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The contributions of the three-dimensional cartography for geomorphologic studies in small watersheds of the Chapada Diamantina, Brazil

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Abstract

This research is mainly aimed to identify the geological and geomorphological structure of watersheds that influence some of the processes of hydrology, from a 3D model, created with tweens numerical terrain models and satellite images. The study area represented located in Northeastern Brazil, state of Bahia, municipality of Lençóis and makes reference to three watersheds. The creation of the model was based on the manipulation of altimetry data from of images orbital’s interferometric the Topodata and SRTM projects, with the support of the images QuickBird, plus some field campaigns of investigation and use of the Navigation System and Global positioning (GPS - GNSS).In possession of these data ,have been applied specific techniques of remote sensing and geoprocessing in GIS with ArcGIS 10.1 software. With the use of geostatistics tools, using filters and optimal arrangement of spectral bands was possible to extract a greater number of information physical and environmental and propose a three-dimensional model that simulates the shapes of the land in a watershed. The results show that with the modeling three-dimensional was possible to identify with a good accuracy level, the slope, types of topographic compartments, structural geology of faults through lineaments and deformation and the dynamics of runoff and infiltration the hydrographic system. With such a model is also evident in the intense correlation structural geology, compartments and hydrological processes.

Keywords: 3D model, SIG, Chapada Diamantina, Brazil

1. Introduction

Among the several concerns of the contemporary geographical science, to represent the geographical space is still considered primordial before any other analysis type, considering that to understand, comprehend and contemplate the landscapes of the events whose relationships society versus nature are present is the first step to obtain success in the resolutions of the current environmental problems.

In this conception, the scientific structure of the current Geography presents several disciplines and tools that allow analyses and characterizations of several types of landscapes starting from space representations. Especially, stand out the GIS's - Geographical Information Systems, that brought a revolution in the way to process and represent environmental data in a fast and digital form, accompanying gradually the technological tendencies of this century, giving other senses and routes to the reflections proposed by the physical and humanist geography (Maceachren, 1995).

However, leaning over on the several roads that the physical geography traveled along its application from the classic time, it is known that the longing of representing the terrestrial surface and its elements is brought categorically by the Cartography. In this way, the whole type of tools and techniques (even the current ones like GIS's) that contribute for the science through maps, letters and plants are categorically fit in the Thematic Cartography (Christofoletti, 1980).

Through the utilization of systematizations and conventions that define as representing the geographical space in an ideal way, it is noticed that the level of information that the terrestrial environment can transmit to the observers is high, inconceivable and changeable. Then it appears the concern in making possible the production of information with the largest level of possible details, bringing similarities of the real world, what generated new characteristics for the Cartography that is named digital or computational cartography, for several areas of the knowledge, from the social followings to lines of geo-environmental works (Figure 1).

The geology, geomorphology and hydrography, for instance, are areas that need the contributions of the cartography to explain in a better way the relationships between the geology, geomorphology and surface elements in the process of water production (Christofoletti, 1999; Petrovic, 2004).

In this aspect, the generated maps whose such information could be put upon are produced historically in a cartesian perspective, the one where the delineations of the sierras, valleys and rivers, would come in a two-dimension formats, building the thematic maps. However, for the analysis type presented by Colavine and Passos (2011), the use of the current geoprocessing allows to generate countless detailed cartographic products, among them the three-dimensional representations of the environment, called Digital Elevation Models - DEM.

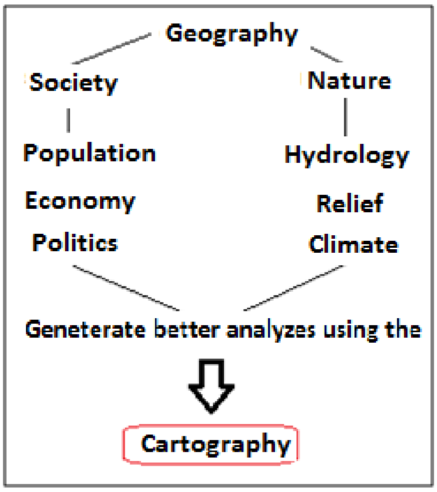

Figure 1 - The Cartography and the other knowledge areas.

The three-dimension models allow a closer visualization of the real characteristics of the study area, making possible several analysis through different points of view, bringing a perception of a virtual reality (Schmidt and Delazari, 2010). Such models are generated starting from interpolation processing that evidence the superficial dynamics, specially the surface hydrology. According to Rennó and Soares (2003), such models constitute a very useful tool for the study and understanding of the factors that affect the hydrograph net, the drainage, the water balance and the flows formation of a hydrograph basin.

Florenzano (2011) affirms that the creation of the three-dimensional modeling through a Geographical Information System of (GIS) has been used more and more for identification of tectonic structures and geomorphologic compartments. Tang et al. (2009) and Nascimento et al. (2008) used digital models of the land 3D's of SRTM to characterize the geomorphology of hydrograph basins in Piauí. Santos (2014) also used three-dimensional models to understand the relationships among the sierras, rivers and estuary of the Low course of the Hydrograph Basin of the Almada´s river.

