

THE CRETACEOUS SANFRANCISCAN BASIN, EASTERN PLATEAU OF BRAZIL

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ABSTRACT The Cretaceous Sanfranciscan Basin, located in the eastern plateau of Brazil, is one of the most impressive continental basin of the country, because of its complex and exceptional association of sedimentary and volcanic rocks. The presence of macro and microfossils, large diamonds and a surprising occurrence of a radiolarian fauna present in chert layers intercalated in eolian sandstones form very interesting topics on the tectonic and paleogeography aspects of the Gondwana during the Cretaceous.

The basin has a south-north elongated shape, from the west of Minas Gerais State (latitude 20° S) to the southern Tocantins, Maranhão and Piauí States (latitude 10° S). It is approximately 1100 km long and has a maximum width of about 270 Km (Fig 1). It occurs in a corridor between 44° and 47° of longitude W. It was filled with Areado and Mata da Corda Groups, and lies over, from south to north, low-grade metamorphic sediments of the Bambuí Group (Upper Proterozoic), Permo-Carboniferous glaciogenic sediments of Santa Fé Group, Archean granitoids of the regional basement and sedimentary rocks of the Paleozoic Parnaíba Basin, in its outermost northern border.

The early Cretaceous Areado Group has 200 m of maximum thickness. It lies over older rocks along a regional disconformity and comprises a basal conglomerate with transported ventifacts deposited in a desert environment, associated to fine-grained lacustrine sediments and eolian and fluviodeltaic sandstones of the Três Barras Formation.

The late Cretaceous Mata da Corda Group has 230 m of maximum thickness. It lies over the Areado Group along a local unconformity, and is composed by ultramafic alkaline rocks and volcanoclastic rocks of the Patos Formation.

Above the latitude 17°S until the north of the basin, occur the Urucua Formation, considered by some authors as part of this formation (Braun 1970, Grossi Sad et al. 1971). It consists of a basal conglomerate with transported ventifacts, lacustrine, eolian and fluvio deltaic sediments. This sequence is very similar to those of the Areado Group and, as will be shown later, there is the possibility of this formation to be part of the early Cretaceous Areado Group and not part of the Mata da Corda Group.

Keywords: Sanfranciscan Basin, Cretaceous continental sedimentation, paleoclimates, paleodesert environment, epiclastic rocks, siliciclastic rocks, alkaline rocks

TECTONIC FRAMEWORK The tectonic framework of the Sanfranciscan Basin is not yet well defined, and large areas still remains without specific studies. The southern Sanfranciscan Basin in the western Minas Gerais state (between latitude 18° 00' and 20° 00' S and longitude 46° 00' W) is positioned at the east border of the Alto do Parnaíba Uplift, a S-N elongated tectonic feature.

This arch was active during the Cretaceous and originated depressions which formed on the western side (filled by Cretaceous sediments and lavas of the Paraná Basin) and on the eastern side, filled by the studied Cretaceous sediments and lavas of the Sanfranciscan Basin. The eastern marginal depression was interpreted by Hasui & Haralyi (1991), as developed under extensional regime, with reactivation of N-S major faults, one transfer fault and many NNE-SSW small accommodation faults.

The Alto do Parnaíba Uplift and the Sanfranciscan Basin were the places of alkaline intrusions and kimberlites diatremes, which represents the Alto do Parnaíba Alkaline-Kimberlite Province. Bouguer anomaly data reported by Hasui and Haralyi (1991) indicate the presence of important lineaments of a NW/SE set, crossing the southwestern half of the arch. The tectonic development was aborted during the Late Cretaceous and the basin is now elevated at about 1100-1150 m.

At the north, in the southwestern Tocantins State (12° 00' latitude S and 46° 30' longitude W), the Urucua Formation overlies metasediments and granitoids rocks of the basement. Borges *et al.* (1992), described this part of the basin as a hemi-graben with NNW-SSE antithetic normal faults and NE-SW transfer faults, mostly of dextral type. The normal faults form an imbricate, listric fan, plunging toward the east, and developed through foot-wall collapse by oblique N50°E extension. According to Fleicher (1998), all these observations on the tectonic of the Sanfranciscana Basin fit very well into a model of successive small grabens filled with sediments.

