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COMANCHEAN AND CRETACEOUS PECTINIDAE OF TEXAS
COMANCHEAN AND CRETACEOUSPECTINIDAE OF TEXAS

THESIS

Presented to the Faculty of the Graduate Department of

The University of Texas

For the Degree of

MASTER OF ARTS

By

Hedwig Thusnelda Kniker

Cibolo, Texas

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PREFATORY NOTE

At the suggestion of Prof. F. L. Whitney, work was begun on the Pectinidae of the Buda Limestone in the fall of 1914. Later, the scope was extended to include all the Pectinidae of the Washita Division. During the past year it was found desirable to figure and describe all species of the family, that could be found in the Comanche and Cretaceous Series in the vicinity of Austin.

Paleontology is practically an unexplored field in Texas, and it is to be regretted that conditions have been such as to interfere with this interesting study of the past. The writer intends to show in a later paper the systematic succession of the Pectinidae and their possible use in correlating European and American formations.

I wish to express my gratitude and sincere appreciation to Professor Whitney for his most valuable suggestions and criticisms during the preparation of this thesis, as well as for his kind assistance in the collecting and photographing of specimens. I am deeply indebted to him for the use of all of the Buda specimens and a number of others, which are in his private collection.

Hedwig Thusnelda Kniker.
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Description of Species

Mollusca
Pelecypoda
Pectinidae
Genus Pecten, Muller

Pecten bonnelanus, n. sp.

Plate I, figures 1-2

Dimensions.--Height 31.5 mm.; length 24 mm.; breadth 4 mm.

Description.--Shell medium to large, suboval, equilateral, appreciably higher than long. Ears large, unequal; hinge line straight.

Only one left valve of this form is in our collection, but it is well enough preserved to justify describing and figuring it.

The ornamentation consists of some twenty main ribs, which are rounded and somewhat elevated. They decrease in strength from the center toward the anterior and posterior borders. On and near the umbo only these principal ribs occur. But a short distance from it, as soon as the interspaces are wide enough, secondary ribs arise in the depressions, usually one at a time. As space permits, other secondary ribs appear in an irregular manner nearer the ventral margin, so that there are from three to six between two principal ribs at the base. The main ribs are always the stronger, although some of the secondary ribs very nearly approach them in size. The ribs are
separated by relatively deep concave furrows.

The ribs are spiny, but owing to the poor state of preservation of the shell, the exact nature and distribution of the spines could not be determined. They appear to be very numerous.

The anterior and posterior areas of the valve are inclined practically perpendicularly to the ribbed portion, and are covered with prominent, strong, and close-set ridges, that are almost perpendicular to the line separating the areas from the main portion of the valve.

The anterior ear is larger than the posterior, and its outer angle is acute. The indications are that the posterior ear would have an obtuse angle, were it preserved completely. On the latter ear we find traces of spiny ribs. The anterior ear shows distinctly about fifteen spiny primary radiating ribs, besides secondary ones.

Additional decoration of the ribbed portion and the ears consists of fine, crowded, concentric lines, which are interrupted at regular intervals by very pronounced concentric ridges.

Remarks.—*Pecten asper* Lam. and *P. Chihuahuaensis* Boese, two species closely resembling ours, have angular ribs.

The ribs of our form are rounded, but better preserved material would perhaps show that they also are angular.

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1 Woods, Cret. Lamellibr. of England, p. 186, pl 35, fig. 12; pl. 36, figs. 1, 2, 3, 4.
2 Boese, Instituto Geol. de México, Boletín 25, p. 93 pl. 15, fig. 1.
Affinities.--*Pecten bonnelanus* n. sp. is easily distin­guished from *P. Chihuahuensis* Boese by its shape, which is higher; by its ribs, which are rounded and spiny; and by its ears, which are covered with spiny radial ribs.

Our species differs from *P. asper* Lam. in being elongate and not circular; in having a different type of spines; in having larger ears; and in having a different arrangement of main and secondary ribs.

**Number of specimens:** 1.

**Occurrence:** Georgetown Limestone, Mt. Bonnel, Austin, Texas.

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*Pecten siederensis*, n. sp.

**Plate I, figures 3-4**

**Dimensions.**--Height 23.5 mm.; length 22 mm.

**Description.**--Shell medium to large, subequilateral, prac­tically equilateral, compressed, suborbicular; postero-dorsal margin decidedly concave, antero-dorsal more nearly straight; umbos sharp. Ears of practically the same size; hinge line straight and relatively short.

Right valve slightly convex, *extremely* thin and more or less transparent. The surface is plain. However, very delicate lines of growth and groups of short irregular microscopic filiform radial lines can be made out. The latter are not on the surface, but in the shell, and may represent small cracks. The greatest convexity is in the median portions of the dorsal half of the shell.
The anterior ear is somewhat longer than the posterior and the far border is gently rounded. A byssal sinus is present. The posterior ear is not separated sharply from the rest of the valve, and its outer angle is obtuse.

The left valve is very much like the right in general characteristics. The ears are almost equal; the outer angle of the anterior is acute, approximately as acute as the corresponding angle of the posterior ear is obtuse.

**Affinities.**—*Pecten manchacensis* is distinguished from this species in several ways which are mentioned in the description of that species.

*P. biederenisis* is not closely related to any of the European forms of the same group.

**Number of specimens:** 20.

**Occurrence:** Upper division of the Buda Limestone, Sieder Springs, Austin, Texas.

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**Pecten manchacensis, n. sp.**

Plate I, figures 5-6

**Dimensions.**—Height 9(?) mm.; length 9(?) mm.

**Description.**—Shell small, orbicular, equilateral, practically equivalve, compressed; antero-dorsal and postero-dorsal margins somewhat concave; umbo pointed and conspicuous; ears unequal; hinge line long.

Right valve gently rounded and solid. Its surface is ornamented with delicate minute concentric folds. These
latter are most pronounced on the areas and ears, where they can easily be distinguished, and on the portions of the valve adjoining the areas. Not on a single specimen can they be made out to any great extent on the main portion of the valve. This may be due to lack of preservation, or perhaps the folds were present on only the ears and adjoining portions of the valve. The anterior area is more nearly perpendicular to a plane separating the right and left valve than the posterior.

The anterior ear is very long, ascending, and curved transversely, and is ornamented with a large number of regular concentric ridges. The posterior ear is long and narrow, and oblique.

The left valve is similar to the right in shape and ornamentation. The concentric ridges are more prominent than on the latter. The anterior ear is subtrigonal, and its outer angle is rounded.

Affinities. — Pecten manchacensis differs from P. siederensis in having a more nearly circular outline, in having thicker valves, in having the ears of a different outline, in having an ascending anterior ear, and in being ornamented with concentric ridges.

Our species is distinguished from P. burlingtonensis Gabb chiefly by its smaller apical angle and ears of a different shape.

Number of specimens: 14.

Occurrence: Lower division of the Buda Limestone, Austin
and Manchaca, Texas.

_Pecten bensoni, n. sp._

Plate I, figures 7-9; Plate II, figures 1-2

Dimensions.—Height 16 mm.; length 14.5 mm.

Description.—Shell medium, circular, subequilateral, equivale, compressed, antero-dorsal margin slightly concave and somewhat longer than postero-dorsal. Ears unequal; hinge line straight.

Right valve slightly convex. The surface is ornamented with radiating diverging dichotomous furrows. These furrows are separated by broader rounded low folds. The latter appear to be the real decoration of the shell, while the furrows seem to have been sunk into the surface of the shell. The valve is further ornamented with very strong concentric ridges that are slightly inclined ventrally. Their distribution is not regular. We have always found them close together on the umbo, but towards the base they are often far apart and may disappear entirely for a distance. They do not interfere with the furrow-fold decoration of the shell and seem to weather more readily than the latter. Consequently, it is often hard to determine whether ridges are normally absent on a given area, or whether they have been eroded. Some of our material shows portions that apparently have only the furrow-fold decoration, but upon closer study, we find remnants of ridges. The anterior ear is long and has a rounded margin at the far side. The
byssal sinus is well-marked. The posterior ear is smaller and its outer angle is obtuse. Both ears show the same manner of decoration as the main portion of the valve.

The left valve is similar to the right in shape and ornamentation. The anterior ear is subtrigonal and practically twice as large as the posterior.

Remarks.—We are inclined to believe that the form described by Roemer\(^1\) as *P. virgatus* is closely related to *P. bensoni* n. sp. Roemer says, on first sight the shell appears to be smooth, and he did not find concentric ridges. However, on a third specimen he noticed these ridges on the left ear. In our species the ornamentation is distinctly visible to the naked eye. As Austin Chalk specimens are not very well preserved, it is possible that Roemer had imperfect *Pectens* as the basis of his work. Under the conditions, we feel justified in considering our form a distinct species. We agree with Gabb\(^2\) that *P. virgatus* Roem. is distinct from *P. virgatus* Nills. Gabb continues by saying: "I have frequently observed casts in the New Jersey marls, and there is a piece of shell from Alabama in the collection of the Academy which I cannot separate from this species as described and figured by Roemer. It may

\(^1\) Kreidebild. v. Texas, 1852, p. 66, pl. 8, fig. 5a, b.

be that they differ by the sides, from the beaks to the widest portion of the shell, being longer and straighter."

He renamed Roemer's form *P. texanus*.

**Affinities.**--*P. bensoni* n. sp. differs from the European forms of *P. virgatus* in being more nearly circular, in having more numerous furrows, and, lastly, in having strong, concentric ridges in addition to the furrow-fold ornamentation.

