Escondido beds.

Exogyra ponderosa has been first and very well described and figured by Roemer.[1] In recent years it has been redescribed and figured by Stephenson.[2] His figures are very characteristic but unfortunately he has not tried to describe and figure the development of the species from the

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[1]Roemer. Kreidebild. v. Texas, p. 71. pl. 9, fig. 2.

[2]L. W. Stephenson, Cret. dep. on the Eastern Gulf region. U. S. Geol. Surv. Prof. Paper 81, 1914, p. 46, pl. 13, fig. 5-7; pl. 14; pl. 15, fig. 1-3.

youngest to the mature individuals. Roemer mentions that specimens about 2.5 cm. long show distinct, unequal, radial folds which begin to grow indistinct near the margin of the valve. Stephenson's Pl. 13, fig. 5 shows clearly this kind of ribs on the beak of a medium-sized specimen. If we imagine this beak detached from the valve and in the form of a young specimen, it would have exactly the shape and ornamentation of a young specimen of our young *Ex. Whitneyi* from the Cerro de Muleros, and be extremely similar to the young of *Ex. arietina* and to the mature specimens of *Ex. plexa*. Stephenson (loc. cit. p. 49, pl. 15, fig. 4; pl. 16, fig. 1, 2) has described a number of shells as *Ex. ponderosa* var. *erraticostata* Steph. It will be rather difficult to sustain this variety because the figure of Roemer's type shows very similar ribs and thus should be part of this variety.

Ex. costata has been quite frequently described and figured; recently Stephenson[1] has very fully described the mature specimens and also has illustrated these profusely. Unfortunately also in this case we lack the exact knowledge of the ornamentation of very young specimens. The species is possibly derived from *Ex. ponderosa* or at least from a form of which *Ex. ponderosa* is a branch, but this cannot be proven at the present time. Specimens should be especially studied in the zone where *Ex. ponderosa* and *Ex. costata* appear to occur together and where the real antecessor of the latter species may be found.

The preceding sketch of the evolution of *Exogyra* in the Texas Cretaceous necessarily has to be deficient, incomplete and in a great part hypothetical, but at least it shows that all the species, even the largest which are practically smooth, came originally from a rather small costate form; and that the great diversity of forms in the upper strata is simply due to the subdivision of a tribe represented at the base by forms that are intimately related to each other and at the same time to *Ex. Boussingaulti* of the European Aptian. It shows also that some of the large species in the

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[1]Stephenson, loc. cit. p. 50 pl. 16, fig. 3, 4; pl. 17, fig. 1, 2; pl. 18; pl. 19, fig. 1-4; pl. 20 fig 1.

higher horizons may not be intimately related, notwithstanding the very similar shape, but rather be convergent forms.

A monograph of the Texas Cretaceous Exogyras would probably show a still much greater variety of forms which were derived from the same original tribe, and at the same time it would not at all be difficult to demonstrate that in Europe, Northern Africa and Asia quite a similar evolution has taken place.

