

The *Patagonian* transgression, early Miocene (Burdigalian age), in Aysén and Magallanes

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Abstract. During the early Miocene an extended eustatic cycle referred to as the *Patagonian* transgression flooded a vast part of southern South America. In Chile, the Guadal Formation in Aysén and the recently identified Estancia 25 de Mayo Formation in Magallanes represent this event. The main facies are thick, massive, fine to middle sandstones interbedded with subordinated thin mudstone levels, with characteristically greyish and bluish colors. Fossil content includes more than 80 species of marine invertebrates, infrequent vertebrates, and traces. Biogeographic similarities of the fossil assemblage are with correlative units in western Argentina, and with the Monte León Formation along the Atlantic coast of Santa Cruz province. Stratigraphy, facies analysis and the fossils suggests a direct Atlantic connection, and the isolation of the basin from the western Pacific depocenters by the existence of an orogenic belt already uplifted.

Key Words: *Patagonian*, Guadal Formation, Estancia 25 de Mayo, Miocene, Chilean Patagonia

1. Introduction

The *Patagonian* transgression represents an early Miocene eustatic event with sedimentary exposures along the Atlantic coast and Andean foothills of Patagonia (Ameghino, 1906). An abundant fossil record includes hundreds of species of marine invertebrates, vertebrates and traces. Although widely described in Argentina, the Chilean exposures have not been analyzed nor described in detail. Similarly, its fossil content has received attention only at Pampa Castillo in the Aysén region (Frassinetti and Covacevich, 1999), with all remaining localities almost totally undescribed (Griffin *et al.*, 2014). The importance of these units goes beyond the pure scientific interest, forming “mythological territories” (history of whales lying in the mountains) for the local residents of the surrounding towns.

Three geographic areas have relevant outcrops of this transgression in Chile (Figure 1): the Meseta Cosmelli south of Lake General Carrera, in Aysén; the Jeinimeni river valley and Quebrada Honda, in the neighboring of Chile Chico, Aysén; and the Sierra Baguales, in Última Esperanza province, Magallanes. Fossil invertebrates assumed to be of early Miocene age have also been reported from Bahía Inútil in Tierra del Fuego, but detailed fieldwork in these horizons is needed to confirm this assumption.

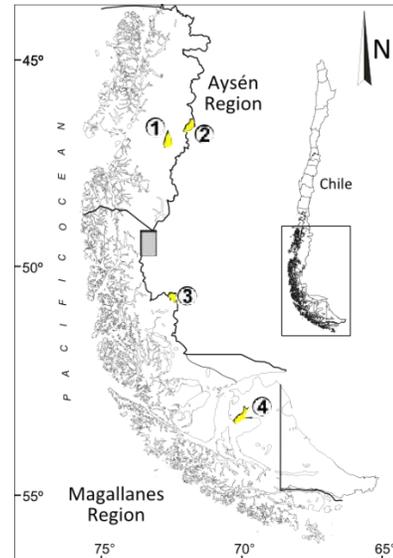


Figure 1. Geographic location of the *Patagonian* sea exposures and correlated horizons in Chilean Patagonia. 1) Meseta Cosmelli; localities of Río San Martín, Pampa Guadal and Pampa Castillo among others, Aysén. 2) Chile Chico area; localities of Jeinimeni River, Quebrada Honda and others, Aysén. 3) Sierra Baguales; Alto Río Bandurrias and tributaries, Magallanes. 4) Bahía Inútil, Tierra del Fuego, Magallanes.

1.1 Stratigraphic context

All Chilean *Patagonian* beds are currently contained within two lithostratigraphic units; the Guadal Formation in Aysén (Niemeyer *et al.*, 1984, De La Cruz and Suárez, 2006), and the Estancia 25 de Mayo Formation in Sierra Baguales (Bostelmann *et al.*, 2013; Griffin *et al.*, 2014). Both units are part of the external domain of the Patagonian Fold-and-thrust Belt, in the Austral retroarc-foreland basin (Gighlione *et al.*, 2009).

Along the Meseta Cosmelli, and specifically at Pampa Guadal and Pampa Castillo, the Guadal Formation overlies the continental, fluvial, deposits of the San José Formation (Flint *et al.*, 1994) assigned to the lower Eocene (De La Cruz and Suárez, 2006). Field observations (Bostelmann, *pers. obs.*) suggest that the San José Formation probably is an Oligo-Miocene stratigraphic unit. The common estimated thickness of the Guadal Formation is ~110 m (De la Cruz and Suárez, 2006). At its top, it grades concordantly to the

continental Santa Cruz Formation (De la Cruz and Suárez, 2006; Ugalde *et al.*, this congress). No radiometric age has been published from this unit, but geochronological research at the neighboring El Chacay Formation recently obtain early Miocene (20.31-18.1 Ma) ages for correlative horizons (Cuitiño *et al.* in press).

