Acta Scientiarum. Technology
ISSN: 1806-2563
eduem@uem.br
Universidade Estadual de Maringá
Brasil

Acta Scientiarum

http://www.uem.br/acta
ISSN printed: 1806-2563
ISSN on-line: 1807-8664
Doi: 10.4025/actascitechnol.v34i1.9944

Seppômen maps for geomorphic developments analysis: the case of Paraná plateau border, Faxinal, State of Paraná, Brazil

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ABSTRACT. This article presents the seppômen map technique through the computer application by using the free GIS software SPRING®. The methodology was applied to the study in the case of the geomorphologhical evolution of the Parana plateaux edges contained in the Faxinal topographic sheet – state of Paraná - Brazil, the results were the digital elevation models (DEM) and topographic shapes that leads to the landform evolution of the area both by differential erosion but also by strong tectonic control.

Keywords: seppômen, Faxinal sheet, Parana plateaux edges, GIS.

Mapas de seppômen para análise da evolução geomórfica: o caso da borda planáltica paranaense, Faxinal, Estado do Paraná, Brasil

RESUMO. O presente artigo apresenta a metodologia da técnica de confecção de mapas de seppômen (mapa de nível de topos) por meio da aplicação computacional pelo geoprocessamento utilizando o software livre SPRING®. A metodologia foi aplicada ao estudo de caso da evolução geomorfológica das bordas planálticas paranaenses presentes na carta de Faxinal, Estado do Paraná, os resultados foram modelos digitais de elevação do terreno e perfis topográficos que apontam para a evolução da área tanto por erosão diferencial como também por forte controle tectônico.

Palavras-chave: seppômen, carta de Faxinal, bordas planálticas paranaenses, geoprocessamento.

Introduction

Seppômen maps (top level map) aimed at the modeled reconstruction of the past relief, and are made from topographic maps. The technique was originally presented by Japanese geologists and geomorphologists (HUZITA; KASAMA, 1977). The English translation of the term "summit level map" was little known in scientific circles. The term seppômen comes from the Japanese language which means the plane formed by the contact with the highest points.

The main seppômen map applications are for paleorelieves and eroded volcanic buildings investigations as well as morphostructural and morphotectonic analysis (HUZITA; KASAMA, 1977; MOTOKI et al., 2007, 2008, 2009; SICHEL et al., 2008).

This paper aims to present the methodology from the use of geoprocessing techniques, using the free software SPRING® version 5 of the National Institute for Space Research (INPE), allowing the minimization of errors in the manual form of preparation and in the runtime.

Through seppômen, combined with field control, it's possible to partially understand the erosion processes that drive the relief evolution, here the Paraná plateau edge, represented by the Triassic-Jurassic Escarpment, as well as the lithostructural and morphoclimatic controls, responsible for these morphologies development.

The working area

This study covers the area represented in the topographical sheet of Faxinal – State of Paraná, on the scale of 1/50.000 (Chart SG-22-V-III-1), located between 24°00' and 24°15' south latitude and 51°15' and 51°30' west longitude, including the municipalities of Faxinal, Cruzmaltina, Grandes Rios, Rosário do Ivaí and Ortigueira in the State of Paraná.

This area is in a part of the Paraná Sedimentary Basin, north-central region of Paraná State. Most of the area is included in the Second Paraná Plateau (MAACK, 1981). The Third Paraná Plateau is represented by a small portion in the northwest and northeast of the sheet. The boundary between both relief units is represented by the Serra Geral (Figure 1).

