

BRACHIOPODS FROM THE RÍO DEL PEÑÓN FORMATION, RÍO BLANCO BASIN, UPPER PALAEOZOIC OF ARGENTINA

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ABSTRACT

This paper reviews the brachiopod fauna from the Río del Peñón Formation, Río Blanco Basin, Upper Palaeozoic of La Rioja province, Argentina. Traditionally, this unit was referred to the Carboniferous, however the braquiopod fauna here studied suggests a new biostratigraphical interpretation, indicating an age range from the latest Carboniferous to Early Permian. Three different brachiopod assemblages can be identified in the section: Assemblage I, from the lower member, includes *Streptorhynchus?* sp., *Dyschrestia?* sp., *Costatumulus* sp. A, *Trigonotreta* sp., *Spiriferellina* sp., *Orbiculoidea* sp., and unidentifiable productids and strophomenids. Assemblage II, from the middle member, includes *Tivertonia jachalensis* (Amos), *Kochiproductus riojanus* (Leanza), *Costatumulus* sp. B, *Trigonotreta riojanensis* (Lech and Aceñolaza) and *Orbiculoidea* sp. Assemblage III, from the highest part of the middle member, includes *Neochonetes pegnonensis* sp. nov., *Costatumulus* sp. C, *Rhynchopora* sp., *Septosyringothyris jaguelensis* Lech, and *Orbiculoidea* sp. These brachiopod assemblages demonstrate close affinities with faunas from the lower Permian of Western Australia and India. Affinities with faunas from Perú and Texas are less close.

Keywords: Brachiopods, Upper Palaeozoic, Systematic Palaeontology, Biostratigraphy, Argentina.

RESUMEN

En este trabajo se revisa la fauna de braquiópodos de la Formación Río del Peñón, cuenca Río Blanco, Paleozoico Superior de la provincia de La Rioja, Argentina. Tradicionalmente, esta unidad ha sido referida al Carbonífero. Sin embargo, la fauna de braquiópodos aquí estudiada sugiere una nueva interpretación bioestratigráfica, indicando un rango de edad Carbonífero terminal-Pérmico Temprano. Tres asociaciones diferentes de braquiópodos pueden ser identificadas en esta sección: La Asociación I, en el miembro inferior, contiene *Streptorhynchus?* sp., *Dyschrestia?* sp., *Costatumulus* sp. A, *Trigonotreta* sp., *Spiriferellina* sp., *Orbiculoidea* sp., productidos y estrofoménidos indeterminados. La asociación II, ubicada en el miembro medio, incluye *Tivertonia jachalensis* (Amos), *Kochiproductus riojanus* (Leanza), *Costatumulus* sp. B, *Trigonotreta riojanensis* (Lech y Aceñolaza) y *Orbiculoidea* sp. La asociación III, en la parte más alta del miembro medio, contiene *Neochonetes pegnonensis* sp. nov., *Costatumulus* sp. C, *Rhynchopora* sp., *Septosyringothyris jaguelensis* Lech y *Orbiculoidea* sp. En términos generales, el conjunto faunístico aquí estudiado exhibe gran afinidad con faunas del Pérmico inferior del Oeste de Australia e India y, en menor grado, con las americanas de Perú y Texas.

Palabras clave: Braquiópodos, Paleozoico Superior, Paleontología Sistemática, Bioestratigrafía, Argentina.

INTRODUCTION

Exposed in the Precordillera of La Rioja as the Rincón Blanco syncline (Fig. 1), the Upper Palaeozoic Río del Peñón Formation (Borrello, 1955; González and Bossi, 1986), was studied from lithofacial, palaeoenvironmental

and palaeoecological points of view by Cisterna (1997) and Simanauskas and Cisterna (2000). This paper is a contribution to the taxonomy of the brachiopod fauna contained in this unit and a new biostratigraphical interpretation, indicating an age range from the latest Carboniferous to Early Permian, is also proposed.

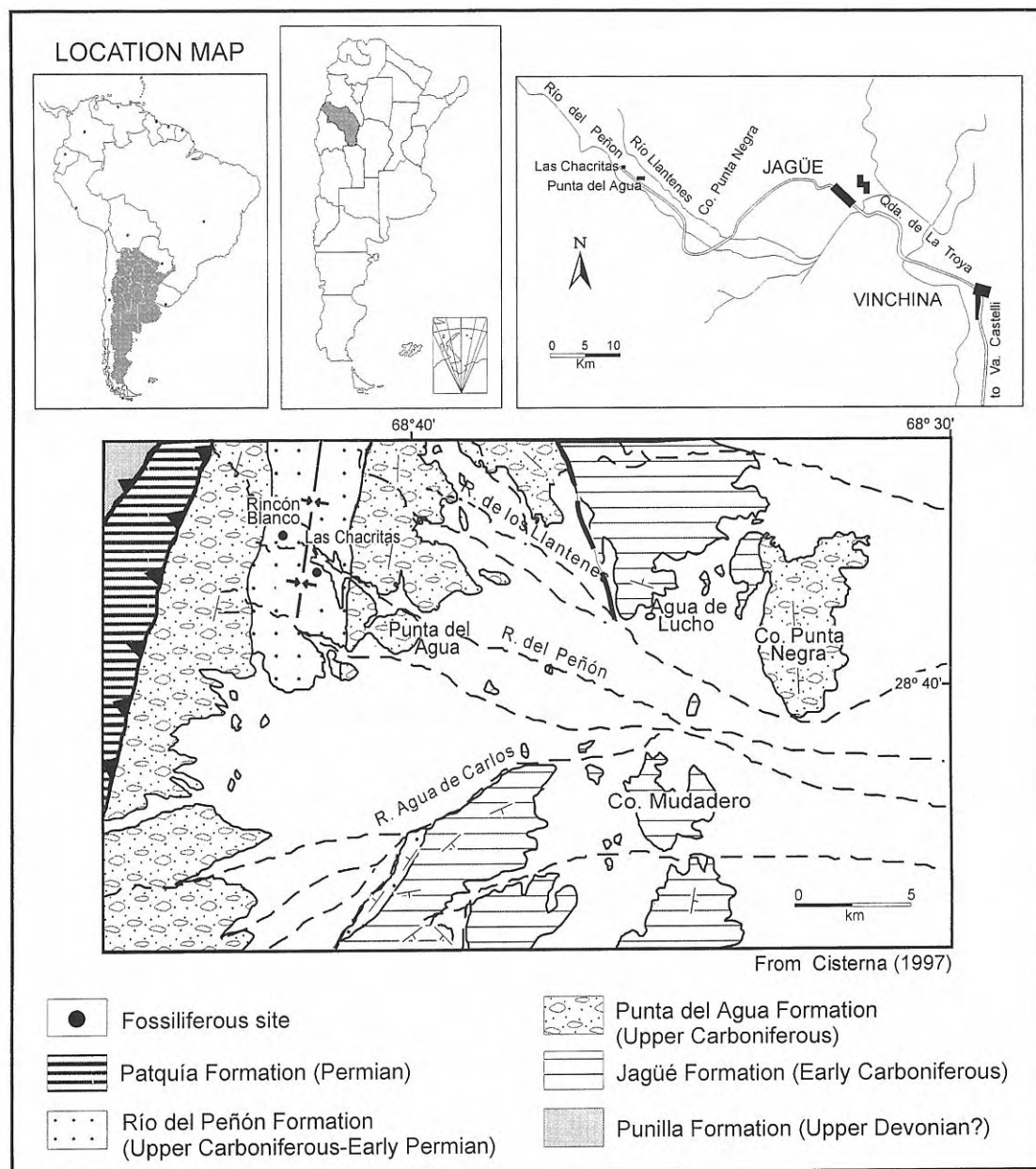


Figure 1. Location map and fossil localities.

Within the faunal assemblages identified in the Río del Peñón section, brachiopods are the most conspicuous element. Earlier studies (Leanza, 1948; Lech and Aceñolaza, 1987) contributed to the knowledge of these faunas. However, new taxa found recently suggest that a revision of the biostratigraphy of the beds containing these brachiopods is now appropriate.

The material studied is housed in the collections of the Miguel Lillo Foundation, Invertebrate Palaeontology Section (PIL).

STRATIGRAPHIC DISTRIBUTION OF THE FAUNA AND BIOSTRATIGRAPHY

Three different brachiopod assemblages can be identified in the Río del Peñón Formation (Fig. 2):

Assemblage I from the lower member, is composed of fragmentary material and the identifications are at the generic level only. Assemblage II occurs in the middle member, and Assemblage III occurs c. 120 m above Assemblage II, at the highest part of the middle member.

Assemblage I is situated immediately above of levels with NBG flora (*Nothorhacopteris-Botrychiopsis-Ginkgophyllum*) and contains *Streptorhynchus?* sp., *Dyschrestia?* sp., *Costatumulus* sp. A, *Trigonotreta* sp., *Spiriferellina* sp., *Orbiculoidea* sp., and unidentifiable productids and strophomenids. Assemblage I requires further collections in order to determine the precise age of the fauna. However, *Trigonotreta* and *Costatumulus* are known only from Permian rocks. *Trigonotreta* sp. here studied is close to *Trigonotreta hesdoensis* (Sanhi and Dutt) from the Asselian-Tastubian faunas of peninsular India (Archbold *et al.*, 1996). *Costatumulus*

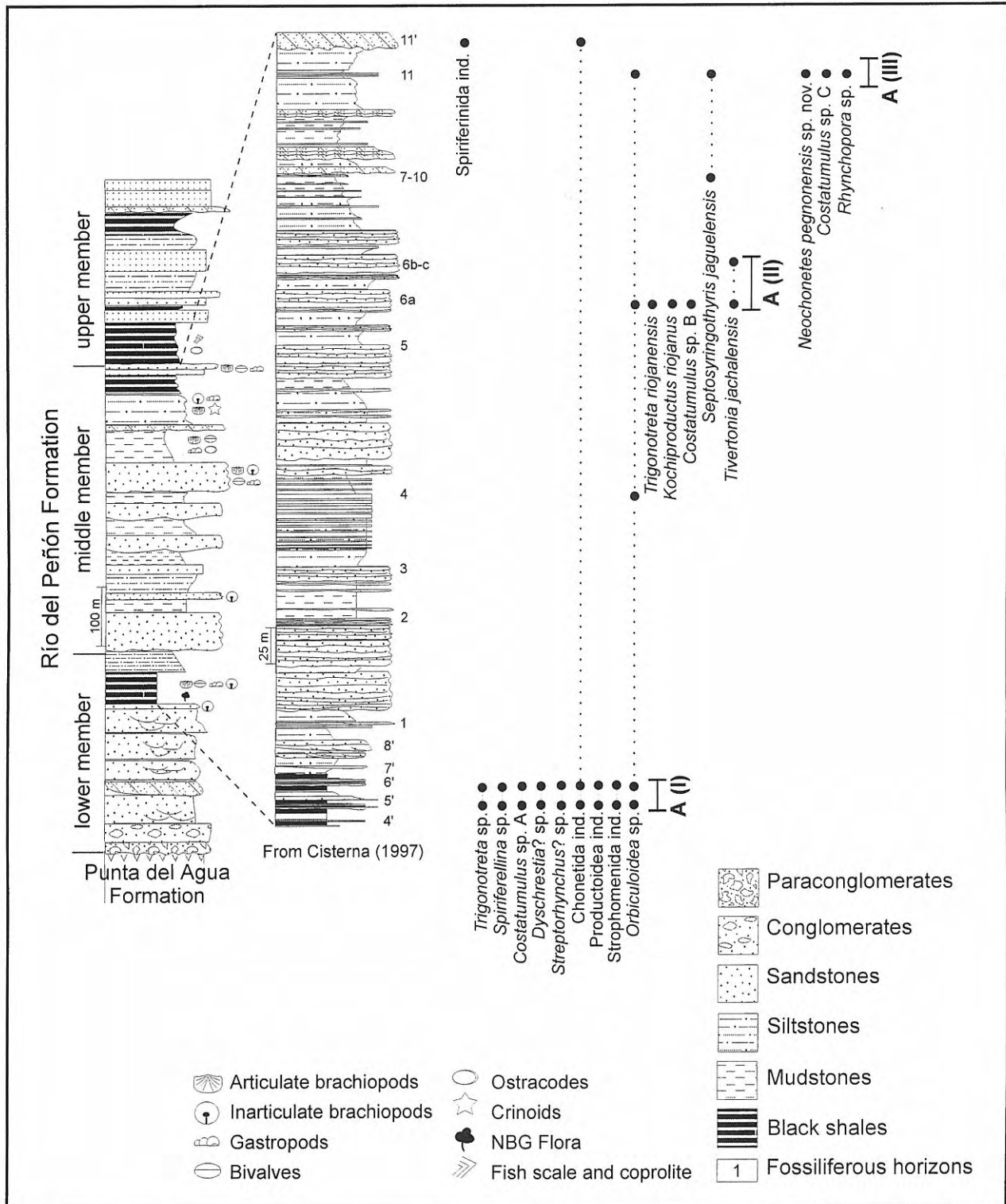


Figure 2. Vertical distribution of the brachiopod assemblages in the faunistic interval of the Río del Peñón Formation.

sp. A resembles *Costatumulus parva* (Cooper and Grant, 1975) from the early Permian of Texas (Neal Ranch and Skinner Ranch formations). Hence, the presence of this assemblage probably indicates an early Permian age for this horizons of the Río del Peñón Formation.

