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A SYNTHESIS OF PALYNOLOGICAL DATA RECOVERED FROM "NEOCOMIAN" DEPOSITS OF THE GOLFO SAN JORGE BASIN

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ABSTRACT

This contribution provides a synthesis of the palynological studies carried out on "Neocomian" units of the Golfo San Jorge Basin. Additionally, a revision of the palynological zones established for these units in previous works is presented, incorporating insights from new contributions and recent taxonomic novelties. Based on the palynological record, the age of the Las Heras Group is considered as not younger than Hauterivian at the northern and southern flanks of the Golfo San Jorge Basin. In contrast, the age of this group extends to the Aptian in the western area. Nevertheless, more detailed palynological studies and an evaluation of the current status of the stratigraphic units recognized in the analyzed wells are needed to confirm and expand these results.

INTRODUCTION

The Golfo San Jorge Basin (GSJB) is located in the central region of Argentinian Patagonia, between 45º and 47º South and 65º and 71º West, in Chubut and Santa Cruz provinces, and extending eastward onto the Continental Platform (Fig. 1). This basin has the distinction of being the oldest and most productive petroleum sedimentary basin in Argentina (Barcat *et al.*, 1989). The GSJB is an intracratonic structure with predominantly extensional characteristics, stretching in an east-west direction from the Andean belt to the Atlantic Ocean. Its sedimentary succession comprises deposits ranging from the Upper Jurassic to the Neogene. The Cretaceous sedimentary record of the basin is included in two successions. The first comprises the formally defined Las Heras Group and the informally named "Neocomian" deposits (and other equivalent formal and informal units; Lesta *et al.*, 1980) dated as Upper Jurassic to Lower Cretaceous. The second consists of the Chubut Group, which includes Barremian? to upper Maastrichtian units (Allard *et al.*, 2018). Despite the basin´s extensive geographical extent and wide stratigraphic range, palynological studies of its succession remain scarce, particularly for the Lower Cretaceous (Archangeslky *et al.*, 1981, 1983, 1984; Vallati, 1993, 2013; Barreda *et al.*, 2003; Perez Loinaze *et al.*, 2019, 2024).

This work aims to provide an updated review of the contributions of palynology from "Neocomian" unit of the GSJB. Additionally, a revision of the paleontological zones is presented, incorporating insights from updated records and recent taxonomic novelties.

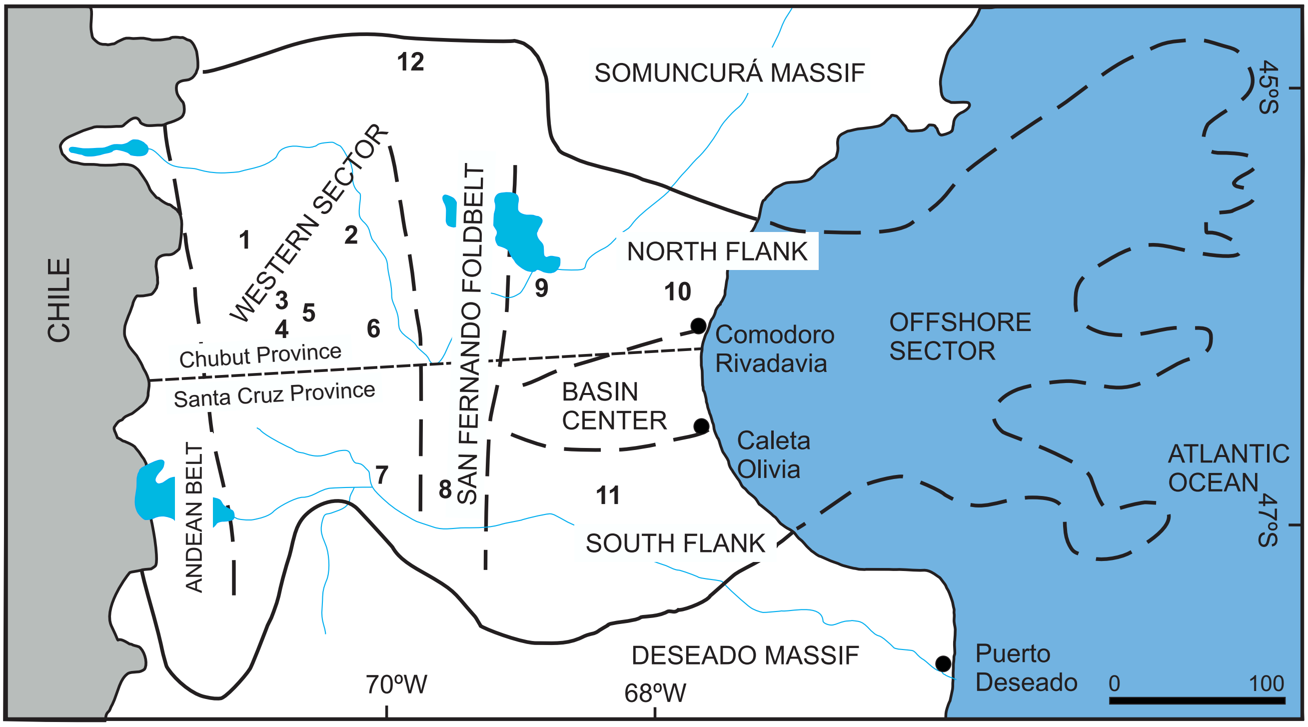

Figure 1. Location map of the Golfo San Jorge Basin, showing the location of the sites referred in the text. 1. UN.OIL.OS-1 (Union Oil) well, 2. YPF.CH.F.x-1 (F) well, 3. YPF.PRM.es-1 (Paso Río Mayo=PRM) well, 4. YPF.CH.EC x-1 (Estancia Centeno) well, 5. YPF. CH.CS.x-1 well, 6. YPF.CRM.es-1 (Confluencia Río Mayo=CRM) well, 7. SC.CEP.x-1 (Cordón El Pluma=CEP) well, 8. Co.Ba.x-1 (Cerro Bagual), 9. EZ.x-1 (El Zanjón) well, 10. D-129 well, 11. YPF.SC.PL.x- 2 (Puesto Luden) well, 12. Puesto Albornoz locality.

LAS HERAS GROUP AND EQUIVALENT DEPOSITS

The "Neocomian" deposits fill grabens and half-grabens formed during the Gondwana break-up (Figari *et al.*, 1996). These deposits reach maximum thickness in the western part of the basin. The Las Heras Group overlies, in angular unconformity, the Lower to Upper Jurassic Complejo Volcánico Sedimentario (*sensu* Clavijo, 1986), a succession of volcanic, volcaniclastic, and, to a lesser degree, sedimentary rocks of different stratigraphic units.

