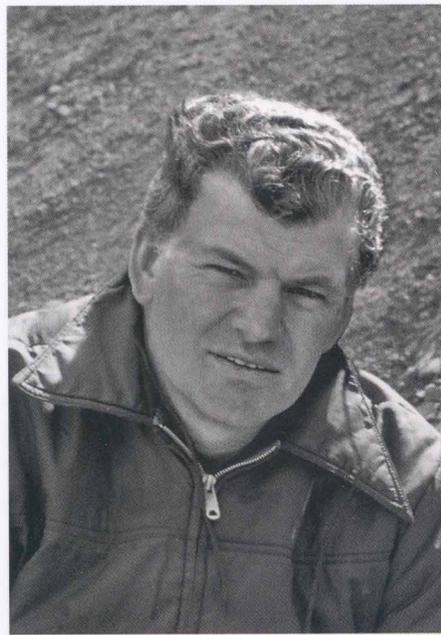


# R E V U E D E PALÉOBIOLOGIE

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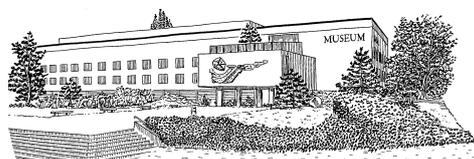
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## Late Triassic bivalves and brachiopods from southern Mendoza, Argentina

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### Abstract

The Atuel river section in southern Mendoza Province, Argentina, is one of the few South American localities where the Triassic/Jurassic transition occurs in fully marine deposits. Bivalves and brachiopods from the poorly diverse Late Triassic macrofauna are described, most of them found below *Choristoceras* cf. *marshi* HAUER. The fauna contains 15 bivalve species and at least 5 brachiopod species recorded from several Norian/Rhaetian fossiliferous levels at Arroyo Malo. The fauna also includes cephalopods, gastropods, a cnidarian, and some foraminifers and ostracods. Bivalves are the most diverse group, with species belonging to 13 superfamilies. Two of the bivalve species are described as new: *Pseudolimea riccardii* DAMBORENEA n. sp. and *Asoella campbellorum* DAMBORENEA n. sp. Only one bivalve species ranges into Early Jurassic deposits. The bivalve fauna contains mostly suspension feeder species, including deep infaunal (*Pholadomya*), shallow infaunal (*Minetrigonia*?, *Nicaniella*?, *Palaeocardita* and *Septocardia*) and epifaunal species (*Cassianella*, *Liostraea*, *Praechlamys*?, *Pseudolimea* and *Otapiria*). Following next in terms of diversity, brachiopods are represented by no fewer than three orders, and four superfamilies, one of the species being new: *Bolilaspirifer riccardii* MANCEÑIDO n. sp. These species are also epifaunal suspension-feeders, and from a biostratigraphical viewpoint are regarded as members of a newly proposed Assemblage Zone that supports the age correlation with similar faunas from other south Pacific areas.

### Keywords

Bivalvia, Brachiopoda, Late Triassic, Biostratigraphy, Mendoza, Argentina.

### Resumen

**Bivalvos y braquiópodos del Triásico tardío del sur de Mendoza, Argentina.**- El alto río Atuel en el sur de la Provincia de Mendoza es una de las pocas localidades en América del Sur donde el pasaje Triásico-Jurásico ocurre en sedimentos marinos. Se describen aquí los bivalvos y braquiópodos de la poco diversa macrofauna triásica hallada. Contiene 15 especies de bivalvos y al menos cinco de braquiópodos del Noriano/Rhaetiano, provenientes de varios niveles fosilíferos del perfil del Arroyo Malo, la mayoría de ellos situados por debajo de *Choristoceras* cf. *marshi* HAUER. La fauna contiene además cefalópodos, gastrópodos, un cnidario, y foraminíferos y ostrácodos. Los bivalvos constituyen el grupo más diverso, con especies pertenecientes a trece familias. Dos de las especies de bivalvos son nuevas: *Pseudolimea riccardii* DAMBORENEA n. sp. y *Asoella campbellorum* DAMBORENEA n. sp. Solamente una de las especies se registra tanto en sedimentos triásicos como del Jurásico temprano. La fauna de bivalvos descrita contiene predominantemente suspensívoros, e incluye tanto formas infaunales profundas (*Pholadomya*), infaunales superficiales (*Minetrigonia*?, *Nicaniella*?, *Palaeocardita* y *Septocardia*) como epifaunales (*Cassianella*, *Liostraea*, *Praechlamys*?, *Pseudolimea*, *Otapiria*). Siguen los braquiópodos en términos de diversidad, estando representados por no menos de tres órdenes y cuatro superfamilias, siendo una de tales especies, nueva: *Bolilaspirifer riccardii* MANCEÑIDO n. sp. Se trata también de especies suspensívoras, epifaunales, las cuales integran, desde el punto de vista bioestratigráfico una nueva Zona de Asociación que apoya su correlación cronológica con faunas similares de otras áreas del Pacífico sur.

### Palabras clave

Bivalvia, Brachiopoda, Triásico tardío, Bioestratigrafía, Mendoza, Argentina.

### INTRODUCTION

There are very few places on the world where the Triassic/Jurassic transition occurs in fully marine environments (MCROBERTS *et al.*, 1997; YIN & MCROBERTS, 2006). The Atuel river section in Argentina is one of them and thus a detailed study of its fauna can provide important information to understand events related to the Triassic/Jurassic boundary and faunal turnover (RICCARDI in STIPANIC & MARSICANO, 2002; RICCARDI *et al.*, 2004;

DAMBORENEA, 2005). The Atuel river succession (Fig. 1) is the only proved marine Triassic locality known so far from Argentina (RICCARDI *et al.*, 1997a, 2004; RICCARDI & IGLESIA LLANOS, 1999; RICCARDI, 2008c). The Triassic sediments crop out on an anticline core about 5 km north of the Atuel river, near El Sosneado lake in the Andes of Mendoza Province (Fig. 2a). As a result of intensive sampling since 1986, the locality has yielded a small but relatively diverse fauna of marine invertebrates. Although the material is scarce and not

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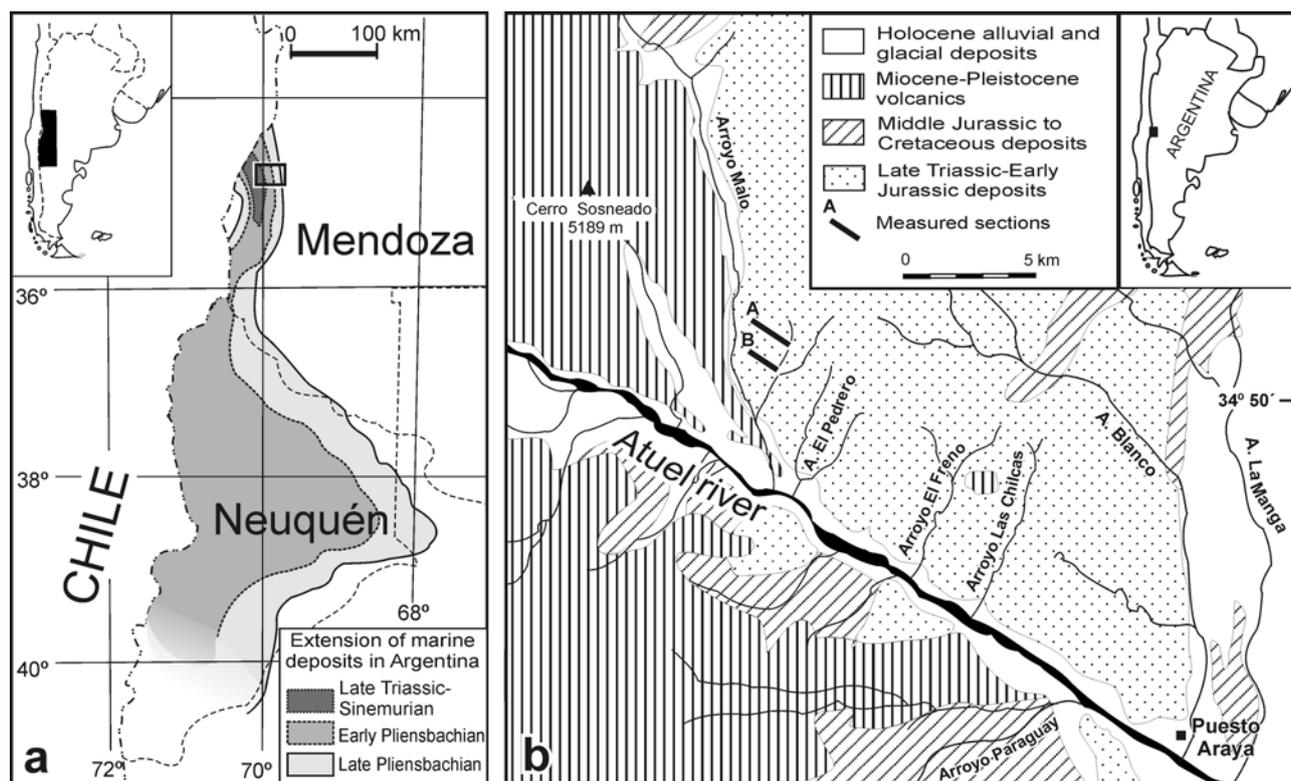


Fig. 1: a. Generalized map of part of the Neuquén basin showing the maximum extent of marine sediments at different ages, box indicates study area. b. Geologic sketch of the area with location of measured sections A and B.

very well preserved, it has special interest and merits description since it adds to the knowledge of the Triassic/Jurassic transition, marked everywhere by the massive end-Triassic extinction. The purpose of this paper is to systematically describe the bivalve molluscs and the brachiopods collected from the Arroyo Malo Formation. This part of the Arroyo Malo section (Fig. 2c, 3a) was logged by A.C. RICCARDI and the authors in 1988 and described by RICCARDI *et al.* (1988, 1997a, b, 2004), who distinguished the Arroyo Malo Formation at the base (RICCARDI *et al.*, 1997a), followed by conglomeratic lenses attributed to the El Freno Formation (REIJENSTEIN in STIPANIC & BONETTI, 1970) and then by deposits of the El Cholo Formation (STIPANIC in STIPANIC & BONETTI, 1970). A supplementary section was logged recently by the authors and H. CAMPBELL (Fig. 2d, 3b). The tectosedimentary evolution of the late Triassic-early Jurassic transgression at the Atuel depocenter was studied in detail by LANÉS (2005) and LANÉS *et al.* (2008), and tectonic and petrographic aspects of the late Triassic sediments were discussed by GIAMBIAGI *et al.* (2008), TUNIK *et al.* (2008) and BECHIS *et al.* (2010). The palaeobiogeographical affinities of this fauna have been briefly discussed in DAMBORENEA & MANCENIDO (1998), MANCENIDO (2002, 2010) and DAMBORENEA *et al.* (2009).

### Marine Triassic deposits from Argentina

The presence of marine Triassic sediments in Argentina had been claimed since the beginning of the 20th century, first from Neuquén and later from Salta Provinces. Both these records were later proved to be based on unreliable evidence and eventually dismissed.

A Triassic age was proposed by GROEBER (1924, 1929, 1958, and in GROEBER & STIPANIC, 1953) on the basis of some bivalves and brachiopods found in marine deposits near Cerro Chachil and near Piedra del Águila (both in Neuquén Province) (see also FRENGUELLI, 1930; WINDHAUSEN, 1931; WEAVER, 1931, 1942). Those fossils were later referred to the Early Jurassic (see A. LEANZA, 1948; FRENGUELLI, 1948; H. LEANZA, 1992; MANCENIDO & LEANZA in RICCARDI & DAMBORENEA, 1993; PÉREZ *et al.*, 1995).

Similarly, the presence of marine Triassic sediments in the Aimara basin of northwest Argentina (Salta) was questioned, since BONARELLI's (1927) gastropod fauna from the Yacoraite Formation (Salta Group) is now regarded as late Cretaceous in age (PARODIZ, 1969; RICCARDI, 1988). On the other hand, the only fossils further attributed to the marine Triassic from that basin were recovered from two localities in the Vitiagua Formation in Bolivia (BELTAN *et al.*, 1987; SUÁREZ RIGLOS & DALENZ-FARJAT, 1993).

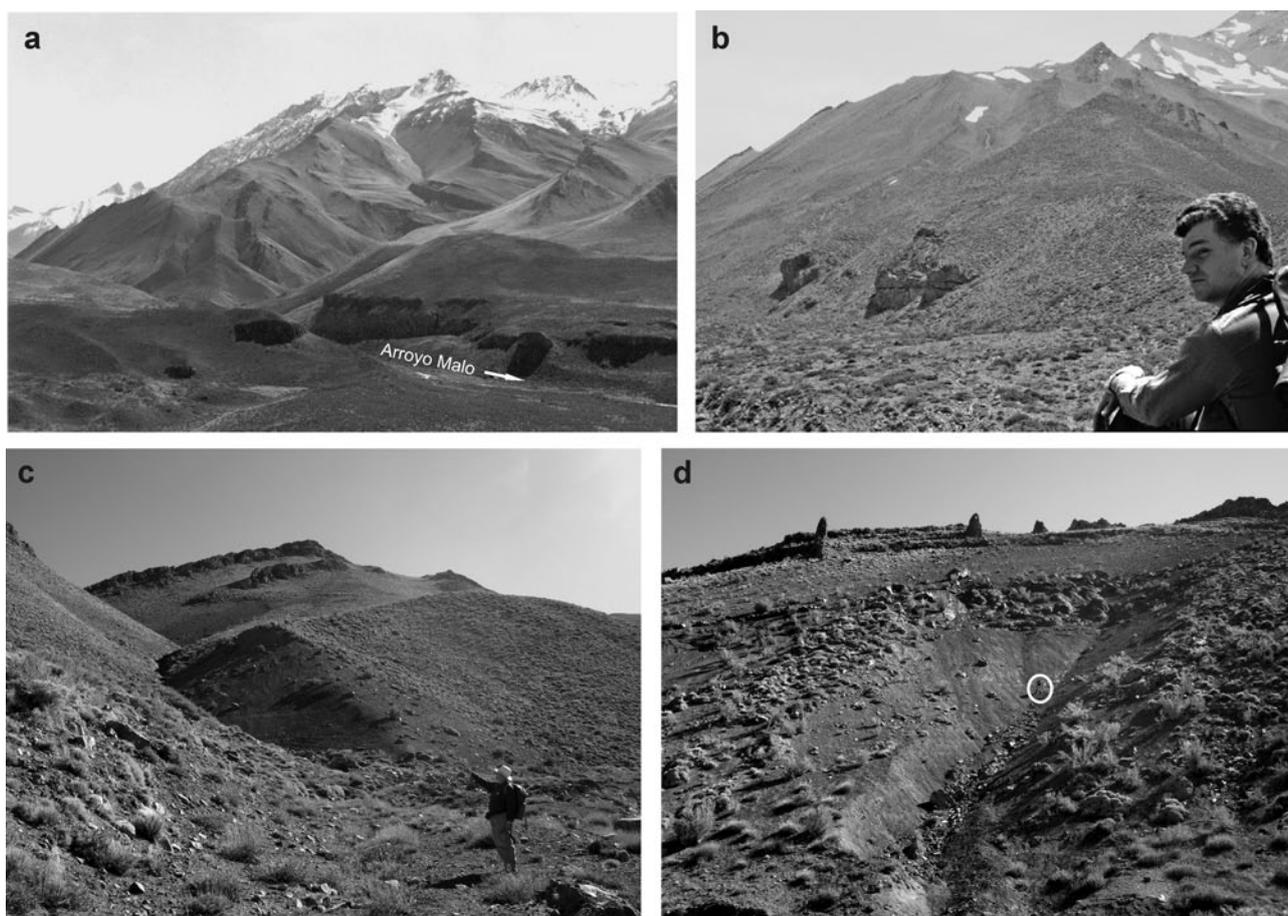


Fig. 2: Field photographs of the study area. **a.** General view of the mountain slope north of Atuel river, showing the anticline structure bearing Late Triassic beds at its core with overlying Early Jurassic beds, and some remnants of Cenozoic volcanics close to Arroyo Malo. **b.** A.C. RICCARDI when first surveying the Arroyo Malo section in November 1986, with Late Triassic-Early Sinemurian outcrops in the background. **c.** View of logged section A, with conglomerates towards the top. **d.** View of logged section B, person for scale (circle).

