[PS]Integrated 3-D Seismic, Outcrop, and Core Data for Characterization of Natural Fractures of the Hunton Limestone and the Woodford Shale in Central Oklahoma*

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Abstract

Karsting is a common feature of carbonate environments that causes topographic irregularities on an unconformity surface. In parts of the Cherokee platform, Central Oklahoma, the Hunton Limestone underlies the Woodford Shale and might have controlled Woodford deposition. The main objectives of this study are to 1) understand the impact of karsting on the natural fractures in the Hunton Limestone 2) study the effect of the unconformity karst surface on the overlying Woodford Shale, and 3) evaluate the hardness of the Hunton Limestone and the Woodford Shale for artificial fracture stimulation. To achieve this understanding, we used a 3D seismic survey and well logs to map the structure and thickness of the Viola Limestone, Sylvan Shale, Hunton Limestone, and the overlying Woodford Shale. In addition, we used core analyses to quantify the fracture aperture and intensity, measure the hardness using a Rebound Hammer^{TM}, and describe the lithology and nature of the boundary contact. The karst features, such as collapse and sinkholes on the Hunton unconformity surface are prominent factors controlling the paleotopography and deposition of the Woodford Shale, as was observed from 3D structural maps. Similarly, there might be a potential effect of the Viola Limestone karstification on the overlying Sylvan Shale. The thickness variations of the Woodford Shale are controlled by paleotopography of the underlying Hunton Group, where thicker Woodford is observed in the karst lows (sinkholes) (Infante et al, in press). Sinkhole features range in diameter from 1150 to 2300 ft. and extend vertically to almost 300 ft. Additionally, there is an inverse correlation between the thickness of limestones (Viola and Hunton) and shales (Sylvan and Woodford). Core data reveals that fractures exist only in the karstified section of the uppermost 15 ft. of the Hunton due to karstification. The fracture aperture (sealed) ranges from 0.003 to 0.01 in. and the fracture intensity ranges from 8 to 30 fractures/ ft. every 6 inches (on average) along the core length. The higher hardness measurements correspond to areas with higher fracture abundance due to more brittle rocks in the karsted zone. An erosional unconformity surface between the Hunton Limestone and the overlying Woodford shale, with possibly some Misener Sandstone occurs in one core. This study predicts the locations of thick Woodford Shale sections suggesting possible spots for landing horizontal wells in the Woodford Shale.

Selected References

Fritz, R.D., and P.L. Medlock, 1994, Sequence stratigraphy of the Hunton Group as defined by core, outcrop, and log data: Bulletin Houston

Geological Society, p. 29-58.

Grotzinger, J.G, and T.H Jordan, 2010, Understanding Earth: W. H. Freeman; Sixth Edition, 672 p.

Moore, C.H., and W.J. Wade, 2013, Carbonate Reservoirs: Chapter 8, Meteoric Diagenetic Environment, v. 67, Elsevier Inc.

Northcutt, R.A., 2002, History of Hunton Oil and Gas Exploration and Development in Oklahoma: Shale Shaker, p. 149-158.

Integrated 3-D Seismic, Outcrop, and Core Data for Characterization of Natural Fractures of the Hunton Limestone and the Woodford Shale in Central Oklahoma

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1- ABSTRACT

The Hunton Limestone and the Woodford Shale represent reservoirs for hydrocarbon production in Oklahoma. Karsting is a common feature of carbonate environments which causes topographic irregularities on an unconformity surface. In parts of the Cherokee platform, Central Oklahoma, the Hunton Limestone underlies the Woodford Shale and might have controlled Woodford deposition. The main objectives of this study are to **1)** understand the impact of karsting on the natural fractures in the Hunton Limestone **2)** study the effect of the unconformity karst surface on the overlying Woodford Shale, and **3)** evaluate the hardness of the Hunton Limestone and the Woodford Shale for artificial fracture stimulation. To achieve this understanding, we used a 3D seismic survey and well logs to map the structure and thickness of the Viola Limestone, Sylvan Shale, Hunton Limestone, and the overlying Woodford Shale. In addition, we used core analyses to quantify the fracture aperture and intensity, measure the hardness using a Rebound HammerTM, and describe the lithology and nature of the boundary contact.

