Remote sensing tools applied to structural lineaments identification at Caraíbas-Itacarambi seismic zone, Minas Gerais, Brazil

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Abstract

In this paper, we present the results of an investigation based in remote sensing to extract lineaments and foliations by the visual method using Landsat +7ETM and by the automatic method using TOPODATA (SRTM). The main objective was to find lineaments that can be associated to the seismogenic fault indentified by the seismological data in the Caraíbas/MG area, where there was an earthquake of 4.9 mb and VII MM (Mercalli Intensity Scale Modifield) in 2007. The combined analysis of these two methods showed the existence of a plane striking N20-40E, agreeing with Brandalise et al., (1980) and Cunha Filho,(2004) suggesting reactivation of a preexisting fault in the region.

Introduction

On December 9, 2007 the village of Caraíbas, north of Minas Gerais State, located in the middle of the São Francisco Craton, was shaken by a 4.9 mb event, causing intense damage to adobe masonry houses and producing the first fatal victim in Brazil (Chimpliganond et al., 2010). This mainshock was felt up to 80 km away from Caraíbas and the maximum intensity reached VII MM (Mercalli Modified Intensity Scale). The focal mechanism solution coupled with hypocentral distribution of the aftershocks suggest a 3 km long fault plane striking N30E and dipping 40 degrees to the Southeast (Chimpliganond et al., 2010). However, no major structural feature is known in the area that could be easily associated with the December 9, 2007 mainshock. So, in this paper we present the results of an investigation based on remote sensing data to find structural lineaments that can be associated to the seismogenic fault identified by the seismological data.

The interpretation of the remote sensing data using the digital or analogical form seeking for indentify printed features and the determination of its meaning have been the subject of many other researchs. One example is Almeida, 2009, that have used the data from the brazilian radar sensor R99SAR, operating under agreements by the General Command of Aerial Operations, where her main objetive was to develop methods for image interpretation in geological mapping. For this reason, we have used in this research a part of her methods in order to extract the lineaments and drainage foliations present in the region.

One of the steps of her research consisted in studying the layout and ordering of the elements identified in the image where landforms and drainage were defined by specific sets property.

According to this research, should be defined the following properties for the textural elements of the drainages: frequency, lineations, alignments, entropy, homogeneity and asymmetry. By these definitions, are set the properties of shapes, textural frequency, structure, degree of structuration and order of structuration. Using this definitions, these shapes properties are set: textural frequency, structure, structuration degree and structuration order .

To Mantelli et al, 2009 the analysis of the drainage properties is in element of great significance in geological studies and may reveal important information about the tectonic setting. This type of study is particularly relevant in areas of very low altitudes, as in our study, where traits linked to relief are meaningless. The results obtained through analysis of remote sensing products, revealed a number of relevant features to thiskind of study, such as the prevalence of drainage lineaments and their directions In this method above, the automatic extraction of drainage utilizing SRTM was used.

Therefore, for this research was based to extract foliations and alignments using TOPODATA image, project prepared by SRTM data available on the Internet, which offers topographic data and their basic derivations at national coverage and Landsat 7ETM+ data are acquired at 30 meters (bands 3, 4 e 5) and the panchromatic band (band 8) 15 meter resolution, which allowed the merger with the RGB composition (bands 3, 4 e 5). "Data fusion consists of a formal structure in which they are expressed concepts and tools for merging data from different sources in order to obtain more qualitative information" according to Wald, 1999 apud Pinho, 2005.

We have used visual and automatic methods in orther to minimize possible errors in the addition or omission of some data.

