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Characterizing and Modelling Fractures and Karst in Carbonate Units - The Porocarste Project

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SUMMARY

We investigated the Quaternary epigenic karst system in the Jandaíra Formation, a Turonian–Campanian carbonate platform in the Potiguar basin, northeastern Brazil. We concentrated our investigation in the vadose zone of the present-day karst, but also used borehole data. The leaching zones are preferentially concentrated along pre-solution openings composed of faults, joints, and bedding planes. These dissolved and enlarged faults and beddings form a system of caves and sinkholes, which must be included in the architecture of karst systems. This controlled-karst architecture presents a predictable geometry. This process occurs when the carbonate platform is exposed for a long period and can be thus affected by surface processes such as dissolution of erosion. The Quaternary epigenic karst features we describe may correlate with paleokarst systems in other carbonate platforms.

Introduction

The knowledge of karst systems has expanded in recent years. Yet some relevant problems remain. First, dissolution along preferential zones creates anisotropy in karst systems, which are seen as heterogeneous and complex (Hopkins, 1999). Many current karst models, however, lack the capability to predict their complexities (Casciano et al., 2004). Second, quantification of porosity and permeability is missing from many karst studies, which tend to be descriptive or qualitatively oriented. Third, scale problems may affect the investigation of karst systems. Although these systems can be observed at a scale from 10 m to 10 km, conduits less than 10 m long can hardly be mapped in sedimentary basins, even with the advent of 3D seismic data (Farzadi and Hestharnmer, 2007). Conversely, conduit architecture is difficult to detect in borehole data (Major and Holtz, 1997), which provide non-systematic and incomplete samples of karst systems. Therefore, analysis of the geometry of karst systems remains elusive in several cases where direct access to karst conduits is not possible.

Our study is a multi-scale investigation that comprises remote sensing, structural and sedimentary mapping, and petrographic/petrophysical analyses. Our main study area is the Jandaíra Formation, a Turonian-Campanian carbonate Platform in NE Brazil (Fig. 1), where we carried out remote sensing and field investigation.

In the present project, we investigated an exposed carbonate platform to assess the role of solution-enlarged faults and sedimentary facies in the evolution of surface (epigenic) karst processes. We used an integrated approach that consisted in the analysis of satellite and drone imagery, structural and facies mapping, and petrographic/petrophysical analyses of outcrop and borehole data.

Preliminary results

Data from carbonate rocks in the region point to the development of Quaternary karst systems in a variety of short periods. In the São Francisco Craton, ~1,000 km south of the study area, the major cave system of South America occurs in carbonate rocks that were drained at least by 778 ka. More precise $^{230}Th/^{234}U$ ages indicate, however, that the main periods of deposition of speleothems and travertine deposits occurred in humid periods at ~400, 145, and 20–10 ka. Most of the exposed karst system in northeastern Brazil is, therefore, Quaternary (Auler et al., 2004). The reader can refer to these studies for detailed descriptions of the Quaternary climatic conditions and chronology of the karst systems in eastern South America.

Most of the present-day epigenic karst system of the Jandaíra Formation is now dry and lies above the nearby river level in the vadose zone. This zone makes up a roughly stratiform horizon of regional extent, associated with tablelands more than 100 km long and where water inflow occurs through rainfall and flooding of the nearby rivers. We estimate the minimum thickness of this karstified–fracture zone to be ~ 30–40 m.

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The dissolution-enlarged faults and sedimentary layers exhibit two types of sediment infill. The first one includes collapse (chaotic) breccias, which are composed of fragments fallen from the damage-fault zones or cave ceilings after karstification. Collapse breccias are poorly sorted, matrix- to clast-supported sediments. Clasts vary from boulders to pebbles. The matrix is composed of silt and sand carbonate grains. The second sediment infill is composed of detrital alluvial sediments derived from

nearby streams, which were transported by traction and suspension, and deposited in solution-enlarged caves. These detrital sediments occur at the surface and in the cores.

