

AV Integrated Geochemistry and Basin Modeling Study of the Bakken Formation, Williston Basin, USA*

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Abstract

The Bakken Formation has been described as a tight, continuous, unconventional shale oil play. Integration of stratigraphy, geochemistry, and basin modeling demonstrates the Bakken petroleum system is conventional, containing all of the essential elements of a conventional petroleum system, but not all of the qualities that lead to high production rates, and high well EUR's. Poor reservoir quality of the middle Bakken reservoir unit plays a significant role producibility. Understanding the geology and controls on reservoir quality and distribution is essential for prospecting in the Bakken.

The geochemistry of Bakken oils has been investigated to gain insight into processes controlling petroleum distribution within the Bakken petroleum system. Initial results indicate petroleum migration is a significant process. The oils being produced from the middle member of the Bakken are derived from the Bakken shale. From oil biomarker data, variable source rock facies are interpreted.

Basin modeling was performed to constrain petroleum generation and migration timing. The modeled temperatures and maturity indicators of the constructed basin model fit independent maturity markers as the source-rock transformation or triaromatic steranes ratio. The model further gives support to the existence of a heat-flow anomaly that has been discussed controversially in earlier publications. With the available kinetic, it was possible to calculate first hydrocarbon composition predictions that are in agreement with average production data. Expulsion from the source rock and migration plays a crucial role when assessing the volumes and composition of hydrocarbons in-place in low-permeability reservoirs. As part of an ongoing study, the impact of different influences, such as overpressure, fracture opening and closing and related possible maturity trapping, will be tested to determine their order of impact on the accumulation of hydrocarbons in the Bakken petroleum system.

