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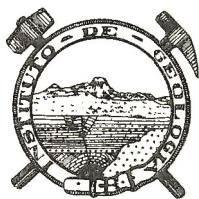
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BIOSTRATIGRAPHY OF THE CARDENAS FORMATION
(UPPER CRETACEOUS) SAN LUIS POTOSI, MEXICO

POR

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RESUMEN

La Formación Cárdenas es una unidad muy fosilífera de 1,050 m de espesor, de rocas sedimentarias clásticas finas que afloran en un sinclinal asimétrico en la plegada Sierra Madre Oriental. Se han publicado 6 versiones sobre la estratigrafía de Cárdenas, pero en ellas se han incluido secuencias parcialmente invertidas debido a que no se había reconocido la estructura del sinclinal. Para este estudio fue cartografiada la región alrededor de Cárdenas en hojas topográficas a la escala de 1:50,000 y el sinclinal de Cárdenas fue cartografiado con alidada y plancheta a la escala de 1:4,800. De once secciones medidas, dos fueron estructuralmente simples y bastante completas para poder establecer la secuencia de las unidades estratigráficas.

La Formación Cárdenas como aquí se define, se divide en tres miembros que se designan informalmente. El miembro inferior es de 180 m de espesor, de capas alternantes de lutita, arenisca y biosparita (Folk, 1959); el miembro medio es de 445 m de lutita y limolita; el miembro superior es de 430 m de limolita, arenisca y biosparudita. La Formación Cárdenas está cubierta discordantemente por la Formación Tabaco, que consiste de limolita no fosilífera, arenisca y conglomerado.

En el presente estudio se colectaron 71 especies de fósiles invertebrados de la Formación Cárdenas: 8 rudistas, 36 bivalvos, 14 gasterópodos, 6 corales, 4 equinoides, 2 serpulidos y 1 braquiópodo. Estos se encuentran en 3 zonas en Cárdenas. La zona media y quizá la zona inferior, son correlativas con la zona de *Exogyra costata* de la planicie costera del Golfo. La zona superior es probablemente más joven que la zona de *Exogyra costata*, pero aún Maestrichtiano. La Formación Cárdenas es un tipo de depósito "regresivo"; durante su formación, la sedimentación cambió repetidamente de depósito de clásticos finos a la acumulación de calizas biogénicas.

PREFACE

Emil Böse brought Cárdenas to the attention of paleontologists sixty years ago. Along the railroad track east of town he found beds with many species of fossil mollusks unlike any then known in North America. These fossiliferous Upper Cretaceous rocks soon attracted oil company geologists working out of Tampico. During the first third of this century W. F. Cummins, Arnold Heim, W. S. Adkins, Bruce Wade, F. K. G. Müllerried, and Carl Burckhardt visited the Cárdenas section.

After the expropriation of foreign oil companies by the Mexican government in 1938, no further work was done at Cárdenas until the present time. In 1960 Drs. Zoltan de Cserna and Carl Fries of the Instituto de Geología suggested to me that a stratigraphic study of these beds would be a useful complement to the well studied Upper Cretaceous section of the Tampico region. I began field work in the summer of 1962 supported by a National Science Foundation Graduate Fellowship.

I mapped, collected fossils, and measured sections in the spring and summer of 1963, aided financially by a loan from the Houston Geological Society. During the academic year 1963-1964 I studied the material collected in the field; this work was supported by a fellowship from the Pan American Petroleum Foundation, which also supported field work in the summer of 1964.

In the 1964-1965 academic year and in the summer of 1965 I prepared and identified the fossils, made the final drafts of the maps and sections, and wrote this dissertation while supported by a National Science Foundation Graduate Fellowship and a University of Texas Summer Fellowship.

Without question I could not have done this work without the financial support of these foundations and the Houston Geological Society. I am sincerely grateful for their aid.

Dr. Zoltan de Cserna of the Instituto de Geología, Universidad Nacional Autónoma de México, procured for me permits to take fossils out of México as well as aerial photographs of the area south of Cárdenas. Dr. de Cserna and Mrs. Gloria Alencaster visited me in the field. Their discussion of the field work and its presentation were most helpful.

Dr. Bob F. Perkins, Shell Development Company, Houston, Texas; Dr. Peter U. Rodda, Bureau of Economic Geology, Austin, Texas; and Professor W. Charles Bell, The University of Texas, have kindly consented to serve on my dissertation committee. Their criticism of the manuscript was invaluable in the preparation of this dissertation; any remaining error are mine alone.

My dissertation advisor, Professor Keith P. Young, joined me in Cárdenas twice for field work. His advice, guidance, and general good humor have made the preparation of this dissertation much more pleasant than could reasonably have been expected.

July 15, 1965

ABSTRACT

The Cárdenas Formation is a very fossiliferous 1050-meter thick unit of finely clastic sedimentary rocks that crops out in an asymmetric syncline in the folded Sierra Madre Oriental. Six versions of the stratigraphy at Cárdenas have been published, but they have included partially inverted sequences because of failure to recognize the structure of the syncline. For this study the region around Cárdenas was mapped on topographic sheets at a scale of 1:50,000, and the Cárdenas syncline was mapped with plane table and alidade at a scale of 1:4,800. Of eleven measured sections, two were structurally uncomplicated and complete enough to establish the sequence of stratigraphic units.

The Cárdenas Formation, herein defined, is divided into three informally designated members. The lower member is 180 meters of alternating shale, sandstone, and biosparite (Folk, 1959); the middle member is 445 meters of shale and siltstone; the upper member is 430 meters of siltstone, sandstone, and biosparudite. The Cárdenas Formation is unconformably overlain by unfossiliferous siltstone, sandstone, and conglomerate, the Tabaco Formation.

In the present study 71 species of invertebrate fossils were collected from the Cárdenas Formation: 8 rudists, 36 other bivalves, 14 gastropods, 6 corals, 4 echinoids, 2 serpulids, and 1 brachiopod. These occur in three assemblage zones at Cárdenas. The middle zone and perhaps the lower zone are correlative with the *Exogyra costata* Zone of the Gulf Coastal Plain. The upper zone is probably younger than the *Exogyra costata* Zone, but still Maastrichtian. The Cárdenas Formation is a "regressive" type of deposit; during its formation sedimentation changed repeatedly from deposition of fine clastics to the accumulation of biogenic limestones.

INTRODUCTION

Böse's (1906a) monograph made known that there was a thick section of very fossiliferous Upper Cretaceous clastic sedimentary rocks at Cárdenas. However, the stratigraphy of the Cárdenas beds has remained an enigma. Several accounts of the section have been published, but they differ greatly in the sequence, kind, and size of units depicted in the Cárdenas Beds. The purpose of this study is to resolve the differences in stratigraphic order, to paleontologically zone the Cárdenas beds, and to correlate these zones with biostratigraphic units elsewhere.

GEOLOGIC SETTING

The Cárdenas Formation crops out in the central part of the Sierra Madre Oriental in the eastern part of the state of San Luis Potosí (Fig. 1). The folded

Cretaceous rocks of the Sierra Madre Oriental are bounded on the east by gently eastward dipping Tertiary coastal plain sedimentary rocks of the Tampico embayment. West of the Sierra Madre Oriental is the Mesa Central, a plateau of Lower Cretaceous inliers, filled Cenozoic bolsons, and Tertiary volcanic rocks. At the latitude of Cárdenas the western border of the Sierra Madre Oriental is just east of the city of San Luis Potosí, 130 km west of Cárdenas. The eastern boundary of the Sierra Madre Oriental is near Ciudad Valles, S.L.P., 90 km east of Cárdenas.

The town of Cárdenas is on the western limb of an asymmetric syncline of Upper Cretaceous sedimentary rocks (Fig. 2). East of the syncline is the eastern slope of the Sierra Madre Oriental, which consists of middle Cretaceous limestone, the Tamazopo, San Felipe, and El Abra formations. West of Cárdenas are anticlinal hills of middle Cretaceous limestone separated by Cenozoic alluvium.

The east limb of the asymmetric Cárdenas syncline is almost overturned to the east (Plate 1, line A-A'). Going from west to east across the syncline along line A-A', the dips are nearly horizontal in the first outcrops east of the alluvium. The dips become progressively steeper until they are vertical near the summit of the Cerro del Ojanchal, at the contact of the Upper Cretaceous marine sedimentary rocks (Cárdenas Formation) with the overlying red beds (Tabaco Formation). The contact of the Tabaco Formation on the Cárdenas Formation is a fault on the western flank of the syncline, and the Tabaco Formation is more intensely folded than the Cárdenas Formation (Plate 1). The Tabaco Formation occupies parts of the summit of the Cerro del Ojanchal and its eastern slope, which overlies the axial portion of the syncline.

The more gently dipping eastern flank of the syncline gradually rises from the topographic low near the synclinal axis to the anticlinal hills of the Tamazopo Limestone. The eastern contact of the red beds on the Upper Cretaceous marine rocks is unconformable. The contact of the Cárdenas beds on the Tamazopo Limestone is a fault; their original stratigraphic relation cannot be determined in this area.

PREVIOUS WORK

Six major versions of the stratigraphy at Cárdenas have been published (Böse and Cavins, 1927; Burckhardt, 1930; Heim, 1940; Müllerried, 1941; and Wade, *in* Imlay, 1944a). With the possible exception of Müllerried's (1941) section all the published stratigraphic columns for the Cárdenas — Canoas area (Table 1) have been based on traverses across more than one structural feature. All of these sections (except possibly Müllerried's) have thus contained a repetition of lithologic units, a partly inverted sequence, or both.

Böse (1906a) was fully aware of the uncertainty of his stratigraphy. He stated (p. 15) that the Cárdenas Division was quite thick and estimated its thickness as 600 meters. However, he cautioned that this was only an approximation because the beds of his upper horizon (*Coralliochama G. Boehmi* Horizon) were strongly folded, and he could not determine their order of superposition.

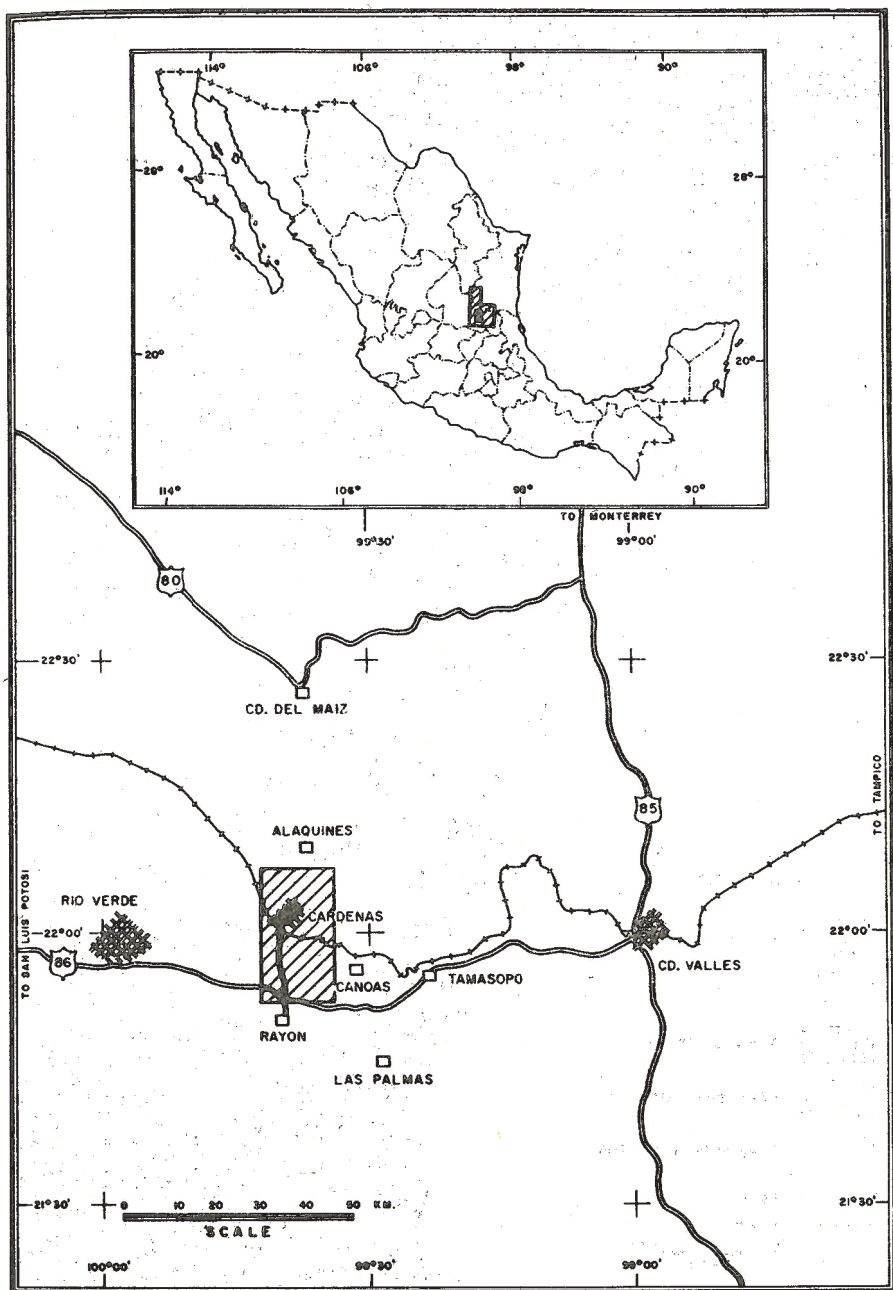


Figure 1. Index map of Eastern Mexico.

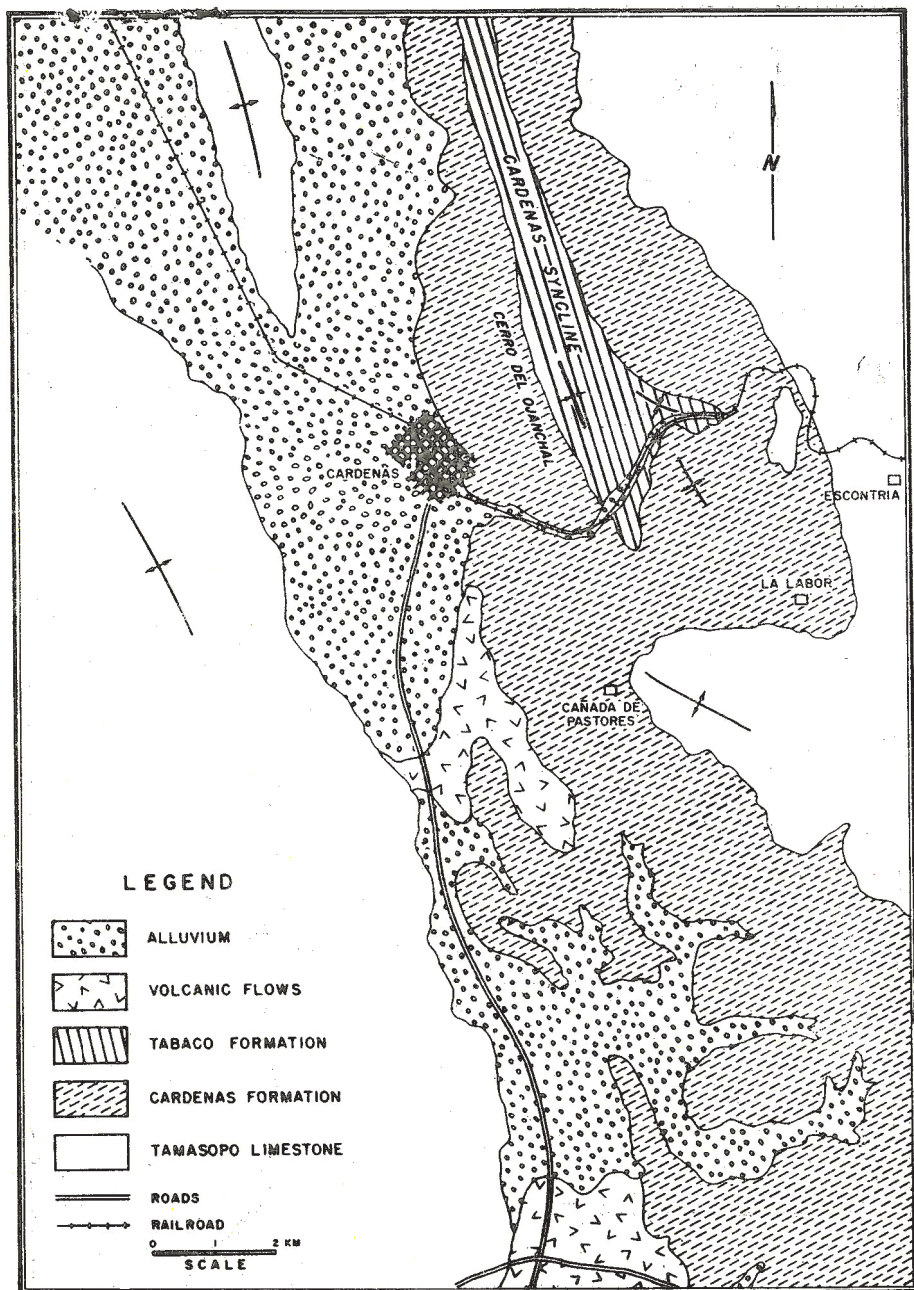


Figure 2. Geologic map of the Cárdenas región

Böse (1906a) recognized four horizons in the Cárdenas División (Table 1) and listed the localities for each by the kilometer marks on the Aguascalientes—Tampico railroad. He began 15 km east of Cárdenas at Km 436 near Canoas (Fig. 1) in shale, limestone, and sandstone that contained *Exogyra costata*, *Gryphaea vesicularis* (= *Pycnodonte mutabilis*) and *Ostrea Aguilerae* (= *Arctostrea aguilerae*); this was his first or *Gryphaea vesicularis* Horizon. He went from there toward Cárdenas across thick-bedded limestone with *Nerinea* and a few rudists (his second horizon, the Tamazopo Limestone of Burckhardt, 1930; Heim, 1940; Müllerried, 1941; and Imlay, 1944a, 1944b). Above the thick-bedded limestone he recognized a yellow shale without fossils (Méndez Shale of Burckhardt, 1930; Heim, 1940; and Müllerried, 1941). The unfossiliferous yellow shale was overlain by fossiliferous yellow shale with intercalated yellow sandstone (Km 420—419 on the Aguascalientes—Tampico rail line, Plate 1). This, Böse's third horizon or *Orbitoides* Horizon, contained orbitoids, corals, *Inoceramus*, *Ostrea*, *Pinna*, *Vola*, and *Turritella*. The top of Böse's Cárdenas División is the *Coralliochama G. Boehmi* Horizon, which Böse recognized at several localities between Km 419 and Km 415. He listed 28 species from this horizon including *Coralliochama G. Boehmi*, *Biradiolites Aguilerae*, *Biradiolites Cardenasensis*, and *Radiolites Austinensis*. Böse believed that he was still ascending the section going west and therefore stated that beds with *Exogyra costata* near Km 415 were at the top of the *Coralliochama G. Boehmi* Horizon.

Thus, Böse reported *Exogyra costata* at the top and at the base of the Cárdenas División, although the *Gryphaea vesicularis* Horizon "is distinguished by the abundance of *Exogyra costata* Say, and the presence of *Gryphaea vesicularis*" (Böse, 1906a, p. 18; author's translation). In 1906 Böse made no further comment on the occurrence of *Exogyra costata* in the Cárdenas División.

By following Böse's traverse on Plate 1, starting in the thick-bedded limestone east of Km 420.4, it is evident that his second, third, and fourth horizons are in stratigraphic order. However, Böse did not recognize a thick unit of shale between his *Orbitoides* Horizon and his *Coralliochama* Horizon. This is understandable because the shale unit (the middle member of the Cárdenas Formation) is represented along the rail line only by a grassy valley. Then Böse recognized the *Coralliochama G. Boehmi* Horizon at Km 417-416 on the small anticline at Bomba, and at Km 415.5 on the west flank of the syncline.

In 1923 Böse stated in a footnote to his "Algunas Faunas Cretácicas de Zacatecas, Durango y Guerrero" (p. 194) that the marls with *Coralliochama* at Cárdenas were 300 meters below the sandstone with *Exogyra costata* (and *Gryphaea vesicularis*, that is, the *G. vesicularis* Horizon). Böse did not explicitly state the basis for this revision of his 1906 work. I believe that he attached more significance to the beds with *Exogyra costata* near Km 415 (Plate 1) because there they seemed to be in clearer stratigraphic relation to the *Coralliochama* Horizon between Km 415.5 and Km 418.6 than was the more remote *Gryphaea vesicularis* Horizon near Canoas, (Fig. 1).

This revision led Böse and Cavins (1927, p. 78) to give the section at

Cárdenas in inverted order relative to the section of Böse (1906a; Table 1). Böse's (1906a) first horizon or *Gryphaea vesicularis* Horizon became the upper unit of the Cárdenas beds and the *Coralliochama* Horizon the lower unit.

Burckhardt (1930, p. 233) adopted the Cárdenas section as emended by Böse and Cavins. He correctly omitted Böse's (1906a) second horizon (Tamazopo Limestone) from the Cárdenas beds, and on the advice of petroleum geologists in Tampico he called the unfossiliferous yellow shale below Böse's (1906a) *Orbitoides* Horizon the Méndez Shale. In addition to removing this basal shale unit from the Cárdenas beds, Burckhardt also removed the upper unit of Böse and Cavins (1927), the sandstone, shale and sandy limestone with *Exogyra costata* and *Gryphaea vesicularis*, thereby limiting the Cárdenas beds to the *Coralliochama* Horizon (above) and the *Orbitoides* Horizon (below). In his interpretation the Cárdenas beds were bounded by the Méndez Shale below and the *Exogyra costata* beds above (Table 1).

Two sections, by Böse and Cavins (1927) and Burckhardt (1930), are partially inverted because their authors followed Böse (1923) in erroneously placing the *Exogyra costata* — *Gryphaea vesicularis* Horizon above the *Coralliochama* beds that crop out along the rail line between Km 415.5 and Km 418.6.

Heim in 1940 published an account of the stratigraphy and structure along the rail line between Tamazopo and Cárdenas (Fig. 1), which he had studied twenty years earlier. He described his traverse across the Cárdenas syncline as a stratigraphic section, but it is actually twice the true section, half of which is in inverted order (Table 1). His "Lower Cárdenas beds" are a complete section of the Cárdenas Formation from the eastern edge of the syncline to the red beds in the axial portion of the syncline. However, Heim placed the red beds in the middle of the section and called his traverse from mid-syncline across the western flank the "Upper Cárdenas".

Müllerried's (1941, p. 29) units, measured along the rail line between Escontría and Cárdenas (Fig. 2), appear to be in stratigraphic order, but they are so generalized as to be useless. He listed five units above the Méndez "marl" all of which are sandy marl with sandstone (Table 1).

Wade (in Imlay, 1944a, p. 1136) measured a section from Cañada de Pastores, 5 km southeast of Cárdenas (Fig. 2), to the rail line near Km 416.3. This is the most detailed section that has been published; it totals 5570 feet and is divided into 103 units. However, Wade's traverse crossed a double thickness of the lower member of the Cárdenas Formation in the nose of a large anticline between Cañada de Pastores and La Labor (Fig. 2). Then Wade crossed the middle member of the Cárdenas Formation going from the anticlinal nose toward the axis of the syncline. He again encountered a repeated section, this time of the upper member of the Cárdenas Formation, in the vicinity of the small anticline at Bomba (Plate 1).

The reason for such divergent interpretation of the Cárdenas beds was failure to recognize the structural configuration of the Cárdenas syncline. There are three main contributing factors to the difficulty. First, distinctive beds are absent: the upper and lower members of the Cárdenas Formation

consist of many thin beds of siltstone, mudstone, sandstone, and biosparite, (Folk, 1959) with like lithologies repeated many times. Second, along the rail line there is essentially only one exposure of each lithologic unit in the Cárdenas beds. Going from east to west across the syncline, the "Méndez Shale" is encountered at Km 420.4 (Plate 1), then the lower member of the Cárdenas Formation between Km 420 and 419. The middle member of the Cárdenas Formation is not exposed on the eastern flank of the syncline. The next outcrops are biosparite of the upper member of the Cárdenas Formation at Km 418.6. The upper member is exposed again in the anticline at Bomba and on the western flank of the syncline at Km 415.5. The middle member of the Cárdenas Formation is encountered for the first time west of Km 415. Valley fill and caliche conceal the lower member further west along the rail line. Thus, a traverse along the rail line could be interpreted as Böse did in 1906 (his second, third, and fourth horizons) or as Heim did in 1940 (Table 1). The difference in the two is that Böse realized that the yellow, red, and white sandstones were above the Cárdenas Formation, but Heim believed them to be in the middle of the Cárdenas Formation.

The third reason for confusion is that the railroad line is a particularly poor place geologically for determining the sequence at Cárdenas. Aside from the discontinuous exposures, the western side of the syncline along the rail line is structurally disturbed by the large anticline between La Labor and Cañada de Pastores, (Fig. 2), which brings a large mass of Tamazopo Limestone to the surface. Then, in the axial portion of the syncline, the small anticline at Bomba (Plate 1, section B-B') brings the upper member of the Cárdenas Formation to the surface again. These major structural complications are in addition to minor folding within the Cárdenas Formation between the first outcrops east of the alluvium at Cárdenas and the center of the syncline near Bomba (Plate 1, section B-B') and again between Km 419 and 420.4 on the eastern flank of the syncline.

Las capas que contienen las faunas descritas en este trabajo forman un conjunto al cual damos por su facies tan diferente de otros depósitos del cretáceo americano el nombre local de división Cárdenas.

Böse, 1906a, p. 15

LITHOLOGIC UNITS

Böse (1906a) called the beds between Cárdenas and Canoas (Fig. 1) the *división Cárdenas*. He recognized four horizons in the Cárdenas Division (Table 1): *Gryphaea vesicularis* Horizon, second horizon (*Tamazopo* Limestone), *Orbitoides* Horizon, and *Coralliochama G. Boehmi* Horizon. Böse wrote that these four horizons were overlain by yellow, red, and white sandstone in which he found no fossils. Subsequent to Böse's 1906 monograph the name "Cárdenas beds" has usually been applied to emended versions of the Cárdenas Division (Burckhardt, 1930, p. 233; Heim, 1940), although Imlay (1944a, p. 1136; 1944b, p. 1025) used the term "Cárdenas formation".

Certainly Böse (1906a) established the distinctiveness of the Cárdenas facies in the Upper Cretaceous of the central Sierra Madre Oriental. He did not determine the boundaries of the Cárdenas Division in 1906, nor was he thinking in 1906 or in 1927 in terms of formational units, lithologic units, as they are understood today in North America. Böse's (1906a) units, the Cárdenas Division and its four horizons, were primarily paleontologically defined units with specified lithologies. His 1927 (Böse and Cavins) units were combined paleontologic-chronologic-lithologic units. Other workers who examined the Cárdenas section described it in terms of fossil units with specified lithologies (Burckhardt, 1930) or in terms of rock units with contained fossils listed (Heim, 1940; Müllerried 1941; Wade, *in* Imlay, 1944a).

Of course the initial studies in any area should use all possible means of recognizing stratigraphic units in order to determine the sequence of beds and decipher the structural configuration. However, continued use of combined lithologic and paleontologic units places an artificial limit on the detail of geologic history that can be determined. The use of combined units obscures the diachroneity of isopic lithologic units. As Shaw (1964, p. 58) has so cogently illustrated, failure to distinguish paleontologic units from rock units can produce a completely inverted picture of the geologic history of an area, transgression being mistaken for regression. Moreover, the use of combined units increases the probability of facies correlation when biostratigraphic correlation is sought. Although the fauna of a biocénose is acted upon by the same physical environment as the sediments being deposited, it is also affected by ecologic and temporal factors that need not be evident in the resultant rock.

