[PS]Detailed Seismic Characterization of a Heavily Karsted Zone*

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Abstract

Producing hydrocarbons in karsted and fractured zones is a very risky procedure. This is the case of the source and reservoir Barnett Shale Formation that is overlying the highly karsted and fractured limestone of the Ellenburger Group in the Fort Worth Basin. Typically, karsted and fractured zones had been avoided because of the potential of the faults to connect with the water in the Ellenburger Group. We propose to generate a geological and geophysical model to delineate and characterize these karsted and fracture features on the production from the Barnett Shale Formation.

Traditional exploratory approach to this area of study may not be the same as the well developed Newark East Field. It is vital to understand the geological setting and petrophysical settings involved in the evolution of this part of the basin to improve exploratory analysis results in this highly prospective zone.

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Abstract

Producing hydrocarbons in karsted and fractured zones is a very risky procedure. This is the case of the source and reservoir Barnett Shale Formation that is overlying the highly karsted and fractured limestone of the Ellenburger Group in the Fort Worth Basin. Typically, karsted and fractured zones had been avoided because of the potential of the faults to connect with the water in the Ellenburger Group. I propose to generate a geological and geophysical model to delineate and characterize these karsted and fractures features on the production from the Barnett Shale Formation.

Traditional exploratory approach to these area of study may not be the same as the well developed Newark East Field. It is vital to understand the geological setting and petrophysical settings involved in the evolution of this part of the basin to improve exploratory analysis results in this highly prospect zone.

Geology

Geologically the study area falls in the Bend Arch-Fort Worth Basin situated in North-central Texas and southwestern Oklahoma. The eastern and southern boundaries of the basin are bound by the Ouachita structural front and Llano uplift (Ball and Perry, 1996). The northern boundary follows Red river/Electra and the Muenster Archs (Thompson, 1982). The western boundary follows the Concho platform that separates the study area from the adjacent to the Permian Basin, (Thompson, 1982; Ball and Perry, 1996). The study area is located to the west from the Newark East Field in the Wise County, Texas. The main difference between the Newark East Field and the study area is that the Viola Limestone and Simpson Group are absent, and the Forestburg Limestone, that separates the upper and lower Barnett, is thinner (Pollastro et al., 2007). These formations are known as barriers that keep hydraulic-induced fracturing to propagate beyond the Barnett Shale formation and keep the original formation pressures when its artificially stimulated (Bowker, 2003; Shirley, 2002; Pollastro et al., 2007). This place the lower Barnett Shale directly on the karsted and potentially water-bearing Ellenburger Group. This creates the potential for water invasion after artificially fracking the reservoir.

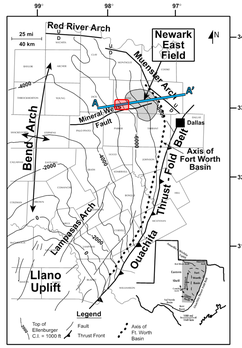


Figure 1. Forth Worth Basin in Texas. The red Box indicates the study area. A-A' is the cross-section on Figure 2. (After Montgomery et al., 2005)

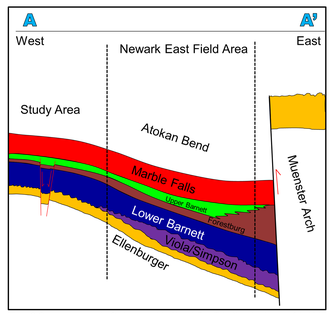
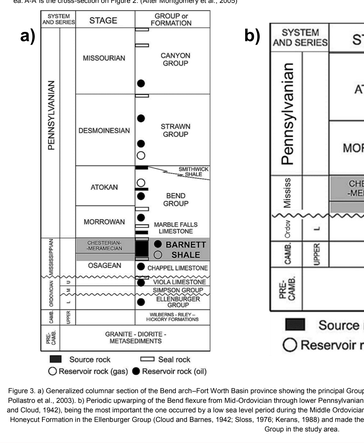


