

***Equisetites pusillus* sp. nov. from the Aptian of Patagonia, Argentina**

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Abstract: Compressions of fertile equisetacean branches belonging to the new species *Equisetites pusillus* are described using light microscopy. The specimens were collected at the Estancia Bajo Tigre locality in strata referred to the Anfiteatro de Ticó Formation, Baqueró Group (Aptian) from the Santa Cruz province, Argentina. The fertile stems bear an oval and solitary terminal cone with spores. The spores are alete, circular and without elaters. *Equisetites pusillus* sp. nov. is compared with other fossil equisetacean taxa from Argentina and elsewhere. The spores are compared with those of two extant *Equisetum* species from Argentina, and also with other mesozoic taxa. The compressions were found in sediments rich in organic matter, deposited in shallow waters surrounded by environments colonized by sphenophytes, ferns and bryophytes. This type of landscape was frequent during the Aptian originating a common type of deposit (lenticular) in the Anfiteatro de Ticó Formation.

Key words: *Equisetaceae*, cones, spores, Aptian, Patagonia, Argentina.

The genus *Equisetites* was established by Sternberg (1833) for specimens of the European Triassic, preserved as casts, impressions and compressions having similar morphological characters with the extant genus *Equisetum* L.

Since the early years of the last century, *Equisetites* was frequently reported in Mesozoic sediments of Argentina and Antarctica. Halle (1913) described the first equisetacean stems from the Middle Jurassic of Antarctica. Roots and stems of a new species (*Equisetites fertilis*) from the Triassic of San Juan and Mendoza provinces were described by Frenguelli (1944 a). Stems with leaf-sheaths (*Equisetites frenguelli*) were analyzed by Orlando (1946) for the Lower Jurassic of Neuquén province. Archangelsky (1964) described new stems (*Equisetites* sp.) from the Lower Cretaceous of Santa Cruz province; and Herbst (1964, 1965, 1966 a, b and c) found different stems (Mendoza and Neuquén provinces), and created a new taxon (*Equisetites patagonica*) from the Liassic of Roca Blanca Formation, in Patagonia.

Menéndez (1958) described the first fertile specimens as *Equisetites quindecimdentata* from the Upper Triassic of San Juan province. The cones although incomplete show sporangiophores and sporangia.

In the present paper, three fertile specimens of the new species *Equisetites pusillus* from the Aptian of Santa Cruz province are described using light microscopy. This is the first *Equisetites*

species with spores found in the Mesozoic of Argentina.

MATERIALS AND METHODS

The fertile specimens occur at Estancia Bajo Tigre, Anfiteatro de Ticó Formation, Baqueró Group (Cladera *et al.*, 2002). The site was first mentioned by Archangelsky (1967) and is located at 48° 30' 33" S and 69° 14' 11" W, in the Deseado Massif of the Santa Cruz province (Argentina), and is of Aptian age (120 Ma; Corbella, 2001).

The specimens are well preserved compressions and were collected in organically rich sediments that were deposited to river banks or seasonal lagoons, and associated with ferns and bryophytes belonging to plant communities that lived near shallow waters.

The material was studied with a Leica MZ 12.5 stereoscopic microscope and photographed with a Canon camera. One specimen was partially treated with HF and HCl, and the residue was mounted in glycerine jelly for its observation with light microscopy. The spores were studied using a Leitz Diaplan microscope, measured using the Leica QWin software and photographed with a Leica DFC 280 camera.

The material is deposited in the Paleobotanical Collection of the Argentine Museum of Natural Sciences «Bernardino Rivadavia» with the acronyms BA Pb (specimens) and BA Pb Pm (microscopic slides).

SYSTEMATIC DESCRIPTIONS

Division Sphenophyta
 Order Equisetales
 Family Equisetaceae Michx. ex DC., 1804
 Genus *Equisetites* Sternberg, 1833

Type Species. *Equisetites muensteri* Sternberg, 1833

***Equisetites pusillus* sp. nov.**

(Fig. 1 A-I)

1964. *Equisetites* sp., Archangelsky, pgs. 225-226, figs. 1-3.

Holotype. BA Pb 13501.

Paratypes. BA Pb 13502; and BA Pb 13503, BA Pb Pm 465, BA Pb Pm 466.

