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Anatomy and controlling factors of a Late Cretaceous Aeolian sand sheet: The Marília and the Adamantina formations, NW Bauru Basin, Brazil

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ABSTRACT

Few previous studies have given significant consideration to the palaeosols in aeolian sand sheet sedimentary successions and, mainly, to their palaeoenvironmental and stratigraphic meaning in interaction with the deposits. These themes are considered in this study that deals with the depositional architecture and the factors controlling the construction, accumulation and preservation of an ancient aeolian sand sheet, that forms part of the Adamantina and Marília formations, in the Bauru Basin (Late Cretaceous, Brazil). In the NW portion of the Bauru Basin, these two units, *ca* 220 m thick, consist of sandstone, and secondarily of sandy conglomerate and mudstone, and are characterised by vertically alternated palaeosols and deposits. Facies analyses of the deposits and macroscopic characterisation of the palaeosols in 45 outcrops were integrated with laboratory analyses that consisted in descriptions of slabs of rock samples, petrographic analyses, clay mineralogy determination, geochemical analyses of the major oxides, and micromorphological characterisation of the palaeosols.

Three architectural elements were recognised: palaeosols, wind-ripple-dominated aeolian sand sheet deposits, and ephemeral river deposits. The palaeosols constitute 66% of the entire sedimentary succession, and consist principally of Aridisols and, subordinately, of Alfisols, Vertisols, and Entisols. The wind-ripple-dominated aeolian sand sheet deposits (25%) are composed of sandstone, organised in translatent climbing wind-ripple strata, and secondarily of sandstone and mudstone deposited by infrequent floods. The ephemeral river deposits (9%) consist of sandy conglomerates 4 m thick and *ca* 2 km wide. Wind-ripple-dominated aeolian sand sheet deposits formed during relatively dry climate period on an unstable topographic surface of an aeolian sand sheet, where aeolian deposition or erosion prevailed. Palaeosols and ephemeral river deposits formed in a more humid climate period on a stable topographic surface of the aeolian sand sheet.

Six bounding surfaces permitted the subdivision of the study formations into genetic geological bodies, revealing different spatial and temporal orders. Two first order surfaces separate mature palaeosol profiles (Aridisols, Alfisols, and Vertisols) from overlying aeolian deposits or other mature palaeosol profiles. A second order surface separates immature palaeosols (Entisols) from overlying aeolian deposits. A third order surface constitutes the channel bottom. A fourth order surface is located at the bottom of flood deposits. A fifth order surface divides translatent wind-ripple.

The constructional phase of the aeolian sand sheet occurred during the relatively dry climate period, when the available sediment was supplied from the material originally deposited by rivers and stored during a more humid period (primary supply), and by soil erosion during a drier climate (secondary supply). The accumulation surface was controlled during the drier climate by cemented Bk horizons over Aridisols and by the force of the wind blowing over the other soils or deposits. Otherwise, during the more humid climate, the accumulation surface was a stabilised surface represented by the soil. Preservation was dominated by tectonically induced subsidence and burial.

1. Introduction

An aeolian sand sheet is defined as a flat or gently-undulating sandy surface above which dunes do not form (Fryberger et al., 1979; Kocurek and Nielson, 1986; Mountney, 2006); it is common in dryland areas in both hot and cold climates. The inhibition of dune formation can be influenced by sparse vegetation, high ground-water level, coarse-grained sediments, armoured or cemented surfaces, and a scarce supply and availability of sediments (Kocurek and Nielson, 1986; Breed et al., 1987).

Aeolian sand sheets form significant part of several of the world's major present-day desertic systems and constitute a portion of ergs,

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as in the case of the Namibia sand seas (Lancaster, 1994), or of other depositional systems such as alluvial fans, ephemeral rivers, playa-lakes, and beaches (Kocurek and Nielson, 1986; Breed et al., 1987; El-Baz et al., 2000). In other cases, they constitute most of the desertic area, as is the case of the Gran Desierto (Mexico) (Lancaster et al., 1987). Aeolian sand sheets commonly have a stabilised topographic surface on which soils form, leading to growth of sparse vegetation. However, they can also constitute unstable topographic surfaces where the changes are dominated by aeolian erosion or sedimentation. The depositional or erosional processes in both ancient and present-day aeolian sand sheet areas are widely described in the literature (e.g. Fryberger et al., 1979; Kocurek and Nielson, 1986; Breed et al., 1987; Langford and Chan, 1989; Trewin, 1993; Kocurek and Lancaster, 1999; El-Baz et al., 2000; Chakraborty and Chakraborty, 2001; Mountney and Russell, 2004; Scherer and Lavinia, 2005; Cain and Mountney, 2009). Nevertheless, little emphasis has been given to the phases of stability and pedogenesis in these areas (Gustavson and Wrinkler, 1988; Gustavson and Holliday, 1999) and to the study of succession, with alternating periods of topographic stability and instability (Basilici et al., 2009).

The objects of this study are the Adamantina and Marília formations (Late Cretaceous), which are the upper units of the NW portion of the Bauru Basin, located in south-east of Brazil (Fig. 1). They are interpreted in this paper as deposited in a desertic system characterised by an extensive aeolian sand sheet.

The main purposes of this study are to define an anatomic organisation and a sequential evolution of the Adamantina and Marília formations. To reach these results the specific objectives are to: (1) provide sedimentologic and palaeopedologic data about these formations; (2) define the architecture and the sequential organisation found in this aeolian sand sheet deposits; and (3) interpret the construction, accumulation and preservation of this aeolian sand sheet, on the basis of the models of Kocurek (1999), Kocurek and Lancaster (1999), and Kocurek (2003).