The incongruity of the two units may be illustrated by reference to the Cárdenas section: On the west side of the syncline *Exogyra costata* occurs at the base of the middle shale member of the Cárdenas Formation. I believe this coincidence to be evidence of ecologic control of *Exogyra costata*, which found conditions favorable in the mud but not in the preceding high-energy environment. I believe also that the lowest occurrence of *Exogyra costata* at Cárdenas is not directly related to the lower limit of its range. *Exogyra costata* occurs at several levels in the middle shale member, and occurs also above the shale in siltstone, limestone, and sandstone of the lower part of the upper member. There is no obvious ecologic cut-off in the highest occurrence of *Exogyra costata*; there are lithologically similar beds higher in the section. Thus, the *Exogyra costata* zone at Cárdenas cannot be meaningfully defined in lithologic terms (for it extends through all the major types of rocks present) nor can the middle shale member or any other lithologic unit be defined in terms of the occurrence of *Exogyra costata*.

Because of the scarcity of distinctive rock types, the units defined by previous workers at Cárdenas have been identifiable only by fossil content, and there has been substantial disagreement about the order of these units. For these reasons I sought first to recognize lithologic units within the Cárdenas Formation. Only after they had been established and the area mapped did I attempt to zone the section biostratigraphically.

CÁRDENAS FORMATION

The Cárdenas Formation is a thick unit predominantly of finely clastic sedimentary rocks (see measured sections in Appendix) that crops out between Cárdenas, San Luis Potosí (Km 413.8) and Km 420.4 along the Aguascalientes — Tampico rail line (Plate 1). It overlies with fault contact the thick to medium-bedded biosparite that extends east of Km 420.4 to Tamazopo (Fig. 1) and that has consistently been called Tamazopo Limestone. Unconformably overlying the Cárdenas Formation is the Tabaco Formation, which consists of red and tan siltstone, shale, sandstone, and conglomerate, and is exposed along the rail line between Km 415.5 to 416.1 and Km 416.7 to 417.7. In the vicinity of Cárdenas, the Cárdenas Formation is 1050 meters thick. I have traced it 8 km north of Cárdenas to Alaquines (Fig. 1) and 15 km south of Cárdenas to the San Luis Potosí — Cd. Valles highway. It has been reported 115 km north of Cárdenas at Tula, Tamaulipas (Fig. 1) by Heim (1940, p. 332) and 15 km east of Cárdenas at Canoas by Böse (1906a, p. 15). Beds believed to belong to the Cárdenas Formation have been described 130 km west of Cárdenas by Cserna and Bello (1963).

The Cárdenas Formation at Cárdenas consists of three lithologic units, the lower member, the middle shale member, and the upper member (Fig. 3). Additional work will show whether or not these units can be recognized elsewhere in the Cárdenas Formation. For the present these informal terms are a convenient means of referring to the rock units of the Cárdenas Formation.

Lower member.—The lowest exposed part of the lower member can be seen along the rail line at Km 420.4 (Plate 1, line B-B'). However, the thickest

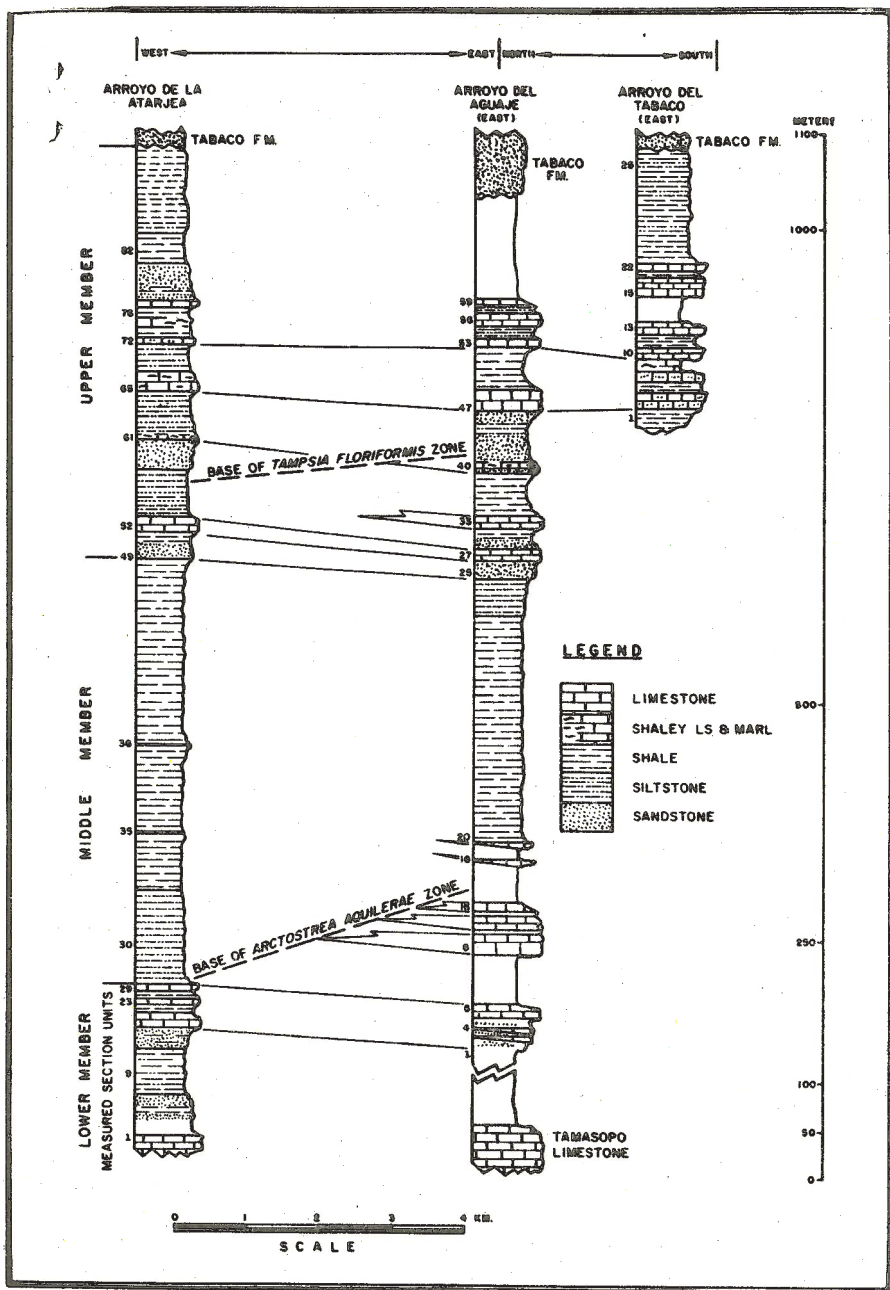


Figure 3. Stratigraphic section of the Cárdenas Formation

exposed section of this member (182 m) is in the Arroyo de la Atarjea, 2.7 km north of Cárdenas. It is also well exposed almost due north of Cárdenas just below the road in the Arroyo del Aguaje and in the Arroyo del Tabaco. In the eastern part of the Arroyo del Aguaje (Plate 1, traverse) only a few resistant beds in the lower member are exposed; most of the member is concealed by soil.

At Km 420.4 (Plate 1) a dusky-yellow blocky weathering shale overlies the Tamazopo Limestone. The contact is faulted and there is a thin breccia at the contact. Heim (1940) stated that this breccia was a basal conglomerate of the dusky-yellow shale, which he called Mendez Shale. The shale at Km 420.4 may be the western extension of the Mendez Shale of the Tampico region, but it is an integral part of the Cárdenas Formation at Cárdenas. The same type of shale occurs higher in the section in the lower member, but thin beds of siltstone, sandstone, and biosparudite become numerous.

In the lower (western) part of the Arroyo de la Atarjea, north of Cárdenas (Plate 1) a structurally uncomplicated partial section of the lower member is exposed (Appendix, Atarjea units 1-29). The lowest exposures above the alluvium are of biosparudite (Atarjea unit 1), overlain by 117 meters of shale, siltstone, and fine-grained sandstone (Atarjea units 2-14). Interbedded biosparudite and olive-gray shale make up the upper 42 meters of the lower member (Atarjea units 15-29).

In the Arroyo del Aguaje only a small part of the lower member is exposed. The exposed strata (Aguaje units 1-6) are biosparite, intrasparite, and sandstone, which I have correlated (Fig. 3) with the upper part of the lower member in the Arroyo de la Atarjea (Atarjea units 15-29). The biosparites are quite similar in both sections, especially beds of distinctive orange limestone that are biosparudite in the Arroyo de la Atarjea (Atarjea units 23 and 27) and biosparite and intrasparite in the Arroyo del Aguaje (Aguaje unit 4).

Middle shale member.—The middle shale member of the Cárdenas Formation is best exposed in the Arroyo de la Atarjea (Plate 1). It is also exposed along the rail line between Km 414.3 and Km 415.0, in the eastern and western segments of the Arroyo del Aguaje, and in the western part of the Arroyo del Tabaco.

This member consists predominantly of fine-grained olive-gray clastic sedimentary rocks. In the Arroyo de la Atarjea it consists of 443 meters of shale, shale interbedded with thin siltstone beds, and siltstone (Appendix, Atarjea units 30-48). Only two thin beds of biosparudite (Atarjea units 35 and 38) in the middle of this member disrupt its lithic homogeneity in the Arroyo de la Atarjea. Several of the thin siltstone beds have well developed mud cracks, and a U-shaped burrow was observed that extended from a siltstone bed into the underlying shale. A few of the siltstone beds are almost coquina, comprised as much of orbitoids as of silt (Atarjea units 30 and 31).

The upper 277 meters of the middle member in the Arroyo del Aguaje is shale, siltstone, and very fine grained sandstone (Aguaje units 21-24). However, the lower 173 meters (Aguaje units 7-20) contains several beds of biosparite that do not occur in the lower member further west. I believe the

orbitoid biosparite beds (Aguaje units 8, 10, 11, 16) to be a more calcareous facies of the silty orbitoid beds in the lower part of the middle member in the Arroyo de la Atarjea (Atarjea units 30 and 31).

Upper member.—The upper member of the Cárdenas Formation is best exposed in the Arroyo de la Atarjea. It is also exposed in the eastern segments of the Arroyo del Aguaje and the Arroyo del Tabaco and along the rail line between Km 415.0 to Km 415.5, Km 416.1 to Km 416.7 and Km 417.7 to Km 418.6.

The upper member is a varied succession of shale, mudstone, siltstone, marl (Pettijohn, 1957, p. 369), and biosparudite. Its lowest bed in the Arroyo de la Atarjea is fine calcareous sandstone with a thin pebble-conglomerate at its base (Appendix, Atarjea unit 49). Above the fine sandstone and a shale unit is a thick biosparudite (Atarjea unit 52). Then, 129 meters of sandstone and siltstone (Atarjea units 53-64) intervene between the biosparudite and the next prominent limestone. The sandstone is fine grained; some beds are ripple marked. Overlying this clastic sequence is 94 meters of biosparudite, marl, silty marl, and siltstone (Atarjea units 65-78). The upper 164 meters of the upper member consists of sandstone, shale, and siltstone with some ripple marked beds.

In the Arroyo del Aguaje the base of the upper member is the same fine sandstone as in the Arroyo de la Atarjea (Aguaje unit 25, Atarjea units 49 and 50), but here it does not have a basal pebble-conglomerate. Overlying the fine sandstone is a sandy intrasparite (Aguaje unit 27) of slightly finer texture than its equivalent (Fig. 3) in the Arroyo de la Atarjea (Atarjea unit 52). Overlying the limestone is only 12 meters of sandstone and shale (Aguaje units 29 and 30), succeeded by 9 meters of biomicrudite (Aguaje units 31 and 33); this biomicrudite is not present further west (Fig. 3). Above the biomicrudite is 41 meters of shale with a few sandstone beds (Aguaje units 34-37). The overlying 67 meters (Aguaje units 38-46) is sandstone with thin fossiliferous limestone interbeds (Aguaje units 40-41); these thin beds of limestone are probably the eastern equivalent of a thin limestone and marl in the Arroyo de la Atarjea (Atarjea unit 61).

Above these strata are beds of limestone interbedded with shale (Aguaje units 47-50) that are generally more indurated than their equivalents in the Arroyo de la Atarjea (Atarjea units 65-68). The next unit is shale (Aguaje unit 52), which is overlain by sandy intrasparite (Aguaje unit 53). Above this intrasparite are shale and fine-grained sandstone (Aguaje units 54-55); these are overlain by fossiliferous biomicrudite, shale, and calcarenite (Aguaje units 56-59), which are better indurated than their western equivalents (Atarjea units 72-78). The highest parts of the upper member of the Cárdenas Formation are covered by soil in the Arroyo del Aguaje.

In the western part of the Arroyo del Tabaco (Plate 1) only 255 meters of the upper member of the Cárdenas Formation is exposed (Appendix). Overlying the lowest exposed unit, a shale (Tabaco unit 1), are beds of sandy sparite, shale, and biomicrudite (Tabaco units 2-9) that I have correlated (Fig. 3) with calcarenite and biosparite interbedded with shale (Aguaje units

47-50) in the Arroyo del Aguaje. The overlying beds (Tabaco units 10-13) are fossiliferous marl and biosparudite with a shale unit between them. These are correlated with Aguaje units 53-59 and Atarjea units 72-78 (Fig. 3). After a covered interval there are thin beds of shale, biomicrudite, and coquina (Tabaco units 15-22) that are not exposed in the Arroyo del Aguaje and that do not occur to the west in the Arroyo de la Atarjea. The upper 110 meters of the upper member is shale with thin beds of limestone (Tabaco units 23-25). In the Arroyo del Tabaco the upper member of the Cárdenas Formation is overlain with slight angular discordance by the Tabaco Formation (light reddish brown siltstone and shale, with light brown sandstone).

TABACO FORMATION

Unconformably overlying the Cárdenas Formation are beds of reddish brown siltstone. Although these red beds cover a large area in the center of the syncline, they are well exposed only in the Arroyo del Tabaco (Plate 1). Therefore, they are provisionally called the Tabaco Formation in this paper solely as a convenient means of reference.

The Tabaco Formation is exposed along the rail line between Km 415.5 to Km 416.1 and on the north and east of the anticline at Bomba (Plate 1). It is the youngest unit folded in the Cárdenas syncline.

In the Arroyo del Tabaco the Tabaco Formation consists of mudstone, siltstone sandy siltstone, sandstone, and conglomerate. Many of the sandy beds are cross bedded. The conglomerate contains pebbles and cobbles of Cárdenas Formation rocks (biosparites of the lower member) as well as limestone and chert pebbles of types that do not crop out near Cárdenas.

The prevailing color of these beds is moderate reddish brown, although there are a few gray-orange and dusky-yellow beds near the base. I found no fossils of any kind in the Tabaco Formation.

BIOSTRATIGRAPHY

The Cárdenas Formation contains a large quantity and variety of invertebrate fossils. Although many of these are well preserved and easily collected from the enclosing rock, others, especially the gastropods, are poorly preserved, fragile molds. Of the seventy-one species that I have collected from Cárdenas, 44 are bivalve mollusks, 14 gastropods, 6 corals, 4 echinoids, 2 serpulids, and 1 brachiopod.

Previous zonations of the Cárdenas Formation have placed the *Exogyra costata* Zone at the top of the section, above the *Coralliochama gboehmi** Zone (Böse and Cavins, 1927; Burckhardt, 1930; see Table 1). Perhaps the most

*Böse (1906a) named the species *Coralliochama G. Boehmi*, and in the preceding discussion of his stratigraphic units and their contained taxa I have used his spelling (for example, the *Coralliochama G. Boehmi* Horizon). However, in accordance with Article 32 (c) (i) of the International Code of Zoological Nomenclature (Stoll, 1961) this binomen should now be written *Coralliochama gboehmi*.

Table 1
PREVIOUS VERSIONS OF THE STRATIGRAPHY OF THE CARDENAS FORMATION

	Böse, 1906a	Böse and Cavins, 1927	Burckhardt, 1930	Heim, 1940	Müllerrid, 1941
CARDENAS DIVISION	Sandstone, yellow. red, and white; with marl intercalations.		UPPER SENONIAN	UPPER CARDENAS BEDS	
			<i>Exogyra costata</i> ,	13. Yellow limestone. with marl.	Sandy marl, soft sandstone, part
		CAMPANIAN	<i>Gryphaea vesicularis</i> ,	12. Green marl.	Reddish, small clams and snails
	CORALLIOCHAMA G. BOEHMI HORIZON	Sandstone, shale, and sandy limestone.	<i>Ostrea aguilerae</i> ,	11. Sandstone and sandy-marly limestone.	at base.
	Marl, gray yellow, with limestone banks.		<i>Inoceramus</i> cfr. <i>simpsoni</i> .	<i>Gryphaea vesicularis</i> , <i>Exogyra costata</i> .	Sandy marl, sandstone, limestone, gray.
	ORBITOIDES HORIZON	<i>Exogyra costata</i> ,		10. Limestone and marl.	<i>Coralliochama</i> ,
	Shale, yellow, with intercalated yellow sandstone.	<i>Gryphaea vesicularis</i> .		9A. Red clay.	<i>Biradiolites</i> ,
	Shale, yellow.			9B. Red and green clay shale.	<i>Actaeonella</i> .
	SECOND HORIZON	SANTONIAN	CORALLIOCHAMA BEDS	LOWER CARDENAS BEDS	
	Limestone, thick bedded.	Shale, sandstone, and limestone.	<i>Coralliochama</i> beds	8. Marl and sandstone, <i>Coralliochama</i> , <i>Exogyra costata</i> .	Sandy marl alternating with sandstone and limestone.
	GRYPHAEA VESICULARIS HORIZON	<i>Coralliochama</i> ,	<i>Orbitoides</i> beds	7. Sandstone, hard gray, calcareous. <i>Turritella</i> .	<i>Lithothamnion</i> , corals.
	Shale, marly and sandy.	<i>Actaeonella</i> .	Mendez Shale	6. Marl and nodular limestone. <i>Gryphaea</i> , oysters.	Sandy marl alternating with sandstone, and limestone.
	Limestone, thick bands, marly in part.			5. Gray shale with limestone.	<i>Exogyra</i> , <i>orbitoids</i> , <i>echinoids</i> .
	Sandstone, calcareous, alternating with marl and shale.		Tamazopo Limestone.	4. Marl and nodular limestone, oysters.	corals, <i>Sphenodiscus pleurisepta</i> .
				3. Gray shale, orbitoid limestone.	Sandy marl and sandstone.
				Méndez Marls	Mendez marl.
				2. Gray sandy shale.	
				1. Conglomerate.	Tamazopo limestone.
				Tamazopo limestone.	

significant biostratigraphic result of the present study has been to show that *Coralliochama gboehmi* extends through almost the entire formation and that *Exogyra costata* is restricted to the middle part of the formation at Cárdenas (Plate 2). I have recognized three zones in the Cárdenas Formation; the *Durania ojanchalensis* Zone below, the *Arctostrea aguilerae* Zone coincident with the local range of *Exogyra costata*, and the *Tampsia floriformis* Zone above the local range of *Exogyra costata* (Plate 2). The species listed for each of these zones are described in the paleontological part of this paper.

Durania ojanchalensis Zone

The following thirteen species of bivalves are restricted to this, the lowest biostratigraphic unit in the Cárdenas Formation:

Arca mcnairyensis rebecca Myers
Arca securiculata armeriai Myers
Cardium (*Granocardium*) *tabacoensis* Myers
Cardium sp. cf. *C. whitfieldi* Weller
Corbula crassiplica Gabb
Cymella bella mexicana Myers
Durania ojanchalensis Myers
Inoperna sp.
? *Linearia belli* Myers
Ostrea tecticosta Gabb
Pholadomya sp.
? *Tellina* sp.
Veniella conradi (Morton)

Three species of gastropods, two echinoids, and two serpulids are also restricted to this zone:

Architectonica sp.
Cerithium potosianum Böse
Turritella guionae Myers
? *Phyllobrissus* sp.
Hardouinia potosiensis Lambert
Hamulus angulatus Wade
Hamulus onyx Morton

In addition, *Coralliochama gboehmi* Böse, *Neithea youngi* Myers, *Actaeonella coniformis* Böse, and ? *Kingena* sp. occur in this zone but are not restricted to it.

The *Durania ojanchalensis* Zone contains eight species in common with the Atlantic and Gulf Coastal Plain of the United States: *Arca mcnairyensis*, *Arca securiculata*, *Corbula crassiplica*, *Cymella bella*, *Ostrea tecticosta*, *Veniella conradi*, *Hamulus angulatus*, and *Hamulus onyx*. These have been recorded from the *Exogyra ponderosa* and *Exogyra costata* Zones by Wade (1926) and Stephenson (1941).

The species that are abundant or common in this zone are: *Coralliochama gboehmi*, *Durania ojanchalensis*, ?*Linearia belli*, *Actaeonella coniformis*, *Turritella guionae*, and *Hardouinia potosiensis*.

Arctostrea aguilerae Zone

The middle zone of the Cárdenas Formation is less fossiliferous, but several of the taxa present are well known and distinctive. Restricted to this zone are:

Arctostrea aguilerae (Böse)
Exogyra costata Say
Flemingostrea sp.
Lima cardenasensis Böse
Mytilus smocki Weller
Paranomia guttiiformis Myers
Pycnodonte mutabilis (Morton)
Turritella trilira Conrad
Hemiaster sp.
Phymosoma sp.

Also found within this zone but not restricted to it are:

Biradiolites aguilerae Böse
Coralliochama gboehmi Böse
Lima azteca Böse
Neitheia youngi Myers
Septifer aguajensis Myers
Actaeonella coniformis Böse
? *Kingena* sp.
Cladocora sp.
? *Lithostrontionoides* sp.
Trochoseris sp.

Of these species, *Arctostrea aguilerae*, *Exogyra costata* and *Mytilus smocki* have been reported only from the *Exogyra costata* Zone of the Gulf Coastal Plain, but *Pycnodonte mutabilis* and *Turritella trilira* from both the *Exogyra ponderosa* and *Exogyra costata* Zone (Stephenson, 1941; Richards, 1958; Sohl, 1960; Sohl and Kauffman, 1964).

Only the ostreids *Arctostrea aguilerae*, *Exogyra costata*, and *Pycnodonte mutabilis* are abundant or common in this zone.

Tampsia floriformis Zone

This, the highest zone in the Cárdenas Formation, has by far the richest fauna. It contains 23 species of bivalves, 10 gastropods, and 6 corals. Only 8 of these species extend into this zone from below:

Biradiolites aguilerae Böse
Coralliochama gboehmi Böse

Lima azteca Böse
Septifer aguajensis Myers
Actaeonella coniformis Böse
Cladocora sp.
 ?*Lithostrontionoides* sp.
Trochoseris sp.

The others, which are restricted to the *Tampsia floriformis* Zone, are:

Anomia csernai Myers
 ?*Aphrodina* sp.
Barbatia sculpta Myers
Biradiolites cardenasensis Böse
Cardium (*Pachycardium*) *cardenasensis* Myers
Cardium (*Trachycardium*) *gordum* Myers
Cardium sp. cf. *C. uniformis* Weller
Cyprina mondragoni Myers
Hippurites muellerriedi (Vermunt)
Hippurites perkinsi Myers
 ?*Kelliella* sp.
Lopha maccoyi Myers
Ostrea semiarmata Böse
Pholadomya coahuilensis Imlay
 ?*Priscomactra* sp. cf. *cymba* Stephenson
Pseudoptera stephensoni Myers
Tampsia floriformis Myers
Tampsia poculiformis Myers
Trigonia eufalensis Gabb
 ?*Achitectonica roddai* Myers
Cerithium subcarnaticum Böse
Cerithium sp. aff. *C. simonyi* Zekeli
Longoconcha sp.
Nerinea burckhardti Böse
Pseudamaura altilirata (Böse)
Turritella potosiana Böse
Turritella waitzi Böse
 ?*Turritella* sp.
 ?*Epistreptophyllum* sp.
Leptoria sp.
Synastrea sp.

Only three of these species have been reported elsewhere: *Hippurites muellerriedi* from the Maastrichtian of Cuba and Jamaica (Vermunt, 1937); *Pholadomya coahuilensis* from the *Exogyra ponderosa* Zone in Coahuila, México (Imlay, 1937); and *Trigonia eufalensis* from the *Exogyra ponderosa* and *Exogyra costata* Zones of the Atlantic and Gulf Coastal Plains (Wade, 1926).

Abundant in this zone are *Biradiolites aguilerae*, *Biradiolites cardenasensis*, *Coralliochama gboehmi*, *Lima azteca*, *Tampsia floriformis*, *Actaeonella con-*

formis, and *Turritella potosina*. The species that are common in the *Tampsia floriformis* Zone are: *Anomia cernai*, *Barbatia sculpta*, *Hippurites muelleriedi*, *Tampsia poculiformis*, *?Architectonica roddai*, and *Pseudamaura altirata*.

These zones are distinctive at Cárdenas and may be characterized intrinsically as well as in relation to each other. The *Durania ojanchalensis* Zone has almost half (47 percent) of its specifically identified taxa in common with species reported from the Gulf Coastal Plain of the United States; it is intermediate in species diversity relative to the *Arctostrea aguilerae* and *Tampsia floriformis* Zones. The *Arctostrea aguilerae* Zone is predominantly ostreid; it has the lowest species diversity of the three zones, but 45 percent of its species in common with the Gulf Coastal Plain. The *Tampsia floriformis* Zone contains primarily taxa endemic to Cárdenas (85 percent); it has by far the largest and most varied fauna in the Cárdenas Formation.

These zones are not coincident with the members of the Cárdenas Formation, nor are the boundaries of the members and zones parallel (Fig. 3). The base of the *Arctostrea aguilerae* Zone is at the base of the middle member in the Arroyo de la Atarjea (Atarjea unit 30) but 130 meters above the base of the middle member in the Arroyo del Aguaje (Aguaje unit 18). The base of the *Tampsia floriformis* Zone is unit 58 in the Arroyo de la Atarjea, 80 meters above the base of the upper member. In the Arroyo del Aguaje it is 125 meters above the base of the upper member in Aguaje unit 42.

INTERPRETACION OF THE CARDENAS FORMATION

In the preceding stratigraphic discussions I have reported my observations of the Cárdenas Formation and its contained fossils. To pass from description to interpretation requires reliance on empirical generalizations, and because they are generalizations they are fallible. Interpretations based on them are in turn fallible, so the speculations that follow should be read with this in mind.

Depositional History

The basis for the following interpretations is not only the sequence of lithologic units at Cárdenas, but also the geologic setting in which depositions occurred. According to de Cserna's (1960) tectonic history of Mexico, the Mexican geosyncline began to be destroyed in late Cenomanian time with the emplacement of batholiths in western Mexico and the deposition of a pre-orogenic clastic wedge over eastern Mexico. Considered in this framework, then the Cárdenas Formation as a whole may be thought of as a "regressive" type of deposit, but there is evidence for many minor oscillations and one major stillstand. The underlying Tamazopo Limestone is autochthonous, a sparite and orbitoid biosparite with some rudists. The Tamazopo Limestone was deposited in water with enough current energy to winnow lime mud, but far enough off shore to be beyond the depositional area of terrigenous clastics.

Deposition of the Cárdenas Formation was initiated by the arrival of mud, probably the result of regression of the sea, which resulted in the deposition of at least 100 meters of shale on top of the Tamazopo Limestone. This regression

placed the Cárdenas region in a pivotal position relative to areas of autochthonous and of allochthonous deposition. In this region the deposition of fine terrigenous material in shallow water alternated with the accumulation of limestone in a high-energy environment throughout the rest of the Cretaceous.

