

LATE TRIASSIC (NORIAN–RHAETIAN) BIVALVES FROM THE ANTIMONIO FORMATION, NORTHWESTERN SONORA, MEXICO

Christopher A. McRoberts*

ABSTRACT

The Norian–Rhaetian bivalve fauna from the upper part of Antimonio Formation is taxonomically and ecologically more diverse than previously reported. Of the 10 bivalve taxa described herein, eight have never been previously described from Sonora and at least four represent previously unknown forms. Two new species are formally recognized: *?Lopha cordillerana* n. sp., a large ostreoid from a Norian bioherm facies, and *Xiaoschuiculana tozeri* n. sp., a nuculanid from fine-grained sand and siltstones of probable Rhaetian age. Other taxa, while ecologically important, are too few in number or too poorly preserved to be adequately assigned to species. Although the Antimonio bivalve fauna shows strong taxonomic affinities with South American faunas, similarity to other North American localities, such as from the Luning-Gabbs sequence of Nevada or coeval rocks in the Cordilleran terranes of California and Oregon, cannot be assessed due to inadequacy in species-level taxonomy.

Key words: Late Triassic, bivalves, Antimonio Formation, Sonora, Mexico.

RESUMEN

En este artículo se consigna una fauna de bivalvos del Norico–Rético de la Formación Antimonio, la cual es taxonómica y ecológicamente más diversa que la previamente descrita de esta unidad. De los 10 taxa de bivalvos que aquí son descritos, ocho no han sido descritos anteriormente de Sonora y al menos cuatro representan formas nuevas. De estas últimas, se reconoce formalmente dos especies nuevas: *?Lopha cordillerana* n. sp., un ostreido gigante de las facies biohermales noricas, y *Xiaoschuiculana tozeri* n. sp., un nuculanídeo que se encontró en limolitas y areniscas de grano fino de probable edad rética. Los otros taxa encontrados, aun cuando son ecológicamente importantes, son escasos en número y presentan una preservación pobre para ser asignados a especies. Aunque la fauna de bivalvos del Antimonio muestra una gran afinidad con faunas de América del Sur, su similitud con la de otras localidades de América del Norte, tales como la de las secuencias Luning-Gabbs de Nevada y con las de rocas contemporáneas de terrenos cordilleranos de California y Oregon, no puede ser evaluada debido a lo inadecuado de la taxonomía en el nivel específico.

Palabras clave: Triásico Tardío, bivalvos, Formación Antimonio, Sonora, México.

INTRODUCTION

Paleontological studies on the late Paleozoic and Mesozoic rocks of northwestern Sonora have revealed many clues to the geologic evolution of the southwestern margin of North America. Now becoming well known for its reef-like fauna of corals, sponges, and spongiomorphs, the collective Late Triassic–Early Jurassic fauna of northwestern Sonora, especially from near El Antimonio within the foothills of the Sierra del Álamo (Figure 1), provides data in support of hypotheses regarding late Paleozoic–early Mesozoic paleogeographies where traditional methods, such as paleomagnetism, have only limited success (e.g., Molina-Garza and Geissman, 1997). This contribution on the paleontology of the Antimonio Formation provides yet another glimpse of the taxonomically and ecologically diverse faunas of the Late Triassic circum-Pacific. The fauna from the Antimonio Formation is significant in that it represents one of the most diverse and abundant low-paleolatitude Late Norian and Rhaetian bivalve faunas known from Mexico. While

it compares in abundance and diversity with other earlier Norian and Carnian bivalve faunas of the North and South American Cordillera, such as those from Oregon (e.g., Newton *et al.*, 1987), Peru and Chile (e.g., Cox, 1949; Hayami *et al.*, 1977), many forms reported here have not been previously described and are entirely endemic to Sonora.

This fauna is also important in that it provides a last glimpse of the biota preceding the crisis marking the end of the Triassic period. The end-Triassic extinction remains one of the least studied and poorly known of the five major extinctions identified by Sepkoski (1996). Once thought to be a possible representative section containing the Triassic–Jurassic boundary (González-León *et al.*, 1996), the section near El Antimonio now is known to contain an erosional surface where uppermost Hettangian or lower Sinemurian strata rest disconformably on top of Rhaetian sediments (González-León, 1997). Due to the unconformity, the taxonomic and paleoecologic data derived from the section cannot directly document the magnitude or causes of extinction; however, data derived from the Norian, and especially Rhaetian, localities near El Antimonio may qualitatively identify factors contributing to extinction. In addition, the fauna provides a unique glimpse into a crucial turning point in Earth's biotic history.

*Department of Geology, State University of New York College at Cortland,
P.O. Box 2000, Cortland, New York 13045, U.S.A. E-mail address:
mcroberts@cortland.edu

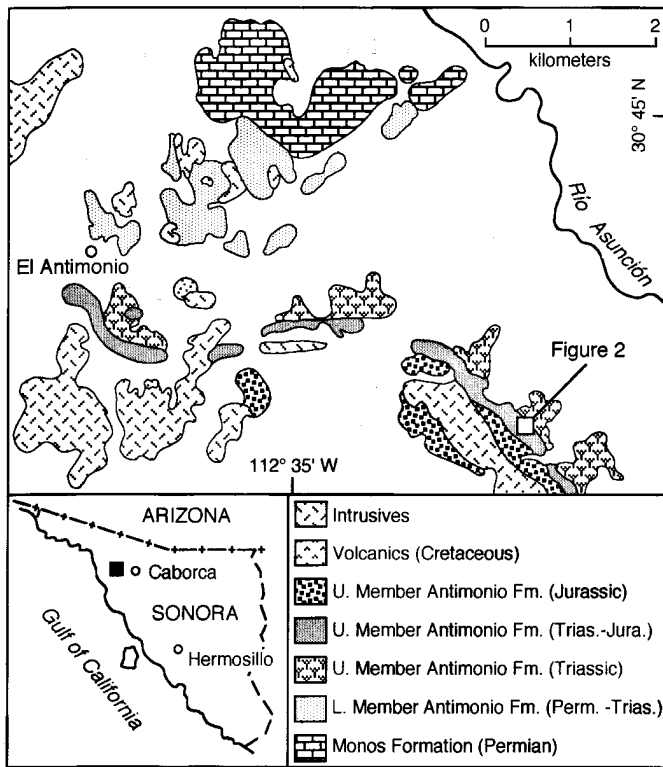


Figure 1. Generalized geology of the El Antimonio area. Note many of the small-scale structural features have been omitted. Modified from González-León (Lucas and Estep, personal communication, 1997).