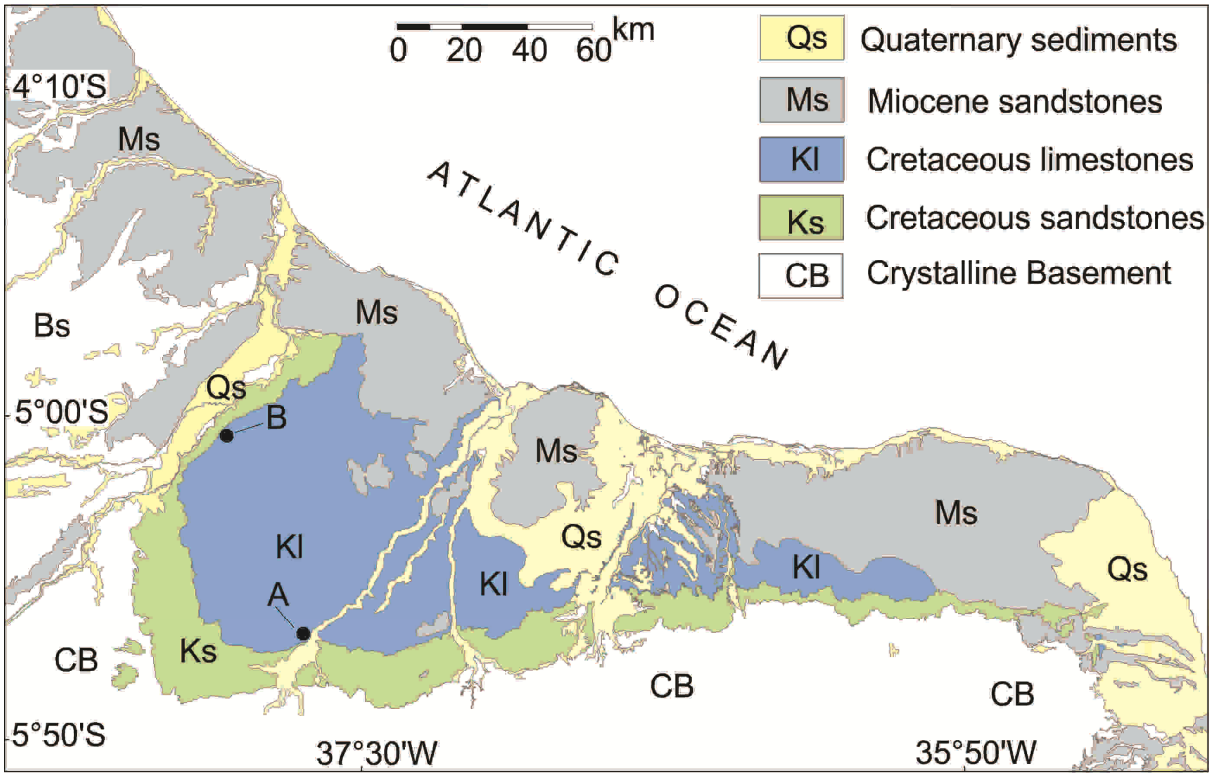

Figure 1 *The Potiguar Basin and main post-rift sedimentary units.*

The study area in the Jandaíra Formation serves as an analog of epigenic paleokarst systems for three main reasons. First, if forms the major exposed Cretaceous carbonate platform along the passive margin of South America. Karst zones roughly similar to the present one have occurred in the stratigraphic record of the Jandaíra Formation.

Second, many examples indicate that faults and preferential sedimentary beddings enlarged by karst processes are interconnected and play a determinant role in karst development. Therefore, understanding structural and carbonate facies of carbonate deposits has a significant role in predicting porosity and its connectivity in karst systems. As a general rule, in thin bedded carbonates, bedding planes seem to be important as links in large karst systems. By contrast, faults and joints are more important as links in karst systems in thick bedded carbonates.

In the Jandaíra Formation, the architecture of faults and joints allowed us to rule out any hypothesis of randomly distributed karst conduits. Little folding and nearly flat-lying layers characterize the study area. In these circumstances, faults and joints act as pathways of high permeability. Leaching mainly advanced through structural channels and through sedimentary bedding. This occurs through dozens of meters to a hundred meters according to our structural mapping. The Jandaíra Formation is a mixed cased where both tectonic and sedimentary features play an important role.

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