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Anatomy of biologically mediated opal speleothems in the World's largest sandstone cave: Cueva Charles Brewer, Chimantá Plateau, Venezuela

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Abstract

Siliceous speleothems can be formed in sandstone caves. Recently, opal "biospeleothems" have been found in the World's largest cave in Precambrian sandstones on the Chimantá Tepui in Venezuela. The speleothems, although reminiscent of normal stalactites and stalagmites from limestone caves, are in fact large microbialites. More than a dozen forms were distinguished, but they share a common structure and origin. They consist of two main types: 1. fine-laminated columnar stromatolite formed by silicified filamentous microbes (either heterotrophic filamentous bacteria or cyanobacteria) and 2. a porous peloidal stromatolite formed by *Nostoc*-type cyanobacteria. The first type usually forms the central part and the second type, the outer part, of speleothems. Fungal hyphae, metazoan and plant remains also subordinately contribute to speleothem construction. The speleothems occur out of the reach of flowing water; the main source of silica is the condensed cave moisture which is the main dissolution–reprecipitation agent. Speleothems which originated by encrustation of spider threads are unique.

Keywords: Tepuis; Sandstone caves; Siliceous speleothems; Microbialites; Stromatolites

1. Introduction

Speleothems are very common in limestone caves, because dissolution and reprecipitation rates of calcite and aragonite are relatively high. Caves formed in silicate rocks, such as sandstones, quartzites, volcanics (e.g., lava tunnels) or even granites are characterized by siliceous speleothems (Urbani, 1976, 1996; Webb and Finlayson, 1984; Wray, 1999; Léveillé et al., 2000; Willems et al., 2002; Forti et al., 2003), in which the dominant mineral is opal (Hill and Forti, 1986). Siliceous sinters precipitated from hot springs (Jones et al., 2001a; Konhauser et al., 2001; Konhauser et al., 2003) are very similar. In cold water, opaline silica has a solubility on the order of 100–200 ppm and quartz silica even lower, less than 10 ppm (Hill and Forti, 1986). Unlike in most of the carbonate speleothems, microbial mediation is common in the precipitation of siliceous speleothems; it is also common in the hot-spring siliceous sinters, but with different biotas being involved, dominated mainly by autotrophic cyanobacteria. In the fossil record, siliceous microbialites occur mainly in the Precambrian and are the main witness of early eucaryotic life since the Archean. Comparison of the microbial communities in the Archean and hot-spring siliceous sinters has been a subject of several studies (e.g., Konhauser et al., 2003). Examination of siliceous speleothems provides a complementary actualistic approach to siliceous stromatolites that originated in non-photic environments.

Siliceous speleothems are commonly small forms (Webb and Finlayson, 1984), rarely exceeding 2 cm in size. Recently, the World's largest sandstone cave, Cueva Charles Brewer, was discovered in Chimantá Tepui, Venezuela (Šmída et al., 2005).

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Within the cave, unusual large examples of previously undescribed speleothems have been found. They represent the largest known cryptic stromatolites and the largest siliceous stromatolites originating in non-aquatic environments. This paper is the first report of their anatomy and composition and it contains inferences concerning their origin.

2. Geological setting — characteristics of the Cueva Charles Brewer and its speleothems

The World's largest sandstone cave Cueva Charles Brewer, was discovered by us (Ch.B.-C.) in 2004 on the Chimantá Plateau (tepui) in south-eastern Venezuela (Fig. 1). The plateau is one of more than 100 tepuis that occur in the area. The tepuis are table mountains of Precambrian quartzites and sandstones of the Guayana Shield, rimmed by steep cliff walls. The tepuis are habitats for a great variety of endemic flora and fauna. During exploration of this isolated environment, karst structures with numerous subterranean systems were discovered.

Cueva Charles Brewer parallels the top of the mountain, 150 to 200 m below the surface. The known length of the cave is 4482 m. In the size of its galleries and its total volume, it exceeds any other known quartzite cave (Fig. 2). The cave appears to be part of a major drainage system for an extensive area of the tepui surface. During the dry season, the water flow of the river inside the cave was estimated to be 200–300 l/s; but during torrential rains, it reaches many cubic meters per second. The cave galleries are typically 40 m wide, but can be much larger. The largest chamber found in the cave, Gran Galería Karen y Fanny, is 40 m in height, more than 355 m in length, and 70 m wide: a volume of about 400,000 m^3.