Late Triassic marine fossils were reported by RICCARDI *et al.* (1997a, b) from the Arroyo Malo in the River Atuel area of southern Mendoza (Fig. 1), in deposits below the early Hettangian sediments with fauna of the *Psiloceras rectocostatum* Assemblage Zone (RICCARDI *et al.*, 1988, 1991; RICCARDI, 2008a, b, c). The molluscan and brachiopod faunas were briefly mentioned and partly figured in RICCARDI *et al.* (1997a, 2004) and DAMBORENEA & MANCENIDO (1998) and were at that moment used as the argument to refer them to the late Triassic (Norian and/or Rhaetian). The report of *Choristoceras cf. marshi* HAUER from some levels of this sequence (RICCARDI & IGLESIA LLANOS, 1999; RICCARDI, 2008c) supports a late Rhaetian age for that part of the succession. Most of the fauna described here was found between 10 and 80 m below the main level with *Choristoceras* (see Fig. 3). The Late Triassic marine sediments belong to the Arroyo Malo Formation (RICCARDI *et al.*, 1997a), and are mainly fandelitaic

facies with planar laminated mudstones, fine sandstones and conglomeratic lenses deposited by low- and high-density turbidity currents and debris flows (LANÉS, 2005; LANÉS *et al.*, 2008). For this reason fossil invertebrates are scarce and dispersed, and scattered plant remains also occur throughout the section (Fig. 3).

#### Material

The material described here was collected over many years from different fossiliferous levels of the Arroyo Malo Formation (see location in Fig. 3) during several field seasons. All material is deposited in the collections of the Invertebrate Palaeontology Department of La Plata Natural Sciences Museum (MLP).

Bivalves are the most numerous and diverse group, with at least 15 species belonging to almost as many families. Apart from the brachiopods described here, and the heteromorph ammonites described by RICCARDI & IGLESIA LLANOS (1999), this fauna also includes three

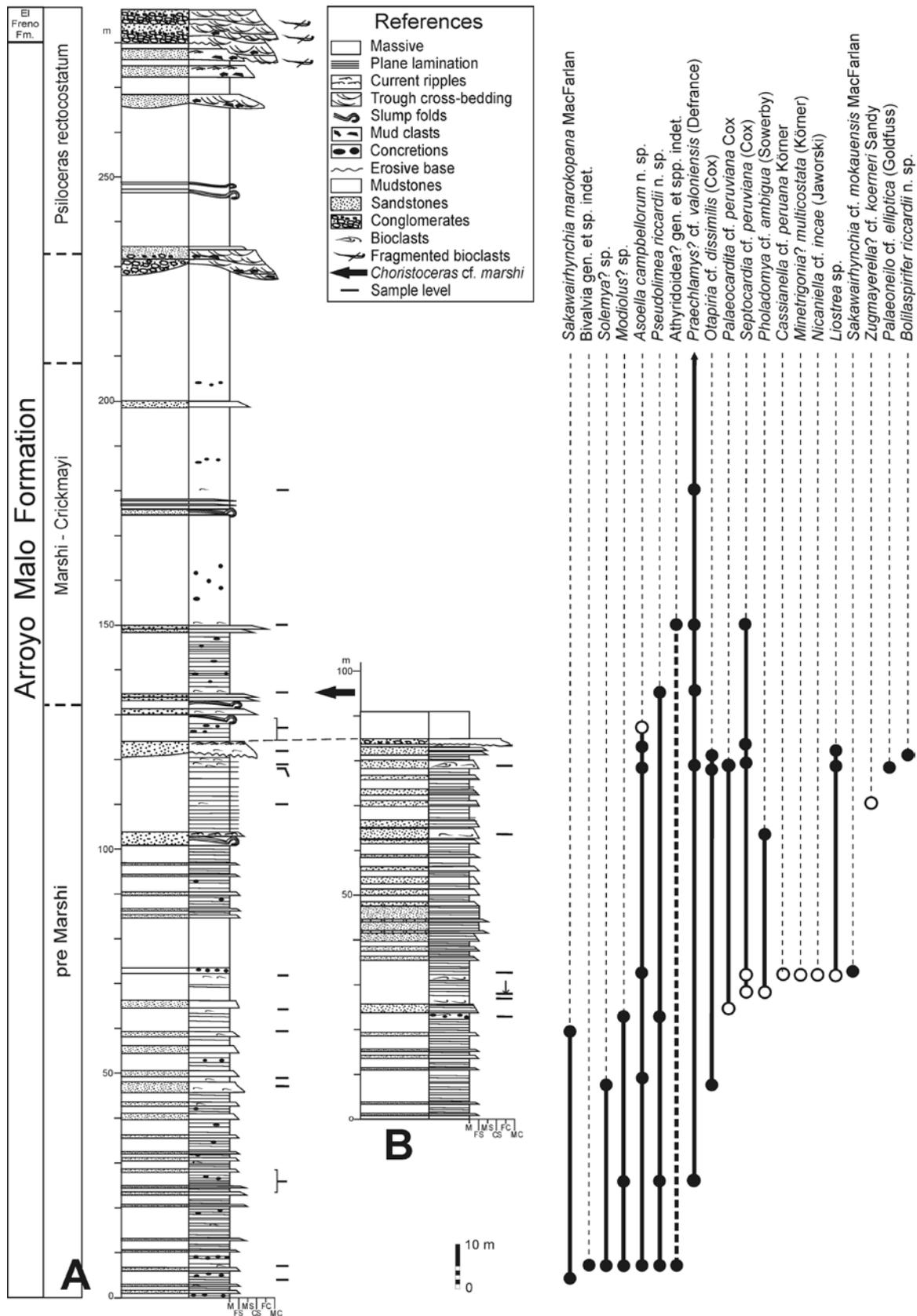


Fig. 3: Stratigraphic sections with location of bivalve and brachiopod faunas described here, and indication of each species stratigraphical range (black circle: *in situ* specimen; white circle: *ex situ* specimen). A. Main section, modified from RICCARDI *et al.* (2004); B. Supplementary section. For location of sections see Figure 1. M: mudstone; FS, MS, CS: fine-, medium- and coarse-grained sandstone; FC, MC: fine- and medium-grained conglomerate.

gastropod species, further cephalopods and a cnidarian (yet undescribed), and some microfossils (foraminifers and ostracods) reported by BALLENT (1994). A few impressions of plant remains are also present, referred to *Zuberia* (see RICCARDI *et al.*, 1997a, 2008c), Equisetales and other plants.

The material is very scarce in the succession due to the depositional processes already mentioned, and preservation is generally poor, though it differs according to the levels. The dark planar laminated mudstones contain scattered complete (articulated or disarticulated) shells of relatively large specimens. The original shell microstructure is not preserved.

The best specimens are preserved as external or internal moulds in nodules. Well-preserved material was found as moulds in local (probably somewhat allochthonous) shell concentrations. These contain a very diverse fauna, but some size sorting appears to have taken place, since most shell pieces are less than 1 cm across. In these local shell concentrations the few complete specimens of any species are all small-sized individuals. The preservation of delicate ornamentation details, the presence of articulated bivalves, and the lack of abraded fragments indicate minor transport, probably only slight local winnowing allowing sorting by size.

Stratigraphical ranges of species described here are represented on Fig. 3. Several species have relatively long ranges, whilst a few are restricted to occurrences at single levels.

## SYSTEMATIC DESCRIPTIONS

### Class Bivalvia LINNÉ, 1758 (by S.E. DAMBORENEA)

For the suprageneric classification of bivalves we follow BOUCHET & ROCROI (2010) with minor modifications.

### Bivalvia gen. (cf. “*Laternula*” auct.) et sp. indet.

#### Pl. I, fig. 1

**Material:** A nearly complete specimen with articulated valves, laterally compressed, preserved as a composite mould, MLP 32718.

**Description:** Elongate, compressed, ovoid, equivalve shell, with low broad umbones placed at mid-length. Anterior margin evenly rounded, ventral margin gently arched, posterior margin narrower than anterior one, postero-dorsal margin straight. Inner margin appears to be smooth. Other internal characters unknown. Surface covered only by faint, regularly spaced, commarginal ridges and growth lines.

**Dimensions:** Length: 33.08 mm, height: 18.39 mm; width (both valves): 11.35 mm.

**Discussion:** The hinge of this specimen is not preserved, and therefore its affinities are very uncertain. It probably belongs to a poorly known group of late Triassic bivalves,

mostly referred to “*Anatina*” or “*Laternula*”, but of doubtful affinities, and badly in need of revision (see discussion in ROS, 2009; ROS *et al.*, in press), especially to the compressed members of this group. The shape, size and low inflation are comparable to “*Laternula*” *zannonii* (STOPPANI, 1860-1865, pl. 29, fig. 23; ALLASINAZ, 1962, pl. 25, fig. 15-16; and SIRNA, 1968, pl. 56, figs. 1, 6, 7) from the Rhaetian of northern Italy.

The specimen shape can also be compared with some nuculanoid bivalves, such as *Palaeoneilo tenelliformis* KOBAYASHI & ICHIKAWA (in ICHIKAWA, 1949, pl. 10, fig. 8), from the Late Triassic of Japan and the Qinghai-Xizang Plateau, China (SHA & GRANT-MACKIE, 1996, fig. 4e) but this has a more anterior umbo; or specimens referred to *Nuculana subperlonga* CHEN from the middle Triassic of Vietnam, figured by KOMATSU *et al.* (2010, fig. 3.3). *Palaeoneilo mundeni* FLEMING (in FLEMING *et al.*, 1954, pl. 4, figs. 1, 2, 4-9), from the Warepan (Norian) of New Zealand has a thicker and larger shell, which is more inflated, and has buttressed anterior adductor scars. This specimen differs from the species described below as *Palaeoneilo* cf. *elliptica* from the same locality by its more central umbo and less inflated, compressed shell.

### Superfamily Nuculanoidea ADAMS & ADAMS, 1858

#### Family Mallettiidae ADAMS & ADAMS, 1858

#### Genus *Palaeoneilo* HALL & WHITFIELD, 1869

**Type species:** *Nuculites constricta* CONRAD, 1842, subsequent designation by HALL (1885, p. xxvii), see discussion in MCALESTER (1968, p. 41) and comments in DAMBORENEA (1987, p. 53-54) and HODGES (2000, p. 27).

#### *Palaeoneilo* cf. *elliptica* (GOLDFUSS, 1837)

#### Pl. I, figs. 2a-b

? 1968. *Palaeoneilo* cf. *elliptica* (GOLDFUSS).- CECIONI & WESTERMANN, pl. 3, fig. 2.

cf. 2000. *Palaeoneilo elliptica* (GOLDFUSS).- HODGES, p. 28, pl. 2, figs. 1-30 (with further synonymy).

**Material:** One complete internal mould of left valve (MLP 32733).

**Description:** Shell small, inequilateral, posteriorly elongated, inflated and ovoid in shape. Anterior, posterior and ventral margins evenly rounded. Posterodorsal margin straight. Umbo wide and low, placed within the anterior third of total shell length. At least 20 small taxodont teeth are present on the posterior portion of the dorsal hinge margin, anterior hinge region not preserved. The specimen shows a sharp ridge extending posteriorly from the umbo, but this feature is probably a preservational artifact, since the whole shell is cracked. Some small fragments probably belonging to external moulds show growth lines only. Other internal and external characters unknown.

**Dimensions:** Length: 10.28 mm; height: 6.81 mm; distance of umbo from anterior margin: 2.40 mm.

**Discussion:** This specimen is probably conspecific with the material described by CECIONI and WESTERMANN (1968, pl. 3, fig. 2) from the late Triassic of Chile. *Palaoneilo elliptica* is a late Triassic-early Jurassic widely distributed species (see HODGES, 2000 for comments, synonymy and illustration of morphological variability). The specimen described here is distinguished only by a more rounded posterior margin, even from the early sharply rounded forms (see discussion in HODGES, 2000). The specimen is very similar in shape to *Palaoneilo patagonidica* (LEANZA) (DAMBORENEA, 1987, pl. 1, figs. 1-3), from Pliensbachian-Toarcian beds of western Argentina, but this has larger shells with a more pointed posterior margin. This last character is also present in *P. hamiltoni* WILCKENS, from the Otamitan (Norian) of New Zealand (see MARWICK, 1953, pl. 3, fig. 7). The two above-mentioned species were regarded as synonyms of *P. elliptica* by HODGES (2000). Also *P. iwaiensis* ICHIKAWA (1954, pl. 17, figs. 1-3) from Japan, and Norian material from the Biobío region in Chile described by PÉREZ-BARRÍA (2004, pl. 2, fig. 3-8) as *Palaoneilo?* sp., show a more pointed posterior end. The type species of the genus, *P. constricta* (CONRAD) (see MCALESTER, 1968, pl. 15, figs. 1-15), from the Devonian of New York, has a pointed posterior margin and a faint posterior radial groove. *Palaoneilo otamitensis* TRECHMANN (1918, pl. 21, fig. 21; MARWICK, 1953, pl. 3, fig. 6), from the Norian of New Zealand is also a very similar species.

