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Bee cell trace fossils associations on paleosols from the Santa Cruz Formation: Palaeoenvironmental and palaeobiological implications

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ABSTRACT

Numerous isolated fossil bee cells and other trace fossils are documented from the Santa Cruz Formation (Santa Cruz, Argentina). The trace fossils are described from paleosols of 7 coastal localities. The paleosols are composed of massive to laminated claystone to siltstone or massive to diffuse laminated very fine tuff and reworked tuff. They are poorly developed but include rich trace fossils and root traces assemblages. The isolated bee cells ($n = 47$) are barrel to oval shaped, with one end rounded to flattened and the other flattened. They lack discrete walls and antechambers but have a smooth lining. They are ascribed to *Celliforma rosellii* ($n = 28$) and to a new ichnospecie, *Celliforma argentina* ($n = 19$). The new ichnospecies differs from *C. rosellii* on the shape of the inferior end of the chamber, been the first rounded to flattened and the *C. rosellii* rounded to pointed, resulting in a final barrel shape in *C. argentina* and an oval shape in *C. rosellii*. *C. rosellii* has an average length and width of 17 mm and 9.8 mm. *C. argentina* average length and width are 9.2 and 5.1 mm. In some specimens of *C. rosellii* below the basal mark in the cell, the infill has a strong organic component that has been identified under SEM. This could indicate the exceptional preservation of the fluid deposited by the adult bee for the nutrition of the larva. The trace fossils assemblage shows moderate diversity and abundance. The ichnoassemblage recorded consist in *Celliforma rosellii, Celliforma argentina, Palaeophycus tubularis, Planolites beverleyensis, Feoichnus challa, Fictovichnus gobiensis, Taenidium barretti* and a variety of root traces. These trace fossils are considered to be part of a *Celliforma* ichnofacies but with a scarce presence of calcareous components. Considering pedogenic features, compositional aspects and ichnoasemblage a relatively warm, semiarid–subhumid and seasonal climate where herbaceous communities dominated can be established for the middle to upper interval of the Santa Cruz Formation.

1. Introduction

The Santa Cruz Formation (SCF), a mainly continental unit of Early Miocene age (Raigemborn et al., 2015b), crops out extensively along southern Patagonia, Argentina, from the eastern area of the Southern Patagonian Andes mountain range (Bande et al., 2008; Cuitiño and Scasso, 2010) southward from Lago Buenos Aires to the Río Turbio area, and eastward from extra-Andean Patagonia to the Atlantic Ocean between Golfo San Jorge and northern Tierra del Fuego (Marshall, 1976; Bown and Fleagle, 1993; Tauber, 1997a; Malumián, 1999). The SCF is has a worldwide fame because of its rich mammalian fossil content, on the basis of which has been erected the Santacrucian South American Land Mammal Age (SALMA) (Pascual et al., 1965; Pascual and Ortiz-Jaureguizar, 1990). The unit is composed mainly of stacked mostly immature paleosols with frequently preserved root traces which varies between delicate, ferric, haloed and calcareous rhizoconcretions (Genise and Bown, 1994; Tauber, 1994; Krapovickas, 2012; Sacomani et al., 2012; Raigemborn et al., 2015a). Also, together with these root traces but less frequently mentioned in the literature other insect trace fossils have been described. Genise and Bown (1994) described 8 internal cast of cylindrical to ovoid cells, for the lower and middle parts of SCF at Monte Observación (Estancia Cañadón de las Vacas), which they assigned to a new ichnospecies of *Celliforma*: *C. rosellii*. More recently, Krapovickas (2012) and Raigemborn et al. (2015b) mentioned the presence of material corresponding to *Celliforma* isp.at the localities of Cañadón las Totoras and Rincon del Buque (Fig. 1). The above mentioned material together with newly found fossil bee cells and other insect trace fossils are analyzed in this contribution.

Along with the bee cells and the root traces there have also been mentioned dung beetle balls (Genise and Bown, 1994), vertebrate