The "Neocomian" sequences present in the eastern zone of the basin, and at Sierra de San Bernardo, are referred to as the Pozo Anticlinal Aguada Bandera and Pozo Cerro Guadal formations in the subsurface (Fig. 2). These successions are also recognized under different names throughout the basin. The Shale Member of the Pozo Paso Río Mayo Formation in the Río Mayo area, the "Pelitas Laminares" in the central basin, and the "Sección Pelítica Basal" in the Lago Colhué Huapí sector are all correlatable with the Pozo Anticlinal Aguada de Bandera Formation. On the other hand, the Sandy Member of the Pozo Paso Río Mayo Formation can be correlated with the Pozo Cerro Guadal Formation. Additionally, the Tres Lagunas, Katterfeld, and Apeleg formations, located near Lago Fontana at the Río Mayo sub-basin and western area, as well as the Puesto Albornoz Formation outcropping in the northwestern part of the basin, are correlatable with the Las Heras Group (Sylwan *et al.*, 2011; Fig. 1 and 2).

The Pozo Anticlinal Aguada Bandera Formation consists mainly of black shales with intercalations of sandstones (Lesta *et al.*, 1980) deposited in a low salinity and anoxic lacustrine environment (Peroni *et al.*, 1995). However, marine elements have been reported in the western sector, suggesting influence from a Pacific transgression (Laffitte and Villar, 1982). The fossil record of this unit includes palynomorphs, scales and other skeletal remains of fishes, foraminifers, conchostracans, and ostracods (Lesta *et al.*, 1980; Laffitte and Villar, 1982).

The age of the Pozo Anticlinal Aguada Bandera Formation has been estimated as Tithonian to lower Valanginian, based on its paleontological content (Barcat *et al.*, 1989). Fitzgerald *et al.* (1990), using biostratigraphic information and correlations with the eustatic cycle chart of Haq *et al.* (1987), proposed an age range from Callovian to Berriasian for the unit. Masiuk and Viña (1987; in Barcat *et al.*, 1989) also assigned a lower Berriasian-lower Valanginian age to the unit, based on non-marine ostracodes and charophytes. Furthermore, this unit has yielded a Late Jurassic foraminifer assemblage (Laffitte and Villar, 1982) and Early Cretaceous palynomorphs (Archangelsky *et al.*, 1984).

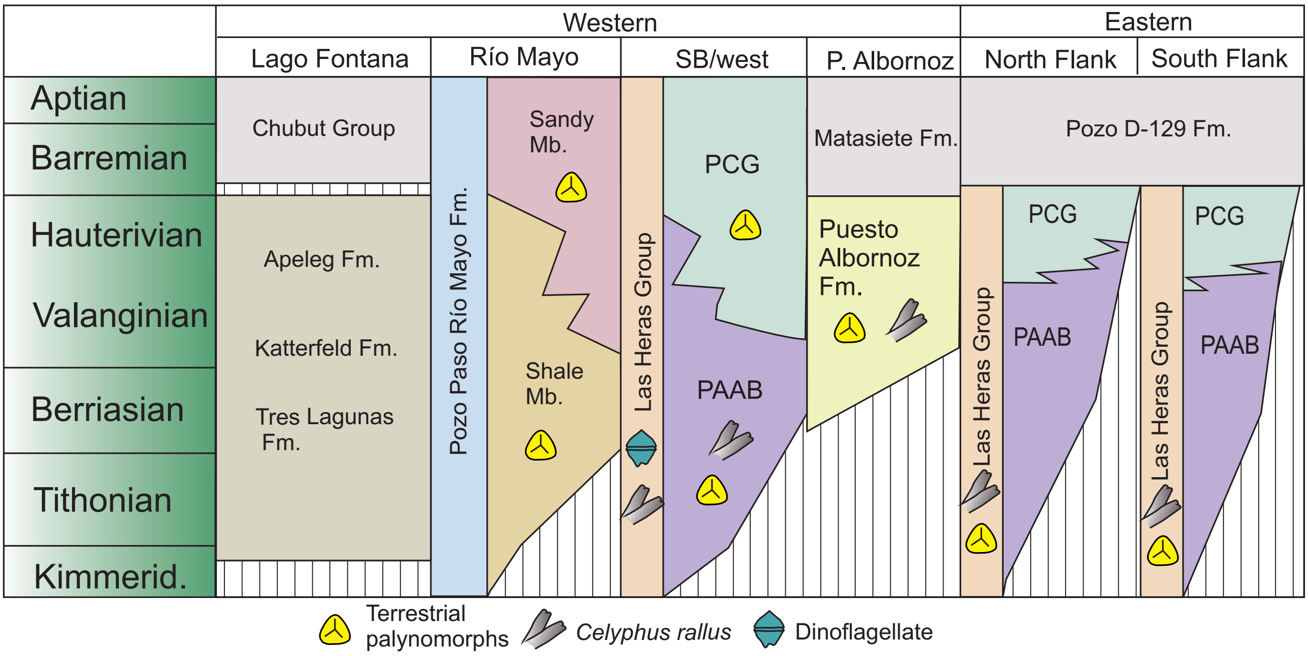

Figure 2. Stratigraphic column of Lower Cretaceous unit of the Golfo San Jorge Basin. Modified from Sylwan *et al.* (2011). PAAB: Puesto Anticlinal Aguada Bandera Formation, PCG: Puesto Cerro Guadal Formation, SB: San Bernardo hill.

Overlying the Pozo Anticlinal Aguada Bandera Formation is the Puesto Cerro Guadal Formation. The contact between both units is unconformable (Sylwan, 2001). The Puesto Cerro Guadal Formation is composed of sandstones, tuffaceous siltstones, and silicified black shales, deposited in marine and transitional paleoenvironments to the west and lacustrine settings to the east (Clavijo, 1986; Figari *et al.*, 1999). This unit represents the moment of maximum flooding of the basin, influenced by marine incursions from the Pacific (Barcat *et al.*, 1989; Figari *et al.*, 1999).

The biostratigraphic record of the Puesto Cerro Guadal Formation is sparse, partly due to the fact that few wells penetrate the interval, and partly because most samples are sterile (Sylwan, 2001). Consequently, there is no consensus regarding the age of this unit. Barcat *et al.* (1989) inferred a Valanginian- Hauterivian age based on marine fauna. Fitzgerald *et al.* (1990) constrained its age to the Valangianian, based on the Hauterivian-Barremian age assigned to the overlying Pozo D-129 Formation. On the other hand, based on palynological data from EZ.x-1 (El Zanjón) well, Seiler and Viña (1996, in Sylwan, 2001) suggested a Berriasian age for the Puesto Cerro Guadal Formation.

Based on the cephalopod fauna as well as foraminifera, recovered from the Katterfeld Formation, a Valanginian-Hauterivian age was suggested for this unit (Russo and Flores, 1953 in Clavijo, 1986). The Pozo Paso Río Mayo Formation has been subdivided into two members: the lower Shale Member and the upper Sandy Member (Clavijo, 1986). The Shale Member consists of mudstones and black shales deposited in a lacustrine environment, while the Sandy Member comprises mudstones, sandstones, and tuffs deposited in both marine and continental conditions. Due to the presence of marine deposits, as well as the similarity in age, these levels have been correlated with the Katterfeld Formation (Ramos, 1976). Based on the foraminiferal content, a Berriasian to lower Valanginian age has been proposed for the Pozo Paso Río Mayo Formation (Clavijo, 1986).

