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The Aestivation Chamber of the Giant Earthworm *Glossoscolex bergi* (Glossoscolecidae) in the Subtropical Rainforest of Misiones (Argentina)

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Glossoscolex bergi **(Glossoscolecidae) is a giant earthworm from the rainforest of Misiones (Argentina). The large size of its aestivation chamber and the meniscate burrows connected to it allow us to describe morphological details and reinterpret some characteristics of the fossil counterpart *Castrichnus incolumis*. The concavity of menisci, either in the burrow or in those pellets lining the chamber, shows concentric ridges and radiating striae that result from the impression of the last segments of the body. The meniscate burrows associated to the chamber are different from described ichnospecies of *Taenidium,* because of the surface texture of the meniscus. The aestivation chamber was produced during an atypical four-month drought in a region that lacks a seasonal climate. This suggests that *Castrichnus incolumis* would be also an indicator of drought periods even in non seasonal climates.**

Keywords Earthworm, *Glossoscolex bergi*, Subtropical rainforest, *Castrichnus incolumis*, Paleoenvironmental indicator

INTRODUCTION

There are only two named ichnotaxa attributed to earthworms in paleosols. *Edaphichnium lumbricatum* is represented by burrows filled with fecal pellets (Bown and Kraus, 1983), whereas *Castrichnus incolumis*, the most complex earthworm trace fossil, are aestivation chambers connected with *Taenidium serpentinum* (Verde et al., 2007).

Castrichnus incolumis is composed of a spherical chamber lined with imbricated pellets that show a concentric surface texture. The chamber may be connected to specimens of *Taenidium serpentinum* (Verde et al., 2007). It was described originally from the Pleistocene Sopas Formation of Uruguay (Verde et al., 2007) and then recorded in the Lower Cretaceous Baquero Group (Bedatou et al., 2009) and the Middle Eocene-Early Miocene Sarmiento Formation of Argentina (Sánchez and Genise, 2009). The original attribution to earthworms was based on comparisons with small aestivation chambers from Colombia and Spain (Verde et al., 2007).

In this contribution is described the aestivation chamber and connected burrows produced by the giant earthworm, *Glossoscolex bergi* (Rosa, 1900). It was excavated in a lateritic soil of a subtropical rainforest in the Karadya Bioreserve (25° 52′ 14"S, 53° 58′ 10"W) near Andresito, Misiones, Argentina. The large size of this aestivation chamber and the meniscate burrows connected to it allow us to describe morphological details and also to reinterpret some characters of the fossil counterpart *Castrichnus incolumis*. Its construction under known climatic conditions enabled a more accurate evaluation of the environmental conditions that triggers its production.

RESULTS

The trace was located in the removed soil surrounding bone remains of a buried dead body of the ant-eater *Myrmecophaga tridactyla* (Myrmecophagidae), which probably provided the earthworm an organic-rich and loose substrate to burrow and feed on.

The complete structure was composed of a subspherical chamber, 6 cm long and 5.5 cm high, located 12 cm below the surface and connected with two inclined burrows about 1.5 cm wide (Fig. 1). One of them was open to the surface. It consisted of a first segment, empty, 17 cm long, followed, at 9 cm from the

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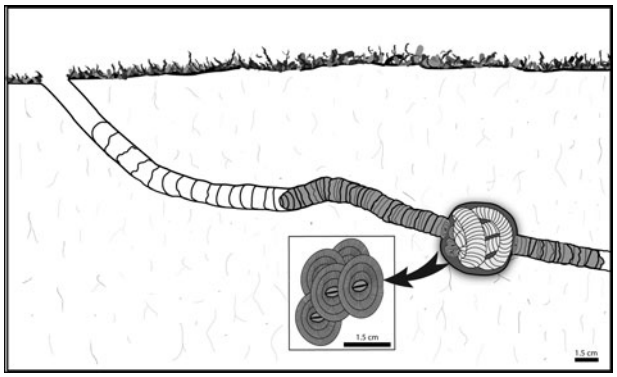

FIG. 1. Schematic drawing of the aestivation chamber and connected burrows of *Glossoscolex bergi*.

surface, by an actively filled segment 13 cm long and connected with the chamber (Figs. 1 and 2A). The chamber was connected with another burrow, consisting of an actively filled segment, 6 cm long, followed by an empty segment, 12 cm long. This burrow reached a depth of 19 cm and continued downward, until it became unrecognizable (Fig. 1).

