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A new Early Jurassic marine locality from southwestern Chubut Basin, Argentina

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ABSTRACT. A shallow marine invertebrate association is reported from a new Early Jurassic locality namely La Casilda, which is situated in the southwestern region of the Chubut Basin (Patagonia, Argentina). The marine deposits of La Casilda are located in the Río Genoa valley and bear a diverse invertebrate fauna including bivalves, gastropods, brachiopods, echinoderms and corals. A preliminary taxonomic analysis of the invertebrate fauna suggests that La Casilda deposits belong to the Mulanguiñeu Formation of late Pliensbachian-early Toarcian age, and may be coeval with those from the marine localities previously sampled in other regions of the Río Genoa valley. The preliminary results of a biodiversity analysis displayed that La Casilda is one of the most diverse localities at the Chubut Basin and could be assigned to the biofacies at the mixed siliciclastic-carbonate ramp proposed for the marine Early Jurassic at the Andean Basin of northern Chile. The evolution of the marine transgression during the early Pliensbachian-early Toarcian is also interpreted here in a time scale based on ammonite faunas, giving a preliminary temporal reconstruction of the entire Chubut Basin.

Keywords: Invertebrates, La Casilda, Mulanguiñeu Formation, Chubut Basin, Argentina.

RESUMEN. Una nueva localidad marina de edad jurásica temprana en la cuenca sudoccidental del Chubut, Argentina. Una asociación de invertebrados marinos de aguas someras se registró en una nueva localidad perteneciente al Jurásico temprano denominada La Casilda, la que se sitúa en la región suroeste de la cuenca del Chubut (Patagonia, Argentina). Los depósitos marinos correspondientes a La Casilda se encuentran en el valle del Río Genoa y comprenden una diversa fauna de invertebrados, incluyendo bivalvos, gastrópodos, braquiópodos, equinodermos y corales. Un análisis taxonómico preliminar de dicha fauna sugiere que los depósitos de La Casilda pertenecen a la Formación Mulanguiñeu, cuya edad es Pliensbachiano tardío-Toarciano temprano, y a su vez podrían ser coetáneos con los depósitos marinos de otras localidades muestreados previamente en el valle del Río Genoa. Resultados preliminares de un análisis de biodiversidad muestran que La Casilda es una de las localidades más diversas en la cuenca del Chubut y podría ajustarse a las biofacies correspondientes a la rampa mixta siliciclástica-carbonatada propuesta para la Cuenca Andina del Jurásico temprano marino del norte de Chile. La evolución de la transgresión marina que tuvo lugar durante el Pliensbachiano temprano-Toarciano temprano también se interpreta aquí en una escala de tiempo sobre la base de la fauna de ammonites, dando una reconstrucción temporal preliminar de toda la cuenca del Chubut.

Palabras clave: Invertebrados, La Casilda, Formación Mulanguiñeu, Cuenca del Chubut, Argentina.

1. Introduction

The first contributions to the paleontological knowledge of Early Jurassic marine invertebrate faunas in the southwestern region of the Chubut Province are those provided by Feruglio (1934, 1949), Piatnitzky (1936) and Wahnish (1942), who supplied data on the taxonomic composition of Early Jurassic marine invertebrate faunas from the Nueva Lubecka and Río Genoa regions. Particularly, Feruglio (1934) and Wahnish's (1942) descriptions and illustrations are still used as the main sources of taxonomic data to interpret the Patagonian's Jurassic marine biota. Bivalves, gastropods, cephalopods, brachiopods and corals were reported by these authors from several localities in the area, including Lomas Occidentales, Cerro La Trampa, Piedra Shotle and Lomas de Betancourt, which have yielded the most important Jurassic fossiliferous beds from the marine Mulanguiñeu Formation (Chubut Province). Another important marine locality was reported at the Early Jurassic of the Osta Arena Formation from the Pampa de Agnia region (central Chubut Province), known as Puesto Currumil (Ferrari, 2009, 2012, 2013; Pagani *et al*., 2012). Preliminary biostratigraphic analyses carried out in the southern and west-central Chubut Province (Pagani *et al*., 2012; Ferrari, 2013, 2014a) indicated a late Pliensbachian-early Toarcian age for these deposits. Moreover, Damborenea and Ferrari (2008), Ferrari (2009, 2011a, b, 2012, 2013, 2014a, b), Ferrari *et al*. (2014) and Pagani *et al*. (2011, 2012) recently carried out new studies on the taxonomic composition of the faunas in the Early Jurassic of south-western and central Chubut Province, including the investigation of new fossil localities and the collection of Early Jurassic material.

The present paper aims to describe a shallow marine invertebrate association from a new Early Jurassic locality in the southwestern region of the Chubut Province (Patagonia, Argentina), giving a preliminary taxonomic, paleoecological and paleobiogeographical interpretation of the community, and a preliminary temporal reconstruction of the marine transgression at the Chubut Basin during the early Pliensbachian-early Toarcian.

2. Geological Setting

Early Jurassic marine deposits from the Chubut Province are known since the pioneering expeditions of Roth (1908) and Keidel (1917) from the Río Tecka and Nueva Lubecka areas, respectively. The stratigraphy of these deposits has been established by several studies. An updated and detailed historical chronology of the Jurassic stratigraphic sequence of this region in Patagonia was recently provided by Ferrari (2009, 2011a, b, 2013, 2014a) and Pagani *et al*. (2011).

The Early Jurassic marine sediments in the Chubut Province are exposed along a north-west to south-southeast trend between 42º30' and 44º30' S, and 69º30' and 71º W (Riccardi, 1983; Giacosa and Márquez, 1999). In the southwestern region of the Chubut Province, the Early Jurassic marine deposits crop out in the Río Genoa and Nueva Lubecka areas (Fig. 1) and belong to the Mulanguiñeu Formation (Fernández Garrasino, 1977), originally described by Suero (1952, 1953, 1958) as "*Serie marina con Vola y Cardinia*", and considered to have an Early Jurassic (late Pliensbachian-early Toarcian) age based on its marine invertebrate faunas (Fernández Garrasino, 1977). The sediments of the Mulanguiñeu Formation lay unconformably over late Palaeozoic rocks belonging to the Río Genoa Formation (Tepuel Group). In the Pampa de Agnia area, the most extensive outcrops of the Osta Arena Formation, a partial equivalent of the Mulanguiñeu Formation, are on the western slope of sierras de Lonco Trapial, Cajón de Ginebra and Cerro Negro. This formation has an early Toarcian age based on hildoceratid ammonoids (Musacchio and Riccardi, 1971; Blasco *et al*., 1980; Ferrari, 2009).

The invertebrate association here described comes from La Casilda, a new fossil locality situated in the Río Genoa valley (Fig. 1). La Casilda is located 3.86 km north-east of Estancia La Casilda and 4.75 km north of Piedra Shotle locality, near the old telegraphic station of Nueva Lubecka (Fig. 1). Based on the diversity of the faunas represented in these marine deposits, which includes bivalves, gastropods, echinoderms, brachiopods and corals it is inferred here that the new locality may be coeval with those described by Feruglio (1934, 1949), Piatnitzky (1936) and Wahnish (1942) in other marine outcrops of the Mulanguiñeu Formation.