PALYNOLOGICAL RECORD

The Las Heras Group and other formal and informal correlatable units from the GSJB have yielded limited palynological data (Perez Loinaze *et al.*, 2019). These palynofloras are characterized by the presence of pioneering cyanobacterial species *Celyphus rallus* (*e.g.*, Archangelsky and Seiler, 1980, Archangelsky *et al.*, 1984; Figari *et al.*, 1999; Peroni *et al.*, 1995; Bellosi *et al.*, 2002; Barreda *et al.*, 2003). However, Archangelsky *et al.* (1984) studied palynofloras from "Neocomian" without *Celyphus rallus*, and Barreda *et al.* (2003) present palynofloras with this taxon referred to Pozo D-129 Formation.

Archangelsky *et al.* (1981, 1983, 1984) analyzed palynofloras recovered from the Pozo Anticlinal Aguada Bandera, Puesto Cerro Guadal and Paso Río Mayo formations and undifferentiated "Neocomian" deposits from several wells of the GSJB (Fig. 2). In the first contribution, Archangelsky *et al.* (1981) presented the relative abundances of the different recovered paleofloristic groups. Later, the authors systematically studied the assemblages, proposing several new taxa (Archangelsky *et al.*, 1983). Finally, Archangelsky *et al.* (1984), based on the distribution of 67 palynomorph species from YPF.CH.F.x- 1, CRM.es-1, PRM.es-1, CBA.x-1, YPF.SC.CEP.x-1 and UN.Oil.OS-1 wells, proposed four palynological zones. These zones, in ascending stratigraphic order, are the *Callialasporites-Contignisporites-Staplinisporites* (late Berriasian-early Valanginian), *Interulobites-Foraminisporis* (late Valanginian-Hauterivian), *tectifera-corrugatus* (Barremian), and *Antulsporites- Clavatipollenites* (Aptian; Fig. 3).

The authors only recognized the first zone in strata referred to as the Springhill Formation of the Austral Basin, whereas the remaining three zones were identified in "Neocomian" units from the GSJB (Archangelsky *et al.*, 1984).

According to Archangelsky *et al.* (1984), the *Interulobites-Foraminisporis* Zone identification is based on the exclusive presence of *Foraminisporis variornatus*, *F. microgranulatus*, *Interulobites pseudoreticulatus*, *I. distannulatus*, *Klukisporites*

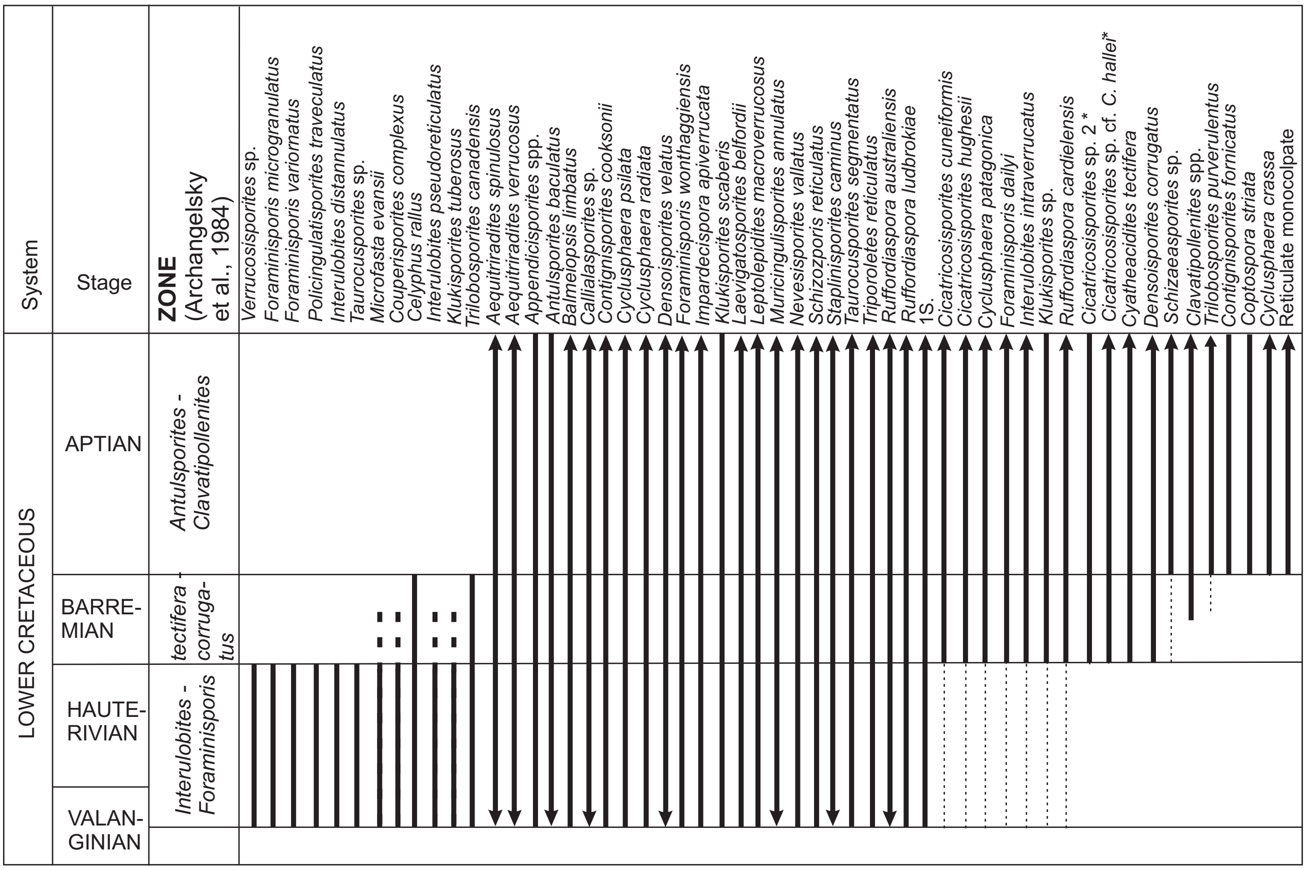

Figure 3. Biostratigraphic framework of Lower Cretaceous palynozones at the austral basins of Argentina, with detail of the stratigraphic ranges of recognized taxa. (*): in Archangelsky and Archangelsky (2010).

tuberosus, *Polycingulatisporites trabeculatus*, and *Taurocusporites* sp. in Archangelsky *et al.* (1983). This zone also records the first appearances of *Balmeiopsis limbatus* and *Cicatricosisporites* sp. 3 in Archangelsky *et al.* (1983), and *Cyclusphaera psilata*, *C. patagonica*, *C. radiata*, *Foraminisporis wonthaggiensis*, *Impardecispora apiverrucatus*, *Laevigatosporites belfordii*, *Taurocusporites segmentatus*, *Triporoletes reticulatus* among other continental taxa and the algae *Microfasta evansii* and *Celyphus rallus* (Archangelsky *et al.*, 1984).

