The Cisuralian faunal succession in Patagonia (Tepuel-Genoa Basin, Argentina): an updated brachiopod biostratigraphic scheme

M. ALEJANDRA PAGANI AND ARTURO C. TABOADA

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The Tepuel-Genoa Basin, located in the Patagonian region (Chubut Province) of southern Argentina, was a wide embayment open to the Panthalassic Ocean at the southwestern border of Gondwana; it was infilled by nearly 7000 m of a continuous succession (Tepuel Group), from the early Carboniferous (late Tournaisian) to the early Permian (Artinskian). Lowermost Permian faunas were recognised in the upper part of the Pampa de Tepuel Formation, but the first record of a *Costatumulus*-like faunal assemblage starts in the lower part of the overlying Mojón de Hierro Formation and ends in the upper part of the Río Genoa Formation. Recently, refined proposals on the stratigraphic arrangement of the Mojón de Hierro and Río Genoa formations, and discrimination of faunal assemblages throughout these units, allowed us to identify a wide spatial and temporal distribution for *Costatumulus* Waterhouse within the basin. New material collected from different localities and fossiliferous horizons throughout the Tepuel-Genoa Basin suggests a greater number of species than the previously recorded single occurrence of *Costatumulus*, and also the presence of its allied genus *Magniplicatina* Waterhouse. Such adjustment in the taxonomic composition of the former *Costatumulus* Biozone allows the recognition of six different and successive faunal assemblages; and also three potentially new species of *Costatumulus*, as follows. The *Cimmeriella* Fauna (~late Asselian-Sakmarian) recorded with *Costatumulus* sp. 1 (formerly *Cancrinella* cf. *C. farleyensis*), and the *Kochiproductus-Costatumulus* Fauna (~latest Sakmarian-earliest Artinskian) bearing *Costatumulus* sp. 2, are both recorded in the upper section of the Mojón de Hierro Formation. The younger *Costatumulus-Tivertonia* Fauna (~early Artinskian) yields *Costatumulus* sp. 3 in the lower part of the Río Genoa Formation, whilst the *Jakutoproductus* (~late early Artinskian), *Piatnitzkya* (~late early -middle Artinskian) and the youngest *Magniplicatina* sp. (~middle Artinskian) faunas characterise the uppermost section of the Río Genoa Formation. The taxonomic composition of the *Costatumulus* Biozone faunal succession in Patagonia initially suggests strong but temporally varied faunal links with western Australia and the Cimmerian regions in south and southeast Asia, as well as moderate but significant links with the Siberian Arctic region and, to a lesser extent, with eastern Australia.

M.A. Pagani (apagani@mef.org.ar), Museo Paleontológico Egidio Feruglio – CONICET, Av. Fontana 140, Trelew, U9100GYO, Chubut, Argentina; A.C. Taboada, Laboratorio de Investigaciones en Evolución y Biodiversidad (LIEB), Facultad de Ciencias Naturales, Sede Esquel, Universidad Nacional de la Patagonia "San Juan Bosco" (UNPSJB). RN 259, km 16.5, Esquel (U9200), Chubut, Argentina. *Received 24 May 2011,*

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THE MARINE Cisuralian deposits in Patagonia were historically characterised by the presence of linoproductid brachiopods originally assigned to *Cancrinella* cf. *C. farleyensis* (Etheridge & Dunn) by Amos (1960) a half century ago. The species characterised the *Cancrinella* Biozone, proposed a few years later (Amos & Rolleri, 1965) for the stratigraphic interval of the upper part of the "Upper Tepuel System" of Suero (1948) which corresponds to the Mojón de Hierro and Río Genoa formations in current terminology (Archangelsky *et al.*, 1996). The Patagonian *Cancrinella* cf. *C. farleyensis* (Etheridge & Dunn) was later included in the synonymy of *Costatumulus amosi* Taboada, 1998, but was subsequently considered to be a different species by Simanauskas & Archbold (2002), with whom we agree here.

In the last few years, new material was collected by the authors from fossiliferous horizons in

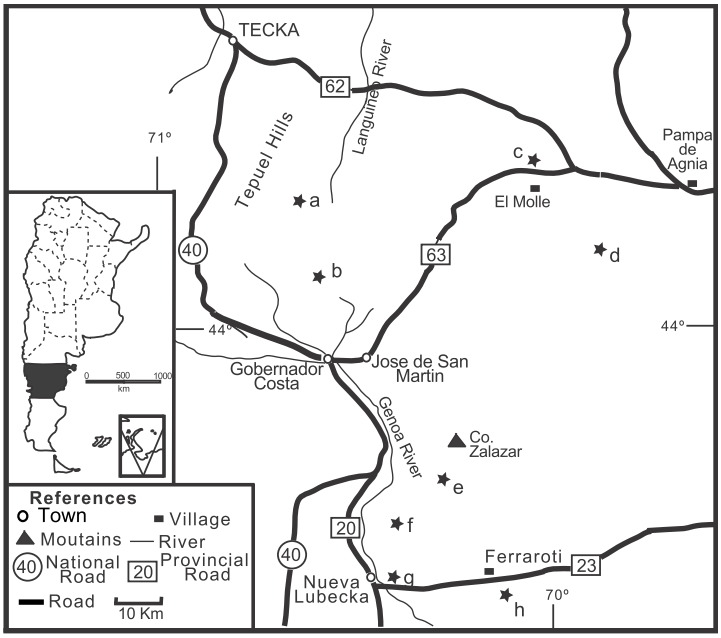

Figure 1. Tepuel-Genoa Basin, locality map. Legend: star symbols are fossil localities; a, Puesto Tres Lagunas; b, Arroyo Garrido; c, El Molle; d, Cañadon Hondo; e, Lomas Chatas; f, Piedra Shotel; g, Cerro La Trampa; h, Ferraroti.

different localities in the Tepuel-Genoa Basin. The new material has allowed us to recognise, besides the conspicuous *Costatumulus*, diverse stratigraphic assemblages of key brachiopod genera. In this way it is possible now to describe a more detailed faunal succession with increased stratigraphic precisions throughout the Lower Permian sequence.

Therefore, the aim of this contribution is to present the recent biostratigraphical advances in the Cisuralian faunal succession of the Tepuel-Genoa Basin. Since a more comprehensive study of the fauna is necessary, in this contribution only the faunal succession is reported, while a biostratigraphic scheme will be the subject of another contribution. However, the accurate faunal succession of the lower Permian deposits presented here and the recognition of new key brachiopod taxa allows movement toward a new, tighter biostratigraphic chart.