The chamber contained a rolled up individual of *Glossoscolex bergi*, 65 cm long and 1.5 cm in diameter, forming a ball (Figs. 2A, B). The chamber wall showed partially superimposed groups of rounded, flattened, and slightly concave pellets, with a concentric pattern (Figs. 1 and 2C, D). The concave surface showed mostly three thin, concentric ridges surrounding a central transversal elliptical ridge. Among concentric ridges there was a faint surface texture composed of radiating striae (Fig. 2D).

Both burrows showed active fillings composed of meniscate packets (Fig. 2E), 4–5 mm thick, whose concavities were oriented toward the chamber. Groups of several packets were separated by more pronounced constrictions (Figs. 1 and 2E). The first packet of this active filling toward the empty burrow showed a lumpy aspect (Fig. 2F). The concave surface of the menisci from the burrow showed the same concentric pattern of those of the chamber. The burrow wall of the tunnel segments from which backfill was removed showed an annulated surface probably corresponding to marks left by missing meniscate packets (Fig. 2A).

DISCUSSION

When originally described, *Castrichnus incolumis* was compared with the aestivation chambers, 1–2 cm in diameter, of *Martiodrilus heterostichon* (Glossoscolecidae) from Colombia and *Hormogaster elisae* (Hormogastridae) from Spain (Verde et al., 2007). The aestivation chamber described herein is several times larger than those found in Colombia and Spain, and the producer is of a different genus and geographical region. Still, most general features are the same. This suggests a relatively uniform behavior in earthworms for constructing aestivation chambers, which in turn should result in more unequivocal identifications of *Castrichnus incolumis*.

The aestivation chamber of *Glossoscolex bergi* lacked the multilayered wall of *Castrichnus incolumis* and the filling with strings of pellets. The former may be the result of less necessity of isolation, incomplete construction, or preservation, and the latter was due to the presence of the earthworm inside the chamber. Verde et al. (2007) suggested that concentric ridges on the surface texture of menisci could be produced by the rhythmic extrusion of fecal material, whereas the central ridge could reflect the interruption of defecation. In the case study presented herein, the concentric surface texture of the menisci is an impression of the earthworm's last body segments and anus. Similarly the radiating striae are impressions of earthworm's skin folds (Fig. 2B).

Concavities of meniscate burrows connected to the chamber were oriented toward the chamber. This indicates that it was produced by the enlargement of a former single empty burrow where the removed soil from the chamber was packed. Righi (1971, Fig. 12) illustrated the aestivation chamber of *Rhinodrilus alatus* (Glossoscolecidae) also as an enlargement at the end of two burrows. The lumpy end of one of the active fillings probably resulted when this surface of the meniscate packet could not be pressed against a firm surface (Fig. 2F). The annulate pattern of the empty segment of the burrow reveals that the excavation and filling took place when the soil was plastic enough to be deformed by the pressure of backfilling. In the original description of *Castrichnus incolumis* the meniscate burrows connected to the chamber were assigned to *Taenidium serpentinum* because of the distance between menisci was equal or slightly less than burrow diameter (Verde et al., 2007). In the case described herein the meniscate packets were shorter than the burrow diameter (Fig. 2E). The concentric pattern in tunnel menisci was not observed in the fossil examples until now (Verde et al., 2007; Bedatou et al., 2009; Sánchez and Genise, 2009). If preserved in fossil examples, this unique pattern would justify the creation of a new ichnospecies of *Taenidium*, attributable to earthworms.

According to observations on extant earthworms, *Castrichnus incolumis* was proposed as an indicator of seasonal climate with a strong dry period (Jiménez et al., 2000; Díaz Cosin et al., 2006; Verde et al., 2007). In contrast, the warm subtropical climate of northern Misiones, where the aestivation chamber of *Glossoscolex bergi* was found, is not seasonal, showing precipitations with an average monthly range of 110–209 mm (period 1981–1990; Servicio Meteorológico Nacional, 2012). When the aestivation chamber was found in March 2012, the region was suffering a strong drought almost without precipitations for a period of approximately four months, revealing that *Castrichnus incolumis* would not be necessarily an indicator of seasonal climate but rather of drought periods irrespectively of the general climate.