3. Materials and Methods

La Casilda locality was first visited in November 2011 and subsequently sampled in February 2014.

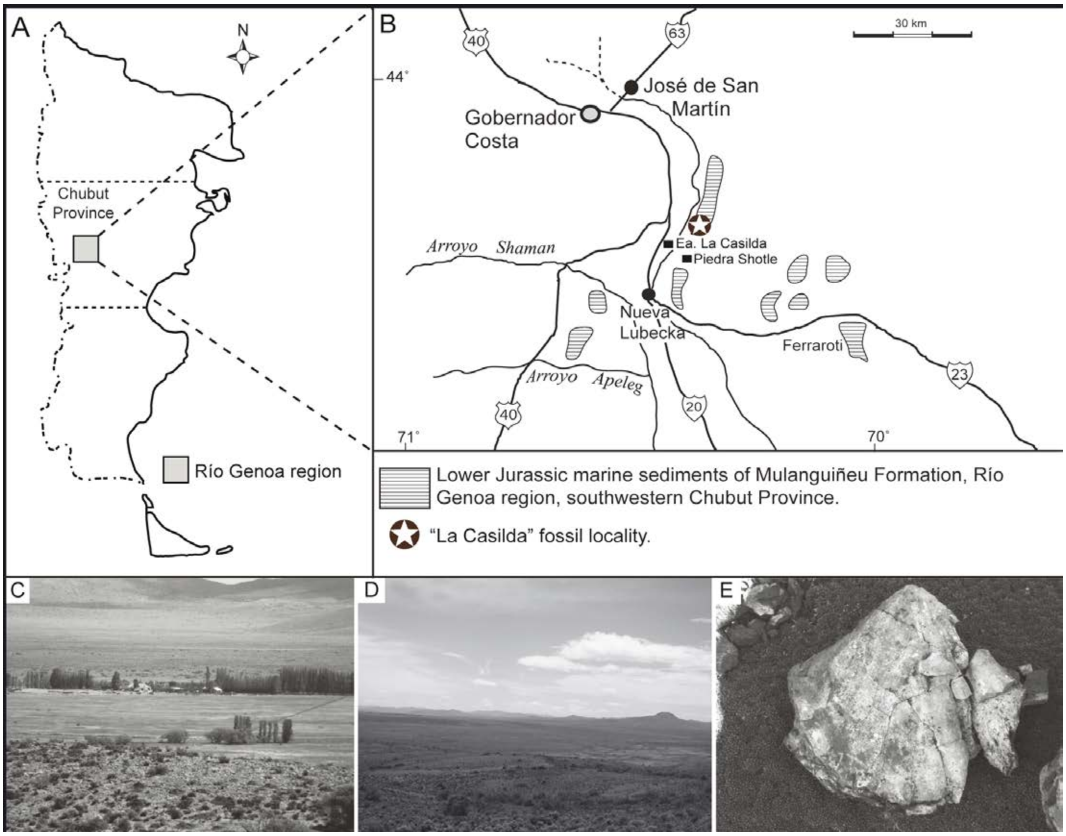

FIG. 1. **A.** Map of Patagonia (Argentina) showing Río Genoa region in southwestern Chubut Province; **B.** Location map of La Casilda fossil locality; **C.** Estancia La Casilda; **D.** General view of La Casilda fossil locality; **E.** *Weyla* (*Weyla*) *alata angustecostata* (Philippi) found at the marine beds of La Casilda.

All the specimens collected there are housed in the Museo Paleontológico "Egidio Feruglio" collection (MPEF-PI), Trelew (Argentina), and were prepared by the technical staff (Tec. Leandro Canessa). The materials were coated with ammonium chloride to enhance sculpture for photography. Photographs were taken with a digital camera at the MEF.

A biodiversity, rarefaction and neighbor joining clustering analyses have been calculated for the marine invertebrate taxa recovered thus far at the Chubut Basin using a statistical software PAST (Hammer *et al*., 2001).

4. Results

4.1.Taxonomic composition at La Casilda locality

The fossil invertebrate assemblage recovered at La Casilda is dominated by bivalves, gastropods and brachiopods, with several echinoid spines and corals also represented. The sedimentary marine deposits rich in invertebrate faunas are predominantly composed of medium- to coarse-grained and brown- to grey-greenish sandstones. Few specimens were contained within the sedimentary rocks, and most of them were found disperse and scattered through the bearing beds. The specimen preservation reveals a *post-mortem* transport, showing broken and disarticulated shells, and many specimens remain undetermined. However, a preliminary taxonomic approach of the marine invertebrate association displays the following taxa:

4.1.1. Bivalves

The bivalve fauna recovered at La Casilda is characterized by epibyssates, including *Agerchlamys* aff. *wunschae* (Marwick) (Fig. 2A-B), *Agerchlamys* sp. (Fig. 2C-D), *Pseudolimea* sp. (Fig. 2P) and