During deposition of the initial shale unit conditions were inimical to marine life, probably because of a soft substrate, of turbidity of the water, or of its freshening implied by the influx of terrigenous sediments. But whatever inhibited marine animals from living in the Cárdenas area did not prevail for long. Orbitoids, echinoids, gastropods, and some bivalves inhabited the area during deposition of the upper part of the shale and into the overlying siltstone, shale, and limestone. During the accumulation of the lower member terrigenous supply, current energy, and faunal diversity varied greatly. Biosparudite originated from a fauna of bivalves and gastropods. Then clastic sedimentation obtained and almost no marine animals continued to live in the area. The return to carbonate deposition at the top of the lower member brought with it a varied fauna of rudists, other bivalves, gastropods, echinoids, and bryozoans.

During deposition of the middle member the environment became stable; there was a steady supply of fine clastics. Four hundred and fifty meters of mud and silt accumulated in shallow water. At times the area was above sea level, for mud cracks formed on some of the silt layers. Oyster beds formed several times, but few other marine animals lived on this mud flat.

Compared with the middle member, the rocks of the upper member indicate higher energy conditions and a more sporadic supply of clastics. Biosparudite and sand predominate in the lower 60 meters. A large and diverse fauna flourished, particularly during the times of carbonate accumulation. Rudists, other bivalves, gastropods, corals, bryozoans, and echinoids are more abundant than they are in any other part of the Cárdenas Formation. The upper 150 meters of the formation accumulated under conditions of fairly steady supply of sand and silt. The diverse fauna of the underlying beds became more restricted until only a few gastropods lived during the accumulation of the uppermost beds.

Correlation

Correlation of at least part of the Cárdenas Formation has been evident since the fauna was first described by Böse in 1906. He described and figured *Exogyra costata* from Cárdenas, and *Exogyra costata* has become a zonal guide for the uppermost Cretaceous beds of the Gulf Coastal Plain. However, the different versions of the position of *Exogyra costata* in the Cárdenas Formation left moot whether most of the formation was above the *Exogyra costata* Zone, below it, or included in it.

The *Arctostrea aguilerae* Zone at Cárdenas is coincident with the local range of *Exogyra costata*. Certainly the *Arctostrea aguilerae* Zone is correlative with part of the *E. costata* Zone of the Gulf Coastal Plain, but I do not believe that there is sufficient evidence to state that the two zones are identical. The lowest occurrence of *Exogyra costata* and *Arctostrea aguilerae* is at the base of the middle shale member of the Cárdenas Formations; the underlying beds are

biosparudite. This sharp lithologic change followed by the first appearance of the oysters suggest that ecologic control may have determined their first occurrence rather than evolutionary development or rate of dispersal. Furthermore, specimens of even the lowest *Exogyra costata* in the Cárdenas Formation have more than 19 costae; this, according to Lerman (1965), indicates a level above the lower part of the *E. costata* Zone. Therefore, I believe that the *Arctostrea aguilerae* Zone at Cárdenas is correlative with the higher parts of the *E. costata* Zone of the Gulf Coastal Plain.

The *Durania ojanchalensis* Zone has almost half of its species in common with the Gulf Coastal Plain. Although these species range through the zone of *Exogyra ponderosa* and *Exogyra costata*, some are more common in the latter zone. Because of this and the correlation of the overlying beds with the upper *E. costata* Zone, I believe that the *Durania ojanchalensis* Zone is correlative with the lower part of the *Exogyra costata* Zone and perhaps the uppermost part of the *E. ponderosa* Zone.

The highest occurrences of *Exogyra costata* and *Arctostrea aguilerae* are in sandstone and siltstone units (in different parts of the Cárdenas Syncline) in the lower part of the upper member of the Cárdenas Formation. Similar lithic units are present above the last occurrence of the two taxa; there is no obvious ecologic cutoff. For this reason I believe that the last occurrence of these oysters may well be directly related to the upper limit of their ranges. Therefore, the *Tampsia floriformis* Zone, above the *Arctostrea aguilerae* Zone at Cárdenas, may also be above the *Exogyra costata* Zone of the Gulf Coastal Plain. The few species of this zone that have been identified elsewhere are compatible with this conclusion, but they do not confirm it.

The large number of endemic species in the *Tampsia floriformis* Zone, however, seems more explicable if this zone is indeed above the *Exogyra costata* Zone. Uppermost Cretaceous beds are absent on the outcrop in the Gulf Coastal Plain of the United States, but they have been reported in the Difunta Formation of the Parras Basin (Murray and others, 1960) and in the Méndez shale of the Tampico embayment (Hay, 1960). The Difunta Formation is a more terrigenous, allochthonous sequence and the Méndez Shale a much deeper water deposit than the Cárdenas Formation. Neither of these formations contains carbonate beds like those of the *Tampsia floriformis* Zone of the Cárdenas Formation, in which most of the fossils of this zone occur. The *Tampsia floriformis* Zone, in my opinion, is correlative with these highest Cretaceous beds.

The overlying unfossiliferous Tabaco Formation is probably latest Cretaceous or perhaps early Paleocene (pre-folding).

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APPENDIX

Measured Sections of the Cárdenas Formation

A. ARROYO DE LA ATARJEA,

Western side of the Cárdenas syncline

Unit	Meters
Tabaco Formation	
Sandstone, light reddish brown, very fine to fine grained, (Wentworth, 1922) medium bedded, (Ingram, 1954); and siltstone.	
Unconformity	
Upper member of the Cárdenas Formation (430.2 m measured)	
87. Shale and siltstone, yellow gray. <i>Actaeonella coniformis</i> .	40.0
86. Sandstone, light olive gray, fine grained, well sorted, well rounded, sugary texture; black, clear, green, and red grains.	0.6
85. Shale and siltstone, yellow gray.	20.0
84. Shale, yellow gray, silty.	32.2
83. Shale, yellow gray.	10.3
82. Shale, light olive gray. <i>Hippurites muellerriedi</i> , <i>Longoconcha</i> sp., <i>Cladocora</i> sp., <i>Synastrea</i> sp., oyster fragments.	21.8
81. Sandstone, gray orange, fine grained, medium bedded, friable, shale partings.	23.6
80. Shale, olive gray.	7.6
79. Sandstone, olive gray, fine grained, ripple marked. <i>Synastrea</i> sp., oyster fragments.	8.5
78. Sandy intrasparite, moderate yellow brown, coarse white clasts, medium green sand.	1.8
77. Covered.	15.2
76. Silty marl, dusky yellow. <i>Coralliochama gboehmi</i> , <i>Biradiolites aguilerae</i> , <i>Pholadomya coahuilensis</i> , ? <i>Aphrodina</i> sp., <i>Lima azteca</i> , ? <i>Architectonica roddai</i> , ? <i>Ephistreptophyllum</i> sp., <i>Trochoseris</i> sp., bryozoans.	12.4
75. Shale and mudstone, olive gray.	8.2
74. Coquinooid marl. <i>Coralliochama gboehmi</i> , <i>Tampsia floriformis</i> , bryozoans.	0.6
73. Sandstone, dusky yellow, fine grained, thin bedded, silty, friable, soft.	5.2
72. Silty marl. <i>Pseudamaura atilirata</i> , <i>Trochoseris</i> sp.	1.8
71. Siltstone, olive gray.	6.4
70. Sandstone, olive gray, fine grained, thick bedded, hard, ripple marked.	0.9

Unit	Meters
69. Shale and siltstone, olive gray.	20.9
68. Biosparite and marl. <i>Coralliochama gboehmi</i> , <i>Tampsia floriformis</i> , <i>Septifer aguajensis</i> , <i>Hippurites perkinsi</i> .	10.0
67. Shale, olive gray.	1.5
66. Shale and siltstone, olive gray.	1.8
65. Marl. <i>Coralliochama gboehmi</i> , <i>Tampsia floriformis</i> , <i>Tampsia poculiformis</i> , <i>Actaeonella coniformis</i> , <i>Cladocora</i> sp.	7.6
64. Sandstone, light olive gray, fine grained, thin bedded; and silty marl. <i>Coralliochama gboehmi</i> , <i>Tampsia floriformis</i> , <i>Biradiolites aguilerae</i> , ? <i>Priscomactra</i> sp. cf. <i>P. cymba</i> , ? <i>Aphrodina</i> sp., <i>Lopha maccoyi</i> , <i>Pseudoptera stephensoni</i> , <i>Pholadomya</i> sp., <i>Pseudamaura altirata</i> , <i>Turritella potosiana</i> , <i>Cerithium</i> aff. <i>C. simonyi</i> , <i>Synastrea</i> sp.	23.7
63. Sandstone, olive gray, fine grained, thick bedded, ripple marked, calcareous, hard; black, clear, and yellow grains in spar.	5.8
62. Mudstone and siltstone, olive gray. <i>Coralliochama gboehmi</i> , <i>Anomia csernai</i> , <i>Barbatia sculpta</i> , <i>Actaeonella coniformis</i> .	18.5
61. Limestone and marl.	2.7
60. Calcarenite, light olive gray, fine to very fine grained; band of snails 0.6 m below top.	3.0
59. Sandstone, olive gray, very fine grained.	27.0
58. Sandstone, light olive gray to dark greenish gray, fine grained, well sorted, thick bedded, and siltstone, olive gray.	12.1
57. Calcarenite, light olive gray, fine grained, medium bedded <i>Exogyra costata</i> , <i>Turritella trilira</i> , ? <i>Linthia</i> sp., <i>Rachiosoma</i> sp.	1.8
56. Mudstone, light olive gray, blocky.	8.8
55. Sandstone, dusky yellow, fine grained, massive, yellow and black speckled.	3.3
54. Shale and siltstone, partly covered, with a foraminifer biosparite, pale yellow brown, white foraminifer hematite stained and white laths in clear spar.	12.1
53. Covered, probably shale.	10.3
52. Biosparudite, pale yellow brown, thin bedded, foraminifers and shell fragments in clayey spar; and biosparite, orbitoids in speckled sandy matrix. <i>Coralliochama gboehmi</i> , <i>Biradiolites aguilerae</i> , <i>Lima cardenasensis</i> , <i>Lima azteca</i> , <i>Tellina</i> sp., bryozoans.	14.9
51. Covered, probably shale.	9.1
50. Sandstone, olive gray, fine grained, medium bedded, black, pink, and clear grains.	9.1
49. Sandstone, olive gray, very fine grained, massive; and sandy intrasparite, moderate yellow brown, black, clear,	

Unit	Meters
and white grains in orange clay matrix; pebble conglomerate at base.	9.1
Middle member of the Cárdenas Formation (443.3 m)	
48. Shale, olive gray.	10.9
47. Siltstone, olive gray, 2 to 4 cm beds.	1.2
46. Shale, olive gray. <i>Anomia</i> sp., bryozoans, burrows.	76.0
45. Siltstone, light olive gray, thin beds, hard; bivalve fragments.	8.2
44. Shale, olive gray.	49.0
43. Sandstone, brownish orange, shell fragments.	1.8
42. Shale, olive gray.	10.3
41. Shale, olive gray, with siltstone beds 1 cm thick.	11.2
40. Siltstone, olive gray, marly medium bedded to massive, oyster fragments.	5.8
39. Shale, olive gray.	20.6
38. Biosparudite, pale yellow brown, fine sandy matrix, speckled green, black, and brown, crinoid columnals.	1.8
37. Shale, olive gray blocky. <i>Exogyra costata</i> .	78.0
36. Shale and thin siltstone beds, olive gray. <i>Lima cardenasensis</i> , <i>Lima azteca</i> , oyster fragments. <i>Paranomina guttiformis</i> .	17.6
35. Limestone, and shale. <i>Exogyra costata</i> , <i>Lima cardenasensis</i> , <i>Trochoseris</i> sp., <i>Paranomina guttiformis</i> .	2.1
34. Siltstone, olive gray, marly. <i>Arctostrea</i> .	4.6
33. Shale, olive gray.	10.0
32. Shale, olive gray, alternating with thin siltstone beds.	21.8
31. Shale, olive gray. Orbitoids.	13.6
30. Siltstone, olive gray, alternating with thin beds of shale. <i>?Kingena</i> sp., <i>Arctostrea aguilerae</i> , <i>Pycnodonte mutabilis</i> , <i>Exogyra costata</i> , abundant orbitoids, bryozoans.	98.8
Lower member of the Cárdenas Formation (182.3 m measured)	
29. Biosparudite, moderate yellow brown, thin bedded, foraminifers, gastropods.	2.4
28. Covered.	4.6
27. Biosparudite, brownish orange, hash of shell fragments.	0.3
26. Covered.	8.0
25. Biosparudite, brownish orange.	0.6
24. Covered, probably limestone and shale.	5.0
23. Biosparudite, dark yellow orange.	1.2
22. Shale alternating with thin beds of limestone.	6.1
21. Biosparudite, pale yellow brown, shaley, foraminifers, gastropods, radiolitics.	1.2
20. Shale in 0.6 m beds with beds of limestone 2 cm thick.	

Unit	Meters
<i>Durania ojanchalensis</i> , ? <i>Linearia belli</i> , <i>Cerithium potosianum</i> , <i>Coralliochama gboehmi</i> , <i>Actaeonella coniformis</i> , bryozoans.	3.6
19. Biosparudite, pale yellow brown, with shale partings.	2.1
18. Shale, with thin ribs of limestone.	2.4
17. Biomicrudite, pale yellow brown. <i>Hardouinia potosiensis</i> , <i>Architectonica</i> sp., oyster fragments.	0.6
16. Shale, olive gray, laminated.	3.6
15. Biosparudite, gray orange.	0.3
14. Sandstone, light olive gray, very fine grained, thin bedded, shell fragments.	4.2
13. Shale, olive gray.	3.6
12. Sandstone, light olive gray, fine grained, thin bedded.	1.8
11. Shale, partly covered.	7.9
10. Sandstone, light olive gray, fine grained, thin bedded.	5.5
9. Shale, olive gray, with occasional 2 to 4 cm beds of hard siltstone.	41.0
8. Shale, olive gray.	7.0
7. Sandstone, light olive gray to dusky yellow, fine grained, thin bedded.	11.8
6. Mudstone, olive gray, thin bedded, with thin limestone and sandstone beds at top; orbitoids, bivalve fragments.	10.9
5. Sandstone, olive gray, fine grained.	1.8
4. Covered, probably siltstone.	6.4
3. Sandstone, dusky yellow, fine grained, thin bedded, friable. <i>Coralliochama gboehmi</i> , <i>Ostrea tecticosta</i> .	1.5
2. Silty marl, dusky yellow. <i>Durania ojanchalensis</i> , <i>Veniella conradi</i> , <i>Cymella bella mexicana</i> , <i>Arca securiculata armeriai</i> , <i>Inoperna</i> sp., <i>Neitheia youngi</i> , ? <i>Linearia belli</i> , <i>Turritella guionae</i> , <i>Pholadomya</i> sp., <i>Actaeonella coniformis</i> , <i>Ostrea tecticosta</i> .	13.9
1. Biosparudite, pale yellow brown, radiolitic, hematite and limonite stains. <i>Durania ojanchalensis</i> , oyster fragments.	23.0
TOTAL	1,055.8 m

Alluvium

B. ARROYO DEL AGUAJE,
eastern side of the Cárdenas syncline

Unit	Meters
Tabaco Formation	
Siltstone, light reddish brown.	
Covered.	106.0
Uncorformity	

Unit	Meters
Upper member of the Cárdenas Formation (298.7 m measured)	
59. Shale, moderate yellow brown, alternating with thin beds of sandy limestone. <i>Lima azteca</i> , <i>Anomia csernai</i> , <i>Septifer aguajensis</i> , <i>Turritella potosiana</i> .	9.1
58. Calcarenite, olive gray, fine grained, well sorted, medium bedded, very hard, clear grains in orange clay matrix.	1.8
57. Shale and calcareous siltstone, gray orange, blocky. <i>Barbatia sculpta</i> , <i>Septifer aguajensis</i> , <i>Turritella potosiana</i> , <i>Pseudamaura altirata</i> , ? <i>Turritella</i> sp.	12.4
56. Biomicrudite, pale yellow brown, thin beds, nodular. <i>Coralliochama gboehmi</i> , <i>Tampsia floriformis</i> , <i>Cyprina mondragoni</i> , <i>Lopha maccoyi</i> , <i>Cardium</i> (<i>Trachycardium</i>) <i>gordum</i> , <i>Barbatia sculpta</i> , <i>Biradiolites aguilerae</i> , <i>Anomia csernai</i> , <i>Turritella potosiana</i> , <i>Leptoria</i> sp., <i>Trochoseris</i> sp., <i>Synastrea</i> sp.	7.3
55. Shale, olive gray. <i>Coralliochama gboehmi</i> , <i>Barbatia sculpta</i> , <i>Turritella potosiana</i> , <i>Cerithium subcarnaticum</i> , <i>Actaeonella coniformis</i> .	6.4
54. Shale and fine grained sandstone, light olive gray to pale yellow brown, lumpy surface. <i>Cardium</i> (<i>Trachycardium</i>) <i>gordum</i> , <i>Barbatia sculpta</i> , <i>Trigonia eufalensis</i> , <i>Turritella waitzi</i> , <i>Trochoseris</i> sp.	15.8
53. Sandy intrasparite, light olive gray, fine grained, clear and a few black grains, hard, smooth fracture.	3.9
52. Covered, probably shale.	43.0
51. Shale, olive gray.	3.6
50. Biosparite, moderate yellow brown, orange fossil fragments in clear spar. <i>Coralliochama gboehmi</i> , <i>Biradiolites aguilerae</i> .	4.3
49. Shale. <i>Coralliochama gboehmi</i> , <i>Cyprina mondragoni</i> , <i>Lopha maccoyi</i> .	2.1
48. Calcarenite, light olive gray, fine to medium grained, clear and black grains, few red.	5.2
47. Limestone, medium bedded, alternating with 0.6 to 0.9 m of shale.	9.1
46. Sandstone, light olive gray, fine to very fine grained, calcareous cement, thick to medium bedded, shale partings.	7.9
45. Sandstone, thin bedded, and olive siltstone; sand fine to medium grained, very well rounded grains. <i>Actaeonella coniformis</i> .	20.9
44. Sandstone and sandy intrasparite, light olive gray, medium grained, medium bedded; black, clear, and white grains in clear spar, speckled.	2.4
43. Sandstone, moderate olive brown, fine grained, medium	

Unit	Meters
bedded, alternating with shale; grains clear and black in white clay matrix.	7.0
42. Covered, probably shale.	19.4
41. Biomicrudite, pale yellow brown. <i>Exogyra costata</i> .	0.6
40. Limestone, medium bedded, oyster fragments.	0.3
39. Sandy marl. <i>Exogyra costata</i> , <i>Arctostrea aguilerae</i> , <i>Flemingostrea</i> sp.	3.3
38. Sandstone, moderate yellow brown, medium bedded, medium grained, 2 to 6 cm shale partings, shell fragments.	5.5
37. Mudstone, light olive gray, worn fossils.	6.1
36. Sandstone, moderate olive brown, fine grained, medium bedded, alternating with mudstone.	3.3
35. Mudstone with sandstone lenses. ? <i>Kingena</i> sp., oyster fragments.	2.7
34. Shale, dusky yellow, blocky. <i>Septifer aguajensis</i> .	29.2
33. Biomicrudite, dusky yellow rubbly.	3.3
32. Covered.	3.0
31. Biomicrudite, dusky yellow. <i>Coralliochama gboehmi</i> , <i>Actaeonella coniformis</i> , <i>Trochoseris</i> sp.	6.1
30. Mudstone, light olive gray, thin to medium bedded, nodular.	6.4
29. Sandstone, sandy intrasparite, moderate yellow brown, medium grained, thin to medium bedded; black, clear, white, and green grains in orange clay matrix.	6.1
28. Covered.	9.1
27. Sandy intrasparite, light olive gray, medium bedded; foraminifers and laths white, blackgreen grains in clear spar. <i>Biradiolites aguilerae</i> , ? <i>Tellina</i> sp.	10.0
26. Covered.	3.0
25. Sandstone, light olive gray, fine to very fine grained, thick bedded, black and clear grains.	19.1
Middle member of the Cardenas Formation (449.8 m)	
24. Siltstone and fine sandstone, olive gray.	10.3
23. Sandstone, light olive gray, very fine grained; and siltstone.	30.0
22. Mudstone, light olive grey, massive shell fragments.	66.7
21. Shale, partly covered.	170.0
20. Biosparudite.	6.1
19. Covered, probably shale.	12.2
18. Sandy intrasparite, olive gray, fine to medium grained, clear, green and black grains. <i>Exogyra costata</i> .	3.0
17. Covered, probably shale.	45.5
16. Orbitoid biosparite, dark yellow orange, clear orbitoids in orange sparry matrix; 1% black gains.	4.6

<i>Unit</i>	<i>Meters</i>
15. Biosparite, yellow gray, white fossils, light olive gray silt and clay in clear spar; partly covered.	9.1
14. Covered.	4.9
13. Sandy biosparudite, gray orange; and biosparudite, dark yellow orange, shell fragments, laths, pellets, thick bedded.	6.4
12. Covered.	3.6
11. Orbitoid biosparite, pale yellow brown; clear orbitoids in orange clay and spar matrix.	2.4
10. Orbitoid biosparite, dark yellow orange.	1.8
9. Covered.	15.2
8. Orbitoid biosparite, dark yellow orange.	3.0
7. Covered.	55.0
Lower member of the Cárdenas Formation (180.9 m measured).	
6. Biosparite, pale yellow brown, clayey and sandy, tan-orange-yellow mottled, thick bedded.	9.4
5. Sandstone, partly covered. <i>Durania ojanchalensis</i> , <i>Actaeonella coniformis</i> .	15.2
4. Biosparite and intrasparite, dark yellow orange, shells and shell fragments.	1.5
3. Covered. Some sandstone beds.	13.6
2. Intrasparite, gray orange to dark yellow orange, coarse shell fragments jumbled.	2.1
1. Covered. Some sandstone beds in upper 6 m.	139.1
TOTAL	926.7 m

Tamazopo Limestone.

C. ARROYO DEL TABACO,
eastern side of the Cárdenas syncline

<i>Unit</i>	<i>Meters</i>
Tabaco Formation	
Siltstone and shale, light reddish brown; sandstone, light brown.	
Unconformity	
Upper member of the Cárdenas Formation (275.2 m measured).	
25. Shale, dusky yellow, alternating with mudstone flags.	81.5
24. Shale, dusky yellow, alternating with 10 to 30 cm beds of limestone.	6.1
23. Shale and mudstone, dusky yellow.	22.4
22. Limestone, moderate yellow brown, medium crystalline, hard, irregular weathered surface, shale partings.	4.5
21. Shale with limestone flags.	13.4
20. Coquina, shaley, irregular surface.	4.5
19. Shale with limestone flags.	4.5

Unit	Meters
18. Coquina, shaley, irregular surface.	1.5
17. Sandstone, dark olive gray, hard medium grained, thick bed.	0.8
16. Shale, dusky yellow.	1.6
15. Biomicrudite, olive yellow, very lumpy, oyster fragments.	1.6
14. Covered.	26.6
13. Biosparudite. <i>Biradiolites aguilerae</i> , <i>Coralliochama gboehmi</i> .	8.0
12. Shale, light olive gray.	15.1
11. Marl. <i>Tampsia floriformis</i> , <i>Coralliochama gboehmi</i> , <i>Biradiolites aguilerae</i> , <i>Actaeonella coniformis</i> .	3.9
10. Biosparudite, lumpy, olive gray.	3.3
9. Biomicrudite, shaley, soft, composed predominantly of bryozoans.	3.4
8. Biosparudite, olive gray, and mudstone.	10.0
7. Shale, olive gray, shell fragments.	3.3
6. Sandy sparite, olive gray, medium to coarsely crystalline, speckled, massive.	11.5
5. Shale, olive gray.	3.3
4. Sandy sparite, olive gray.	0.4
3. Shale, olive gray.	7.3
2. Sandy sparite, olive gray.	16.7
1. Shale, dusky yellow.	20.0
	TOTAL 275.2 m

Covered

SYSTEMATIC PALEONTOLOGY

In the following descriptions the bivalve orders and families of Dechaseaux (1952) are used with few exceptions. The gastropods are arranged in the order used by Sohl (1960, 1964a). The arroyos and railroad cuts in which the fossils were collected are located on plate 1. Specimens from the Arroyo de la Atarjea, Arroyo del Aguaje, and Arroyo del Tabaco are referred to measured section units (Appendix).

Type specimens of the new species have been deposited in the W. S. Adkins Collection in the Department of Geology, The University of Texas (hence the specimen numbers are preceded by WSA.) In addition to having Böse's type specimens, the Instituto de Geología, Universidad Nacional Autónoma de México, has topotype material of most of the new species described.

Phylum MOLLUSCA

Class BIVALVIA

Order RUDISTACEA

Family CAPRINIDAE

Genus *Coralliochama* White, 1885

Coralliochama gboehmi Böse

Pl. 3, figs. 1-3

Coralliochama G. Boehmi Böse, 1906a, p. 54-56, pl. 6, figs. 4, 5; pl. 9, fig. 5; pl. 10, fig. 1, pl. 11, fig. 2, pl. 12, fig. 1, pl. 13, figs. 1, 9; pl. 14, figs. 5, Müllerried, 1932, p. 175-177.

White erected the genus *Coralliochama* for a caprinid from Lower California that had a "hinge essentially the same as that of *Plagioptychus* Matheron, that *Ichthyosarcolithes* Desmarest and *Caprina* d'Orbigny" (White, 1885, p. 357) but, unlike other caprinids, a cellular shell layer. He named one species, *Coralliochama orcutti*. As MacGillavry (1937, p. 155) has pointed out, the so-called cells of *Coralliochama* are comparable to the pyriform canals of other caprinids. *Coralliochama gboehmi*, the only other species of the genus, is very similar to *C. orcutti* externally; both have a high, twisted conical lower valve and a strongly incurved upper valve (Pl. 3, fig. 1). *C. gboehmi* has an outer laminated shell layer approximately 2 mm thick on a small shell (diam. 50 mm); next is a band of elongate canals (pl. 3, fig. 2), which pass into more nearly circular to irregularly polygonal cells with no distinct boundary between the elongate canals and the cells (pl. 3, fig. 3). A very thin lamellar layer lines the body cavity.

The shell structure of *C. gboehmi* differs from that of *C. orcutti* primarily in the development of the middle "cellular" layer. In *C. orcutti* the "cell" walls



are thin, and the structure is comparable in section to radiolitic cells. This "cellular" portion comprises almost the entire thickness of the shell of *C. orcutti*. In *C. gboehmi* the "cell" walls are much thicker; they appear less like cells and more like canals than do those of *C. orcutti*. The pseudocellular layer is much thinner than in *C. orcutti*. On all the specimens from Cárdenas the outer shell layer of the upper valve is yellow brown with a waxy luster, providing a distinctive varnished appearance. The upper valve is smooth except for occasional concentric swellings and constrictions. The lower valve is not at all waxy and is characterized by slightly undulose concentric growth lamellae.

C. gboehmi at Cárdenas ranges through most of the Cárdenas Formation, from the middle of the *Durania ojanchalensis* Zone to the upper part of the *Tampsia floriformis* Zone (Aguaie units 31, 49, 50, 55, 56; Atarjea units 3, 20, 52, 62, 64, 65, 68, 74, 76; Tabaco units 11, 13; Km 415 to Km 416 on Aguascalientes-Tampico rail line; and Bomba). Its greatest abundance is in the beds with *Tampsia* and *Biradiolites* in the lower part of the *Tampsia floriformis* Zone.

