Geophysical evidence of basement controlled faulting in the Ellenburger Group and Viola Limestone, Fort Worth Basin, Texas

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Summary

The Fort Worth Basin (FWB) is a shallow north – south elongated foreland basin, encompassing roughly 15,000 sq. mi in north Texas. It formed during the late Paleozoic Ouachita orogeny (Walper, 1982) and displays a complex structural basement mainly due to the collision of the North and South American plates during the Paleozoic.

This work compares horizontal derivative of the tilt derivative maps (HD_TDR), seismic attributes including most positive curvature and image enhancing over most positive curvature-sliced along the Viola Lm. and Ellenburger Group horizons, and azimuth frequency diagrams (rose diagrams) for two different areas in order to compare the Maximum and Minimum Horizontal stress of lineaments related to collapse structures, and faults and fracture patterns at specific horizons with the discontinuities in the basement.

The main conclusion of this work is that intra-sedimentary features such as collapse structures, faults and fracture patterns for the Viola Lm. and Ellenburger Group horizons are mainly related to basement structures because they tend to align along these discontinuities.

Introduction

The Fort Worth Basin (FWB) is a shallow north – south elongated foreland basin, encompassing roughly 15,000 sq. mi in north Texas. It formed during the late Paleozoic Ouachita orogeny (Walper, 1982) due to collision of the North and South American plates during the Paleozoic. This collision continued during the early Pennsylvanian and caused overthrusting along the eastern margin of the basin, the formation of the Ouachita structural front, and the onset of the orogeny. The basin is delimited in the east by the Ouachita Thrust Front, to the north by the Red River Arch, to the north – northeast by the Muenster Arch, to the west by the Bend arch, Eastern shelf and Concho arch, and to the south by the Llano Uplift (Figure 1).

Although the FWB is considered to be a mature basin and has been extensively explored for hydrocarbons, very little has been published about its basement. Sullivan et al. (2006), hypothesizes that the basement influences collapse features and fracture patterns in shallower horizons and Aktepe et al. (2008), used pre-stack depth migration data to show that basement structures can be quite complex.

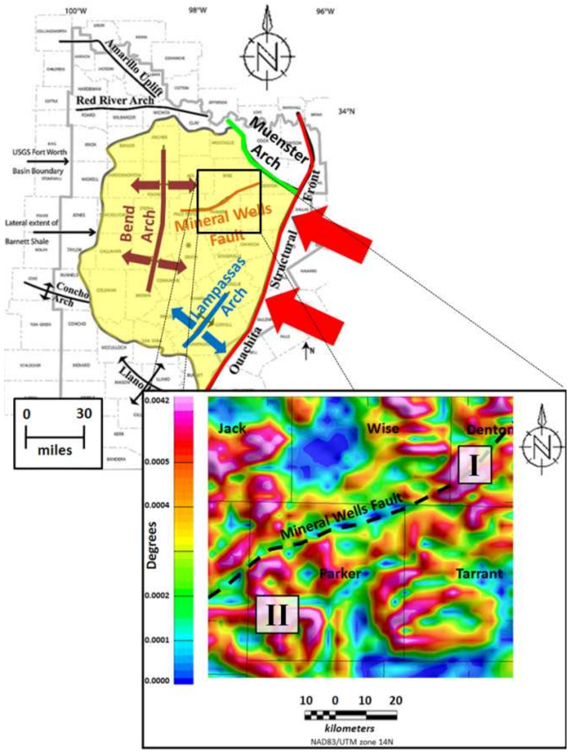

Figure 1: Main structural features in the FWB (Modified from Pollastro, 2007) and the horizontal derivative of the magnetic tilt derivative map of the area.

Figure 1 reveals the complexity of the basement in the area of study. The black dashed line shows the location of the most prominent structural element known as the Mineral Wells fault (MWF). This MWF is a major northeast-southwest striking fault extending for more than 65 miles (100 km). It is a normal fault with a strike-slip component.

For this work, horizontal gradient magnitude (HMG) maps were generated from high resolution aeromagnetic (HRAM) data. HMG maps derived from HRAM data reflects abrupt lateral changes in magnetization in the area (Elebiju, 2008) and the tilt derivative (TD) maps help to enhance the continuity of such anomaly if it is close to a magnetic source. Thus, the horizontal derivative of the tilt derivative map (HD_TDR) enhances prominent edges of a magnetic source that could be related to faults and discontinuities in the basement.

Derivative maps are designated to enhance edges of magnetic sources providing better understanding of basement intra-sedimentary features. These features might be hard to resolve using just HRAM considering that they are usually non-magnetic or very low in magnetization.

This paper shows the integration of magnetic data with seismic attributes extracted along the Viola Limestone for survey 1 and the Ellenburger Group for survey 2 and compares Maximum Horizontal stress (MHS) and Minimum Horizontal stress (mHS) of lineaments related to faults and fracture patterns with the discontinuities in the basement.