Type locality. Estancia Bajo Tigre, Santa Cruz province, Argentina

Stratigraphic horizon. Fossiliferous bed BTO, Anfiteatro de Ticó Formation, Baqueró Group, Aptian.

Derivation of name. Refers to the small size of the cones.

Diagnosis. Stems 3 mm wide of unknown length, with 2 to 3 ridges, internodes 5 - 10 mm long and leaf-sheaths with 12 - 13 leaves at nodal diaphragms. Apical, single cones with rounded apex and convex sides supported by bracts. Sporangioophores helically arranged. Rhomboidal to hexagonal sporangioophore heads up to 1 mm in diameter. Alete spores, circular to subcircular outline, 46 - 69 μm in diameter. Exine smooth to slightly scabrate, thinner in the central region, without elaters.

Description. *Equisetites pusillus* sp. nov. is represented by sterile and fertile compressions with sporangioophores lacking cuticle. The fertile stem fragments are probably terminal branches, but the main axis was not found.

Specimen BA Pb 13501 has a stem 2 mm wide and 20 mm long with three well defined ridges. At the base of the apical cone, the stem is enlarged bearing six imbricate and lanceolate bracts having rounded apices (Fig. 1B). The stem is topped by an oval cone 5 mm wide and 6 mm long, with a rounded apex and convex sides (Fig. 1B). The helically arranged sporangioophores have a rhomboidal external head. Each shield has a depressed upper margin and a rising lower margin (Fig. 1B). Sporangia are not visible.

Specimen BA Pb 13502 is a small stem fragment bearing a terminal cone. The branch is thin, up to 2.7 mm wide and 3.5 mm long. It has two

longitudinal ridges, however nodes, internodes or leaf-sheaths are not seen. The branch ends with an irregular transversal margin (Fig. 1C). The cone is complete and oval, 5 mm wide and 6.5 mm long, with a rounded apex and convex sides. The sporangioophores are arranged helically. They are rhomboidal, 1 mm in diameter, with a slightly depressed central area (Fig. 1C). Sporangia are not seen.

Specimen BA Pb 13503 is a fragment of stem bearing a terminal cone. The stem is thin, 2 mm wide and 32 mm long. It has two evident ridges, but leaf-sheaths are not observed (Fig. 1A). The cone is incomplete and wedge-shaped, 5 mm wide and 5 mm long, with truncate apex and convex sides. The sporangioophore heads are slightly marked and have a rhomboidal to hexagonal outline (Fig. 1A). This cone fragment was chemically treated and in the residue inaperturate spores and few *Classopollis* pollen grains (conifer family Cheirolepidiaceae) were found.

The spores are alete with a thinner exine (leptome) in the central region. They have a circular to subcircular outline and a diameter of 46.5 - 68.2 μm . The exine is 1.30 - 2.20 μm thick, smooth or slightly scabrate. Frequent folds occur on the spore surface. Elaters are not present (Fig. 1D - I). Abundant remnants of the tapetal membrane are adhered to the spores. Isolated Ubisch bodies are also irregularly distributed on the tapetal membrane and the spore surface, being more conspicuous on the former (Fig. 1E - H).

Equisetites sp. (Archangelsky, 1964) from the Anfiteatro de Ticó Formation (Lower Cretaceous of Santa Cruz province) has sterile branches up to 3 mm wide, with internodes 5 - 10 mm long and leaf-sheaths with 12 - 13 leaves at the nodal diaphragms. This material was found at the Anfiteatro de Ticó locality in a kaolinic bed in which poorly preserved bennettitalean and filicinean remains also occur (Archangelsky, *op. cit.*). *Equisetites* sp. is interpreted as the vegetative stems of *Equisetites pusillus*, and is included in the new species.

The palynological records of the Baqueró Group show the presence of equisetalean-type spores, being described as *Calamospora* aff. *mesozoica* Couper 1958. During Mesozoic times, there were equisetalean plants that have produced two types of spores, some with trilete laesura and others inaperturate (Archangelsky & Villar de Seoane, 1994).

