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Quaternary Limestones of the Pantanal Area, Brazil

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ABSTRACT

The extensive plain of the Pantanal of Western Brazil is bordered by the Serra da Bodoquena and the Maciço do Urucum, both formed in considerable part by carbonates of the Corumbá Group (Neoproterozoic-Eocambrian). This situation promoted the formation of Quaternary limestones of different origins. The oldest, probably Pleistocene, is described in the Maciço do Urucum as the Xaraiés Formation. Another comprises low elevations within the Pantanal plain itself (Pantanal do Miranda limestone). A third type (tufa) is common in the drainage system of the Serra da Bodoquena and is still in process of formation. The study of the Quaternary limestones helps to unravel part of the complex history of the Pantanal, whose area of 180,000 km^2 makes it one of the largest flooded interior plains in South America.

Key words: quaternary limestone, tufa, Pantanal, Serra da Bodoquena, Mato Grosso do Sul, Brazil.

INTRODUCTION

The Pantanal Plain is a significant physiographic region in South America located in westernmost Brazil (Mato Grosso and Mato Grosso do Sul States), extending into adjacent parts of Paraguay and Bolivia. This huge area (180,000 km^2) is characterized by the coalescence of sandy alluvial fans of Pleistocene Pantanal Formation (Del'Arco *et al.*, 1982). Periodic floods alternating with dry periods comprise a complex hydrological regime.

Flooding results mainly from drainage difficulties due to the low declivity of this region (about 0.25 cm per km from east to south-west). In spite of this flooding, the regional climate is semi-arid, with an annual water deficit of more than 300 mm (Affonsi & Camargo, 1984). The basin is endorheic because of natural barriers in the Fecho dos Morros region which define local base level.

A large part of the plain is formed by the 50,000 km^2 alluvial fan of the Rio Taquari, in the southeastern portion of the region. This alluvial fan is the main determining factor in the distribution of the rivers flowing westward into the Rio Paraguay (Ab'Saber, 1986). Paleozoic and Mesozoic sediments of the intracratonic Paraná Basin and their basement are exposed on the eastern edge of this fan. Limestones and dolomites of the Corumbá Group (Neoproterozoic) form the Maciço do Urucum and the Serra da Bodoquena at the periphery of the fan and the Serra das Araras further to the northwest (Fig. 1).

In this scenario, we can distinguish three groups of Quaternary limestones of different origins: 1) Xaraiés limestone, 2) Pantanal do Miranda limestone, and 3) Serra da Bodoquena tufa.

