Organic-Inorganic Distribution of the Woodford Shale in Kingfisher County, STACK play, Northern Oklahoma*

Andreina Liborius[1] and Andrew Sneddon[1]

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[1]University of Oklahoma, Norman, OK, United States (andreinaliborius@ou.edu)

Abstract

The Woodford Shale represents one of the main reservoirs in the Mid Continent U.S.A. In recent years, the well-known STACK (Sooner trend Anadarko Basin Canadian and Kingfisher County) play started to generate a high amount of interest due to its potential reserves. The Woodford Shale in the study area is characterized by variable thickness that can be related to the subaerial erosion surface (unconformity) at the top of the shallow water carbonate platform deposit of the underlying Hunton Group before deposition of the Woodford Shale. The typical paleo-surface is represented by karsted minibasins (sinkholes) and incised valleys. A well-developed complete section of Woodford deposits in this setting show the transition from a deeper, anoxic, and organic rich environment to a shallower, thinner, and less organic interval going from the northeast towards the southwest. By considering the organic (Rock Eval Parameters); inorganic parameters (X-ray Fluorescence and X-Ray Diffraction) and the sequence stratigraphy of The Woodford Shale, a preliminary geological characterization in Kingfisher county was generated using its mineralogical proxies and organic content as a main objective to understand its depositional history and its relationship with hydrocarbon potential.

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AAPG Southwest Section
May, 2017

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Outline

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Introduction

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- The well-known STACK (Sooner trend Anadarko Basin Canadian and Kingfisher County) play has generated a high amount of interest due to its potential reserves in oil and condensates.

- In fact, it is known that "Kingfisher represents one of the top five counties in new production capacity from the Woodford Shale with an oil production of approximately 1800 (BOE/day) and gas production of 3300 (BOE/day)"

Source: Drilling info Basin-Level NPC reports, 2017.

- The Woodford Shale in the study area is characterized by variable thickness that can be related to subaerial erosion, karsted unconformity and a shallow water platform of the underlying Hunton Group before deposition of the Woodford Shale.

- By considering the organic (Rock Eval Parameters), inorganic parameters and sequence stratigraphy of The Woodford Shale, a geological characterization was generated in Kingfisher county to relate to hydrocarbon potential.

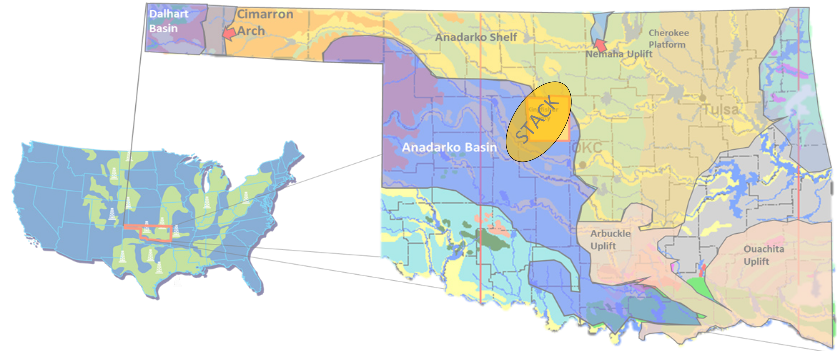

Figure 1. Geological map of Oklahoma showing the location of the Stack and the study area in Kingfisher County, northwestern Oklahoma represented by the green oval and the blue square. Modified after Oklahoma Geological Survey, 2015.

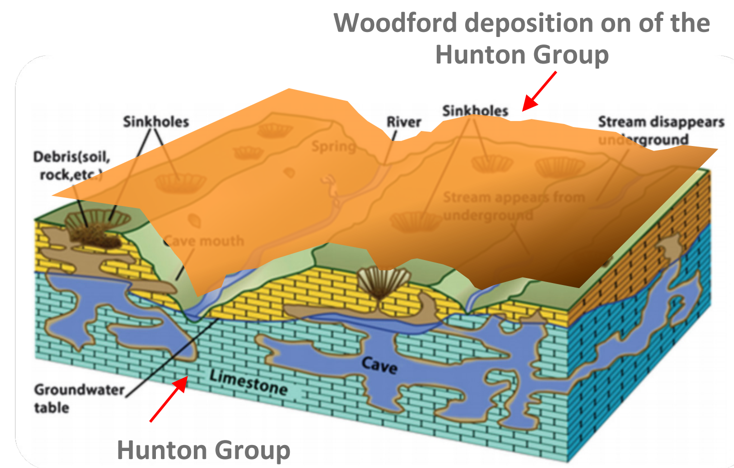

Figure 2. Generalized model of surface features on a carbonate unconformity (modified after Grotzinger and Jordan, 2010), including incised valleys, collapsed caves, and karst sinkholes.