Figured specimens

Pl. 3, fig. 1

Height 72 mm

Diam. 39 mm dorso-ventral,
(at commissure)

WSA 15567

Atarjea unit 62

fig. 2

Height 45 mm

WSA 15583

Atarjea unit 62

Fig. 3

Greatest diam. 46 mm

Least diam. 37 mm

WSA 15582

Atarjea unit 62

Family HIPPURITIDAE

Genus *Hippurites* Lamarck, 1890

Hippurites muellerriedi (Vermunt)

Pl. 3, figs. 4-6

Hippurites (*Hippuritella* H. Douvillè; *Orbignya Toucas*) cf. *incisus* H. Douvillè) Toucas, Müllerried, 1930, p. 165-168, figs. 1, 2.

Orbignya muellerriedi Vermunt, 1937, p. 261-264, pl. 36, figs. 1-3.

Hippurites muellerriedi (Vermunt) MacGillavry, 1937, p. 110-111, pl. 5, fig. 6.

Hippurites (*Orbignya*) *müllerriedi* (Vermunt) Chubb, 1956, p. 19, pl. 4, figs. 4, 8.

Hippurites (*Orbignya*) *ceibarum* Chubb, 1956 (part), p. 19-21.

First formed part of lower valve conical, but rapidly becomes almost cylindrical with gently tapering sides (pl. 3, fig. 4). Rounded ribs all around shell, separated by grooves approximately as wide as ribs. Grooves corresponding to internal pillars E, S, and L are V-shaped; E groove no wider than regular peri-

peral grooves; S groove is larger than peripheral grooves; and L is a much wider open groove.

Internally E is the longest pillar (pl. 3, fig. 5); it is widest at its interior extremity and constricted at the base. S is shorter and evenly U shaped with no constrictions. L is a low arch.

Remarks.—Vermunt (1937) included Müllerried's (1930) specimen in *Orbignya muellerriedi* along with specimens from Cuba and Jamaica. Chubb (1956) restricted *Hippurites* (*Orbignya*) *muellerriedi* to the Cuban and Jamaican forms; he included Müllerried's specimen in a new species, *H. (Orbignya) ceibarum*, which was based on Jamaican material. Chubb placed the Cárdenas specimen in *H. ceibarum* because (1) its L to E angle was closer to *H. ceibarum* than to *H. muellerriedi* (Vermunt) Chubb (120° vs. 145°) and (2) its smaller size was closer to the size of *H. ceibarum*. The specimens I collected from Cárdenas (over 8) have a large size range (diam. 23 mm to 47 mm); almost all are larger than the dimensions given for *H. ceibarum*. These *Hippurites* do not have regularly geometrical sections; the angular distance from L to E cannot be easily obtained with accuracy. Internally *H. muellerriedi* and *H. ceibarum* are similar; they are both placed by Chubb in the same subgenus. But externally there is no resemblance between *H. ceibarum* and the specimens from Cárdenas. For these reasons I believe the Cárdenas specimens to be *H. muellerriedi* (Vermunt).

At Cárdenas *H. muellerriedi* occurs in the upper part of the *Tampsia floriformis* Zone (Atarjea unit 82); there it is common.

Figured specimens

Pl. 3, fig. 4, 6

Height 56 mm

Diam. 36 mm (through E, largest shell)

WSA 15568

Atarjea unit 82

Fig. 5

Diam. (through E) 41 mm

WSA 15584

Atarjea unit 82

Hippurites perkinsi, n. sp.

Pl. 4, figs. 5, 6

Lower valve cylindrical, straight or slightly curved, often twisted. Narrow ribs all around shell are separated by broad, flat-bottomed grooves (pl. 4, fig. 5); ribs have an average width at their apex of 2.5 mm, grooves are two to three times as wide. Widest groove corresponds to the S pillar. Number of ribs increases by bifurcation as shell grows: A shell 22 mm in diameter has 8 ribs, 29 mm in diameter has 10 ribs, and 34 mm in diameter has 18 ribs. S and E grooves are V-shaped rather than flat-bottomed. E is the sharper of the two and has a very thin sinus at the base of the V. Radial markings are faint, and there are no longitudinal striae.

In transverse section E is narrower, more elongate, and pinched more at

the base than is the S pillar (pl. 4, fig. 6). L is a broad inward fold of the shell, broadly open externally.

Remarks.—The internal features of *H. perkinsi* are very similar to those of *H. muellerriedi* (Vermunt, 1937) although the angular distance from L to E is slightly greater for *H. perkinsi*. A flanged tooth (N) has not been observed on *H. perkinsi*. However, the sharp narrow ribs of *H. perkinsi* readily distinguish it from similar forms of the Gulf Upper Cretaceous, such as *H. muellerriedi* and *H. ceibarum* Chubb (1956). Collected from Atarjea unit 68, *Tampsia floriformis* Zone; it is rare in the Cárdenas Formation.

Figured specimen.

Pl. 4, figs. 5, 6 (Holotype)
(Incomplete)

WSA 15569

Height 47 mm (incomplete)
Diam. 29 mm (dorso-ventral)

Atarjea unit 68

Family RADIOLITIDAE

Genus *Biradiolites* d'Orbigny, 1850

Biradiolites aguilerae Böse

Pl. 5, figs. 1-4

Biradiolites aguilerae Böse, 1906a, p. 58-59, pl. 5, fig. 4; pl. 8, figs. 1, 4; pl. 9, figs. 1, 2; pl. 12, figs. 3, 4.

Lower valve is a slightly curved cone, sub-triangular to almost round in transverse section. Approximately one third of shell perimeter occupied by three to five ribs (downfolds), which are variable in size. Remaining two third of shell nearly smooth, mark only by growth lamellae (pl. 5, figs. 2-4).

Upper valve opercular, flat or slightly convex (pl. 5, fig. 4). It is folded conformably with lower valve; projections of upper valve cover downfold of lower valve. Concentric growth lines are the only other ornamentation. Umbo eccentric, displaced away folded part of valve.

Remarks.—The thin shells of all specimens collected were recrystallized; only the ghost of cellular structure could be seen on a few shells.

Small *Biradiolites aguilerae* are abundant in the *Tampsia floriformis* Zone at Bomba and in the eastern part of the Arroyo del Tabaco (Tabaco unit 11) and rare in the upper part of the *Arctostrea aguilerae* Zone in the Arroyo del Aguaje (Aguaje unit 27).

Figured specimens.

Pl. 5, fig. 1
Length 58 mm (several shells)
Breadth 24 mm

WSA 15560

Bomba

Pl. 5, fig. 2, 3
Height 25 mm
Diam. 15 mm

WSA 15580

Bomba

Pl. 5, fig. 4

Height 32 mm

Diam. 20 mm

WSA 15581

Bomba

Biradiolites cardenasensis Böse

Pl. 4, figs. 1-4

Biradiolites Cardenasensis Böse, 1906a, p. 59-60, pl. 11, fig. 3; pl. 12, fig. 3.

Biradiolites potosianus Böse, 1906a, p. 60-61, pl. 5, figs. 2, 3; pl. 11, fig. 4; pl. 12, fig. 5.

The small, very rugose *Biradiolites cardenasensis* is conical, slightly curved, and covered by sharp, salient, usually unequal ribs (pl. 4, figs. 1-3). On some specimens two or three grooves (upfolds) are much wider than the rest (pl. 4, fig. 1); on others there is no regular difference in their size (pl. 4, figs. 2, 3). The growth lamellae are prominent. The upper valve is warped, irregularly concave and convex (pl. 4, fig. 4). Its basic outline is oval, but digitate extensions of varying strength cover the ribs (downfolds) of the lower valve. Cell structure rectangular.

Remarks.— Böse (1906a) described *B. cardenasensis* and *B. potosianus* from Km 416-417 (= Bomba). These two are indistinguishable on the basis of Böse's descriptions or figures; they should be united as *B. cardenasensis*. This species is abundant in the *Tampsia floriformis* Zone at Bomba.

Figured specimens.

Pl. 4, fig. 1

Height 78 mm

Diam. 52 mm

WSA 15011

Bomba

Pl. 4, fig. 2

Height 83 mm

Diam. 50 mm

WSA 15013

Bomba

Pl. 4, figs. 3, 4

Height 69 mm

Diam. 42 mm

WSA 15012

Bomba

 Genus *Tampsia* Stephenson, 1922

Thick-shelled, subconical to cylindro-conic, no ligament. Outer shell layer cellular; cells small, quadrangular to irregularly polygonal; cells enclosed in growth lines (= traces of funnel plates in cross section). Upper rim of lower valve marked by radial depressions, one cell wide, that bifurcate toward the periphery. A unique character of *Tampsia* is a sinus that extends from a groove on the periphery of the shell to within a few millimeters of the body cavity. On the upper rim of the lower valve the sinus is mounted on a rounded ridge. The ridge is enclosed in a triangular depression, which has its base on the margin of the body cavity, its apex at or near the intersection of the sinus with the periphery of the shell.

The upper valve is a low, concentrically striated cap on top of the body cavity with a thin brim that extends over the upper surface of the lower valve.

Stephenson (1922) called the sinus the anterior siphonal channel (*E*, *entrée*, inhalent siphon) following the convention established by Douvillé (1886) in describing radiolitids and hippuritids. On the two species described by Stephenson (1922; *T. bishopi*, the type species; and *T. chocoyensis*) there is another pronounced groove (upfold) without a sinus counterclockwise from *E*, which is by convention called *S* (*sortie*, exhalent siphon). On the only other described species of *Tampsia* (*T. rutteni* Vermunt, 1937) *E* is a sinus, but *S* is said to be a broad rib (downfold).

Tampsia floriformis, n. sp.

Pl. 5, fig. 5; pl. 6, figs. 1, 2; pl. 7, fig. 1

Sinus *E* projects inward from a pronounced V-shaped groove. Counterclockwise from *E* is another pronounced groove (*S*), which is wider than the channel of *E* and is round bottomed. Between *E* and *S* is the largest rib (downfold) on the shell. The remainder of the lower valve is strongly folded around the periphery; folds may be angular or rounded. Growth lamellae are the only other ornamentation (pl. 6, fig. 1).

Top of lower valve gently convex to very slightly concave. Upfolds on side of shell form rounded ribs on upper surface, downfolds form grooves that are usually narrower than the ribs (pl. 6, fig. 2). Radial depressions, one cell wide, cross this surface and may bifurcate one, two or three times in dendritic patterns. The *E* sinus is marked by a notch on shell periphery (pl. 7, fig. 1); on upper surface of attached valve it is mounted on a broad swelling that slopes gently away from the sinus to deep bordering grooves, the sides of the enclosing triangular depression. The *S* groove forms an arch on the upper surface of the attached valve and a rounded notch at the shell periphery.

The upper valve is a round cap over the body cavity. It is concentrically striated and may be gently folded (pl. 5, fig. 5), folds corresponding to those on attached valve. A thin, tightly fitting brim extended over the upper surface of attached valve.

Cross sectional shape elliptical. Body chamber almost circular, but slightly indented at *E* and flattened at *S*. Greatest shell thickness on a diameter perpendicular to diameter through *E*.

Remarks.—This species is abundant at Cárdenas and is remarkable for the great variation in the shape of its shell. It is always folded, but the folds may be few and large or many and small. The upper surface of the lower valve may be strongly folded as on WSA 14925 (pl. 6, fig. 2) or very gently undulose. The *E* sinus is always well marked, but *S* is not clearly distinguishable on some shells. The outline of some shells is very elongate rather than round.

T. floriformis is readily distinguishable from *T. bishopi* Stephenson and *T. chocoyensis* Stephenson by its much more rugose sides, the irregularly oriented upper surface of its lower valve, and its less distinctly set off *S* channel.

E is on a sharply set off ridge on the upper surface of *T. bishopi* and *T. chocoyensis*, on a broad swell on *T. floriformis*; *T. floriformis* does not have S on a rib or downfold as does *T. ruttleri* Vermunt, nor does it have fine longitudinal striations on the shell surface.

T. floriformis has been collected from Bomba, Tabaco unit 11, Aguaje unit 56, and Atarjea units 64, 68, 74; it is restricted to the *Tampsia floriformis* Zone where it is locally abundant.

Figured specimens.

Pl. 5, fig. 5	WSA 14955
Greatest diam. 141 mm	Atarjea unit 64
Least diam. 98mm	
Pl. 6, figs. 1,2 Holotype	WSA 14925
Height 170 mm	Atarjea unit 64
Diam. 140 mm (through E)	
Pl. 7, fig. 1	WSA 14925
Length of peel 85 mm	

Tampsia poculiformis, n. sp.

Pl. 5, figs. 6, 7; pl. 7, fig. 2

Attached valve cylindro-conic with very gently tapering sides. Steeply inclined laminae (funnel plates) produce a usually smooth exterior (pl. 5, fig. 7). Growth lines are seen as even lamellae on weathered surfaces. Aside from siphonal area the shell usually has only gentle undulations but may have two to four sharp folds. There are five elements in the siphonal area: three upfolds and two downfolds. E is a slit on a shallow depression distinctly bounded on one side by a rib, but not clearly bounded on the other side. S is a broad shallow depression. There is a large smoothly rounded upfold between S and E; growth laminae cross it approximately horizontally. Laminae dip downward on E and S. Some specimens have distinct bounding folds on either side of S and E; on others only the central fold between S and E is distinct.

The top of the attached valve is concave, smooth with only slight undulations (pl. 5, fig. 6). E is a slit on an inflated swelling in a depressed, almost flat bottomed, triangular area bounded by rounded, raised sides. S is marked only as a slight inward curve of shell periphery.

Remarks.—*T. poculiformis* more closely resembles *T. bishopi* Stephenson and *T. chocoyensis* Stephenson than it resembles any other species of *Tampsia*. However, E and S are much more distinct channels on Stephenson's species. On the upper surface of the attached valve the E sinus is on a narrow ridge that extends almost to the inner margin on *T. bishopi* and *T. chocoyensis*; on *T. poculiformis* the E slit is on a short, blunt, inflated ridge that extends only slightly more than half way to the body cavity. *T. poculiformis*

is found only in the middle of the *Tampsia floriformis* Zone in the Arroyo de la Atarjea; there it is common.

Figured specimens.

Pl. 5, fig. 6 (Holotype)	WSA 14921
Diam. 125 (through E)	Atarjea unit 65
fig 7	WSA 14933
Height 110 mm	Atarjea unit 65
Diam. 111 mm	
Pl. 7, fig. 2	WSA 14921
Length of peel 62 mm	

Genus *Durania* Douvillé, 1908

Durania ojanchalensis, n. sp.

Pl. 8, figs. 1, 2

Attached valve cylindro-conic, very gently tapering. Funnel plates nearly horizontal, grouped in bundles that vary in extension and thereby form ledges. Thickness of bundles variable; they are usually 3 to 5 mm thick, but shell surface may be even for 10 to 20 mm. There are weak rounded longitudinal ribs and shallow grooves perpendicular to the bundles of growth lamellae. Ribs are simple, 2 to 2.5 mm from crest to crest, with imbricate appearance due to layering of thin lamellae. E is a depression 20 to 30 mm wide, 10 mm deep, not ribbed, smooth except for downward bent growth lamellae (pl. 8, fig. 2). S is not so deeply depressed as E, 20 to 25 mm wide, smooth. Fold between S and E is round, inflated, ribbed like the rest of the shell. Cell structure regularly polygonal (pl. 8, fig. 1).

Remarks.—Böse (1906a) identified *Radiolites austinensis* from Cárdenas but his figures and description do not warrant specific identification. He may have had a specimen of *Durania ojanchalensis*, but it could not have been collected in place from Km 415 and Km 416, the localities of Böse's "*Radiolites austinensis*".

Fragments of *Durania ojanchalensis* are very similar in appearance to fragments of *Durania austinensis* (Römer) (Römer, 1852). However, *D. austinensis* has finely ribbed S and E grooves; on *D. ojanchalensis* they are smooth, narrower, and not so distinct. *D. austinensis* has even sides, without ledges.

Durania ojanchalensis occurs only in the lowest part of the Cárdenas Formation, the *Durania ojanchalensis* Zone, where it is abundant (Atarjea units 1, 21; western Arroyo del Aguaje; western Arroyo del Tabaco).

Figured specimens.

Pl. 8, fig. 1
Length of peel 88 mm

WSA 14984
Atarjea unit 1

Pl. 8, fig. 2 (Holotype)
Height 90 mm (incomplete)
Diam. 115 mm

WSA 14996
Western Arroyo del Tabaco

Order TAXODONTA

Family ARCIDAE

Genus *Arca* Linne, 1758

Arca securiculata Wade, 1926

Arca securiculata armeriai, n. subsp.

Pl. 9, fig. 1

Inequilateral, inflated, extended postero-ventrally, tear shaped. Anterior margin rounded; auricles small, obtuse. Thirty-two strong, high, rounded ribs separated by only slightly narrower round bottomed grooves. Grooves in central part of shell have a medial lira. Posterior extended along umbonal ridge to form acute angle.

Remarks.— This subspecies closely resembles *A. securiculata securiculata* Wade, but it differs from the specimens from Coon Creek in having more nearly equal ribs and in the shape of the posterior margin. *A. securiculata securiculata* is truncate, *A. securiculata armeriai* is extended posteriorly to form a rounded acute angle.

One specimen found in the *Durania ojanchalensis* Zone (Atarjea unit 2).

Figured specimen.

Pl. 9, fig 1 (Holotype)
Height 8 mm
Length 11 mm
Thickness 5 mm (one valve)

WSA 15042
Atarjea unit 2

Arca mcnairyensis Wade, 1926

Arca mcnairyensis rebecca, n. subsp.

Pl. 9, fig. 2

Inequilateral, inflated, elliptical outline. Twenty-five strong, rounded, radial ribs. Growth lines on postero-ventral border produce a quasi-cancellate pattern. Ribs nearly equal in strength. Ventral margin rounded.

Remarks.— This subspecies differs from *A. mcnairyensis mcnairyensis* Wade from Coon Creek in having nearly equal ribs and a round ventral mar-

gin; the ribs of *A. mcnairyensis mcnairyensis* from Coon Creek are smaller in the central part of the shell than on the margins.

At Cárdenas I found one specimen in the *Durania ojanchalensis* Zone in a railroad cut 40 m west of Km 419.7.

Figured specimen.

Pl. 9, fig. 2 (Holotype)

Height 9 mm

Length 10 mm

WSA 15073

Km 419.7

Genus *Barbatia* Gray, 1840

Barbatia sculpta, n. sp.

Pl. 8, figs. 4, 5

Almost equivalve, left valve slightly larger than right valve; inequilateral, procline; biconvex, inflated; subquadrangular. Anterior margin rounded. Main part of shell covered with rounded ribs separated by narrow shallow grooves. Ribs vary in size; on some valves fine and coarse ribs alternate. Ribs generally larger toward the anterior and toward the posterior of the main part of the shell than in the middle. Growth stages marked by irregularly spaced concentric variations in thickness of the shell; this produces on some valves a faint irregularly cancellate appearance. A. pronounced rounded carina separates the posterior from the main part of the shell. Posterior of each valve is a concave surface with slightly obtuse angled margins both dorsally and ventrally. Posterior surface ornamented with twelve longitudinal ribs, which vary much more in size than the ribs of the central part of the shell, and grooves wider than those on the central part of the shell. Faint concentric lines in the grooves with corresponding nodes on the ribs produce a trellis pattern.

Hinge line straight; ligament area large, lens shaped, concave; marked by numerous irregularly spaced grooves perpendicular to commissure. Beaks incurved and widely separated. Ventral margin broadly rounded, slightly compressed.

Remarks.— There are many similar small Cretaceous *Barbatia*: *Arca carinata* (Sowerby) (d'Orbigny, 1847), *Arca securis* (Leymerie) (d'Orbigny, 1847), *Arca guillanioni* Collignon (1934), and *Arca cymodon* Coquand (1866).

Barbatia sculpta differs from all of these with its more sharply set off posterior area bounded by a distinct carina. *A. carinata* has larger ribs, chevron grooves in the ligamentary area, and is produced more anteriorly than *B. sculpta*. The posterior area of *A. securis* is ornamented with four large ribs, and the ligamentary area is much narrower than on *B. sculpta*. *A. guillanioni* has six to seven strong ribs on the main shell. *A. cymodon* has a shorter and narrower ligamentary groove than *B. sculpta*.

Thirty specimens of *B. sculpta* were collected from the *Tampsia floriformis* Zone (Aguaje units 54, 55, 56, 57; and Bomba).

Figured specimen

Pl. 8, figs. 4, 5 (Holotype)

Height 6.7 mm

Length 13.2 mm

Thickness 7.6 mm

WSA 15023

Aguaje unit 57

Order DYSODONTA

Family ANOMIDAE

Genus *Anomia* Linne, 1767*Anomia csernai*, n. sp.

Pl. 9, figs. 3, 4

Anomia argentaria Morton, Böse, 1906a, p. 38-40, pl. 1, fig. 8. Not *Anomia argentaria* Morton, 1834, p. 61, pl. 5, fig. 10; Whitfield, 1886, p. 42, pl. 4, figs. 9-11; *et auctorum*.

Nearly equilateral; outline variable, round to oval. Ventral margin round, anterior and posterior margins round to gently convex; hinge line short and straight. Left valve convex, umbo inflated; right valve unknown. Beak varies from simply marginal to incurved. Surface marked by broadly rounded radial costae, which are separated by slightly narrower to much narrower grooves with gently concave bottoms. Costae are sometimes off-set at growth lines producing an irregularly distorted appearance. Growth lines are faint, but some form cross bars on the ventral part of the shell. Although off-set, costae are continuous; they are not interrupted at growth lines.

Remarks.—Böse (1906a) identified a specimen from his *Corallochama G. Boehmi* Horizon as *Anomia argentaria* based on Whitfield's (1886) description of a shell that Whitfield doubtfully placed in this species. Böse believed *A. argentaria* to be a senior synonym of *A. truncata* Geinitz (1842) and *A. subtruncata* d'Orbigny (1850). *Anomia csernai* differs from these forms in its consistently strong radial costae; it also has a narrower and more prominent umbo, and it is more convex. The beak of *A. csernai* is curved inward like that of *A. forteplicata* Gardner, 1916, but the ribs of *A. csernai* are much weaker.

At Cárdenas *Anomia csernai* is restricted to the *Tampsia floriformis* Zone. It is common in the silty mudstone of this zone and was collected from Atarjea units 62 and 64, Aguaje units 57 and 59, and from the upper member of the Cárdenas Formation at Bomba.

Figured specimen

Pl. 9, figs. 3, 4 (Holotype)

Height 15.3 mm

Length 12.8 mm

WSA 15067

Bomba

Genus *Paranomia* Conrad
Paranomia guttiformis, n. sp.

Pl. 9, fig. 11

Inequilateral, slightly convex, subtriangular, drop or tear shaped. Shell thin. Anterior and posterior margins straight, ventral margin round, dorsal margin forms an acute angle. Radial ornamentation consists in broad, low, nodose ribs. In ventral half of shell are irregularly spaced flat concentric ridges. Resiliter subovate, very variable in size.

Remarks.—I have been able to see only the interiors of right valves; the soft internal layer is not preserved, therefore no muscle scars are visible. External sculpture may be similar to *Paranomia scabra* (Morton, 1834), but *P. guttiformis* has broader ribs. The shape of *P. guttiformis* is more regular than other Cretaceous *Paranomia*, and it has a distinctive development of concentric ridges.

At Cárdenas *P. guttiformis* occurs only in the lower part of the *Arctostrea aguilerae* Zone (Atarjea units 35 and 36).

Figured specimen

Pl. 9, fig. 11 (Holotype)

Height 20.8 mm

Length 17.7 mm

WSA 15057

Atarjea unit 35

Family LIMIDAE

Genus *Lima* Bruguière, 1792

Lima azteca Böse

Pl. 9, fig. 9

Lima (Plagiostoma) azteca Böse, 1906a, p. 36, pl. 1, figs. 3, 4, 7.

Lima azteca is similar in shape and ribbing to *L. reticulata* Lyell and Forbes (Richards, 1958, p. 144-145, pl. 22, figs. 9, 10), but the ribs of *L. azteca* are not crenulate or subspinose, nor is *L. azteca* marked concentrically like *L. reticulata*.

Lima azteca is abundant in the *Tampsia floriformis* Zone, but also occurs in the *Arctostrea aguilerae* Zone. Over 140 specimens were collected from the Cárdenas Formation from Bomba; between Km 415 and 415.5; and from Atarjea units 82, 76, 72, 68, 64, 52; Aguaje units 57, 54, 45, 44, 31; Tabaco units 11 and 13.

Figured specimen

Pl. 9, fig. 9

Height 23.7 mm

Length 20.4 mm

WSA 15020

Km 415.4

Lima cardenasensis Böse

Pl. 9, fig. 12

Lima cardenasensis Böse, 1906a, p. 35, pl. 1, figs. 1, 2.

Only two small, worn shell belonging to this species were found, both in the upper part of the *Arcostrea aguilerae* Zone in the eastern part of the Arroyo del Aguaje (Aguaje unit 27). The outline of this species is variable: Böse's specimen was subtrigonal, the two I found are oval and subquadrate. The umbo is slightly more prominent than shown on Böse's Pl. 1, figs. 1 and 2.

Figured specimen

Pl. 9, fig. 12

Height 18.6 mm

Length 20.3 mm

WSA 15070

Aguaje unit 27

Family MYTILIDAE

Genus *Mytilus* Linne, 1758*Mytilus smocki* Weller

Pl. 8, fig. 3

Mytilus smocki Weller, 1907, p. 502, pl. 55, figs. 1-4; Richards, 1958, p. 151, pl. 25, fig. 3.

The Cárdenas specimen has two strong growth lamellae that are prominent on the posterior and central parts of the shell. There are fine growth lamellae on the concave anterior margin of the shell, but they become much less distinct on the central and posterior parts of the shell. Very fine, regular, low, rounded costae are best developed on the posterior and central parts of the shell.

Richards (1958) states that in New Jersey *Mytilus smocki* is found in the Mt. Laurel and Navesink Formations (lower part of the *Exogyra costata* Zone). At Cárdenas *M. smocki* was found in the western part of the Arroyo del Aguaje at the base of the *Arctostrea aguilerae* Zone.

Figured specimen

Pl. 8, fig. 3

Height 32 mm (incomplete)

Length 13 mm

Thickness 17.7 mm (both valves)

WSA 15074

Western Arroyo del Aguaje

Genus *Inoperna* Conrad, 1873*Inoperna* sp.

Pl. 9, fig. 5

Fragment of one valve, elongate, slightly convex. Transversely wrinkled by irregularly spaced concentric ridges separated by narrow, shallow, grooves.

Although they vary in size, the ridges are generally broad; they form sinusoidal curves.

Remarks.—The Cárdenas specimen is similar to *I. bellarugosa* Popenoe (1937, p. 382-383, pl. 45, figs. 6, 7) but has more sinuous growth lamellae.

One specimen was collected from the *Durania ojanchalensis* Zone (Atarjea unit 2).

Figured specimen

Pl. 9, fig. 5
Height 22 mm
Length 15 mm

WSA 15066
Atarjea unit 2

Genus *Septifer* Recluz, 1848

Septifer aguajensis, n. sp.

Pl. 9, fig. 14

Inequilateral, convex, elongate, subtriangular, prosogyral. Anterior margin gently concave; posterior margin convex; posteroventral margin broadly rounded; antero-ventral margin more sharply rounded; dorsum forms an acute angle. Main part of shell slopes posteriorly and ventrally. At umbo both posterior and anterior slopes steep and concave. Posterior slope flattens out ventrally. Anterior slope becomes steeper until it forms a right angle with the main part of the shell at the ventral margin.

Main shell and posterior slope bear rounded costae separated by narrow grooves. Costae are added ventrally by intercalation. Costae are much finer and closer together on the steep anterior slope. Angle of costae with line of commissure increases from 40° near beak to approximately 80° at the antero-ventral margin. Growth lamellae, which are only evident on ventral one quarter of shell, are widely spaced.