The material mentioned and illustrated here was collected at different times by the authors, and it is housed at the Museo Paleontológico Egidio Feruglio (MPEF-PI), the Laboratorio de Investigaciones en Evolución y Biodiversidad de la Universidad Nacional de la Patagonia San Juan Bosco (LIEB-PI), and the Instituto de Paleontología de la Fundación Miguel Lillo (FML-PI).

GEOLOGICAL AND STRATIGRAPHIC SETTING

The Tepuel-Genoa Basin is located in the central-west Patagonian region (Chubut Province) of southern Argentina (Fig. 1). The basin was a wide embayment open to the Panthalassic Ocean at the southwestern margin of Gondwana, and was infilled by nearly 7000 m of a continuous succession (Tepuel Group) from the early Carboniferous (late Tournaisian) to the early Permian (Artinskian). The sediments crop out along a north-northwest to south-southeast trend, being exposed in the Tepuel and Tecka hills and Río Genoa Valley. The material figured in this contribution has been sampled from various localities such as: east of Tres Lagunas Post and Arroyo Garrido Creek in the Tepuel Hill, El Molle and Cañadón Hondo in the Pampa de Agnia area, and Piedra Shotel (or Shottle), Cerro La Trampa and the Ferraroti salt lake in the Río Genoa Valley (Fig.1).

The stratigraphic succession and current formational scheme for the Tepuel Group have been established by numerous studies during the last 40 years. An updated and detailed historical chronology of the stratigraphic sequence of Patagonia is reported by Taboada & Pagani (2010) and Pagani & Taboada (2010). Basically, the upper Palaeozoic formations lay unconformably over the Catreleo Devonian granite (Robbiano 1971) and are overlain, also unconformably, by Lower Jurassic marine strata. In the current lithostratigraphical scheme, five units have been recognised (Andreis *et al*. 1996) from the base to the top: the Jaramillo, Pampa de Tepuel and Mojón de Hierro formations at the type locality of Tepuel Hill, the Las Salinas Formation to the east-northeast of the basin, at Languiñeo Hill, partially equivalent to the Pampa de Tepuel Formation, following González (1972) and our

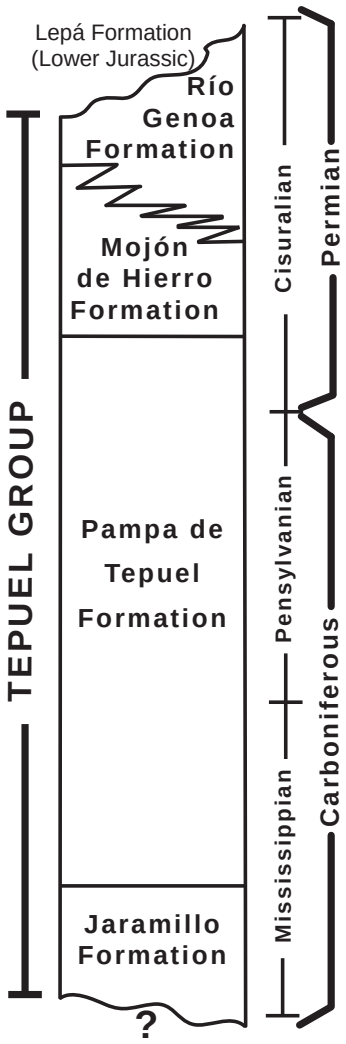

Figure 2. Lithostratigraphic subdivision of the Tepuel Group.

own observations). The Río Genoa Formation was classically considered a lateral equivalent of the middle and upper part of Mojón de Hierro Formation, but other authors have suggested only a partial equivalence between the units. Recently, Taboada & Pagani (2010) and Pagani & Taboada (2010) have discussed this point and they proposed a younger age for the upper part of the Río Genoa Formation and a possible lateral interfingering between the uppermost levels of the Mojón de Hierro Formation and lowermost levels of the Río Genoa Formation, but the precise boundary between both formations still needs to be defined with accuracy (Fig. 2). Taboada & Pagani (2010) have supported the last assertion on the base of the recognition of two major faunas, one in the upper part of the type section in Tepuel Hill, and the other a slightly younger fauna in the lower part of Río Genoa Formation, which will be discussed further on.

PREVIOUS BIOSTRATIGRAPHIC PROPOSALS

Amos & Rolleri (1965) proposed the *Cancrinella* cf. *C. farleyensis* Zone to characterise the late Carboniferous-early Permian deposits in both the Calingasta-Uspallata Basin in central-western Argentina and the Tepuel-Genoa Basin in Patagonia, now a distance of 2000 km from each other. Later, Amos *et al.* (1973) and subsequent authors progressively adjusted the age of the biozone to the early Permian (Sabattini, 1978) or Asselian (González 1981, 1985). More recently, Simanauskas & Sabattini (1997) modified the first and traditional biostratigraphic scheme, which lasted for more than three decades, into a new version where the Permian deposits were characterised by four biozones/faunules, with the previous *Cancrinella* Biozone restricted to the Sakmarian-Artinskian interval (Fig. 3). One year later, with the inclusion of the Patagonian *Cancrinella* cf. *C. farleyensis* in the synonymy of *Costatumulus amosi* Taboada, 1998, the homonym biozone was simply renominated. Later, Pagani & Sabattini (2002) proposed two new schemes, one of them on the basis of bivalve and gastropod distribution, and another one on the basis of cephalopod distribution (Fig. 3).

An updated and detailed historical chronology of the different biostratigraphical schemes proposed for Patagonia is given by Taboada & Pagani (2010) and Pagani & Taboada (2010).

FAUNAL SUCCESSION IN PATAGONIA

Earliest Permian faunas were recognised in the upper part of the Pampa de Tepuel Formation (Taboada *et al*. 2005; Taboada 2008), but the first record of a *Costatumulus*-like faunal assemblage starts in the lower part of the overlying Mojón de Hierro Formation and ends in the uppermost Río Genoa Formation (Taboada 2001). New material collected by the authors from different localities and fossiliferous beds of the last mentioned stratigraphic interval suggests a greater number of species than the previously reported single *Costatumulus* occurrence, and also the presence of its allied genus *Magniplicatina* Waterhouse, 1983.