GEOLOGIC AND STRATIGRAPHIC SETTING

The rocks of much of northwestern Sonora, including those from the Sierra del Álamo and El Antimonio, have been recognized as being tectonically and stratigraphically distinct from coeval strata associated with the southwestern margin of the North American Craton (Coney and Campa, 1987). While traditionally these mostly marine late Paleozoic–early Mesozoic rocks have been assigned to various structural units, they are now assigned to the Antimonio terrane which has been interpreted as tectonically distinct from the underlying and adjacent miogeosynclinal rocks of the Caborca terrane (González-León, 1980; Stanley and González-León, 1995).

The stratigraphic nomenclature and age relationships of fossil-bearing marine strata near El Antimonio and throughout the Sierra del Álamo are subject to debate and currently undergoing revision. The Antimonio Formation was originally defined by González-León (1980) for a 3.4-km-thick section of mixed siliciclastic and carbonate sediments located on the northeastern flanks of the Sierra del Álamo (Figure 1). The type locality is fraught with structural problems such as the numerous high-angle and small thrust faults that disrupt much of the type locality (personal observations, 1997). Furthermore, the stratigraphic relationship between the upper half of the Antimonio Formation, from where the fossils described in this report come, and the lower half which contains large limoid bivalves described by Damborenea and González-León (1997) remains unclear.

Regardless of the structural complexities, several key fossils have been discovered which shed light on the age relationships of the upper Antimonio Formation. Figure 2 shows the five informal lithostratigraphic and biostratigraphic units which are equivalent to “packages 1–5” of González-León and collaborators (1996). Unit 1 contains several taxa, including the hydrozoan *Heterastridium conglobatum*, and the ammonoids *Pinacoceras cf. metternichi*, *Sagentites cf. schaubachi*, and *Catenohalorites*, all of which are characteristic of the Norian stage (González-León *et al.*, 1996). A Rhaetian age for the upper part of unit 2 is based on an undescribed species of *Sagen-*

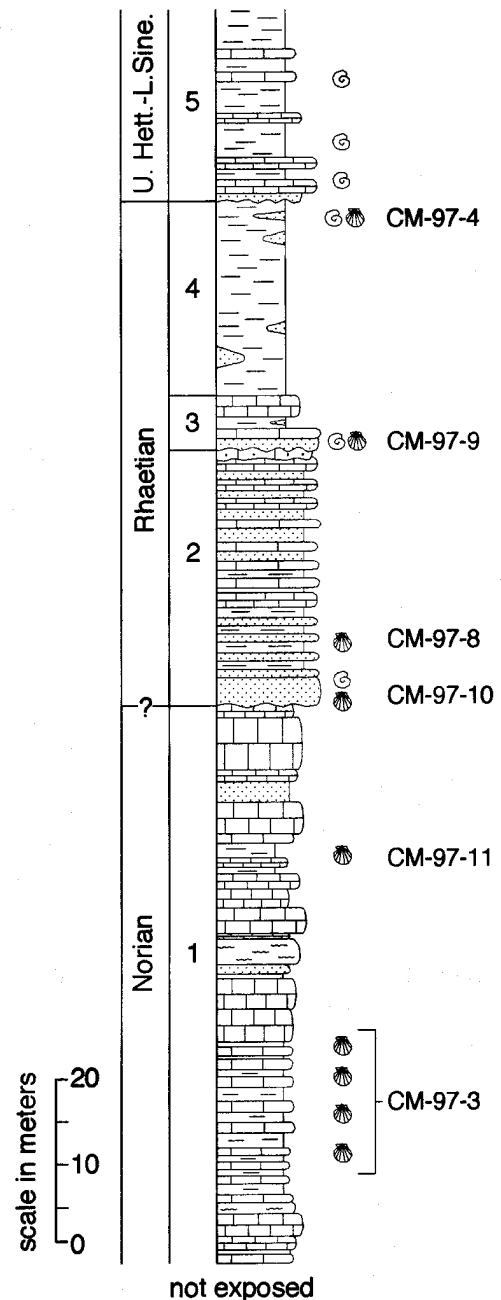


Figure 2. Stratigraphy of part of the upper member of the Antimonio Formation. Fossil-bearing horizons, where age-significant ammonoids and bivalves have been reported, are indicated. Modified from Lucas and Estep (personal communication, 1997).

tites characteristic of the Rhaetian Amoenum Zone (González-León *et al.*, 1996). Usage of the term Rhaetian is here restricted to the Amoenum and Crickmayi Zones (*sensu* Dagys and Dagys, 1994). Both units 3 and 4 contain the diagnostic heteromorph ammonoid *Choristoceras crickmayi* (González-León *et al.*, 1996; González-León, 1997) representative of the Rhaetian which is uppermost stage of the Triassic. The ammonoids *Badouxia* and *Sunrisites* occur in unit 5, immediately above the topmost *Choristoceras*-bearing horizon (González-León *et al.*, 1996; see also González-León, 1997) indicating a later Hettangian or early Sinemurian age. Older Jurassic ammonoids, such as the earliest Hettangian *Psiloceras*, are unknown from Sonora. Their absence suggests a significant biostratigraphic gap in the sequence. This biostratigraphic gap is manifested in the obviously erosional contact observed in the field between units 4 and 5.

BIVALVE FAUNA OVERVIEW

The Norian–Rhaetian bivalve fauna of the Antimonio Formation is one of the most diverse but poorly known Late Triassic faunas recovered from Mexico. More than 12 bivalve species are now known to occur in Norian–Rhaetian marine sediments at the El Antimonio locality (Table 1). With the exception of *Palaeocardita* and *Myophorignia*, and a large alatomorph bivalve (Stanley *et al.*, 1994), none of the fauna described below has been reported from the Upper Triassic of Sonora. For this reason alone, it is deemed appropriate to include a more detailed account of the bivalve fauna from the Antimonio Formation, including illustrations, than might be warranted given the small sample sizes and preservational condition of much of the material.

