

Regional geomorphologic mapping of the Araguaia River Basin, Central Brazil

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Abstract. The upper and middle Araguaia River is particularly important from the geomorphologic point of view due to the activity of many processes and to the related presence of several landforms from the denudation and aggradation systems. Neotectonic activity (uplift and subsidence) was a main factor that favored the development of the denudation and aggradation systems. Geomorphologic mapping was based on the identification of these landforms and subsequent categories according to their relief features, altitude, erosive stage and depositional characteristics. Three major Regional Planation Surfaces scheduled between 1000 and 165m altitudes above sea level were mapped. Several associations of hills, folded structures, and hogbacks occur with strong structural control, generally associated to intrusive and metamorphic rocks. The aggradation system is characterized by a complex of morphosedimentary units represented mainly by fluvial plains and floodplain belts with abandoned meanders, oxbow lakes, meander cutoffs, and swampy areas that remain flooded during the rainy season (December to March). This system is associated to the Quaternary intracratonic Bananal Basin and Holocene alluvial deposits. Avulsions, abandoned channels, and underfit rivers are geomorphologic registers associated with paleoclimatical and paleohydrological changes and neotectonic reactivation that acted in the region during the Middle and Upper Pleistocene. Results at the reconnaissance level describe the geographic distribution of major landforms, at a scale of 1:250.000, based on morphogenetic criteria. This study had as its aim the use of new techniques of geomorphologic mapping in tropical areas using remote sensing products, mainly SRTM and ETM images and integration in GIS environment.

Keywords: Geomorphologic Systems; Araguaia River Basin; Bananal Basin

1. Introduction

Tocantins-Araguaia Basin constitutes a large Central Brazil fluvial system, with an area close to 800,000 km² and a mean annual water discharge ca.12,000 m³s⁻¹. The upper and middle Araguaia River Basin is object this study.

The upper Araguaia region is located on the highlands, with quotas predominating between 1000 and 550m of altitude above sea level. In this region the rivers drain on bedrock that encompasses the Precambrian granite-gneiss and metasedimentary basements and Paleozoic-Mesozoic sedimentary basin rocks of the Paraná Province. On another level, the middle Araguaia River drains on lower quotas between 550 and 165m above sea level, dominantly associated on Quaternary sediments of the Bananal Basin and is made up by varied and well-developed alluvial and fluvial units. The extensive Bananal Basin plain with 106,000km² and which occupies approximately 27% of the study area is seasonally flooded during the rainy season, a result of both the local rainfall and a saturated water table (Valente and Latrubesse, 2007). The Araguaia River consists of an anabranching system of straight and meandering patterns with low sinuosity.

In this region the antecedents of geomorphologic mapping are scarce and in large-scale. Presently, the cartographies more utilized are those generated conceptually by Radambrasil Project (Mamede et al., 1981), in the large-scale (1:1:000.000). However, the geomorphologic knowledge of the Quaternary fluvial records of the floodplain belt of the middle Araguaia River has advanced significantly in this last decade (Bayer, 2002; Vieira, 2002; Morais, 2006; Latrubesse and Carvalho, 2006, Valente, 2007).

The dominant vegetal of the study area covering is the Cerrado biome that shows a diverse range of physiognomies and floristic composition with many species adapted to frequent fires and to the high aluminum content of the soils.

Situated in Central Brazil among the states of Goiás, Tocantins, Mato Grosso, and Pará, in the upper and middle Araguaia River Basin, the study area presents an irregular shape of approximately 298,700km² (Figure 1).