In that scenery of modeling and detailed representations of the relief and analyses based on the environmental components, the area of Chapada Diamantina, in the state of Bahia, appears as complete place for studies of that gender. Inserted in an international tourist route, its landscape is portrayed for the most part by the portliness of its sierras, testimonies hills, valleys, picks, waterfalls, among other, being well-known the paper of the geomorphology in the characterization of the territory.

That environmental diversity of the Chapada is derived of several geological events, that appear from the end of the removal process of the tectonic plates, passing through the formation of seas and lakes, formation of sedimentary basins, and the most recent events of disaggregates the knowledge areas mentioned and rule the analyses by itself. Even being a complex task, the difficulty in obtaining such relationships and identifying the existent geomorphologic patterns can be mitigated by the use of the current geotechnologies, where the three-dimensional representations are inserted (Walsh, 2009).

In this way, the objective of this work was to characterize the relief and the hydrograph of three small hydrographic basins in the municipal district of Lençóis (Chapada Diamantina, BA) using physiographic indexes and a three-dimensional modeling in a GIS structure. Being fold and rising of the compartments, with a final retouching of the current erosive processes and its geological flaws (Mattos and Fernandes, 2013)

However, such information on the geological structure, relief and hydrograph can come together from certain point of view, in a different perspective from the one tha

studied basins important for the local anthropic activities (Mattos and Fernandes, 2013), the focus was to classify the geomorphology and to identify the relationships of the structures of flaws and geological folds, in an attempt of understanding the routes taken by the water, forming one of the landscapes more acquaintances of Brazil. It consists of a new way of the environmental analysis that allows to visualize and to conceive the dimensions and forms of the sierras, valleys and plains, being a new technique that thickens the relief studies.

2. Materials and methods

2.1 Area of Study

The three studied hydrographic basin (up to 50km² according to Botelho (2011)) make part of the hydrographic system of the São José river, one of Paraguaçu's river main tributaries and make part of the basins that part of the East Atlantic hydrographic area. The main rivers of each studied basin are the rivers Lençóis, Ribeirão and Capivara, which drain areas in the limits of the municipal district of Lençóis, in the central portion of Bahia, area of Chapada Diamantina. The basins are located among the coordinates 12º31'00 "; 12º40'00" S and 41º 23'00 "; 41º 29'30" W. Approximately 90% of the total area of the three basins are inserted inside the perimeter of the National Park of the Chapada Diamantina, a conservation unit of integral protection (Figure 2). The springs of the rivers are for the most part located in that area, suggesting a preservation that allows a regulated flow of water during the year.

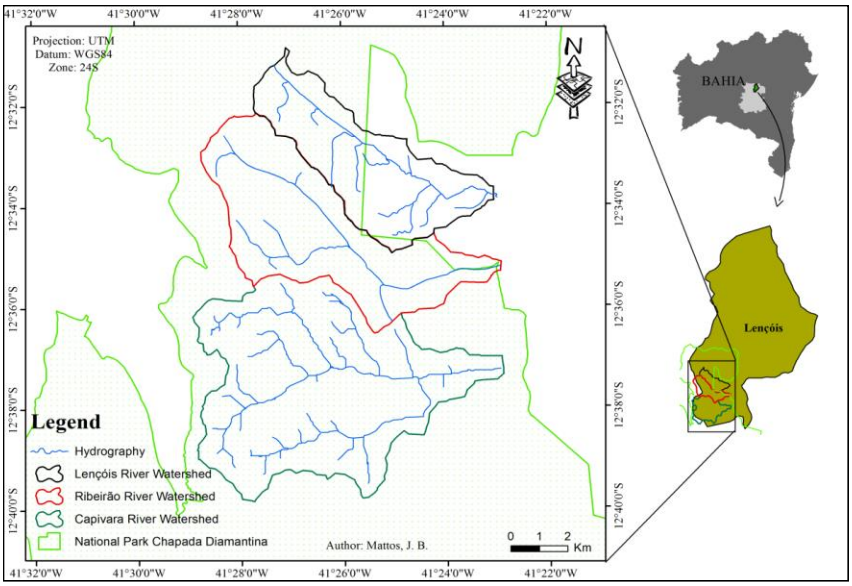

Figure 2 - Location of hydrographic basins in study.

According to the Koppen´s Classification (1948) the studied area presents a climate type Cwb (tropical of altitude), with annual mean temperature varying between 22°C and 24°C, with two very well defined stations: The spring and the summer with warm and rainy periods and the autumn and winter with dry and cold regimes.

The mean annual precipitation oscillates among 830 mm to 1192 mm, with the historical discharge series of the three basins of about 0,1m³/s (Derby et al., 1997). It is a transition zone among the Atlantic forest biome, savanna and savannah, being that last one the majority biome in the area. The savannah features are consists of a robust vegetation due to water availability.

