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Early Jurassic bivalves of the Antimonio terrane (Sonora, NW Mexico): Taxonomy, biogeography, and paleogeographic implications

Annemarie Scholz*
Museum für Naturkunde der Humboldt-Universität zu Berlin, Invalidenstraße 43, 10115 Berlin, Germany

Martin Aberhan*
Museum für Naturkunde der Humboldt-Universität zu Berlin, Invalidenstraße 43, 10115 Berlin, Germany

Carlos M. González-León*
Instituto de Geología, ERNO, Universidad Nacional Autónoma de México, Apartado Postal 1039, Hermosillo, Sonora, Mexico 83000

ABSTRACT

The Early Jurassic (late Hettangian to early Toarcian) bivalve fauna of the Sierra de Santa Rosa Formation of the Antimonio terrane (Sonora, NW Mexico) is analyzed taxonomically and biogeographically. Fifty taxa are recognized, representing 36 genera and subgenera. Thirty-four of these taxa have not been mentioned from the Jurassic of this region previously. This fauna is of great biogeographical interest, because Early Jurassic bivalves from low paleolatitudes of the tectonically complex western margin of North America are still poorly documented. About half of the described species are also known from other localities along the eastern Pacific margin. The second largest group is composed of widespread taxa, which, in addition to eastern Pacific occurrences, are also reported from other regions, particularly from Europe. The smallest group is endemic taxa that appear to be limited to Sonora during the analyzed time intervals. Geological evidence indicates that the Antimonio terrane was tectonically transported southeastward between the Middle and Late Jurassic from an original position at the southwestern margin of the United States by the Mojave-Sonora megashear. We calculated similarities of contemporaneous pectinoid bivalve faunas from seven eastern Pacific regions to independently constrain Early Jurassic paleolatitudinal positions of this terrane. Cluster analyses and similarity coefficients tentatively suggest that tectonic displacement of the Antimonio terrane toward lower paleolatitudes may already have started in Early Jurassic (Pliensbachian) time.

Keywords: bivalvia, Jurassic, paleobiogeography, taxonomy, northwest Mexico.

*E-mails: annemarie.scholz@yahoo.de; martin.aberhan@museum.hu-berlin.de; cmgleon@servidor.unam.mx

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INTRODUCTION

The western part of North America, i.e., the North American Cordillera, is geologically highly complex. Since the Paleozoic, more than 200 allochthonous terranes have been accreted to an active continental margin (Coney et al., 1980; Frisch and Loeschke, 1993). The origin of many of these terranes remains unresolved, and their fossil faunas are still poorly documented. Here, we study the Jurassic bivalve fauna from one of those terranes, the Antimonio terrane of Sonora, Mexico. In particular, we (1) describe in detail and illustrate the numerous bivalves from the Early Jurassic Sierra de Santa Rosa Formation; (2) analyze these new data biogeographically by comparing them with contemporaneous faunas from other regions along the eastern margin of the paleo-Pacific; and, on this basis, (3) address the question of postdepositional tectonic displacement of the Antimonio terrane.

Apart from short faunal lists (see Damborenea and González-León, 1997, for references), previous documentation of Early Jurassic bivalves from Sonora was provided by Jaworski (1929) and, more recently, by Damborenea and González-León (1997). From the material collected by Keller (1928) and housed at the Naturhistorisches Museum Basel, Jaworski (1929) described and partly figured seven species from the Sierra de Santa Rosa. Damborenea and González-León (1997) described and illustrated 15 taxa from the Sierra del Álamo and Sierra de Santa Rosa, 12 of which had not been reported previously from this region. The material studied by Damborenea and González-León (1997) is housed in the collections of the Estación Regional del Noroeste, Instituto de Geología, Universidad Nacional Autónoma de México in Hermosillo (ERNO). The bivalve fauna analyzed in the study at hand comprises 50 taxa, 34 of which are documented from the Lower Jurassic of Mexico for the first time.

GEOLOGICAL SETTING, LOCALITIES AND STRATIGRAPHY

The Antimonio terrane has been proposed as an allochthonous terrane that rests on the Proterozoic to Permian basement of the Caborca terrane (González-León, 1989; Stanley and González-León, 1995). It is composed of the Permian (Guadalupian) Monos Formation (Cooper and Arellano, 1946) and the Upper Permian to Lower Jurassic El Antimonio Group (González-León et al., 2005) that disconformably overlies it. The Caborca terrane along with the Antimonio terrane is considered to have been tectonically transported southeastward between the Middle and Late Jurassic from an original position at the southwestern margin of the United States by the Mojave-Sonora megashear, a fault for which geological evidence suggests a left lateral displacement of 800–1000 km (Fig. 1) (Silver and Anderson, 1974; Anderson et al., 1979; Anderson and Schmidt, 1983; Campa and Coney, 1983; Marzolf, 2003).

The El Antimonio Group is interpreted as a sedimentary succession that records shallow to deep marine sedimentation in a fore-arc basin that developed adjacent to the southwestern

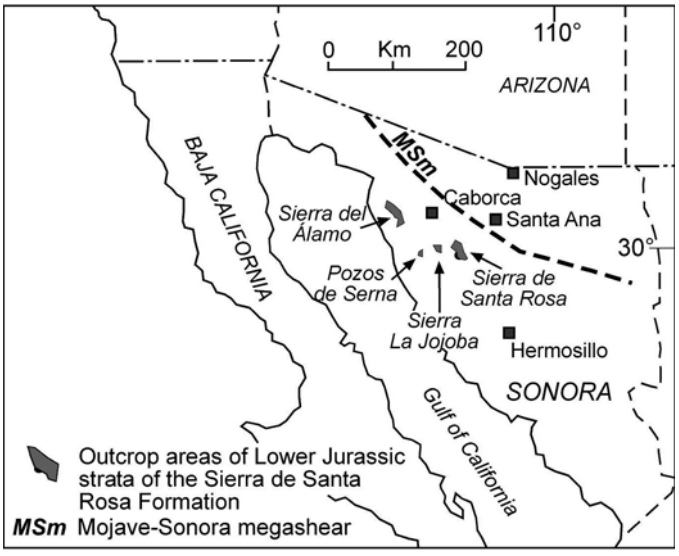

Figure 1. Location of outcrops of the Lower Jurassic Sierra de Santa Rosa Formation in northwestern Sonora, Mexico, and position of the Mojave-Sonora megashear.

margin of the United States (González-León et al., 2005). It is also inferred that it was thrust over the Caborca terrane, which was part of the North American craton at some time during the Middle Jurassic, just prior to, or contemporaneous with, displacement along the Mojave-Sonora megashear (Stanley and González-León, 1995; González-León et al., 2005).

The Early Jurassic bivalve fauna of Sonora occurs in the Sierra de Santa Rosa Formation of the El Antimonio Group. Outcrops of this group, which encompasses the Upper Permian to Triassic Antimonio Formation, the Upper Triassic Rio Asunción Formation, and the Lower Jurassic Sierra de Santa Rosa Formation (Hardy, 1981; Lucas and Estep, 1999; González-León et al., 2005), are scattered in several ranges of northwestern Sonora. The most complete sections of the El Antimonio Group occur in the Sierra del Álamo and Sierra de Santa Rosa mountains (Fig. 1). Other bivalve-bearing sections of the Sierra de Santa Rosa Formation are incomplete and occur in the Pozos de Serna area and in the Sierra de la Jojoba.

Sierra del Álamo Section

The El Antimonio Group in the Sierra del Álamo is divided into 14 stratigraphic sequences, which are numbered from base upward and have been further subdivided into several units (Fig. 2). Whereas sequences I to VI represent the Antimonio Formation and sequences VII to IX are part of the Río Asunción Formation, sequences X to XIV compose the lower (late Hettangian to late Sinemurian) part of the Sierra de Santa Rosa Formation at that locality.

Sequence IX of Rhaetian age and sequence X of latest Hettangian to earliest Sinemurian age are separated by an erosional unconformity that marks the Triassic-Jurassic boundary in this

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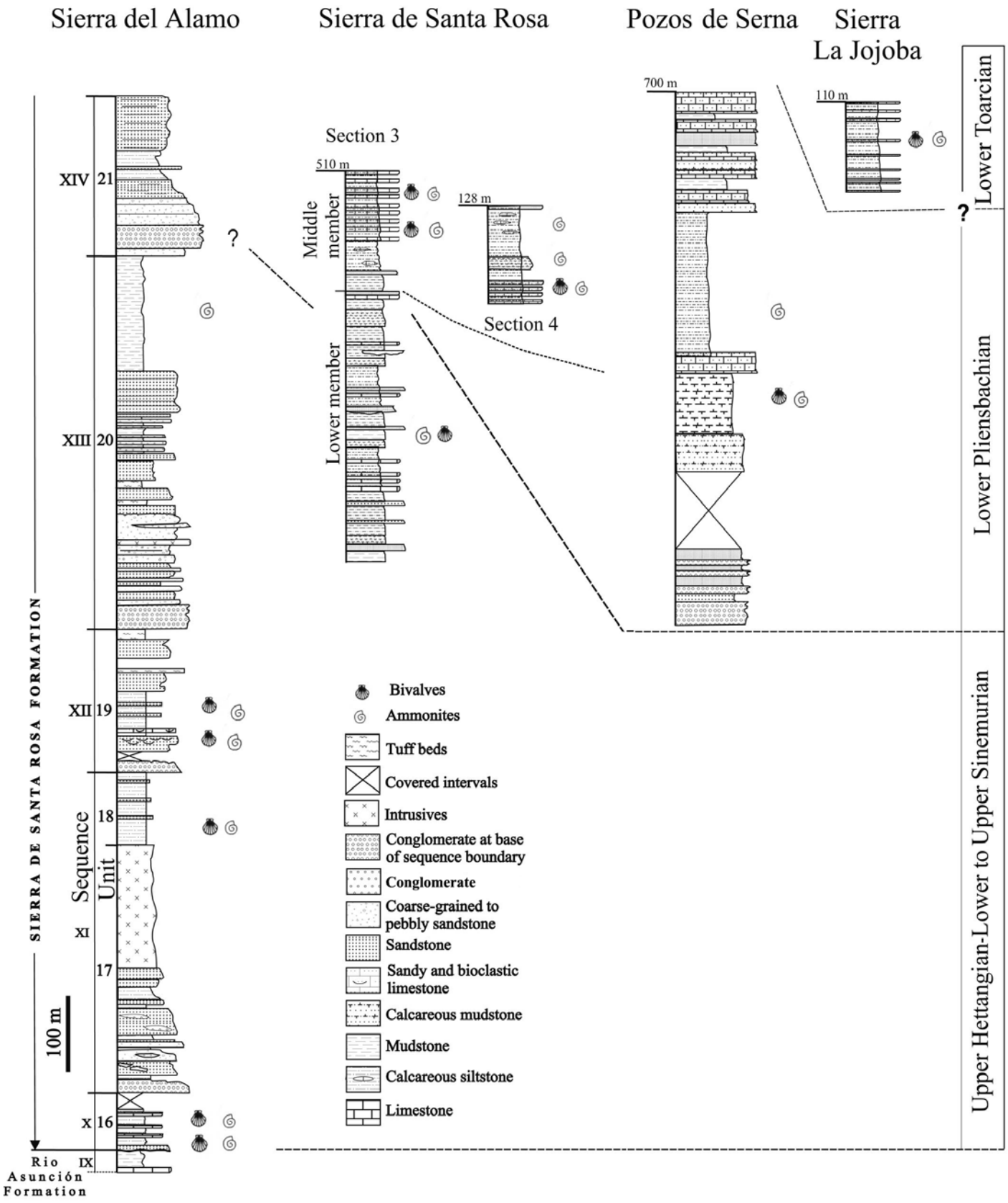

Figure 2. Sections of the Sierra de Santa Rosa Formation in northwestern Sonora showing fossiliferous intervals with ammonites and bivalves.

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area (Fig. 2). Sequence X is 60 m thick; its base is erosional and composed of coarse-grained to pebbly sandstone that grades upward into mudstone, siltstone, and interbedded limestone of shallow marine origin. This sequence contains abundant ammonites that have been assigned to the Canadensis and Trigonatum Zones by Taylor et al. (2001). From this sequence, the following bivalves were collected within an area of a few hundred square meters around Universal Transverse Mercator (UTM) position 3399704 351128: *Grammatodon sulcatus*, *Agerchlamys wunschae*, *Weyla unca*, *Protocardia truncata*, *Neocrassina gueuxi*, *Cardinia concinna, Cardinia*? sp. A, and Lucinidae gen. et sp. indet. B.

Sequence XI is 280 m thick and overlies sequence X with a covered contact (Fig. 2). The basal 20 m are composed of a clast-supported pebble conglomerate that grades upward into interbedded sandstone and siltstone of fluvial origin. The middle part of this sequence is intruded by a dioritic dike and its upper part consists of massive to finely laminated calcareous mudstone and siltstone with ammonites of early Sinemurian (Leslei Zone) age (Taylor et al., 2001). The bivalve fauna from the upper part of this sequence, collected from an area of a few meters around UTM 3398025 351313, includes *Palaeoneilo elliptica*, *Parallelodon* cf. *hirsonensis*, *Grammatodon sulcatus*, *Bakevellia* sp. A, *Gervillella araucana*, *G. leesi*, *Mytiloperna*? sp. A, *Plicatula* sp. A, *Oxytoma* cf. *inequivalvis*, *Entolium corneolum*, *Agerchlamys wunschae*, *Weyla alata*, *W. bodenbenderi*, *W. titan*, *W. unca*, *Modiolus hillanus*, *Osteomya dilata*, *Frenguelliella poultoni*, *Prosogyrotrigonia* sp. A, *Protocardia truncata,* and *Neocrassina gueuxi*.

The 115-m-thick sequence XII starts at its base with a 5-m-thick pebble conglomerate that grades into coarse-grained, thick-bedded, cross-stratified sandstone and sandy coquina. The upper part of this sequence is composed of massive mudstone and siltstone with intercalations of thin-bedded bioclastic limestone, fine-grained sandstone, and thin volcanic ash tuff beds. The bioclastic limestone beds contain ammonites of the lower upper Sinemurian Carinatum and Jamesi Zones (Pálfy and González-León, 2000, Taylor et al., 2001) and the bivalves *Weyla alata*, *W. unca*, *Protocardia luggudensis*, and *Neocrassina gueuxi*.

The remainder of the Sierra de Santa Rosa Formation at this locality is formed by sequences XIII and XIV. Sequence XIII is 465 m thick, and in its lower part is composed of thick beds of conglomerate, pebbly to coarse-grained sandstone, and minor interbeds of mudstone, siltstone, and tuff beds. Its middle and upper parts are composed of fine-grained sandstone and thin-bedded to laminated mudstone and siltstone with sedimentary and biogenic structures that indicate sedimentation in basinal settings with turbidite currents. Ammonites of these strata suggest a late Sinemurian age (Pálfy and González-León, 2000). Sequence XIV is 150 m thick and in its lower part is composed of very thick beds of conglomerate, sandstone, and siltstone and in its upper part of medium- to coarse-grained sandstone. No bivalves were found in these two sequences.

Sierra de Santa Rosa Section

The Lower Jurassic strata that crop out in the Sierra de Santa Rosa mountains were assigned to the Sierra de Santa Rosa Formation by Hardy (1981). He divided this section of shallow- to deep-marine sedimentary strata into lower, middle, and upper members.

The most complete thickness of the lower member is 353 m and was measured along section 3, which starts at UTM 3326285 430123 and ends at UTM 3326318 429239 (for location see also Damborenea and González-León 1997, fig. 3). The base of the Lower Jurassic section in this area is tectonically thrust onto a Precambrian metamorphic basement. The measured section of the lower member is composed of fine- to coarse-grained sandstone, minor conglomerate lenses, and dark-gray siltstone and mudstone in its lower part (Fig. 2). The middle part consists of fine-grained sandstone with interbedded laminated mudstone, and sandy limestone with bivalves and ammonites. Its upper part consists of interbedded fine- to coarse-grained sandstone, mudstone, and bioclastic, locally encrinitic limestone. From this lower member we have identified *Weyla alata*, *W. bodenbenderi*, *Frenguelliella poultoni*, Lucinidae gen. et sp. indet. A, and Lucinidae gen. et sp. indet. B. Ammonites reported by Pálfy and González-León (2000) indicate that the lower member belongs to the uppermost Sinemurian Harbledownense Zone.

In section 3, the middle member is 160 m thick and gradationally overlies the lower member from UTM 3326318 429239 to 3326256 429037. It consists of thin- to medium-bedded calcareous mudstone and siltstone and interbedded sandy to silty, bioclastic limestone. This member is also well exposed along section 4 (UTM positions 3327598 435179 to 3327489 434972) in this area (for location see also Damborenea and González-León 1997, fig. 3). This member is the most fossiliferous part of the Sierra de Santa Rosa Formation at this locality. Ammonites most likely indicate an early Pliensbachian age for this member (Pálfy and González-León, 2000), and the identified bivalves include *Parallelodon* cf. *hirsonensis*, *Grammatodon sulcatus*, *Gervillella araucana, G. leesi, Cercomya peruviana*, *Plagiostoma schimperi*, *Plagiostoma* sp. A, *Pinna* cf. *folium*, *Antiquilima* cf. *nodulosa*, *Ctenostreon* sp. A, *Entolium corneolum, Agerchlamys wunschae, Eopecten velatus, Weyla alata, W. titan, W. unca*, *Modiolus giganteus, M.* cf. *baylei, Pholadomya fidicula*, *Ph. idea, Pachymya*? sp. A, *Goniomya* sp. A, *Pleuromya uniformis, Ceratomya concentrica, Frenguelliella poultoni, Protocardia striatula, P. luggudensis, Neocrassina gueuxi, Myoconcha neuquena*, Lucinidae gen. et sp. indet. A, Lucinidae gen. et sp. indet. B, and *Isocyprina ancatruzi.*

Pozos de Serna Section

At the Pozos de Serna locality, the Sierra de Santa Rosa Formation is not complete (Figs. 1 and 2) as it is faulted against Proterozoic strata. The lower part consists of interbedded sandstone and conglomerate, which is ~100 m thick and is followed by

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a covered interval ~100 m thick. Above is a 50-m-thick package of thin-bedded, fine-grained, calcareous sandstone that is overlain by 75 m of calcareous shale with ammonites and bivalves and a 30 m interval of reddish-brown, cross-stratified, sandy limestone beds with interbedded siltstone. The 180-m-thick middle part of the formation is dominated by thin-bedded to laminated calcareous shale with rare thin interbeds of dark-colored, micritic limestone where an interval with ammonites is present. The upper part is formed by a 150-m-thick section composed of fine- to medium-grained, thin- to medium-bedded calcareous sandstone with interbedded thick beds of sandy limestone and minor intervals of blue shale. An assemblage of ammonites from the lowermost fossiliferous interval indicates an early Pliensbachian age (Linares et al., 1997; Pálfy and González-León, 2000), and bivalves from the same interval, collected from an area of several hundred square meters around UTM 3336001 385940, include *Grammatodon sulcatus*, *Gervillia (Cultriopsis)* sp. A, *Pinna* cf. *folium*, *Plicatula* sp. A, *Pseudolimea*? sp. A, *Agerchlamys wunschae*, *Weyla alata*, *W. bodenbenderi*, *Modiolus giganteus*, *Ceratomya petricosa*, *Frenguelliella poultoni*, *Groeberella* sp. A, *Protocardia* sp. A, *Cardinia* sp. A, and *Neocrassina gueuxi.*

Sierra de la Jojoba Section

The Sierra de la Jojoba section, which is considered to be part of the Sierra de Santa Rosa Formation, is 110 m thick and is tectonically placed between Proterozoic and Jurassic? strata (Figs. 1 and 2). It consists of massive calcareous shale and siltstone and interbedded medium- to thick-bedded sandy limestone and calcareous sandstone. The bioclastic limestone contains bivalves (*Weyla alata*, *W. titan*, and *Pholadomya* cf. *voltzi*) and ammonites of probably early Toarcian age (Pálfy and González-León, 2000).

MATERIAL AND METHODS

This study is based on more than 500 specimens of Early Jurassic bivalves, which were collected by two of the authors (MA and CMG-L) in 1997 and 1998 in Sonora, Mexico. All figured specimens are deposited at the Estación Regional del Noroeste, Instituto de Geología, Universidad Nacional Autónoma de México in Hermosillo (ERNO). Additional material is housed in the collections of the Museum für Naturkunde, Berlin (MB.M.).

The material is preserved mostly as external and internal molds, and only a small number of specimens show shell preservation. These shells are often abraded or incompletely preserved. Most specimens were prepared mechanically and latex casts were taken from external molds.

Many specimens were identified on the basis of the relevant literature on bivalves from western North and South America. For the identification of species that had not yet been previously described from these regions, the Jurassic bivalve catalog proved very helpful; it contains photocopies of ~85% of Jurassic bivalves figured in the literature including an indication of age and region. The original of this catalog is housed at the GeoBio-Center in Munich, but copies also exist in Würzburg and Berlin.

The classification of higher taxa follows the schemes of Amler et al. (2000) and Carter (1990). The synonymy lists contain the first reference of the particular taxon and focus on literature records from North and South America or refer to recently published synonymy lists. If a taxon was hitherto unknown from America, the most important references from regions outside America are given. Concerning open nomenclature, the recommendations of Bengtson (1988) were applied.

Taxa represented by at least several well-preserved specimens were measured with a sliding caliper. Measured dimensions, together with certain morphological features of some taxa, are given in Figure 3.

For the multivariate analyses of paleobiogeographic affinities, we used SPSS 12.0 for Windows. We compiled a presence-absence data set containing all known pectinoid bivalves of Sonora and six other regions. These regions are northern Chile (from 22° to 31°S present-day latitude), central Chile and Argentina (from 31° to 41°S present-day latitude; regionally known as the Neuquén Basin), and, from western North America, the Brooks-Mackenzie Basin (northern and central Yukon and adjacent Northwest Territories and Alaska), the Western Canada Sedimentary Basin (central and southern Canadian Rocky Mountains and foothills of Alberta and British Columbia), and the allochthonous Canadian terranes of Stikinia and Wrangellia (both British Columbia).

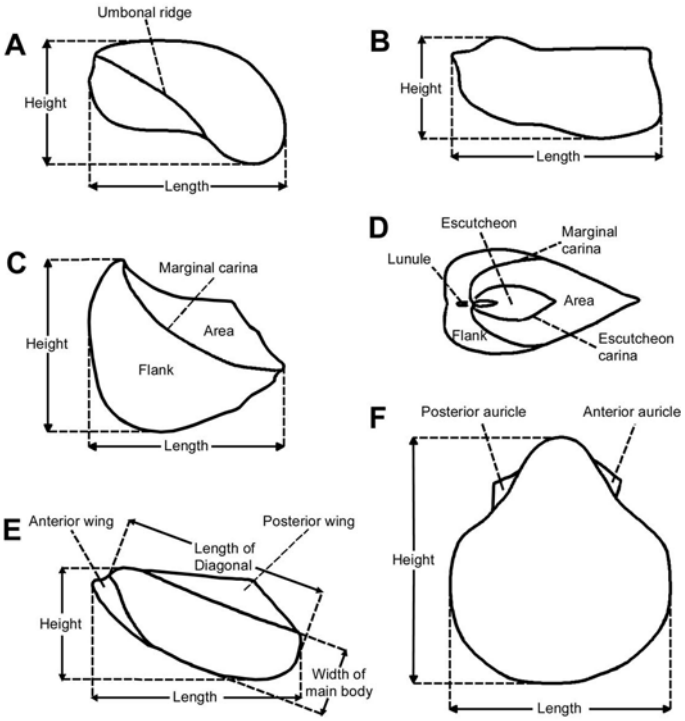

Figure 3. Measured dimensions and morphological features of selected bivalve taxa: A—*Modiolus*, B—*Parallelodon*, C, D—trigoniid bivalves, E—bakevelliid bivalves, F—*Weyla*.

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We analyzed the data set separately for two time slices, Hettangian–Sinemurian and Pliensbachian. Hettangian and Sinemurian bivalves are analyzed together because, in Sonora, several taxa are from the Canadensis Zone of unit 16 of the Sierra del Álamo section. This zone comprises late Hettangian and early Sinemurian sediments, but the Hettangian-Sinemurian boundary cannot be defined precisely.

A hierarchical cluster analysis was used in order to find regions with similar faunal composition. The procedure of unweighted pair-group method using arithmetic average (UPGMA) was used herein with the Jaccard coefficient as the distance measure. In addition, we calculated the Dice coefficient to clarify the relations between Sonora, Argentina, and Chile.

SYSTEMATIC PALEONTOLOGY

Class Bivalvia Linné, 1758
Subclass Palaeotaxodonta Korobkov, 1954
Order Nuculoida Dall, 1889
Family Malletiidae H. Adams and A. Adams, 1858
Genus *Palaeoneilo* Hall and Whitfield, 1873

Type species. *Nuculites constricta* Conrad, 1842, subsequent designation by Hall, 1885.

Palaeoneilo elliptica (Goldfuss, 1837)
Figs. 4A and 4B.

1836 *Nucula striata* Lamarck—Roemer: 99, pl. 6, fig. 11.
1837 *Nucula elliptica* sp. nov.—Goldfuss: 153, pl. 124, figs. 16a–e.
1942 *Nucula patagonidica* sp. nov.—A. Leanza: 151, pl. 1, figs. 1–4.
1987a *Palaeoneilo patagonidica* (A. Leanza 1942)—Damborenea: 54, pl. 1, figs. 1–3; text-fig. 6.
1987a *Palaeoneilo galatea* (d'Orbigny 1850) ?—Damborenea: 56, pl. 1, fig. 4; text-fig. 7.
2000 *Palaeoneilo elliptica* (Goldfuss, 1837)—Hodges: 28, pl. 2, figs. 1–30; text-figs. 25–33 (see for extensive synonymy list).

Material: One internal mold of a left valve (ERNO-8151) and one internal mold of a right valve (ERNO-8152) from the lower Sinemurian, unit 18, Sierra del Álamo.

Description: *Palaeoneilo elliptica* is medium-sized, slightly inequilateral, equivalved, gently inflated, and subelliptical in outline. Its length is about twice its height. The anterior margin is convex. The ventral margin is slightly convex and nearly parallel to the slightly convex dorsal margin. The posterior margin is well rounded. The umbones are slightly prominent, prosogyrate, and are situated between one-third and one-half of the shell length from the anterior end.

The taxodont hinge has about ten teeth anteriorly and about 18 teeth posteriorly, which decrease in size from both ends toward the umbo. As is typical of the genus, they are chevron-shaped toward the umbones. The internal mold of the left valve shows tear-shaped muscle scars, the posterior one being larger than the anterior one.