Seismic attributes and image enhancement

In addition to other attributes including coherence and acoustic impedance, we computed most positive and most negative curvature volumes and sliced them along the appropriate horizon. We found most positive curvature attribute to be a most useful tool in identifying polygonal compartments containing collapse features (typically, karst), in the FWB. These collapse features can be recognized as negative values of most-positive curvature indicating bowl-shaped features (Figure 4a and 7a).

To enhance linear features in most-positive curvature volumes we applied a commercial "ant-tracking" algorithm described by Pedersen el at. (2002), then constructed azimuth frequency rose diagrams by picking the individual lineaments with the goal of analyzing their directional trend for each horizon. Each petal in the rose diagram corresponds to 10 degrees.

Cases of study:

Survey 1.-

The first seismic survey is located in the northern part of the FWB, close to the Muenster Arch, where the basin reaches its maximum depth. The main structural element present in the area is the MWF. Figure 2 shows the boundaries of the seismic survey 1, and the main structural elements present in the area. Black-dashed lines show the location and extent of the MWF.

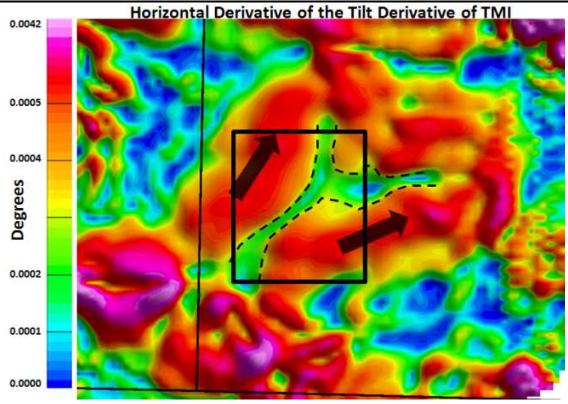

Figure 2: Detail of the HD_TDR map corresponding to seismic survey 1 area.

Figure 3 shows the time-structure map corresponding to the Viola Lm for seismic survey 1. Notice that the horizon dips to the north-east side of the FWB and shows two NE-SW branches of the MWF.

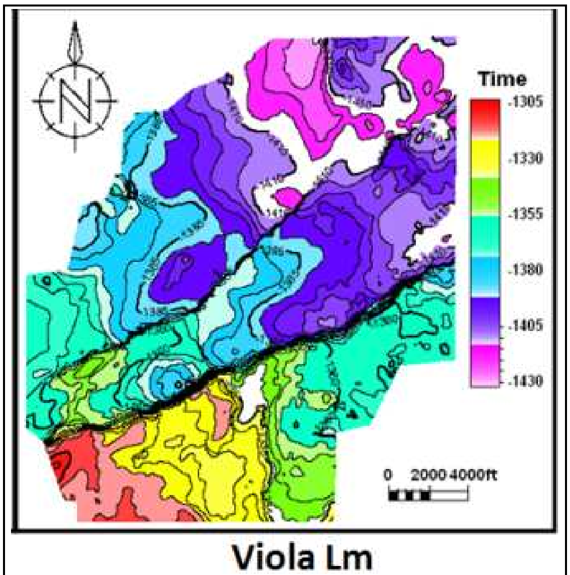

Figure 3: Time-structure map corresponding to the Viola Lm for seismic survey 1.

Figure 4 shows the result of the most-positive curvature and rose diagram of the most-positive curvature attribute corresponding to the Viola Lm. The lineaments corresponding to the Viola Lm. show a preferential direction (MHS) close to 45 degrees. This trend matches

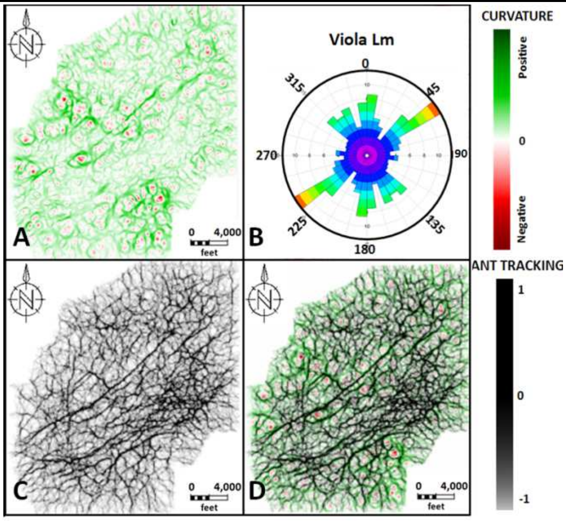

Figure 4: (a) Horizon slice along the top Viola Lm through the most-positive curvature volume for survey 1, and (b) its corresponding rose diagram, (c) image enahncement of (a), and (d) superposition of (a) and (c).

with the direction of the main structural element in the area, in this case the MWF.

Survey 2.-

The second seismic survey is located in the southern part of the FWB and south of the MWF, where the basin is shallower. In this case there are no prominent structural elements present. Figure 5 shows the boundaries of seismic survey 2, and two major trends with directions NE-SW and NW-SE. These trends are not associated with any major structural element in the area.