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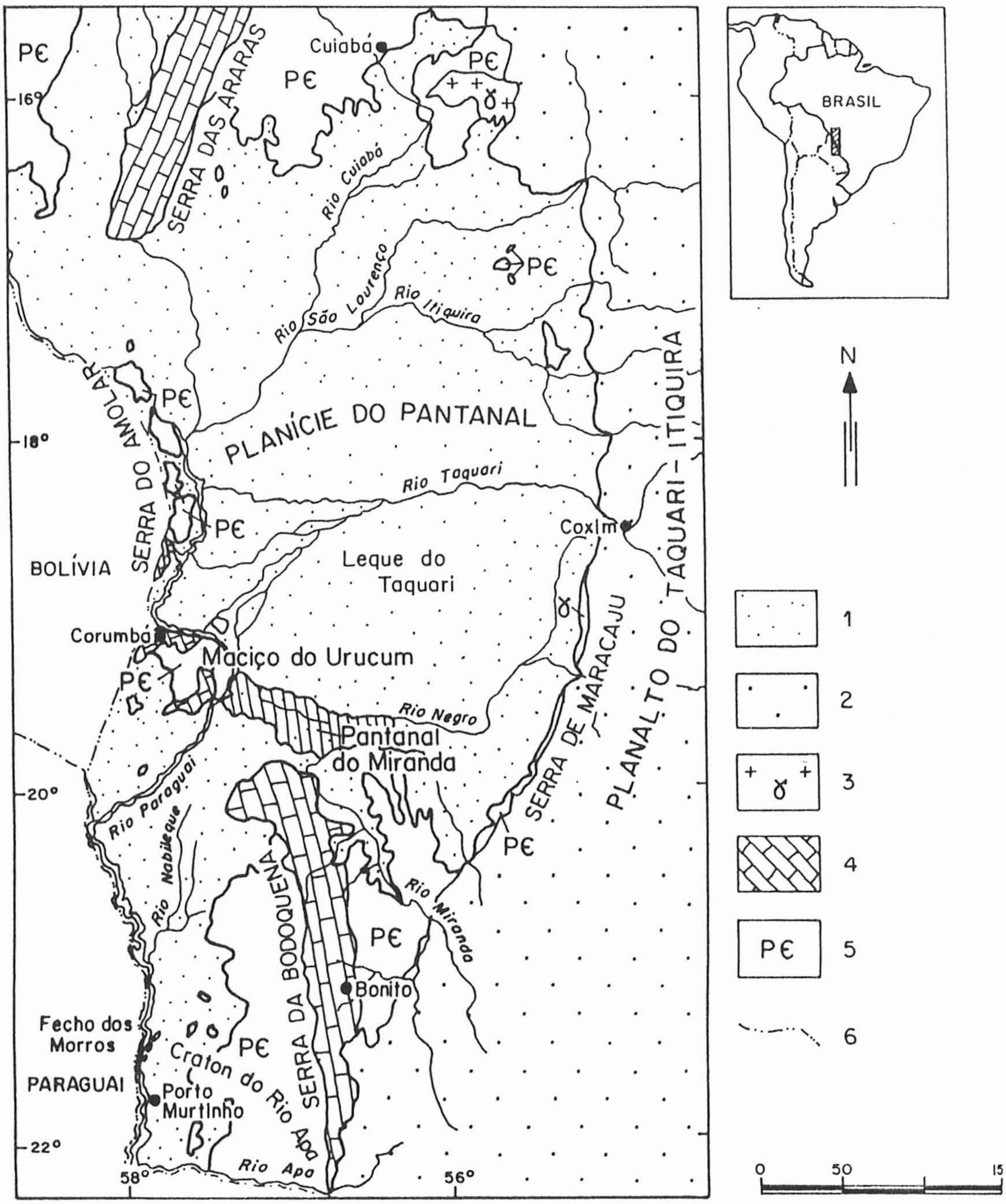


Fig. 1 — Geological map of the area. 1) Pantanal formation, 2) Paleozoic sediments of the Paraná Basin, 3) granites, 4) limestc and dolostones of the Corumbá Group (Neoproterozoic-Eocambrian), 5) undifferentiated Precambrian rocks, 6) internatio boundaries; (modified from Schobbenhaus Filho *et al.*, 1984).

XARAIÉS LIMESTONE

The Xaraiés Limestone, found mainly at the margins of the Maciço do Urucum in Corumbá (Fig. 2), originated through pedogenesis (calcretes) in talus cones formed by torrential rains in a semi-arid climate, probably during the Pleistocene (meida, 1943, 1945). Fractures in shale of Corumbá Group may be filled by Xaraiés li stones. These features are more frequent close the surface of the ground than at the depth and