Comparisons with similar species. Several equisetacean species are known in the Mesozoic and Cenozoic of Argentina. Table 1 shows their sizes and morphological characters, the tiny

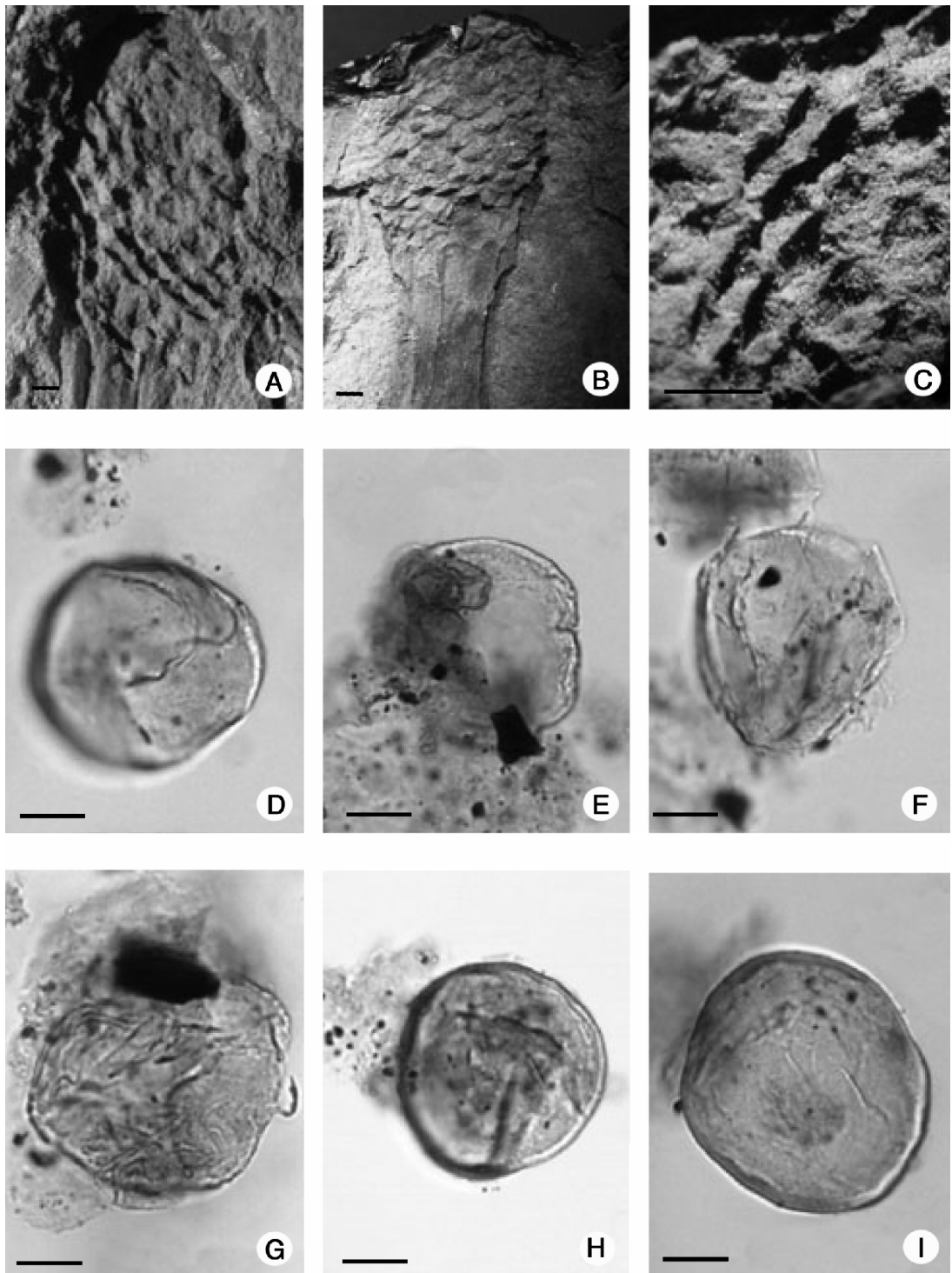


Fig. 1. A-I. *Equisetites pusillus* sp. nov. B-C, BA Pb 13501, holotype, B, General view of the fertile branch. C, Detail of the cone, BA Pb 13502, paratype, A, General view of the cone. BA Pb 13503, paratype, D-I, BA Pb Pm 466, D and I, General view of a spore with folds on its surface. E-H, Details of the spores with tapetal membrane and Ubböck bodies. Scale bars represent: A-C = 1mm, D-I = 20 μ m.