TAPHONOMY AND PALEOECOLOGY

The collective fauna and associated lithofacies from the Antimonio Formation type locality suggest a warm,

shallow–water setting of probably normal salinities. Together with sedimentary structures such as wave ripples, common storm beds, and channeled lag deposits, the moderate to high degree of skeletal breakage of the shelly bivalve fauna further suggests very shallow and highly agitated waters. Given the shallow-water sedimentary features, it is probable that much of the described fauna does, to some degree, represent reworked and therefore time-averaged samples. This is especially true in apparent lag deposits of the basal portions of several key beds, such as from the bases of units 2, 3, and 5, which rest on erosional surfaces. Additional data on the taphonomic and biostatinomic aspects of the fossil-bearing beds can be found elsewhere in this volume (*cf.* Goodwin and Stanley, 1997).

Ecologic diversity throughout the upper member of the Antimonio Formation is variable. Taken from disparate stratigraphic horizons, the 12 bivalve taxa from the Antimonio Formation represent five autecologic groups or guilds. The Norian fauna (unit 1), which is associated with the biostrome facies, contains nearly equal proportions of epi- and infaunal taxa. This unit also contains the somewhat aberrant alatomorph bivalve which, based on its unique chambered wing-like projections and large size, is inferred to have housed photo-symbionts (Stanley *et al.*, 1994). This fauna, taken together with corals and sponges, is indicative of shallow-subtidal settings. As one moves up section, bivalve diversity decreases to three in unit 2, three in unit 3, and one in unit 4. Personal observations suggest that the fauna of unit 3 represents a concentration of reworked and lag deposits. The low diversity found in unit 4, consisting of very rare *Chlamys* and the ammonite *Choristoceras crickmayi*, attests to a somewhat restricted environment which may have been stressed by large amounts of epiclastic volcanic sediments.

BIOGEOGRAPHIC AFFINITIES

The bivalve fauna has both endemic and non-endemic taxa. Of the bivalve species known from El Antimonio, two occur in South America, one may be equivalent to a west-Tethyan

Table 1. Occurrence and autpaleoecology of Antimonio bivalves.

Taxon	Age	Living Habit		
		Substrate	Locomotive	Trophic
<i>Xiaoschuiculana tozeri</i>	?Rhaetian	infaunal	mobile	detritus
<i>Gervillaria</i> sp.	Norian	epifaunal	sessile (byssate)	suspension
? <i>Lopha cordillerana</i>	Norian	epifaunal	sessile (cementing)	suspension
<i>Propeamussium</i> cf. <i>P. schafhaeutli</i>	Norian	epifaunal	sessile (byssate)	suspension
<i>Chlamys</i> sp.	Rhaetian	epifaunal	sessile (byssate)	suspension
<i>Myophorignia jaworskii</i>	Norian	infaunal	mobile	suspension
<i>Palaeocardita peruviana</i>	Norian	infaunal	mobile	suspension
<i>Schafhaeutlia</i> sp.	Rhaetian	infaunal	mobile	suspension
<i>Cardinoides</i> sp.	?Rhaetian	infaunal	mobile	suspension
<i>Monotis</i> sp.*	Norian	epifaunal	sessile (byssate)	suspension
<i>Pseudolima</i> sp.*	?Rhaetian	epifaunal	sessile (byssate)	suspension
alatomorphid*	Norian	epifaunal	sessile (free-lying)	suspension
<i>Septocardia</i> *	Norian–Rhaetian	infaunal	mobile	suspension

* not illustrated

form, and one may also occur in Nevada. The remainder of the described bivalves appear to be endemic to Sonora. In contrast to the coral and sponge fauna from this locality (e.g., Stanley *et al.*, 1994), the bivalves have surprisingly little in common with other Late Triassic faunas known from Peru and the North American Cordillera (e.g., the Luning and Gabbs Formations of Nevada; the Eastern Klamath terrane of California, and the Wallowa terrane of Oregon). With few notable exceptions, it is difficult to assess much of the affinity in these regions as much of the material has not at present undergone systematic treatment and is only poorly known (e.g., Laws, 1982). Establishing the taxonomic composition of the bivalve fauna of the Luning sequence should therefore be a priority to aid in comparisons with that of the Antimonio Formation.

SYSTEMATIC PALEONTOLOGY

Specimen and locality abbreviations: ERNO—Instituto de Geología, Universidad Nacional Autónoma de México (Hermosillo); UMIP—University of Montana Paleontology Museum (Missoula). Following the recommendation by the International Code of Zoological Nomenclature (Ride *et al.*, 1985) the suffix '-oidea' is used in superfamily names.

Class Bivalvia Linné, 1758

Order Nuculoida Dall, 1889

Superfamily Nuculanoidea Adams and Adams, 1858

Family Nuculanidae Adams and Adams, 1858

Genus *Xiaoschuiculana* Chen, 1983

Type species—*Reticulana elegans* Li and Li (in Zhang *et al.*, 1977), by original designation.

Xiaoschuiculana tozeri new species

(Figures 3.1–3.3)

Material and repository—The collection consists of three specimens representing two individuals: an external mold of a right valve (holotype, ERNO-1929) and an internal mold of the hinge margin of an articulated valve pair (paratype, ERNO-1914).

Diagnosis—*Xiaoschuiculana* with beaded parallel sculpture oblique to commissural margin and posteriorly elongated rostrum.

Description—Shell probably equivalved, right valve small (length = 1.4 cm, height = 0.6 cm); posteriorly elongate and rostrate, central body cavity inflated with respect to narrow rostrum; exterior surface covered with more than 50 ribs parallel to anterior margin, ribs rounded exhibiting faint beaded texture on crests, somewhat coarser and wider spaced on ventral side of rostrum; rostrum 3 mm long, dorsal side devoid of parallel ribbing, somewhat flattened and delimited from ventral half by a

poorly developed keel or carina; taxodont dentition clearly observable on one specimen (ERNO-1914) indicating at least five anterior and 11 posterior denticles.