Among taxa characteristic of the *Interulobites-Foraminisporis* Zone as defined by Archangelsky *et al.* (1984), it is worth mentioning the presence of *Cyclusphaera psilata*, a species first recorded from upper Valanginian strata (Volkheimer, 1980; Quattrocchio *et al.*, 2003), which allows defining the oldest temporal range of the zone, and separating it from the *Callialasporites-Contignisporites-Staplinisporites* Zone, where this species is absent. The presumed freshwater algal form *Microfasta evansii* is recorded from Berriasian to Aptian deposits in Australia (Morgan *et al.*, 2002). *Celyphus rallus* is recorded from Upper Jurassic to Lower Cretaceous non-marine deposits (Batten *et al.*, 1994 and references therein) whereas in Argentina, this taxon is known only from late Valanginian to Barremian assemblages (Barreda *et al.*, 2003; Quattrocchio *et al.*, 2003 and references therein). However, the presence of *Celyphus rallus* is constrained by the paleoenvironmental conditions and, as such, has limited stratigraphic value.

Archangelsky *et al.* (1984) correlated the section between 2050 to 2600 m in depth of the YPF. SC.CEP.x-1 well with the *Interulobites-Foraminisporis* Zone (Fig. 4). These levels were referred to the Pelitas laminares (currently named Pozo Anticlinal Aguada Bandera Formation) and Puesto Cerro Guadal Formation (although the authors do not clarify the boundary between both units). However, Clavijo (1986) noted that in the YPF.SC.CEP.x-1 well, only the Puesto Anticlinal Aguada Bandera Formation is recorded, as the erosive contact with the overlying Pozo D-129 Formation resulted in the absence of the Puesto Cerro Guadal Formation.

The *Interulobites-Foraminisporis* Zone is also identified from the YPF.CH.F.x-1 well at a depth of 2220-2320 m, referred to as undifferentiated "Neocomian", and at the UN.Oil.OS-1 well (probably from 1314-1926 m, but this is not clearly stated; Archangelsky *et al.*, 1984).

The *tectifera-corrugatus* Zone was characterized by Archangelsky *et al.* (1984) by the appearance of *Cicatricosisporites* sp. 9 in Archangelsky *et al.* (1983), *Cyatheacidites tectifera*, *Densoisporites corrugatus*, *Leptolepidites macroverrucosus*, and *Trilobosporites purverulentus*. Several taxa present in minor proportions in the older assemblages become more common in this zone, such as *Cicatricosisporites* sp. 1 in Archangelsky *et al.* (1983), *C.* sp. 2 in Archangelsky *et al.* (1983), *C.* sp. 4 in Archangelsky *et al.* (1983), *C.* sp. 5 in Archangelsky *et al.* (1983), and *Foraminisporis dayli*. On the other hand, *Celyphus rallus*, *Cyclusphaera radiata*, *Interulobites pseudoreticulatus*, *Laevigatosporites belfordii*, *Microfasta evansii*, and *Trilobosporites canadensis* have their last appearances in this zone (Archangelsky *et al.*, 1984).

Recently, the species *Cyclusphaera radiata* was found in younger units (Vallati *et al.*, 2013; Perez Loinaze *et al.*, 2019, 2021). Archangelsky and Archangelsky (2010) systematic review of the genera *Cicatricosisporites* and *Ruffordiaspora* recovered from Lower Cretaceous units from Argentina and proposed new taxonomic combinations. In this context, *Cicatricosisporites* sp. 9 was referred to *Ruffordiaspora ludbrokiae*, *Cicatricosisporites* sp. 1 and *C.* sp. 2 to *C. cuneiformis*, and *C.* sp. 4, *C.* sp. 5 was assigned to *Ruffordiaspora cardielensis* (Fig. 3).

Palynological assemblages referred to the *tectifera-corrugatus* Zone were identified by Archangelsky *et al.* (1984) from the upper part of Puesto Cerro Guadal Formation at the CRM.es-1, PRM.es-1 well (2200-2400 m), the Shale Member of the Paso Río Mayo Formation at the PRM. es-1 well (1350-1685 m), the upper levels of the UN.Oil.OS-1 well (1281-1314 m), and from the undifferentiated "Neocomian" at the YPF.CH.F.x-1 well (1940-2220 m). Based on dinoflagellate cysts, Seiler (1979) suggested an age not older than upper Hauterivian and not younger than upper Aptian for the 1281-1290 m levels of the UN.Oil.OS-1 well, not contradicting the Barremian age of the *tectifera-corrugatus* zone as proposed by Archangelsky *et al.* (1984).

The *Antulsporites-Clavatipollenites* Zone was defined by Archangelsky *et al.* (1984) as characterized by the first appearance of angiosperm pollen grains (*Clavatipollenites* spp.), along with *Antulsporites baculatus*, *Cyclusphaera crassa*, *Coptospora striata*, and *Contignisporites fornicatus*.

More recent studies have shown that the species *Antulsporites baculatus* and *Cyclusphaera crassa* are also present in older units (upper Valanginian to Barremian; Guler *et al.*, 2015; Perez Loinaze *et al.*, 2019, 2024). Additionally, primitive angiosperm pollen grains have been recorded from older strata, dated as upper Barremian (Springhill Formation; Quattrocchio *et al.*, 2006; Guler *et al.*, 2015) and upper