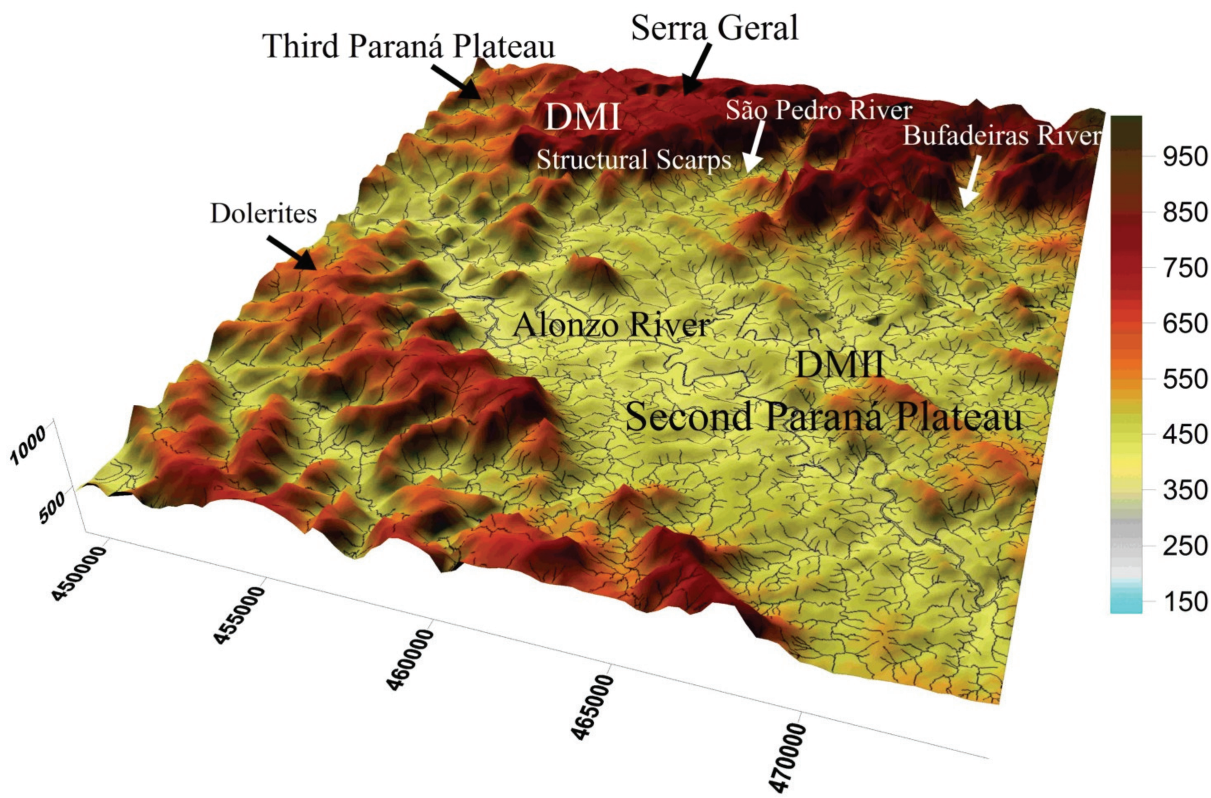

Figure 1. Location of the study area - digital elevation model of the Faxinal topographic sheet (Chart SG-22-V-III-1).

In lithostratigraphic terms, the study area comprises a combination of red to purple siltstones and mudstones, laminated and with friable aspect, with gray and red tabular sandstone layers. These lithologies are from the Paleozoic and correspond to the older units in the area, belonging to the Rio do Rasto Formation. The contact with the Piramboia Formation, superimposed, is through lithological and mild angularity disagreement and marks the beginning of the Mesozoic (SOARES, 1975).

The Piramboia Formation corresponds to a fine to very fine and very crispy sandstone, in a package that can reach up to 20 meters thick. The color is light gray to white, with low-angle cross-bedding and sigmoidal and plane-parallel.

The Botucatu Formation occurs over the previous one and includes red and quartz sandstone, fine to very fine until conglomeratic, very resistant to erosion, and displaying medium to large slotted cross bedding.

Superimposed on the Botucatu Formation and occupying the stratigraphic column of the study area, there are basalts and dolerites of the Serra Geral Formation. This Formation is composed of successive basalt flows with sandy intercalations from Botucatu Formation at the base.

In the geomorphological context, the area comprises the Morphostructural Compartment I (DMI) from Fortes et al. (2008), located at the northern end of the study area (Figure 1). The most singular aspect of this relief unit is the structural scarps, which mark the contact with the Morphostructural Compartment III (DMII) from Fortes et al. (2008).

The Morphostructural Compartment III (FORTES et al., 2008) corresponds to a zone located in the western area (Figure 1), and comprises the scarps controlled by basalts and dolerites of the Serra Geral Formation and sandstones of the Botucatu Formation.

Lower areas are represented by more friable lithologies, formed by siltstones and sandstones of the Rio do Rasto Formation that outcrop in the central-southern area (Figure 1). It corresponds to the Morphostructural Domain IV (DMIV) proposed by Fortes et al. (2008). It presents residual relief supported by silicified sandstones of the Botucatu Formation. Diabase dikes cut this relief unit, forming flat tops elongated mountains.