The soil use of the studied basins according to Mattos and De Paula (2013) is I subdivide in five classes: Rupestrian fields - feature that collects sediment areas and hillsides of the hills; Riparian forest - usually associated with the presence of bodies of water; Forests - grasses vegetation and small bushes; Several cultivations; Urban area - restricted to the city of Lençóis.

2.1.1Geology and Geomorphology

According to Santos (2008) and Bonfim and Pedreira (1990), in a general way the area of the Chapada Diamantina presents actually characteristics resultants of two processes: a) Tectonic movement happened in the Precambrian age, forming an extensive sedimentary basin, which was filled out by sediments along approximately 700 million years and it suffered folder processes; b) later, such basin suffered another tectonic activity, of that time orogenic, leading off the features of Sao Francisco group.

The Espinhaço group embraces the formations Tombador, Caboclo e Morro do Chapéus, surfaced predominantly in the west and central of the portions of the Chapada. The Sao Francisco group contemplates the formations Bebedouro e Salitre, presents in the oriental portion of the Chapada Diamantina (Derby, 1997) (Table 1).

Table 1 – Geologic information of the Chapada Diamantina.

	Espinhaço Group (1800>1100 m.a, Proterozóico)			São Francisco Group (1100>400 m.a, Neoproterozóico, actual)	
Formation	Tombador	Caboclo	Morro do Chapéu	Bebedouro	Salitre
Lithology	Quartzite and sandstone of fluvial wind origin	Mudstone and siltstone of quartzite matrix of marine origin and strongly weathered	Banks of quartzites of marine origin	Conglomerate of glacial origin, strongly cemented by clayey material and strongly weathered	Marine carbonates responsible for calcareous formations (Calcareous basins)

Adapted from Toth (1997)

The study area is inside of Grup Espinhaço, specifically in the Formation Tombador. As presented in Table 1, it is formed by sedimentary, metassedimentary and mesoproterozoic rocks, being the majority f the sandstones conglomerate of quartz and clasts. The lithologic material of the study area is for the most part a condition for the forms of local relieves. In a zone marked by folds of the sedimentary package, the area was sculpted by erosion, forming the relief tabuliforme with plains, cornices, scarps and fluvial valleys well defined through the processes pediplaination and pedimentation (Figure 3)

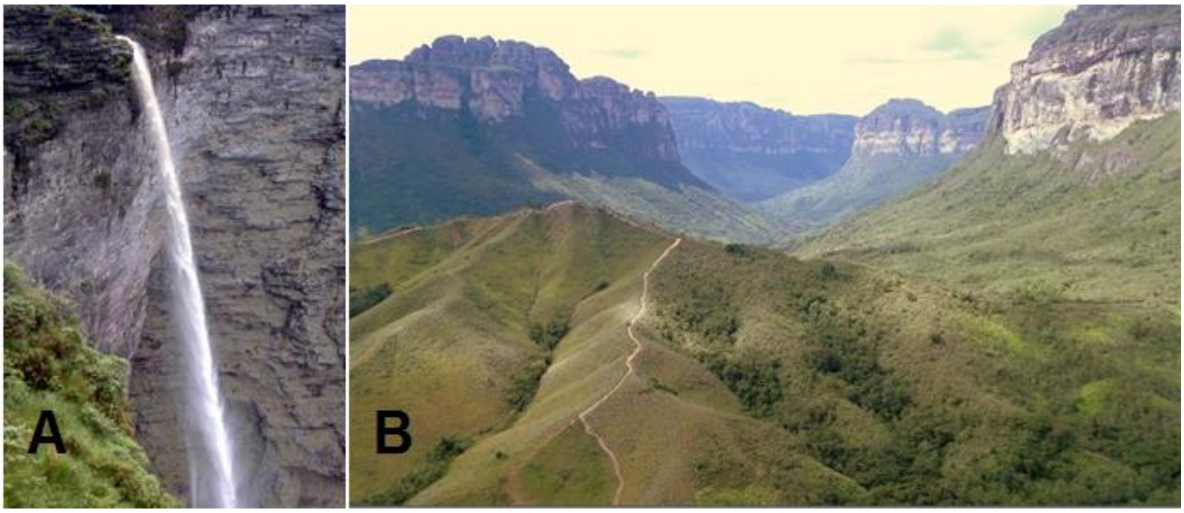

Figure 3 - A) The cliff of Fumaça Waterfall; B) Relief Tabuliforme of the basins.

2.2 Three-dimensional Modeling

2.2.1 Geodatabase

Three-dimensional representations of the relief in hydrographic basins are more appropriate from the moment that the data bank is built in connection with other data, as satellite images, GPS's reference points collected in field, contour level curves and hydrograph files. That range of information is gathered in the intention of accomplishing a overlapping of data and consequently to reproduce the relief in the possible most real way, in scale of details (Haeberling et al, 2008).