Remarks.—*Septifer acutus* Trechmann (1927, p. 50-51, pl. 3, fig. 9) from the Jamaican Providence shale (Upper Campanian) is similar to *S. aguajensis*. However the umbo of *S. acutus* is narrower and more prolonged, and its umbonal ridge is more angular. The anterior margin of *S. aguajensis* is much less concave and therefore has much less overhang than does *S. acutus*. *S. aguajensis* occurs in the *Tampsia floriformis* Zone and in the *Arctostrea aguilera* Zone (Atarjea unit 68; Aguaje units 34 and 59), but is rare at Cárdenas.

Figured specimen

Pl. 9, fig. 14 (Holotype)
Height 30.1 mm
Length 20.2 mm

WSA 15055
Atarjea unit 68

Family OSTREIDAE

 Genus *Lopha* Bolten, 1798

Lopha maccoyi, n. sp.

Pl. 9, figs. 10, 13

Ostrea (Alectryonia) cfr. *Nicaisei* Coquand, Böse, 1906a, p. 47, pl. 2, figs. 3, 4.
Not *Ostrea Nicaisei* Coquand, 1869, p. 34-35, pl. 6

Slightly inequivalve, inequilateral, biconvex, round to oval outline. Large plicae are crossed by prominent growth lamellae. In section plicae form isosceles triangles with slightly rounded apices. Plicae bifurcate; six or seven plicae at the ventral margin. Line of commissure denticulate. Anterior, ventral, and posterior margins round; dorsal margin broken on this specimen.

Remarks.—As Böse indicated, this form is very similar in appearance to *Ostrea nicaisei* Coquand (1869) from the Lower Campanian of Algeria. *Lopha maccoyi*, however, is more nearly round, has more plicae, and its plicae are sharper than those of *O. Nicaisei*. In the American Cretaceous the most similar form is *Ostrea knappi* Stephenson (1923, p. 133-134, pl. 28, figs. 1-7) from the *Exogyra upatensis* Zone in South Carolina. *Lopha maccoyi* has much sharper plicae, is almost twice as large, and is more rounded than *O. knappi*.

At Cárdenas *Lopha maccoyi* is rare, it occurs only in the *Tampsia floriformis* Zone (Atarjea units 64 and 82; Aguaje units 49, 54, and 56).

Figured specimen

Pl. 9, fig. 10, 13 (Holotype)

Height 71 mm

Length 69 mm

WSA 15557

Aguaje unit 54

 Genus *Exogyra* Say, 1820

Exogyra costata Say

Pl. 10, fig. 1

Exogyra costata Say, 1820, p. 43; Morton, 1834, p. 55-56, pl. 6, figs. 1-4; Whitfield, 1886, p. 39-41, pl. 6, figs. 1, 2; Böse, 1906a, p. 51-54, pl. 6, fig. 3; pl. 7, fig. 1; pl. 8, figs. 2, 3; pl. 9, fig. 3; Gardner, 1916, p. 564-566, pl. 25, fig. 5; pl. 26, figs. 1, 2; pl. 27, figs. 1, 2; Stephenson, 1941, p. 122-125, pl. 19, figs. 1, 2; pl. 20, figs. 1, 2; pl. 21, fig. 2; Stephenson, 1955, p. 111-112, pl. 16, fig. 18; Richards, 1958, p. 117-119, pl. 20, figs. 1, 4.

Beds of *Exogyra costata* occur at several localities within the *Arctostrea aguilerae* Zone; Atarjea units 30, 34, 37, 58; Aguaje units 18, 39; in the western part of the Arroyo del Aguaje; in a railroad cut at Km 419.64; and on the San Luis Potosí-Valles Highway southeast of Canoas. There is considerable variation in the shell size and in the ornamentation within each bed. In

general, however, the specimens from the base of the *Arctostrea aguilerae* Zone have wider ribs and furrows than the *Exogyra* above them.

Most specimens from the middle part of the *Arctostrea aguilerae* Zone have higher ribs and narrower grooves than the underlying forms. The highest *E. costata* have moderately wide ribs with well defined grooves.

The specimens from southeast of Canoas are from Böse's (1906a) first horizon, the *Gryphaea vesicularis* Horizon. They include large medium ribbed forms and small high ribbed forms; I believe that the *Exogyra costata* beds at and southeast of Canoas are in the lower and middle part of the *Arctostrea aguilerae* Zone.

Figured specimen

Pl. 10, fig. 1
Height 60 mm
Length 58 mm

WSA 15570
Atarjea unit 30

Genus *Arctostrea* Pervinquier, 1910

Arctostrea aguilerae (Böse)

Pl. 10, figs. 2, 3, 7

Ostrea (Alectryonia) Aguilerae Böse, 1906, p. 47-49, pl. 2, fig. 2; pl. 4, fig. 5; pl. 6, figs. 1, 2.

Arctostrea aguilerae (Böse), Sohl and Kauffman, 1964, p. 14-19, pl. 1, figs. 1, 2; pl. 2, figs. 1-4; pl. 3, figs. 1-7; pl. 4, figs. 1-4, 6-8.

Arctostrea aguilerae has recently been fully described by Sohl and Kauffman (1964). In addition to its occurrence at Cárdenas, they reported *A. aguilerae* from beds of Maastrichtian age in Cuba, Mississippi, and Alabama.

At Cárdenas *A. aguilerae* occurs only in the *Arctostrea aguilerae* Zone, which is coincident with the local range of *Exogyra costata*. It is locally abundant (Aguaje unit 39; Atarjea units 30, 34; western Arroyo del Aguaje).

Figured specimens

Pl. 10, figs. 2, 7
Height 140 mm
Length 77 mm

WSA 15572
Western Arroyo del Aguaje

fig. 3
Height 106 mm
Length 52 mm

WSA 15573
Atarjea unit 34

Genus *Pycnodonte* Fischer de Waldheim, 1835

Pycnodonte mutabilis (Morton)

Pl. 11, figs. 1, 3, 6

Gryphaea mutabilis Morton, 1828, p. 81, pl. 4, fig. 3; Morton, 1834, p. 53-54, pl. 4, fig. 3; Stephenson, 1941, p. 115-117, pl. 17, figs. 1-6.

Gryphaea vesicularis Lamarck, Whitfield, 1886, p. 36-39, pl. 3, figs. 15, 16; pl. 4, figs. 1-3; pl. 5, figs. 1-3; Böse, 1906a, p. 49-51, pl. 4, figs. 1-3; pl. 7, fig. 2; pl. 9, fig. 4; pl. 11, fig. 6; Stephenson, 1923, p. 161, pl. 42, figs. 1-5; pl. 43, fig. 6, pl. 44, figs. 1, 2; Wade, 1926, p. 58, pl. 17, figs. 1, 2; pl. 18, figs. 1, 2; pl. 19, figs. 1, 2.

Gryphaea (Pycnodonte) vesicularis (Lamarck), Gardner, 1916, p. 572-578, pls. 28-32, pl. 33, figs. 1-3.

Whitfield (1886) and Böse (1906a) included in *Gryphaea vesicularis* ovate shells with a long straight hinge line and higher shell that had narrower umbones (and therefore a short hinge line). Stephenson (1941) included in *G. mutabilis* Whitfield's and Böse's ovate shells, but he excluded Whitfield's shells with narrower umbones (1886, pl. 3, fig. 15; pl. 4, figs. 2, 3) and questioned the inclusion of Böse's higher shells (1906a, pl. 4, figs. 2, 3).

At Cárdenas ovate forms like those figured by Stephenson as *G. mutabilis* (pl. 11, fig. 6) occur with the higher and narrower forms he questioned (pl. 11, fig. 1), together with shells of intermediate shape (pl. 11, fig. 3). Here the ovate, high, and intermediate forms are considered to be conspecific, just as they were by Whitfield and Böse. Stenzel (1959) has pointed out that these shells with vesicular shell structure, which is unique among oysters, are *Pycnodonte*, not *Gryphaea*.

Pycnodonte mutabilis (Morton) ranges through the Santonian and Maastichtian from New Jersey to México; it is the largest of the Upper Cretaceous *Pycnodonte*. At Cárdenas *P. mutabilis* occurs in the lower part of the *Arctostrea aguilerae* Zone, where it is abundant. (Atarjea unit 30; western part of Arroyo del Aguaje).

Figured specimens

Pl. 11, fig. 1

Height 86 mm

Length 84 mm

WSA 15578

Western Arroyo del Aguaje

fig. 3

Height 98 mm

Length 84 mm

WSA 15016

fig. 6

Height 97 mm

Length 98 mm

WSA 15579

Genus *Ostrea* Linne, 1758

Ostrea semiarmata Böse

Pl. 11, fig. 2

Ostrea (Alectryonia) semiarmata Böse, 1906a, p. 44-46, pl. 2, fig. 1; pl. 3, figs. 1, 2; pl. 4, fig. 4; pl. 5, figs. 1, 5.

Shell subtriangular to elongately oval. Surface covered with strong angular ribs, which diverge from the umbo and increase in number ventrally by bifurcation. Growth lamellae clearly marked producing scaley appearance that Böse described. Muscles scar central, oval.

Ostrea semiarmata has been found only in the *Tampsia floriformis* Zone at Bomba; rare.

Figured specimen

Pl. 11, fig. 2
Height 117 mm
Length 69 mm

WSA 15558
Bomba

Ostrea tecticosta Gabb

Pl. 11, figs. 4, 5

Ostrea cfr. *goldfussi* Holzapfel, Böse, 1906a, p. 40-41, pl. 1, figs. 10, 11.

Ostrea tecticosta Gabb, 1860, p. 403, pl. 68, figs. 47, 48; Gardner, 1916, p. 560-561, pl. 24, figs. 2-4; Stephenson, 1923, p. 143-146, pl. 38, figs. 1-9; Wade, 1926, p. 54, pl. 14, figs. 4, 5; Stephenson, 1941, p. 107-108, pl. 14, figs. 5, 6; Richards, 1958, p. 107-108, pl. 16, figs. 13, 14.

This small oyster is common in the shale and siltstone of the *Durania ojan-chalensis* Zone at Cárdenas (Atarjea units 2, 3; Km 420). Stephenson (1941) states that *O. tecticosta* occurs rarely in the *Exogyra ponderosa* Zone of the Coastal Plain, but that it is common in the *Exogyra costata* Zone.

Figured specimen

Pl. 11, fig. 4
Height 20.0 mm
Length 14.9 mm

WSA 15049
Atarjea unit 2

fig. 5
Height 13 mm
Length 6 mm

WSA 15061
Atarjea unit 3

Genus *Flemingostrea* Vredenburg, 1916*Flemingostrea* sp.

Pl. 11, fig. 7

Ostrea glabra Meek and Hayden, Böse, 1906, p. 41-42, pl. 2, fig. 5
Not *Ostrea glabra* Meek and Hayden, 1857, p. 146.

Several poorly preserved ostreids were found in the upper part of the *Arctostrea aguilerae* Zone (Aguaje unit 57); they have the peculiar terebratuloid fold on the ventral margin that is characteristic of *Flemingostrea*. Most of the shell has spalled off these specimens, and the shape is indicated only by the siltstone filling. One specimen shows the concentric ridges and furrows that are typical of the genus.

Flemingostrea sp. is less elongate than *F. glabra* and has a broader dorsal margin. The regular ovate outline and ornamentation of these specimens are more like *F. sigmoidea* (Imlay 1937) than any other species of the genus, although *Flemingostrea* sp. is larger than *F. sigmoidea*. These specimens are not well enough preserved for certain specific identification.

Figured specimen

Pl. 11, fig. 7

Height 66 mm

Length 59 mm

WSA 15015

Aguaje unit 57

Family PECTINIDAE

Genus *Neithea* Drouet, 1824*Neithea youngi*, n. sp.

Pl. 9, figs. 6-8

Subtriangular outline, slightly inequilateral, very inequivalve. Height approximately equal to width. Right valve strongly and evenly convex, semicircular in profile. Hinge line short, less than half the width, almost straight. Beak is strongly incurved and passes beyond hinge line; angular distance from beak to ventral margin is almost 360°. Dorsal slopes are steep, partially overhang auricles. Auricles small, curved; each is separated from the main shell by a deep narrow sulcus.

Right valve ornamented with 16 principal ribs. Counting from either side, ribs 1-4-7-10-13-16 are higher and wider than the two ribs between each pair. Grooves between each rib are almost equal. On a large shell, 38 mm high and 38 mm wide, the mean width of the six larger ribs is 2.2 mm, of the ten smaller ribs 1.7 mm, of the 15 grooves 1.5 mm. The ribs are about half a millimeter high. Ribs and furrows are generally round, only the smallest ribs are very slightly flattened. They are smooth, but may have 1 to 3 faint radial striae. Only in shells greater than 30 mm wide do these striae widen into very shallow grooves thereby dividing some of the principal ribs.

There are 3 low thin secondary ribs between the first major rib and the anterior auricle, 4 low thin secondary ribs between last major rib and the posterior auricle.

Remarks.—*Neithea youngi* belongs to the group of *Neithea alpinus* (d'Orbigny, 1847, which includes *Pecten texanus* Roemer (1852), *Vola subalpina* Böse (1910a), *Neithea georgetownensis* Knicker (1918), *Neithea budensis* Knicker (1918), *Neithea austinensis* Knicker (1918), *Neithea theodori* Knicker (1918), and *Pecten (Neithea) bexarensis* Stephenson (1941). *Neithea youngi* is much more convex than most of these species and may be distinguished from all by its subequal grooves separating simply rounded ribs of two distinct sizes, distributed as described above. *Neithea youngi* most closely resembles *Pecten (Neithea) bexarensis* in shape and ornamentation. However, *N. youngi* does not have the 2 to 5 developed subribs on each principal rib, and its grooves are relatively much wider.

Neithea youngi has been collected from the *Durania ojanchalensis* Zone in railroad cuts between Km 419.5 and Km 419.7; and from the *Arctostrea aguilerae* Zone at Km 414.5.

Figured specimens

Pl. 9, figs. 6, 7 (Holotype)

Height 22.3 mm

Length 21.2 mm

Thickness 11.8 mm (right valve)

WSA 15031

Km 419.5

fig. 8

Height 22 mm

WSA 15587

Km 419.5

Family PTERIIDAE

Genus *Pseudoptera* Meek, 1873

Pseudoptera stephensoni, n. sp.

Pl. 10, figs. 4, 5

Elongate, inequilateral, inflated. Central part of shell very convex, flattening toward postero-ventral margin. Anterior auricle separated from main shell by a deep narrow sulcus. Ornamented with rounded concentric ridges that are irregularly spaced and sometimes discontinuous. Ridges are much weaker on the auricles.

Remarks.—*P. stephensoni* is readily distinguished from other Cretaceous *Pseudoptera* (such as *P. serrata* Stephenson, 1952; *P. hornensis* Stephenson 1952; *P. viana* Stephenson, 1952; and *P. rushana* Stephenson, 1952) by its much stronger concentric ornamentation; on the other species of *Pseudoptera* this ornamentation is weakly developed. However, the ornamentation of *P. stephensoni* is similar to that of *Pseudoptera* sp. (Stephenson, 1952, p. 73, pl. 15, fig 9) from the Woodbine Formation of Texas, although Stephenson's specimen is not complete enough for a positive identification.

At Cárdenas four incomplete specimens were found in the *Tampsia floriformis* Zone (Atarjea unit 64).

Figured specimens

- | | |
|-----------------------------|-----------------|
| Pl. 10, fig. 4 (Holotype) | WSA 15065 |
| Height 25.8 mm (incomplete) | Atarjea unit 64 |
| Length 22.3 mm (incomplete) | |
| fig. 5 | WSA 15559 |
| Height 40.9 mm | Atarjea unit 64 |
| Length 17.0 mm (incomplete) | |

Order PREHETERODONTA

Family TRIGONIIDAE

Genus *Trigonia* Bruguière, 1789

Trigonia eufalensis Gabb

Pl. 10, fig. 6

Trigonia eufalensis Gabb, 1860, p. 396, pl. 68, fig. 32; Whitfield, 1886, p. 113-114, pl. 14, figs. 1-4; Gardner, 1916, p. 582-584, pl. 34, figs. 1, 2; Wade, 1926, p. 61-62, pl. 20, figs. 3, 4; Stephenson, 1955, p. 112-113, pl. 16, figs. 15-17; Richards, 1958, p. 123, 124, pl. 21, fig. 7, pl. 22, fig. 1.

The number and disposition of ribs, lunule ornamentation, and shape of the shell of the Cárdenas specimen correspond to the published descriptions of this species. One specimen was found in the *Tampsia floriformis* Zone (Atarjea unit 54).

Figured specimen

- | | |
|----------------|-----------------|
| Pl. 10, fig. 6 | WSA 15047 |
| Height 12.8 mm | Atarjea unit 54 |
| Length 18.0 mm | |

Order HETERODONTA

Family CARDIIDAE

Genus *Cardium* Linne, 1758

Cardium sp cf. *Cardium uniformis* Weller

Pl. 12, fig. 1

One steinkern was collected from the *Tampsia floriformis* Zone (Aguaje unit 49) that conforms to Richards (1958, p. 209-210, pl. 33, figs. 7-13) description of *C. uniformis* Weller (1907). However, certain identification can not be made without knowing the dentition or ornamentation of this specimen.

Figured specimen

Pl. 12, fig. 1

Height 43 mm

Length 36 mm (incomplete)

Thickness 30 mm

WSA 15027

Aguaje unit 49

Cardium sp. cf. *C. whitfieldi* Weller

Pl. 12, fig. 2

Equivalve, slightly inequilateral, inflated biconvex. Almost circular outline. This internal cast is similar in shape and dimensions to *C. whitfieldi* (Richards, 1958, p. 203, pl. 32, fig. 3). However, neither the dentition nor the ornamentation is preserved, and specific identification is not possible.

Collected from the *Durania ojanchalensis* Zone, Km 419.5.

Figured specimen

Pl. 12, fig. 2

Height 38 mm

Length 34 mm

Thickness 29 mm

WSA 15026

Km 419.5

Subgenus *Granocardium* Gabb, 1869*Cardium* (*Granocardium*) *tabacoensis*, n. sp.

Pl. 12, figs. 8, 12

Inequilateral, convex, elliptical. Hinge line short and straight. Grooves simple, rounded; bear nodes on anterior and posterior flanks. Nodes are oval, elongated parallel to ribs. Nodes are irregularly spaced along the height of the shell. The nodes of some grooves are larger than the nodes of other grooves, but there is no regular alternation; the distinction of rows of large and small nodes is not always clear.

Remarks.—*Cardium* (*Granocardium*) *tabacoensis* differs from other species in this subgenus in the lack of regular alternation of rows of large and small nodes. The nodes are less regularly aligned than in other *Granocardium*. Another *Granocardium* with somewhat irregularly spaced spines or nodes, *Cardium* (*Granocardium*) *lowei* Stephenson (1955), has much wider and flattened ribs.

Only one specimen was found at Cárdenas, in the upper part of the *Durania ojanchalensis* Zone in the western part of the Arroyo del Tabaco.

Figured specimen

Pl. 12, figs. 8, 12 (Holotype)

Height 52 mm (incomplete)

Length 40 mm (incomplete)

WSA 15072

Western Arroyo del
Tabaco

Subgenus *Pachycardium* Conrad, 1869
Cardium (*Pachycardium*) *cardenasensis*, n. sp.
Pl. 12, figs. 5, 6

Inequilateral, convex subovate. Anterior margins broadly rounded, dorsum forms almost a right angle. Broad umbonal ridge in posterior one-quarter of shell. Only ornamentation is irregularly spaced fine growth ridges. Beak low, incurved.

Posterior cardinal tooth large, straight, makes a slight angle with hinge line. Anterior cardinal forms an obtuse angle with hinge line.

Remarks.—This species small for the subgenus, but it is similar in form to other Upper Cretaceous *Pachycardium*, such as *Cardium* (*Pachycardium*) *wadei* Stephenson (1941) and *Cardium* (*Pachycardium*) *stantoni* Wade (1926). However, it is much less elongate than *C. stantoni* and does not have the pronounced sulcus in front of the umbonal ridge of *C. wadei*. The cardinal teeth of the Cárdenas *Pachycardium* are stronger than those of *C. stantoni*, and its posterior cardinal forms a much lower angle with the hinge line than the posterior cardinal of *C. wadei*.

At Cárdenas *Cardium* (*Pachycardium*) *cardenasensis* is rare; it has been found only in the *Tampsia floriformis* Zone (Atarjea unit 64).

Figured specimen

Pl. 12, figs. 5, 6 (Holotype)
Height 36.2 mm
Length 28.6 mm

WSA 15024
Atarjea unit 64

Subgenus *Trachycardium* Moersch, 1853
Cardium (*Trachycardium*) *gordum*, n. sp.
Pl. 12, figs. 3, 4

Equivalve, inequilateral, biconvex inflated, oval to subquadrate. Higher than wide, greatest shell width near ventral margin. Beaks prominent. Lunule and escutcheon short, shallow. Anterior margin round, posterior margin straight. Surface covered by narrow ribs separated by much wider flat bottomed grooves, which bear two very small, low secondary ribs. Primary ribs thicken toward antero-ventral margin, are serrate with many closely but irregularly spaced nodes. There are approximately 29 ribs.

Remarks.—This species resembles *Cardium* (*Trachycardium*) *incomtum* Sowerby from the Trichinopoly Group in India and from the Turonian of Madagascar (Collignon, 1934, p. 23). However, *Cardium* (*Trachycardium*) *gordum* has wider grooves and narrower ribs than *C. incomtum*, and the nodes of *C. incomtum* are much larger.

Two shells of this species were found in the *Tampsia floriformis* Zone in the Arroyo del Aguaje (Aguaje unit 56).

Figured specimen

Pl. 12, figs. 3, 4 (Holotype)

Height 19.5 mm

Length 17.5 mm

Thickness 15.4 mm

WSA 15034

Aguaje unit 56

Family CORBULIDAE

Genus *Corbula* Bruguière, 1792*Corbula crassiplica* Gabb

Pl. 12, fig. 13

Corbula crassiplica Gabb, 1860, p. 394, pl. 68, fig. 25; Whitfield, 1886, p. 178-179, pl. 23, fig. 30; Gardner, 1916, p. 713-715, pl. 43, figs. 6-7; Wade, 1926, p. 96, pl. 31, figs. 9, 13; Stephenson, 1941, p. 234, pl. 44, figs. 16-17; Richards, 1958, p. 251-252, pl. 38, fig. 6.

One specimen of *Corbula crassiplica* was collected from the *Durania ojan-chalensis* Zone in the western part of the Arroyo del Tabaco. Stephenson (1941) states that *C. crassiplica* ranges through the zones of *Exogyra ponderosa* and *Exogyra costata*.

Figured specimen

Pl. 12, fig. 13

Height 5 mm

Length 5 mm (incomplete)

WSA 15039

Western Arroyo del

Tabaco

Family CYPRINIDAE

Genus *Cyprina* Lamarck, 1812*Cyprina mondragoni*, n. sp.

Pl. 13, figs. 1, 2

Equivalve. Width equal to height. Inequilateral; antero-ventral region higher, wider, and less convex than postero-ventral. Concentric ornamentation consists of irregularly spaced small, rounded ribs and grooves, 0.3 — 0.5 mm wide. Some ribs occur in groups of 2 or 3 with very narrow grooves between them; others are separated by smooth bands 1.2 — 2.5 mm wide. Grooves occur adjacent to ribs or between smooth bands. These concentric markings become noticeably stronger at the midheight of the shell. They are present but more crowded and less distinct in the dorsal half of the shell. The only radial markings are straight or slightly crooked faint ridges on the smooth bands between ribs and grooves. These are lower, narrower, and less distinctly bounded than the concentric ribs. The radial ridges are confined to the central and ventral regions of the shell. Beaks large; sharply coil forward near tip. Lunule and escutcheon large and deep. Escutcheon lens shaped. Lunule round dorsally; divided along comisure by extensions of shell margin into kidney shaped halves.

Cyprina mondragoni is similar in form to *C. bifida* Zittel (1865), but *C. mondragoni* is much more convex and has more widely spaced concentric markings.

At Cárdenas *Cyprina mondragoni* occurs in the *Tampsia floriformis* Zone in the Arroyo de la Atarjea (unit 64) and in the Arroyo del Aguaje (unit 49); it is rare in the Cárdenas Formation.

Figured specimen

Pl. 13, figs. 1, 2 Holotype
Height 39 mm
Length 37 mm
Thickness 30 mm

WSA 15031
Aguaje unit 49

Genus *Veniella* Stoliczka, 1871

Veniella conradi (Morton)

Pl. 12, figs. 14, 15

Veniella conradi Morton, 1833, p. 294, pl. 8, figs. 1, 2; Morton, 1834, p. 67, pl. 8, figs. 1, 2.

Veniella conradi (Morton), Stoliczka, 1871, p. 190; Whitfield, 1886, p. 144-145, pl. 19, figs. 8-10; Gardner, 1916, p. 643, pl. 38 figs. 2-7; Stephenson, 1941, p. 168-170, pl. 27, figs. 6-8, Stephenson, 1955, p. 117, pl. 18, figs. 1, 2; Richards, 1958, p. 173, 174, pl. 26, fig. 11; pl. 28, figs. 3, 5; pl. 29, fig. 14.

Stoliczka (1871) replaced the preoccupied generic name *Venilia* with *Veniella*. Stephenson (1941) states that this variable species ranges through the zones of *Exogyra ponderosa* and *Exogyra costata* in the Atlantic and Gulf Coastal Plains. A right and a left valves were collected from the *Durania ojanthalensis* Zone (Atarjea unit 2). These correspond closely to the figures of *V. conradi* except that the lunule is less well marked than in Stephenson's Pl. 27, fig. 6. The umbonal ridge is very sharply set off.

Figured specimen

Pl. 12, figs. 14, 15
Height 29.8 mm
Length 32.0 mm

WSA 15048
Atarjea unit 2

Family KELLIELLIDAE

Genus *Kelliella* Sars, 1865

?*Kelliella* sp.

Pl. 12, fig. 11

A fragment of a small bivalve shell was found in the *Tampsia floriformis* Zone at Bomba that is similar in shape and ornamentation to *Kelliella? evansi*.

Gardner (1933, pl. 16, figs. 5, 6). The Cárdenas specimen is ornamented with broad, flat concentric ridges separated by narrow grooves.

Figured specimen

Pl. 12, fig. 11
Height 8 mm
Length 7 mm

WSA 15590
Bomba

Family MACTRIDAE

Genus *Priscomactra* Stephenson, 1952

?*Priscomactra* sp. cf. *Priscomactra cymba* Stephenson, 1952

Pl. 12, figs. 9, 10

Slightly inequilateral, convex, subtriangular. Anterior and posterior margins rounded, ventral margin gently rounded. Surface marked only by fine concentric striae. Broad umbonal ridge near posterior margin. Beak low.

Remarks.—This specimen from the *Tampsia floriformis* Zone (Atarjea unit 64) is externally very similar to *Priscomactra cymba* Stephenson (1952, p. 124-125, pl. 31, figs 6, 10). Stephenson (1952, p. 124) states that *Cymbophora* Gabb, *Spisula* Gray, *Mactra* Linne, and *Priscomactra* Stephenson are similar in outline, form, and surface features, but differ in ligament apparatus and certain hinge features. Without knowing the hinge characters of this specimen, it cannot be placed with confidence in any of these genera although its form is more nearly like that of *Priscomactra cymba* than that of any other species I have seen.

Figured specimen

Pl. 12, figs. 9, 10
Height 17.6 mm
Length 19.5 mm
Thickness 7.0 mm

WSA 15037
Atarjea unit 64

Family PHOLADOMYACIDAE

Genus *Pholadomya* Sowerby, 1823

Pholadomya coahuilensis Imlay

Pl. 13, figs. 5, 6

Pholadomya coahuilensis Imlay, 1937, p. 1833, pl. 15, fig. 3.