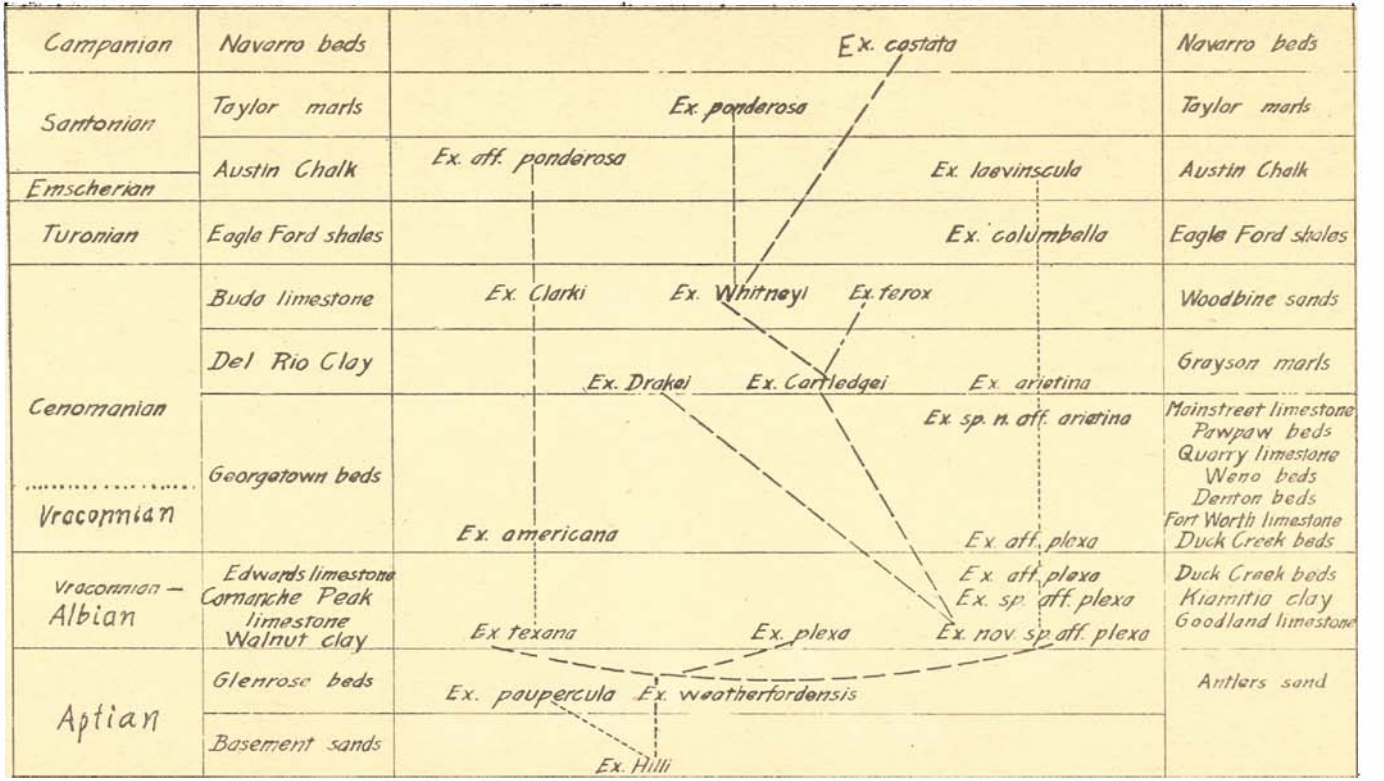

Fig. 1. Probable relationships of the species of Exogyra in Texas.

DESCRIPTION OF SPECIES

Exogyra Cartledgei nov. sp.

Pl. I, fig. 7-13; Pl. II, fig. 1-4; Pl. III, fig. 1-8.

Shell medium-sized, very thick, elongate to sub-oval, somewhat oblique up to the beak, which is spirally coiled downward and outward.

Inferior valve.

Shape very variable, elongate to obliquely suboval up to the beak, strongly convex, the highest part forming an obtuse, curved, umbonal ridge which follows approximately the middle line of the height of the shell, and which disappears toward the inferior margin of the valve. The slope toward the anterior margin is sometimes much steeper than toward the posterior side.

Beak generally spirally twisted or coiled downward and outward; sometimes pressed against the body of the shell, sometimes almost entirely free in the shape of a ramshorn. The beginning of the beak is never free, but always pressed against the shell, which shows that in the juvenile stage the beak was not detached from the rest of the valve and that the development in the form of a ramshorn is the latest stage caused by the spiral coiling of the valve during the later stages. The point of the beak often shows a scar, due to its having been attached to some small object, such as shells, etc.

The ornamentation consists of about fifteen coarse longitudinal ribs which on each of the slopes (anterior and posterior) are nearly parallel on the upper half of the valve. The series on the anterior side is not parallel to that on the posterior one, but forms an angle of about 40 degrees. On the umbonal ridge the two series are united by an intervening space covered by intercalated, bifurcating ribs. The ribs on the anterior side form a wide angle with the axis of the umbonal ridge but on the last part of the beak they

become nearly parallel to the ridge. The opposite side of the beak always appears to be entirely smooth, which probably is in part due to the state of preservation. The ribs are crossed by lines of growth and by strong lamellae which give them a scaly aspect. The lines of growth and lamellae cover also the beak.

The ligamental groove is generally spirally curved, deep, broad, triangular, very long to very short, according to the shape of the beak, limited on both sides by a ridge. Below the groove on the posterior side is a shelf-like fold finely crenulated, on the anterior side a similar one but rounded and less distinct. The shell outside of these ridges is also finely crenulated along the upper part of the animal cavity, the crenulation becoming very faint on the lower half until it disappears, entirely. The muscular impression is deep and very near the posterior margin. The cavity often extends somewhat into the beak.

Upper valve.

Rather thick, slightly convex to flat, operculiform, subovate with a nearly flat spiral twist, the beak being near the margin. Beak very little prominent, nearly pressed down to the rest of the shell. Sometimes there is a very obtuse, spirally curved umbonal ridge which disappears toward the postero-inferior margin. On the posterior side right near the beak is a distinct depression.

On a well preserved specimen the ornamentation consists of numerous concentric growth lines and lamellae which cover the whole surface. The lamellae are not of circular form, but show an angular prolongation on the umbonal ridge. Where this is absent the lamellae follow a more or less elliptical course. Fine radiating ribs are visible on the postero-superior part of the shell in the region close to the beak. The margins are distinctly crenulated.

