

A hypothetical scenario for the Middle Jurassic in the southern part of the Neuquén Basin, Argentina

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Abstract. A hypothetical scenario for the Middle Jurassic in the southern part of the Neuquén Basin, is proposed on the basis of sedimentary facies and palynological data obtained from the study of eight stratigraphic sections. During the Middle Jurassic in the study area, the Los Molles, Lajas and Challacó Formations of the Cuyo Group constitute an overall prograding system deposited in a distal to shallow marine deltaic environment, with correlative fluvial deposits. The marine environment was characterized on the basis of sedimentary facies and paleomicroplankton contents (30 species). The analysis of the terrestrial palynological assemblages (102 species of sporomorphs) shows that certain plant groups dominated the scenario, in particular the Cheirolepidiaceae, Araucariaceae and Podocarpaceae and to a lesser degree Cyatheaceae, Osmundaceae, Marattiaceae, Dipteridaceae, Lycopodiaceae, Schizaeaceae, Anthocerotaceae, Ricciaceae, Cycadales/Bennettitales, Caytoniaceae and Gnetales. In addition to the conventional approach using percentage values, principal component analysis proves to be an excellent and complementary tool, because reduces the data set into definitive groups of representative taxa. Modern analogues - the Chilean-Argentinean forest and Planalto of southern Brazil- are used to explain the paleoclimatic and paleoenvironmental conditions during the Middle Jurassic. In the Planalto (about 1000 m above sea level) the Araucariaceae and Podocarpaceae grow together, but the latter disappear with an increase of temperature and humidity farther north in Brazil. The influence of acid effusives of the Serra Geral Formation conditioned the low pH of the soils. In the Neuquén Basin, rhyolites of Choiyoi Group (Permo-Triassic) and other acid rocks of the basement (Colohuincul and Huechulafquen formations) could have been the substratum of the ancient Araucariaceae. According to the above assessment, a plateau scenario, with warm to temperate conditions and variable precipitation rates through the Middle Jurassic, is proposed.

Key words. Palynology. Sedimentology. Paleoenvironment. Middle Jurassic. Cuyo Group. Neuquén Basin. Argentina.

Introduction

During the Middle Jurassic in the study area (southwestern Neuquén Basin), the sedimentites of Los Molles, Lajas and Challacó formations of Cuyo Group, were deposited, corresponding to marine inner to shelf near-shore and fluvial deposits. Outcrop sequence stratigraphic analysis allows the recognition of eight depositional sequences in these deposits, with an internal organization into system tracts. The study area comprises eight stratigraphic sections, respectively named: Portada Covunco, Lohan Mahuida, Puesto Bascuñán, Cerro Chacaico, Estancia Charahuilla, Puente Picún Leufú, Rincón del Aguila and Bosque Petrificado (figure 1). These sections were studied taking into account their palynological contents. Two transects, north-south and east-west

oriented were studied, and each sequence being laterally correlated for paleoenvironmental purposes. The first comprises the localities of Cerro Chacaico - Estancia Charahuilla and the second Rincón del Aguila - Lohan Mahuida.

Pollen analysis has proven to be an excellent tool for the reconstruction of past vegetation, especially for sediments of Quaternary age. However, there are a lot of difficulties in delineating the flora of the Middle Jurassic, since the habitats of the plants that lived more than 100 million years ago cannot be directly ascertained. This paper tries to give a tentative approach to those habitats.

The character of the vegetation depends particularly on soil conditions, altitude, climate and oceanic changes. A modern analogue is used to determinate the characteristics of the flora, the paleoenvironment conditions and the paleoclimate, of the Middle Jurassic, in the Neuquén Basin.