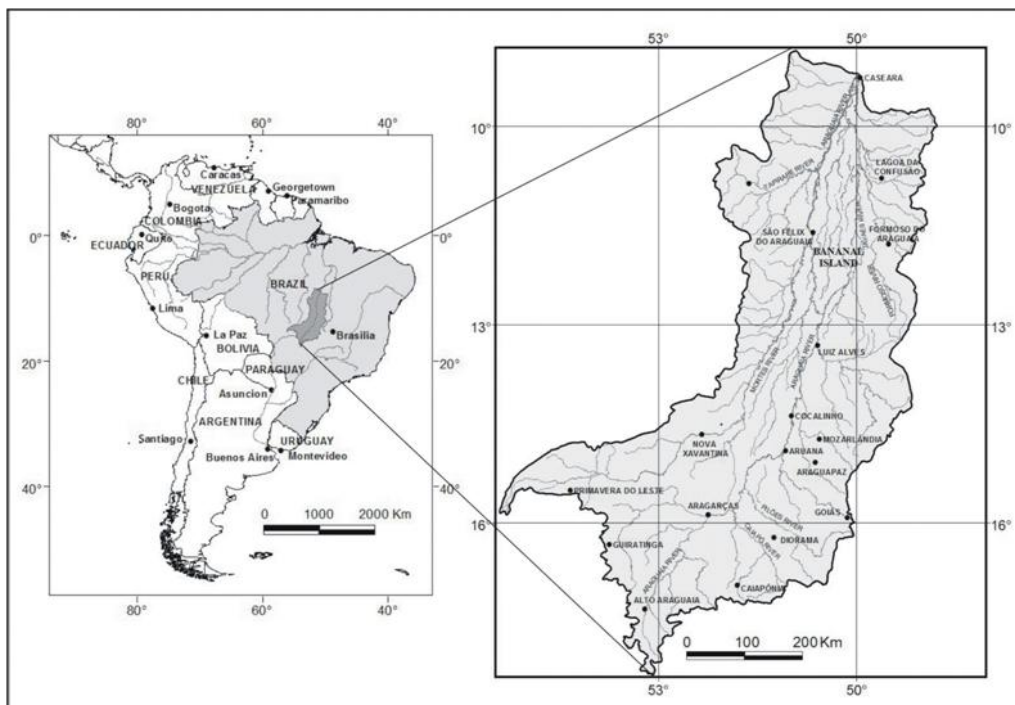


Figure 1 - Location of the study area.

The region is affected by a current tropical climate characterized by a dry and a moist season that corresponds to the Aw in Koppen's Climatic Classification. Annual rainfall varies from 1,400 to 2,200 mm/year. The rainiest season occurs between December and March, while from June to August the rainfall is zero and extends until mid-September. The annual mean temperature vary from 22°C in the upper Araguaia Basin and 26°C in the middle Basin.

2. Materials and methods

For the mapping of the geomorphologic units, state variables (lithology, structure, regional pendent, etc) and transformation processes (erosion, transport, sedimentation, weathering, etc) that modulated geofoms with the geological time are taken into account. In this mapping, the classification of the dynamic and genetic type was applied, based on the proposals of Latrubesse and Carvalho (2006) with some modifications by Iriondo (1986).

Fieldwork was developed during the dry season, in order to find out and describe characteristics of the morphological features, sediment characteristics, and profiles in the Araguaia River with the use of a boat. This fieldwork was carried out in two periods, the first from August to September 2005 and the second in August 2006.

In the development of this study, we used digital data from the Shuttle Radar Topography Mission (SRTM). In addition, the Enhanced Thematic Mapper Plus (ETM+) bands of Landsat-7 satellite were used during the period of dry season from July to September. For the mapping of the geomorphologic units we employed interpretation techniques in SRTM and ETM⁺ images which were integrated in a Geographic Information System (GIS).

3. Geomorphologic characteristics

In general, in order to reach the greatest understanding of morphological systems, the grouping of lithologic information and transformation agents is often necessary. The drainage network, as the landscape's modeling agent, allows one to observe the sense and the dissection degree of the relief as well as in which direction the regional planation surface is being eroded. The distribution of landforms as portrayed shows relief patterns that were developed through geological ages under various endogenic and exogenic processes.

The criterion here adopted considers chemical weathering processes, variation of rock resistance (diversity of lithologic composition), fluvial system, climatic changes, and tectonic activations. The regional interactions of the tectonic events from the opening of the South Atlantic and the Andean orogeny transferred efforts to the crystalline basement rocks and of the Paraná Basin during all the Cenozoic, causing uplift movements that may have been true geomorphologic "triggers" in favor of the generation of different Regional Planation Surfaces.

In this context, erosion processes in the study area had acted on rocks of very distinctive chemical composition, tectonic paleoenvironment, and age. In this geological scenario a great variety of landforms were developed in association with denudational and aggradational systems. The spatial distribution of the major geomorphologic units is illustrated in the geomorphologic map (Figure 2) and is discussed below.

4. Denudational System

The denudational units are generated by erosion and planation of a terrain surface inside a given interval of quotas. The spatial distribution this system does not necessarily respect lithologic limits, rock ages, or tectonic styles. This system is composed by: (i) Regional Planation Surface (RPS); (ii) Zone of Receding Erosion (ZRE); (iii) isolated landforms (hills, inselbergs, folded and dome structures).