Figure 2. Cross-section over the Study area and the Newark East Field. Note the absence of the Viola/Simpson and the thinning of the Forestburg Limestones, natural fracture barrier. The lower Barnett shale lays directly over the highly karsted Ellenburger Group. (After Bowker, 2003)



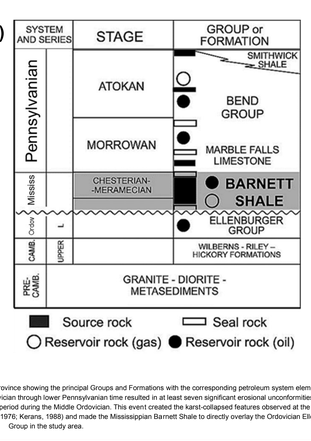


Figure 3. a) Generalized columnar section of the Bend arch–Fort Worth Basin province showing the principal Groups and Formations with the corresponding petroleum system element (After Pollastro et al., 2003). b) Periodic upwarping of the Bend flexure from Mid-Ordovician through lower Pennsylvanian time resulted in at least seven significant erosional unconformities (Barnes and Cloud, 1942), being the most important the one occurred by a low sea-level period during the Middle Ordovician. This event created the karst-collapsed features observed at the top of the Honeycut Formation in the Ellenburger Group (Cloud and Barnes, 1942; Sloss, 1976; Kerans, 1988) and made the Mississippian Barnett Shale to directly overlay the Ordovician Ellenburger Group in the study area.

Results

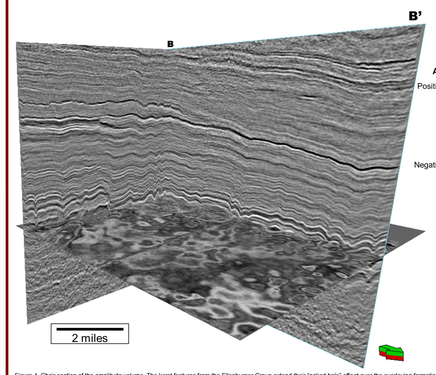


Figure 4. Chair section of the amplitude volume. The karst features from the Ellenburger Group extend their "poked hole" effect over the overlaying formations.

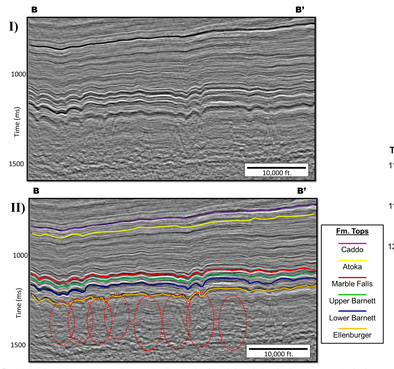


Figure 5. I) Vertical section through the amplitude volume. II) interpretation of the principal seismic horizon in the area. Note the migration artifacts below the Ellenburger Group top probably due to the implementation of wrong migration velocities. This could be explained because of the original interest in the shallower Caddo and Atoka profitable formations.

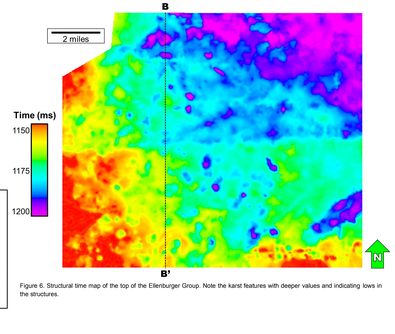


Figure 6. Structural time map of the top of the Ellenburger Group. Note the karst features with deeper values and indicating lows in the structures.

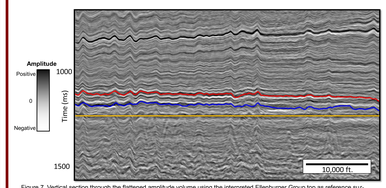


Figure 7. Vertical section through the flattened amplitude volume using the interpreted Ellenburger Group top as reference surface. Note the exaggeration of the migration artifacts crossing the zone of interest.