stems of *Equisetites pusillus* sp. nov. being only comparable to *Equisetites quindecimdentata* Menéndez, a fertile species with axes bearing terminal cones, found in the Upper Triassic of Hilario, San Juan province. The fertile stems are up to 37 mm wide, and have internodes, leaf-sheaths and stellate nodal diaphragms. The axes end in terminal, incomplete and large cones (up to 20 mm wide) with strongly umbonate sporangiophores and triangular to subtriangular sporangia (Menéndez, 1958). This species differs from *Equisetites pusillus* sp. nov. in having larger cones and sporangiophores.

Equisetites fertilis (Frenguelli) Frenguelli from the Upper Triassic of the Quebrada de Los Rastros (San Juan province) and Potrerillos Formation (Mendoza province) includes specimens firstly referred to *Macrotaenia fertilis* Frenguelli (1943 a) and *Equisetites scitulus* Frenguelli (1943 b). A new interpretation of the fragments that were originally thought to be leaves bearing fertile bodies, allowed Frenguelli (1944 b) to propose the new combination *Equisetites fertilis*. This is the most complete sterile species found thus far in Argentina. It has thin roots, stems up to 45 mm wide, leaf-sheaths and stellate nodal diaphragms (Frenguelli, 1944 b). *Equisetites fertilis* does not have cones and the stems are larger than *Equisetites pusillus* sp. nov.

Palynological comparisons. Few fertile species with preserved spores are known in the Mesozoic of Laurasia and Gondwana.

The spores of *Equisetites pusillus* sp. nov. are mostly comparable with *Pilasporites allenii*, and spores found in cones of *Equisetites muensteri*, *Equisetites lyellii* and *Equisetostachys suecicus*. They share the size and the exine ornamentation (see Table 2).

Watson (1983), and Watson & Batten (1990) found globose and alate spores (28 - 48 μm in diameter) with a smooth or scabrate exine and without elaters in the cones of *Equisetum lyellii* Mantell, from the Wealden of Sussex (England). These spores are similar to *Pilasporites allenii* Batten.

Batten (1968) described *Pilasporites allenii* from the soil-bed sediments from the Wadhurst Clay in the southern region of England (Lower Cretaceous), finding circular and alate spores with a smooth or scabrate exine and a mean diameter of 36.7 μm . These spores lack elaters.

Equisetites muensteri Sternberg from the Upper Triassic of Greenland (Harris, 1931) has rounded spores 40 - 50 μm in diameter, with thin and smooth wall without elaters. He discussed the absence of elaters suggesting that they may have been destroyed during the fossilization or

preparation of the spores. Halle (1908) and Batten (1968) shared this opinion.

Halle (1908) described two species of *Equisetostachys* from the Rhaeto-Liassic of Sweden: *E. nathorstii* and *E. suecicus*. The first species has globose and usually folded spores with a short trilete mark and smooth exine. They are 35 - 40 μm in diameter. *E. suecicus* spores are slightly larger (40 - 50 μm), alate and smooth.

The spores of *Equisetites pusillus* sp. nov. also differ from other species, in the size and the exine ornamentation (see Table 2).

Harris (1978) found spores with attached elaters in the cones of *Equisetum columnare* Brongniart from the Middle Jurassic of Yorkshire (England). These spores are globose, alate, about 40 - 50 μm in diameter and have a scabrate exine.

Equisetum laterale Phillips from the Lower Jurassic of Australia has ovate and terminal cones with numerous spores. They are small (24 - 41 μm in diameter), globose and alate with a scabrate to microrugulate exine (Gould, 1968).

Vozenin-Serra & Laroche (1976) studied spores from *Equisetum boureaui* Vozenin-Serra & Laroche from the Chres Formation (Upper Triassic of Western Cambodia). These spores are 30 μm in diameter and have an ornamented exine.