Two incomplete shells of *P. coahuilensis* were found in the middle part of the *Tampsia floriformis* Zone in the Arroyo de la Atarjea, (Atarjea unit 76). These *Pholadomya* are slightly larger than Imlay's figured specimen. However, the shape and arrangement of the costae are identical. Moreover, the more anterior position of the beaks compared with similar forms, such as *P. littlei* Gabb, serve to identify the Cárdenas material with *P. coahuilensis*.

Imlay found *P. coahuilensis* as float in the El Pozo-Boquillas area, Coahuila, México, in the Difunta Formation, *Exogyra ponderosa* Zone.

Figured specimen

Pl. 13, figs. 5, 6

Height 56.7 mm

Length 79.5 mm

WSA 15043

Atarjea unit 76

Pholadomya sp.

Pl. 13, fig. 7

Equivalve, very inequilateral, procline, elongate subquadrate outline. Radial ribs sharp; wide flat grooves between them. Concentric markings are weak in ventral half of shell.

One fragile internal mold was found in the *Durania ojanchalensis* Zone near Km. 419.7.

Figured specimen

Pl. 13, fig 7

Height 16 mm

Length 29 mm

Thickness 13 mm

WSA 15028

Km 419.7

Family THRACIDAE

Genus *Cymella* Meek, 1864

Cymella bella Conrad, 1875

Cymella bella mexicana, n. subsp.

Pl. 12 fig. 7

Equivalve, slightly inequilateral, biconvex, oval. There are approximately 15 broad concentric ridges separated by narrow, shallow depressions. Radial grooves are faintly impressed on external shell layer, but where this is worn off the concentric depressions and radial grooves are of nearly equal strength; central part of shell cancellate. Radial grooves and ribs are confined to medial one-third of shell; 5 or 6 broad ribs between the radial depressions.

Remarks.—This subspecies is very similar to *Cymella bella bella* Conrad (1875), *Cymella meeki* Whitfield (1886), and *Cymella bella* var. *texana* Stephenson (1941). All have cancellate ornamentation, but they differ in the size and number of radial markings. *Cymella meeki* has the radial ribs and depressions over nearly or quite the entire shell; on *C. bella texana* a "dozen or more rather broad, round-crested radiating ribs with narrower interspaces, extend from the beak down the central part of the shell, leaving a little more than the anterior fourth and the posterior fourth unribbed" (Stephenson, 1941, p. 165). *C. bella bella* Conrad has 6 to 9 acute ribs. *C. bella mexicana* has only 5 or 6

broad ribs, which are confined to the medial third of the shell. Stephenson (1941) states that "the shells of this group (*C. bella texana*) show considerable variation, from those having the relatively few and typically narrow costae of *C. bella* to those having more and broader costae like *C. bella texana*..." Whether this range of variation included forms with a few broad ribs (*C. bella mexicana*) can not be determined from Stephenson's discussion or figures.

If *C. bella* var. *texana* and *C. bella mexicana* are shown to belong to the same subspecies, they should, at any rate, be united under the name *C. bella mexicana*.

Cymella bella mexicana is from the *Durania ojanchalensis* Zone (Atarjea unit 2); it is rare in the Cárdenas Formation.

Figured specimen

Pl. 12, fig. 7 (Holotype)
Height 22.3 mm
Length 27.8 mm

WSA 15025
Atarjea unit 2

Family TELLINIDAE

Genus *Linearia* Conrad, 1860

?*Linearia belli*, n. sp.

Pl. 13, figs. 3, 4

Equivalve, nearly equilateral, biconvex, subquadrate. Concentric ridges are sharply defined, nodose, rounded, and much higher than radial costae. Nodes occur at the intersections of concentric ridges with radial costae. The ridges pass over the costae but do not interrupt them as they appear to do without magnification. Ridges and costae are nearly equal in size on antero dorsal and postero-dorsal margins; there the ornamentation is cancellate. Although the ridges are not regularly spaced, they usually occur at intervals of 0.8 to 1.2 mm.

Hinge line straight, slightly less than shell length. Beaks slightly prominent. Anterior and posterior cardinal areas are open, lens-shaped; posterior more open than anterior, greatest inflation above mid-height, compressed marginally.

Remarks.—?*Linearia belli* has the same type of ornamentation and similar form as other Upper Cretaceous *Linearia* (*L. metastriata* Conrad, 1860; *L. ornatissima* Weller, 1907; *L. lirulifera* Stephenson, 1954), but it cannot be placed in this genus with certainty without knowing its dentition. It has a more pronounced umbonal ridge than the named species of *Linearia*.

?*Linearia belli* has much finer ornamentation than *L. metastriata* Conrad and *L. ornatissima* Weller. It most closely resembles *L. lirulifera* Stephenson (1954, p. 34), but ?*L. belli* has more widely spaced ridges and costae, is larger and more quadrate, and has much straighter hinge line.

Well preserved specimens of ?*L. belli* are common in the *Durania ojanchalensis* Zone in the Arroyo de la Atarjea (Atarjea units 2, 19, and 20).

Figured specimen

Pl. 13, figs. 3, 4 (Holotype)

Height 21.7 mm

Length 29.6 mm

Thickness 11.4 mm

WSA 15029

Atarjea unit 19

Genus *Tellina* Linne, 1758*?Tellina* sp.

Pl. 13, fig. 8

Equivalve, inequilateral, biconvex, compressed ventrally, oval outline. Anterior margin rounded, ventral margin straight, posterior margin more sharply rounded than anterior. Surface marked by flat concentric ridges separated by narrow grooves. Umbo inflated. Lunule deep, escutcheon open posteriorly.

A few poorly preserved specimens of *?Tellina* were found in the *Durania ojanchalensis* Zone (Atarjea unit 2).

Figured specimen

Pl. 13, fig. 8

Height 13 mm

Length 21 mm

Thickness 7 mm

WSA 15033

Atarjea unit 2

Family VENERIDAE

Genus *Aphrodina* Conrad, 1869*?Aphrodina* sp.

Pl. 13, figs. 9, 10

Equivalve, inequilateral, biconvex, subovate outline. Antero-ventral margin widely rounded, antero-dorsal margin concave forming a lunule. Ventral margin broadly curved. Postero-ventral margin rounded more sharply than antero-ventral. Postero-dorsal margin nearly straight. Shell inflated in dorsal three-quarters, compressed at ventral margin. Umbo prominent, excavated anteriorly to form well-marked lunule. Depressed escutcheon, but not so clearly set off as lunule. Surface marked by numerous irregularly spaced concentric growth striae.

Remarks.— *?Aphrodina* sp. cannot be placed with certainty in any venerid genus without knowing its hinge characters. *?Aphrodina* sp. is similar in general form to *Aphrodina tippiana* (Conrad, 1858), but *?Aphrodina* sp. is much less strongly sculptured and has a depressed escutcheon compared to the flattened escutcheon of *A. tippiana*. *?Aphrodina* sp. is abundant in the *Tampsia floriformis* Zone in the Arroyo de la Atarjea (Atarjea unit 64).

Figured specimen

Pl. 13, figs. 9, 10
 Height 30.5 mm
 Length 35.2 mm
 Thickness 22.4 mm

WSA 15032
 Atarjea unit 64

Class GASTROPODA
 Order MESOGASTROPODA
 Superfamily CERITHIACEA
 Family ARCHITECTONICIDAE
 Genus *Architectonica* Bolten, 1798
 ?*Architectonica roddai*, n. sp.

Pl. 14, figs. 2, 3

Trochiform, umbilicate, spiral angle 70° . Suture deeply impressed; whorls overhang suture. Six whorls ornamented only by fine spiral lirae that weaken toward the periphery. Base smooth. Umbilicus narrow, deep, ornamented with faint spiral lirae.

Remarks.—? *Architectonica roddai* is questionably placed in *Architectonica* because it has a higher spire and narrower umbilicus than are normal for this genus, which, however, it more closely resembles than any other genus.

? *Architectonica roddai* is readily distinguished from other Upper Cretaceous *Architectonica* by its smooth, sharply set off whorls. It occurs in the *Tampsia floriformis* Zone at Cárdenas (Atarjea unit 76, and Km 415.4).

Figured specimen

Pl. 14, figs. 2, 3
 Height 11.8 mm
 Width 10.7 mm

WSA 15086
 Km 415.4

Architectonica sp.

Pl. 14, fig. 12

One specimen of *Architectonica* that is too worn for specific identification was found in the *Durania ojanchalensis* Zone (Atarjea unit 18). It is trochoid, with a flat spire and flat sided whorls. The suture is slightly impressed and the spiral angle is 83° .

Figured specimen

Pl. 14, fig. 12
 Height 10 mm
 Width 16 mm

WSA 15089
 Atarjea unit 18

Family TURRITELLIDAE

Genus *Turritella* Lamarck, 1799*Turritella guionae*, n. sp.

Pl. 14, fig. 11

Small, slender, turreted shell, spiral angle 15° . Whorl sides flat; periphery and base inflated, overhang deeply impressed suture. Sutural depression wide. There are five major nodose spiral lirae. The posterior three are coarser and more widely separated than the anterior two. There is a secondary spiral lira between each pair of major lirae and one in the sutural depression.

Remarks.—This species belongs to the group of *T. vertebroides* Morton (1834) but is easily distinguished from similar forms by its slightly nodose lirae and deeply impressed wide sutural depression.

Turritella guionae is common in the *Durania ojanchalensis* Zone (Atarjea unit 2; western part of the Arroyo del Tabaco; Km 419.5; Km 419.7).

Figured specimen

Pl. 14, fig. 11 (Holotype)
Height 18 mm (incomplete)
Width 6 mm

WSA 15503
Western Arroyo del Tabaco

Turritella trilira Conrad

Pl. 14, fig. 8

Turritella trilira Conrad, 1860, p. 285; Sohl, 1960, p. 71-73, Pl. 7, figs. 8, 10, 17, 20, 27, 28 (synonymy to date).

Turritella trilira has been reported from Maryland to México in the *Exogyra ponderosa* and *Exogyra costata* Zones. At Cárdenas it occurs in the *Arctostrea aguilerae* Zone (Km 414.5 and Atarjea unit 58); rare.

Figured specimen

Pl. 14, fig. 8
Height 10 mm (incomplete)
Width 4 mm

WSA 15513
Km 415.5

Turritella waitzi Böse

Pl. 14, fig. 4

Turritella Waitzi Böse, 1906a, p. 64-65, pl. 14, fig. 7; pl. 15, fig. 1.

Slender, turreted, spiral angle 20° . Sutural depression wide and deep, bounded anteriorly and posteriorly by slightly carinate spiral ribs. Sides of whorls concave, ornamented with three slightly nodose lirae between the major

ribs. Anterior and posterior margins of each whorl slope steeply to suture. Because of deep sutural depression, shell tends to break into individual whorls.

Turritella waitzi is rare at Cárdenas; it occurs in the *Tampsia floriformis* Zone (Aguaje unit 54 and Bomba).

Figured specimen

Pl. 14, fig. 4
Height 11 mm (4 whorls)
Width 6 mm

WSA 15516
Aguaje unit 54

Turritella potosiana Böse

Pl. 14, figs. 6, 16

Turritella potosiana Böse, 1906a, p. 62-64, pl. 14, figs. 2, 4, 8-10; pl. 15, fig. 2.

Böse amply described the form and complex ornamentation of *T. potosiana*. This species is abundant in the *Tampsia floriformis* Zone at Cárdenas (Atarjea unit 64; Aguaje units 55, 56, 57, 59; Bomba; Km 415.4).

Figured specimen

Pl. 14, fig. 6
Height 39 mm
Width 14 mm
fig. 16
Height 43 mm
Width 13 mm

WSA 15077
Bomba

WSA 15577
Aguaje unit 56

Turritella sp.

Pl. 14, fig. 17

Large turreted shell, spiral angle 30° . Whorls broadly rounded, sutural depression deep. The only ornamentation that can be observed on the mold are two spiral grooves, which are centrally located on the whorls.

This steinkern is similar in the shape of the whorls and sutural depression to Dacqué's (1939) *Turritella multistriata* Fric (non Reuss). Dacqué's specimen, however, has only one spiral groove, whereas the *Turritella* sp. from Cárdenas has two. Found in the *Tampsia floriformis* Zone, near Km 415.5.

Figured specimen

Pl. 14, fig. 17
Height 76 mm (5 whorls)
Width 34 mm

WSA 15093
Km 415.4

Family CERITHIIDAE

Genus *Cerithium* Adanson, 1757*Cerithium potosianum* Böse

Pl. 14, fig. 14

Cerithium potosianum Böse, 1906a, p. 69, 79, pl. 15, figs. 23, 25, 26.

Cerithium potosianum has three spirals of nodes on each whorl; the posterior nodes are larger than those of the other two spirals. Spiral angle 20° . From his well preserved material, Böse (1906a) observed that on the anterior whorls there are two secondary spiral lirae anterior to three primary nodose spirals.

Cerithium potosianum is common in the *Durania ojanchalensis* Zone; collected from Km 419.4 and Atarjea unit 20.

Figured specimen

Pl. 14, fig. 14

Height 23 mm (incomplete)

Width 10 mm

WSA 15091

Atarjea unit 20

Cerithium subcarnaticum Böse

Pl. 14, fig. 9

Cerithium subcarnaticum Böse, 1906a, p. 67-69, pl. 15, figs. 19-22.

Only one very poorly preserved specimen of *C. subcarnaticum* was found in the *Tampsia floriformis* Zone (Aguaje unit 55). Böse described and figured several well preserved specimens from near Km. 415.

Figured specimen

Pl. 14, fig 9

Height 13 mm (incomplete)

Width 10 mm (incomplete)

WSA 15090

Aguaje unit 55

Cerithium sp. aff. *C. simonyi* Zekeli

Pl. 14, fig. 5

Cerithium aff. *Simonyi* Zekeli, Böse, 1906a, p. 73, pl. 16, figs. 1, 2.

Böse (1906a) found two very poorly preserved specimens of *Cerithium* that were similar to *C. simonyi*; the Cárdenas *Cerithium* sp. has two spirals of nine spines on each whorl, *C. simonyi* has seven spines on each spiral. The specimens I collected are in even poorer condition than those of Böse; they provide no additional information about the shell.

Cerithium sp. aff. *simonyi* is rare at Cárdenas; it occurs in the *Tampsia floriformis* Zone (Atarjea unit 76, Aguaje unit 56).

Figured specimen

Pl. 14, fig. 5
Height 103 mm
Width 45 mm

WSA 15083
Atarjea unit 76

Superfamily NERINEACEA

Family NERINEIDAE

Genus *Nerinea* DeFrance, 1825

Nerinea burckhardti Böse

Pl. 14, fig. 13

Nerinea (Plesioptygmatis) burckhardti Böse, 1906a, p. 66-67, pl. 15, figs. 3-13.

Slender conical shell, spiral angle 10° . Whorls concave, suture slightly impressed.

Böse found abundant specimens of this species between Km 418 and Km 419, which includes the upper part of the *Arctostrea aguilarae* Zone and the lower part of the *Tampsia floriformis* Zone. I have found *N. burckhardti* only in the *Tampsia floriformis* Zone (Atarjea unit 81).

Figured specimen

Pl. 14, fig. 13
Height 18 mm (4 whorls)
Width 9 mm

WSA 15085
Atarjea unit 81

Superfamily NATICACEA

Family AMPULLINIDAE

Genus *Pseudamaura* Fischer, 1885

Pseudamaura altirata (Böse)

Pl. 14, figs. 1, 7

Natica (Ampullina) altirata Böse, 1906a, p. 61-62, pl. 13, figs. 2, 3, 7.

High spire, spiral angle 60° , six whorls, whorls much wider than high. Anterior of each whorl almost straight, bends sharply to posterior to form an almost flat ramp. Böse states that umbilicus is half covered and crescent shaped. Suture appears to be in shallow channel.

Böse compared this species to *Natica bulbiformis* Sowerby (1832) but believed *N. altirata* distinct because of its crescent shaped umbilical opening and aperture. However, I believe *N. altirata* and *N. bulbiformis* to be congeneric and therefore in the genus *Pseudamaura*, of which *N. bulbiformis* is the type species.

Poorly preserved shells of *P. altirata* are common in the *Tampsia floriformis* Zone (Atarjea units 64, 72; Aguaje unit 57; Bomba).

Figured specimens

Pl 14, fig. 1

Height 16 mm (incomplete)

Width 16 mm (incomplete)

WSA 15501

Aguaje unit 57

fig. 7

Max. width 21 mm

WSA 15589

Bomba

Order NEOGASTROPODA

Superfamily VOLUTACEA

Family VOLUTIDAE

Genus *Longoconcha* Stephenson, 1941*Longoconcha* sp.

Pl. 14, fig. 15

Abundant internal molds of a *Longoconcha* were found in the *Tampsia floriformis* Zone (Atarjea unit 82). These molds have a rather straight sided whorl outline, steeply inclined toward the axis. Spiral angle 20°. Body-whorl is shorter than on similar molds of *Longoconcha* from the Prairie Bluff Chalk of Mississippi (Sohl, 1964, p. 252, pl. 37, figs. 10-12, 14, 18).

Figured specimen

Pl. 14, fig. 15

Height 30 mm (6 whorls)

Width 11 mm

WSA 15512

Atarjea unit 82

Order CEPHALASPIDEA

Superfamily ACTEONACEA

Family ACTEONIDAE

Genus *Actaeonella* d'Orbigny, 1842*Actaeonella coniformis* Böse

Pl. 7, figs. 3-5

- Actaeonella* (*Trochactaeon*) *coniformis* Böse, 1906a, p. 78-79, pl. 16, figs. 12-21.
Actaeonella (*Trochactaeon*) *acutissima* Böse, 1906a, p. 79-80, pl. 16, figs. 4-11.
Actaeonella (*Trochactaeon*) *occidentalis* Böse, 1906a, p. 81-82, pl. 17, figs. 2-10.
Actaeonella (*Trochactaeon*) *inconstans* Böse, 1906a, p. 83-84, pl. 17, figs. 11-19.
Actaeonella (*Trochactaeon*) *irregularis* Böse, 1906a, p. 84-85, pl. 17, figs. 20-27.
Actaeonella (*Trochactaeon*) *brevis* Böse, 1906a, p. 85-86, pl. 18, figs. 1-7.
Actaeonella (*Trochactaeon*) *planilateris* Böse, 1906a, p. 87-88, pl. 18, figs. 8-13.
Actaeonella (*Trochactaeon*) *potosiana* Böse, 1906a, p. 88-89, pl. 18, figs. 14-25.
Actaeonella (*Trochactaeon*) *variabilis* Böse, 1906a, p. 90-91, pl. 18, figs. 26-34.

Böse named nine new species of *Actaeonella* from the same horizon in the Cárdenas Formation. In his key to these species the first major division is into

forms with flat whorl sides and forms with convex whorl sides. These two groups are each subdivided according to the shape of the spire: conical, obtuse, or irregular. These six groups are further divided into forms that have smooth sided spires and forms that have "stepped" whorls (suture impressed).

Böse explained his approach to naming species of *Actaeonella*, stating that each locality had a distinctive development of *Actaeonella* and that it would be good to recognize each different form with a distinct name even though one realizes that all these species of *Actaeonella* are intimately related to each other. In his descriptions of the species Böse states that: *A. acutissima* grades into the forms that he described as *A. coniformis*; *A. coniformis*, *A. acutissima*, *A. occidentalis*, *A. inconstans*, and *A. variabilis* are very variable; and that *A. irregularis* is similar to *A. variabilis*, which is similar to *A. conica* Münster, which is intimately related to *A. coniformis*.

These different forms of *Actaeonella* are common both in the *Durania ojan-chalensis* Zone and in the *Tampsia floriformis* Zone, particularly in the rudist-bearing beds. Although the end members are distinct, there are series of forms gradational between each of Böse's species.

Based on Böse's own descriptions and the specimens I have collected at Cárdenas, I do not believe that a meaningful taxonomic distinction can be made between these forms of *Actaeonella*. Böse's (1906a) nine species are members of the same variable species, *A. coniformis* Böse.

Actaeonella coniformis ranges through all three zones of the Cárdenas Formation, although it is rare in the *Arctostrea aguilerae* Zone (Atarjea units 2, 20, 62, 65, 87; Aguaje units 5, 31, 45, 55; Bomba; western Arroyo del Tabaco; Km 419.5).

Figured specimens

Pl. 7 fig. 3

Height 54 mm

Width 18 mm

fig. 4

Height 45 mm

Width 25 mm

Fig. 5

Height 34 mm

Width 18 mm

WSA 15554

Atarjea unit 65

WSA 15585

Atarjea unit 65

WSA 15586

Atarjea unit 65

Superfamily BUCCINACEA

Family BUCCINIDAE

Genus *Stantonella* Wade, 1926

?*Stantonella* sp.

Pl. 14, fig. 10

Internal molds of a high spired shell. Whorls inflated, ramp almost flat. Spiral angle 70°. Strong transverse ribs preserved on one specimen. These molds

resemble molds of ?*Stantonella* figured by Sohl (1964, pl. 23, figs. 19, 18) from the Prairie Bluff Chalk in Mississippi, but insufficient characters are preserved for definite identification.

?*Stantonella* sp. is rare in the Cárdenas Formation. The molds of ?*Stantonella* sp. occur in the *Tampsia floriformis* Zone in the Arroyo del Aguaje (Aguaje units 54, 56).

Figured specimen

Pl. 14, fig. 10

Height 55 mm

Width 38 mm

WSA 15095

Aguaje unit 56

Phylum ECHINODERMATA

Class ECHINOIDEA

Order STIRODONTA

Genus *Phymosoma* D' Archiac and Haime, 1853

Phymosoma sp.

Pl. 15, fig. 6

Primary tubercles apparently extend along margin; poriferous zones biserial.

A fragment of this regular echinoid was found in the *Arcoctrea aguilerae* Zone in the Arroyo de la Atarjea.

Figured specimen

Pl. 15, fig. 6

Height 19 mm

WSA 15537

Atarjea unit 57

Order CASSIDULOIDA

Genus *Phyllobrissus* Cotteau, 1860

?*Phyllobrissus* sp.

Pl. 15, figs. 4, 5

Horizontal outline oval, truncated behind. Apical system and peristome anteriorly eccentric. Periproct in large sulcus that extends almost to the height of the apex. Margins inflated, upper surface evenly arched, lower surface concave. Petals long and narrow.

Five specimens of ?*Phyllobrissus* sp. were found in the *Durania ojanchensis* Zone near Km. 419.7.

Figured specimen

Pl. 15, figs. 4, 5

Height 11 mm

Width 18 mm

Length 23 mm

WSA 15541

Km 419.7

Genus *Hardouinia* Haime, 1853

Hardouinia potosiensis Lambert

Pl. 15, figs. 1, 2

Hardouinia potosiensis Lambert, 1936, p. 5-6, pl. 1, figs. 2, 3, 4.

Large species, oval, rounded anterior, a little enlarged and subrostrate posteriorly. Upper surface subconical, apical system eccentric to anterior, shows four genital pores. Petals relatively narrow, short, lanceolate, closed. Posteriors do not reach level of periproct, which is elongated and acuminate. Lower surface slightly concave toward peristome, which is subcentral, less eccentric than apex; dominated by salient bourrelets between which are large phyllodes.

Hardouinia potosiensis occurs in the *Durania ojanchalensis* Zone; collected from Km 419.5 and Atarjea unit 17. It is common at those two localities.

Figured specimen

Pl. 15, figs. 1, 2

Height 23 mm

Width 52 mm

Length 57 mm

WSA 15540

Km 419.5

Order SPATANGOIDA

Family SPATANGIDAE

Genus *Hemiaster* Desor, 1847

Hemiaster sp.

Pl. 15, fig. 3

Horizontal outline round, indented in front, flattened behind. Upper surface high, margins inflated, lower surface slightly inflated. Paired petals straight; anterior pair the longer.

Two specimens of *Hemiaster* sp. have been found in the upper part of the *Arctostrea aguilerae* Zone at Cárdenas (Atarjea unit 57; Km 414.5).

Figured specimen

Pl. 15, fig. 3

Height 21 mm

Length 29 mm

Width 30 mm

WSA 15542

Km 414.5

Phylum ANNELIDA

Class CHAETOPODA

Order TUBICOLA

Family SERPULIDAE

Genus *Hamulus* Morton, 1834

Hamulus onyx Morton

Pl. 15, fig. 8

Hamulus onyx Morton, 1834, p. 73, 74, pl. 2, fig. 8; pl. 16, fig. 5; Wade, 1926, p. 30-31, pl. 2, figs. 4-7, 12; Stephenson, 1941, p. 58, 60, pl. 4, figs. 8, 9 (synonymy to date).

One incomplete specimen of *H. onyx* was found in the *Durania ojanchalensis* Zone in a railroad cut near Km 419.5. Stephenson (1941) states that *Hamulus onyx* has been found from South Carolina to Cárdenas and that it ranges through the zones of *Exogyra ponderosa* and *Exogyra costata*.

Figured specimen

Pl. 15, fig. 8

Height 10 mm

Diam. 3.6 mm

WSA 15556

Km 419.5

Hamulus angulatus Wade

Pl. 15, fig. 7

Hamulus angulatus Wade, 1926, p. 31, pl. 2, figs. 14-17.

One broken tube of a *Hamulus* was found in the *Durania ojanchalensis* Zone in the western part of the Arroyo del Tabaco; it is probably conspecific with *H. angulatus*. The Cárdenas specimen has the "six low, sharp angular axial ridges; (and) interaxial spaces broad and gently concave..." (Wade, 1926, p. 31) of *H. angulatus*. The axial line on alternate interaxial spaces is less consistently developed on the Cárdenas tube. It is sharp and clear on one interaxial space, present but not clearly marked on a second, and not discernible on the third. This variation may have been produced by partial erosion of the tube.

Wade collected this species from the Ripley Formation in Tennessee.

Figured specimen

Pl. 15, fig. 7

Height 8.7 mm

Diam. 2.7 mm

WSA 15531

Western Arroyo del Tabaco.

Phylum BRACHIOPODA
 Class ARTICULATA
 Order TEREBRATULIDA
 Family ZEILLERIIDAE
 Genus *Kingena* Davidson, 1852
?Kingena sp.
 Pl. 16, figs. 4 6

Outline oval, pedicle beak incurved. Brachial valve more inflated than pedicle valve. Very weak, broad sulcus on anterior margin of pedicle valve with corresponding fold on brachial valve. Foramen round. Placement of these specimens is uncertain because cardinalia are unknown.

?Kingena sp. occurs in the lower part of the *Arctostrea aguilerae* Zone in the Arroyo de la Atarjea (Atarjea unit 30) and in the *Durania ojanchalensis* Zone at Km 419.5.

Figured specimens

Pl. 16, fig. 4	WSA 15533
Height 16 mm	Km 419.5
Width 16 mm	
Thickness 9 mm	

figs. 5, 6	WSA 15532
Height 11 mm	Atarjea unit 30
Width 10 mm	
Thickness 6 mm	

Phylum COELENTERATA
 Class ANTHOZOA
 Order SCLERACTINIA
 Family CALAMOPHYLLIDAE
 Genus *Epistreptophyllum* Milaschewitch, 1875
?Epistreptophyllum sp.
 Pl. 16, figs. 1, 2

Solitary, slender cylindrical, epitheca not well developed.

?Epistreptophyllum sp. occurs in the *Tampsia floriformis* Zone in the Arroyo de la Atarjea (Atarjea unit 76); it is rare at Cardenas.

Figured specimen.

