RAPID COMMUNICATION

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

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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

Megafossils of Silurian land plants are rare and, except for the Australian *Baragwanathia* assemblage (Garratt *et al.* 1984), usually found in the northern hemisphere (Edwards, 1990*a*, *b*; Richardson & Edwards, 1989). Here we report on an unequivocally fertile rhyniophytoid (*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 & Súarez-Soruco (1989) who illustrated by line drawings, smooth, bifurcating axes assignable to *Hostinella*, some with elongate swollen terminations. These were compared with *Steganotheca* Edwards (1970) although they lacked all the major diagnostic characters of that genus. The new fossils have more convincing sporangia, which are short, wide and terminate naked isotomously branching axes.

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 isotomous. 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 Přídolí Xinjiang/Kazakhstanian 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 Kazakhstanian 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

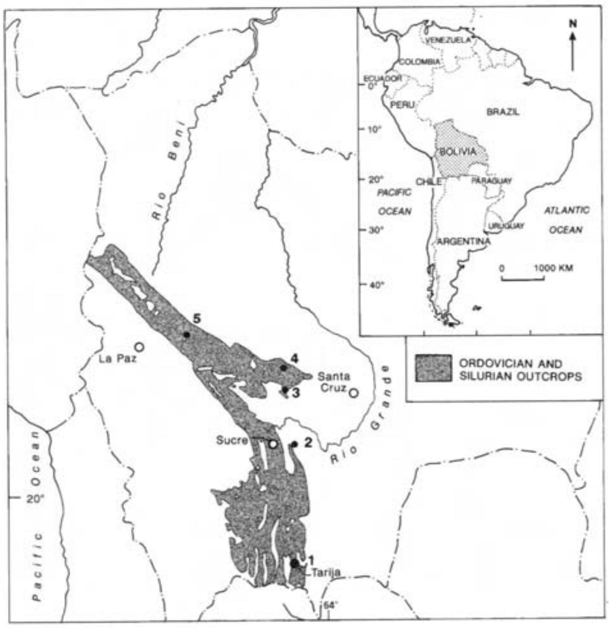

Figure 1. Ordovician and Silurian outcrops in Bolivia with localities mentioned in text. 1 = Negra Muerta locality, with Silurian plants; 2 = Tarabuco; 3 = Kirusillas; 4 = Pojo; 5 = Lampaya. Redrawn from Ahlfeld & Branisa (1960).

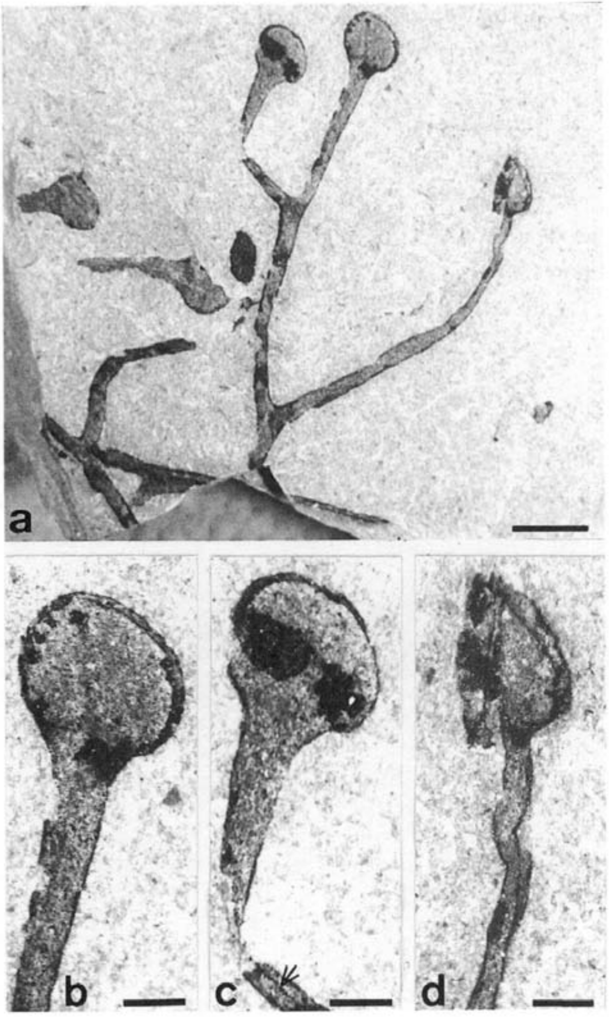

Figure 2. *Cooksonia* cf *caledonica*, Tarija, southern Bolivia. LPPB 12744. (a) View of entire specimen, including two isolated terminal sporangia. Scale bar = 2.1 mm. (b–d) Sporangia, showing marginal band; sporangium in (d) is folded. Note possible central strand (arrowed) in (c). Scale bars = 0.5 mm.