Equisetites arenaceus (Jaeger) Schenk from the Upper Triassic (Keuper) of Germany has three cones attached to the fertile branches. The cone has sporangiophore heads bearing a circle of sporangia on their lower surface. They include globose spores (50 - 60 μm in diameter), alate or with a small trilete, and scabrate to microrugulate exine. None of these spores showed any attached elaters, except in one case in which there was a possible indication of this structure (Kelber & van Konijnenburg-van Cittert, 1998).

Discussion. The Equisetales include two families: Calamitaceae and Equisetaceae. Both have similar morphological and anatomical characters, such as the structure of the primary vascular tissue and the presence of spores with elaters (Taylor & Taylor, 1993).

The Calamitaceae are Paleozoic and differ from the Equisetaceae (mostly Mesozoic to recent) in having arborescent habits. They present secondary vascular tissue, larger leaves and cones with a different morphology, size and position. The cones may be mono, bisporangiate or grouped in nodal sporangiophores, being axial in the branches or in terminal bracts (Taylor & Taylor, *op. cit.*).

The geological history of the equisetalean plants begins in the Devonian and has its most

Table 1. Comparison between the different fossil *Equisetites* and *Equisetum* of Argentina.

Species	<i>Equisetites pusillus</i> sp. nov.	<i>Equisetites approximatus</i> Nathorst (Halle, 1913)	<i>Equisetites feritilis</i> Frenguelli 1944	<i>Equisetites frenguelli</i> Orlando 1946	<i>Equisetites patagonica</i> Herbst 1965	<i>Equisetites quindecimdent.</i> Menéndez 1958	<i>Equisetites</i> sp. (Frenguelli, 1944)	<i>Equisetites</i> sp. (Archangelsky, 1964)	<i>Equisetum</i> sp. (Durango de Cabrera et al., 1997)
Age	Lower Cretaceous	Mid. Jurassic	Upper Triassic	Lower Jurassic	Lower Jurassic	Upper Triassic	Upper Triassic	Lower Cretaceous	Upper Miocene
Geographic locality	Santa Cruz province	Antarctica	San Juan - Mendoza provinces	Neuquén province	Mendoza - Neuquén - Chubut - Santa Cruz prov.	San Juan province	Mendoza province	Santa Cruz province	Catamarca province
Stem (wide)	2.7 mm	25-30 mm	45 mm	8 mm	11-24 mm	2.5 mm	14 mm	3 mm	5-20 mm
Internodes		25 mm	38-45 mm		30-35 mm	8-30 mm		5-10 mm	
Nodal diaphragm					3.5-7 mm				
Leaves		15-35	8-13 mm	12	28-38	15	14	12-13	
Leaf-sheath				10 mm	10-12 mm	21 mm	15 mm	1-3 mm	
Cones	5-6.5 mm					20 mm ?			
Sporangio-phores	1 mm					2-2.5 mm			
Spores	47-68 µm								

Table 2. Comparison between *Equisetites pusillus* sp. nov. spores and several mesozoic *Equisetites*, *Equisetum* and *Equisetostachys* spores.

Species	<i>Equisetites pusillus</i> sp. nov.	<i>Equisetites arenaceus</i> (Jaeger) Schenk (Kelber & Van Cittert, 1998)	<i>Equisetites lyellii</i> Mantell (Watson, 1983)	<i>Equisetites muensteri</i> Sternberg 1833	<i>Equisetum bouraoui</i> Vozenin-Serra & Laroche 1976	<i>Equisetum columnare</i> Brongniart (Harris, 1978)	<i>Equisetum laterale</i> Phillips (Gould, 1968)	<i>Equisetostachys nathorstii</i> Halle 1908	<i>Equisetostachys suecicus</i> Halle 1908
Age	Lower Cretaceous	Upper Triassic	Lower Cretaceous	Upper Triassic	Upper Triassic	Middle Jurassic	Middle Jurassic	Lower Jurassic	Lower Jurassic
Geographic locality	Argentina	Germany	England	Australia	Cambodge Occidental	England	Australia	Sweden	Sweden
Spores: diameter	47-68 µm	50-60 µm	28-48 µm	40-50 µm	30 µm	40-50 µm	24-41 µm	35-40 µm	40-50 µm
aperture	alete	alete or trilete	alete	alete	—	alete	alete	trilete	alete
exine	smooth	scabrate to microrugulate	smooth or scabrate	smooth	smooth	scabrate	scabrate to microrugulate	smooth	smooth
elaters	—	only one case	—	—	—	yes	—	—	—