Remarks: This is the first record of the genus from Mexico. The Mexican material strongly resembles Early Jurassic specimens from Argentina that have been described by Damborenea (1987a) as *Palaeoneilo galatea* (d'Orbigny, 1850) ? and *P. patagonidica* (A. Leanza, 1942). Both have been included into *P. elliptica* by Hodges (2000), a view that is followed here. In his detailed examination of *P. elliptica*, Hodges (2000) analyzed several samples with a large number of specimens from the Lower Lias of southwest Britain, and found a wide range of morphological variability. *P. galatea* from the Middle Lias of Europe can be distinguished from *P. elliptica* by having an angulate posterior margin (Hodges, 2000).

Subclass Pteriomorphia Beurlen, 1944
Order Arcoida Stolizka, 1871
Family Parallelodontidae Dall, 1898
Subfamily Parallelodontinae Dall, 1898
Genus *Parallelodon* Meek and Worthen, 1866

Type species. *Macrodon rugosus* Buckman, 1845.

Parallelodon cf. *hirsonensis* (d'Archiac, 1843)
Figs. 4E and 4F.

cf. 1843 *Cucullaea hirsonensis* sp. nov.—d'Archiac: 374, pl. 27, figs. 5, 5a.
cf. 1969 *Parallelodon hirsonensis* (d'Archiac)—Fischer: 78, pl. 9, fig. 3a–b (see for extensive synonymy list).
cf. 1994 *Parallelodon hirsonensis* (d'Archiac 1843)—Aberhan: 12, pl. 1, figs. 15, 17–20; text-fig. 5.

Material: One internal mold of a left valve (MB.M.4501) from the lower Sinemurian, unit 18, Sierra del Álamo; two internal molds of left valves and one steinkern (ERNO-8155 to 8156, MB.M.4502) from the lower Pliensbachian, middle member, section 4, Sierra de Santa Rosa.

Description: *Parallelodon* cf. *hirsonensis* is medium-sized, equivalved, inequilateral, elongated, and subrectangular in outline. The shell is moderately inflated. Its length is about

Figure 4. (A–B) *Palaeoneilo elliptica* (Goldfuss, 1837). (A) internal mold of a left valve, × 4, ERNO-8151. (B) internal mold of a right valve, × 4, ERNO-8152; all lower Sinemurian of Sierra del Álamo. (C–D) *Grammatodon (Grammatodon) sulcatus* Aberhan, 1994. (C) internal mold of a right valve, × 2, ERNO-8153. (D) Latex cast of a left valve, × 2, ERNO-8154; all lower Sinemurian of Sierra del Álamo. (E–F) *Parallelodon* cf. *hirsonensis* (d'Archiac, 1843). (E) internal mold of a left valve, lower Pliensbachian of Sierra de Santa Rosa, × 1, ERNO-8155. (F) internal mold of a left valve, lower Pliensbachian of Sierra de Santa Rosa, × 1.5, ERNO-8156. (G) *Bakevellia* sp. A; internal mold of a left valve, lower Sinemurian of Sierra del Álamo, × 1.5, ERNO-8157. (H–J) *Gervillella araucana* Damborenea, 1987; (H) left valve, lower Pliensbachian of Sierra de Santa Rosa, × 1, ERNO-8158. (I) left valve, lower Sinemurian of Sierra del Álamo, × 1, ERNO-8159. (J) internal mold of a left valve, lower Pliensbachian of Sierra de Santa Rosa, × 1, ERNO-8160. (K–L) *Gervillella leesi* Aberhan and Muster, 1997. (K) articulated specimen, left valve view, lower Sinemurian of Sierra del Álamo, × 1, ERNO-8161. (L) articulated specimen, left valve view, lower Pliensbachian of Sierra de Santa Rosa, × 1, ERNO 8162.

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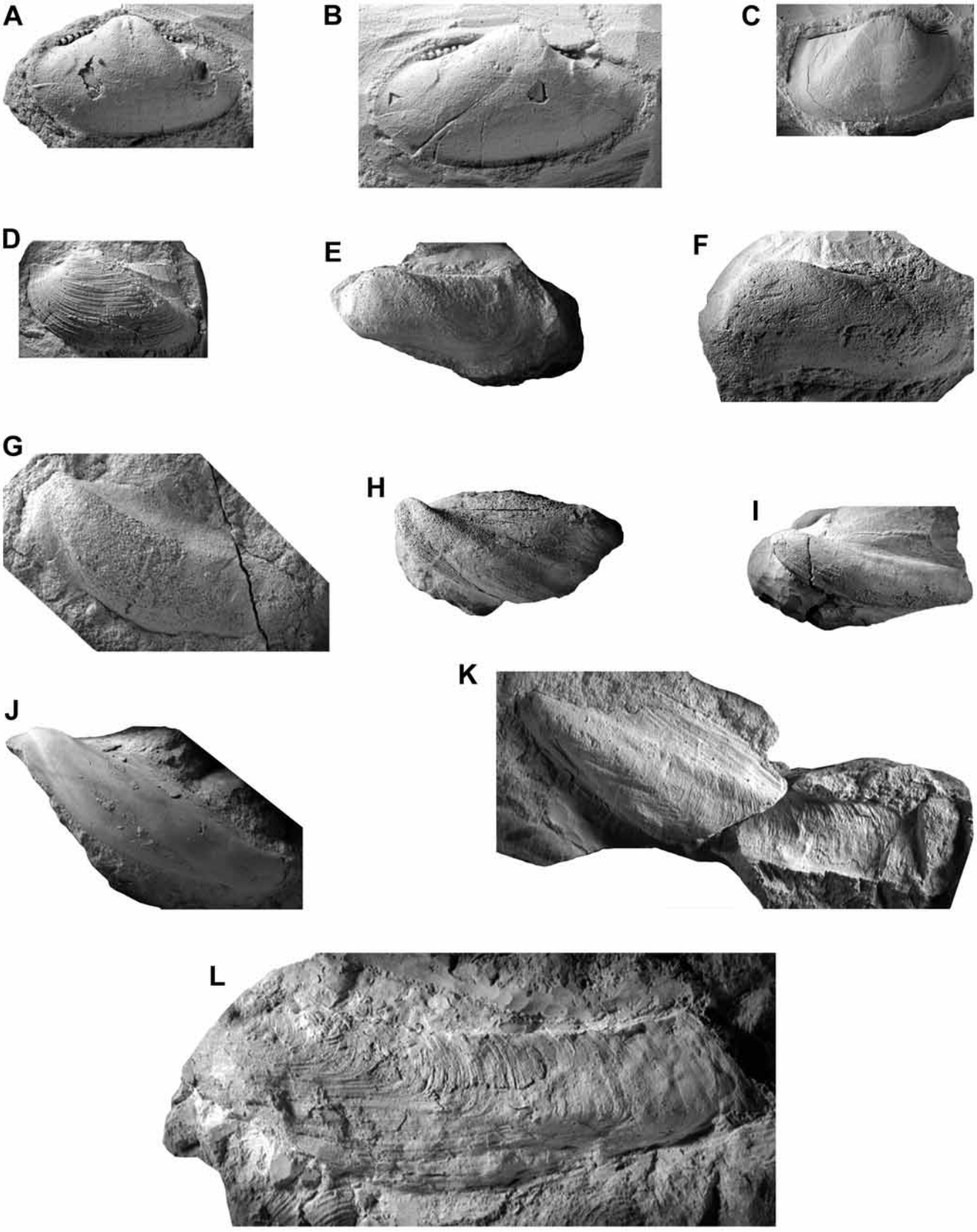

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twice its height. The hinge line is straight, but not as long as the total length. The posterior margin is convex and meets with the hinge margin at an obtuse angle. The ventral margin is nearly parallel to the dorsal margin, but is slightly concave mesially. The anterior margin is short and convex. The umbo is prosogyrate, wide, and low, and is placed about one-fourth of the total shell length from the anterior end. A weak umbonal ridge runs from the umbo to the postero-ventral corner. The surface of the shell is smooth except for commarginal growth lines. The ligament area has the shape of an elongated triangle.

Remarks: This is the first record of the genus from the Lower Jurassic of Mexico. In overall shape and outline, *P.* cf. *hirsonensis* has a great similarity to the type material of *P. hirsonensis* d'Archiac (1843, pl. 27, figs. 5, 5a). As the Mexican material is only moderately well preserved, and important characters such as hinge features are not known, it is only referred to *P. hirsonensis* with reservation. Nevertheless, with its rectangular outline and the obtuse postero-dorsal angle, it shows typical features of *P. hirsonensis* as described by Aberhan (1994). Damborenea (1987a, p. 66, pl. 1, figs. 10–12) described *Parallelodon* sp. from the Pliensbachian of Argentina, which is very similar to *P. hirsonensis*, but has a wider hinge plate and more numerous teeth than *P. hirsonensis* described by Aberhan (1994).

Genus *Grammatodon* Meek and Hayden, 1861

Type species. *Arca (Cucullaea) inornata* Meek and Hayden, 1859, by original designation.

Subgenus *Grammatodon*

Grammatodon (Grammatodon) sulcatus Aberhan, 1994

Figs. 4C and 4D.

1994 *Grammatodon (Grammatodon) sulcatus* sp. nov.—Aberhan: 13, pl. 1, figs. 21–24; text-fig. 7.

Material: Internal molds of one right valve and one left valve (MB.M.4503 to 4504) from the upper Hettangian–lower Sinemurian, unit 16, three external and two internal molds of right valves, and six internal and four external molds of left valves (ERNO-8153 to 8154, MB.M.4506 to 4518) from the lower Sinemurian, unit 18, Sierra del Álamo; one internal and one external mold of left valves (MB.M.4521 to 4522) from the lower Pliensbachian, Pozos de Serna; one internal mold of a right valve (MB.M.4523) from the lower Pliensbachian, middle member, section 4, Sierra de Santa Rosa.

Description: *Grammatodon (G.) sulcatus* is small and inequilateral and has a subtrapezoidal outline. Its height is about the half of the total length. The umbones are situated at about one-third of the shell length from the anterior, and are broad and slightly prosogyrate. The dorsal margin is straight and extends along one-third of the shell length. The posterior margin is obliquely truncated, forming an obtuse angle with the dorsal margin and a right angle with the convex ventral margin. The anterior margin is straight, meets the ventral margin also at a right angle, and is slightly projecting beyond the anterior end of the hinge line. A relatively sharp, straight to slightly curved umbonal carina extends from behind the umbo to the postero-ventral corner of the shell; the carina becomes less sharp during ontogeny. In right valves, anterior to the carina, there is a shallow sulcus, which is very pronounced near the umbo but becomes less prominent and finally disappears toward the ventral margin. The left valve lacks this sulcus.

The whole surface of the shell is covered with smooth commarginal growth lines. The postero-dorsal part of the right valve wears numerous radial riblets, which extend to the carina. One to two of these riblets are slightly more prominent than the others. The interspaces are about half as wide as the riblets. On the flanks and the sulcus of the right valve only commarginal growth lines can be seen. The anterior part of both valves also wears faint, fine radial striae, which are more pronounced than the commarginal growth lines.

The preservation of the material does not allow an accurate description of the hinge. Some specimens show several small anterior teeth, which are slightly oblique near the umbo and become more horizontal toward the anterior end. Some other specimens possess two to three posterior elongated pseudolaterals, which are oriented in a horizontal to subhorizontal direction. Other internal structures are unknown.

Remarks: This is the first record of the species outside Chile. *G. sulcatus* was first described by Aberhan (1994) from the upper Sinemurian of northern Chile. The specimens described herein agree well with the material from Chile. Only the radial components of the ornamentation of the shell are more pronounced in the Chilean material.

Grammatodon (G.) concinnus (Phillips, 1829), which was documented by Aberhan (1994, p. 12, pl. 2, figs. 1–5) from the Lower Jurassic of Chile, can be distinguished from *G. sulcatus* by its greater inflation and the lack of a sulcus on the right valve. Also similar is *Grammatodon (G.) costulatus* (A. Leanza, 1942, p. 152, pl. 1, figs. 5–6; Damborenea, 1987a, p. 69, pl. 2, figs. 14–17; text-fig. 16b) from the Lower Jurassic of Argentina. Unlike *G. sulcatus*, the whole shell of *G. costulatus* is covered with regular radial riblets, the interspaces being twice as wide as the ribs.

Order Pterioida Newell, 1965

Family Bakevelliidae King, 1850

Genus *Bakevellia* King, 1848

Type species. *Avicula antiqua* Münster, 1836, by subsequent designation (King 1850).

Bakevellia sp. A

Fig. 4G.

Material: Two internal molds of left valves (ERNO-8157, MB.M.4524) from the lower Sinemurian, unit 18, Sierra del Álamo.

Description: *Bakevellia* sp. A has a rhombic outline, is well inflated and has an anterior auricle and a posterior wing. The umbo is slightly prosogyrate and projects somewhat above the hinge line. The shell is slightly longer than high. The ratio of the length of the diagonal to the maximum width

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of the main body of the shell is about 2:1. The hinge line is half the length of the total shell length. The posterior margin has a sigmoidal shape, being concave at the posterior wing and turning highly convex near the posterior end of the shell. The ventral margin is evenly convex and passes gradually into the anterior margin.

The anterior auricle is small, narrow, and rounded, and extends along half of the anterior margin. It is separated from the main body of the shell by a shallow groove. The posterior wing is nearly right-angled and pointed, and is separated from the disc of the shell by a wide sulcus.

One elongated posterior tooth, which runs parallel to the hinge margin, is developed in both specimens, a juvenile and an adult. Other internal features, such as anterior teeth or muscle scars, are unknown. The surface of the shell is covered with commarginal growth lines.

Remarks: This is the first Lower Jurassic record of the genus from Mexico. *Bakevellia* sp. A is similar to *Bakevellia (B.) waltoni* (Lycett, 1863), which is a common species in the Lower Jurassic of North and South America (Aberhan, 1994, p. 16, pl. 2, figs. 10–14; text-fig. 8; 1998a, p. 71, pl. 2, fig. 17, pl. 3, figs. 5–7; Aberhan and Muster, 1997, p. 801, text-fig. 2D–G). Similar to *Bakevellia* sp. A, *B. waltoni* also has a rhombic shape and one (to two) elongated posterior teeth. As the presence of anterior teeth in *Bakevellia* sp. A cannot be confirmed with the material at hand, a comparison with the anterior teeth of *B. waltoni* cannot be performed. In addition, *Bakevellia* sp. lacks some of the prominent features that are significant of *B. waltoni*, in particular the presence of an acute anterior auricle and a sharply pointed, elongated posterior wing.

Among other species of *Bakevellia* that are similar to *Bakevellia* sp. A, *Bakevellia (B.) nana* Fürsich and Werner (*in* Muster, 1995) from the Upper Jurassic of Portugal has two to three posterior teeth rather than one. *Bakevellia (B.) binneyi* Brown also has a small and rounded anterior auricle, but two posterior teeth, and is known from the Upper Permian to the Lower Jurassic of Greenland, Europe, and Asia (see Muster, 1995). *Gervillaria hartmanni* (Münster in Goldfuss, 1835, p. 122, pl. 115, figs. 7a–f) is less curved, the posterior wing is separated from the disc of the shell by only a slight flexure, not a sulcus, and occasionally wears weak radial ribs on the shell.

Genus *Gervillella* Waagen, 1907

Type species. *Perna avicuolides* J. Sowerby, 1814 (pl. 147, pl. 66), by subsequent designation (Cox 1940).

Gervillella araucana Damborenea, 1987

Figs. 4H–4J.

1987b *Gervillella araucana* sp. nov.—Damborenea: 133, pl. 1, figs. 6–10; text-fig. 6.

1994 *Gervillella araucana* Damborenea 1987—Aberhan: 18, pl. 3, figs. 8–10.

1995 *Gervillella araucana* Damborenea 1987—Muster: 61, pl. 12, figs. 3–4; text-fig. 45.

1997 *Gervillella araucana* Damborenea 1987—Aberhan and Muster: 807, text-figs. 4F–G, 5C.

1998a *Gervillella araucana* Damborenea 1987—Aberhan: 74, pl. 2, figs. 14–15.

Material: One left valve and two internal molds of left valves (ERNO-8159, MB.M.4525 to 4526) from the lower Sinemurian, unit 18, Sierra del Álamo; one left valve and four internal molds of left valves (ERNO-8158, ERNO-8160, MB.M.4527 to 4529) from the lower Pliensbachian, middle member, section 3, Sierra de Santa Rosa.

Description: *Gervillella araucana* is medium-sized, twisted, and has an elongated, lanceolate outline. The left valves are very globose and twisted anticlockwise in posterior view. The dorsal margin is straight and half as long as the total shell. The posterior margin is concave at the posterior wing and convex near the posterior end and therefore has a sigmoidal shape. The ventral and the anterior margins are evenly rounded. The height is about half of the shell length.

The umbo is prosogyrate, acute, and anteriorly placed but not terminal. A relatively sharp carina leads from the umbo toward the postero-ventral corner of the shell. This carina is not at the greatest inflation of the shell, but lies dorsally of it, and is preceded ventrally by a shallow but distinct furrow.

The anterior auricle is lobate, extends along the anterior margin, and is separated from the disc of the shell by a shallow sulcus on the left valve. The posterior wing is narrow, obtuse, and separated from the disc of the shell by a deep sulcus.

The surface of the shell is covered with regular growth lines. On the anterior part of the shell, they become imbricate. Internal features are not preserved.

Remarks: This is the first record of *Gervillella* from the Lower Jurassic of Mexico. *G. araucana* can be distinguished from other species of *Gervillella* by its highly twisted shell and the presence of a carina on the left valve.

***Gervillella leesi* Aberhan and Muster, 1997**

Figs. 4K and 4L, 5A–5C, 6A.

1934 *Gervillia* sp. nov.—Lees: 41, pl. 4, fig. 1.

1997 *Gervillella leesi* sp. nov.—Aberhan and Muster: 805, text-figs. 4A–E, 5D.

1998a *Gervillella leesi* Aberhan and Muster 1997—Aberhan: 74, pl. 3, figs. 8–11; pl. 4, figs. 1; text-fig. 4.

Material: One articulated specimen (ERNO-8161) from the lower Sinemurian, unit 18, Sierra del Álamo; one articulated specimen, one external and two internal molds of left valves, and one steinkern (ERNO-8162, MB.M.4530 to 4533) from the lower Pliensbachian, middle member, section 3, and one articulated specimen, two external and three internal molds of left valves, and four steinkerns (ERNO-8163 to 8165, MB.M.4534 to 4540) from the lower Pliensbachian, middle member, section 4, Sierra de Santa Rosa.

Description: *Gervillella leesi* is large-sized, thick-shelled, nearly equivalved, with the left valve slightly more inflated than the right valve. The shape is elongated, slightly curved

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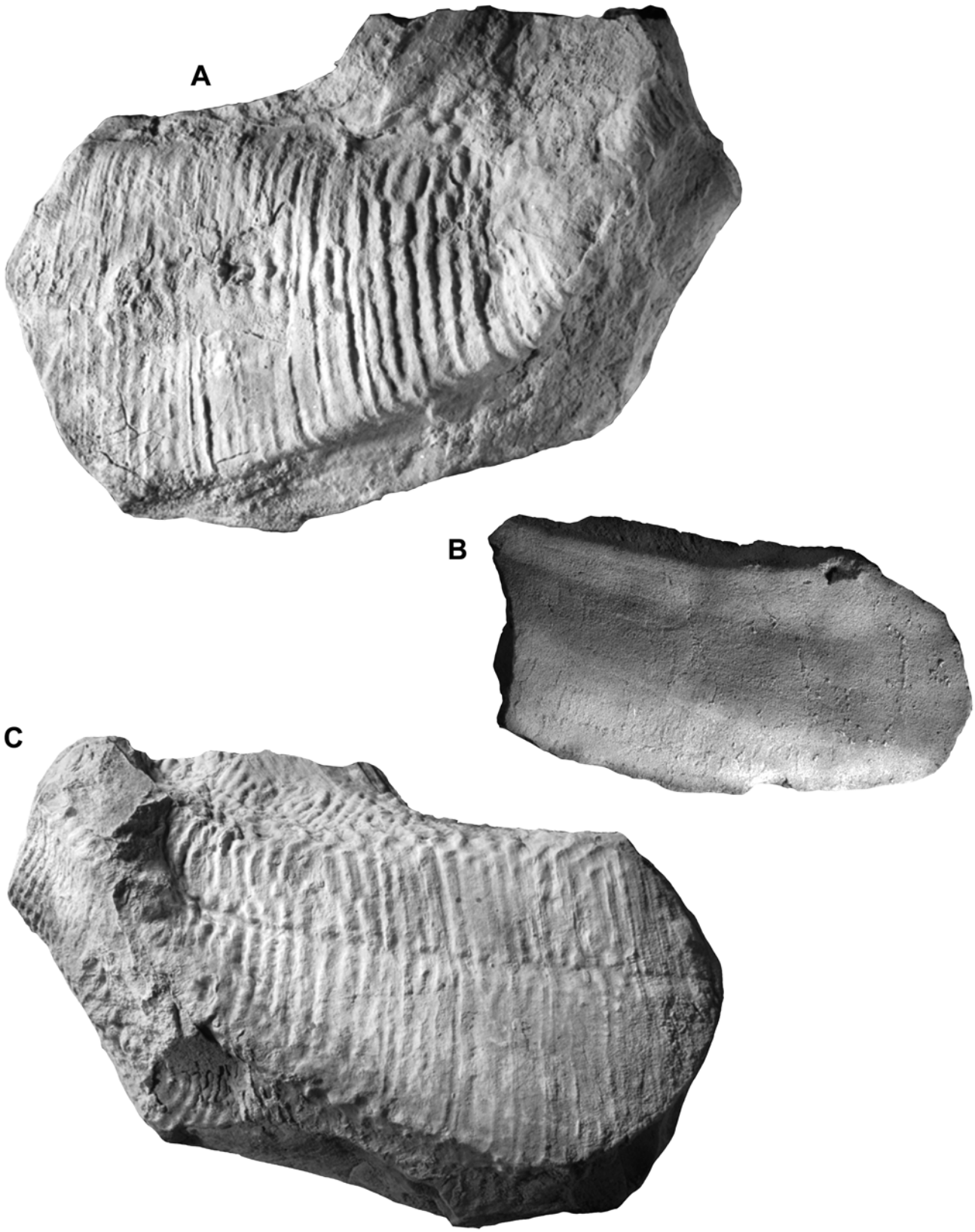

Figure 5. (A–C) *Gervillella leesi* Aberhan and Muster, 1997. (A) articulated specimen, right valve view, × 1, ERNO-8163; (B) Steinkern, left valve view, × 1, ERNO-8164; (C) articulated specimen, left valve view, × 1, ERNO-8163; all lower Pliensbachian of Sierra de Santa Rosa.

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upward posteriorly, but not twisted. The anterior auricle is lobate, small relative to the overall size of the specimens, and separated from the main body of the shell by a shallow sulcus. The posterior wing is large and obtuse. A cross section through the body of the shell at about mid-length is rhombic. The umbones are prosogyrate, pointed, and low.

The shell carries two carinae. One carina leads from below the umbo to the postero-ventral corner of the shell. The other one originates behind the umbo below the posterior wing and separates the main body of the shell from the posterior wing. Between the two carinae runs a shallow sulcus. In medium-sized specimens, the surface of the shell is covered by numerous regular growth lines that bend where they meet the carinae. Large-sized specimens develop conspicuous, strong knobs and wrinkles that follow the growth lines between the two carinae, but cross them in nearly right angles on the antero-ventral part of the shell and on the posterior part of the posterior wing.

The ligament is multivincular. One of the specimens shows five ligamental pits. Anteriorly, the interspaces between the pits are narrower than the pits, but get wider in the posterior half of the ligamental area. Other internal features are unknown.

Remarks: This is the first record of *Gervillella leesi* outside western Canada. It was first described by Aberhan and Muster (1997) from the Hettangian and upper Sinemurian of western Canada. Other Lower Jurassic carinate bakevelliids are *Gervillella araucana* and *Gervillaria pallas* (A. Leanza, 1942, p. 155, pl. 4, fig. 1). *G. araucana*, which is also described herein, is twisted, much more elongated, and wears only one carina. *G. pallas*, which is known from the Lower Jurassic of Argentina, Chile, and Canada (see Aberhan and Muster, 1997, for synonymy list), also is inequivalved and twisted, and has a pointed posterior wing.

Although incomplete, the majority of the Mexican material is represented by very large specimens, reaching an estimated length of nearly 20 cm. A very conspicuous feature of these large specimens is well-developed knobs and wrinkles on the shell exterior. We interpret this feature as a phenomenon typical of adult and gerontic growth stages of *G. leesi*. This kind of ornamentation is very similar to that observed in fully grown specimens of another bakevelliid, *Gervilleioperna (Gervilletia) turgida* (A. Leanza, 1942), in which transverse, broad, and irregular rugae, which in some instances become true nodes, develop on the upper and lower carinae of the shell.

Genus *Gervillia* Defrance, 1820

Type species. *Gervillia solenoidea* Defrance, 1824, subsequent monotypy.

Subgenus *Cultriopsis* Cossmann, 1904

Type species. *Gervillia (Cultriopsis) falciformis* Cossmann, 1904, original designation.

Gervillia (Cultriopsis) sp. A

Fig. 6B.

Material: One internal mold of a left valve (ERNO-8166) from the lower Pliensbachian, Pozos de Serna.

Description: *Gervillia (Cultriopsis)* sp. A is small, arched and only slightly inflated. It has a very slender, elongated, ensiform outline, with its height being about one-third of its length (H = 8 mm, L = 26 mm). The ratio of the length of the posterior wing to the length of the diagonal is 1:5; the ratio of the length of the diagonal to the maximum width of the main body of the shell is 5:1. A faint carina runs from behind the umbo toward the postero-ventral corner. The umbo is pointed, orthogyrate, and protrudes slightly beyond the hinge line. The anterior auricle is very small, pointed, and forward-turned; the posterior wing is relatively small (L = 5 mm), acute-angled in a posterior direction, and separated from the disc of the shell by a shallow sulcus. The internal mold shows the imprint of two posterior lateral teeth that are subparallel to the dorsal margin. Anterior teeth cannot be observed. The ligament and muscle scars are unknown. The shell surface is smooth and wears only commarginal growth lines.

Remarks: This is the first documentation of the subgenus *Cultriopsis* from the Lower Jurassic of Mexico. Species of *Cultriopsis* have been revised by Muster (1995). The Mexican specimen has closest affinities to *Gervillia (Cultriopsis) dundriensis* Cox, 1946, and *Gervillia (Cultriopsis) northamptonensis* Cox, 1946. The former agrees well in size and outline, especially in the ratio between the length of the posterior wing and the diagonal (1:5), but lacks an anterior auricle, the umbo is terminal, and the posterior wing is obtuse. *G. (C.) northamptonensis* is similar in overall shape, but has no teeth and no carina.