Figure 6 shows the time-structure map corresponding to the Ellenburger Group for seismic survey 2. The horizon shows a preferential area of low relief trending NE-SW.

Figure 7 shows the result of the most-positive curvature and rose diagram of the most-positive curvature attribute corresponding to the Ellenburger Group.

The lineaments corresponding to the Ellenburger Group show a preferential direction (MHs) close to 45 degrees and a secondary direction (mHs) close to 315 degrees. These trends match with the direction of the major trends in the basement and are not associated with any major structural element in the area.

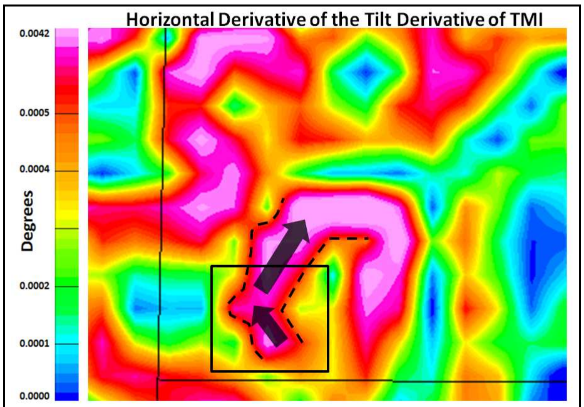

Figure 5. Detail of the HD_TDR map corresponding to seismic survey 2.

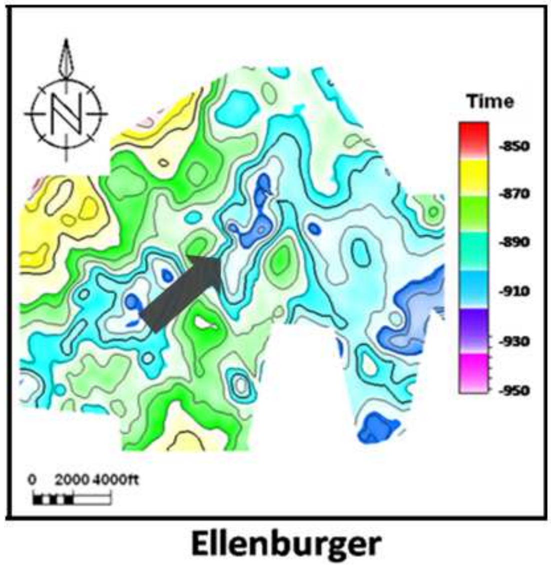

Figure 6. Time-structure maps corresponding to the basement and Ellenburger Group for seismic survey 2

Result analysis / Conclusions

For survey 1 and 2, the results allow us to infer that the maximum horizontal stress (MHS) at the time of structural deformation remained fairly constant between the basement-Viola Lm and basement-Ellenburger Group horizons, respectively. Also in the azimuth frequency diagram (rose diagram) for the Viola Lm., the minimum

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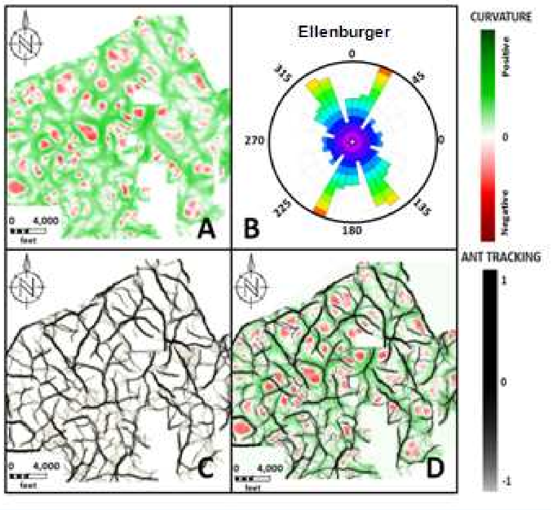

Figure 7. (a) Horizon slice along the top Ellenburger Group through the most-positive curvature volume for survey 2 and (b) its corresponding rose diagram. (c) Image enhancement of (a), and (d) superposition of (a) and (c)

horizon stress (mHS) is not perpendicular to the MHS, and is divided into two NS and NW to SE components. In the case of the Ellenburger Group, the azimuth frequency diagram (rose diagram) shows a similar pattern for the mHs, but just one major component trending NW-SE.

Normally, it is possible to estimate stress through break outs in image logs, velocity anisotropy, and microseismic emissions for fractures. In this research we design a workflow in order to use independent geophysical measures to estimate the stress at the time of structural deformation for two different regions in the FWB.

In this work we demonstrate the importance of mapping the basement in order to understand the lineaments pattern of some of the naturally induced fractures in the FWB.

In both examples we conclude that the intra-sedimentary features such as collapse structures in limestone formations are mainly related to basement structures and tend to align along these discontinuities.

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