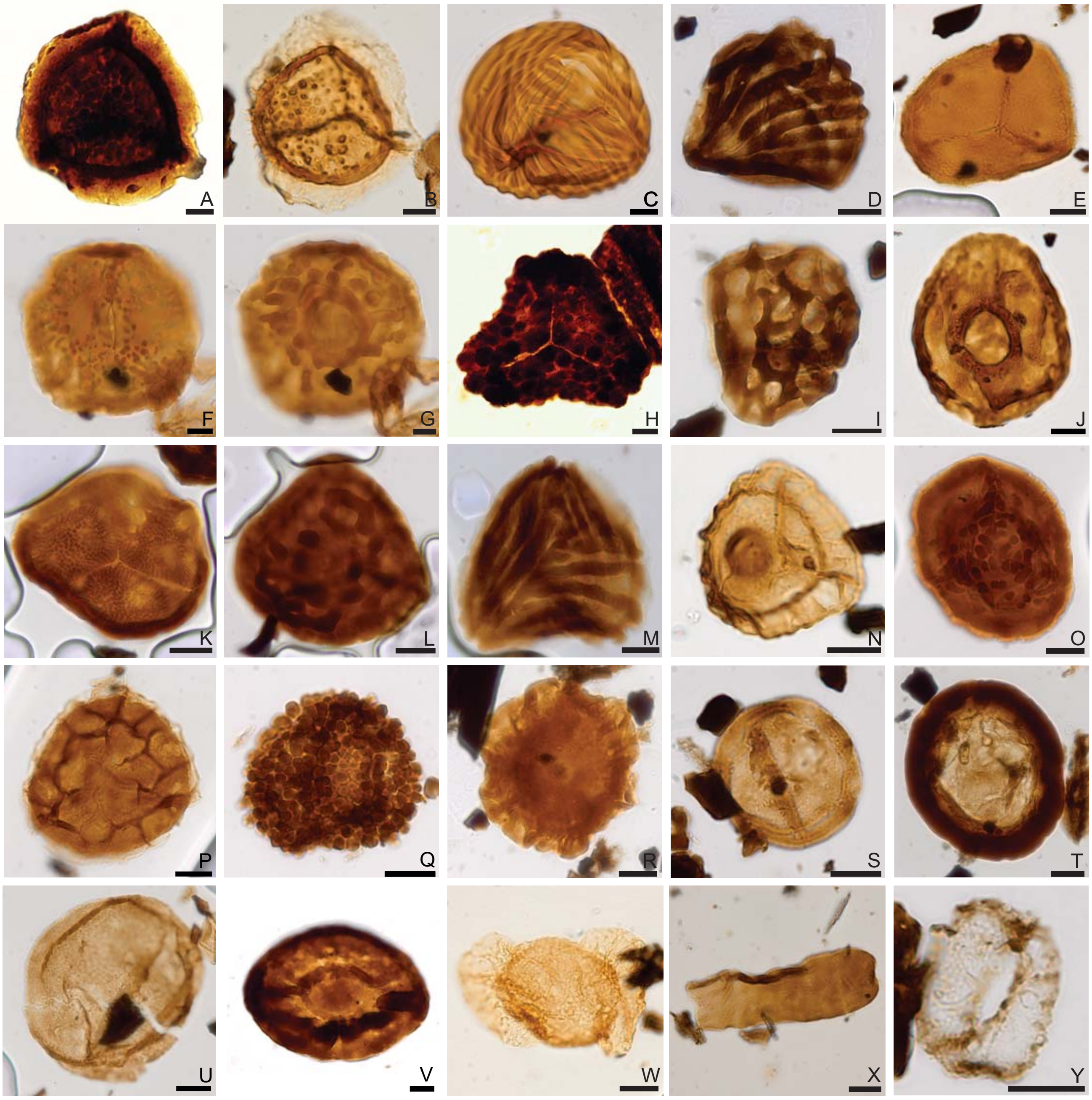

Figure 4. a) *Aequitriradites verrucosus*, BA Pal 6011-2:F56/2. **b)** *Aequitriradites spinulosus*, BA Pal 6025-2:B50/4. **c)** *Cicatricosisporites cuneiformis*, BA Pal 6021-1:W45/0. **d)** *Contignisporites cooksoniae*, BA Pal 6011-1:P43/1. **e)** *Densoisporites velatus*, BA Pal 6022:G31/4. **f-g)** *Foraminisporis variornatus*, BA Pal 6024:D31/4. **h)** *Impardecispora apiverrucata*, BA Pal 6011- 2:J43/4. **i)** *Klukisporites* sp., BA Pal 6012-1:F53/1. **j)** *Polycingulatisporites trabeculatus*, BA Pal 6022:R30/1. **k)** *Nevesisporites radiatus*, BA Pal 6023:O24/1. **l)** *Interulobites pseudoreticulatus*, BA Pal 6017:U51/1. **m)** *Ruffordiaspora ludbrookiae*, BA Pal 6015-2:X33/1. **n)** *Staplinisporites caminus*, BA Pal 6017:E45/0. **o)** *Taurocusporites segmentatus*, BA Pal 6021-1:K50/0. **p)** *Triporoletes reticulatus*, BA Pal 6020-2:D41/4. **q)** *Verrucosisporites* sp., BA Pal 6016:U40/4. **r)** *Callialasporites trilobatus*, BA PAL 6019:B26/0. **s)** *Classopollis* sp., BA PAL 6016:F56/2. **t)** *Cyclusphaera psilata*, BA PAL 6019:H28/0. **u)** *Araucariacites australis*, BA PAL 6011-1:M37/0. **v)** *Cyclusphaera radiata*, BA PAL 6012-2:N32/0. **w)** *Podocarpidites* sp., BA PAL 6022:Y28/0. **x)** *Celyphus rallus*, BA PAL 6018:E43/4. **y)** *Microfasta evansii*, BA PAL 6012-1:F53/4. Scale bar: 10 μm.

Barremian-lower Aptian (Pozo D-129 Formation; Vallati, 2013; Perez Loinaze *et al.*, 2019; Fig. 3).

This zone was recognized by Archangelsky *et al.* (1984) from the upper part of the Shale Member (correlated with the Puesto Anticlinal Aguada Bandera Formation by Clavijo, 1986) and the lower part of the Sandy Member (considered equivalent to the Puesto Cerro Guadal by Clavijo, 1986) of the Paso Río Mayo Formation at the PRM.es-1 well (1160-1350 m), and the upper part of Puesto Cerro Guadal Formation from the CRM.es-1 well (2200-2400 m).

Based on the palynozones defined by Archangelsky *et al.* (1984), the Las Heras Group and equivalent formal and informal units would reach the Aptian, at least in the western sector of the GSJB, where the wells that provided the palynological assemblages studied by Archangelsky *et al.* (1984) are located.

Barreda *et al.* (2003) studied palynological samples recovered from 3059- 3570 m of the D-129 well (Fig. 2), the type locality of Pozo D-129 Formation, on the northeast flank of GSJB. These authors reassigned the interval of 3335- 3570 m, previously referred to as the Pozo D-129 Formation, to the Las Heras Group. These palynofloras of the Las Heras Group are characterized by the dominance of *Celyphus rallus*, associated with *Aequitriradites verrucosus*, *Cyclusphaera psilata*, *Densoisporites velatus*, *Foraminisporis wonthaggiensis* and *Taurocusporites segmentatus*, among others. Barreda *et al.* (2003) included this interval in the *Interulobites-Foraminisporis* Zone and referred it to the Hauterivian.

More recently, Perez Loinaze *et al.* (2019) studied palynological assemblages recovered from cutting samples of the YPF.SC.PL.x-2, from sections referred to the Las Heras Group (2534–2936 m) and the Pozo D-129 Formation (1584–2330) on the southeast flank of GSJB (Fig. 2). Among the species identified from the Las Heras Group are *Cyclusphaera psilata*, *C. radiata*, *Foraminisporis variornatus*, *Impardecispora apiverrucata*, *Laevigatosporites belfordii* and *Celyphus rallus*, being the latter taxon present in most samples without being dominant. These palynological assemblages were correlated by Perez Loinaze *et al.* (2019) with the late Valanginian–Hauterivian *Interulobites-Foraminisporis* Zone.