Another very similar species is *Gervillia olifex* Quenstedt (1856: 86, pl. 11, figs. 4–5) from the Lower Jurassic of Dusslingen, southern Germany, which can be distinguished by a larger ratio (~1:3) of the length of the posterior wing to the diagonal, and by a slightly larger width (ratio of diagonal to width 4:1). Damborenea (1987b, p. 130) also mentioned *G. olifex* and noted a similarity to *Gervillia* cf. *angusta* von Münster described by Escobar (1980, p. 41, pl. 2, fig. 1d) from the lower Sinemurian of El Culebreada, Chile, which has an obtuse posterior wing and a ratio of the length of the posterior wing to the diagonal of the shell of ~1:3. Damborenea (1987b, p. 131, pl. 3, figs. 4–6; text-fig. 5) also described *Gervillia (Cultriopsis)* sp. from the Toarcian of Argentina, which differs by the absence of an anterior auricle and the shape of the posterior wing.

Family Isognomonidae Woodring, 1925

Genus *Mytiloperna* von Ihering, 1903

Type species. *Perna americana* Forbes in Darwin, 1846.

Mytiloperna? sp. A

Fig. 6C.

Material: One external mold of a left valve (ERNO-8167) from the lower Sinemurian, unit 18, Sierra del Álamo.

Description: *Mytiloperna*? sp. A is subrectangular, slightly inflated, with a terminal umbo. A conspicuous carina extends from the umbo to the antero-ventral corner of the shell. The

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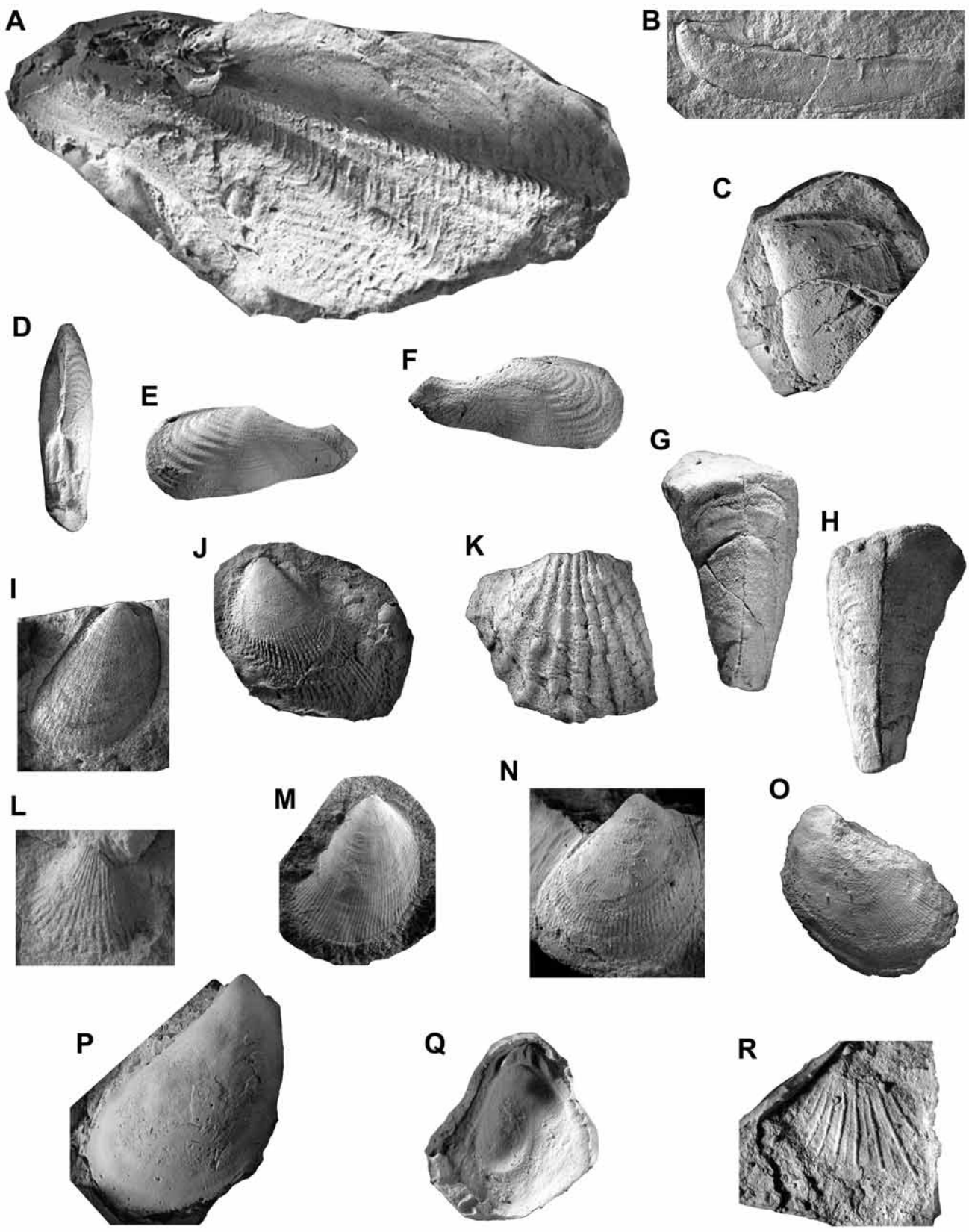

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part anterior of this carina is slightly concave; the posterior part is slightly convex. The dorsal margin is straight and longer than half the total shell length. The posterior and the ventral margins are slightly convex. The anterior margin is slightly concave. The posterior wing is undifferentiated. The surface of the shell is covered with weak, regularly spaced growth lines. Internal features are not preserved.

Remarks: Internal features such as the extension of the ligamental area and the presence or absence of posterior hinge teeth are needed to distinguish *Mytiloperna* from the externally very similar bakevelliid genus *Aguilerella*. In particular, *A. kobyi* (Loriol) is similar in overall shape to the Mexican specimen (e.g., see Muster 1995, p. 15, pl. 1, figs. 1–4, text-fig. 8). Nevertheless, the outline of the specimen also strongly resembles that of other species of *Mytiloperna*, for example *Mytiloperna mytiliformis* (Schlippe) (e.g., Ma et al., 1976, p. 298, pl. 31, figs. 7–9). The type species of *Mytiloperna*, *M. americana* (Forbes) from the Lower Jurassic of Chile (Forbes, 1846: 266, figs. 4–6; Philippi, 1899, p. 45, pl. 22, fig. 8; Ihering, 1903, p. 123, fig. 1), is very large and has a mytiliform rather than subrectangular outline. From North America, only one species of *Mytiloperna* has been described until now, i.e., *Mytiloperna charlottensis* Aberhan (1998a, p. 75, pl. 4, figs. 7–10; text-fig. 5) from the Pliensbachian of the Queen Charlotte Islands, western Canada. In contrast to the subrectangular outline of the Mexican specimen, however, this species is subtrigonal in shape. If our generic identification can be confirmed when additional material becomes available, this would be the first record of the genus from Mexico.

Figure 6. (A) *Gervillella leesi* Aberhan and Muster, 1997; Latex cast of an external mold of a left valve, lower Pliensbachian of Sierra de Santa Rosa, × 1, ERNO-8165. (B) *Gervillia (Cultriopsis)* sp. A; internal mold of a left valve, lower Pliensbachian of Pozos de Serna, × 2, ERNO-8166. (C) *Mytiloperna*? sp. A; latex cast of an external mold of a left valve, lower Sinemurian of Sierra del Álamo, × 2, ERNO-8167. (D–F) *Cercomya (Capillimya) peruviana* Cox, 1956; composite mold of an articulated specimen; (D) dorsal view; (E) left valve view; (F) right valve view, lower Pliensbachian of Sierra de Santa Rosa, × 1, ERNO-8168. (G, H) *Pinna (Pinna)* cf. *folium* Young and Bird, 1822. Steinkern; (G) right valve view; (H) left valve view, lower Pliensbachian of Sierra de Santa Rosa, × 1, ERNO-8169. (I, J) *Antiquilima (Antiquilima)* cf. *nodulosa* Hayami, 1959; (I) internal mold of a left valve, lower Pliensbachian of Sierra de Santa Rosa, × 1, ERNO-8170; (J) latex cast of an external mold of a right valve, lower Pliensbachian of Sierra de Santa Rosa, × 1, ERNO-8171. (K) *Ctenostreon* sp.; composite mold of a right valve, lower Pliensbachian of Sierra de Santa Rosa, × 1, ERNO-8172. (L) *Pseudolimea*? sp. A; composite mold of a right valve, lower Pliensbachian of Pozos de Serna, × 2, ERNO-8173. (M, N) *Plagiostoma schimperi* (Branco, 1879); (M) latex cast of an external mold of a left valve, × 1, ERNO-8174; (N) internal mold of a left valve, × 1, ERNO-8175; all lower Pliensbachian of Sierra de Santa Rosa. (O, P) *Plagiostoma* sp. A. (O) composite mold of a right valve, × 1, ERNO-8176; (P) internal mold of a left valve, × 1, ERNO-8177; all lower Pliensbachian of Pozos de Serna. (Q) *Plicatula (Plicatula)* sp. A; latex cast of an internal mold of a left valve, lower Sinemurian of Sierra del Álamo, × 2, ERNO-8178. (R) *Oxytoma (Oxytoma)* cf. *inequivalvis* (J. Sowerby, 1819); latex cast of an external mold of a left valve, lower Sinemurian of Sierra del Álamo, × 2, ERNO-8179.

Family Pinnidae Leach, 1819
Genus *Pinna* Linné, 1758

Type species. *Pinna rudis* Linné, 1758, subsequent designation by Children, 1823.

Subgenus *Pinna*

Pinna (Pinna) cf. *folium* Young and Bird, 1822
Figs. 6G and 6H.

cf. 1822 *Pinna folium* sp. nov.—Young and Bird: 243, pl. 10, fig. 6.
1987a *Pinna (Pinna)* cf. *folium* Young and Bird 1822—Damborenea: 95, pl. 4, figs. 6, 11a–b, 12a–b, 13–14; text-fig. 24 (see for extensive synonymy list).
1994 *Pinna (Pinna)* cf. *folium* Young and Bird 1822—Aberhan: 22, pl. 7, figs. 3–4.
1997 *Pinna* sp.—Damborenea and González-León: 183, fig. 5.1.
1998a *Pinna (Pinna)* cf. *folium* Young and Bird 1822—Aberhan: 80, pl. 5, figs. 10–12; pl. 6, fig. 1.

Material: One fragmentary valve (MB.M.4544) from the lower Pliensbachian, middle member, section 3, one external mold and five partially fragmented steinkerns (ERNO-8169, MB.M.4545 to 4549) from the lower Pliensbachian, middle member, section 4, Sierra de Santa Rosa; one fragmented steinkern with remains of shell (MB.M.4551) from the lower Pliensbachian, Pozos de Serna.

Description: *Pinna (P.)* cf. *folium* is medium-sized and has a cuneiform outline. The apical angle is very acute (about 30°). The dorsal margin is straight to slightly convex, the ventral margin is slightly concave. The posterior margin is straight and slightly rounded, and the posterior end has a wide gape. The medium carina is strong. In some well-preserved specimens, a faint furrow is sitting on the medium carina.

The shell is ornamented by about eight radial ribs, which cover the area dorsal to the medium carina. The shell also is covered with smooth growth lines and a large number of commarginal folds. These folds intersect with the radial ribs and form a bulging reticulate pattern. The cross section of the shell is rhombic with rounded edges.

Remarks: *P.* cf. *folium* is a common element of the Lower Jurassic of North and South America with occurrences reported from Argentina, Chile, British Columbia, and Alberta (Damborenea, 1987a; Aberhan, 1994, 1998a). The material studied by Damborenea and González-León (1997) from the same locality in Mexico (section 4, Sierra de Santa Rosa) and described as "*Pinna* sp." resembles the specimens described herein and is included in *P.* cf. *folium*. We regard the somewhat larger apical angle of about 40° as part of the intraspecific variation of the species. An extensive comparison with similar species of *Pinna* is given by Damborenea (1987a).

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Order Limoida Rafinesque, 1815
Family Limidae Rafinesque, 1815
Genus *Antiquilima* Cox, 1943

Type species. *Lima antiquata* J. Sowerby, 1818.

Subgenus *Antiquilima*

Antiquilima (Antiquilima) cf. *nodulosa* Terquem, 1855

Figs. 6I and 6J.

cf. 1855 *Lima nodulosa* sp. nov.—Terquem: 322, pl. 22, fig. 3.
1929 *Lima nodulosa* Terqu.—Jaworski: 6, pl. 1, fig. 6.
1942 *Lima succincta* Schloth.—Leanza: 178, pl. 10, fig. 7.
1984 *Antiquilima* sp.—Manceñido and Damborenea: 425, pl. 1, fig. 18.
1959 *Lima* aff. *compressa* Terquem—Frebold: 10, pl. 4, fig. 3.
1994 *Antiquilima (Antiquilima)* cf. *nagatoensis* Hayami 1959—Aberhan: 22, pl. 8, figs. 1–3.
1998a *Antiquilima (Antiquilima)* cf. *nagatoensis* Hayami 1959—Aberhan: 81, pl. 7, figs. 9–10.

Material: One external mold of a left valve (MB.M.4555) from the lower Pliensbachian, middle member, section 3, and one internal and four external molds of right valves, and one internal mold of a left valve (ERNO-8170 to 8171, MB.M.4553 to 4554, MB.M.4556 to 4557) from the lower Pliensbachian, middle member, section 4, Sierra de Santa Rosa.

Description: *Antiquilima (A.)* cf. *nodulosa* is medium-sized, equivalved, inequilateral, and has an obliquely ovate, rather compressed, and only slightly inflated shell. It shows the typical ornamentation of sinuous radial ribs of two different orders of strength and commarginal growth rugae. The radial ribs carry imbricate lamellae on their crests, which may develop into spines in larger specimens and are conspicuously stronger on the primary than on the secondary ribs. The interspaces between the primary ribs are wider than the ribs and bear no or one to three intercalated secondary riblets, which are of different width and do not reach the same strength as the primary riblets.

Remarks: This taxon is also known from the Sinemurian of northern Chile (Aberhan, 1994), the Lower Jurassic of Argentina (e.g., *Lima succincta* Schlotheim in A. Leanza, 1942) and the Sinemurian to Pliensbachian of western Canada (Aberhan, 1998a). In previous studies, Aberhan (1994, 1998a) tentatively assigned the material from South America and western Canada to *A. nagatoensis* Hayami, 1959, a species known from the Sinemurian of Japan. Assignment was with reservation because of differences in the length-height ratio. Furthermore, all the above mentioned material from America, including that described here as well as *Lima nodulosa* Terqu. of Jaworski (1929) from the same locality in Mexico, is characterized by the presence of imbricate lamellae on the crests of the ribs. This feature is less clearly developed in the holotype of *A. nagatoensis*, in which primarily the higher-order riblets appear to be jagged. For this reason, the American specimens are here referred to *Antiquilima nodulosa* (Terquem, 1855, p. 322, pl. 22, fig. 3 a–c, Dumortier, 1864, p. 57, pl. 8, figs. 6–8) from the Hettangian of France, with which they share the distinct lamellae on the crests of the radial ribs. Because of a lower length-height ratio in the European material, assignment to this species is with reservation.

A. cf. *nodulosa* can be distinguished from the closely related *Antiquilima (A.) succincta* (v. Schlotheim, 1813) by the presence of imbricate lamellae on the crests of the ribs (see also Aberhan, 1994, 1998a).

Genus *Ctenostreon* Eichwald, 1862

Type species. *Ostracites pectiniformis* Schlotheim, 1820.

Ctenostreon sp. A

Fig. 6K.

Material: One fragmented composite mold of a right valve (ERNO-8172) from the lower Pliensbachian, middle member, section 3, Sierra de Santa Rosa.

Description: The single available specimen of *Ctenostreon* sp. A suggests a subcircular outline of the valve. The fragment carries ten strong, sinuous, rounded radial ribs. The interspaces vary in width but generally have the same width as the ribs. The whole surface of the shell is covered with fine commarginal, imbricate lamellae that form conspicuous knobs on the ribs.

Remarks: The genus *Ctenostreon* was hitherto unknown from the Lower Jurassic of Mexico. Aberhan (1994, p. 23, pl. 8, figs. 4–7; 1998a, p. 84, pl. 7, figs. 1–5) described *Ctenostreon* cf. *rugosum* from the Lower Jurassic of Chile and western Canada, which is very similar in size and ornamentation, and considered the better known species *Ctenostreon pectiniforme* (Schlotheim) and *C. proboscideum* (J. Sowerby) as likely junior synonyms of *C. rugosum*. As the Mexican specimen is represented only by a fragment, an identification at species level is not possible at the moment.

Genus *Pseudolimea* Arkell in Douglas and Arkell, 1932

Type species. *Plagiostoma duplicata* J. de C. Sowerby, 1827.

Pseudolimea? sp. A

Fig. 6L.

Material: One composite mold of a right valve (ERNO-8173) from the lower Pliensbachian, Pozos de Serna.

Description: *Pseudolimea*? sp. A is small, trigonal in outline and slightly inflated. It carries about 16 radial ribs, which have about the same width as their interspaces. Its anterior and posterior ends bear only weak riblets. Other structures such as internal characters cannot be observed.

Remarks: *Pseudolimea* has not been reported from the Lower Jurassic of Mexico before. In the single, poorly preserved specimen at hand, the presence of secondary riblets cannot be verified. Therefore, the specimen is referred to *Pseudolimea* with reservation. *Pseudolimea hettangiensis* (Terquem, 1855), which has been described from the Hettangian of Chile (Aberhan, 1994, p. 27, pl. 11, fig. 6), has a slightly higher number of radial ribs (17 to 18), but additional material would be needed for a more detailed comparison.

Genus *Plagiostoma* J. Sowerby, 1814

Type species. *Plagiostoma giganteum* J. Sowerby, 1814.

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Plagiostoma schimperi (Branco, 1879)
Figs. 6M and 6N.
1879 *Lima schimperi* sp. nov.—Branco: 111, pl. 6, fig. 4.
1900 *Lima (Plagiostoma) schimperi* Branco—Greppin: 130, pl. 15, fig. 7; pl. 16, figs. 2, 5.
1929 *Plagiostoma* cf. *exaltata* Terqu.—Jaworski: 5, pl. 1, figs. 5a–b.
1936 *Plagiostoma schimperi* Branco—Dechaseaux: 22, text-fig. 6.
1943 *Lima (Plagiostoma) schimperi* Branco—Cox: 160, pl. 11, figs. 15–18, pl. 12, figs. 19–22.
1986 *Plagiostoma schimperi* (Branco)—Jaitly: 43, pl. 1, fig. 6.
1995 *Plagiostoma schimperi* (Branco 1879)—Jaitly et al.: 180, pl. 12, fig. 3.
1997 *Plagiostoma* cf. *P. punctatum* J. Sowerby, 1814—Damborenea and González-León: 188, fig. 5.2.

Material: One external mold of a right valve, one external mold of a left valve, and two almost complete left valves (ERNO-8174 to 8175, BM.M.4558 to 4559) from the lower Pliensbachian, middle member, section 4, Sierra de Santa Rosa.

Description: *Plagiostoma schimperi* is medium-sized, equivalved, inequilateral, and has an obliquely ovate, subtrigonal shell, with the ventral margin being well rounded and slightly asymmetrical. The posterior auricle is relatively large. Because preservation is incomplete, the size and outline of the anterior auricle are unknown. The surface of the shell is covered by numerous (50–70) faint radial riblets, which are separated by narrow, linear to undulating, fine, punctate grooves. Toward the ventral margin, the riblets become slightly stronger. They are of unequal width and have flat to slightly rounded tops. The riblets are crossed by irregularly spaced commarginal grooves. Very fine growth lines are visible on the posterior auricle, which also is ornamented with very fine radial threads.

Remarks: *P. schimperi* is very common in the Middle Jurassic of England, France, Switzerland, and Germany (Cox 1943), but so far has not been described from North or South America. Damborenea and González-León (1997) figured one specimen from section 3 and referred to it as *Plagiostoma* cf. *punctatum* J. Sowerby 1815. This species has also been reported from the Lower Jurassic of Chile, but differs from *P. schimperi* by a very high number (100–140) of ribs (Aberhan 1994). Therefore, we include the specimen described by Damborenea and González-León (1997) in *P. schimperi*.

Also from the same locality, Jaworski (1929) identified *Plagiostoma* cf. *exaltatum* Terquem. Whereas we include Jaworski's record in *P. schimperi*, the European *P. exaltatum* has a larger size and more numerous ribs (~100) than the Mexican specimens.

***Plagiostoma* sp. A**
Figs. 6O and 6P.

Material: Two internal molds of left valves and one composite mold of a right valve (ERNO-8176 to 8177, MB.M.4563) from the lower Pliensbachian, Pozos de Serna.

Description: *Plagiostoma* sp. A is medium-sized, equivalved, and has a conspicuously slender, obliquely ovate shape. It is distinctly higher than long. The anterior auricle is relatively large and obtuse. The ventral margin is well rounded and slightly asymmetrical. The posterior margin is relatively long and straight. The outline of the posterior auricle is unknown.

The composite mold carries numerous faint, thin radial riblets, which are broad and flat-topped. The interspaces are narrower than the riblets.

Remarks: *Plagiostoma* sp. A is very conspicuous because of its slender outline, which is much higher than long, a feature that separates this taxon from *P. schimperi*, which exhibits a more rounded shape and an almost equal length-height ratio. *Plagiostoma bilibini* Milova (1969, p. 177, pl. 1, fig. 11, pl. 2, fig. 3) from the Pliensbachian of Siberia has a similar outline and ornamentation, but is conspicuously larger than *Plagiostoma* sp. A. *Lima ridigula* Phillips, described by Lycett (1863, p. 42, pl. 33, fig. 7a) from the Bathonian of England, has a similar ornamentation, but differs in having a more pronounced anterior auricle. *Plagiostoma northamptonensis* Cox (1943, p. 165, pl. 16, figs. 35–37) is only slightly higher than long, and has a different ornamentation consisting of sinuous riblets of variable width.

Order Ostreoida Férussac, 1822
Family Plicatulidae Watson, 1930
Genus *Plicatula* Lamarck, 1801
Type species. *Spondylus plicatus* Linné, 1758; subsequent designation by Schmidt, 1818.
Subgenus *Plicatula*
Plicatula (Plicatula) sp. A
Fig. 6Q.

Material: One internal mold of a left valve (ERNO-8178) from the lower Sinemurian, unit 18, Sierra del Álamo; one internal mold of a right valve (MB.M.4564) from the lower Pliensbachian, Pozos de Serna.

Description: *Plicatula (Plicatula)* sp. A is small sized, higher than long, and only slightly inflated. In one of the internal molds, about four radial plicae can be seen at the ventral margin. Because the material consists only of internal molds, other external features are unknown.

Both molds show a triangular resilifer, which is followed anteriorly and posteriorly by narrow ridges, sockets, and finally by prominent crura. The divergent crura are straight, narrow, and slightly crenulated. The adductor scar of the valves is relatively small, sub-orbicular in shape, and situated in the posterior part of the shell.

Remarks: This is the first record of *Plicatula* from the Lower Jurassic of Mexico. Following the thorough comparison of the taxa *Plicatula* and *Harpax* by Damborenea (2002), the here described specimens can be placed in the subgenus *Plicatula*. The main differences between *Plicatula* and *Harpax* are the hinge region and the reversed relation of convexity of the valves (see Damborenea, 2002, for details). *Plicatula*

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(P.) armata Goldfuss, described by Aberhan (1994) from the upper Sinemurian of Chile, differs from *Plicatula (P.)* sp. A by having more radial plicae (9 to 25) and a more centrally placed adductor muscle scar.

Order Pectinoida Rafinesque, 1815
Family Oxytomidae Ichikawa, 1958
Genus *Oxytoma* Meek, 1864

Type species. *Avicula münsteri* Bronn, 1830.

Subgenus *Oxytoma*

Oxytoma (Oxytoma) cf. *inequivalvis* (J. Sowerby, 1819)
Fig. 6R.

cf. 1819 *Avicula inequivalvis* sp. nov.—J. Sowerby: 78, pl. 244, figs. 2–3.

cf. 1987b *Oxytoma (Oxytoma) inequivalvis* (J. Sowerby 1819)—Damborenea: 160, pl. 6, figs. 9–12; text-fig. 15 (see for synonymy list).

cf. 1994 *Oxytoma (Oxytoma) inequivalvis* (J. Sowerby 1819)—Aberhan: 35, pl. 17, figs. 1–5.

cf. 1998a *Oxytoma (Oxytoma) inequivalvis* (J. Sowerby 1819)—Aberhan: 95, pl. 9, figs. 8–14 (see for synonymy list of North American records).

Material: One external mold of a left valve (ERNO-8179) from the lower Sinemurian, unit 18, Sierra del Álamo.

Description: The fragmented Mexican specimen assigned to *Oxytoma (O.)* cf. *inequivalvis* is relatively small, weakly inflated, and ornamented with thin and straight primary radial ribs. In some of the interspaces second order riblets are developed.

Remarks: *O. (O.) inequivalvis* is a common species with a cosmopolitan distribution, but has not been documented from the Lower Jurassic of Mexico before. It has been described in detail by Duff (1978) and Damborenea (1987b). Ornamentation of the Mexican specimen is very similar to that of *O. inequivalvis*, but due to poor preservation it is assigned to the latter taxon with reservation.

Family Entoliidae von Teppner, 1922
Genus *Entolium* Meek, 1865

Type species. *Entolium demissus* Phillips, 1829.

Subgenus *Entolium*

Entolium (Entolium) corneolum (Young and Bird, 1828)
Figs. 7A, 7B, and 8.

1828 *Pecten corneolus* sp. nov.—Young and Bird: 234, pl. 9, fig. 5.

1984 *Entolium (Entolium) corneolum* (Young and Bird 1828)—Johnson: 45, pl. 1, figs. 24–26, ?20, ?22, ?27 (see for extensive synonymy list).

1994 *Entolium (Entolium) corneolum* (Young and Bird 1828)—Aberhan: 37, pl. 17, figs. 15–19 (see for synonymy list of South American records).

1997 *Entolium (Entolium) disciforme* (Schübler in Zieten, 1833)—Damborenea and González-León: 190, figs. 5.3–5.5.

1998a *Entolium (Entolium) corneolum* (Young and Bird 1828)—Aberhan: 105, pl. 11, figs. 8, 12–14, 16, 17 (see for synonymy list of North American records).

Material: One right valve (ERNO-8180) from the lower Sinemurian, unit 18, Sierra del Álamo; one articulated specimen, six right valves, three left valves, and three single valves (MB.M.4565 to 4577) from the lower Pliensbachian, middle member, section 3, and six right valves, two left valves, and two fragmented valves (ERNO-8181, MB.M.4579 to 4587) from the lower Pliensbachian, middle member, section 4, Sierra de Santa Rosa. The specimens are preserved as molds and show only remains of shell preservation.

