Fault Visualization Enhancement Using Ant Tracking Technique and Its Application in the Taranaki Basin, New Zealand

Tianze Zhang, Yani Lin, Kelly H. Liu, Aamer Alhakeem, and Stephen S. Gao, Missouri University of Science and Technology, Rolla, Missouri, 65409, USA

Summary

The ant tracking technique has been widely used in fault interpretation. However, the reliability of the results is highly dependent on appropriately choosing signal processing method and volume attributes. In our study area, which lies in the southern Taranaki Basin, we applied Graphic Equalizer as the processing tool and the Chaos attribute before running the ant tracking algorithm. Results show that the procedure has better quality and can map both the major and minor faults more efficiently than the conventional fault interpretation procedure.

Introduction

Making correct fault interpretation is a crucial step for understanding fault development in a region, as fault movements have great impacts on oil migration and trap formation (Roncaglia and Lucia, 2006). Ant tracking is an innovative technique utilized in fault identification and interpretation. It can capture and track fractures continuously on fracture-sensitive attributes, and highlight the faulting areas effectively (Basir et al., 2013). The ant tracking technique includes three steps, including data conditioning, edge detection, and running the ant tracking algorithm (Henery et al., 2011). The typical data conditioning procedure uses Automatic Gain Control (AGC) or Structural Smoothing, which is suitable at displaying large-scaled faults. However, it lacks the ability for reserving small fracture features, as demonstrated in this study.

In our study area, faults are developed in various scales. The traditional processing procedure is insufficient for processing the data with variable fault scales and providing reliable data for ant tracking. In order to distinguish the discontinuity for weak events, we first use the Graphic Equalizer processing to manually adjust the frequency component of input signal by following the local geological context. The ant tracking technique is applied on edge enhanced attributes which derived from processed data set. The results show a much detailed ant tracking map, which not only contains the main faults, but also minor fractures which are unable to be identified using the typical ant tracking workflow.

Data and Methodology

The study area is located in the Kupe area in the south of the Taranaki Basin (Fohrmann et al., 2012). Faults are highly developed in the study area. The Manaia Fault is a significant reverse fault trending from north to south and cutting through the west boundary of the study area. The fault was a normal fault originally, but reactivated and formed the Manaia Anticline after the late Eocene (Stagpoole and Nicol, 2008). The Rua Fault, which was once part of the Manaia Fault, is located in the south of the study area. Other regional faults in the area trend northeast-southwest (Figure 1).

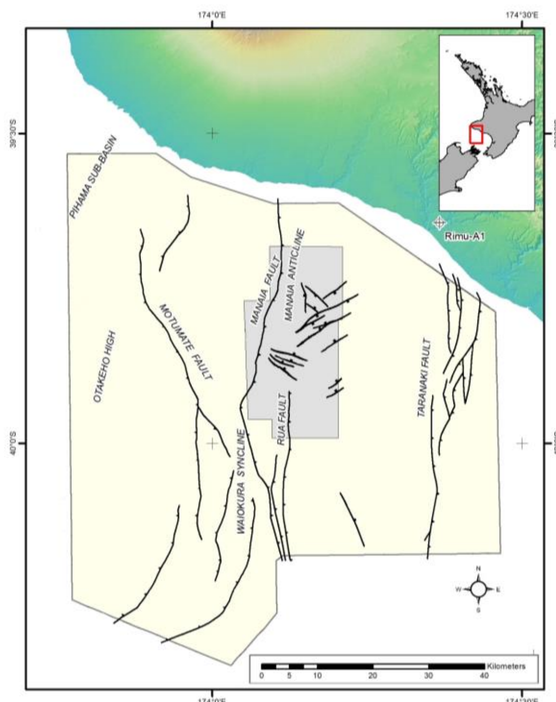

Figure 1. Main structure feature of the study area. The Kerry 3D is marked by the grey polygon. The Kupe area is outlined by the cannary polygon (Fohrman et al., 2012).

The poststack data set used in the study is the Kerry 3D, which is a marine seismic survey conducted in 1996. The area is located close to the south of the coastline, and covers 407 km^2. The data set consists of 287 inlines and 735 crosslines with 50 meters line spacing.

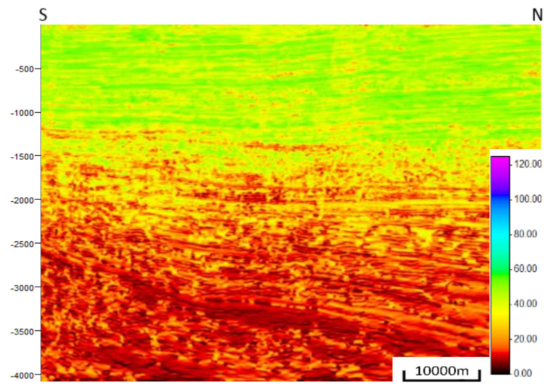

Figure 3. Instantaneous frequency attibute of inline 585.