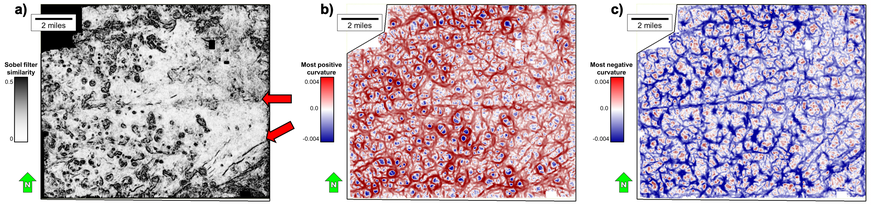


Figure 8. Structural attributes extracted along the flattened cube using the Ellenburger Group top as reference surface: a) Sobel Filter Similarity, b) Most positive curvature, and c) Most negative curvature. Note how the high incoherent zones are associated with the highly fractured/faulted zones due to the dissolution of the upper formation of the Ellenburger Group that formed the karsts. The Mineral Wells fault complex is highlighted with red arrows and can be trace through the most positive and most negative curvature as well. Karsted negative features show high values of most negative curvature and their edges show high most positive curvature values.

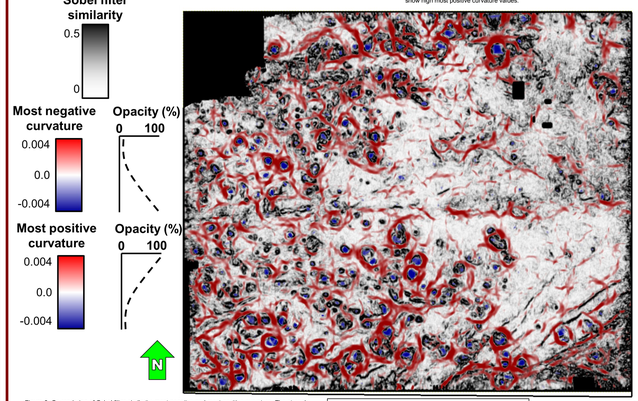


Figure 9. Co-rendering of Sobel filter similarity, most negative and most positive curvature. The strongly incoherent edges are highlighted with low values of similarity and, due to the shape of the karsts, with high most positive values. The center of those karsts have high most negative curvature. Note the Mineral Wells Fault crossing the area of study with E and W direction as pointed out on Figure 10.

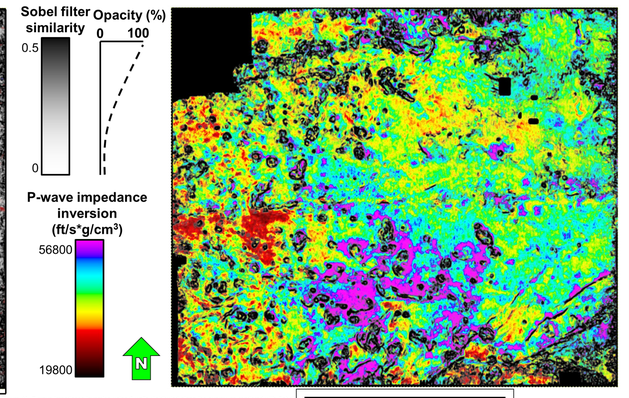


Figure 10. P-wave impedance inversion using 6 wells distributed along the survey, co-rendered with Sobel filter similarity. From the inversion it is possible to infer the highly variability of the rock properties associated with the Ellenburger Group geology. The scale of the area of study is big enough for changes in the composition of the Devonian carbonates deposits to be consider in further analysis.

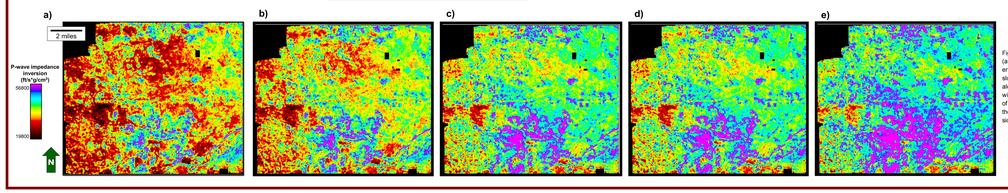


Figure 11. Horizontal slice through the flattened poststack acoustic impedance inversion at (a) 4ms and (b) 2ms above the reference surface Ellenburger Group, and through the lower Barnett shale. Lower values of acoustic impedance are associated with the presence of slower and less dense lower Barnett shale deposits. The horizontal slice (c) is extracted along the reference surface, hence, zones with high acoustic impedance are associated with stronger and more dense limestone of the top of the Ellenburger Group. Lower values of acoustic impedance at (d) 2ms and (e) 4ms below the reference surface and through the Ellenburger Group formations could be related with the lower Barnett shale fillings inside the collapsed karst features as observed on the west of the study area.

