Automatic Fault Extraction Using Ant Tracking Algorithm in the Marlim South Field, Campos Basin

Celina C. Silva[1], Cristiano S. Marcolino[1] and Fabrizio D. Lima[2]
[1] Schlumberger, [2] Petrobras

This paper was prepared for presentation at the 9th International Congress of the Brazilian Geophysical Society held in Salvador, Brazil, 11-14 September 2005.

Abstract

The main objective of this paper is to present a comparison between manually interpreted faults and automatically generated fault surfaces using an innovative workflow recently introduced in the geophysical community. The manual fault interpretation performed in an area of Marlim South Field at Campos Basin, located offshore the southeastern Brazilian coast, took 10 days of work, during which a geophysicist delineated the main regional faults. On the other hand, the automated fault extraction approach allowed the interpreter to perform the same task in 3 days. The results showed a good match between the manually and the automatically interpreted faults. The Ant Tracking attribute was significantly helpful for the identification of the fault framework and the extraction of the fault surfaces for later editing, analysis and filtering.

Introduction

Marlim South is a giant offshore oil field located in the Campos Basin, southeast Brazil. It is a deep/ultra deep water field with water depths ranging from 600 to 2600 m. Petróleo Brasileiro S.A. (Petrobras) started Marlim South production in 1994 and expects the peak of production to happen in 2007.

The reservoir is composed of Oligocene/Miocene sand-rich turbidite lobes and channels. The average porosity ranges around 30-35%, and permeability 2000 – 10000 mD. Oil gravity varies from 15 to 26º API. The reservoir total in-place volume is 2500 MMBOE and proven reserves reach 1500 MMBOE.

The Oligocene/Miocene reservoirs are deeply affected by the salt tectonics in the area. In the Albian-Createceous period, the area had an intense extensional deformation related to the salt tectonic developing listric faulting. The main trends of faulting are NE and NW, with a secondary N trend.

The Ant Tracking attribute was generated in a 3D area of the Marlim South field, where Petrobras had previously acquired seismic data, with the objective of comparing and analyzing the results between manual and automatic fault interpretation.

Methodology

The Ant Tracking algorithm was developed by Schlumberger Stavanger Research and is commercially available in the Petrel™ software. This unique algorithm is part of an innovative workflow that introduces a new paradigm in fault interpretation. It emulates the behavior of ant colonies in nature and how they use pheromones to mark their paths in order to optimize the search for food. Similarly, virtual ants are put as seeds on a seismic discontinuity volume to look for fault zones. Virtual pheromones deployed by the ants capture information related to the fault zones in the volume. The result is an attribute volume that shows very sharp and detailed fault zones**,** since it better enhances horizon discontinuities when compared to other traditional edge enhancing attributes (e.g. Chaos, Variance). A second optional output is the automated extraction of "fault surfaces" out of the volume.

The manual interpretation revealed about 300 faults in the study area, after 10 days of work. Ant Tracking was then applied to the seismic cube, in order to automatically extract faults and compare the results. The workflow for the Ant Tracking algorithm was performed by the completion of 4 main steps:

- Pre-Processing – Edge enhancing attribute generation to be used as input for the Ant Tracking. The goal was to enhance major faults, by the extraction of two attributes: Variance and Chaos. Variance estimates the local Variance in the signal and Chaos measures the "lack of organization" in the dip and azimuth estimation method. These algorithms were generated on-the-fly (virtual seismic volumes) in a small area of the cube to find out the best parameters to be used. After that the entire Variance and Chaos cubes were generated and the results were analyzed. As the Variance cube better enhanced the faults, it was chosen to be used as input for the Ant Tracking algorithm (Figure 1).

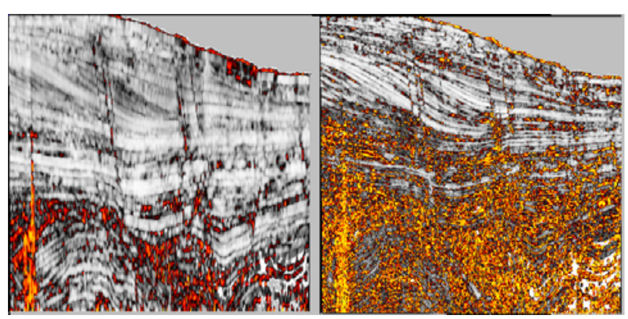

Figure 1: The same inline showing the Variance Attribute (left) and Chaos Attribute (right).