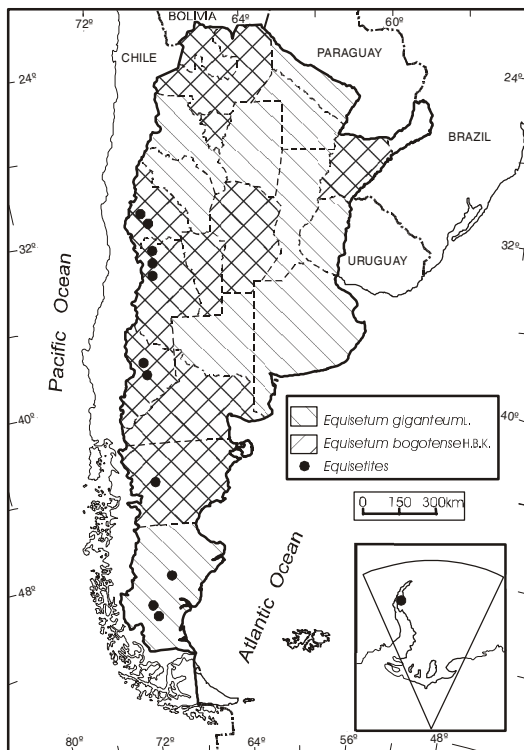


Fig. 2. Map of Argentina showing the distribution of the fossil genus *Equisetites* Sternberg and the living species *Equisetum bogotense* H.B.K. and *Equisetum giganteum* L.

important development during the Carboniferous, where it is possible that both families coexisted or the Equisetaceae evolved from the Calamitaceae. The first known equisetacean remains are Triassic, and in Argentina the oldest *Equisetites* species are of Early Triassic age.

Up to now, specimens of *Equisetites* have been found in Mesozoic strata of San Juan, Mendoza, Neuquén, Chubut and Santa Cruz provinces (Argentina), and in the Jurassic of Antarctica (Fig. 2).

At present, the Equisetaceae are represented by one genus: *Equisetum* L., with approximately 30 herbaceous species, with terminal cones and sporangiophores arranged in whorls, and a worldwide distribution, except Australia. The spores are spheroidal, with a very small aperture, granulate surface with scattered spherules and two long and spatulate elaters coiled around the body (Tryon & Lugardon, 1991).

In Argentina, two extant species are known to occur growing crowded in moist or wet places: *Equisetum giganteum* L. and *Equisetum bogotense* H.B.K., both with an extended geographical distribution.

E. giganteum L. is a large plant with elongated cones 4 mm wide and 8 mm long. The spores are 54 μm in diameter and have two elaters. The species is found in all Argentinean provinces, except Misiones and Tierra del Fuego (Ponce, 1996) (Fig. 2).

E. bogotense H.B.K. is a small plant (15 - 20 cm high) with oblong cones 3 mm wide and 6-8 mm long. The spores are 40 μm in diameter and have two elaters. This species occurs in Jujuy, Salta, Tucumán, Corrientes, Córdoba, San Juan, San Luis, Mendoza, Neuquén, Río Negro and Chubut provinces (Ponce, *op. cit.*) (Fig. 2) and has a similar size to *Equisetites pusillus* *sp. nov.*

CONCLUSIONS

In the Baqueró Group, equisetalean remains are very scarce, and *Equisetites pusillus* *sp. nov.* becomes an important addition because of its fertile condition including spores, that are first mentioned for the Anfiteatro de Ticó Formation, and indeed for the Cretaceous of Argentina.

The stems and cones of *Equisetites pusillus* are similar to the other Argentinean and Gondwanan fossil species except for their sizes, while the northern *Equisetites arenaceus* differs in having three cones per branch.

The spores of *Equisetites pusillus* are similar to the fossil *Pilasporites allenii* and those of *Equisetites muensteri*, *Equisetites lyellii* and *Equisetostachys suecicus*. They are alete, have a smooth surface and their diameters are similar.

The fertile branches and the cones of *Equisetites pusillus* are similar to those of the extant *Equisetum bogotense*, except that the fossil spores lack elaters.

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