Study area and geological background

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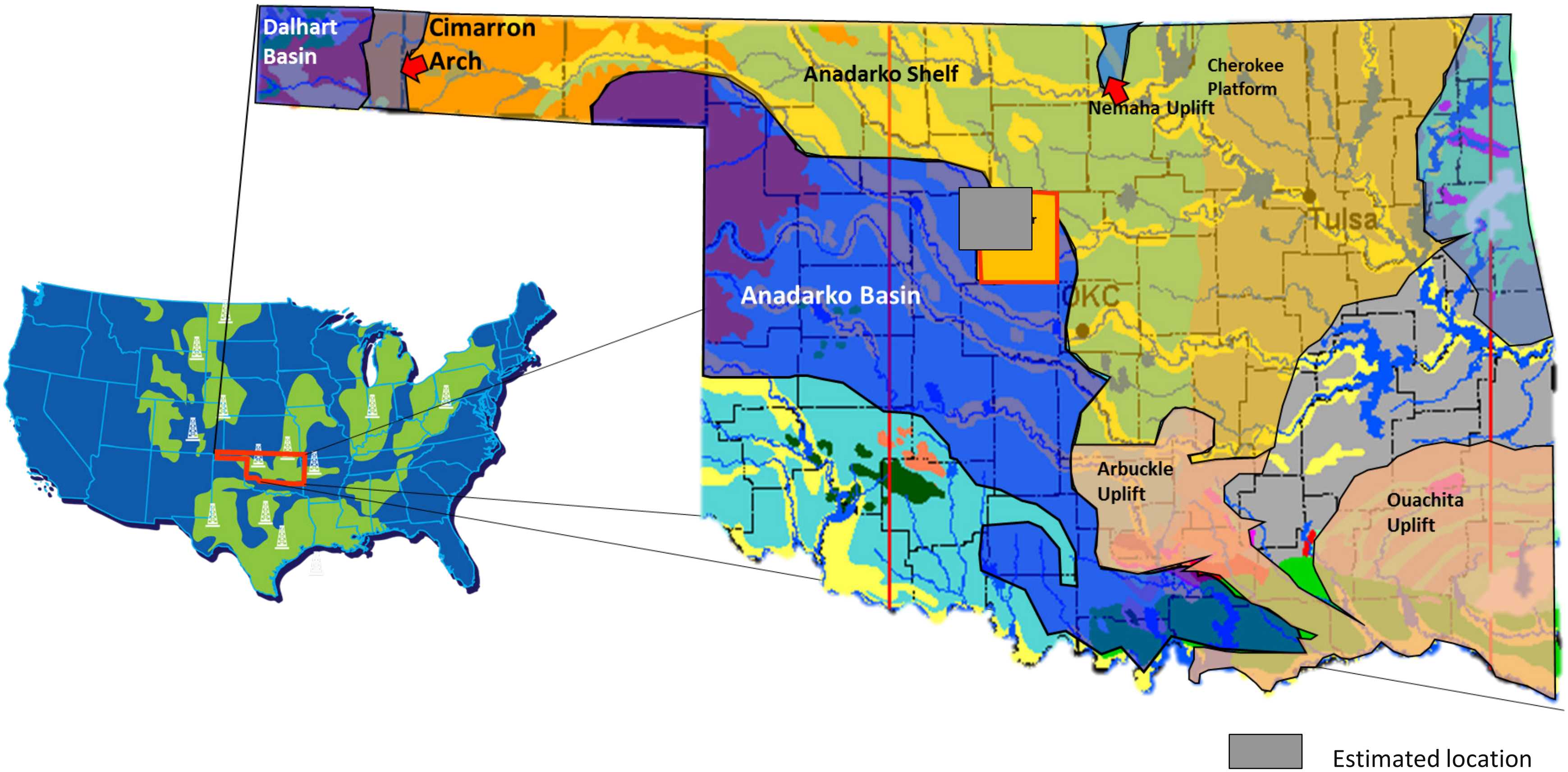

Figure 3. Geological map of Oklahoma showing the location of the Stack play and the study area in Kingfisher County, northwestern Oklahoma represented by the green oval. Modified after Oklahoma Geological Survey, 2015.

Study area and geological background

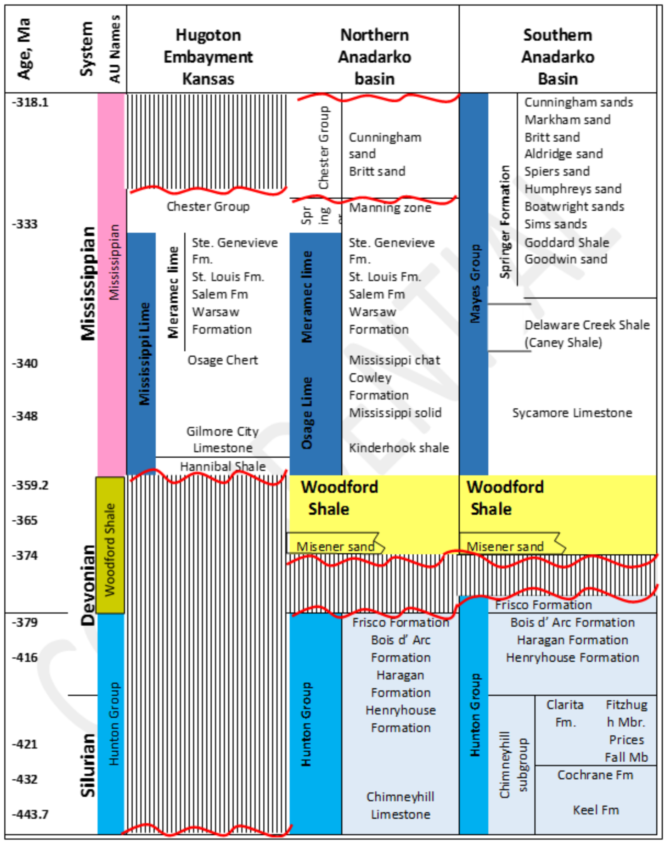

Figure 4. Generalized stratigraphic column of the Silurian through Pennsylvanian section displaying the Upper Devonian Woodford Shale and its major subdivisions. Modified from Higley, D. K. (2013).

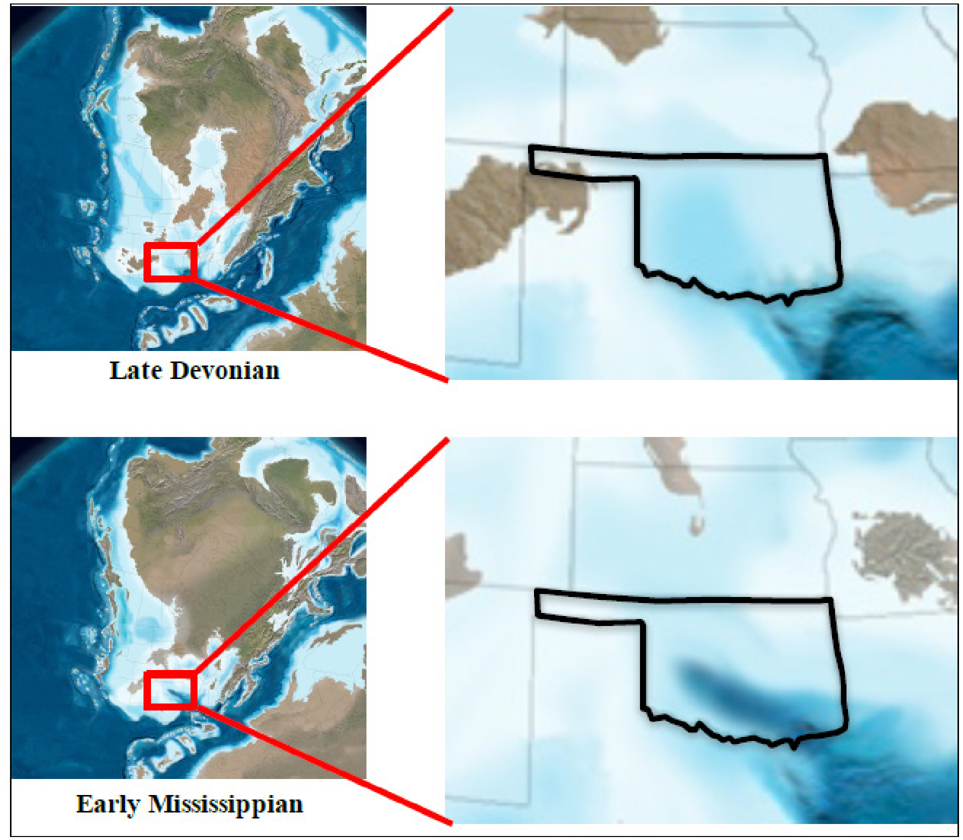

Figure 5. Paleogeography of North America in Late Devonian time and Early Mississippian age, and the location of current day Oklahoma on paleo-North America continent (Modified from Blakey, 2012).

