
The coupled occurrence of *Cimmeriella-Jakutoproductus* (Brachiopoda: Productidina) in Patagonia: implications for Early Permian high to middle paleolatitudinal correlations and paleoclimatic reconstruction

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| A B S T R A C T |

The brachiopod species *Jakutoproductus sabattinae* sp. nov. and *Cimmeriella willi* sp. nov. from the Cisuralian deposits of the Tepuel-Genoa basin are described here. Biostratigraphy and stratigraphy of the uppermost section of the Tepuel Group (Mojón de Hierro and Río Genoa formations) are analyzed and a distinctive faunal succession is recognized: the *Cimmeriella* and *Jakutoproductus* faunal assemblages of late Sakmarian (Sterlitamakian) and early Artinskian estimated ages, respectively. The lower Permian correlations of these faunal occurrences and the chronology of mostly early Permian glacial episodes between Western and Eastern Argentina with Patagonia are discussed. The coupled *Verchojania-Jakutoproductus*, *Eurydesma-Cimmeriella* and *Cimmeriella-Jakutoproductus* faunal records have been used as a tool for the correlation of early Permian marine sequences from the high to middle paleolatitudinal settings of both hemispheres.

KEYWORDS | Cisuralian. Patagonia. *Jakutoproductus*. *Cimmeriella*. High paleolatitude correlations.

INTRODUCTION

The marine upper Paleozoic of Patagonia has yielded representatives of most invertebrate groups: brachiopods, bivalves, gastropods, cephalopods, hyolithids, echinoderms, cnidarians, ostracods and scarce trilobites, but warm-water fossil remains (foraminifers and conodonts) are absent. The faunal succession of the type section of the Tepuel Group in the Tepuel-Genoa Basin is relatively well known (although not completely described), even though some southernmost localities have an incomplete sampling

of marine strata due to the predominance of continental facies (Río Genoa Formation). As a result, insufficient information is presently available concerning the invertebrate faunal diversity in the area. In order to obtain as much data as possible about the systematic composition and distribution of the biotic succession, it is necessary to carry out more detailed research in the Río Genoa region to improve and complement the marine biostratigraphical scheme of the Tepuel-Genoa Basin. Brachiopoda is one of the most abundant and highly diversified fossil group in the sedimentary column of the Tepuel-Genoa Basin.

Systematic and biostratigraphic works on this group have been made by several authors in the past fifty years (Amos, 1958, 1960; Amos and Roller, 1965; González, 1985a; Cúneo and Sabbatini, 1987; Simanaukas, 1991, 1996a-c; Simanaukas and Sabbatini, 1993, 1997; Simanaukas and Archbold, 2002; Taboada, 1993, 2001a, 2008). The findings here described have relevant paleobiogeographical implications and have allowed conspicuous early Permian biotic events in Patagonia to be identified. As a result, solid correlation levels of intrabasinal, regional and intercontinental value, especially with median to high paleolatitude faunas of both hemispheres are established.

GEOLOGICAL AND STRATIGRAPHIC SETTING

In central-west Patagonia, the upper Paleozoic rocks extend over vast areas between 43°-44° 20'S and 69° 30'-71°W, and are distributed with north-northwest to south-southeast trends. In the Chubut Province the neopaleozoic deposits belong to the foreland Tepuel-Genoa Basin, and outcrops are found in the Tepuel, Languiño, Tecka, Valle Chico and Excursión hills, and the Río Genoa valley (Figure 1). The Tepuel-Genoa Basin outcrops show a continuous sequence of more than 5000m thickness, accumulated at the southwestern border of Gondwana during Mississippian-Cisuralian times. In this sense, the Tepuel-Genoa basin is possibly the most complete open marine sequence of that age in all Gondwana.

Early descriptions of the upper Paleozoic of central-west Patagonia were made by Keidel (1922) and Piatnitzky (1933, 1936). Suero (1948, 1953, 1958) recognized the late Paleozoic age of these deposits and outlined the stratigraphy of the basin. The upper Paleozoic column unconformably overlies the Catreleo Devonian granite (Robbiano 1971) and is overlain also unconformably by Lower Jurassic marine strata. Its contact with the lower sections in the north of the basin when compared with the southern region, provides a north to south “rejuvenation” of the sequence. Other stratigraphic studies were later supplied by Perrot (1960), Freytes (1971), Lesta and Ferello (1972), Franchi and Page (1980) and Page et al. (1984). These last authors (Page et al. 1984) proposed the current mostly accepted stratigraphic scheme of the area north to 44°S, with a tripartite succession of the Jaramillo, Pampa de Tepuel and Mojón de Hierro formations constituting the Tepuel Group, a major lithostratigraphic unit with its type section throughout the Tepuel hill. Other units were locally defined in the Languiño (Las Salinas Formation of González 1972) and Esquel areas (Esquel and Valle Chico formations of Cucchi 1980) and correlated with different sections of the Tepuel Group. In the area of the Río Genoa valley and south to 44°S, the uppermost sections of the upper

Paleozoic were determined by Suero (1953, 1958) and Ugarte (1966), and later formalized by Lesta and Ferello (1972) as the Río Genoa Group, including the Piedra Shotel and Nueva Lubecka formations. Afterward, an alternative interpretation was offered by Andreis et al. (1986), who downgraded the Río Genoa Group to formational rank and wholly correlated it with the median and upper parts of the Mojón de Hierro Formation, as it was redefined by Page et al. (1984). Finally, Andreis and Cúneo (1989) recognized the uppermost stratigraphic beds as belonging also to a single and youngest unit, the Río Genoa Formation, but conformably overlying the Mojón de Hierro Formation at Lomas Chatas locality (the “Upper Tepuel System” in Ugarte, 1966). This last conception is here followed in a general way (Figure 2), nevertheless the precise boundary or a possible lateral interfingering between the uppermost beds of the Mojón de Hierro Formation and the lowermost strata of the Río Genoa Formation, is still in need of definition with accuracy.

The material described in this contribution comes from the Mojón de Hierro Formation, Tres Lagunas and La Carlota Posts surrounding areas, and from the Río Genoa Formation, sampled at Cerro La Trampa and Piedra Shotel localities (Figure 1).

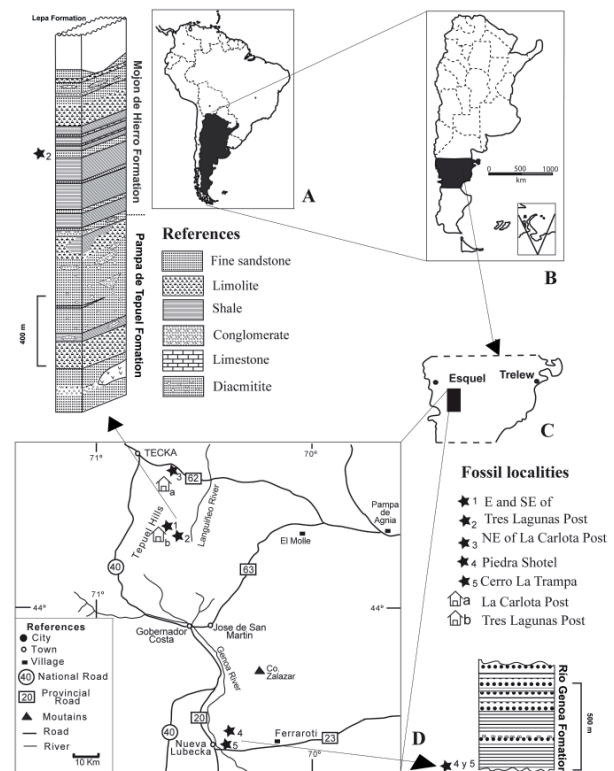


FIGURE 1 | Location map showing fossiliferous localities.

Previous biostratigraphical and biochronological proposals

The first biozonation scheme proposed to the Tepuel-Genoa basin was done by Amos and Roller (1965), who recognized two biostratigraphic units based on brachiopods described by Amos (1960): the *Levipustula levis* (Moscovian) and *Canocrinella* cf. *farleyensis* (late Carboniferous) biozones. These two units also extend 2000 km to the north, reaching the Calingasta-Uspallata sub-basin in western Argentina (Precordillera) (Amos and Roller, 1965). Later, the ages of these biozones were adjusted by Amos et al. (1973), Sabattini (1978) and González (1981, 1985b), with Namurian-Westphalian? and early Permian (Asselian) ages suggested to the *Levipustula* and *Canocrinella* zones respectively. Amos and Roller's scheme for Patagonia was later substantially modified and replaced by a new one with five zones/faunules, based on a multivariate grouping analysis of the invertebrate faunal composition of the Tepuel-Genoa basin (Simanaukas and Sabattini, 1997). These authors proposed the *Lanipustula* Zone (Namurian-Stephanian) (formerly *Levipustula levis* Zone of Amos and Roller, 1965), the *Pyramus* faunule (Asselian), the *Tuberculatella* Zone (Sakmarian), the *Canocrinella* faunule (Sakmarian-Artinskian) (formerly *Canocrinella* cf. *farleyensis* Zone of Amos and Roller, 1965) and the *Neochonetes* Zone (Artinskian-Kungurian). One of the "guide fossils" of the previous schemes, *Canocrinella* cf. *farleyensis* (Etheridge and Dun, 1909), described by Amos (1960) from Patagonia, and material assigned to this species from western Argentina (Amos and Roller, 1965), were included in the synonymy of *Costatumulus amosi* Taboada, 1998 and *Marginovatia peregrina* (Taboada) (formerly *Balakhonia peregrina* Taboada, 1997, which is here reassigned to *Marginovatia* Gordon and Henry, 1990), respectively. Consequently in western Argentina, the originally indicated stratotype of the former *Canocrinella* cf. *farleyensis* Biozone, became the type section (short stratigraphic interval within the Pituil Formation of Amos and Roller, 1965, *nom. nov.* to Barreal Group of Mésigos, 1953, *emend.* Taboada, 1997) of the older *Marginovatia-Maemia* Zone, estimated to be of late Westphalian age (Taboada, 1997, 2006). The *Costatumulus amosi* Biozone was restricted only to outcrops of the Agua del Jagüel Formation of western Argentina and also extended to the Mojón de Hierro and Río Genoa Formations of Patagonia (Taboada, 1998). Nevertheless, Simanaukas and Archbold (2002) suggested a different specific condition of the Patagonian *Costatumulus* assigned to *C. amosi* by Taboada (1998). New material collected from Patagonia allow us here to confirm the interpretation of Simanaukas and Archbold (2002), and to anticipate the existence of more than one species of *Costatumulus* throughout the Cisuralian of Patagonia. Alternatively, the most recent age estimations for the Ferrarotti faunal assemblage from the Río Genoa For-