Such new findings in the brachiopod taxonomic composition of the classical *Costatumulus* Biozone, in addition to the new faunas recently described by Taboada (2008) and Taboada & Pagani (2010), allow for the recognition of seven different and successive faunal assemblages within the Cisuralian of the basin. In other words, the wide ranging and almost invariant (for more than 30 years) *Costatumulus* Biozone

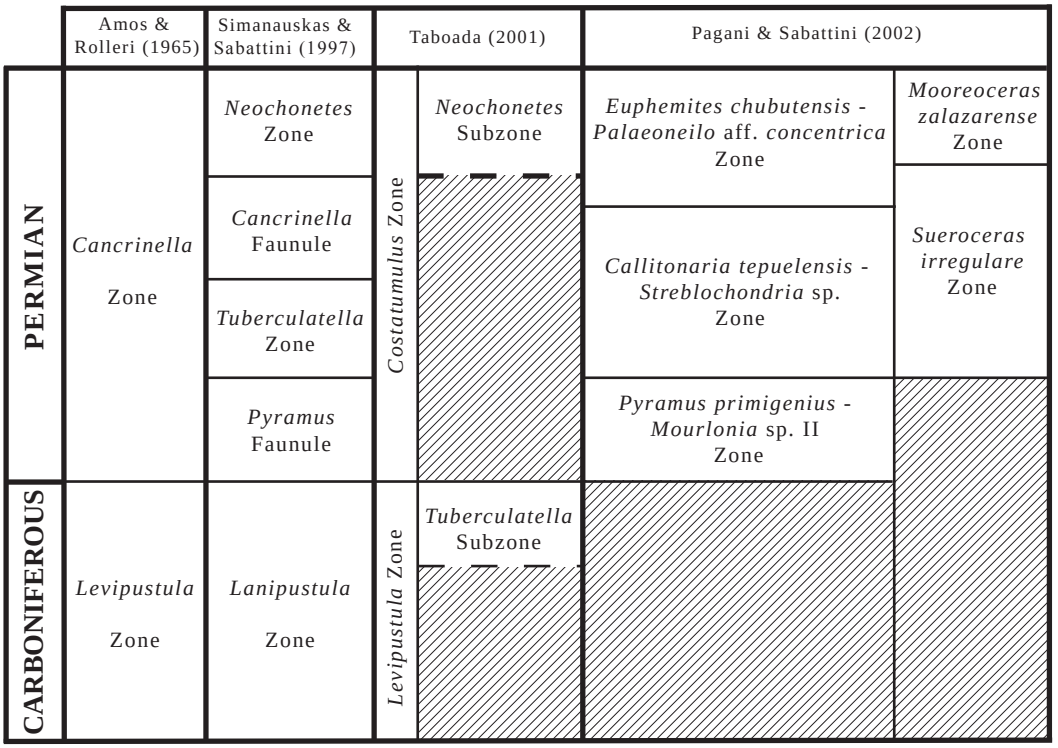

Figure 3. Correlation chart showing biostratigraphic units recognised in the marine Upper Palaeozoic of Patagonia.

(formerly *Cancrinella* Biozone) can be now split into several different assemblages with more stratigraphical precision.

In this contribution the different assemblages are briefly discussed and partially figured (Fig. 4), improving and constraining the different correlation schemes that have been previously proposed.

***Verchojania archboldi* Fauna**

Recently reported by Taboada (2008), this fauna represents the earliest Permian deposits in the Tepuel-Genoa Basin. It is recorded in the upper part of the Pampa de Tepuel Formation near the Tres Lagunas Post in the Tepuel Hill (level Ft1-23 of Freytes 1971/E 21 of Suero 1948; see Taboada 2001) and in the lower beds (level 11 of Perrot 1960) at the El Molle locality (Fig. 1). The species that characterise this fauna are *Verchojania archboldi* Taboada, 2008, (Figs. 5A-B) and other brachiopods such as *Amosia sueroi* Simanauskas, 1996, *Tuberculatella*? *laevicaudata* (Amos, 1960) (Taboada, 2008). In addition, more recent findings have also included *Neilotreta*? sp., *Tuberculatella* sp., and *Tomiopsis*? sp., all of which will be described in a future paper. The *Verchojania archboldi* cold water fauna is stratigraphically located within a major glacial-related horizon (with minor glacial advances and retreats), documented by several glaciomarine diamictites, shales with dropstones and striated pavements (Fig. 8). The known range of *Verchojania* (Late Carboniferous-Asselian) and the stratigraphic position of *V. archboldi* underlying beds with the late Sakmarian *Cimmeriella* fauna (formerly *Globiella* fauna of Taboada 2001) (Taboada & Pagani 2010), suggests an age probably no younger than Asselian (Taboada 2008; Taboada *et al*. 2005) (Fig. 4). The older record of *Verchojania* in Patagonia corresponds to *V. incayali* Taboada, 2008, estimated to be Moscovian-Kasimovian in age (Taboada 2008) and found stratigraphically 700 m below beds bearing *V. archboldi*.

***Cimmeriella-Costatumulus* Fauna**

This fauna is recorded in the Mojón de Hierro Formation throughout the Tres Lagunas Valley. The *Cimmeriella* fauna first appears in the lower part of the Mojón de Hierro Formation, 100 m above the contact with the Pampa de Tepuel Formation. Although the fauna exhibits scarce records of specimens and low diversity in its initial occurrence, profuse fossiliferous beds are exposed in the upper part of the unit (Taboada 2001) (Fig. 1). The *Cimmeriella-Costatumulus* fauna is overlain by the first beds with *Glossopteris*