Remarks—The clearly observable taxodont dentition and rostrate shell shape are consistent with the family assignment to *Nuculanidae* even though a resilium was not observed in the specimens. The obliquely radial ornamentation permits the designation of these specimens into the veteranelline genus *Xiaoschuiculana* erected by Chen (in Chen *et al.*, 1983). This new species differs from other Triassic *xiaoschuiculana* in its obliquely radial ribbing.

Stratigraphic and paleoecologic remarks—*Xiaoschuiculana tozeri* occurs within a moderately thick siltstone bed in the middle part of unit 2 of the upper Antimonio Formation (locality CM-97-8, Figure 2). At this locality, it is associated with the bivalves *Septocardia* and *Pseudolima*, pentacrino columnals, as well as fossilized wood fragments. Given their position in beds below the Rhaetian ammonoid *Choristoceras* (see González-León *et al.*, 1996), this species is likely early Rhaetian in age. Other occurrences of this species are unknown.

Etymology—Trivial name *tozeri* after E.T. Tozer, significant contributor to our understanding of Triassic faunas.

Order Ostreoida Férussac, 1822

Superfamily Ostreoidea Rafinesque, 1815

Family Ostreidae Rafinesque, 1815

Genus *Lopha* Röding, 1798

Type species—*Mytilus cristagalli* Linné, 1758, by subsequent designation (Dall, 1889).

?*Lopha cordillerana* new species

(Figures 4.1–4.3)

Material and repository—The collection consists of an articulated valve pair (holotype, ERNO-1315) and a single right valve (paratype, ERNO-1316). Additionally, more than 10 specimens were observed as *in situ* field observations.

Diagnosis—Large, elongated, slightly crescentically curved, and thick-shelled ?*Lopha*, with more than 10 dichotomous curved plicae with subangular crests on right valve, left valve with large attachment area extending nearly its entire length.

Description—Shells very large (maximum length > 16 cm, maximum width > 10 cm), equivalved to slightly inequivalved with right (upper) valve only slightly larger than left valve; beak terminal; left valve xenomorphic in attachment area, and right valve highly variable; surface of right valve consists of slightly rounded radial plicae which diverge along a somewhat strong