Further information about sedimentological data of the studied area is given in Zavala (1993, 1996a, 1996b). Previous palynological results were

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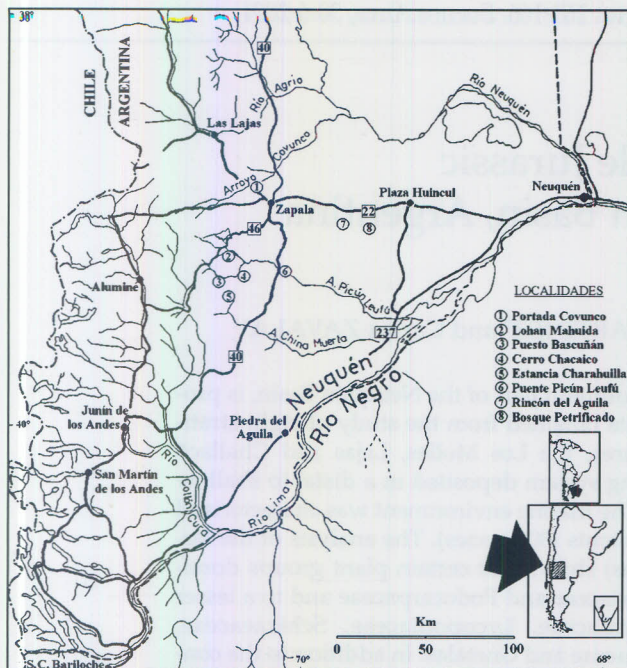


Figure 1. Location map.

presented by Quattrocchio *et al.* (1996b); García *et al.* (1994), García (1998), Martínez *et al.* (1996) and Martínez (1999). The studied stratigraphic interval corresponds to the *Callialasporites turbatus* (late Toarcian - early Bajocian) and to the *Ischyosporites marburgensis* (latest early Bajocian - late Bajocian) sub-biozones of the *Callialasporites dampieri* Biozone (late Toarcian - Oxfordian), defined by Quattrocchio *et al.* (1996a).

For the present purpose there is no need to list all the species described from the Middle Jurassic succession. In figure 2, the families/orders to which they have been referred are listed.

Methodology

The systematic study included 61 palynologically productive levels. For statistical purposes, relative and absolute pollen frequency (APF: number of pollen per gram of sediment = grains g^{-1}) and species diversity (number of species in each association) were considered. The relative frequencies were calculated from the sums between 150 and 200 palynomorphs (spores, pollen and microplankton) from each level. The foreign pollen was added to compute the absolute palynomorph frequency.

Principal Component Analysis was applied to the palynological data coming from the study of the Lohan Mahuida section (Martínez *et al.* 1996).

For paleocommunities evaluation, the spore/pollen taxa were compared with modern equivalents (table 1).

Results

In eight sections from the Middle Jurassic in Neuquén Basin, 61 spores, 40 pollen grains and 31 paleomicroplankton taxa were identified. The distribution of the palynomorphs is related to sedimentary facies; thus, in the same sequence in different positions of each transect, the composition of the microfloristic assemblages changes in a lateral chronocorrelation. In the lowermost Early Bajocian (High-Stand Systems Tract, HST), in JC4.1, the Cheirolepidiaceae dominated the spectrum (up to 91%), associated with Araucariaceae (up to 26%). During the middle Early Bajocian (Transgressive System Tract, TST), in JC4.2, a similar situation is present as HST; here, however, the Osmundaceae and Dipteridaceae are also common elements (up to 26%). Dinoflagellates and acritarchs are also present. During the uppermost Early Bajocian (Low-Stand Systems Tract (LST) and TST), in JC4.3, the Cheirolepidiaceae (37%) are associated with the Podocarpaceae (34.6%). Above this (JC4.4), the Cheirolepidiaceae (up to 78.5%) are associated with Podocarpaceae (up to 17%) and Araucariaceae (up to 10%). Microplankton are present with *Nannoceratopsis pellucida* Defl., *Escharisphaeridia pocockii* Sarj. and *?Kalyptea* sp. cf. *K. jurassica* Alb. In JC4.5 the Cheirolepidiaceae (up to 68.3%) are again the most representative element, associated with acritarchs (49.5%) and dinoflagellates (up to 39%) including *Jansonia psilata* Mart. (36.3%). Upwards the Araucariaceae (37.7%), are followed by the Podocarpaceae (up to 11.2%). In the Late Bajocian (JC5), the Cheirolepidiaceae dominated the spectrum, associated with Araucariaceae (up to 48%: see Quattrocchio *et al.*, 1996b and Martínez, 1999).