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April 12, 2011

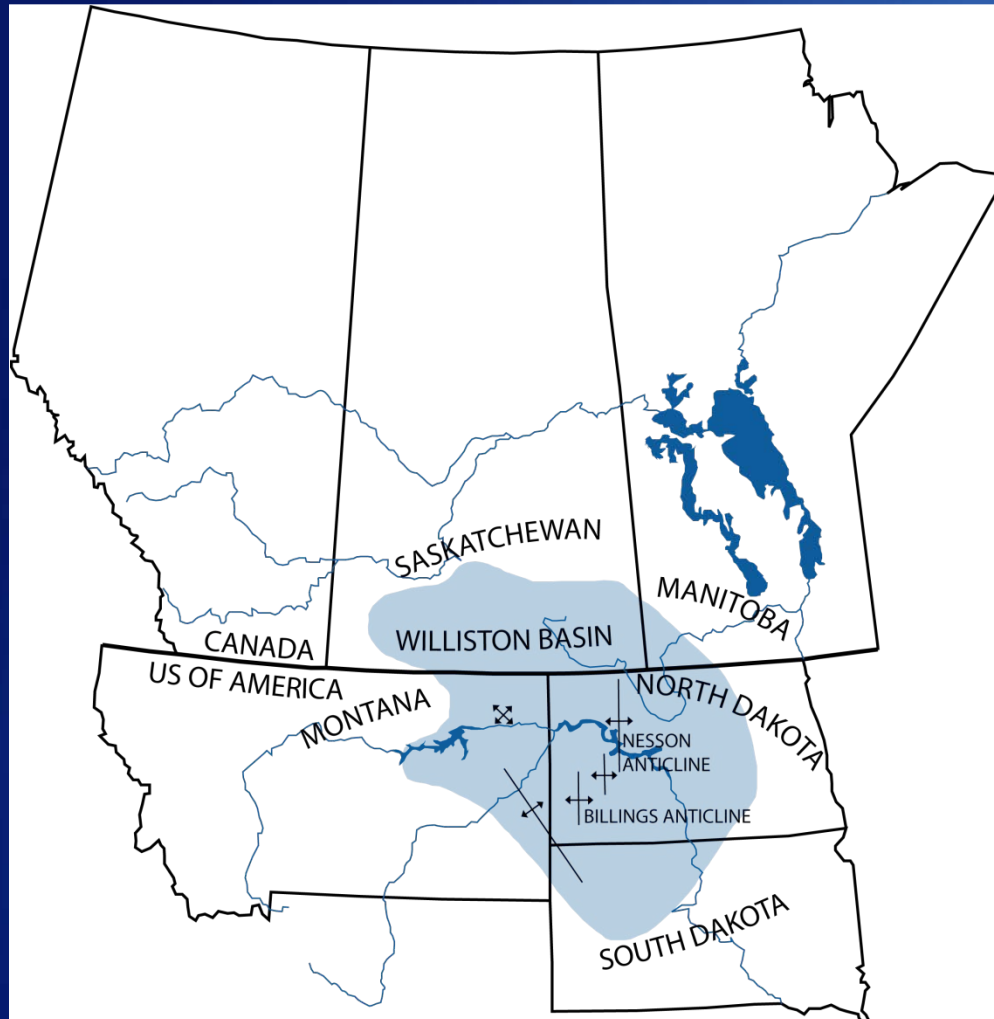

Marathon

Objectives



- ♦ **Bakken source rock facies variation from Bakken produced oils**
- ♦ **Range of Bakken oil maturity and implications for basin history**
