The Phanerozoic Tectonic Evolution of the Western Minas Gerais State *

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(With 2 text-figures)

INTRODUCTION

Between the borders of the Paraná and Sanfranciscana basins (LADEIRA *et al.*, *1971*) occurs a strip of intensely deformed precambrian rocks metamorphosed in the grenschist and amphibolite facies. These precambrian rocks have been included in the Bambuí, Ibiá, Canastra and Araxá Groups and in a more ancient basement (BARBOSA *et al.*, 1970). In a general view, the precambrian structures are aligned NW-SE at the Southern Goiás and Western Minas Gerais States.

The tectonic behavior of this region during Mesozoic times was firstly observed by BRAJNIKOV (1953), who admitted the existente of a horst (Serra dos Cristais Horst) and a graben (Goiânia Trench) paired longitudinally. This two unities were not comproved, but other authors are unanimous about the ascensional behavior of that strip which separates the two sedimentary basins and therefore was named as Quebra-Anzol Corridor (HASUI AND PENALVA, 1970), Alto Paranaíba Anteclesis (SAD *et al.*, 1971), Alto Paranaíba Arch (LADEIRA *et al.*, 1971) and Canastra Arch (SUGUIO, 1973).

The activity of this strip is also known during the Paleozoic, when it composed the Goiânia Arch (MESNER AND WOOLDRIDGE, 1964), Canastra Arch (NORTHFLEET *et al.*, 1969) or Três Lagoas Arch (RAMOS 1970).

Several researches about the geology of the Western Minas Gerais were accomplished during the last decade. The assemblage of the obtained data permits the general analysis of the tectonic evolution of the area between the Paraná and Sanfranciscana basins, which is the scope of the present paper.

ANALYSIS OF THE GEOLOGICAL DATA

The dynamic role of that strip during the Paleozoic was related by MESNER AND WOOLDRIDGE (1964), NORTHFLEET *el al.*, (1969), RAMOS (1970) and FÚLFARO (1971). Figure 1-A shows the isopachs of the Paraná, Tubarão and Passa-Dois Groups and figure 2-A presents the succession of the strata. It seems to be clear a flexural behavior controlled by the precambrian structural trends, and not an arch-like behavior of the Triângulo Mineiro area. To avoid a desnecessary multiplication of names, we prefer to maintain the designation Goiânia to the flexure.

It was during the end of the Jurassic and the Cretaceous when the sedimentary and magmatic processes related to the Wealdenian Reactivation of the South American Platform (ALMEIDA, 1967) took place in the Triângulo Mineiro, Alto Paranaíba and the southeastern Goiás. This region adquired a