Geological setting

The study area is located at the northern part of Minas Gerais State, in the middle of the São Francisco Craton (Fig. 1). The São Francisco Craton is part of the Gondwana Neoproterozoic supercontinent, formed by agglutination of continental masses which were involved in multiple and successive collisions (Cordani et al., 2000). The basement of São Francisco Craton comprises medium to high-grade metamorphic terranes of Archean age, mainly gneiss and granitic rocks, of the Januária Complex (Nobre-Lopes, 2002; CPRM, 2003; Martínez, 2007). These rocks were last deformed/metamorphosed before 1.8 Ga. During Neoproterozoic times, a sequence of platform to continental sedimentary rocks of the Bambuí Group was deposited over the cratonic basement. This group is represented in the study area by limestones, dolomites, siltstones and marbles (Sete Lagoas, Serra de Santa Helena, Serra da Saudade and Lagoa do Jacaré formations) (Nobre-Lopes, 2002; Martínez, 2007). Overlying these units are Mesozoic eolic sandstones of the Urucuia Group and alluvium and detritic-lateritic covers of Cenozoic age (Fig. 1). Structural lineaments mapped to the south of Caraíbas show NE-SW trend, being rotated anti-clockwise to the north to NW-SE (CPRM, 2003; Nobre-Lopes, 2002; Martínez, 2007).

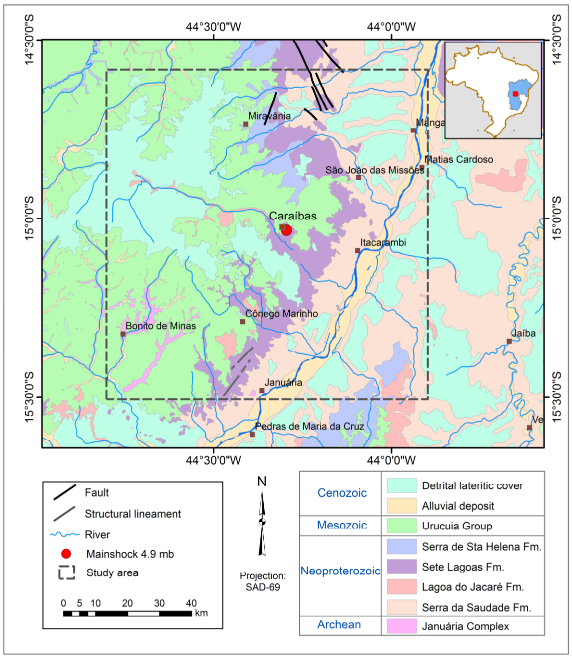


Fig 1 – Geological map of the Caraíbas-Itacarambi seismic area.

Method

The interpretation of digital and/or analogical remote sensing data to identify features and to define their meaning has been the subject of various papers. Almeida (2009) used R99SAR sensor data to develop methods of image interpretations in geologic mapping. In the present paper we used some of these methods to extract lineaments and foliations from drainage of the Caraíbas region that can be correlated to the observed seismicity.

We extracted drainage features from Landsat 7ETM+ satellite image using a visual procedure. An automatic procedure was applied to the TOPODATA data, a geomorphometric derivation from SRTM (Shuttle Radar Topography Mission) freely supplied from INPE (Brazilian Spatial Research Institute) (http://www.dsr.inpe.br/topodata/).

3.1 – Visual Method

The Landsat 7ETM+ satellite image was used due to the good resolution for natural resources and the spatial resolution of the panchromatic band (15 meters). Two scenes of the study area from September 21, 2000 and October 23, 2001 were freely downloaded from the GLCF - Global Land Cover Facility homepage. The orbits used were 219/070 and 219/071. The images from this site are already orthoretified and georeferenciated to UTM projection zone 23 South WGS-84 datum.

We used the code ENVI 4.4 to process the images and create a mosaic of bands 3,4,5, with 30 meters of resolution, combined in RGB composition. The next step was the fusion of these bands with the pancromatic one (band 8) that resulted in a higher quality image (15 meters of spatial resolution). To make the fusion we used the Gram-Schmidt Spectral Sharpening in the spectral domain (more details in Smith, 2003 apud Pinho, 2005). After that we applied a linear realce of 2 percent.