The fossil record from the Puesto Cerro Guadal Formation recovered by Seiler and Viña (1996; in Sylwan, 2001) from the EZ.x-1 (El Zanjón) well (3019-3196 m) on the northeast flank of the GSJB (Fig. 2), is composed of *Coptospora striata*, *Cyclusphaera psilata*, *Ruffordiaspora australiensis*, along with ostracods of the genus *Candona*. These levels were dated as Berriasian by Seiler and Viña (1996; in Sylwan, 2001). Similar palynofloras to the El Zanjón well have been also identified at the YPF.SC.AAB.x-1 ("Anticlinal Aguada Bandera"), YPF.CH.AdP.es-1 ("Anticlinal de Papelía"), and YPF.CH.CDS.x-1 ("Codo del Senguerr") wells, and all correlated by these authors. Nevertheless, the presence of *Cyclusphaera psilata* in the assemblages suggests an age not older than late Valanginian (Volkheimer, 1980; Quattrocchio *et al.*, 2003). Additionally, *Coptospora striata* has only been recorded for the Aptian *Antulsporites-Clavatipollenites* Zone in Argentina (Archangelsky *et al.*, 1984). A more detailed study is necessary to clarify the age of these deposits.

Seiler and Moroni (1984) presented a preliminary study of palynological assemblages recovered from the YPF.CH.EC.x-1 and YPF.CH.CS.X-1 wells, located in the western area of the GSJB (Fig. 2), which are not associated with a formal stratigraphic unit. Among the identified species are *Araucariacites australis*, *Balmeiopsis limbatus*, *Cyclusphaera psilata*, *Callialasporites segmentatus*, *C. trilobatus*, *Podocarpidites ellipticus*, *Taurocusporites segmentatus*, and *Vitreisporites signatus*, along with dinoflagellate cysts (Seiler and Moroni, 1984). Based on the recognized taxa, an Early Cretaceous age, and probably Hauterivian to Barremian age, was suggested for these assemblages. However, as recognized taxa can be found in both the *Interulobites-Foraminisporis* and *tectifera-corrugatus* zones, a proposal of a conclusive Hauterivian to Barremian age is not supported, only suggesting that these assemblages cannot be older than late Valanginian. More detailed studies are necessary to assign a more precise age.

The first palynological record from the Puesto Albornoz Formation was presented by Vallati (1993). The author conducted a detailed palynological study, recognizing 36 taxa, though most of them were presented under open nomenclature. Among the palynomorphs Vallati (1993) identified *Gleicheniidites senonicus*, *Interulobites intraverrucatus*, *Callialasporites segmentatus*, and *Cyclusphaera* spp. An upper Valanginian to Aptian age, more likely Hauterivian to Barremian, was suggested for this unit (Vallati, 1993). More recently, Perez Loinaze *et al.* (2024) presented new palynological assemblages from the Puesto Albornoz Formation, expanding the list of known taxa for the unit with the recognition of the spore taxa as *Antulsporites baculatus*, *Cicatricosisporites cuneiformis*, *C. hughesi*, *Densoisporites velatus*, *Foraminisporites wonthaggiensis*, along with pollen grains such as *Cyclusphaera radiata*, *Ticoites gamerroi*, among others. Interestingly, the algae *Celyphus rallus* was also recorded. The palynological assemblages from Puesto Albornoz Formation were correlated with the *Interulobites-Foraminisporis* Zone (Perez Loinaze *et al.*, 2024), given the record of many taxa that first appear or are exclusive of this zone. Additionally, species that first appear in the overlying *tectifera-corrugatus* Zone, such as *Trilobosporites purverulentus* and *Densosporites corrugatus*, were not found in the Puesto Albornoz assemblages. *Cyatheacidites tectifera* is also considered as having its oldest records in the *tectifera-corrugatus* Zone and was identified in the assemblage by a single specimen. The palynofloras from the Puesto Albornoz Formation are closely comparable to those studied by Perez Loinaze *et al.* (2019) from the Las Heras Group, which were correlated to the *Interulobites-Foraminisporis* Zone.

Based on palynological record, the Las Heras Group´s age is considered upper Valanginian to Hauterivian on the northern and southern flanks of GSJB (Fig. 1). However, this unit presents levels older based on another paleontological record. In contrast, the age of this group extends to the Aptian in the western area, where palynological assemblages from the upper levels of the Puesto Cerro Guadal Formation, the upper part of Shale Member, and the lower part of the Sandy Member of the Paso Río Mayo Formation are referred to the *Antulsporites-Clavatipollenites Zone*.

PALEOENVIRONMENTAL INFERENCES

The genus *Classopollis*, a pollen type related to the extinct conifer family Cheirolepidiaceae, is the dominant pollen form in most samples from the palynofloras studied by Archangelsky *et al.* (1981), mainly from levels referred to the *Interulobites-Foraminisporis* Zone in the YPF.CH.F.x-1 and YPF.SC.CEP.x-1 wells. The genus *Callialasporites*, related to the Podocarpaceae, co-dominates, while spores are in low abundances. In the levels of the YPF.CH.F.x-1, PRM.es-1, and CRM.es-1 wells referred to the *tectifera-corrugatus* Zone, *Classopollis* remains dominant, but the abundance of spores increases, while *Callialasporites* decreases. Finally, in the levels of the PRM.es-1 and CRM.es-1 wells assigned to the *Antulsporites- Clavatipollenites* Zone, *Classopollis* continues being the dominant taxon. In these levels, spores show either abundances similar to the previous Zone (CRM.es-1 well), or an increase in proportion (PRM.es-1 well; Archangelsky *et al.*, 1981).

Many studies have linked the high abundance of Cheirolepidiaceae to arid climates, citing the xeromorphic traits of their vegetative structures (*e.g.*, Vakhrameev, 1991). Nevertheless, more recent studies indicate that this family might have thrived in a broader range of environments (Tosolini *et al.*, 2015). In addition to its ecological requirements, the high relative abundance of *Classopollis* pollen grains could be influenced by several factors, including the high production of parent plants, the abundance of these plants in the assemblage, and transportation sorting (Schrank, 2010). Therefore, high percentages of *Classopollis* are not always indicative of xeric conditions in Gondwanan palynological assemblages, necessitating other climatic proxies to support or contrast this hypothesis (Perez Loinaze *et al.*, 2024). Additionally, the increase in spores may reflect more humid conditions. A rise in Podocarpaceae is also considered a paleoclimatic indicator of an increase in humidity as representatives of the family are, with few exceptions, typically found in humid climates (Zhang *et al.*, 2021).

The increased abundance of spores in the *tectifera-corrugatus* and *Antulsporites-Clavatipollenites* zones could suggest a rise in humidity during the deposition of the bearing strata. Based on apparent vertical changes in organic matter type and richness within lacustrine depositional systems in the GSJB, Peroni *et al.* (1995) suggested that the uppermost Jurassic-lower “Neocomian” organic-rich accumulations (Puesto Anticlinal Aguada Bandera Formation) developed in deeper, anoxic, and mildly brackish conditions, likely in humid climates with little seasonal contrast. On the other hand, the upper “Neocomian” organic facies (Puesto Cerro Guadal Formation) seem to represent shallower lakes with ooidal benches, containing brackish to saline (alkaline) waters, which were likely promoted by semiarid climates. More detailed palynological studies are necessary to better understand the condition under which the Las Heras Group was deposited.