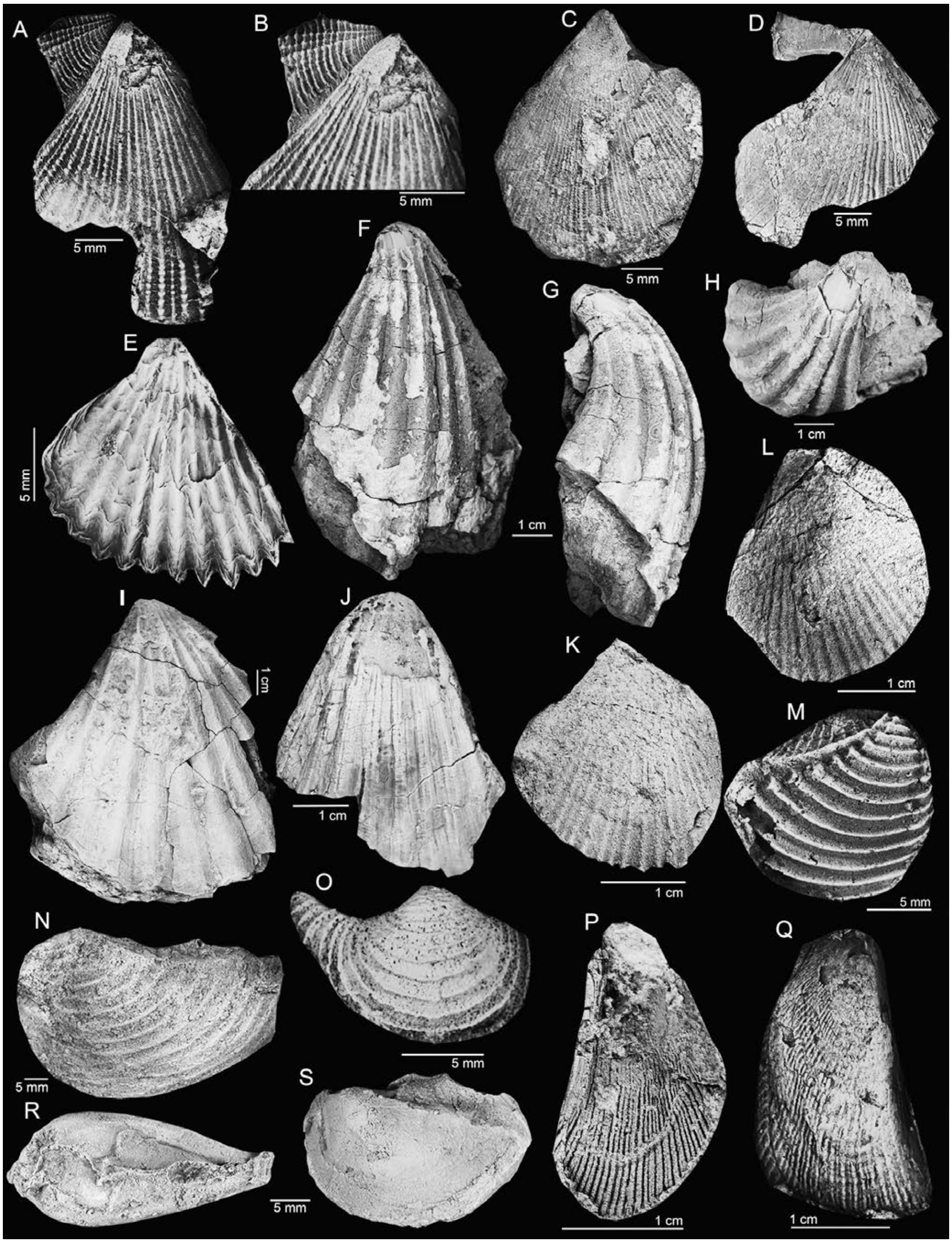

FIG. 2. **A-B.** *Agerchlamys* aff. *wunschae* (Marwick), MPEF-PI 6001, right valve, external mould; **A.** Lateral view; **B.** Detailed of dorsal region; **C-D.** *Agerchlamys* sp.; **C.** MPEF-PI 6003, external mould, lateral view; **D.** MPEF-PI 6002, right valve, external mould, lateral view; **E.** *Pseudopecten dentatus* Sowerby, MPEF-PI 4200, external mould, lateral view; **F-I.** *Weyla* (*Weyla*) *alata angustecostata* (R. Philippi); **F-H.** MPEF-PI 6004, left valve; **F.** Lateral view; **G.** Dorsal-lateral view; **H.** Anterior view; **I.** MPEF-PI 6005, left valve, external view; **J.** *Weyla* (*Weyla*) *bodenbenderi* (Behrendsen), MPEF-PI 4192, left valve, external view; **K-L.** *Kolymonectes* sp., MPEF-PI 5559, external views; **M.** *Frenguelliella* aff. *inexspectata* (Jaworski), MPEF-PI 4199, latex cast, right valve, lateral, external view; **N-O.** *Frenguelliella* sp.; **N.** MPEF-PI 6006, left valve, external view; **O.** MPEF-PI 4198, latex cast, right valve, external view; **P.** *Pseudolimea* sp., MPEF-PI 5558, negative mould, external view; **Q.** *Antiquilima* sp., MPEF-PI 6008, latex cast, right valve, external, lateral view; **R-S.** Frenguelliellinae gen. et sp. indet., MPEF-PI 4191; **R.** Steinkern; dorsal, internal view; **S.** left valve, lateral, internal view.

Antiquilima sp. (Fig. 2Q). Shallow burrowers such as *Freguelliella* aff. *inexpectata* (Jaworski) (Fig. 2M), *Frenguelliella* sp. (Fig. 2N-O) and *Cucullaea*? sp. (Fig. 3A) are also found at the marine deposits in La Casilda. Bivalves with a semi-infaunal reclining mode of life include *Weyla* (*Weyla*) *alata angustecostata* (Philippi) (Fig. 2F-I) and *Weyla* (*W.*) *bodenbenderi* (Behrendsen) (Fig. 2J) as stated by Damborenea and Manceñido (1979) and Damborenea (1987); *Gryphaea*? sp. (Fig. 3B-D) is also present within the semi-infaunal biota. Particularly, *Pseudopecten dentatus* (Sowerby) (Fig. 2E) and *Kolymonectes* sp. (Fig. 2K-L), were byssally attached early in ontogeny, but became free and epifaunal recliners as adults with a limited swimming ability (Damborenea, 2002b).

4.1.2. Gastropods

The gastropod fauna is represented by small turriteliform (*Cryptaulax*, *Procerithium, Pseudomelania*; Fig. 3I-O) to large trochiform and slightly cyrtoconoid (*Lithotrochus*; Fig. 3E-H) shell shapes. Particularly, members of *Lithotrochus* show a change in the translation rate along the coiling axis during ontogeny, which has been interpreted as a change in the organism's life habit (Damborenea and Ferrari, 2008). Members of *Lithotrochus humboldtii* (von Buch) (Fig. 3E-H) are well known as grazers inhabiting firm substrates in well-lit and oxygenated waters, and they are also common in sublittoral deposits, associated to a varied benthonic fauna such as the thick-shelled *Weyla* and *Cardinia*, and also near coralliferous facies (Damborenea and Ferrari, 2008). Representatives of Procerithiidae (*Cryptaulax*, *Procerithium*) as well as members of *Pseudomelania*, reveal small and turriculate shells forming a very low angle between the coiling axis and the substratum; this feature makes the shell very easy to be transported on consolidated sediments. Members of *Cryptaulax damboreneae* Ferrari (Fig. 3I-K)*, Procerithium* (*Rhabdocolpus*) *patagoniensis* Ferrari (Fig. 3L-M), *Procerithium* (*Infacerithium*) cf. *nodosum* Ferrari (Fig. 3N) and *Pseudomelania* sp. (Fig. 3O) are frequently found in the Jurassic marine sandstones of the Chubut Province in shallow environments, associated to diverse invertebrate faunas, but rarely mixed with *Lithotrochus* (Ferrari, 2012, 2014a).

4.1.3. Brachiopods and other taxa

Few but well preserved brachiopod specimens recovered at La Casilda represent members of the orders Spiriferinida and Terebratulida, including the species tentatively assigned to *Quadratirhynchia*? sp. (Fig. 3P-R), *Spiriferina*? sp. (Fig. 3S-T), *Zeilleria*? sp. (Fig. 3U-V) and *Terebratula*? sp. (Fig. 3W-X). A systematic review of the Early Jurassic Chubut brachiopod faunas is currently in process and new preliminary data were recently supplied by Manceñido and Ferrari (2013).