**Number of specimens**: 50.

**Occurrence**: Austin Chalk, Austin, Texas.
Genus *Vola*, Klein.

*Vola irregularis* Böse.

Plate II, figures 3-7

*Vola irregularis* Böse, 1910, Instituto Geol. de México Boletín 25, pp. 97-98, Lám. 15, figs. 10-18.

**Dimensions.**--Height 17 mm.; length 14 mm.; breadth 5 mm.

**Description.**--Shell small to medium, subtrigonal, more or less elongate, almost equilateral; ventral margin polygonal. Ears large; hinge line straight.

Right valve convex, rounded; umbo incurved. The surface is ornamented with sixteen principal radiating ribs. These are high, narrow, and rounded on top. In young specimens they have a triangular shape. But on all large shells the ribs are rounded, and are never flattened on top. As in *Vola texana*, every third rib is raised only slightly above the others. These prominent ribs are decidedly wider than those in the depressions, which are subequal, although they appear to be equal in the smaller specimens. The intercostal spaces are concave and are narrower than the ribs, more decidedly so in large specimens. The furrows adjoining the raised ribs are wider than the ones separating the ribs in the depressions. At the base of the slope of the prominent ribs are found very thin secondary ribs that are much lower than the others. They are, however, distributed in an irregular
manner. On some specimens there are almost as many as are possible under the conditions, while on others there is a small number. They are missing altogether on a few of our shells. Thus far, we have not been able to determine a law of distribution. But, whenever present, these secondary ribs are at the base of raised ribs. The second and fourth of these latter, more frequently than the others, have a secondary rib on each side. Böse has sometimes found a very low secondary rib on the areas, but this has not as yet been noticed on the Texas specimens. Rather coarse lines of growth are found all over the shell.

The left valve is decorated with sixteen or seventeen sharp radiating ribs, which correspond to the principal furrows of the right valve. Whenever there is a secondary rib in a furrow of the right valve, we find a twin-rib in the corresponding place on the left valve. Naturally, these double ribs are distributed irregularly. Thus, beginning at the posterior side, we find that on one specimen the fourth, seventh, eighth, eleventh, fourteenth, and seventeenth ribs show this characteristic. On another specimen the first, fourth, eleventh, fourteenth, and seventeenth ribs are double. Böse noticed that these ribs are higher than the others, but this is characteristic of the group, as mentioned in the discussion of *V. texana*.

Affinities.—This species is closely related to *V. subalpina* Böse, and belongs to the group of *V. alpina* d'Orb.
There are, however, clear distinctions between *V. irregularis* and *V. subalpina*. The former is higher, shorter, and less convex than the latter. Also, the secondary ribs and their irregular distribution, so characteristic of *V. irregularis*, are never met with in *V. subalpina*. In addition to this, the ribs are more triangular, and there is less difference in their height in *V. irregularis*. Furthermore, there are marked differences in the left valve. *V. irregularis* has sharp triangular ribs, whereas *V. subalpina* has rounded ones. Besides, *V. subalpina* never has the double ribs that are found distributed in an irregular manner on *V. irregularis*.

**Number of specimens:** More than 100.

**Occurrence:** Walnut Clay, Mt. Barker, Austin, Texas.

*Vola duplicicosta* Roemer.

Plate II, figures 8-9; Plate III, figures 1-2

*Pecten duplicicosta* Roemer, 1849, Texas, p. 398.

*Pecten duplicicosta* Roemer, 1852, Kreidebild. v. Texas, p. 65, Pl. 8, fig. 2a, b.

*Neithaea duplicosta* Gabb, 1864, Smithsonian Miscellaneous Collections, No. 177, p. 7.


Original description (translated).—The larger left valve strongly arched, almost circular, somewhat broader than long, periphery angular, polygonal on the surface covered with radiating folds and ribs. The folds are thick, protrude and form angles at the base. The radiating ribs are regular, of almost the same width, and cover in the same manner the folds and the spaces between them. In the almost level depressions between every two folds there are two or three of them. The surface of each fold proper is covered with three or four ribs.

This species has caused considerable discussion. Hill² thought it was the same as *V. roemerii* Hill, but Cragin³ later stated that the two forms were distinct species and that *V. duplicicosta* Roem. belonged either to the Fredericksburg Division or to the Alternating Beds.

We have found a form in the Edwards Limestone that is so similar to Roemer's species that we consider the two identical. Roemer admits that his type was an imperfect specimen, and a cast at that. It came from the upper course of the Pedernales River. Most of our specimens are casts and, furthermore, are badly distorted. However, a few individuals have the shell preserved, although the specimens are imperfect. Roemer described and figured

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¹ Roemer evidently mistook the right valve for the left, and confused the dimensions.
only the right valve.

We might add to Roemer's description that the ribs are relatively low and flattened. On a weathered specimen they are very low and flat. The middle rib in the depressions is broader than its neighbor on either side. The ribs on the folds are nearer together than is the case in the depressions, and there is often a small one next to the summit rib. No secondary ribs have been found on the areas.

The ears are large and strong and the hinge line straight. The whole shell is covered with very pronounced concentric lines.

The left valve is flat and has six raised areas corresponding to the folds of the right valve. The folds and depressions are covered with radiating flattened ribs that correspond to the depressions on the right valve. Prominent growth ridges cover the ribbed area and the ears.

**Affinities.** Roemer pointed out that *V. duplicicosta* Roem. differs from *Pecten striato-costatus* Goldf. and *Janira striato-costata* d'Orb. in not having in the depressions, secondary folds covered with ribs. Furthermore, in the European forms the radiating ribs are more unequal, smaller, and more numerous.

However, the European species most resembling ours is *V. stefanoi* Chof., from which *V. duplicicosta* Roem. differs principally in its form, which is not so long; and
in its ribs, which are more or less flattened. But there is a possibility that in well preserved specimens the ribs of our species are also rounded. Choffat\(^1\) does not mention folds, but says that the sectors are separated by ribs that are somewhat stronger than those in the depressions. On our specimens these ribs are not stronger, and there are several close together on most folds.

As has been stated above, our species and *V. roemeri* Hill were at first considered identical. But the ornamentation of the latter is much more elaborate than that of *V. duplicicosta*, and the shape of the left valves is entirely different. In *V. roemeri* the folds are very prominent and a rather broad depression separates the last rib on one fold from the first rib on the adjoining one. On the other hand, in *V. duplicicosta* the folds are not so prominent and there are definite spaces between two neighboring ones. Moreover, in this form the ribs are subequal, while in *V. roemeri* they vary greatly. In the latter species the left valve is almost as globose as the right, whereas in *V. duplicicosta* it is flat. Then there are the differences in the ribs. Furthermore, *V. roemeri* has radiating ribs on the ears, which are missing in *V. duplicicosta*.

Shattuck\(^2\) has described a form from the Buda Limestone as *Pecten duplicicosta* (?). His description fits

\(^1\) Faune Crét. du Portugal, p. 155.

Roemer's species approximately, but the illustration shows that the two are distinct. We have not found any specimens similar to Shattuck's form in the Buda Formation. Neither have we come across any Volas that resemble his Pecten quinquecostatus (?). Evidently these forms are very rare, for Prof. Whitney and paleontology students of the University of Texas have collected fossils from the Buda Limestone for the past eight years, without seeing them. Number of specimens: About 50. Occurrence: Edwards Limestone, Austin, Texas.

Vola bellula Cragin.

Plate III, figures 3-8


Dimensions.--Height 19.5 mm., length 17 mm., breadth 7 mm.

Description.--Shell medium, subtrigonal, practically equilateral, fragile, length almost equaling height; posterodorsal margin slightly longer than antero-dorsal, ventral margin subsemicircular with six faint prominences. Ears imperfect on our specimens, but appear to be conspicuous and unequal.

Right valve globose, beak rounded and incurved. The valve in this case is ornamented with forty-four fine, radiating, subequal, low, flattened ribs separated by depressions that are narrower or practically equal to them.
No ribs are raised noticeably, but at definite intervals there is a change in the size and arrangement of the ribs which makes these areas appear prominent. Thus, the surface is divided into six facets comprising unequal groups of ribs. Often it is hard, or even impossible, to designate the boundary ribs between two groups. By comparing different specimens we find that there is no definite arrangement of the boundary ribs. Frequently two adjoining groups are separated by a prominent rib noticeably wider than its neighbors. This boundary rib is often separated from the rib on each side by a furrow equal to it in width. At other places a double rib takes the place of the wide one. In such cases, naturally, the two individual ribs are narrower than those of the groups. Also, two ordinary ribs separated by a very narrow depression may serve as a boundary. Sometimes the boundary is formed by three or four narrow ribs, or by two double ones. In some instances the boundary is entirely obliterated, there being a normal arrangement between two groups, so that no transition can be detected. In the most anterior and most posterior section the ribs are smaller and usually unequal in size, and the depressions are wider than the ribs. Besides the above mentioned irregularity, there is also a slight difference in the strength of ribs in different specimens. In such specimens as the one on which the description above is based the ribs are low and flattened, and there are narrower
interspaces. On other shells the ribs appear to be slightly higher and the intercostal depressions wider in proportion. However, these changes are not constant and, with the material on hand, we can look upon them as only individual variations. The number of ribs on the different specimens is not constant, varying from forty to forty-eight, the larger numbers being found on specimens with double ribs or a larger number of boundary ribs. Ribs are absent on the areas and ears.

