Fungal fruiting bodies in the Cullen Formation (Miocene) in Tierra del Fuego, Argentina

Juan L. GARCÍA-MASSINI¹, María del C. ZAMALOA² and Edgardo J. ROMERO³

Abstract. An abundant and diverse fungal assemblage was recovered from the Cullen Formation suggesting humid paleoenvironmental conditions. Thirty one different forms of fungal fruiting bodies, mostly belonging to the Microthyriales (Ascomycota), were recognized. Nineteen were assigned to fossil genera, including 6 known species. The others are presented as twelve different Types, and possibly represent new morphogenera. The genera/species Plochmopeltinites cooksonia Ramanujan and Rao, Microthyriella diporata Rao and Ramanujan, Microthyrites, Phragmothyrites eocaenicus Edwards, P. kiandrensis Selkirk and Perisporiacites are recorded for the first time in Argentina, enlarging their palaeogeographical distribution. A Miocene age is proposed for this formation in coincidence with that suggested for the fungal spore content and other palynological data.

Resumen. Cuerpos fructíferos fúngicos de la Formación Cullen (Mioceno) en Tierra del Fuego, Argentina. Se estudia una abundante y diversa micoflora de la Formación Cullen que sugiere condiciones paleoambientales de elevada humedad. Se reconocieron 31 diferentes cuerpos fructíficos, la mayoría pertenecientes a los Microthyriales (Ascomycota). Diecinueve de ellos fueron asignados a géneros fósiles incluyendo 6 especies conocidas. Los restantes se describen como Tipos, y posiblemente representan nuevos morfogéneros. Los géneros/especies Plochmopeltinites cooksonia Ramanujan y Rao, Microthyriella diporata Rao y Ramanujan, Microthyrites, Phragmothyrites eocaenicus Edwards, P. kiandrensis Selkirk y Perisporiacites se registran por primera vez en Argentina, ampliando su distribución palaeogeográfica. Se propone una edad miocena para esta formación en coincidencia con la sugerida por el contenido de esporas fúngicas y por la evidencia de otros datos palinológicos.

Key words. Fungal fruiting bodies. Microthyriales. Miocene. Tierra del Fuego. Argentina.


Introduction

Fruiting bodies, particularly the Microthyriales, are some of the best known fungal remains throughout the geological record (Dilcher, 1965; Elsik, 1968). Assignment to extant genera and species has been based on morphological features, and the fact that many have been found “in situ” associated with leaf surfaces, stems and flowers of higher plants (Elsik, 1992).

In spite of the preliminary nature of the palaeomycological studies carried out in Argentina, some papers describing fruiting bodies of Microthyriales suggest their potential as palaeoenvironmental mark-

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Materials and methods

Three palynological sections taken from the Cullen Formation by Zamaloa (1999) have been examined for the presence of fungal fruiting bodies. Standard palynological techniques were used to process the samples (Traverse, 1988). Slides examined are housed in the Laboratorio de Paleobotánica, Departamento de Ecología, Genética y Evolución, Universidad de Buenos Aires, Argentina, as BAFCB p.m. The coordinates given are those from the microscope Dialux 20 N° 967412 in that department.

For the classification and identification of the fungal material, we have followed Elsik (1992) and Kalgotkar and Jansonius (2001). Primary diagnostic characters used include: 1) Presence or absence of radiate symmetry, 2) Presence or absence of an ostiole, 3) Nature of the margin of the ascoma, 4) Character of the cells composing the ascoma, 5) Other special features such as porate cells. Descriptions were based on the terminology of Elsik et al. (1983).