The karst features, such as collapse and sinkholes on the Hunton unconformity surface are prominent factors controlling the paleotopography and deposition of the Woodford Shale, as was observed from 3D structural maps. Similarly, there might be a potential effect of the Viola Limestone karstification on the overlying Sylvan Shale. The thickness variations of the Woodford Shale are controlled by paleotopography of the underlying Hunton Group, where thicker Woodford is observed in the karst lows (sinkholes) (Infante et al, in press). Sinkhole features range in diameter from 1150 to 2300 ft. and extend vertically to almost 300 ft. Additionally, there is an inverse correlation between the thickness of limestones (Viola and Hunton) and shales (Sylvan and Woodford).

Core data reveals that fractures exist only in the karstified section of the uppermost 15 ft. of the Hunton due to karstification. The fracture aperture (sealed) ranges from 0.003 to 0.01 in. and the fracture intensity ranges from 8 to 30 fractures/ ft. every 6 inches (on average) along the core length. The higher hardness measurements correspond to areas with higher fracture abundance due to more brittle rocks in the karsted zone. An erosional unconformity surface between the Hunton Limestone and the overlying Woodford shale, with possibly some Misener Sandstone occurs in one core. This study predicts the locations of thick Woodford Shale sections suggesting possible spots for landing horizontal wells in the Woodford Shale.

2- GEOLOGICAL SETTING

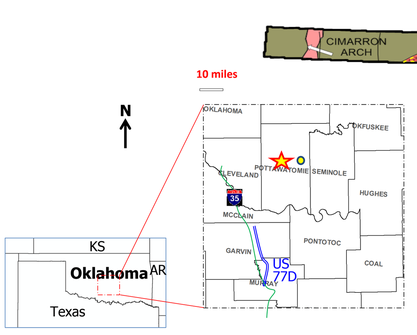
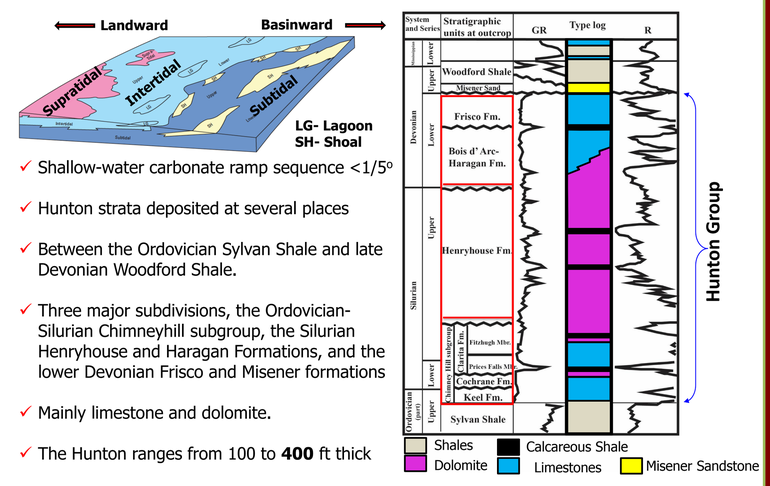


Figure 1. The location of the core in the circle simple, the location of the 3D seismic volume in the star simple, and the location of the outcrop in the rectangular simple.

Figure 2. The map of Oklahoma showing geologic provinces and the Hunton Group distribution (Northcutt, 2002). Yellow dash lines show the boundaries of the Hunton Group.



- ✓ Shallow-water carbonate ramp sequence <1/5º
- ✓ Hunton strata deposited at several places
- ✓ Between the Ordovician Sylvan Shale and late Devonian Woodford Shale.
- ✓ Three major subdivisions, the Ordovician-Silurian Chimneyhill subgroup, the Silurian Henryhouse and Haragan Formations, and the lower Devonian Frisco and Misener formations
- ✓ Mainly limestone and dolomite.
- ✓ The Hunton ranges from 100 to **400** ft thick

Figure 3. Hunton Group stratigraphic column in central Oklahoma with gamma ray (GR) and resistivity (R) type logs. This figure modified from Fritz and Medlock, 1994. The Misener Sandstone was added to this stratigraphic column as it was observed in the core and subsurface logs in the Cherokee Platform.