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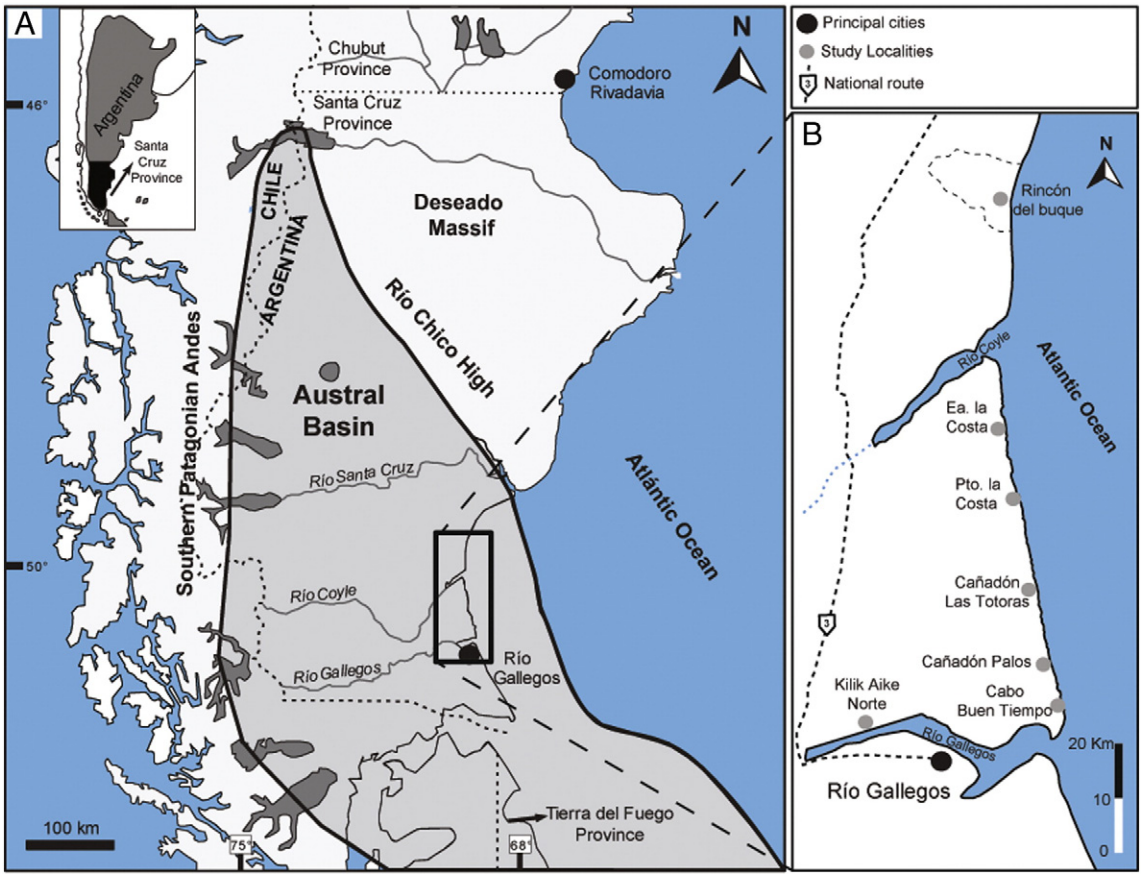

Fig. 1. A) Location of the Austral basin and the study area. B) Detailed of the study area showing the different localities analyzed in this paper.

footprints (Krapovickas et al., 2013), horizontal and internally meniscated dwelling burrows (*Taenidium barretti*), freshwater crab burrow (*Capayaichnus isp.*) and possible mammalian dwelling burrows (Krapovickas, 2012). Also Tauber (1994) mentioned the presence of krotovinas and presumed anthills in the locality of Cañadón Silva. To the west (at the localities of Antena and Puesto el Chacay) Cuitiño et al. (2015) also describe the presence of *Skolithos* isp. and *Taenidium* isp. in fluvial overbank deposits at the base of the SCF. Although all these material has been mentioned, considering the wide areal extension of the SCF the complete ichnological content and distribution within this formation it is still poorly known (Krapovickas, 2012).

The objectives of the present contribution are to (1) document the presence of isolated fossil bee cells along the coastal exposures of the Santa Cruz Formation; (2) to analyze the bee-cell-bearing sedimentary facies associations; (3) describe the ichnoassemblage preserved together with the dominant bee cell trace fossils; and (4) to consider the palaeobiological and palaeoenvironmental significance of the bee cell ichnoassemblages.

2. Materials and methods

Seven sedimentary sections exposed in the study area were measured. Facies and facies associations were described, following Miall (1996) and Bridge (2003) with modification for pyroclastic deposits (Smith, 1987). In the field, paleosols and rock colors were determined using the Geological Rock-Color Chart (2011). The external shape of the bodies were described following the width/thickness (W/Th) criteria of Gibling (2006) as broad sheets (W/Th > 100), narrow sheets (W/Th > 15, <100), broad ribbons (W/Th > 5, <15) and narrow ribbons (W/Th < 5).

The trace fossils collected during three field seasons (January 2011, 2012, 2013), are stored at the Museo Regional Provincial Padre M. J. Molina (MPM-PIC), Santa Cruz Province, Argentina. To check for micromorphological differences between the inner surfaces of the cells wall and the transverse marks into the cell walls and their surrounding matrix, 2 *Celliforma* molds were analyzed by scanning electron microscope (SEM) samples were coated with Au and were examined with a FEI Quanta 200 SEM housed in the Facultad de Ingeniería, La Plata, Argentina. Their composition was analyzed using X-ray energy dispersive spectroscopy (EDS) with an EDAX Phoenix 40.

In order to define the composition of the trace fossils-bearing paleosols, a total of twelve paleosol samples were analyzed using X-Ray diffraction (XRD). Soft grinding with a rubber mortar was used to disaggregate the more indurated samples, followed by repeated washes in distilled water until deflocculating occurred. XRD patterns from randomly oriented mounts of the powdered mudstones were collected from 3 to 37°2θ.For the whole-rock analysis semi-quantification was obtained from the intensity of the main peak for each mineral. The estimation of the mineralogical components is classified according to the following abundances: traces (tr: <1%); very scarce (vs: 1–5%); scarce (s: 5–15%); moderate (m: 15–25%); abundant (a: 25–50%) and very abundant (va: >50%). The <2 μm fraction was separated by gravity settling in suspension, and oriented mounts were prepared on glass slides. Clay mineralogy was determined from diffraction patterns obtained from samples that were air dried ethylene glycol solvated and heated to 550 °C for 2 hours (Brindley and Brown, 1980). Diffractograms were run on X PANanlytical model X'Pert PRO diffractometer (Centro de Investigaciones Geológicas, Universidad Nacional de La Plata, Argentina), using Cu/Ni radiation and generation settings of 40 KV and 40 mA. Routine air dried mounts were run between 2 and 32°2θ at