mation, probably the youngest faunal association and top of the *Costatumulus* Zone of the Tepuel-Genoa Basin, considered its age as Artinskian-Kungurian (Simanaukas and Sabattini, 1997; Hlebszevitch and Sabattini, 2005) and late Sakmarian (Sterlitamakian) (Simanaukas and Archbold, 2002). Moreover, Pagani and Sabattini (2002) introduced two new biozonations for the Tepuel-Genoa Basin, one of them based exclusively on the distribution of gastropods and bivalves: *Mourlonia* sp. II-*Pyramus primigenius*, *Calitomaria tepuelensis*-*Streblochondria* sp., and *Euphemites chubutensis*-*Palaeoneilo* aff. *concentrica* zones; and the other based on cephalopods distribution: *Sueroceras irregulare* and *Mooreoceras zalazarensis* biozones. Pagani and Sabattini's biozones were dated as early Permian age (Cisuralian). Finally, Taboada (2008) recognized an early Permian age (early Asselian) for the top of the "*Tuberculatella*" Biozone of Simanaukas and Sabattini (1997).

It is important to remark that all the charts mentioned above correspond to the distribution of fauna mostly re-



FIGURE 2 | Lithostratigraphic subdivisions of the Tepuel Group.

corded in the northern half of the Tepuel-Genoa Basin, with only a few isolated data points from the Río Genoa Valley. The new material described in this paper allows us to refine the different correlation charts previously proposed.

Since a more comprehensive study of the fauna is necessary, in this contribution, only a faunal succession is mentioned, and a biostratigraphic chart is not proposed. This will be the scope of another contribution.

SYSTEMATIC PALEONTOLOGY

Terminology follows Muir-Wood and Cooper (1960), Muir-Wood (1965) and Brunton et al. (1995, 2000). Classification of *Cimmeriella* largely agrees with Waterhouse's (2001, 2002, 2004) position, whilst *Jakutoproductus* is located according Taboada's (2008) proposal.

Repository: The material was collected at different times by the authors, being housed at the Invertebrate fossil collections of the Paleontological Institute of the Miguel Lillo Foundation, Tucumán, Argentina (FML-PI), the Evolution and Biodiversity Research Laboratory of the San Juan Bosco Patagonian National University (LIEB-PI) and the Egidio Feruglio Paleontological Museum (MPEF-PI).

Order PRODUCTIDA Sarycheva and Sokolskaya, 1959
 Suborder PRODUCTIDINA Waagen, 1883
 Superfamily LINOPRODUCTOIDEA Stehli, 1954
 Family LINOPRODUCTIDAE Stehli, 1954
 Subfamily LINOPRODUCTINAE Stehli, 1954
 Tribe STEPANOVIELLINI Waterhouse, 1975
 Subtribe STEPANOVIELLINAI Waterhouse, 1975
 Genus **Cimmeriella** Archbold and Hogeboom, 2000

Type species: Productus tenuistriatus var. *foordi* Etheridge, 1903, from the Late Sakmarian (Sterlitamakian) lower Calytharra Formation, Carnarvon Basin, Western Australia.

Diagnosis: Small to medium sized, globose Stepanoviellinai with relatively coarse costellae and wide intercostal valleys. Anterior half of dorsal valve interior reflects external ornamentation. Ventral posterior adductor scars deeply impressed; anterior diductor scars weakly striate. Dorsal median septum arises close to cardinal process. Rugae weak or absent, spines restricted to hinge region of ventral valve.

Discussion: *Cimmeriella* was originally included in the Subfamily Linoproductinae (Archbold and Hogeboom, 2000; Shen et al., 2000) and later in the Subtribe Stepanoviellinai, within the Tribe Stepanoviellini, in a refined classification (Waterhouse, 2001, 2002, 2004) here followed. This last position was also indicated to the type

species of *Cimmeriella* in a previous paper by Archbold (1983). On the other hand, *Cimmeriella* was incorporated to the Family Schrenkiellidae Lazarev, 1990, by Lazarev (2004), and although this family is still retained by Lazarev (2006) and with subfamily rank by Brunton (2007), it was substantially downscaled to a subtribe rank and relocated within the Linoproductini, according to Waterhouse (2001, 2002, 2004). More recently, Brunton (2007) followed the *Cimmeriella* suprageneric classification consigned by Archbold and Hogeboom (2000).

Cimmeriella groups a distinctive set of species with comparatively coarse costellae previously assigned to *Stepanoviella* Zavodowsky, 1960 or to *Globiella* Muir-Wood and Cooper, 1960, being both genera now restricted to the Kazanian-Tatarian of northeastern Siberia (Grigorjeva et al., 1977) and the Kazanian of European Russia (Archbold and Hogeboom, 2000), respectively (scarce material without interiors assigned to *Globiella* from the Bashkirian of Spain by Martínez Chacón, 1979, and Martínez Chacón and Winkler Prins, 1985, are assignments with doubt; Martínez Chacón, pers. comm. 2008). An additional generic difference between *Cimmeriella* and *Globiella*, here added to those indicated by Archbold and Hogeboom (2000), is the reflected external ornamentation in the anterior half of the dorsal valve interior in the former, unlike the nonreflecting condition in *Globiella*.

Reports of species currently referred to *Cimmeriella* include those from the Sakmarian-Artinskian of Western Australia (Waterhouse, 1970; Archbold, 1983; Archbold and Shi, 1993; Skwarko, 1993; Archbold and Hogeboom, 2000), southeast Asia (Timor, Malaysia, Yunnan, Tibet and Karakorum) (Angiolini, 1995; Shi et al., 1996; Shen et al., 2000; and other references in Archbold and Hogeboom, 2000) and Yukon (Bamber and Waterhouse, 1971; Shi and Waterhouse, 1996). *Cimmeriella willi* sp. nov. constitutes the first record of the genus in western Gondwana (Figure 3).

Cimmeriella willi sp. nov.

Figs. 4A-R, 5A-G

2001a *Globiella* sp. Taboada, p. 299.

Derivatio nominis: from Mapundungun (Mapuche aboriginal language of Patagonia), *willi*, belonging to the south.

Material: 60 specimens of articulated valves, isolated dorsal and ventral valves and external, internal and composed moulds of both valves. Holotype LIEB-PI 209 (Fig. 4A-D); paratypes LIEB-PI 202, FML-PI 2560, 2562, 2565, 2567-2568, 2570; other material LIEB-PI 203-208, 257-284, FML-PI 2404-2405, 2561, 2564, 2566, 2569, 2571-2584, 2704-2706.

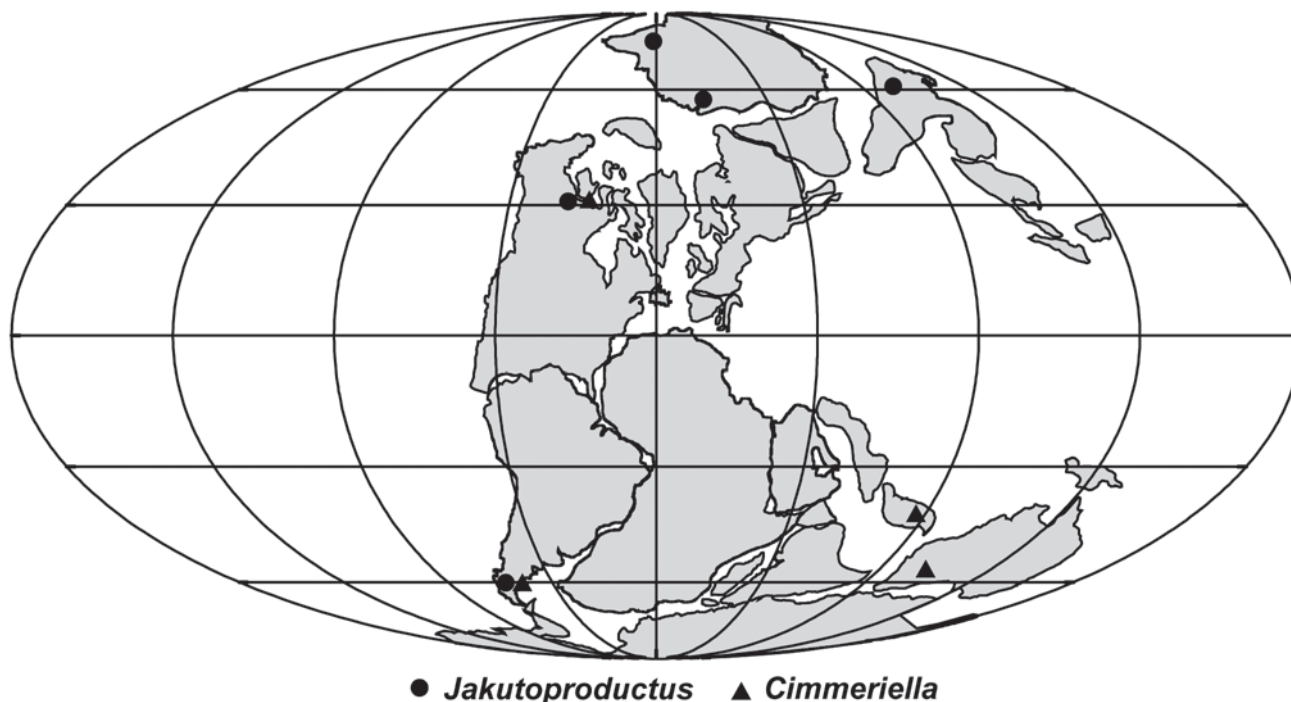


FIGURE 3 | Early Permian paleogeographic reconstruction with *Cimmeriella* and *Jakutoproductus* occurrences (modified from Scotese et al., 1979).