STRATIGRAPHY OF THE BASIN AREADO GROUP ABAETÉ FORMATION

It is represented mainly by conglomerates and sandstones, formed in desert environments. It was here divided in two facies:

Carmo Facies Was deposited by alluvial fans or torrential fluvial streams of wadi-type, in the southern part of the basin, near scarps of the south and southwestern borders of the basin. It consists of a 9 m of maximum thickness of petromictic rock, matrix-supported, formed mainly by fragments of pebbles or cobbles of metasilstone, quartz, quartzite, limestone, silcrete and granitoid rocks. The rock displays transported ventifact-like clasts. Its matrix is formed by rounded fragments of metasilstone of sand-size, locally cemented by authigenic calcite.

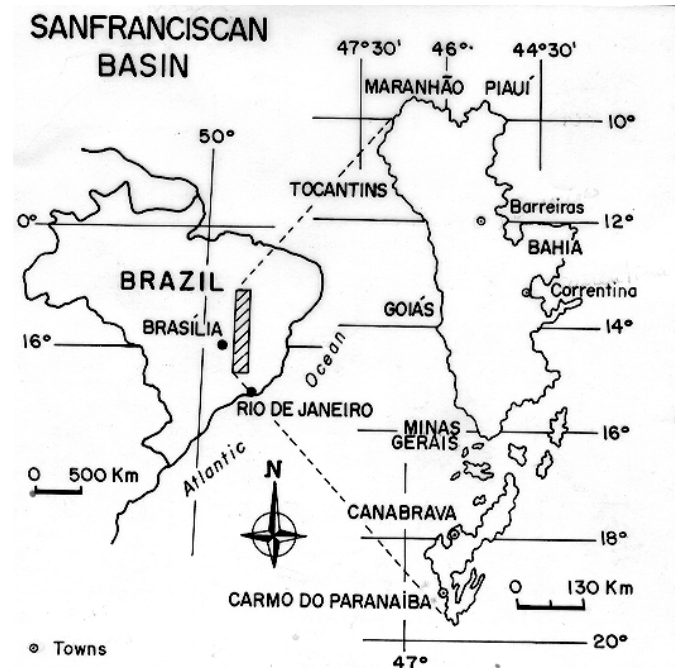


Figure 1

The sedimentation filled depressions, in arid or semi-arid climate. Its origin is related to a Jurassic-Cretaceous regional uplift which affected and old and extensive denudation surface of the Gondwanaland, stabilized since the early Triassic. In the southern part of the basin its thickness varies from a few decimeters to a maximum of 8 meters. Cross-bedding in associated sandstone indicates a paleoflow direction approximately from south to north. Locally this conglomerate is affected by north-south inverse faults showing tectonic vergence toward east, from the Alto do Parnaíba Uplift to the São Francisco Craton. The top of the conglomerate is normally covered by a level of caliche of hard-pan type with plant microfossils.

Canabrava Facies This facies represents a northern continuity of the basal conglomerates of the Carmo Facies. It was developed in a flatter surface than the Carmo's area and the deposits were formed by a very large fluvial braided system, in the central part of the basin. It is a clast-supported conglomerate, with very well-rounded pebbles and

cobbles of quartzite, with lenses of red sandstones associated. Directional structures like imbrication of clasts and cross-bedding in sands and gravels also indicate sense of paleoflow approximately from south to north. This conglomerate seems to have a low diamond content. Tompkins and Gonzaga (1989), Gonzaga *et al.* (1994) and Campos and Dardenne (1995) suggest that these gems were originated from the São Francisco Craton, positioned underneath and at the eastern side of the basin. These gems would have been transported to the basin by late Proterozoic and Permian-Carboniferous glaciation events.