Using this conception the Digital Elevation Models (DEM) appeared, which are geo-referenced files produced by the union of information regarding the altitude, hydrography and satellite images of high resolution. Nowadays federal organizations, like INPE (TOPODATA Project, Brazil), NASA and USGS (SRTM 3 and 4, United States) make available images through on-line projects in digital format of several areas of the planet.

In order to represent the relief of the studied river basins and to observe the relationships with the hydrography and structural geology, it was selected the following group of data:

a) Vector cartographic base (or shapefiles) of the hydrographic basins in a scale of 1:50.000; Shapefiles of folds and geological flaws in a scale of 1:50.000 made available by CPRM (2005). b) Digital Terrain Model - DTM with a space resolution of 30 meters made available through the project TOPODATA - INPE (2011), specifically the layers Altimetry and Shaded Relief of the pages 12_42_ZN and 12_42_RS;

c) Monochromatic image and multispectral QuickBird of high resolution (0,6 m and 2 m respectively) for shaded effects of the year of 2015.

d) Software ArcMap 10.1 and extensions ArcGis (to organize and to overlay data) and ArcScene (modeling 3D)

An entire previous bibliography review related with the geology, geomorphology and hydrology of the study area were accomplished. Research made by Pereira (2010), Bonfim and Pedreira (1990) and Mattos and Fernandes (2013) were consulted in order to discuss the the results obtaining in this work.

2.2.2 Geoprocessing

Once the data were organized, the geoprocessing were made using the GIS ArcGis 10.1. In the composition of the layers, firstly the hydrographic vectors, folds and geological flaws were inserted. After the QuickBird image was inserted and last the altimetry bands and shaded relief of MDE Topodata. The datum of all the shapefiles were projected to WGS1984 in UTM, Zone 24S of Southern Hemisphere starting from the tool Dates Management tolls>Projections.

The QuickBird image presents a space covering of approximately 25.000 km², being a file of extensive size, what commits the speed of the GIS processing. For a faster processing it was extracted only the sierraous area around the basins, through the tool Tollbox>Extraction>Script Extract by mask. The bands of altimetry and shaded relief of the MDE

Topodata also presented an extensive land covering (32.000 km²), and it was submitted to the same extraction process.

The combination of the altimetry and shaded relief bands were developed observing the orientations of Valeriano (2008). Para better three-dimensional representation of the relief it is necessary to follow parameters such as: to simulate the solar brightness in the sky in 90º (using the tool Ilumination>altiude); azimuth illumination in the East direction (Ilumination>Azimuth). These combinations allowed the creation of the depth impression (or high relief).

It was applied in the altimetry band the effects strech>histograms and hilshade that modify the colors characteristics and enhance the forms of the land, giving clearness to the features of the valleys, slopes and hill tops. It was also applied to the shaded relief band for enhancing all the ash tones with values closer to zero (darkness) that represent the bottoms of the valleys. It was possible then to detach the shaded areas and to visualize with larger precision the direction of surface hydrology.

2.2.3 Three-dimensional Representation

According to Luedeling (2007) and Chen et al (2012), after accomplished the geoprocessing the three-dimensional representations (models) can be produced in two ways: One is the format TIN and the other is the Vertical Exaggeration of the Raster (Figure 4).

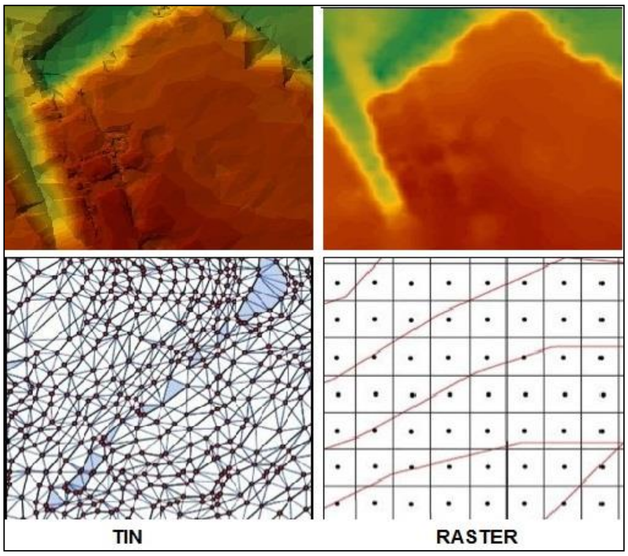

Figure 4 - Differences between a TIN and a Raster.

To generate TIN (Irregular Triangular Network) it is necessary the extraction of the contour level curves from the used MDE. The TIN is a structure where a mesh of points generates triangles. The contour level curves are references for the formation of the triangular vertexes, which link with the lines above or below its altimetry. It is generated a more punctual xyz data, joining more details in the representation of the land, defining better the features of small dimension.

The Vertical Exaggeration of Raster is a simple interpolation of the xyz values, with less details of the land. It is a simpler process and of fast processing, without the need to extract contour level curves, because the MDE is obtained in raster format, and it just need to apply a vertical exaggeration in the altimetry values, distorting the image and giving features of “high relief”.