Geographic and stratigraphic distribution: Specimens labeled LIEB-PI 202-209 and FML-PI 2560-2584 from 4km to the east of Tres Lagunas Post, Tepuel hill, upper part of Mojón de Hierro Formation (level 6 of Taboada 2001a) (Fig. 1 *1); FML-PI 2404-2405, 2704-2706 from 6km to the southeast of Tres Lagunas Post, Tepuel hill, upper part of Mojón de Hierro Formation (bed 6 of Taboada 2001a) (Fig. 1 *2); LIEB-PI 257-284 from 3km to the northeast of La Carlota Post (S43°31'49.7" W70°42'10.6"), provincial route 62, upper part of Mojón de Hierro Formation (Fig. 1 *3).

Diagnosis: *Cimmeriella* finely costellate (12-13/5mm) of medium size with strong concavo-convex profile and slightly transverse outline, moderate geniculation and trail at maturity. Maximum width at hinge line and 3-4 cardinal spines on each flank. Ventral diductor scars subcuadrate of 1/3 to 1/2 valve length, stronger impressed anteriorly, with 5-7 radial ridges separated by wide flat smooth valleys.

Description: *Cimmeriella* of medium size with accentuate concavo-convex profile and shallow corpus, slightly transverse semi-elliptical to subcircular outline with maximum width coincident with hinge line. Valves commonly up to 18mm in width and 17mm in length, with maximum width of 30mm (FML-PI 2565, Fig. 4P-R) and maximum length of 26mm (FML-PI 2562, Fig. 4H). Ventral valve convexity flattens anteriorly into geniculation with moderate trail. Well differentiated ears (rarely preserved) with a

row of at least 3-4 cardinal spines on each flank. Ornamentation of radial costellae (12-13/5mm at 1cm from umbo) and weak concentric growth lines. Costellae increased by intercalation, commonly straight but it may flex and occasionally twist. Weak rugae on ears which do not cross the venter but with antero-ventral growth steps occasionally. Dorsal valve ornamentation similar to ventral valve but with stronger concentric growth lines and costellae increasing by bifurcation.

Ventral valve interior: Thin myophragm of 1/4 to 1/5 of valve length separate adductor scars which extend anteriorly up to 1/3 of valve length. Adductor scars commonly weakly impressed, narrow, smooth with elongate subrectangular outline (FML-PI 2560, Fig. 4G), varying to exceptionally preserved feebly striate subtriangular impressions (FML-PI 2570, Fig. 4N-O). Diductor scars subcuadrate, usually well marked and stronger impressed anteriorly, extend 1/3 to 1/2 of valve length, bearing 5-7 ridges, separated by wide flat and smooth valleys. Numerous pustules, more densely grouped anteriorly to muscle scars, are arranged on the internal surface of the valve.

Dorsal valve interior: An exceptionally well preserved mould of a dorsal valve interior (holotype LIEB-PI 209, Fig. 4A-D) exhibits a strong median septum tapered anteriorly, reaching 2/5 of valve length. Other two internal moulds (LIEB-PI 280; FML-PI 2567, Fig. 4E-F) show a posteriorly located, shallow sulcate platform with a thin

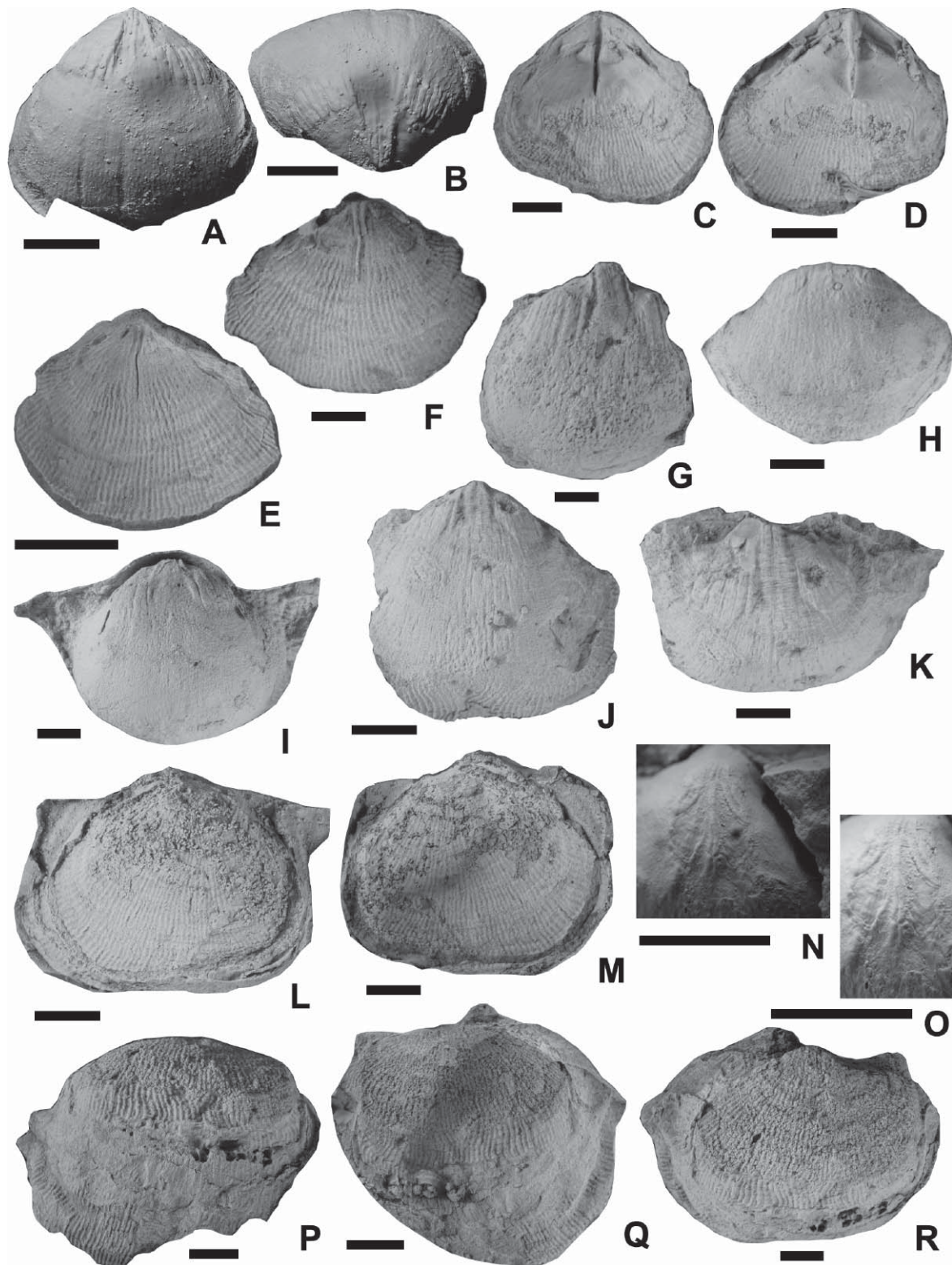


FIGURE 4 | *Cimmeriella willi* sp. nov. A-D) LIEB-PI 209, holotype, internal mould of both valves in antero-ventral, ventral and dorsal views, and latex cast of dorsal valve interior. E-F) FML-PI 2567, paratype, dorsal valve internal mould, and latex cast of dorsal valve interior. G) FML-PI 2560, paratype, ventral valve internal mould. H) FML-PI 2562, paratype, ventral valve internal mould in anterior view. I) FML-PI 2563, ventral valve internal mould. J-K) LIEB-PI 202, paratype, ventral valve internal mould in ventral and postero-ventral views. L-M) FML-PI 2564, external mould of a dorsal valve, and latex cast of the same specimen. N-O) FML-PI 2570, paratype, posterior part of a ventral internal mould showing adductor scars. P-R) FML-PI 2565, paratype, external mould of dorsal valve and ventral trail in anterior view, latex cast of the same specimen in dorsal view, and dorsal valve external mould in ventral view. Scale bar = 5mm.

breviseptum in front of it, reaching 1/3 of valve length. Two short thin ridges at 40°-45° to the median septum, separate interior and exterior adductor scars. Internal adductor scars smooth, with deeply impressed subtriangular outline with its anterior end of 2mm length. External adductor scars smooth, slightly bigger than internal adductor scars, of stretched drop shape located on a postero-lateral slope surface. Brachial ridges feebly impressed with a relatively tight anterior loop, enclosing a smooth brachial field. The rest of the valve reflects the costellate ornamentation. Other features not observed.

Discussion: *Cimmeriella willi* sp. nov., although finely costellate, fits well within the genus because its transverse outline, subglobose profile, spines restricted to the cardinal margin and internal features. Moreover, the presence of geniculation and trail, in addition to the reflected ornamentation in the anterior half of the dorsal valve interior, clearly separate the Argentine species from the closely related but younger genus *Globiella* Muir-Wood and Cooper, 1960.