The maximum thickness is 40 m near Canabrava town. General geologic features of this conglomerate were reported by Campos and Dardenne (1994). In the north, between the latitudes 11°N and 10°N, this facies also exhibits a poor content in diamond (Chaves 1991).

QUIRICÓ FORMATION These Aptian lacustrine sediments cover a large area of occurrence, from south to north. They are fine-grained sandstones, mudstones, marls and limestones with intercalated caliche levels of hardpan type.

They have a maximum thickness of 60 m and are rich in depositional structures and syngenetic deformations. The fossiliferous content are ostracoda (Barbosa *et al.* 1971; Sgarbi 1989, 1997; Arai *et al.* 1995), conchostraca faunulas (Cardoso 1971), plant remains and pollens (Duarte 1968; Arai *et al.* 1995) and fish-bones fragments of *Dastilbe Moraensi* (Santos 1955, 1985). Carvalho *et al.* (1995) described bone fragments of *Coelacanth Mawsonia*, a freshwater and giant fish which represents, after Wenz (1980), the third occurrence in Brazil. There are also four occurrences in Africa and this fact is an important indication of the faunal identity between Brazil and Africa during early Cretaceous.

Chemical analysis indicate that these lacustrine sediments have negative correlation between SiO₂ and CaO, and the generally high B (180 ppm) contents suggest a shallow lake with high evaporation rate. Carbon and oxygen isotope data of carbonates ($\delta^{18}\text{O}$ between -1.0 ‰ and +1.0 ‰ and $\delta^{13}\text{C}$ between -2.0 ‰ and -2.5 ‰) also indicate also that the sediments were formed in a continental evaporitic lake, with decrease in salinity from the bottom to the top of the sequence (Sgarbi *et al.* 1993).

TRÊS BARRAS FORMATION Its is divided in aeolian and fluviodeltaic sandstones. The fluviodeltaic terms occur as small Gilbert-like deltaic bodies superimposed on the lacustrine Quiricó sequence, with 20-30 m of maximum thickness. The cross-bedding assembly shows sense of transport from NE to SW and the sandstones exhibit a poorly-sorted, fine to medium-grained framework in a mud-size interstitial ground mass. They have a subarkose modal composition and exhibit the presence of K-feldspar overgrowths (sanidine and adularia) developed in detrital microcline and orthoclase assembly (Sgarbi 1989, De Ros *et al.* 1994, Sgarbi 1996). Bulk chemical analyses by ICP show that the rock have a abnormally high potassium content, the compositional Na₂O/K₂O ratio is very low and lies outside the range for typical subarkose and arkose reported in the literature (Sgarbi and De Ros 1994).

The eolian sandstones have a maximum thickness of 70 m. Large tangential base cross-beddings show the direction of transport from south to north and from west to east. It is formed by well-rounded medium size of frosted quartz and K-feldspar grains, exhibiting a well-sorted and bimodal granulometric distribution.

They also show, as the fluviodeltaic sandstones of this Formation, extensive cementation by authigenic K-feldspar (Sgarbi 1996).

Kattah (1991) registered the occurrence of a radiolarian fauna and sponge spicules, in thin levels of chert intercalated in these eolian sandstones. How marine fossils are present into a continental sequence in central Brazil? It is a surprising geologic puzzle, with many and large paleogeographic implications, with interest for the geology of the Gondwana and the opening of the South Atlantic ocean. To answer the question Pessagno and Dias-Brito (1996) and Dias-Brito *et al.* (1999) have made considerable efforts to elucidate this question; however the problem still persists.

MATA DA CORDA GROUP PATOS FORMATION It is the basal unit of the Group and consists of ultrabasic, alkaline, potassic to ultrapotassic lavas dated (at 80-87 My ($^{40}\text{K}/^{40}\text{Ar}$) (Hasui and Cordani 1968, Ulbrich and Gomes 1981), compatible to $\text{Ar}^{40}/\text{Ar}^{39}$ data reported by Gibson *et al.* (1995). The lava crops out in the southern part of the basin as discontinuous small flow which are commonly highly weathered. The presence of kalsilite in these rocks (Sgarbi 1991, Sgarbi and Valença 1993) makes these rocks chemically and

petrographically close to the kamafugitic rocks of Toro-Ankole, SW Uganda and San Venanzo area, Italy.