The ligamental groove is mostly broad and flat, seldom narrow and deep; in the first case strongly spirally curved, in the second case much less so. In the first case, the ligamental groove is almost parallel to the superior margin; in the second case it nearly forms a right angle with it.

This seemingly depends on the thickness of the valve. Toward the interior and posterior side of the groove, a striated protuberance elevates itself more or less highly; it is opposite the depression formed by the striated shelf and crenulated margin of the lower valve, and probably fits into it.

The muscular impression is deep and near the posterior side, far below the region of the beak.

Relation to other species:

Ex. Cartledgei has a certain similarity to *Ex. arietina*, but its strong ribs and large size make it easy to distinguish the two. It probably has been derived from the same tribe, that of *Ex. plexa*, or a similar form, as has been explained in the first chapter of this paper.

Occurrence:

The species has been found very frequently in the Del Rio clay in a horizon about 10 to 30 feet below the Buda limestone. The Del Rio clay has at this place a thickness of 120 feet or more. It is associated with *Nodosaria texana*, which occurs in abundance above it, *Gryphaea* sp., *Enallaster* cf. *bravoensis*, and *Hemiaster* sp. According to Dr. Udden, *Exogyra arietina* is rare at this locality but was noted at a level not far from the middle height of the Del Rio clay.

Locality:

Reed Plateau, point almost exactly one mile south from the Chisos Mining Company's mine, in Brewster County, Texas.

Exogyra arietina Roemer

Pl. IV, fig. 1-18; Pl. V, fig. 1-23.

1852. Ferd. Roemer. *Die Kreidebildungen von Texas und ihre organischen Einschlüsse*. Bonn. P. 68, Pl. 8, fig. 10.

Roemer's description of this species is very careful and his illustrations are quite good, but figures of the juvenile stages of the species are lacking, as these were not given overmuch importance by the paleontologists of that time.

Roemer remarks that the surface of the lower valve in the region of the beak is covered by delicate longitudinal striae interrupted by the lamellae of growth and which generally can be seen only in the more juvenile specimens, the region of the beak being more or less corroded in the larger individuals.

A study of well preserved specimens of *Ex. arietina* of different ages shows at once that Roemer is absolutely correct in his description, but also that the development of the species shows three clearly marked stages.

Leaving aside the protoconch which is of the size of about a common pinhead, the first stage of development (Pl. V, fig. 7-10) has the following character: In shells up to about 3 mm. in length, the surface does not show a trace of ribs, even where not the slightest corrosion has taken place; it is only covered by rounded, concentric, relatively broad and not very distinct folds and the growth lines. At this size, the posterior side of the shell is distinctly flat with the beak pressed against the rest of the valve; only the very first part of the beak in a length of 0.5 to 1.0 mm. elevates itself a little above the surface of the shell. The umbonal ridge is relatively sharp and high and reaches from the beak to the postero-inferior margin. The anterior side forms an angle of about 50 degrees with the posterior side, and is rounded in height as well as in width. This angle between the two sides causes the prominent umbonal ridge. The outline of the valve is triangular-suboval at this stage.

The second stage is represented by specimens of a length of about 10 mm. or a little more (Pl. V, fig. 11-16). In these individuals the shell of the first part of the beak, up to about 3 mm. from its point, is of course smooth, but on the next wrinkles of growth, fine radial ribs appear suddenly in the number of about 30 to 35. They are very distinct on the anterior side, the umbonal ridge, and the greater part of the posterior side, but become indistinct in this latter region on the surface near the end of the beak. The ribs reach higher on the anterior than on the posterior side, and pass obliquely over the umbonal ridge. The lamellae

of growth begin to develop, interrupting the ribs and imparting to them the aspect of roof tiles.

The umbonal ridge is as prominent as in the preceding stage at least in the umbonal region, but toward the postero-inferior region it becomes rounded and less distinct.

The shape of the shell begins to change. It has no longer the triangular form but begins to coil spirally. In connection with this circumstance the growth lines and lamellae no longer form a perfect elliptical curve, but begin to show in their course a distinct protuberance or tongue-like prolongation on the umbonal ridge.

The next stage represents the beginning of the mature development (Pl. IV, fig. 10-15; Pl. V, fig. 1-3). The ribs disappear about as suddenly as they began, the shell becomes smooth and is only covered by lines of growth and lamellae which appear more distinct the more the shell grows. They no longer form a simple curve, but are rather wavy, especially on the posterior side and a little less on the anterior side, showing a pronounced tongue-like prolongation or protuberance in their outline on the umbonal ridge. The wavy appearance of the lamellae on both sides corresponds to the development of shallow furrows (Pl. V, fig. 4, 17), one more distinct on the anterior side and one generally less so on the posterior side.

The shape of the shell now changes very rapidly, coiling spirally so that the umbonal region becomes twisted and detached from the rest of the valve.