Description: *Entolium (E.) corneolum* is medium-sized, sub-equilateral, and nearly equivalved. The disc is sub-orbicular and compressed. The surface of the shell is covered with regularly spaced, commarginal growth lines, and wears no other ornamentation. The auricles of the right valve extend beyond the hinge line dorsally, whereas the left valve auricles meet at an angle of about 180°.

Remarks: *E. corneolum* differs from *E. lunare* (Roemer, 1839) by the lack of a byssal notch in early ontogenetic stages and from *E. orbiculare* (J. Sowerby, 1817) by the lack of commarginal grooves on the right valve (Johnson, 1984). The specimens from the Lower Jurassic of Mexico are indistinguishable from European representatives of this species. From Mexico, Damborenea and González-León (1997) described *Entolium (E.) disciforme* (Schübler in Zieten, 1833). This species was included in *E. corneolum* by Johnson (1984), and this view is followed here. Affinities to species of *Entolium* from the Jurassic of western North America were discussed by Aberhan (1998a).

Figure 7. (A, B) *Entolium (Entolium) corneolum* (Young and Bird, 1828); (A) latex cast of an external mold of a left valve, lower Sinemurian of Sierra del Álamo, × 1, ERNO-8180; (B) right valve, lower Pliensbachian of Sierra de Santa Rosa, × 1, ERNO-8181. (C, D) *Agerchlamys wunschae* (Marwick, 1953); (C) latex cast of an external mold of a left valve, lower Sinemurian of Sierra del Álamo, × 1, ERNO-8182; (D) composite mold of a right valve, upper Hettangian–lower Sinemurian of Sierra del Álamo, × 2, ERNO-8183. (E) *Eopecten velatus* (Goldfuss, 1833); latex cast of an external mold of a left valve, lower Pliensbachian of Sierra de Santa Rosa, × 1, ERNO-8184. (F–J) *Weyla (Weyla) alata* (von Buch, 1838); (F–H) articulated specimen; (F) right valve view; (G) dorsal view; (H) left valve view, lower Pliensbachian of Sierra de Santa Rosa, × 1, ERNO-8185; (I) right valve, lower Pliensbachian of Sierra de Santa Rosa, × 1, ERNO-8186; (J) external mold of a left valve, lower Sinemurian of Sierra del Álamo, × 1, ERNO-8187. (K) *Weyla (Weyla) bodenbenderi* (Behrendsen, 1891); latex cast of an external mold of a right valve, upper Sinemurian of Sierra de Santa Rosa, × 1, ERNO-8188. (L) *Weyla (Weyla) titan* (Möricke, 1894). External mold of a left valve, lower Toarcian of Sierra de La Jojoba, × 1, ERNO-8189. (M–O) *Weyla (Weyla) alata* (von Buch, 1838); (M) latex cast of an external mold of a right valve, × 1.5, ERNO-8190; (N) latex cast of an external mold of a left valve, × 1, ERNO-8191; (O) latex cast of an external mold of a left valve, × 1, ERNO-8192; all lower Sinemurian of Sierra del Álamo.

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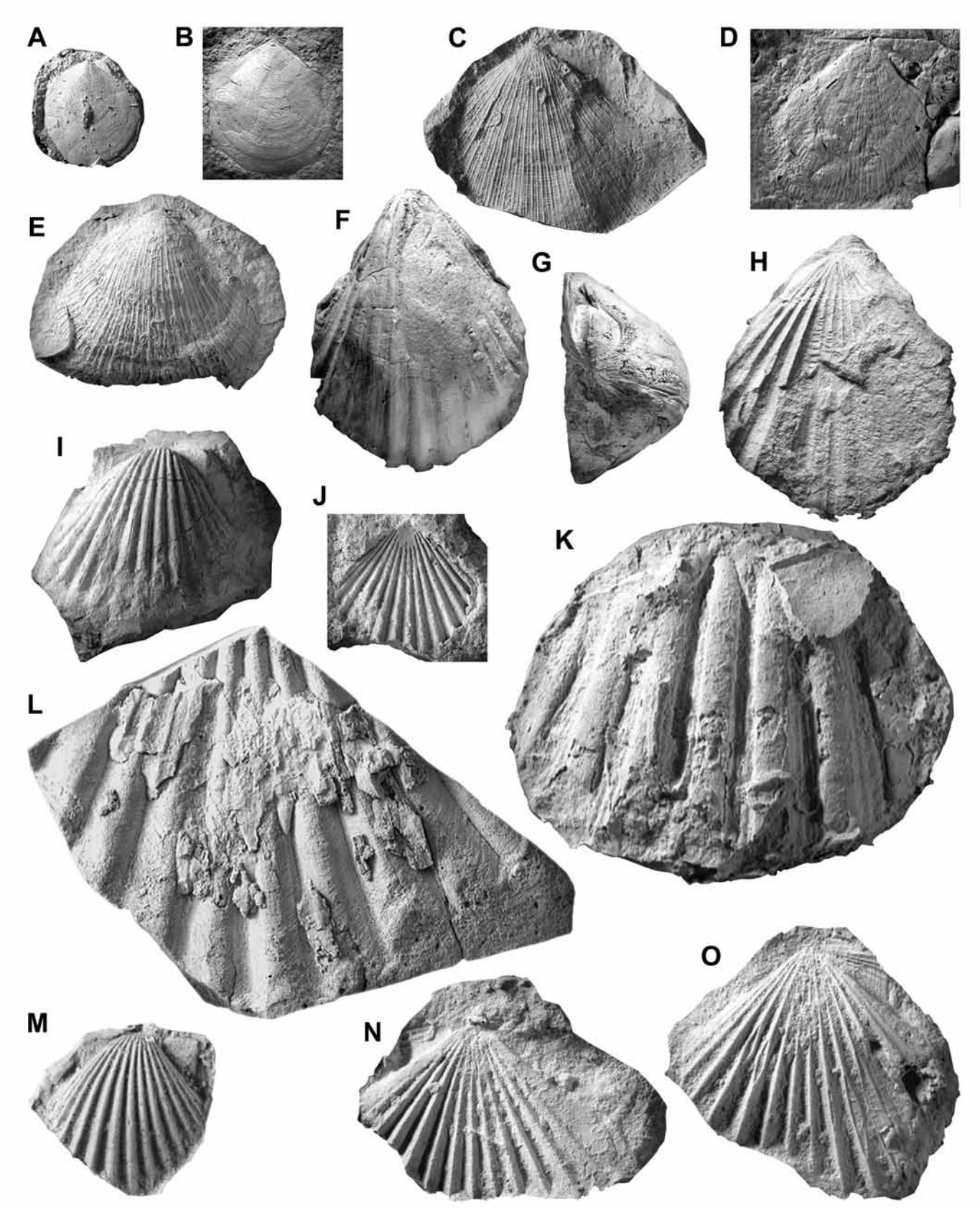

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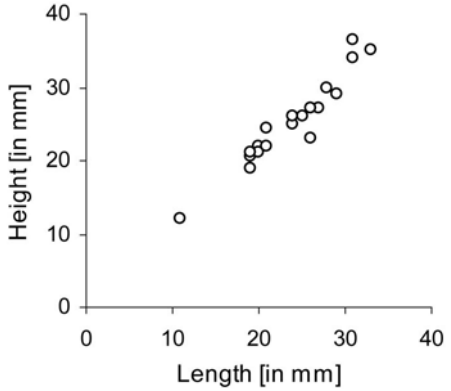

Figure 8. Scatter diagram showing the length-to-height ratio of *Entolium (Entolium) corneolum* (Young and Bird, 1828).

Family Pectinidae Rafinesque, 1815
Genus *Agerchlamys* Damborenea, 1993

Type species. *Chlamys (Camptochlamys) wunschae* Marwick, 1953a.

Agerchlamys wunschae (Marwick, 1953)
Figs. 7C and 7D.

1942 *Pecten (Chlamys) textorius* Schloth. var. *torulosa* Quenst.—A. Leanza: 173, pl. 7, fig. 4.
1953 *Chlamys (Camptochlamys) wunschae* sp. nov.—Marwick: 98, pl. 10, figs. 23–24.
1993 *Agerchlamys wunschae* (Marwick)—Damborenea, figs. 4a–j.
1994 *Agerchlamys wunschae* (Marwick 1953)—Aberhan: 38, pl. 18, figs. 1–6.
1998a *Agerchlamys wunschae* (Marwick 1953)—Aberhan: 108, pl. 12, figs. 1–5.
2002 *Agerchlamys wunschae* (Marwick 1953)—Damborenea: 68, pl. 7, figs. 1–10; text-figs. 8l, 8q, 32, 45c (see for extensive synonymy list).

Material: One right valve (ERNO-8183) from the upper Hettangian–lower Sinemurian, unit 16, one right valve and one left valve (ERNO-8182, MB.M.4590) from the lower Sinemurian, unit 18, Sierra del Álamo; one right valve (MB.M.4594) from the lower Pliensbachian, Pozos de Serna; one fragmented left valve (MB.M.4597) from the lower Pliensbachian, middle member, section 3, Sierra de Santa Rosa. Most specimens are preserved as molds, only few show shell preservation.

Remarks: This is the first record of the genus from Mexico. *A. wunschae* has been extensively described recently by Damborenea (2002) and no further description is needed here. Similar to the Chilean specimens described by Aberhan (1994), the Mexican representatives lack the fine divaricate striae reported by Damborenea (1993, 2002) in specimens from the Pliensbachian of Argentina and New Zealand.

Taylor and Guex (2002, p. 14, pl. 1, figs. 1–4, 8–11; pl. 4, figs. 1–3) described *Agerchlamys boellingi*, a new species from the upper Hettangian of Oregon. This species has a great similarity to *A. wunschae*, but differs in its left valve being more inflated than the right one, and its posterior auricle being more than half the length of the anterior auricle.

Genus *Eopecten* Douvillé, 1897

Type species. *Hinnites tuberculatus* Goldfuss, 1835 (errore pro *Spondylus tuberculosus* Goldfuss, 1835), original designation by Douvillé, 1897.

Eopecten velatus (Goldfuss, 1833)
Fig. 7E.

1833 *Pecten velatus* sp. nov.—Goldfuss: 45, pl. 90, fig. 2.
1984 *Eopecten velatus* (Goldfuss 1833)—Johnson: 150, pl. 5, figs. 4, 5, 7, 8; text-figs. 137–141 (see for extensive synonymy list).
1994 *Eopecten velatus* (Goldfuss 1833)—Aberhan: 41, pl. 21, figs. 2, 6–7 (see for synonymy of South American records).
2002 *Eopecten* cf. *velatus* (Goldfuss 1833)—Damborenea: 54, pl. 6, figs. 1–3.

Material: Four partly fragmented left valves (ERNO-8184, MB.M.4608 to 4610) from the lower Pliensbachian, middle member, section 4, Sierra de Santa Rosa. The specimens are preserved as internal and external molds, rarely with remains of shell attached.

Description: Only left valves of *Eopecten velatus* were recovered. They are medium-sized, inflated, prosocline, and have a sub-orbicular outline. The umbo is placed at mid-length. The anterior wing passes gradually into the disc of the shell, without any demarcation. The disc is covered with about 25 primary radial ribs, between which smaller second- and third-order riblets are intercalated. The ribs and riblets are narrow and have smooth tops. In one specimen, toward the ventral margin some second order riblets reach the same thickness as the primary ribs. The anterior wing is ornamented by numerous ribs of equal strength, which are not as prominent as the primary ribs on the disc.

Remarks: Affinities to other species of *Eopecten* were established by Johnson (1984), Aberhan (1994) and Damborenea (2002) and no further comments are necessary here. These are the first finds of the genus from the Lower Jurassic of Mexico.

Family Neitheidae Sobetzky, 1960
Genus *Weyla* J. Böhm, 1920

Type species. *Pecten alatus* von Buch, 1838.

Subgenus *Weyla*
Weyla (Weyla) alata (von Buch, 1838)
Figs. 7F–7J, 7M–7O, and 9.

1838 *Pecten alatus* sp. nov.—v. Buch: 55.
1839 *Pecten alatus* sp. nov.—v. Buch: 3, pl. 1, figs. 1–3.
1929 *Neithea mexicana* sp. nov.—Jaworski: 2, pl. 1, figs. 1–3.
1987b *Weyla mexicana* (Jaworski) ?—Damborenea: 189, pl. 11, fig. 3; text-fig. 22d.
1987b *Weyla (Weyla) alata alata* (von Buch

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1838)—Damborenea: 170, pl. 9, fig. 1; pl. 10, figs. 1a–b, 2–3, 4a–c, 5; text-figs. 18, 19-1, 22a (see for extensive synonymy list).
1987b *Weyla (Weyla) alata angustecostata* (R. Philippi 1899)—Damborenea: 177, pl. 6, fig. 17b; pl, 7, figs. 1a–b, 2; pl. 8, figs. 1, 2a–b, 3a–b; pl. 9, figs. 2a–b, 3; text-figs. 2, 19-2, 21.
1997 *Weyla*—Lucas and Estep: 45, figs. 1A–B (only).
1994 *Weyla (Weyla) alata* (von Buch 1838)—Aberhan: 43, pl. 22, figs. 1–3; pl. 23, figs. 1–2.
1997 *Weyla (Weyla) alata* (von Buch, 1838)—Damborenea and González-León: 190, figs. 5.6–5.9.
1998a *Weyla (Weyla) alata* (von Buch 1838)—Aberhan: 119, pl. 15, figs. 3, 5–8; pl. 16, figs. 3, 12 (see for synonymy of North American records).

Material: Fifteen right valves, 14 left valves, and one articulated specimen (ERNO-8187, ERNO-8190 to 8192, MB.M.4611 to 4636) from the lower Sinemurian, unit 18, and one left valve (MB.M.4637) from the upper Sinemurian, unit 19, Sierra del Álamo; two fragmented right valves and one left valve (MB.M.4638 to 4640) from the upper Sinemurian, lower member, section 3, Sierra de Santa Rosa; four right valves and three partly fragmented left valves (MB.M.4690 to 4696) from the lower Pliensbachian, Pozos de Serna; four right valves, three left valves, and one articulated specimen (MB.M.4641 to 4648) from the lower Pliensbachian, middle member, section 3, and 21 right valves, 16 left valves, and six articulated specimens (ERNO-8185 to 8186, MB.M.4649 to 4689) from the lower Pliensbachian, middle member, section 4, Sierra de Santa Rosa; one fragmented right valve and two fragmented left valves (MB.M.4697 to 4699) from the lower Toarcian, Sierra de La Jojoba. Preservation is as internal mold, as external mold, or with shell material.

Remarks: For a full description of *W. (W.) alata* refer to Damborenea (1987b) and Aberhan (1994). Recently, Mexican specimens of *W. alata* were described by Damborenea and González-León (1997). These authors concluded that *Weyla mexicana* (Jaworski, 1929) is a junior synonym of *W. alata*. Having studied Jaworski's type material of *W. mexicana* and additional material from the type locality, we follow this view here. Aberhan (1998a) regarded *W. mexicana* as a synonym of *Weyla meeki* Damborenea (1987b), a problematic species first described as *Pecten acutiplicatus* by Meek (1864) from the Lower Jurassic of California. According to present knowledge, we cannot exclude *W. meeki* as another junior synonym of *W. alata*. Clearly, more well-preserved, articulated specimens of *W. meeki* are needed from the type locality to settle this issue.

In the studied sections, *W. alata* is by far the most common species of *Weyla*. In comparison with *Weyla (W.) bodenbenderi* (see below), its ribs are always simple and do not exhibit intercalations of secondary ribs or splitting of primary ribs. *Weyla (Lywea) unca* (see below) has triangular ribs on both valves and is biconvex in all ontogenetic stages.

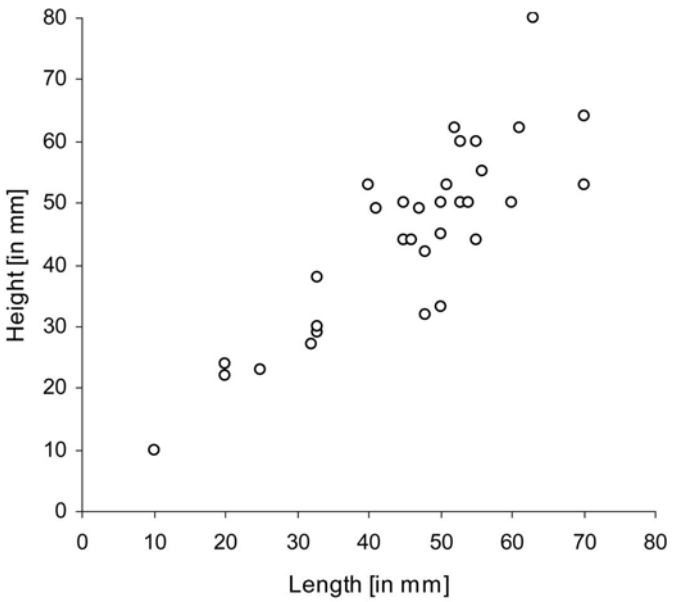

Figure 9. Scatter diagram showing the length-to-height ratio of *Weyla (Weyla) alata* (von Buch, 1838).

***Weyla (Weyla) bodenbenderi* (Behrendsen, 1891)**

Fig. 7K.
1891 *Pecten Bodenbenderi* sp. nov.—Behrendsen: 391, pl. 22, fig. 3.
1987b *Weyla (Weyla) bodenbenderi* (Behrendsen 1891)—Damborenea: 178, pl. 7, fig. 3; pl. 10, fig. 6; pl. 11, fig. 1–2; pl. 12, figs. 1–3 ; text-fig. 22b–c (see for extensive synonymy list).
1994 *Weyla (Weyla) bodenbenderi* (Behrendsen 1891)—Aberhan: 44, pl. 23, figs. 3–4 (see for synonymy list of South American records).
1998a *Weyla (Weyla) bodenbenderi* (Behrendsen 1891)—Aberhan: 120, pl. 14, fig. 13, pl. 15, fig. 2, pl. 16, fig. 5, pl. 19, fig. 2 (see for synonymy list of North American records).

Material: One fragmented left valve (MB.M.4701) from the lower Sinemurian, unit 18, Sierra del Álamo; one external mold of a fragmented right valve (ERNO-8188) from the upper Sinemurian, lower member, section 3, and one fragmented left valve (MB.M.4700) from the lower Pliensbachian, middle member, section 3, Sierra de Santa Rosa; one fragmented right valve (MB.M.4702) from the lower Pliensbachian, Pozos de Serna.

Description: *Weyla (W.) bodenbenderi* has a medium-sized, pectiniform, inequivalved shell. The convex right valves carry strong radial ribs, which are broad and rounded and have slightly flattened tops with steep flanks. The interspaces between the ribs are smaller than the ribs or of the same size. In some specimens, fine radial striae are present in these interspaces. In one specimen, the ribs split up before they

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reach the ventral margin. The flat to slightly convex left valve carries 12 rounded primary ribs, which increase in number by splitting of secondary ribs.

Remarks: These are the first records of the species from Mexico. A much more complete description of *W. bodenbenderi* was given by Damborenea (1987b) and Aberhan (1994) based on Lower Jurassic specimens from Argentina and Chile, respectively. In Mexico, it occurs together with *W. alata* at the same localities in the Sierra de Santa Rosa, Sierra del Álamo, and Pozos de Serna, although in much smaller numbers.

Weyla (Weyla) titan (Möricke, 1894)

Fig. 7L.

1894 *Vola alata* (v. Buch) var. *titan*—Möricke: 41.
1899 *Pecten titan* Mör.—Philippi: 26, pl. 15.
1994 *Weyla (Weyla) titan* (Möricke 1894)—Aberhan: 45, pl. 24, fig. 3; pl. 25, fig. 1.

Material: One fragmented external mold of a left valve (MB.M.4703) from the lower Sinemurian, unit 18, Sierra del Álamo; one fragmented right valve and one fragmentary articulated specimen (MB.M.4705 to 4706) from the lower Pliensbachian, middle member, section 3, Sierra de Santa Rosa; one fragmented external mold of a left valve (ERNO-8189) from the lower Toarcian, Sierra de La Jojoba.

Remarks: *W. titan* was described in some detail by Aberhan (1994), and this is the first record of the species from Mexico. Damborenea and González-León (1997) suggested that *W. titan* could be just a "gerontic" variant of *W. alata* and that the two taxa be separated at subspecies level at most. The poorly preserved Mexican specimens at hand do not add to this discussion. However, a comparison of right valves of both taxa, based on Early Jurassic specimens from northern Chile, reveals that, at identical stages of growth, the radial ribs of *W. titan* are more than twice as broad than those of *W. alata*. Similarly, the interspaces between ribs are considerably narrower than the ribs in *W. titan*, whereas the interspaces are of about the same width as or wider than the ribs in *W. alata*. In our view, this warrants distinction of both taxa at the species level.

Subgenus *Lywea* Damborenea, 1987

Type species. *Pecten uncus* Philippi, 1899.

Weyla (Lywea) unca (Philippi, 1899)

Figs. 10A and 10B.

1899 *Pecten uncus* Ph. sp. nov.—Philippi: 30, pl. 17, fig. 3a–c.
1942 *Pecten* cf. *uncus* Phil.—A. Leanza: 170, pl. 9, figs. 1–3, 6.
1987b *Weyla (Lywea) unca* (R. Philippi 1899)—Damborenea: 187, pl. 12, fig. 4; pl. 13, figs. 1–4, 5a–b, 6a–b, 7a–c, 8, 9a–d, 10a–d, 11a–b; text-fig. 25 (see for extensive synonymy list).
1987b *Weyla (Lywea) meeki* nov. nom.—Damborenea: 186, 189, text-fig. 26.
1992 *Weyla (Weyla) unca* (Philippi)—Damborenea, pl. 115, fig. 16a–b.
1994 *Weyla (Lywea) unca* (Philippi 1899)—Aberhan: 46, pl. 23, fig. 5; pl. 24, fig. 2; pl. 25, fig. 2.
1994 *Weyla* (*Lywea*) aff. *unca* (Philippi)—Aberhan: 46, pl. 24, fig. 1.
1998a *Weyla (Lywea) unca* (Philippi 1899)—Aberhan: 128, pl. 16, figs. 4, 6, 7, 9; pl. 18, figs. 7, 10, 13; pl. 19, figs. 4, 6; text-fig. 10.
1998b *Weyla (Lywea) unca* (Philippi)—Aberhan, fig. 4F.

Material: One fragmented internal mold of a right valve (MB.M.4707) from the upper Hettangian–lower Sinemurian, unit 16, four fragmented right valves, two left valves, and two external molds of left valves (ERNO-8193 to 8194, MB.M.4708 to 4713) from the lower Sinemurian, unit 18, and two fragmented right valves (MB.M.4714 to 4715) from the upper Sinemurian, unit 19, Sierra del Álamo; two right valves (MB.M.4716 to 4717) from the lower Pliensbachian, middle member, section 4, Sierra de Santa Rosa.

Description: In contrast to other species of *Weyla* described above, *Weyla (Lywea) unca* is biconvex at all ontogenetic stages. The right valve is more convex than the left valve. The right valve is higher than long, whereas the left one is longer than high.

The ribs, 12 to 13 in number, and the interspaces are V-shaped in cross section on both valves. They decrease in strength toward the ventral margin. The interspaces are of the same width as the ribs. On the flanks of the ribs, a fine radial striation and subtle growth lines can be seen.

Figure 10. (A–B) *Weyla (Lywea) unca* (Philippi, 1899); (A) latex cast of an external mold of a left valve, × 1, ERNO-8193. (B) latex cast of an external mold of a left valve, × 1, ERNO-8194; all lower Sinemurian of Sierra del Álamo. (C–F) *Modiolus (Modiolus) giganteus* Quenstedt, 1857. (C) internal mold of a right valve, × 1, ERNO-8195; (D–F) steinkern; (D) right valve view, (E) dorsal view, (F) left valve view; × 1, ERNO-8196; all lower Pliensbachian of Sierra de Santa Rosa. (G) *Modiolus (Modiolus)* cf. *baylei* (Philippi, 1899); latex cast of an external mold of a right valve, lower Pliensbachian of Sierra de Santa Rosa, × 1, ERNO-8197. (H) *Modiolus (Cyranus) hillanus* (J. Sowerby, 1818). Plaster cast of an external mold of a left valve, lower Sinemurian of Sierra del Álamo, × 1, ERNO-8198. (I–J) *Frenguelliella poultoni* H. A. Leanza, 1993. (I) latex cast of an external mold of a left valve, × 2, ERNO-8199; (J) latex cast of an external mold of a right valve, × 2, ERNO-8200; all lower Sinemurian of Sierra del Álamo. (K) *Groeberella* sp. A; composite mold of a left valve, × 1.5, ERNO-8201, lower Pliensbachian of Pozos de Serna. (L–M) *Prosogyrotrigonia* sp. A. (L) latex cast of an external mold of a left valve, × 1, ERNO-8202; (M) latex cast of an external mold of a right valve, × 2, ERNO-8203; all lower Sinemurian of Sierra del Álamo. (N) Lucinidae gen. et sp. indet. A; composite mold of a right valve, × 1, ERNO-8204, lower Pliensbachian of Sierra de Santa Rosa. (O–R) Lucinidae gen. et sp. indet. B. (O) internal mold of a left valve, × 2, ERNO-8205, upper Hettangian–lower Sinemurian of Sierra del Álamo; (P) internal mold of a right valve, × 2, ERNO-8206, lower Pliensbachian of Sierra de Santa Rosa; (Q) slab with internal molds of an articulated specimen in butterfly position, × 2, ERNO-8207, upper Hettangian–lower Sinemurian of Sierra del Álamo; (R) latex cast of a slab with several densely packed valves, × 2, ERNO-8208, upper Hettangian–lower Sinemurian of Sierra del Álamo.