Results

Of the three studied sections from the Cullen Formation, 23 stratigraphic levels yielded fungal remains. More than 500 different forms were recognized. Those samples that contain the best preserved and abundant spores also contain a large number of fruiting bodies. The forms described and/or illustrated in this contribution were selected because of their excellent preservation and/or similarity to modern fungi. None of the fruiting bodies were found in association with mycelia, spores, or attached to the leaf cuticles of any recognizable plant. Some form genera and species could be assigned to modern taxa based on information provided in the current literature (Dilcher, 1965; Romero and Castro, 1986; Durango de Cabrera and Rodriguez de Sarmiento, 1995; among others). Nineteen different forms of fruiting bodies could be accommodated within 9 known form genera, including 6 known form species, 12 forms could not be unequivocally assigned to any known taxa and are described as Types.

Systematic paleontology

Selected fruiting bodies identified in the present study are listed in Table 1. In addition, for the Types we have assigned a number only reflecting a sequential ordering, and these are presented below qualified by a brief description.

Type I (aff. Arnaudiella "andina" Butin and Peredo 1986)
Figure 3.G
Description. Circular fruiting body formed of a single layer of elongate-lobulate cells; more than one layer in its central portion. Cells radially arranged. Circular ostiole present in a raised central position, surrounded by a ring of thick-walled cells. The margin is lobulate. Overall size is 119 µm, ostiole 9.1 µm in diameter.
Comments. This specimen has most of the morphological features found in the extant Arnaudiella "andina" (Ascomycota, Microthyriaceae), a common parasitic fungus of the Podocarpaceae of the Chilean Andean region (Butin and Peredo, 1986).
Studied material. BAFCB p.m. 240, 48.8/111.6.

Type II (aff. Arnaudiella "andina" Butin and Peredo 1986)
Figure 3.H
Description. Polygonal fruiting body, formed by one layer of elongated cells. Two layers appear to develop toward the central part of the body. The body has 2 approximately circular slightly raised ostioles. Around each ostiole the cell wall is markedly thicker forming circular rings. The cells are approximately...
Table 1. List of taxa of fungal fruiting bodies recognized in the Cullen Formation. Those marked with * are recorded for the first time in Argentina / Lista de taxones de cuerpos fructíferos reconocidos en la Formación Cullen. Los indicados con * son citados por primera vez en Argentina.

<table>
<thead>
<tr>
<th>Family</th>
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<th>Species</th>
<th>Figure</th>
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<td>Micropeltaceae</td>
<td>Plochmopeltinites</td>
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<td>sp. 2</td>
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<td>sp. 4</td>
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<td>Phragmothyrites</td>
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<td>Microthyrites</td>
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<td></td>
<td>Microthyriella</td>
<td>diporata Rao &amp; Ramanujam 1976</td>
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<td>Microthyriella</td>
<td>ecaenicus Edwards 1922</td>
<td>2O-Q</td>
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<td>Phragmothyrites</td>
<td>kiandrensis Selkirk 1975</td>
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<td>Microthyrites</td>
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<td>Trichothyrites</td>
<td>sp. Figure 3.G-S</td>
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<td>sp. 1</td>
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<td>Microthyriella</td>
<td>sp. 2</td>
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<td>Incertae sedis</td>
<td>Types I to XII</td>
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**Description.** Fruiting body with an irregular to quadrangular shape, and formed of one to two layers of large lobulate, thin-walled, radially arranged cells. The body shows a large pseudo-ostiole of irregular to near circular outline. The margin is lobulate. Size 67 x 59 µm, 35 x 29 µm, pseudo-ostiole 14 to 16 µm, 5 to 9 µm.

**Comments.** The main feature of this type is the cells, considered individually, resemble those designated as "germlings of Microthyriaceae" by Dilcher (1965).

**Studied material.** BAFCB p.m. 240, 44.3/ 102.

**Type IV ("Parabrefeldiellites" Elsik 1992)**

**Figure 3.K**

**Description.** Flattened fruiting body of polygonal outline with 7 sides. Body formed of one layer of cells, apparently two layers occur in the central part of the body. Cells rectangular to quadrangular, with thick walls, and arranged in parallel rows that develop in four directions. Margin smooth and entire. Astomate body. Size 85 x 59 µm.