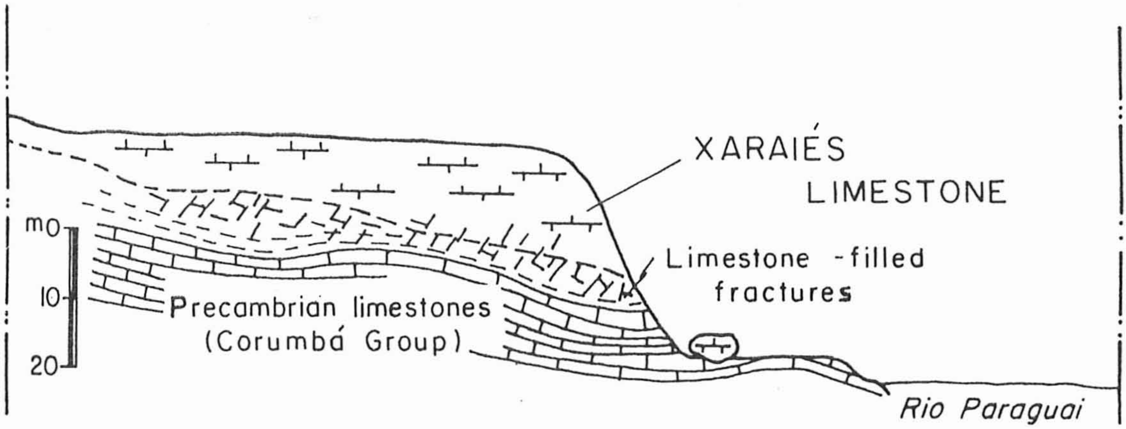


Fig. 2 — Xaraies Limestone in the Maciço do Urucum, Corumba.

limestone is more massive. The limestones may form compact, lithified beds about 10m thick as exposed in the cliffs along the Rio Paraguai. Gastropod shells are sporadically preserved within the carbonate matrix.

The Xaraiés Limestone was originally described in the Maciço do Urucum (Almeida, 1943, 1945) as the "Xaraiés Formation". Later, Nogueira *et al.* (1978) extended this denomination to include the tufas which are found in the Serra da Bodoquena. The Tufas, however, should be treated separately from the Xaraiés Formation since they are still forming along the present drainage system.

PANTANAL DO MIRANDA LIMESTONE

The Pantanal do Miranda is formed by the coalescence of the flood plains of the Aquidauana, Abobral and Miranda rivers. The Rio Miranda has bicarbonated water, as tributaries along its left bank drain carbonates of the Serra da Bodoquena. On this plain there are limestone lenses about a meter thick and, less frequently, centimetric nodules (5 × 2 cm) in clayrich sediments (Fig. 3).

The lenses of massive limestone form flat dome-shaped elevations (Fig. 4) directly above fine-grained quartz sand (Holocene alluvium). Within the limestone, subrounded quartz grains are supported by a fine calcite matrix. Additionally, entire shells of freshwater molluscs can be found in the limestone. This leads us to believe that the limestones originated by carbonate precipitation in a lacustrine environment rather than by pedogenetic process.

Carbonate also occurs as light beige porous and brittle nodules precipitated around roots on the banks of the Rio Miranda at a lower topographic level than that of the carbonate lenses mentioned above. The nodules are vertical randomly spaced (5-10 cm apart) and vertically oriented within dark brown clay.

SERRA DA BODOQUENA TUFA

The rivers from the Serra da Bodoquena have clear and bicarbonated waters, in which slightly lithified and unlithified calcareous sediments are deposited in different forms and by various processes.

The lithified tufas, which are porous and light beige in color, may form dams and waterfalls (Fig. 5). Internally, they exhibit a layered arrangement of cm-thick beds with parallel vertical filaments which are sometimes separated by a sheet of mm-thick massive limestone. Exposed moss stems may be partially covered by carbonate, which has been precipitated under the influence of diatoms and cyanobacteria attached the moss, in a manner similar to that of the tufas of the Plitvice Park in Croatia (Emeis *et al.*, 1987). In active waterfalls and slopes with sporadically dripping water tufa forms concaves shell-shaped, overhanging projections (Figs. 5, 6). Sometimes these structures collapse due to their weight.