Cimmeriella willi sp. nov. can be differentiated from almost all other known species of *Cimmeriella* by its distinctive finer costellae. *Cimmeriella* sp. (= *Globiella* cf. *rossiae*) described by Angiolini (1995), from the Sakmarian of Karakorum is the only other species with a density of costellae (10-12/5mm) similar to *Cimmeriella willi* sp. nov.

Nevertheless, *Cimmeriella* sp. (Angiolini) has its hinge line slightly inferior to the maximum width and ventral costellae increasing by bifurcation, unlike the Argentine species that has equal hinge line and maximum width, and intercalated ventral costellae.

Cimmeriella willi sp. nov. was formerly mentioned (but not described) as *Globiella* sp. by Taboada (2001a).

Superfamily PRODUCTELLOIDEA Schuchert, 1929
Family OVERTONIIDAE Muir-Wood and Cooper, 1960
Subfamily PLICATIFERINAE Muir-Wood and Cooper, 1960

Tribe LEVIPUSTULINI Lazarev, 1985
Genus **Jakutoproductus** Kaschirtzev, 1959

Type species: *Marginifera vechoyanica* Fredericks (1931) from the Lower Permian (lower Echi Suite, lower Artinskian) of the Kharaulakh mountains (Verchojansk range), eastern Siberia.

Observations: The Levipustulini *Jakutoproductus* is placed within the same classification indicated to *Verchojania* Abramov, 1970 by Taboada (2008), and discussion of this classification does not need to be repeated here.

Twenty one species of *Jakutoproductus* are known from the Kasimovian-Artinskian of the northern hemi-

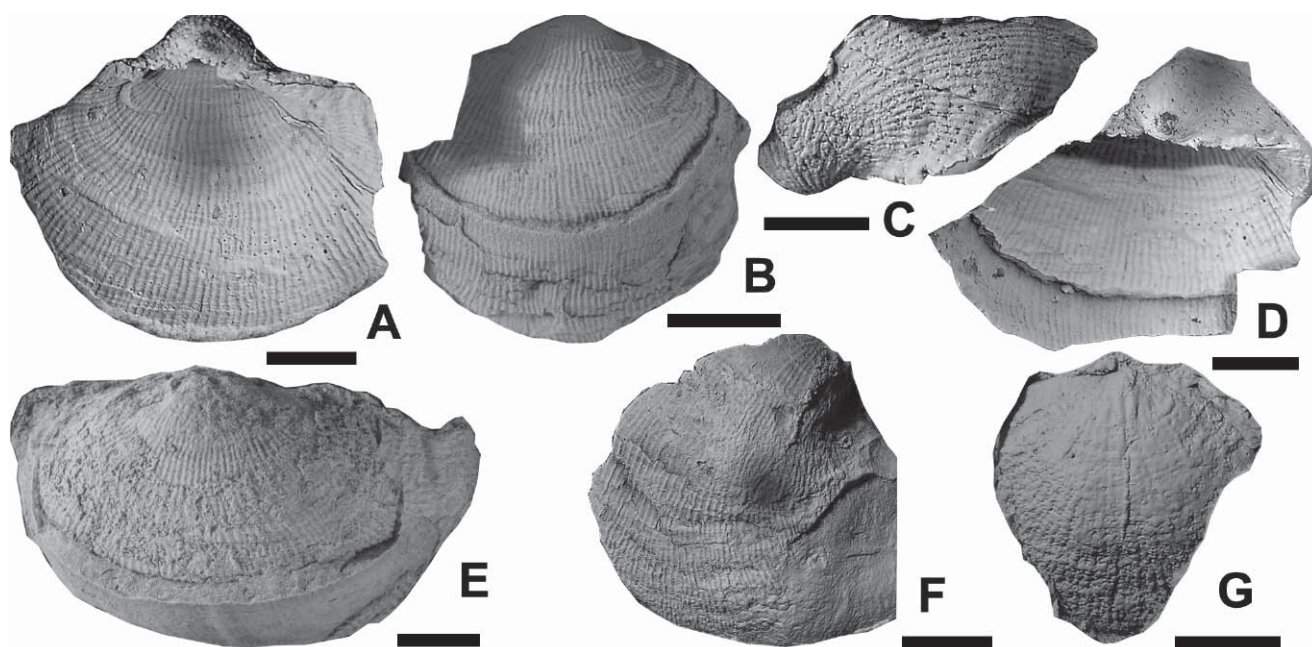


FIGURE 5 | *Cimmeriella willi* sp. nov. A-D) FML-PI 2568, paratype, latex cast of a mould of an articulate specimen in postero-dorsal view showing dorsal valve exterior and umbonal region, dorsal valve external mould and ventral trail internal mould in antero-ventral view, latex cast of ventral valve exterior in lateral view, and the same latex cast in postero-dorsal view. E) FML-PI 2571, dorsal valve external mould in ventral view. F) LIEB-PI 281, slightly distorted and fragmentary ventral valve exterior in lateral view. G) LIEB-PI 280, latex cast of a dorsal valve interior. Scale bar = 5mm.

sphere, most of them from the Kolyma-Omolon and Verchojansk regions of the Russian Siberia (Fredericks, 1931; Stepanov, 1946; Kaschirtzev, 1955, 1959, 1960; Abramov, 1970, 1974; Solomina, 1970, 1978, 1981; Zavodowsky and Stepanov, 1971; Abramov and Grigorjewa, 1983, 1988; Ganelin, 1991; Klets, 2005a), but also from the Canadian Arctic (Bamber and Waterhouse, 1971; Shi, 1994; Shi and Waterhouse, 1996), Novaya Zemlya (Licharew and Einor, 1939), Taimyr Peninsula (Ustritsky and Tchernjak, 1963), northeast China (Li and Gu, 1976; Li et al., 1980), Mongolia (Pavlova, 1988; Manankov, 2004) and the Trans-Baikal region (Kotlyar and Popeko, 1967; Zavodowsky and Stepanov, 1971; Kotlyar et al., 2002). Other two species come from the southern hemisphere, one of them is the recent described *Jakutoproductus australis* Simanaukas and Archbold, 2002 and the other is reported here, the slightly older *Jakutoproductus sabattinae* sp. nov., being both records from the Lower Permian of Argentine Patagonia (Figure 3).

Jakutoproductus sabattinae sp. nov.

Figs. 6A-O, 7A-O

2005 *Jakutoproductus* sp. Ferrari and Pagani, p. 27R.

2008 *Jakutoproductus* sp. Pagani and Taboada, p. 30.

Derivatio nominis: Dedicate to the paleontologist Dr. Nora Sabattini.

Material: 50 specimens of articulated valves, isolated dorsal and ventral valves and external, internal and composed moulds of both valves. Holotype MPEF-PI 1443 (Fig. 6A-D), paratypes MPEF-PI 1214, 1253-1254, 1435, 1437-1438, 1450, 1801a, 1807, 1820; Other material: MPEF-PI 1217-1218, 1236, 1244, 1258, 1264, 1280-1281, 1287, 1302, 1304, 1308-1309, 1431, 1433-1434, 1441, 1443-1445, 1448-1449, 1453, 1458-1459, 1461-1462, 1468, 1471, 1487, 1508, 1511, 1515, 1518, 1778, 1787-1788, 1790, 1801b, 1808-1809, 1817-1818, 1823, 1829, 1831, 1847-1848, 1853, 2748, 2755, 2764-2767.

Geographic and stratigraphic distribution: MPEF-PI 1214, 1217-1218, 1236, 1244, 1508, 1511, 1515, 1518, 1778, 1787-1788, 1790, 1801a, 1801b, 1807-1809, 1817-1818, 1820, 1823, 1829, 1831, 1848, 1853 from Cerro La Trampa locality, 4km W Nueva Lubecka (Fig. 1 *5). MPEF-PI, 1253-1254, 1258, 1264, 1280-1281, 1287, 1302, 1304, 1308-1309, 1431, 1433-1435, 1437-1438, 1441, 1443-1445, 1448-1450, 1453, 1458-1459, 1461-1462, 1468, 1471, 1487, 1847, 2748, 2755, 2764-2767 from Piedra Shotel locality, 18km NW Nueva Lubecka (Fig. 1 *4).

Diagnosis: Medium size *Jakutoproductus*, transversely semielliptical in outline, gently concave-convex in profile with deep corpus, abrupt geniculation and moderate trail. Ventral ornament of concentric growth lines and irregular, discontinuous and undulant weak rugae. Suberect small

spines distributed roughly in quincunx (3-4/5mm²) and halteroid spines (5-7mm of length). Narrow subrectangular and anteriorly expanded semielliptical adductor scars and flabellate diductor scars. Dorsal valve with concentric ornament similar to ventral valve, with dimples, and very scarce small erect spines mostly on dorsal trail.

Description: Shell of medium size, transversely semielliptical in outline, almost flat to gently concave-convex in profile with deep corpus, abrupt geniculation and moderate trail at maturity. Hinge width slightly less than maximum width, which is placed in the posterior third of shell length; adult valves commonly up to 25mm in width and 15mm in length with maximum width of 34mm and maximum length of 20mm (MPEF-PI 1253, Fig. 6G-I); width/length ratio varying between 1.40 (Holotype, Fig. 6A-D) and 1.70 (MPEF-PI 1253, Fig. 6G-I), with an average of 1.57.