Algae in the palynofloras from the Las Heras Group and other correlatable deposits from the GSJB, referred to as the *Interulobites-Foraminisporis* and *tectifera-corrugatus* zones, are mainly represented by *Celyphus rallus* and *Microfasta evansii*. *Celyphus rallus* is a probable pioneering blue-green algae belonging to the family Rivulariaceae, adapted to brackish to freshwater transitional environments (Batten and Van Geel, 1985). Local abundances of this algae may reflect "blooms" in neutral or slightly alkaline conditions, but they could also be related to seasonal changes in productivity. The presence of abundant *Celyphus rallus* occurs mainly in shale deposits, which typically show good oil-generation potential (Figari *et al.*, 1999; Sylwan, 2001). In addition, the presence of the presumed freshwater algal form *Microfasta evansii* suggests deposition in a lacustrine environment and supports the potential for oil-prone source rocks (Morgan *et al.*, 2002).

FINAL COMMENTS AND PERSPECTIVES

Despite the economic importance of the "Neocomian" units of GSJB, their palynological knowledge remains scarce. The age of the Las Heras Group is inferred to be not younger than Hauterivian at the northern and southern flanks of GSJB. However, this unit is suggested to reach the Aptian in the western area of the GSJB. Nevertheless, more detailed palynological studies and an evaluation of the current status of the stratigraphic units recognized in the studied wells are needed to confirm these results.

Another issue observed in the scarcely available palynological studies is that palynofloras recovered from the Las Heras Group are not always segregated between the Puesto Anticlinal Aguada Bandera and Puesto Cerro Guadal formations. Better characterization of these units results critical to clarify the biostratigraphy of the group, and future studies should focus on addressing this topic.

While the *Antulsporites-Clavatipollenites* Zone needs revision, as some of the diagnostic species have been found in older strata, it is worth mentioning that the pioneering studies carried out by Archangelsky *et al.* (1981, 1983, 1984), as well as the biostratigraphic scheme proposed by these authors, continue, four decades later, to be a valuable tool for understanding the stratigraphy and relationship of these "Neocomian" units.

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REFERENCES

Allard, J. O., Foix, N., Ferreira, M. L., and Atencio, M. (2018). *Revisión de secuencias sedimentarias cretácicas en pozos profundos de la cuenca del Golfo San Jorge: litoestratigrafía, quimioestratigrafía y controles externos.* 10° Congreso de Exploración y Desarrollo de Hidrocarburos (pp. 731–753).

Archangelsky, S., and Seiler, J. (1980). *Algunos resultados palinológicos de la perforación UN Oil OS-1, del SO de la provincia del Chubut, Argentina.* 2° Congreso Argentino de Paleontología y Bioestratigrafía y 1° Congreso Latinoamericano de Paleontología (pp. 215– 225).

Archangelsky, S., Baldoni, A., Gamerro, J. C., Palamarczuk, S., and Seiler, J. (1981). *Palinología estratigráfica del Cretácico de Argentina austral. Diagramas de grupos polínicos del suroeste de Chubut y noroeste de Santa Cruz.* 8° Congreso Geológico Argentino (pp. 719–742).

Archangelsky, S., Baldoni, A., Gamerro, J. C., and Seiler, J. (1983). Palinología estratigráfica del Cretácico de Argentina austral II. Descripciones sistemáticas. *Ameghiniana*, 20(3-4), 199–226. https://www.ameghiniana.org.ar/index.php/ameghiniana/article/view/1775

Archangelsky, S., Baldoni, A., Gamerro, J. C., and Seiler, J. (1984). Palinología estratigráfica del Cretácico de Argentina austral III. Distribución de las especies y conclusiones. *Ameghiniana,* 21(1), 15–33. https://www.ameghiniana.org.ar/index.php/ameghiniana/article/view/1726

Archangelsky, S., and Archangelsky, A. (2010). Revisión taxonómica y estratigráfica de esporas cicatricosas del Cretácico Inferior de Patagonia. 2. Géneros *Cicatricosisporites* Potonié y Gelletich y *Ruffordiaspora* Dettmann y Clifford. *Revista del Museo Argentino de Ciencias Naturales Nueva Serie*, 12(2), 179–201.

Barcat, C, Cortiñas, J., Nevistic, V., and Zucchi, H. (1989). Cuenca Golfo San Jorge. In W. Chebli, and L. A. Spalletti (Eds.), *Cuencas Sedimentarias Argentinas*, (pp. 319–345). Universidad Nacional de Tucumán.

Barreda, V., Bellosi, E. S., and Jalfin, G. (2003). *Celyphus rallus* Batten en depocentros del Cretácico Temprano, flanco norte de la Cuenca San Jorge: significado estratigráfico y oleogenético. *Revista del Museo Argentino de Ciencias Naturales Nueva Serie*, 5(2), 215– 224.

Batten, D. J., and van Geel, B. (1985). Celyphus rallus, probable Early Cretaceous rivulariacean blue-green alga. *Review of Palaeobotany and Palynology*, 44(3-4), 233–241. https://doi.org/10.1016/0034-6667(85)90018-1

Batten, D. J., Koppelhus, E. B., and Nielsen, L. B. (1994). Uppermost triassic to middle jurassic palynofacies and palynomiscellanea in the Danish Basin and Fennoscandian Border Zone. *Cahiers de Micropaleontologie*, 9(2), 21–45.

Bellosi, E. S., Villar, H. J., and Laffitte, G. A. (2002). *Un nuevo sistema petrolero en el Flanco Norte de la cuenca del Golfo San Jorge: revalorización de áreas marginales y exploratorias*. 5° Congreso de Exploración y Desarrollo de Hidrocarburos.

Clavijo, R., 1986. Estratigrafía del Cretácico Inferior en el sector Occidental de la Cuenca del Golfo San Jorge. *Boletín de Informaciones Petroleras*, 9, 15–32.

Figari, E. G., Cid de la Paz, M. S., and Laffitte, G. (1996). Neocomian half graben in the western San Jorge Basin, Argentina: petroleum systems, origin and tectonic inversion. *American Association of Petroleum Geologists Bulletin*, 80(8), 1289–1290.

Figari, E. G., Stelkov, E. E., Laffitte, G., Cid de la Paz, M., Courtade, S., Celaya, J., Vottero, A., Lafourcade, P., Martinez, R., and Villar, H. J. (1999). *Los sistemas petroleros de la Cuenca del Golfo San Jorge: Síntesis estructural, estratigráfica y geoquímica.* 4° Congreso de Exploración y Desarrollo de Hidrocarburos (pp. 197–237).