Graphic Equalizer

The Graphic Equalizer allows us to enhance or reduce different frequency composition in order to adjust seismic resolution in various time ranges. As the first step in the workflow, the Instantaneous Frequency attribute is derived to observe the frequency distribution (Figure 3). The attribute indicates that the shallow section is sensitive to frequencies between 40 and 80 Hz, and the deeper part is responsive to frequencies between 10 and 40 Hz. By carefully reducing the amplitude in the frequency band between 40 and 80 Hz, the structure in the upper part is highly smoothed. As the result, irrelevant details are removed and edge information is more detectable.

Edge Detection

The Variance attribute is normally utilized to detect the edges, and the Chaos attribute can examine the degree of organization and mark the area where organization is lacking (Randen et al., 2000). For conventional edge enhancement procedures, Variance and Chaos attributes are combined to enhance the discontinuity. However, in this study, we found that the attribute combination strongly decreases the fracture details and distorts the ant tracking results. Hence only the Chaos attribute is used in this study.

Ant Tracking

Ant tracking is an innovative technique in the modern interpretation field. The principle of ant tracking is to set “ant agents” around the data volume, and let them track the possible discontinuities of seismic reflectors within the deviation preset. Firstly, we put one ant agent per 5 voxels to fully cover the seismic volume. Then we set the parameters of track deviation and illegal steps to ensure all possible fractions were traced. Since most of the faults in the study area are high-angled faults, tracking paths with angle smaller than 30° were rejected.

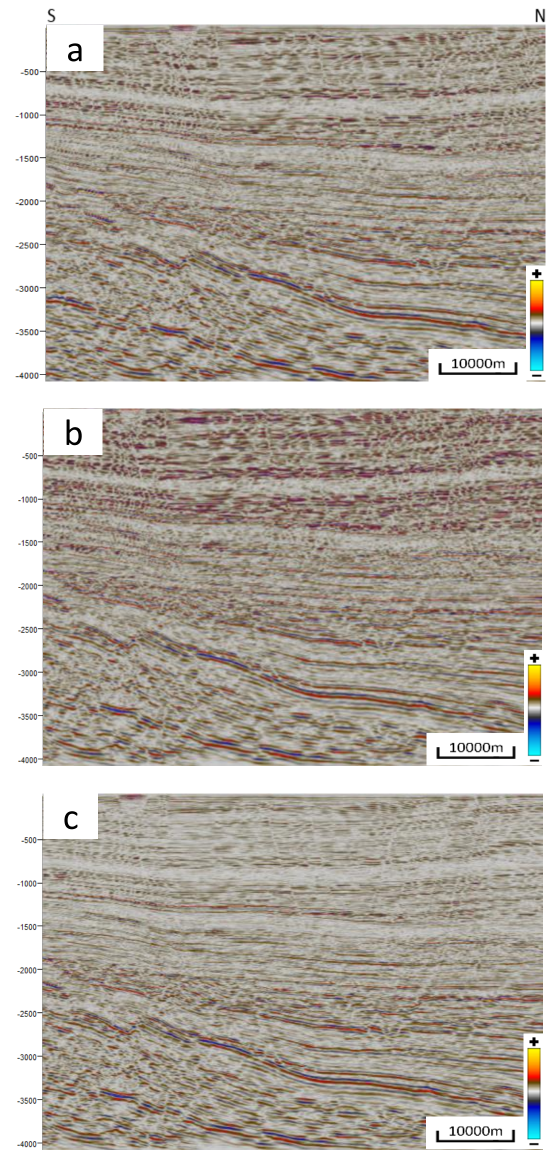

Figure 4. Comparison of the original and processed data of inline 585. (a) Original seismic section. (b) Resulting section after increasing the amplitude of frequency band between 40 and 80 Hz. (c) Resulting section after decreasing the amplitude of frequency band between 40 and 80 Hz.