Exceptionally it can be observed that very faint and somewhat irregular longitudinal ribs appear again on larger shells up to a distance of about 35 mm. from the beak, measured along the umbonal ridge (Pl. V, fig. 17).

In the last stage of mature specimens the shell attains its characteristic shape similar to a ramshorn, as described by Roemer (Pl. IV, fig. 1-9, 16-18; Pl. V, 4-6, 17).

The opercular upper shell does not change essentially (Pl. IV, fig. 4; Pl. V, fig. 16, 18-23). It appears to have the same character from the size of about 2 mm. to the largest mature forms with a length of 25 mm. and more. The valve is sometimes nearly flat, always with a rather deep

depression on the posterior side near the spirally coiled beak, the point of which is pressed down against the surface of the shell. Sometimes this valve is entirely oval, especially in immature individuals; in other specimens it is distinctly spirally coiled, developing a relatively high umbonal ridge.

The ornamentation of the surface consists only of spiral lines of growth and lamellae. Only the superior margin of the umbonal region is finely crenulated. Traces of fine crenulation show sometimes on the inferior margin.

The interior of the lower valve does not change materially from the immature stage to the well developed specimen. The ligamental groove is always very narrow and deep, spirally coiled, and follows the superior margin. A faintly crenulated ridge is below it, the margin on the upper half of the cavity being always slightly crenulated.

The cavity continues into the beak, more or less.

The muscular impression is near the posterior side and close to the region of the beak.

The interior of the upper valve does not change materially from the immature stages to the final development of the species. The ligamental groove is very long, very narrow and deep, spirally coiled, follows the superior margin of the valve, and obliquely crosses the spiral lamellae of growth. The space between the groove and the superior margin is finely crenulated.

The muscular impression is strong and exactly under the umbo, as has already been observed by Roemer.

Occurrence:

Del Rio clay.

Locality of the specimens studied:

Shoal Creek, Austin, Texas.

EXPLANATIONS OF PLATES

PLATE I

Fig. 1, 2...*Exogyra weatherfordensis* Cragin.—Glenrose formation. One-fourth of a mile west of Weatherford, Parker County, Texas. Page 5

Fig. 3, 4...*Exogyra plexa* Cragin.—From bed with *Exogyra texana* below the Kiamitia clays. Texas and Pacific Railway, three miles west of Benbrook, Tarrant County, Texas. Page 8

Fig. 5.....*Exogyra* nov. sp. aff. *plexa* Crag. From bed with *Exogyra texana* below the Kiamitia clays. Texas and Pacific Railway, three miles west of Benbrook, Tarrant County ..... Page 8

Fig. 6.....*Exogyra* sp. aff. *plexa* Crag.—Kiamitia clay. Little Mineral Creek, north of Pottsboro, Grayson County, Texas.

Fig. 7-13...*Exogyra Cartledgei* nov. sp.—Del Rio clay. Reed Plateau, about one mile from the Chisos Mining Company's mine in Brewster County, Texas .....Page 17

Fig. 7-9, 11-13, beaks of the lower shell showing the different stages of development. Fig. 10, Ligamental groove of a large and slender specimen.