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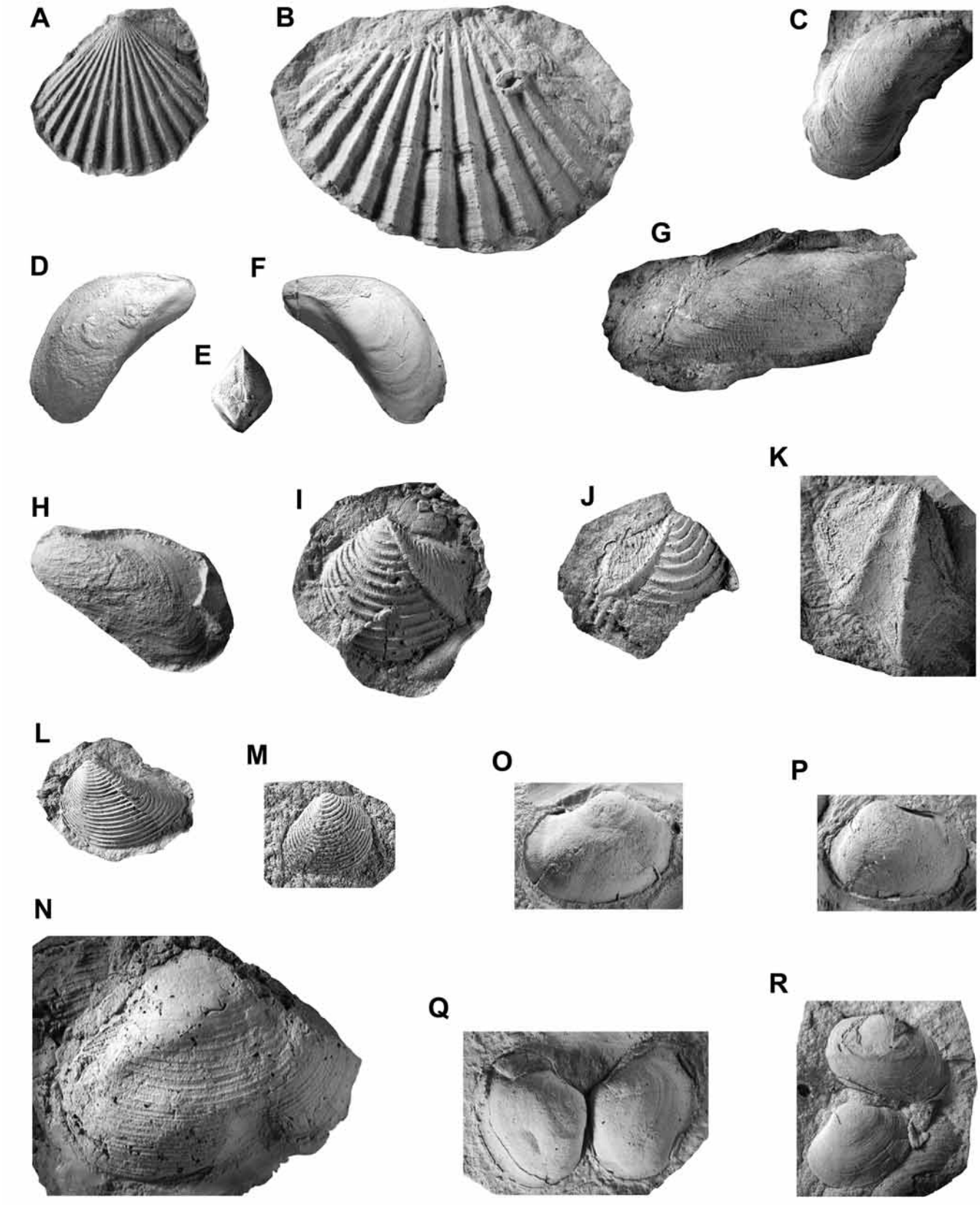

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Remarks: *W. unca* is the only species of *Weyla* described here that is biconvex. The specimens figured by Damborenea (1987b) as *Weyla (Lywea) meeki* are considered to belong to *W. unca* (see Aberhan, 1998a, p. 122). *W. meeki* (proposed by Damborenea, 1987b, to replace *Pecten acutiplicatus* Meek) has a plano-convex shell (Aberhan 1998a) and possibly is another junior synonym of *W. alata* (see above). This is the first record of this species from the Lower Jurassic of Mexico.

Subclass Isofilibranchia Iredale, 1939
Order Mytiloida Férussac, 1822
Family Mytilidae Rafinesque, 1815
Genus *Modiolus* Lamarck, 1799

Type species. *Mytilus modiolus* Linné, 1758.

Subgenus *Modiolus*

Modiolus (Modiolus) giganteus Quenstedt, 1857

Figs. 10C–10F.

1857 *Modiola gigantea* sp. nov.—Quenstedt: 439, unnumbered text-fig.
1942 *Modiolus gigantoides* sp. nov.—A. Leanza: 182, pl. 11, fig. 3.
1987a *Falcimytilus* ? *gigantoides* (A. Leanza 1942)—Damborenea: 85, pl. 3, figs. 5–7; text-figs. 21, 22.
1992 *Falcimytilus* (?) *gigantoides* (Leanza)—Damborenea, pl. 117, fig. 3.
1994 *Modiolus (Modiolus) giganteus* Quenstedt 1857—Aberhan: 49, pl. 27, figs. 6–9 (see for synonymy list).
1997 *Falcimytilus* sp.—Damborenea and González-León: 191, fig. 5.11.

Material: One steinkern, one external and three internal molds of left valves, and four internal molds of right valves (ERNO-8195 to 8196, MB.M.4738 to 4744) from the lower Pliensbachian, middle member, section 4, Sierra de Santa Rosa; one internal mold of a right valve (MB.M. 4745) from the lower Pliensbachian, Pozos de Serna.

Description: *Modiolus (M.) giganteus* is medium-sized, moderately inflated, and equivalved with a subtriangular to sickle-shaped outline. Its height almost equals its length. The dorsal margin is straight to slightly convex and somewhat longer than half the total shell length. The posterior margin is convex and meets the dorsal margin with an obtuse angle of about 130°. The ventral margin is slightly concave, whereas the anterior margin is very short and convex.

The umbo is prosogyrate and terminal. A faint umbonal ridge extends from the umbo to the postero-ventral corner of the shell. The strength of the umbonal ridge varies. A shallow sulcus, which lies anteriorly of the umbonal ridge, meets the ventral margin at its greatest concavity. The outer surface of the shell is covered with regularly spaced growth lines.

Remarks: For a detailed description of the species, affinities to other representatives of *Modiolus*, and comments on differences in size between Lower Jurassic specimens from South America and Middle Jurassic specimens from Europe see Damborenea (1987a) and Aberhan (1994).

***Modiolus (Modiolus)* cf. *baylei* (Philippi, 1899)**

Fig. 10G.

cf. *Mytilus scalprum* Goldf.—Bayle & Coquand: 15, pl. 7, figs. 3–4.
cf. 1899 *Modiola baylei* sp. nov.—R. A. Philippi: 48, pl. 24, fig. 8 (copy from Bayle and Coquand 1851, pl. 7, figs. 3–4),
cf. 1987a *Modiolus baylei* R. Philippi 1899 ?—Damborenea: 91, pl. 4, figs. 2, 3a–b, 4–5 (see for detailed synonymy list).
cf. 1994 *Modiolus (Modiolus) baylei* (Philippi 1899)—Aberhan: 47, pl. 26, figs. 1–4.
1997 *Modiolus* cf. *M. baylei* Philippi, 1899—Damborenea and González-León: 191, fig. 5.10.

Material: One articulated specimen (MB.M.4707) from the upper Hettangian–lower Sinemurian, unit 16, Sierra del Álamo; one fragmented composite mold of a left valve (MB.M.4746) from the lower Pliensbachian, middle member, section 3, and one external mold of a right valve (ERNO-8197) from the lower Pliensbachian, middle member, section 4, Sierra de Santa Rosa.

Description: *Modiolus (Modiolus)* cf. *baylei* has a very elongated, narrow shell with an umbonal ridge. The umbo is prosogyrate and subterminal. The height is less than half of the length of the shell. The dorsal margin is straight and nearly half as long as the shell. The posterior margin is slightly convex. The ventral margin is straight and becomes slightly concave at the point where it meets the umbonal ridge.

The surface of the shell is covered with concentric growth lines. Together with radial striae on the ventral side of the umbonal ridge, these growth lines produce a delicate reticulate pattern on the shell surface.

Remarks: The specimens closely match those described and illustrated as *M.* cf. *baylei* in Damborenea and González-León (1997, fig. 5.10) from the same locality. Compared with *M. baylei* Philippi (Damborenea, 1987a; Aberhan, 1994), they are more elongated, and therefore are referred to *M. baylei* with reservation.

Subgenus *Cyranus* Hodges, 2000

Type species. *Modiola hillana* J. Sowerby, 1818, designated by Hodges, 2000.

Modiolus (Cyranus) hillanus (J. Sowerby, 1818)

Fig. 10H.

1818 *Modiola Hillana* sp. nov.—J. Sowerby: 21, pl. 212, fig. 2.
1915 *Modiola hillana* Sow.—Jaworski: 419.
1925 *Modiola hillana* Sow.—Jaworski: 66.
1987a *Modiolus* cf. *thiollierei* (Dumortier 1869)—Damborenea: 91, pl. 3, fig. 8.
2000 *Modiolus (Cyranus) hillanus* (J. Sowerby, 1818)—Hodges: 57, pl. 5, figs. 18–24; text-figs. 61, 62 (see for extensive synonymy list).

Material: One external mold of a left valve (ERNO-8198) from the lower Sinemurian, section 18, Sierra del Álamo.

Description: *Modiolus* (*Cyranus*) *hillanus* is a medium-sized

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mytilid with an elongated to trapezoidal outline (L = 35 mm, H = 21 mm). Its dorsal margin is straight and half as long as the shell. The posterior margin is convex and well rounded and meets the dorsal margin at a very obtuse angle. The form of the ventral margin is straight to slightly convex.

The umbo lies subterminal. A slightly curved umbonal ridge extends from the umbo to the postero-ventral corner of the shell. The outer surface of the shell is covered with faint, regularly spaced concentric growth lines.

Remarks: This is the first record of *M. (C.) hillanus* from Mexico. A very similar species is *Modiolus (Cyranus) ventricosus* Roemer 1836, in which Hodges (2000) also included *Modiolus thiollierei* Dumortier. According to Hodges, *M. hillanus* can be distinguished from *M. ventricosus* by a greater oblique height–oblique length ratio and a more strongly curved body.

Modiolus (M.) scalprum J. Sowerby, as described by Aberhan (1994) from the Lower Jurassic of Chile, can be distinguished from *M. hillanus* by the straighter, narrower, and more elongated outline.

Damborenea (1987a, p. 91, pl. 3, fig. 8) figured a specimen from the Pliensbachian of Rio Atuel, Argentina, which has been described by Jaworski (1915, 1925) as *Modiola hillana* Sow., and placed it into *M.* cf. *thiollierei*. In our view, this specimen corresponds much better to *M. (C.) hillanus* described herein and therefore is considered the first record of *M. hillanus* from South America.

In comparison with the other species of *Modiolus* described herein, *M. hillanus* is less elongated than *M.* cf. *baylei*, and is not as curved and sickle-shaped as *M. giganteus*.

Subclass Heteroconchia Hertwig, 1895
Order Modiomorphoida Newell, 1969
Family Myoconchidae Newell, 1957
Genus *Myoconcha* J. de C. Sowerby, 1824

Type species. *Myoconcha crassa* J. de C. Sowerby 1824, by monotypy.

Myoconcha neuquena A. Leanza, 1940
Figs. 13A–13C.

1929 *Myoconcha* cf. *Valenciennesi* Bayle and Coquand—Jaworski: 8, pl. 1, fig. 8a–b (non Bayle and Coquand).
1940 *Myoconcha neuquena* sp. nov.—A. Leanza: 126, pls. 1–2.
1997 *Myoconcha neuquena* Leanza, 1940—Damborenea and González-León: 192, figs. 5.12–5.14 (see for synonymy list).

Material: Three specimens (MB.M.4826 to 4828) from the lower Pliensbachian, middle member, section 3, and 16 specimens (ERNO-8209 to 8210, MB.M.4829 to 4842) from the lower Pliensbachian, middle member, section 4, Sierra de Santa Rosa. Most of the specimens are articulated and preserved with shell.

Description: *Myoconcha neuquena* is medium- to large-sized (L = 82–145 mm), thick-shelled and equivalved with a mytiliform outline. The umbo is narrow, acute, and terminal. A rather prominent, acute posterior ridge runs from the umbo to the postero-ventral corner. This ridge makes the shell look slightly quadrate in cross section. The greatest inflation of the shell is at about mid-length. The ventral margin is nearly straight and meets the posterior margin with a narrow curve of about 90°. The posterior margin is slightly convex and oblique. The dorsal margin is evenly convex. The surface is covered with numerous regularly spaced, commarginal folds.

Remarks: Damborenea and González-León (1997) describe *M. neuquena* from the same locality. Their specimens are similar in many characters, such as size, ornamentation and state of preservation.

Order Trigonioida Dall, 1889
Family Trigoniidae Lamarck, 1819
Genus *Frenguelliella* A. Leanza, 1942

Type species. *Trigonia inexspectata* Jaworski, 1915.

Frenguelliella poultoni H. A. Leanza, 1993
Figs. 10I, 10J, and 11.

1929 *Trigonia* cf. *inexspectata* Jaw.—Jaworski: 7, pl. 1, fig. 4.
1979 *Frenguelliella* sp. B.—Poulton: 18, pl. 1, fig. 10.
1993 *Frenguelliella poultoni* sp. nov.– H. A. Leanza: 26, pl. 2, figs. 3–6.

Material: Three external molds of right valves and four external molds of left valves (ERNO-8199 to 8200, MB.M.4749 to 4753) from the lower Sinemurian, unit 18, Sierra del Álamo; one composite mold of a right valve (MB.M.4757) from the upper Sinemurian, lower member, section 3, Sierra de Santa Rosa; one internal and two external molds of right valves and one external mold of a left valve (MB.M.4758 to 4761) from the lower Pliensbachian, Pozos de Serna; one articulated specimen, one steinkern, and internal molds of one left valve and one right valve (MB.M.4762 to 4765) from the lower Pliensbachian, middle member, section 3, and one external mold of a left valve and one steinkern (MB.M.4768 to 4769) from the lower Pliensbachian, middle member, section 4, Sierra de Santa Rosa.

Description: *Frenguelliella poultoni* is inequilateral, small- to medium-sized and has an oval to subrectangular outline. The umbo is situated mesially. The postero-dorsal margin is slightly concave. The postero-dorsal corner forms an obtuse angle. The posterior margin is straight. The postero-ventral corner of the shell forms an angle of about 90°. The ventral margin is well curved and passes gradually into the anterior margin.

The flank is covered with 8–15 simple, concentric ribs, which start at the anterior margin and end shortly before the distinct marginal carina. The marginal carina wears faint beads. The area is divided by a subtle median groove and covered with fine commarginal lamellae.

Remarks: Our specimens apparently are identical to *Trigonia* cf. *inexspectata* described by Jaworski (1929) from the same locality at Sierra de Santa Rosa. This specimen is an incomplete external mold of a left valve, which superficially resembles *Frenguelliella inexspectata* (Jaworski, 1915,

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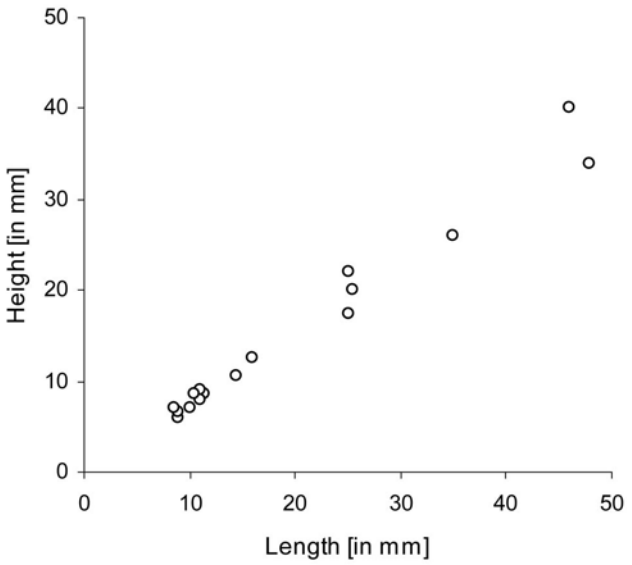

Figure 11. Scatter diagram showing the length-to-height ratio of *Frenguelliella poultoni* (H.A. Leanza, 1993).

p. 377, pl. 5, fig. 2) from the Lower Jurassic of Argentina but also shows some differences, such as a smaller number of concentric ribs and a less distinct marginal carina. Because of the poor preservation of the specimen, Jaworski referred it to *T. inexspectata* with reservation and hoped for a better determination when better-preserved material would become available. Later, Poulton (1979) described a similar specimen as *Frenguelliella* sp. B from the lower Sinemurian of the Laberge Group, Yukon Territory, Canada. Finally, Leanza (1993) described this species from the Pliensbachian of the Neuquén Basin, Argentina, under the new name *Frenguelliella poultoni*. He separated *F. poultoni* from *Frenguelliella tapiai* Lambert, 1944, which occurs in the same formation, by the subquadrate shape of *F. tapiai* and the greater number of costae on its flanks, and by the style of ornamentation of the area.

Trigonia chubutensis, first described by Feruglio (1934, pl. 4, figs. 9, 11) from the Lower Jurassic of Rio Genua, Patagonia, is very similar to *F. poultoni* in the style of ornamentation on the flank and on the area, but the latter species has a more prominent marginal carina and a smaller area.

Family Groeberellidae Pérez, Reyes, and Damborenea, 1995

Genus *Groeberella* H. A. Leanza, 1993

Type species. *Myophoria neuquensis* Groeber, 1924.

Groeberella sp. A

Fig. 10K.

Material: One composite mold of a left valve (ERNO-8201) from the lower Pliensbachian, Pozos de Serna.

Description: *Groeberella* sp. A is medium-sized, subtrigonal to oval in outline, and has an opisthogyrate, mesial umbo. The posterior margin is short and slightly concave. The ventral margin is divided by the second costa from the anterior into a posterior part, which is slightly concave, and an anterior part, which is straight. The anterior margin is short and slightly convex. The postero-dorsal margin is not preserved.

The flank wears two strong radial costae. The marginal carina and the escutcheon carina are very prominent and stronger than the two radial costae on the flank. Other characters cannot be observed.

Remarks: The genus *Groeberella* is known from the Lower and Middle Jurassic of Argentina and Chile (see Pérez et al., 1995, and H. A. Leanza, 1993, for details) and this is the first record from Mexico. So far, there is only one species that has been assigned to this genus, *Groeberella neuquensis* (Groeber, 1924). This species has a conspicuously larger shell than the Mexican specimen, and it carries commarginal growth lines, which cover the whole shell and develop into thick transverse rugae on the marginal carina and the second costa. H. A. Leanza (1993) and Pérez et al. (1995) both described some other specimens of the genus *Groeberella* that cannot be assigned to *G. neuquensis*. These specimens differ from *G. neuquensis* by their smaller size, a thinner shell, and a different outline.

Family Prosogyrotrigoniidae Kobayashi, 1954

Genus *Prosogyrotrigonia* Krumbeck, 1924

Type species. *Prosogyrotrigonia timorensis* Krumbeck, 1924.

Prosogyrotrigonia sp. A

Figs. 10L and 10M.

Material: One external mold of a left valve and one external mold of a right valve (ERNO-8202 to 8203) from the lower Sinemurian, unit 18, Sierra del Álamo.

Description: *Prosogyrotrigonia* sp. A is small, inequilateral, suboval in outline, and slightly longer than high. Its umbo is small and prosogyrate. The dorsal margin is slightly concave. The posterior margin is slightly convex and meets the evenly convex ventral margin at an obtuse angle. The anterior margin is also evenly convex.

The flank is covered with regular commarginal riblets (about 11 per cm in a specimen with $L = 23$ mm and $H = 16$ mm). The interspaces between these ribs are concave and about twice as wide as the ribs. Their width increases gradually with the growth of the shell. Instead of a marginal carina, the border between shell flank and area is marked by a slight angulation in the surface of the shell. Additionally, flank and area are separated by a change in ornamentation, as the area is covered with weaker and more numerous commarginal riblets. In early growth stages, the ribs on the area are similar in number and strength to the ones on the flank. In one juvenile specimen ($L = 9$ mm, $H = 7.5$ mm), only the most ventral rib splits into two weaker riblets at the border between flank and area. On an even smaller specimen, all ribs on flank and area are similar in strength and number. The escutcheon is long and narrow.

Remarks: *Prosogyrotrigonia* sp. A shows all characteristic elements of the genus, such as absence of a marginal carina and change in ornamentation. So far, representatives of this

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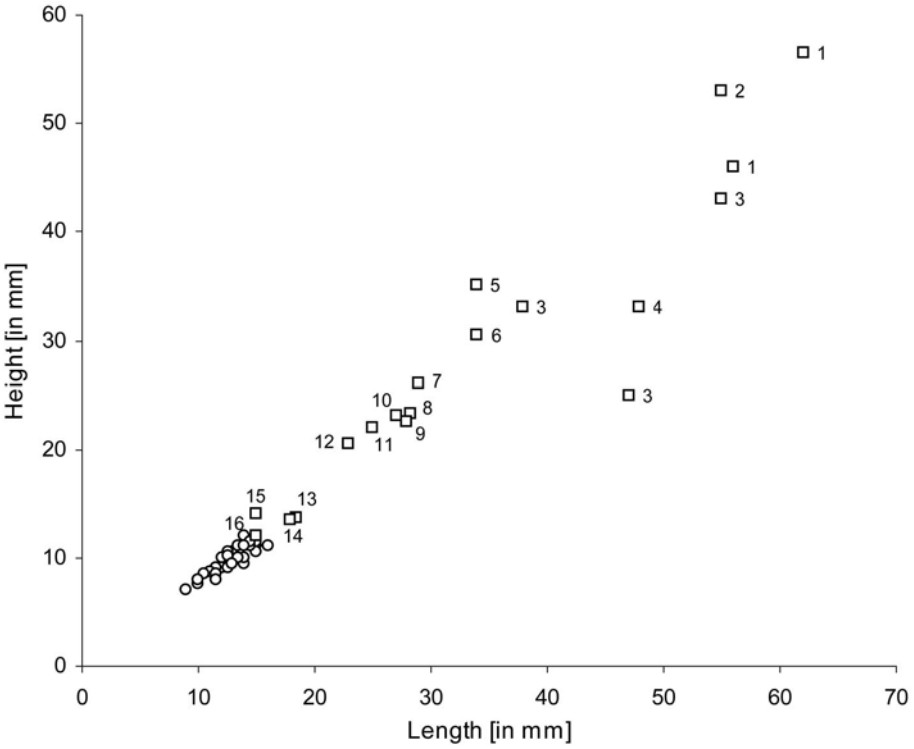

Figure 12. Scatter diagram showing the length-to-height ratio of Lucinidae gen. et sp. indet. B (circles) and other lucinids (squares) from the Jurassic of North and South America, based on typical specimens illustrated in the literature. 1—*Lucina goliath* Gottsche; 2—*Lucina neuquensis* Weaver; 3—*Lucina bellona* d'Orbigny; 4—*Lucina liasina* Steinmann; 5—*Lucina payllalefi* A. Leanza; 6—*Lucina huayquimili* A. Leanza; 7—*Lucina lotenoensis* Weaver; 8—*Lucina chubutensis* Wanish; 9—*Lucina plana* v. Zieten; 10—*Lucina atacamensis* Möricke; 11—*Lucina laevis* Gottsche; 12—*Lucina intumescens* Gottsche; 13—*Lucina feruglioi* Wanish; 14—*Lucina argentina* Behrendsen; 15—*Lucina dosiniaeformis* Gottsche; 16—*Lucina problematica* Terquem.

genus are known from Timor and Japan. The type species, *Prosogyrotrigonia timorica* Krumbeck (1924, pl. 19, figs. 19–22), has been described from the Rhaetian of Timor. This species differs from the Mexican specimens in a more rectangular outline and finer ribs on the flank. *Prosogyrotrigonia inouyei* (Yehara) has been described, among others, by Kobayashi and Mori (1954, p. 157, pl. 15, figs. 3–5) and Hayami (1959, p. 70, pl. 7, figs. 12–14) from the Lower Jurassic of Japan. In comparison with the Mexican specimens, *P. inouyei* is nearly as long as high and has fewer and much coarser ribs. Very similar to the Japanese species is a specimen from the Hettangian of the Yukon Territory, Alaska, described as *Prosogyrotrigonia* (?) sp. cf. *P. inouyei* (Yehara) by Frebold and Poulton (1977, p. 96, pl. 2, figs. 5–9). The here described *Prosogyrotrigonia* sp. A seems to be conspecific to as yet undescribed material from the Hettangian and Sinemurian of northern Chile (pers. observation).

Order Veneroida H. Adams and A. Adams, 1856
Family Lucinidae Fleming, 1828

Lucinidae gen. et sp. indet. A

Fig. 10N.

1997 Lucinidae gen. et sp. indet.—Damborenea and González-León: 192, fig. 9.2.

Material: Composite molds of one right and two single valves, one internal mold of a left valve, and one steinkern (ERNO-8204, MB.M.4771 to 4774) from the lower Pliensbachian, middle member, section 3, Sierra de Santa Rosa; one external mold of a left valve (Mb.M.4780) from the lower Pliensbachian, Pozos de Serna.

Description: This lucinid bivalve is large, equivalved and sub-equilateral, only slightly inflated, and subquadrate in outline. The posterior margin is truncated. The anterior margin is slightly concave and meets the ventral margin at an obtuse angle. The ventral margin is slightly convex. The shell is covered with numerous, regularly spaced commarginal ribs (~10 ribs per cm). The inner margin seems to be smooth.

Remarks: Damborenea and González-León (1997, p. 194) described a similar specimen from the same locality in Mexico and, in their remarks, mentioned affinities to the genus *Mesomiltha* Chavan. These authors also discussed affinities to related lucinid taxa. In addition, *Lucina atacamensis* Möricke, 1894 (53, pl. 4, fig. 10a–b) from the middle and upper Lower Jurassic of Chile can be mentioned, which differs in a more strongly inflated shell and an ornamentation that consists of weak commarginal growth lines.

Lucinidae gen. et sp. indet. B

Figs. 10O–10R and 12.

Material: Twelve internal and 13 external molds of left valves, nine internal and four external molds of right valves (ERNO-8205, ERNO-8207 to 8208, MB.M.4795 to 4825), with only rare shell preservation from the upper Hettangian–lower Sinemurian, unit 16, Sierra del Álamo; one internal mold of a left valve (ERNO-8206) from the lower Pliensbachian, middle member, section 3, Sierra de Santa Rosa.

Description: Lucinidae gen. et sp. indet. B is small (see Fig. 12), inequilateral, equivalved, and oval to subquadrate in

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outline. It is slightly inflated, and longer than high (Fig. 12). The anterior margin is slightly convex, and the ventral margin is well rounded and passes gradually into the well-rounded posterior margin. The postero-dorsal margin is slightly concave; the antero-dorsal margin is straight. The umbo is orthogyrate and is situated at about one-third of the shell length from the anterior. The escutcheon is lanceolate, the lunule small and narrow.

The external molds show fine, regular, commarginal growth lines, which cover the whole surface. Except for these growth lines, the shell surface is smooth. The specimens have an integripalliate pallial line. Other internal characters cannot be observed.