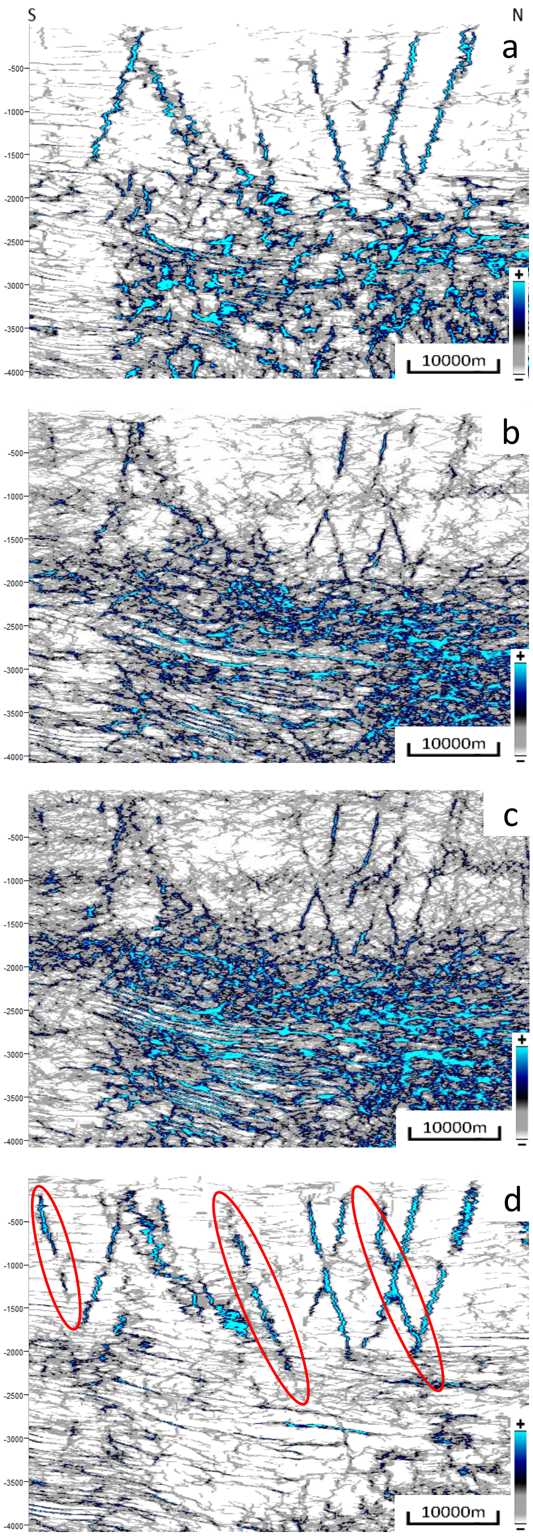

Figure 5. Inline 665 and resulting ant tracking maps using different attributes. (a) Chaos and Variance combined attributes applied after AGC and structure smoothing. (b) Combined attributes applied after Graphic Equalizer. (c) Same as (b) but after Variance attribute. (d) Same as (b) but after Chaos attribute. Red oval areas represent areas with highlighted enhancement on fault visualization.

Results

Figure 4 shows the comparison of the processed data using the Graphic Equalizer with different strengths of the frequency bands. By reducing the amplitude in frequency band ranging from 40 to 80 Hz, the structures are smoothed and the edges are highly detectable. The results show that the frequency band we chose has significantly improved the capability for identifying seismic discontinuity without jeopardizing any detailed information.

We compared the resulting ant tracking maps using different data processing workflows and various attributes (Figure 5). Running the ant tracking attribute on the combined Variance and Chaos shows a result that lack of information, especially when the attribute is derived upon the data set processed by AGC and structure smoothing. In addition, the ant tracking map using the Variance attribute calculated from the frequency modified data set contains too much noise, especially in the deeper part of the area (Figure 5c).

The best result comes from the map using the Chaos attribute (Figure 5d). For the shallow part of the study area, the map contains much comprehensive detail of fracture components, which are invisible in other maps. For the deeper part, the disordered area is replaced by horizontally linearized tracks representing the strata.

The ant tracking map also shows promising results compared with previous study (Sykes, 2012). Most faults are fully presented in our map, and minor faults that were not covered in the previous interpretation are identified as well (Figure 6). Time slices of 600 ms and 1368 ms are extracted from the data volume that displayed with ant tracking results (Figure 7), which clearly suggest that the ant tracking results match with the geological structure well in both shallow and deep layers.

Conclusions

Our study using a complex 3D marine seismic data set indicates that the ant tracking technique is an outstanding tool in fault identification and interpretation. However, the reliability of the results is based on proper selection of signal processing methods and volume attributes. In the typical processing procedure, Automatic Gain Control and

Fault Visualization Enhancement Using Ant Tracking Technique and Its Application in the Taranaki Basin, New Zealand

Structural Smoothing are sufficient to process the data and increase the signal to noise ratio. In our study area, the complex geological structure and various data quality require a more comprehensive signal processing technique to provide accurate fracture information. Graphic Equalizer by adjusting amplitudes of different frequencies appropriately can help us to achieve this goal. Our results show that in such geological conditions, the Chaos attribute performs well for edge detection, leading to clearer and detailed results than combining the Variance and Chaos attributes or the Variance attribute alone.