- ♦ **Integration of basin modeling**
- ♦ **Implications for gas shales**

Bakken Shale Resource Play Western North Dakota



Petroleum System Study area



US region of Williston Basin

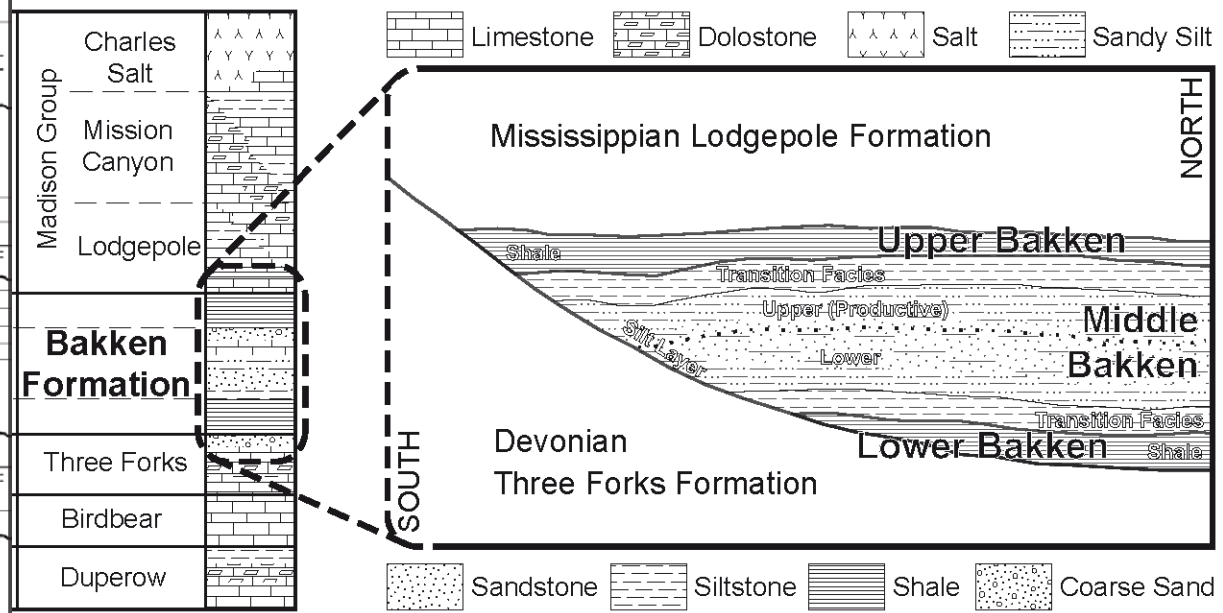
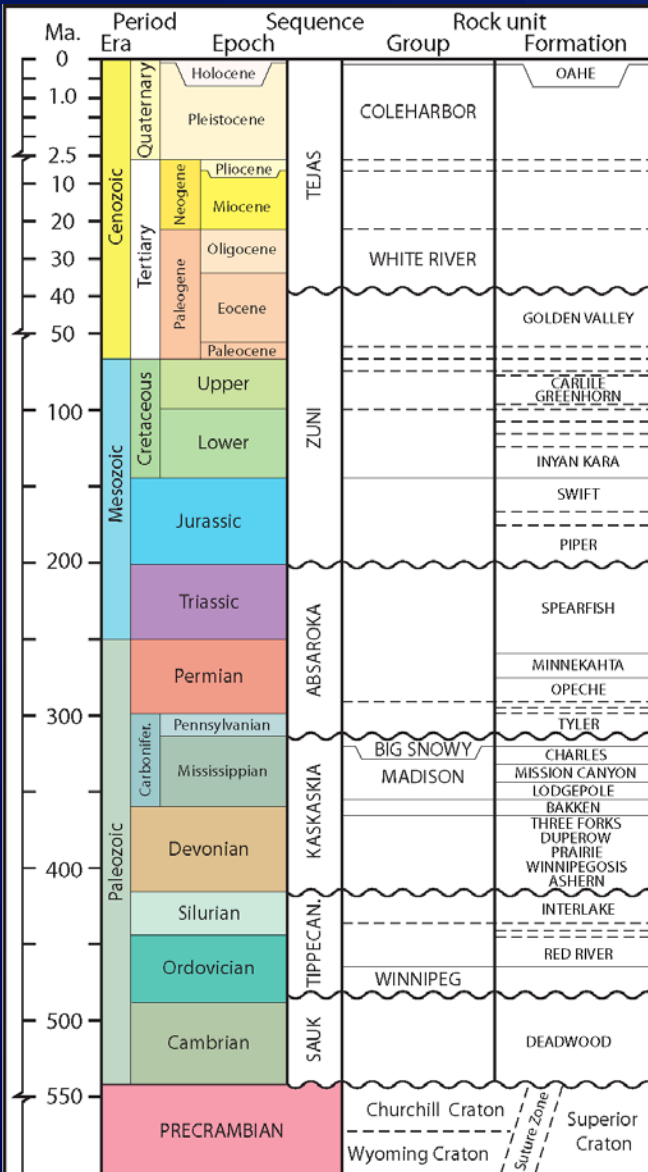