Species identified in Assemblage II are *Tivertonia jachalensis* (Amos), *Kochiproductus riojanus* (Leanza), *Costatumulus* sp. B, *Trigonotreta riojanensis* (Lech and

Aceñolaza) and *Orbiculoidea* sp. This assemblage contains fossils characteristic of the *Tivertonia jachalensis*-*Streptorhynchus inaequiornatus* Zone and the section of the Río del Peñón is considered the parastratotype of this biozone (Sabattini *et al.*, 1990).

Costatumulus and *Trigonotreta* constitute new elements for *Tivertonia jachalensis*-*Streptorhynchus inaequiornatus* Zone. Also, among the species identified

in the Assemblage II, *Kochiproductus riojanus* and *Trigonotreta riojanensis* are important fossils for intra- and inter-basinal correlation. *Kochiproductus riojanus* has been recorded from the Quebrada Larga Formation (Antelo, 1972) within the Río Blanco Basin. *Trigonotreta riojanensis* is close to *Trigonotreta pericoensis* (Leanza) described from the Tupe Formation at the Quebrada de la Herradura, Paganzo Basin (Leanza, 1945). Also, the material described as *Punctothyris sanjuanensis* from the Del Salto Formation, Calingasta-Uspallata Basin (Lech and Aceñolaza, 1990) is very close to our *Trigonotreta riojanensis*. The genus *Tivertonia* Archbold includes smooth chonetids from the early Permian of Australia, Himalayas and Argentina. *Tivertonia jachalensis* is similar to *Tivertonia yarrolensis* (Maxwell) and *Tivertonia chumukensis* Archbold and Gaetani, 1993, from the early Permian of eastern Australia and north-western Himalayas, respectively.

The *Tivertonia jachalensis*-*Streptorhynchus inaequiornatus* Zone, originally called *Lissochonetes jachalensis*-*Streptorhynchus inaequiornatus* Zone, was referred to the late Carboniferous (Sabattini *et al.*, 1990). However, recent studies of its invertebrate fauna (Cisterna, 1997; Cisterna and Sabattini, 1998), as well as the new age obtained by the K-Ar method from the Punta del Agua Formation (Fauque *et al.*, 1999), underlying to the Río del Peñón Formation, and the stratigraphical distribution of all other species of the genus *Tivertonia*, suggest an early Permian age.

At the highest part of the middle member appears Assemblage III, which contains *Neochonetes pegnonensis* sp. nov., *Costatumulus* sp. C, *Rhynchopora* sp., *Septosyringothyris jaguelensis* Lech, and *Orbiculoidea* sp.

Neochonetes pegnonensis sp. nov. is close to species of the *Neochonetes* (*Sommeriella*) *pratti* lineage, in particular the small species from the early Permian of Western Australia.

Rhynchopora sp. allows comparisons with Permian species such as *Rhynchopora australasica* Archbold described from the Asselian horizons of the Lyons Group in the Carnarvon Basin, Western Australia (Archbold, 1995). Also, the presence of *Rhynchopora* sp. in this assemblage is important because it is the first description of the genus from Argentina.

Septosyringothyris is an ubiquitous element in the Carboniferous-Permian of Argentina. *Septosyringothyris jaguelensis* Lech is described from the Permian Agua del Jagüel Formation of the Precordillera, Mendoza province. Here it is associated with *Costatumulus amosi* Taboada, *Streptorhynchus inaequiornatus* Leanza, *Crurithyris* sp., *Orbiculoidea* aff. *saltensis*, *Orbiculoidea* sp., among others (Lech, 1990). In the section studied by us, *Septosyringothyris jaguelensis* is not restricted exclusively to Assemblage III, and appears also in lower beds with a diverse fauna of bivalves and gastropods (Fig. 2).

Generally speaking, the brachiopod fauna studied here is a characteristic early Permian fauna of Gondwana. It particularly shows similarities with the Asselian-

Tastubian faunas of Western Australia and with the Asselian-Sakmarian faunas of Tasmania and Eastern Australia. This group of genera appears repeatedly in fossil assemblages of this age in those regions, i.e. *Trigonotreta*, *Costatumulus*, *Tivertonia*, and *Neochonetes* accompanied by *Spiriferellina*, *Streptorhynchus* and *Rhynchopora* (Archbold, 1995; Archbold *et al.*, 1996).

Thus, the age of the three brachiopod assemblages studied would range between the earliest Asselian and the early Sakmarian (Tastubian). As to the age of the lower member of the Río del Peñón Formation, it is important to point out that Assemblage I is immediately above the beds carrying the NBG Phytozone (Archangelsky and Azcuy, 1985). This phytozone is represented by endemic fossils that prevent a precise chronological correlation and the age is believed to be late Westphalian-Stephanian because of its stratigraphic relation to the overlying *Tivertonia jachalensis*-*Streptorhynchus inaequiornatus* Zone (Archangelsky *et al.*, 1996). However, in beds equivalent to the Río del Peñón Formation that are exposed in the Agua de Carlos locality (to the south of the Rincón Blanco locality), the NBG flora appears in association with elements of the Interval phytozone (Archangelsky and Cúneo, 1991), including *Krauselcladus argentinus* Archangelsky. These elements suggest a younger age still, perhaps latest Carboniferous (Carrizo and Azcuy, 1995; Carrizo, 1998). Thus, the age of the first beds of the Río del Peñón Formation, placed immediately below Assemblage I (Fig. 2), may be latest Carboniferous.

Assemblage II shows elements characteristic of the *Tivertonia jachalensis*-*Streptorhynchus inaequiornatus* Zone. Inclusion of elements belonging to Assemblages I and II in this biozone would require the study in depth of the fauna at other equivalent sections (Quebrada Larga and Quebrada de la Herradura formations). Assemblage III represents a new faunal assemblage that is obviously younger than the *Tivertonia jachalensis*-*Streptorhynchus inaequiornatus* Zone. Therefore, future studies may allow the establishment of a new biostratigraphical unit for the Upper Palaeozoic of the Precordillera.

SYSTEMATIC PALAEOLOGY

Phylum BRACHIOPODA

Order STROPHOMENIDA Öpik, 1934

Suborder ORTHOTETIDINA Waagen, 1884

Superfamily ORTHOTETOIDEA Waagen, 1884

Family **Streptorhynchidae** Stehli, 1954

Genus *Streptorhynchus* King, 1850

Type species: *Terebratulites pelargonatus* Schlotheim, 1816.

Streptorhynchus? sp.

Fig. 3 a-g

Locality: Eastern limb of the Rincón Blanco syncline, left bank of the Río del Peñón, 35 km west of Jagüé, La Rioja province.

Stratigraphic horizon: Río del Peñón Formation, lower member, horizons 5' and 6'.

Material: Ten incomplete internal moulds of dorsal valves, four of them with their matching externals (IPI 3126a-b, 3127a-b, 3128a-b, 3129, 3130a-b, 3131, 3135, 3136, 3137 and 3138A); one external mould of a dorsal valve (IPI 3133); one external mould of a ventral valve (IPI 3134); one internal mould of an articulate specimen (IPI 3138B); one internal mould of a ventral valve with its matching external (IPI 3132a-b). All material from horizon 6'.

Description

Shell of small size for the genus (maximum width 15 mm); outline transversely subquadrate with maximum width anterior to the hinge line. Ventral valve flat with low and slightly concave interarea. Dorsal valve moderately convex with larger convexity at about mid-length. Surface finely costellate with costellae that increase usually by bifurcation; generally 10 costellae per 5 mm in the ventral valve and 12 to 13 per 5 mm in the dorsal valve, both measured at about mid-length of the valves. Shell pseudopunctate, typically of the *Streptorhynchus* type, preserved on internal moulds as small tubercles arranged in regular radial rows. Dorsal interior with a pair of short and divergent socket plates, joined to a moderately long and bilobate cardinal process. Muscle area sub circular, divided by a very weak median ridge in some specimens. Other characters unknown.

Discussion

The specimens described possess the characteristic dorsal cardinalia of *Streptorhynchus*. However, *Streptorhynchus* species are generally more deeply conical with a proportionately narrower hinge and costellae that increase by intercalation more typically than by bifurcation. Because these features have not been observed in our material, the generic position of this species is questionable.

Streptorhynchus? sp. is characterised fundamentally by its small size for the genus and its fine costellae. This species appears to be close to the finely costellated, thin-shelled group of Western Australian *Streptorhynchus* described by Thomas (1958), particularly with *Streptorhynchus johnstonei* Thomas (1958, p. 55, pl. 14, figs. 1-6). Both species are similar in terms of general shell morphology and number of costellae but *Streptorhynchus?* sp. is notably smaller.

In relation with the larger Argentinean species *Streptorhynchus inaequiornatus* Leanza (1945, p. 286, pl. 3, figs. 1-7, pl. 4, figs. 1-9; pl. 5, fig. 6), described from the Paganzo Basin (Tupe Formation, Quebrada de la Herradura locality), *Streptorhynchus?* sp. possess the same number of fine costellae per mm. However, in *Streptorhynchus inaequiornatus* the costellae show a typical pattern formed by two orders of size.

Order PRODUCTIDA Waagen, 1883
Suborder CHONETIDINA Muir-Wood, 1955
Superfamily CHONETOIDEA Bronn, 1862
Family Rugosochonetidae Muir-Wood, 1962

Subfamily **Rugosochonetinae** Muir-Wood, 1962
Genus *Neochonetes* Muir-Wood, 1962

Type species: *Chonetes dominus* King, 1938.

Remarks

Archbold (1981) proposed the existence of three lineages within *Neochonetes*. The first lineage, of *N. (Neochonetes) carboniferus*, comprises upper Carboniferous to lower Permian (Asselian) species from Russia, Spain and China. The second lineage, of *N. (N.) granulifer* includes species from the upper Carboniferous to the lower Permian (Sakmarian) of Great Britain, Germany, North America, Bolivia, and Perú. The third lineage, of *Neochonetes (Sommeriella) pratti*, grouped species from the Permian of the Himalayas, Arabia, Afghanistan, Iran, the Urals, Alaska, and Western Australia.