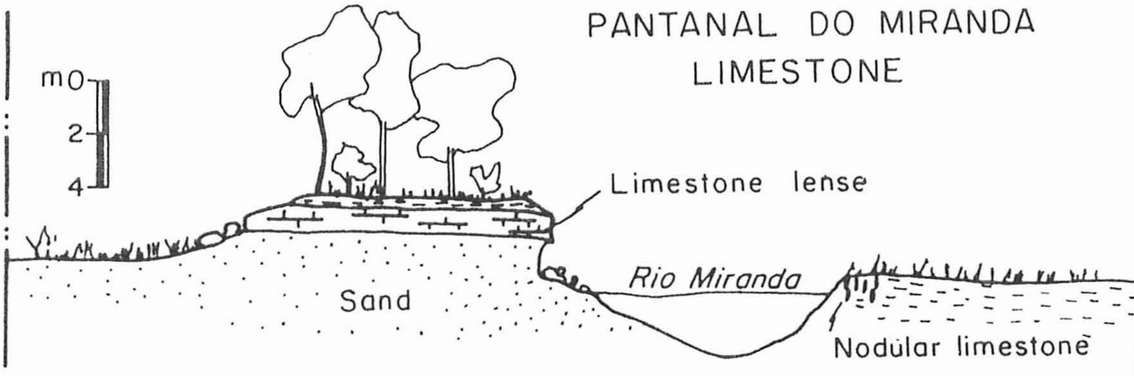


Fig. 3 — Pantanal do Miranda limestone.

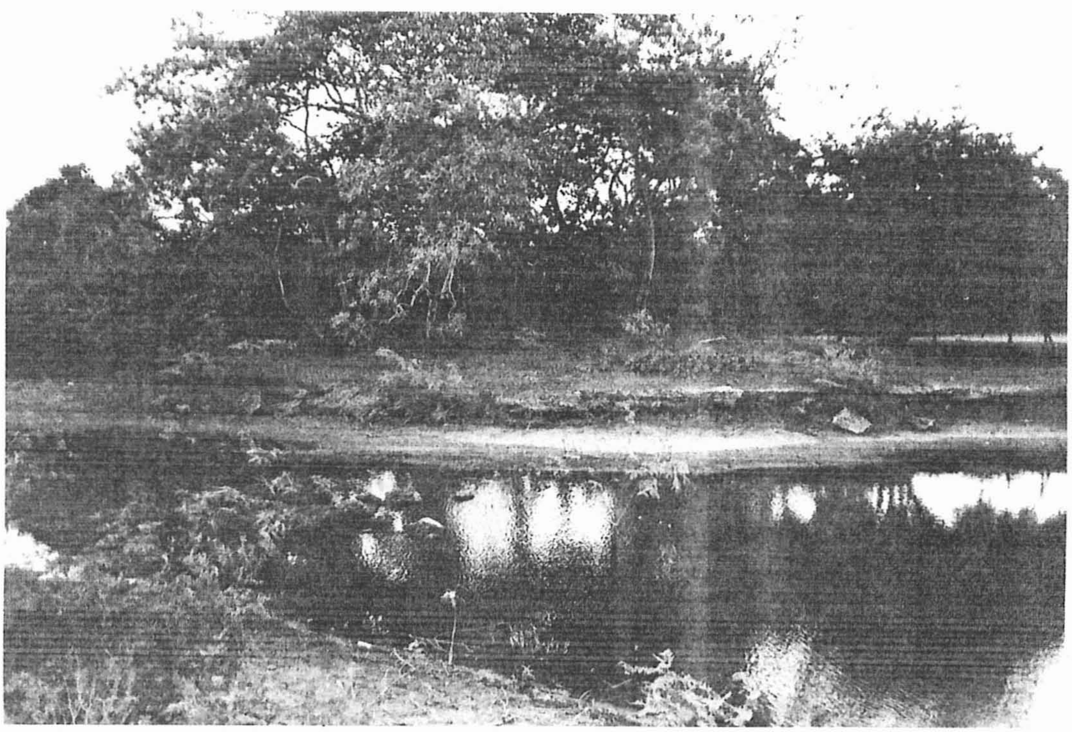


Fig. 4 — Limestone lenses near the Pantanal Research Station of the Universidade Federal de Mato Grosso do Sul (UFMS), at the margin of the Rio Miranda. The vegetation ("capão") on the lenses is rarely, if ever, flooded.

Concentrations of millimetric calcareous tubes are frequently found on the active beds of rivers. These have been originated by the incrustation and permineralization of the stems of characean algae.

The proliferation of characean algae is very common in alkaline waters where little or no free carbonic gas is available, because this gas is integrated into soluble HCO_3^- ions. To supply their CO_2 needs, characean algae absorb HCO_3^- directly. As a result, carbonate may precipitate on the surface and inside the stems of the algae, permineralizing parts of the plant.