Structural and isopach maps

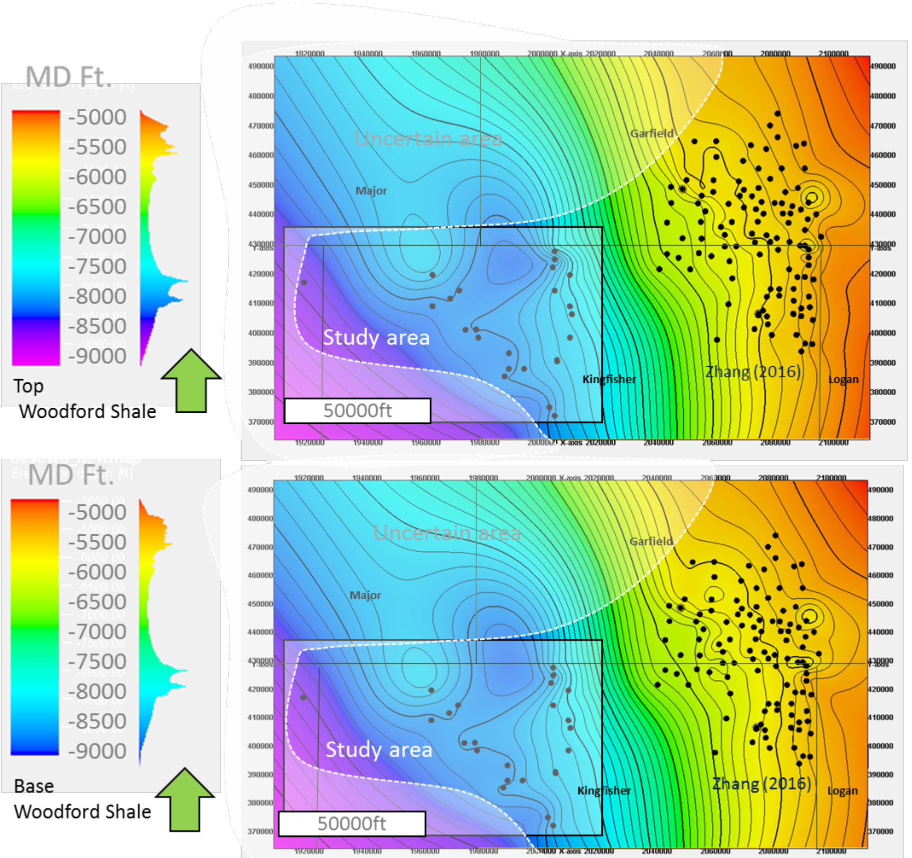

Figure 6. Woodford formation top and base structural maps in Kingfisher and Garfield Counties indicating dips towards the southwest. The black dots are the well locations with Woodford formation top picks. Black square show the location of the study area. Wells located to the east belong to Zhang (2016).

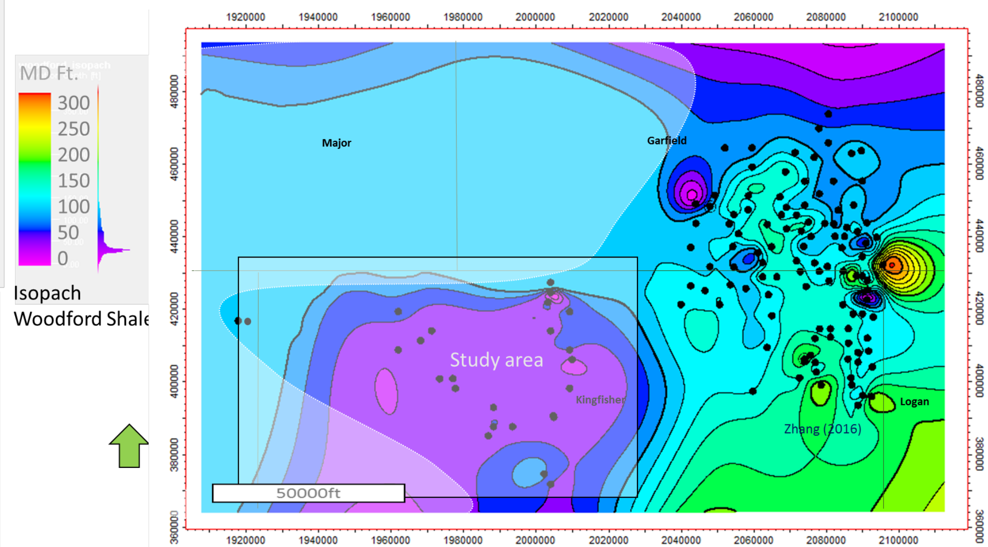

Figure 7. Isopach map showing the thickness distribution of the Woodford Shale in Kingfisher County. The black dots are the well locations of the Woodford isopach map. Black square show the location of the study area. Wells located to the east belong to Zhang (2016).