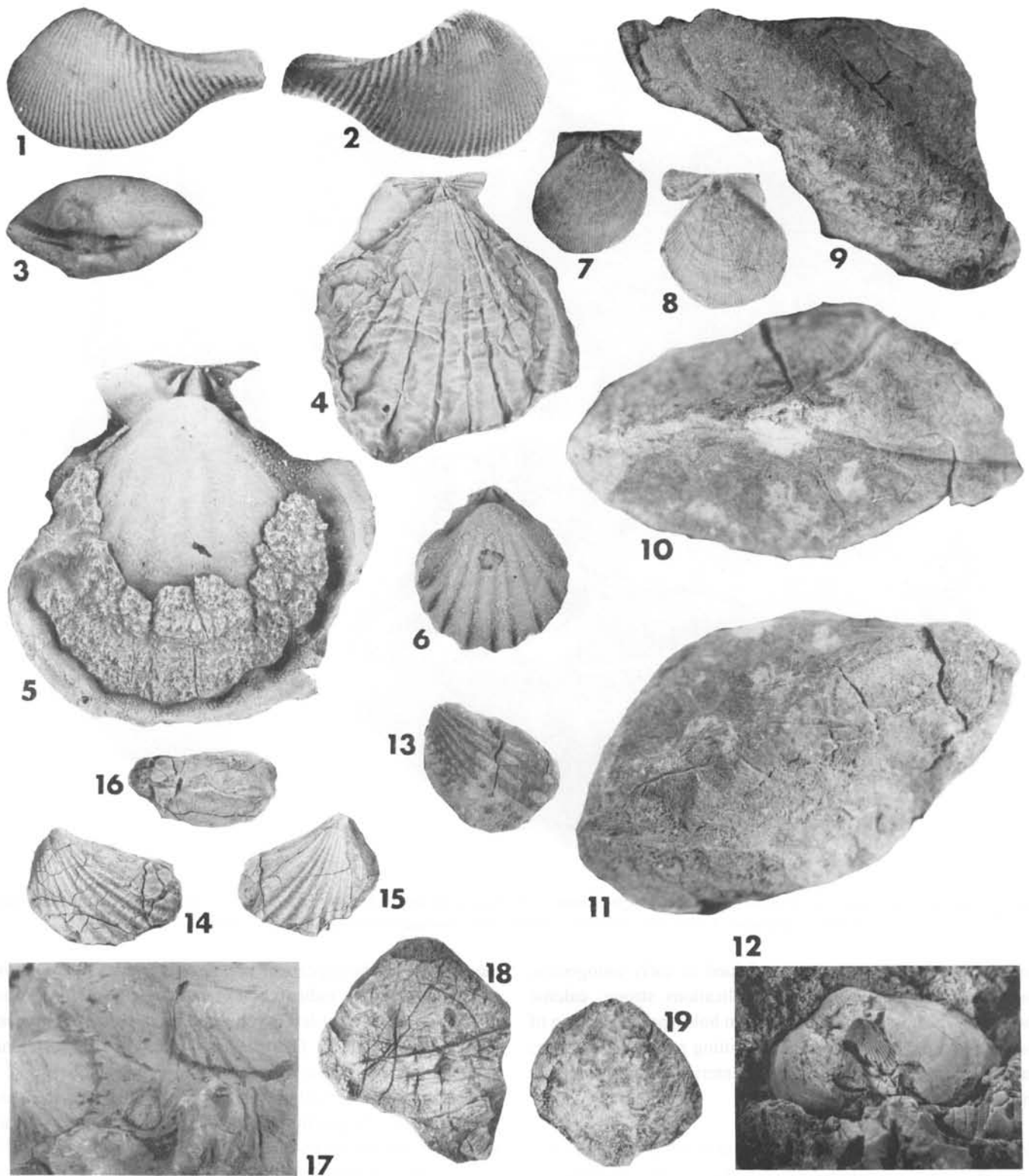


Figure 3. Norian and Rhaetian bivalves from the Antimonio Formation. All stratigraphic references refer to levels identified in Figure 2. All figures are natural size unless indicated otherwise. 1-3: *Xiaoschuiculana tozeri* n. sp., 4x natural size; 1: latex cast of an external mold of the holotype; 2: original specimen (ERNO-1929, locality CM-97-8); 3: dorsal margin of paratype (ERNO-1914, locality CM-97-3). 4: *Propeamussium* cf. *P. schafhaeutli* (Winkler, 1859) (ERNO-1927, locality CM-97-3). 5-6: ?*P.* cf. *schafhaeutli*; 5: large partial mold with recrystallized shell along ventral half of main disc (ERNO-1928, locality CM-97-5); 6: internal mold (ERNO-1926, locality CM-97-3). 7, 8: *Chlamys* sp., locality CM-97-4, 4x natural size; 7: left valve (ERNO-1925a); 8: counter part (ERNO-1925b). 9-11: *Gervillaria* sp., locality CM-97-3; 9: left valve (ERNO-1923); 10: dorsal view of articulated valve pair (ERNO-1924); 11: side view of same specimen. 12, *Cardinioides* sp., internal mold of left valve (ERNO-1922, CM-97-10). 13-16: *Myophorogonia jaworskii* (Steinmann, 1929); 13: left valve exterior (ERNO-1918, locality CM-97-3); 14: left valve of articulated valve pair (ERNO-1917, float near CM-97-3); 15: right valve of same specimen; 16: dorsal view of same specimen. 17, Slab with *Palaeocardita peruviana* Cox (ERNO-1919, locality CM-97-3). 18-19: *Schafhaeutlia* sp., locality CM-97-9; 18: left valve exterior (ERNO-1920); 19: ?right valve exterior (ERNO-1921).

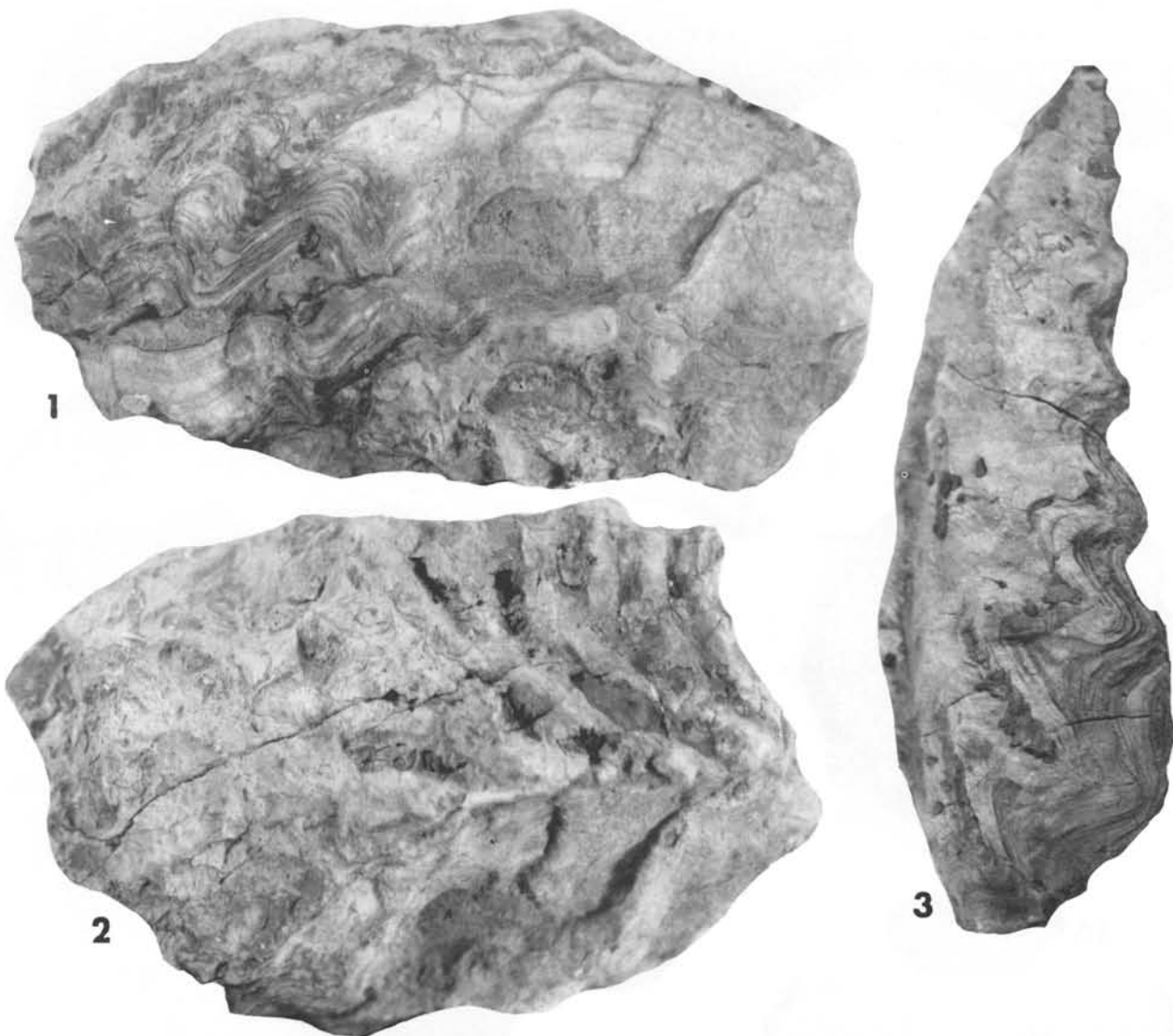


Figure 4. ?*Lopha cordillerana* n. sp. from the upper member of the Antimonio Formation, locality CM-97-11. 1: Dorsal view of holotype (ERNO-1915). 2: Marginal view of same specimen showing plications. 3: Side view of paratype (ERNO-1916) showing commissural plications. All figures are natural size.

carina or fold, plicae are more subdued in early ontogenetic stages in beak area; commissural plications strong; calcitic shells very thick (greater than 1.1 cm in holotype), consisting of multiple laminar sublayers each exhibiting prismatic structure; inner shell layers unobserved; valve interiors and musculature are unknown.