- Ant Tracking parameters definition – As Ant Tracking is a time consuming operation, a smaller Variance cube (150 MB) was selected to run Ant Tracking and to find out the best parameters to be used on this data set.
- Automatic Fault Extraction – After the parameters definition, the Ant Tracking attribute was calculated for the whole seismic volume (1.5 GB). During this operation the fault surfaces were generated automatically.
- Fault Surfaces Edition - The process generates lots of fault surfaces (Figure 2). The interpreter needs to filter the faults and to edit some of them. To do so, the interpreter could filter the set of faults surfaces based on different fault properties such as azimuth, dip, size, vertical extent...

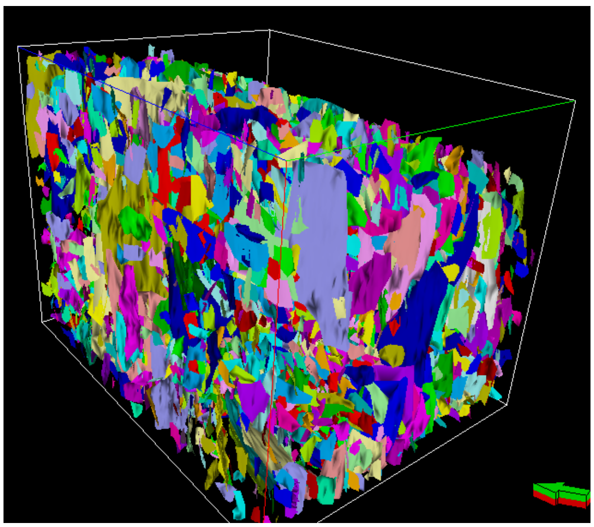

Figure 2: Fault Surfaces created during the Ant Tracking attribute calculation.

Extracted Fault Analysis and Edition

Before running the Ant tracking algorithm the interpreter can adjust the parameters in order to avoid faults misinterpretation. However, it is usually necessary as a final step to edit the fault surfaces created during the process. On the Marlim South data set the edition was useful to eliminate artifacts of seismic acquisition and processing (Figure 3) and to filter small faults with no interest at the time. The edition was performed using the stereonet diagram (Figure 4), which allows eliminating the surfaces aligned with the inline and crossline direction, and histograms to filter the small faults based on their size.

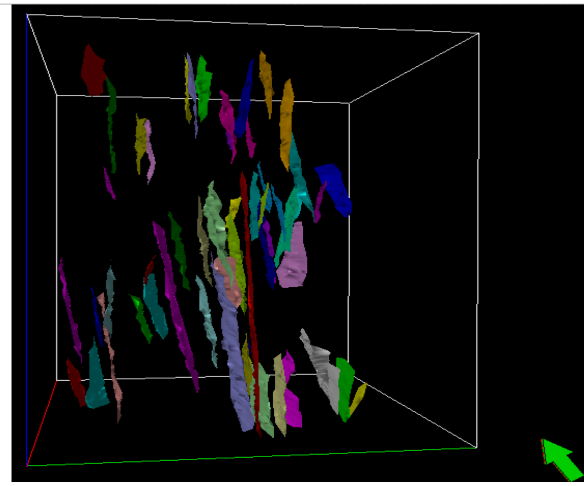

Figure 3: Fault surfaces oriented along inline direction (effect of seismic acquisition/processing).

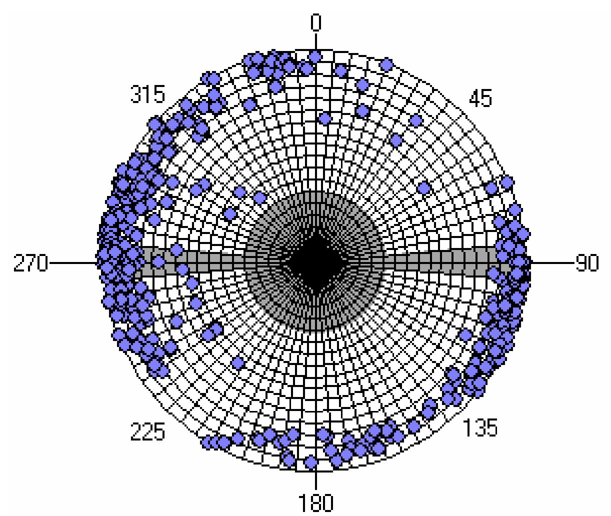

Figure 4: Stereonet diagram used to filter fault surfaces aligned with inline and crossline directions. Each point represents one fault surface and those plotted in the grayed areas were filtered out.

Based on geological knowledge, the interpreter was also able to merge fault surfaces when he recognized that distinct faults surfaces actually belonged to the same feature. Thus, after filtering/editing faults based on size, orientation, vertical extent, dip, inline/crossline extent and fault systems, the interpreter ended up with a set of faults that he considered important for the geological model. These faults were ready to be included in the geological model or could be transformed in fault interpretation. As our goal was to compare automatically extracted faults and those manually interpreted, they were converted to interpretation.