Neochonetes pegnonensis sp. nov. is close to the species of the *Neochonetes (Sommeriella) pratti* lineage, particularly with the species that are small in size and lack a sulcus. The species of the *N. (Neochonetes) granulifer* lineage are different from *Neochonetes pegnonensis* sp. nov. in showing the maximum width at the hinge. *N. pegnonensis* sp. nov. possibly belongs to the *N. (Sommeriella) pratti* lineage, or more probably to a new, related lineage of the genus *Neochonetes*.

Neochonetes pegnonensis sp. nov.

Fig. 3 h-o

Holotype: An internal mould of a ventral valve, IPI 2959 (Fig. 3h).

Type Locality: Western limb of the Rincón Blanco syncline, 35 km west of Jagüé, La Rioja province.

Type horizon: Río del Peñón Formation, middle member, horizon 11.

Material: One external mould of ventral valve (IPI 2981); ten internal moulds of ventral valves (IPI 2957, 2959, 2960, 2961, 2962, 2967, 2971, 2974, 2976, 2977); three ventral valves (IPI 2958, 2966, 2968); four external moulds of dorsal valves (IPI 2963, 2964, 2972, 2978); two internal moulds of dorsal valves (IPI 2965, 2979); three dorsal interiors (IPI 2969, 2970, 2975). One hundred incomplete moulds and valve fragments (IPI 2973 and 2980).

Derivatio nominis: From the Río del Peñón Formation, Upper Palaeozoic of La Rioja province, Argentina.

Diagnosis

Shells small, concave-convex, wider than long, subquadrate to subrectangular; hinge line width equal to or slightly shorter than the maximum width, measured at mid-length of shell. External surface covered by very fine radial ribs (*capillae*), four to five per mm near the anterior commissure. Interior of ventral valve showing a very short

| IPI N° | W | L | VTL | MS | DS |
|--------|------|-----|-----|----|-----|
| 2957 | 10.5 | 9 | 6.5 | 1 | - |
| 2958 | 12.7 | 10 | - | - | - |
| 2959 | 13 | 9.5 | 6.9 | - | - |
| 2960 | 12 | 8.7 | 6.5 | - | 3.1 |
| 2961 | 11 | 9 | 7 | 1 | - |
| 2966 | 8.1 | 6.3 | - | - | - |
| 2967 | 10.8 | 9 | 6.7 | - | 3.4 |

Ventral valve

| IPI N° | W | L | MS |
|--------|------|------|-----|
| 2963 | 12 | 8.5 | - |
| 2964 | 12.6 | 7.8 | - |
| 2965 | 13.4 | 10.3 | 4.7 |
| 2970 | 11 | 8.2 | 5 |
| 2972 | 11.6 | 7.4 | - |
| 2978 | 10.5 | 7 | - |
| 2979 | 11.8 | 8 | 5 |

Dorsal valve

Table 1 Measurements in mm of *Neochonetes pegnonensis* sp. nov. IPI: "Instituto de Paleontología, Sección invertebrados, Fundación Miguel Lillo"; W: maximum width; L: length; VTL: vascular trunk length; MS: median septum; DS: diductor scars.

but high median septum, anteriorly two vascular trunks form prominent ridges with large endospines (papillae) on them. The interior of the dorsal valve shows an anteriorly elevated median septum and well developed brachial ridges with large endospines on them.

Description

Exterior: Shell small (for measurements see Table 1), concavo-convex, transversally subrectangular in outline. Maximum length slightly larger than two thirds of the maximum width. The width of the hinge line is equal to or slightly shorter than the maximum width, measured at mid-length of shell. Cardinal extremities straight or slightly tapering. Sulcus weak to absent. Both valves ornamented with fairly obvious growth lines and very fine ribs (capillae). These ribs number 4, and more commonly 5 per mm near the anterior commissure. Along the posterior edge of ventral interarea there are at least three spine bases on each side of the umbo; they form an angle of more than 40° with the hinge.

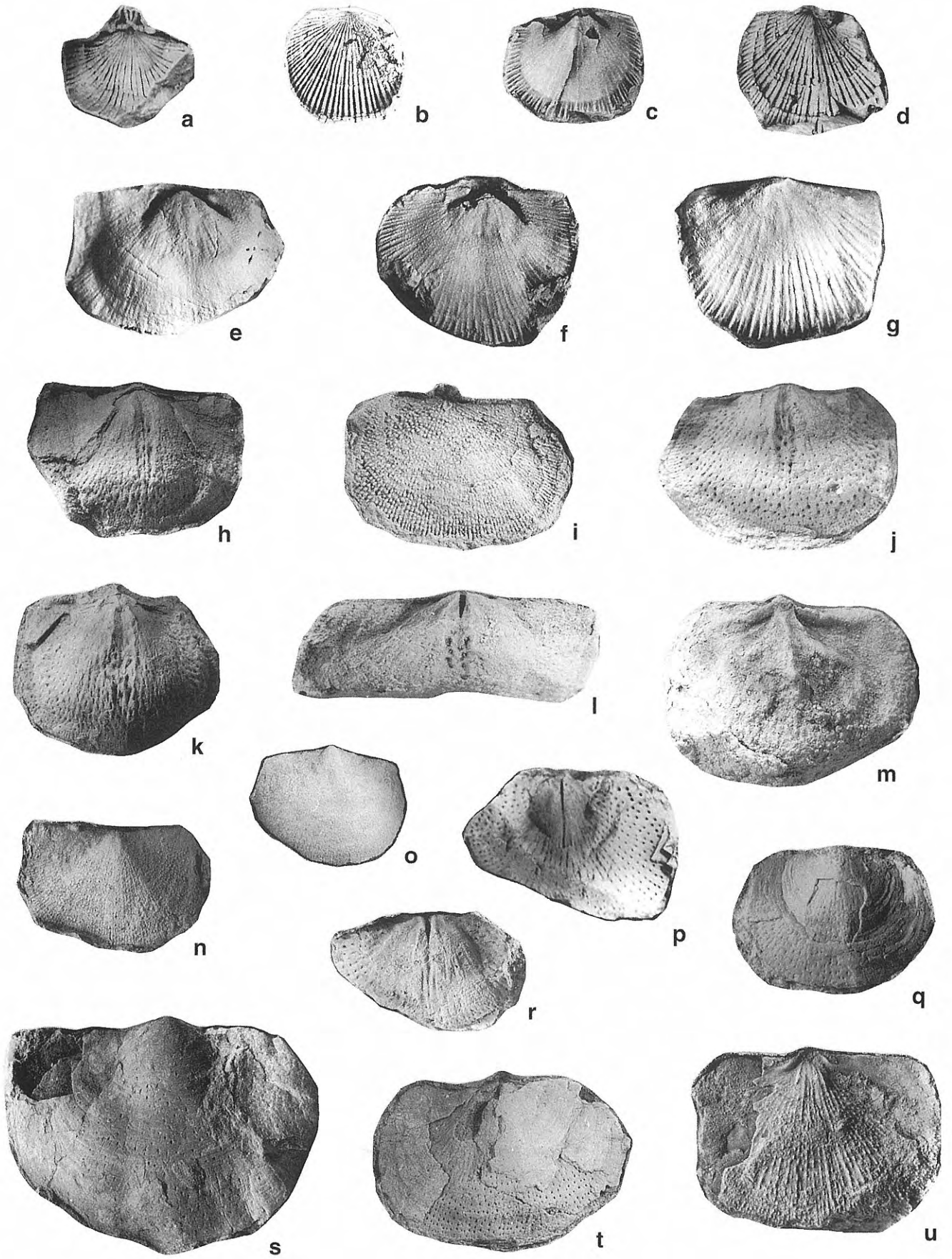
Interior: Ventral interior shows a high and short median septum, extending approximately one seventh of the valve length. Anteriorly two vascular trunks form prominent ridges with large endospines (papillae) on them. At both sides of the septum are long adductor muscle scars, surrounded by large, round diductor muscle scars, which reach almost mid-length of the valve. Dorsal valve interior carries a tetralobate cardinal process, with a deep pit at its base. Socket ridges thick and long, forming a low angle with the hinge line. In front of the pit there is a very long median

septum, about three quarters of the valve length; the anterior end of the septum is formed by a group of large endospines. The anderidia are also long (about half of median septum length). The muscle scars are very well developed and include deep and rounded anterior adductors. The brachial ridges in the adult specimens are raised and formed by large endoespines. The anterior portions of these ridges are curved toward the anterior end of the median septum. The rest of the interior of the valves has few large endospines that tend to be arranged in radial lines. Along the commissure the endospines are thinner, longer and more numerous.

Remarks

Neochonetes pegnonensis sp. nov. is similar to *N. (Sommeriella) hockingi* Archbold, 1991, from the Aktastinian Wooramel Group, Carnarvon Basin, Western Australia. They present similarities in shell size, outline and internal morphology of the dorsal valve, but both species differ in the capillae density. *Neochonetes (Sommeriella) obrieni* Archbold, 1995, from the Tastubian Wye Worry Member of the Carolyn Formation (Canning Basin, Western Australia), presents the same density of capillae as the Argentine species, but differs in shell size and outline. Other similar small-sized species are *N. (Sommeriella) hardmani* Archbold, 1993, and *N. (S.) robustus* Archbold, 1981, both from the Permian of Western Australia; with the first species, *N. pegnonensis* sp. nov. differs in detail of the ornament and in the development of the sulcus and fold, and with the second species, in shell outline.

Figure 3. a-g. *Streptorhynchus?* sp. a, external mould of dorsal valve, IPI 3133, x3. b, external mould of dorsal valve, IPI 3130b, x3. c, d, internal and external mould of dorsal valve, IPI 3127a-b, x3. e, internal mould of dorsal valve, IPI 3126a, x3. f, internal mould of dorsal valve, IPI 3129, x3. g, internal mould of ventral valve, 3132a, x3.5. **h-o.** *Neochonetes pegnonensis* sp. nov. h, internal mould of ventral valve, IPI 2959, x3. i, external mould of dorsal valve, IPI 2978, x4. j, internal mould of ventral valve, IPI 2960, x3.5. k, internal mould of ventral valve, IPI 2957, x3.5. l, internal mould of ventral valve, IPI 2977, x4. m, dorsal interior, IPI 2969, x3. n, external mould of dorsal valve, IPI 2964, x3. o, ventral valve exterior, IPI 2966, x3.5. **p-u.** *Tivertonia jachalensis* (Amos). p, internal mould of ventral valve, IPI 2951, x3.5. q, partially decorticated ventral valve, IPI 2943, x3. r, internal mould of ventral valve, IPI 2953, x3. s, partially decorticated ventral valve, IPI 2941, x3. t, partially decorticated ventral valve, 2952a, x3. u, dorsal valve interior, IPI 2942, x3.



Subfamily **Svalbardiinae** Archbold, 1982Genus *Tivertonia* Archbold, 1983

Type species: *Lissochonetes yarrolensis* Maxwell, from the Yarrol Formation in Eastern Australia (Sakmarian).

Diagnosis

Shell smooth to pseudocapillate, concavo-convex, maximum width at mid-length of shell, sulcus poorly defined or absent, cardinal spines short, forming a moderate angle with the hinge line; interior of the brachial valve with a pit, median septum long.

Geographical and stratigraphical distribution: Early Permian of Australia, Himalayas and Argentina.

Discussion

The inclusion of *Lissochonetes brevisseptum* Amos, 1961, in *Tivertonia* by Archbold and Gaetani (1993) can't be supported. Most of the specimens housed in the fossil invertebrate collection at the La Plata Museum, which were studied by Amos himself and included in *Lissochonetes brevisseptum*, show features completely opposed to *Tivertonia* and probably belong to genus *Gatia* Archbold, 1993; other specimens were included in the productid *Aseptella patriciae* Simanauskas, 1996. The material illustrated by Pujanas (1989) does not belong to *Lissochonetes brevisseptum*, and probably can be included in the genus *Neochonetes*.