Fitzgerald, M. G., Mitchum, R. M., Uliana, M. A., and Biddle, K. T. (1990). Evolution of the San Jorge Basin, Argentina. *American Association of Petroleum Geologists Bulletin*, /4(6), 879–920. https://doi.org/10.1306/0C9B23C1-1710-11D7-8645000102C1865D

Guler, M. V., Berbach, L., Archangelsky, A., and Archangelsky, S. (2015). Quistes de dinoflagelados y polen asociado del Cretácico Inferior (Formación Springhill) de la Cuenca Austral, plataforma continental Argentina. *Revista Brasileira de Paleontologia*, 18(2), 307–324. http://dx.doi.org/10.4072/rbp.2015.2.10

Haq, B. U., Hardenbol, J., and Vail, P. R. (1987). Chronology of fluctuating sea levels since the Triassic. *Science*, 235(4793), 1156–1167. https://doi.org/10.1126/science.235.4793.1156

Laffitte, G. A., and Villar, H. J. (1982). *Poder reflector de la vitrinita y madurez térmica: Aplicación en el sector NO de la Cuenca del Golfo San Jorge.* 1° Congreso Nacional de Hidrocarburos, petróleo y gas (pp. 171–182).

Lesta, P., Ferello, R., and Chebli, G. (1980). Chubut Extraandino. In J. C. Turner (Ed.), *2° Simposio Geología Regional Argentina* (vol 2., pp. 1306–1387). Academia Nacional de Ciencias.

Masiuk, V. and Viña, F. J. 1986. Estratigrafía de la Formación Agrio de la Cuenca Neuquina. *Boletín de Informaciones Petroleras*, 6, 2–38

Morgan, M., Rowett, A. L., and White, M. R. (2002). Biostratigraphy. *The Petroleum Geology of South Australia* 5, 1–45.

Perez Loinaze, V.S., Césari, S. N., Giordano, S. R., Stach, N. H., and Ansa, A. (2019). Palynological analysis of a Lower Cretaceous subsurface succession from the south flank of the Golfo San Jorge Basin, Argentina. *Cretaceous Research*, 97, 94–106. https://doi.org/10.1016/j.cretres.2019.01.008

Perez Loinaze, V. S., Limarino, C. O., and Giordano, S. R. (2021). Late Cretaceous palynomorphs from the Golfo San Jorge Basin, Argentina. *Journal of South American Earth Sciences*, 107, 103151. https://doi.org/10.1016/j.jsames.2020.103151

Perez Loinaze, V. S., Llorens, M., Rodriguez, A. R., Allard, J. O., and Foix, N. (2024). New palynological record for the Puesto Albornoz Formation (Golfo San Jorge basin, Argentina): Stratigraphic and paleoenvironmental implications. *Journal of South American Earth Sciences*, 135, 104916. https://doi.org/10.1016/j.jsames.2024.104804

Peroni, G., Hegedus, A., Cerdan, J., Legarreta, L., Uliana, M., and Laffite, G. (1995). Hydrocarbon accumulation in an inverted segment of the Andean Foreland: San Bernardo Belt, Central Patagonia. In A. Tankard, R. Suárez Soruco, H. J. Welsink (Eds.), *Petroleum Basins of South America* (Vol. 62, pp. 403–419.). American Association of Petroleum Geologists Memories.

Quattrocchio, M. E., Martínez, M. A., García, V. M., and Zavala, C. A. (2003). Palinoestratigrafía del Tithoniano-Hauteriviano del Centro-Oeste de la Cuenca neuquina, Argentina. *Revista Espaúola de Micropaleontología*, 35, 51–74.

Quattrocchio, M. E., Martínez, M. A., Carpinelli Pavisich, A., and Volkheimer, W. (2006). Early Cretaceous palynostratigraphy, palynofacies and palaeoenvironments of well sections in northeastern Tierra del Fuego, Argentina. *Cretaceous Research*, 27(4), 584–602. https://doi.org/10.1016/j.cretres.2005.11.012

Ramos, V. 1976. E*stratigrafía de los Lagos La Plata y Fontana, Provincia de Chubut, República Argentina.* 1° Congreso Geológico Chileno (pp. 43–64).

Russo, A. and Flores, M. A. 1953. *Levantamiento Geológico de la zona situada al norte del arroyo El Gato. Departamento Alto Río Senguerr y Tehuelches, Gobernación Militar Comodoro Rivadavia*, [Inédito].

Schrank, E. (2010). Pollen and spores from the Tendaguru Beds, Upper Jurassic and Lower Cretaceous of southeast Tanzania: palynostratigraphical and paleoecological implications. *Palynology*, 34(1), 3–42. https://doi.org/10.1080/01916121003620106

Seiler, J. (1979) Paleomicroplancton del Cretácico Inferior en el subsuelo del sudoeste de la provincia de Chubut. *Ameghiniana*, 16(1-2), 183–190. https://ameghiniana.org.ar/index.php/ameghiniana/article/view/1587

Seiler, J. and F. Viña, 1997. *Informes palinológicos de los pozos RChN.x-1 y EZ.x-1* [Inédito].

Seiler, J. and Moroni, A. M. (1984). *Zonación palinológica del subsuelo en el oeste del Golfo San Jorge. Correlación con pozos de la misma zona*. 3° Congreso Argentino de Paleontología y Bioestratigrafía (pp. 115–123).

Sylwan, C.A. (2001). Geology of the Golfo San Jorge Basin, Argentina. *Journal of Iberian Geology*, 27, 123–157.

Sylwan, C., Droeven, C., Iñigo, J., Mussel, F., and Padva, D. (2011). *Cuenca del Golfo San Jorge*. 8° Congreso de Exploración y Desarrollo de Hidrocarburos (pp. 139–183).

Tosolini, A. M. P., McLoughlin, S., Wagstaff, B. E., Cantrill, D. J., and Gallagher, S. J. (2015). Cheirolepidiacean foliage and pollen from Cretaceous high-latitudes of southeastern Australia. *Gondwana Research*, 27(3), 960–977. https://doi.org/10.1016/j.gr.2013.11.008

Vakhrameev, V. A. (1991). *Jurassic and Cretaceous Floras and Climates of the Earth*. Cambridge University Press.

Vallati, P. (2013). A Mid-Cretaceous palynoflora with Tucanopollis crisopolensis from D-129 Formation, San Jorge Gulf Basin, Argentina. *Revista Brasileira de Paleontologia*, 16(2), 237–244. https://doi.org/10.4072/rbp.2013.2.06

Vallati, P. (1993). Palynology of the Albornoz Formation (Lower Cretaceous) in the San Jorge Gulf Basin (Patagonia, Argentina). *Jahrbuch für Geologie und Paläontologie, Abhandlungen*, 187(3), 345–373. https://doi.org/10.1127/njgpa/187/1993/345

Volkheimer, W. (1980). *Microfloras del Jurásico Superior y Cretácico Inferior de América Latina*. 2° Congreso Argentino de Paleontología y Bioestratigrafía y 1° Congreso Latinoamericano de Paleontología (pp. 121–136).

Zhang, J., Lenz, O. K., Wang, P., and Hornung, J. (2021). The Eco-Plant model and its implication on Mesozoic dispersed sporomorphs for Bryophytes, Pteridophytes, and Gymnosperms. *Review of Palaeobotany and Palynology*, 293, 104503. https://doi.org/10.1016/j.revpalbo.2021.104503