The brachiopod species of the orders Terebratulida and Spiriferinida also represent benthic, epifaunal and semi-infaunal forms. Terebratula specimens are adhered to the substratum by the pedicle during their entire life while Spiriferinida ones are adhered only when they are young loosing their pedicles when mature and hence shells lying on the mud. They are frequently found in shallow marine environments.

Solitary cnidarians doubtfully assigned to *Montlivaltia*? sp. (Fig. 3Y) and undetermined cnidarians (Fig. 3Z) are also present. Several echinoid spines were recovered at the marine deposits of La Casilda (Fig. 3A'-B').

4.2. Paleobiogeographical considerations

The bivalve, gastropod and brachiopod fauna represented at La Casilda is similar to that of coeval marine assemblages known from the Neuquén Basin and other regions of the world. According to Damborenea (2002a), the genera *Kolymonectes* and *Agerchlamys* show a bipolar distribution, restricted to high latitudes and present in both hemispheres but absent from low latitudes. In the Jurassic of Argentina, species of *Kolymonectes* are distributed from southern Mendoza Province to the Piedra Pintada region at southern Neuquén, having their southernmost occurrence at the Chubut Province (Damborenea, 2002b; Pagani *et al*., 2011). Species of *Agerchlamys* are also found in the Andean region of Argentina, at the late Pliensbachian (*Fanninoceras* Zone) of Mendoza and Neuquén provinces, and some specimens have been recovered at the Chubut Basin in the Pampa de Agnia area (Damborenea, 2002b). Particularly, *Agerchlamys wunschae* (Marwick) occurs in the Pliensbachian of New Zealand (Damborenea, 2002b). On the other hand, the genus *Weyla* is mainly a trans-temperate genus, commonly found along the margins of the Paleo-Pacific Ocean, both in low and medium paleolatitudes (Damborenea, 2002a). *Weyla* (*W.*) *alata angutecostata* has a wide geographical range in the South American Andes, from Perú and

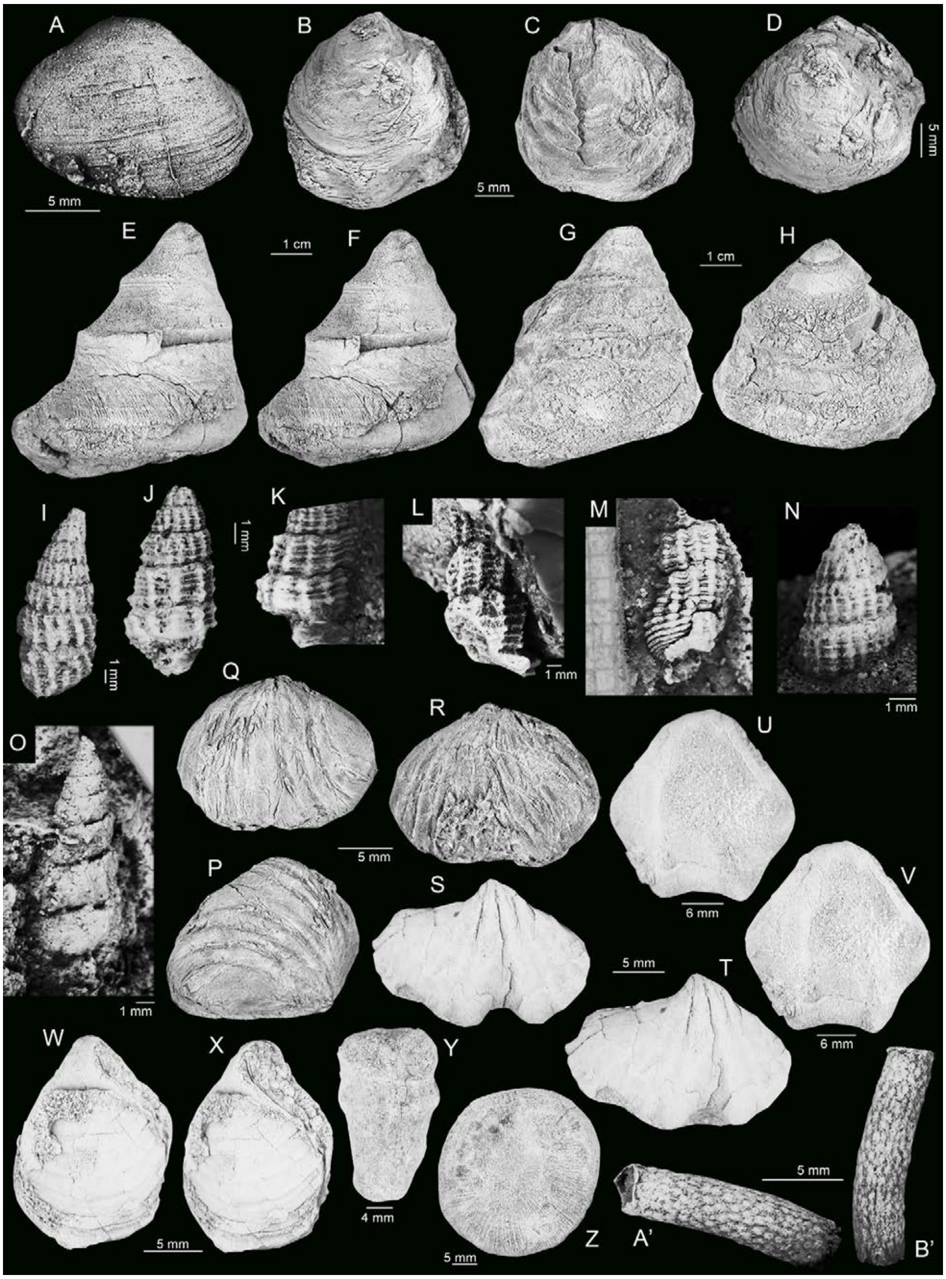

FIG. 3. **A.** *Cucullaea*? sp., MPEF-PI 6007, latex cast, lateral, external view; **B-D.** *Gryphaea*? sp., MPEF-PI 4190; **B.** right valve, lateral view; **C.** left valve, lateral view; **D.** left valve, lateraldorsal view; **E-H.** *Lithotrochus humboldtii* (von Buch); **E-F.** MPEF-PI 4188, teleoconch in lateral view; **G.** MPEF-PI 4186, teleoconch in lateral view; **H.** MPEF-PI 4187, teleoconch in lateral view; **I-K.** *Cryptaulax damboreneae* Ferrari; **I.** MPEF-PI 4193, teleoconch in lateral view; **J-K.** MPEF-PI 6009; **J.** teleoconch in lateral view; **K.** ornament detail; **L-M.** *Procerithium* (*Rhabdocolpus*) *patagoniensis* Ferrari; **L.** MPEF-PI 4196, fragmentary teleoconch in lateral view; **M.** MPEF-PI 6011, fragmentary teleoconch in lateral and basal view; **N.** *Procerithium* (*Infacerithium*) cf. *nodosum* Ferrari, MPEF-PI 6010, teleoconch in lateral view; **O.** *Pseudomelania* sp., MPEF-PI 6012, teleoconch in lateral view; **P-R.** *Quadratirhynchia*? sp., MPEF-PI 4189; **P.** oblique lateral view; **Q.** dorsal view; **R.** ventral view; **S-T.** *Spiriferina*? sp., MPEF-PI 6017, ventral views; **U-V.** *Zeilleria*? sp., MPEF-PI 6018, ventral views (with different lightings); **W-X.** “*Terebratula*”? sp., MPEF-PI 6019, ventral and oblique ventral views; **Y.** *Montlivaltia*? sp., MPEF-PI 6014; **Z.** Cnidaria gen. et sp. indet., MPEF-PI 6015; **A’-B’.** Echinoidea gen. et sp. indet., MPEF-PI 4194.