X-ray Diffraction mineralogy

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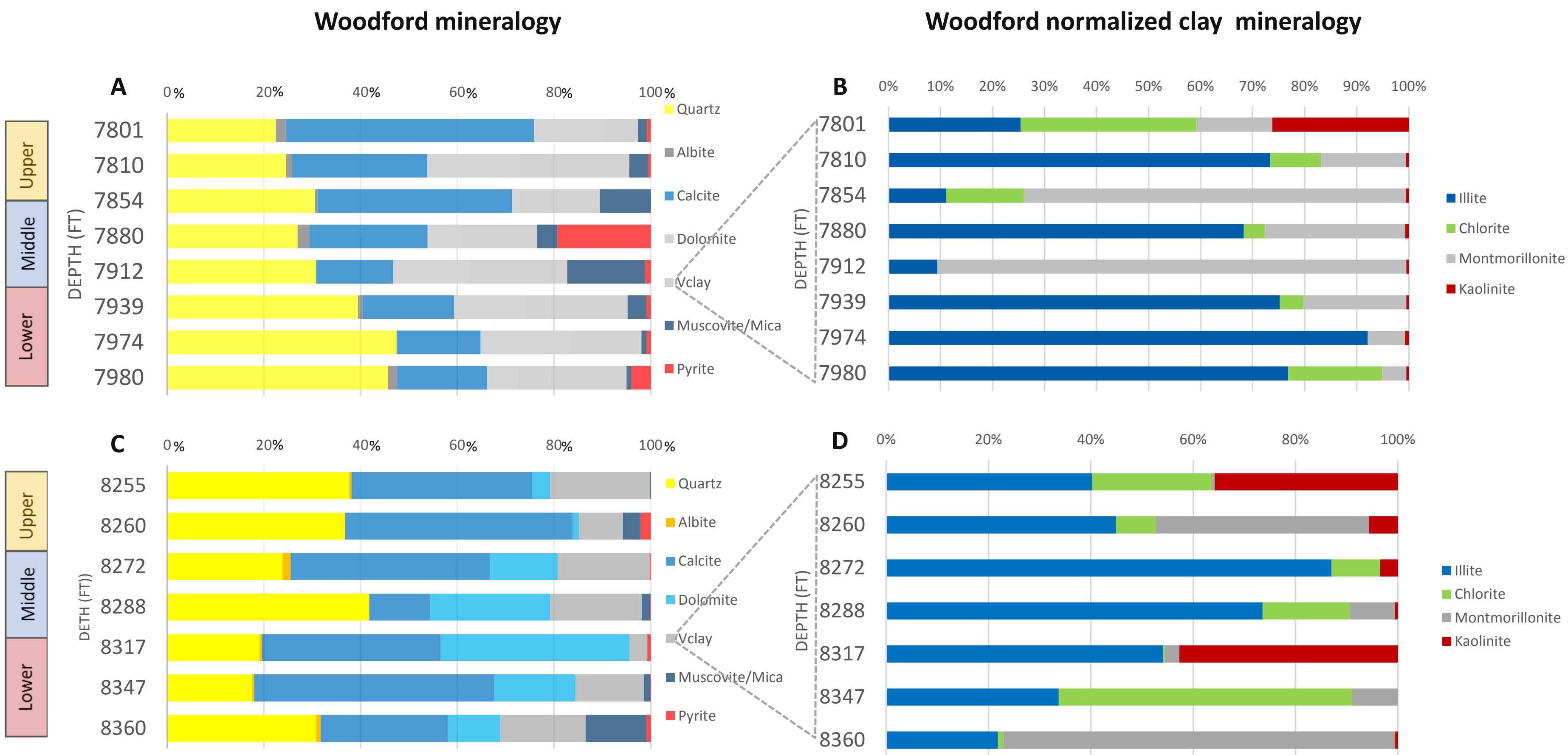

Figure 8. A and C Representation of the average dominant mineralogical composition of the Woodford Shale in northwest and southeast Kingfisher County, Oklahoma. Quartz content is represented by the yellow color, dolomite content by light blue, calcite content by dark blue, clay content by gray and pyrite content by red color. B and D. Normalized mineralogical clay content of the Woodford Shale northwest Kingfisher County, Oklahoma. Illite content is represented by blue, chlorite by green, montmorillonite by gray and kaolinite by crimson color.

X-ray Fluorencense chemostratigraphy

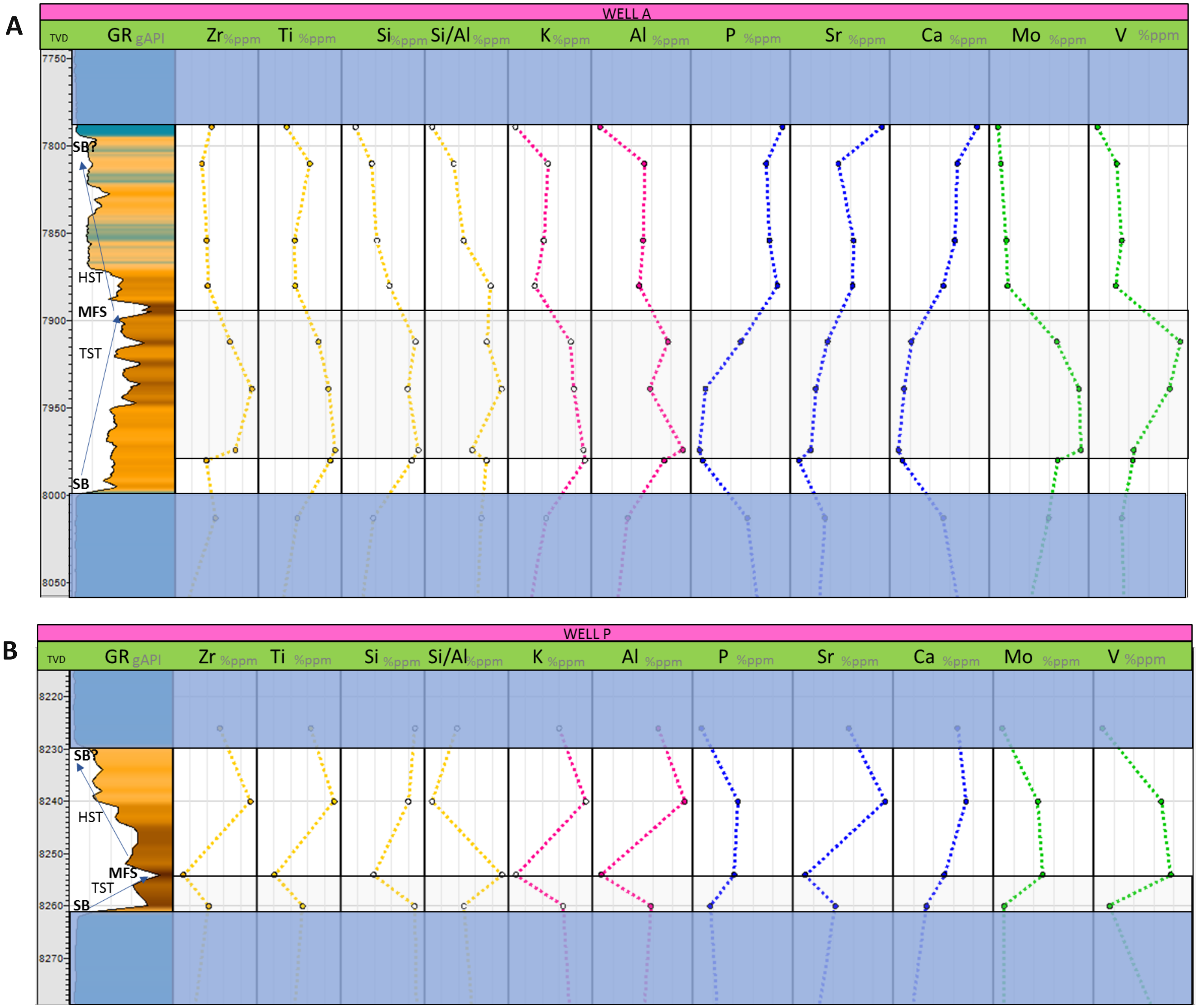

Figure 9. GR and XRF profile of the Woodford Shale Formation in Kingfisher County towards the northwest (A) and towards the southeast (B).First Track shows GR profile; elements situated in the first part of the profile colored in yellow are Zirconium (Zr), Titanium (Ti); Silicon (Si) and Silicon/Aluminum (Si/Al) representing the continental source and a clastic provenance (Pearce and Jarvis, 1992; Pearce et al., 1999); elements situated in the second part of the profile colored in pink are Potassium (K) and Aluminum (Al) associated with clay minerals and feldspars (Pearce et al, 1999);the third part colored in blue comprises Calcium (Ca), Strontium (Sr), Phosphorous (P) and is essentially related to the carbonate content (Tribovillard et al., 2006) and the fourth part colored in green is Molybdenum (Mo), and Vanadium (V) which are associated with a more anoxic environment (Tribovillard et al., 2006; Rowe et al., 2008; Algeo and Rowe, 2012 in Turner et al, 2015). Red circles represent the spatial relationship between well A and P.