The Regional Planation Surface (RPSIIB) represents the most eroded, oldest, and highest surface of the region with an altitude between 1000 and 750m, associated to Paleozoic-Mesozoic Paraná Province. This surface is characterized by Tabular Relief (TR) or plateau which was generated on sediments with horizontal to sub-horizontal bedding, associated to Paraná Province (Furnas, Serra Geral, Aquidauana, and Bauru formations).

The dissection pattern is generally very low-to-low with much located occurrence of strong dissection. Figure 3 shows the characteristics of the relief patterns of the RPSIIB-BT surface and its relationships with RPSIVC1, RPSIVC2, and ZRE in association with of the Paraná and Bananal basins.

The regional planation surfaces with the most elevated quotas, called RPSI (1.250- 1.600m) and RPSIIA (900-1250m) occur outside the study area, respectively, in Chapada dos Veadeiros and Federal District regions (Latrubesse and Carvalho (2006).

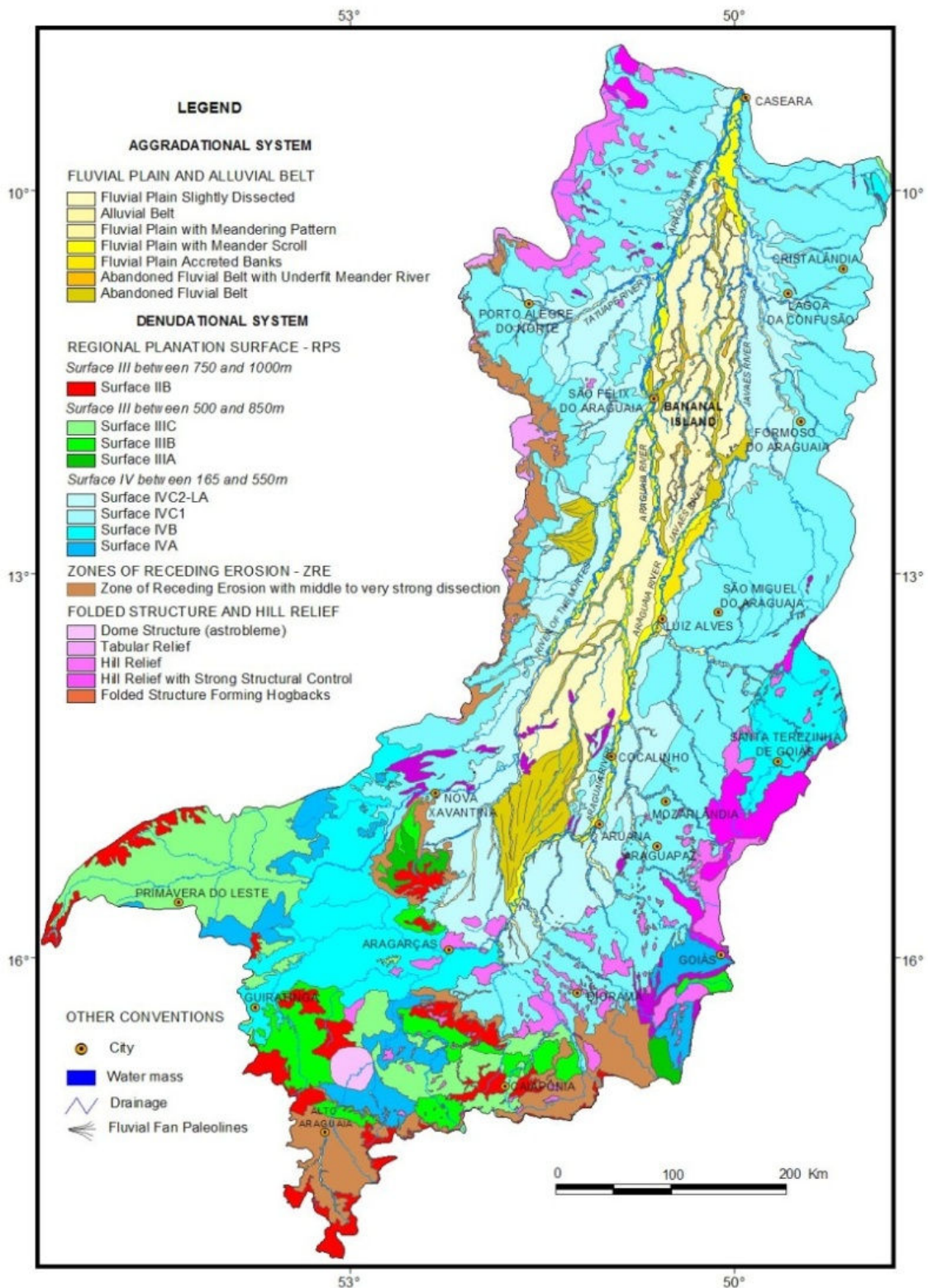


Figure 2 - Geomorphic map of the Middle and Upper Araguaia River Basin.

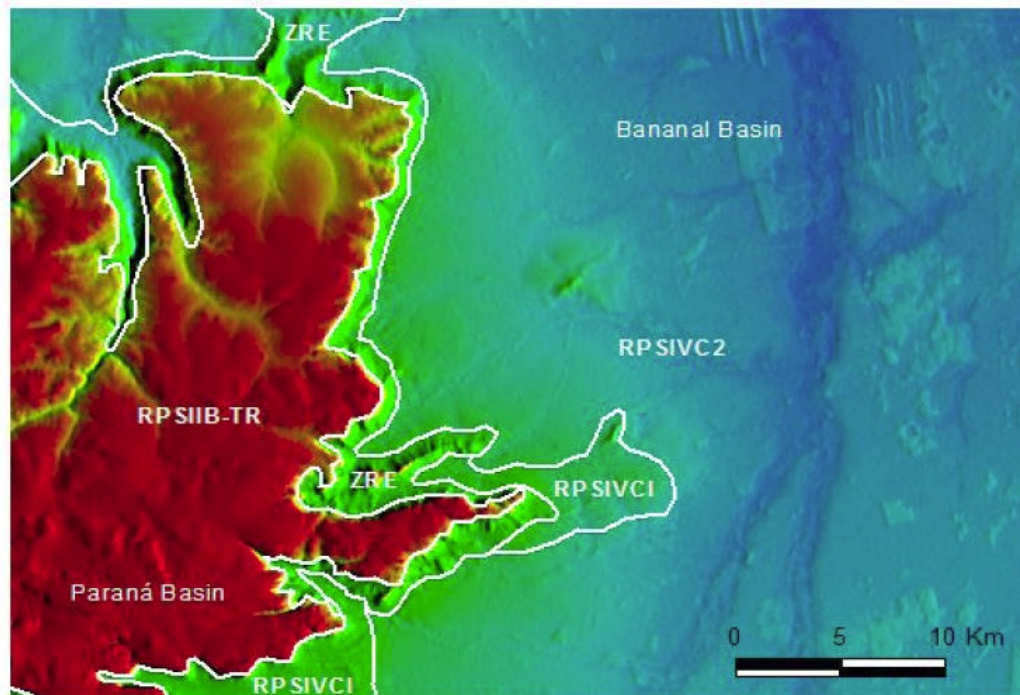


Figure 3. Relationships between Regional Planation Surfaces (RPSIIB-TR, RPSIVCI, RPSIVC2) and Zone of Receding Erosion (ZRE). SRTM shade color image.

The Regional Planation Surface (RPSIII) reveals quotas between 850 and 500m above sea level, with middle and very strong dissection developed on sedimentary rocks from the Paraná Province (Bauru, Aquidauana, Furnas, and Ponta Grossa formations). The RPSIII surface was subdivided into three geomorphologic units represented by RPSIIIA, RPSIIIB, and RPSIIIC (Figure 2). The RPSIIIA surface reveals quotas between 850 and 750m, with middle and strong dissection, associated to the Tabular Reliefs (TR) of the Paraná Basin. The RPSIIIB surface is situated in quotas between 550 and 750m with relief dissection varying from very low to very strong. The RPSIIIC with altitudes between 500 and 700m developed on sedimentary rocks with tabular relief associated to Bauru Formation rocks.

The Regional Planation Surface (RPSIV) is the youngest surface and possesses the lowest quotas of the region, between 165 and 550m above sea level. It is dominant by occupying approximately 60% of the study area, exhibiting relief patterns with varied dissection degrees, predominantly low to very low on rocks with different origins, tectonism, and ages that vary from the Neoproterozoic to Quaternary. In the analysis process, four geomorphologic units were identified: RPSIVA, RPSIVB, RPSIVC1, and RPSIVC2 (see Figure 2).