Chile (Aberhan, 1992, 1993) to the Neuquén Basin, reaching its southernmost occurrence at the Chubut Province (Damborenea and Manceñido, 1979; Feruglio, 1934; Wahnish, 1942). Representatives of *Freguelliella* and *Pseudolimea* show a cosmopolitan distribution (Damborenea, 2011).

The Procerithiidae fauna recovered at La Casilda is well known in the Early Jurassic of the Neuquén Basin, and also shows a cosmopolitan distribution. It has been reported in coeval marine sediments from the western Tethys (Kaim, 2004), reaching their southernmost occurrence at Antarctica (Edwards, 1980; Thompson and Turner, 1986) and New Zealand (Bandel *et al*., 2000). In addition, the late Triassic marine communities at the Pucará Group in central Perú yield representatives of the family Procerithiidae (Haas, 1953). The genera *Cyptaulax* and *Procerithium* are common along the Andean region of South America, from the Late Triassic of Perú (Haas, 1953), to the Early Jurassic of Chile (Gründel, 2001) and Argentina (Ferrari, 2009, 2012). The genus *Lithotrochus* is endemic of the Andean region of South America for a short time range in the Early Jurassic, from the early Sinemurian to the late Pliensbachian (Damborenea and Ferrari, 2008). The genus is found in Perú (Romero *et al*., 1995) and Chile (Hillebrandt, 1980; Aberhan, 1992, 1993; Gründel, 2001), reaching its southernmost occurrence in Argentina, from the Neuquén Basin to the Chubut Province.

The brachiopods found at the Chubut Province also shows paleobiogeographical connections with the faunas reported in coeval marine deposits of the Neuquén Basin, such as the representatives of Spiriferinida (Manceñido, 1981; Manceñido and Ferrari, 2013). Zeilleria has also been reported by Manceñido (1990) from the Early Jurassic of Mendoza and Neuquén provinces.

A preliminary paleobiogeographical interpretation of the marine invertebrate fauna found at the Chubut Province may be suggestive of the existence of a shallow marine connection between the Western Tethys and the eastern Pacific as early as Hettangian times, related to the opening of a Mid-Atlantic seaway: The Hispanic Corridor (Damborenea and Manceñido, 1979; Damborenea *et al*., 2012; Ferrari, 2014a). Based on the genus *Weyla*, Damborenea and Manceñido (1979) proposed the hypothesis of the Hispanic Corridor as the main dispersion seaway for biotic exchange between these areas during the Early Jurassic. Vicente (2005) summarized the evolution of the Jurassic Andean retroarc basin at a global scale for the Central Andes, checking the time of the marine transgressions along the Andean region of South America and distinguishing two main gulfs through the arc from which waters flowed simultaneously northwards and southwards in a narrow retroarc furrow; one of these gulfs was located at 35º S namely the Curepto Pacific Gulf (Fig. 4A). According to Vicente (2005), the Curepto Gulf was established as a Pacific connection of the Neuquén Basin as earliest as Hettangian times, and at the beginning of the early Pliensbachian, the marine transgression began to spread longitudinally towards the north and south. Finally, during the late early Pliensbachian to the early Toarcian times, the Curepto Gulf reached the central Chubut Basin (Fig. 4A). Thus, the shallow marine connection between the Neuquén and Chubut basins during the early Pliensbachian-early Toarcian throughout the Paleo-Pacific seaway (black arrows Fig. 4A) may explain the similarity on the taxonomic composition of the invertebrate biotas in both regions at that time.

5. Biodiversity analysis and evolutionary interpretation of the Chubut Basin

The Early Jurassic was a time of widespread, extended marine transgression, which is also represented in the Chubut Basin by several invertebrate communities. One of these associations is reported here from La Casilda locality. Another five marine assemblages were previously recovered in the Chubut Province and include Lomas Occidentales locality (Wahnish, 1942; Lesta *et al*., 1980), which is situated to the west of the old telegraphic station of Nueva Lubecka in southwestern Chubut Province (Fig. 4B. A). Cerro La Trampa locality (Wahnish, 1942), is situated 15 km east of Lomas Occidentales (Fig. 4B. B). Further east of the Cerro La Trampa locality, the marine sequences are also exposed at Aguada Loca locality (Wahnish, 1942) (Fig. 4B. C). Lomas de Betancourt (Cortiñas, 1984) (Fig. 4B. D) is located 4 km north of Aguada Loca; the presence of *Canavaria* cf. *naxensis* (Gemmellaro) at Lomas de Betancourt, indicates a latest Pliensbachian age (*Fanninoceras disciforme* Zone, see local zonation of Riccardi, 2008) for this association. The marine sequences at Lomas Occidentales, Cerro La Trampa, Aguada Loca and Lomas de Betancourt belong to the Mulanguiñeu Formation. Finally, the north-eastern Early Jurassic