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Figure 1 -

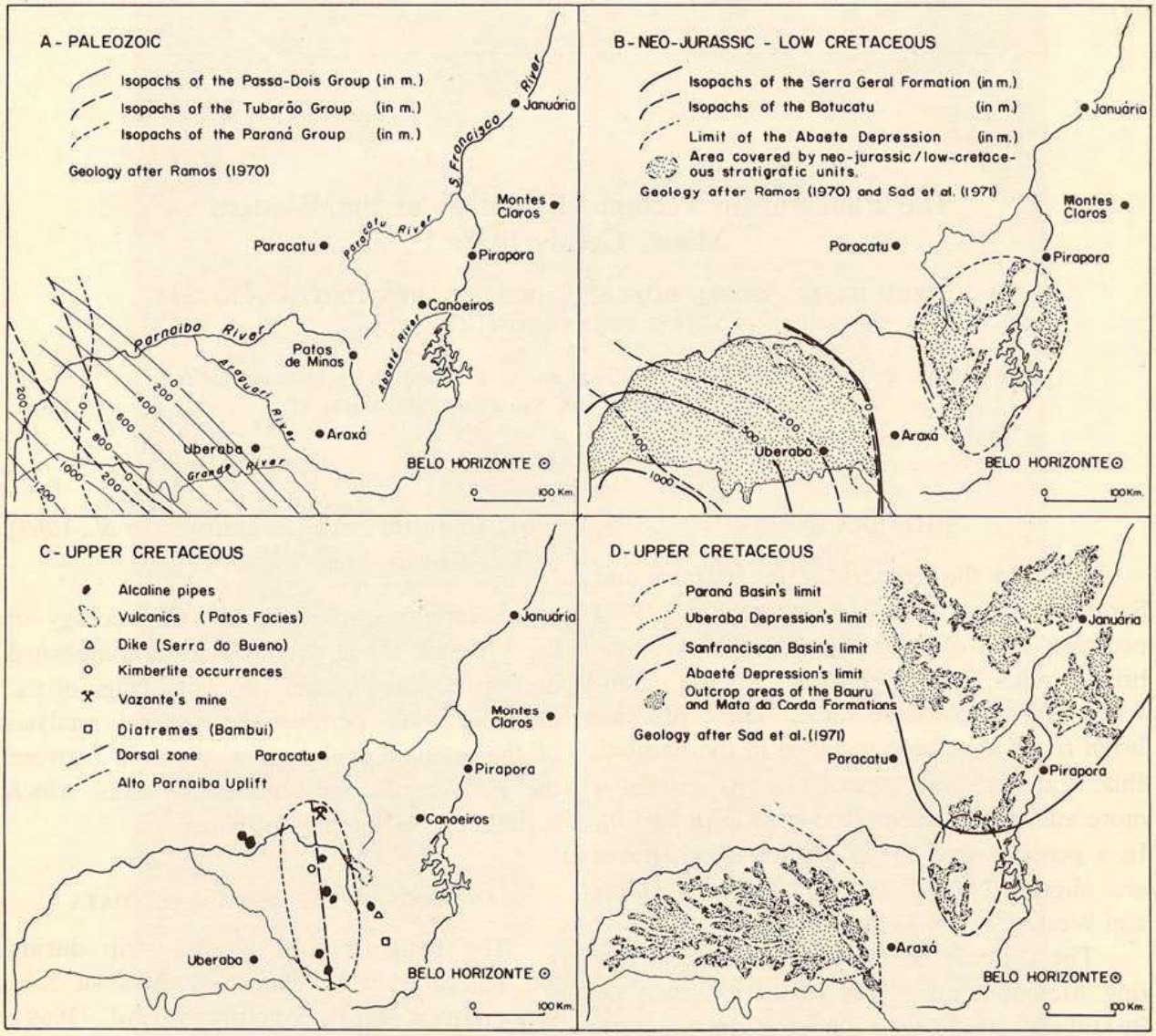

FIG. 1 — Tectonic Evolution of West Minas Gerais.

remarkable dynamism vinculated to that tectonic event.

The São Bento Group, represented by the Botucatu and Serra Geral Formations, is the first stratigraphic unit belonging to this phase. The Botucatu Formation overlies precambrian rocks unconformably and shows exposures with a thickness of some tenths of meters. The Serra Geral Formation, constituted by basalts and intercalated sandstones (Botucatu type) covers the further one and generally overlies the precambrian basement. The K/Ar age of this sequence was determined by AMARAL *el al.* (1966) as neo-jurassic to Eo-Cretaceous (140-100 m. y.) At this time, the NW-SE basin border was controlled by a reactivation of the Goiânia Flexure in the Southeastern Goiás. In Western Minas Gerais, the basin edge changes its orientation to a general NNE-SSW direction. There, the flexuring was substituted by faulted blocks movements and we can observe a quicker thinning of the stratigraphic units. These movements occurred by reactivation of the ancient faults mapped by BARBOSA *et al.* (1970). Figure 1-B shows the distribution of the São