**Comments.** This specimen is closely similar to the informal genus "Parabrefeldiellites" Elsik 1992, previously reported from sediments of Miocene to Recent age (Elsik, 1992).

**Studied material.** BAFCB p.m. 193, 40.8/ 100.

**Type V**

**Figure 3.L**

**Description.** This specimen is represented by approximately half of a spherical body, and formed by thin-walled, rectangular to circular cells. Extending from the convex part of the body are septate processes, 3 to 5 cells long. These processes have a slightly pyramidal shape and blunt apex. Diameter of the body 40 µm; length of processes 25 to 30 µm; cell wall thickness 1 to 2 µm.

**Comments.** According to its shape and cell arrangement, this fruiting body looks similar to Appendicisporites Saxena and Khare 1992, but differs in the presence of septa in the processes that arise from the central body. The named genus was originally described as dispersed spores from the Tertiary of India (Saxena and Khare, 1992) but later suggested as a fruiting body either of Microthyriaceae or Coelomyctes (Kalgutkar and Jansonius, 2001).

**Studied material.** BAFCB p.m. 240, 30.6/ 99.

**Type VI**

**Figure 3.M**

**Description.** Circular fruiting body of, at least, two layers of cells of irregular shape, arranged in approximately radial pattern. Four zones are distinguishable constituting triangular sectors of a circle; cells inside are heavily pigmented. A pseudo-ostiole of irregular shape is in the center of the body. The margin is lobulate to irregular. Diameter of the body 58.5 µm, pseudo-ostiole 9 µm.

**Studied material.** BAFCB p.m. 240, 44/ 98.

**Type VII**

**Figure 3.N**

**Description.** Circular fruiting body constructed of one to two (centrally located) layers of cells, of a roughly polygonal shape. Cell walls located in the periphery of the body are less thick compared to those of the more centrally located cells. Astomate body. The cells are radially arranged. Margin is not continuous but formed by the wall projections of the peripheral cells. Diameter of the body 87 µm; thickness of the cell walls 1 to 2 µm.

**Studied material.** BAFCB p.m. 249, 32.8/ 112.8.
Description. Circular to elongate fruiting body constructed of a layer of elongate and lobulate cells; this feature is evident at the periphery. The cells are radially arranged and a large ostiole of irregular contour is distinguished. The margin is lobulate. Diameter of the body 115 \( \mu \text{m} \), ostiole 20 \( \mu \text{m} \).

**Studied material.** BAFCB p.m. 240, 26.5/98.8.
- Type IX
  - Figure 3.P

Description. Circular fruiting body, constructed of semicircular to ovoid cells, arranged in a radial pattern. The cell walls are thin and no ostiole is distinguished. The margin appears irregular because the cells in the periphery are not intact. Diameter of the body 59 \( \mu \text{m} \).

**Studied material.** BAFCB p.m. 249, 39.9/102.2.
- Type X
  - Figure 3.Q

Description. Large circular fruiting body having several layers of heavily pigmented cells. Cells appear to be elongated, thick-walled and radially arranged. There is a slightly raised circular central ostiole. The margin is irregularly sinuate. Diameter 303.5 \( \mu \text{m} \); ostiole 24 \( \mu \text{m} \).

**Studied material.** BAFCB p.m. 235, 37.3/96.9.
- Type XI
  - Figure 3.R

Description. Fruiting body of irregular to polygonal shape. Body formed of large lobulate cells radially arranged with respect to one or two central cells. Astomate body. From most cells elongate appendages emerge perpendicularly showing a rather circular swollen head, which is curved. In some cases, more than one appendix protrudes from the same cell. The margin of the body is slightly lobulate. Size 35 \( \mu \text{m} \).

**Studied material.** BAFCB p.m. 240, 38.8/110.6.
- Type XII
  - Figure 3.S

Description. Fruiting body of quadrangular shape, formed of four central cells and eleven lobulate peripheral cells. Astomate body, lobulate margin. Central cells with differentially thickened walls of up to 2 \( \mu \text{m} \) in thickness. Size 33 \( \times \) 30 \( \mu \text{m} \).