For the composition of the three-dimensional maps of the study area, the two techniques were used, executed in the module ArcScene of ArcMap 10.1 For understanding the geomorphologic context of the area, it was also represented the sierras around the studied basins. The generated models (Figures 6 and 7) cover an area of approximately 860 km²: for a faster processing, to represent the adjacent basins areas through the Vertical Exaggeration of Raster (less details), since it is an area of secondary analysis.

For the threedimensional representation of the hydrographic basins of the rivers Lençóis, Ribeirão e Capivara it was used the TIN model, more sensitive the hillside features presented in the area. The model was generated starting from the extracted contour level curves of the MDE (altimetry of Topodata, leaf 12_42_ZN). The curves were obtained in equidistance of 10 meters. It was used the tool 3D Analyst that generated, through the technique of Krigagem, a mesh of triangles and irregular cubes that simulates the geo-forms of the area by the three axes of information xyz: latitude, longitude and altimetry.

3. Results and discussion

3.1 Hydrographic Basins

After formation of the data bank it was organized the shapefiles in a way that the overlaid was evidenced in the first moment, the valleys, as well as the features of the slopes and tops of the hill of the area. In the initial geoprocessing, the tool Tollbox > Extraction > Script Extract by mask was used to extract information of MDE Topodata of Altimetry and Relief only shadowed the studied hydrographic basins (Figure 5).

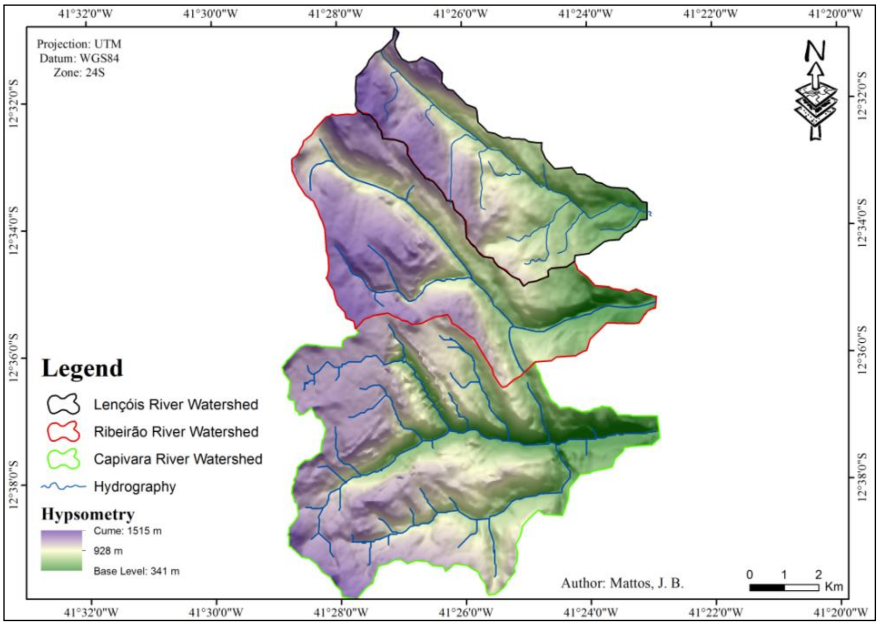

Figure 5 - Shaded relief of the hydrographic basins.

It is then observed the hydrographic file overlaid with the fluvial beds, contemplating the intermittent and perennial springs. The topographical characteristics along the fluvial channels of all the basins configure the formation of waterfalls, that has important for the water oxygenation, mainly the one of River Lençóis, that provides water for the city population (Bushes and Of Paula, 2013).

Another important point is the real representation of the plateaus noticed as the water divisors of the river Capivara basin. Exists enhances of the hillsides starting from the effect hilshade applied, because even not being a three-dimensional representation (model), the composition of the shades allows to identify the movement of the land, giving a “high-relief " aspect to the map.

Concerning the characteristics of the studied basins and in agreement with the concepts of fluvial hierarchy of Strahler, (1957): a) The River Lençóis hydrographic basin presents fluvial hierarchy of 3rd order, whose river principal possesses an extension of 10,3 km and 11 drainage channels. Presents an area of drainage of 24 Km² with perimeter of 26 km; b) the river Ribeirão hydrographic basin also presents fluvial hierarchy of 3rd order and the extension of the main river is 13,9 km, possessing 8 drainage channels. It drains an area of 28 km² with perimeter of 32 km; c) the river Capivara hydrographic basin is of the 3rd order, the length of the main river is 11,3 km, presenting 31 fluvial channels. The drainage area is of 51 km², with perimeter of 39,5 km. Figure 2 shows the landscape of this basin.

The drainage of the studied basins is classified like lattice (Cristofolleti, 1999). That pattern is characterized by the hydrographic development valleys that present confluences in right angles, conditioned by the synclines undulation and derived *anticlines* of the processes of geological folding. The three basins are prolonged, with values of *circularity* index varying from 0,43 to 0,49 and coefficient of compactness from 1,40 to 1,48, what denotes a structural control (geological) of the hydrology. The drainage density is of 0,81km/km², showing that the hydrography of the area is scattered and presents a deep fluvial dissection, in function of the accentuated slope from the springs to the basins outlet.