In the Alto Río Bandurrias, at Sierra Baguales, the Estancia 25 de Mayo Formation transitionally overlies the Río Leona Formation. The upper contact is also transitional with the Santa Cruz Formation. U/Pb and $^{87}\text{Sr}/^{86}\text{Sr}$ dates of the same horizons south of Lago Argentino render Burdigalian (20.05-18.96 Ma) ages for the unit (Cuitiño *et al.*, 2012).

2. Methods

Fieldwork was carried out during 2011 and 2014 in Pampa Guadal, and 2012 to 2015 in Alto Río Bandurrias. Stratigraphic sections were measured and described at the centimeter-scale, taking fresh rock color data, lithology, sedimentary structures, erosive surfaces and depositional styles. Sandstone and key pyroclastic levels were sampled for radiometric dating. Fossils were deposited in the National Museum of Natural History, Santiago. Selected fossils from Sierra Baguales were also deposited at the J.L. Oyarzún Paleontological Collection, in Puerto Natales.

3 Results

3.1 Stratigraphy and lithology

Pampa Guadal– The basal contact with the San José Formation (Figure 2.A) covers the first 8 m. Strong bioturbation characterize this contact (*Ophiomorpha* and *Thalassinoides*, isp.) affecting a conspicuous reddish erosive surface. The package comprises middle, massive, yellow sandstones carrying an abundant fauna of fossil invertebrates, mostly preserved as internal moulds (>40%). It also includes at least three levels of bioherms formed by articulated specimens and disarticulated valves of “*Ostrea*” *hatcheri*. The top of the section is cut by the recent erosive surface at Pampa Guadal.

The following 50 m were measured in several ravines above the erosive surface, constituting the superior portion of the unit. They include mainly greyish to greenish, middle to coarse, massive, metric sandstones, which develops diverse sedimentary structures up section i.e. parallel-, trough-, planar- and *herringbone* bedding. The sand bodies are tabular, with up to 3 m thick subordinate mudstones. The invertebrate fossils are usually represented by moulds, the exception being “*Ostrea*” *hatcheri*, which appears in at least three well developed beds at 20, 25 and 28 m. Quaternary colluvial deposits of the surrounding high plateau cover the upper contact (50-67 m) with the Santa Cruz Formation. The basal beds of this unit include massive brownish, metric-scale mudstones, and wide clast-to matrix-supported conglomerates towards the top.

Alto Río Bandurrias– the total thickness of the Estancia 25 de Mayo Formation here is 143.8 m, with a basal contact generally covered and exposed upper transitional beds showing a gradual environmental change from estuarine/marginal marine to continental deposits of the Santa Cruz Formation (Ugalde *et al.*, this congress). The integrated section begins with a base formed by greyish, poorly preserved vegetation-bearing mudstones with parallel lamination. It is followed by packages dominated by fine to medium bluish massive sandstones, interbedded with tabular marine invertebrate-rich beds and calcareous concretions (Griffin *et al.*, 2014). Directly overlying these levels is a whitish tabular ~1.55-2m dacitic tuff, referred as the *Lower Pyroclastic Level* by Cuitiño and Scasso (2010). This horizon denotes a regional volcanic event of great magnitude, which acts as a conspicuous regional guide level. U/Pb dated samples of this tuff in localities south of Lago Argentino at Estancia Quién Sabe rendered a 19.1 Ma age (Cuitiño *et al.*, 2012). Massive mudstones and concretion levels with decapod crustaceans dominate the next section. Towards the top, the unit is characterized by massive fine sandstones, with poorer fossil content (36–74 m). Middle to coarse sandstone levels continue with a relative increment in the fossil invertebrate content (90.8–109.5 m). Bioclastic-dominated massive beds of aggregated and disarticulated specimens of “*Ostrea*” *hatcheri* mark the top of this sandstone. The last portion has massive or structure-bearing, middle to coarse inverse sandstone grading (114.2–143.7m). The transitionally overlying horizons that (>144 m) are characterized by their greater thickness, an abrupt interruption of the marine fossil remains, the apparition of organic matter, channelized geometries and less abundant concretions. These beds constitute the base of Santa Cruz Formation. The initial 74 m of the section correspond to the Quién Sabe Member, while the last 52.9 m are associated to the Río Bandurrias Member, both originally described by Cuitiño and Scasso (2010).