The valve is further ornamented with very fine concentric striae, which are almost invisible on the body of the shell, but can be plainly distinguished, with the aid of the microscope, on the areas and ears. On these latter, growth ridges, also, are present.

Our collection does not contain perfect specimens of the left valve. But we notice that this valve is slightly concave, has ribs corresponding to those of the right valve, and, furthermore, has six distinctly elevated regions, corresponding to the boundary ribs of the right valve. The depressions between the elevated areas are gently curved. The concentric striae are distinct.

Affinities.—*V. bellula* differs from *V. dutrujei* Coq. var. *beirensis* Chof. in its shape and ornamentation. Our form is shorter in the dorsal regions. *V. dutrujei* var. *beirensis* is larger, has more ribs, and appears to be more robust than *V. bellula*. Furthermore, the ribs of Choffat's variety are rounded and are present on the areas, on the
posterior ear, and perhaps on the anterior ear, whereas on our species they are flattened and are absent on the areas and ears. Moreover, Choffat says that no facets are distinguishable on the left valve, however, on the left valve of our form six areas are prominently raised and are separated by rounded depressions. There is, nevertheless, a marked similarity in the arrangement of ribs on the right valve of the two forms. In both cases the number of ribs between two prominent areas varies, and, furthermore, the boundary ribs of the two Volas show the same system of arrangement.

Number of specimens: About 60.

Occurrence: Georgetown Limestone, Austin, Texas.

Vola wrightii Shumard.

Plate IV, figures 1-2


Neithia Wrightii Gabb, 1864, Smithsonian Miscellaneous Collections, No. 177, p. 7.


Dimensions:—Height 42 mm.; length 37 mm.; breadth 14 mm.
Description.—Shell large, subtrigonal, inequilateral, anterior and posterior sides of approximately the same length. Anterior ear pointed, prominent, surface rounded transversely; posterior ear rudimentary. Ventral margin sinuous.

Right valve convex, beak incurved, posterior slope truncate. On this valve are found four prominent ribs, rounded, but having a prominent costella at the summit, which gives them an angular appearance. A smaller costa is found at the posterior side of the shell, while a still smaller inconspicuous one is found on the slope of the anterior rib near the anterior margin. The middle costa is the most conspicuous one, but is practically equal to the adjacent one on the posterior side. The two anterior ribs are almost equal, but the most anterior one curves outward considerably and is higher. The costae are separated by broad, unequal, flattened depressions. The depression anterior to the middle costa is the widest one, being somewhat wider than this costa. Posteriorly to the middle and to the most anterior costa are found furrows practically equal to these ribs. At the base of the shell the ribs are prolonged into prominent extensions which are separated by broad, rounded sinuses corresponding to the intercostal depressions.

Left valve almost flat. The costae correspond to those of the right valve and have similar ornamentation.

As in Vola whitneyi n. sp. growth ridges are
found on both valves, especially near the base and on the anterior ear. Also, each valve has a fluted border on the interior side.

Remarks.—Cragin, in his discussion of this species, says: "Summits of costae in both valves formed, in each instance, by a somewhat salient round-backed costella, there being on the two slopes and included valley which constitute the surface between any two summit-costellae, ten or twelve feebly elevated radial costellae delimited by impressed striae and crossed by innumerable raised lines of such fineness as to be barely visible to the naked eye."

The costellae are not always so pronounced on our specimens, nor arranged in so regular a fashion as described by Cragin and shown in his drawings of *V. wrightii*. The "raised lines" are distributed on our species as on *V. whitneyi* n. sp.

In the original description of this species, we do not find any mention of costellae. This is probably explained by the fact that this ornamentation is often very indistinct on young individuals, and, according to Shumard's measurements, his was an immature specimen.

Affinities.—The species which we describe under the name of *V. whitneyi* differs from *V. wrightii* in several ways, which are mentioned in that description. *V. wrightii* is distin-

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guished from \textit{V. (Janira) cometa} d'Orb. and \textit{J. longicauda} d'Orb. by its shape, which is more inequilateral and broader; and by its ears, which are smaller and more triangular. Furthermore, the interspaces are flat or flattened in our form, whereas they are rounded in the French forms. In \textit{J. longicauda} the ribs of the right valve show distinct costellae, are very broad, and the intercostal spaces are narrow, and there are prominent costellae and tubercles on the left valve. Thus, this species differs considerably from ours in ornamentation.

\textbf{Number of specimens: 18.}

\textbf{Occurrence:} Georgetown Limestone, Austin, Texas.

\textbf{Vola texana} Roemer.

\textit{Plate IV, figures 4-7}

\textbf{Pecten aequicostatus} Roemer, 1849, Texas, p. 398.

\textbf{Pecten texanus} Roemer, 1852, Kreidebild, v. Texas, p. 65, Pl. 8, fig. 3a, b.

\textbf{Neithea texana} Conrad, 1857, Mexican Boundary Report, p. 151, Pl. 5, fig. 2a, b.

\textbf{Vola texana} Bose, 1910, Instituto Geol. de México, Boletín 25, pp. 93-95, Lám. 15, fig. 3.

\textbf{Dimensions.}--Small specimen: height 29 mm.; length 28 mm.; breadth 9.5 mm. Large specimen: height 39 mm.; length 35.5 mm.; breadth 11 mm.

\textbf{Description.}--Shell medium to large, subtrigonal, subequi-
lateral, solid; height exceeding length only slightly; pos-
tero-dorsal margin distinctly longer than antero-dorsal
margin; ventral margin semicircular with six projections
formed by the extensions of the six raised ribs of the
right valve. Ears large; hinge-line straight.

Right valve inflated, umbo greatly incurved, ex-
tending beyond the hinge line. Ornamentation consists of
sixteen radiating principal ribs. In a young specimen
these, on first sight, appear to be flattened only towards
the base. But in a mature specimen they are distinctly
flattened, especially as they increase in size towards the
ventral margin. The ribs are separated by narrower flat-
tened depressions. Each third rib is raised above the ad-
joining ones, the first and the last rib being among the
prominent ones. The raised ribs, however, differ very lit-
tle in height from the others, but are not quite so wide,
are rounded, and only slightly flattened on top. Between
the last rib and the margin anteriorly and posteriorly, is
found a semi-lunar band or area. This is at times entirely
plain, but more often shows a few low and rounded secondary
ribs near the principal ones. The ornamentation is not
always symmetrical. On some shells one of the areas is
plain and the other one covered with two or three ribs, or
there are one or two ribs on one side and three or four on
the other. On our specimens the last rib posteriorly usual-
ly shows a shallow sinus on top, dividing it into two smaller
ribs, and thus beginning a group of secondary ribs. The lines of growth are extremely fine.

The left valve is slightly concave and is ornamented with sixteen very narrow ribs corresponding to the furrows of the other valve. The ribs have steep slopes and are more or less flattened on top. They are separated by very wide, flat furrows, which are practically twice as wide as the ribs.

Even in this simple form we can detect the center of symmetry. On the right valve the fourth raised rib is slightly higher and more rounded than the others. On the left valve, the ribs corresponding to the depressions at the side of the raised ribs of the valve, are raised slightly. Therefore, we always find a pair of them prominent. The fourth, fifth, seventh, eighth, tenth, eleventh, thirteenth, fourteenth, and the two most anterior and the posterior rib are thus higher than the others. Furthermore, the tenth and eleventh ribs are the most prominent ribs among the prominent ones, and are the center of symmetry.

Remarks and Affinities.--Most of our own specimens have been compressed somewhat, which accounts for the fact that the breadth is less in proportion to the other measurements than in Böse's measurements. Roemer¹ at first referred this species to *V. equicostata* Lam., but it belongs to an entirely distinct group of which *V. alpina* d'Orb. is an

¹ Texas, p. 398.
example. *V. alpina*, like our form, has sixteen ribs on the right valve. Every third rib is higher than the others, but these raised ribs are much more marked than those of our species. Consequently the ventral margin of the French form is more polygonal in outline than is the case in *V. texana* and the depressed areas are very pronounced, which is not the case in our species. Also, the ribs of *V. alpina* are distinctly rounded, and not flattened as in our form. Furthermore, the left valve shows a marked difference. In d'Orbigny's species the ribs are much wider and the depressions narrower than in *V. texana*.

Shattuck\(^1\) seems to have confused *V. subalpina* (?) and a similar species under the name of *V. texana*. He lists *Pecten texanus* Gabb\(^2\) as synonymous with *P. (Vola) texanus*. The former is a *Pecten* and is considered by Gabb to be identical with *P. virgatus* Roem.

Roemer\(^3\) says: "Die obere Klappe ist eben und mit ganz flachen, ungleichen, ausstrahlenden Rippen bedeckt, deren ebene Zwischenräume den Rippen selbst on Breite etwa gleichkommen." This evidently is a mistake, if Roemer's form and ours are the same. For, in the Texas species, the ribs are narrow and the depressions about twice as wide.

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3 Kreidebild. v. Texas, p. 65.
The right valves, however, are alike.

**Number of specimens**: About 30.

**Occurrence**: Georgetown Limestone, Austin, Texas.

*Vola texana* Roemer, var. *elongata* Bose.

Plate V, figures 1-2

*Vola texana* var. *elongata* Bose, 1910, Instituto Geol. de Mexico, Boletín 25, p. 95, Lam. 15, figs. 2, 4, 6.