This volcanic alkaline province of the Sanfranciscan Basin also includes intrusive associations of kimberlite, carbonatite and lamproite (Leonardos and Meyer 1991, Leonardos *et al.* 1991, Bizzi 1993).

The area where the Areado and Mata da Corda Group occur represents one of the most important diamond provinces of the country, the Alto do Paranaíba Province. The Patos volcanism seems to have been the responsible for the diamonds historically found in this province in recent fluvial deposits, and exceptionally in late Cretaceous sedimentary rocks of the Romaria Mine. Corroborating this idea, the first diamond prospect of the country in kimberlitic rocks - the Serra da Canastra pilot plant - was recently opened in the region (Jornal Alto São Francisco, 1999).

Capacete Formation It consists of epiclastic conglomerates and sandstones deposited by alluvial fan and fluvial streams, and pyroclastic rocks, which occurs in the southern part of the basin. These rocks are mainly represented by weathering products of the volcanic rocks of the Patos Formation.

These rocks, with a maximum thickness of 150 m form the upper portion of the Mata da Corda Plateau, a extensive and flattened surface actually worked for large scale agriculture devices. The soil originated contain large amounts of maghemite former magnetite, present as reservoir of micro-nutrients for the plants (Ferreira *et al.* 1995; Silva *et al.* 1995)

Urucuia Formation It consists of muddy sandstones formed in fluvial and lacustrine environments, with intercalated conglomerate lenses and mud levels. Eolian sandstones were described too. The Formation also displays conglomerate with ventifacts deposited in an arid climate and overlies the Areado Group. It shows in the central do northern parts of the basin, a maximum thickness of 360 m (western Bahia State). This sequence is unfossiliferous and there is not any dating focussing it.

This basal conglomerate (as the Canabrava Facies of the Abaeté Formation) is diamond-bearing, however, at very low grades. Braun. (1970) and Grossi Sad *et al.* (1971) have interpreted this sequence as a lateral facies variation of the Capacete Formation of the Mata da Corda Group, based in the regional geomorphologic pattern. On the other hand, Pedrosa Soares *et al.* (1997) interpreted this Formation as an individual sedimentary sequence, not belongin to the Areado and Mata da Corda Groups.

However, investigations focusing this sequence in northern Minas Gerais (this paper) have shown that there is no differences between this Formation and the Areado Group. Their geomorphologic patterns, lithologic association and sedimentary environments are the same of the Areado Formation. No unconformity was observed between them and they probably form the same chronostratigraphic unit. Corroborating this point of view, Campbell *et al.* (1942) and Borges (1991), did not describe any clear disconformity in these sediments studied in a northern area of the basin.

CORRELATIVE CRETACEOUS CONTINENTAL DEPOSITS IN BRAZIL AND AFRICA

Sedimentary sequences similar to the ones of the Sanfranciscana Basin occur in the western and central parts of the African Continent (Angola, Zaire and Central African Republic). Both areas probably have similar geotectonic origin. Ages and lithologies are also similar. According to Chaves (1991), the correlative sequences are:

a) Early Cretaceous Continental Intercalate System (Angola) and Lualaba Series (Congo), (prekimberlite magmatism of the region), are formed by sediments of fluvial and lacustrine environments, and are similar to the Areado Group (also prealkaline-ultramafic magmatism of the Sanfranciscan Basin).

Late Cretaceous Calonda Formation (Angola) and Kwango Series (Central African Republic), (post-kimberlite magmatism of the region), are formed by a basal epiclastic and diamoniferous conglomerate of alluvial-fan or fluvial-lacustrine origin, and are similar to the Capacete Formation of the Mata da Corda Group (also postalkaline magmatism of the Sanfranciscan Basin).

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