**Studied material.** BAFCB p.m. 240, 46.6/101.9.

**Discussion**

It has been suggested that with the origin of the angiosperms a major diversification within the Ascomycetes occurred giving rise to epiphytic and saproprophylactic groups such as the Microthyriales (Kalgutkar and Jansonius, 2001). Elsik (1978, 1992) hypothesized that from the Early Cretaceous on Microthyriales and Angiosperms coexisted in the same habitats promoting a continuous enrichment of the community and creating additional microhabitats occupied by other fungi. As a consequence, it is not unusual to find a high diversity of fossil fungi associated to the presence of angiosperms in sediments spanning the Cretaceous, Paleogene and Neogene. The Cullen Formation is a representative example of such situation.

The sediments studied here contain numerous morphologically diverse fungal fruiting bodies. Based on the affinities with known extant and fossil forms, some ideas may be presented regarding previously suggested palaeoenvironmental conditions at the time of deposition (Zamaloa, 1999, 2000). Other specimens found in this formation could not be assigned to extant taxa or known fossil forms; however, some of these display characteristic morphological features, which facilitate their identification and may be useful as palaeoenvironmental and/or perhaps stratigraphic markers in future works. Particularly, the specimens designated as Types I and II result similar to extant Arnaudiella “andina” (Ascomycota, Microthyriaceae), a common parasitic fungus of the Chilean Andean region (Butin and Peredo, 1996).

During the time of deposition of the sediments comprising the Cullen Formation, it is postulated that a temperate humid forest, mostly composed of angiosperms of the Nothofagaceae and gymnosperms of the Podocarpaceae and Araucariaceae, formed the environment where an abundant mycoflora developed. Among angiosperms, representatives of about 30 different families were recorded. These include Apiaceae, Asteraceae, Chenopodiaceae, Cunoniaceae, Cyperaceae, Gunneraceae, Malvaceae, Menyanthaceae, Myrtaceae, Onagraceae, Poaceae, Proteaceae, Rosaceae, Rubiaceae, Sapindaceae, Sparganiaceae/ Thyphaceae and Winteraceae. A
diverse flora of bryophytes and pteridophytes was also documented (Zamaloa, 2000). It is suggested that these bioclimatic conditions promoted the large fungal diversity found in this formation. Additionally, taphonomic conditions, particularly the high rate of sedimentation, in part, as a consequence of the periodic overflow of the meandriform rivers, created an anoxogenic microenvironment that enabled the excellent preservation of many of the fungal remains.

Most of the recovered fruiting bodies are members of the Ascomycota representing the families Micropeltaceae (Plochmopeltinites cooksonia, P. masonii, Plochmopeltinites sp. 1, Plochmopeltinites sp. 2, Plochmopeltinites sp. 3, Plochmopeltinites sp. 4), Microthyriaceae (Asterothyrites sp., Callimothallus persutus, Callimothallus sp., Microthyriella sp., Microthyriella diporata, Microthyriella sp., Phragmothyrites eocanicus, Phragmothyrites sp., Trichopeltinites sp., Trichothyrites sp. 1, Trichothyrites sp. 2), and Perisporiaceae (Perisporiacites sp.), the first four families belonging to the Microthyriales and the Perisporiaceae belonging to the Dothidiales (Tiffney and Barghoorn, 1974; Kalgutkar and Jansonius, 2001).

Dilcher (1965) described fruiting bodies of Callimothallus and Microthyriella from the Eocene of Tennessee epiphytically associated to cuticles of Sapindaceae and Rosaceae. These latter angiosperm families were also part of the flora of the Cullen Formation and pollen grains with these affinities were found in stratigraphic levels coincident with those where fruiting bodies of Callimothallus and Microthyriella were found, further establishing a positive correlation between both observations.