#### Superfamily Solemyoidea GRAY, 1840

##### Family Solemyidae GRAY, 1840

##### Genus *Solemya?* LAMARCK, 1818

**Type species:** *Solemya mediterranea* LAMARCK, 1818 = *S. togata* (POLI, 1795), living, Mediterranean, subsequent designation by CHILDREN, 1823.

##### *Solemya?* sp.

##### Pl. I, fig. 3

**Material:** About 6 fragmentary isolated valves, 2 specimens with both valves displaced (one preserved as an internal and the other as an external mould) and one specimen with both valves in butterfly position (MLP 32717, 32724).

**Description:** Small equivalve and inequilateral shells, oblong in shape, with nearly parallel dorsal and ventral margins. Shell very thin. Umbones broad and low, placed at a quarter of total shell length near one end, assumed to be posterior. Some specimens show faint irregular lines radiating from the umbo to the ventral margin. Surface with faint commarginal growth lines. Other internal or external characters unknown.

All specimens are incomplete and cannot be measured,

but their shell length was between 10 and 12 mm, not exceeding 5 mm high.

**Discussion:** The generic affinities of this taxon are very doubtful, and it is referred to *Solemya* on the basis of its general shape and size, with fragile shell marked by faint radial lines. During the Triassic-Early Jurassic, *Solemya* was only reported from the Tethys (Anisian of Hungary, VÖRÖS & PÁLFY, 2002; Lower Jurassic of Germany, SEILACHER, 1990), whereas it is mentioned from a wider geographic range from the Jurassic (ROS, 2009). Nevertheless, there are certain evidences (*Solemyatuba* isp.) of its possible presence in Rhaetian beds of Germany and Permian of Russia (SEILACHER, 1990).

It is interesting to note that most specimens were found in one sample of dark mudstone, and many are preserved with both valves slightly displaced, commonly one valve as an internal and the other as an external mould.

#### Superfamily Mytiloidea RAFINESQUE, 1815

##### Family Mytilidae RAFINESQUE, 1815

##### Genus *Modiolus?* LAMARCK, 1799

**Type species:** *Mytilus modiolus* LINNÉ, 1758, living, north Atlantic, subsequent designation by GRAY, 1847.

##### *Modiolus?* sp.

##### Pl. I, fig. 4

**Material:** MLP 32722: two external moulds of incomplete shells, one incomplete right valve, crushed (MLP 32727), and fragments (MLP 32718).

**Description:** The material is too poor to allow a proper description. The shell shape is subtriangular elongate but it cannot be described in detail. Umbones are small, not prominent, and placed very near the anterior end of the straight dorsal line. A faint depression parallel and very near to the hinge line may correspond to a ligamental groove. The surface is covered by irregular growth lines.

**Dimensions:** MLP 32727: length 20.40 mm; height 13.35 mm.

**Discussion:** The described fragments of isolated shells can be referred to *Modiolus* in a very broad sense. None of them shows the complete outline of the shell, and thus no proper comparison can be attempted.

#### Superfamily Pterioidea GRAY, 1847

##### Family Cassianellidae ICHIKAWA, 1958

##### Genus *Cassianella* BEYRICH, 1862

**Type species:** *Avicula gryphaeata* von MÜNSTER, 1836, p. 127, Carnian of Italy, by original designation.

This genus, one of the most characteristic Late Triassic bivalves, was particularly abundant and diverse in low-latitude regions of the northern hemisphere during the Late Triassic, but was in fact widely distributed latitudinally (NEWTON *et al.*, 1987, p.25; ROS, 2009),

being known from as far north as south-western Alaska (MCROBERTS in MCROBERTS & BLODGETT, 2002), Bear Island (BÖHM, 1903) and northeast Siberia (KIPARISOVA *et al.*, 1966). Further south, along the Pacific brim, it has been reported from Burma (HEALEY, 1908), Sumatra (KRUMBECK, 1914), Peru (KÖRNER, 1937), northern Chile (CHONG & HILLEBRANDT, 1985), and New Zealand (TRECHMANN, 1918; MARWICK, 1953; BEGG & CAMPBELL, 1985, Appendix I not published).

***Cassianella cf. peruana* KÖRNER, 1937**

**Pl. I, figs. 5-6, 7?**

- cf. 1937. *Cassianella peruana* KÖRNER, p. 199-200, pl. 12, figs. 10a-d.  
 1997a. *Cassianella cf. peruana* KÖRNER.- DAMBORENEA in RICCARDI *et al.*, p. 231, fig. 3.4.  
 1997b. *Cassianella cf. peruana* KÖRNER.- DAMBORENEA in RICCARDI *et al.*, p. 579.  
 2004. *Cassianella cf. peruana* KÖRNER.- RICCARDI *et al.*, p. 76, figs. 3.r-s.  
 2008c. *Cassianella cf. peruana* KÖRNER.- RICCARDI, p. 234, fig. 4th row from top.

**Material:** Six left valves, only one of them with parts of shell preserved, others as internal and external moulds, MLP 27765, 27766, 27768. All specimens, about 70 m above base of measured section and 80 m below level with *Choristoceras cf. marshi* HAUER.

**Description:** Shell very small, orthocone, length and height nearly equal. Left valve globose, with broad strongly incurved umbo. Bialate, anterior auricle small and only slightly convex, with pointed anterior end; posterior auricle broader and larger, though never preserved intact. Anterior auricle separated from disc by a deep radial depression, posterior auricle not clearly separated from disc of shell. Exterior bears commarginal growth-lines and very faint radial threads on some specimens. Right valve unknown. Inner surface of shell smooth, adductor muscle scar not impressed. Other internal characters unknown.

**Dimensions:**

Specimen	Length	Height
MLP 27766-a	7.42 mm	8.18 mm
MLP 27766-b	5.80 mm	--
MLP 27765	6.29 mm	5.97 mm
MLP 27768	6.52 mm	6.50 mm
?MLP 27766c	12.31 mm	12.69 mm

**Discussion:** The species *C. peruana* was originally described by KÖRNER (1937) on the basis of only one left valve very well preserved from Nevado de Acrotambo, Perú. The specimens here described are very similar in shape and size, but their internal characters are unknown. KÖRNER's species was not mentioned again in South American literature, but *Cassianella* sp. was later recognized and figured by CHONG & HILLEBRANDT (1985, p. 175, pl. 3, figs. 8-9) from Norian or Rhaetian

beds at Sierra de Varas and quebrada Granate, northern Chile. That species is quite different from the Argentinean specimens, being of larger size and having a more elongated shell with very narrow umbonal region.

This taxon belongs to the group of species which lack umbonal carina and radial posterior sulcus. It is similar in shape and size to the type species, *C. gryphaeata* (MÜNSTER) from Late Triassic beds in Europe (MÜNSTER, 1836, pl. 116, fig. 10; STOPPANI, 1860-65, pl. 11, figs. 3-5; BITTNER, 1895, pl. 6, figs. 1-3; SCALIA, 1910, pl. 3, figs. 24-28), and probably southern China (COWPER-REED, 1927, pl. 18, fig. 25; see also *C. nyanangensis* WEN and LAN, in WEN *et al.*, 1976, pl. 7, figs. 16-18, 20; GOU, 1993, pl. 2, fig. 30). *Cassianella* sp. from the upper Rhaetian of Tibet (YIN & MCROBERTS, 2006) is also similar in shape. The similarities are also great with *C. praecursor* FRECH from Hungary (SZENTE & VÖRÖS, 2003, pl. 1, 20-22) and *C. simplex* KIPARISOVA (in KIPARISOVA *et al.*, 1966, pl. 2, figs. 5-8), from NE Siberia, but this last species has the posterior auricle of the left valve more clearly separated from the disc.

Other group of species, for instance *C. angusta* BITTNER from Europe and USA, *C. lingulata* GABB from North America, *C. crickmayi* MCLEARN from Canada, *C. longitudina* CHEN from China, *C. verbeeki* KRUMBECK from Sumatra, have a narrower shape, with shells clearly higher than long (BITTNER, 1893, pl. 5, fig. 1; 1895, pl. 5, figs. 23-26; SCALIA, 1910, pl. 3, figs. 29-40; KRUMBECK, 1914, pl. 16, figs. 5-6; COWPER-REED, 1927, pl. 18, fig. 38; MCLEARN, 1942, pl. 1, figs. 5-9; WEN *et al.*, 1976, pl. 7, figs. 14-15; TOZER, 1962, pl. 12, fig. 1; 1970, pl. 18, fig. 19; GOU, 1993, pl. 2, fig. 31). The material from Oregon (NEWTON, 1986, pl. 2.1, figs. 1-5; NEWTON *et al.*, 1987, figs. 18.7-18.17, 19.1-19.17) is also more prosocline than the specimens here described and bears a posterior radial furrow. *Cassianella tulongensis* CHEN (in WEN *et al.*, 1976, pl. 7, figs. 22-24, 27-29; see also YIN & MCROBERTS, 2006, fig. 4.4) from China (Tibet), and all species described by HEALEY (1908) from Burma, have a radially ornamented shell and left valves with strong umbonal carina.

**Superfamily Monotoioidea FISCHER, 1886**

**Family Monotiidae FISCHER, 1886**

**Genus *Otapiria* MARWICK, 1935**

Despite other suggestions, this genus is placed in the Monotiidae as done by many authors on the basis of ligamental features (see discussion in MCROBERTS, 2011, p. 647). The mainly circumpacific distribution of this genus, quite evident during Early Jurassic times, was already established by the Late Triassic (MCROBERTS, 2011).

**Type species:** *Pseudomonotis marshalli* TRECHMANN, 1923, p. 270, early Jurassic of New Zealand, by original designation.

***Otapiria* cf. *dissimilis* (S. COX, 1878)****Pl. I, figs. 8-9**

- cf. 1878. *Monotis dissimilis* COX, p. 45.  
 cf. 1953. *Otapiria dissimilis* (COX).- MARWICK, p. 59, pl. 3, figs. 10-12.  
 1997a. *Otapiria* sp.- DAMBORENEA in RICCARDI *et al.*, p. 231, fig. 3.1.  
 1997b. *Otapiria* sp.- DAMBORENEA in RICCARDI *et al.*, p. 579.  
 2004. *Otapiria?* sp.- DAMBORENEA in RICCARDI *et al.*, p. 76.  
 cf. 2011. *Otapiria dissimilis* (COX).- GRANT-MACKIE, fig. 3.

**Material:** One almost complete right valve (MLP 32724), and one incomplete left valve with its external mould (MLP 27764), about 45 to 130 m above base of measured section, the youngest one immediately below level with *Choristoceras* cf. *marshi* HAUER, and fragments of shell probably belonging to this species, MLP 29414.

**Description:** Shell small, biconvex, moderately inflated. Both valves obliquely elongated, longer than high, with umbo placed anterior to mid length, left valve densely ornamented by about 30 well-defined slightly wavy radial ribs, which increase in number by intercalation near the ventral margin, and faint commarginal rugae. Ligamental and other internal characters unknown. Right valve ornamented by less conspicuous radial plicae and stronger commarginal folds. Anterior auricle of right valve not preserved.

**Dimensions:** MLP 27764: length: 16.69 mm; height: 12.53 mm. MLP 32724: length: 15.06 mm; height: 12.77 mm.

**Discussion:** The material is left in open nomenclature in the absence of key ligamental characters and well-preserved right valves, but shell shape and ornamentation pattern are similar to those of the Otapirian (latest Triassic) New Zealand species *O. dissimilis* (S. COX, 1878) (see MARWICK, 1953, pl. 3, figs. 10.12; GRANT-MACKIE, 2011, fig. 3). *Otapiria norica* McROBERTS (2011, fig. 33), from the Norian of British Columbia, Canada, has nearly flat valves and bears more numerous radial plicae. *Otapiria* sp. in CHONG & HILLEBRANDT (1985, pl. 4, fig. 4-6), Rhaetian of Chile, is also comparable and may be conspecific with our material, but apparently has flatter valves.

The radial ornamentation is coarser and stronger than in other *Otapiria* species found higher up in the same section, as *O. pacifica* COVACEVICH & ESCOBAR and *O. neuquensis* DAMBORENEA (see figures in DAMBORENEA, 2002, pl. 1, figs. 1-3 and 4-5 respectively).

**Family Asoellidae BEGG & CAMPBELL, 1985****Genus *Asoella* TOKUYAMA, 1959**

**Type species:** *Eumorphotis (Asoella) confertoradiata* TOKUYAMA, 1959, from the Carnian (or lower Norian) of Japan, by original designation.

***Asoella campbellorum* DAMBORENEA n. sp.****Pl. I, figs. 10-13**

**Material:** The holotype is a nearly complete left valve, MLP 32730-a. Paratypes: six right valves and nine left valves, preserved as internal and external moulds, MLP 27760, 32725, 32730-b-i, 32731-a-c, 33681 and 33682. Other material: an isolated right valve MLP 32717, and isolated right and left valves, 32735, 32738, 33683.

**Derivation of name:** Species dedicated to J. Douglas and Hamish CAMPBELL for their substantial contributions to the southern hemisphere Triassic faunas. While Doug could not fulfill his wish to see the South American Triassic, his son Hamish visited key sections in Chile and Argentina, and actively participated in a survey of the sections described here. He also made important contributions to this particular group of bivalves.

**Diagnosis:** Small, biconvex but inequivalve, thin, acline shells. Left valve more inflated than right, and ornamented with two orders of straight, round-topped, radial ribs; right valve exterior with only faint radial costae. Right anterior auricle clearly separated from disc and with parallel-sided byssal notch. Inner surface smooth.