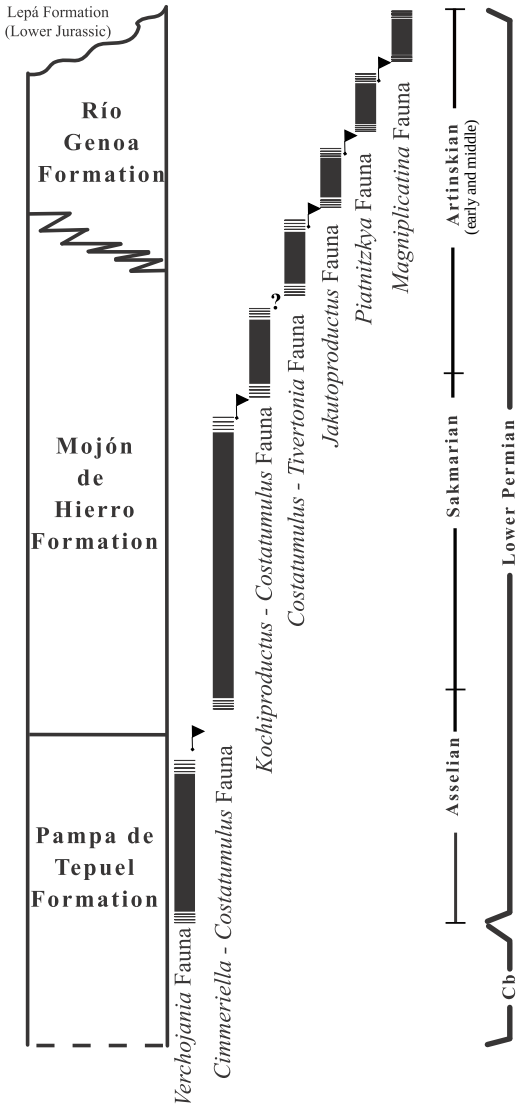

Figure 4. Main brachiopod assemblages characterising the Cisuralian of Patagonia. The dashed line indicates boundaries under revision. Black flags: barren intervals.

and the latest glacial-related horizon recognised in the sequence (Taboada *et al*. 2005; Taboada 2008; Taboada & Pagani 2010). The stratigraphic interval where the *Cimmeriella-Costatumulus* fauna occurs corresponds to a major interglacial episode and it probably suggests cool water conditions. The most abundant and conspicuous brachiopod species in the fauna is *Cimmeriella willi* Taboada & Pagani, 2010, which is associated with *Costatumulus* sp. 1 (=*Cancrinella* cf. *C. farleyensis* of Amos, 1960) (Fig. 5C-I), *Spirelytha* sp., *Quinquenella* sp., *Brachythyrinella* sp., *Arctitetra* sp. and *Neochonetes* sp. among others.

The biostratigraphic meaning of the *Cimmeriella-Costatumulus* fauna has allowed an important discussion of regional and global correlation (Taboada & Pagani 2010; Pagani & Taboada 2010). Following the correlation criteria adopted by Taboada & Pagani (2010) the *Cimmeriella* fauna could be assigned to the late Asselian-Sakmarian (Fig. 4).

***Kochiproductus-Costatumulus* Fauna**

A distinctive faunal assemblage characterised by a profusion of *Kochiproductus* sp. was recognised in the upper part of the Mojón de Hierro Formation at the Arroyo Garrido locality (Fig. 1). Although first mentioned by Taboada *et al*. (2005) the fauna remains undescribed. Besides the previously reported *Kochiproductus* sp. (Fig. 5J-L), *Trigonotreta* sp. and *Costatumulus* sp. 2 (Fig. 5M-N), *Permospirifer* sp. and *Strophalosia* sp. have recently been found to occur here. This assemblage succeeds the preceding *Cimmeriella-Costatumulus* fauna and stratigraphically is located just above the second and final early Permian glacial-related horizon of the basin. The beds bearing the *Kochiproductus-Costatumulus* fauna are located 50 m above this glacial-related horizon, suggesting stratigraphical proximity to cold water conditions. Beds bearing the *Glossopteris* flora and *Nothorhacopteris major* Cúneo, 1990, also covered this glacial-related horizon. The *Kochiproductus-Costatumulus* fauna partially fills the faunal gap between the *Cimmeriella* and the *Jakutoproductus* faunas of Taboada & Pagani (2010), which would suggest a latest Sakmarian-earliest Artinskian age (Fig. 4). In addition to the biostratigraphical meaning, Taboada & Pagani (2010) have suggested that the appearance of the genus *Kochiproductus* Dunbar, 1955 (probably a genus tolerant of a wide water temperature range) in Patagonia, would also reflect the incipient recovery of the faunal migration pathways along the western margin of Gondwana. The migration was probably favoured during episodes of climate amelioration after early Permian glaciation drawdowns. *Kochiproductus* Dunbar, a common element of the *Tivertonia-Streptorhynchus* fauna (Leanza 1948; Cistena & Simanauskas 2000) from western Argentina lower palaeolatitudes, insinuates the end of the marine faunal disconnection between this region and Patagonia that previously (middle late Carboniferous-Sakmarian) existed due to different palaeoclimatic conditions: temperate in the former and colder and with glacial influence in Patagonia.

***Costatumulus-Tivertonia* Fauna**

This assemblage is recorded in the uppermost part of the Mojón de Hierro Formation at the