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 Cancañiri 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, Súarez-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–Přídolí acritarchs (Lobo, Súarez-Riglos & Súarez-Soruco, 1976). In the same area, but in different sections, early Ludlow graptolites are recorded (Cuerda & 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 palaeontological 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 150 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 Přídolí based on brachiopod evidence from the Lampaya and Tarabuco regions (Lopez Pugliessi & Lopez Murillo, 1975), although McGregor (1984) had reported a spore assemblage of Lower Devonian aspect and a Přídolí/Gedinnian 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 Přídolí (Racheboeuf *et al.* 1993). Collectively such data suggest that in the Tarija area, the Kirusillas Formation was deposited in post-Llandovery to pre-Přídolí 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, Bachtase & 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

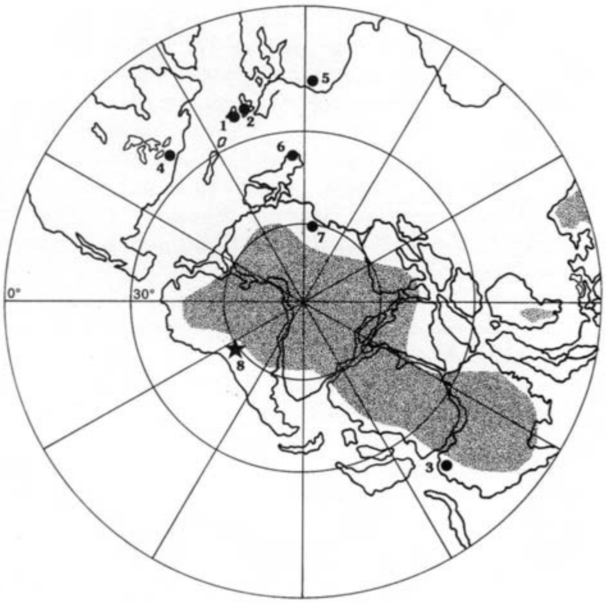

Figure 3. Distribution of plant megafossil assemblages in the late Silurian southern hemisphere. Land areas stippled. 1: Wenlock, Ireland; 2: Ludlow-Přídolí, southern Britain; 3: Ludlow, Australia; 4: Přídolí, New York State; 5: Přídolí, Podolia; 6: Přídolí, Bohemia; 7: Přídolí, Libya; 8: Tarija. Localities in Greenland, Siberia, Kazakhstan and Xinjiang are in the Silurian northern hemisphere. Locality details in Edwards (1990*b*); continental positions based on Denham & Scotese (1987).

high throughout the year (Parrish, 1990). The sediments of the Kirusillas Formation offer little information on palaeoclimate, unlike the diamictites of the Cancañiri (Zapla) Formation. Originally interpreted as true marine tillites (Rodrigo, Castaños & Carrasco, 1977) these are now considered turbidites (Bossi & Viramonte, 1975), although continental mountain glaciers may well have contributed significantly to the sources of sediment (Hambrey, 1985). However, the faunas at the base of the Kirusillas Formation (Upper Llandovery), preserved in a progradational delta system, are typical of Malvinokaffric assemblages. The siltstones 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; Přídolí of Libya; Obrhel, 1962: Přídolí 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 *Baragwanathia*-dominated assemblages from coeval sediments in Australia, at lower latitudes in the Silurian southern hemisphere (Fig. 3). Euramerican Ludlow assemblages are rare (Richardson & Edwards, 1989) and less diverse than Přídolí ones. The most extensive (Capel Horeb, South Wales: Ludfordian (Whitcliffe) rocks) contains *Steganotheca* and several types of *Cooksonia*. One isolated sporangium (Edwards & Rogerson, 1979; pl. ld.) shares a border and sporangial outline with the Bolivian specimen and was also named *C.* cf *caledonica*. The new data from Bolivia indicate the widespread geographical distribution of *Cooksonia*, including its spread into higher latitudes soon after its appearance in the Wenlock (Edwards, Feehan & Smith, 1983). Finally, this discovery, together with numerous sterile axes from Negra Muerta and fossils from a second locality at Padcaya, south of Tarija, demonstrates the great potential of Bolivia for discovering more about global Silurian land vegetation.

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