Conclusions

Carbonate deposits are all but continuous and isotropic. Environmental conditions such as oxygen, water depth, and type and distribution of "reef-builder" animals will be vital in the understanding of the limestones shape, characteristics and rock properties. In this case, the shape, extension and orientation of the collapsed features may be controlled by the collapsed paleocaves. The posterior burial and collapse affected the overlaying sediments, as explained by Loucks (2008) at his analysis of the Lower Ordovician Ellenburger Group of the Permian Basin. These process **went across the lower Barnett shale**, reaching sometimes the Marble Falls limestone. This could be explained by the **absence of the natural fracture barriers** such as Viola/Simpson interval and Forestburg limestone in the area.

Exploratory approach in this particular area should be **different** to the one apply previously to closer productive fields.

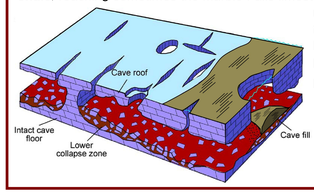


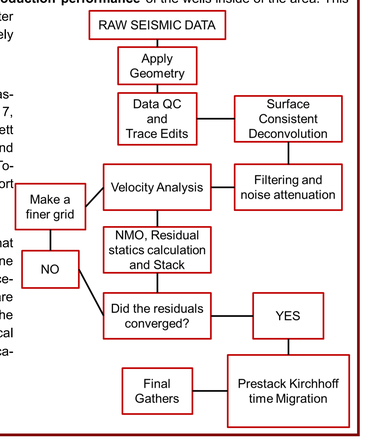
Figure 12. Schematic block diagram of a cave in the Lower Ordovician of West Texas showing cave floor, cave roof, cave-sediment fill and collapsed breccia. In the case of the area of study, the lower Barnett shale is filling the cave during posterior transgression due to the absence of the Viola/Simpson sediments. This will give a peculiar distribution of the productive sweet spots, different from the western Permian Basin and even to the more closer and eastern Newark East Field. (After Loucks, 2008)

Future Works

- **Microseismic** data should be include to better understand the extension, distribution and intensity of the fractures in the target zone of the lower Barnett shale. This will allow to verify the effect of the proximity to the fractures associated with the Ellenburger Group karsts.
- Using the well log data available inside the study area, we will generate **Fracture Toughness** and **Fracture Gradient** models using the interpreted horizon as references surface. This will give an idea of how fracture prone are the different formations and how this fractures will propagate through them.
- Take into account the **stress and strain regimes** in the area. These mechanical properties will be different to that in the near Newark East Field due to the presence of the Mineral Wells fault and the more prominent karst features.
- **Process the raw 3D prestack seismic** data in a way to improve the seismic image of the target zone. The vintage poststack time migrated amplitude volume have migration artifacts in the interval of interest that will be corrected by doing a more careful velocity analysis. New techniques will be applied, such as residual statics calculation and prestack Structural Oriented Filtering
- These results will be compared with the **production performance** of the wells inside of the area. This will allow us to determine new and better prospective zones in a more quantitatively manner.

There is important **productive potential** associated with the 2003 Assessment Unit 7, the Ellenburger Subcrop Fractured Barnett Shale Gas for the USGS National Oil and Gas Assessment of the Barnett-Paleozoic Total Petroleum System in the Bend Arch-Fort Worth Basin Province.

An important observation is that it seems that the exploration of the area of study was done following the same approaches and procedures than in Newark East Field. But this are not necessarily effective in this area since the stratigraphic, structural, and petrophysical settings seems to be **particular** of these location.



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