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Two million years of river and cave aggradation in NE Brazil: Implications for speleogenesis and landscape evolution

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ABSTRACT

This study characterizes and provides ages for an extensive sedimentary record occurring in Lapa Doce and Torrinha caves, NE Brazil. With >40 km of surveyed passages, these caves integrate a distributary cave system fed by allogenic recharge from the surrounding sandstone plateaus. Sediment petrography together with descriptions of depositional facies and architectural elements shows four depositional units related to fluvial and standing water environments. These include, from bottom to top: (1) a channel unit including lateral bars deposited during an ordinary flood regime; (2) a sandy flood unit including minor channel and scour fills derived from bank-full equivalent flood events; (3) mud caps deposited in standing water that often reach the ceiling; and (4) intraclast breccias associated with collapse of the mud caps under saturated conditions. The deposits were dated using a combination of cosmogenic nuclide burial dating and U-series dating of flowstone. Cosmogenic nuclide data point to fluvial aggradation being active since 1.91 + 0.12 My and extending until 0.36 ± 0.08 My, with intensive cave and valley aggradation events between 0.78 ± 0.10 My and 0.44 ± 0.12 My. Long term alluviation of the cave system seems to be important in forming passages, determining their configuration, and setting up a general distributary pattern evident in passage morphology and sedimentary sequences. Mud caps overlapping the fluvial deposits are interpreted as the products of successive rising and lowering of the water table (static level). Radiometric ages of interstratified flowstones and speleothems show that these oscillations were active at least since 115 ky ago and finally ceased around 12 ky ago, indicated by the recurrent age obtained from uneroded capping flowstones. These long-term water table oscillations may drive paragenetic expansion of the whole cave system. Valleys, caves and other landforms in our study area are part of an ancient landscape with multiple episodes of burial and exhumation. Despite the possibility of much older sediment being preserved somewhere in the cave system, our data indicate a younger Quaternary age for the bulk of the sediment filling the study caves.

1. Introduction

Cave systems offer a unique environment for sediment transport, deposition and preservation. Because cave sediments are protected from weathering and bioturbation, caves often act as sediment repositories that may provide unique records of geomorphic events even where no river terraces can be found in the surface. Cave deposits are thus archives of landscape evolution (Anthony and Granger, 2007; Lisker et al., 2010; Wagner et al., 2011) as well as paleontology and archaeology (Moriarty et al., 2000; Piló et al., 2005; Carbonell et al., 2008; Dirks et al., 2010). They record climate and environmental changes (Moeyersons, 1997; Panno et al., 2004; Ellwood and Gose, 2006) and play an important role when trying to understand contaminant migration through karst aquifers (Mahler et al., 1999, 2007). Nevertheless, karst and cave text-books offer no consensus on describing cave sediments (White, 2007); comprehensive models summarizing clastic deposition in underground systems address specific local flow conditions (Gillieson, 1986) or are based in simplistic sedimentary variables (Bosch and White, 2007). Although there has been progress in understanding sediment transport through karst aquifer systems (Herman et al., 2012) there is still an enormous gap when compared to