Ventral valve gently convex with short to moderate trail at maturity, small pointed umbo slightly extended beyond hinge line, ears well developed slightly differentiated from lateral umbonal slopes, sulcus varies from inconspicuous to shallow broadly U-shaped, slightly more depressed towards the anterior region. Hinge line with 3-5 cardinal spines (up to 5mm of length) in each flank disposed toward the auricles at varied angles to the cardinal line. Ornament of spines, concentric growth lines and irregular, discontinuous and undulant weak rounded rugae, stronger anteriorly. Spines distributed roughly in quincunx (3-4/5mm²), relatively small and suberect over the venter, rising from slightly longitudinally swollen spine bases. Larger slightly curved halteroid spines (5-7mm of length) with circular (1mm in diameter) to elliptical (2mm of maximum diameter) bases anteriorly, are at high angle on auricles and flanks, and in 2-3 irregular rows in the venter or trail near the geniculation. Trail without spines anteriorly, ornamented only with concentric growth lines. Ventral interior with very fine myophragm (5mm of length), separating posteriorly narrow subrectangular (2.5mm of length) and anteriorly expanded semielliptical (2mm of length and 1mm of maximum width) adductor scars. Diductor scars strongly impressed, flabellate, subtriangular in outline reaching 2/5 of valve length. Minute endospines with radial arrangement and holes corresponding to external spine bases cover the rest of the interior.

Dorsal valve moderately concave with greatest concavity in the visceral disc and more or less abruptly geniculate (60°-90°). Ornament of shallow dimples, fine concentric growth lines and irregular, discontinuous and undulant weak rugae, stronger and lamellose anteriorly. Scarce small erect spines (up to 2mm of length) without particular arrangement are disposed mostly on the posterior part of the trail. Trail short, anteriorly ornamented

only with fine growth lines. Dorsal fold varies from a low longitudinal constriction to a relatively narrow fold. Dorsal interior with anteriorly sharp brevisseptum and posterior wide sulcate platform of 2/3 valve length. Inner and outer adductor scars smooth, of similar size (up to 4mm of length and 1.5mm of maximum width) and with subelliptical, posteriorly narrow outline. Lateral septa at 18°-20° to the median septum and cardinal ridges slightly divergent (10°-17°) to hinge line. Braquial ridges at right angle to the median septum and curved antero-laterally 45°, with subrectangular outline and smooth braquial field. Numerous small endospines, radially grouped over the rest of the valve surface. Cardinal process bilobed internally, trifold externally.

Discussion: The closest species to *Jakutoproductus sabattinae* sp. nov. is *J. parenensis* Zavodowsky (Zavodowsky and Stepanov, 1971; Solomina, 1981; Abramov and Grigorjewa, 1988) from the Paren Horizon, Lower Permian of the Kolyma-Omolon Massif, northeast of Siberia. Both species share similar size, weak concentric rugae, spine pattern on the venter and 2-3 rows of coarser spines anteriorly. *Jakutoproductus sabattinae* sp. nov. can be differentiated from *J. parenensis* by its more transverse outline, hinge width less than maximum width of the valve and weaker sulcus and fold on the ventral and dorsal valves, respectively. Another comparable Russian species is *Jakutoproductus irreprensus* Ganelin, 1991, from the Lower Munugudjak Horizon (Sakmarian to Artinskian), Kolyma-Omolon Massif, northeast of Siberia, but it has finer and numerous ventral spines and a well developed narrow sulcus.

The late species of *Jakutoproductus* (Artinskian) generally have a larger size, a more complicated ornament (stronger and sharp more undulating rugae), coarser spines, deeper angular sulcus and more marked geniculation and trail (Shi, 1994), besides a quadrifid cardinal process externally (Manankov, 2004), unlike the precedent species, including *Jakutoproductus sabattinae* sp. nov.

Jakutoproductus australis Simanaukas and Archbold, 2002, in comparison to the slightly older and possible direct ancestor *Jakutoproductus sabattinae* sp. nov., has a similar weak concentric low undulating rugae, but the former has a less transverse outline, wide sulcus, maximum width at mid-length, few halteroid spines and ventral spines with less expanded bases, less cardinal spines, and internally the dorsal median septum is reabsorbed medially.

Jakutoproductus sabattinae sp. nov. has very scarce small and fine external dorsal spines, a possible recessive character currently not observed in none other known *Jakutoproductus* species.

MARINE EARLY PERMIAN CORRELATIONS

Correlation among the marine Permian faunas are difficult to establish due to the strong faunal provincialism. The progressive study and integration of data from different levels in Patagonia are yielding significant advances in refined time control. The faunas associated with *Cimmeriella willi* sp. nov. and *Jakutoproductus sabattinae* sp. nov., with its short stratigraphic distribution and paleobiogeographic links, allow reaching some improvements related to regional and transcontinental correlations.

Intrabasinal and interbasinal regional correlations

Intrabasinal correlation. The Mojón de Hierro Formation at its type locality, represents the lower part of the *Costatumulus* Zone (in a broad sense) with the conspicuous *Cimmeriella* fauna (Taboada et al., 2005) (formerly *Globiella* fauna of Taboada, 2001a) estimated of late Asselian-Sakmarian age (Taboada, 1998, 2001a; Taboada et al., 2005). As mentioned above *Cimmeriella* occurs in upper beds of the Mojón de Hierro Formation, whereas the records of *Jakutoproductus* come from the southernmost Río Genoa Formation. This last lithostratigraphic unit has been interpreted in two ways: partially or totally equivalent with the median and upper parts of the Mojón de Hierro Formation (Lesta and Ferello, 1972; Page et al., 1984; Andreis et al., 1986), in opposition to the original conception (Suro, 1953, 1958; Ugarte, 1966), also followed by Andreis and Cúneo (1989) and Hlebszevitch and Sabattini (2005). A faunal diachronism between the faunas of the Mojón de Hierro and Río Genoa Formations was also suggested by Taboada (2001). Based on the brachiopod fauna identified in the upper parts of the Mojón de Hierro Formation at its type locality, north of La Carlota Post and possible El Molle place at Cañulef Post, we propose a conspicuous horizon characterized by the presence of the named *Cimmeriella* fauna (Taboada et al., 2005). This faunal assemblage is composed by the brachiopods *Cimmeriella willi* sp. nov., *Costatumulus* sp. (Amos, 1960), *Spirelytha* sp. (Taboada and Cisterna, 1996), *Quinquenella* sp. (Amos, 1960; Taboada and Shi, 2009), and other brachiopod still not described, such as *Brachythyrinella* cf. *occidentalis* Thomas, *Arctitetra* Whatfield, *Neochonetes* Muir-Wood, etc. With the exception of *Costatumulus* and *Neochonetes* (with possibly different species), neither of the above mentioned genera are at the moment recorded in the localities sampled by us in the Río Genoa Formation. The median to upper parts of the last mentioned formation are characterized by a fauna bearing the genus *Jakutoproductus* Kaschirtzev as a distinctive element. Two different species are known: *J. australis* Simanaukas and Archbold, 2002, from the Ferrarotti locality, and *J. sabattinae* sp. nov., here described, from Piedra Shotel and Cerro La Trampa localities. Both species have some features that reveal a relative age in