**Description**.—In our collection are a number of specimens that differ from *Vola texana* in certain definite respects. But since no perfect shells have been found, and since the differences between the typical *V. texana* and this form are not very great, we shall, for the time being, consider it as a variety of *V. texana*. It is distinguished from this latter species by being higher, and, consequently, having a smaller apical angle. Moreover, the ribs on the right valve are slightly higher and the six prominent ones appear to be somewhat stronger than in the type. But the shape and arrangement of the ribs is the same in the two forms; that is, the ribs are flattened on top and every third one is raised and is somewhat rounded on top. However, the ribs are slightly narrower than in the type, and the intercostal spaces are proportionally wider.

At one locality this variety was found in the upper layers of the Del Rio Clay, in the transition beds, and in the lower beds of the Buda Limestone.

**Number of specimens**: About 20.
Occurrence: Lower division\(^1\) of the Buda Limestone, Austin; and Del Rio Clay, Austin and San Marcos, Texas.

**Vola subalpina** Böse.

Plate V, figure 3

*Vola subalpina* Böse, 1910, Instituto Geol. de México, Boletín 25, pp. 96-97, Lám. 15, figs. 5, 7, 8, 9.

**Dimensions.**—Height 29 mm.; length 27 mm.; breadth 8 mm.

**Description.**—Shell medium to large, subtrigonal, not much higher than long; ventral margin polygonal. Ears prominent; hinge line straight.

Right valve globose; umbonal slope curved, passing beyond the hinge line. The ornamentation of this valve consists of sixteen prominent radiating ribs, high, narrow, and rounded. Even in adult individuals they are very little flattened on top. The ribs are separated by narrower furrows having a slightly flattened bottom. Every third rib, including the first and the last, is raised. Thus, between every two raised ribs we find two narrower, lower ones which are practically equal. The areas are generally smooth, but on some shells one or two secondary ribs have been noticed. Prominent growth ridges are present on both valves.

The slightly convex left valve is decorated with

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\(^1\) "In the vicinity of Austin the Buda Limestone displays two distinct phases: a lower, chalky or marly, soft, white rock, and an upper, hard, yellowish to reddish rock." Whitney.
seventeen principal radiating ribs. A cross section of these presents a more or less wavy appearance. As in similar species, the ribs correspond to the depressions, and the furrows to the ribs, of the right valve.

Remarks.--Bose\(^1\) says the furrows of the left valve have a level bottom, but this is hardly the case in our specimens, since the ribs of the right valve are only slightly, if at all, flattened. However, the ribs of the former valve are narrower than the furrows.

Affinities.--\textit{V. subalpina} is easily distinguished from \textit{V. texana} by its shape, which is longer and narrower; by its rounded and narrower ribs; by its deeper furrows; and by its more angular ventral margin. This latter is due to the more prominent raised ribs. In our discussion of \textit{V. texana} we said that the six prominent ribs were only slightly raised above those in the depressions and equaled them in width. However, in \textit{V. subalpina} these prominent ribs are noticeably higher and wider than in the former species. Furthermore, there is considerable difference in the ribs of the left valve of the two species. In \textit{V. texana} the depressions and tops of the ribs are flattened, and the slopes of the ribs are very abrupt. In \textit{V. subalpina}, on the other hand, both ribs and depressions are rounded more or less, and the slopes are gentle. Besides, there is less difference in width between ribs and depressions in the

\(^1\) Inst. Geol. de México, Bol. 25, p. 96.
latter species than is the case in \textit{V. texana}.

A part of what Shattuck\textsuperscript{1} describes as \textit{V. texana} is evidently closely related to \textit{V. subalpina}, if not identical with it.

Our species clearly belongs to the group of \textit{V. alpina} d'Orb. This latter species also has six raised ribs and between each pair of these two narrower and lower ribs. The chief difference is in the broader shape of \textit{V. alpina} and in its stronger ribs. Also, the ribs in the depressions are lower in our species. Moreover, the left valve shows some differences.

Cragin's\textsuperscript{2} \textit{V. fredericksburgensis} is perhaps identical with \textit{V. subalpina}. He says: "This name is proposed for the species of \textit{Vola} described by Roemer from Fredericksburg, Texas, in his \textit{Kreidebildungen von Texas}, as 'Pecten quadricostatus, var.,' and is based on his description and illustrations......It is easily distinguished from \textit{V. texanus}. Roemer, by its much narrower and more elevated ribs, more triangular form, and usually (in adult examples) by its larger size. It has been referred to by authors under various names; but it is distinct from any of the species to which it has hitherto been referred. It is, however, closely allied to \textit{V. alpina}, d'Orb." The horizon given is the Fredericksburg Division. Cragin seems to have confused

\textsuperscript{1} U. S. Geol. Surv. Bull. 205, p. 17, Pl. 5, fig. 6.

\textsuperscript{2} Colorado College Studies, 1894, p. 52.
several species. Roemer's *P. quadricostatus* var. is an Austin Chalk (Upper Cretaceous) form and is distinct from the *alpina* group. We have found fragments of specimens closely related to *V. irregularis* Bose in the Fredericksburg Series, and since Cragin considers his species identical with Roemer's variety, we are inclined to believe that he had a form with secondary ribs and mistook it for a representative of the *quinquecostata* group of the Upper Cretaceous.

**Number of specimens:** More than 50.

**Occurrence:** Del Rio Clay, Austin and San Marcos; and lower division of the Buda Limestone, Austin, Manchaca, Buda, and San Marcos, Texas.

**Vola subalpina** Bose, var. *linkii* n. var.

*Plate V, figures 4-5*

**Dimensions.**—Height 49 mm.; length 44 mm.; breadth 15 mm.

**Description.**—Among the Volas of the Georgetown Limestone, we find a form that is so closely related to *V. subalpina* that we regard it as a variety of this species. Like the type, it has sixteen radiating ribs on the right valve, and every third one is raised. But the ribs, instead of being high, narrow, and rounded, are lower, broader, and rounded, presenting a depressed appearance. Since they are broader, they appear to be more flattened than those of the type. The relation of width of ribs and intercostal spaces is the same in both forms. Moreover, the left valve shows
some differences. In the Georgetown form the ribs are lower and the interspaces flatter than in V. subalpina.

Number of specimens: 10.

Occurrence: Georgetown Limestone, Austin, Texas.

_Vola georgetownensis_ n. sp.

Plate VI, figures 1-3

**Dimensions.**—Large specimen: Height 46 mm.; length 40 mm.; breadth 16 mm. Small specimen: Height 34.5 mm.; length 29 mm.; breadth 11 mm.

**Description.**—Shell medium to large, solid, subtrigonal, higher than long, globose, subequilateral. Ears small and triangular. Ventral margin semicircular and polygonal in outline. Postero-dorsal margin appreciably longer than antero-dorsal.

The right valve is strongly convex and has a prominent incurved umbo that passes beyond the short hinge line. As in the other forms of this group, there are six prominent radiating ribs, the anterior and posterior being slightly smaller. In each one of the level depressions there are two lower ribs. The ribs, especially the prominent ones, are exceedingly strong in this species. Moreover, in this form we find compound ribs, each having a number of elevations and depressions on top. In addition to this, there is a fine rib in each intercostal depression, extending from the umbo to the base. The prominent ribs are high, broad, and round, while those in the depressions
are also broad, but low, and flattened considerably. The latter usually have one main depression in the middle of the top and a smaller one on each side. On a few ribs we notice a riblet in the middle, but this seems to be an exception. Occasionally the main depression is somewhat to the side, and there have been found two secondary depressions on one side. The prominent ribs are wider than the others, and, as a rule, have one or two more depressions on their upper portion. Usually two of the furrows on top are more or less equal. On account of the fine ribs in the intercostal spaces, these latter are wide, often approximating the ribs in width, or even surpassing them occasionally, especially in the anterior and posterior groups of ribs. As a rule, they are somewhat narrower. On the areas there usually are from one to four fine ribs.

On both valves, on the areas, and on the ears are found delicate concentric lines of such fineness that they are barely visible to the naked eye.

Since at the base the convexities of one valve fit into the concavities of the other, we do not have so very much difference in width between ribs and intercostal spaces in the left valve. The fine ribs in the spaces of the right valve are usually to one side. So we find the main furrow on the ribs of the left valve in the same position. Near the base of the slope there is often a secondary furrow corresponding to a small rib far down on the slope of a rib of the right valve. In the depressions there is
usually one principal rib and a few secondary ones. This valve is slightly concave and usually has a few secondary ribs on the areas.

Remarks.--Only a very well preserved specimen shows the characteristics as described above. In a weathered shell the prominent ribs of the right valve are rounded and have a few faint radial lines impressed upon them. A cross-section is dome-shaped. The lower ribs show a sinus down the center. There are also variations in the ornamentation. Occasionally there is not a complete set of fine ribs in the intercostal spaces, and sometimes some of the secondary sinuses on the ribs are missing.

Affinities.--This species is not very closely related to any one of the Volas described heretofore in this paper. In Vola budaensis n. sp. we find that the prominent ribs are made up of a number of secondary ones, and that the two in the depressions are always plain. In V. georgetownensis the secondary ribs on the prominent ones are not nearly so marked as those in the form mentioned above. The two species are, furthermore, distinguished by the split ribs and the fine ribs in the interspaces of both valves of V. georgetownensis, which are not found in V. budaensis. Moreover, the antero-dorsal and postero-dorsal margins of V. georgetownensis are shorter and, consequently, the ventral margin longer than is the case in V. budaensis. This, naturally, causes them to differ in shape.
In *V. texana* we also have rounded prominent ribs, and flat ones in the depressions. But these differ from the ribs of *V. georgetownensis* in being plain, wider, and closer together. Also, the shape of the two species is entirely different, *V. georgetownensis* being more convex and more elongate than *V. texana*. Besides, the raised ribs of the former species are much more prominent and the ventral margin more sinuous than is the case in the latter.