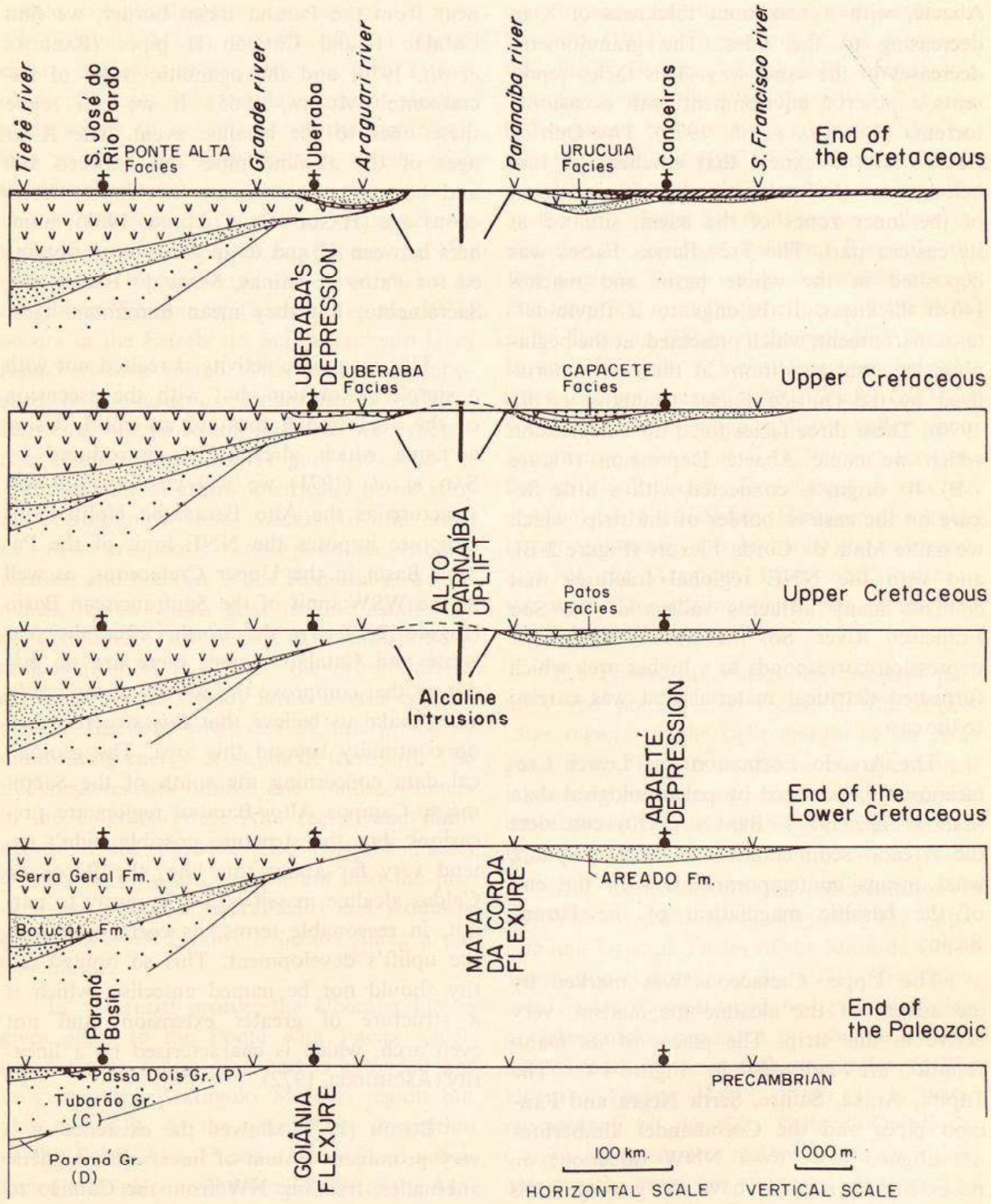

FIG. 2 — Tectonic Evolution as Seen in the Uberaba Canoeiros Geological Section.

Bento Group and its thickness. Figure 2-B shows the correspondent vertical section.

Also in the Lower Cretaceous the Areado Formation was accumulated in the Sanfranciscan Basin (LADEIRA *et al.*, 1971). It begins with the Abaeté Facies, which is an unit discontinuously distributed (paleo-channels) between São Gonçalo do Abaeté and

Abaeté, with a maximum thickness of 8 m decreasing to the sides. The granulometry decreases in the same way. This facies represents a desertic environment with occasional torrents (BARBOSA *et al.*, 1970). The Quiricó Facies, with thickness that reaches 100 mm belongs to the paleo-lacustral environment of the inner zones of the basin, situated at its eastern part. The Três Barras Facies was deposited in the whole basin and reaches 140 m thickness. It belongs to a fluvio-deltaic environment, which presented, at the beginning, lacustral conditions at the east materialized by the Quiricó Facies (BARBOSA *et al.*, 1970). These three facies filled up a depression which we name Abaeté Depression (Figure 1-B). Its origin is connected with a little flexure on the eastern border of the strip, which we name Mata da Corda Flexure (Figure 2-B), and with the NNE regional fractures that controls many affluents valleys of the São Francisco River. So, the western border of depression corresponds to a higher area which furnished detritical material that was carried to the east.

The Areado Formation has Lower Cretaceous age, as stated by paleontological data (SAD *et al.*, 1971). BRAUN (1970) considers the Areado sedimentation as Albian-Aptian, what means contemporaneous with the end of the basaltic magmatism of the Paraná Basin.