Remarks—Because no internal features have yet been observed in these Antimonio forms, their probable assignment to *Lopha* is based entirely on external morphology. The specimens could conceivably be placed into *Palaeolopha* erected by Malchus (1990) to accommodate some Triassic and Jurassic ostreoids lacking chomata. Assignment is deferred until better specimens which illustrate characters are available. Although many ostreoids have somewhat similar external morphologies to some pectinacean genera such as *Enantiostreon*, such designation is warranted on the grounds of nearly identical external

morphology of the upper, and presumably right, valve. Discovery of musculature indicating a cementing right (as in *Enantiostreon*), rather than left (as in *Lopha*), valve would necessitate transfer from the Ostreidae and provide an exceptional example of convergence in external morphology.

This species closely resembles forms attributed to *Lopha montiscaprilis* (Klipstein) known from various Carnian localities in the alpine regions of Europe. Although *L. montiscaprilis* has also been reported from the Norian Luning Formation of Nevada (e.g., Muller and Ferguson, 1939; Stenzel, 1971; Stanley, 1979), these forms have never been adequately described nor illustrated and therefore their taxonomic affinity to the Alpine species remains questionable. *Lopha cordillerana* differs from the Alpine *L. montiscaprilis* in having a larger attachment area and fewer plicae.

?*Lopha cordillerana* also resembles *Palaeolopha haidingeriana* (Emmrich) known from mostly Rhaetian localities of

the northern and southern Alps (e.g., Golebiowski, 1991). It differs from Alpine *P. haidingeriana* as well as from early Norian *L. cf. L. haidingeriana*, described by Newton and collaborators (1987) from the Wallowa terrane of northeastern Oregon, in its larger size, greater attachment area, and more elongated shape. Other comparable species are unknown from the circum-Pacific or Tethyan Triassic.

Stratigraphic and paleoecologic setting—The specimens assigned to *?Lopha cordillerana* occur within red, impure molluscan wackestones positioned approximately in the middle of unit 1 (locality CM-97-11, Figure 2). The lophid bed is overlain by coral-sponge-spongiomorph wacke-bound- and framestones and may therefore have provided a stabilized substrate for the overlying corals and spongiomorphs. Given their position immediately below the age-diagnostic ammonoids *Sagentites cf. schaubachi* Mojsisovics and *Catenohalorites* (González-León *et al.*, 1996), the lophid bed likely occurs in the Norian Columbianus Zone. Large specimens, which after preliminary study are attributable to *?Lopha cordillerana*, have been recently discovered in Norian strata of the Luning Formation at Dunlap Canyon of west-central Nevada.

Etymology—Trivial name *cordillerana* for its only known occurrence in North American Cordillera.

Order Pectinoidea Rafinesque, 1815
 Superfamily Pectinoidea Rafinesque, 1815
 Family Propeamussiidae Abbott, 1954
 Genus *Propeamussium* De Georgio, 1884

Type species—*Pecten ceciliae* De Georgio, 1884, by original designation.

Propeamussium cf. P. schafhaeutli (Winkler, 1859)
 (Figures 3.4, (?)3.5–3.6)

Cf. *Pecten schafhaeutli* Winkler, 1859, p. 8, pl. 1, fig. 4.

Material—A single internal mold of left valve (ERNO-1926) in addition to other fragmentary material.

Description—Shells medium sized (maximum height = 2.8 cm, maximum length = 2.6 cm), equilateral, with low convexity; average umbonal angle as measured on internal molds 58°; auricles flattened, well differentiated from disc and extending above hinge-line, without observable byssal notch, joining main part of disc at an acute angle, anterior auricle covered with fine commarginal lirae; hinge line demarked by single straight longitudinal groove; resilifer teeth diverging from narrow triangular resilifer; exterior sculpture not observed; interior sculpture consists of 10 or 11 radial riblets running entire distance from beak to shell margin and separated by broad flat interspaces that may or may not be observable on all specimens.

Discussion—Assignment to *Propeamussium* is based on the typical internal ribs, which are clearly observable on some of the specimens (e.g., Figure 3.4). Other illustrated specimens (ERNO-1927, ERNO-1928) may be poorly preserved representatives of this species. These pectinaceans are also very similar to forms attributed to *P. margariticostatus* (Diener) from the Norian of the Himalayan region of India (Diener, 1908, pl. 18, figs. 1–3), from which the present material differs mainly in size and having a greater number of ribs expressed on the inner shell surface. Based on their general locality and shape, it is likely that similar taxa were described as *Camptonectites* by early authors (e.g., González-León *et al.*, 1996).

Stratigraphic and paleoecologic setting—These specimens occur as molds in a fine-grained sandstone within unit 1 (locality CM-97-3, Figure 2) and another, probably correlative, locality (CM-97-5) about 1.5 km northeast of the type locality. Given their stratigraphic position below the age-diagnostic ammonoids *Sagentites cf. schaubachi* Mojsisovics and *Catenohalorites*, the specimens are assigned to the Norian Columbianus Zone.

Family Pectinidae Rafinesque, 1815
 Genus *Chlamys* Röding, 1798

Type species—*Pecten islandicus* Müller, 1776, by subsequent designation (Herrmannsen, 1874).

Chlamys sp.
 (Figures 3.7–3.8)

Material and repository—Two right valves (one of which, ERNO-1925a–b, consists of both part and counterpart) and several smaller fragments. Specimens are preserved as external molds which are enhanced by a thin coating of hematite staining.

Description—Right valve small (maximum height = 0.6 cm, maximum width = 0.7 cm), relatively low convexity, beak central, hinge straight; auricles moderately large, not extending above hinge margin, posterior auricle flat with free margin joining hinge-line at an obtuse angle, anterior auricle covered with weak radial sculpture, free margin joining hinge line at an acute angle and is demarked from main disc by auricular sulcus and clearly defined byssal notch; exterior sculpture of right valve consists of more than 60 narrow radial ribs of nearly equal strength, somewhat bundled to produce a secondary order of ribbing; ribbing has faint appearance of “tubercle” texture possibly indicating presence of faint commarginal sculpture; ribbing increases in number by both division and intercalation; ctenolium not observed.

Remarks—The specimens, which most certainly represent a new species, are comparable in many regards to forms known as *Chlamys mojsisovicsi* from the Carnian–early Norian rocks of

Japan (e.g., Hayami, 1975) and the Wallowa terrane of north-eastern Oregon (Newton *et al.*, 1987). However, the present specimens differ in several important ways, most significantly in the absence of strong commarginal sculpture producing a nodose texture, which is observable on the holotype of *Chlamys mojsisovicsi* (see Hayami, 1975, pl. 3, fig. 8) and other specimens.