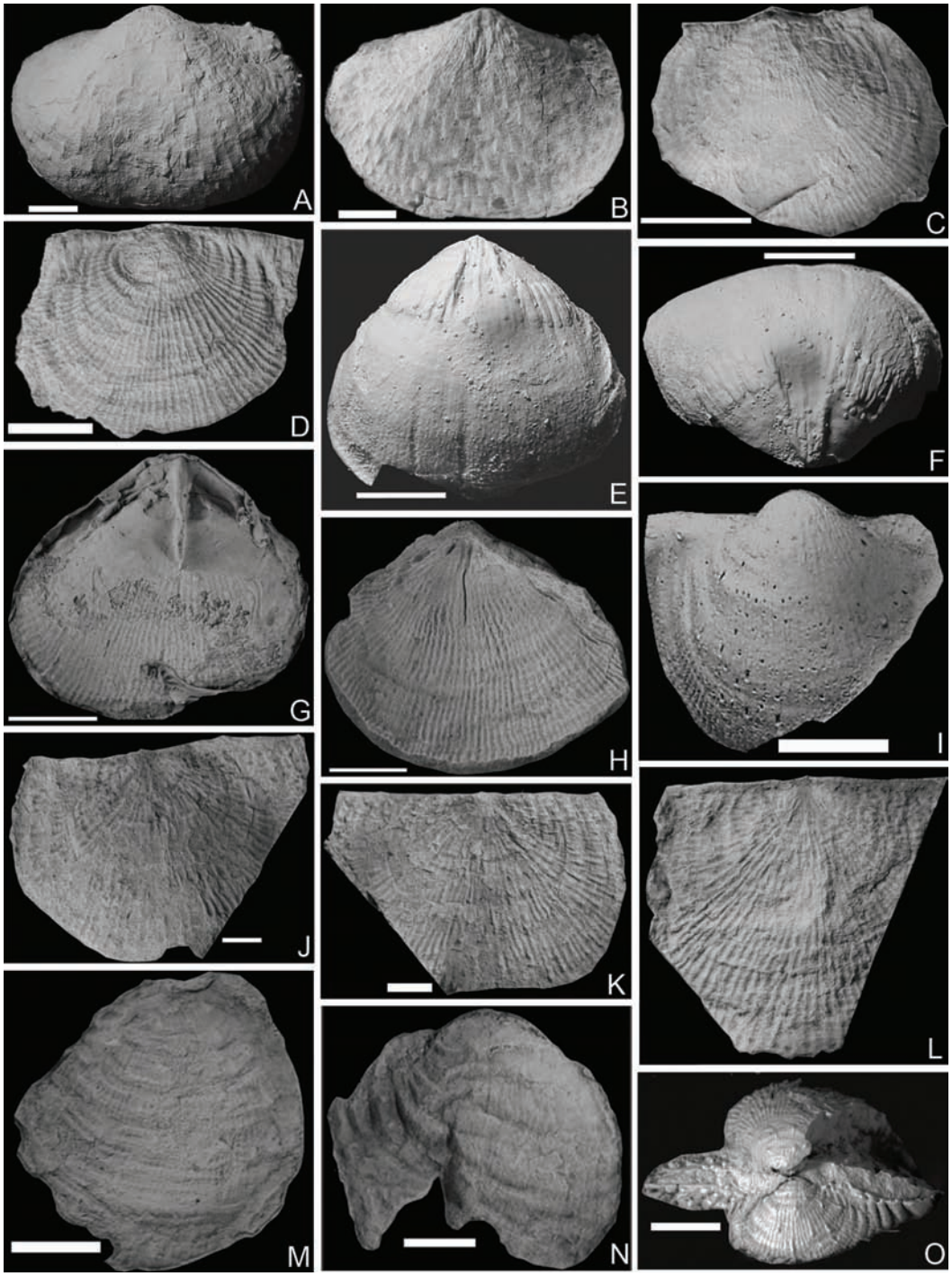

Figure 5. **A**-**B**, *Verchojania archboldi* Taboada, 2008, **A**, LIEB-PI 4, ventral valve exterior, **B**, IPI 3834, ventral valve internal mould. **C**-**D**, *Costatumulus* sp. 1, **C**, MPEF-PI 3871, mould of dorsal valve exterior in ventral view, **D**, MPEF-PI 3872, mould of dorsal valve exterior in dorsal view. **E**-**I**, *Cimmeriella willi* Taboada & Pagani, 2010, **E**-**G**, internal mould of both valves in ventral, antero-ventral and dorsal views, LIEB-PI 209, **H**, FML-PI 2567, dorsal valve internal mould, **I**, IPI 2429, ventral valve internal mould. **J**-**L**, *Kochiproductus* sp., **J**-**K**, MPEF-PI 3873, exterior of dorsal valve and mould of dorsal valve exterior, **L**, MPEF-PI 3874, mould of dorsal valve exterior. **M**-**N**, Costatumulus sp. 2, **M**, MPEF-PI 3875, latex mould of ventral valve exterior, **N**, MPEF-PI 3876, exterior of ventral valve. **O**, *Costatumulus* sp. 3, MPEF-PI 1637. Scale bar = 5 mm.