Material and methods

The Faxinal topographic sheet, scale 1/50,000, published by the Ministry of Defense, Chart SG-22-V-III-1, was used as a database to conduct this work, subsequently the topographic data processing was executed through the softwares "SPRING® version 5, (INPE, 2004) and "Surfer for Windows®, version 7 (GOLDEN SOFTWARE, 1999).

The seppômen maps elaboration, hand made, is done from the transparent graph paper overlapping on the topographic map, and based on graph paper, a mesh is defined which may be 0.5, 1 and 2 km. In each area defined in the mesh, the highest point is plotted, as well as latitude and longitude are determined.

By the defined points, a table with the obtained data is create (latitude, longitude, highest mesh altitude) and in the Surfer® software, these values are interpolated generating isolines (contour lines) and allowing to generate digital terrain elevation models (DEMs) and topographic profiles.

The seppômen maps development obeys the following steps: a) topographic map division into square areas from a pre-defined grid of 0.5 km, b) the highest point marking in each square defined in the mesh, c) a new topographic map elaboration from the contour construction, using only the highest point in each quadrant, as shown in Figure 2 (MOTOKI et al., 2008).

For a computational form development, first, a database is prepared in SPRING ® Software and after the georeferencing and digitizing of topographic maps, by the isolines (contour lines), it was generated a rectangular grid or a regular grid. It is defined according Felgueiras and Câmara (2001) "as a digital model that approximates surfaces through a rectangular polyhedron faces."

In the rectangular grid generation process, with SPRING® software, you should inform the type of input (sample) consisting of the contour and the plane of output information (PI), where the ready grid will be stored.

The interpolator used for generating the grid was weighted average per share and per quadrant, where the weighted average is calculated, the value of the share of each grid point is calculated from the weighted average of shares of the eight closest neighbors to this point, but attributed to varying weights to each sampled by the function that considers the distance from the quoted point to the grid point, as shown in Figure 3 (FELGUEIRAS; CÂMARA, 2001).

Through this method it was possible to highlight the highest points, as shown in Figure 4. Thus, it was possible to plot the chosen points more precisely, since we do not have the problem of superimpose the paper to the chart and the information loss that occurs in the traditional seppômen map preparing method.

After this stage of the study, fine meshes were compiled, as already shown in the values of 0.5 and 1 km, and superimposed on a rectangular, as shown in Figure 4.

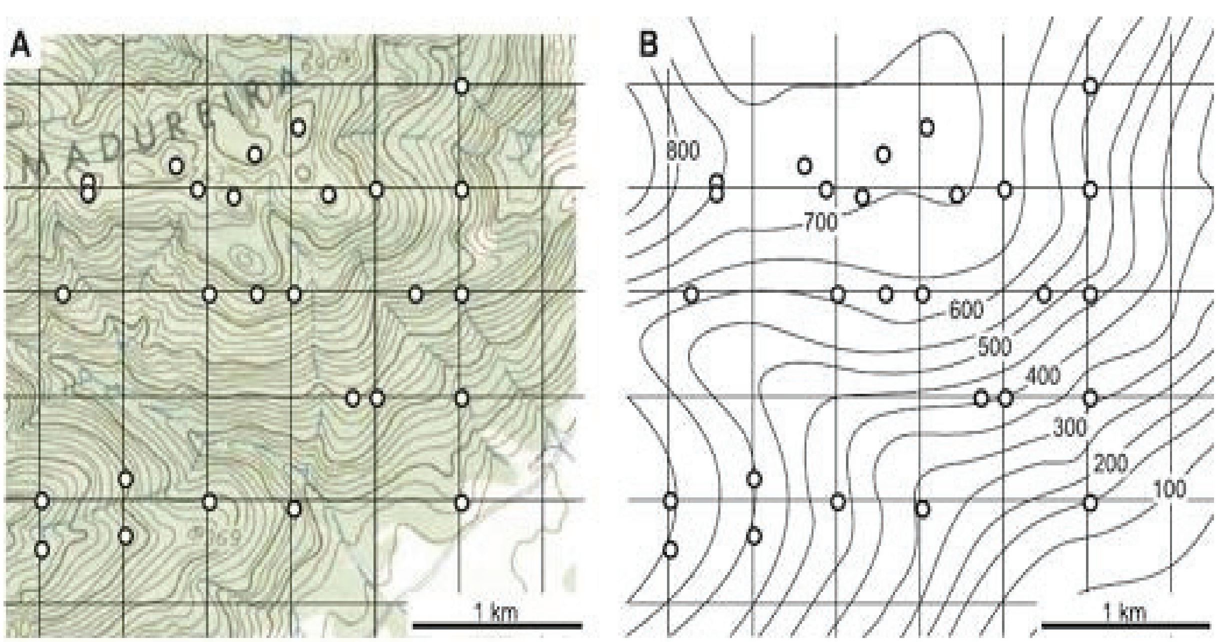

Figure 2. Illustration of the conventional method to prepare the seppômem map (MOTOKI et al., 2008).