Tivertonia jachalensis (Amos, 1961)

Fig. 3 p-u

1945 *Chonetes scitula* Leanza, 280-284, pl. 1, figs. 1-9.

*1961 *Lissochonetes jachalensis* nom. nov.; Amos, 83-84.

1991 *Lissochonetes jachalensis* Amos; Simanauskas, 136, pl. 1, fig. 13.

Locality: Western limb of the Rincón Blanco syncline, 35 km west of Jagüé, La Rioja province.

Stratigraphic horizon: Río del Peñón Formation, middle member, horizons 6a and 6b-c.

Material: Six ventral valves (IPI 2941, 2943, 2945, 2946, 2949, 2952a); one dorsal interior (IPI 2942); one external mould of dorsal valve (IPI 2944); two internal moulds of ventral valves (IPI 2951, 2953); two internal moulds of dorsal valves (IPI 2950-2955). Several fragments of internal

and external moulds (IPI 2956). All material is from the horizon 6b-c.

Remarks

Archbold and Gaetani (1993) recently removed this species from *Lissochonetes* and placed it in *Tivertonia*. This new placement is correct only for the specimens from the type locality of the species, Quebrada de la Herradura, San Juan province, Argentina (Leanza, 1945) and for those described herein.

Description

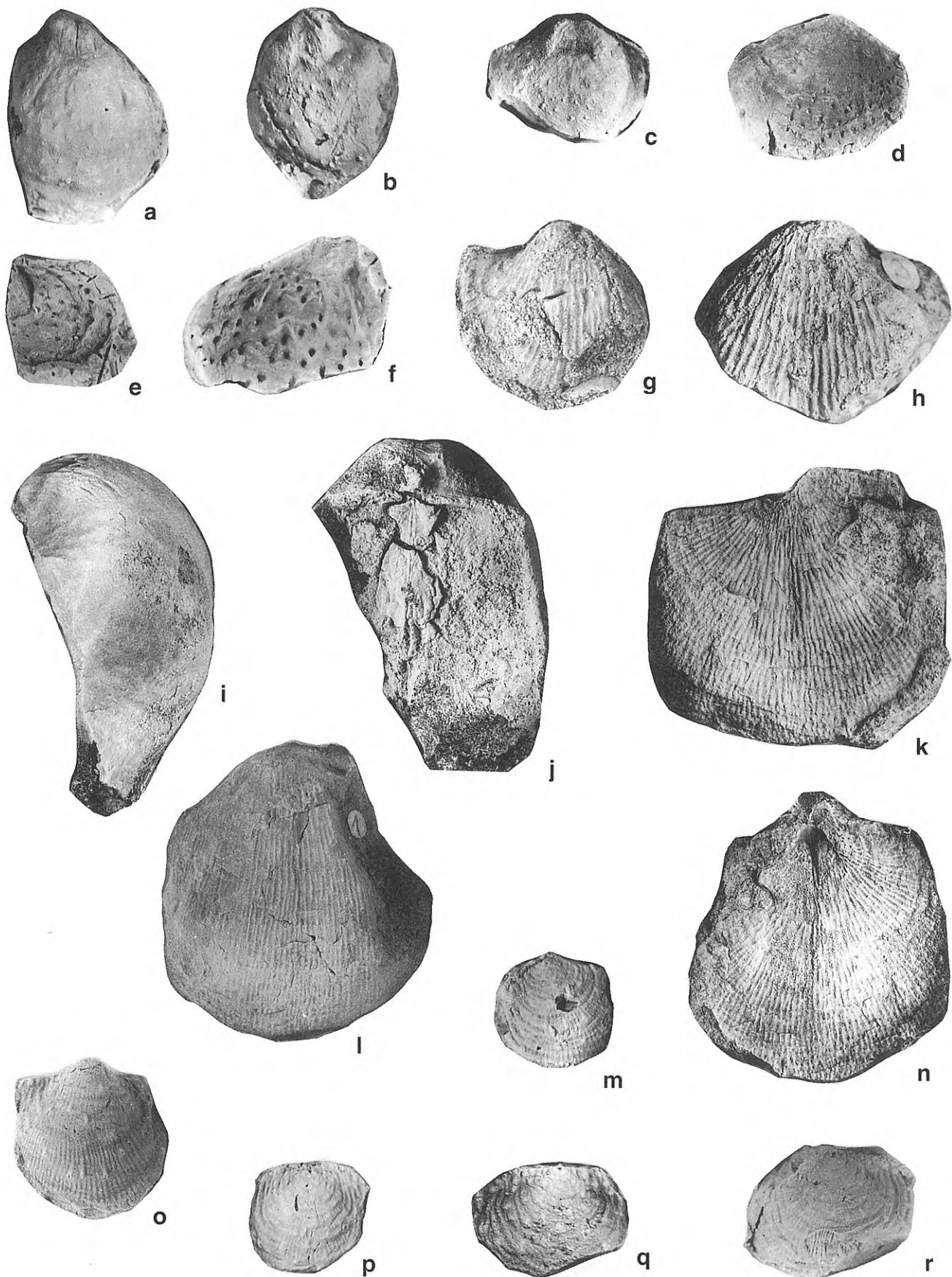
Exterior: Shell concave to plano-convex, slightly wider than long; width of the hinge line shorter than the maximum width, which is measured at mid-length of shell. Cardinal extremities blunt and rounded. Surface smooth, with very fine growth lines and bases of spinules. Partially decorticated specimens show a pseudocapillate surface.

Interior: Ventral interior with a long median septum, extending to about mid-length of the valve; it is higher and thinner in its anterior part and slightly wider at its posterior end. A shallow and parallel ridge is observed at both sides of the anterior portion of the median septum. Vascular trunks not observed. The adductor muscle scars are smooth and elongated. Diductor muscle scars anteriorly striated, reaching to about mid-length of valve. The rest of the shell carries very small and numerous endospines, arranged in radial lines. The interior of the dorsal valve shows a tetralobate cardinal process with a pit at its base. The socket ridges are weak and short. In front of the cardinal pit there is a very thin and long median septum; in some specimens it is barely distinguished, as is the case also with the brachial ridges. The rest of the interior shows numerous rows of small endospines.

Discussion

The studied specimens differ only slightly from the type material of *Tivertonia jachalensis* from Quebrada de la Herradura, San Juan province, Argentina (Leanza, 1945). The interior of this species is similar to that of the type species of *Tivertonia*, but they can be differentiated by their size and the external appearance of the shell. The Argentine species resembles *Tivertonia chumukensis* Archbold and Gaetani, 1993, from the lower Permian of the northwestern Himalayas, by their size. However, the shape of the brachial ridges is different in both species. *T. jachalensis* can be separated from *T. tatamariensis* Singh and Archbold, 1993, by the absence of a sulcus and less transverse outline. *T. pillahuinsensis* (Harrington, 1955), from the lower Permian Bonete Formation of the Sierras

Figure 4. a-f. *Dyschrestia?* sp. a, f, internal and external moulds of ventral valve, IPI 3097a-b, x2.5. b, internal mould of ventral valve, IPI 3103a, x3.5. c, internal mould of ventral valve, IPI 3106 A, x3. d, external mould of ventral valve, IPI 3098, x2. e, fragment of external mould of ventral valve, IPI 3104, x3.5. **g-l, n.** *Kochiproductus riojanus* (Leanza). g, incomplete ventral valve, IPI 3175, x1.5. h, ventral view of fragmentary articulate specimen, IPI 3171a, x1.5. i-j articulate specimen, lateral and dorsal view, PIL, 10502, x1. k, external mould of dorsal valve, IPI 3169a, x1. l, n, articulate specimen, ventral and dorsal view, IPI 3169b, x1. **m, o-r.** *Costatumulus* sp. A. m, external mould of dorsal valve, IPI 3111, x3.5. o, ventral valve exterior, IPI 3110, x3. p, external mould of dorsal valve, IPI 3107b, x3.5. q, external mould of dorsal valve, IPI 3114, x4. r, external mould of dorsal valve, IPI 3109, x3.



Australes of Argentina, is clearly different from *T. jachalensis*. The Bonete Formation species is robust, more round and with internal features very pronounced, rather similar to specimens of *T. yarrolensis* from the Farley Formation in eastern Australia, illustrated by Archbold (1986).

Suborder PRODUCTIDINA Waagen, 1883

Superfamily PRODUCTOIDEA Gray, 1840

Family Productellidae Schuchert, 1929

Subfamily Overtoniinae Muir-Wood and Cooper, 1960

Genus *Dyschrestia* Grant, 1976

Type species: *Dyschrestia spodia* Grant, 1976, from the Permian of southern Thailand.

Dyschrestia? sp.

Fig. 4 a-f

Locality: Eastern limb of the Rincón Blanco syncline, left bank of the Río del Peñón, 35 km west of Jagüé, La Rioja province.

Stratigraphic horizon: Río del Peñón Formation, lower member, horizons 5' and 6'.

Material: Seven internal moulds of ventral valves, three of them with their matching external moulds (IPI 3097a-b, 3098a-b, 3099, 3100, 3103a-b, 3106A and 3106B); one fragmentary external mould of a ventral valve (IPI 3104); one fragmentary ventral valve partially decorticated (IPI 3106C); one fragmentary external mould of a dorsal valve (3106D); one poorly preserved internal mould of dorsal valve with its matching external (3102a-b). All material from the horizon 6'.

Description

Small shell with moderately convex ventral valve, ornamented with numerous small spines (density of c. 3 spines per 4 mm² at about mid-length), that are randomly distributed over the entire shell surface. Conspicuous growth lines (density c. 8 to 9 per mm at anterior margin). Ventral interior showing a small muscle scar divided in two sub-triangular areas by a weak median ridge. Dorsal valve very poorly preserved. The only features observed are the moderate concavity of the valve, weak growth lines and, internally, a bilobate cardinal process and a poorly preserved median septum. Other characters unknown.

Discussion

External features of the ventral valve indicate *Dyschrestia*, or an allied genus. However, this assignment can only be provisional due to the poor preservation of the material studied, fundamentally the lack of better information concerning the dorsal valve. In fact, *Dyschrestia* is very close to *Krotovia* Fredericks in the external features but possess a more strongly developed dorsal median septum.

Family Productidae Gray, 1840

Subfamily Buxtoniinae Muir-Wood and Cooper, 1960

Tribe Buxtoniini Muir-Wood and Cooper, 1960, *sensu*

Brunton, Lazarev & Grant, 1995

Genus *Kochiproductus* Dunbar, 1955

Type species: *Productus porrectus* Kutorga, 1844.

Remarks

Kochiproductus includes a number of large to gigantic buxtoniids widely distributed in Permian rocks, characterised by external ornament of simple radiating costae interrupted by elongate "ramps" (Shi and Waterhouse, 1996). It is very similar to *Buxtonia* and can be separated from it by a marked reticulation on the dorsal visceral disc and, interiorly, because the dorsal median septum lacks a bifid base (Sarytcheva, 1968). However, the posterior part of the dorsal median septum, generally bifurcated in *Buxtonia*, appears to be nothing else as the ridges developed in connection with the base of the cardinal process (Likharev, 1938). Thus, it seems preferable to emphasise the differences in external ornament.

Kochiproductus riojanus (Leanza, 1948)

Fig. 4 g-l, n

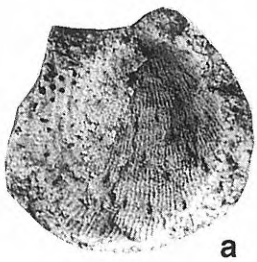
*1948 *Productus riojanus* Leanza, 240-242, pl. 1, figs. 1, 2, 5.

1972 *Buxtonia riojana* (Leanza); Antelo, 167, pl. 167-168, figs. 3, 5, 7, 8.