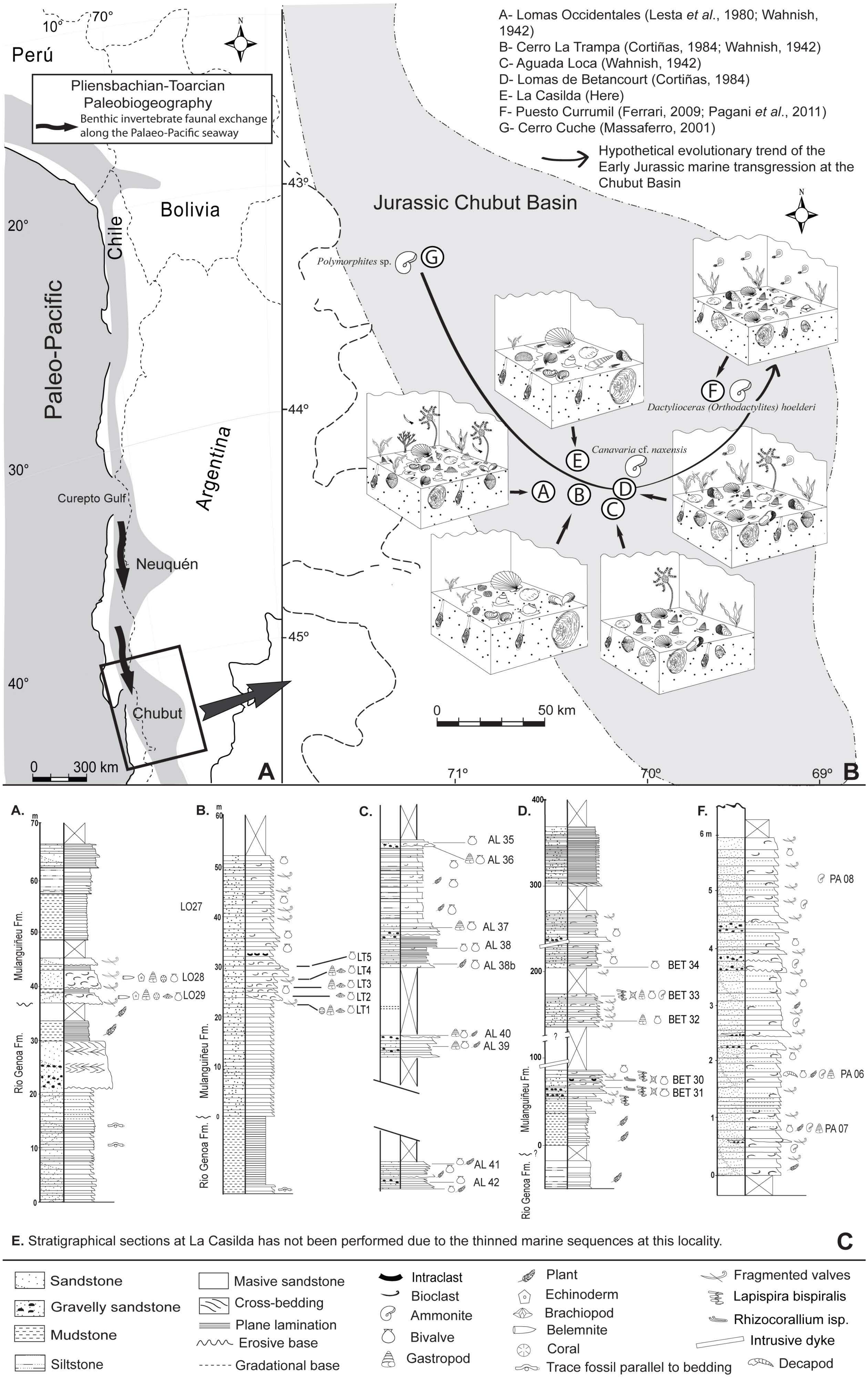

FIG. 4. **A.** Palaeobiogeographical map of the Andean region of South America during the Early Jurassic (early Pliensbachian-early Toarcian). Note the marine connection between the Chubut and Neuquén Basin throughout the Curepto Pacific Gulf; **B.** Chubut Basin section showing the preliminary temporal reconstruction of the marine transgression during the early Pliensbachian-early Toarcian; **C.** Stratigraphical sections of the main Early Jurassic marine localities at the Chubut Basin.

marine sediments crop out in the Pampa de Agnia region at Puesto Currumil locality (Ferrari, 2009; Pagani *et al*., 2011) (Fig. 4B. F), which belong to the Osta Arena Formation. The presence of *Dactylioceras* (*Orthodactylites*) *hoelderi* Hillebrandt and Schmidt-Effing (*Dactylioceras hoelderi* Zone; Riccardi, 2008; Riccardi *et al*., 2011) at Puesto Currumil locality indicates an early Toarcian age for the Pampa de Agnia region, the youngest marine sequences reported until now in the Chubut Basin during the Early Jurassic.

In order to assess the invertebrate biodiversity in the Chubut Basin, an analysis was performed using PAST statistical software (Hammer *et al*., 2001) and integrating all accessible data retrieved thus far from the five marine assemblages mentioned above plus the new material collected from La Casilda. The invertebrate data includes representatives of Bivalvia, Gastropoda, Brachiopoda, Echinodermata, Cephalopoda, Cnidaria and Crustacea. The biodiversity analysis calculated Simpson, Shannon and Margalef indices for the included samples. Simpson and Shannon indices provide an estimate of the variation in abundance among species within an assemblage; Margalef index estimates the biodiversity of a community based on the numerical distribution of individuals of different taxa. The primary results of the analysis show that the invertebrate faunal associations from Lomas Occidentales, Cerro La Trampa and La Casilda localities display the highest diversity in the Chubut Basin (Table 1). However, these data are preliminary, and further collection effort is to be undertaken in order to obtain a more complete data set from the marine localities of the study area. This is also reflected in the rarefaction analysis (Fig. 5A), which has been calculated for the six sampled localities. Rarefaction curves indicate the taxonomic richness in a function of the collection effort. The results of the analysis show that the Chubut localities are far from saturation regarding invertebrate sampling, being Lomas Occidentales and La Casilda the most riches localities (Fig. 5A). Finally, a neighbor joining clustering was performed integrating 92 marine invertebrate taxa (Table 2) reported at Lomas Occidentales, Cerro La Trampa, La Casilda, Aguada Loca, Lomas de Betancourt and Puesto Currumil. Four different sets of sampled localities are clearly discernible from this analysis. These are: **1)** Lomas Occidentales next to Cerro La Trampa; **2)** Lomas de Betancourt next to Aguada Loca; **3)** La Casilda next to Lomas Occidentales-Cerro La Trampa; and **4)** Puesto Currumil distant from the other three clusters (Fig. 5B). The good clustering of La Casilda together with Lomas Occidentales-Cerro La Trampa relies on the similar taxonomic composition of these marine assemblages, and this similarity coincides with the results of the biodiversity analysis (Table 1).

In order to compare La Casilda invertebrate association with other coeval marine communities of the Andean region of South America, the model of Aberhan (1993) was followed. Aberhan (1993) reconstructed the distribution of facies and benthic faunas in segments from the marine Early Jurassic Andean Basin of northern Chile based on sedimentological, taphonomic and paleoecological evidene. The author reconstructed the depositional system as a homoclinal ramp reflecting the distribution of several environmental factors (water energy, input of terrigenous material, carbonate production, oxygen supply) and distinguished four depositional facies where benthic faunas could clearly be assigned: **1)** shallow siliciclastic ramp; **2)** mixed siliciclastic-carbonate ramp; **3)** middle carbonate ramp; and **4)** deep carbonate ramp. The Early Jurassic marine association here described from La Casilda may be

TABLE 1. DIVERSITY OF THE INVERTEBRATE FAUNA AT THE CHUBUT BASIN DURING THE EARLY JURASSIC IN COMPARISON: TAXA, SPECIES RICHNESS, SIMPSON, SHANNON AND MARGALEF DIVERSITY INDICES.