To reach these objectives, 13 stratigraphic sections, each 6 to 40 m thick, were measured and analysed in detail and other 32 outcrops were examined over an area of some 15,000 km^2 between the towns of Cassilândia and Quirinópolis (Fig. 1). Limited expositions of the sedimentary succession of the Adamantina and Marília formations obliged a research over an extensive area. However, substantial differences in sediments and palaeosols have never been observed, suggesting the same depositional environment developed for all the 15,000 km^2. In the field, the sediments were described according to facies analysis methods. 15 slabs of rock samples and 11 thin sections analyses of the sediments contributed to the definition of the mechanisms of transport and deposition, and petrographical characterisation. Pedological structures, horizons, roots and other biogenic traces, colour, and texture have been used to recognise and describe palaeosol profiles in the field (Birkeland, 1999; Retallack, 2001). 35 thin sections, 14 X-ray diffraction, 33 geochemical analyses of palaeosol samples, and 24 SEM analyses of clay minerals helped to distinguish the palaeosol horizons and identify the palaeosol profiles. Sediments are interpreted using comparison with analogous lithofacies and applying principles of hydraulic. The palaeosols are classified according to the US Soil Taxonomy (Soil Survey Staff, 1999). The comparison of the genetic conditions of sediments and palaeosols has been used to interpret the palaeoenvironmental characteristics, the depositional architecture, and the evolution of the aeolian sand sheet.

2. Adamantina and Marília formations

The Adamantina and Marília formations are the youngest units of the Bauru Basin (Late Cretaceous). This is the last of the great

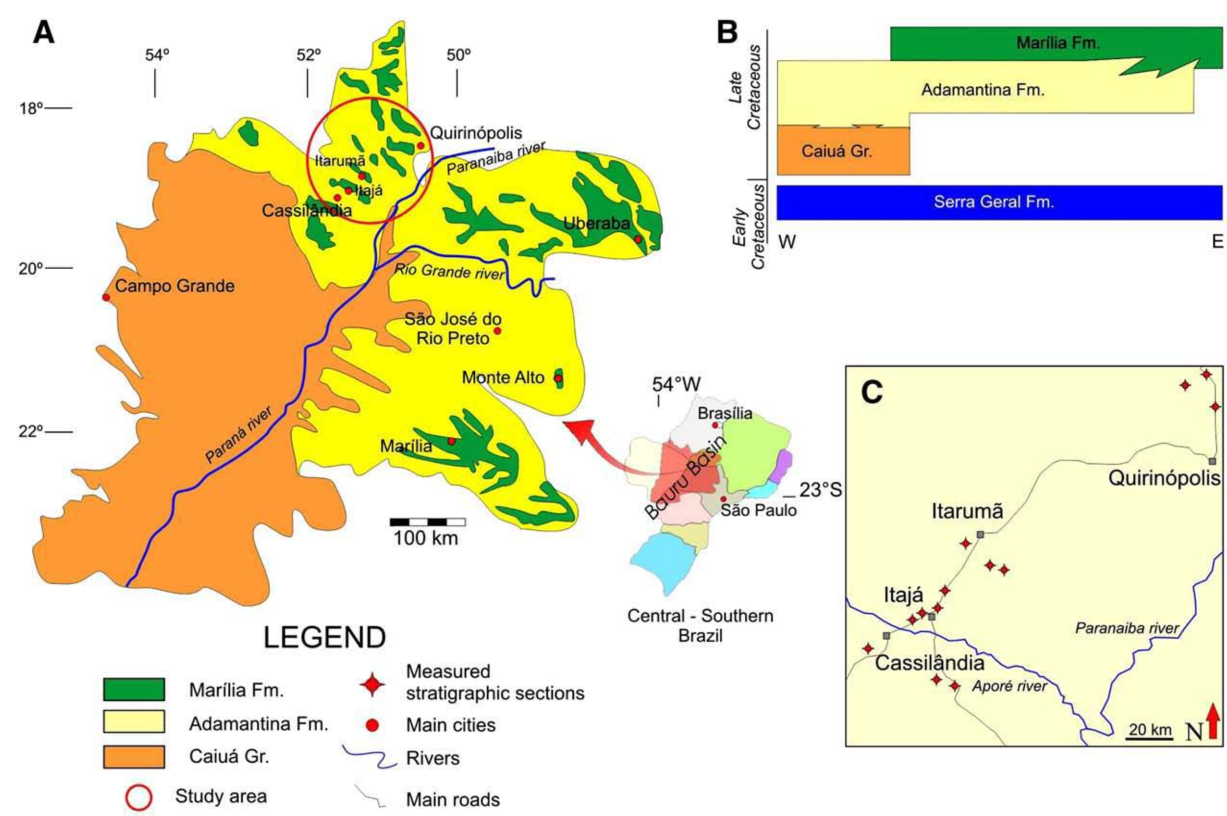

Fig. 1. (A) Simplified map of the Bauru Basin and location of the study area in the NW of the basin. Modified after Fernandes and Coimbra (1996) and CPRM — Serviço Geológico do Brasil (2004). (B) Stratigraphic synthesis of the Bauru Basin, modified after CPRM — Serviço Geológico do Brasil (2004) and Zaher et al. (2006). (C) Detailed map of the location of the 13 measured sections.