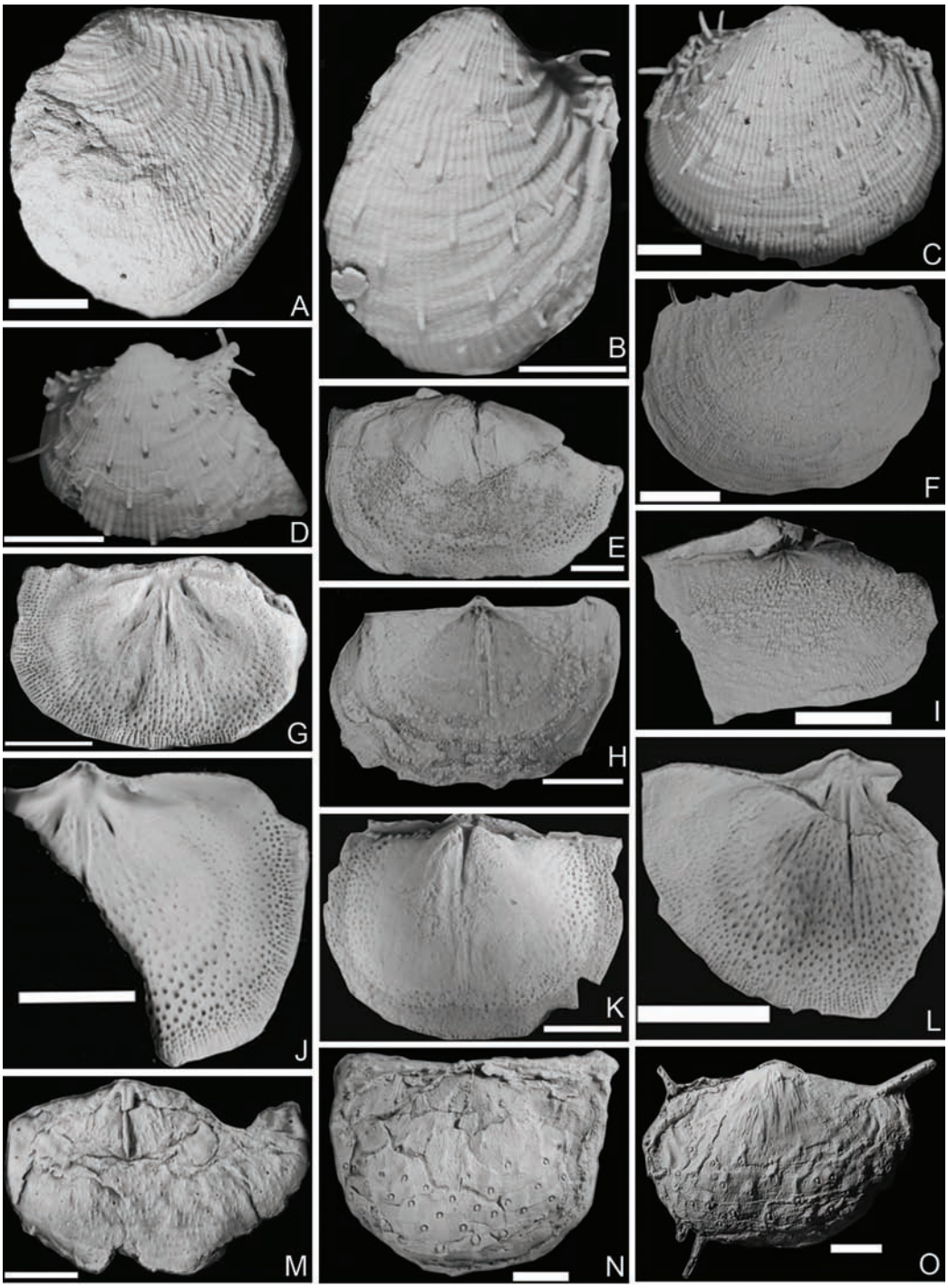

Figure 6. **A**-**D**, *Costatumulus* sp. 3, **A**, MPEF-PI 1747a, **B**, MPEF-PI 1694, latex mould of ventral valve exterior, **C**, MPEF-PI 1637, latex mould of ventral valve exterior, **D**, MPEF-PI 1637, latex mould of ventral valve exterior. **E**-**L**, *Tivertonia* sp., **E**, MPEF-PI 3854, internal mould of ventral valve, **F**, MPEF-PI 1638, partially decorticate dorsal valve exterior, **G**, MPEF-PI 1655, mould of dorsal valve interior, **H**, MPEF-PI 1693e, interior of ventral valve, **I**, MPEF-PI 1693d, decorticate dorsal valve interior and mould of cardinal process, **J**, MPEF-PI 1643, mould of dorsal valve interior, **K**, MPEF-PI 1643, internal mould of ventral valve, **L**, MPEF-PI 3716 mould of dorsal valve interior. **M**-**O**, *Jakutoproductus sabattiniae* Taboada & Pagani, 2010, **M**, MPEF-PI 1787, latex mould of dorsal valve interior, **N**, MPEF-PI 1435, ventral valve internal mould, **O**, MPEF-PI 1443, ventral valve internal mould. Scale bar = 5 mm.

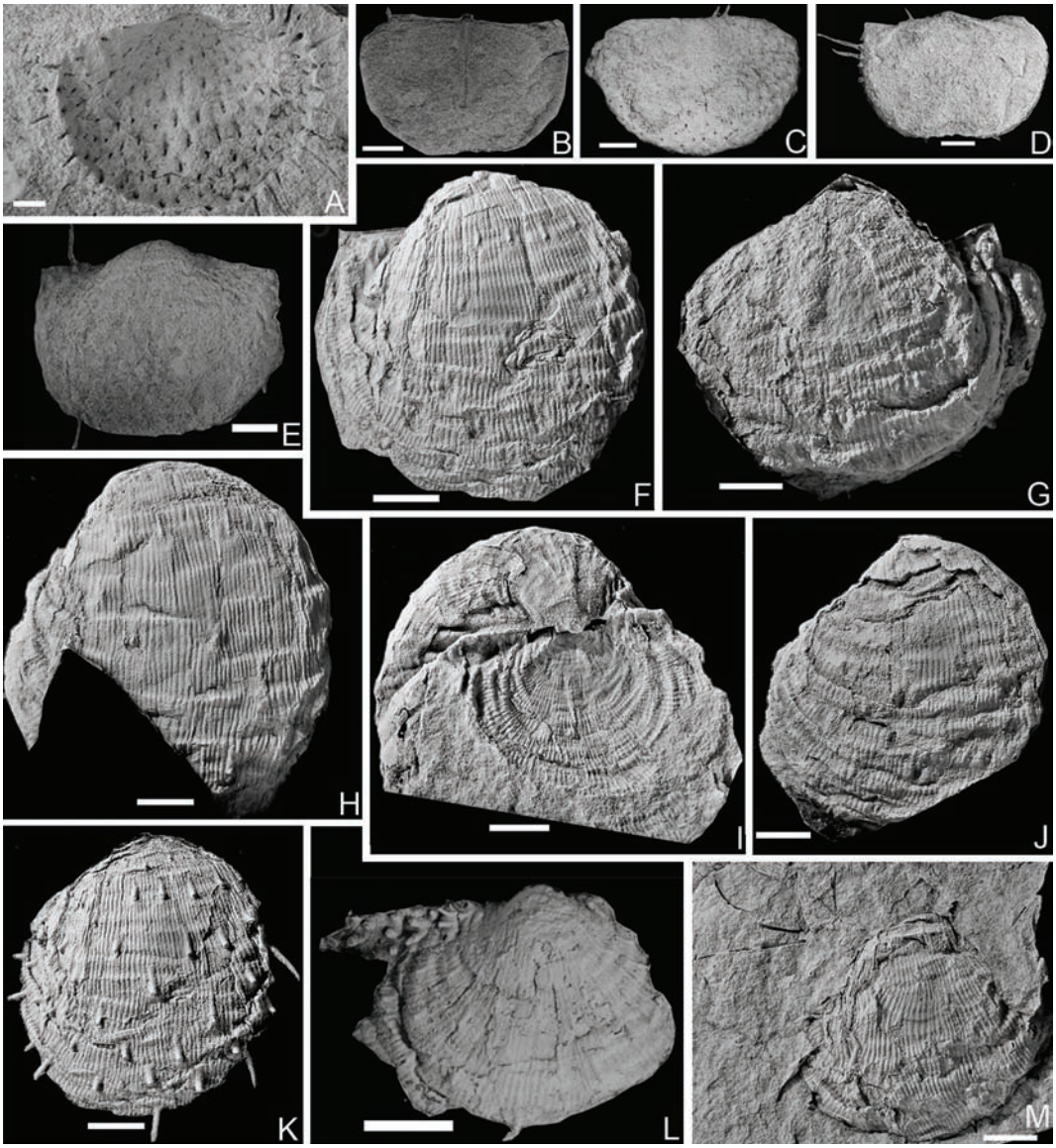

Figure 7. **A-E**, *Piatnitzkya borreloi* Taboada, 1993. **A**, IPI 766a, mould of ventral valve exterior, **B**, MPEF-PI 3879, mould of dorsal valve interior, **C**, MPEF-PI 3880, mould of dorsal valve exterior, **D**, MPEF-PI 3878, mould of ventral valve exterior, **E**, MPEF-PI 3881, mould of ventral valve exterior. **F-M**, *Magniplicatina* sp., **F**, MPEF-PI 1839a, ventral valve external mould of an articulate specimen in ventral view, **G**, MPEF-PI 2800, ventral valve external mould, **H**, MPEF-PI 2801a, ventral valve external mould, **I**, MPEF-PI 1839a, articulate specimen, dorsal valve external mould in dorsal view, **J**, MPEF-PI 2802a, ventral valve external mould, **K**, MPEF-PI 1839b, latex mould of ventral valve exterior, **L**, MPEF-PI 2758, latex mould of ventral valve exterior, **M**, MPEF-PI 2803, ventral valve external mould. Scale bar = 5 mm.

