The first record of *Cooksonia* from South America in Silurian rocks of Bolivia

E. MOREL*, D. EDWARDS† & M. IÑIGEZ RODRIGUEZ‡

* Department of Palaeobotany, La Plata Museum, Paseo del Bosque s/m, 1900 La Plata, Argentina
† Department of Earth Sciences, University of Wales Cardiff, P.O. Box 914, Cardiff CF1 3YE, UK
‡ C.I.G. Calle 1 No. 644, 1900 La Plata, Argentina

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Abstract

Plant megafossils resembling *Cooksonia caledonica* Lang are described from the Kirusillas Formation in southern Bolivia. Faunal and lithological evidence together with field relationships advocate a late Silurian (Ludlow) age. Palaeocontinental reconstructions suggest that the plants grew on the western edge of Gondwana at 50–60° S and indicate that *Cooksonia* had spread to higher latitudes soon after its appearance in the Wenlock.

1. Introduction

Mega-fossils of Silurian land plants are rare and, except for the Australian *Baragwanatha* assemblage (Garratt et al., 1984), usually found in the northern hemisphere (Edwards, 1990a, b; Richardson & Edwards, 1989). Here we report on an unequivocally fertile rhyophytoid (*sensu* Edwards & Edwards, 1986) from southern Bolivia, which provides insight into land vegetation at high latitudes on the west of the largest Silurian palaeocontinent, Gondwana, in late Silurian times. Plants were first recorded in the area near Tarija by Petriella & Suárez-Soruco (1989) who illustrated by line drawings, smooth, bifurcating axes assignable to *Hostinella*, some with elongate swollen ter-}

2. Locality and description

The specimen was collected from an otherwise almost barren yellow-grey siltstone interbedded with thin blocky sandstones of the Kirusillas Formation (Ahlfeld & Branisa, 1960), exposed on the steep north side of a gully formed by the Jarcas stream. Abundant fragmentary sterile axes also occur in more micaceous siltstones 3–4 m below. The locality is c. 500 m northeast of Negra Muerta Farm, c. 30 km northeast of Tarija and some 8 km east of San Lorenzo (Fig. 1). The plants are coalified compressions, although most of the organic matter has been destroyed revealing dark staining in the matrix beneath. The most complete specimen, 12.5 mm long, has two branch points and three attached terminal sporangia of very uniform size (Fig. 2).

Branching is isomomous. Between bifurcations the naked axes are parallel-sided when complete and range between 0.5 mm in diameter proximally and 0.3 mm distally. There is a gradual widening below a sporangium such that the limits of sporangium and axis are difficult to determine (Fig. 2b). Sporangial height is thus estimated at c. 1.3 mm. Two further sporangia and axes lie alongside. All sporangia are 1.5 mm wide and possess a narrow, but well-defined border (0.12 mm maximum width) around the convex margin. Spores were not recovered.

3. Identity of specimen

As defined by Lang (1937), the fossils belong to *Cooksonia*. Sporangial shape and border suggest closest affinity with Lochkovian *C. caledonica* Edwards (1970) although the curved junction between sporangium and axis has not been observed. The *Pfdolfi Xinjiang/Kazakhstania* terminal sporangia (*Junggaria/Cooksonella*) have much wider borders with a different outline and terminate axes with occasional spines (Cai, Dou & Edwards, 1993) while the much larger *C. crassiparietilis* from Kazakhstania Lower Devonian is better placed in a new genus (*Yurina, 1969; Edwards & Edwards, 1986*). The specimen may represent a lateral branching unit of a pseudomonopodial system as in *Renalia* (Gensel, 1976; Fanning, Edwards & Richardson, 1992), although such branching patterns are not recorded at the locality.

There are problems with unconditional assignation of the Bolivian specimen to *C. caledonica*, the latter being based on impression fossils. Certain Welsh Borderland Lochkovian sporangia have a narrow border and reniform outline reminiscent of *C. caledonica*, but on spore characteristics and mode of dehiscence they are unlike any other *cooksonias* and require a new genus. Thus, until more information becomes available on the Bolivian plant, it is better named *C. cf. caledonica*.

4. Correlation and age determination

The Kirusillas Formation (Ahlfeld & Branisa, 1960) at the Negra Muerta locality is identified by its lithology. Elsewhere in the same region, it is underlain unconformably by the Cancañiri Formation, the local equivalent of the Zapla Formation to the south in Argentina and also known as the Sacta Formation in Bolivia (Branisa et al., 1972). The overlying
Figure 1. Ordovician and Silurian outcrops in Bolivia with localities mentioned in text. 1 = Negra Muerta locality, with Silurian plants; 2 = Tarabuco; 3 = Kirusillas; 4 = Pojo; 5 = Lampaya. Redrawn from Ahlfeld & Branisa (1960).

Tarabuco Formation, again recognized by its lithology, outcrops in the hillside to the south of the Jarcas stream nearer the farm. Elsewhere the Kirusillas Formation passes conformably into the Tarabuco Formation which in certain areas is replaced by the lateral equivalent, the Santa Rosa Group (Berry & Boucot, 1972). Interpreting the geology of this little-studied area is thus confounded by lateral changes in facies, the variety of names applied to the diachronous units and a dearth of fossils. However, the fossils were undoubtedly found in the Kirusillas Formation whose age is constrained by fossils in overlying and underlying formations and by fossils in the Kirusillas Formation itself elsewhere.