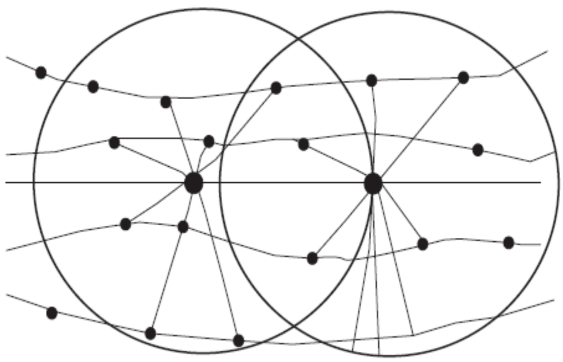

Figure 3. Source Felgueiras and Câmara (2001). Neighbors selection per quadrant and per share.

The highest points were sampled, first to the 0.5 km grid and then to 1 km grid. In this step, we used the SPRING® editing tool. The points were edited into information plans in MNT categories to allow the possibility of informing the altitude value of each point at the edition moment, using the tools to edit points and so provide the highest points and graphics editing checked to assign the altimetric values of each point. Thus, we have another points type sample with values of x, y, and z, the points collected for the grids 0.5 and 1 km can be observed in Figure 5.

From the points collected, you can create other isoline values for the respective grids 0.5 and 1 km, the actual SPRING® software automatically generates the new isolines from a new triangular grid compiled from the collected samples.

After the triangular grid generation (TIN), using the same MNT tool in isolines generation, you can choose the completed file or a sample on screen, the software sets the minimum and maximum values and after it is chosen the desired interval between the isolines.

Results and discussion

Seppômen maps were made for Faxinal topographic sheet based on 0.5 km and 1 km meshes (Figure 6).