Cañadón Hondo and El Molle localities, and in the lower beds of the Río Genoa Formation at the Lomas Chatas locality (Fig. 1). The fauna is principally recovered from spherical concretions at all localities. The most remarkable species, in its abundance, is *Costatumulus* sp. 3 (Figs. 5O, 6A-D). It is associated with *Tivertonia* sp. (Figs. 6E-L), *Neochonetes* sp. and *Coolkilella* sp. The beds bearing this fauna (collected at the Lomas Chatas locality) are stratigraphically below the first occurrence of the *Jakutoproductus* Fauna (collected at the Piedra Shotel locality). This circumstance, together with the biochronological estimation for the *Jakutoproductus* fauna by Taboada & Pagani (2010) suggests an early Artinskian age, slightly older than the early *Jakutoproductus* fauna in Patagonia. This is in agreement with the known range of the identified

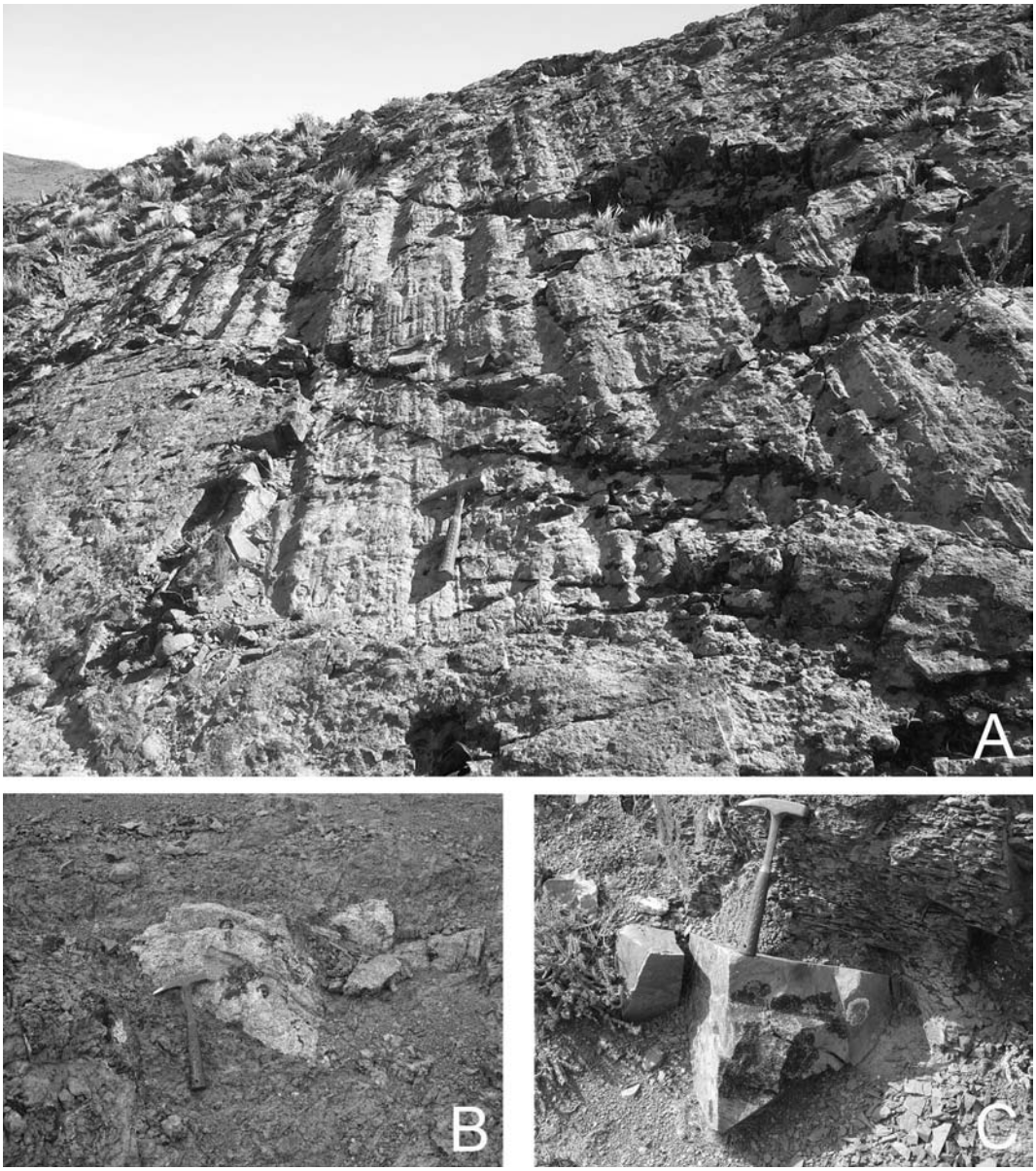

Figure 8. Glacial evidence associated with *Verchojania archboldi* Fauna. **A**, intratill glacial pavement in the upper part of the Pampa de Tepuel Formation at El Molle place, NE of the Lefiú Post, 200 m stratigraphically below beds bearing the invertebrate fauna with *Verchojania archboldi* Taboada, 2008. **B**, Dropstone in shales in the upper part of the Pampa de Tepuel Formation at El Molle place below the glacial pavement. **C**, Granitic boulder in diamictite from the upper part of the Pampa de Tepuel Formation at El Molle place, above the glacial pavement.

brachiopod genera. Both the *Kochiproductus-Costatumulus* and the succeeding *Costatumulus-Tivertonia* faunal assemblages complete the faunal record between the *Cimmeriella* and the *Jakutoproductus* associations.