**Number of specimens:** 20.

**Occurrence:** Georgetown Limestone, Austin, Texas.

*Vola georgetownensis* n. sp., var. *subirregularis*, n. var.

**Plate VI, figures 4-5**

**Description.**—We have in our collection some specimens which resemble *Vola georgetownensis* in shape and proportions, but have smooth ribs. It is a fact that there is a good deal of individual variation in *V. georgetownensis* (see Remarks on that species), but the ribs are always split. On the specimens under consideration, we occasionally find a few fine intercostal ribs distributed in an irregular manner on the valve, but the ribs are always without furrows and costellae. Thus, we have very globose, rounded, and prominent raised ribs, and in each depression two narrower subequal and very low flat ribs. The relation between width of ribs and intercostal spaces varies in different specimens. In fact, there is a series of gradations.
Ordinarily, the ribs are appreciably wider than the spaces, but the width of the former gradually decreases until it approximates that of the spaces.

The left valve is missing.

**Affinities.**—This form is similar to *V. texana var. elongata*, because of its rounded raised ribs, and flat ribs in the depressions. However, there are great differences between the two. In the first place, *V. georgetownensis var. subirregularis* is more globose than the above mentioned variety, and there is a greater difference between raised and low ribs. In *V. texana var. elongata* we noticed that the prominent ribs were raised only slightly above the others, and all were of practically the same width.

In the variety described above, the raised ribs are far more conspicuous and wider than the others, and these latter are very low and flat, lower than those of *V. texana var. elongata*. Furthermore, the prominent ribs of the former have a more rounded cross-section than those of the latter.

**Number of specimens:** 30.

**Occurrence:** Georgetown Limestone, Austin, Texas.

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**Vola theodorana n. sp.**

*Plate VI, figures 6-9*

**Dimensions.**—Large specimen: Height 33 mm.; length 31 mm.; breadth 14 mm. Small specimen: Height 27 mm.; length 25.5 mm.; breadth 9 mm.
Description.--Shell medium to large, almost equilateral, broad, height practically equaling length, polygonal outline, ventral margin subsemicircular with six definite angles. Ears missing.

Right valve convex; umbo gently incurved. On the surface are found sixteen plain principal radiating ribs. Every third one is raised above the others high enough to be distinctly recognized on first sight. These prominent ribs are rounded, while those in the depressions are low and flat on top. All have rather steep sides. The depressions as a whole, as well as the intercostal spaces, are flat or flattened. The raised ribs, if at all, are only slightly wider than the others. The intercostal spaces approach the ribs in width. In some specimens the most posterior rib is a double one, while in others the anterior one shows this characteristic. Secondary ribs are distributed on the areas in an irregular manner. Sometimes there is none, whereas on other areas there is one or as many as three or four. Moreover, on the two areas of the same specimen, we do not always find the same number.

Fine concentric lines are found on the body of the shell, areas and ears.

Remarks.--In the above description we mentioned that the ribs are plain. There are, however, a number of specimens among our material that show a slight variation from this condition; namely, split ribs. Since there is a gradual transition from the plain ribbed specimens to the more
ornamented ones, and since those specimens which show the split ribs in the greatest abundance do not show this characteristic to a very great extent, we do not feel justified in classing the specimens having split ribs as a distinct variety. Moreover, no difference in shape, and proportions of the shell, and relative size of the ribs can be detected in the two forms.

The prominent ribs are hardly ever affected, but occasionally a few show a very faint sinus. If only a few ribs on the shell show the furrow, these are located in the middle and never near the anterior and posterior borders. As it is, most specimens show the splitting to a very limited extent, but we have a few specimens in which practically all the ribs have a shallow groove on top.

The left valve has sixteen prominent flat-topped ribs. These are plain, low, and not very much narrower than the intercostal spaces. In the spaces there is an extremely fine rib, whenever we have, corresponding to the former, a split rib in the right valve.

Affinities.—There is considerable likeness between *V. theodorana* and *V. georgetownensis* and its variety *subirregularis*. The typical specimens of the former resemble more the variety of the latter, and the two split forms are more or less alike. But there are some marked differences. *V. georgetownensis* and its variety are elongate forms, whereas *V. theodorana* is broad and short. In the latter species the prominent ribs are only slightly wider and not much higher
than those in the depressions, and there are no fine ribs in the intercostal spaces, while in *V. georgetownensis* and its variety we have very conspicuous raised ribs that are much higher and wider than the others, and fine ribs in the spaces. The split ribbed forms of *V. theodorana* differ from *V. georgetownensis* primarily in the shape of the shell and relative size and proportions of the ribs, the differences having been pointed out above. Furthermore, there are no ribs in the interspaces and the manner of splitting is much more simple in the former than in the latter form.

This species differs from *V. texana* in its shape, which is more globose; in the greater difference in height between low and raised ribs; in its narrower ribs; and in its more sinuous ventral margin.

**Number of specimens:** About 175.

**Occurrence:** Georgetown Limestone, Austin, Texas.

Vola altana *n. sp.*

Plate VII, figures 1-2

**Description.**--Shell medium, short and broad (?), subtrigonal; ventral margin gently rounded; ears imperfect, but appear to be prominent.

Right valve moderately convex, rounded.

We have not been able to find perfect specimens of this form, but it is so different from the other Georgetown Volas that we consider it worth while to describe and figure it.
As in the other species of this group, there are sixteen strong radiating ribs on the right valve. But, contrary to the ordinary arrangement, every third rib is raised so slightly that it can be detected only with difficulty. Furthermore, the ribs are high and narrow. All are flattened on top and equal in width. They are practically twice as wide as the interspaces. On account of this, and because they are narrow, they seem to be crowded in the umbonal region, and, consequently, appear to be sharp, and not flattened on top. However, near the base of the shell they are distinctly flattened. A few secondary ribs are sometimes found on the areas. The lines of growth are indistinct on our specimens.

The left valve is missing.

Affinities. --Our species is easily distinguished from V. subalpina by its ribs, which are practically equal in height and width and are distinctly flattened on top.

Number of specimens: About 15.

Occurrence: Georgetown Limestone, Austin, Texas.

Vola budaensis n. sp.

Plate VII, figures 3-9

Dimensions. --Height 22 mm.; length 18 mm.; breadth 10 mm.

Description. --Shell medium to large, subtrigonal, slightly higher than long, equilateral. Ears conspicuous, but not well preserved on the type. Other specimens show the anterior ear to be short and triangular and separated from
the body of the shell by a groove. The posterior ear appears to be larger and is a continuation of the posterior area. Basal margin sinuous.

Right valve ventricose, umbo curved over the hinge line which is short. Decorations consist of six prominent trifid ribs radiating from the umbo to the angles of the ventral margin, with two smaller ribs in the depressions between these raised areas. Two of these areas form the anterior and posterior boundary of the ribs. The three ribs on the prominent ridges are arranged in a characteristic manner. The middle rib is the highest one and is smaller than the two ribs in the depressions but approaches them in width.

The fourth ridge is the center of symmetry. Here we find the only exception to the trifid arrangement. Instead of having a more prominent rib between the other two, we have, in this case, two smaller ribs in place of the central one. They are equal, are on top of the ridge, and are separated by a gently rounded depression equaling them in width. Halfway down on the posterior slope is a smaller rib separated from the adjoining rib on top of the ridge by a very narrow depression. On the lower part of the anterior slope we find a conspicuous rib somewhat stronger than the two on top of the ridge.

The arrangement of the ribs on the fifth and sixth ridges is the reverse of that on the first three. In each case the middle rib is the larger one. On the extreme up-
per portion of the slope on all five ridges we find a slightly smaller rib on the side towards the center of symmetry. On the other side at the base of the slope there is a rib similar to the other secondary rib on the same ridge. All ribs are flattened on top and have almost perpendicular sides, which give them a rectangular appearance. The two ribs in the depressions are, relatively speaking, higher than those on the ridges, so that they extend upward almost as high. The ribs on the ridges are, for the most part, separated by very narrow furrows. This is, however, not the case in the depressions, which are flat as a whole. The different ribs have between them gently curved narrower depressions. At the base the ridges form irregularly curved projections which are separated by sinuses that are practically equal to them.

This species is further ornamented with very pronounced growth ridges, which are so prominent that they give the ribs a ropy appearance. Ribs are absent on the areas, but prominent lines of growth are found here. The ears are covered with similar crowded concentric lines.

Not all of our specimens show the above ornamentations completely. The shells weather easily, thus obliterating the concentric striae and often the ribs on the ridges. Then these prominent areas have the appearance of smooth elevations that have had a few radial lines impressed upon them. The ribs in the depressions are protected and are not affected so much.
No perfect left valves are in our collection, but we notice that this valve is slightly concave and has six elevated areas corresponding to those of the right valve. As far as can be determined, the arrangement of ribs on the areas seems to be more regular than on the right valve. Here we find three ribs, practically equal, on top of the ridges. On the fourth ridge there is added a smaller rib on the posterior slope. There are two larger ribs in each depression. The furrows separating the ribs are practically equal to the latter in width. The shape of the ribs and pronounced concentric lines correspond to those of the right valve.