**Description:** Small inequivalve shell, left valve more inflated and larger than right one. Both valves thin-shelled. Shell outline subcircular to subquadrate, shell length and height approximately equal. Right valve with long and straight dorsal margin and rounded anterior, ventral and posterior margins, with centrally placed low umbo and well-defined anterior auricle, separated from disc by a deep groove, and a parallel-sided byssal notch below it. Auricle long with externally convex surface. A faint flattened right posterior auricle can be also recognized, especially in small specimens, but this is not separated from the disc. Left valve well inflated, with wide and prominent, slightly prosogyrous umbo placed at about mid-length, dorsal line straight, other margins evenly rounded. Left valve with ill-defined, flat posterior and anterior auricles, which are not separated from disc. Outer surface differently ornamented on both valves. Right valve with only faint commarginal rugae seen on the internal mould, and traces of very faint radial lines present near the margin on some specimens. Left valve densely ornamented by rather irregular but straight radial ribs of at least two orders, which increase in number by intercalation, about 30 primary ribs counted at the margin. Rib tops rounded and low, intervals flat and narrow. Very fine commarginal growth-lines are also present on the left valve. Internal surface of both valves smooth. Right valve adductor muscle scar almost circular in shape, placed slightly posterior to mid-length. Other internal characters unknown.

**Dimensions:** In mm.

MLP	Valve	Length	Height
32739-a	holotype	left	6.98 8.68
32730-b	paratype	left	7.08 8.07

32730-e	paratype	left	8.01	7.58
32730-g	paratype	left	4.77	6.40
32725	paratype	right	9.06	8.63
32731-a	paratype	right	6.35	6.65
27760	paratype	right	4.85	4.56
33681	paratype	left	7.21	7.07

**Discussion:** This species can be confidently referred to the Late Triassic-Early Jurassic genus *Asoella*, although the ligamental characters are not completely seen on the material. The poorly differentiated ears on the left valve are similar to those in the Anisian genus *Etalia* BEGG & CAMPBELL (1985), but the left valve ornamentation is stronger in the specimens described and similar to other *Asoella* species shells. *Asoella campbellorum* is comparable with the type species, the Late Triassic *A. confertoradiata* (TOKUYAMA, 1959, pl. 1, figs. 1-6, text-fig. 1; HAYAMI, 1975, pl. 2, figs. 8-9) in shell shape and size, and also in the radial ornamentation pattern with two orders of fine ribs, but the Japanese species has commarginal folds as well, and the ornamentation is equally developed on both valves. *Asoella laevigata* (TOKUYAMA, 1959, pl. 1, figs. 7-10) is easily distinguished because its shell surface is smooth.

WALLER (in WALLER & STANLEY, 2005) doubtfully referred to *Asoella* three left valves from the Ladinian of Nevada (USA), but all of them are less inflated than the species described here, and also clearly differ in ornamentation, being smooth or with sparse radials only. The same characters distinguish the described species from *Asoella* sp. from the Middle Triassic of North Vietnam (KOMATSU *et al.*, 2010, figs. 4.21-23). Only right valves of *Asoella ireneana* (MCLEARN) are known (MCROBERTS, 2011, fig. 26) from the lower Norian of British Columbia, which are larger than *A. campbellorum* and have more conspicuous radial ribs and a different anterior auricle with a shallower byssal notch.

The species here described is distinguished from *A. asapha* (LEANZA, see DAMBORENEA 2002, pl. 9, figs. 1-15, text-fig. 8 f-g), from the Sinemurian-Early Pliensbachian of the Neuquén Basin, by a smaller size and a different ornamentation pattern, lacking the regular commarginal folds of the Early Jurassic species.

This species is the most widely recorded and one of the most abundant in the sections studied, but was not recognized before due to difficulty in collecting good specimens of these very fragile shells. Right and left valves were found in equal proportion, but disarticulated.

#### Superfamily Pectinoidea WILKES, 1810

##### Family Pectinidae RAFINESQUE, 1815

##### ?Genus *Praechlamys* ALLASINAZ, 1972

**Type species:** *Pecten (Chlamys) inaequalternans* PARONA, 1889, from the Triassic of Lombardy, Italy, by original designation.

See discussion of this genus in DAMBORENEA (2002) and

MCROBERTS (2011). The material is tentatively referred to *Praechlamys* pending a revision of this group.

##### *Praechlamys? cf. valoniensis* (DEFRANCE, 1825)

##### Pl. I, figs.14a-b

- cf. 1984. *Chlamys (Chlamys) valoniensis* (DEFRANCE).- JOHNSON, p. 179-185, pl., 9, figs. 1-6 (with further synonymy).  
 1994. *Chlamys (Chlamys) valoniensis* (DEFRANCE).- ABERHAN, p. 40, pl. 19, figs. 7-9.  
 1998. *Chlamys (Chlamys) valoniensis* (DEFRANCE).- ABERHAN, p. 112, pl. 12, figs. 14, 17, 19, 22.  
 2002. *Praechlamys cf. valoniensis* (DEFRANCE).- DAMBORENEA, p. 74-75, pl. 8, figs. 9-15.  
 2004. *Praechlamys cf. valoniensis* (DEFRANCE).- RICCARDI *et al.*, p. 76, fig. 3.t-u.  
 2006. *Chlamys valoniensis* (DEFRANCE).- YIN & MCROBERTS, p. 109, figs. 4.5-4.12.

**Material:** One large fragment of right valve, preserved as internal/external mould (MLP 30825) and several small fragments of shell (MLP 29415, 29417). Some small pieces of shell with radial ornamentation could belong here too (MLP 32723, 32735). This species is also found in Hettangian to early Pliensbachian beds of the same region (cf. DAMBORENEA, 2002).

**Description:** Medium sized right valve, slightly convex, subcircular in outline. Umbonal angle slightly wider than 90°. Anterior and posterior auricles large, of about equal size, clearly separated from disc by deep sutures. Dorsal margin of anterior auricle bearing dorsally projecting spines. Right anterior auricle with wide byssal sinus bearing ctenolium with numerous small teeth. Posterior margin of posterior auricle meeting dorsal line at an obtuse angle. Anterior auricle meeting hinge line and disc at nearly right angles. Disc ornamented by about 30 very fine radial costae separated by wider intervals which bear fine regular commarginal lines. Number of costae increases by intercalation. Anterior auricle with at least 4 radial costae. Apparently no antimarginal ornamentation is present. The internal surface is smooth, with only very faint traces of the primary radials. Internal margin smooth, at least posteriorly.

**Dimensions:** Length of dorsal margin: 17.3 mm, anterior dorsal length: 8.58 mm.

**Discussion:** This species was originally referred to *Chlamys* RÖDING, but this, according to WALLER & MARINCOVICH (1992), is a Cenozoic genus. Taxonomy of Mesozoic Chlamidinae is not yet resolved (see discussion in MCROBERTS, 2011, p. 648), and thus the species here described is provisionally referred to *Praechlamys* since the shells lack strong antimarginal sculpture. Radial costae are fewer than in Hettangian and Sinemurian specimens from the same locality (DAMBORENEA, 2002, pl. 8, figs. 9-15; compare figs. 3.t and 3.u in RICCARDI *et al.*, 2004), intervals are wider and commarginal lines more conspicuous. Also the anterior auricle is

relatively shorter in the material here described. All these differences are well within the observed morphologic variation of similar pectinids (see JOHNSON, 1984). Open nomenclature is used on account of the few specimens available, which have narrower radial costae and more convex right valve than in *P. valoniensis* (as understood by JOHNSON, 1984).

This species has fine commarginal threads intersecting the narrow radial costae similar to the ornamentation in *Agerchlamys* DAMBORENEA, 1993, but it can be distinguished from species of that genus by the equally-sized auricles, lack of antimarginal ornamentation and fewer radial costae. *Agerchlamys inspecta* (KIPARISOVA, in KIPARISOVA *et al.*, 1966, pl. 17, figs. 7-11, pl. 18, figs. 1-2) from the Carnian-Norian of Siberia has a typical *Agerchlamys* ornamentation with more radial ribs. The lack of antimarginal ornamentation also distinguishes this species from similar ones referred to *Lyrioichlamys* SOBETSKI (see discussion in MCROBERTS, 2011).

This species ranges from Late Triassic to Pliensbachian in the river Atuel region (DAMBORENEA, 2002; RICCARDI *et al.*, 2004). *Praechlamys valoniensis* has a similar stratigraphical range in Europe and elsewhere, spanning the Triassic-Jurassic boundary (see for instance IVIMEY-COOK *et al.*, 1999, p. 105, pl. 14, figs. 8-10; YIN & MCROBERTS, 2006, p. 109-110, figs. 4.5-4.12).

### Superfamily Limoidea RAFINESQUE, 1815

#### Family Limidae RAFINESQUE, 1815

#### Genus *Pseudolimea* ARKELL in DOUGLAS & ARKELL, 1932

**Type species:** *Plagiostoma duplicata* J. DE C. SOWERBY, 1827, early Jurassic of Europe, by original designation.

#### *Pseudolimea riccardii* DAMBORENEA n. sp.

#### Pl. I, figs. 15-17

? 1985. *Pseudolimea* sp.- CHONG & HILLEBRANDT, pl. 4, fig. 2-3.

2004. Limidae gen. et sp. indet.- DAMBORENEA in RICCARDI *et al.*, p. 76.

**Material:** Holotype: one almost complete right valve (MLP 32726). Paratype: one crushed left valve and small fragments of external moulds (MLP 29415). Other material: fragments MLP 32715, 32720.

**Derivation of name:** Dedicated to Dr. Alberto C. RICCARDI for his heart and soul devotion to the study of Mesozoic biostratigraphy of South America.

**Diagnosis:** Slightly opisthocline *Pseudolimea* with shallow byssal gape, ornamented by 21-26 radial ribs. Section of ribs and interval V-shaped, intervals with fine radial thread. Auricles small, right anterior auricle with 3 oblique teeth.

**Description:** Small, obliquely ovate shell, moderately inflated, slightly opisthocline, a little longer than high.

Anterior and posterior auricles small but well defined and flat, and not separated from disc by suture. Hingeline short and straight, dorsal length just a little less than one third of total shell length. Umbo broad and placed near the middle of hinge line. No pedal gape, but with a shallow byssal gape below the anterior auricle. Exterior of disc ornamented by 21-26 simple and evenly distributed radial costae, section of costae and of intervals V-shaped but shallow. Some portions of the shell and external moulds show that a very fine radial thread occupies each interspace between costae. Auricle surface, anterior and posterior portions of disc without costae. The anteriormost and posteriormost costae are shallower. The whole shell also bears faint commarginal growth lines, more evident towards the ventral margin. Three oblique pseudotaxodont teeth are seen on the dorsal angle of the right anterior auricle. Other internal characters unknown. **Dimensions:** Holotype, MLP 32726: length: 7.9 mm; height: 6.8 mm; approximate length of dorsal line: 2.5 mm.

**Discussion:** Material from the Rhaetian of northern Chile figured by CHONG & HILLEBRANDT (1985, pl. 4, figs. 2-3) as *Pseudolimea* sp. may belong to this species. The new species is similar to the widely distributed *Pseudolimea naumanni* (KOBAYASHI & ICHIKAWA, 1949, pl. 6, figs. 13-15; NAKAZAWA, 1952, pl. 9, figs. 7-8, pl. 10, fig. 3; KIPARISOVA *et al.*, 1966, pl. 24, figs. 1-7; NEWTON *et al.*, 1987, figs. 22.8-22.11), from the Norian of Japan, Siberia and USA, but the shell is smaller and has more radial ribs. *Pseudolimea chongi* HAYAMI & MAEDA (in HAYAMI *et al.*, 1977, pl. 28, figs. 5-9), from the late Triassic of northern Chile, has larger strongly inflated shells with more distinct secondary ribs. *Lima subdistincta* KIPARISOVA (in KIPARISOVA *et al.*, 1966, pl. 24, figs. 8-14), from the Late Triassic of Siberia, is also nearly orthocline but shells are larger.

*Pseudolimea fida* MARWICK (1953), originally Aratauran from New Zealand, differs by having interspaces of radial ribs covered by fine radial threads, this taxon was later mentioned from two Otapirian localities by BRAITHWAITE (cf. GRANT-MACKIE, 2011), but see also MACFARLAN (1998, fig. 8, table 1), who recorded an un-named taxon for the Otapirian different from *P. fida*, considered exclusively Aratauran.

### Superfamily Ostreoidea RAFINESQUE, 1815

#### Family Gryphaeidae VYALOV, 1936

#### Genus *Liostrea* DOUVILLÉ, 1904

**Type species:** *Ostrea sublamellosa* DUNKER, 1846 (p. 41, pl. 6, figs. 27-30), by original designation.

The type species has a long stratigraphical range (Rhaetian-Sinemurian) and was re-illustrated by STENZEL (1971, fig. J61-1). Shell thickness decreases towards the northern part of its distribution area (Arctic). The genus is characterised by small shells with irregular outline but

tending to be spatulate or slightly crescentic, with large attachment area, orbicular adductor scar and without umbonal cavity nor chomata.

***Liostrea* sp.**  
**Pl. I, figs. 18-19**

1997a. *Liostrea* sp.- DAMBORENEA in RICCARDI *et al.*, p. 231.

1997b. *Liostrea* sp.- DAMBORENEA in RICCARDI *et al.*, p. 579.

2004. *Liostrea* sp.- RICCARDI *et al.*, p. 76, figs. 3.1-m.

**Material:** One internal mould of right valve, almost complete (MLP 27766), one internal mould of left valve (MLP 32734) and several fragments (MLP 27769, 32735, 32736).

**Description:** Shell small, flat to slightly convex, subcircular to pear-shaped and varying from equidimensional to much higher than long. Shell apparently thin. Inner surface smooth, with faint commarginal rugose corrugations. Adductor muscle scar rounded and large, placed close to shell posterior margin. Ligamental area narrow. Attachment area not known. Inner cavity without distinct umbonal cavity. External characters unknown.

**Dimensions:** MLP 32734: length: 17.33 mm; height, 17.60 mm; MLP 27766: length: 12.12 mm, height: 14.73 mm.

**Discussion:** The only species previously referred to *Liostrea* from Triassic beds in South America is *L. cimana* (COX), originally described from Cerro de Pasco in central Perú (COX, 1949) and later mentioned from Punta El Viento, northern Chile (CHONG & HILLEBRANDT, 1985, p. 186). The widespread European species *L. hisingeri* (NILSSON) has a similar shape and size (see IVIMEY-COOK *et al.*, 1999, pl. 13, fig. 7), and the Argentine specimens probably belong to this species group. *Liostrea tibetica* YIN & MCROBERTS (2006, figs. 6.19, 6.22-6.29, 6.30b, 6.31-6.33) also has a very similar shell outline but is more inflated. On the other hand, *L. newelli* NEWTON *et al.* (1987, figs. 29, 30), from Norian beds of Oregon, has a more rounded shell shape.