	Lomas Occidentales	Cerro La Trampa	La Casilda	Aguada Loca	Lomas de Betancourt	Puesto Currumil
No. Taxa	6	4	5	2	4	4
Individuals	39	12	23	16	16	21
Simpson	0.58	0.68	0.64	0.21	0.6	0.6
Shannon	1.12	1.24	1.25	0.37	1.06	1.14
Margalef	1.36	1.2	1.27	0.36	1.08	1.31

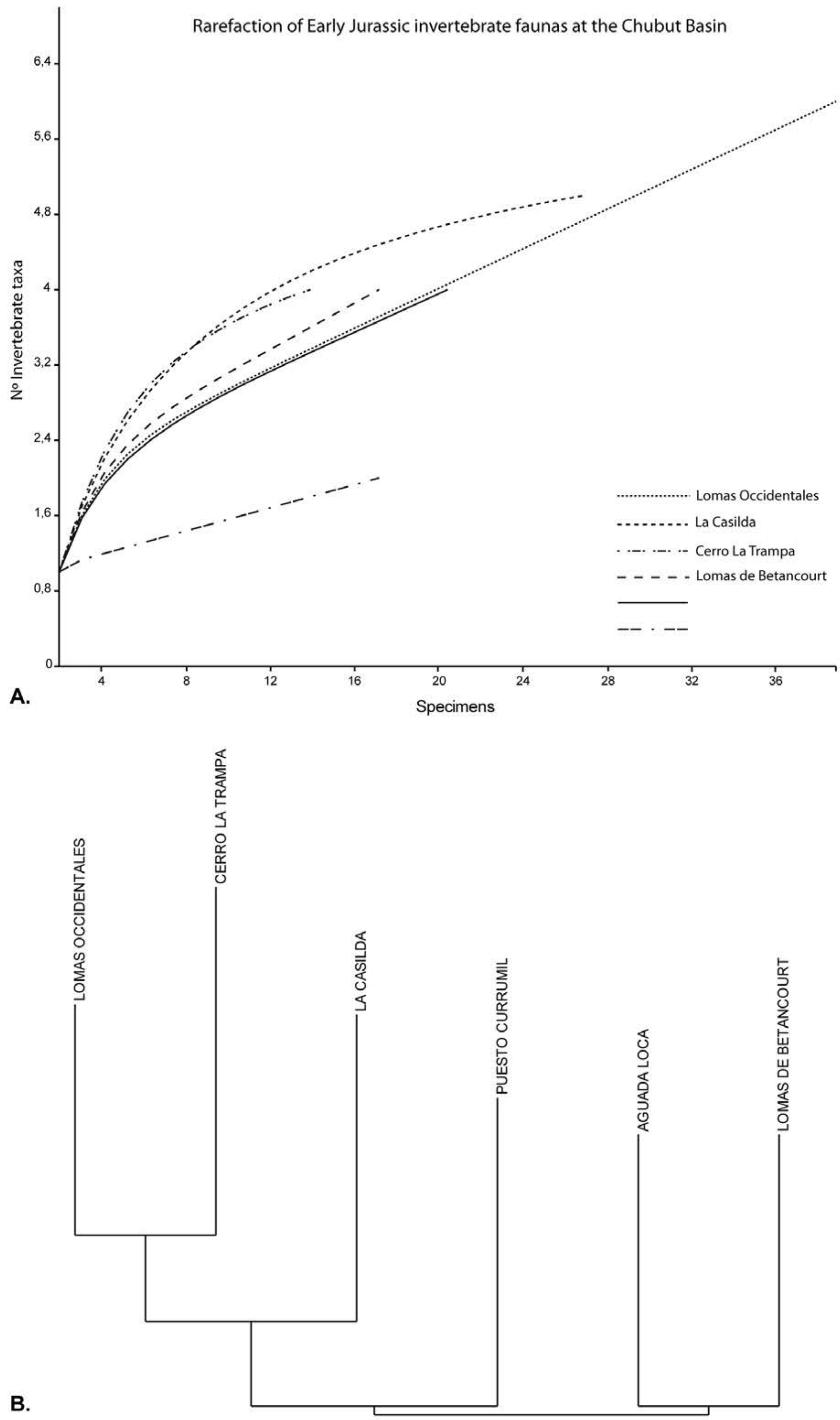

FIG. 5. **A.** Rarefaction analysis of the Early Jurassic invertebrate faunas at the Chubut Basin; **B.** Neighbor joining clustering, Simpson similarity measures with root final branch algorithm. Note good clustering of La Casilda locality next to Cerro La Trampa and Lomas Occidentales.

TABLE 2. SUMMARIZED INFORMATION OF THE MARINE INVERTEBRATE BIOTAS REPRESENTED AT THE SIX LOCALITIES OF THE CHUBUT BASIN DURING THE EARLY JURASSIC. NOTE THAT LA CASILDA LOCALITY IS HIGHLIGHTED.