Affinities.—This species is perhaps a descendent of *V. irregularis*. In that form we found secondary ribs distributed in an irregular manner. Here the six raised ribs have practically disappeared, and we find ridges in their place with secondary ribs grouped upon them in a definite manner. Besides this difference, there are other definite ones. The shape of the ribs is entirely different in the two forms. Also, *V. budaensis* is more globose and not so high. Furthermore, in the left valve there are ridges covered with ribs in *V. budaensis* in contrast to the double ribs in *V. irregularis*.

Shattuck and Bose have described a form from the Lower Cretaceous as *V. quinquecostata*. Evidently *V. budaensis*, or a similar species, was the basis of the description of these two authors.
Number of specimens: 21.

Occurrence: Both divisions of the Buda Limestone, Austin, Round Rock, and Manchaca, Texas.

**Vola whitneyi** n. sp.

Plate VII, figure 10; Plate VIII, figures 1-4

*Pecten wrightii* Whitney, 1911, Univ. of Texas Bull. No. 184, p. 13, Pl. I, fig. 4.

Dimensions.—Height 10 mm.; length 7 mm.; breadth 4.5 mm.

Description.—Shell small, subtrigonal, higher than long, almost equilateral; postero-dorsal margin slightly shorter than antero-dorsal margin. Anterior ear large and prominent, pointed, rounded transversely; posterior ear rudimentary, triangular and pointed. Ventral margin convex and sinuous.

Right valve strongly convex, the beak considerably incurved, posterior slope truncate. The ornamentation consists of four simple, but very prominent, subtriangular radiating costae or ribs, with a smaller one at the posterior side. In addition to these, there is a minute rib near the anterior margin on the slope of the prominent anterior rib. The central costa is the most prominent one. The two adjacent ribs, which are practically equal, do not differ greatly from it. The anterior rib differs from the second one somewhat more than this latter differs from the central costa. The posterior rib is really a part of the posterior area. The central costa is separated from the
two adjoining ones by moderately deep furrows slightly flattened at the bottom and practically equaling the ribs in width. The anterior and posterior ribs are separated from the others by narrower angular depressions. At the ventral margin the ribs are produced as subtriangular extensions which have between them sinuses corresponding to the intercostal depressions. Over the whole surface are found fine concentric ridges barely visible to the naked eye. These are parallel to the undulated ventral margin and are inclined towards the base of the shell. From the anterior and posterior ribs the ridges are continued on the areas where they run parallel to the margin and are greatly crowded and become growth ridges. From the posterior area the ridges pass on to the posterior ear. On the anterior ear are seen concentric ridges and undulations. Humps which are probably due to growth thickenings are occasionally found on the ribs.

The left valve is more or less flat. The costae correspond to those of the right valve in ornamentation and relative size, but are more globose and somewhat more prominent, and the interspaces are comparatively wider than in the other valve. Growth ridges are found on both valves, especially along the ventral margin. The interior of each valve shows a distinct fluted border.

Remarks.—The above is a description of a young shell. In older specimens the relative proportions are the same. On mature forms are found indications of the costellae that
are so characteristic of *V. wrightii*.

**Affinities.**—This species is distinguished from *V. wrightii* by its shape, which is more nearly equilateral, narrower, and more convex; by the ribs of its right valve, which are bluntly pointed at the summit, more solid, more triangular, and more prominent; and by its furrows, which are deep, narrow, and more or less angular, whereas those of the Georgetown form are broad and flat. Moreover, the ribs of the left valve of *V. whitneyi* are more prominent than those of *V. wrightii*, having steep sides, whereas those of the latter species have sloping sides.

Our form belongs to the same group as *J. longicauda* d'Orb. and *J. cometa* d'Orb. It is distinguished from the former by being more robust and shorter in proportion. In *J. longicauda* there are distinct costellae or secondary ribs, on both valves, besides tubercles in the furrows of the left valve, which are all absent in our species. Moreover, the ribs of the French form are broad, rounded, and low, whereas those of our form are subtriangular, bluntly pointed, and high. In *J. cometa* we find broad rounded depressions between the narrow, sharp ribs, and prominent costellae contrasting with the narrow furrows and prominent ribs of our species. In addition to this, *V. whitneyi* is shorter, broader, and has less convex ventral margin than *J. cometa*. This form is relatively rare in the Buda Limestone. When Mr. Whitney described it as *V. wrightii* a few years ago, the material on hand did not justify making it a new species.
Number of specimens: 14.

Occurrence: Lower division of the Buda Limestone, Austin and Manchaca, Texas.

Vola simondsii n. sp.

Plate VIII, figures 5-11

Dimensions.—Height 5.5 mm.; length 5 mm.; breadth 2 mm.

Description.—Shell small, almost as long as high; ventral margin semicircular and rounded. Ears subtriangular and relatively large; hinge line straight and short.

Right valve moderately convex, umbonal slope gently curved over the hinge line, antero-dorsal and postero-dorsal margins relatively long. This valve is ornamented with nineteen prominent, flattened, radiating ribs of which every fourth one, beginning at the anterior and posterior borders, is slightly raised, in the umbonal region, above the three at each side which lie in a broad, shallow, gently sloping valley. In the middle and the basal regions of the shell, however, all ribs are of the same height. The four ribs that are raised on the umbo are always somewhat wider than the others. The ribs are separated by rather deep, narrower, flattened depressions. Adjoining the four wide ribs we find furrows wider than those that separate the other ribs. Moreover, all ribs are scaly on the umbo and for some distance farther down on the valve. The anterior ear is separated from the body of the shell by a groove, while the posterior one is an extension of the posterior
area. Both areas and ears are covered by prominent concentric ridges, and the former show no secondary ribs. However, on a few specimens we notice a shallow depression on the areas and adjoining the ribs, but it dies out before reaching the umbonal regions.

The left valve is missing.

Remarks.—On weathered specimens the scales on the ribs are indistinct or entirely obliterated.

One of our specimens shows a modification of the ordinary arrangement of ribs. Instead of having four wider ribs, it shows four groups of two wide ribs each. There are three narrower ribs in the median group of the valve, but at the other places there are only two. Thus, the usual number of nineteen is retained.

Affinities.—Of all the Texas Cretaceous Volas heretofore described, _V. bellula_ Crag. resembles _V. simondsi_ n. sp. most. There is a general similarity between the shape of the shell and the shape of the ribs of the right valve of the two species. But the facets and varying number of ribs in each, so characteristic of the former species, are not found on the latter. In _V. simondsi_ there is great regularity in the distribution of ribs. There are always three between two wider ones, and the wide ribs are never replaced by twin-ribs or a group of very narrow ribs. Here we find only four wide ribs, whereas there are six such areas in _V. bellula_. Furthermore, the number of ribs in _V. bellula_ is more than twice that in _V. simondsi_ n. sp.
Our species is distinguished from *V. irregularis* Böse, *V. subalpina* Böse, *V. texana* Roem., and allied species principally in having three ribs between two broader ones and having all of the same height, except in the umbonal regions, whereas in the forms mentioned above there are only two principal ribs between the prominent ones, and every third rib is distinctly raised. Moreover, there are no secondary ribs on the areas of *V. simondsi* n. sp., which is not the case in these other species.

*V. simondsi* n. sp. differs from *V. bössei* n. sp. in certain definite ways that are mentioned in the discussion of that species. The former species can be easily distinguished from *V. laevis* Drouet by its higher shape and its ribs, which are totally different.

**Number of specimens:** 13.

**Occurrence:** Both divisions of the Buda Limestone, Austin, Manchaca, and Round Rock, Texas.

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**Vola bössei** n. sp.

*Plate IX, figures 1-4*

**Dimensions.**—Height 14 mm.; length 10.5 mm.; breadth 5 mm.

**Description.**—Shell small, not much higher than long, ventral margin rounded. Ears subtriangular and conspicuous; hinge line short and straight.

Right valve moderately globose, umbo broad and curved over the hinge line. The decoration consists of twenty-one subequal, subtriangular radiating ribs which are
narrow, very high, and scarcely flattened on top. Every fourth rib and the most anterior and the most posterior ribs are somewhat wider and higher than the others, but only so slightly that it is hardly noticeable. The ribs are separated by narrower depressions. In the anterior and posterior regions, the ribs are distinctly inclined towards the median line. On the umbo we find concentric folds instead of ribs. Below this, there are the radiating ribs but much interfered with by very strong lines of growth. On the remainder of the shell, we find ordinary concentric lines which are also found on the areas and ears where they increase in strength as they approach the umbo. As in V. simondsi, a groove separates the anterior ear from the anterior area, while there is no such demarcation on the posterior side. No secondary ribs have been found on the areas.

The left valve is missing.

Affinities.—This species differs from V. simondsi n. sp. in its form, which is somewhat higher; in the number of ribs on the right valve, having two more, a prominent one being added anteriorly and posteriorly; in the shape of the ribs, which are subtriangular, slightly flattened on top, and considerably higher; and, lastly, in having concentric ridges, and not scales, on the umbo.

V. bösei n. sp. is distinguished from V. altana in being much higher; in having rather sharp, and not rectangular ribs; and, moreover, in having three ribs
between every two conspicuous ones.

Number of specimens: 14.

Occurrence: Both divisions of the Buda Limestone, Austin and Round Rock, Texas.

Vola roemerí Hill.

(not Pecten roemerí Weerth\(^1\))

Plate IX, figures 5-7; Plate X, figure 1


Dimensions.--Height 60(?) mm.; length 70 mm.; breadth 31(?) mm.