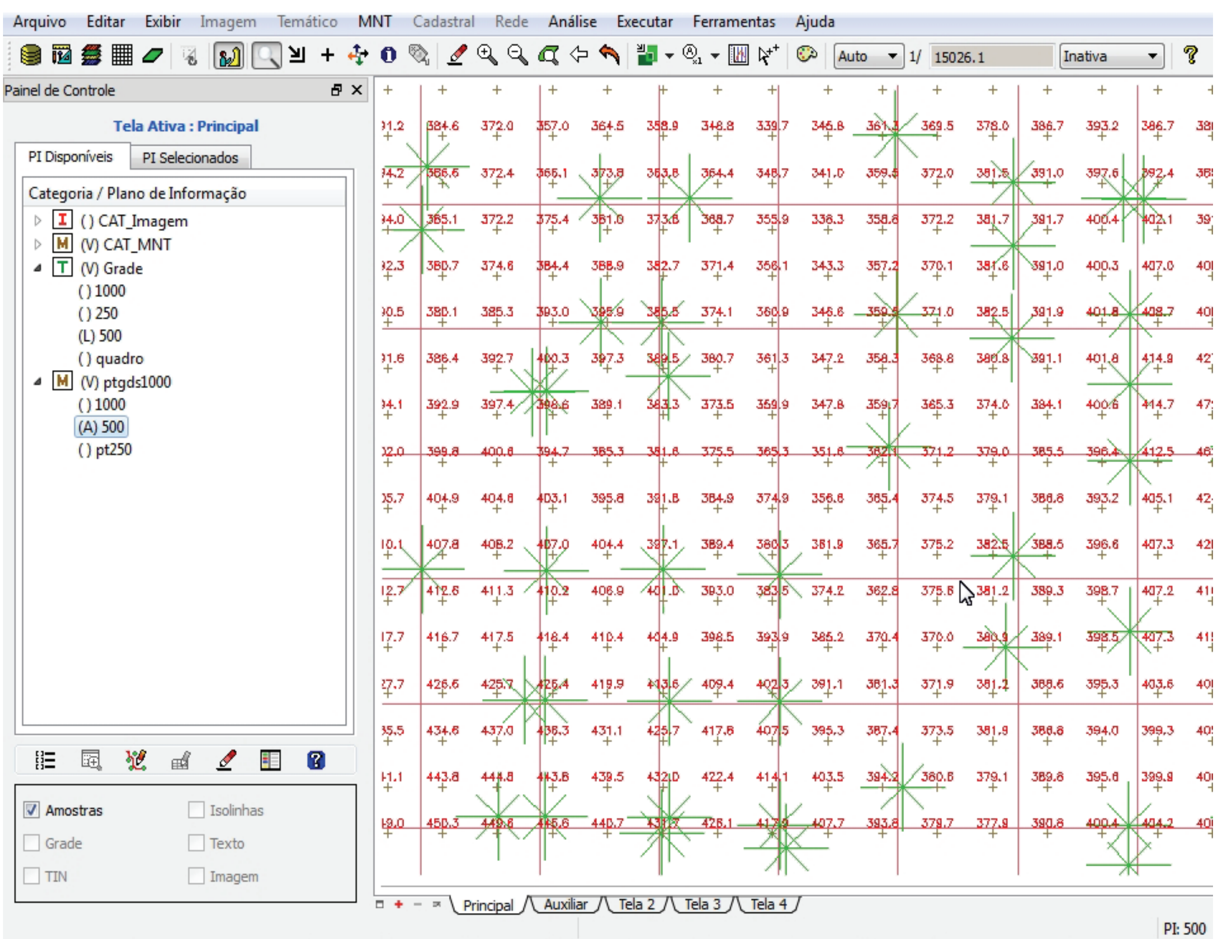

Figure 4. Rectangular grid or regular grid. The screen contains items with altitude values, of which the information of the highest points are extracted for the elaboration of the seppômen map.

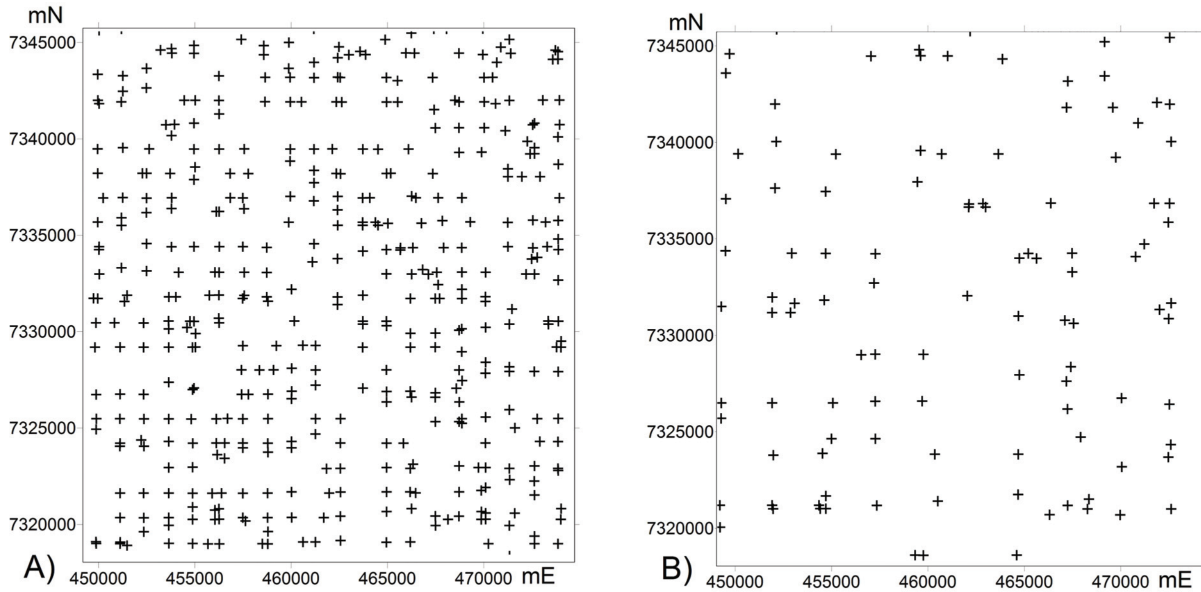

Figure 5. Quoted points samples, A) 0.5 km sample grid and B) 1 km sample grid.