Organic geochemical parameters

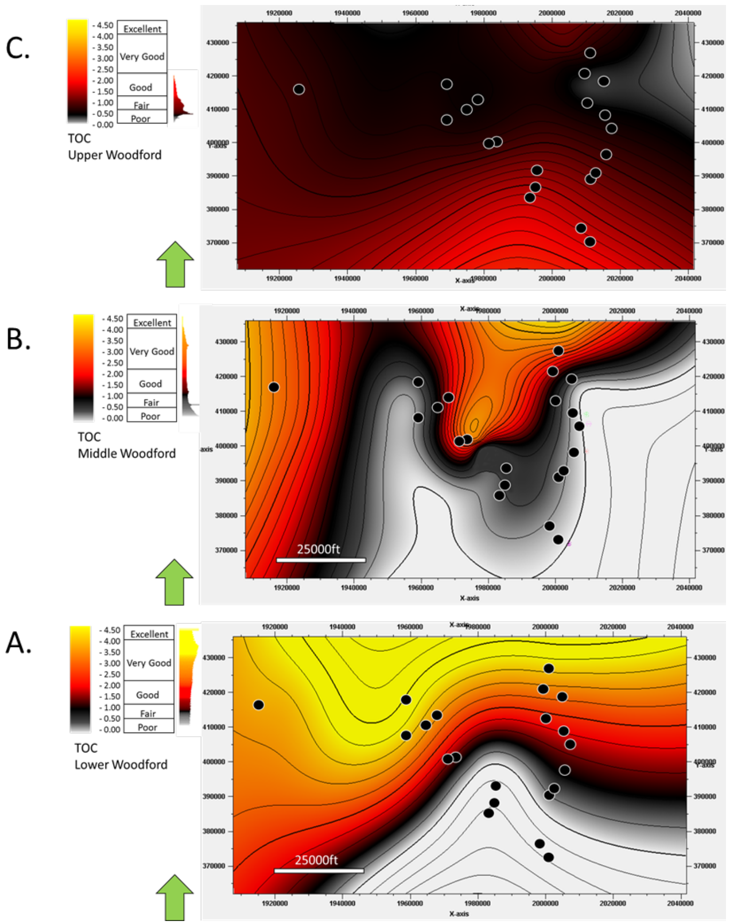

Figure 10. Distribution of the TOC in Lower (A), Middle (B) and Upper (C) Woodford shale in Kingfisher County, Oklahoma.

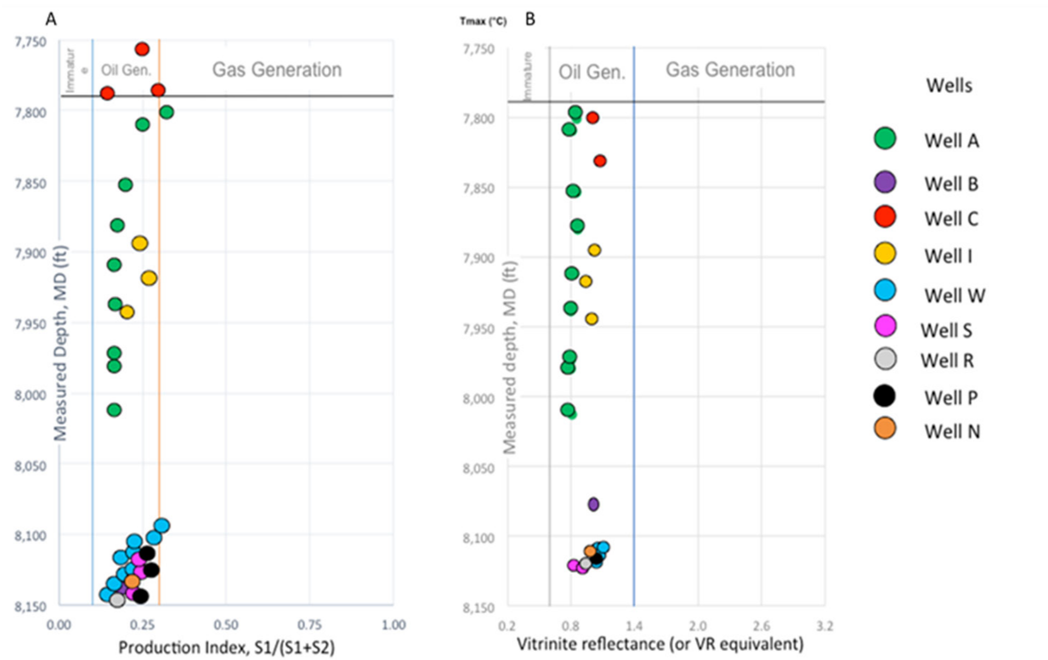

Figure 11. Source Potential logs showing the production index (A) and the calculated vitrinite reflectance (B) of Woodford Shale with depth.