The average difference of altitude among the water divisors (1515m) and the outlets (341m) in the three basins generates a *scale* of approximately 1150m: the average steepness of the basins correspond to 22,19%, characterizing a wavy strong relief, according classification of

EMBRAPA (1999). The morphometric parameters indicate that the basins do not present a format similar to a circumference, corresponding, therefore, to a prolonged basins, making possible larger speed in the superficial drainage and smaller capacity of water retention of the system, decreasing in that way the possibility of floods in lowered zones, as the city of Lençóis.

3.2 Three-dimensional Representation

In the perspective of representing the forms of the relief of the studied area, the three-dimensional model made possible the identification of the structural alignments (geological flaws) that condition the direction of the superficial flow of the studied hydrographic's basins. It is possible to visualize in a clear way the contours of the formation Tombador, characterized by the sierras that t composes the interfluvial of the basins, in a defined conception as "sedimentary package ". In the same higher compartment group, it is possible to visualize the direction of the sierras (NW-SE): this landscape geomorphological pattern is the residual of the geological folds development happened at the end of the first tectonic event that molded the Chapada Diamantina.

Besides allowing the understanding of the regional geomorphological dynamics, characterized by altimetric differences of about 488 m in sharp hillsides, the model in TIN explained also the hydrological patterns of the basins. The *lattice* morphology of the rivers is understood through the several valleys in "V" format, more fit, allowing a linearity in the surface and subsurface flows. It is a representation that conceives the erosion processes and dissolution, mainly the quartzites rocks. Figure 6 illustrates the model.

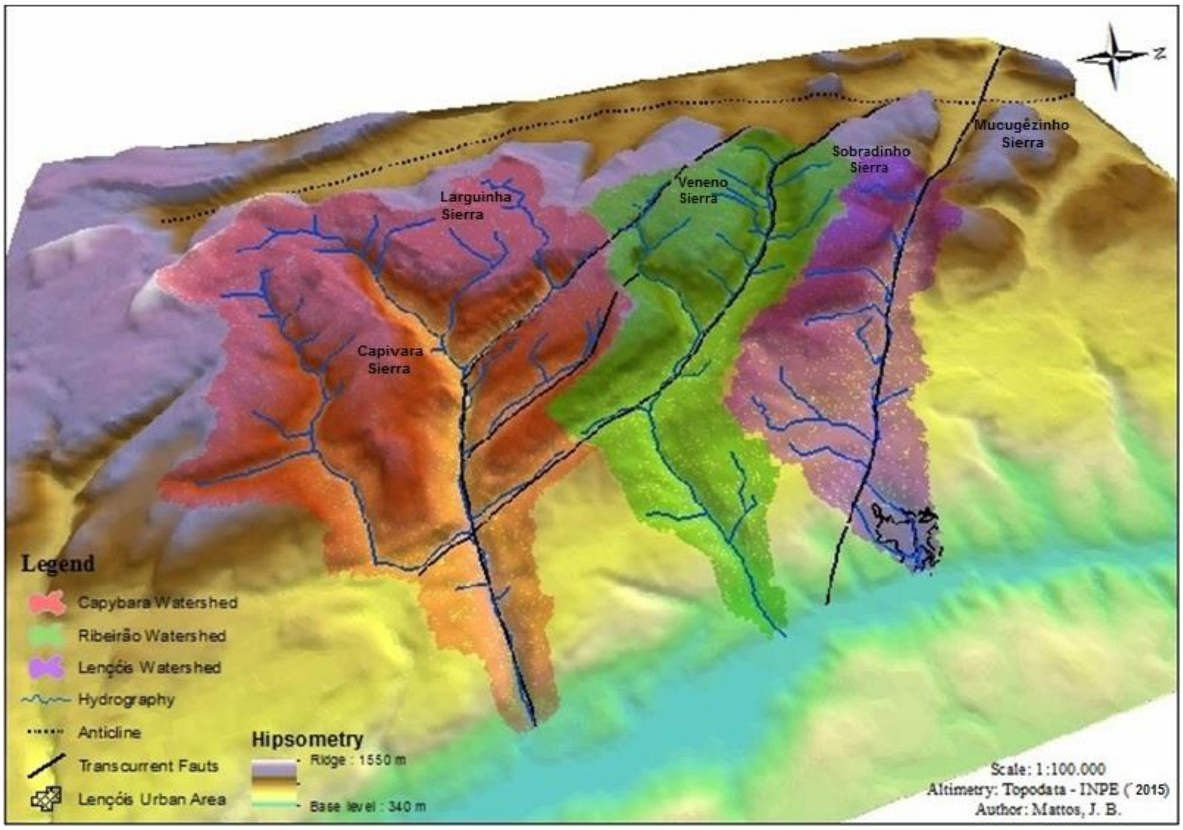

Figure 6 - Three-dimensional model of the basins.