3- KARSTIFICATION

- Karsting is a common feature of tropical carbonate during green house period (Moore, 2013).
- During lowstands, erosion is dominantly chemical (Moore, 2013).
- Long-term exposure leads to karsting (Moore, 2013).
- The chemical diagenesis including dissolution, remobilization, and precipitation of calcium carbonate produce karst.
- Dissolution Processs: $CaCO3 + H2O + CO2 \leftrightarrow Ca+2 + 2HCO3^-$

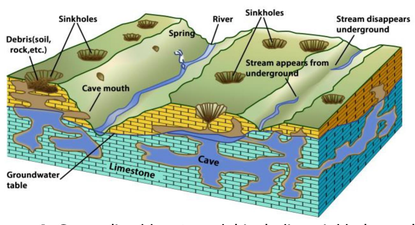


Figure 4. Generalized karst model including sinkholes, collapsed caves, and incised valleys. (Grotzinger and Jordan, 2010).

Karst features and Woodford-Hunton Contact

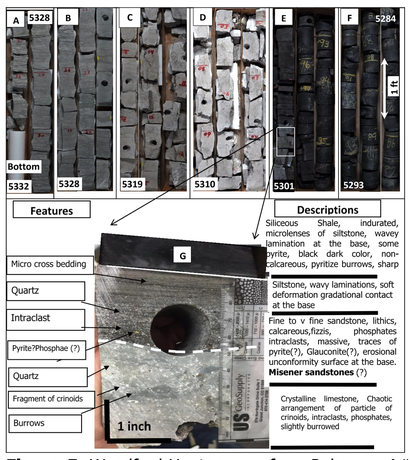


Figure 5. Woodford-Hunton core from Roberson A#1 well in Pottawatomie County in Oklahoma. A) Dolomitized Wackstone with more bioturbation content. B) Wackstone with no effect of the karstifications. C) Brecciated and crystallized Hunton with stylolites. D) Brecciated packstone of the Chimneyhill subgroup carbonate rock highly fractured. E) Woodford Shale core with pyrite phosphate nodules. F) Woodford Shale with high organic matter and silicious, which is slightly laminated. G) Detailed descriptions of four inches of the transition zones between underlying the Chimenyhill subgroup carbonate and overlaying the Woodford Shale

Karst features in the US 77D Outcrop

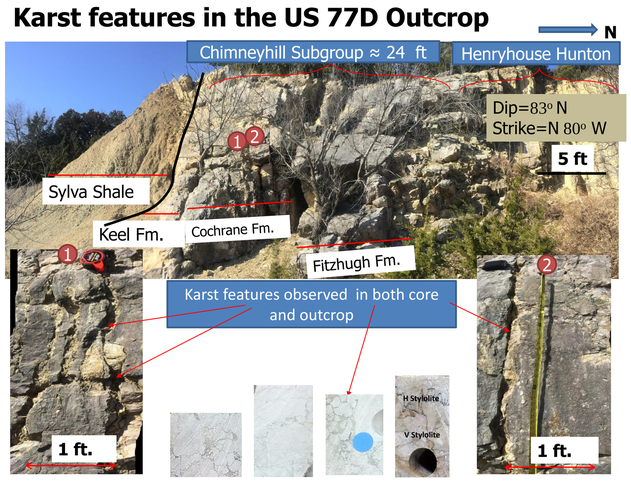
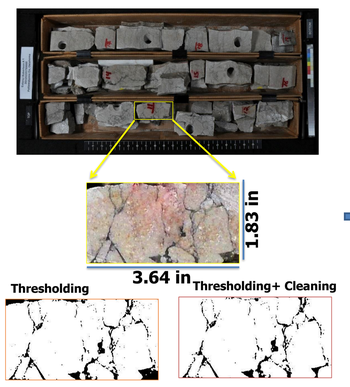


Figure 6. Hunton Group outcrop at the US-77 D roadcut. Karst features are observed in this section, especially at the zoomed beds 1 and 2. Karst features are observed in the core (Figure 5).

4- METHODOLOGY

Fracture Analysis



Vertical Fracture Intensity= (Total Fra length)/(area)= (7.1949/(3.64*1.83))=1.08 Fra/in

Figure 7. Fracture intensity analysis using Image J Software. First, we selected a specific area of the core, set the scale, enhanced the resolution of the picture by changing the saturations, and conducted thresholding. Next we cleaned the picture where we thought some features were not fractures when compared it with the original picture. Then we extracted the fracture length and width for the sample and calculated the fracture intensity per area as shown in this formula.