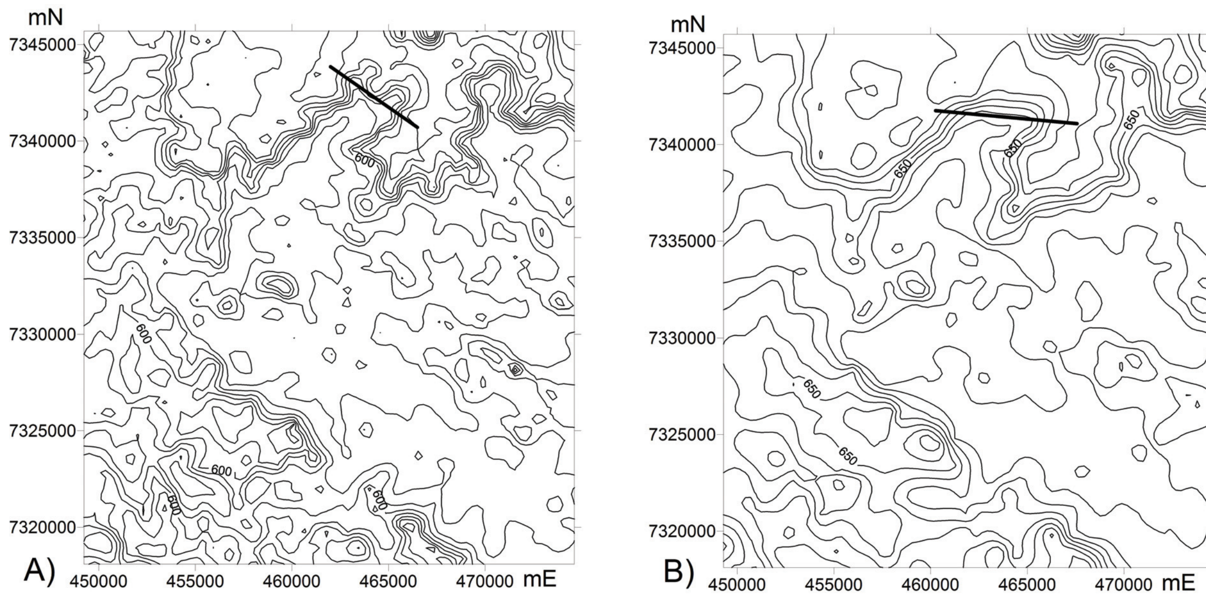

Figure 6. A) Paleosurfaces Maps based on seppômen technique, based on 0.5 km grid, and B) 1 km grid.

The cliffs that surround the sedimentary basin of Paraná edges, present in the topographic sheet of Faxinal, show high topographic variations, with values less than 380 m in the valleys and reaching close to 1,100 m in the cliff tops. They also present high angle with slopes above 40 degrees or 47% at the cliff edges, hills and dikes, as it can be seen in Hipsometry and slope maps (Figure 7).

The comparative analysis of the seppômen maps and Digital Elevation Models (Figures 6 and 8) show that despite the small retreat of the escarpment, the valleys widths were already very substantial, very close to the current situation.

The profiles of Figure 9 show a sharp vertical kneeling process of the landscape, typical of morphoclimatic humid areas, which can range from 20 to over 100 m depth, to 0.5 km scale, and from 20 to over 150 m when considering the 1.0 km scale. These evidences can be verified from the thick alteration mantle, whose thickness can reach up to 25 m, like those developed on basaltic rocks of the Serra Geral Formation, located in the northern area (Figure 9).

Although the topographic profiles extracted from the seppômen map indicate morphogenetic activity associated with the relief intense supergenic change, evidence of relief polycyclic evolution associated with morphoclimatic areas more stringent than the current one can be determined by the different grades of levels and thresholds, as well as by residual relief and correlative deposits of these stages, as detrital pediments, all observed in the field (Figure 9B and C).