***Jakutoproductus* Fauna**

This fauna is recorded in the lower part of the Río Genoa Formation at Piedra Shotel, Cerro La Trampa and lower beds of the Ferraroti localities (Fig. 1). This fauna is characterised by two different species of the genus *Jakutoproductus* Kaschirtzev: *J. sabattiniae* Taboada & Pagani, 2010, and *J. australis* Simanauskas & Archbold, 2002, (Fig. 6M-O). *Costatumulus* sp., *Quinquenella* sp., *Attenuatella* sp. and *Leiorhynchus* sp. are also associated with the *Jakutoproductus* occurrences. Rare hollow moulds of glendonite are present

in the horizon with the fossilferous concretions (bed M1 of Ugarte, 1966; NF-1 of Cúneo & Sabattini, 1987), occurring just below the bed with *Jakutoproductus australis*. This suggests that cold to cool water faunas were still occurring near the top of the faunal record in Patagonia.

The well known morphological evolutionary trends of the Russian set of *Jakutoproductus* species, and those recorded by the Patagonian, not heavily ornamented *Jakutoproductus* allowed inference of a relative age not much younger than late early Artinskian for the species recorded in the Río Genoa Formation (Taboada & Pagani, 2010). Nevertheless, *J. sabattiniae* was considered slightly older than *J. australis* by the stratigraphical relationships in the succession where they occur. Beds with *J. sabattiniae* at Piedra Shotel and Cerro La Trampa are in stratigraphic continuity with the lower *Costatumulus-Tivertonia* fauna, while in the Ferrarotti locality, the overlying beds above the uppermost occurrence of *J. australis* have yielded the youngest known faunas at the top of the Río Genoa Formation (Fig. 4).

Piatnitzkya Fauna

This fauna was only recorded in the middle part of the sequence (bed M3 of Ugarte 1966) of the Río Genoa Formation at the Ferrarotti locality (the sandstone quarry of Piatnitzky also mentioned by Ugarte [1966] and Taboada [1993]) (Fig. 1). This fauna has a very low diversity, being dominated in great numbers by the endemic *Piatnitzkya borrelloi* Taboada, 1993 (Fig. 7A-E), with subordinate occurrences of *Rhynchopora* sp. The slightly higher stratigraphic position of the horizon with *P. borrelloi*, which is above the strata (bed M2 of Ugarte 1966; NF-2 of Cúneo & Sabattini 1987) bearing *J. australis*, suggests a relative age near the middle Artinskian for this faunal assemblage (Fig. 4).

Magniplicatina Fauna

This is the stratigraphically highest faunal record of the Rio Genoa Formation at the Ferraroti locality (bed M4 of Ugarte 1966) (Fig. 1) and possibly also the youngest fauna of the Tepuel-Genoa Basin. Faunal remains are scarce and monospecific, but with well preserved specimens here assigned to the genus *Magniplicatina* Waterhouse, 1983 (Fig. 7F-M). The extremely low diversity palaeocommunity would have resulted from adverse palaeoecological conditions indicated by the freshwater influences from a delta complex recognised in the uppermost part of the Río Genoa Formation (Andreis & Cúneo 1989). The uppermost stratigraphic position of *Magniplicatina* in the Ferrarotti sequence, above the horizons with *Jakutoproductus* and *Piatnitzkya*, suggests a relative age close to the middle Artinskian (Fig. 4).

Magniplicatina has been widely recorded in the Sakmarian-Artinskian of eastern Australia, New Zealand and peri-Gondwanan and Cimmerian blocks (Karakorum in Pakistan, southern Oman, Nepal, Inner Mongolia in China) (e.g.Waterhouse 1983; Briggs 1998; Angiolini 1996, 2001). The strong faunal links with Western Australia and the Cimmerian regions enhanced by the *Cimmeriella* fauna from Patagonia was progressively vanished toward the Artinskian by the incoming of highly endemic faunas and the extremely low diversity (monospecific) of faunal remains preserved. The palaeobiogeographical links of Patagonia, apparently changed during the Artinskian but further investigation and data are necessary to explain this possibility.

CONCLUDING REMARKS

In contrast to what was thought in the past, the genus *Costatumulus* Waterhouse in Patagonia is represented by three different species, preliminarily assigned to *Costatumulus* sp.1, *Costatumulus* sp. 2, and *Costatumulus* sp. 3. *Costatumulus* sp. 1 includes specimens previously assigned to *Cancrinella* cf. *C. farleyensis* by Amos (1960) which can be differentiated from *Costatumulus amosi* Taboada, 1998, the latter being the single species of the genus recognised in western Argentina (Calingasta-Uspallata Subbasin). These three, possibly new species, together with other Permian genera and species newly recognised in the basin, such as *Kochiproductus* sp., *Tivertonia* sp., *Neochonetes* sp., *Coolkilella* sp. and *Magniplicatina* sp., are here illustrated for the first time. Their taxonomic descriptions will be presented in a future paper.

The *Verchojania archboldi* fauna is recognised as characterising the first (oldest) Permian beds in the basin. The traditional *Costatumulus* Biozone (formerly *Cancrinella* Biozone of Amos & Rolleri 1965) can be split into four different and successive faunal assemblages, and its stratigraphic range is restricted with greater accuracy to the Sakmarian-early Artinskian interval. The four different faunal assemblages are: the *Cimmeriella-Costatumulus* and *Kochiproductus-Costatumulus* assemblages from the Mojón de Hierro Formation, the *Costatumulus-Tivertonia* fauna extending to the lower part of the Río Genoa Formation, and the *Jakutoproductus* fauna restricted to the latter unit. In addition, another two younger brachiopod assemblages have been identified in the Río Genoa Formation: the *Piatnitzkya* and *Magniplicatina* faunas, together estimated to range in age from early to middle Artinskian.

There were strong faunal links between Patagonia, Western Australia and the Cimmerian regions in south and southeast Asia, as shown by the faunas with *Costatumulus* and particularly with the *Cimmeriella* fauna from Patagonia. These links progressively decreased toward the Artinskian by an incoming of highly endemic faunas and a drastic decrease in biodiversity. Nevertheless, adverse palaeoecological conditions hindering the development of rich marine faunas were evident as indicated by freshwater input from the delta complex developed in the uppermost part of the Río Genoa Formation. Also, the appearance of *Magniplicatina* during middle Artinskian times, apparently introduced new and wide palaeobiogeographical links for Patagonia with Australia and Asia, although further investigation and data are necessary to explain the origins and development of these new links.

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