Micritic unconsolidated deposits (0.5 to 6.0 m thick) are generally covered by layers of peat can be found in abandoned meanders of rivers which

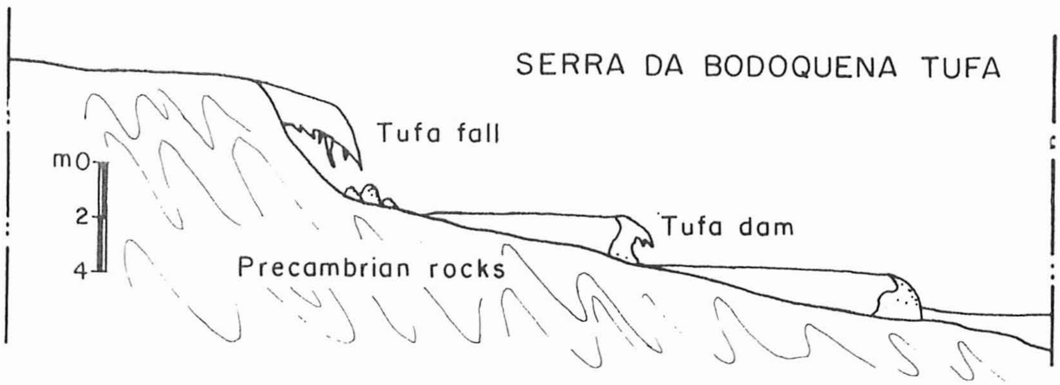


Fig. 5 -- Distribution of tufa along the active drainage in the Serra da Bodoquena.

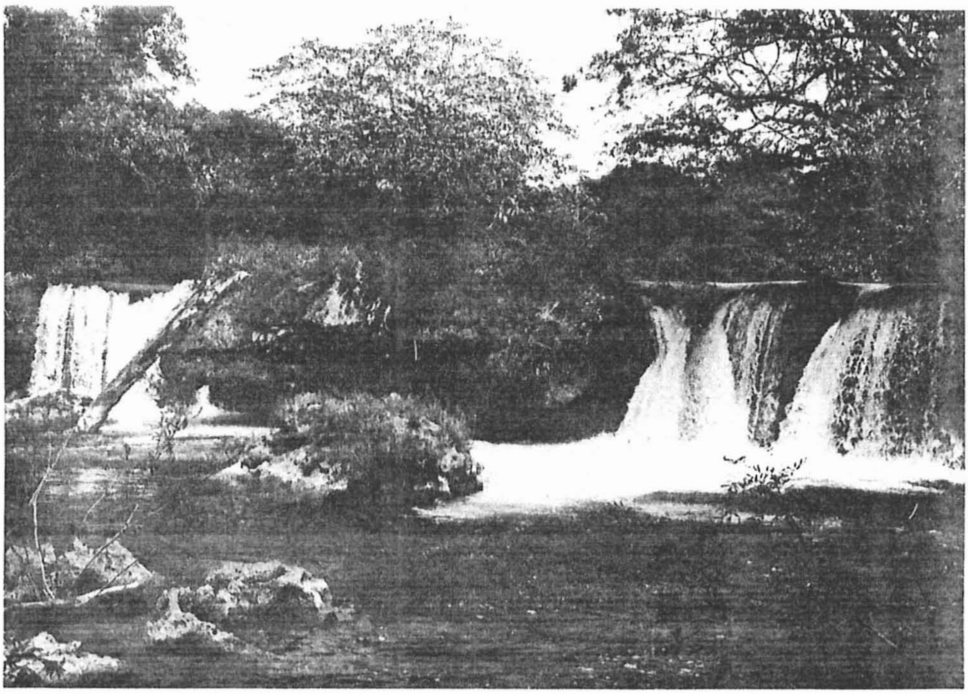


Fig. 6 — Tufa dams along Rio Formoso, Serra da Bodoquena, with concave shell-shaped overhangs.

drain the Serra da Bodoquena. In scanning electron microscopy (SEM) they show tablet shaped calcite crystals, 10 to 15 μm long and 0,5 to 1,0 μm wide (Fig. 7). Radiocarbon dating of tufa from near the Rio Salobra (Turcq *et al.*, 1987), north of Bonito, yelded ages of 5200 years B.P. for micritic tufa and 2150 years B.P. (minimum age) for the peat covering the tufa.