Principal Component Analysis was applied to the palynological data coming from the study of the Lohan Mahuida section (Martínez *et al.*, 1996). Similar information was obtained from the different ways of evaluation of the palynological data, relative percentages of each taxa in the microfloristic associations and in an objective manner (Principal Component Analysis). The association of taxa in the microfloristic association reflects paleocommunities, while the evolution of these paleocommunities reflects paleoclimatic trends. During the deposition of the JC4.1 and the JC4.2 sequences, the conditions may have been warm and relatively humid, due to the presence of high percentage of Cheirolepidiaceae (thermophilic) associated with the Araucariaceae. Due to the consideration that the Araucariaceae could grow together with the Cheirolepidiaceae under warm but relative humid climates Vakhrameev (1981, 1987). The sequences JC4.3 and JC4.4 show the beginning of a relative climate deterioration, indicated by the increase

Table 1. The modern equivalent and fossil families of some fossil taxa present in Cuyo Group.

TAXA	FAMILY / ORDER
<i>Deltoidospora</i>	Cyatheaceae - Dicksoniaceae
<i>Todisporites</i> - <i>Biretisporites</i> - <i>Rugulatisporites</i> - <i>Osmundacidites</i> - <i>Baculatisporites</i>	Osmundaceae
<i>Punctatosporites</i>	Marattiaceae
<i>Dictyophyllidites</i> - <i>Granulatisporites</i>	Dipteridaceae
<i>Retitriletes</i>	Lycopodiaceae
<i>Ischyosporites</i>	Schizaeaceae
<i>Gleichenioidites</i> - <i>Divisisporites</i>	Gleicheniaceae
<i>Nevesisporites</i>	Anthocerotaceae
<i>Camptozonotriletes</i>	Ricciaceae
<i>Podocarpidites</i> - <i>Microcachryidites</i> - <i>Alisporites</i> - <i>Callialasporites</i> - <i>Cerebropollenites</i>	Podocarpaceae
<i>Vitreisporites</i>	Caytoniaceae
<i>Inaperturopollenites</i> - <i>Araucariacites</i>	Araucariaceae
<i>Cycadopites</i> - <i>Monosulcites</i>	Cycadales / Bennettitales
<i>Equisetosporites</i>	Gnetales
<i>Classopollis</i>	Cheirolepidiaceae

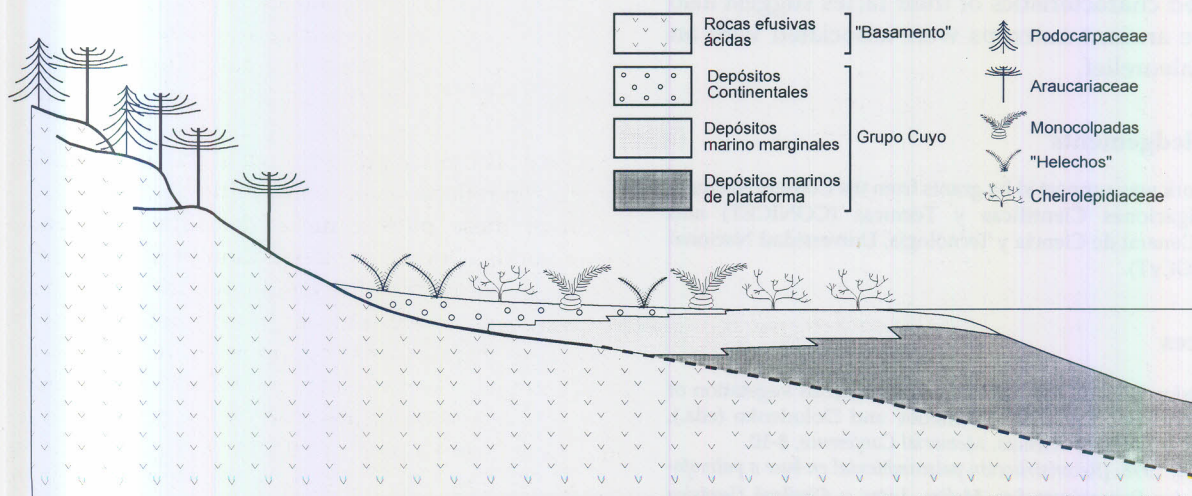
of Podocarpaceae in relation with the lower sequences. The extensive representation of upland communities suggests a lowering of the ecotones, bringing these communities into closer proximity to the basin. This is consistent with temperate and less humid conditions. In JC4.5 and JC5 the climate became warm and wet, in accord with the above considerations and also indicated by higher representation of thermophilic spores (eg. Schizaeaceae, Gleicheniaceae, Dipteridaceae and Marattiaceae) and pollen grains of Cycadales/Bennettitales.