**Superfamily Trigonioidea LAMARCK, 1819**  
**Family Trigoniidae LAMARCK, 1819**  
**Subfamily Minetrigoniinae KOBAYASHI, 1954**

The species here described belongs to a large group of late Triassic species with trigoniid hinge and trellised ornamentation on the flanks, which have been referred to *Minetrigonia* KOBAYASHI & KATAYAMA, 1938, *Maoritrigonia* FLEMING, 1962, *Perugonia* KOBAYASHI & TAMURA, 1968, or *Myophorignonia* COX, 1952. The discrimination between these genera is difficult and the criteria used have varied widely according to the authors (see KOBAYASHI & ICHIKAWA, 1952; MAEDA *et al.*, 1983; ISHIKAWA *et al.*, 1983; TAMURA & MCROBERTS, 1993; PÉREZ & REYES, 1994). TAMURA & MCROBERTS (1993)

restricted *Myophorignonia* to species with diagonal (pseudo concentric) costae on the anteriormost part of the disc. The group is still in need of a systematic revision.

**Genus *Minetrigonia*? KOBAYASHI & KATAYAMA, 1938**  
**Type species:** *Trigonia hegiensis* SAEKI, 1925, p. 35, from late Triassic of Japan, by original designation.

***Minetrigonia*? *multicostata* (KÖRNER, 1937)**  
**Pl. I, figs. 20-21**

1937. *Myophoria multicostata* KÖRNER, p. 183-184, pl. 12, figs. 3a-b.

1949. *Myophoria multicostata* KOERNER.- COX, p. 25.

1973. *Gruenewaldia multicostata* (KÖRNER).- GEYER, p. 30-31, fig. 9.b.

1997a. *Minetrigonia*? *multicostata* (KÖRNER).- DAMBORENEA in RICCARDI *et al.*, p. 231, fig. 3.5.

1997b. *Minetrigonia*? *multicostata* (KÖRNER).- DAMBORENEA in RICCARDI *et al.*, p. 579.

2004. *Minetrigonia*? *multicostata* (KÖRNER).- RICCARDI *et al.*, p. 76, fig. 3.q.

2008c. *Minetrigonia*? *multicostata* (KÖRNER).- RICCARDI, p. 234, fig. 5th row from top.

**Material:** One fragment of external mould of right valve, showing portion of flank and carina, MLP 27765. Internal moulds of one right and one left valve could also belong to this species, MLP 27766, 27768.

**Description:** The available fragment of external mould belongs to a very small shell and only allows description of part of the external surface. Very high, straight umbonal carina, accompanied by a deep smooth sulcus anteriorly. Flank with nodose radial ribs and commarginal costae, nodes at the intersection of both ornamentation elements arranged to form a lattice pattern. Area with commarginal growth lines only. Escutcheon unknown.

Assuming the internal moulds belong to the same species, they show a clearly opisthogyrous umbo and smooth internal surface, only the posterior carina is marked. A deeply impressed anterior muscle scar is present in one of the moulds, and both show part of strong crenulated schizodont teeth radiating from the umbo.

**Discussion:** All preserved characters support the assignment to *M.?* *multicostata* (KÖRNER). The generic affinities of this species are not clear, particularly because neither the hinge region nor the anteriormost part of the shell are well known. COX (1952) mentioned it in the discussion of his new genus *Myophorignonia*, but stated that, although *Myophoria multicostata* KÖRNER is similar to the type species, its hinge structure is not well known. On the other hand GEYER (1973) referred it to *Gruenewaldia* WÖHRMANN, thus implicitly emphasizing affinities with the Myophoriidae. The ornamentation pattern on the flanks is similar in members of the Minetrigoniinae, but both *Minetrigonia* and *Maoritrigonia* are characterised by a trellised ornament on the area (FLEMING, 1987), which is lacking in *M.?* *multicostata*.

The available fragment is similar to the specimen described as *Maoritrigonia?* sp. by ISHIKAWA *et al.* (1983, pl. 1, figs. 11-13) from the Upper Triassic of Huancavélica, Perú.

This species shares with *Minetrigonia* sp. from Oregon (NEWTON *et al.*, 1987, figs. 47.14-15) and *M. bulunensis* KIPARISOVA from Siberia (in KIPARISOVA *et al.*, 1966, pl. 30, figs. 1-3) the lack of oblique threads on the area, but the ornament on the flanks is quite different.

*Minetrigonia pascoensis* (STEINMANN) from Perú and Chile has oblique ornamentation on the area (JAWORSKI, 1922, pl. 5, fig. 8; STEINMANN, 1929, fig. 56; PÉREZ & REYES, 1977, pl. 3, fig. 12; CHONG & HILLEBRANDT, 1985, pl. 2, figs. 6-9; VILLAVICENCIO & RANGEL, 1987, pl. 1, figs. 2, 4). *M. heslingtonensis* (TRECHMANN, 1918) has a similarly smooth umbonal carina but the antecarinal sulcus is wider and the area ornamentation quite different in this late Triassic New Zealand species (MARWICK, 1953, pl. 4, fig. 7; FLEMING, 1987, pl. 3, figs. 9-16, 19, 21). The ornamentation pattern of the flank is similar in *Myophorigonia heslingtonensis regalis* (MCLEARN) from British Columbia (MCLEARN, 1946, pl. 2, figs. 4-5) but this is much larger.

The material described differs from the type species of *Minetrigonia*, *M. hegiensis* (SAEKI) (see KOBAYASHI & ICHIKAWA, 1952, pl. 3, figs. 4-11, FLEMING, 1987, figs. 9a-d) by a nearly smooth area and more prominent umbonal carina.

#### Superfamily Crassatelloidea FÉRUSSAC, 1822 Family Astartidae D'ORBIGNY, 1844

Although the family Astartidae extends from at least Devonian times to the present, Late Triassic species are very poorly known, despite being present worldwide. Probably for this reason, there is no recent revision of the Triassic representatives of this family and most authors have preferred to refer such incompletely known species to *Astarte* s.l. (as done in previous reports with the material described here). On the other hand, Jurassic species are far better known and several genera are well-characterised, but comprehensive revisions are still lacking (see GARDNER & CAMPBELL, 2002). It is evident that the family diversified around early-middle Jurassic times, but further studies will probably indicate that some of the Jurassic genera range back from Triassic times, as HAUTMANN (2001) demonstrated for *Praeconia*. The material described here does not show details of the hinge, therefore it cannot be referred with certainty to any genus and its relationships remain dubious.

#### ?Genus *Nicaniella* CHAVAN, 1945

**Type species:** *Astarte communis* ZITTEL & GOUBERT, 1861, Late Jurassic of France, by original designation.

#### *Nicaniella?* cf. *incae* (JAWORSKI, 1922) Pl. I, figs. 22-23

- cf. 1922. *Astarte Incae* JAWORSKI, p. 128-130, pl. 5, figs. 12-14.  
cf. 1949. *Astarte incae* JAWORSKI.- COX, p. 29.  
1997a. "*Astarte*" *incae?* JAWORSKI.- DAMBORENEA in RICCARDI *et al.*, p. 231, fig. 3.7.  
1997a. *Tutcheria?* sp.- DAMBORENEA in RICCARDI *et al.*, p. 231.  
1997b. "*Astarte*" *incae?* JAWORSKI.- DAMBORENEA in RICCARDI *et al.*, p. 579.  
2004. "*Astarte*" cf. *incae* JAWORSKI.- RICCARDI *et al.*, p. 76, figs. 3.n-o.  
2004. *Tutcheria* aff. *densestriata* (KÖRNER).- DAMBORENEA in RICCARDI *et al.*, p. 76.

**Material:** One almost complete external mould of both valves closed showing dorsal region and most of shell exterior (MLP 27767), and one complete internal mould of right valve showing hinge (MLP 27768).

**Description:** Shell slightly inequilateral, obliquely subquadrate with pointed prosogyrous umbones. Beaks low, placed slightly anterior to mid-length. Shell moderately inflated, slightly longer than high, with maximum width at mid-length. Exterior ornamented by about 8 regular commarginal folds which are strong posteriorly and disappear towards the anterior margin and ventral region. Ventral region with very regularly spaced commarginal lines. In cross-section folds are steeper towards the umbo and less steep ventrally. On the wider ventral slope of each fold 4 to 6 regular growth lines can be seen. Escutcheon long, deep and limited by a very sharp carina, escutcheon surface smooth. Short deep and narrow nymph. Lunule deep and smooth, limited by a rounded margin. Lunule and escutcheon of similar width. Hinge of right valve with at least one strong triangular tooth (3b?) and a large triangular socket behind it. There are no traces of lateral teeth. Inner shell margin only slightly crenulated. Muscle scars not seen.

**Dimensions:** MLP 27767: length: 6.62 mm, height: about 5 mm, width (both valves): 3.19 mm.

**Discussion:** The available specimens are very similar in shape and size to *Astarte incae* JAWORSKI (1922, pl. 5, figs. 12-14) from the late Triassic of Perú. The only difference from JAWORSKI's figured specimens is that the commarginal folds become obsolete before reaching the ventral margin, but this tendency was already mentioned by JAWORSKI. Similarly, they share the regular growth lines that cover the ventral slopes of the commarginal folds. JAWORSKI (1922, pl. 5, figs. 12a and 14) illustrated and discussed details of the hinge of *A. incae*, which can be interpreted as having a subtrigonal 3b and an obsolete 3a on the right valve, and a strong 2 on the left valve, with 5b, 6b and probably also 4b absent. His figures also show the possible presence of anterior and posterior laterals. The inner ventral margin of the shell is crenulated (JAWORSKI, 1922, pl. 5, fig. 12a), but this is an intraspecific variable character, in some cases related to sexual dimorphism (see GARDNER & CAMPBELL, 2002). Though not definitive, the characters described and figured by JAWORSKI allow the discussion of the generic affinities

of *A. incae*. Species referred to *Nicaniella* CHAVAN (1945) commonly have ventrally fading concentric ornament, well-defined lunule and escutcheon, laminar laterals and lack 3a, but they are usually more inflated and with higher umbo. For these reasons, the species is here tentatively referred to *Nicaniella*. GARDNER & CAMPBELL (2002) provided an emended generic diagnosis of this genus, discussed its relationships and re-illustrated several European Jurassic species. *Astarte* s.s. species differ in important hinge details. From the species included in *Notoastarte* GARDNER & CAMPBELL (2002) this species differs by having an obsolete 3b cardinal, commarginal ornament not regular on the whole shell, with folds of different cross-section, and sharp escutcheon crest. The commarginal folds, not compound, distinguish *N. incae* from *Oxyurax* species (GARDNER & CAMPBELL, 2002, 2007). *Leckhamptonia* COX & ARKELL (1948) species are clearly inequilateral.

There are only few references to this family in the American Late Triassic. *Astarte* sp. from the Norian of Oregon (NEWTON *et al.*, 1987, figs. 58-59) is comparable but has a more subquadrangular outline and concentric ornament more restricted to the area near the umbo. *Astarte andicola* COX (1949, pl. 2, fig. 3), from the Late Triassic of Perú, has a much larger and compressed shell, with truncated posterior margin.

*Astarte* sp. from the latest Triassic of Tibet (YIN & GRANT-MACKIE, 2006, figs. 6.34, 6.36-6.41) has a similar shape and size but more commarginal folds.

### Superfamily Carditoidea FÉRUSAC, 1822

#### Family Palaeocarditidae CHAVAN, 1969

##### Genus *Palaeocardita* CONRAD, 1867

**Type species:** *Cardita austriaca* (= *Cardium austriacum* HAUER, 1853), from the Rhaetian of Tyrol, by original designation.

The genus *Palaeocardita* had a cosmopolitan distribution during the Late Triassic, but it is badly in need of revision.

#### *Palaeocardita* cf. *peruviana* L. COX, 1949

##### Pl. I, figs. 24, 29

- cf. 1949. *Palaeocardita peruviana* COX, p. 31-32, pl. 2, fig. 4.
- cf. 1977. *Palaeocardita peruviana* COX.- HAYAMI *et al.*, p. 214-215, pl. 30, figs. 1-4.
- cf. 1985. *Palaeocardita peruviana* COX.- CHONG & HILLEBRANDT, p. 173, 181, 186, pl. 3, figs. 2-3.
- cf. 1994. *Palaeocardita peruviana* COX.- TAMURA in STANLEY *et al.*, p. 27, figs. 17.13-17.20.
- 1997a. *Palaeocardita peruviana?* COX.- DAMBORENEA in RICCARDI *et al.*, p. 231, fig. 3.2a-b.
- 1997b. *Palaeocardita peruviana?* COX.- DAMBORENEA in RICCARDI *et al.*, p. 579.
- cf. 1997. *Palaeocardita peruviana* COX.- MCROBERTS, p. 175, fig. 3.17.
- 2004. *Palaeocardita* cf. *peruviana* COX.- RICCARDI *et al.*, p. 76, figs. 3.j-k.

- 2008c. *Palaeocardita peruviana?* COX.- RICCARDI, p. 234, figs. 2nd row from top.

**Material:** One almost complete left valve, MLP 27770, partly covered by an epizoan coral. One fragment of external mould also referred to this species: MLP 27762.

**Description:** Medium-sized shell, trapezoidal in outline, slightly inequilateral and very inflated. Shell thick. Umbo only slightly anteriorly displaced from mid-length, prosogyrous, narrow and prominent. All margins evenly rounded, forming an obtuse angulation at the posteroventral corner of the shell, coinciding with a very low umbonal carina. Shell ornamented by at least 16 strong acute radial ribs, narrower and more closely spaced on the anterior part of the shell, separated by V-shaped interspaces. Wide interspaces with conspicuous regular growth-lines, which are convex towards the margin of the shell. The ribs are irregularly nodose. Commarginal growth-lines are sometimes scaly and become nodose in the interception with the radial ribs (Pl. I, fig. 29). Internal shell surface nearly smooth. Hinge and other internal characters unknown.

**Dimensions:** MLP 27770: length: 39.66 mm; height 42.97 mm; width: about 20 mm.

**Discussion:** The reference of these specimens to *Palaeocardita* is doubtful since the hinge region is not known. It is based mainly on the trapezoidal outline of the shell and other details which are present in *P. peruviana* COX. Shape and ornamentation details are close to *P. peruviana* COX from Perú, Chile and Mexico, as figured by COX (1949), HAYAMI *et al.* (1977), CHONG & HILLEBRANDT (1985), TAMURA (in STANLEY *et al.*, 1994) and MCROBERTS (1997), though the umbonal carina seems less pronounced in the Argentinean specimen. The closest species seems to be *P. quadrata* TRECHMANN (1918), from the Carnian of New Zealand [MARWICK, 1953, pl. 6, fig. 20; reproduced by KRISTAN-TOLLMANN, 1987, pl. 2, fig. 6 and referred there to *P. trapezoidalis* (KRUMBECK)].