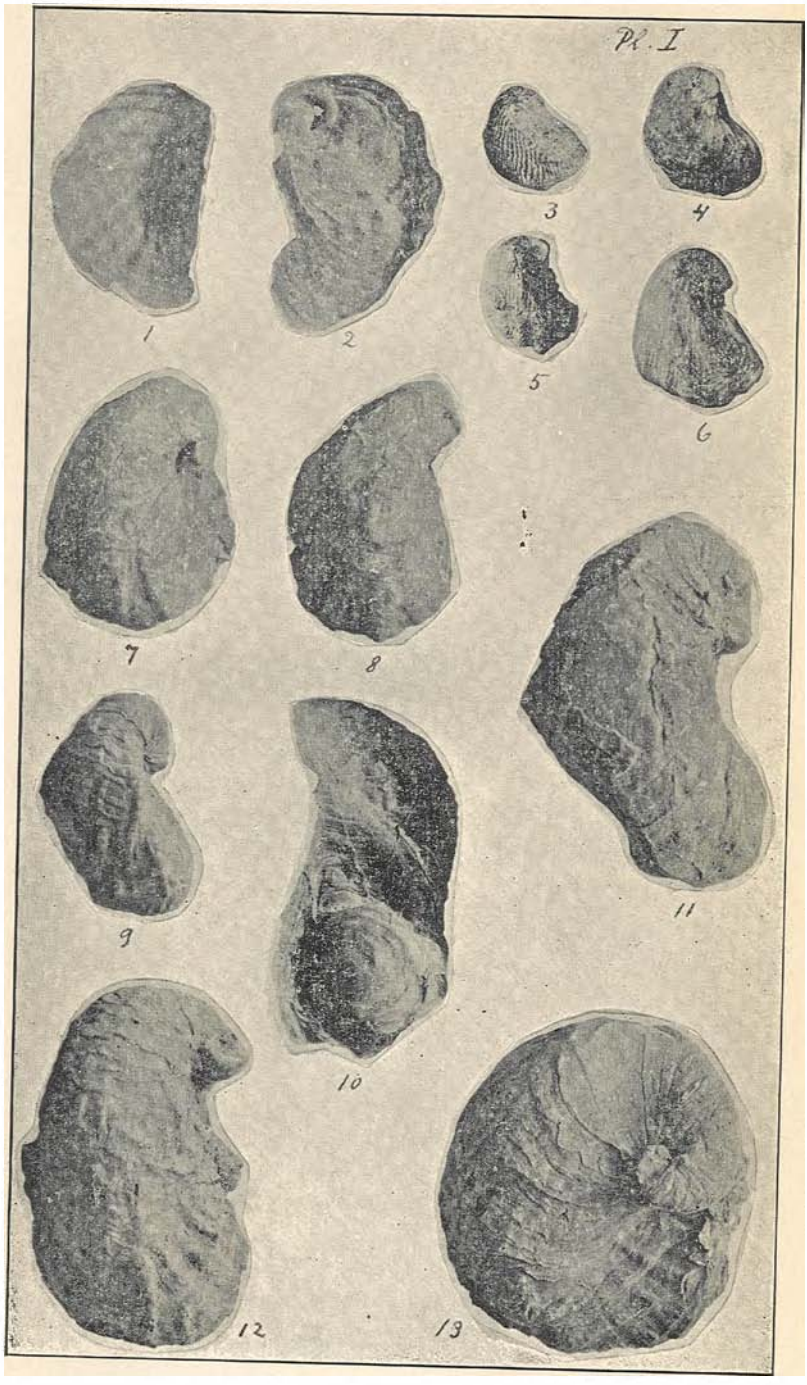
Pl. I
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PLATE II

Fig. 1-4...*Exogyra Cartledgei* nov. sp.—Del Rio clay. Reed Plateau, about one mile south from the Chisos Mining Company's mine, in Brewster County, Texas .....Page 17

Fig. 1..large slender shell, lower valve.
Fig. 2..inside of same.
Fig. 3..broad adult shell with coiled beak.
Fig. 4..inside of same.

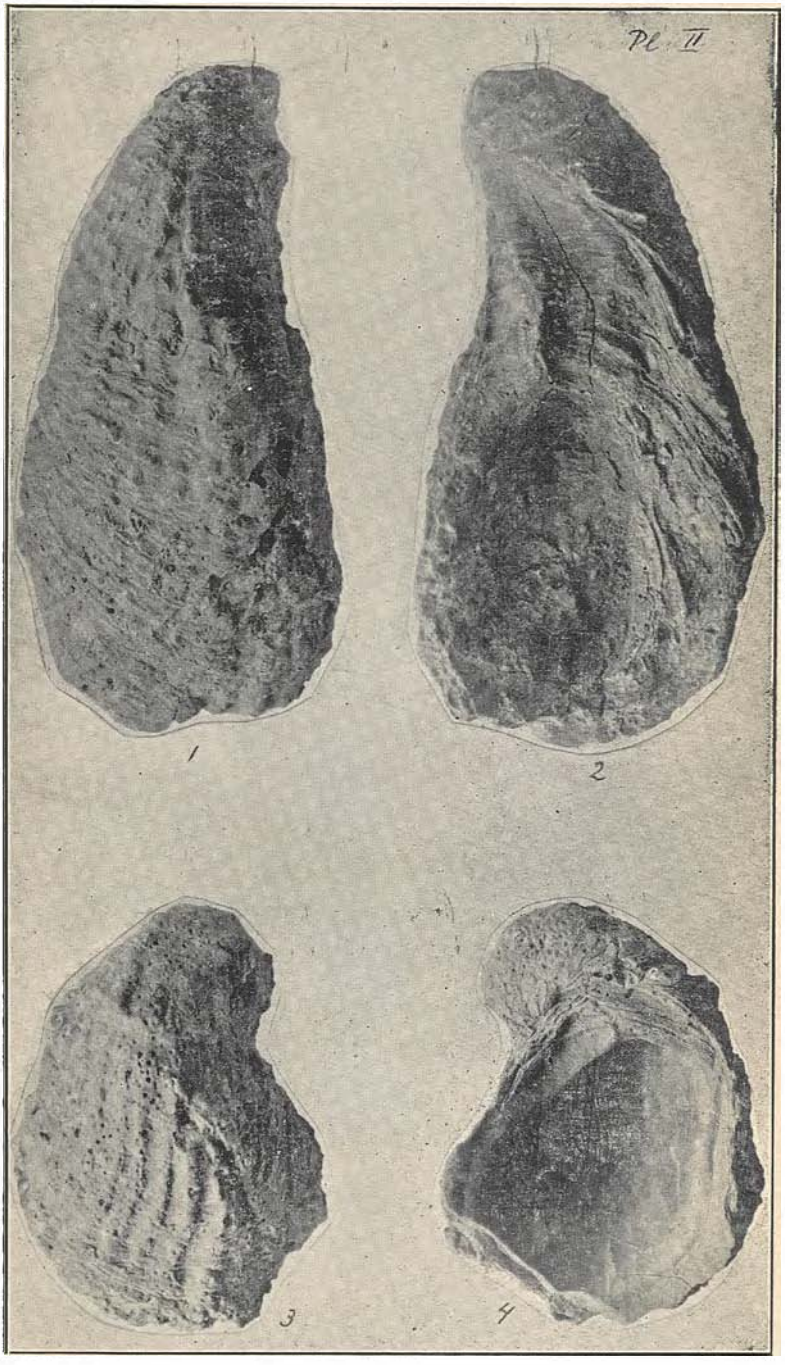
Pl II
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PLATE III