The RPSIVA represents the most elevated altitudes between 400 and 550m and exhibits four dissection degrees (low, middle, strong, and very strong). This unit is developed over Paleozoic sedimentary rocks (Aquidauana and Ponta Grossa formations) and Neoproterozoic Goiás Magmatic Arc. The second level with quotas between 300 and 550m is represented by the RPSIVB surface with three dissection degrees (middle, strong, and very strong).

The RPSIVC1 is widespread and dominant in the study area and is made/formed on the border with the Bananal Plain. This third unit dips softly in the direction of the axis of the plain with quotas between 180 and 400m. This surface developed mainly on Precambrian rocks. The fourth planation surface is more distal and less dissected, represented by the RPSIVC2 generally

associated with a big quantity of small lakes. This unit shows a flat relief with lower quotas lower between 165 and 400m, developed on Pleistocene Bananal Basin.

Zone of Receding Erosion (ZRE) is a responsible Polygenic Planation model for the development of the fluvial system, as an antecedent element which is superimposed in the landscape, evolves strongly by receding erosion, expanding while generating rejuvenations of the landscape and the scheduling of old surfaces in more elevated distinct quotas. During the evolution of the ZRE hill reliefs are developed, all of which are constituted by rocks which are more resistant to erosion, mainly granite and quartzite. In general, the relief's main erosive agents are hydrologic conditions and climate, mainly rainfall, high temperature, and winds.

This way, while a ZRE evolves, recoil also the front of the escarpment that supports the pre-existing surface with the generation of a complex grouping called hills, inselbergs, folded and dome structures. Agents from the chemical and physical weathering that is more characteristic in tropical areas are eroding these reliefs with time.

5. Aggradational system

The main geomorphologic categories identified in the Aggradational System are the fluvial plain, in the broad sense including functional and/or non-functional units, and the alluvial plain, related to the floodplain of the Araguaia and Mortes rivers and its main tributaries. This system is characterized by a flat widespread surface with a low slope along 730km of the longitudinal axis of south-north direction situated in quotas between 300 and 165m above sea level (Figure 2).

The alluvial plains consist of a complex mosaic of morphosedimentary units (Latrubesse and Stevaux, 2002) formed by sediments of the Holocene and probably of the Upper Pleistocene. In this floodplain six dominant geomorphologic units were recognized: 1) Alluvial Belt (AB) develops along the active channels; 2) Fluvial Plain with Accreted Banks (FPab) where accretion deposits of sandbanks in shallows near the river are dominant; 3) Fluvial Plain with Impeded Floodplain (FPif) constitutes a difficult area for the water flux in the alluvial belt; 4) Fluvial Plain with Meandering Pattern (FPm) represents a river channel having a pattern of successive windings which broadly resembles the trace of a meandering stream; 5) Fluvial Plain with Meander Scrolls (FPms) where meander and paleochannel features are dominant and 6) Abandoned Fluvial Belt with Underfit Meander River (AFBum) is characterized by floodplain with continuous or discontinuous channels, asymmetric and non-harmonic meanders that are generally associated to the oxbow lakes.

On the other hand, the oldest geomorphologic units that are registers of the behavior of the past's fluvial system developed during the Middle and Upper Pleistocene inside the Fluvial Plain which can be divided into three units: 1) The Slightly Dissected Fluvial Plain (SDFP) is constituted by waterproof clayey soils that is periodically waterlogged as a result of the high rainfall during the rainiest season. This surface is low structural that functions like a floodplain of water accumulation on the surface and underground; 2) Abandoned Fluvial Belt (AFB) represents areas of abandoned channels originated through avulsions and river migrations (Figure 4).

Avulsion is defined by Makaske (2001) as the diversion of flow from an existing channel onto the floodplain, eventually resulting in a new channel belt. The geometry and distribution of channel incisions in the Bananal Basin suggest that avulsion processes were controlled by neotectonic events associated to the Goiás-Tocantins Seismogenic Zone that occurred mainly in the Middle Pleistocene between 56.6 ± 5.9 and 34.0 ± 4.6 ka BP and during the Upper Pleistocene between 26.4 ± 3.1 and 17.2 ± 2.3 ka BP (Valente and Latrubesse, 2007); and 3) Dissected Alluvial Fan (DAF) developed a large number of ephemeral and small channels and simultaneously suffered active deflation on the oldest alluvial belts.