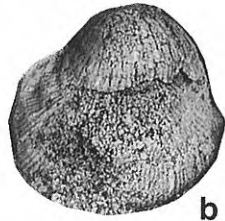
1979 *Buxtonia riojana* (Leanza); Amos, 76, figs. A-C.

Locality: Western limb of the Rincón Blanco syncline, 35 km west of Jagüé, La Rioja province.

Figure 5. a-d. *Costatumulus* sp. B. a-b, external and internal mould of ventral valve, IPI 3176a1-b1, x2. c, dorsal view of articulate specimen, 3181a, x2. d, external mould of dorsal valve, IPI 3181b, x2. **e-l.** *Costatumulus* sp. C. e-f, ventral valve, ventral and lateral view, IPI 3060, x2. g, ventral valve, IPI 3392, x2. h, detail of the ventral exterior, IPI 3055, x2.5. i, external mould of dorsal valve, IPI 3389, x2.5. j, external mould of dorsal valve, IPI 3058a, x2.5. k, incomplete ventral valve, IPI 3061, x2.5. l, detail of the ventral exterior, IPI 3056, x2.5. **m-v.** *Rhynchopora* sp. m, external mould of ventral valve, IPI 3375, x2. n, internal mould of dorsal valve, IPI 3374a, x2. o, internal mould of articulate specimen, anterior commissural view, IPI 3367, x2. p, internal mould of ventral valve, IPI 3364, x2. q, external mould of ventral valve, IPI 3371, x2. r, internal mould of articulate specimen, IPI 3362, x2. s, internal mould of ventral valve, IPI 3361, x2. t-u, internal mould of dorsal valve, IPI 3372a, x3, detail x10. v, internal mould of dorsal valve, IPI 3373a, x2.



a



b



c



d



e



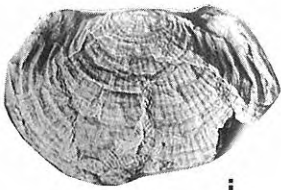
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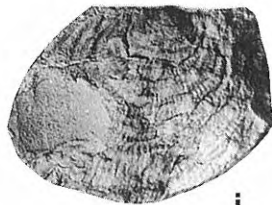
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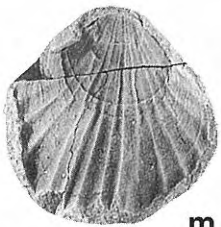
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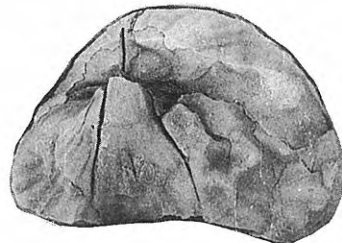
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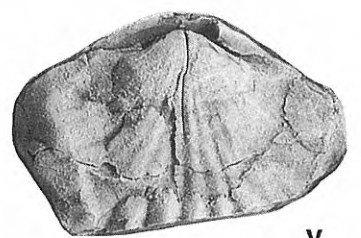
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t



u



v

Stratigraphic horizon: Río del Peñón Formation, middle member, horizon 6a.

Material: Three articulate specimens, one of them incomplete (IPI 3169b, 3171a; PIL 10502); two internal moulds of ventral valves (IPI 3172 and 3174); two incomplete external moulds of dorsal valves (IPI 3169a and 3171b); two incomplete ventral valves (IPI 3173 and 3175); several fragments of internal and external moulds.

Description

Shells plano-convex, medium to large, slightly elongate in outline. Ventral valve moderately to strongly convex with umbonal region strongly swollen; umbo strongly incurved over the hinge line; umbonal angle c. 90°. Ears inconspicuous in juvenile specimens and unknown in mature specimens. Median sulcus distinct, commencing about 20 mm from the umbo and well defined only at mid-length of valve. Lateral slopes high, almost vertical set. Ventral ornament of distinct costae and inconspicuous rugae. Costae (10 to 12 in 10 mm at mid-length) are interrupted by elongate swollen nodes ("ramps"), corresponding to spine bases. Internal characters of the ventral valve unknown. Dorsal valve with flat visceral disc and short trail. Pattern of costae similar to the ventral valve; distinct concentric rugae, crossing the costae and producing a reticulation; small and abundant spines crowded on anterior trail. Interior with a bilobate cardinal process in ventral view; conspicuous median septum that reaches two thirds of the valve length and buttress plates fused with the posterior end of the median septum. Other internal characters unknown.

Discussion

The characters observed in the available material identify it as *Productus riojanus*, as described by Leanza (1948, p. 240, pl. 1, figs. 1, 2 and 5). This author worked with material from the same levels of the Río del Peñón Formation, from which we obtained our specimens.

Productus riojanus Leanza was later included in *Buxtonia* Thomas by Antelo (1972, p. 167, pl. 1, figs 3-4, 7-8) when studying the brachiopods from the Quebrada Larga Formation. Also, he included in this assignation specimens from the Río del Peñón Formation housed in the Miguel Lillo Institute of Tucumán, Argentina (collection number PIL 10502). However, the revision of the material studied by Antelo, part of which is re-figured in this paper (Fig. 4 i-j), suggests its inclusion in the genus *Kochiproductus*.

Kochiproductus riojanus has been compared by some authors (Leanza, 1948; González, 1993) with the South American species *Kochiproductus peruvianus* (d'Orbigny), described from the Asselian Copacabana Formation of Bolivia (Kozłowski, 1914, p. 38, pl. 4, figs. 1-4; Chronic, in Newell *et al.*, 1953, p. 83, pl. 3-4). However, *Kochiproductus riojanus* is slightly more elongate with deeper sulcus and vertical lateral slopes, in relation to *Kochiproductus peruvianus* (d'Orbigny). Also, the Argentine species shows a different ornamentation with finer costae.

Superfamily **LINOPRODUCTOIDEA** Stehli, 1954
Family **Monticuliferidae** Muir-Wood and Cooper, 1960
Subfamily **Auriculispinae** Waterhouse, 1986
Genus *Costatumulus* Waterhouse, 1983

Type species: *Auriculispina tumida* Waterhouse in Waterhouse *et al.*, 1983.

Remarks

Considering the last emended diagnosis of *Costatumulus*, this genus includes "linoproductidae with variably arched ventral valve and evenly concave dorsal valve; ventral ornament of fine costellae, very low, narrow rugae, recumbent spines set on distinct spine ridges, and narrow band of spines alongside hinge. Dorsal ornament of fine costellae and dimples but no spines. Ventral adductor scars smooth in early maturity, later becoming posteriorly striated and ultimately dendritic" (Briggs, 1998, p. 155).

Two genera closely related to *Costatumulus* are *Canocrinella* Fredericks and *Magniplicatina* Waterhouse. From the first one it can be differentiated by the absence of spines on the dorsal valve and from the second by the lack of strong rugae.

In Argentina, some species of *Costatumulus* have originally been referred to *Canocrinella*. Archangelsky and Lech (1985) and Sessarego and Lech (1985) mentioned the presence of *Canocrinella* aff. *farleyensis* from the Del Salto and Santa Helena formations (Calingasta-Uspallata Basin). Also, Lech (1990) mentioned *Canocrinella farleyensis* from the Agua del Jagüel Formation (Calingasta-Uspallata basin) and Lech and Aceñolaza (1987) described *Canocrinella* sp. from the Río del Peñón Formation (Río Blanco Basin). Recently, Taboada (1998) described *Costatumulus amosi* sp. nov. from the Agua del Jagüel Formation at different localities of the Uspallata area (Calingasta-Uspallata Basin).

Our material referred to *Costatumulus* is scarce and fragmentary. This prevents adequate specific identification. However, sufficiently clear external differences allow to discriminate three species in the Río del Peñón Formation and to compare them with material from other regions.

Costatumulus sp. A

Fig. 4 m, o-r

Locality: Eastern limb of the Rincón Blanco syncline, 35 km west of Jagüé, La Rioja province.

Stratigraphic horizon: Río del Peñón Formation, lower member, horizons 5' and 6'.

Material: Five external moulds of dorsal valves (IPI 3107b, 3109, 3111, 3112, 3114); two internal mould of dorsal valves (3107a, 3108); one ventral valve (IPI 3110). All material from horizon 6'.

Description

Small shell with length and maximum width about equal; ventral valve slightly convex; regularly curved lateral profile, umbo incurved and ears small. Ornamentation of fine costellae (3 to 4 per millimeter on the median-anterior region) and few irregularly distributed spines. The spine bases suggest that they must have grown at a low angle to the surface. Rugae are weak, slightly stronger on the ears. On a few fragments it is possible to observe "spine bunches" on the ears. However, we are not sure if this fragmentary material belongs to the same taxon (*i.e.* *Costatumulus* sp. A). Dorsal valve gently concave, with costellae and rugae. The rugae are significantly stronger than on the ventral valve, especially on the ears. Others features unknown.

Discussion

Costatumulus sp. A is characterised by its small size, shell approximately as wide as long and ventral valve gently convex. These features are comparable with those observed in *Costatumulus parva* (Cooper and Grant, 1975, p. 1153, pl. 428, figs. 19-40), from the lower Permian of Texas (Neal Ranch and Skinner Ranch formations). Likewise, both species are closely comparable in the number of costellae and the spine arrangement. Unfortunately, the material described herein is not well enough preserved to corroborate the identity of both taxa.

Costatumulus sp. B

Fig. 5 a-d

1987 *Canocrinella* sp. Lech and Aceñolaza, 108, figs. 2a-c.

Locality: Western limb of the Rincón Blanco syncline, 35 km west of Jagüé, La Rioja province.

Stratigraphic horizon: Río del Peñón Formation, middle member, horizon 6a.

Material: Two internal moulds of ventral valves (IPI 3176a1 and 3176a2); one external mould of ventral valve (IPI 3176b1); one incomplete ventral valve partly decorticated (IPI 3180); one articulate specimen partly decorticated (IPI 3181a); three poorly preserved external moulds of dorsal valves (IPI 3178, 3179 and 3181b).

Description

Small concavo-convex shells with slightly elongate outline; hinge width slightly narrower than maximum width, which is measured at mid-length of shell. Ventral valve moderately convex with prominent umbonal region and incurved umbo. Costellae fine, about 2-3 in 1 mm (measured at anterior half of the valve) and weak rugae which are slightly more conspicuous on the ears. Costellae carry randomly distributed spines, with a density of about 4-5 spines per 25 mm² (near anterior margin of the valve). The ears carry a double row of spines, slightly larger than the body spines. Dorsal valve gently concave, with a similar ornament to the ventral one but without spines and with stronger rugae. Other shell features unknown.

Discussion

The specimens described herein come from the same fossil bed from which Lech and Aceñolaza (1987, p. 108, figs. 2a-c) identified *Canocrinella* sp. As far as can be inferred from their fragmentary material, it appears to be conspecific with ours.

Costatumulus sp. B is larger and more convex than *Costatumulus* sp. A, described from the lower member of the Río del Peñón Formation.

Although inadequate for detailed comparison, *Costatumulus* sp. B is close to *C. sparsispinosus* (Cooper and Grant, 1975, p. 1154, pl. 430, figs. 15-47) from the lower Permian of Texas (Bone Spring and Skinner Ranch formations) and *C. irwinensis* Archbold (1983, p. 240, figs. 1P-C) from the Sakmarian of Western Australia (Callytharra Formation and Fossil Cliff Member), in details of costellae. However, both species show different general shell morphology in relation with *Costatumulus* sp. B. Also, the Australian species is much larger than the Argentine one.

Costatumulus sp. C

Fig. 5 e-l

Locality: Western limb of the Rincón Blanco syncline, 35 km west of Jagüé, La Rioja province.

Stratigraphic horizon: Río del Peñón Formation, middle member, horizon 11.