Remarks: Lucinidae gen. et sp. indet. B is a new representative of the family Lucinidae in South America. As hinge characters are not known, an exact assignment at the genus level is not possible. Many lucinids have been described from the Jurassic of America (see also Fig. 12), mostly from the Middle and Upper Jurassic of South America, but only a few are similar to Lucinidae gen. et sp. indet. B in outline and ornamentation.

Strongest affinities exist to *Lucina feruglioi* Wanish de Carral Tolosa (1942, p. 53, pl. 5, figs. 2a–b) from the Lower Jurassic of Argentina, which agrees well in size and in the length-to-height ratio but is covered with numerous strong commarginal ribs. From the same locality, Wanish de Carral Tolosa (1942, p. 54, pl. 5, fig. 3) described *Lucina chubutensis*, which has an almost circular outline and also strong commarginal ribs.

Lucina huayquimili A. Leanza (1942, p. 193, pl. 18, figs. 3, 5) from the Lower Jurassic of Argentina, which probably belongs to the genus *Mesomiltha*, is medium-sized, sub-orbicular, slightly longer than high, only slightly inflated, and wears concentric riblets. It differs mainly by its larger size and its ornamentation from the Mexican specimens. *L. payllalefi* A. Leanza (1942, p. 192, pl. 18, fig. 2) from the Lower Jurassic of Argentina carries numerous commarginal ribs and is higher than long.

Lucina problematica Terquem (1855, p. 119, pl. 20, fig. 7) from the Hettangian of France is similar in size, outline, and length-to-height ratio, but has numerous prominent, regular, and narrow costae.

Gottsche (1878) described several lucinids from the Middle Jurassic of Argentina. *Lucina laevis* Gottsche (1878, p. 27, pl. 5, fig. 9) also has a smooth shell surface but is nearly circular, and thus has a lower length-to-height ratio than the Mexican specimens. Similarly, *Lucina intumescens* Gottsche (1878, p. 27, pl. 5, fig. 10) is almost circular in outline and strongly inflated, and is covered with faint concentric riblets. *Lucina dosiniaeformis* Gottsche (1878, p. 28, pl. 6, fig. 13) is small, circular, has pointed umbones, and is ornamented with numerous commarginal riblets. A species that also has been described by Steinmann (1929, p. 79, fig. 92) and Cox (1956, p. 1184, pl. 128, fig. 4) from the Middle Jurassic of Peru is *Lucina goliath* Gottsche (1878, p. 28, pl. 5, fig. 11). With its height and length exceeding 50 mm, this species is conspicuously larger than the Mexican material. It is ornamented by numerous commarginal riblets.

Lucina plana von Zieten (1833, p. 96, pl. 72, fig. 4a–b) is a common species in the Lower and Middle Jurassic of Europe (e.g., Quenstedt, 1856: 319, pl. 44, fig. 4; Gottsche, 1878, p. 27, pl. 5, figs. 7, 8; Palmer, 1966, pl. 1, figs. 3–5). It is medium-sized, has strong commarginal ribs and fine radial riblets, and its length-to-height ratio is slightly lower than that of the material described herein.

Lucina argentina Behrendsen (1891, p. 415, pl. 25, fig. 3) has first been described from the Upper Jurassic of Argentina. It is small, suboval, equilateral, and has relatively strong growth lines and a lower length-to-height ratio than the Mexican species. Haupt (1907, p. 218) and Weaver (1931, p. 350) also describe *L. argentina* from the Upper Jurassic and the Lower Cretaceous of Argentina.

Lucina atacamensis Möricke (1894, p. 53, pl. 4, figs. 10a–b) from the Lower Jurassic of Chile is suboval in outline, medium-sized, strongly inflated, and carries concentric growth lines, which increase in prominence toward the posterior part of the shell. Its length-to-height ratio is only slightly lower than that of Lucinidae gen. et sp. indet. B.

Lucina liasina Steinmann (1929, p. 67, fig. 71) from the Hettangian of Peru is medium-sized, suboval, and has a relatively small and acute umbo. It is ornamented with numerous regular commarginal growth rugae, and its length-to-height ratio is larger than that of the specimens described herein.

L. neuquensis Haupt (1907, p. 217, pl. 10, figs. 3 a–b) from the Upper Jurassic of Argentina is relatively large and has a circular outline and prominent concentric ribs.

Lucina bellona d'Orbigny is known from the Middle Jurassic of Europe (e.g., Morris and Lycett, 1853, pl. 67, pl. 6, figs. 18–18a) and the Lower and Middle Jurassic of Argentina, Mexico, and Peru (e.g., Cox, 1956, p. 1184, pl. 128, fig. 2). It is relatively large and has a circular outline and well-defined commarginal lamellae.

L. corbisoides d'Orbigny var. *loteonensis* Weaver (1931, p. 351, pl. 39, fig. 241) from the Lower Cretaceous of Argentina has a circular outline and is ornamented with fine commarginal growth lines. A specimen figured by Damborenea (1992, pl. 119, fig. 8) from the Tithonian of Argentina has a slightly lower length-to-height ratio than the Mexican specimens.

Family Astartidae d'Orbigny, 1844

Genus *Neocrassina* Fischer, 1886

Type species. *Astarte obliqua* Deshayes 1830 (= *Cypricardia obliqua* Lamarck 1819).

Neocrassina gueuxi (d'Orbigny, 1850)

Figs. 13D–13F and 14.

1850 *Astarte gueuxi* sp. nov.—d'Orbigny, p. 216, n° 80.

1853 *Astarte consobrina* sp. nov.—Chapuis and Dewalque, p. 149, pl. 22, fig. 3.

1856 *Astarte psilonoti* sp. nov.—Quenstedt, p. 45, pl. 3, fig. 14.

1864 *Astarte dentilatum* sp. nov.—Etheridge, p. 112, text-figs. 5–7.

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1867 *Astarte cammertonensis* sp. nov.—Moore, p. pl. 17, fig. 3.
1869 *Astarte fontis* sp. nov.—Dumortier, p. 268, pl. 30, figs. 12–14.
1907 *Astarte gueuxi*—Thévenin, p. 25, pl. 8, figs. 8–10.
1966 *Astarte gueuxi* d'Orbigny—Palmer, p. 75, pl. 2, figs. 1–4 (see for comments on synonymy).
1997 *Neocrassina*? sp.—Damborenea and González-León, p. 194, fig. 9.1.
1998 *Astarte gueuxii*—Harper et al., p. 356, fig. 1B–C.

Material: Eleven right valves and 10 left valves (ERNO-8212 to 8213, MB.M.4843 to 4861) from the lower Sinemurian–upper Hettangian, unit 16, two right valves and one left valve (MB.M.4866 to 4868) from the lower Sinemurian, unit 18, and three articulated specimens and three left valves (MB.M.4869 to 4874) from the upper Sinemurian, unit 19, Sierra del Álamo; one right valve and two left valves (MB.M.4875 to 4877) from the lower Pliensbachian, middle member, section 3, Sierra de Santa Rosa; one articulated specimen, two left valves, and two right valves (ERNO-8211, MB.M.4881 to 4884) from the lower Pliensbachian, Pozos de Serna. Specimens are preserved as molds or with shell.

Description: *Neocrassina gueuxi* is inequilateral and of medium size. Its outline varies from oval and suboval to subquadrate. The umbo is placed at about one-third of the shell length from the anterior end and is prosogyrate. The anterior margin is short and straight to slightly concave. The ventral margin is slightly convex. The posterior margin is slightly convex. The dorsal margin is straight to slightly convex.

The shell of adult specimens is covered with at least 25 regularly spaced, acute, commarginal ribs, which are separated by more or less equally wide interspaces. The intervals between the ribs are narrower on the anterior than on the postero-ventral part of the shell. A lunule and a small escutcheon are present.

The details of the hinge are not completely preserved in both valves, but the most significant features of the left valve can be recognized. It has two well-developed, oblique, trigonal cardinal teeth (2 and 4b) and a posterior lateral (PII). The nymph is narrow. The inner part of the ventral margin is slightly crenulated.

Remarks: This species has been described as *Neocrassina*? sp. by Damborenea and González-León (1997) from the same locality in the Sierra del Álamo. According to Damborenea and González-León (1997, p. 194), an exact classification was not possible because significant internal features were missing. On the basis of hinge characters observed in our specimens this identification can be confirmed. These authors mentioned a high similarity in shape and size to *Neocrassina aureliae* (Feruglio), a very common species in the Lower Jurassic of the Andes of South America (Feruglio, 1934, pl. 4, figs. 14–16; Wanish de Carral Tolosa, 1942, p. 47, pl. 4, figs. 1–2; A. Leanza, 1942, p. 190, pl. 17, figs. 4–7). However, the shape of *N. aureliae* varies from oval-triangulate to oval and slightly elongated, but never reaches such an elongated and subquadrate shape as in *N. gueuxi*. Furthermore, the umbo of *N. aureliae* is situated in a more anterior position, and the posterior margin is descending more strongly.

Astarte gueuxi, described by Palmer (1966) from the Middle Lias Day's Shell Bed in Dorset, Great Britain, exhibits a variability very similar to the material described herein. He plotted length against height as a percentage of length into a scatter diagram and concluded that *A. gueuxi* is a highly variable species, and many similar species are younger synonyms of this species (see also Fig. 14). These include *Astarte fontis* Dumortier (1869, p. 30, figs. 12–14) from the Middle Lias of Saint-Julien, France, and *Astarte psilonoti* Quenstedt (1856) from the Lias of Germany.

Another similar and widespread species is *Astarte andium* Gottsche from the Lower and Middle Jurassic of Argentina (Gottsche, 1878, p. 29, pl. 7, fig. 8; Tornquist, 1898, p. 170, pl. 20, fig. 11; Wanish de Carral Tolosa, 1942, p. 49, pl. 4, figs. 4–5; Rangel, 1978, p. 29, pl. 4, fig. 1). As for *N. aureliae*, the outline of the shell does not agree with that of *N. gueuxi*. Furthermore, Riccardi et al. (1990, p. 88) mentioned that Lower Jurassic records of *A. andium* belong to *N. aureliae*.

Astarte clandestina Gottsche (1878, p. 30, pl. 7, fig. 11) from the Middle Jurassic of Paso del Espinacito, Argentina, most closely resembles the material described herein. A difference to *N. gueuxi* is that the inner part of the ventral margin is not crenulated. *Astarte keideli* Wanish de Carral Tolosa (1942, p. 51, pl. 4, fig. 6) from the Lower Jurassic of Argentina is very similar in shape, but has fewer and stronger commarginal ribs than *N. gueuxi*.

In *Astarte* cf. *antipodum* Giebel, Jaworski (1929, p. 7, pl. 1, fig. 7) described another astartid from the Sierra de Santa Rosa area. It has a sub-orbicular outline and 11 strong commarginal ribs, which are separated by much broader intervals, and therefore has little similarity with *N. gueuxi*.

Jaworski (1915) described *A. fontis* Dumortier from the middle Lower Jurassic of South America. He mentioned a high similarity to the original material of Dumortier (1869) from the Middle Liassic of Saint-Julien, France. However, he did not figure his material. A. Leanza (1942) recognized a similarity of Jaworski's material to his specimens of *N. aureliae* from the Lower Jurassic of Piedra Pintada, and included it into the synonymy list. A thorough revision of the concerned species is necessary to resolve this issue. This is the first report of *N. gueuxi* from America.

Family Cardiniidae Zittel, 1881

Genus *Cardinia* Agassiz, 1841

Type species. *Unio listeri* J. Sowerby, 1817, subsequent designation by Opinion 292 of the International Commission on Zoological Nomenclature.

Cardinia concinna (J. Sowerby, 1819)
Figs. 13G and 13H.
1819 *Unio concinnus* sp. nov.—J. Sowerby: 43, pl. 223, figs. 1–2.

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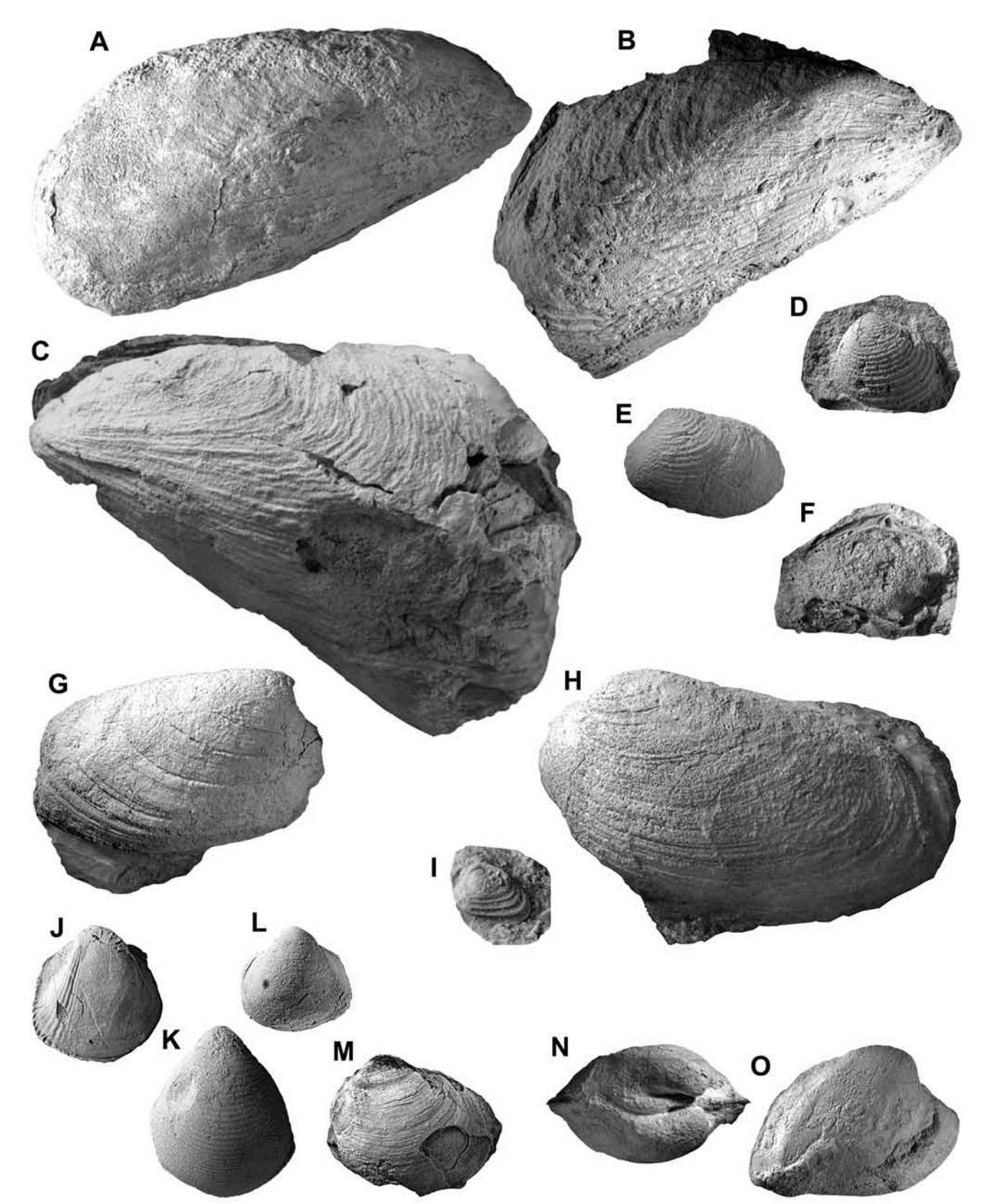

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1833 *Unio concinnus* Sowerby—v. Ziethen: 80, pl. 60, figs. 2–5.
1862 *Cardinia concinna*—Chapuis: 79, pl. 16, fig. 3.
1867 *Cardinia concinna* (Sowerby, spec.)—Dumortier: 207, pl. 47, figs. 2–3.
1885 *Cardinia concinna* (Sowerby)—Choffat: 2, pl. 3, fig. 4.
1934 *Cardinia concinna* (Sowerby)—Rosenkrantz: 94, pl. 4, fig. 1.
1975 *Cardinia concinna* (J. Sowerby 1819)—C. P. Palmer: 26, pl. 3, figs. 1, 2.
1977 *Cardinia* sp. aff. *C. concinna* (J. Sowerby)—Frebold and Poulton: 96, pl. 2, fig. 14.
2002 *Cardinia concinna* (J. Sowerby 1819)—Gahr, pl. 4, fig. 5.

Material: 2 right valves and one left valve (ERNO-8214 to 8215, MB.M.4885) from the upper Hettangian–lower Sinemurian, unit 16, Sierra del Álamo.

Description: *Cardinia concinna* is medium-sized, elongated-ovate, and slightly inflated. Its thick shell is twice as long as high. The umbo is slightly prosogyrate and situated at one-fifth of the total shell length from the anterior end. The dorsal margin is slightly convex and meets the posterior margin with a well-rounded, obtuse angle. The posterior margin is slightly convex and passes gradually into the evenly rounded ventral margin. The anterior margin is straight to slightly convex. The surface of the shell is ornamented with regular and very distinct growth lines.

Although the shells are slightly eroded, the usual cardiniid dentition with a single, elongated cardinal tooth below the umbo, and the anterior and posterior lateral tooth are identifiable in one right valve from the Sierra del Álamo. Other internal features are not preserved.

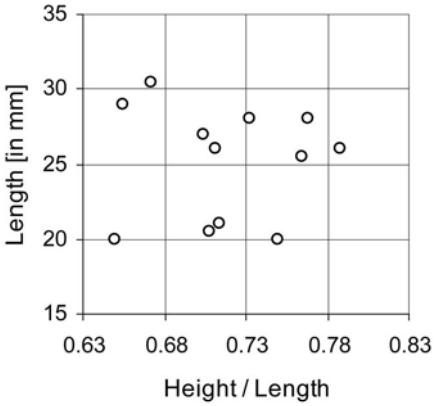

Figure 14. Scatter diagram showing the ratio of height-length to length of *Neocrassina gueuxi* d'Orbigny, 1850.

Remarks: *C. concinna* is primarily known from the Lower Jurassic of Europe, especially from Great Britain (see Palmer, 1975, for details), and this is the first report of the genus from Mexico. This species seems to be somewhat variable, as the material described by J. Sowerby (1819, p. 43, pl. 223, figs. 1–2) is characterized by a well-rounded posterior margin, whereas, for example, Goldfuss (1837, p. 181, pl. 132, fig. 2a–b) and Chapuis (1862, p. 79, pl. 16, fig. 3b) illustrated forms with a somewhat truncated posterior margin. The material from Mexico corresponds well to Sowerby's material. From North America, only one poorly preserved specimen has been described so far by Frebold and Poulton (1977) from the Hettangian of Yukon Territory.

Cardinia andium (Giebel) (e.g., Damborenea, 1992, pl. 117, fig. 1), which is a common and typical species of the Lower Jurassic of Argentina and Chile, is less elongated and therefore has a much more rounded outline. *Cardinia chubutensis* Wanish de Carral Tolosa (1942, p. 44, pl. 3, fig. 3) has a similar ornamentation but is more elongated, and the posterior margin is truncated. In *Cardinia densestriata* Jaworski (1915, p. 375, pl. 5, fig. 1), the umbo is situated at about one-third of the total length from the anterior end, the intervals between the growth lines are narrower than in *C. concinna*, and the outline is less oval.

***Cardinia*? sp. A**

Fig. 13I.

Material: One external mold of a left valve (ERNO-8216) from the upper Hettangian–lower Sinemurian, unit 16, Sierra del Álamo; one external mold of a right valve (MB.M.4886) from the lower Pliensbachian, Pozos de Serna.

Description: *Cardinia*? sp. A is small-sized, equivalved and inequilateral, subquadrate in outline, and moderately inflated. The umbones are small and are situated at one-third of the total shell length from the anterior end. The dorsal margin is short and straight to slightly convex. The posterior margin is straight to slightly convex and obliquely

Figure 13. (A–C) *Myoconcha neuquena* A. Leanza, 1940. (A) articulated specimen, right valve view, × 1, ERNO-8209; (B–C) articulated specimen; (B) right valve view, (C) left valve view; × 1, ERNO-8210; all lower Pliensbachian of Sierra de Santa Rosa. (D–F) *Neocrassina gueuxi* d'Orbigny, 1850. (D) latex cast of an external mold of a right valve, × 2, ERNO-8211, lower Pliensbachian of Pozos de Serna; (E) left valve, × 1, ERNO-8212; (F) latex cast of an internal mold of a left valve, × 1, ERNO-8213; all upper Hettangian–lower Sinemurian of Sierra del Álamo. (G–H) *Cardinia concinna* (J. Sowerby, 1819). (G) right valve, × 1, ERNO-8214; (H) left valve, × 1, ERNO-8215; all upper Hettangian–lower Sinemurian of Sierra del Álamo. (I) *Cardinia*? sp. A; latex cast of an external mold of a left valve, × 1, ERNO-8216, upper Hettangian–lower Sinemurian of Sierra del Álamo. (J) *Protocardia (Protocardia) truncata* (J. de C. Sowerby, 1827); composite mold of a right valve, × 1.5, ERNO-8217, lower Sinemurian of Sierra del Álamo. (K) *Protocardia (Protocardia) luggudensis* (Troedsson, 1951); right valve view of a composite mold of an articulated specimen, × 1.5, ERNO-8218, lower Pliensbachian of Sierra de Santa Rosa. (L) *Protocardia striatula* (J. de C. Sowerby, 1829); composite mold of a left valve, × 1.5, ERNO-8219, lower Pliensbachian of Sierra de Santa Rosa. (M) *Protocardia* sp. A; composite mold of left valve, × 1.5, ERNO-8220, lower Pliensbachian of Pozos de Serna. (N–O) *Isocyprina ancatruzi* (A. Leanza, 1942); steinkern. (N) dorsal view, (O) right valve view; × 1, ERNO-8221, lower Pliensbachian of Sierra de Santa Rosa.

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slopes to the postero-ventral corner. The ventral margin is straight, the anterior margin slightly convex. The shell is covered with seven to eight thick, commarginal, imbricate folds with upturned, rounded edges. Internal characters are not preserved.

Remarks: Because of the lack of internal features, the generic assignment to *Cardinia* is questionable and based on the great resemblance of our specimens to *Cardinia rugulosa* Tate (1875, p. 508, text-fig. 3) from the lower Pliensbachian of Great Britain. Following the first description by Tate, Palmer (1975, p. 32, pl. 5, fig. 5) described a new specimen that corresponds very closely to our material. The specimens of Tate (1875), although similar in ornamentation and size, differ somewhat in being more elongated and having a convex posterior margin.

C.? sp. A differs from the here described *C. concinna* by its smaller size and its different ornamentation and outline.

Family Cardiidae Lamarck, 1809

Genus *Protocardia* von Beyrich, 1845

Type species. *Cardium hillanum* J. Sowerby, 1813, subsequent designation by Herrmannsen, 1847.

Subgenus *Protocardia*

Protocardia (Protocardia) truncata (J. de C. Sowerby, 1827)

Fig. 13J.

1827 *Cardium truncatum* sp. nov.—J. de C. Sowerby: 102, pl. 553, fig. 3.

1852 *Cardium truncatum* Sowerby—Quenstedt: 540, pl. 45, fig. 19.

1871 *Cardium truncatum* Sow.—Phillips: 136, pl. 8, fig. 28.

1936 *Protocardia truncata* Phil. (Sow.)—Kuhn: 267, pl. 12, fig. 22.

1948 *Protocardia truncata* (J. de C. Sowerby)—Wilson: 18, fig. 5D.

1951 *Protocardia truncata* (Sow.)—Troedsson: 180, pl. 14, figs. 3–5.

Material: One external mold of a right valve (MB.M.4887) from the upper Hettangian–lower Sinemurian, unit 16, and two composite molds of right valves and two external molds of left valves (ERNO-8217, MB.M.4888 to 4890) from the lower Sinemurian, unit 18, Sierra del Álamo.

Description: *Protocardia (P.) truncata* is small, subquadrate, equivalved, and sub-equilateral. The height and length are almost equal. The valves are moderately inflated. The umbones are well rounded, slightly prosogyrate, rising above the hinge-line. The anterior and posterior margins are straight to slightly convex. The ventral margin is well curved. An umbonal ridge extends from the umbo to the postero-ventral corner.

The surface of the shell is covered with fine, commarginal growth lines. The posterior part of the shell is ornamented with radial ribs. Four to six of these ribs are situated anterior of the umbonal ridge, and about the same number of ribs occur posterior to the umbonal ridge. The first one or two are very faint. The ribs become gradually fainter posteriorly and disappear before reaching the posterior margin, where the surface is smooth. The interspaces between the ribs are very narrow. The inner part of the postero-ventral margin is slightly crenulated where the ribs meet the margin; otherwise it is smooth. Other internal features are unknown.

Remarks: So far, *P. truncata* has not yet been described from North or South America. It is known from the Lower and Middle Jurassic of Europe (Sweden, Great Britain, Germany). Among other species of *Protocardia* described from the Lower Jurassic of America, *Cardium (Protocardium) appressum* Gabb, 1877 (286, pl. 40, fig. 17) from Peru differs from *P. truncata* by a larger size and a more prominent umbo. Affinities to *Protocardia striatula* (J. de C. Sowerby), which also is known from Canada and Argentina, are discussed below.

Related species from the European Jurassic include *Protocardia (P.) oxynoti* Quenstedt, 1856 (110, pl. 13, fig. 46), which is similar in outline but has a much fainter umbonal ridge, and only two or three ribs are situated anterior to the ridge. *Protocardia (P.) philippiana* Dunker (1847, p. 116, pl. 17, figs. 6a–c) has a more trigonal outline, a weak umbonal ridge, and no radial ribs anterior to the ridge.

***Protocardia (Protocardia) striatula* (J. de C. Sowerby, 1829)**

Fig. 13L.

1829 *Cardium striatulum* sp. nov.—J. de C. Sowerby: 576, pl. 553, figs. 1–2.

1931 *Protocardia striatula* (Sowerby?) Phillips—Weaver: 353, pl. 38, figs. 236–237.

1957 *Protocardia striatula* (Phillips)—Frebold: 13, pl. 3, figs. 11–12.

1964 *Protocardia striatula* (Phillips)—Frebold, pl. 7, fig. 15.

Material: Composite molds of one left valve and one right valve (ERNO-8219, MB.M.4897) from the lower Pliensbachian, middle member, section 4, Sierra de Santa Rosa.

Description: *Protocardia (P.) striatula* is medium-sized, orbicular, and equivalved. The shell is very globose and nearly as high as long. Its umbones are well rounded, orthogyrate, and protrude considerably beyond the hinge line. The anterior margin and the ventral margin are evenly rounded. The posterior margin is only slightly convex. A faint post-umbonal ridge leads from behind the umbo to the postero-ventral corner.

The shell is ornamented with regular, fine, commarginal ribs. Additionally, the posterior part of the shell is covered with 11 to 15 radial ribs. About eight of these ribs are situated anterior of the post-umbonal ridge, the first one or two being more subtle than the others. The radial ribs do not reach the postero-dorsal margin. Internal characters cannot be observed.