Discussion

From comparison of the families present in the Middle Jurassic of the Neuquén Basin with modern analogue, a paleoenvironment similar to the Planalto of southern Brazil (Lorscheitter, 1996) could be rec-

ognized. The Serra Geral Formation constitutes the Planalto, a mountain region characterized by plateaus where graminous steppes, *Araucaria* forests and bogs developed. The maximum heights are nearly 1000 m above sea level and the acid effusive rocks conditioned the low pH of the soils. The vegetation, due to the high humidity, is very characteristic, presenting elements in common with the Sub-Antarctic Forest and Andes of southern South America. The Araucariaceae and Podocarpaceae are associated in the Planalto, but with an increase of temperature and humidity, the Podocarpaceae disappeared.

Towards to the NW of Brazil with an increase of temperature only the Araucariaceae grows in the lower part of the valleys (with high humidity). In Principal Component Analysis by Martínez *et al.* (1996), the third principal component shows the same tendency between the Podocarpaceae and

**Figure 2.** Hypothetic scenario for the Middle Jurassic in the Cuyo Group, Neuquén Basin.

Araucariaceae. An element also present in the *Araucaria* forest are the Dicksoniaceae, while the Osmundaceae are present in the bogs.

Until the Miocene (Villagrán and Hinojosa, 1997), there was a geographic continuity of forest similar to some of the present types of subtropical and temperate forest across subtropical South America, under mesic climatic conditions with little seasonality. This would explain the present floristic relationship between the southern South America forest and those found in Planalto of southern Brazil and in the NW of Argentina.

An ancient representation of some elements (Podocarpaceae, Araucariaceae, Dicksoniaceae and Osmundaceae) of this forest associated with mire elements like the Anthocerotaceae and Ricciaceae and the fossil families: Caytoniaceae and Cheirolepidiaceae, could be recognized in the Neuquén Basin in the Middle Jurassic. This forest extended into Patagonia. The vegetation cover was dense in some areas as demonstrated by the huge araucarian trees ("*Araucaria* flora") found in the Santa Cruz Petrified Forest; some stems have a diameter of more than 2.5 m and a height over 50 m (Archangelsky, 1996).

The Choiyoi Group (rhyolites) and acid rocks of the basement could have been the substratum of the ancient Araucariaceae in the Neuquén Basin. A scenario with plateaus, warm to temperate conditions and variable precipitation rates through the Middle Jurassic is proposed (figure 2). The effusive acid rocks conditioned the low pH of the soils.

The paleocurrent data and petrological constituents of some Jurassic and Cretaceous coarse grained units from the Neuquén Basin (i.e. Lajas, Tordillo and Mulichinco Formations) strongly suggest the existence in the past of extensive exposures of acid effusive rocks located westward. The flood-dominated characteristics of their facies suggest also that these ancient outcrops were associated with an abrupt paleorelief.

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