Opal speleothems were found on many places within the cave but mostly out of reach of flowing water. They have various shapes and forms; more than a dozen types were distinguished by speleologists during the initial phases of exploration. Inorganically precipitated opal to chalcedony flowstone crusts are beyond the scope of this paper, which is mainly focused on dropstone-like speleothems. Mushroom-like speleothems over 10 cm high, with white stems and dark brown caps were named "dolls" (Spanish: muñecos — Fig. 3A, B). Other forms, "black corals" (Spanish: corales negros — Fig. 3) and "guácimos" (Fig. 3D), have more bizarre, branching shape. They resemble coraloid speleothems described from other silicate caves (Swartzlow and Keller, 1937). The lower sides of some

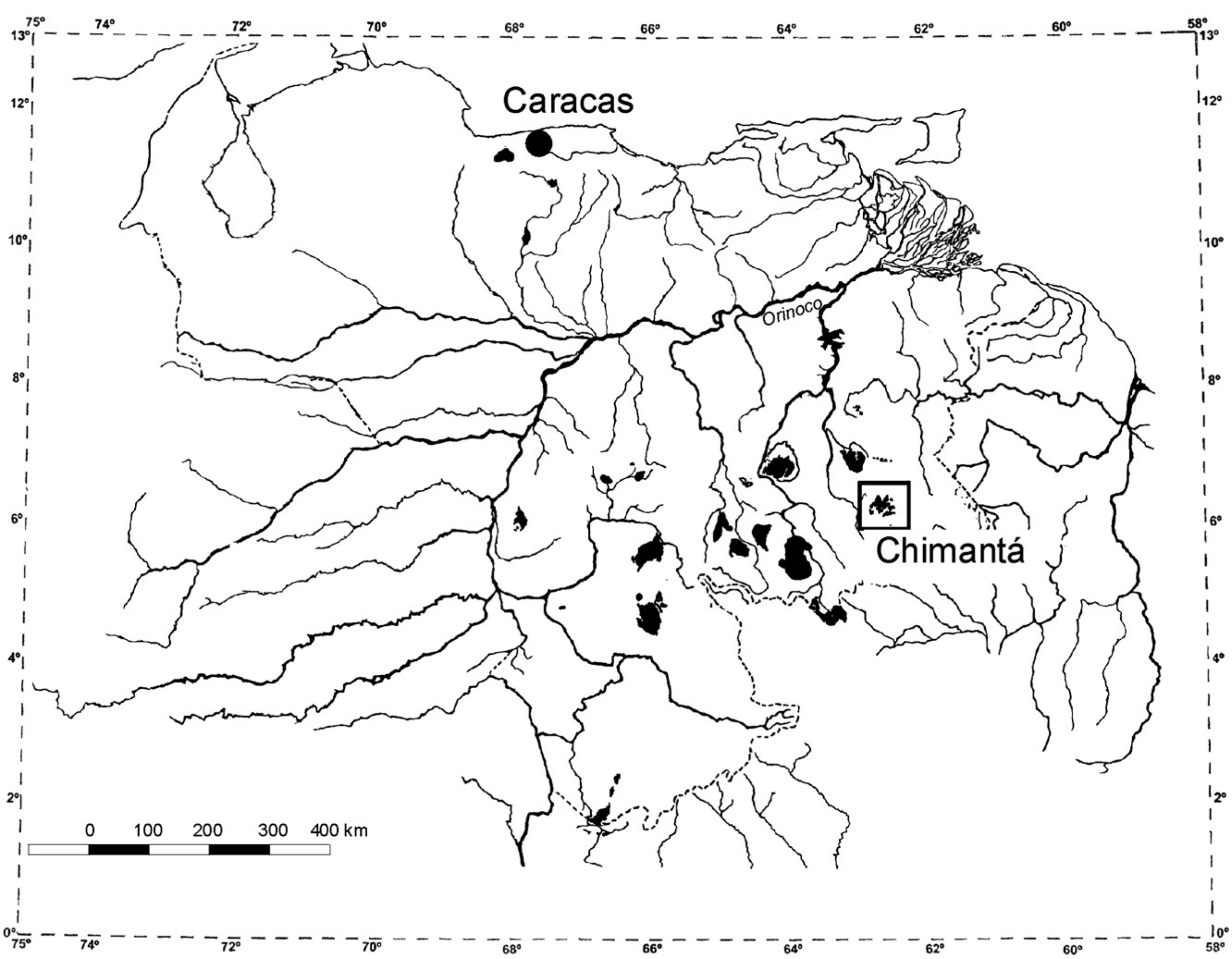

Fig. 1. Position of the Chimantá Tepui.