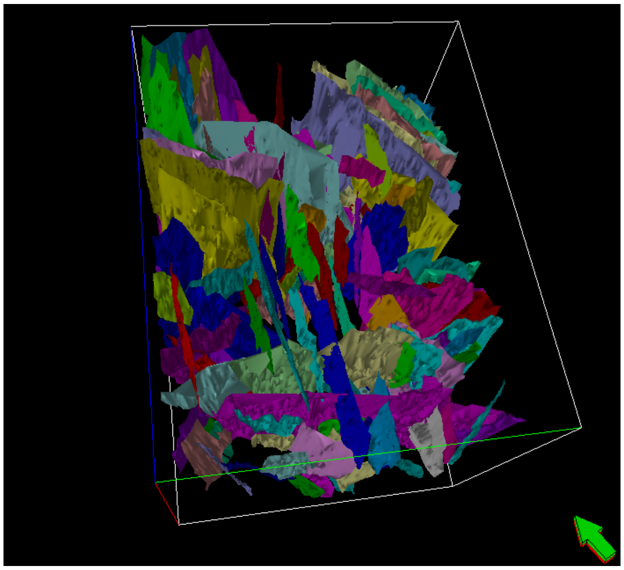

Figure 5: The final faults set, in Marilim South Field, after filtering, analyzing and editing.

Results

1) The Ant Tracking attribute showed to be an excellent tool to map the faults in the Marlim South area, working better than other edge enhancing attributes like Variance, since noise and other structures (e.g. horizons, unconformities…) were filtered out. Besides that, the Variance attribute was not able to reveal the actual extension of some faults (Figures 6 and 7) when compared to Ant Tracking.

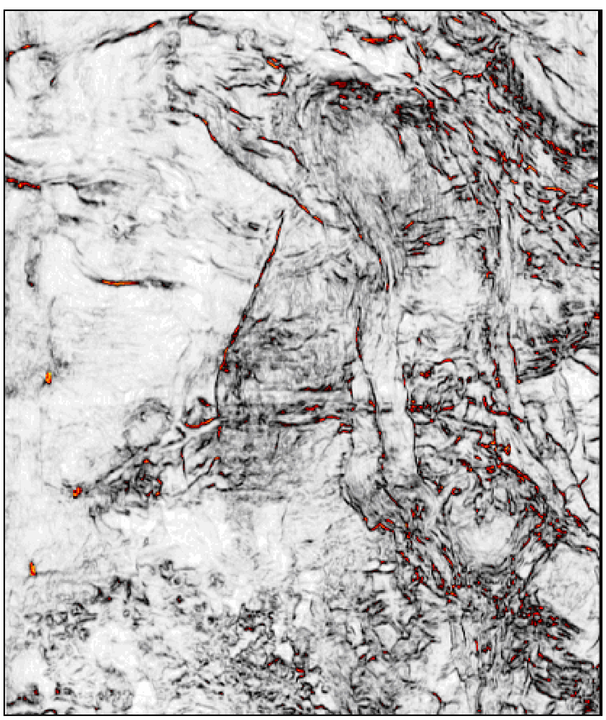

Figure 6: Time slice showing the Variance attribute.

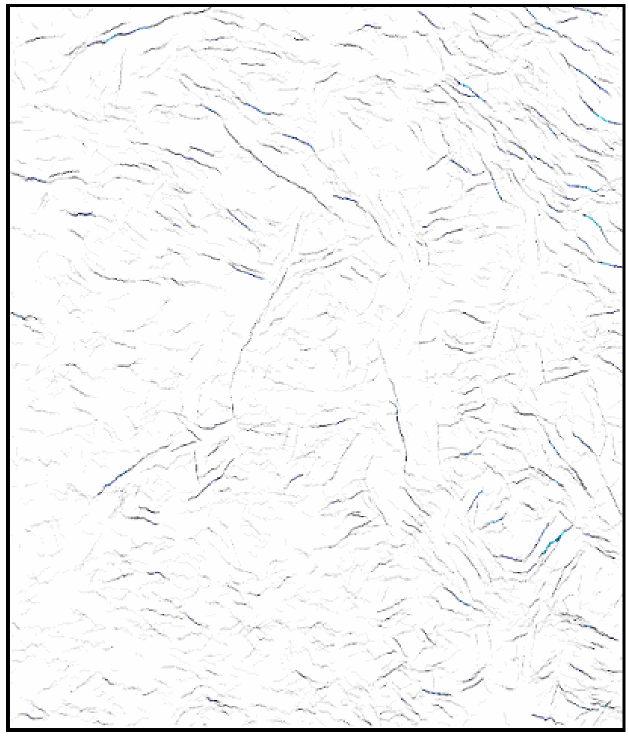

Figure 7: The same time slice showing the Ant Tracking attribute.