The image obtained after the previous steps was used to digitize the drainage network using the code ArcGis 9.3 and visual identification of different colors, forms, roughness and texture patterns (Fig. 2)

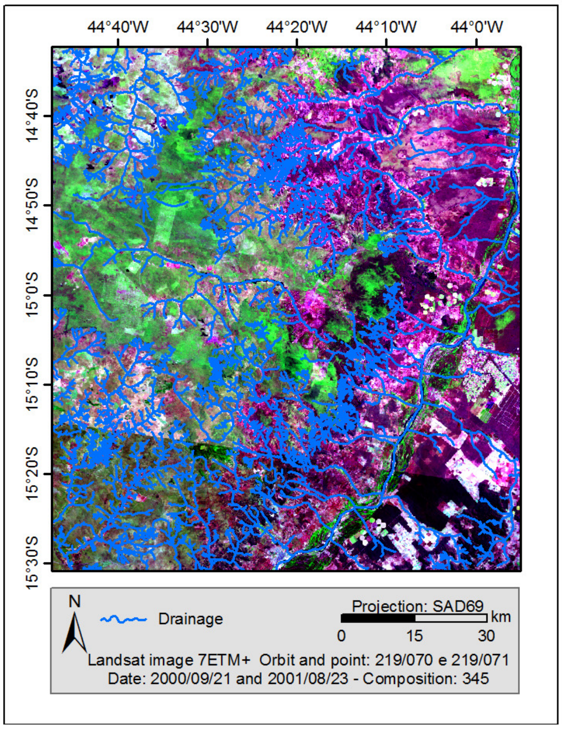


Fig 2 – Drainage obtained from the visual method.

3.2 – Automatic Method

The TOPODATA data used (14_45 and 15_45 articulations) were processed using Global Mapper 8.0 code to project in UTM_WGS84 Zone 23 South coordinate system and transformed to GRID data.

In ArcGis software some procedures were applied using the Spatial Analyst tools. First of all, we used Hydrology>Fill to apply a filter. Following we used the Hydrology>Flow Direction and next Hydrology>Flow Accumulation. Later, we applied a conditional separation of values less than 1000 meters: Spatial Analyst Tools>Conditional>CON (value>1000). To remove the excess of information and improve the visual of the image we applied Spatial Analyst Tools>Hydrology>Stream to Feature. Finally, we converted the raster to shapefile (Fig. 3).

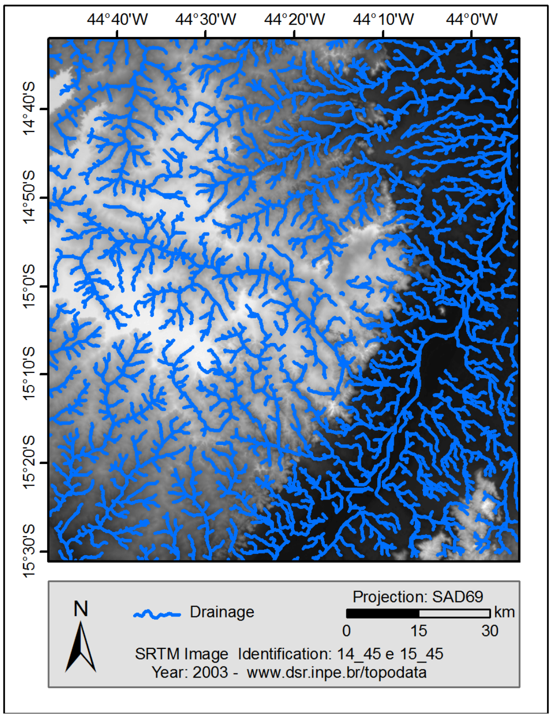


Fig 3 – Drainage obtained from the automatic method.

Results

For both the drainage obtained by visual and automatic methods we applied topologic correction and generalization. The generalization promotes the simplification of the drainage lines, removing small fluctuations and curves, but maintaining the essential directions. We applied the Point Remove algorithm with maximum tolerance of 1 km e 10 km.

Finally, the shapes were divided into alignments (length more than 4 km) and foliations (less than 4 km) for each one we perform rose diagrams using code Stereo32.