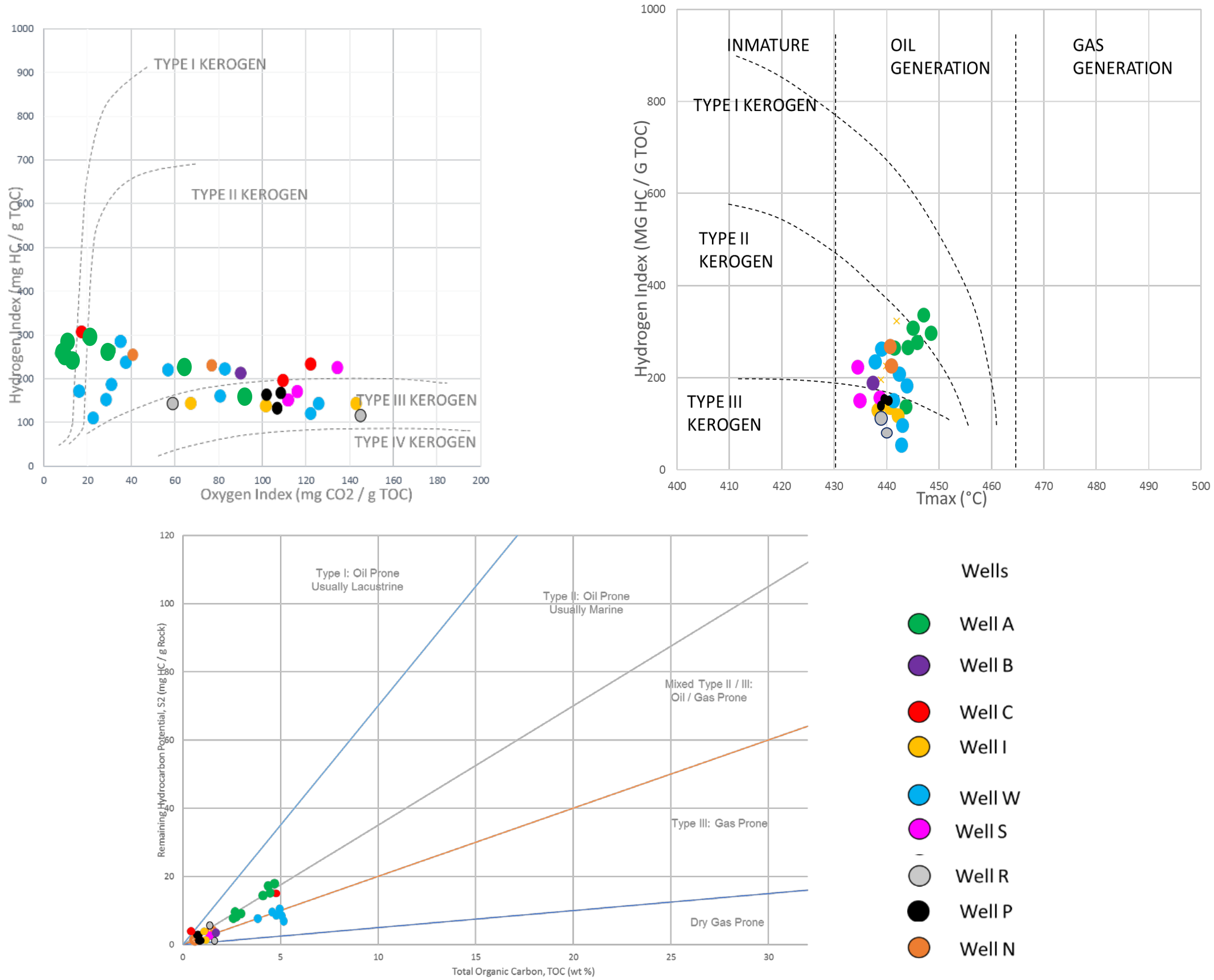

Figure 12. A. Pseudo Van Krevelen diagram showing four different types of kerogen at different maturity levels. B. Kerogen type and maturity plot that displays the relationship between the Tmax and the Hydrogen index. C. Kerogen Quality Plot that correlates TOC and S2.

Sequence stratigraphy interpretation

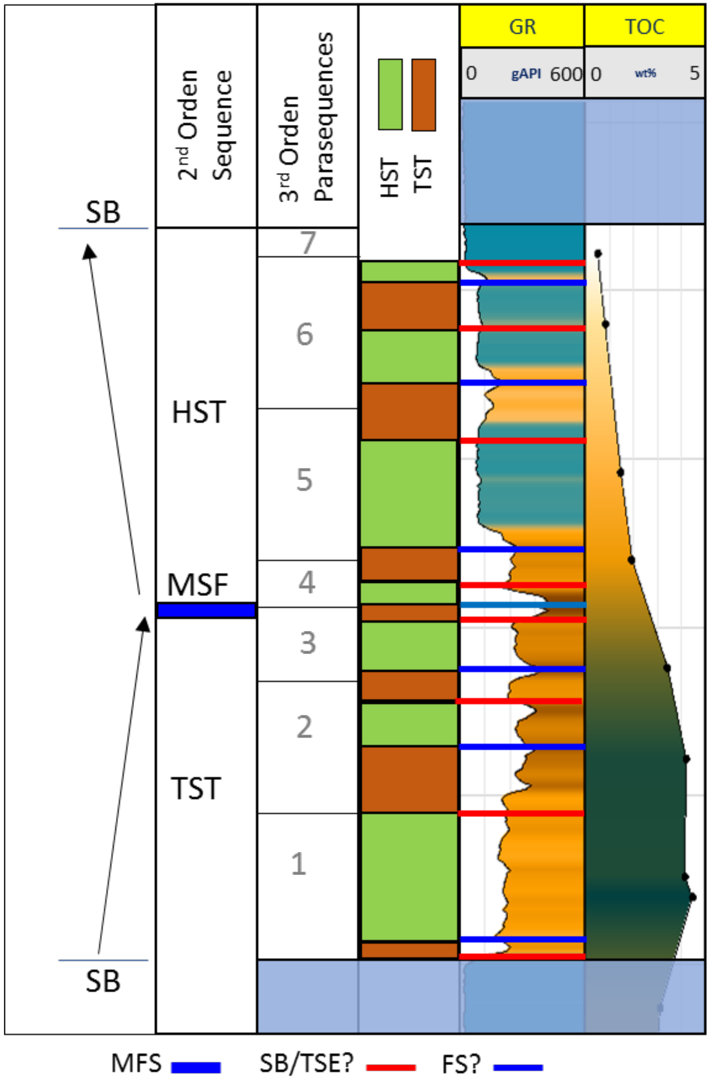

Figure 13. Type log of the Woodford Shale and TOC content in Kingfisher County showing the 2nd order sequence boundaries (SB) of the Woodford Shale and the interpreted and superimposed 3rd order parasequences. MFS is interpreted based on regional well correlation of the study area.