When compared with the bi-dimensional plan (Figure 5), the three-dimensional model presented advantage in the sense of supplying a larger clearness on the influence of the geological flaws in all the relief system of the basins. Such fractures in the area also follow the direction NW - SF, in the wrapped up of the mentioned geological folds.

The basin of the Lençois river is moulded by the geological flaw north of the analyzed compartment. In the high course, it is strictly a drainage basin fit among two sierras: the Mucugezinho Sierra to the north, with 1430 m of altitude and the Sobradinho Sierra to the south, with 1435m of altitude. The bottom of the valley in that portion is in an altitude of 1100 m, showing an altimetric scale of approximately 420 meters. In the medium and low course, the width is not so accentuated with relationship to the interior portion: a decrease of the scarps is observed, what characterizes the relief *in loco* as slightly ripened (Guerra and Guerra, 2011). The low course shows zones of the alluvial plain of the River São José.

The basin of the river Ribeirão is conditioned by three central geological flaws in the analyzed compartment. The high and medium course proceeds precisely delineated in the direction of two flaws: the most extensive under the bottom of the main valley and the other two under the high areas in the east portion. In valley with an altitude of 1080 m, the Ribeirão river travels an extension of approximately 9 km over the flaw. Observing the model (Figure 6), it is noticed that the fracture proceeds until the river Capivara basin: however, a sedimentation process interrupted the hydrographic continuity among the rivers Ribeirão and Capivara, forming a water divisor. The Sobradinho sierra to the north and the Veneno sierra to the south (1455m) formed the divisors of the basins. In this last one, the two geological flaws are observed under the boards of the east portion. The river Fundão, affluent of the Ribeirão river, is the one that travels on such flaws, and after 2 km reaches the main river in the form of a waterfall of the same name, in a fall of water of 110 meters. The low course is characterized by the eroded relief of the alluvial plain of São José river.

Finally, the river Capivara basin presented molded for four geological flaws: three in the north compartment, adjacent the Veneno Sierra and one located in the central space. The three flaws around the Veneno Sierra are the same ones that also condition the morphology of the neighbor basin of the Ribeirão river (Figure 6). According to Mattos et al (2013), possibly that lineal configuration of the flaws that connects the basins is responsible for the hydrological flows that feed the fluvial channels.

The sierra of Larguinha (1488 m) and the sierra of the Capivara (1555 m) form the divisors of the high and medium course of the basin. On the flaw located more to east, travels for 2 km the river Fumaça, that forms the waterfall of same name, considered the largest fall of water of Brazil with 420 meters (CPRM, 2015). On the geological central flaw in the direction L-W, the river Capivara travels 8 km up to the river São José. It is the only main river of the analyzed basins that has the outlet on the end of the geological flaw. The medium and the low course of the basin are completed defined by the hydrological fit in the valley formed by the flaw, in a "V" form. All the rivers that reach the river Capivara are waterfalls.

3.3 Geomorphology

The types of the geomorphological compartments of the study area were easily identified in a three-dimensional model. However, for studies in hydrographyfic basins it is necessary to observe more detailed features initially on the identified classes, because several other lithologic influences are observed on the processes of mass movement and water flow. It is what is proposed by Guerra e Guerra (2011), in a conduction for a better differentiation among the hydrographic basins. In the case of the studied basins, a geomorphologic classification was used starting from features presented by Casseti (2005) and Guerra (1995), specifically defined for sedimentary reliefs, typical pattern of the Chapada Diamantina. It was identified six classes: Sierras, Anticlinal Valley, Fit Valleys, Lines of Flaw Valleys, Suspended Valley, Fluvial Terrace and Flood Plain, as shown in Figure 7.

The Sierras are basically the higher portions of the study area, embracing the boards (flat tops) and the smaller elevations than 45º. They are located in the high and medium courses of the analyzed basins and compose the head office of the local geomorphological landscape. There are a total of five sierras, as shown in Figure 6.

The valleys of the Flaw Lines (put upon and conditioned by geological flaws) were observed in the three basins, however two are only valleys. The first is in River Lençóis basin and is the feature of whole central valley. The second starts in the basin of the Ribeirão river and ends in the one of Capivara river. Even with defined valley, the hydrograph of the two basins is not connected due to the sedimentation process.

The Inserted Valleys are in form of "V" and usually present slopes of 45º or superior. It was identified in the basins of the Ribeirão and Capivara rivers, mainly in places where the 2nd order rivers begin, proceeding until the medium course. The Palmital valley is the only exception of that pattern: its feature is of a Suspended Valley, with scarps of medium steepness of 50º that reach the Capivara river in the form of a waterfall (of same name) of 137 meters of height.

Finally, the Fluvial Terraces and Flood Plains form the low courses of the analyzed basins. They are characterized for the most part by the flat feature, located on the flood plain of the São José river. In the low course of the basins, the eroded sediments are deposited and later removed during the periods of high discharges of the São José river.