Stratigraphic and paleoecologic setting—These small pectinaceans occur only within the upper part of unit 4 (locality CM-97-4, Figure 2). By association with *Choristoceras* ammonites from the same bed (package 4 in González-León, 1997), this locality is assigned to the Rhaetian stage of the latest Triassic.

Order Pterioida Newell, 1965
Superfamily Pterioidea Gray, 1847
Family Bakevilliidae King, 1850
Genus *Gervillaria* Cox, 1951

Type species—*Modiola? alaeformis* J. Sowerby, 1819, by original designation.

Gervillaria sp.
(Figures 3.9–3.11)

Material—The collection consists of one left valve (ERNO-1923) and one articulated valve pair (ERNO-1924). Both specimens have undergone severe recrystallization precluding determination of skeletal ultrastructure.

Description—Shell large (maximum dimension as measured along umbonal ridge = 9.5 cm), inflated (maximum width of articulated specimen = 5.4 cm); beak subangular, extending about 2 mm above straight hinge margin; umbonal ridge narrow, rounded and straight, umbonal angle approximately 35°; anterior auricle, clearly delimited from main part of shell; posterior auricles delimited from main body of shell by sloping intersection; internal features of shell not observed.

Remarks—Because hinge dentition is unobservable in the specimens, both generic and specific assignments are tentative. Nonetheless, both the large size of the specimens and general shape are similar in many regards to described *Gervillia shaniorum* Healey from Rhaetian rocks of Myanmar and elsewhere in southeastern Asia (Healey, 1908; Vu-Khuc, 1991), which might best be placed with *Gervillaria* according to the criteria set forth by Muster (1995).

Stratigraphic and paleoecologic setting—The two specimens were recovered *in situ* from the middle part of unit 1 of the upper member of the Antimonio Formation (locality CM-97-3, Figure 2). Given their stratigraphic position below the age-diagnostic ammonoids *Sagentites* cf. *schaubachi* Mojsisovics and *Catenohalorites*, they are assigned to the Norian Columbianus Zone.

Order Unioida Stoliczka, 1871
?Superfamily Unionioida Fleming, 1828
?Family Pachycardiidae Cox, 1961
Genus *Cardinioides* Kobayashi and Ichikawa, 1952

Type species—*Cardinioides japonicus* Kobayashi and Ichikawa, 1952, by original designation.

Cardinioides sp.
(Figure 3.12)

Material—The collection consists of a single internal mold of a left valve (ERNO-1922).

Description—Left valve moderately large (length = 4.4 cm, height = 2.8 cm), inflated (width = 0.4 cm), posteriorly elongated; beak inflated, probably overhanging, subcentral, positioned about one-third the distance from anterior margin, extending above sloping hinge margin; anterior hinge margin sloping at a greater angle than posterior hinge margin; ventral margin rounded in outline and somewhat flattened; internal surface devoid of any observable structure.

Remarks—While the cardinal dentition was not observed, assignment of the single specimen to *Cardinioides* is supported by the general outline and shape characteristics of the shell.

Stratigraphic and paleoecologic setting—The single specimen is from the base of unit 2 of the upper member of the Antimonio Formation (locality CM-97-10, Figure 2). Specimens occur in unit 2 which contains possible Rhaetian ammonoids and occur below the Rhaetian ammonoid *Choristoceras* (González-León *et al.*, 1996), so this species is likely early Rhaetian in age.

Order Trigonioida Dall, 1889
Superfamily Trigonioida Lamarck, 1819
Family Trigoniidae Lamarck, 1819
Genus *Myophorignonia* Cox, 1952

Type species—*Myophoria paucicostata* Jaworski, 1923, by original designation.

Myophorignonia jaworskii (Steinmann, 1929)
(Figures 3.13–3.16)

Myophoria ex. aff. *vestitae* Alberti. Jaworski, 1923, p. 124, pl. 5, figs. 5–7.

Myophoria jaworskii Steinmann, 1929, p. 57, text-fig. 55a-b; Cox, 1949, p. 25, pl. 1, fig. 16; Boit, 1966, p. 8, pl. 1, figs. 1, 2.

Myophorignonia jaworskii (Steinmann, 1929). Tamura (*in Stanley et al.*, 1994, p. 27, figs. 17.1–17.5).

Myophorignonia salasi Alencaster. Tamura (*in Stanley et al.*, 1994, p. 27, figs. 17.6–17.12).

Material—The present collection consists of more than 10 articulated specimens in varying degrees of preservation.

Description—Shells moderately large (maximum length = 38 mm, maximum height = 31 mm), moderately inflated (maximum width = 14 mm); inequilateral with beak situated in anterior third of hinge area. Inequivalved, with slightly smaller right valve; beaks incurved, with left beak slightly overhanging right valve; posterior area flattened and relatively smooth, separated from main part of disc by somewhat strong carina; main part of disc covered by 10–12 rounded, slightly curved radial ribs, which are weak to absent on anterior third of disc; very faint commarginal growth lines can be seen on well preserved portions of the main disc, especially on the raised portions of the radial ribs; radial sculpture is obliquely crossed by numerous (>15) concentric, although not commarginal, riblets whose intersection with radial sculpture produced a finely tubercate texture; dentition and musculature has not been observed on any specimen in the present collection.

Remarks—The specimens illustrated by Tamura as *Myophorignonia salasi* appear to be remarkably similar to those regarded here as *M. jaworskii*; the main differences appear to be size and quality of preservation. Based on observations of Tamura's figured material, it seems likely that both forms represent variation within a single species from one or more populations. The El Antimonio myophorignonids are quite distinct from the type *M. salasi* originally described by Alencáster (1961, pl. 3, figs. 6–9) from the Carnian Santa Clara Formation in that *M. salasi* is generally smaller in size, has fewer radial ribs with less pronounced tuberculation in the obliquely concentric sculpture on the anterior side which is wholly lacking in the posterior side of the disc.