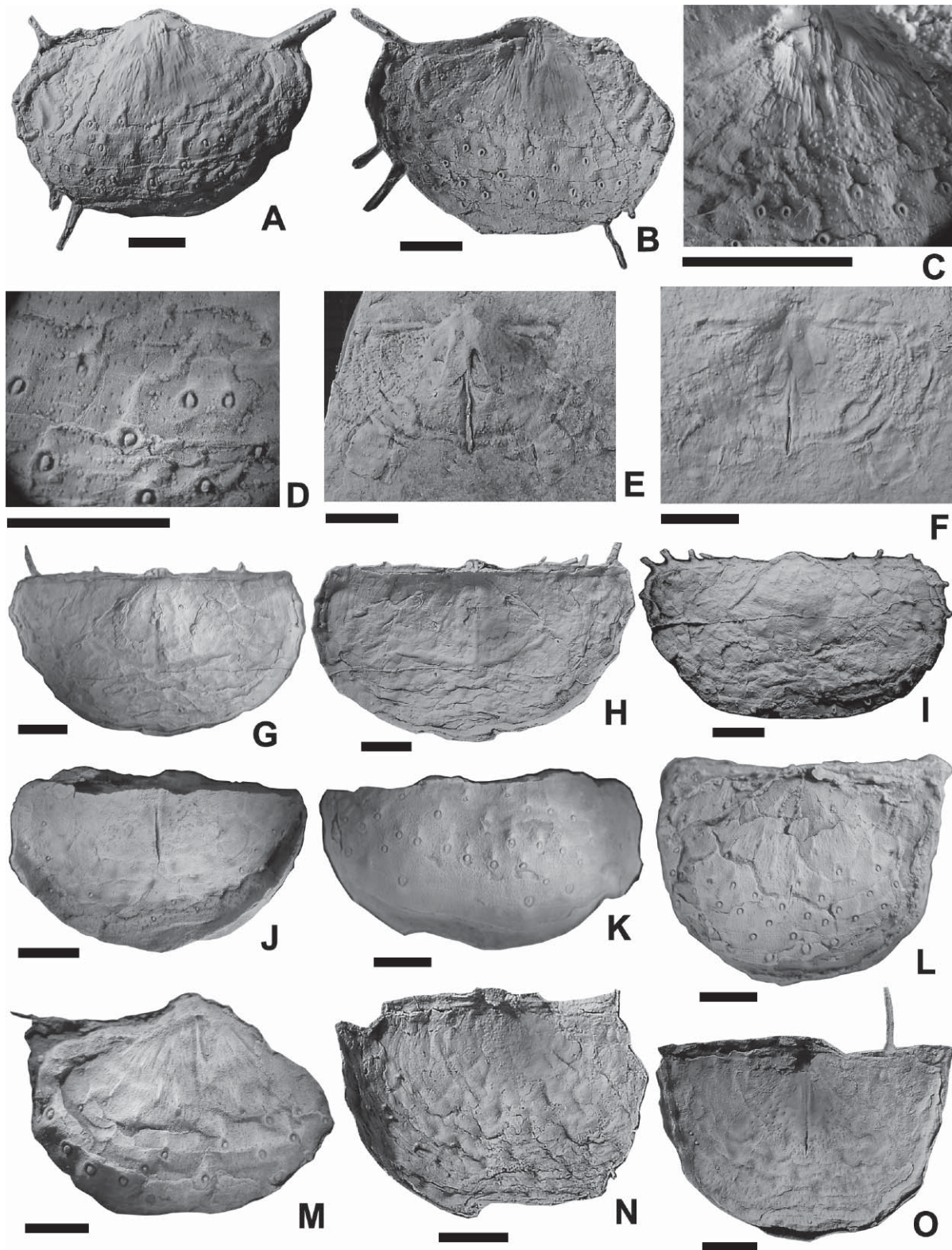


FIGURE 6 | *Jakutoproductus sabattinae* sp. nov. A-D) MPEF-PI 1443, holotype, ventral valve internal mould, latex cast (B) and details of the internal mould showing muscle scars (C), and endospines and external spine bases (D). E-F) MPEF-PI 1214, paratype, dorsal valve internal mould and, latex cast. G-I) MPEF-PI 1253, paratype, dorsal valve external mould, and its latex cast, and latex cast of the ventral exterior. J-K) MPEF-PI 1254, paratype, incomplete internal mould of both valves in dorsal and ventral views. L) MPEF-PI 1435, paratype, ventral valve internal mould. M) MPEF-PI 1437, paratype, ventral valve internal mould. N) MPEF-PI 1438, paratype, latex cast of a dorsal valve exterior showing scarce erect, minute spines. O) MPEF-PI 1450, paratype, dorsal valve internal mould.

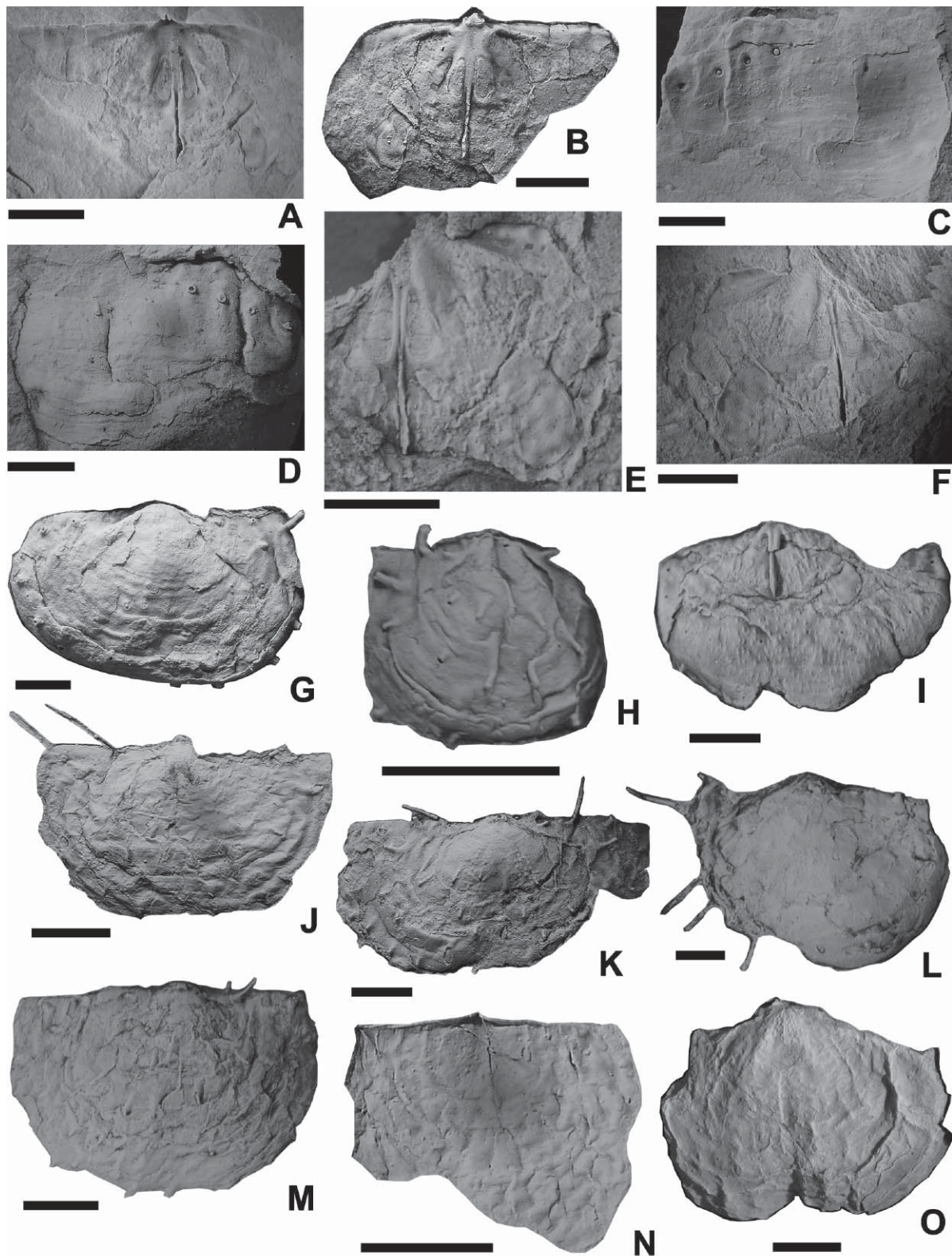


FIGURE 7 | *Jakutoproductus sabattinae* sp. nov. A-B) MPEF-PI 1801a, paratype, dorsal valve internal mould, and its latex cast. C-D) MPEF-PI, 1801b, ventral trail external mould, and latex cast of ventral trail exterior. E-F) MPEF-PI 1820, paratype, latex cast dorsal valve interior, and dorsal internal mould. G) MPEF-PI 1807, paratype, latex cast ventral valve exterior. H) MPEF-PI 1778, latex cast ventral valve exterior of a juvenile specimen. I) MPEF-PI 1787, latex cast of dorsal valve interior. J) MPEF-PI 1445, ventral valve external mould. K) MPEF-PI 1434, latex cast of ventral valve exterior. L) MPEF-PI 1431, latex cast of ventral valve exterior. M) MPEF-PI 1459, latex cast of ventral valve exterior. N) MPEF-PI 1790, dorsal valve exterior. O) MPEF-PI 1829, decorticate dorsal valve interior. Scale bar = 5mm.

agreement with the Permian evolutionary trends known for the *Jakutoproductus* Russian set of species (this point will be further discussed below), which can be taken as having biochronological value, therefore a slightly younger age in regards to the *Cimmeriella* fauna of Patagonia (Figure 8).

On the other hand, the record of several glaciomarine beds in the Tepuel Group, outcropping in the north half of the basin, and its absence in the southernmost Río Genoa Formation, was indicated a half century ago by Suero's survey (1953, 1958). Taboada (2008) identified four main glaciomarine horizons throughout the Tepuel type section, three of them belonging to the Pampa de Tepuel Formation, the lower at its base, the second encompassing beds containing *Lanipustula patagoniensis* Simanaukas, 1996b, and the third at the top in strata with and just below occurrences of *Verchojania archboldi* Taboada, 2008. The fourth and youngest is a more discrete glaciomarine sequence, laterally variable, in the upper half of the Mojón de Hierro Formation, just above horizons bearing the *Cimmeriella* faunal assemblage. In contrast, no section with more or less direct glacial influence (except rare hollow moulds of glendonite) has been registered where the Río Genoa Formation crops out.

The total equivalence of Río Genoa with Mojón de Hierro formations must be reconsidered, on the grounds of biochronologic meaning and intrabasinal distribution of the brachiopods *Cimmeriella* and *Jakutoproductus*, together with the stratigraphic arrangements of the Mojón de Hierro and Río Genoa formations. In this way, it is possible to reject the total equivalency previously proposed for these units. Nevertheless, as noted above, until the precise boundary between these units can be defined with accuracy, a possible relative minor lateral interfingering between the uppermost part of the Mojón de Hierro Formation and lowermost part of the Río Genoa Formation (specially at the key sections of Arroyo Garrido and Lomas Chatas), cannot be discarded.

Argentine interbasinal correlation: Besides the marine Permian faunas from Patagonia, two other Argentine regions have yielded distinctive early Permian faunal assemblages. One of them is western Argentina along the San Rafael Block (San Rafael basin of Polansky, 1970) and the Precordillera-central Andes (Uspallata-Iglesia basin of González, 1985b), and the other one is placed in the eastern region of the country (Sauce Grande basin of Andreis et al., 1987). A Permian marine correlation approach between them and Patagonia is discussed here (Figure 8).