The results were divided into the following groups: foliation (Fig. 5 a) 1 km b) 10 km) and lineament (Fig. 6 a) 1 km b) 10 km) extracted from the visual method and foliation (Fig. 7 a) 1 km b) 10 km) and lineament (Fig. 8 a) 1km b) 10km) extracted from the automatic method.

a)

b)

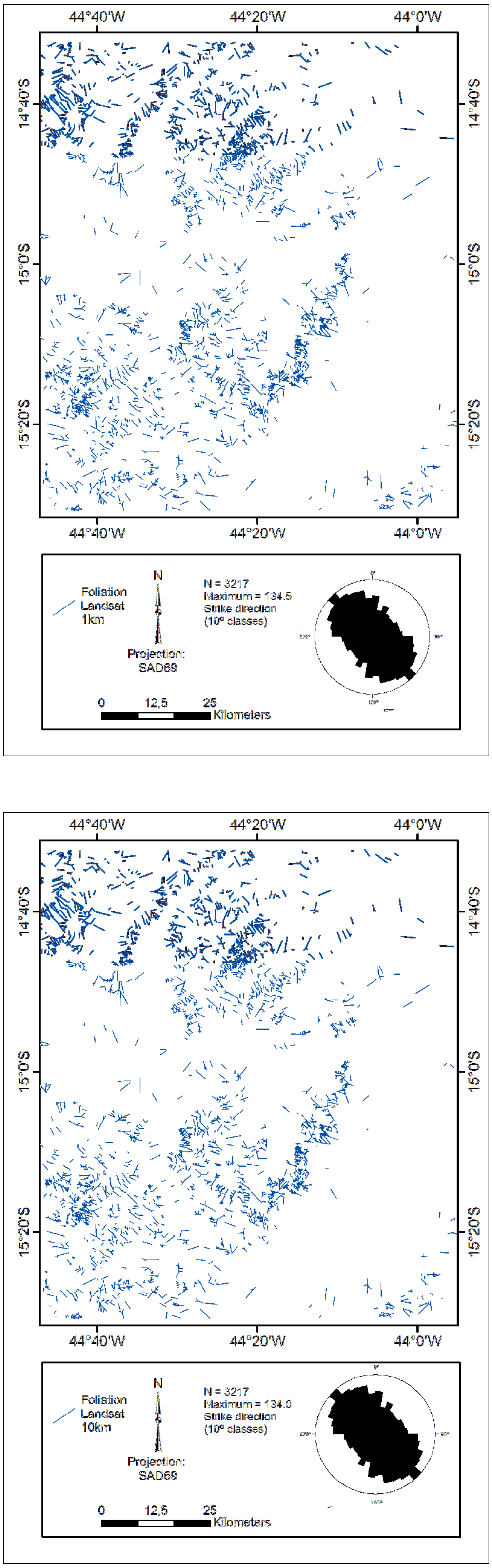


Fig 5 - Foliation extracted from the visual method a) 1km and b) 10 km a)

b)