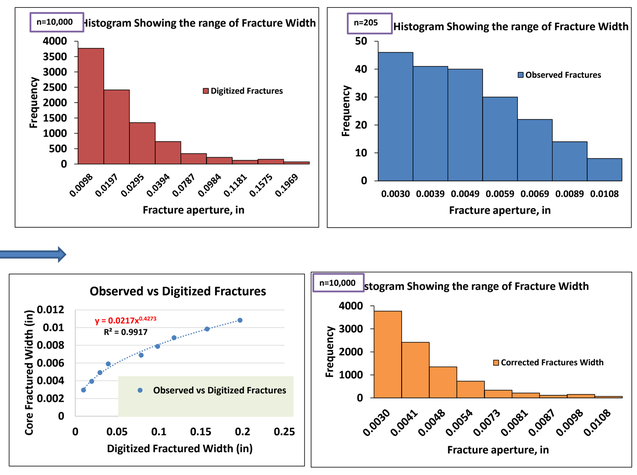


Figure 8. Method of correcting fracture apertures extracted from the Image J Software against the fracture aperture measured manually on the core site.

Hardness

Figure 9. Measurements of the hardness of the core using a Rebound Hammer™.

Hardness:

- ✓ It measures the strength of the rock through estimating the hardness when force is applied by the tool.
- ✓ 5-10 measurements were taken on every 6 inches. Then the average value was taken.
- ✓ High values means more brittle rock, which will not absorb the shock produced by the applied force of the tool.

5- RESULTS

Core Analysis: Fractures and hardness

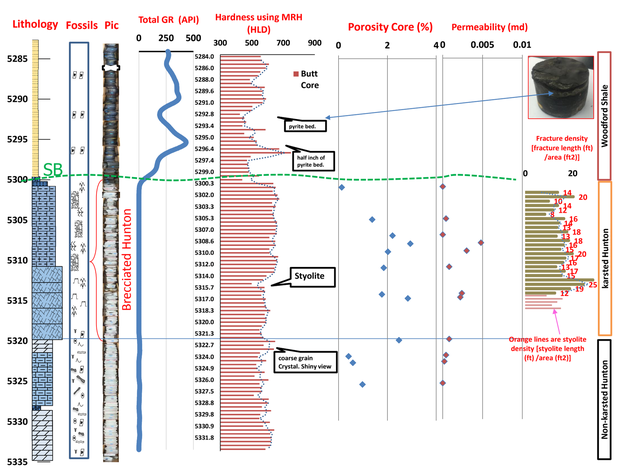


Figure 10. Core analysis for Robertson A#1 well including lithology profile, fossil distribution, core photograph, core gamma ray, core hardness measurements, core porosity, core permeability, and natural fracture intensities. This core is divided into three sections: non-karsted Hunton, karsted Hunton, and Woodford Shale. Fractures occur only in the brecciated zones due to karstification processes. The fractured zone possessed the highest hardness measurements (brittle rock). The brecciated section had enhanced porosity and permeability due to the karsting. In the Woodford section, there is a consistent relation between GR and hardness measurements, which is unusual. This is due to the pyrite presence, which gives high GR and high harness.

Structure maps

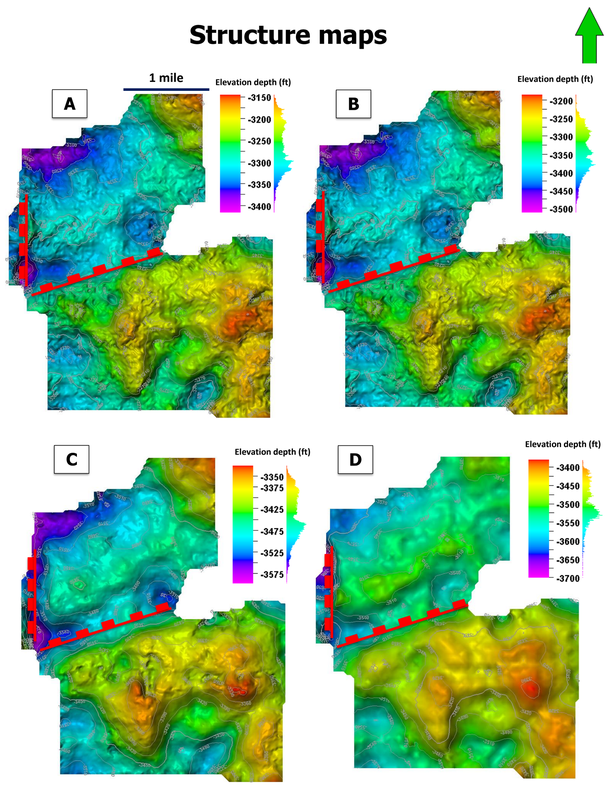


Figure 11. Surface structure maps in depth domain. A) Woodford structure map. B) Hunton structure map. C) Sylvan structure map. D) Viola structure map. Yellow lines indicate the locations of normal faults.