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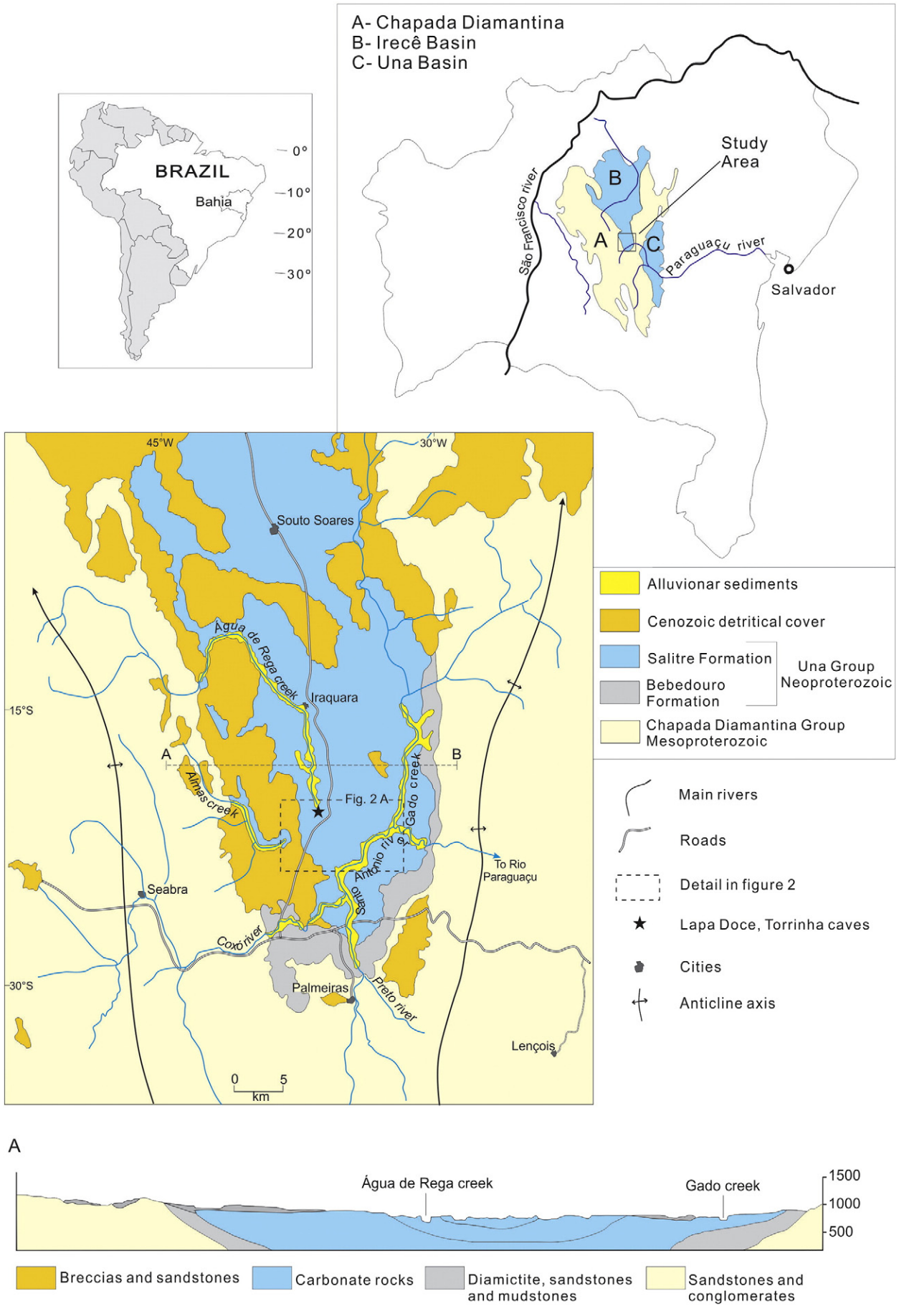
A- Chapada Diamantina
B- Irecê Basin
C- Una Basin
BRAZIL
Bahia
0°
10°
20°
30°
Study Area
São Francisco river
Paraguaçu river
Salvador
45°W
30°W
15°S
30°S
Souto Soares
Água de Rega creek
Iraquara
Fig. 2 A
Almas creek
Gado creek
Antonio river
Seabra
To Rio Paraguaçu
Coxo river
Palmeiras
Preto river
Lençois
0 5 km
Alluvionar sediments
Cenozoic detritical cover
Salitre Formation
Bebedouro Formation
Una Group Neoproterozoic
Chapada Diamantina Group Mesoproterozoic
Main rivers
Roads
Detail in figure 2
Lapa Doce, Torrinha caves
Cities
Anticline axis
A
Água de Rega creek
Gado creek
1500
1000
500
Breccias and sandstones
Carbonate rocks
Diamictite, sandstones and mudstones
Sandstones and conglomerates