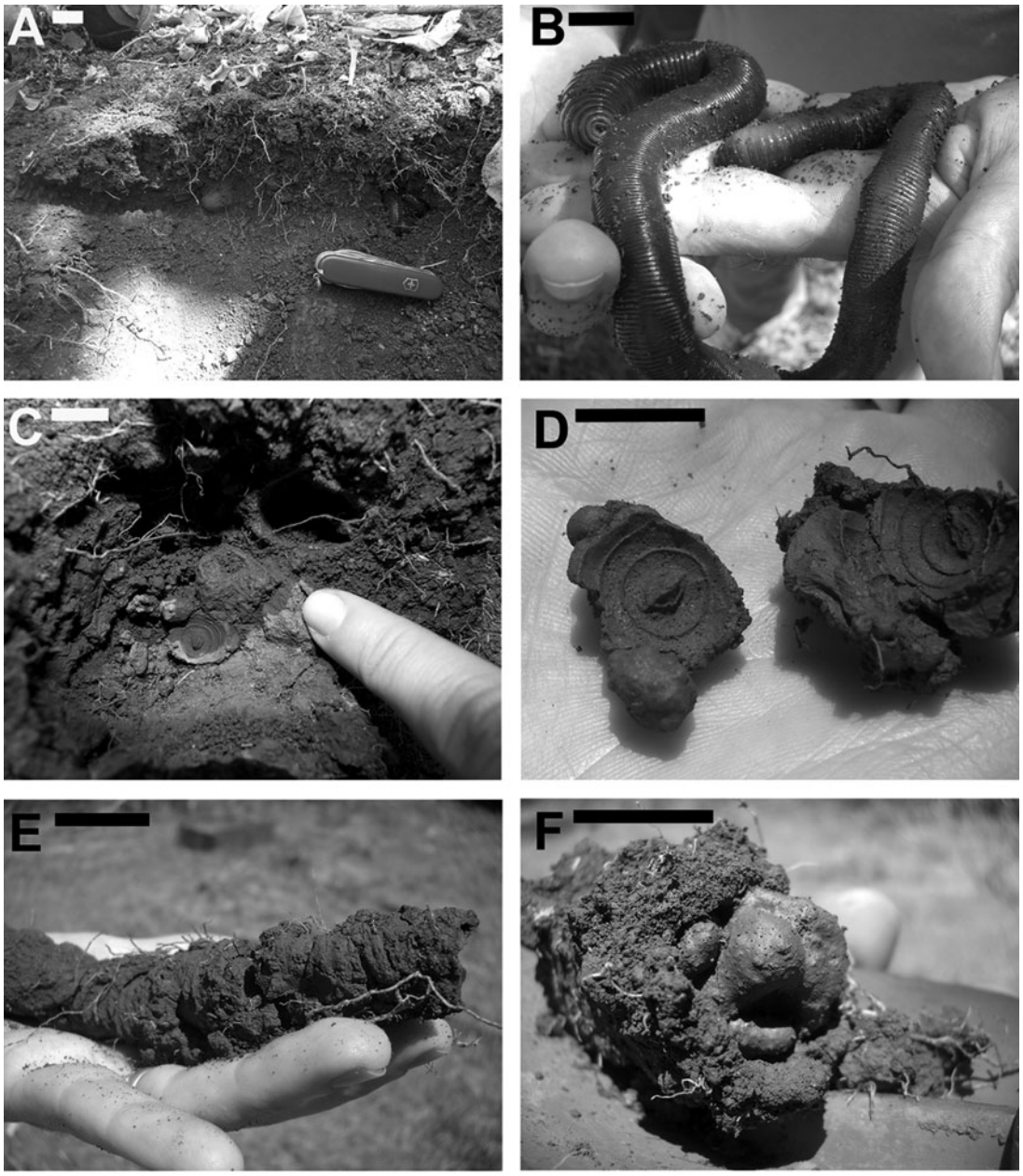

FIG. 2. **(A)** *Glossoscolex bergi* rolled up inside the aestivation chamber. One of the burrows, partially filled and opened to the soil surface (left), shows the smooth convex ending of a meniscate packet and the wall with annulations along the empty portion. **(B)** *Glossoscolex bergi* showing the last segments and anus. **(C)** The interior of the chamber showing one of the pellets with a concentric pattern (center) and the entrance to one of the burrows (over the finger). **(D)** Individual pellets from the chamber wall showing the concentric rings, radiating striae, and central ridge. **(E)** Filling of the left burrow showing the meniscate packets. **(F)** Free end of the filling of the right burrow showing the lumpy pattern. Scale bars: 1.5 cm. (See Color Plate I.)