Pl. 16, fig. 1	WSA 15527
Height 28 mm	Atarjea unit 76
Diam. 5 mm	

fig. 2
Height 13 mm
Diam. 6 mm

WSA 15574
Atarjea unit 76

Family AGARICIIDAE

Genus *Trochoseris* Milne-Edwards and Haime, 1849

Trochoseris sp.

Pl. 16, figs. 8, 9

Solitary, trochoid to almost cylindrical, no epitheca.

This small coral is common in the *Tampsia floriformis* Zone. (Atarjea units 72, 76; Aguaje units 56, 54; and Bomba).

Figured specimen.

Pl. 16, fig. 9
Height 21 mm

WSA 15519
Aguaje unit 56

fig. 8
Diam. 14 mm

WSA 15575
Aguaje unit 56

Family SYNASTREIDAE

Genus *Synastrea* Milne-Edwards and Haime, 1848

Synastrea sp.

Pl. 15, fig. 10

Thamnasteroid, corallites united to summit. Colony almost spherical.

Found in the *Tampsia floriformis* Zone in the Arroyo del Aguaje (Aguaje unit 56); it is rare in the Cárdenas Formation.

Figured specimen.

Pl. 15, fig. 10
Diam. 54 mm

WSA 15565
Aguaje unit 56

Family FAVIIDAE

Genus *Leptoria* Milne-Edwards and Haime, 1848

Leptoria sp.

Pl. 16, fig. 3

Meandroid, collines are simple, fused, septothecal.

One large specimen was found in the western part of the Arroyo del Aguaje *Arctostrea aguilerae* Zone.

Figured specimen.

Pl. 16, fig. 3
Height 87 mm
Width 79 mm

WSA 15518
Western Arroyo del Aguaje

Genus *Cladocora* Ehrenburg, 1834

Cladocora sp.

Pl. 16, fig. 7

Phaceloid colonies of *Cladocora* sp. are common at several horizons in the upper part of the *Arctostrea aguileræ* Zone and in the *Tampsia floriformis* Zone in the Arroyo de la Atarjea, as high as Atarjea unit 83.

Figured specimen.

Pl. 16, fig. 7
Corallite diams. 2-3 mm

WSA 15564
Atarjea unit 83

Family ASTROCOENIIDAE

Genus *Lithostrontionoides* Alloiteau, 1952

?*Lithostrontionoides* sp.

Pl. 15, fig. 9

This massive astrocoeniid with small corallites and thin walls was found in the western part of the Arroyo del Aguaje, *Arctostrea aguileræ* Zone.

Figured specimen.

Pl. 15, fig. 9
Corallite diams. 1-2 mm

WSA 15566
Western Arroyo del Aguaje

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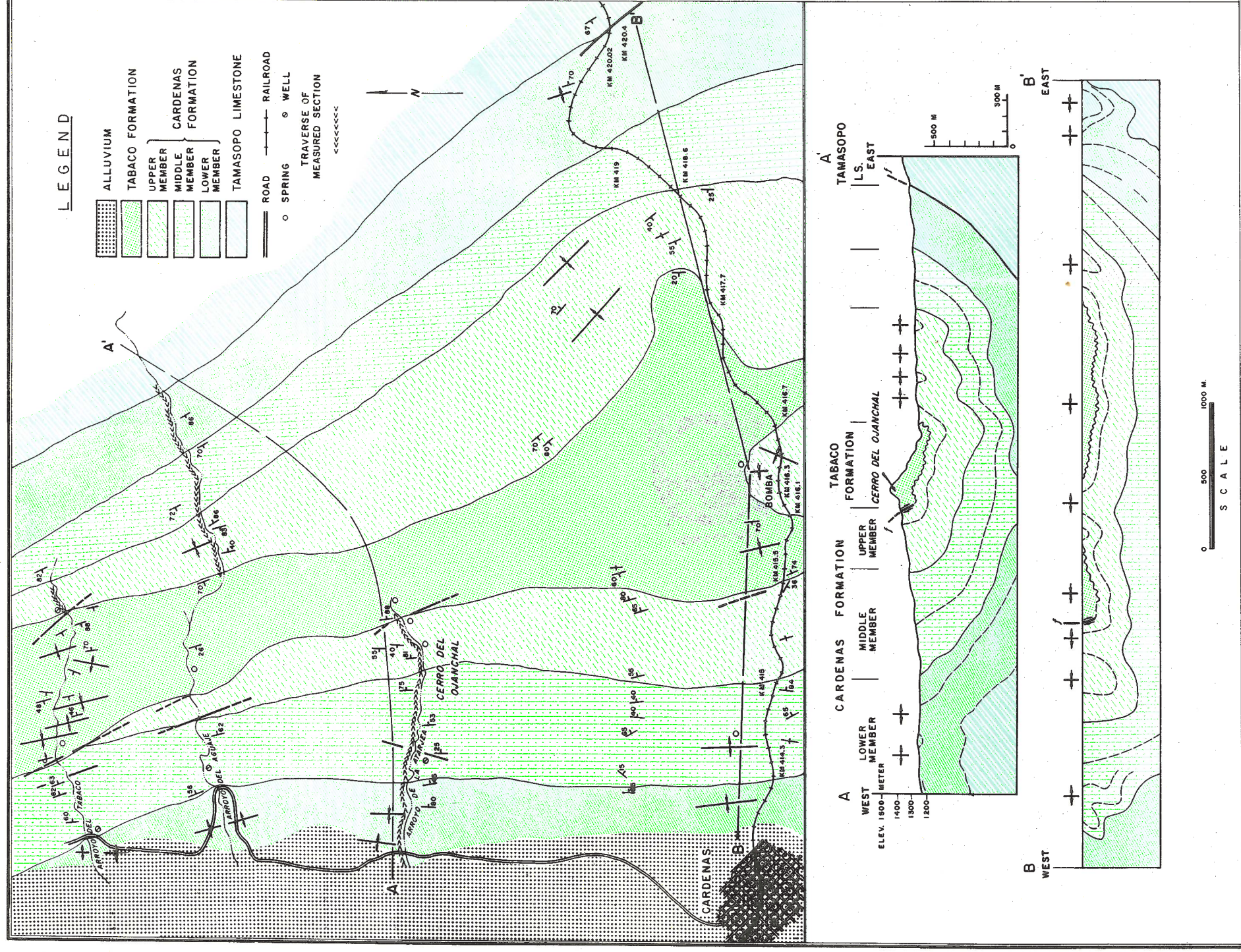
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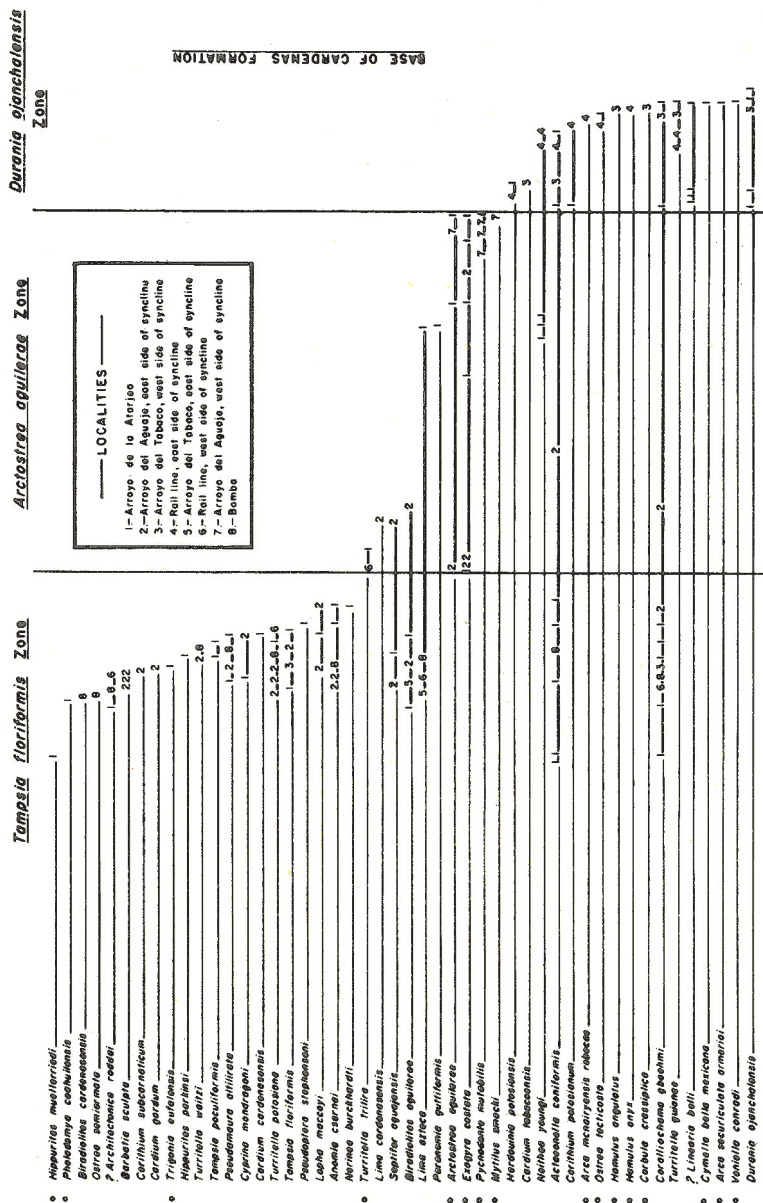
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PLATES



Geologic map and cross sections of the Cárdenas syncline

RANGES OF SPECIES IN THE ZONES OF THE CARDENAS FORMATION



Ranges of species in the zones of the Cárdenas Formation

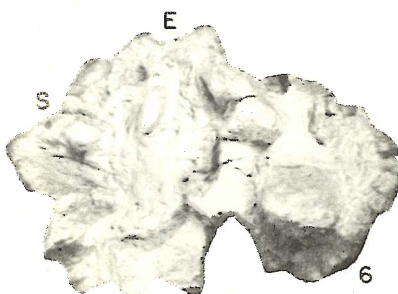
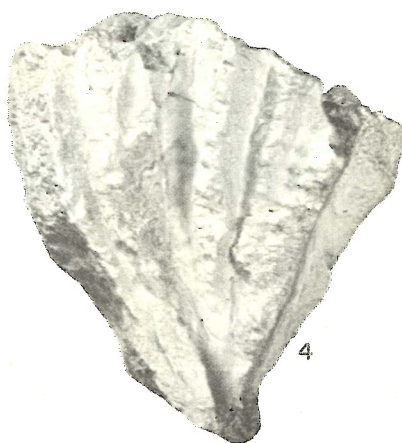
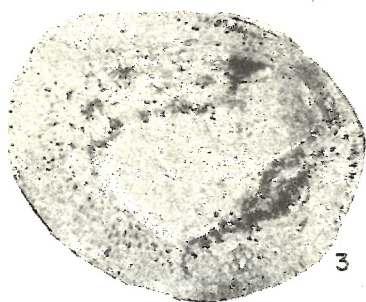
PLATE 3

Figs. 1-3. *Coralliochama gboehmi* Böse

1) Both valves of WSA 15567; 2) fragment of WSA 15582, weathered interior of free valve showing longitudinal canals; 3) peel of transverse section of free valve of WSA 15583 showing marginal longitudinal canals (lower right) and pseudo-cellular structure, (all X 1).

Figs. 4-6 *Hippurites muellerriedi* (Vermunt)

4) Profile of two attached valves, WSA 15563; 6) upper surface of same specimen; 5) peel of transverse section of attached valve of WSA 15584, shell recrystallized, but showing E, S. and L (ligament) inflections, (all X 1).



RUDISTS OF THE CARDENAS FORMATION

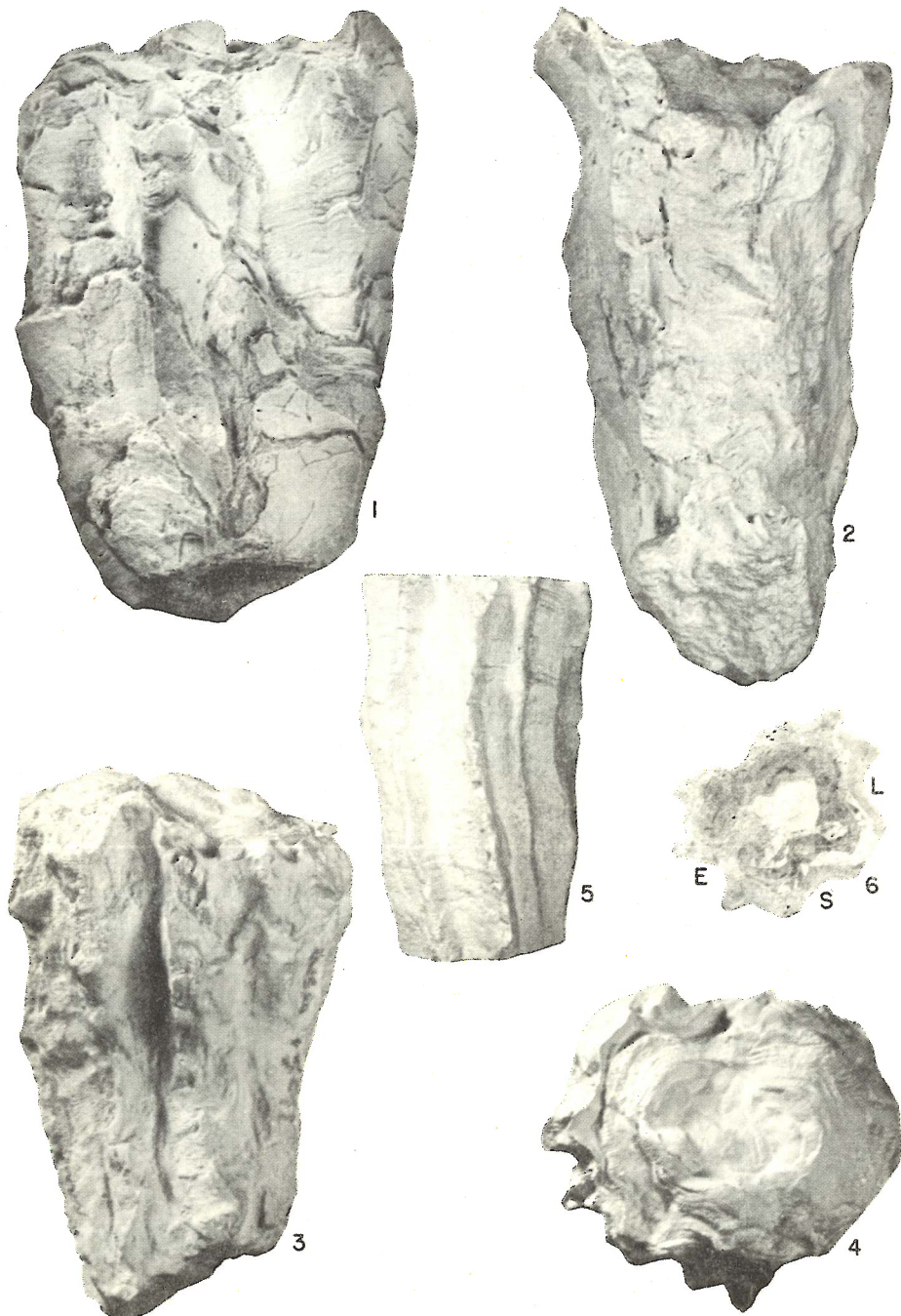
PLATE 4

Figs. 1-4. *Biradiolites cardenasensis* Böse

1) Attached valve of WSA 15013; 2) attached valve of WSA 15012; 3, 4) attached and free valves of WSA 15011, (all X 1).

Figs. 5-6. *Hippurites perkinsi*, n. sp.

5) Incomplete attached valve, WSA 15569, holotype; 6) peel of transverse section of same specimen showing E, S, and L (ligament) inflections, (X 1).



RUDISTS OF THE CARDENAS FORMATION

PLATE 5

Figs. 1-4. *Biradiolites aguilerae* Böse

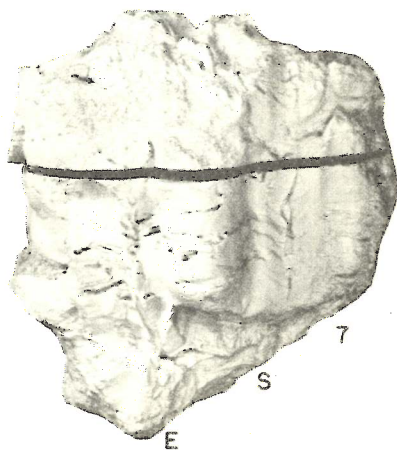
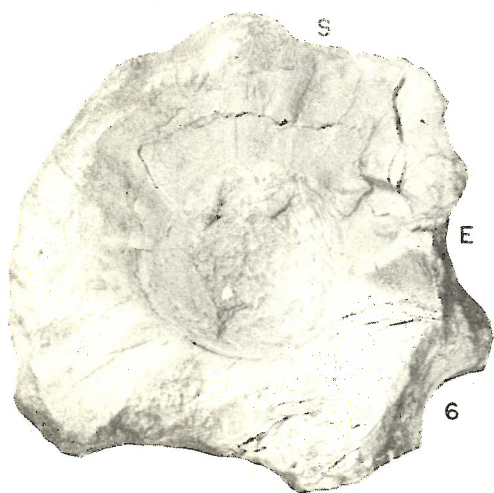
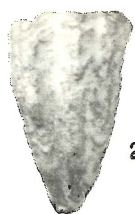
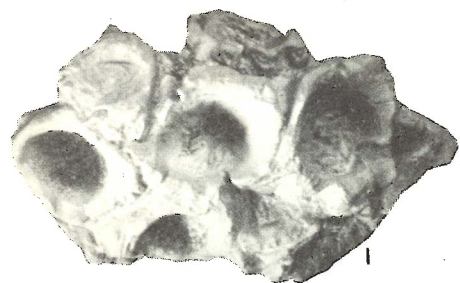
1) Colony of six shells, WSA 15560; 2, 3) attached valve of WSA 15580 showing downfolds on one side of shell; 4) both valves of WSA 15581, (all X 1).

Fig. 5. *Tampsia floriformis*, n. sp.

Cap-like free valve and upper surface of attached valve of WSA 14955, (X 1/2).

Figs. 6-7. *Tampsia poculiformis*, n. sp.

6) Upper surface of attached valve of WSA 14921, holotype (see also Pl. 7, fig. 2) showing E slit on a swelling in depressed triangular area; 7) attached valve of WSA 14933 showing smooth E and S grooves with round fold between them, (X 1/2).

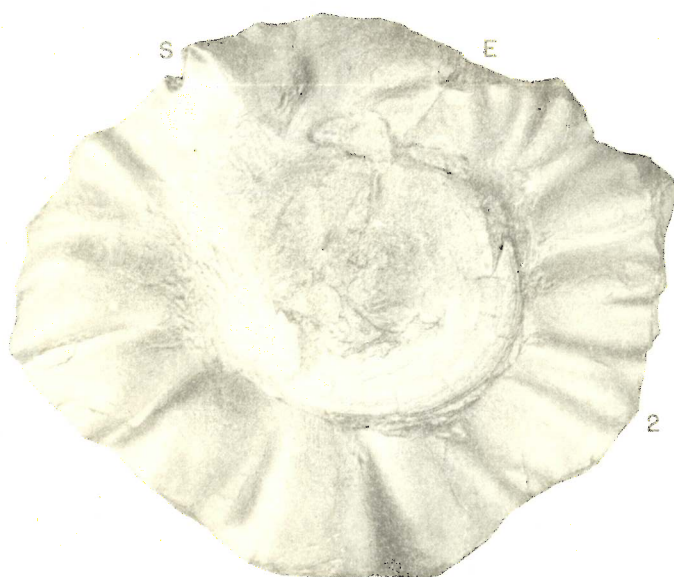
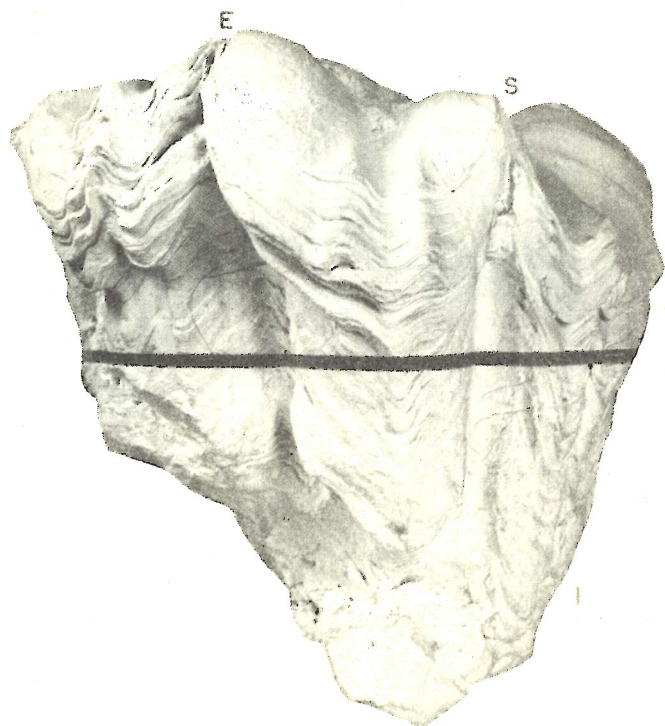


RUDISTS OF THE CARDENAS FORMATION

PLATE 6

Figs. 1-2. *Tampsia floriformis*, n. sp.

WSA 14925, holotype (see also Pl. 7, fig. 1). 1) attached valve showing deep smooth E and S channels; 2) upper surface of same specimen showing E slit on broad swelling, S notch, folded periphery of entire shell, and the central cap-like part of the free valve, (X 1/2).



RUDISTS OF THE CARDENAS FORMATION

PLATE 7

Fig. 1. *Tampsia floriformis*, n. sp.

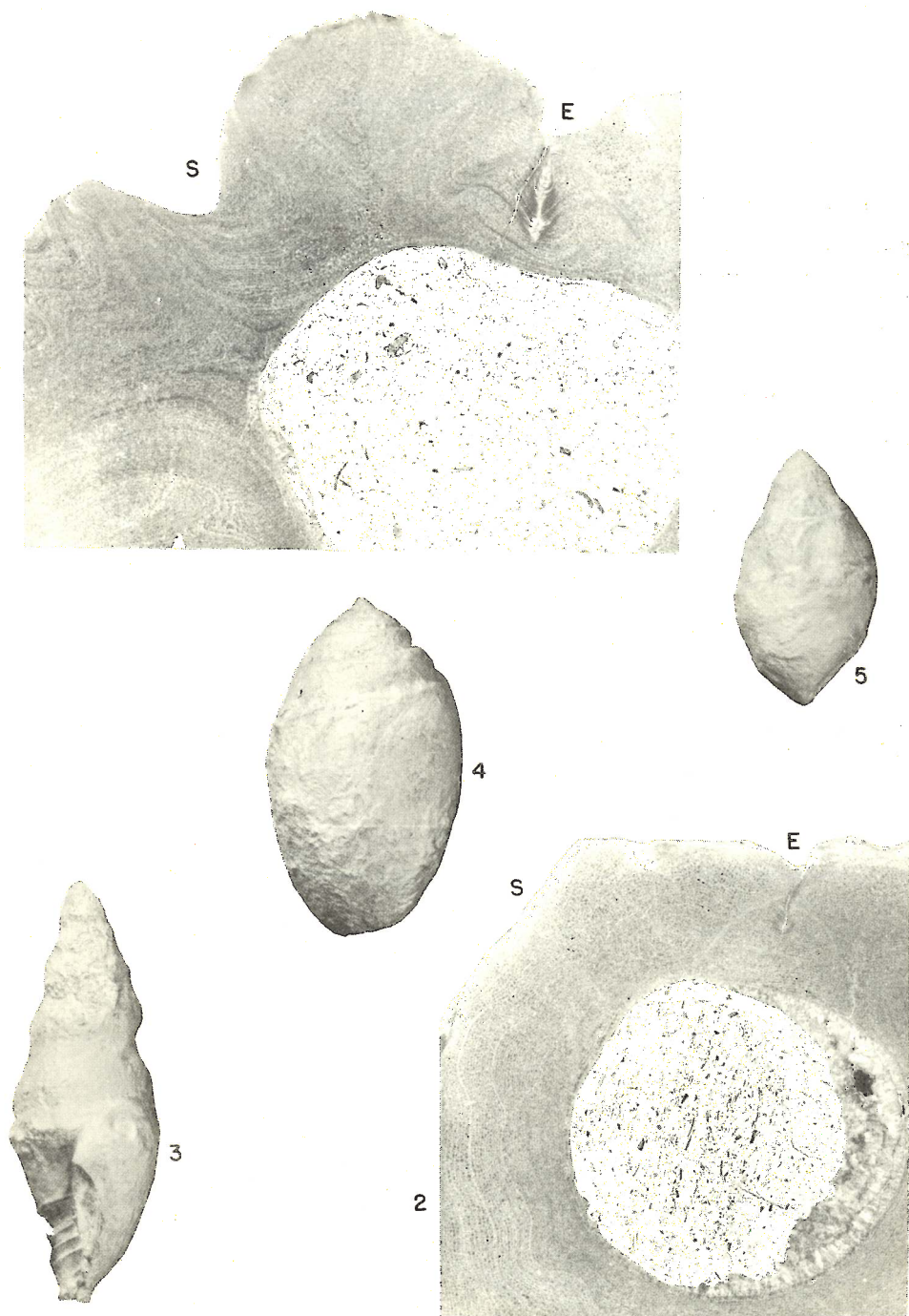
Peel of part of transverse section of attached valve of holotype, WSA 14925, showing E sinus, S indentation, and cell structure (see also Pl. 6, figs. 1, 2), (X 1).

Fig. 2. *Tampsia poculiformis*, n. sp.

Peel of part of transverse section of attached valve of holotype, WSA 14921, showing E sinus and slight change in cellular texture marking position of S (see also Pl. 5, fig. 6), (X 1).

Figs. 3-5. *Actaconella coniformis* Böse

3) WSA 15554; 4) WSA 15585; 5) WSA 15586.



RUDISTS AND GASTROPOD OF THE CARDENAS FORMATION

PLATE 8

Figs. 1, 2. *Durania ojanchalensis*, n. sp.

1) Peel of part of transverse section of attached valve of WSA 14984 showing E and S indentions and polygonal cell structure; 2) incomplete attached valve of WSA 14996, holotype, showing ribbed sides, slight development of ledges, and unribbed E channel, (X 1).

Fig. 3. *Mytilus smocki* Weller

Fragment of both valves, right valve on top, WSA 15074, (X 1).

Figs. 4, 5. *Barbatia sculpta*, n. sp.

4) Dorsal view of holotype, WSA 15023, showing lens shaped ligamentary area; 5) right valve of same specimen showing pronounced carina, (X 2).



RUDISTS AND PELECYPODS OF THE CARDENAS FORMATION

PLATE 9

Fig. 1. *Arca securiculata armeriai*, n. subsp.

Left valve, holotype, WSA 15042, (X 2).

Fig. 2. *Arca mcnairyensis rebecae*, n. subsp.

Left valve, holotype, WSA 15073, (X 2).

Figs. 3, 4. *Anomia csernai*, n. sp.

Two views of holotype, left valve, WSA 15067, (X 1).

Fig. 5. *Inoperna* sp.

Fragment of one valve with pieces of a small oyster and a limid attached, WSA 15066, (X 1).

Figs. 6-8. *Neithea youngi*, n. sp.

6, 7) Right valve of holotype, WSA 15030; 8) broken valve, WSA 15587, (X 1).

Fig. 9. *Lima azteca* Böse

Left valve, WSA 15020, (X 1).

Figs. 10, 13. *Lopha maccoyi*, n. sp.

Two views of holotype, WSA 15557, showing strong marginal plicae, (X 1).

Fig. 11. *Paranomia guttiiformis*, n. sp.