Several authors have pointed out the value of Microthyriaceous fungi as indicators of moist and humid climates rather than on the temperature. Additionally, the presence of fungal spores referred to Dyadosporites bhardwaji (Varma and Rawat) Kalgutkar and Jansonius 2001 (Eocene to Miocene), D. cannarensis Ramanujan and Rao 1978 (Miocene), Pucciniaropsites arcotensis Ramanujan and Ramachar 1980 (Miocene) and Frasnacritetrus sivalicus Saxena, Singh and Rao 1987 (Miocene to Pliocene) (age ranges taken from Kalgutkar and Jansonius, 2001) and “Parabrefeldiellites” (Miocene to Recent) (Elsik, 1992) indicate a Miocene age. Additionally, the presence of fungal spores referred to Appendicisporites may characterize a Miocene age (age ranges taken from Kalgutkar and Jansonius, 2001) in the Cullen Formation assemblage supports a Miocene age. This age is coincident with that obtained by analyzing the overall pollen/ spore contents (Zamaloa, 2000). According to these results, this is the first record of Perisporiacites, Callimothallus persutus and Phragmothyrites eocanicus in sediments younger than Eocene.

**Figure 3.** Fossil fungal fruiting bodies from the Cullen Formation. Graphic scale = 20 µm / Cuerpos fructíferos fúngicos de la Formación Cullen. Escal gráfica = 20 µm. A, Phragmothyrites kiandrensis Selkirk BAFCB p.m. 240: 37.9/ 99.1; B, Phragmothyrites sp. BAFCB p.m. 240: 38.1/ 110.1; C, Perisporiacites sp. BAFCB p.m. 240: 31.2/ 104.8; D, Trichothyrites sp. 1 BAFCB p.m. 187: 32.1/ 92.2; E, Trichothyrites sp. 2 BAFCB p.m. 240: 47.6/ 101; F, Trichopeltinites sp. BAFCB p.m. 235: 36.7/ 100.5; G, Type I (aff. Arnaudiella “andina” Butin & Peredo) BAFCB p.m. 240: 48.8/ 111.6; H, Type II (aff. Arnaudiella “andina” Butin & Peredo) BAFCB p.m. 240: 43.8/ 101.3; J, BAFCB p.m. 240: 44.1/ 102; K, Type IV (“Parabrefeldiellites” Elsik) BAFCB p.m. 193: 40.8/ 100; L, Type V BAFCB p.m. 240: 30.6/ 99; M, Type VI BAFCB p.m. 240: 44/ 98; N, Type VII BAFCB p.m. 249: 32.8/ 112.8; O, Type VIII BAFCB p.m. 240: 26.5/ 98.8; P, Type IX BAFCB p.m. 249: 39.8/ 102.2; Q, Type X BAFCB p.m. 235: 37.3/ 96.9; R, Type XI BAFCB p.m. 240: 38.8/ 110.6; S, Type XII BAFCB p.m. 240: 46.6/ 101.9.
Conclusions

The Cullen Formation sediments have yielded a great diversity of fungal fruiting bodies, which are abundant in several samples. Of the hundreds of specimens observed, 31 different forms are presented in this contribution. Of these, 19 were assigned to known fossil genera, including 6 known fossil species. The others correspond to 12 different types and possibly represent new morphogenera.

The genera and/or species Phlochompetnitites cottsonia, M icrorthyrella diporata, M icrorthyrites, Phragmothyrites ecaucus, P. kiandrensis and Perisporiacites are recorded for the first time in Argentina, thus enlarging their palaeogeographical distribution. The genus and/or species Perisporiacites, Callimothallus persutus and Phragmothyrites ecaucus are recorded for the first time in sediments younger than Eocene. A positive correlation appears to exist between the diversity of fungal fruiting bodies and the diversity of spores and pollen, especially to that of angiosperm source.

The fungal palaeoflora flourished under rather humid climate conditions. A Miocene age is proposed for this formation coinciding with that suggested for the fungal spore content, as well as other palynological data.

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