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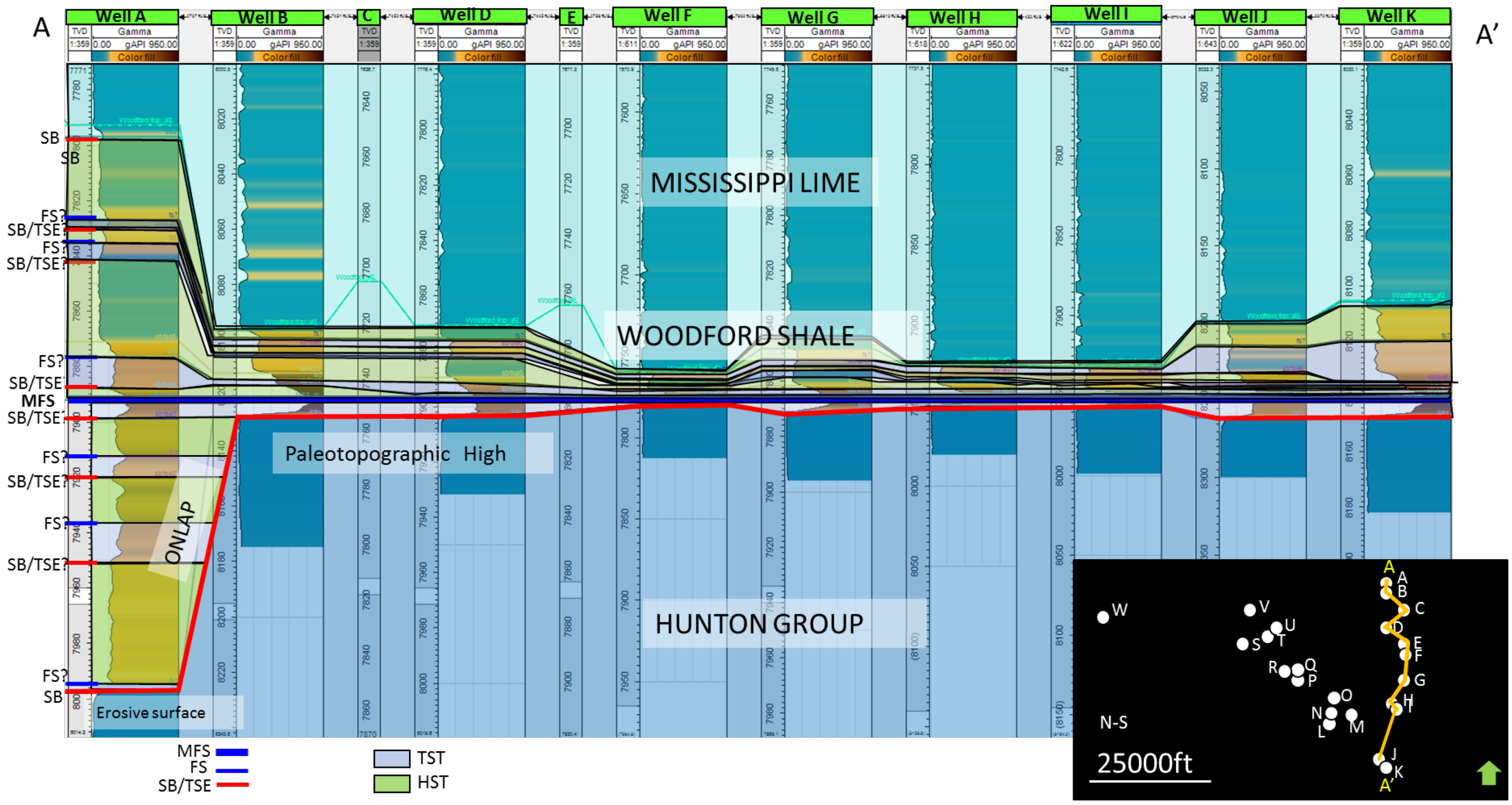

Figure 14. Stratigraphic Cross section AA' and parasequences correlation. Green colors are represented by the transgressive system tract and Red colors represent the highstand system tract flattened on MFS.

Sequence stratigraphy interpretation

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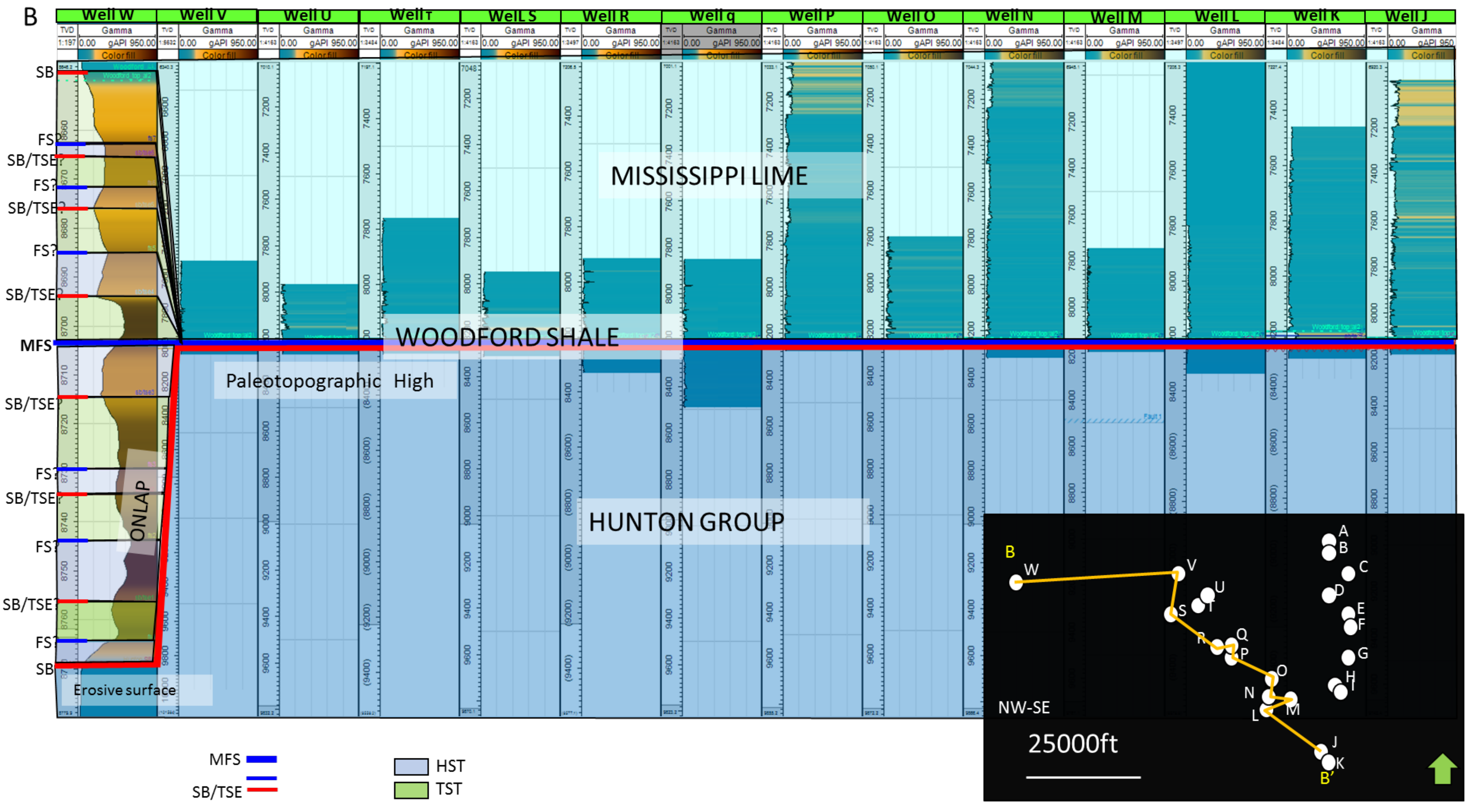

Figure 15. Stratigraphic Cross section BB' and parasequences correlation. Green colors are represented by the transgressive system tract and Red colors represent the highstand system tract flattened on MFS.