Remarks: The Mexican specimens correspond well to the material described from the Toarcian of western Canada (Frebold, 1957, 1964) and from the Bajocian of Argentina (Weaver, 1931). They are somewhat larger than European specimens described by Benecke (1905, p. 228, pl. 17, figs. 1–6) from the Liassic of Alsace-Lorraine and by Gahr (2002,

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p. 126, pl. 4, figs. 10–11) from the Toarcian of Spain.

Protocardia (P.) substricklandi Tornquist (1898, p. 38, pl. 10, fig. 2) from the Middle Jurassic of Argentina is very similar to *P. striatula*, but its ornamentation is weaker.

In comparison with *P. truncata* (see above), *P. striatula* attains a larger size, is more inflated, and exhibits a conspicuous commarginal ornamentation.

***Protocardia (Protocardia) luggudensis* (Troedsson, 1951)**

Fig. 13K.

1951 *Anisocardia luggudensis* sp. nov.—Troedsson: 185, pl. 14, fig. 1a–c.

Material: One internal mold of a right valve (MB.M.4893) from the upper Sinemurian, unit 19, Sierra del Álamo; one composite mold of an articulated specimen and one internal mold of a right valve (ERNO-8218, MB.M.4896) from the lower Pliensbachian, middle member, section 3, and two steinkerns (MB.M.4894 to 4895) from the lower Pliensbachian, middle member, section 4, Sierra de Santa Rosa.

Description: *Protocardia (P.) luggudensis* is medium-sized, trigonal in shape, equivalved, and sub-equilateral. The shell is slightly higher than long. The valves are highly inflated. The umbones are well rounded, very prominent, and slightly prosogyrate. The anterior margin is straight to slightly convex. The ventral margin is evenly convex. The posterior margin is convex.

A weak post-umbonal ridge runs from behind the umbo to the postero-ventral corner. The surface of the shell is covered with fine, commarginal striae. The posterior part of the shell, behind the post-umbonal ridge, wears about five faint radial ribs. Internal characters are not preserved.

Remarks: *P. luggudensis* is a poorly known species that, until now, was only known from the lower Pliensbachian of Sweden (Troedsson, 1951). Troedsson (1951) incorrectly attributed it to *Anisocardia* because of its hinge characters and its great similarity to *Anisocardia globosa* (Roemer, 1839) from the Upper Jurassic of Europe (e.g., Arkell, 1934, p. 272, pl. 36, figs. 3–7). In comparison with *P. luggudensis*, *A. globosa* is more strongly inflated and has a more asymmetric umbo. Furthermore, as *P. luggudensis* exhibits posterior radial ribs, a typical feature of the genus *Protocardia*, it belongs to *Protocardia*, and not to *Anisocardia*.

P. luggudensis differs from the here described *P. striatula* by its highly inflated shell and posterior radial ribs, which are restricted to the part of the shell posterior to the umbonal ridge. *P. truncata* has a less inflated shell, and the posterior ribs nearly cover the whole posterior half of the shell. *P.* sp. A (see below) differs by its elongated outline.

***Protocardia (Protocardia)* sp. A**

Fig. 13M.

Material: One composite and one internal mold of left valves (ERNO-8220, MB.M.4898) from the lower Pliensbachian, Pozos de Serna.

Description: *Protocardia (P.)* sp. A is oval-elongated in outline, inequilateral, and clearly longer than high. The umbo is small and orthogyrate. The posterior margin is slightly convex. The ventral margin is well rounded and passes gradually into the evenly convex anterior margin. The antero-dorsal margin and the postero-dorsal margin are slightly convex.

The surface of the shell is covered with fine, regular, commarginal growth lines. The posterior part of the shell, behind a smooth umbonal ridge, is ornamented with numerous fine, radial striae that extend from the umbo to the postero-ventral part of the shell.

Remarks: Because of the presence of posterior radial ribs, the material can confidently be referred to *Protocardia*, even if its elongated form is quite unusual for the genus. Most species of *Protocardia* are higher than long or have a lower length-to-height ratio than *P. (P.)* sp. A.

A similar specimen has been described as *Protocardia (P.)* sp. A by Fürsich et al. (2000, p. 114, pl. 12, fig. 13) from the Callovian and Oxfordian of Kachchh, India. It resembles the Mexican material but is larger and has a more distinct commarginal ornamentation.

Family Arcticidae Newton, 1891

Genus *Isocyprina* Röder, 1882

Type species. *Cardium cyreniforme* Buvignier, 1852; subsequent designation by Cossmann, 1921.

Isocyprina ancatruzi (A. Leanza, 1942)

Figs. 13N and 13O.

1915 *Venilicardia (Cyprina) cornuta* d'Orb.—Jaworski: 387, pl. 6, figs. 1–4.

1942 *Cypricardia ancatruzi* sp. nov.—A. Leanza: 188, pl. 15, fig. 3; pl. 17, figs. 1–3.

Material: Ten steinkerns (ERNO-8221, MB.M.4899 to 4907) from the lower Pliensbachian, middle member, section 4, Sierra de Santa Rosa.

Description: *Isocyprina ancatruzi* is trigonal to trigonally suboval, medium-sized, inequilateral, equivalved, and moderately inflated. The umbo is broad, slightly enrolled, prosogyrate, and is situated at one-fifth of the shell length from the anterior end. A weak posterior carina runs from behind the umbo to the postero-ventral corner of the shell. Posterior to this carina, the shell is less inflated, and is slightly concave in cross section.

The dorsal margin is convex and oblique, and meets the posterior margin at a very obtuse angle. The posterior margin is short, straight to slightly convex, and oblique. It meets the ventral margin at nearly a right angle. The ventral margin is convex and meets the straight anterior margin at a right to slightly obtuse angle. The surface of the shell is smooth except for regular growth lines. No internal features are observable because of the moderate preservation.

Remarks: *I. ancatruzi* was reported by Jaworski (1915) and Wanish de Carral Tolosa (1942) as *Venilicardia cornuta*

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d'Orbigny, a species that is known from the Upper Jurassic of northern France, northern Germany, and the Swiss Jura Mountains. Jaworski (1915, p. 391) provided good illustrations and a very detailed description of the hinge features. Subsequently, Damborenea (*in* Riccardi et al., 1990, p. 88) referred to it as *Isocyprina ancatruzi*, a view that is followed here.

Order Pholadomyoida Newell, 1965
Family Pholadomyidae Gray, 1847
Genus *Pholadomya* G. B. Sowerby, 1823

Type species. *Pholadomya candida* G. B. Sowerby, 1823, subsequent designation by Gray, 1847.

Subgenus *Pholadomya*

Pholadomya (Pholadomya) fidicula J. de C. Sowerby, 1826
Figs. 15A–15C.

1819 *Lutraria lirata* sp. nov.—J. Sowerby: 47, pl. 225, figs. 1–2.
1826 *Pholadomya fidicula* nom. nov.—J. de C. Sowerby: 86.
1874 *Pholadomya fidicula*, Sow.—Moesch: 25, pl. 8, figs. 4–7; pl. 9, figs. 6–8 (see for synonymy list).
1965 *Pholadomya fidicula* Sowerby—Alencáster and Buitrón: 36, pl. 9, figs. 1–4.
1997 *Pholadomya* cf. *P. fidicula* (J. Sowerby, 1819)—Damborenea and González-León: 195, fig. 9.3.
2004 *Pholadomya (Pholadomya) fidicula* J. de C. Sowerby 1826—Aberhan: 121, pl. 2, figs. 1–6 (see for extensive synonymy list).

Material: Seventeen composite molds of articulated specimens (ERNO-8222 to 8223, MB.M.4908 to 4922) from the lower Pliensbachian, middle member, section 4, Sierra de Santa Rosa.

Remarks: *Ph. fidicula* was recently described by Aberhan (2004) from the Lower Jurassic of Chile and no further description is necessary here. This is the most abundant species of *Pholadomya* in the study area. Compared with *Pholadomya (Ph.) idea* (see below), it has a more elongated outline, more numerous radial ribs, and is less inflated. *Pholadomya (Ph.)* cf. *voltzi* (see below) has a more rounded and less elongated outline and wears only eight very faint ribs. For further discussion see Aberhan (2004).

***Pholadomya (Pholadomya) idea* d'Orbigny, 1850**
Figs. 15D–15F.

1833 *Pholadomya ambigua* Sowerby—von Zieten: 86, pl. 65, fig. 1.
1850 *Pholadomya idea*, d'Orb., 1847—d'Orbigny: 7e étage, p. 216.
1915 *Pholadomya ambigua* Sow.—Jaworski: 423.
1991 *Pholadomya idea* d'Orbigny—Poulton: 32, pl. 4, figs. 4–12, 14–15.
1997 *Pholadomya* cf. *P. ambigua* (J. Sowerby, 1819)—Damborenea and González-León: 195, fig. 9.4.
2004 *Pholadomya (Pholadomya) idea* d'Orbigny 1850—Aberhan: 124, pl. 3, figs. 4, 6; pl. 4, fig. 1; pl. 10, fig. 6.

Material: Seven composite molds of articulated specimens (ERNO-8224, MB.M.4923 to 4928) from the lower Pliensbachian, middle member, section 4, Sierra de Santa Rosa.

Remarks: The recent description of *Ph. idea* by Aberhan (2004) perfectly fits the Mexican specimens. *Ph. (Pholadomya)* cf. *ambigua* described by Damborenea and González-León (1997) from the same locality in the Sierra de Santa Rosa is included in *Ph. idea* herein. Although similar in style of ornamentation, the length-to-height ratio of *Ph. ambigua* J. Sowerby is close to 1, and thus the shell is noticeably less elongated than that of *Ph. idea*.

***Pholadomya (Pholadomya)* cf. *voltzi* Agassiz, 1842**
Fig. 15G.

cf. 1842 *Pholadomya Voltzii* sp. nov.—Agassiz: 122, pl. 3c, figs. 1–6 (non-figs. 8–9).
cf. 1874 *Pholadomya Voltzi*, Ag.—Moesch: 20, pl. 6, figs. 2–3; pl. 9, figs. 1, 3 (see for short synonymy list).
cf. 2004 *Pholadomya (Pholadomya) voltzi* Agassiz 1842—Aberhan: 128, pl. 1, figs. 1–3; text-fig. 3A–D.

Material: One composite mold of a left valve (ERNO-8225) from the lower Toarcian, Sierra de La Jojoba.

Description: *Pholadomya (Ph.)* cf. *voltzi* is medium-sized, oval to slightly elongated in outline, and moderately inflated. The umbones are well rounded and narrow. It has a slightly concave postero-dorsal margin and a well curved ventral and anterior margin. The posterior margin is only weakly convex.

The shell is ornamented with rounded, commarginal

Figure 15. (A–C) *Pholadomya (Pholadomya) fidicula* J. de C. Sowerby, 1826. (A) right valve view of a composite mold of an articulated specimen, × 1, ERNO-8222; (B–C) composite mold of an articulated specimen; (B) right valve view, (C) left valve view; × 1, ERNO-8223; all lower Pliensbachian of Sierra de Santa Rosa. (D–F) *Pholadomya (Pholadomya) idea* d'Orbigny, 1850; composite mold of an articulated specimen. (D) right valve view, (E) dorsal view, (F) left valve view; × 1, ERNO-8224, lower Pliensbachian of Sierra de Santa Rosa. (G) *Pholadomya (Pholadomya)* cf. *voltzi* Agassiz, 1842; Composite mold of a left valve, × 1, ERNO-8225, lower Toarcian of Sierra de La Jojoba. (H) *Goniomya (Goniomya)* sp. A; composite mold of a right valve, × 1, ERNO-8226, lower Pliensbachian of Sierra de Santa Rosa. (I–J) *Osteomya dilata* (Phillips, 1829). (I) composite mold of a right valve, × 1, ERNO-8227; (J) latex cast of an external mold of a right valve, × 1, ERNO-8228; all lower Sinemurian of Sierra del Álamo. (K–M) *Pachymya*? sp. A; composite mold of an articulated specimen. (K) left valve view, (L) dorsal view, (M) right valve view; × 1, ERNO-8229; all lower Pliensbachian of Sierra de Santa Rosa. (N) *Ceratomya concentrica* (J. de C. Sowerby, 1825); composite mold of a right valve, × 1, ERNO-8230, lower Pliensbachian of Sierra de Santa Rosa. (O) *Pleuromya uniformis* (J. Sowerby, 1813); steinkern, right valve view, × 1, ERNO-8234, lower Pliensbachian of Sierra de Santa Rosa. (P–R) *Ceratomya petricosa* (Simpson, 1855). (P) internal mold of a left valve, × 1, ERNO-8231; (Q) internal mold of a right valve, × 1, ERNO-8232; (R) internal mold of a right valve, × 1, ERNO-8233; all lower Pliensbachian of Pozos de Serna. (S) *Pleuromya uniformis* (J. Sowerby, 1813); steinkern, left valve view, × 1, ERNO-8234, lower Pliensbachian of Sierra de Santa Rosa.

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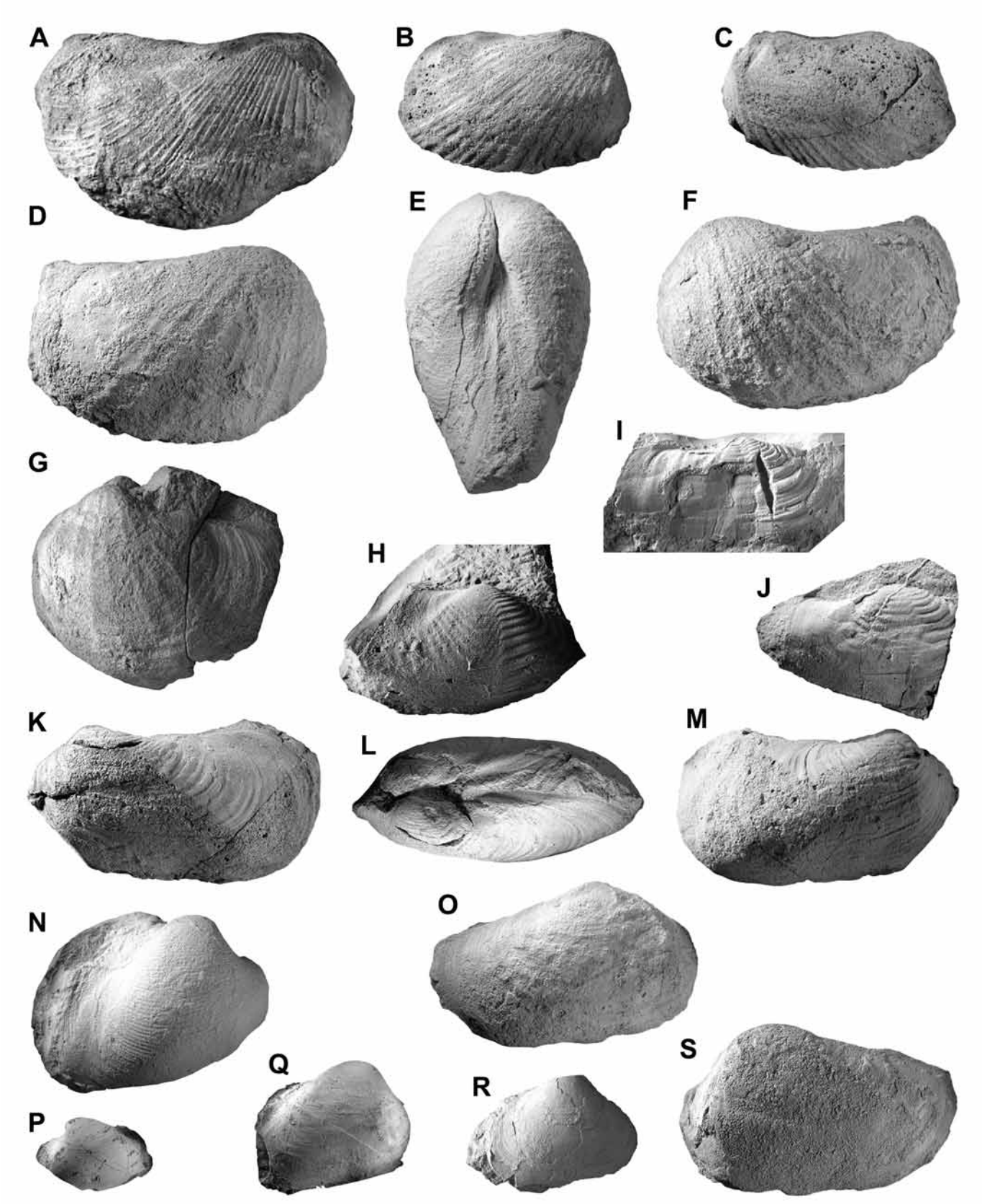

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growth rugae, which are regularly spaced. Seven radial, straight, very faint ribs lead from the umbo to the ventral margin. These ribs cover the whole surface of the shell except for the postero-dorsal part, where only commarginal rugae are present.

Remarks: This is the first record of *Ph.* cf. *voltzi* from Mexico. Although there is only one specimen available for study, it is clearly distinguishable from the other species of *Pholadomya* described herein. Compared with specimens from Europe and northern Chile (see synonymy list) it is less elongated and therefore has been assigned to *Ph. voltzi* with reservation.

Genus *Goniomya* Agassiz, 1841

Type species. *Mya angulifera* J. Sowerby, 1819; subsequent designation by Herrmannsen, 1847.

Subgenus *Goniomya*

Goniomya (Goniomya) sp. A

Fig. 15H.

Material: One composite mold of a right valve (ERNO-8226) from the lower Pliensbachian, middle member, section 3, Sierra de Santa Rosa.

Description: *Goniomya (G.)* sp. A is medium-sized, elongated, and moderately inflated. The umbones are orthogyrate and are situated mesially. The antero-dorsal and postero-dorsal margins are slightly concave. The short and evenly curved anterior margin passes smoothly into the slightly convex ventral margin. The posterior margin is nearly straight. A weak diagonal ridge extends from the umbo to the postero-ventral corner. The form of the escutcheon and the lunule are unknown.

The ornament consists of commarginal ribs that cover the anterior half of the shell. At a length shortly anterior to the umbo, they deviate and run toward the ventral margin. Having passed the midline of the shell, they deviate again and run obliquely toward the postero-dorsal margin, forming a more or less rectangular angle at the second bend. The ribs disappear when they reach the diagonal ridge. Posterior to this ridge, only commarginal growth lines can be seen.

Remarks: This is the first report of *Goniomya* from the Lower Jurassic of Mexico. A different species, *Goniomya (G.) calderoni* Castillo and Aguilera (1895, p. 9, pl. 5, figs. 17–18), was described from the Upper Jurassic of Mexico. *Goniomya* sp. A has a conspicuous ornamentation that resembles a mathematical root sign. This ornamentation has not yet been described in any other species of *Goniomya*, which usually have a trapezoidal or v-shaped ornamentation. With only one specimen available, intraspecific variations of morphological characters are unknown, and erection of a new species must await more material.

Genus *Osteomya* Moesch, 1874

Type species. *Mya dilata* Phillips, 1829.

Osteomya dilata (Phillips, 1829)

Figs. 15I–15J.

1829 *Mya dilata* sp. nov.—Phillips: 155, pl. 11, fig. 4.

1991 *Osteomya dilata* (Phillips 1829)—Yin and Fürsich: 156, pl. 11, fig. 2 (see for synonymy list).

2004 *Osteomya dilata* (Phillips 1829)—Aberhan: 134, pl. 6, figs. 4–5.

Material: One composite and one external mold of right valves with partial shell preservation (ERNO-8227 to 8228) from the lower Sinemurian, unit 18, Sierra del Álamo.

Description: *Osteomya dilata* is medium-sized, elongated-ovate, and moderately inflated. Its umbones are broad and opisthogyrate and are situated about two-fifths of the shell length from the anterior end. The postero-dorsal margin is strongly concave, the antero-dorsal margin straight to slightly concave. The ventral margin is slightly convex and passes with a slight curve into the also slightly convex anterior margin. The posterior margin is truncated. A weak posterior ridge extends from the umbo to the postero-ventral corner of the shell. The surface of the shell wears faint, irregularly spaced, commarginal folds.

Remarks: This is the first record of the genus from Mexico. The studied specimen, although laterally deformed, agrees well with specimens of *O. dilata* recently documented from the Middle Jurassic of Kachchh, western India (Pandey et al., 1996), and the Lower Jurassic of northern Chile (Aberhan, 2004).

Genus *Pachymya* J. de C. Sowerby, 1826

Type species. *Pachymya gigas* J. de C. Sowerby, 1826.

Pachymya? sp. A

Figs. 15K–15M.

1997 *Pachymya*? sp.—Damborenea and González-León: 195, fig. 9.5.

Material: One steinkern and one composite mold of an articulated specimen (ERNO-8229, MB.M.4929) from the lower Pliensbachian, middle member, section 4, Sierra de Santa Rosa.

Description: *Pachymya*? sp. A is medium- to large-sized, inequilateral and has an elongated, subrectangular form, with the postero-dorsal margin reaching nearly the same height as the umbones. The umbones are narrow and orthogyrate, and are situated at about one-fifth of the shell length from the anterior end. The shell is moderately inflated, with the greatest inflation in the antero-dorsal part of the shell. A smooth posterior ridge extends from the umbo to the postero-ventral corner of the shell. The postero-dorsal margin is slightly concave and meets the posterior margin at an obtuse angle. The posterior margin is convex and gaping. It passes into the nearly straight ventral margin with a slight curve. The antero-dorsal margin descends rapidly to the short and well-curved anterior margin. The escutcheon is long and narrow and bordered by smooth ridges. The surface of the shell is covered with commarginal, irregularly spaced growth lines.

Remarks: The available specimens certainly belong to the same species that was described as *Pachymya*? sp. by Damborenea and González-León (1997) from the same locality. These authors also discussed affinities to various

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species of the genus *Homomya* Agassiz. Because of the presence of a very faint umbonal carina, the specimens are doubtfully assigned to *Pachymya*. *Pachymya*? sp. A from the Sinemurian of Chile (Aberhan, 2004, p. 138, pl. 9, figs. 1, 6) also has a very low umbonal carina, but is more strongly inflated, the umbones are in a more anterior position, and the ventral margin is convex rather than straight.

Family *Ceratomyidae* Arkell, 1934

Genus *Ceratomya* Sandberger, 1864

Type species. *Isocardia excentrica* Roemer, 1836.

Ceratomya concentrica (J. de C. Sowerby, 1825)

Fig. 15N.

1825 *Isocardia concentrica* J. de C. Sowerby: 147, pl. 391, fig. 1.
1934 *Ceratomya concentrica* (J. de C. Sowerby)—Arkell: 315, pl. 43, fig. 10 (see for extensive synonymy list).
1997 *Ceratomya* sp.—Damborenea and González-León: 196, fig. 9.6.

Material: One composite mold of a right valve (ERNO-8230) from the lower Pliensbachian, middle member, section 3, and one internal mold of a left valve (MB.M.4930) from the lower Pliensbachian, middle member, section 4, Sierra de Santa Rosa.

Description: *Ceratomya concentrica* is small to medium-sized, slightly inequilateral, and has an oval outline. Its umbones are large, tumid, prosogyrate, and strongly incurved, and are situated about one-fourth to one-third of the shell length from the anterior end. The shell is slightly longer than high and well inflated. The posterior part is flattened and slightly elongated. The posterior margin is straight to slightly convex and meets the evenly convex ventral margin with an angle of about 100°. The ventral margin passes gradually into the well-curved anterior margin. The antero-dorsal margin is short and slightly concave. The surface of the shell is covered with faint, regularly spaced, commarginal undulations, which cover the entire surface of the shell.

Remarks: *C. concentrica* has not been identified from North or South America before. The present specimens are very similar to those described and figured by Arkell (1934) from the Upper Jurassic of England. Many other authors also described *C. concentrica* from the Middle and Upper Jurassic of Europe (e.g., Scholz, 2005). Only Bernad (1997, p. 24, pl. 3, fig. 10) and Gahr (2002, pl. 5, fig. 8) figured *C. concentrica* from the Lower Jurassic of Spain.

Ceratomya sp. of Damborenea and González-León (1997) from the same locality in Mexico, is identical in ornamentation and outline to the specimens described in this study, and is therefore included into the synonymy list. Similar in ornamentation is ?*Ceratomya* sp. of Alencáster (1977, p. 160, fig. 14) from the Upper Jurassic of Mexico, but it differs in being slightly higher than long. *Ceratomya* sp. A, which has been described by Aberhan (2004, p. 138, pl. 7, fig. 2) from the Pliensbachian of Chile, differs from the Mexican specimens by a higher length-height ratio.

***Ceratomya petricosa* (Simpson, 1855)**

Figs. 15P–15R.

1855 *Venus petricosa* sp. nov.—Simpson: 121.
1867 *Isocardia liassica* sp. nov.—Moore: 217, pl. 7, fig. 3.
1876 *Ceromya petricosa*, Simpson—Tate and Blake: 408, pl. 14, fig. 1a+b.
1928 *Ceratomya petricosa* (Simpson)—Cox: 244, pl. 18, fig. 4a+b.
1973 *Ceratomya petricosa* (Simpson) 1855—Palmer: 254, pl. 1, fig. 12.

Material: Internal molds with rare shell preservation of 13 right valves and six left valves and one steinkern (ERNO-8231 to 8233, MB.M.4931 to 4947) from the lower Pliensbachian, Pozos de Serna.

Description: *Ceratomya petricosa* is medium-sized, equivalved, inequilateral, and has a suboval outline. The umbones are prominent, prosogyrate, and strongly involute. The anterior margin is convex and passes gradually into the straight to slightly convex ventral margin. The posterior margin is slightly convex and meets the ventral margin at an obtuse angle. The shell has its strongest inflation in its anterior half. The shell, which is relatively thin, is ornamented with numerous narrow, fine, commarginal ribs. In internal molds, only commarginal growth lines can be seen.

Remarks: Hitherto, *C. petricosa* was known only from the Lower Jurassic of Great Britain. Simpson (1855) and Cox (1928) mentioned radiating rows of very small pustules on the surface of *C. petricosa*. This is a common feature of anomalodesmatan bivalves in general, but, as in the Mexican specimens, it often is not preserved. *C. petricosa* differs from *C. concentrica* by its more elongated outline and less inflated shell. Additionally, *C. petricosa* has finer and more numerous ribs.

Family Pleuromyidae Dall, 1900

Genus *Pleuromya* Agassiz, 1843

Type species. *Mya gibbosa* J. de C. Sowerby, 1823.

Pleuromya uniformis (J. Sowerby, 1813)

Fig. 15O and 15S.

