CHAPADAS: RELICT OF MID-CRETACEOUS INTERIOR SEAS IN BRAZIL (1)

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ABSTRACT In the mid-Cretaceous, particularly during Albian-Turonian time, the greatest eustatic sea level rise in Phanerozoic history triggered a global transgressive event. This resulted in sedimentary filling of then-existing intracontinental depressions. Following the Highstand Phase, the non-subsiding areas ceased receiving sediment and underwent erosion at their margins. In Brazil, these areas were subsequently uplifted, mainly in post-Neogene time, to constitute plateau-like geomorphologic units termed chapadas (e.g., Apodi, Araripe, Parecis, and Urucuia).

The relationship between the mid-Cretaceous marine transgression and the origin of chapadas has been pointed out in our previous works. Chapadas have tabular geometry, and their lithostratigraphic units are horizontal and have notable lateral continuity. Marine fossils of some strata of the chapada units reinforce this model. The only chapada that does not have marine paleontologic evidence is Parecis. However, this may simply reflect inadequate knowledge. Paleontological and paleocurrent data available point to interconnection among the chapada-bearing basins and, moreover, their connection to the Pacific and Central and South Atlantic oceans.

Keywords: Chapada, Brazil, South Atlantic, mid-Cretaceous

INTRODUCTION

Extensive plateau-like geomorphologic units, known as chapadas, occur in several regions of Brazil. Their origin has not been well understood; some authors (e.g., Ab'Sáber 1969) suggest they are products of pediplanation. Recent data (e.g., Arai *et al.* 1998, Arai 1999) relate the origin of chapadas to the mid-Cretaceous marine transgression.

The global marine transgression of the mid-Cretaceous – virtually unparalleled in the Earth's Phanerozoic history - elevated sea level to about 300 m above the present datum (Vail *et al.* 1977) and left its signature in several parts of the world. However, in Brazil there remains a considerable reluctance to accept the existence of mid-Cretaceous interior seas. Thus, most paleogeographic reconstructions of the Brazilian Cretaceous do not show any significant marine flooding of inland areas. At its maximum, the marine invasion probably produced a system of seaways extending across South America and connecting the Pacific Ocean with the North and South Atlantic oceans.

This paper aims to demonstrate that, during mid-Cretaceous (Aptian through Cenomanian) time, an interior sea developed over the area of present-day Brazil, and that chapadas represent relics of that paleo-sea.

HISTORICAL SYNOPSIS

Although the idea of Brazilian interior sea may seem audacious, even incongruous, it is not entirely new. Termier and Termier (1952, p. 326-327, carte XXVIII) presented a Late Cretaceous paleogeographic map, wherein seas designated "mers mal connues" (poorly known seas) were identified over areas corresponding to the Parnaíba, São Francisco, and Parecis basins.

Subsequently, Stokes (1965, p. 260, fig. 12.10a) depicted an extensive belt of Cretaceous marine sedimentation encompassing several Brazilian basins; viz., São Francisco, Paraná (northern part thereof), Parecis, Acre, and interior basins of northeast Brazil (Araripe, Sousa, Iguatu, etc). He suggested the connection of these basins with coeval, predominantly marine basins of Peru and Colombia.

These publications can be regarded as having pioneered the hypothesis advanced herein. However, they provided no concrete data in support to their interpretations.

Unequivocal evidence of the mid-Cretaceous presence of interior sea in Brazil is traditionally cited from the area embracing the Parnaíba and Araripe basins of northeast Brazil (Beurlen 1971, Braun 1966, Arai *et al.* 1994). Some authors also propose that these basins were connected to the Sergipe/Alagoas Basin (Silva-Santos 1991) or to the Potiguar Basin (Lima 1978, Viana 1998).

Kattah (1991) suggests more extensive development of Cretaceous interior sea. Based on the occurrence of radiolarians in the Sanfranciscan Basin, this author advocates interconnection, during Aptian time, of the Sanfranciscan, Parnaíba, Araripe, and Potiguar basins.

EVIDENCE

The presence of mid-Cretaceous interior sea in Brazil can be advocated on the grounds of geomorphological, stratigraphic, sedimentological, paleontological, and geochemical information.

Geomorphological evidence The concept that chapadas are the most conspicuous remnants of the mid-Cretaceous marine transgression is proposed by Arai *et al.* (1998), based on their tabular geometry, horizontality, and lateral extent. According to IBGE (1993), Brazil has four Cretaceous geomorphological units that constitute true chapadas: viz., Araripe, Meio-Norte, Sanfranciscan, and Parecis. The chapada of Araripe is the topographic expression of the Araripe Group, which comprises the Rio da Batateira, Santana, Arajara, and Exu formations. The Areado, Codó, and Itapecuru formations (and their correlatives) constitute the chapadas of Meio-Norte. The Chapada of São Francisco is made up of the Areado, Urucuia, and Mata da Corda formations.

The summits of the chapadas are constituted by primitive surfaces (*sensu* Fortes 1992) and represent neither erosion surfaces (pediplains) nor exhumed surfaces. They result from abrupt interruptions in deposition.

Stratigraphic evidence In several Brazilian basins, mid-Cretaceous sequences are characterized by very extensive, laterally continuous units: e.*g.*, Jaquirana Group in the Acre Basin; Alter do Chão Formation (lower part), Amazonas Basin; Grajaú/Codó/Itapecuru system, Parnaíba Basin; Alagamar/Açu/Jandaíra system, Potiguar Basin; Araripe Group, Araripe Basin; Areado/Urucuia/Mata da Corda system, Sanfranciscan Basin; and Parecis Formation, Parecis Basin. These units are coeval and were deposited during the Highstand Eustasy, and originally extended well beyond the limits of the basins in which they now occur. The sandy units capping and preserving most chapadas are considered to be fluvial; these originated by normal regression (progradation occurred under high standing sea level) which culminated in the infilling of the basins.