Karst features from a 3D seismic volume

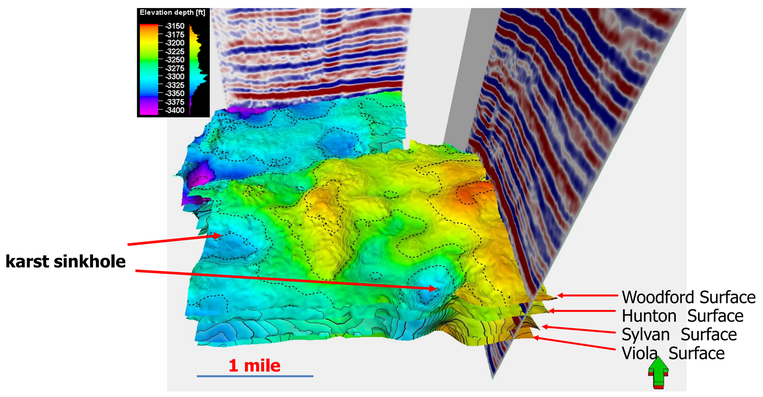


Figure 12. 3D view of the Woodford, Hunton, Sylvan, and Viola structure surfaces, showing low and high paleotopgraphies. The karst features, such as collapse and sinkholes on the Hunton unconformity surface are prominent factors controlling the paleotopography and deposition of the Woodford Shale. Sinkhole features range in diameter from 1150 to 2300 ft. and extend vertically to almost 300 ft.

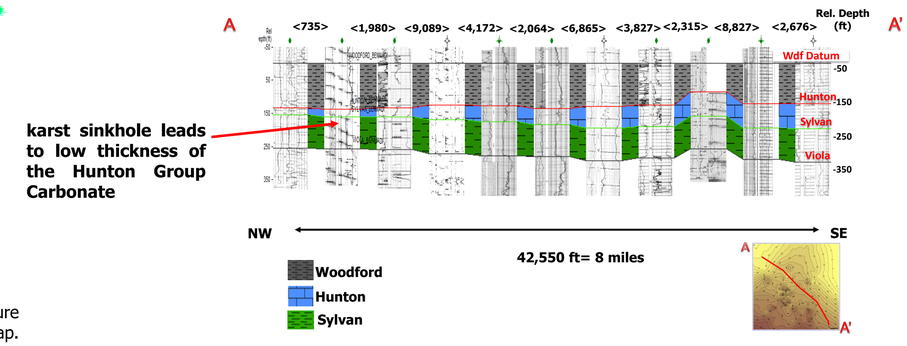


Figure 13. NW to SE Stratigraphic Cross Section. The thickness variations of the Woodford Shale are controlled by paleotopography of the underlying Hunton Group, where thicker Woodford is observed in the karst lows (sinkholes).

6- CONCLUSIONS

1) Core fractures are related to the karstification processes.
2) Most fractures in the core occur in the karstified stratigraphic section where the rocks have high hardness values.
3) The karst features, such as collapse and sinkholes on the Hunton unconformity surface are prominent factors controlling the paleotopography and deposition of the Woodford Shale.
4) Sinkhole features range in diameter from 1150 to 2300 ft. and extend vertically to almost 300 ft.

REFERENCES

- Grotzinger, J.G and T.H Jordan, 2010, Understanding Earth. W. H. Freeman; Sixth Edition, 672 p.
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- Infante et al, in press, 2017
- Moore, C. H., and W. J. Wade, 2013, Carbonate Reservoirs: Chapter 8. Meteoric Diagenetic Environment, v. 67, Elsevier Inc. Chapters.
- Northcutt, R. A., 2002, History of Hunton Oil and Gas Exploration and Development in Oklahoma: Shale Shaker, p. 149-158.

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