	Localities Taxa	Lomas Occidentales	Cerro La Trampa	La Casilda	Aguada Loca	Lomas de Betancourt	Puesto Currumil
BIVALVIA	“*Astarte*” sp.	X					
	“*Lucina*” sp.				X		
	Agerchlamys aff. *wunschae* (Marwick)			X			
	Agerchlamys sp.			X	X		
	Agerchlamys? sp.						X
	Antiquilima sp.			X			
	Campotonectes? sp.						X
	Cardinia sp.	X					
	Chlamys textoria (Schlotheim)		X				
	Ctenostreon sp.	X					
	Cucullaea? sp.			X			
	Entolium sp.	X					X
	Freguelliella aff. *inexpectata* (Jaworski)			X			
	Frenguelliella sp.	X		X	X	X	
	Gervillaria pallas Leanza					X	
	Gervillaria sp.				X		
	Grammatodon costulatus (Leanza)						X
	Grammatodon sp.				X		
	Groeberella neuquensis? (Groeber)	X					
	Gryphaea? sp.			X			
	Isocyprina sp.	X					
	Isognomon sp.		X				
	Jaworskiella sp.	X					
	Kolymonectes weaveri Damborenea					X	X
	Kolymonectes sp.			X	X		
	Malletia sp.				X		
	Myophorella sp.	X					
	Neocrassina? sp.	X					
	Notoastarte? sp.					X	
	Nuculana? sp.				X		
	Oxytoma? sp.						X
	Palaeoneilo? sp.				X	X	X
	Parainoceramus apollo (Leanza)				X		
	Parainoceramus sp.						X
	Pholadomya sp.		X		X	X	
	Plicatula sp.		X				
	Posidonotis cancellata (Leanza)						X
	Prosogyrotrigonia sp.					X	
	Pseudolimea sp.			X	X		X
	Pseudopecten dentatus (Sowerby)			X			
	Radulonectites sp.				X		
	Ryderia sp.				X		
	Venericardia sp.	X					
	Weyla (Weyla) alata angustecostata (Philippi)	X		X			X
	Weyla sp.		X				
	Weyla (W.) bodenbenderi (Behrendsen)			X			
GASTROPODA	*Ambercyclus espinosus* (Ferrari)						X
	Ambercyclus? *isabelensis* Ferrari *et al.*	X					X
	Anulifera chubutensis Ferrari	X					
	Ataphrus mulanguiniensis Ferrari	X					
	Calliotropis (*R.*) cf. *keideli* Ferrari *et al.*				X		
	Calliotropis (*R.*) *keideli* Ferrari *et al.*	X			X	X	X
	Calliotropis (*R.*) sp. Ferrari *et al.*					X	
	Calliotropis? sp.	X					
	Chartronella gradata Ferrari	X	X				
	Chartronella paganiae Ferrari	X					
	Chartronella spiralis Ferrari	X					
	Colpomphalus musacchioi Ferrari						X
	Cryptaulax damboreneae Ferrari			X		X	X
	Cryptaulax redelii Ferrari	X					
	Globularia cf. *catanlilensis* (Weaver)	X					
	Globularia sp.		X				
	Hamusina? *wahnishae* Ferrari	X					
	Jurassiphorus? cf. *triadicus* Haas	X					
	Leptomaria sp.	X					
	Lewisiella? sp.					X	
	Lithotrochus cf. *rothi* Damborenea & Ferrari	X					
	Lithotrochus humboldtii (von Buch)	X	X	X			
	Naricopsina? sp.					X	
	Nerinea? sp.	X					
	Pleurotomaria sp.		X				
	Procerithium (Infacerithium) cf. *nodosum* Ferrari			X			
	Procerithium (*Infacerithium*) *nodosum* Ferrari	X					
	Procerithium (Rhabdocolpus) patagoniensis Ferrari	X		X			
	Procerithium nulloi Ferrari	X					X
	Pseudomelania feruglioi Ferrari	X				X	
	Pseudomelania sp.	X		X			
	Scurriopsis? sp.	X					
	Striatoconulus sp.						X
BRACHIOPODA	*Fissirhynchia?* sp.						X
	Quadratirhynchia? sp.			X			
	Rhynchonellida?	X	X				
	Spiriferina? sp.			X			
	"Terebratula"? sp.			X			
	Terebratullida?		X				
	Zeilleria (Z.) cf. sarthaecencis (d'Orbigny)	X					
	Zeilleria? sp.			X			
ECHINODERMATA	Apiocrinitidae	X					
	Echinoidea			X			
	Pentacrinites sp.					X	
CNIDARIA	Scleractinia	X	X	X			
CEPHALOPODA	*Canavaria cf. naxensis (Gemmellaro)*					X	
	Dactylioceras (Orthodactylites) hoelderi Hillebrandt and Schmidt-Effing						X
	Belemnite	X					
DECAPODA	*Mecochirus robbianoi Pagani et al.*						X

tentatively assigned to the mixed siliciclastic-carbonate ramp biofacies following Aberhan's (1993) model. The biofacies at the mixed siliciclastic-carbonate ramp represent marine associations from the upper Pliensbachian and Toarcian strata, which exhibits a relatively broad spectrum of life habits, a high diversity and its constituent samples possessing a high faunal density. The dominant organisms of the mixed siliciclastic-carbonate ramp are bivalves, represented by different guild and morphotypes, including shallow infaunal suspension-feeders, free-lying epifaunal suspension-feeders and cemented epifaunal suspension-feeders. The invertebrate taxonomic composition is characterized by the presence of *Weyla*, *Entolium*, *Gryphea*, *Pinna*, *Pholadomy*a, *Terebratula*, *Quadratirhynchia* and *Montlivaltia*, between others (Aberhan, 1993, p. 115, fig. 7). Most of these taxa also occur at La Casilda locality (Table 2). Table 2 provides the summarized information of the marine invertebrate biotas represented at the Early Jurassic of the Chubut Basin; note that La Casilda locality is highlighted.

The evolution of the marine transgression in the Chubut Basin during the Early Jurassic was interpreted by Vicente (2005) based on the ammonite fauna. The author suggested the existence of a late early Pliensbachian-early Toarcian transgression in the Chubut Province and accepted a marine connection between Neuquén and Chubut during the Toarcian; the author considered a northern origin of the Chubut transgression. The hypothesis of Vicente (2005) is also interpreted here in a time scale. The Paleo-Pacific marine embayment seems to have initiated early in the Pliensbachian at the Cerro Cuche locality (Massaferro, 2001) in the north-western region of the Chubut Province. Massaferro (2001) reported the occurrence of *Polymorphites* sp. (assigned to the *Eoamalitheus meridianus* Zone, Hillebrandt, 1987; Riccardi *et al*., 2011) at the Sierra de Tecka region. The marine embayment widespread toward the south-western region of the Chubut Province at the Río Genoa valley during the latest Pliensbachian, which is indicated by the presence of *Canavaria* cf. *naxensis* (Gemmellaro) (*Fanninoceras disciforme* Zone; Riccardi, 2008; Riccardi *et al*., 2011) at Lomas de Betancourt locality. After the latest Pliensbachian crisis, the marine transgression reached the central Chubut Province at the Pampa de Agnia region during the early Toarcian; this is interpreted by the occurrence of *Dactylioceras* (*Orthodactylites*) *hoelderi* Hillebrandt and Schmidt-Effing (*Dactylioceras hoelderi* Zone; Riccardi, 2008; Riccardi *et al*., 2011) at Puesto Currumil locality.

6. Concluding Remarks

The new data here reported from La Casilda fossil locality supply new evidence on Early Jurassic marine deposits in the Chubut Basin, and contribute toward increasing and updating the paleontological knowledge of Jurassic marine invertebrate biotas in Patagonia.

The summarized taxonomic information obtained from the six localities sampled at the Chubut Basin displayed that La Casilda is one of the most diverse associations together with Lomas Occidentales and Cerro La Trampa. Moreover, La Casilda could tentative be assigned to the coeval biofacies at the mixed siliciclastic-carbonate ramp following Aberhan's (1993) model for the marine Early Jurassic Andean Basin of northern Chile.

The evolution of the marine transgression during the Early Jurassic is also interpreted here in a time scale based on ammonites and it seems to have had its origin during the early Pliensbachian in northern Chubut Basin reaching the central Chubut Province in the early Toarcian. However, this interpretation is preliminary and needs more accurate systematic data (especially those provided by ammonites) and the investigation of new fossiliferous localities at the study area.

The recovery of new invertebrate collections in the Early Jurassic of the Chubut Basin provides new systematic data which may greatly assist in studies focused on the systematic, paleoecological and paleobiogeographical knowledge of the whole invertebrate biota in Patagonia. Particularly, the recognition of new ammonite, bivalve and brachiopod material will help to correlate the marine sequences at the Chubut Basin with coeval deposits of the Neuquén Basin, based on the available biostratigraphic schemes proposed by Manceñido (1981, 1983, 1990, 2002, 2010), Manceñido and Damborenea (1990), Damborenea and Manceñido (1992), Manceñido and Dagys (1992), Baker and Manceñido (1997) Riccardi (2008) and Riccardi *et al*. (1994, 2011).

This approach provides a preliminary reconstruction of the entire Early Jurassic marine Chubut Basin, very poorly known until now and one of the southernmost records of the Jurassic in Gondwana.

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