Similar unconsolidated micrites were described by Davis (1900, 1901) in lakes in the state of Michigan (USA), and were related to the photosynthetic activity of algae of the genus *Chara*. For alkaline lakes, Dean (1981) also considered that the most important mechanism for the precipitation of carbonate was the absorption of CO_2 by phytoplankton (bio-induced precipitation). Similar car-

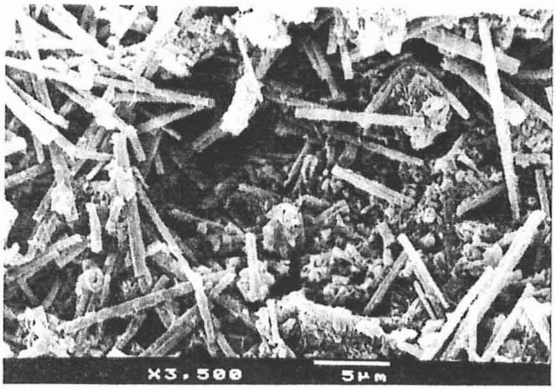


Fig. 7 — Scanning electron micrograph of powdery tufa of Rio Formoso showing calcite crystals.

bonates have been described as shallow lake-fill deposits by Chafetz & Folk (1984).

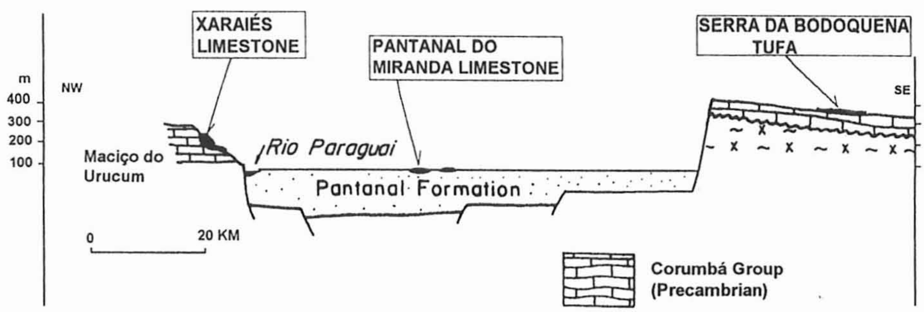
Emeis *et al.* (1987) suggested that lacustrine limestone muds are related to planktonic blooms. When this happens, the sudden increase in pH due to the absorption of carbonic gas by the algae provokes the nucleation of carbonate crystals.

It is interesting to note that the micrite remains unconsolidated. This is may be due to the presence of organic material at the top of the deposits, which acidifies the infiltrating water, sufficiently to prevent the cementation and the lithification of the tufas yet not enough to cause their dissolution.

FINAL COMMENTS

Among the deposits here described, the Xaraiés Limestone would be the oldest, probably Pleistocene. The lenses of the Pantanal do Miranda limestone would form next. The Serra da Bodoquena tufa is the most recent and it is still in formation (Fig. 8).

The Xaraiés Limestone marks a period of a semi-arid climate with torrential rains in the history of the Pantanal. The limestone lenses of Pantanal do Miranda can be interpreted as having originated in ancient lakes and did not necessarily originate under a more arid environment than at present. The fact that they are topographically higher in relation to the actual plain shows that their base level has changed. The verticalized nodules might represent a drier climate, which would have helped the formation of calcretes by capillary ascension of bicarbonate solutions. Finally, the



QUATERNARY	HOLOCENE	Serra da Bodoquena tufa Pantanal do Miranda limestone alluvium
	PLEISTOCENE	Pantanal Formation Xaraiés Formation

Fig. 8 — Distribution and suggested chronology of Quaternary limestones in the Pantanal area.

Serra da Bodoquena tufa, formed under wet climatic conditions, is related to biological activity in bicarbonated water.

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