Material: Seven incomplete ventral valves (IPI 3054, 3055, 3056, 3060, 3061, 3062 and 3392); one incomplete dorsal valve with its matching external mould (IPI 3058a-b); one external mould of dorsal valve (IPI 3389). Additional material with number IPI 3016.

Description

Small shell, rounded to transverse in outline, with the maximum width at about mid-length of shell. Ventral valve strongly convex with incurved umbo. Ears relatively small and sharp. Ornament of fine costellae (5 to 6 in 2 mm at mid-length of valve) and gentle rugae. Rugae significantly stronger over the ears. Spines reaching a density of 6 to 7 per 25 mm², measured at mid-length of valve. The spines exhibit a low angle with the valve surface; on the ears they are grouped into "bunches". Dorsal valve flat to slightly concave, ornamented with costellae and rugae, that are notably more conspicuous than in the ventral valve, becoming wavy on the ear region. Internal features unknown.

Discussion

In relation to *Costatumulus* sp. A and *Costatumulus* sp. B described from the Río del Peñón Formation, *Costatumulus* sp. C is distinctively more convex. Compared with *Costatumulus* sp. A, *Costatumulus* sp. C is notably larger and it shows a greater density of costellae and spines than *Costatumulus* sp. B.

Costatumulus irwinensis Archbold, 1983, has a strongly convex ventral valve like *Costatumulus* sp. C but the Australian species is larger.

Compared with *Cancrinella villiersi* (d'Orbigny) from the lower Permian Tarma Group of Perú (Chronic, in Newell *et al.*, 1953, p. 89, pl. 6, figs. 10-14), *Costatumulus* sp. C has a strongly convex ventral valve with strongly incurved umbo but both species are rather close in details of costellae and rugae.

Order RHYNCHONELLIDA Kuhn, 1949

Superfamily RHYNCHOPOROIDEA Muir-Wood, 1955

Family Rhynchoporidae Muir-Wood, 1955

Genus *Rhynchopora* King, 1865

Type species: *Terebratula geinitziana* de Verneuil, 1845. Late Permian, northern Russian platform.

Remarks

The diagnosis of the genus has been revised by Erlanger (1981), using topotypical material of the type species from the Archangel province (European Russia), Kazanian Stage, upper Permian.

Rhynchopora is known from the Devonian, Carboniferous and Permian of Europe, Asia, North Africa, America and Australia. This is the first record from Argentina.

Rhynchopora sp.

Fig. 5 m-v

Locality: Western limb of the Rincón Blanco syncline, 35 km west of Jagüé, La Rioja province.

Stratigraphic horizon: Río del Peñón Formation, middle member, horizon 11.

Material: Five internal moulds of ventral valves (IPI 3361, 3364, 3376, 3382, 3384); five internal moulds of articulated specimens (IPI 3362, 3365, 3366, 3367, 3368); three external moulds of ventral valves (IPI 3363, 3371, 3375); eleven internal moulds of dorsal valves (IPI 3369, 3370, 3372a, 3373a, 3374a, 3378a, 3379, 3380, 3381, 3383, 3385); six external moulds of dorsal valves (IPI 3372, 3373b, 3374b, 3377, 3378b, 3379b); additional internal and external ventral and dorsal moulds (IPI 3386).

Description

Exterior: Medium size, subtriangular to rounded in outline. Maximum width slightly anterior to the mid-length of shell. Ventral valve gently convex with greatest convexity at umbo; beak pointed and strongly recurved; sulcus shallow commencing from mid-length and widening anteriorly up to about 2/3 of the maximum width. Dorsal valve more inflated, with a very gentle middle fold that is barely distinguishable from the lateral flanks. Sulcus and fold carrying about 5 costae and the lateral flanks 6 costae each. Costae start from umbo, posteriorly fine and becoming wider towards the anterior margins; on the postero-lateral margins they are barely noticeable. Surface with fine concentric growth lines; punctae coarse up to 5 or 6 per mm anteriorly.

Interior: Dental plates distinct, divergent about 20°, reaching up to 1/3 of the valve length. Dorsal interior with small septalium supported by a distinct median septum that extends to mid-length of valve. Dental sockets slightly crenulate. Other internal structures unknown.

Discussion

The described material is larger than the specimens of the type species *Rhynchopora geinitziana* studied by Erlanger (1981, p. 66, pl. 9, figs. 1-10). Also, our material shows fewer costae on the flanks in relation with the specimens described by Erlanger.

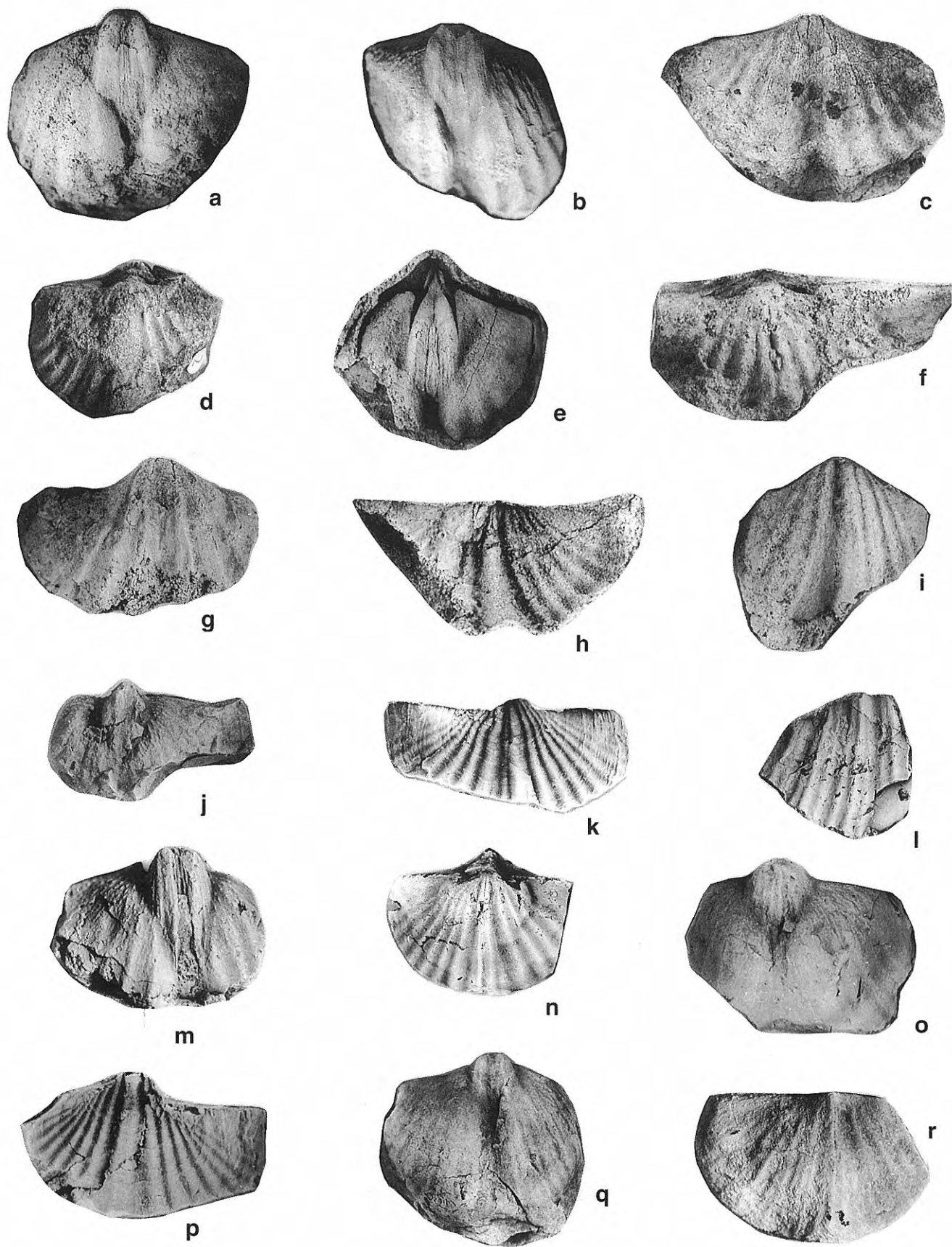
Rhynchopora sp. is very close to *R. australasica* Archbold, described from the Asselian horizons of the Lyon Basin in the Carnarvon Basin, Western Australia (Archbold, 1995, p. 110, figs. 8F-R), which is however larger. Both species have similar external and internal morphological features.

Specimens of *R. culta* Waterhouse described from the Tastubian faunas of Peninsular Thailand (Waterhouse, 1982, p. 345, pl. 2, fig. 6-11) and from the upper Sakmarian fauna of western Malaysia (Shi and Waterhouse, 1991), show the same kind of crenulate dental sockets as our specimens. However, *R. culta* has a more inflated shell with a more trigonal outline and stronger costae than *Rhynchopora* sp.

Also, *R. arctica* Licharev and Einor (in Abramov and Grigorieva, 1983, p. 110-111, pl. 15, fig. 12-17) is close to *Rhynchopora* sp. in its external features of size and shape.

In comparison with South American species described from the Tarma Group, Perú (Chronic in Newell *et al.*, 1953), *Rhynchopora* sp. appears to be close to *R. aff. illinoisensis* (Worthen) (Chronic in Newell *et al.*, 1953, p.

Figure 6. a-i. *Trigonotreta riojanensis* (Lech). a, internal mould of ventral valve, IPI 3153, x2. b, internal mould of articulate specimen, ventral view, IPI 3168, x2. c, ventral valve, IPI 3164, x2. d, internal mould of articulate specimen, dorsal view, IPI 3152, x1. e, internal mould of ventral valve, IPI 3155a, x2. f, internal mould of articulate specimen, dorsal view, IPI 3151, x1.5. g, ventral valve, IPI 3157, x2. h, external mould of ventral valve, IPI 3154, x2. i, incomplete ventral valve, IPI 3163, x1. **j-r.** *Trigonotreta* sp. j, internal mould of ventral valve, IPI 3120, x1.5. k, external mould of dorsal valve, IPI 3125A', x3. l, detail of costae, 3125E, x2. m, p, internal and external mould of ventral valve, IPI 3125B (x4)-B' (x3.5). n, internal mould of articulate specimen, dorsal view, IPI 3125C, x2. o, internal mould of ventral valve, IPI 3116, x1.5. q, internal mould of ventral valve, IPI 3115, x1.5. r, internal mould of articulate specimen, dorsal view, IPI 3117, x1.5.



94-95, pl. 17, fig. 1a-3b). General morphology of the shell and internal features are rather similar in both species. However, *R. aff. illinoisensis* is rather smaller and possesses a greater number of costae than *Rhynchopora* sp.

Order SPIRIFERIDA Waagen, 1883
 Suborder SPIRIFERIDINA Waagen, 1883
 Superfamily SPIRIFEROIDEA King, 1846
 Family **Trigonotretidae** Schuchert, 1893
 Subfamily **Trigonotretinae** Schuchert, 1893
 Genus *Trigonotreta* Koenig, 1825

Type species: *Trigonotreta stokesii* Koenig, 1825. Early Permian of Tasmania.

Remarks

The diagnosis of *Trigonotreta* was discussed by Clarke (1979) when redescribing the type species. The genus includes medium to large non-punctate spiriferids with lateral fasciculate costae and without delthyrial plate but with the apex of the delthyrium usually blocked by a bulbous pedicle callist; dental plates and ventral cardinal region heavily thickened by callus (Clarke, 1979). Related genera also included in the Subfamily *Trigonotretinae* were discussed by Archbold and Thomas (1984) and Archbold (1991).