Description.--Shell large, thick, compressed, asymmetrical, inequivalve, length only slightly greater than height; outline suboctahedral; subsemicircular, scalloped, ventral margin shows six projections formed by the extensions of the folds; at the base, convexities of one valve fit into concavities of the other. Ears prominent, posterior larger than anterior; hinge line long and straight, and equal to about three-fourths the length of the shell.

Right valve convex, somewhat larger than the left, beak prominent and elevated. The surface is

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sculptured by six unequal radiating folds that are distributed in an irregular manner and ornamented with costae and costellae of different sizes and shapes. On first sight it appears as if there is no regularity whatsoever about the arrangement, but upon closer investigation, we can make out some system. When we number the folds, we always begin at the anterior side. Each fold has a prominent rib at the summit and others of different sizes on the slopes. The summit costae are practically equal, and similar in shape. Between the several folds are found narrow depressions scarcely wider than those between the prominent ribs.

The fourth fold, although not the largest, is most pronounced and projects farther out than the others at the ventral margin. It is also the highest one and the center of symmetry. Its summit is formed by a narrow rib rounded on top. On each slope are two small ribs varying somewhat in size, the lower ones tending to be more prominent. The anterior slope of the fifth fold shows a broad, flat-topped rib near the summit, followed by a prominent costa at the summit. On the posterior slope are two smaller ribs, one of them being almost in the interfold furrow. On the anterior slope of the sixth fold is a small rib practically equal to its neighbor across the furrow. On the posterior slope are found four ribs, the first and last being insignificant, and the second more prominent than the third.
The third fold is broader than any of the others. Its summit also shows a prominent narrow, rounded rib, which has a fine radial plication on the anterior side. The ribs on its posterior slope correspond in shape and arrangement to those on the anterior slope of the fifth fold. On the anterior slope are found two prominent unequal ribs. The larger rib is similar to the corresponding one on the other slope of this fold and is nearer the summit.

The second fold has a conspicuous rib near the base on either side, and a smaller one higher up on the anterior slope.

There is a prominent costa on the posterior slope of the first fold, being even larger than the one forming the summit. On the slope adjoining the ear there are three small ribs, more or less alike.

In young specimens the folds are relatively higher than in the more mature forms.

The conspicuous ears are ornamented with prominent radiating and practically uniform costae.

Left valve somewhat less convex than the right, beak depressed. As in the right valve, there are six folds. But as the ribs alternate with those of the right valve, we here have a furrow on the summit of each fold. Most furrows tend to be wider than the ribs, in contrast to the relation of the right valve.

On the anterior slope of the first fold we find three rather conspicuous ribs. Then there is a prominent
one posterior to the summit furrow, which is followed by a depression. On the anterior slope of the next fold, we find two well developed ribs, then the depression at the summit, and then a smaller rib leaning against a very broad sloping costa. In the valley between this fold and the next lies a narrow, sharp rib. On the third fold two very prominent ribs enclose the summit furrow. On the fourth fold, we find first a narrow high rib, then a broad low one separated from the former by a deep rounded depression, then another deep narrow depression, and, finally, two medium sized costae separated by a line sunk into the surface. The ornamentation of the posterior slope corresponds to that on the anterior. Between this fold and the next occurs the broadest depression. The fifth fold consists of merely a distinct rib on either side of the summit furrow. This fold and the next are separated by a deep rounded furrow. On the anterior slope of the sixth fold is found a small rounded rib and then a broad one adjoining the summit depression. On the posterior slope the ribs merge into those of the posterior ear. The ears are marked as on the right valve.

On some specimens additional fine ribs have been noticed in some of the depressions.

The posterior ear extends almost from the end of the projection of the posterior fold in a gentle curve to the end of the long hinge line. The anterior ear is smaller and is separated from the body of the shell by a deep groove.
Further ornamentation consists of fine concentric striae, which are always parallel to the serrate margin, passing from the body of the shell to the ears. Growth ridges are also evident.

Remarks.—This species attains great size, our largest specimens having a height of 120 mm. and a length of 130 mm.

Affinities.—This form groups with *V. fleuriausiana* d'Orb. and *V. lapparenti* Chef. *V. roemeri* differs from d'Orbigny's species in having its folds more unequal in every respect, in having fewer ribs and these very dissimilar, and in having broad furrows which are not found in the French form. The hinge line and the ears also are different. Our species has the former longer and the latter more unequal than *V. fleuriausiana*. As has been mentioned in the description, the posterior of the right valve of *V. roemeri* extends almost to the projection of the posterior fold. Furthermore, our shell is more asymmetrical and shows a different relation between the valves. In *V. fleuriausiana* the left valve is only slightly convex, whereas in our species both valves are inflated, there being only a slight difference in the convexity.

Our form is not so long in proportion and the valves are evidently more convex than those of *V. lapparenti*. Moreover, the shape and distribution of the ribs is entirely different in the two species.

Number of specimens: 22.

Occurrence: Upper division of the Buda Limestone, Austin, Texas.
**Vola austinensis** n. sp.

Plate IX, figure 8; Plate X, figures 2-3

**Dimensions.**—Height 32.5 mm.; length 28.5(?mm. ; breadth 10.5(? mm.

**Description.**—Shell rather large, subtrigonal, practically equilateral, solid; ventral margin shows six blunt projections formed by the prolongations of the six prominent ribs. Ears triangular and medium; hinge line straight.

Right valve moderately globose, umbo gently incurved. This valve is decorated with sixteen prominent and rather high, radiating ribs of which every third one, including the most anterior and the most posterior, is somewhat stronger and is raised slightly above the others. We find an unusual arrangement of the two ribs in each depression. These ribs are close together and are separated by a furrow that is shallower than those by the side of the prominent ribs. The ribs appear to be rounded, but upon closer investigation we find that they are flattened to some extent. The intercostal spaces adjoining the raised ribs are flattened and are as wide as, or slightly wider than, these latter. The ribs in the median depression are separated by a very narrow groove scarcely half as wide as one of these ribs. In the depressions anterior and posterior to the median one, the corresponding groove is slightly wider. And in the two remaining depressions grooves and ribs are practically equal in width. However, the ribs in the latter depressions are greatly reduced in size.
As in similar species, the anterior ear is separated from the shell by a deep groove, while the posterior ear curves outward from the posterior area.

This valve is further ornamented with delicate radial ridges. From two to five or more can be made out on each rib. In the intercostal spaces they are not so abundant, and not more than two have been noticed in any one space. Better material might show these ridges distributed in a regular manner.

On the areas we find very fine radiating ribs. The number is not constant, but usually there are five, and they are distributed over the whole surface of the area. Fine, crowded, concentric lines cover the whole shell and the ears.

The left valve is flat and is ornamented with fifteen principal radiating ribs, the ribs corresponding to the depressions on the right valve. And the ribs that correspond to the furrows by the side of the prominent ribs of that valve, are the raised ribs of the left valve. However, they are broad and flattened and appear in pairs. In the depression between two adjoining pairs, there is a low, narrow, sharp rib.

As on the right valve, we find radial ridges or fine secondary ribs on these ribs, distributed in an irregular manner, and more on the ribs than in the interspaces. A few fine secondary ribs are present on each area. On the posterior ear there are some marks that lead us to think
that perhaps several small, radiating ribs are present near the hinge line. However, the specimens are not well enough preserved to determine them definitely. Delicate, yet distinct, concentric lines cover the whole shell. They are somewhat stronger on the ears.

Affinities.—*V. austinensis* n. sp. differs from all similar Texas Comanchean and Cretaceous Volas in having the two ribs in the depressions close together and separated by a furrow that is shallower than the other interspaces.

Our species differs from *V. budapestei* n. sp. in being less globose, in having radial ridges on the ribs and in the depressions, in not having its prominent ribs trident in character, and in the general shape of the ribs. Moreover, the left valves are entirely different.

From *V. georgetownensis* n. sp., *V. austinensis* n. sp. differs in its form, which is much less convex and not so solid; in the ribs in the depressions of the right valve, which are higher and more rounded, in the raised ribs of this valve, which are not so prominent; in the ornamentation of radial ridges on both valves, which, however, have a parallel in the stronger riblets and depressions on the shell of *V. georgetownensis*.

Number of specimens: About 25.

Occurrence: Austin Chalk, Austin, Texas.
Vola hartmani n. sp.
Plate X, figures 4-5

Pecten quadricostatus Roemer, 1852, Kreidebild. v. Texas, p. 64.

Dimensions.--Height 11 mm.; length 10.4 mm.; breadth 5 mm.

Description.--Shell small, subequilateral, subtrigonal, length practically equaling height; gently curved base with six prominent projections formed by the extensions of the raised ribs and separated by shallow concavities; postero-dorsal margin longer than antero-dorsal, but both rather long. Greatest length below the middle. Ears medium; hinge line straight.

Right valve moderately convex, umbo prominent and incurved. The ornamentation consists of twenty-one simple, principal radiating ribs of which every fourth one, including the first and the last, is much stronger than the others. The ribs curve gently outward. Of the three ribs in the depressions, the middle one is sometimes very slightly stronger than the other two, or two are of the same strength and an outside one is somewhat smaller. In other depressions no difference in the strength of the ribs can be made out. When there is a difference, as in the cases mentioned above, it is so slight that it can be detected only upon close study. The prominent ribs are practically three times as wide and as high as those in the depressions, which really are very insignificant. On all of our specimens the most posterior prominent rib, which is
reduced in size, has a smaller rib on its anterior side. All ribs are rounded, and the depressions as a whole are flat. The intercostal spaces are rounded and are as wide as, or wider than, the ribs in the depressions, those adjoining the prominent ribs being no exception. The ribs of the first and the last group are not so strong as those in the others. At the base the six prominent ribs form blunt projections, and the depressions are bounded by gently curved incisions. Narrow, radial, secondary ribs are present on the areas. On the posterior area there are usually five, but one specimen distinctly shows six. On the anterior area the number could not be determined definitely, due to lack of preservation of these areas. But indications are that secondary ribs are just as abundant here as on the other area. Although the ears are poorly preserved, the posterior one of one specimen clearly shows radial ribs. These have the same shape and arrangement as those on the areas and seem to be but a continuation of the ribs on the areas.