Stratigraphic and paleoecologic setting—Specimens of *Myophorignonia* are quite abundant in the middle part of unit 1 of the upper Antimonio Formation (locality CM-97-3, Figure 2). Here, they are typically weathered, and preserved free from enclosing matrix. Given their position within 1–2 m below the age-diagnostic ammonoids *Sagentites* cf. *schaubachi* Mojsisovics and *Catenohalorites*, they are assigned to the Norian Columbianus Zone.

Order Veneroida Adams, 1854–1858
 Superfamily Carditoidea Fleming, 1820
 Family Cardidae Fleming, 1828
Palaeocardita Conrad, 1869

Type species—*Cardium austriaca* Hauer, 1853, by original designation.

Palaeocardita peruviana Cox, 1949
 (Figure 3.17)

Cardita aff. *benecke* Bittner. Körner, 1937, pl. 12, figs. 7a–c.

Palaeocardita peruviana Cox, 1949, p. 31–32, pl. 2, fig. 4; Hayami, Maeda, and Fuller, 1977, p. 214–215, pl. 30, figs. 1–5; Chong and Hillebrandt, 1985, pl. 3, figs. 2, 3; Tamura (in Stanley *et al.*, 1994, p. 27, figs. 17.13–17.18).

Cf. *Septocardia peruviana* (Cox). Chong and Hillebrandt, 1985, pl. 3, figs. 4, 5.

Material—The present collection includes a single slab (ER-NO-1919) with at least three individuals and 30 mostly articulated specimens in varying degrees of preservation. In addition, previously illustrated material (UMIP 20811 and UMIP 22014) by Tamura (in Stanley *et al.*, 1994) was also examined.

Description—Shells moderately large (maximum length = 3.7 cm, maximum height = 3.2 cm) moderately inflated (maximum width of closed valve pair = 2.4 cm), and posteriorly elongated; inequivalved, left valve slightly larger than right with overhanging beak; beak situated about one fourth the distance from the anterior margin, slightly incurved, opisthogyrous; shell transversed by moderately sharp carina or fold extending from beak along most inflated part of valve to posterior-ventral margin; sculpture on valve exterior consists of more than 21–28 slightly curved radial ribs extending from beak to ventral and posterior margins.

Remarks—The present material compares well with the figured types from Peru (Cox, 1949), those from the Norian–Rhaetian of Chile (Chong and Hillebrandt, 1985), and specimens from the Antimonio locality previously illustrated by Tamura (in Stanley *et al.*, 1994). In her discussion of the Tethyan affinities of American palaeocarditids, Kristan-Tollmann (1987) illustrated specimens that she identified with *P. trapezoidalis* (Krumbeck) from the Carnian calcareous mudstones at El Antimonio. Given the similar morphologies of Kristan-Tollmann's illustrated material, it is likely they are derived from a correlative Norian horizon as described herein from within unit 1. Additionally, Kristan-Tollmann (1987) synonymized Chong and Hillebrandt's (1985, pl. 3, figs. 4–6) *Septocardia peruviana* (Cox) into *P. peruviana*. While these Chilean specimens may indeed belong to *P. peruviana*, they appear to represent a somewhat posteriorly shortened and more quadrate variety. While similar in many regards, *P. peruviana* may be contrasted to *P. silberlingi* described from the Early Norian of Oregon (Newton *et al.*, 1987) in having fewer radial ribs (21–28 compared to 25–35). A more complete assessment of the relationship between *P. peruviana* and *P. silberlingi* awaits analysis of better preserved internal material of the South American and Mexican species and collection of more samples.

Stratigraphic and paleoecologic setting—This species is one of the most common bivalves known from unit 1 of the upper Antimonio Formation (locality CM-97-3, Figure 2). Here, specimens occur primarily within impure carbonate beds commonly associated with other infaunal bivalves (*e.g.*, *Myophorignonia*).

Given their position within 1–2 m below the age-diagnostic ammonoids *Sagentites* cf. *schaubachi* Mojsisovics and *Catenohalorites*, they are assigned to the Norian Columbianus Zone. Besides the Sonoran occurrence, this species is known from Peru and Chile.

Superfamily Lucinoidea Fleming, 1828
Family Fimbriidae Nicol, 1950
Genus *Schafhaeutlia* Cossmann, 1897

Type species—*Gonodon ovatum* Schafhaeutl, 1853, by original designation.

Schafhaeutlia sp.
(Figures 3.18–3.19)

Material—The collection consists of one ?right (ERNO-1920) and one left valve (ERNO-1921) from two different individuals.

Description—Shells moderately large (maximum height = 3.4 cm, maximum width = 3.6 mm); trigonally suboval; umbonal region broad with rounded, slightly prosogyrate to opisthogyrate beaks; exterior surface covered with numerous closely spaced concentric growth lines. Internal features including dentition and musculature unobserved.

Remarks—Generic assignment is based on the external morphology and, specifically, the inflated and slightly prosogyrous beaks and apparently thick shells which are typical of the genus. Although the specimens could be compared to *Schafhaeutlia americana* from the Norian of Peru (Cox, 1949, pl. 2, figs. 1, 2) and Norian or Rhaetian of Chile (Chong and Hillebrandt, 1985, pl. 3, fig. 1), the Sonoran specimens have slightly less inflated umbones, a feature which may be attributed to severe skeletal diagenesis and other taphonomic factors.

Stratigraphic and paleoecologic setting—The specimen is from the base of unit 3 of the upper Antimonio Formation (locality CM-97-9, Figure 2). This locality has produced a mixed fauna containing the ammonoid *Choristoceras* in addition to reworked older ammonoids suggesting a Rhaetian age.

CONCLUSION

This preliminary study on the Norian–Rhaetian bivalve fauna from the Upper part of the Antimonio Formation provides a more complete account of bivalve diversity and paleoecology than previously known. Of the 10 bivalve taxa described herein, eight have never been described from Sonora and at least four represent previously unknown forms. The two new species described are particularly significant in that *?Lopha cordillerana* n. sp. may share some affinities on the specific level with specimens from the Luning Formation of west-central Nevada and, at least at the generic level, *Xiaoschuiculana tozeri* n. sp.

shares some affinities with forms described from China. Other taxa, while ecologically important, are too few in number or too poorly preserved to be adequately assigned to species.

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