Trigonotreta was recorded from the Permian of Australia (Thomas, 1971; Archbold and Thomas, 1986; Archbold, 1995), India (Sahni and Dutt, 1959; Waterhouse and Gupta, 1978; Singh and Archbold, 1993; Archbold *et al.*, 1996) and from other peripheral Gondwanan regions such as the Baoshan Block (Shi *et al.*, 1995, 1996), Selong (Shi and Shen, 1997), Oman (Angiolini *et al.*, 1997) and recently from Northern Peninsular Thailand (Archbold, 1999).

In Argentina, Leanza (1945) described *Spirifer* (*Spirifer*) *pericoensis* from the Tupe Formation, Quebrada de la Herradura locality (Paganzo Basin). We have studied conspecific material from the same locality and re-assign Leanza's species to *Trigonotreta*. Recently, Taboada (1999) regarded the occurrence of *Trigonotreta occidentalis* Thomas from the Permian of Patagonia (Mojón de Hierro Formation, Tepuel-Genoa Basin). However, this material wasn't described. Topotypic specimens of *Trigonotreta occidentalis* have been examined by one of us (G.C.) from the collections of the Australian Geological Survey Organisation. These specimens show characteristics clearly different from those of the Argentinean *Trigonotreta* species.

Trigonotreta riojanensis (Lech and Aceñolaza, 1987)

Fig. 6 a-i

Locality: Western limb of the Rincón Blanco syncline, 35 km west of Jagüé, La Rioja province.

Stratigraphical horizon: Río del Peñón Formation, middle member, horizon 6a.

Material: Four articulate specimens, three of which are internal moulds (IPI 3151, 3152, 3158, 3168); three internal moulds of ventral valves (IPI 3153, 3155a, 3156); seven external moulds of ventral valves (IPI 3154, 3155b, 3159b, 3160, 3161, 3162, 3167); six incomplete ventral valves (IPI 3157, 3159a, 3163, 3164, 3165, 3166).

Description

Exterior: Shell of medium size, maximum width along the hinge line. Rate length/maximum width about 0.5 to 0.75. Angular cardinal extremities. Ventral valve more convex than dorsal one, with a prominent and strongly incurved umbo; umbonal angle about 90° to 115°. Interarea low and moderately concave with distinctive denticle grooves and fine growth lines. Delthyrial angle about 60°. Sulcus narrow, widening towards the anterior margin (1/6 of maximum width of the valve). The sulcus is bounded by a costa on each side and the flanks show 6-7 costae. The costae are weakly fasciculated anteriorly. Dorsal valve weakly and regularly convex with an incurved umbo. Fold narrow, with one pair of anteriorly fasciculate costae. The costae pattern on the flanks is similar to that of the ventral valve. Concentric growth lamellae poorly preserved.

Interior: Low apical callus at the apex of delthyrium. Dental plates short (2-3 mm), sub-parallel to weakly divergent. Muscle field distinct, rhomboidal and oval in outline, bisected by a variably developed median ridge. Anterior part of the muscle area strongly elevated. Muscle scars arranged longitudinally. Genital marks radially arranged as pits on each side of the muscle field. Dorsal valve with a weak median myophragm extends anteriorly of the cardinal process. Ventral and dorsal interiors weakly reflect the external costae. Other features unknown.

Discussion

The material described herein is certainly conspecific with the one assigned to *Punctothyris riojanensis* by Lech and Aceñolaza (1987, p. 259, pl. 2, figs. 8-9), from the same horizons of the Río del Peñón Formation. However, the generic attribution by those authors was incorrect. The type species of the genus *Punctothyris* (*Punctothyris argus* Hyde, 1953), from the Carboniferous of North America, shows a "punctate shell" that, according to some authors (Boucot *et al.*, in Moore *et al.*, 1965) should be interpreted as bases of spines. This spinose ornament is absent in Lech and Aceñolaza's material, and is considered a diagnostic character for the family Gerkispiridae in which the genus *Punctothyris* is included (Carter *et al.*, 1994).

The array of diagnostic characteristics observed in the material described (e.g. external shell morphology, absence of cardinal plates, presence of cardinal callus and dental plates), suggests its inclusion in *Trigonotreta*. However, *Trigonotreta riojanensis* shows some differences from the type species such as the absence of

*1987 *Punctothyris riojanensis* Lech and Aceñolaza, 259-260, pl. 2, fig. 8-9; pl. 3, fig. B.

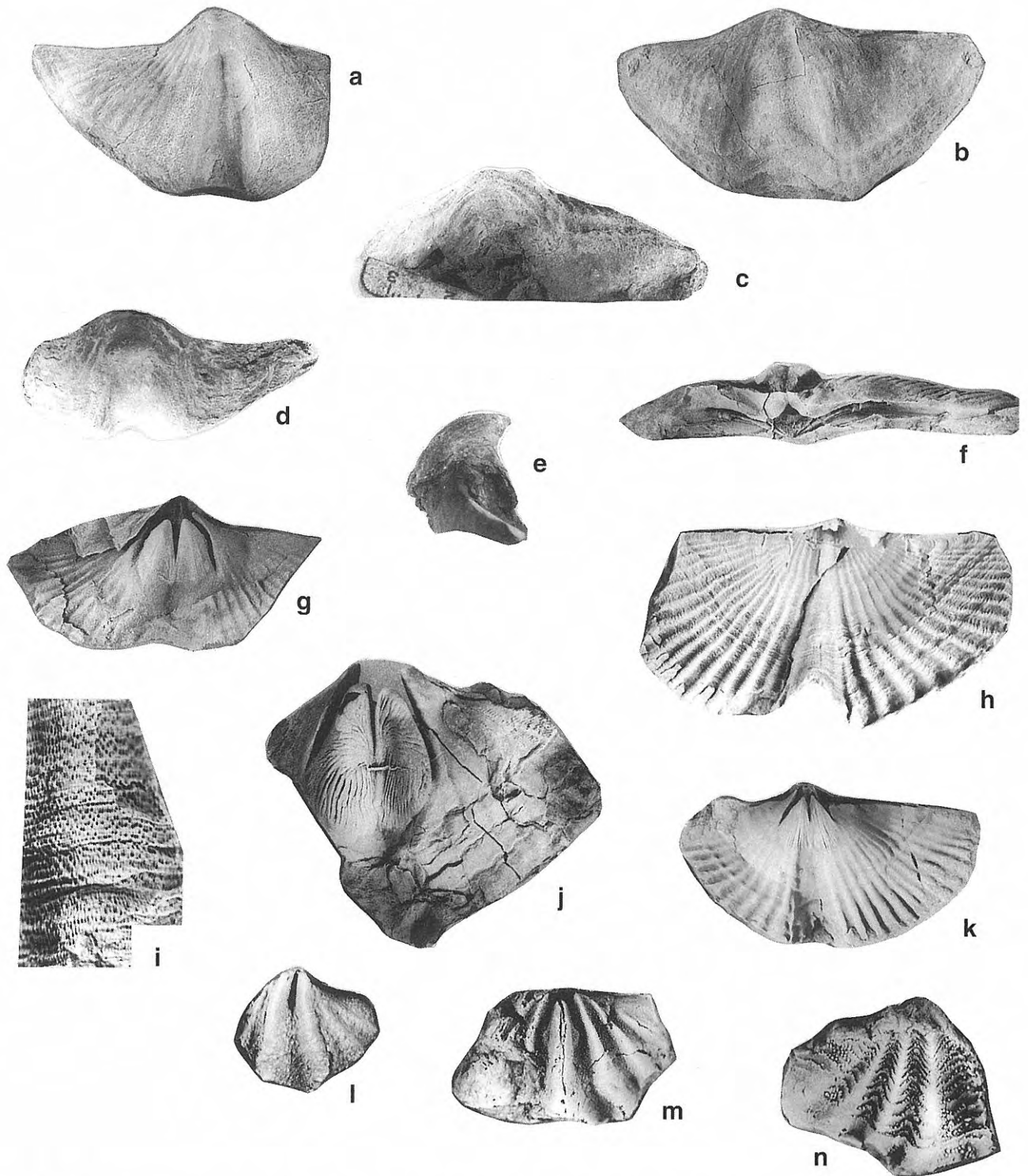


Figure 7. a-k. *Septosyringothyris jaguelensis* Lech. a, d. ventral valve, ventral and anterior views, IPI 3066, x1. b, c. dorsal valve, dorsal and anterior views, IPI 3067, x1. e, incomplete ventral valve, lateral view, IPI 3009, x2. f, internal mould of dorsal valve, posterior view, IPI 3021, x1. g, internal mould of ventral valve, IPI 3049, x1. h, k, external and internal moulds of ventral valve, IPI 3001 b (x1.5), 3001a (x1). i, detail of the micro-ornament of fragmentary external mould of ventral valve, IPI 3026, x4. j, ventral valve internal mould of mature specimen, IPI 3053a, x1. **l-n.** *Spiriferellina* sp. l, internal mould of incomplete articulate specimen, ventral view, IPI 3183 A', x5. m-n, internal and external mould of dorsal valve, IPI 3183B-B', x3.5.

the typical fasciculation of the lateral costae into groups of three, and less developed apical callus. Nevertheless, these differences do not justify, in our opinion, a different

generic placement. Carter (1990) also suggested that the costae pattern of the *Trigonotreta* species could be highly variable.

In relation with Australian species, *T. riojanensis* is morphologically close to juvenile and submature specimens of *T. victoriae* Archbold, described from the Asselian-early Tastubian of eastern Australia (Archbold, 1991, p. 323, figs. 2A-X). However, large adult specimens of *T. victoriae* have rounded cardinal extremities and a typical costae pattern in fascicles of three costae.

The Himalayan species *T. orientensis* Singh and Archbold (1993, p. 70, fig. 10A-J) differs from our species in the number and nature of the costae pattern. However, both species show the transverse character of adult individuals. *T. hesdoensis* (Sanhi and Dutt), a species recorded from peninsular India (Sanhi and Dutt, 1959; Archbold *et al.*, 1996), resembles the Argentine species in its weakly fasciculate costae pattern.

Material from the Del Salto Formation referred by Lech and Aceñolaza (1990, p. 84-85, pl. 1, A, photographs 1-3) to *Punctothyris sanjuanensis* is very close to our *T. riojanensis* specimens. These authors point out three diagnostic features to differentiate *P. sanjuanensis*, i.e. angular cardinal extremities, maximum width coincident with the cardinal line and the absence of a small septum in the ventral valve. Of these characters, the first two were also observed in the material from Río del Peñón. It should be noted that in the genus *Trigonotreta*, individuals within a single species vary from rounded to transverse according to the ontogenetic stage of the specimens. As to the third diagnostic feature mentioned by Lech and Aceñolaza, these authors themselves state that the presence of an apical callus could be masking the median septum. However, we would need a better review of the Del Salto material to confirm a conspecific condition with our material from Río del Peñón.

Trigonotreta sp.

Fig. 6 j-r

Locality: Eastern limb of the Rincón Blanco syncline, 35 km west of Jagüé, La Rioja province.

Stratigraphical horizon: Río del Peñón Formation, lower member, horizons 5' and 6'.

Material: Six internal moulds of ventral valves (IPI 3115, 3116, 3118, 3120, 3123, 3125B); two incomplete internal moulds of dorsal valves (IPI 3122, 3124); four internal moulds of articulate specimens (IPI 3117, 3119, 3121, 3125C); one external mould of ventral valve (IPI 3125B'); one external mould of dorsal valve (IPI 3125A'). Additional fragmentary material (IPI 3125E). All this material proceed from the horizon 6'.

Description

Exterior: Small to medium-sized shell with angular cardinal extremities; maximum width immediately anterior to hinge line. Ventral valve more convex than the dorsal

one; umbo incurved; sulcus narrow, starting at the umbo and widening towards the anterior commissure. Dorsal valve with a narrow fold, better differentiated from the flanks at the anterior margin.