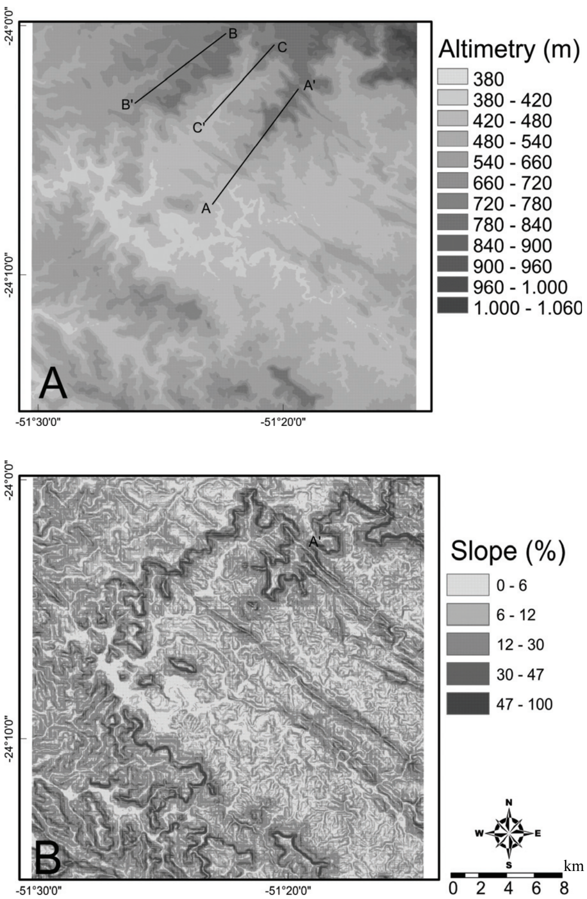

Figure 7. A) Hipsometry and B) Slope of the Faxinal topographical sheet. Chart SG-22-V-B-III-1.

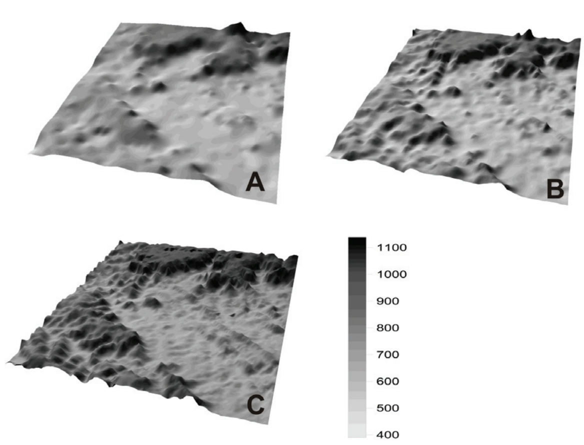

Figure 8. Digital terrain elevation model for the Faxinal topographic sheet isolines, A) 1 x 1 km resolution, and B) 0.5 x 0.5 km resolution and finally C) MDT without the seppômen technique application.

The presence of residual relief in the lower third of the São Pedro basin, near the watersheds of the left margin of the basin also show paleoclimatic legacies associated with parallel retreat of the Serra Geral slopes (Figure 10). However, their presence recorded on seppômen maps indicates that the activity of harsher climates in ancient times is older than that covered by the maps in question.

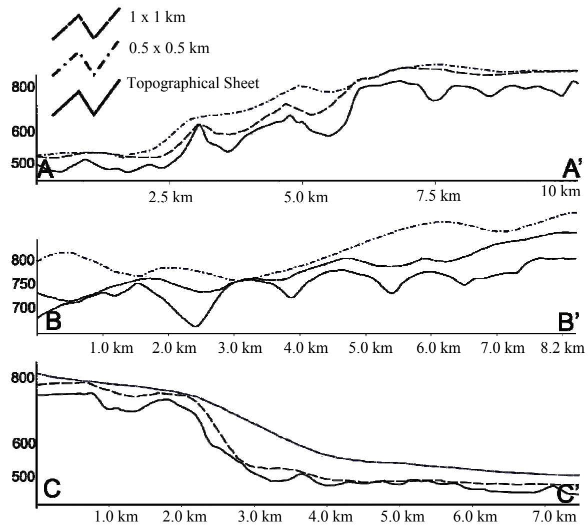

Figure 9. Faxinal Topographic sheet profile. In all profiles, it is evident the relief lowering by the vertical erosion. The residual relief and the cliffs show decreases of about 1.0 to 1.0 km scale and less 300 m to 0.5 km scale.