The Cancaniri Formation was recently described as Ashgill on the basis of brachiopods found near Cochabamba in rocks of similar and distinctive lithology (Benedetto, Sanchez & Brussa, 1992) although Berry & Boucot (1972) assigned it a Llandovery age. Crowell, Suarez-Soruco & Rocha-Campos (1981) placed it in the Wenlock on evidence from *Duvernaysphaera jelinii* Zone acritarchs and chitinozoans.

The lower part of the Kirusillas Formation in the Pojo and Lampaya regions, c. 260 km north and 450 km northwest of Tarija, contains upper Ludlow–Pfidol acritarchs (Lobo, Suarez-Riglos & Suarez-Soruco, 1976). In the same area, but in different sections, early Ludlow graptolites are recorded (Cuenda & Antelo, 1973). This age determination is consistent both with one based on brachiopods from exposures to the west of Tarabuco (Racheboeuf & Branisa, 1985; Benedetto, Sanchez & Brussa, 1992) and on brachiopods and graptolites (Davila & Rodriguez, 1967). In summarizing all paleontological evidence, Berry & Boucot (1972) proposed a late Llandovery to early Devonian age range in the Pojo area (the early Devonian palynomorphs occurring in the top 130 m) and a late Llandovery into Wenlock or Ludlow age elsewhere, including the Tarija area (Fig. 1). Benedetto, Sanchez & Brussa (1992) concluded that the overlying Tarabuco Formation ranged from Ludlow into Pfidol based on brachiopod evidence from the Lampaya and Tarabuco regions (Lopez Pugliesi & Lopez Murillo, 1975), although McGregor (1984) had reported a spore assemblage of Lower Devonian aspect and a Pfidol/Gedinian one from the older. Chitinozoans recovered from the uppermost Kirusillas Formation and base of the Tarabuco Formation to the west of Tarabuco are typical of the Pfidol (Racheboeuf et al. 1993). Collectively such data suggest that in the Tarija area, the Kirusillas Formation was deposited in post-Llandovery to pre-Pfidol time and that the fossils are probably of Ludlow age.

5. Palaeogeography

Of the considerable number of palaeocontinental reconstructions for the late Silurian (e.g. Van der Voo, 1988; Scotese & Barrett, Bachtas & Briden and Boucot in McKerrow & Scotese, 1990; Cocks & Scotese, 1991) we chose the base-map of Denham & Scotese (1987), because it shows a polar projection extending to the equator (Fig. 3). The Bolivian locality is between 50° S and 60° S on the edge of the Gondwana land mass.

As the pole occurs more or less centrally on the latter, glaciation would have been at a minimum (see models of Crowley, Mengel & Short, 1987), while precipitation would have been...
Greenland, Siberia, Kazakhstan and Xinjiang are in the Silurian originally interpreted as true marine tillites (Rodrigo, Castanos et al. 1984). These are now considered turbidites (Bossi & Viramonte, 1975), although continental mountain glaciers may have contributed significantly to the sources of sediment (Hambray, 1985). However, the faunas at the base of the Kirusillas Formation (Upper Llandovery) are typical of Malvinokaffric assemblages. The silstones and sandstones derive from an early Palaeozoic land mass to the west, presumably the sites of the growth of the plants (Andreis et al. 1982; Böttcher et al. 1984). The excellent preservation of the specimen described here suggests minimal transport.

6. Significance of the new find

This is the first record of a Silurian land plant with unequivocal sporangia in South America and only the fourth Silurian record from Gondwana (Daber, 1971; Přídolf of Libya; Obrehl, 1962: Přídolf of Bohemia). On admittedly very limited evidence, the plant has more in common as regards level of organization with those of the northern hemisphere than with the southern hemisphere. Land areas stippled. 1: Wenlock, Australia; 4: Přídolf, New York State; 5: Přídolf, Podolia; 6: Přídolf, Bohemia; 7: Přídolf, Libya; 8: Tarija. Localities in Greenland, Siberia, Kazakhstan and Xinjiang are in the Silurian northern hemisphere. Location details in Edwards (1990b): continental positions based on Denham & Scotese (1987).

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References


high throughout the year (Parrish, 1990). The sediments of the Kirusillas Formation offer little information on palaeoclimate, unlike the diamictites of the Cancaniri (Zapla) Formation. Originally interpreted as true marine tillites (Rodrigo, Castanos & Carrasco, 1977) these are now considered turbidites (Bossi & Viramonte, 1975), although continental mountain glaciers may well have contributed significantly to the sources of sediment (Hambray, 1985). However, the faunas at the base of the Kirusillas Formation (Upper Llandovery) are typical of Malvinokaffric assemblages. The silstones and sandstones derive from an early Palaeozoic land mass to the west, presumably the sites of the growth of the plants (Andreis et al. 1982; Böttcher et al. 1984). The excellent preservation of the specimen described here suggests minimal transport.

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