The bifurcate costae pattern is poorly preserved. In the juvenile specimens the flanks show 7 costae (measured on the posterior region of the valves). Adult specimens exhibit fasciculate costae at mid-length of shell, where they number about 10 costae on each flank. Fold costate, with two fasciculate costae. Costae in the sulcus are not preserved. Concentric growth lamellae poorly preserved.

Interior: Apical callus at the apex of delthyrium. Muscle field distinct, sub-rhomboidal to oval, postero-laterally bounded by short and divergent dental plates. Strong muscle scars impressed longitudinally throughout the field. Genital marks radially arranged as pits on each side of the muscle field. Dorsal valve with a delicate median myophragm. Other characters unknown. Ventral and dorsal interior weakly reflecting the external costae pattern.

Discussion

Although very fragmentary, this material shows enough diagnostic characteristics to place it in *Trigonotreta*. Because the preservation of these specimens is so poor, it is difficult to compare with *Trigonotreta riojanensis*, described from the middle member of the Río del Peñón Formation. However, in *Trigonotreta* sp. the maximum width occurs slightly anterior to the hinge line. Both species are very similar internally, but in *T. riojanensis* the dental plates are slightly longer and less divergent and the muscle area is more elevated. The costae appear finer than in the species discussed above.

Specimens here studied are inadequate for precise comparison with other described *Trigonotreta* species. Nevertheless, *Trigonotreta* sp. shows a weakly fasciculate costae pattern characteristic of the oldest Indian species, such as *Trigonotreta hesdoensis* (Sanhi and Dutt) from the Asselian-Tastubian faunas of peninsular India (Archbold *et al.*, 1996).

Order SPIRIFERINIDA Ivanova, 1972

Suborder SPIRIFERINIDINA Ivanova, 1972

Superfamily SYRINGOTHYRIDOIDEA Fredericks, 1926

Family Syringothyrididae Fredericks, 1926

Subfamily Septosyringothyridinae Massa, Termier and Termier, 1974

Genus *Septosyringothyris* Vandercammen, 1955

Type species: *Septosyringothyris demaneti* Vandercammen, 1955. Lower Carboniferous of Belgium.

Remarks

Vandercammen (1955) proposed the genus *Septosyringothyris* for punctate syringothyrid species sharing the following characters: smooth sulcus and fold, transverse delthyrial plate with a syrinx connected to the ventral valve floor by a conspicuous median septum.

These features allow to separate it easily from *Syringothyris* Winchell.

In the latest revision of the spiriferids (Carter *et al.*, 1994) the *Septosyringothyridinae* includes only *Septosyringothyris* and *Histosyrinx* Massa *et al.*, 1974. *Histosyrinx* lacks a transverse delthyrial plate; instead it has two partly joined plates (equivalent to the stegidial sheets), where the syrinx is directly inserted at the junction of these plates.

Septosyringothyris has been recorded from the lower Carboniferous of Belgium (Vandercammen, 1955), and the upper Carboniferous of the Pamirs, Russia (Volgin, 1965). Recently, Isaacson and Dutro (1999) described from the lower Carboniferous of the Northern Chile, the oldest occurrence of the genus in western South America.

In Argentina, *Septosyringothyris* was first described from the Carboniferous of the Precordillera (in Keidel and Harrington, 1938) with the species *S. keideli* (Harrington). Afterwards, many authors have mentioned it for rocks from Patagonia and the Precordillera, being an ubiquitous element of the Carboniferous-Permian of this region.

Septosyringothyris jaguelensis Lech, 1986

Fig. 7 a-k

*1986 *Septosyringothyris jaguelensis* Lech, 57-60, pl. 1, fig. 1-5.

1987 *Septosyringothyris jaguelensis* Lech; Lech and Aceñolaza, 259, pl. 3, fig. 7; pl. 3, fig. A.

Locality: Western limb of the Rincón Blanco syncline, 35 km west of Jagüé, La Rioja province.

Stratigraphical horizon: Río del Peñón Formation, middle member, horizons 7, 10 and 11.

Material: Fifteen internal moulds of ventral valves (horizon 10: IPI 3078, 3083, 3086a, 3091; horizon 11: IPI 3001a, 3002, 3019, 3022a, 3023, 3034, 3037a, 3049, 3050, 3051, 3053a); eight external moulds of ventral valves (horizon 7: IPI 3064b; horizon 10: IPI 3076b, 3081b, 3086b; horizon 11: IPI 3001b, 3022b, 3037b, 3053b); fifteen internal moulds of dorsal valves (horizon 10: IPI 3085, 3089; horizon 11: IPI 3004, 3005a, 3007, 3008, 3017, 3018, 3021, 3024, 3025, 3036a, 3047a, 3048, 3052a); four external moulds of dorsal valves (horizon 7: 3074b; horizon 11: IPI 3005b, 3036b, 3052b); ten ventral valves (horizon 7: IPI 3064a, 3066, 3071, 3072; horizon 10: 3076a, 3081a, 3082, 3090, 3092; horizon 11: IPI 3009); twelve dorsal valves (horizon 7: IPI 3063, 3065, 3067, 3068, 3069, 3070, 3073, 3074; horizon 10: IPI 3079, 3080, 3084, 3087); two internal moulds of articulate specimens and its external moulds (horizon 11, IPI 3006a-b and 3020a-b); one hundred incomplete internal and external moulds and valve fragments (IPI 3026, 3075, 3093).

Description

Exterior: Shell punctate, large, transverse (length/maximum width 0.5 to 0.7), with angular cardinal

extremities. Ventral valve gently convex, umbo weakly inflated, moderately to strongly incurved over a high and weakly concave interarea. Umbonal angle 95° to 110° and delthyrial angle of 45° to 65°. Sulcus broad and distinct, widening anteriorly about 0.25 to 0.20 of the maximum width. Dorsal valve with a weakly prominent umbo; fold clearly distinct from the flanks, with a rectangular section and a weak median sulcus. Costae pattern is similar on each valve. Ontogeny reflects three changes in the costae number, ranging from juvenile stages with 8-12 costae, juvenile-submature stage with 12-18 and matures stages with 16-18 costae on each flank. Micro-ornament of fine radial striae with fine elongate pustules between striae producing textile-like appearance. Concentric growth lines very conspicuous, c. 2-3 per mm near mid-length of shell.

Interior: Dental plates strong, reaching up to 0.35 to 0.33 of valve length; dental plates divergent 50° to 65°. Delthyrial plate poorly developed (3.5 to 4 mm), connecting the posterior ends of dental plates. Distinct median septum connecting the syrinx with the valve surface. In juveniles, the median septum is a delicate ridge, becoming very conspicuous only in mature specimens. Muscle field better defined in mature specimens. Two sorts of ventral diductor scars lie between and in front of the dental plates: longitudinal scars occupying the anterior part of the muscle field and radial scars disposed at the posterior part of it. Dorsal interior with a distinctive large and striated cardinal process and deep, extended dental sockets. Weak median septum rising anteriorly to cardinal process, reaching up to 0.5 of the valve length.

Discussion

The morphological features observed on our specimens allow us to include them in *Septosyringothyris jaguelensis* Lech, described from the Agua de Jagüel (Lech, 1986, p. 57, pl. 1, figs. 1-5) and Río del Peñón (Lech and Aceñolaza, 1987, p. 259, pl. 2, fig. 7) formations. Some differences (umbonal curvature, number of costae in mature specimens and umbonal angle) with the type material, does not warrant specific differentiation.

Also, Lech and Aceñolaza (1987, p. 257-259, pl. 2, fig. 4-6; pl. 3, fig. C) described *S. jaguensis* from the Río del Peñón Formation and stated as distinctive characteristics in relation to *S. jaguelensis*, the number of costae per flank (15 vs. 18) and the shell length/width ratio. The specimens referred by us to *S. jaguelensis* show a considerable range of variation in these characteristics according to the ontogenetic stage (costae per flank: 10 to 18; L/W ratio: 0.5 to 0.7). However, they could not be compared more closely with *S. jaguensis* since this species was based on very fragmentary material and its original description is too vague. For this reason, we can't decide whether *S. jaguensis* and *S. jaguelensis* are conspecific.

S. jaguelensis shows significant differences (internal and external) with the Carboniferous species *S. keideli* (Harrington) from the Leoncito and La Capilla Formations (Keidel and Harrington, 1938; Amos *et al.*, 1963; Cisterna, 1997). *S. jaguelensis*, herein described,

lacks the pyramidal shape of the ventral valve of *S. keideli*, the umbo is generally stronger incurved and the sulcus is narrower and deeper. The dorsal valve shows a high fold of sub-rectangular section, generally provided of a median sulcus. Internally, the dental plates and the median septum are longer and thicker than in *S. keideli*.

S. amosi Lech and Aceñolaza, 1990 (p. 85-86, pl. 1, A, photographs 4-7) and *S. globosa* Lech, 1993 (p. 564-566, pl. 1, fig. 4-5), described from the Del Salto Formation, have inflated shells that can be very large at maturity, with rounded cardinal extremities and a smaller variation of the delthyrial angle.

In relation to the South American species *S. covacevichi* Isaacson and Dutro, 1999 (p. 629, figs. 3.1-3.8), *S. jaguelensis* has a smaller umbonal angle and the ventral interior shows more conspicuous dental plates and median septum.

The type species of *Septosyringothyris*, *S. demaneti*, described from the Carboniferous of Belgium (Vandercammen, 1955, p. 2; pl. 1, figs. 1-8) is smaller, with a narrower sulcus and a smooth fold. It also usually shows a bifid ventral median septum.

S. tomiensis Sokolskaya (Sarytcheva *et al.*, 1963, p. 279, pl. 49, figs. 11-19), can be separated from *S. jaguelensis* by its smaller size and more numerous lateral costae (19-20). Also, the Russian species *S. pamirensis* Volgin, 1965 (p. 146, figs. a-g), can be differentiated from *S. jaguelensis* fundamentally because its outline is more transverse and the fold smooth and weaker than in the Argentine species.

Superfamily **PENNOspiriferinoidea** Dagus, 1972
 Family **Crenispiriferidae** Cooper and Grant, 1976
 Genus *Spiriferellina* Fredericks, 1924

Type species: *Terebratulites cristatus* Schlotheim, 1816. Late Permian, Pössneck, Thuringia (Germany).

Spiriferellina sp.

Fig. 7 1-n

Locality: Eastern limb of the Rincón Blanco syncline, 35 km west of Jagüé, La Rioja province.

Stratigraphical horizon: Río del Peñón Formation, lower member, horizons 5' and 6'.

Material: One incomplete internal mould of an articulated specimen with its external mould of the ventral valve (IPI 3183A'-A); two internal moulds of ventral valves (IPI 3183D, 3183E); two internal moulds of dorsal valves (IPI 3183B, 3183C); one external mould of dorsal valve (IPI 3183 B'). All material from the horizon 6'.

Description

Small punctate shell with angular cardinal extremities; maximum width near hinge line; sulcus and fold strong, smooth, about one third of the maximum width, slightly

wider than lateral costae. Lateral slopes with 2 to 3 strong and subangular costae. Surface pustulose; conspicuous concentric lamellae (about 2 per mm at anterior part of the valve). Ventral interior with short dental plates and conspicuous median septum. Dorsal interior with a delicate median myophragm. Other features unknown.

Discussion

Although incomplete, this material is figured for completeness of the brachiopod faunas from the Río del Peñón Formation and is tentatively referred to *Spiriferellina* Fredericks.

Spiriferellina sp. is distinguished by its small size for the genus and small number of lateral costae. Even though inadequate for detailed specific comparisons, *Spiriferellina* sp. is remarkably smaller in relation to *Spiriferellina octoplicata* (Sowerby) from the Carboniferous of Argentina (Keidel and Harrington, 1938; Amos, 1958, 1979; Amos *et al.*, 1963). Also, *Spiriferellina octoplicata* generally shows four lateral costae on each flank and slightly smaller number of concentric lamellae per mm.

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