Fine, crowded, concentric ridges further ornament this valve, including the areas and ears.

The left valve is flat or slightly concave, and is ornamented with prominent radiating ribs that correspond to the intercostal spaces of the right valve. We find the same general manner of arrangement of ribs as in \textit{V. texana} and allied forms, only there are always two ribs in each depression, instead of one. Thus, we have alternately two high and two low ribs. The ribs are rounded, subequal, and
generally are wider than the interspaces. Of course, the furrow separating each pair of raised ribs is an exception to this and is considerably wider than the ribs. Concentric ridges are present as on the right valve.

The areas and ears are missing.

Remarks.—On one right valve we notice only two ribs in one of the depressions, and on one left valve there is a small rib in one of the broad furrows. Whether these are abnormalities or variations is an open question. Stoliczka has found all manners of gradations between *V. quadricostata* Low. and *V. quinquecostata* Low. of the Southern Indian Cretaceous. There is a possibility that a similar condition exists in the Austin Chalk between *V. hartmani* n. sp. and *V. casteeli* n. sp. More extensive collecting in different portions of the State is necessary in order to determine this.

Affinities.—D'Orbigny and many writers after him have described a Senonian form as *Janira quadricostata*. Later Picket and Campiche showed that d'Orbigny's species is distinct from Sowerby's, and named the former *Janira faujasi*. Choffat believes *J. faujasi* to be identical with *V. regularis* Schl. D'Orbigny's species differs from Sowerby's

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4 Faune Crét. Portugal, 1901-02, Vol. 1, ser. 4, p. 149.
in being smaller, in having much smaller ears and a shorter hinge-line; in the anterior and posterior areas sloping outward only slightly; in a smaller apical angle; in having seven or eight ribs on the areas, instead of a smaller number like the true quadricostata; in the six prominent ribs being of a lesser elevation and consequently the groups less clearly demarcated; and in having the greatest length of the shell below the middle.

It remains for us to show how our form differs from similar forms of Senonian age.

V. hartmani n. sp. differs from J. quadricostata d'Orb. chiefly in its shape, which is not so long and less globose; in its more angular base; in its stronger raised ribs; and in having longer antero-dorsal and postero-dorsal margins and more secondary ribs on the areas.

Zittel, too, describes an Upper Cretaceous form as J. quadricostata. It differs from our species in being higher, less angular at the base, and in having only two or three secondary ribs on the areas, or none at all. Moreover, Zittel says, six of the ribs on the left valve are characterized by greater strength. This certainly is not the case with the Texas specimens, where we find alternate pairs raised. Judging from Zittel's figures, the arrangement of ribs on the left valve of his form is entirely

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1 Die Biv. der Gosangeb., pt. 2, p. 115, pl. 13, fig. 4.
different from that of the left valve of \textit{V. hartmani} n. sp.

Another quadricostata of the Upper Cretaceous is White's 1 form from Brazil (province Sergipe). It is slightly higher than our species, and has no secondary ribs on the areas. Furthermore, judging from White's pictures, there is less difference in size between the prominent ribs and those in the depressions, than in our species. The intercostal spaces in \textit{V. hartmani} seem to be wider.

In conclusion we ought to mention that our species varies from the Upper Cretaceous quadricostata form, as generally described, in having radial ribs on the ears and only five or six ribs on the areas, instead of seven or eight, and in having the prominent ribs at least three times as strong as those in the depressions, instead of nearly the same size. As has been pointed out above, other Upper Cretaceous forms have only two or three ribs on the areas, or none at all.

\textbf{Number of specimens:} 12.

\textbf{Occurrence:} Upper layers of the Austin Chalk, Walnut Creek, Sprinkle, Texas.

\textit{Vola casteeli} n. sp.

\textbf{Plate X, figures 6-10}

\textbf{Dimensions.}—Height 28 mm.; length 26 mm.; breadth 10 mm (distorted specimen).

\textbf{Description.}—Shell large, subovate, almost equilateral;

\^1 Contrib. to the Paleon. of Brazil, 1888, p.37,pl.4,fig.1-2.
height slightly greater than length; base broad, angular; antero-dorsal and postero-dorsal margins long; greatest length below the middle. Ears large; hinge line straight.

Right valve gently convex, umbo broad and incurved. This valve is decorated with twenty-six prominent radiating ribs. Every fifth one, including the most anterior and the most posterior is distinctly elevated. The ribs curve moderately outward. Among the ribs in the depressions the two middle ones, which are practically equal, are sometimes stronger than the other two. More often three are of practically the same size and an external one is smaller. The two outer ones usually differ somewhat in size. The prominent ribs are appreciably higher than those in the depressions, and almost twice as wide as the widest in these groups. The ribs are rounded, and the depressions are flat. The most posterior (prominent) rib is split by a radial sinus.

The intercostal spaces are rounded, subequal, and usually narrower than the ribs. An exception to the latter characteristic is often found in the first and the last group, where the strength of the ribs is reduced. As in similar species, the extensions of the prominent ribs form the angles at the base. The concavities between these projections are not very deep.

The anterior area is not preserved, but on the posterior we notice very prominent secondary ribs. Six can be made out distinctly and a few more may have
been obliterated by weathering. They are relatively broad, high, and rounded and decrease in size as they are located nearer the margin. However, they are continued on the ear, where they are very prominent and numerous.

Fine, regular, concentric lines cover the ribs, interspaces, areas, and ears.

The left valve is flat or somewhat concave. The ornamentation consists of subequal radial ribs corresponding to the interspaces of the right valve. The ribs are subtrigonal in shape, rounded on top, and narrower than the intercostal spaces. The two ribs adjoining the furrows corresponding to the raised ribs of the right valve, are elevated above a group of three on each side, that lie in a slightly concave depression. Hardly any two adjoining ribs are of the same strength. Most of the broader ones are elevated, thus showing that the corresponding furrows at the side of prominent ribs of the right valve were wide. On this valve we find concentric ridges arranged as on the right valve. Only fragments of this valve are in our collection.

Remarks.—We have already called attention to the fact that the ribs in the depressions of the right valve vary in strength. We notice that in one of the groups of one specimen there are only three ribs. This leads us to believe that probably the same variations exist in our form that have been observed in *V. quinquecostata* by European paleontologists. It is very seldom that one of the small exterior
ribs in the depressions is so near the prominent rib as to seem to be connected with it. Usually a broad furrow separates the two. This is indicated also by the raised ribs of the left valve, which are often exceptionally broad. Affinities.—Roemer, ¹ Conrad, ² Gabb, ³ and Boese ⁴ have pointed out that the quinquecostata form of North America is distinct from the typical V. quinquecostata.

Roemer ⁵ described a quinquecostata form from Fredericksburg as Pecten quadricostata var. His right valve differs from ours in having a fine linear rib on each side of the prominent rib, combined more or less with this latter, thus giving the raised ribs a trifid appearance. With regard to the left valve, he says: "Je vier Rippen sind buendelweis gewissermassen zu einer einzigen flachen Rippe vereinigt und die Mitte des Zwischenraums zwischen je zwei solchen breiten, flachen Falten nimmt eine einzelne schmale gerundete Falte ein. Die breiten aus der Vereinigung von Lage den fuenf staerkeren vier entstehenden Falten entsprechen uebrigens in ihrer/Rippen der anderen Klappe und stossen mit diesen am Rande zusammen." There is no such arrangement on our left valves.

¹ Kreidebild. v. Texas, 1852, p. 64.
⁴ Instituto Geol. de Mexico, Boletín 25, p. 99.
⁵ Kreidebild v. Texas, 1852, p. 64.
Moreover, Roemer's shell is higher and has shorter areas than ours, and the author does not mention secondary ribs on the areas and ears.

Conrad lists Roemer's *quadricostatus* var. as synonymous with his *occidentalis*. His species differs from ours in being higher, in having shorter areas, and in not having fine ribs on the areas and ears.

*Pecten quinquecostatus* Mort. was included by Gabb in his species *Neithsea mortoni*. Gabb, in speaking of the left valve, says: "There is, very rarely, the slightest approach to the sexradiate arrangement of the other valve."

As has been mentioned in our description, this arrangement is very pronounced in *V. casteeli*. Furthermore, there seems to be a greater variation in the strength of the ribs of our species. Judging from Morton's figure, there are certain definite differences between the shape of *P. quinquecostatus* Mort. and our species. Since Gabb considers Roemer's *quadricostata* var. identical with his species, and since we believe the former to be distinct from our form, we regard *V. mortoni* as distinct from *V. casteeli*.

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Böse's *V. quinquecostata* is not closely related to the other American *quinquecostata* forms, since the latter are Upper Cretaceous species. His specimens came out of Lower Cretaceous Formations.

**Number of specimens:** About 40.

**Occurrence:** Austin Chalk, Austin, Texas.
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Fig. 7. Portion of another right valve.
Fig. 8. Right valve.
Fig. 9. Portion of left valve.
Fig. 10. Portion of left valve.