Fig. 1-8. . *Exogyra Cartledgei* nov. sp.—Del Rio clay. Reed Plateau about one mile from the Chisos Mining Company's mine, in Brewster County, Texas ..... Page 17

Fig. 1. . upper valve.

Fig. 2. . inside of the same.

Fig. 3, 6, 7. . surface of upper valves.

Fig. 4, 8. . inside of upper valves.

Fig. 5. . inside of lower valve showing a strongly curved beak and a corresponding ligamental groove.

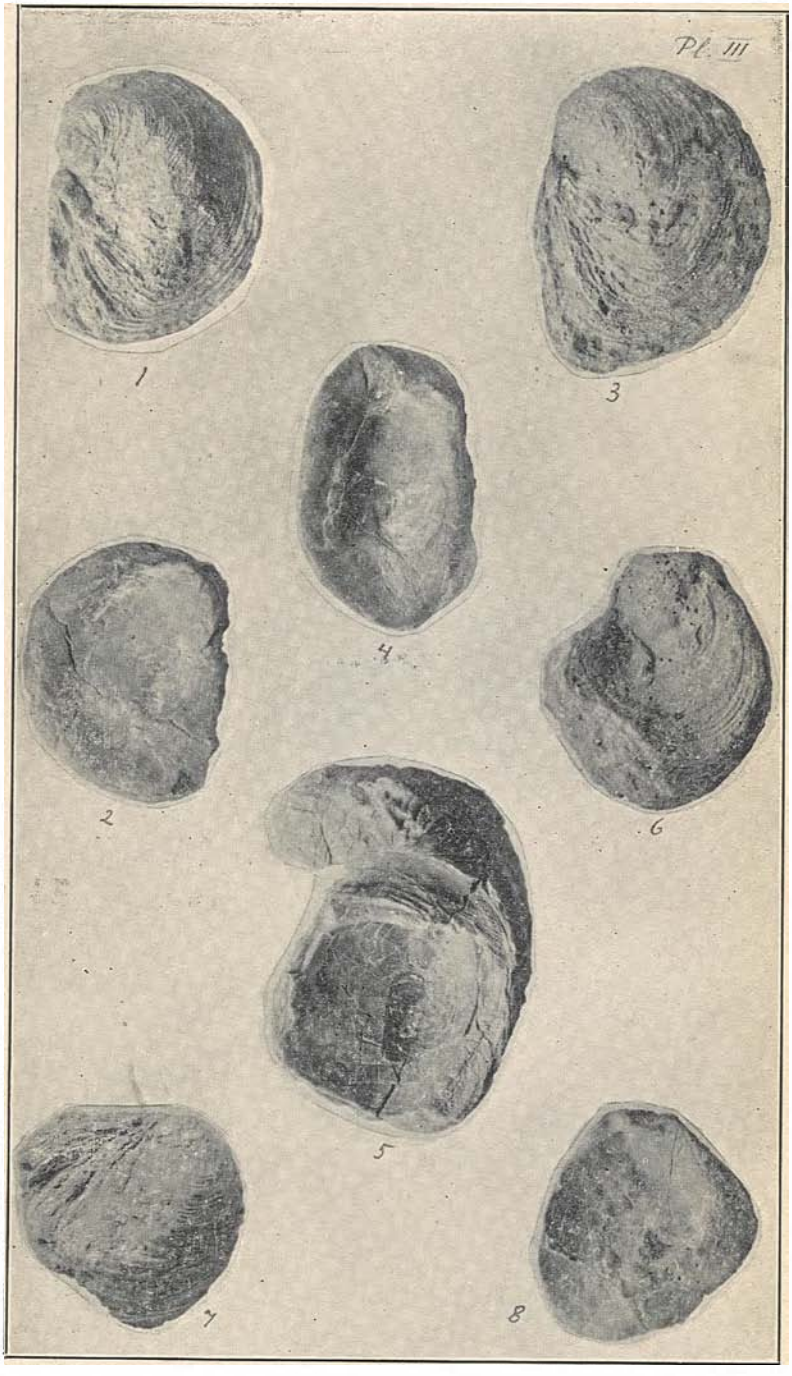
Pl. III
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PLATE IV