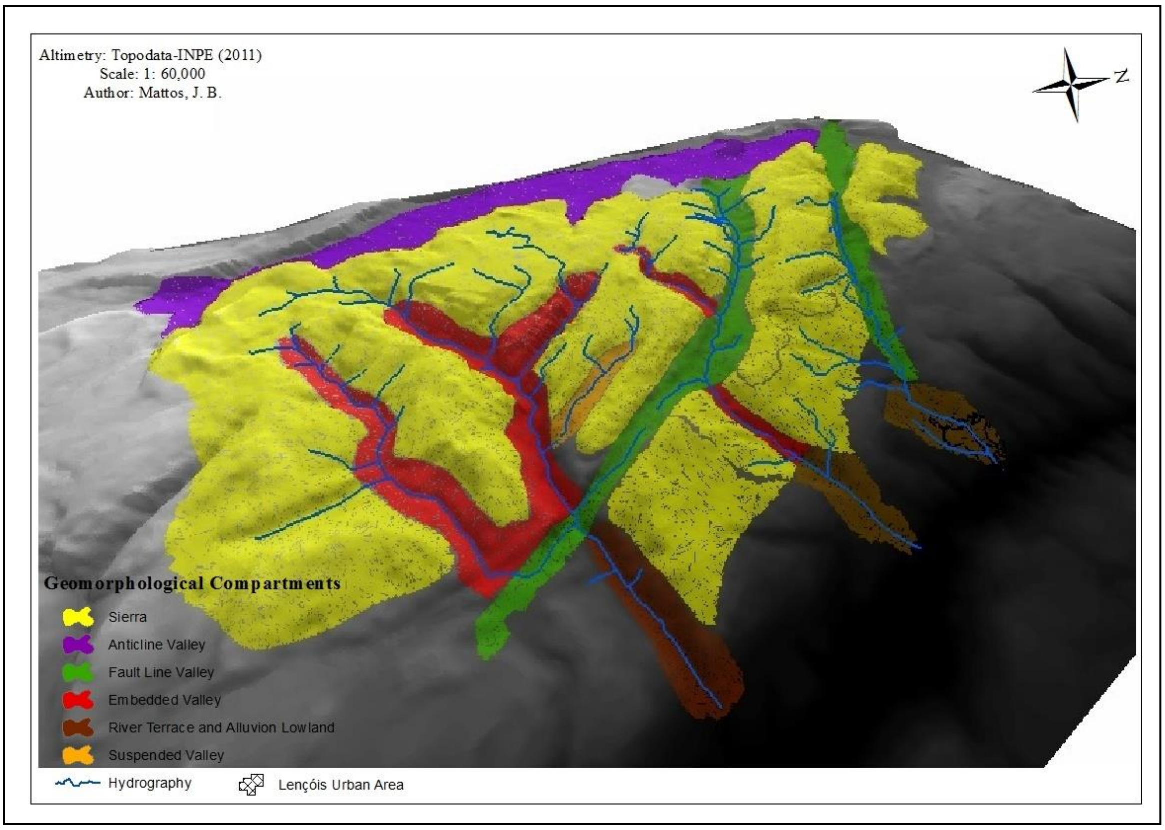

Figure 7 - Three-dimensional model of the hydrograph basins with the detected geomorphologic compartments.

4. Conclusions

The use together of the knowledge in geology and hydrology obtained from the bibliography, and the structural *sketches* in the generated models made possible to identify and to classify the structural geology, the geomorphologic compartments, as well as the dynamics of the surface runoff, drainage and infiltration.

The use of the three-dimensional modeling as methodology for identification of features and structures of the terrestrial surface was characterized as an efficient tool, capable to turn more precisely the classification in comparison with planned and bi-dimensional models. It was possible to identify that the basins of the rivers Lençóis, Ribeirão e Capivara, in the municipal district of Lençóis (BA), presented similar tectonic structures, slanted by tearing flaws of sinister typology, with vertical reject, where the increase of your maximum displacement is systematic and related with the length of the flaw. In the basins of the area of Lençóis these flaws control most of the drainage network.

The drainage pattern observed in the model, as well as the features of the flows direction evidence the influence of the geological typology and geomorphology of the study area in the water dynamics. The determined geomorphologic compartments that were predominant in the landscape were the sierras, the fluvial valleys in the flaw lines, well fit and in jovial period of the relief modeling, fluvial terraces and flood plains.

The application of such a model is shown effective and it appears as a good possibility that facilitates the whole process of identification of the terrestrial surface, however, in the current days, the generation of that modeling type depends on computer equipments capable to process a great number of information and at the same time it makes possible the handling of the same ones in a short interval of time, optimizing the methodological application.

These features if well represented, following a correct methodological route together with the geotechnical and climatological studies can serve as base to foresee hydrological behaviors in a hydrograph basin and the load capacity of a hillside. Depending on the consistence of the data, cartographic artifices can be dispensable, as the case of the moderating of the classes and of the vertical exaggerations, but everything will depend on the convention adopted for execution of a certain job.

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