The peculiar nodose radial ribs intercepted by scaly commarginal ornamentation pattern (Pl. I, fig. 29) is identical in *Palaeocardita iranica* HAUTMANN (2001, pl. 33, figs. 9-15, 17; also in FÜRSICH *et al.*, 2005, pl. 13, fig. 13), from the Upper Triassic of Iran. This species also has a similar shell shape.

Some authors (NEWTON, 1986, pl. 2.1, figs. 12-13) figured specimens assigned to "*Septocardia*" sp. which have an unusual subquadrate outline, but later (NEWTON *et al.*, 1987, fig. 54) referred them to the species *Palaeocardita silberlingi* NEWTON. This species from North America has a more elongated shape than the Argentinean material, with more numerous radial ribs and an anteriorly placed umbo (see also material from Perú illustrated as *Cardita* aff. *benecke* BITTNER in KÖRNER, 1937, pl. 12, figs. 7a-c, included in *P. silberlingi* by NEWTON).

*Palaeocardita* aff. *singulata* HEALEY from Japan (TAMURA, 1990, pl. 1, figs. 17-18) has very similar shape

but fewer radial costae, and *P. globiformis* BOETTGER from Sumatra (KRUMBECK, 1914, pl. 17, fig. 20) has a more distinct umbonal carina.

**Superfamily Cardioidea LAMARCK, 1809**

**Family Cardiidae LAMARCK, 1809**

**Genus *Septocardia* HALL & WHITFIELD, 1877**

**Type species:** *Septocardia typica* HALL & WHITFIELD, 1877, p. 295, from the Norian of North America, by original designation.

COX (in SILBERLING, 1959, p. 60) noted that external and internal characters of *Pascoella* COX, 1949 do not allow distinction from *Septocardia*. KEEN in COX *et al.* (1969) placed this genus within the Cardiidae and considered it to be the ancestral stock in Cardiaceae, but indicated its close affinities with *Palaeocardita*.

***Septocardia peruviana?* (L. COX, 1949)**

**Pl. I, figs. 25-28**

- ? 1937. *Cardita* n. sp., ex aff. *gumbeli* PICHLER- *pichleri* BITTNER.- KÖRNER, p. 190-192, pl. 12, figs. 6a-c.
- ? 1949. *Pascoella peruviana* sp. nov. COX, p. 35-36, pl. 1, figs. 9, 12-15; ?pl. 2, fig. 5.
- ? 1977. *Septocardia peruviana* (COX).- HAYAMI *et al.*, p. 215-217, pl. 29, figs. 8-10.
- ? 1969. *Septocardia typica* HALL & WHITFIELD.- KEEN in COX *et al.*, figs. E85.1a-f (only) [*non* HALL & WHITFIELD, 1877]
- ? 1985. *Septocardia peruviana* (COX).- CHONG & HILLEBRANDT, p. 173, 174, 177, 181, 186, pl. 3, figs. 4-6.
- 1997a. *Septocardia* cf. *peruviana* (COX).- DAMBORENEA in RICCARDI *et al.*, p. 231, fig. 3.6.
- 1997b. *Septocardia* cf. *peruviana* (COX).- DAMBORENEA in RICCARDI *et al.*, p. 579.
- cf. 2002. *Septocardia* cf. *S. peruviana* (COX, 1949).- MCROBERTS in MCROBERTS & BLODGETT, p. 62, pl. 2, figs. 9-14.
- 2004. *Septocardia peruviana?* (COX).- RICCARDI *et al.*, p. 76.
- ? 2004. *Septocardia?* sp.- RICCARDI *et al.*, p. 76, fig. 3p.
- 2008c. *Septocardia* cf. *peruviana* (COX).- RICCARDI, p. 234, fig. last row from top.

**Material:** Several external, internal and composite moulds of incomplete valves, (MLP 27766 to 27769, 32735, 32737) referred to pre-Marshi beds and three isolated valves (MLP 29416, 32739), from the Marshi-Crickmayi Zone.

**Description:** Shell small, slightly inequilateral, suborbicular in outline, nearly as long as high and strongly inflated. Young shells higher than long, large shells slightly longer than high. Umbo subcentral and prominent. Surface ornamented with about 10-15 angular radial ribs separated by V-shaped intervals. Radial ribs are more numerous on the posterior half of the shell

surface. Inner surface of shell smooth with crenulated margin.

**Dimensions:** MLP 29416a: length: 20.22 mm; height: 19.20 mm; width (one valve): about 10 mm. MLP 29416b: length: 10.91 mm, height: 12.77 mm, width: 5.89 mm.

**Discussion:** This species has a very wide geographical distribution in western America, from probably Alaska (MCROBERTS in MCROBERTS & BLODGETT, 2002), Nevada (SILBERLING, 1959), and Perú (KÖRNER, 1937; COX, 1949) to Chile (HAYAMI *et al.*, 1977; CHONG & HILLEBRANDT, 1985) and now probably also Argentina. The material described here agrees in every detail with the specimens from the Domeyko range in northern Chile (HAYAMI *et al.*, 1977), but is very fragmentary and thus difficult to compare with well-preserved specimens.

*Cardita viligensis* KIPARISOVA from northern Siberia (in KIPARISOVA *et al.*, 1966, pl. 35, figs. 4-6) is probably a *Septocardia*, though its hinge region is not well known. It is similar to the species here described in shape and size, but ornamentation is different, with strong commarginal lamellae.

**Superfamily Pholadomyoidea KING, 1844**

**Family Pholadomyidae KING, 1844**

**Genus *Pholadomya* G.B. SOWERBY, 1823**

**Type species:** *Pholadomya candida* G.B. SOWERBY, 1823, living near the Virgin Islands, subsequent designation by GRAY, 1847.

***Pholadomya (Pholadomya) cf. ambigua***

**(J. SOWERBY, 1819)**

**Pl. I, figs. 30-31**

cf. 1819. *Lutraria ambigua* SOWERBY, p. 48, pl. 227.

**Material:** Two almost complete specimens with both valves closed, preserved as steinkerns, MLP 32728 and 32729.

**Description:** Shell medium sized for genus, equivalve and inequilateral. Valves with suborbicular margin, a little longer than high, well inflated. Wide umbos placed slightly anterior to midlength. The whole shell surface bears commarginal irregular rugae and about ten very faint but nearly straight radial ribs in the central portion of each valve. These ribs are more evident in the umbonal region and fade away towards the ventral margin. The anteriormost 3 ribs are more separated than the posterior ones. Anterior and posteriormost regions of the shell are ribless. No anterior gape, siphonal gape narrow. The specimens do not show muscle scars or other internal features, and the shell is not preserved and thus it is impossible to describe details of its surface and microstructure.

**Dimensions:** MLP 32728: length: 40.20 mm; width: 25.78 mm. MLP 32729: height: 22.90 mm; width: 18.44 mm.

**Discussion:** The specimens described here have a similar shape and ornamentation pattern as *Pholadomya ambigua* (J. SOWERBY) from the Early Jurassic of Europe (J. SOWERBY, 1819; WATERHOUSE, 1969, fig. 3), but in the European species the umbo has an anterior position. This species has also been repeatedly mentioned from the Americas (see discussion in DAMBORENEA & GONZÁLEZ-LEÓN, 1998).

*Pholadomya castellanensis* D'ORBIGNY (THEVENIN, 1907, p. 96, pl. 14, figs. 15-17), from the Sinemurian of France, has a similar ornamentation pattern but the umbones are more anteriorly placed. The specimens here described are very similar to the Early Jurassic *P. oretiensis* (CAMPBELL & GRANT-MACKIE, 1995, fig. 2A-H) from New Zealand, they only differ by having less prominent ribs and shorter shells.

#### Phylum Brachiopoda (by M.O. MANCENIDO)

For the suprageneric classification of brachiopods we follow WILLIAMS *et al.* (2002, 2006), who in the case of spire-bearers adopted the scheme by CARTER *et al.* (1994), rather than DAGYS' (1996).

#### Order Spiriferinida IVANOVA, 1972

#### Superfamily Spondylospiroidea HOOVER, 1991

#### Family Spondylospiridae HOOVER, 1991

#### Subfamily Spondylospirinae HOOVER 1991

#### Genus *Zugmayerella* DAGIS 1963

**Type species:** *Spiriferina koessenensis* ZUGMAYER, 1880, from the Rhaetian Kössen Fm. of Austria, by original designation.

#### *Zugmayerella* ? cf. *koeneri* SANDY, 1994

#### Pl. II, figs. 1a-c

- 1997a. *Zugmayerella* ? cf. *koeneri* SANDY.- MANCENIDO in RICCARDI *et al.*, p. 231, 233, figs. 3.3a-c  
 1997b. *Zugmayerella* ? cf. *koeneri* SANDY.- RICCARDI *et al.*, p. 579.  
 1998. *Zugmayerella* ? cf. *koeneri* SANDY.- DAMBORENEA & MANCENIDO, p. 12.  
 2002. *Zugmayerella* ? cf. *koeneri* SANDY.- MANCENIDO, p. 180, 184, figs. 6.1.b,d.  
 2004. *Zugmayerella* ? sp. cf. *koeneri* SANDY.- MANCENIDO in RICCARDI *et al.*, p. 76, figs. 3e-g.  
 2008c. *Zugmayerella* ? cf. *koeneri* SANDY.- RICCARDI, p. 234, figs. 3rd row from top.

**Material:** A somewhat deformed internal mould of ventral valve (MLP 27763).

**Description:** Medium sized shell, with straight hinge line apparently shorter than maximum width and with rounded shoulders; ventral valve nearly pyramidal; interarea relatively high, gently curved, apsa- to catacline; ribbing coarse, sharply subangular: 3-4 plicae on each lateral slope, flanking the well-developed, unribbed, subparabolic to rounded, ventral median

sulcus (2-3 successive flank costae are contained along the commissure in an interval equal to the width of the uniplication). Ventral median septum well developed, longer than midlength; neither denticulate hinge line, nor "washboard" structure could be observed, due to deficient preservation.

**Dimensions:** MLP 27763: maximum length: [20.6] mm ( $\approx$ 22.0 mm); maximum width: [28.7] mm ( $\approx$ 40.0 mm); ventral thickness: 13.5 mm; height of uniplication: 8.5 mm; width of uniplication: 13.0 mm.

**Discussion:** One of the most closely related species is the Norian-Rhaetian *Z. koeneri* SANDY, which has a similar size range, costation pattern and overall proportions; however, material illustrated from central to northern Peru (SANDY, 1994, p. 107-108, pl. 2, figs. 11-20; KÖRNER, 1937, p. 165-167, pl. 11, figs. 2a-e, 3a-d) as well as from northern Chile (CHONG & HILLEBRANDT, 1985, p. 196, 197, pl. 1, figs. 16-18) consistently differ in their almost catacline interarea and more angular shoulders; therefore, the tentative identification advanced initially for the Argentinean form is maintained with reservations. Another extremely similar species is recorded in the late Norian-Rhaetian (late Warepan-Otapirian) of New Zealand and New Caledonia (CAMPBELL, 1990, 1991). *Zugmayerella taringaturaensis* CAMPBELL agrees well in overall size, shape, and form of the uniplication, except that ribbing on its flanks appears somewhat denser and less sharp than in the Andean material (cf. CAMPBELL, 1991, figs. 4-34, but notice figs. 31-32 in particular).

*Z. uncinata* (SCHAFHÄUTL) is recorded from mainly Rhaetian and Norian, even Liassic deposits (though this latter needs confirmation) over most of southern Europe, up to Iran and western USA (Luning Fm. of Nevada), is another species akin to ours in size, proportions and coarse ribbing style, but it has distinctive, more angular, costae, and subtriangular uniplication (see for instance, ZUGMAYER, 1880, pl. 3, figs. 1, 6; TRAUTH, 1909, pl. 1, fig. 1; DOUGLAS, 1929, text-figs. 1-4; DAGIS, 1963, pl. 11, figs. 7-9, pl. 13, fig. 5; PEARSON, 1977, pl. 2, figs. 6-10; STANLEY, 1979, pl. 8, figs. 10-12; SANDY & STANLEY, 1993, pl. 1, figs. 11-20; SULSER, 1999, text-fig. p. 120).

The type species of the genus, *Z. koessenensis* (ZUGMAYER) is known from the Norian and Rhaetian of the northern Alps, eastern Europe up to the Caucasus-Crimea (e.g. ZUGMAYER, 1880, pl. 3, figs. 2, 3, 13; DAGIS, 1963, pl. 13, figs. 1-4; PEARSON, 1977, pl. 2, figs. 1-2; SIBLIK, 1988, pl. 3, fig. 5), but it disagrees in terms of its higher interarea, narrower umbonal angle and median fold, and denser ribbing on lateral slopes.

Two Chinese species are clearly distinguishable in having a wider sulcus, finer flank costae and narrower umbonal angle, in addition our material further differs from them because its interarea is taller than that of *Z. yuelianpingica* JIN & FANG but lower than that of *Z. hemipyramida* SUN (cf. CHING & FENG [= JIN & FANG], 1977, pl. 2, figs. 22-32, from late Triassic of western Yunnan, vs. SUN, 1981, pl. 8, figs. 15-18, and JIN *et al.*, 1985, pl. 16, figs. 23-26 from the Norian of Xizang [=Tibet]).

Two species from Siberia are readily separable, *Z. inaequiplicata* DAGIS, from the Norian of Chukotka-Kamchatka, bears much coarser and sharper plications, whereas *Z. eurea* DAGIS, from the Norian-Rhaetian of Chukotka-Okhotsk coast, bears a flat-topped dorsal fold and more densely ribbed slopes (cf. DAGIS, 1965, pl. 15, figs. 1-3, vs. pl. 14, figs. 3-7).

Most recently, a new species *Z. bogalica* has been reported and described by MACFARLAN *et al.* (2010, 2011, text-figs. 13-14) from the late Triassic (probably Carnian) Bogal Fm, of Misool (Indonesia), which differs in having sharper, more numerous costae and a more pyramidal ventral valve.