Isolated occurrences of strata correlative with those of the chapadas occur as small remnants on crystalline basement terranes. One of the more recently reported occurrences of such vestiges, correlated with the Abaeté Formation (=Abaeté Member of Areado Formation) of the Sanfranciscan Basin, occurs in the vicinity of Brasília-DF (Campos *et al.* 1999).

Sedimentological evidence Facies typical of fluvial systems are conspicuous within the chapada strata, but recent studies reveal features of transitional and marine environments in some of the cited above units (e.g., Souto *et al.* 1990, Anaisse Jr. *et al.* 1999, Dias-Lima and Rossetti 1999). In the Sanfranciscan Basin, Barcelos and Suguio (1981) documented sedimentological characteristics consonant with shallow marine deposition in some samples of the Areado and Urucuia formations. Castro (1996), who reported sedimentary structures suggestive of a transgressive, marginal-marine setting associated with cherty strata reaffirms the marine nature of the Areado Formation. Primary structures in the regressive caprock units of the Araripe (Exu Formation) and Sanfranciscan (Urucuia Formation) Basins indicate that paleocurrents flowed respectively to the west (Assine 1997) and southwest (Campos and Dardenne 1997), implying in the existence of a westerly major marine depositional basin in mid-Cretaceous.

Paleontological evidence Mid-Cretaceous marine fossils occur in several Albian-Aptian formations of interior Brazil. The following inventory is based on records by Lima (1979a,b; 1982), except where specifically credited to other authors.

AREADO FORMATION: fishes, dinoflagellates (Arai, *apud* Kattah 1991), radiolarians (Kattah 1991, Kattah and Koutsoukos 1992, Pessagno and Dias-Brito 1996, Dias-Brito *et al.* 1999), and

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foraminifers (Dias-Brito *et al.* 1999).
CODÓ FORMATION: fishes, mollusks, dinoflagellates (Arai, *apud* Paz and Rossetti 1999; Antonioli *et al.* 1999), and foraminifers.

SANTANA FORMATION: fishes, mollusks, dinoflagellates, foraminifers (Arai and Coimbra 1990), echinoids, and turtles.

The marine fossils occur in transgressive units that characterize the basal portions of the cited above formations. Lithology becomes progressively more sandy upward, concomitant with increasing fluvial influence, thereby diminishing the likelihood of recovering body fossils. However, trace fossils can be found in the regressive deposits. For example, the Arajara Formation (="Exu inferior", Araripe Basin) contains *Diplocraterion* (unpublished data), *Skolithos*, and *Taenidium*. Besides two later genera, Fernandes *et al.* (1998) report other indeterminate trace fossils. This formation has several intervals rich in trace fossils, suggesting deposition under neritic conditions.

Geochemical evidence The most convincing geochemical data are of gypsite/anhydrite beds of the Codó Formation. According to Rodrigues (1995), these present $^{87}Sr/^{86}Sr$ isotopic ratios between 0.708000 and 0.708800, compatible with a marine origin. The shales just below the gypsite/anhydrite represent the maximum flooding surface of the Codó Formation, whose biomarkers are marine (e.g., dinosterane e C_{30} sterane). The same biomarkers were found in the transgressive tract of the Alagamar Formation (Potiguar Basin), represented by the Ponta do Tubarão beds and by the basal unit of the Galhinhos Shale (Vasconcelos 1995).

DISCUSSION AND CONCLUSION Besides the eustatic rise of the sea level, the geodynamic situation immediately prior to the Brazil-Africa separation - involving depression of the continental crust under an extensional tectonic regime - would probably, in itself, have promoted invasion by an extensive interior sea during the latest Early Cretaceous (Aptian).

The subsequent eustatic sea level drop had extensive erosional consequences. The initial major decline occurred at the end of Albian, producing the worldwide sequence boundary that is evident at the upper Albian-lower Cenomanian transition (Pereira 1996). This event resulted in a rapid influx of coarse clastic sediments into basins of the continental margin, and, thereby, the formation of important turbiditic petroleum reservoirs (e.g., Namorado Sandstone of the Campos Basin).

As shown by figure 1, there is a relationship between the areas of chapadas and the Mesoproterozoic Domain. Further investigation of this relationship, added to study of the origin of Brazilian kimberlites (which seem to occur in areas adjacent to chapadas), could well improve the understanding of the influence of the crystalline basement on subsidence and uplift of the cratonic area. This would, moreover, improve the knowledge of the original geographic extent of the now-denuded sedimentary cover.

Among the basin relics represented by the chapadas, only the Parecis Basin does not, as yet, provide any concrete evidence of association with the mid-Cretaceous interior sea. Its inclusion in that paleogeographic scenario is currently based exclusively on geomorphological and stratigraphic characteristics. However, the lack of evidence may simply reflect insufficient knowledge of the Parecis Basin. Siliceous concretions are reportedly common in sandstones of the Parecis Formation (Oliveira 1915, p. 33, *apud* Santos and Loguercio 1984, p. 122). It is possible that these are actually chert bodies containing radiolarians similar to those known from the Sanfranciscan Basin.

Figure 1 – Possible extent of mid-Cretaceous interior sea in Brazil and its relationship with occurrences of present-day chapadas and the Mesoproterozoic Domain (the latter after Brito Neves et al. 1996). Legend: 1. Mid-Cretaceous interior seas, 2. Cretaceous chapadas, 3. Mesoproterozoic domain.

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