Sequence stratigraphy interpretation

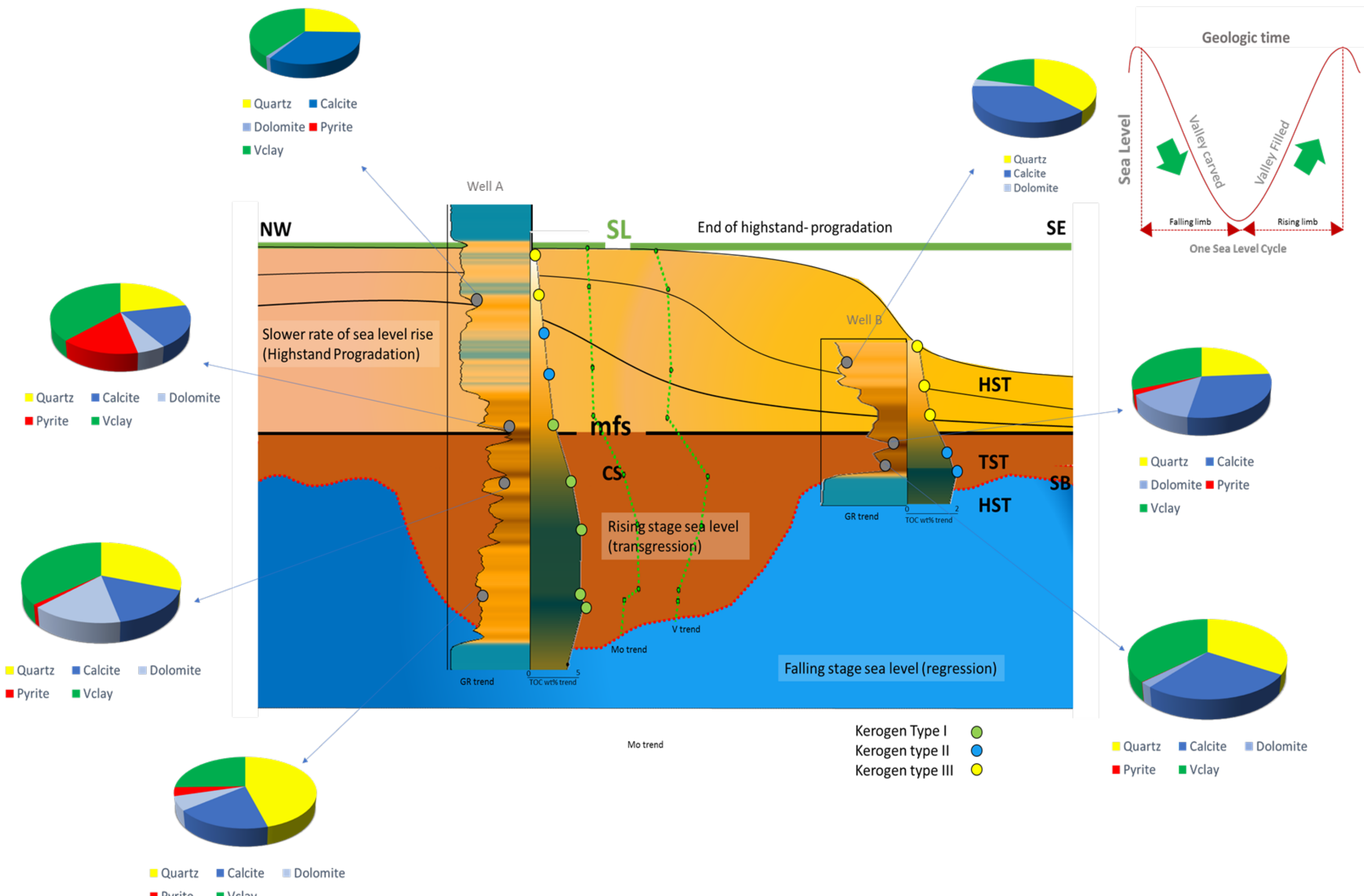

Figure 16. Schematic model and generalized 2nd order sequence of the Woodford Shale northwest Kingfisher County displaying average composition of mineralogy; Vanadium; Molybdenum; TOC; and kerogen type. Due to the uncertainty in the location of the cuttings, samples have been placed within a 20ft window for Well A and 10ft window for Well B. SB= Sequence Boundary; HST= Highstand Systems Tract; TST= Transgressive System Tract; CS= Condensed section and mfs= maximun flooding surface

Preliminary Conclusions

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- In the Lower Woodford, both the continental and anoxic proxies increase upward proportionally. This can be interpreted as reworking of some continental sediments into a possible incised valley fill or embayment during the Devonian transgression up to the maximum flooding surface (MFS).

- Pyrite content is higher in the Middle Woodford due to an euxinic and semi-euxinic environment. Clay is also present in high proportions throughout the whole interval but slightly decreases upwards.

- -Wells located towards the south and southeast trend are different, not only in thickness but in mineral content.

- -The best total organic content (TOC) is located in the Lower and Middle Woodford in the northwest study area.

- Woodford Shale kerogen types are type II but also a Type I in less amounts. A type II/III it's mostly related to the samples deposited on the second order HST in which hydrogen index gets low and oxygen index gets high, thus is more related to a gas type hydrocarbon.

- Some samples, especially those located in the northern trend are forming a possible incised valley or embayment. This area display a Type I kerogen that can be related to the high intervals of organic matter content that were deposited in a more restricted anoxic or lacustrine environment due to the paleo-structure left by the Hunton Group.

- However, as the maturity of the sample increases, identification of an accurate kerogen type in the Pseudo Van Krevelen Plot can be difficult due to low oxygen and hydrogen index values. Therefore, even when certain geological analysis (such as XRD; XRF and Rock Eval analysis) are indicators of the presence of this lacustrine type environment, other analyses (visual maceral analysis; biomarkers; thin sections) are also needed to interpret a Type I kerogen on possible incised valleys or embayment.

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