2) The manual interpretation performed by a Marlim South geophysicist was posted on the Ant Tracking attribute cube, showing an excellent match (Figure 8). Some of the fault surfaces enhanced on the attribute cube extend further than the interpreted ones, showing that the algorithm was able to reveal the fault even when the geophysicist failed to interpret it due to the seismic resolution.

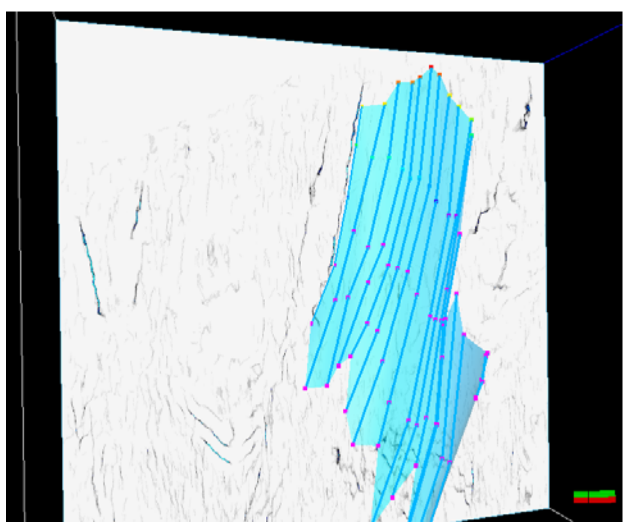

Figure 8. Manually interpreted fault posted on the Ant Tracking attribute cube where the match can be checked.

3) The comparison between the major faults automatically extracted by the Ant Tracking algorithm and those interpreted by the geophysicist showed a very good match (Figure 9).

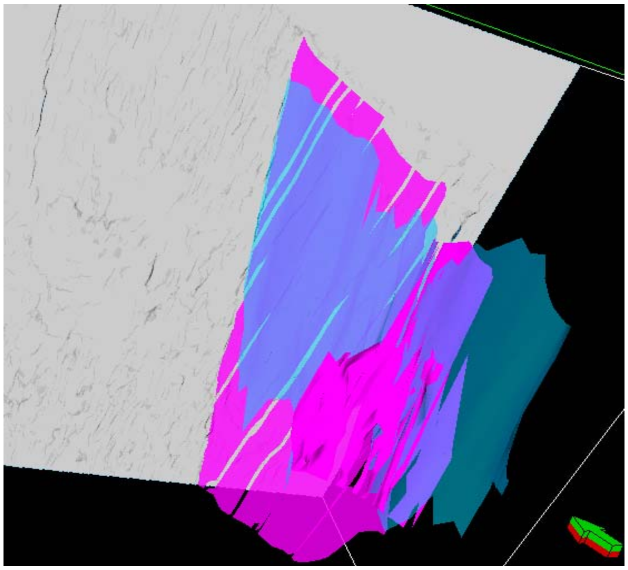

Figure 9: Comparison between a fault extracted automatically by the Ant Tracking algorithm (pink) and a fault interpreted by the geophysicist (blue).

Conclusion

The traditional manual fault interpretation is a time consuming task. The use of the new Ant Tracking attribute helps a lot the geologist/geophysicist in the fault interpretation job. The geological knowledge of the area, and the experience of the interpreter allied with this useful tool remarkably save time during the fault interpretation task. The regional fault interpretation in an area of the Marlim South field at Campos Basin lasted 10 days of manual interpretation. The new workflow decreased the time to 3 days, including the Ant Tracking attribute generation, the automatic fault extraction and the fault surfaces edition and filtering.

Acknowledgments

We wish to thank Petrobras for the collaboration and permission to publish this paper and Schlumberger for the use of the appropriate software.

References

Skov, T., Perdensen, T., Valen, T., Fayemendy, P., Grønlie, A., Hansen, J., Hetlelid, A., Inversen, T., Randen, T. and Sønneland, L. , 2003, Fault System Analysis Using a New Interpretation Paradigm: EAGE 65th Conference & Exhibition – Stavanger , Norway, 2-5 June

Randen, T., Perdensen, S., Sønneland, L., 2001, Automatic Extraction of Fault Surfaces from Three-Dimensional Seismic Data, Ann. Int. Mtg., SEG. Exp. Abstr.