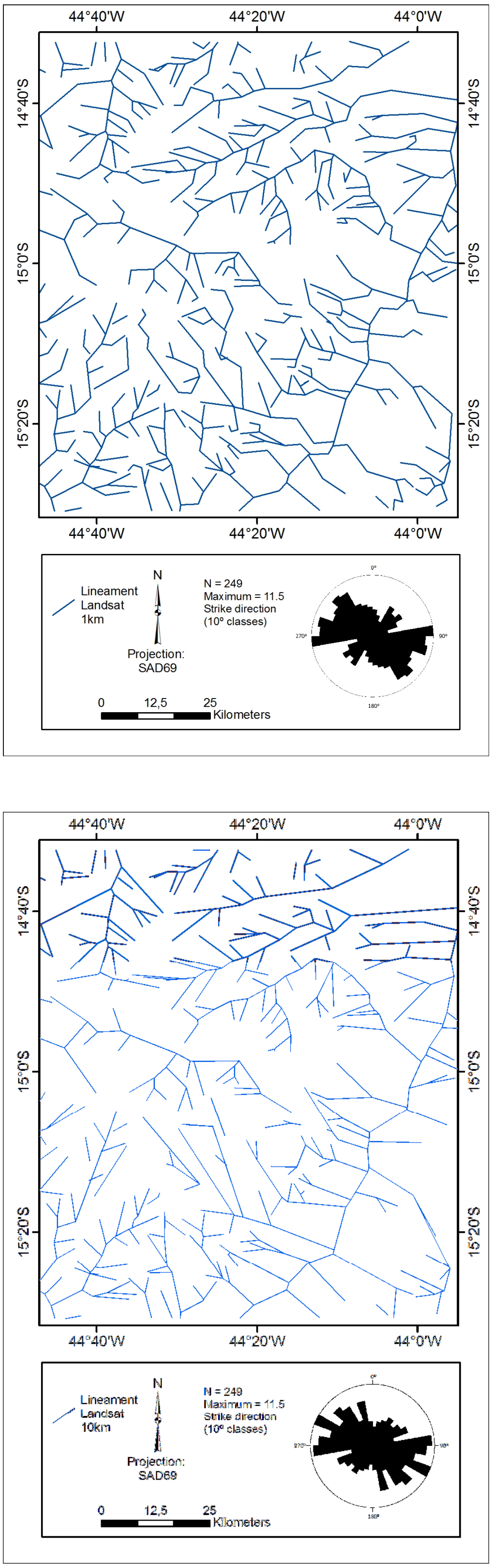


Fig 6 - Lineament extracted from the visual method a) 1km and b) 10 km

a)

b)

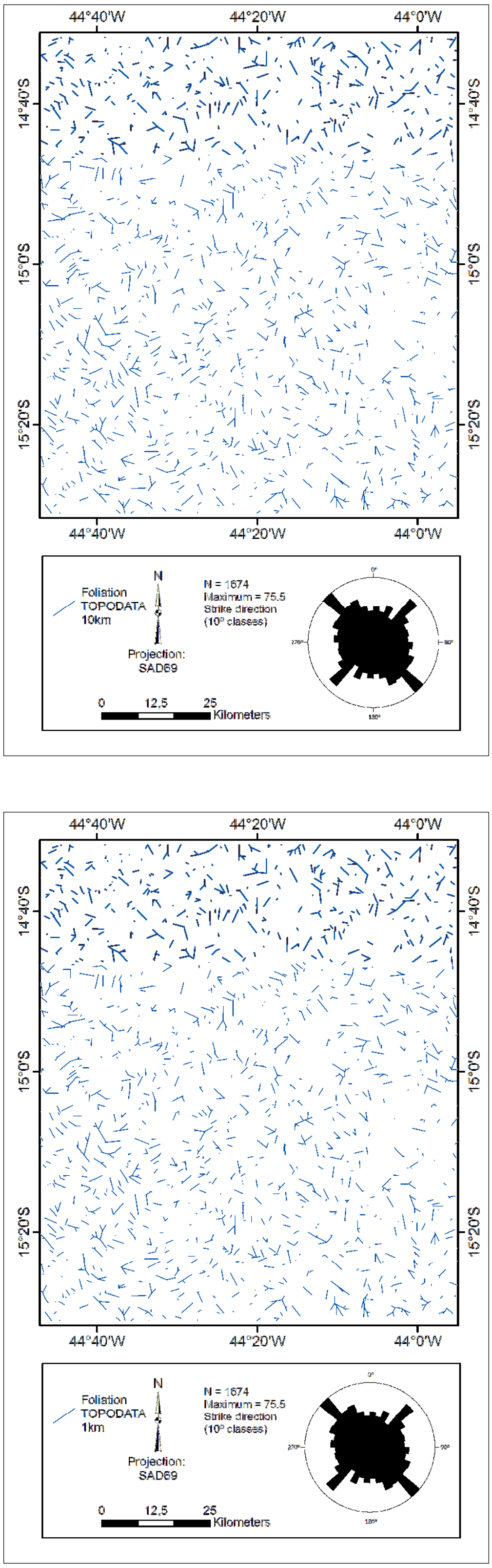
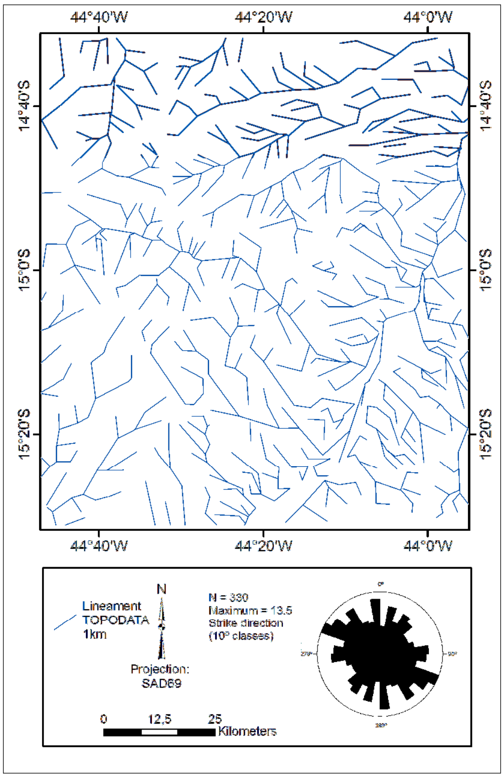