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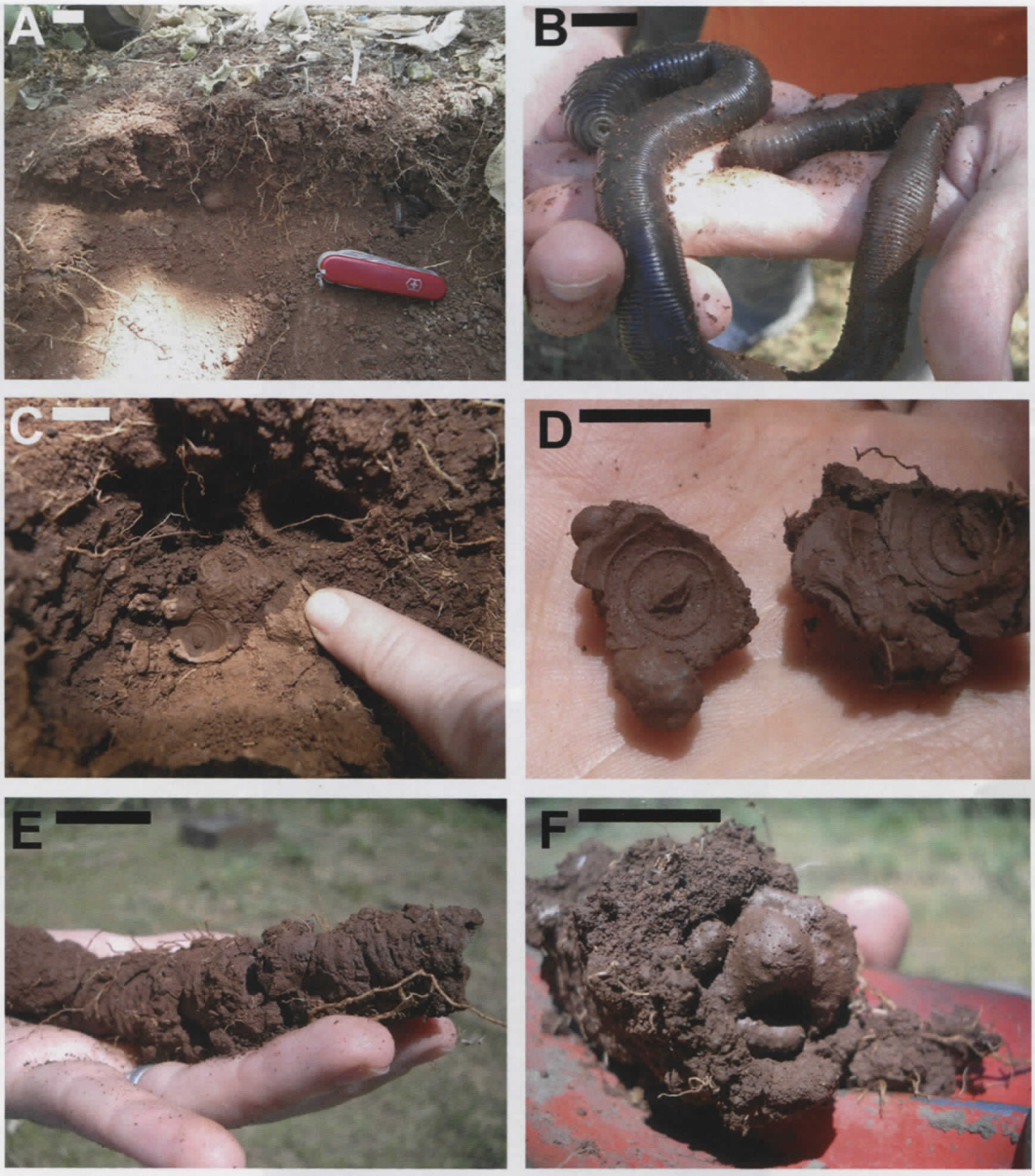

Color Plate I. See Figure 2 on page 118.—(**A**) *Glossoscolex bergi* rolled up inside the aestivation chamber. One of the burrows, partially filled and opened to the soil surface (left), shows the smooth convex ending of ameniscate packet and the wall with annulations along the empty portion. (**B**) *Glossoscolex bergi* showing the last segments and anus. (**C**) The interior of the chamber showing one of the pellets with a concentric pattern (center) and the entrance to one of the burrows (over the finger). (**D**) Individual pellets from the chamber wall showing the concentric rings, radiating striae, and central ridge. (**E**) Filling of the left burrow showing the meniscate packets. (**F**) Free end of the filling of the right burrow showing the lumpy pattern. Scale bars: 1.5 cm.