Fig. 1-18. . . *Exogyra arietina* Roemer.—Del Rio clay. Shoal Creek, at Austin, Texas. . . . . Page 17

Fig. 1-3. . adult normal specimen shown in three positions.

Fig. 4-6. . adult normal specimen shown in three positions.

Fig. 7-9. . adult normal specimen shown in three positions.

Fig. 10-12. . young normal specimen shown in three positions.

Fig. 16-18. . adolescent stage shown in three positions.

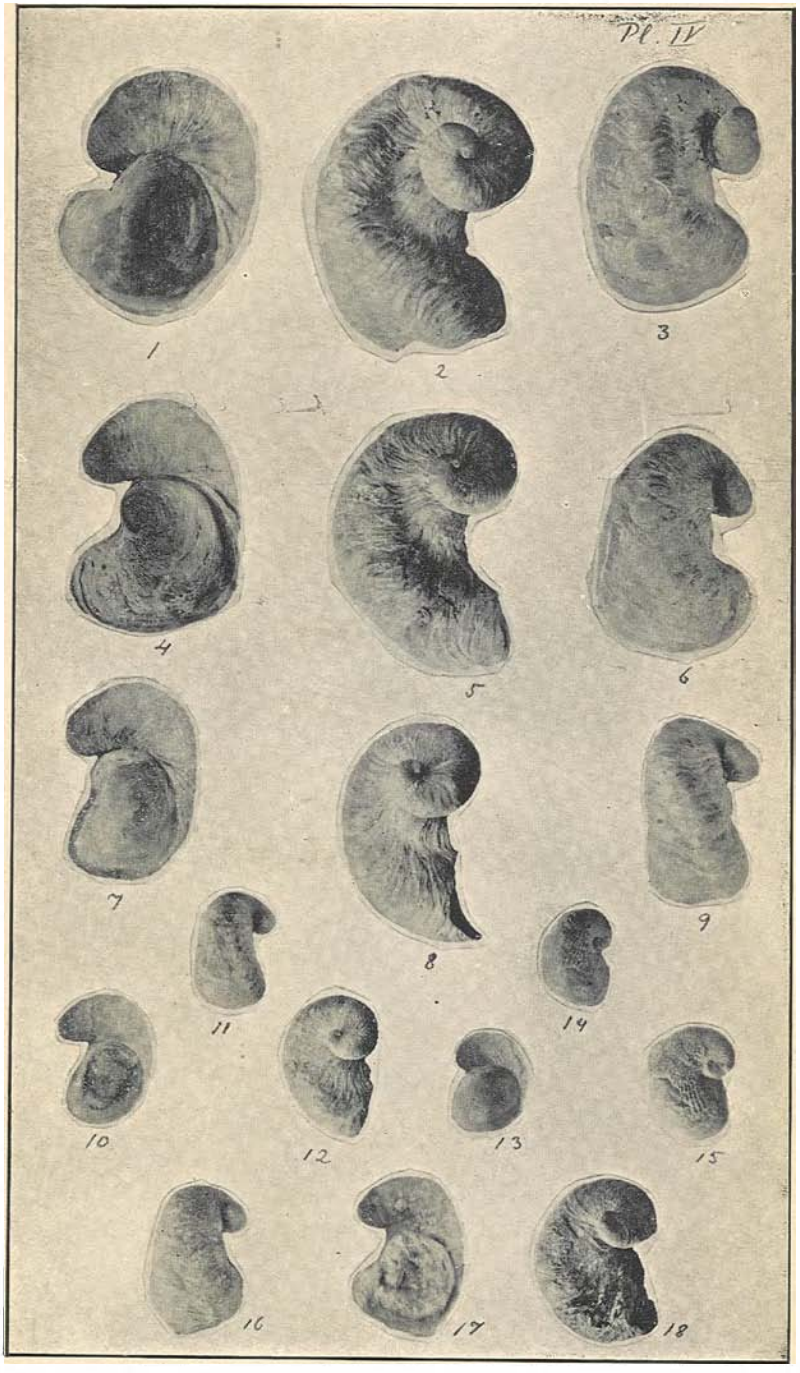
Pl. IV
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PLATE V

Fig. 1-23...*Exogyra arietina* Roemer.—Del Rio clay. Shoal Creek at Austin, Texas.