Fig 7 - Foliation extracted from the automatic method a) 1km and b) 10 km a)



b)

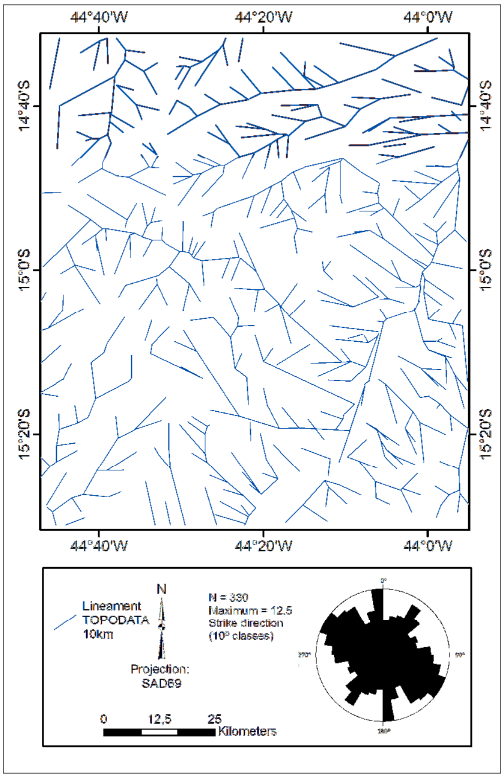


Fig 8 - Lineament extracted from the automatic method a) 1km and b) 10 km

Discussions and Conclusions

The Landsat image vectorization by scanning can prevent some errors, but may omit others datas in the region where it was impossible to type, there may be errors and interpret trends, meanwhile TOPODATA-SRTM vectorizes following parameters pre-established neutralizing some of these errors But we can also find noise to be eliminated manually.

The automatic vectorization by the image-TOPODATA SRTM occurs according to pre-established parameters, but there is also generation of noise, which can be manually reduced. Meanwhile, in the Landsat image, the manual scanning prevents erroneous data, which may appear in the previous method. However, there may occur errors of omission and trends from the interpretation. Thus, when analyzing the methods together, the errors are neutralized, increasing the accuracy of the results.

Very near to the Caraíbas-Itacarambi seismic area a horst-anticlinal feature with axis striking N45W was mapped (Brandalise et al., 1980), been limited by longitudinal faults. Analysis of regional geophysical data shows gravimetric and magnetic lineaments trending to NW-SE, NE-SW, ENE-WSW and WNW-ESE (Cunha Filho, 2004).

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The analysis of lineaments of the data obtained from Landsat ETM+ and TOPODATA (SRTM) predominantly identified a strong orientation of N20-40W, but in the lineaments also appears the azimuths directions EW (260-290).

Moreover, all the rose diagrams showed the existence of a plane striking N(20-40) and agreed with Brandalise et al. (1980) and Cunha Filho (2004), suggesting reactivation of a preexisting seismic fault in the region.

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