Western Argentina-Patagonia: Two early Permian faunas were recognized in western Argentina. The oldest is the *Tivertonia-Streptorhynchus* Biozone (Sabattini et al., 1990) (formerly Intermediate fauna of González, 1985b), with regionally widespread distribution having encompassing the greatest late Paleozoic marine transgression in the area (Taboada, 2001b). The most recent considerations for this fauna have suggested an Asselian-Sakmarian (Cisterna and Simanaukas, 2000) or more precisely medium to late Asselian (Archbold and Simanaukas, 2001; Archbold et al., 2004; Taboada, 2006) age estimations, which are also supported by absolute ages (Fauqué et al., 1999; Gutierrez and Limarino, 2006). The short but regionally extensive marine transgression characterized by the *Tivertonia-Streptorhynchus* fauna would be linked with the beginning of the global major sea level rise that occurred during Asselian-Sakmarian times. This early Permian transgression has been indicated also in Patagonia for the lower section of the Mojón de Hierro Formation (Taboada, 2001a). Scarce fossils have been found in the lowermost levels of this last unit (a small species of *Costatumulus* and the bivalves described by González, 2006; and Waterhouse, 2008), which are possibly contemporary with the *Tivertonia-Streptorhynchus* association of western Argentina but do not exhibit a clear faunal link with it. Nevertheless, some common brachiopod genera which first appear in western Argentina, such as *Coolkilella* Archbold and *Kochiproductus* Dunbar (unpublished specimens from Del Salto Formation), and possibly *Saltospirifer* Cis-

Series/Epoch	Stage/Age	PATAGONIA, TEPUEL-GENOA BASIN	WESTERN ARGENTINA CALINGASTA - USPALLATA BASIN	EASTERN ARGENTINA, SAUCE-GRANDE COLORADO BASIN
		CISURALIAN	Kungurian	
Artinskian	<i>Jakutoproductus australis</i> Fauna <i>Jakutoproductus sabattinae</i> Fauna			
	Sakmarian		<i>Cimmeriella willi</i> Fauna	<i>Costatumulus amosi</i> Biozone
Asselian			<i>Verchojania archboldii</i> Fauna	<i>Tivertonia - Streptorhynchus</i> Biozone

FIGURE 8 | Cisuralian Biozones/faunal assemblages correlation chart between western Argentina (Uspallata-Iglesia Basin), eastern Argentina (Sauce Grande Basin) and Patagonia (Tepuel-Genoa Basin).

terna and Archbold, would also be present in younger beds from Patagonia. This circumstance would be evidence not only of a probable ancestral character of the *Tivertonia-Streptorhynchus* fauna in regard with the slightly younger early Permian faunas of Patagonia, but also would reflect the incipient recovery of the faunal migration pathways along the western margin of Gondwana. This faunal similarity indicates the end of the marine faunal disconnection between western Argentina and Patagonia that previously (middle late Carboniferous-earliest Permian) existed due to previous different paleoclimatic conditions: temperate interglacial in the former (González, 1981, 1990, 1993; López Gamundi et al., 1992; Taboada, 2004; González and Díaz Saravia, 2007) and colder and with glacial-influence, in Patagonia (González, 1993, 1997, 2002; Taboada et al., 2005; González and Díaz Saravia, 2007; Taboada, 2008).

The other recognized early Permian marine faunal assemblage from western Argentina is the *Costatumulus amosi* Biozone (formerly *Canocrinella* Biozone of Amos and Roller, 1965, partially; Taboada, 1998) estimated of late Asselian-Sakmarian age (Taboada, 2001a,b, 2006). This fauna is in biochronological succession with the *Tivertonia-Streptorhynchus* Biozone, but is only recorded in a possible paleogeographically restricted embayment at the southernmost region of the Uspallata-Iglesia basin (Taboada, 2001b, 2006). The marine transgression bearing the *Costatumulus amosi* fauna occurred after a regressive non marine stratigraphic interval intercalated between the last mentioned biotic event and the preceding *Tivertonia-Streptorhynchus* faunal records. After that, a transient colder paleoclimatic episode evidenced by glaciomarine deposits stratigraphically enclosed by the *Costatumulus amosi* Biozone, briefly interrupted the temperate paleoclimatic conditions established in the region since the late Carboniferous. This transient Alpine type glacial episode (González, 1981) would be contemporary with another lithologically similar glaciomarine horizon recorded in the upper section of the Mojón de Hierro Formation in Patagonia, which was estimated to be as likely Sakmarian in age (Taboada, 2001a, 2006, 2008). The temperature-sensitive *Cimmeriella*, which occurs stratigraphically just below these glaciomarine deposits in Patagonia, would have not surpassed stratigraphically the incoming of this transient colder episode. On the other hand, the records of *Costatumulus* represented by more than one species throughout the column, start in the lower section of the Mojón de Hierro Formation and reach the uppermost stratigraphic beds of the basin in the Río Genoa Formation at the Ferrarotti locality, where it is associated with *Jakutoproductus australis* Simanaukas and Archbold, 2002, among others. The *Cimmeriella* record from Patagonia, is probably of late Sakmarian age (most likely Sterlitamakian), consequently the overlying glaciomarine deposits (laterally associated with lowermost records of the *Glossopteris* flora in the basin) of the Mojón

de Hierro Formation would be no younger than late Late Sakmarian (late Sterlitamakian). A Sakmarian age is also reinforced by the *Costatumulus amosi* fauna from western Argentina and a possible slightly younger age for its uppermost record has as limit the incoming of the San Rafael diastrophic phase (Azcu, 1985) in the Precordillera, close to Sakmarian-Artinskian times (Melchor, 2000; Césari, 2007). Alternatively, González and Díaz Saravia (2007) have indicated an Asselian age for these same glacial deposits linked with the *Costatumulus* fauna in both regions, Patagonia and western Argentina. This interpretation is probably due at least partially, to regard the section of the Mojón de Hierro Formation at the Arroyo Garrido creek (Arroyo Garrido Formation of Freytes, 1971), as being located in a lower stratigraphical position, contrary with its original characterization (Freytes, 1971). Furthermore, the mentioned glaciomarine deposits are intercalated in a likely continuous sequence, at 900m stratigraphically from the base of the Mojón de Hierro Formation. This level also correlates well laterally with the conglomerate-diamictite facies outcropping to the north, at the Eje Grande and Eje Chico hills (close to the type profile) and beyond extending to a few kilometers south of Palenque Post.

Eastern Argentina-Patagonia: A low diversity but significant *Eurydesma* fauna (Harrington, 1955; Rocha Campos and Carvalho, 1975; Pagani, 1998, 2000) is known from the Bonete Formation in the Sauce Grande Basin (Andreis et al., 1987), located at the Southern hills of Buenos Aires Province, eastern Argentina. This fauna was estimated to be of early Permian age (Harrington, 1955), between early Asselian (González, 1981), Asselian-Sakmarian (Rocha Campos, 1970) to Asselian-Artinskian (Pagani, 2000). More precisely, the *Eurydesma* fauna was a biotic event indicative of a cold-water marine paleoenvironment (Fossa Mancini, 1944, Dickins, 1957), also present in overseas Permian sequences of Australia, India and South Africa, related to a widespread (Tastubian) marine transgression by post-glacial eustatic rise in sea level (Dickins, 1978, 1985a,b, 1996, 1997). Precedent glacial and post-glacial records have been recognized in the Sauce Grande and Piedra Azul formations interval, which conformably underlies the Bonete Formation where the *Eurydesma* fauna occurs (Andreis and Torres Ribero, 2003, among others). This sequence has been recently estimated as late Pennsylvanian-Cisuralian age (Di Pasquo et al., 2008). The late Carboniferous?-early Permian glacial-postglacial sequence, represented by the upper part of the Tepuel Group (upper section of the Pampa de Tepuel and Mojón de Hierro formations), would be correlationable with a likely analogous sequence from Eastern Argentina, although the *Eurydesma* fauna has not been founded yet in Patagonia. Instead of this faunal association, two different Permian faunal assemblages have been identified in Patagonia. The older assemblage comes from the upper

section of the Pampa de Tepuel Formation and is characterized by *Verchojania archboldi* and *Tuberculatella? laevicaudata* (Amos), associated with glaciomarine deposits of possibly early Asselian age (Taboada, 2008). González et al., (2003) and González and Glasser (2008) have reported a glacial pavement (Figure 9) at El Molle place (contact between beds 9 and 10 of Perrot, 1960, 600m to the east of Lefiú Post), 200m stratigraphically below horizons bearing the invertebrate fauna with *Verchojania archboldi*. Another set of glacial pavements (bed 5 of Perrot, 1960, 130m to the west of Lefiú Post) (Figure 10A-D) was recorded 300m stratigraphically below the former, revealing at least two main different glacio-horizons in this locality (as in eastern Argentina, according to Andreis and Torres Ribeiro, 2003). In the type section of the Tepuel Group, glacially-related diamictites and associated facies bearing *Verchojania archboldi* are stratigraphically separated by more than 1000m from the older and precedent major glacial-related horizon with *Lanipustula patagoniensis* Simanaukas (Serpukhovian-Bashkirian) or the “*Productus* and *Fenestella*” beds of Suero (1948), where glacial pavements have been also recorded. This latest Carboniferous-earliest Asselian glacial episode associated with *Verchojania archboldi* in Patagonia, would be almost absent in western Argentina due to contemporary profuse volcanic activity in the region (Remesal et al., 2004), or at best could be very locally represented, where Ezpeleta and Astini (2008) have reported glacial-related deposits close to the base of the Río del Peñón Formation in the Río Blanco sub-basin. The other younger assemblage from Patagonia, was broadly grouped within the *Costatumulus* faunal association or biozone. The *Cimmeriella* fauna characterizes the *Costatumulus* Biozone in the upper section of the Mojón de Hierro Formation and has been linked with the major early Permian postglacial



FIGURE 8 | Glacial pavement in the upper section of the Pampa de Tepuel Formation at El Molle place, NE of the Lefiú Post and 200m stratigraphically below beds bearing the invertebrate fauna with *Verchojania archboldi*.

transgression recognized in this unit (López Gamundi, 1989; Taboada, 2001a). Although *Eurydesma* has not been recorded in Patagonia, it commonly occurs in other regions coupled with *Cimmeriella*, and a slightly younger age (usually Sterlitamakian) is currently accepted for the late (Waterhouse, 1970; Archbold et al., 1993). Although *Eurydesma* persisted in eastern Australia until Kungurian times due to persistent cold paleoclimatic conditions (Dickins, 1978), a late Sakmarian (Sterlitamakian) age is here suggested for the strata bearing *Cimmeriella willi* sp. nov. in Patagonia.