The Upper Cretaceous was marked by the advent of the alcaline magmatism, very active in this strip. The places of its manifestation are indicated in Figure 1-C. The Tapira, Araxá, Salitre, Serra Negra and Pântano pipes and the Coromandel kimberlites are aligned close to a NNW direction; on its extension, we also have the gravity faults zinc mineralizations of the Vazante region, which AMARAL (1968) considered as related to the Wealdenian Reactivation. The volcanic foci of Patos de Minas, the São Gotardo intrusion (ELLERT AND HASUI, 1969) on the Serra do Bueno dike and the Bambuí diatremes (CORREA, 1971) are located on the Mata da Corda Flexure region. On the western side, near from the Paraná Basin border, we find Catalão I and Catalão II pipes (BARBOSA *et al.*, 1970) and the uganditic rocks of Sacramento (MURTA, 1965), if we can relate these ones to the alcaline event. The K-Ar ages of the alcaline pipes are between 100 and 80 m.y., what means an Upper Cretaceous age (HASUI AND CORDANI, 1968); numbers between 45 and 65 m.y. has been obtained for Patos de Minas, Serra do Bueno and Sacramento, but they mean minumum ages.

This magmatic activity is realted not with a simple flexuration, but with the ascension of the area in the form of an uplift. Using a name which already was introduced by SAD *et al.* (1971) we will cognominate this structure as the Alto Paranaíba Uplift. This structure imposes the NNE limit of the Paraná Basin in the Upper Cretaceous, as well as the WSW limit of the Sanfranciscan Basin (Figure 2-C). To the north, after the Vazante and Catalão region, there are no evidences that comprove the activity of the uplift, what make us believe that this structure had no continuity beyond this area. The geological data concerning the south of the Sacramento-Campos Altos-Bambuí region are precarious, but the structure possibly didn't extend very far about this line; the Poços de Caldas alcaline massif is too far away to permit, in reasonable terms, its correlation with the uplift's development. This so limited entity should not be named anteclise, which is a structure of greater extension, and not even arch, which is characterized by a linearity (ASCHGIREI, 1972).

BOSUN (1973) showed the existence of a very prominent system of linear aeromagnetic anomalies, trending NW from the Catalão to the Divinópolis region, and probably corresponding to deep fractures filled by basic dikes. Accordingly to the geologic maps presented by BARBOSA *et al.* (1970), in the region of Abadia dos Dourados-Catalão there are dikes of diabase and metadiabase with NW direction, in coincidence with the anomalies. One sample of metadiabase from Brejão was sub-

mitted to K-Ar dating and an age of 450 m.y. was obtained (HASUI, *unpublished*): the fractures are ancient and probably was filled in two or more events. The emplacement of alcaline pipes seems to be related to the superposition zone of that deep fracture system with the described uplift.

A sequence of epiclastic volcanoclastic rocks denominated Uberaba (RIMANN, 1971) and which is considered the basal facies of the Bauru Formation (LADEIRA *et al.*, 1971) occurs in the Estrela do Sul-Sacramento-Uberaba-Veríssimo region. This facies was deposited in sub-aqueous conditions, in a basin restricted to this region and that we denominate Uberaba Depression (Figure 1-D and 2-D). A dominancy of granulometrically better sorted petrographic terms occurs to the west, i.e., there are poorly sorted polimictic conglomerates and breccias in the Romaria or Sacramento region which pass to fine sandstones at Veríssimo. This points to a transport of clastics from E to W. On the other side, in a vertical section, sandy terms overlie conglomeratic fractions what can be interpreted as diminishing energy of sediment transport. The thickness reaches almost one hundred meters in the Uberaba-Ponte Alta region and diminishes at the borders. The Uberaba Facies covers not only the basalts, but also the precambrian rocks of Sacramento and Romaria and in this last locality it occurs filling a paleo-channel.

In a vertical profile, the Uberaba Facies gives place to the Ponte Alta Facies which has a larger distribution and is extended not only over the Triângulo Mineiro region but also out of it. At the time of the deposition of the Ponte Alta Facies a generalized subsidence took place at the W and SW of the Araguari River valley; however, this unit has its greatest thickness in the Peirópolis-Ponte Alta-Almeida Campos region (HASUI, 1968), showing that the subsidence conditions of the Uberaba Depression persisted after the deposition of the volcanoclastic rocks (Figure 2-E). This subsidence would explain the remarkable development of the so named "casco de burro" conglomerate in this region, as noted by BARBOSA (1934). To the top of the sequence, this facies becomes dominantly arenaceous. The layers are tilted to the SW, what can be constated by the upper surface of the basalts. FRANGIPANI (1961/1962) already observed that although this surface is irregular at the São Paulo State, it shows a clear inclination to the Paranapanema River. In the Rio Grande River valley the altitudes oscilate from 300 m at the junction with the Paranaiba River to 600 m at the region of Franca. In the Triângulo Mineiro there are irregularities too, but generally the altitudes fall from 800-900m in the Araguari River valley (from Sacramento to Araguari) to 300m at the confluence cited above. This means a medium gradient of 15 m/100 km. However, this value is not real, while it is higher at the surroundings of the Araguari River and lower to the west. This inclination is not represented in the Figure 2-E.