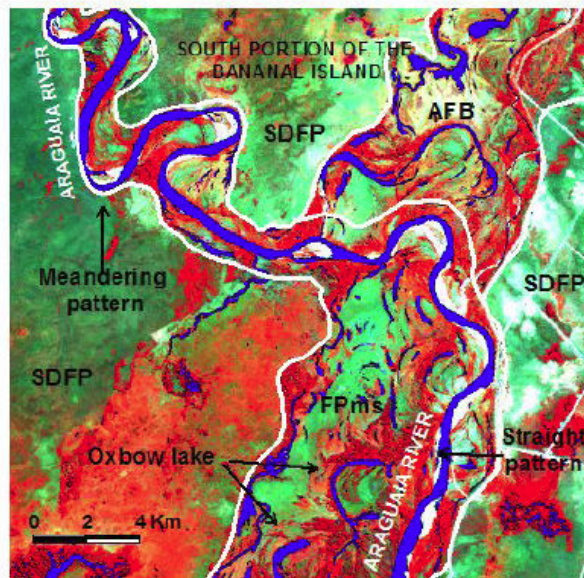


Figure 4. Characteristics of the Abandoned Fluvial Belt (AFB) generated by avulsion of the floodplain from the Araguaia River (FPms).

6. Lacustrine System

This system possesses a relatively restricted spatial distribution and occurs in association with the RPSIVC1, RPSIVC2, and very subordinately with the SDFP. The majority of these lakes is small, whose diameter is generally lower than 1000m. They have a rounded form that can evolve to bigger lakes through the coalescing of lakes with elongated forms in the direction of the regional subsurface hydrological gradient. The genesis of the lakes is related to the dissolution processes of laterite crust in association with fracture systems with NESW and NW-SE trends (Vieira, 2002, Latrubesse and Carvalho, 2006).

On another level, the lakes of the karstic system occur locally in the Lagoa da Confusão and in the Serra Dourada and developed, respectively, on limestone from Couto Magalhães Formation and Cuiabá Group. This karstic type is characterized by lakes in dolines and underground drainage.

5. Conclusions

Tectonic reactivations by uplift and subsidence movements that occurred during the Cenozoic may have been true geomorphologic triggers favoring the erosion process with generation of three different Regional Planation Surfaces (RPSII, RPSIII, and RPSIV). These surfaces of the denudation system are scheduled and separated by Zones of Receding Erosion (ZRE) in the following quotas: RPSII surface between 1000 and 750m; RPSIII with intermediate altitudes of 750 to 550m; and the RPSIV surface encompasses the flat reliefs with the lowest quotas between 550 and 165m altitude above sea level.

The RPSII and RPSIII are the oldest remaining surfaces with a predominance of strong dissection associated to the rough and hilly reliefs associated to occurrences of Paleozoic-Mesozoic sedimentary rocks of the Paraná Province. On another level, the youngest and most widespread geomorphologic unit of the denudation system is the RPSIV surface developed dominantly on Precambrian basement metamorphic rocks.

As a result of erosive processes one of the biggest and most important Quaternary intracratonic basins of Central Brazil was generated: the Bananal Basin. Internally, the

aggradational system of the Bananal Plain contains several morphosedimentary units formed by sediments of the Pleistocene and Holocene. The most representative geomorphologic units of this system is made up of Fluvial Plain Slightly Dissected, Fluvial Plain with Meander Scrolls, Fluvial Plain with Meandering Pattern, Abandoned Fluvial Belt, and Abandoned Fluvial Belt with Underfit Meander River.

The lacustrine system consists of innumerable lakes with rounded forms developed on lateritic crusts in association with RPSIVC2 and RPSIVC1. On the other hand, the lakes associated to karstic relief have occurrences in the Serra Dourada and Lagoa da Confusão regions.

Avulsions, abandoned channels, underfit rivers, and channel pattern changes in the Bananal Basin are direct consequences of neotectonic movements that can be associated to the seismic activity from the Goiás-Tocantins Seismogenic Zone.

This study has demonstrated how SRTM data integrated with optical remote sensing and fieldwork data can be used to support geomorphologic mapping in a tropical area.

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