Transcontinental correlation: the coupled *Eurydesma-Cimmeriella*, *Cimmeriella-Jakutoproductus* and *Verchojania-Jakutoproductus* occurrences

Western Australia-Patagonia early Permian correlation. Marine basins of Western Australia show an extensive development of early Permian marine strata, of which the most complete sequence is located in the Carnarvon Basin. In this basin, the genus *Cimmeriella* was found in the Callytharra Formation and Wooramel Group (Waterhouse, 1970; Archbold, 1983; Archbold and Hogeboom, 2000), overlying the glacial and postglacial sequence of the Lyons Group, which has yielded the cold *Eurydesma* fauna (Dickins, 1957). The common occurrence of the widespread key

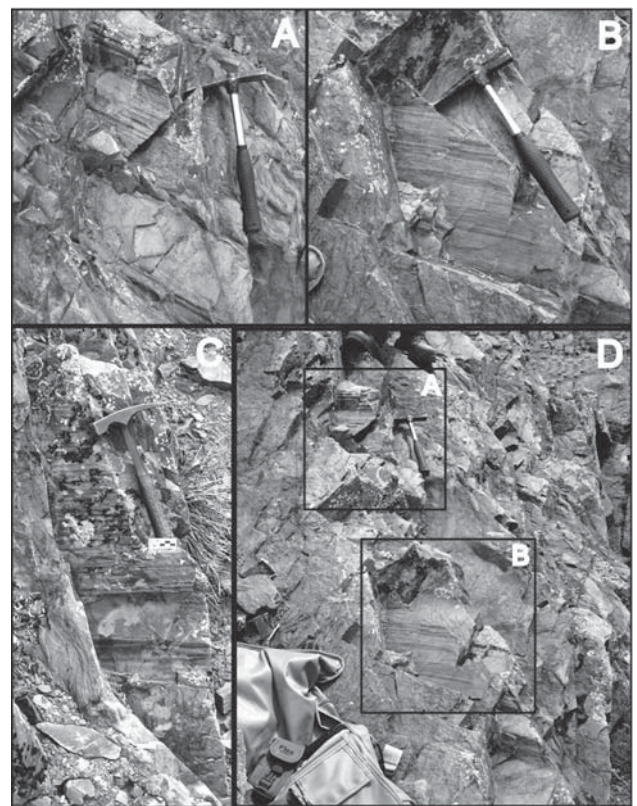


FIGURE 10 | Set of glacial pavements in the upper section of the Pampa de Tepuel Formation at El Molle place, W of Lefiú Post.

Series/Epoch	Stage/Age	PATAGONIA, TEPUEL-GENOA BASIN		WESTERN AUSTRALIA, CARNARVON BASIN		CANADIAN ARTIC		NORTHEAST ASIA AND EQUIVALENTS											
		Horizon	Biozones and Faunas	Litostratigraphic units	Biozones	Litostratigraphic units	Biozones	Horizons	Biozones										
CISURALIAN	Kungurian	Upper Tepuelian	Costatumulus Biozone	Byro Group	Wooramel Group	JIMBA MEMBER	JUNGLE CREEK FORMATION UPPER	Khalalian	Khalalian	Megousia kuliki - Aphanaiia andrianovi Zone									
											Svalvardia thomasi Zone	F. wandageensis Zone	F. cundlegeonsis Zone	Tornquistia magna Zone	Fusispirifer byroensis Zone	Wynthamia colemani Zone	Echinalosia prideri Zone	Koargichanian	Megousia aagardi - Aphanaiia lima Zone
											? ?	Cimmeriella wilii Fauna	Callytharra Formation	Sandstone Member	Strophalosia irwinensis Zone	Yakolevia transversa Zone (Ey Zone)	Jakutoproductus terekhovi - Cypricardinia eopermica Zone		
																		Jakutoproductus Fauna	Lyons Group
											Asselian	Upper Tepuelian	Verchojania archboldii Fauna	Lyons Group	Lyonia lyoni Zone	Yakolevia transversa Zone (Ey Zone)	Verchojania expositus - Palaeoneilo parenica Zone		
	Orochian	Verchojania mirandus - Palaeoneilo parenica Zone																	

FIGURE 11 | Transcontinental correlation chart of median to high paleolatitudes sequences, based on the coupled faunal occurrences of *Verchojania-Jakutoproductus*, *Eurydesma-Cimmeriella* and *Cimmeriella-Jakutoproductus*.

genus *Cimmeriella* in Patagonia, allows refining a proposal of intercontinental correlation between both regions, which probably have been at a similar paleolatitude (50°-60° to the Carnarvon basin in Archbold, 2000, or even higher) and paleoclimatic conditions. In Western Australia *Cimmeriella* is a typical component of the *Strophalosia irwinensis* and *S. jimbaensis* zones. The *S. irwinensis* Zone is characterized by *Cimmeriella foordi* (Etheridge, 1903), *Costatumulus irwinensis* (Archbold, 1983) and *Neochonetes (Sommeriella) pratii* (Davidson, 1859), and it was assigned to the Sterlitamakian (Archbold, 2000; Archbold and Hogeboom, 2000). The *Strophalosia jimbaensis* Zone is characterized by *Cimmeriella flexuosa* (Waterhouse) and *Neospirifer (Quadrospira) hardmani* (Foord), and was considered to be early Artinskian. In this way the *Cimmeriella* fauna in Patagonia

probably correlates with the *Strophalosia irwinensis* Zone (Figure 11). The *Cimmeriella* fauna (formerly *Stepanoviella* or *Globiella* faunas) was widespread and has been recognized in Western Australia, Umara, India and other Cimmerian regions, sometimes coupled with the *Eurydesma* fauna. This fauna was interpreted as evidence of a cold-temperate faunal association linked to a general trend towards paleoclimatic amelioration (Waterhouse, 1970; Archbold et al., 1993; Dickins et al., 1993; Shi and Archbold, 1993, 1996). A complete analysis of Gondwanan, early Permian correlations of this time interval was offered by Archbold (2000, 2001, 2002) and Foster and Archbold (2001).

Sibero-Mongolian and *Canadian Arctic-Patagonia* early Permian correlation: The key for correlation of Pat-

agonian outcrops with the Boreal Realm is given by the shared records of the bipolar genera *Verchojanina*, *Jakutoproductus* and *Cimmeriella*. Besides Patagonia, the only region where *Jakutoproductus* and *Cimmeriella* occur in a stratigraphic succession, is the Yukon Territory, Arctic Canada, where they were recorded in the upper member of the Jungle Creek Formation (Shi, 1994; Shi and Waterhouse, 1996). Following Shi and Waterhouse (1996), *Cimmeriella costellata* (Shi and Waterhouse, 1996) first appears in the Tastubian *Yakovlevia transversa* Assemblage Zone (Ey Zone) and persists through the Sterlitamakian *Ogilviecoelia inflata* Zone (Eog Zone), reaching the Aktastinian *Jakutoproductus verchoyanicus* Zone (Ej Zone). This last biozone allowed correlation of the Canadian Arctic with other lower Permian marine sequences of the Siberian-Arctic region (Shi and Waterhouse, 1996), where *Jakutoproductus* occurs profusely. In northeastern Asia this genus is known by several species which characterized widespread regional assemblages that have existed surrounding the marginal seas of Angaraland (full references in Ganelin and Biakov, 2006; Klets et al., 2006; Manankov, et al., 2006). In Asselian-Sakmarian times the *Jakutoproductus* acme was reached, the genus declined gradually in late Sakmarian and finally disappeared by the end of the Artinskian (Ganelin, 1991; Shi, 1994). Although the precise position of the Asselian-Sakmarian boundary in Northeast Asia has not yet been finally established, the base of the *Verchojanina mirandus-Palaeoneilo parenica* assemblage of the Orochian Horizon, is indicated as the conventional boundary for Asselian/Sakmarian in the Kolyma-Omolon region, based on the presence of Sakmarian goniatitids in the higher Ogonerian Horizon (Ganelin and Biakov, 2006). In northeast Asia (Kolyma-Omolon region) the Superhorizon Munugudzhakian is characterized by the predominance of the latest *Verchojanina* and the incoming of the *Jakutoproductus* faunas. The lower Koargychanian Horizon with the latest records of *Jakutoproductus* correlates with the end of the Artinskian (Ganelin and Biakov, 2006). Most of the Munugudzhakian Superhorizon of the Kolyma-Omolon region and its partially correlative regional sections as well as the Upper Kygyltassian and Khorokytian horizons of Verchojan area (Klets, 2005a,b; Klets et al., 2006) could be broadly correlated with the upper Tepuelian sequence (upper part of the "System of Tepuel" of Suero, 1948 = upper section of the Pampa de Tepuel Formation besides the Mojón de Hierro and Río Genoa formations) from Patagonia, where *Verchojanina* and *Jakutoproductus* coupled occurrences are also documented. Alternatively, the late species of *Jakutoproductus* of the Artinskian Echian Horizon of Verchojan (Klets, 2005a,b; Klets et al., 2006), Adatzag Horizon of Mongolia (Manankov, 2004; Manankov et al., 2006), Zhiphoshin Horizon of Transbaikalia (Kotlyar et al., 2002), and Ej Zone of Yukon (Shi, 1994; Shi and Waterhouse, 1996) usually have a bigger size, heavier ornament, deeper angular sulcus and more marked geniculation

and trail (Shi, 1994), besides a quadrifid cardinal process externally (Manankov, 2004), unlike the precedent species, including the Patagonian *Jakutoproductus*. Consequently and in accordance with the generic morphological trend, *Jakutoproductus australis* as the youngest occurrence of the genus in Patagonia would be not younger than early Artinskian, whilst an earliest Artinskian age is suggested to the slightly older *Jakutoproductus sabattinae* sp. nov. (Figures 8 and 11).

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