The Ponte Alta Facies also overlaps partially the precambrian rocks, at the Alpercatas region, on the right margin of the Araguari River. This transgressive character which is observed on successive mesozoic stratigraphic units shows the activity of the basin border region.

The Upper Cretaceous sedimentation in the Sanfranciscana Basin originated the Capacete and Urúcuia Facies of the Mata da Corda Formation (LADEIRA *et al.*, 1971). The Capacete Facies is constituted by epiclastic volcanoclatisc rocks, deposited in subaqueous conditions and is in everything similar to the Uberaba Facies (HASUI, 1968). It is better represented in the São Gotardo-Quintinos-Carmo do Paranaíba region, where the thickness reach over one hundred meters. The accumulation of this facies implies in a renewal of the subsidence process at the Abaeté Depression (Figures 1-D and 2-D).

The Urucuia Facies appears in the northern extremity of the Serra da Mata da Corda ridge and extends beyound the Paracatu River demarking the northern extension of the Sanfranciscana Basin (Figures 1-D and 2-E). This

facies of essentially arenaceous nature reflects a downwarping of an enormous region which reached the Maranhão State (BRAUN, 1970).

Several occurrences of epiclastic volcanoclastic rocks which are isolated on the highlands of the Coromandel and Patrocínio region are known since a long time (HASUI, 1968) and are similar to the Uberaba and Capacete Facies. These occurrences, survivals of the erosional process, seem to have been deposited in a depressed area in the northern part of the Paranaíba Uplift dorsal zone.

With the calming of the tectonic activity, the sculpture of the Pratinha Erosional Surface (ALMEIDA, 1958) continued and finished. Its 1100-1200 m elevated remains can be seen now cutting the ridge systems sustented by precambrian quartzites (Canastra, Sacramento, Pirapetinga, Óculos Ridges) and also by the Bauru (Almeida Campos Plateau) and Mata da Corda Formations (at the homonimous ridge). The later erosion of this surface, already during the Cenozoic, reflects epeirogenetic movements of great geographical extension.

CONCLUSIONS

The presented data about the sedimentation and the magmatism activity allow us to visualise the behavior of the divisory belt between the Paraná and Sanfranciscana Basins, in the southern Goiás and western Minas Gerais States.

During the Paleozoic this belt behaved as a flexure, with a western subsidence where the Paraná, Tubarão and Passa-Dois Groups laid down. There are no elements to characterize an active arch and so it seems to us that the designation Goiânia Flexure would be the most adequate for this structure.

In the Neo-Jurassic and Low Cretaceous that flexure suffered a reactivation, and the belt constituted a geographic limit of the São Bento Group at the southern Goiás. In the western Minas Gerais the basin edge was conditioned by block-faulting with reactivation of old discontinuities; so, the border has a NW direction in Goiás State and changes to NNE in Minas Gerais. The aeromagnetic anomalies, with linear pattern trending NW from Catalão to Divinópolis region, are related to ancient bodies of metabasites filling prominent fractures, and also to diabase dikes probably related to the mesozoic basic magmatism.

During the Lower Cretaceous, still when the basaltic magmatism was occurring at the Paraná Basin, on the other side, at the Mata da Corda Ridge, another flexure appeared, the so called Mata da Corda Flexure, which allowed the devellopment of the Abaeté Depression.

The belt was flexed during the Upper Cretaceous with characteristics of an uplift, which is called Alto Paranaíba uplift. The active alcaline magmatism is related to this structure, with aid of the ancient deep fracture system.

Right after or during this process the Uberaba Depression was implanted and the Abaeté Depression suffered a new subsidence and both basins were covered by epiclastic volcanoclastic rocks, deposited in subaqueous conditions.