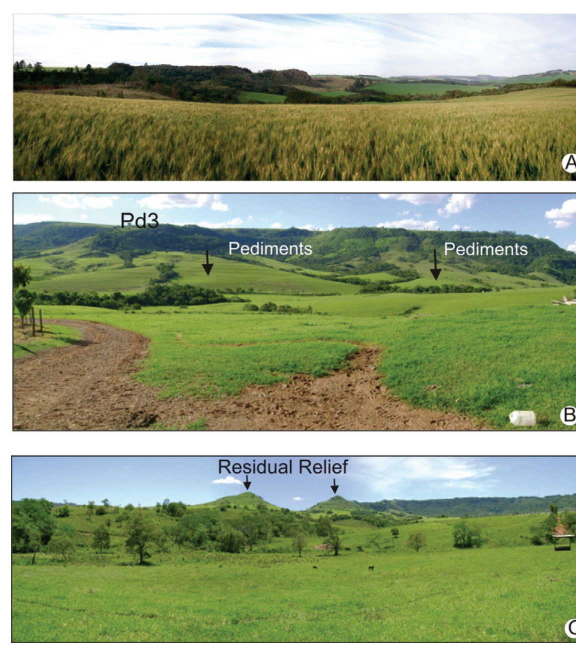

Figure 10. Partial view of the northern part of the area, which highlights the modeled wavy relief on basaltic rocks of Serra Geral Formation and with thick soil predominance (A). Partial view of the scarped fronts relieves, which form the First to the Second Paraná Plateau edges (B, C). The residual relief in forms of inselbergs and pediments (B and C) testify parallel slope retreat processes in semiarid climates.

The Figure 10 shows that this area of study has always been at least two distinct compartments of relief. The first located in the north and southwest, where the higher surfaces are almost flat (Figure 10A). This feature shows the basalt flows importance in the relief configuration, which horizontal arrangement and lithological resistance represent the main controlling factors of the hilly morphology current and past. The second compartment is represented by the most lowered areas, whose residual relieves were already present (Figure 10).

The digital elevation models of Figure 10 show an increasing process of vertical landscape dissection, which could lead to the conclusion in a change in climatic conditions from dry to more humid. However, this fact demonstrates the limitation of the technique, because it assumes that the highest tops were always at that same altitude. Figure 10 serves to show, in this case, the role of differential erosion in the definition and reworking of inherited forms (Figure 11).

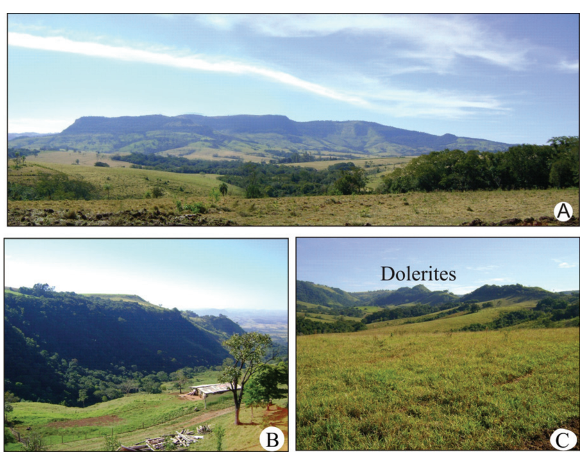

Figure 11. Extensive alignments of diabase dikes of the Serra Geral Formation. These dikes can control the structure of the escarpment and underline the differential erosion action in the reworking of the inherited relieves from drier climates of the past.

Paleoclimatic interpretations alone do not justify the rotation from E - W to NW - SE (Figures 6 and 8), observed mainly in the amount of São Pedro and Bufadeiras river which remains to this day. This rotation also shows strong diabase dikes influence in the differential erosion process.

The present direction (NW-SE) is associated with the presence of numerous diabase dikes. It is possible that the rotation is related to erosion and escarpment retreat on more friable lithologies of the Rio do Rasto, Piramboia and Botucatu Formations. Thus, the escarpment retreat would have been aborted or even reduced when erosion has reached the diabase dikes, lending this geometry for the escarpment. The topographic profiles and the digital terrain models demonstrated the differential erosion importance on relief reorganization and on the vertical landscape lowering.

The litoestructural influence was evidenced by the rotation of the main escarpment, the upper course of São Pedro river, and that limits the Second of the Third Paraná Plateau, from a position in the first stage substantially W-E to NW-SE today (Figure 6). The lithologic control is achieved by the increased strength of diabase dikes in NW-SE, for the pelitic and psammitic lithologies surrounding the areas.

Conclusion

The cyclic morphoclimatic evolution is well represented by typical relief features and correlative deposits of cliffs retreat, which were not presented in this study by the limitations of space in the article. These palaeoclimates testimonials relieves show themselves quite reworked by the action of differential erosion.

In referring to the limitations of this technique, these are related to the impossibility of the chronological treatment, it is only possible to infer relative dating by altimetry correlation with known paleosurfaces already addressed in scientific literature.

The association between paleosurfaces data with neotectonic evidence also has serious limitations, although it may submit a good correlation with structural elements. The paleosurfaces data analysis, based on the seppômen technique requires to start from local tectonic stability, considering that subsiding tectonic movements may obscure or even alter the landscape development interpretations. Therefore, interpretations of morphotectonic character require careful analysis.

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Received on April 11, 2010.
Accepted on August 2, 2010.