1813 *Unio uniformis* sp. nov.—J. Sowerby: 83, pl. 33, fig. 4.
1935 *Pleuromya uniformis* (J. Sowerby)—Arkell: 325, pl. 45, figs. 1–13 (see for extensive synonymy list).
1977 *Pleuromya tellina* Agassiz—Alencáster: 161, figs. 16a–c.
2004 *Pleuromya uniformis* (J. Sowerby 1813)—Aberhan: 146, pl. 8, figs. 8–14 (see for extensive synonymy list).

Material: One steinkern (MB.M.4955) from the lower Pliensbachian, middle member, section 3, and two steinkerns (ERNO-8234, MB.M.4956) from the lower Pliensbachian, middle member, section 4, Sierra de Santa Rosa.

Description: *Pleuromya uniformis* is medium-sized, inequilateral, and elongated-ovate. The umbones are broad, orthogyrate, and are situated at about one-third of the shell length from the anterior end. Its postero-dorsal margin is long and straight to slightly concave, whereas the antero-dorsal margin is very short and descends toward the well-curved

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TABLE 1. DISTRIBUTION OF EARLY JURASSIC BIVALVES PRESENT IN SONORA DURING THE HETTANGIAN–SINEMURIAN AND/OR PLIENSBACHIAN

Taxon	Hettangian–Sinemurian	Pliensbachian
Palaeoneilo elliptica	W	
Parallelodon cf. *hirsonensis*		E
Grammatodon (G.) sulcatus	E	END
Gervillella araucana	E (N)	E
Gervillella leesi	E (N)	END
Cercomya (Capillimya) peruviana		END
Plagiostoma schimperi		END
Pinna (P.) cf. *folium*		W
Antiquilima (A.) cf. *nodulosa*		E
Oxytoma (O.) cf. *inequivalvis*	W	
Entolium (E.) corneolum	E	E
Agerchlamys wunschae	E (T)	E (T)
Eopecten velatus		W
Weyla (W.) alata	E	E
Weyla (W.) bodenbenderi	E	E
Weyla (W.) titan	E	E
Weyla (Lywea) unca	E	E
Modiolus (M.) giganteus		E
Modiolus (M.) cf. *baylei*		E
Modiolus (Cyranus) hillanus	W	
Pholadomya (Ph.) fidicula		E
Pholadomya (Ph.) idea		W
Pholadomya (Ph.) cf. *voltzi*		W
Pleuromya uniformis		W
Ceratomya concentrica		END
Ceratomya petricosa		W
Osteomya dilata	E	
Groeberella sp. A		END
Frenguelliella poultoni	E (N)	E
Protocardia (P.) truncata	W	
Protocardia (P.) striatula		E
Protocardia (P.) luggudensis	END	W
Neocrassina gueuxi	W	W
Cardinia concinna	W	
Isocyprina ancatruzi	END	E
Myoconcha neuquena		E
Lucinidae gen. et sp. indet. B	END	END

Note: E—East Pacific; END—endemic to Sonora during that particular time slice; N—restricted to North America during the particular time; T—trans-temperate; W—widespread. See text for details.

anterior margin. The posterior gape is narrow. The ventral margin is straight to smoothly convex and passes gradually into the anterior margin and the convex posterior margin. The surface of the shell is covered with regularly spaced, commarginal growth lines.

Remarks: This is the first record of the genus from the Lower Jurassic of Mexico. Many authors commented on the great variability in shape in *P. uniformis* (see Aberhan, 2004, and references therein), and the Mexican specimens fit well into the known morphological range of this species.

Family Laternulidae Hedley, 1918
Genus *Cercomya* Agassiz, 1843

Type species. *Cercomya pinguis* Agassiz, 1843.

Subgenus *Capillimya* Crickmay, 1936

Type species. *Capillimya capillifera* Crickmay, 1936.

Cercomya (Capillimya) peruviana Cox, 1956

Figs. 6D–6F.

1956 *Cercomya peruviana* sp. nov.—Cox: 1185, pl. 128, fig. 7.
1992 *Cercomya peruviana* Cox—Damborenea, pl. 118, fig. 6.
2004 *Cercomya (Capillimya) peruviana* Cox 1956—Aberhan: 148, pl. 9, figs. 7–9.

Material: One composite mold of an articulated specimen (ERNO-8168) from the lower Pliensbachian, middle member, section 4, Sierra de Santa Rosa.

Description: *Cercomya (Capillimya) peruviana* is rostrate, inequilateral, and only slightly inflated, and has an elongated, tapering posterior end with a narrow posterior gape. The umbones are narrow, orthogyrate, and are situated mesially. The antero-dorsal margin is slightly convex, the postero-dorsal margin concave. The ventral margin is slightly undulated and passes laterally into the convex anterior margin. The escutcheon is long and narrow and bordered by fine ridges.

The anterior part of the shell is covered with strong and rounded commarginal folds. They terminate at a shallow sulcus, which extends from the umbo to the ventral margin. Behind this sulcus, the surface of the shell is covered with commarginal growth lines and faint radial ribs, which become stronger toward the posterior end of the shell. These two ornamental elements produce a subtle reticulate pattern, especially on the middle part of the shell.

Remarks: This is the first record of the genus from the Lower Jurassic of Mexico. *C. peruviana* shows the typical rostrate shape, which separates representatives of *Cercomya* from other species of the Anomalodesmata. It differs from *Cercomya undulata* (J. Sowerby, 1827), which has been described by Aberhan (1994, p. 21, pl. 6, figs. 7–9) from the Toarcian of Chile, by the shallow sulcus extending from the umbo to the ventral margin, and fine, distinct riblets covering the posterior part of the shell. A comparison with other species of *Cercomya* has recently been performed by Aberhan (2004).

EARLY JURASSIC BIVALVE PALEOBIOGEOGRAPHY

Early Jurassic bivalves of western North and South America are fairly well known. This offers the opportunity to analyze the bivalves of the Antimonio terrane documented herein in a paleobiogeographic context. Following the description of distributional patterns, we quantitatively compare the Antimonio bivalves with contemporaneous faunas along the eastern paleo-Pacific margin and discuss implications for the paleogeographic position of the Antimonio terrane during Early Jurassic times.

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TABLE 2. LIST OF STUDIED AREAS AND MAIN SOURCES OF DATA

Area	Source
Brooks-Mackenzie Basin	Imlay, 1967; Poulton, 1991; collections of the Geological Survey of Canada, Calgary and Ottawa
Western Canada Sedimentary Basin	Frebold, 1957, 1964, 1966, 1969; Aberhan, 1998a
Wrangellia	Whiteaves, 1900; Aberhan, 1998a
Stikinia	Lees, 1934; Thomson and Smith, 1992; Stanley and McRoberts, 1993; Aberhan, 1998a
Northern Chile	Bayle and Coquand, 1851; Möricke, 1894; Philippi, 1899; Covacevich and Escobar, 1979; von Hillebrandt, 1980; Pérez, 1982; Aberhan, 1994; Damborenea, 1996
Neuquén Basin	Behrendsen, 1891; Burckhardt, 1900; Jaworski, 1914; Weaver, 1931; Leanza, 1942; Escobar, 1980; Manceñido and Damborenea, 1984; Damborenea, 1987b, 1992, 1993, 1996, 2002; Riccardi et al., 1988, 1991; Damborenea and Manceñido, 1992
Sonora	Jaworski, 1929; Damborenea and González-Léon, 1997; present study

Biogeographic Affinities

With respect to their paleogeographic distribution we assigned all taxa that have been resolvable at species level (including open nomenclature) to one out of three broad distributional categories (Table 1): endemic to Sonora, eastern Pacific, and widespread. It should be noted that geographic ranges of taxa may change through time, leading to a different categorization for the same taxon. Although the distributional patterns vary slightly between the Hettangian–Sinemurian and the Pliensbachian, the general proportions of these categories remain constant.

Species apparently restricted to the eastern Pacific margin of North and/or South America form about half of the total fauna. Documentation of these taxa in Sonora provides further evidence of the paleolatitudinal continuity of species such as *Gervillella araucana*, *Antiquilima* cf. *nodulosa*, *Entolium corneolum*, *Frenguelliella poultoni*, various species of *Weyla*, and *Pholadomya fidicula*. Known from western North and South America and New Zealand—which was fairly close to the South Pole during the Early Jurassic—*Agerchlamys wunschae* was previously considered a bipolar eastern-Pacific form. However, because of the new low-paleolatitude Sonoran record of this species, it is now better categorized as a trans-temperate taxon (see also Kauffman, 1973).

Widespread taxa are those that, in addition to occurring in the eastern Pacific, are reported from other regions, particularly Europe. These include species that were only known from northwestern Europe and/or western Tethys until now (e.g., *Modiolus hillanus*, *Ceratomya petricosa*, *Protocardia truncata, Neocrassina gueuxi*), but also species with a more widespread distribution (e.g., *Palaeoneilo elliptica*, *Oxytoma* cf. *inequivalvis*, *Pholadomya* cf. *voltzi*). About one-fourth (Pliensbachian) to one-third (Hettangian–Sinemurian) of the described species belongs to the category of widespread taxa.

Species that appear to be limited to Sonora at the indicated time are classified as endemic. These taxa either are known only from Sonora, as is the case for *Groeberella* sp. A and Lucinidae gen. et sp. indet. B, or occur also in other regions earlier or later. For example, *Grammatodon sulcatus* is recorded from the Sinemurian of northern Chile and Sonora, but in the Pliensbachian is only known from Sonora. Conversely, *Cercomya peruviana* seems to have originated in Sonora in the Pliensbachian and subsequently dispersed to northern Chile (Toarcian to Aalenian), and to Peru and the Neuquén Basin (Bajocian) (Aberhan 2004). For *Protocardia luggudensis* (endemic to Sonora during the Hettangian–Sinemurian) and for *Ceratomya concentrica* and *Plagiostoma schimperi* (endemic during the Pliensbachian), these are the first records in America and also the oldest occurrences globally. About one-seventh (Hettangian–Sinemurian) and one-fourth (Pliensbachian) of the described species belong to the endemic category.

Comparison with Other Eastern Pacific Faunas

To document faunal similarities of the Antimonio terrane to other eastern Pacific regions we utilized all taxa of the bivalve order Pectinoida. This group was selected because its Early Jurassic members are rather common and widespread in the area, well studied, and latitudinally distinct, and they have already proved useful in similar paleobiogeographic analyses (Aberhan 1998b, 1999). The seven regions compared herein are northern Chile (22° to 31°S present-day latitude) and the Neuquén Basin (31° to 41°S present-day latitude) from South America, and, from western North America, the Brooks-Mackenzie Basin, the Western Canada Sedimentary Basin, the allochthonous Stikinia and Wrangellia terranes of Canada, and the Antimonio terrane of Sonora (Table 2; Fig. 16). Wrangellia and Stikinia are the two largest terranes of the Canadian Cordillera. Their time of accretion to the North American craton and interactions with other terranes prior to docking are debated, but it seems that Wrangellia had not yet collided and Stikinia at best had just started to collide with the craton by Middle Jurassic time (e.g., Monger et al., 1982; van der Heyden, 1992; Rowley, 1992). Biogeographic patterns suggest that no significant latitudinal shifts of Wrangellia and Stikinia occurred from Sinemurian to Pliensbachian times, but substantial post-Pliensbachian northward displacement relative to the craton was inferred (e.g., Aberhan 1998b, 1999; Smith et al. 2001). However, this is in conflict with reinterpretations of paleomagnetic data that suggest that the allochthonous terranes were in much the same latitudinal positions relative to the craton as they are today (Irving and Wynne 1990; Vandall and Palmer 1990).

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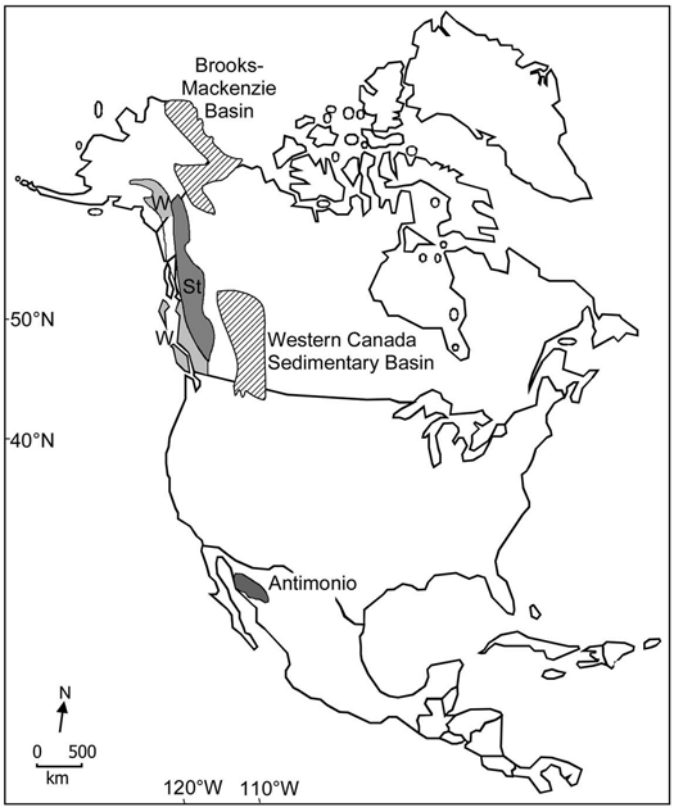

Figure 16. Present-day position of selected allochthonous terranes (gray shading) and autochthonous sedimentary basins (oblique hatching) along the western margin of North America.

Paleobiogeographic Results

Not surprisingly, cluster analysis of Hettangian–Sinemurian data (Table 3) shows a high degree of faunal similarity between northern Chile and the Neuquén Basin, two autochthonous areas located immediately next to each other (Fig. 17). A high degree of similarity also exists between Wrangellia and Stikinia, suggesting that their geographic distance was relatively small at that time. At a lower similarity level the Brooks-Mackenzie Basin and the Western Canada Sedimentary Basin cluster together. The Antimonio terrane of Sonora has strongest links to Wrangellia and Stikinia.

In the Pliensbachian, faunal ties again are strong between Wrangellia and Stikinia. Also, northern Chile and the Neuquén Basin are grouped in the same cluster. In contrast to the Hettangian–Sinemurian, however, the Antimonio terrane now forms a cluster together with the Neuquén Basin and particularly northern Chile (Fig. 17).

Paleogeographic Interpretations

Assuming that the similarity between faunas roughly reflects their geographic distance from each other, the relatively high faunal concordance of the Antimonio terrane with Wrangellia and Stikinia during the Hettangian–Sinemurian argues in support of relative spatial proximity of these three regions. In the Pliensbachian, geographic distance to Wrangellia had increased and the Antimonio terrane was closer to the Andean basins of Argentina and Chile. There are two possible, mutually non-exclusive mechanisms to explain these patterns: First, Stikinia and Wrangellia might have moved northward from Hettangian–Sinemurian to Pliensbachian times and thus lost their proximity to Sonora. Substantial northward movement of Wrangellia and Stikinia has indeed been postulated previously (see above). However, biogeographic data suggest that the paleolatitudinal position of Wrangellia and Stikinia remained largely stable relative to the craton from Sinemurian to Pliensbachian times, and northward movement only started in the Toarcian–Early Aalenian (Aberhan 1999).

Alternatively, the Antimonio terrane was displaced toward the south, thereby moving closer to northern Chile and the Neuquén Basin, and at the same time losing similarity to Wrangellia and Stikinia. This scenario gains support from a direct comparison of similarity coefficients between the Antimonio terrane and autochthonous regions (Table 4). Dice and Jaccard coefficients between the Antimonio terrane and Argentina/Chile are markedly higher in the Pliensbachian than during the Hettangian-Sinemurian. However, a southward shift of the Antimonio terrane already starting in the Pliensbachian is in contrast to the conclusions of Campa and Coney (1983) and Marzolf (2003) that a displacement of this region did not occur until the Middle or Late Jurassic, when the Antimonio Group, together with the Caborca block, was displaced southward along the Mojave-Sonora megashear.

Caveats

Occurrence-based data stored in the Paleobiology Database (http://paleodb.org) indicate a generally very good correlation between percent similarity of contemporaneous marine invertebrate faunas from different regions and their geographic proximity (measured as great circle distance) during the Phanerozoic (A.I. Miller, 2005, personal commun.). Nevertheless, it can be argued that the assumption of a rough correspondence between the similarity of faunas and their geographic distance from each other is an oversimplification that neglects other important factors that control faunal distribution, such as sedimentary facies and prevailing paleocurrents. With regard to facies, a wide spectrum of lithologies is represented in the upper Hettangian to Pliensbachian of Sonora, comprising fine-grained and coarse-grained siliciclastics, carbonates, and mixed siliciclastic-carbonate sediments (see above). Most pectinoid bivalves from Sonora were notably eurytopic with respect to the substrate, and occurred predominantly in fine-grained siliciclastics and carbonates, bioclastic limestones, and calcareous sandstones. A similarly weak dependence on substrate conditions was found in most pectinoids from the other regions analyzed here (Aberhan, 1998b). An exception is the Western Canada Sedimentary Basin, the Pliensbachian samples of which are limited to black shales and dark calcareous mudstones, reflecting low-diversity, oxygen-deficient benthic environments. Altogether, however, the represented range of upper Hettangian to Pliensbachian lithologies and environments is comparable for the analyzed regions.

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TABLE 3: GEOGRAPHIC AND TEMPORAL DISTRIBUTION OF EARLY JURASSIC PECTINOID BIVALVES ALONG THE EASTERN MARGIN OF THE PALEO-PACIFIC

Taxon	Hettangian–Sinemurian	Pliensbachian
Otapiria neuquensis Damborenea, 1987b	Chi; Neu	Neu
Otapiria pacifica Covacevich and Escobar, 1979	Chi; Neu	
Otapiria tailleuri Imlay, 1967	WCSB	
Lupherella boechiformis (Hyatt, 1894)		Sti
Oxytoma (O.) inequivalvis (J. Sowerby, 1819)	Chi; Neu; WCSB; Bro; So	Chi; Neu; Wra; Sti; WCSB; Bro
Palmoxytoma cygnipes (Young and Bird, 1822)	Chi; Neu; WCSB; Bro	Wra; Bro
Arctotis (A.) sp. A		WCSB
Meleagrinella ferniensis (McLearn, 1924)	Sti	
Meleagrinella cf. *oxytomaeformis* Polubotko, 1968	Wra	Wra
Meleagrinella sp.[a]	Bro	Bro
Asoella asapha (Leanza, 1942)	Neu	Neu
Placunopsis radiata (Phillips, 1829)	Chi; Neu; Sti	Chi; Neu; Sti
?terquemiid gen. et sp. nov.?[b]	Wra	
Kolymonectes carlottensis (Whiteaves, 1900)		Wra; Sti
Kolymonectes weaveri Damborenea, 1997		Neu
Kolymonectes staeschei (Polubotko, 1968)	WCSB; Bro	
Kolymonectes sp.[c]	Neu	
Entolium (E.) corneolum (Young and Bird, 1828)	Chi; Wra; Sti; WCSB; Bro; So	Chi; Neu; Wra; Sti; Bro; So
Entolium (E.) cf. *lunare* (Roemer, 1839)	Chi; Neu	Chi; Neu
Entolium (E.) mapuche Damborenea, 2002		Neu
Agerchlamys wunschae (Marwick, 1953)	Chi; Wra; WCSB; So	Neu; So
Agerchlamys sp. A[d]		Wra
Camptonectes (C.) auritus (Schlotheim, 1813)		Neu
Camptonectes (C.) subulatus (Münster, 1836)[e]	Neu; WCSB; Bro	Neu; WCSB
Canadonectites paucicostatus Aberhan, 1998a	Wra	Wra
Chlamys (Ch.) textoria (Schlotheim, 1820)	Chi; Neu; Wra; Sti; WCSB	Chi; Neu; Wra; Sti
Chlamys valoniensis (Defrance, 1825)	Chi; Neu; Sti; WCSB; Bro	
Eopecten hartzi (Rosenkrantz, 1957)	Sti; WCSB	Neu
Eopecten velatus (Goldfuss, 1833)	Chi; Neu	Chi; Neu; So
Ochotochlamys cf. *bureiensis* Sey, 1984		WCSB
Ochotochlamys aequistriata Aberhan, 1998a	Wra; Sti; WCSB	Wra; Sti; WCSB
Ochotochlamys sp.[f]		Neu
Pseudopecten (P.) equivalvis (J. Sowerby, 1816)		Chi; Neu
Radulonectites sosneadoensis (Weaver, 1931)[g]		Chi; Neu; Sti; Bro
Radulonectites sp. A[h]	Bro	
pectinid gen. et sp. indet.[i]		Chi
Weyla (W.) alata (von Buch, 1838)	Chi; Neu; Sti; Wra; WCSB; So	Chi; Neu; Sti; Wra; So
Weyla (W.) bodenbenderi (Behrendsen, 1891)	Chi; Wra; Sti; So	Chi; Neu; Wra; Sti; So
Weyla (W.) titan (Möricke, 1894)	So	Chi; So
Weyla (Lywea) unca (Philippi, 1899)	Chi; Neu; Wra; Sti; So	Chi; Neu; Sti; So
Weyla (Lywea) yukonensis Aberhan, 1998a	Sti; Wra; WCSB	

Note: Bro—Brooks-Mackenzie Basin; Chi—northern Chile; Neu—Neuquén Basin; So—Sonora; Sti—Stikinia; WCSB—Western Canada Sedimentary Basin; Wra—Wrangellia.

Taxonomic notes: a—*Meleagrinella* sp. *in* Poulton (1991, pl. 6, figs. 8-10; pl. 9, figs. 15-16; pl. 11, figs. 12-13); b—?terquemiid gen. et sp. nov.? *in* Aberhan (1998a, pl. 10, figs. 20-21); c—*Kolymonectes* sp. *in* Damborenea (2002, pl. 2, figs. 16-19); d—*Agerchlamys* sp. A *in* Aberhan (1998a, pl. 12, figs. 6, 7, 9); e—Includes *Entolium*(?) sp. and *Camptonectes (C.)* sp. of Poulton (1991, pl. 6, figs. 31, 33-37); f—*Ochotochlamys* sp. *in* Damborenea (2002, pl. 9, figs. 16-22; text-figs. 8j—); g—Includes *Camptonectes (Camptochlamys)* sp. of Poulton (1991, pl. 11, figs. 17-21); h—*Eopecten*(?) sp. *in* Poulton (1991, pl. 6, fig. 38); i—pectinid gen. et sp. indet. *in* Aberhan (1994, pl. 20, fig. 3).

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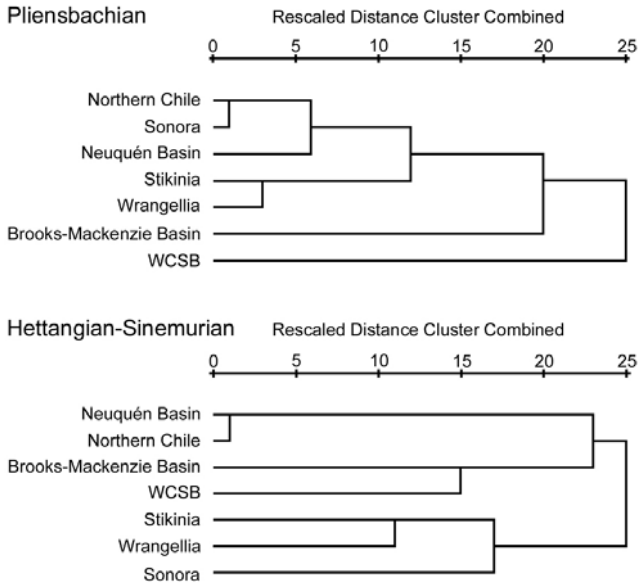

Figure 17. Dendrograms (unweighted pair-group method using arithmetic average with the Jaccard coefficient as distance measure) of geographic units defined by the distribution of eastern Pacific pectinoid bivalves during the Hettangian–Sinemurian and the Pliensbachian. WCSB—Western Canada Sedimentary Basin.

Other factors, such as oceanic current systems and climatic regimes clearly influenced distribution patterns in the geological past as they do today. However, we are unaware of any Early Jurassic changes in these factors that could explain the observed shift in faunal similarity. For example, oceanic conditions in the eastern paleo-Pacific are expected to have been relatively stable and comparable to those of the modern Pacific (Parrish, 1992). Sonora would have been under the influence of a stable so-called paleo-California current, flowing toward the equator in mid-northern to low paleolatitudes (see also discussion *in* Aberhan, 1999). Nevertheless, we consider our paleogeographic results as preliminary because (1) they are based on a small sample of organisms; and (2) too few paleontological data are currently available from key areas in the southwestern United States, which can be regarded as autochthonous since the Jurassic.

CONCLUSIONS

This study provides a detailed account of the taxonomy and biogeographic affinities of Early Jurassic bivalves from the Antimonio terrane of Sonora, Mexico, and considerably expands our previous state of knowledge. Fifty taxa are described and illustrated, 34 of which are reported from this region for the first time. Almost half the taxa are represented by very few (one to three), often poorly preserved specimens. As a consequence, continued fieldwork is expected to further increase sampled Early Jurassic bivalve diversity in this region, and to lead to a more precise identification of those taxa, which could only be determined at the supra-specific level herein.

Clearly, more comprehensive faunal data should be used in the future to corroborate or revise our tentative conclusion that southward displacement of the Antimonio terrane had already commenced in the Pliensbachian. Thus, a broader range of faunal groups as well as areas should be included in the analysis. For example, it is critical to include data from the southwestern United States, in particular California, Oregon, and Nevada, which play a key role in paleogeographic reconstructions of western North American terranes. To cite but one example, the New York Canyon sections in the Gabbs Valley Range, Nevada, are known for their diverse Early Jurassic fauna of ammonites and bivalves, but the latter are still very insufficiently documented.

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Table 4. Diversity and similarity coefficients between Sonora and various regions along the eastern paleo-Pacific margin during the Hettangian–Sinemurian and the Pliensbachian, expressed as Dice (D) and Jaccard coefficient (J)

Hettangian–Sinemurian				Pliensbachian			
Sonora	Σ = 7			Sonora	Σ = 7		
Neuquén Basin	Σ = 14	D = 20	J = 9	Neuquén Basin	Σ = 20	D = 50	J = 20
N. Chile	Σ = 14	D = 50	J = 20	N. Chile	Σ = 13	D = 67	J = 25
Wrangellia	Σ = 11	D = 59	J = 23	Wrangellia	Σ = 11	D = 42	J = 17
Stikinia	Σ = 11	D = 47	J = 19	Stikinia	Σ = 11	D = 53	J = 21
WCSB	Σ = 13	D = 32	J = 14	WCSB	Σ = 5	D = 15	J = 7
Brooks-M. Basin	Σ = 8	D = 14	J = 7	Brooks-M. Basin	Σ = 5	D = 31	J = 13

Note: Σ—number of taxa per region. WCSB—Western Canada Sedimentary Basin; Brooks-M.—Brooks-Mackenzie.

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