The Ponte Alta Facies reflects an environment change, with rudaceous and mineralogically mature sediments. The conglomeratic character of the inumerous sedimentary levels shows a high transport energy, which was general at the beginning and decreased with time, and consequently, argillaceous sandstones dominate the upper part of the Bauru Formation (SUGUIO, 1973).

The Urucuia Facies is not sufficiently known, but its essentially sandy constitution shows that tectonic conditions for sedimentation were not so intense as at the Paraná Basin side.

So, we have seen that in what concerns the Cretaceous subsidence as by total thicknesses of the superposed stratigraphic units, the tectonic activity was much more intensive in the Paraná Basin than in the Sanfranciscana Basin. This inequality conferred to the Alto Paranaíba Uplift an asymmetrical character.

SUMMARY

The divisory belt between the Paraná and Sanfranciscana Basins in the Southern Goiás and Western Minas Gerais has been active during at last two Phanerozoic episodes. Firstly, the *Goiânia Flexure* had an important role in the Paraná Basin's paleogeography, defining its edge with NW direction. Later, the movements become more complexes and related to the Wealdenian Reactivation of the South American Platform.

At the end of the Jurassic, the Goiânia Flexure was reactivated mainly in Southern Goiás; in Western Minas Gerais block-faulting movements determinated the general NNW direction of the Paraná Basin edge.

During the Low Cretaceous, a minor flexure, named *Mata da Corda Flexure*, was established on the homonimous ridge, constituting the western limit of the *Abaetè Depression* where the Areado Formation was deposited.

The Upper Cretaceous was marked by the development of the *Alto Parnaíba Uplift*. The most important focuses of alcalic magmatic activity (Tapira, Araxá, Salitre, Serra Negra, Pântano, Catalão I, Catalão II, Coromandel, Patos de Minas, São Gotardo, Serra do Bueno and Bambuí) are related to this structures and pre-existing WNW fractures.

Afterwards, the *Uberaba Depression* was formed and the Abaeté Depression suffered a new subsidence, what permitted the accumulation of the Capacete, Uberaba and partly of the Ponte Alta Facies.

At the end of the Cretaceous these basins were enlarged by regional subsidences, which expanded the area of sedimentation and so the Bauru Formation and the Urucuia Facies could cover vast regions.

The attenuation of the tectonic movements permitted to finish the sculpture of the Pratinha Erosion Surface which nivelated the last Cretaceous stratigraphic units.

The later movements, which possibilitated the rene wal of the erosional processes, are epeirogenetic and involved greater extensions.

RESUMO

A faixa divisória entre as bacias do Paraná e Sanfranciscana no sul de Goiás e oeste de Minas Gerais esteve ativa durante pelo menos dois episódios no Fanerozóico. De início, a *Flexura de Goiânia* teve um papel importante na paleogeografia da Bacia do Paraná, impondo-lhe um contorno de direção NW. Posteriormente, os movimentos foram mais complexos e se processaram em conexão com a Reativação Wealdeniana da Plataforma Sul-Americana.

Em fins do Jurássico, a Flexura de Goiânia retomou a sua atividade, sobretudo no sul de Goiás; no oeste mineiro, tem lugar uma movimentação de blocos ao longo de falhas pré-existentes, de maneira tal a impor um contorno de direção aproximada NNW à Bacia do Paraná.

No Cretáceo Inferior, a *Flexura da Mata da Corda*, de menor invergadura, se estabelece na zona da serra homônima, constituindo um limite ocidental para a *Depressão do Abaeté*, que recebeu então a sedimentação da Formação Areado.

No Cretáceo Superior é que se dá o aparecimento do *Soerguimento do Alto Paranaíba*, que em conjunção com fraturamentos WNW pré-existentes, permitiu o advento dos focos de magmatismo alcalino (Tapira, Araxá, Salitre, Serra Negra, Pântano, Catalão I, Catalão II, Coromandel, Patos de Minas, São Gotardo, Serra do Bueno e Bambuí).

A *Depressão de Uberaba* se instala em seguida e a do Abaeté tem sua subsidência renovada, o que permite a acumulação das Fácies Capacete, Uberaba e parte da Ponte Alta.

No fim do Cretáceo as bacias se ampliam graças a subsidências regionais, possibilitando à Formação Bauru e à Fácies Urucuia cobrir grandes extensões.

A atenuação dos movimentos tectônicos permitiu o término da escultura da Superfície Pratinha, que se nivela com as últimas unidades estratigráficas cretáceas. Os movimentos posteriores, que vieram possibilitar a retomada da erosão são epirogenéticos e generalizados.

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