### Superfamily Pennospiriferinoidea DAGIS, 1972

#### Family Lepismatinidae XU & LIU, 1983

#### Subfamily Pseudocyrtininae CARTER, 1994

#### Genus *Bolilaspirifer* SUN, 1981

**Type species:** *Bolilaspirifer jomdaensis* SUN, 1981, from the Late Triassic of Jomda County, Xizang [=Tibet], China, by original designation.

#### *Bolilaspirifer riccardii* MANCENIDO n. sp.

#### Pl. II, Figs. 2a-g

**Holotype:** A complete bivalved steinkern MLP 28800.

**Derivation of name:** Dedicated to Dr. Alberto C. RICCARDI, mentor and leader, for his lasting substantial contributions to Andean Mesozoic stratigraphy and palaeontology.

**Diagnosis:** A *Bolilaspirifer* with shell nearly twice as large as the type-species; with a subangular to rounded dorsal central uniplication, and lateral slopes bearing 5-6 plicae each; umbonal angle wider than 90°, apsacline ventral interarea somewhat but not quite approaching the catacline condition.

**Description:** Medium sized shell, transversely subpentagonal, with straight hinge line a bit shorter than maximum width and with rounded shoulders; strongly ventribiconvex, with evenly convex dorsal valve and nearly pyramidal ventral valve; interarea relatively high, weakly apsacline, flattish to slightly concave, divided by a high, open, narrow-based, triangular delthyrium; ribbing coarse, subangular to blunt: 5-6 plicae on each lateral slope, flanking the well-developed, unribbed, subtriangular to rounded, dorsal median fold (3-4 successive flank costae are contained along the commissure in an interval equal to the width of the uniplication). Dental plates run along the axis of the sulci immediately bounding the ventral median sulcus, and are partly fused by callus (near the apex), to intervening ventral median septum (see Pl. II, fig. 2e), which is well developed, shorter than midlength; cardinal process is simple, boss-like (Pl. II, fig. 2f).

**Dimensions:** MLP 28800: maximum length: 24.0 mm; maximum width: 29.6 mm; total thickness: 18.9 mm;

dorsal length: 19.6 mm; height of uniplication: 6.0 mm; width of uniplication: 11.0 mm; height of interarea: 10.9 mm; umbonal angle: 110°.

**Discussion:** Proposal of a new species is justified on the basis of the peculiar combination of characters displayed by the excellently preserved material. From inspecting artificial latex casts no evidence of pustulose microornament could be detected (albeit sampled area was very reduced). Genuine absence of microornament would preclude further comparisons with the externally similar genus *Tulungospirifer* CHING & SUN (in CHING *et al.*, 1976, pl. 7, fig. 23-40), coming from Mid Triassic deposits in Tibet (near Mt. Everest = Jolmo Lungma). Within pseudocyrtinines, greater affinities are apparent with *Bolilaspirifer* SUN (1981), from late Triassic strata, also from Tibet (= Xizang), rather than with *Pseudocyrtina* DAGIS from the Norian of the Caucasus, which features a more pyramidal ventral valve, with narrower umbonal angle, taller interarea, and sharper costae (cf. DAGIS, 1963, pl. 13, figs. 6-7; CARTER in WILLIAMS *et al.*, 2006, figs. 1285.1a-e).

The material from Mendoza differs mainly from *B. jomdaensis* SUN (the type species of *Bolilaspirifer*), because the latter besides being less transverse in dorsal view, bears more angular costae and almost catacline interarea (SUN, 1981, pl. 7, figs. 14-18; CARTER in WILLIAMS *et al.*, 2006, figs. 1285.3a-f).

### Order Rhynchonellida KUHN, 1949

#### Superfamily Rhynchonelloidea D'ORBIGNY, 1847

#### Family Rhynchonellidae D'ORBIGNY, 1847

#### Subfamily Piarorhynchiinae SHI & GRANT, 1993

#### Genus *Sakawairhynchia* TOKUYAMA, 1957

**Type species:** *Sakawairhynchia tokomboensis* TOKUYAMA, 1957, p. 126, from the Carnian of Shikoku, Japan, by original designation.

#### *Sakawairhynchia marokopana* MACFARLAN, 1992

#### Pl. II, figs. 3a-5d

1953. *Rhynchonella* sp.- DROT, p. 99, pl. 22, figs. 4a-c.

1992. *Sakawairhynchia marokopana* new species.- MACFARLAN, p. 114-118, figs. 9.5a-e, 9.6, pl. 10, figs. 1-20, pl. 11, fig. 1-15.

**Material:** Two steinkerns and an internal mould of ventral valve, MLP 33673, 33674 and 33675.

**Description:** Large, transversely subpentagonal, depressed dorsibiconvex, shells; dorsal valve with long smooth stage, flat-topped dorsal median fold (somewhat wider than half width of valve), broad convex lateral slopes, and gently convex anterior margin; coarsely paucicostate, marginal plicae few, broad, subangular to rounded (usually two on each flank) with a bi- to tridentate broad uniplication; both valves ornamented with sparse commarginal growth lines of variable strength, otherwise smooth; ventral beak slightly obtuse,

with broadly rounded tip and blunt beak ridges. Short, thick, dental plates, fairly divergent anteriorly.

**Dimensions:** MLP 33673: maximum length: [24.1] mm; maximum width: 28.3 mm; total thickness: [14.0] mm (diminished by dorsoventral compaction); dorsal length: [21.9] mm; height of uniplication: 11.0 mm; width of uniplication: 20.0 mm; MLP 33674a: dorsal (=maximum) length: [22.5] mm; maximum width: 27.3 mm; total thickness: [10.6] mm (diminished by dorsoventral compaction); height of uniplication: 6.5 mm; width of uniplication: 15.6 mm; MLP 33675a: maximum length: [20.9] mm; maximum width: 25.3 mm.

**Discussion:** The species was described from New Zealand and New Caledonia, where it occurs in Otapirian (Rhaetian) deposits (albeit extending into slightly older and younger strata), and the original degree of variability finds a nearly perfect match in the Argentinean specimens available. Thus, bidentate forms (Pl. II, fig. 5) are almost indistinguishable from those illustrated by MACFARLAN (1992, pl. 10, figs. 1-4, 8-11, 18-20, pl. 11, figs. 3-4, which include the holotype), and tridentate forms (Pl. II, fig. 3) are likewise strictly comparable with MACFARLAN's (1992, pl. 10, figs. 7, 14-17, pl. 11, figs. 1-2, 5-6, 11-13). Observed similarities of the Andean specimens to other paucicostate late Triassic rhynchonellides illustrated in the literature appear less striking (cf. DAGIS, 1965, pls. 4-8; STANLEY, 1979, pl. 8).

***Sakawairhynchia* ? cf. *mokauensis* MACFARLAN, 1992  
Pl. II, figs. 6a-c**

cf. 1992. *Sakawairhynchia mokauensis* new species.-MACFARLAN, p. 126-127, figs. 9.5j-k, pl. 12, figs. 10-17.

**Material:** Flattened steinkern (with beak missing) plus its partial external mould, MLP 33676a-b.

**Description:** Transversely elliptical to subpentagonal, flat (exaggerated by compaction?), rectimarginate, non-costate, ornamented only with moderately closely-spaced stepped (but non foliaceous), growth lamellae. Internal characters unknown.

**Dimensions:** MLP 33676a: dorsal (=maximum) length: [12.9] mm; maximum width: 13.6 mm; total thickness: [2.4] mm (strongly diminished by dorsoventral compaction).

**Discussion:** The single, distorted specimen shows a remarkable resemblance to the genuine *S. mokauensis*, as illustrated by MACFARLAN (1992, pl. 12, figs. 10-11, 14-15, in particular) from the Otapirian (Rhaetian) of Awakino Gorge, New Zealand. The possibility that perhaps it might correspond to a crushed athyrid (?) instead, was also considered (and it could not be totally ruled out).

**Order Athyridida BOUCOT, JOHNSON  
& STATON, 1964**

**? Superfamily Athyridoidea DAVIDSON, 1881**

**Athyridoidea ? gen. et spp. indet.**

**Pl. II, figs. 7-11b**

**Material:** MLP 28801a-b and MLP 33677-33680.

**Description:** Shells transversely to elongate elliptical in outline, mostly smooth, showing only commarginal growth lines, incipiently lamellose sometimes. The few visible internal characters, such as presence of dorsal median ridge (Pl. II, fig. 8b) or dorsal adductor muscle scars (Pl. II, fig. 11a-b) appear insufficiently diagnostic.

**Dimensions:** MLP 33678a-b: maximum length: [22.1] mm ( $\approx 23$  mm); maximum width: 18.8 mm; total thickness: [2.0] mm (strongly diminished by dorsoventral compaction); dorsal length: [19.6] mm ( $\approx 20.5$  mm). MLP 33677a: maximum length: 15.4 mm; maximum width: [12.5] mm (diminished by lateral compaction:  $\approx 13.5$  mm). MLP 28801a: dorsal (= maximum) length: 19.0 mm; maximum width: [19.0] mm.

**Discussion:** The scanty material and its imperfect, deformed, preservation hinder an accurate identification (actually, more than one taxon may be involved). Overall, specimens vaguely resemble certain Clavigerinae, like *Oxycolpella*, or other (cf. MARWICK, 1953; DAGIS, 1963, pls. 15-20; DAGIS, 1965, pl. 24; PEARSON, 1977, pls. 3, 5; CHING *et al.*, 1976, pls. 5, 6; CHING *et al.*, 1979, pls. 47, 51; CHONG & HILLEBRANDT, 1985, pl. 1, figs. 11-12; KRISTAN-TOLLMANN, 1986, figs. 6-7; SIBLIK, 1988, pl. 1); yet the chances that some of them could even turn up having terebratulide affinities cannot be dismissed.

**DISCUSSION**

**Biostratigraphy**

The age of these faunas was discussed in RICCARDI *et al.* (1997a) on the basis of the bivalves and brachiopods, and by RICCARDI & IGLESIA LLANOS (1999) for the level with *Choristoceras* cf. *marshi*. RICCARDI *et al.* (2004), RICCARDI (2008c), and DAMBORENEA *et al.* (2009) provide an assessment of available evidence.

JAWORSKI (1922) and STEINMANN (1929) referred their faunas from Perú, which include some species here recognised, to the Norian, on account of their occurrence some 30-40 m above a bed containing unmistakable Norian cephalopods. The fauna from Nevado de Acrotambo in Perú, to which our fauna has many similarities, was originally compared with the Trias of St. Cassian-Raibl by KÖRNER (1937), i.e. early Late Triassic in age. KÖRNER based this assumption on the stratigraphical distribution of bivalves, gastropods and brachiopods, since he did not have any cephalopods. COX (1949) later described very similar assemblages from central Perú (Cerro de Pasco, near Junín) and assigned them to the Norian, arguing that equally strong arguments to those of KÖRNER could be put forward to support an age younger than Carnian. He concluded that the age of

Cerro de Pasco fauna “must be very high in the Trias and most probably Norian” (cf. also HAAS, 1953).

Some of the bivalves and brachiopods described here are significant in the discussion of the age of the Arroyo Malo assemblages. Among the bivalves, at the generic level *Cassianella*, *Minetrigonia*, *Palaeocardita* and *Septocardia* do not extend up beyond the Rhaetian worldwide (ROS, 2009; ROS *et al.*, in press). Most relevant, *Otapiria* cf. *dissimilis* is very close (if not the same) as a species distinctive of the Otapirian (Rhaetian) of New Zealand and New Caledonia (J. CAMPBELL, 1956, 1990, 1997; MACFARLAN, 1998; H. CAMPBELL, 2004; MCROBERTS, 2010; GRANT-MACKIE, 2011).

In the Atuel River area, very few bivalves have been found around the Triassic-Jurassic boundary and in earliest Hettangian strata. After the boundary beds, the first bivalves appear in Hettangian levels with ammonites of the *Kammerkarites bayoensis* Zone, separated by about 150 m of sediments from the last Triassic bivalve recorded so far. The only bivalve species which appears both below and above the boundary is *Praechlamys?* cf. *valoniensis* (DEFRANCE), which was found around the level with *Choristoceras* cf. *marshi* and extends up to Early Pliensbachian *Eoamalthus meridianus* Zone (DAMBORENEA, 2002). This pectinoid species has a similar stratigraphical range across the boundary in other parts of the world as well (see for instance JOHNSON, 1984; MCROBERTS *et al.*, 1997; IVIMEY-COOK *et al.*, 1999; YIN & MCROBERTS, 2006). All other bivalve species are restricted either to Triassic or Jurassic deposits. Besides *Praechlamys?* cf. *valoniensis* (DEFRANCE), the earliest Jurassic bivalve faunas at Arroyo Malo contain instead: *Palmoxytoma* cf. *cygnipes* (YOUNG & BIRD), *Camptonectes?* cf. *subulatus* (MÜNSTER), *Entolium?* sp., *Gryphaea* sp., undetermined oysters, *Plagiostoma?* sp., *Pinna* sp., Astartidae gen. et sp. indet., and *Pleuromya* sp. (see DAMBORENEA, 2002).

Among the brachiopods, *Sakawairhynchia marokopana* is by far the commonest and most widely distributed Otapirian rhynchonellide in New Zealand (at both Kawhia and Southland synclines) and New Caledonia (MACFARLAN, 1992: 116; CAMPBELL, 1997, p. 231), it may also occur in northern Chile (MANCENIDO, 2002, p. 180). Although its full range starts late in the Warepan (late Norian), and ends in the earliest Aratauran (early Hettangian), the co-occurrence with *S. mokauensis* in the Ngutunui Fm. appears as a typical Rhaetian (late Otapirian) feature (MACFARLAN, 1992, fig. 3.3, 1998, fig. 8, table 1).

In addition, the known vertical distribution of the genera *Zugmayerella* (Carnian to earliest Jurassic?) and *Bolilaspirifer* (late Triassic) are compatible with the age denoted by the rhynchonellides. Thus far, the brachiopod fauna has been informally referred to as the “*Zugmayerella* faunule”, yet, as a result of the present study, it seems preferable to choose, as name givers, taxa that are found *in situ* and that encompass the full range. Therefore, it is here proposed to formally recognize a

biostratigraphic unit to be called the *Sakawairhynchia-Bolilaspirifer* Assemblage Zone.