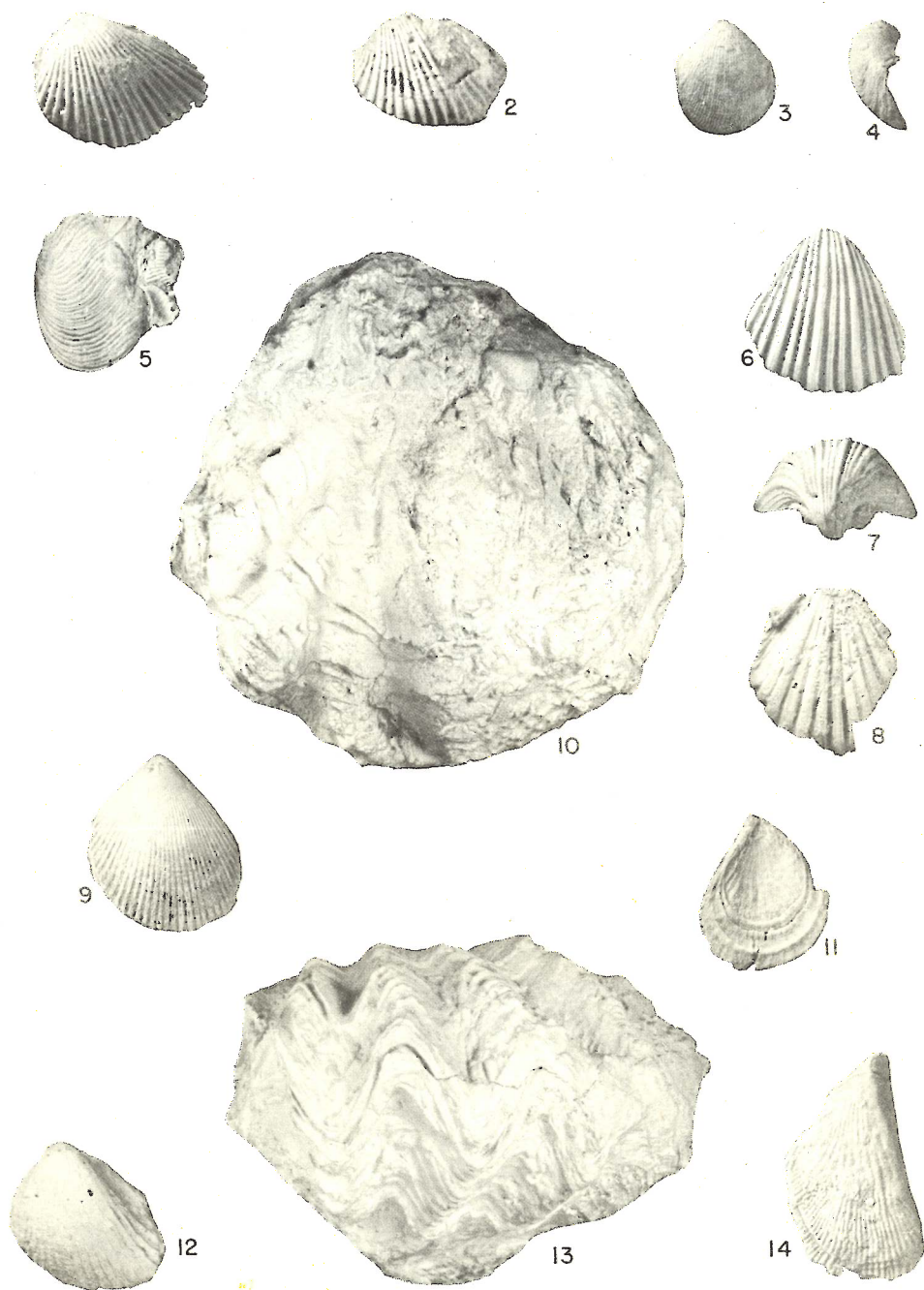
Right valve, holotype, WSA 15057, (X 1).

Fig. 12. *Lima cardenasensis* Böse

Left valve, WSA 15070, (X 1).

Fig. 14. *Septifer aguajensis*, n. sp.

Holotype, WSA 15055, (X 1).



PELECYPODS OF THE CARDENAS FORMATION

PLATE 10

Fig. 1. *Exogyra costata* Say

Left valve of small specimen, WSA 15570, (X 1).

Figs. 2, 3, 7. *Arctostrea aguilerae* Böse

2, 7) Two views of WSA 15572 showing sharp plicae; 3) interior of a smaller shell, WSA 15573, (all X 1/2).

Figs. 4, 5. *Pseudoptera stephensoni*, n. sp.

4) Holotype, WSA 15065; 5) fragment showing deep anterior sulcus, WSA 15559, (X 1).

Fig. 6. *Trigonia eufalensis* Gabh

Right valve, WSA 15057, (X 1).



PELECYPODS OF THE CARDENAS FORMATION

PLATE 11

Figs. 1, 3, 6. *Pycnodonte mutabilis* (Morton)

1) High form with short hinge line, WSA 15578; 3) oval form with short hinge line, WSA 15016; 6) form with long hinge line, WSA 15579, (all X 1/2).

Fig. 2. *Ostrea semiarmata* Böse

WSA 15558, (X 1/2).

Figs. 4, 5. *Ostrea tecticosta* Gabb

4) Fragment of a partially covered specimen, WSA 15049, (X 1); 5) small, complete valve, WSA 15061, (X 2).

Fig. 7. *Flemingostrea* sp.

Worn specimen with concentric ornamentation almost obliterated showing broad ventral sulcus, WSA 15015, (X 1).



PLATE 12

Fig. 1. *Cardium* sp. cf. *Cardium uniformis* Weller
Steinkern, WSA 15027, (X 1).

Fig. 2. *Cardium* sp. cf. *Cardium whitfieldi* Weller
Steinkern, WSA 15026, (X 1).

Figs. 3, 4. *Cardium* (*Trachycardium*) *gordum*, n. sp.

3) Left valve of holotype, WSA 15034; 4) dorsal view of specimen, (X 1).

Figs. 5, 6. *Cardium* (*Pachycardium*) *cardenasensis*, n. sp.

5) Interior of holotype, WSA 15024, showing dentition; 6) exterior of same specimen, (X 1).

Fig. 7. *Cymella bella mexicana*, n. subsp.

Complete left valve with dorsal fragment of right valve, holotype, WSA 15025, (X 1).

Figs. 8, 12. *Cardium* (*Granocardium*) *tabacoensis*, n. sp.

Two views of holotype, WSA 15072, (X 1).

Figs. 9, 10. ? *Priscomactra* sp. cf. *Priscomactra cymba* Stephenson

WSA 15037, (X 1).

Fig. 11. ? *Kelliella* sp.

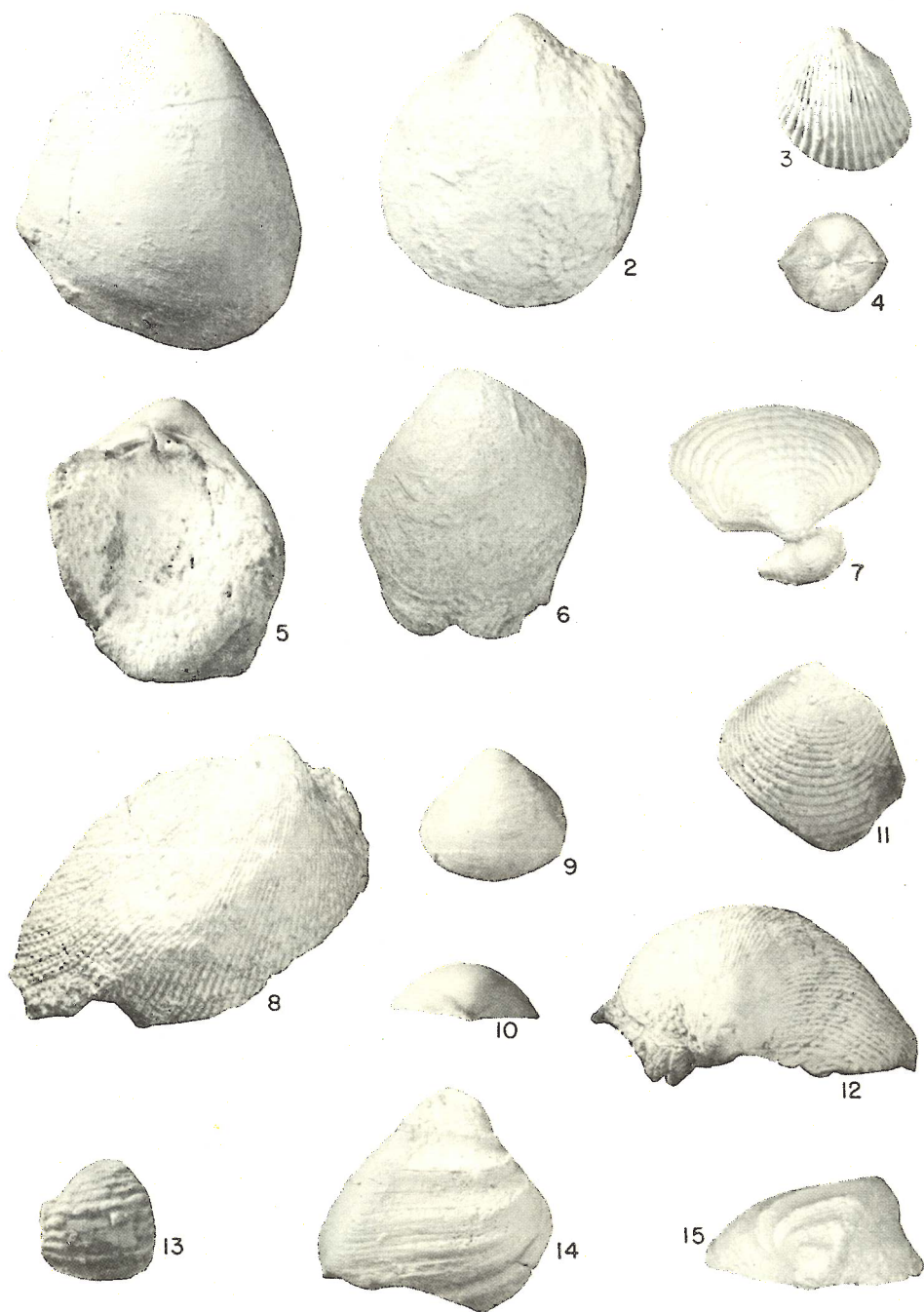
WSA 15590, (X 3).

Fig. 13. *Corbula crassiplica* Gabb

WSA 15039, (X 3).

Figs. 14, 15. *Veniella conradi* (Morton)

WSA 15048, (X 1).



PELECYPODS OF THE CARDENAS FORMATION

PLATE 13

Figs. 1, 2. *Cyprina mondragoni*, n. sp.

Holotype, WSA 15031, (X 1).

Figs. 3, 4. ?*Linearia belli*, n. sp.

3) Left valve of holotype, WSA 15029; 4) dorsal view of same specimen, (X 1).

Figs. 5, 6. *Pholadomya coahuilensis* Imlay

5) Right valve, WSA 15043; 6) anterior of same specimen, (X 1).

Fig. 7. *Pholadomya* sp.

Steinkern, WSA 15028, (X 1).

Fig. 8. ?*Tellina* sp.

Worn right valve, WSA 15033, (X 1).

Figs. 9, 10. ?*Aphrodina* sp.

9) Dorsal view of WSA 15032; 10) right valve of same specimen, (X 1).

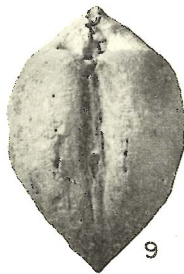
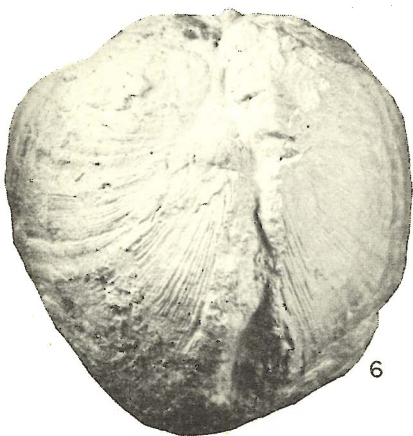
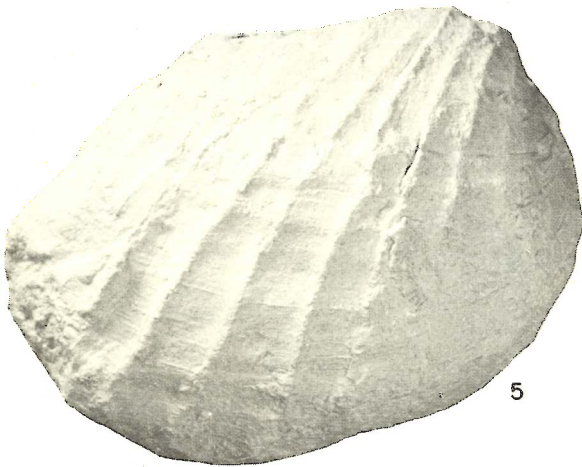
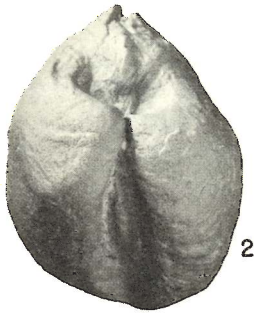


PLATE 14

Figs. 1, 7. *Pseudamaura altilirata* Böse
1) WSA 15510; 7) WSA 15589, (X 1).

Figs. 2, 3. ? *Architectonica rodldai*, n. sp.
2) Holotype, WSA 15086; 3) base of same specimen, (X 1).

Fig. 4. *Turritella waitzi* Böse
WSA 15516, (X 2).

Fig. 5. *Cerithium* sp. aff. *Cerithium simonyi* Zekeli
Steinkern, WSA 15083, (X 1).

Figs. 6, 16. *Turritella potosiana* Böse
6) WSA 15077; 16) WSA 15577, (X 1).

Fig. 8. *Turritella trilira* Conrad
WSA 15513, (X 2).

Fig. 9. *Cerithium subcarnaticum* Böse
WSA 15090, (X 1).

Fig. 10. ?*Stantonella* sp.
WSA 15095, (X 1).

Fig. 11. *Turritella guionae*, n. sp.
WSA 15503, holotype, (X 2).

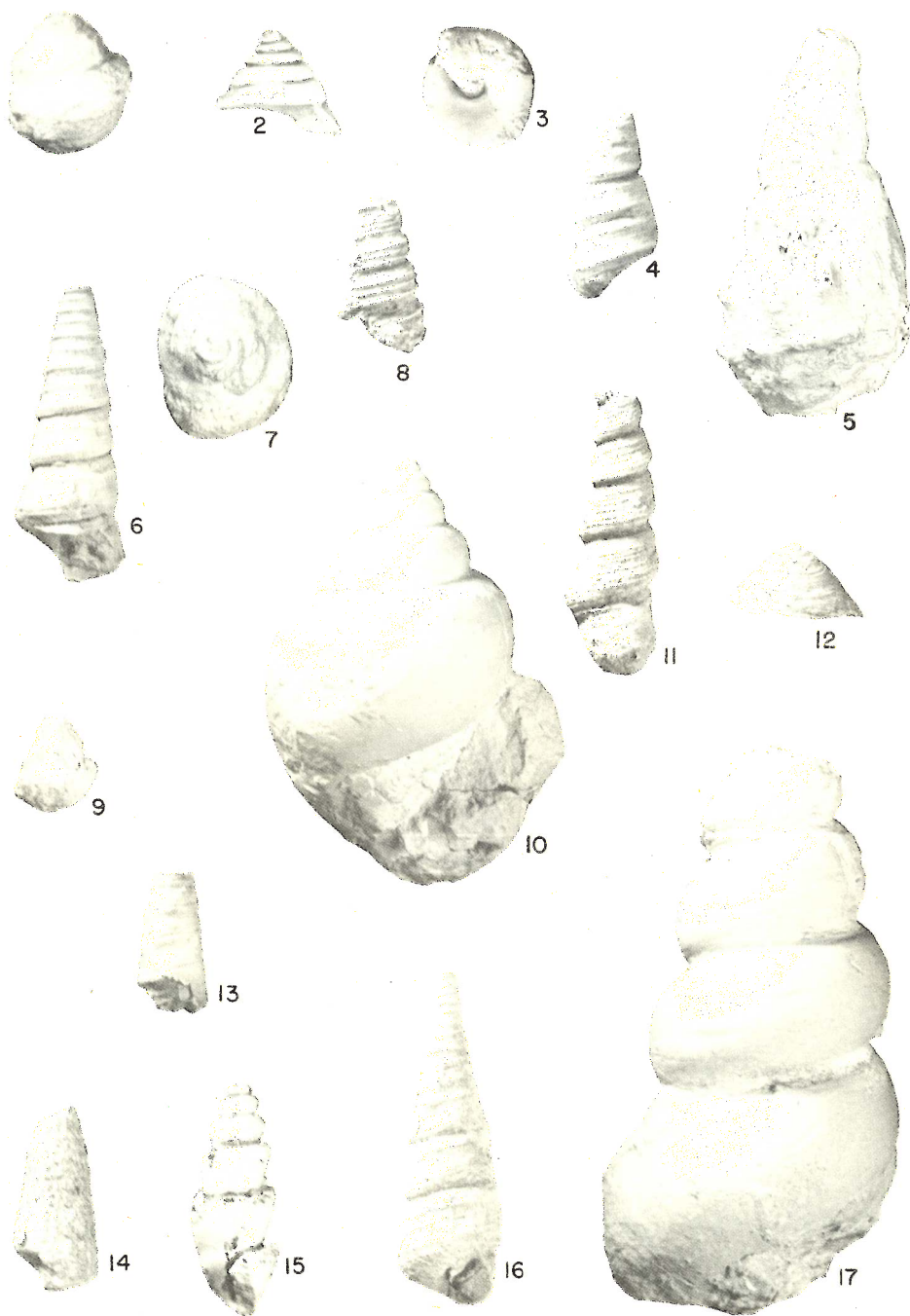
Fig. 12. *Architectonica* sp.
WSA 15089, (X 1).

Fig. 13. *Nerinea burchardti* Böse
WSA 15085, (X 1).

Fig. 14. *Cerithium potosianum* Böse
WSA 15091, (X 1).

Fig. 15. *Longoconcha* sp.
Steinkern, WSA 15512, (X 1).

Fig. 17. *Turritella* sp.
Steinkern, WSA 15093, (X 1).



GASTROPODS OF THE CARDENAS FORMATION

PLATE 15

Figs. 1, 2. *Hardouinia potosiensis* Lambert

1) Apical view, WSA 15540; 2) peristomal view of same specimen, (X 1).

Fig. 3. *Hemiaster* sp.

Crushed specimen, WSA 15542, (X 1).

Figs. 4, 5. *?Phyllobrissus* sp.

4) Apical view of WSA 15541; 5) peristomal view of same specimen, (X 1).

Fig. 6. *Phymosoma* sp.

Incomplete test, WSA 15537, (X 1).

Fig. 7. *Hamulus angulatus* Wade

WSA 15531, (X 2).

Fig. 8. *Hamulus onyx* Morton

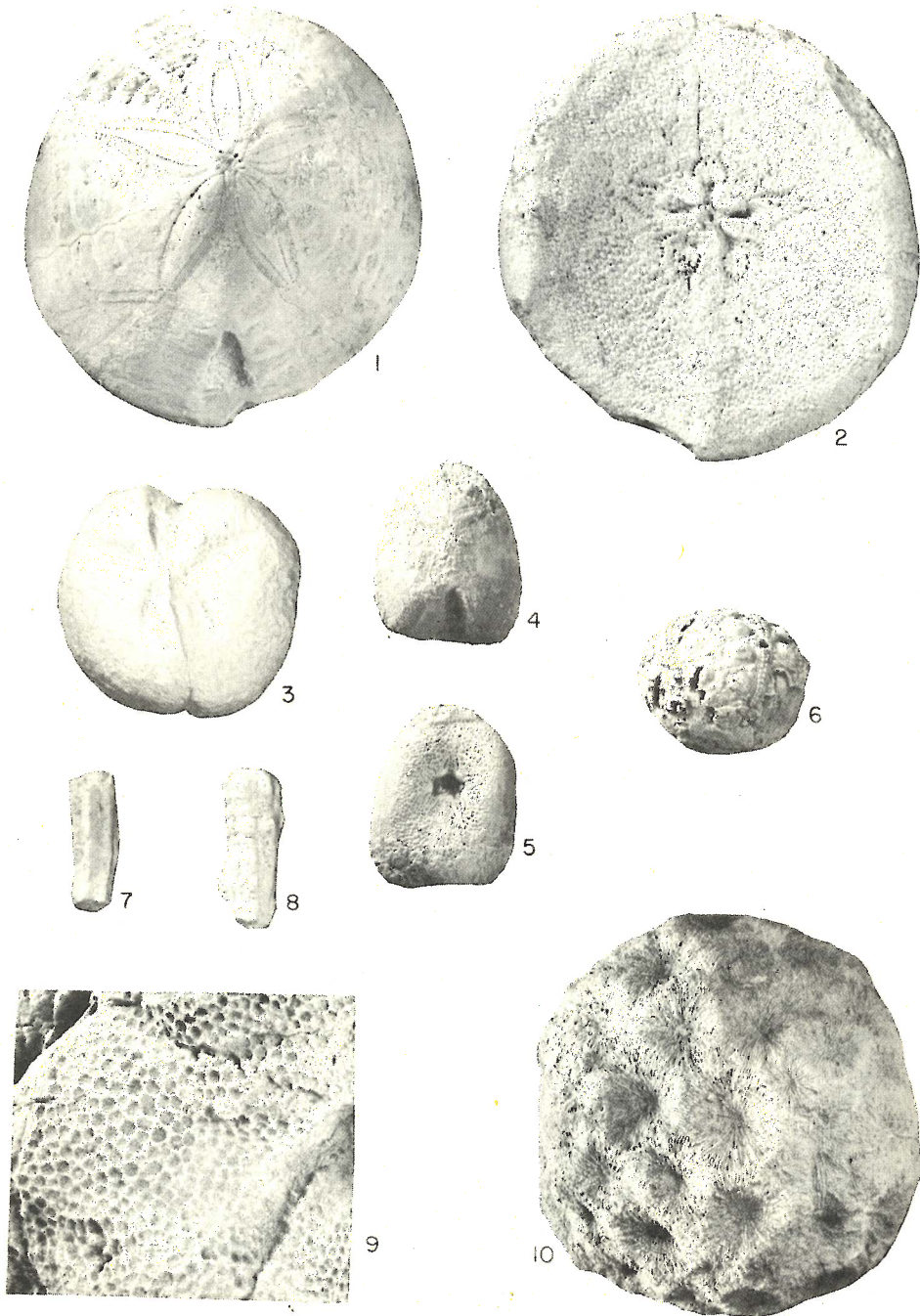
WSA 15556, (X 2).

Fig. 9. *?Lithostrontionoides* sp.

Part of a large corallum, WSA 15566, (X 1).

Fig. 10. *Synastrea* sp.

WSA 15565, (X 1).



ECHINOIDS, SERPULIDS AND CORALS OF THE CARDENAS FORMATION

PLATE 16

Figs. 1, 2. ?*Epistreptophyllum* sp.

1) WSA 15527; 2) WSA 15574, (X 1).

Fig. 3. *Leptoria* sp.

WSA 15518, (X 1).

Figs. 4-6. ?*Kingena* sp.

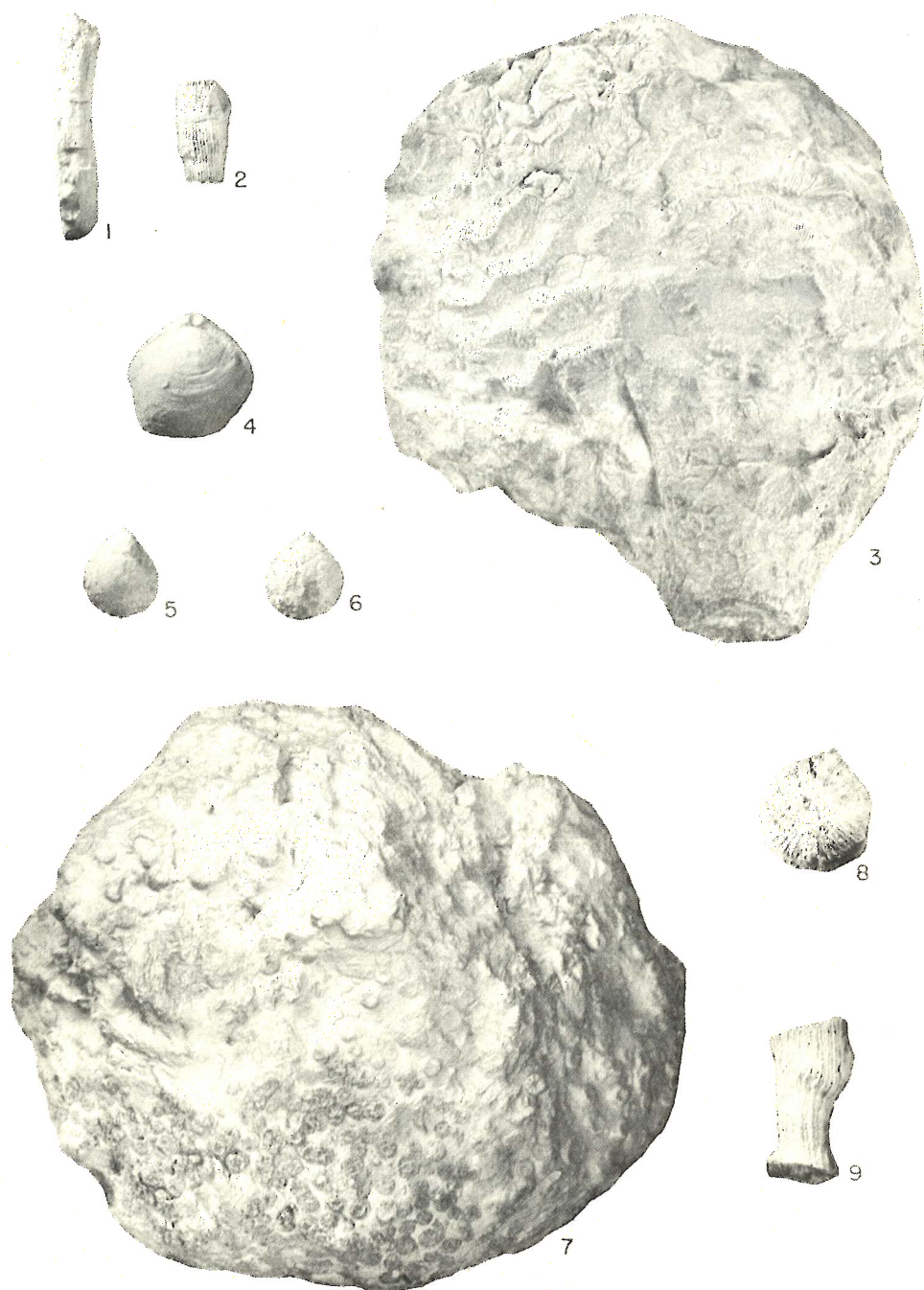
4) Brachial valve and posterior of pedicle valve, WSA 15533; 5) pedicle valve, WSA 15532; 6) brachial valve, WSA 15532, (X 1).

Fig. 7. *Cladocora* sp.

WSA 15564, (X 1).

Figs. 8, 9. *Trochoseris* sp.

8) Calyx of WSA 15575; 9) corallite of WSA 15519, (X 1).



CORALS AND BRACHIOPOD OF THE CARDENAS FORMATION

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