3.3 Fossil content

In both formations marine invertebrates dominate the fossils record, and include antozoa, brachiopods, mollusks, echinoderms, arthropods and annelids. Marine vertebrates are infrequent. Taxonomic identity and relative abundances of each group shows little change between formations but are sensitive to facies arrangement. Contrarily, taphonomic and diagenetic alterations are significantly different between the Guadal and Estancia 25 de Mayo formations attesting to different conditions during burial.

More than 80 species have been described for the Guadal Formation at Pampa Castillo (Frassinetti and Covacevich, 1999). Fossils are preserved almost exclusively as moulds, but some brachiopods and the giant Patagonian oyster “*Ostrea*” *hatcheri* show diagenetically altered shell material. At the Chile Chico outcrops, altered shells are also recorded in other bivalves and balanids.

Good preservation is observed in the fossils of the Estancia 25 de Mayo Formation at Sierra Baguales. Recent collections raised the recognized diversity of the macro-invertebrates in these horizons up to 50 species (Griffin *et al.*, 2014). Brachiopods are represented by two different terebratulids currently under review. Identified Gastropods include *Glossaulax secundum*, *Polinices santacrucensis*, *Valdesia dalli*, *Trochus laevis*, *Miomelon gracilior*, *Ficus carolina*, *Peonza* sp. and *Acteon* sp. Specially abundant are *Perissodonta ameghinoi* and *Turritella ambulacrum*, classic indicators of the Patagonian beds at Monte León. Common bivalves include the pectinids *Jorgechalmys centralis* and *Zigochlamys geminata*, and the mytiloids *Modiomytilus argentinensis*, *Modiolus arctus* and least frequent *Modiolus ameghinoi*. Equally abundant are *Iheringinucula tricesima*, *Lahillia patagonica*, *Cucullaea alta*, *Cardium puelchum*, *Cardium philippi*, *Ameghinomya argentina*, *Panopea bagualesia*, *Arca patagonica* and *Nuculana* sp. Contrary to the Guadal Formation, in Sierra Baguales the echinoderms are rare. Also reduced is the diversity of crustaceans, represented by few specimens of balanids and the decapod *Chaceon peruvianum*. Vertebrate remains are infrequent and include shark teeth (Otero *et al.*, this congress) and fragmentary bones of undetermined cetaceans. Fossil traces include a vast array of galleries and burrows of *Domichnia*.

4 Discussion and conclusions

4.1 Depositional environments

The Guadal Formation is mostly formed by massive, medium to coarse tabular sandstones, massive siltstones, parallel-stratified sandstones, cross bedding sandstones, sandstones thin interbedded with mudstones and ripple marks. In general sense, the formation characterize a shallow siliciclastic marine platform system (0-31 m), on the northwestern margin of the early Miocene engulfment (Flint *et al.*, 1994). The notable sand content suggests proximity to the *shoreface*, while at the top (31-50 m) it evidences a tidally dominated transitional zone.

Main sedimentary facies in the Estancia 25 de Mayo Formation include fine and middle massive sandstones, with an increment in thickness towards the upper half. The change characterizes variations in the depositional system, with the basal beds representing a sub-tidal marine environment, with homogeneous sedimentary input and low energy conditions (0-74 m). The middle beds reflect a shallow intertidal zone, with brief pulses of higher energy (90.8-114.2 m), while the upper beds mark the transition from a marginal marine/estuarine environment to fully continental, fluvial, conditions.

4.2 Biogeographic relationships

Taxonomic similarity of the Chilean fossils in both formations matches well the Atlantic faunas of the Monte León Formation and the Lago Argentino area. Frassinetti and Covacevich (1999) noted this for the Guadal Formation, suggesting an Atlantic origin for the fauna. Good

preservation at Sierra Baguales confirms this, although a detailed taxonomic revision of all the fossil material is still pending. Geochronology, sedimentology and provenance analysis of the deposits in Magallanes shows that the *Patagonian Sea* was flanked to the west by an orogenic-belt. In Aysén, the common fossil content, lithofacies analysis, reevaluation of the San José Formation age, and the syntectonic deposition observed in some of the beds (Flint *et al.*, 1994; De La Cruz and Suárez, 2006), also suggest the existence of a western uplifted orogeny, raised during the initial compressional tectonics in the late Oligocene early Miocene. Geochronology and provenance analysis currently underway may prove key elements to demonstrate the full Atlantic nature of the deposits in this region.

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