### Palaeoecology

The fauna described here contains both shallow infaunal and epifaunal suspension feeders and at least one species of deposit-feeding bivalve (*Palaeoneilo* cf. *elliptica*). *Cassianella* was probably reclining or epibyssate (FÜRSICH & WENDT, 1977; LAWS, 1982; NEWTON *et al.*, 1987), while *Praechlamys?* and *Otapiria* were epibyssate bivalves. It is interesting to note that right valves of *Asoella campbellorum* n. sp. are often associated with drift wood debris or fragments of ammonite shells, which could have been suitable hard substrates for attachment of these small epibyssate shells. They sometimes appear forming small clusters near these substrate pieces, and thus a pendant habit on floating objects is suggested. *Liostrea* was a permanently cemented oyster. *Minetrigonia?*, *Nicaniella?*, *Palaeocardita* and *Septocardia* were all shallow burrowers (NEWTON *et al.*, 1987), whereas *Pholadomya* was a deep burrower.

The Atuel river fauna is relatively poor in epifaunal bivalve species, and this is in agreement with world-wide trends at the same age range (ROS, 2009; ROS *et al.*, 2011, fig. 3A).

In New Zealand, both species of *Sakawairhynchia* (*S. marokopana* and *S. mokauensis*) occur in rhynchonellide assemblages that have been regarded as representatives of offshore facies (MACFARLAN, 1992, table 4.1).

With regard to the clear Maorian and Pacific palaeobiogeographical affinities of this fauna, the reader is referred to our previous contributions DAMBORENEA & MANCENIDO (1998), MANCENIDO (2002, 2010) and DAMBORENEA *et al.* (2009).

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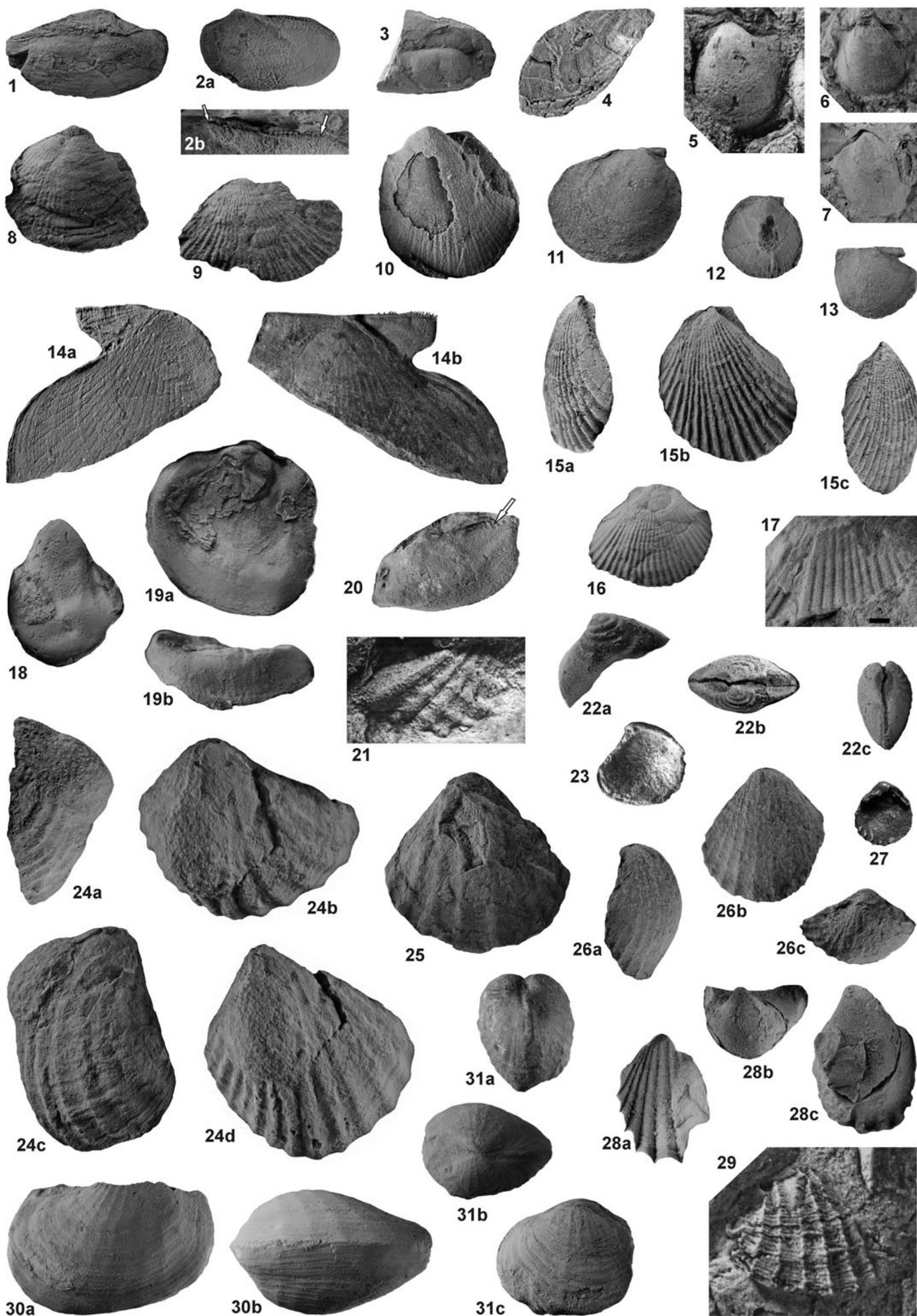
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### Plate I

Late Triassic bivalves from Arroyo Malo Formation, Mendoza Province, Argentina.

- Fig. 1: *Bivalvia* get. et sp. indet. (cf. "*Laternula*" sp.), MLP 32718, composite mould of both valves, right lateral view (x1).
- Fig. 2: *Palaeoneilo* cf. *elliptica* (GOLDFUSS), MLP 32733, internal mould of left valve; **a**: lateral (x2.5) and **b**: oblique dorsal view showing hinge teeth (x4).
- Fig. 3: *Solemya*? sp., MLP 32717-a, dorsal view of specimen with both valves open (x2).
- Fig. 4: *Modiolus*? sp., MLP 32727, crushed right valve, composite mould (x1.5).
- Fig. 5-7: *Cassianella* cf. *peruana* KÖRNER, internal moulds of left valves, **5**, MLP 27766a (x2.5); **6**, MLP 27765 (x2.5); **7**, MLP 27766b (x1.5).
- Fig. 8-9: *Otapiria* cf. *dissimilis* (COX), **8**, MLP 32724, right valve (x2); **9**, MLP 27764, left valve (x2).
- Fig. 10-13: *Asoella campbellorum* DAMBORENEA n. sp., **10**, holotype, MLP 32730-a, left valve (x4); **11**, MLP 32725, paratype, internal mould of right valve (x3); **12**, MLP 32731-a, internal mould of right valve (x3); **13**, MLP 27760, paratype, internal mould of right valve (x3).
- Fig. 14: *Praechlamys*? cf. *valoniensis* (DEFRANCE), MLP 30825, right valve (x2), **a**: external, and **b**: internal mould.
- Fig. 15-17: *Pseudolimea riccardii* DAMBORENEA n. sp., **15**, holotype, MLP 32726, **a**: anterior, **b**: lateral, and **c**: posterior views of right valve (x3); **16**, paratype, MLP 29415, lateral view of left valve (x3); **17**, detail of fragment of external mould showing ornamentation, MLP 29415 (x4).
- Fig. 18-19: *Liostrea* sp. (all x2), **18**, internal mould of right valve, MLP 27766; **19**, left (?) valve internal mould, MLP 32734, **a**: lateral, and **b**: ventral views.
- Fig. 20-21: *Minetrigonia*? *multicostata* (KÖRNER) (all x3); **20**, postero-dorsal oblique view of right valve internal mould showing crenulated tooth (arrow), MLP 27766; **21**, latex cast of right valve, MLP 27765.
- Fig. 22-23: *Nicaniella*? cf. *incae* (JAWORSKI) (all x3), **22**, latex cast MLP 27767, **a**: left lateral, **b**: dorsal and **c**: anterior views; **23**, latex cast of right valve internal mould, MLP 27768.
- Fig. 24, 29: *Palaeocardita* cf. *peruviana* COX, **24**, left valve MLP 27770 (x1), **a**: anterior, **b**: dorsal, **c**: posterior and **d**: lateral views; **29**, latex cast of external mould of left (?) valve to show ornamentation, MLP 27762 (x2).
- Fig. 25-28: *Septocardia peruviana*? (COX) (all x2), **25**, left valve lateral view, MLP 29416a; **26**, small right valve composite mould MLP 29416b in **a**: anterior, **b**: lateral and **c**: dorsal views; **27**, latex cast of internal moulds, MLP 32739; **28**, right (?) valve, MLP 27769, **a**: partial external mould, **b**: dorsal, and **c**: lateral views of internal mould.
- Fig. 30-31: *Pholadomya* (*Pholadomya*) cf. *ambigua* (J. SOWERBY) (all x1); **30**, MLP 32728, **a**: right lateral, **b**: ventral views; **31**, MLP 32729 in **a**: anterior, **b**: dorsal, and **c**: left lateral views.

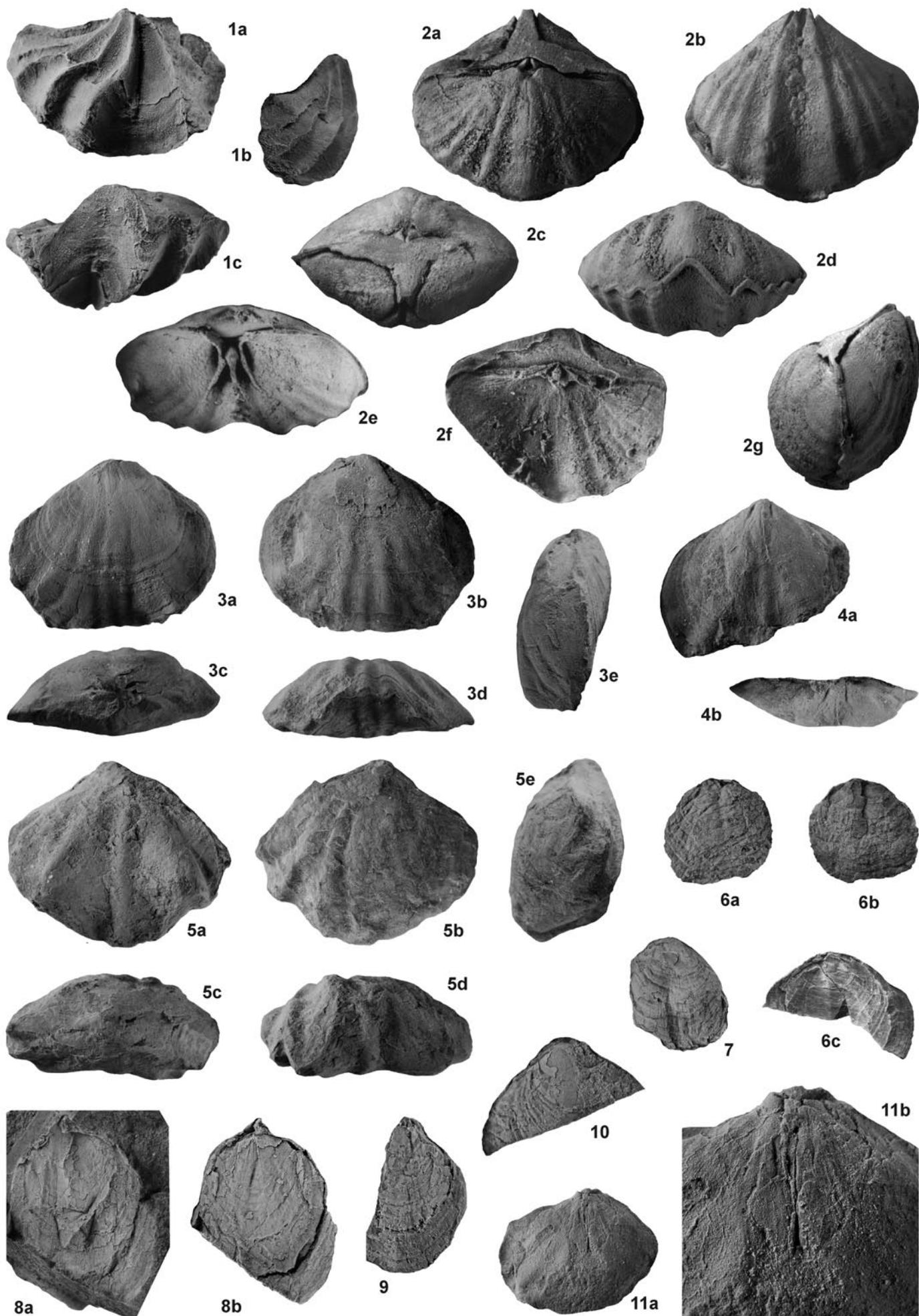


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## Plate II

Late Triassic brachiopods from Arroyo Malo Formation, Mendoza province, Argentina (all x1.5, except 11b = x4).

- Fig. 1: *Zugmayerella* ? cf. *koernerii* SANDY, **a**, ventral, **b**, lateral, and **c**, anterior, views of internal mould MLP 27763.
- Fig. 2: *Bolilaspirifer riccardii* MANCENIDO n. sp., holotype, **a**, dorsal, **b**, ventral, **c**, posterior, **d**, anterior, **g**, lateral, views of steinkern MLP 28800, **e**, ventral interior, and **f**, dorsal interior (showing cardinalia) from latex casts of same specimen.
- Fig. 3-5: *Sakawairhynchia marokopana* MACFARLAN, **3a**, ventral, **3b**, dorsal, **3c**, posterior, **3d**, anterior, and **3e**, lateral, views of steinkern MLP 33674a, **4a**, ventral, and **4b**, posterior, views of internal mould MLP 33675a, **5a**, ventral, **5b**, dorsal, **5c**, posterior, **5d**, anterior, and **5e**, lateral, views of steinkern MLP 33673.
- Fig. 6: *Sakawairhynchia* ? cf. *mokauensis* MACFARLAN, **6a**, dorsal, and **6b**, ventral, views of steinkern MLP 33676a, and **6c**, its external mould MLP 33676b.
- Fig. 7-11: *Athyridoidea* ? gen. et sp. indet., **7**, ventral view of internal mould MLP 33677a, **8a**, ventral view of external mould MLP 33678b, **8b**, dorsal view of steinkern MLP 33678a, **9**, dorsal view of internal mould MLP 33679, **10**, ventral view of internal mould MLP 33680, **11a**, dorsal view of internal mould MLP 28801a, **11b**, close up of muscle scars on same specimen.



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