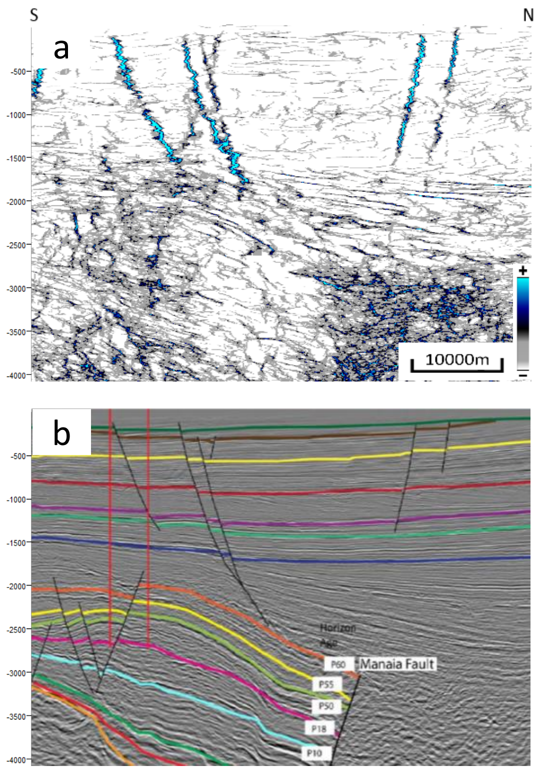

Figure 6. Comparison of the ant tracking result and the conventional fault interpretation. (a) Ant tracking map of inline 692. (b) Conventional fault interpretation of the same inline (Sykes, 2012).

Acknowledgments

We acknowledge the New Zealand Petroleum & Minerals for providing the comprehensive data set. We also gratefully acknowledge the generous software donation from Schlumberger.

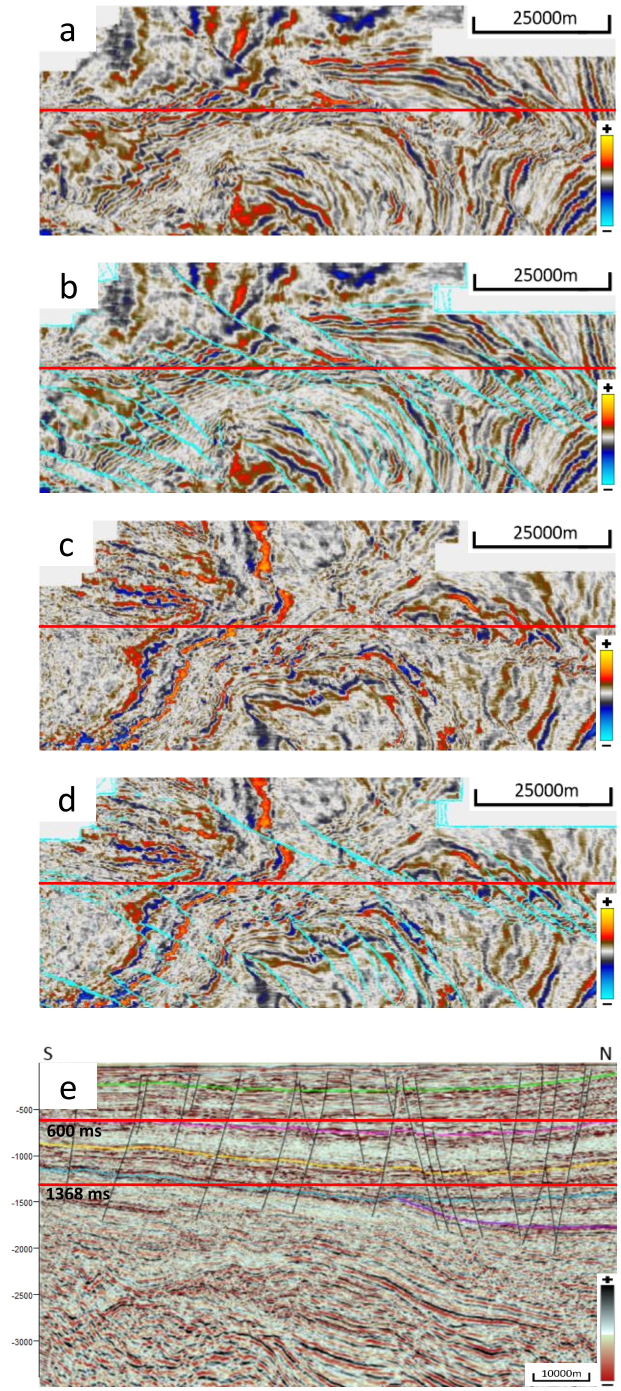

Figure 7. (a) Time slice at 600 ms. (b) Combined ant tracking with seismic volume. (c) Time slice at 1368 ms. (d) Combined ant tracking with seismic volume. (e) Vertical section of inline 665.