Fig. 1-3..young normal specimen shown in three positions.

Fig. 4....young individual showing a strong spiral groove.

Fig. 5....aberrant adult specimen with exceptionally coiled beak.

Fig. 6....aberrant adult specimen with strongly coiled beak.

Fig. 7....very young specimen, natural size.

Fig. 8....the same, strongly amplified, showing a smooth surface on the greater part of the shell, ribs beginning to appear at the margin.

Fig. 9....very young specimen, natural size.

Fig. 10....the same, strongly amplified, showing the smooth surface of the shell at this stage of development.

Fig. 11....very young specimen, natural size.

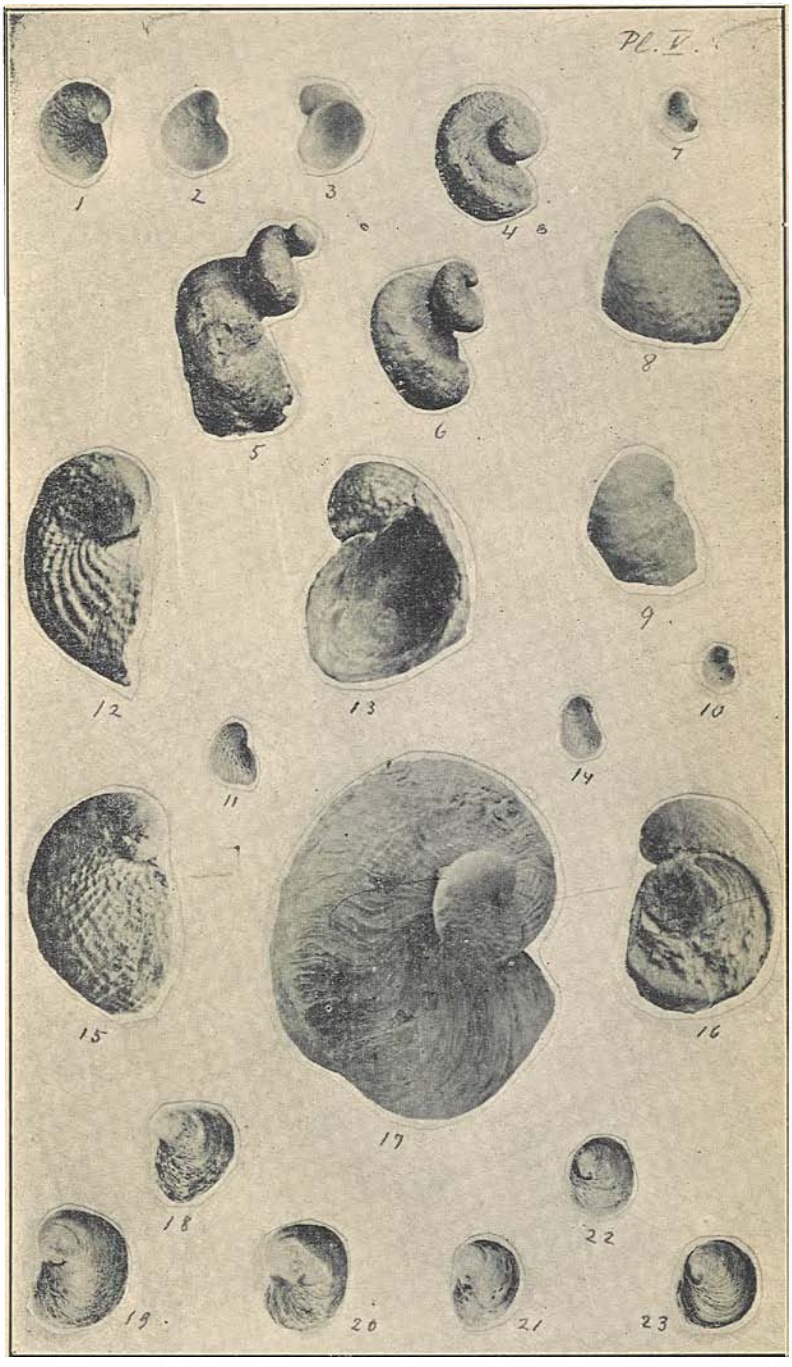
Fig. 12, 13.the same, strongly amplified to show the ornamentation. The shell is smooth on the point of the beak, and develops radial ribs farther down.

Fig. 14....very young specimen, natural size.

Fig. 15, 16.the same, strongly amplified to show the ornamentation. The shell is smooth on the point of the beak, and develops radical ribs farther down.

Fig. 17....adult specimen twice amplified to show the ornamentation on the point of the beak, and its similarity with that of the small individuals illustrated in fig. 11-16.

Fig. 18-23.upper valves of small specimens. The slit apparently limiting the umbo in figure 19 is due to fracturing and is not natural.


Pl. V.
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