Williston Basin Stratigraphy in Western North Dakota



Immature Devonian Bakken shale

- TOC up to 33%
- HI approaching 900

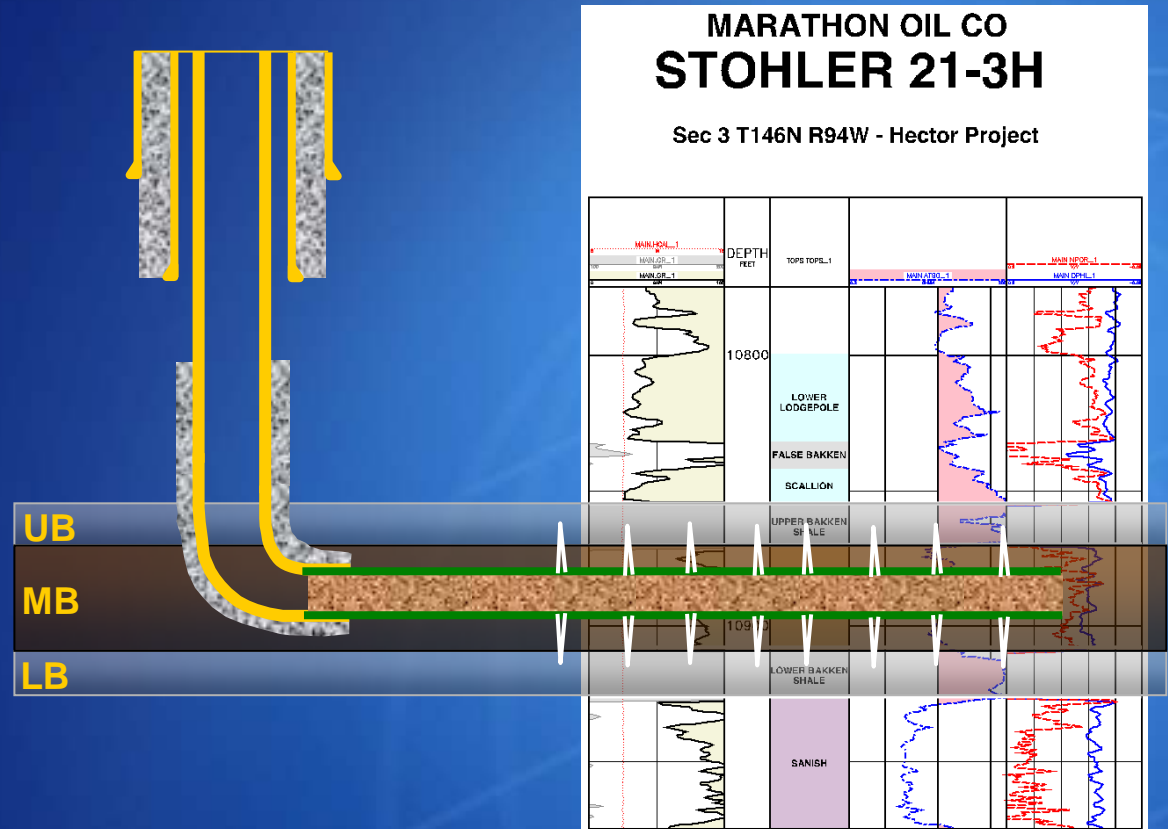


Bakken Study



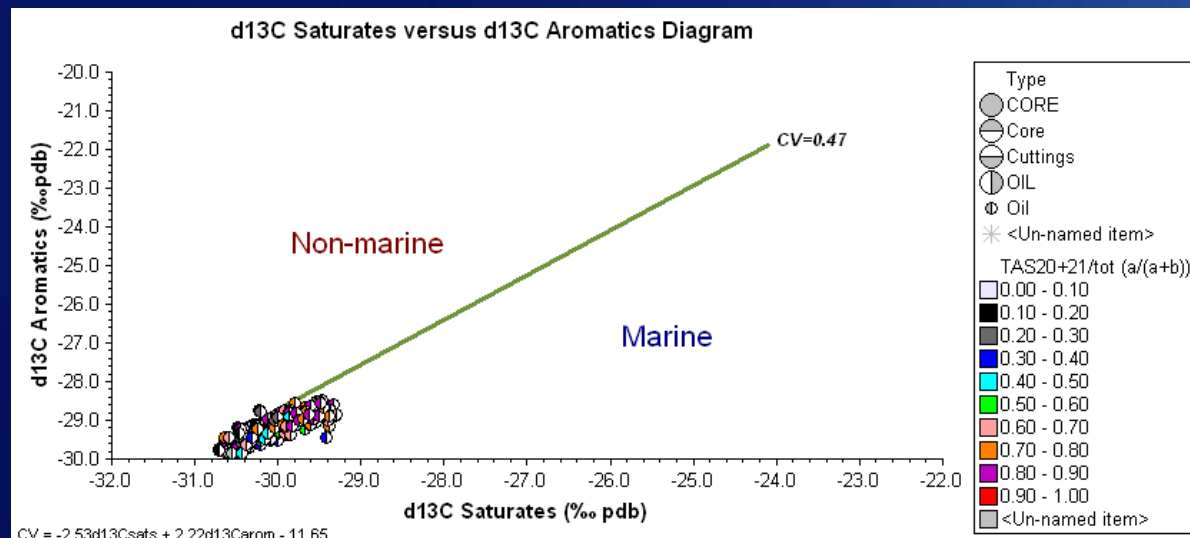
Bakken production

- > 14,000 bbl/day
- 33 MOC oils, 228 GeoMark oils
- 8 Core and cuttings samples being analyzed from 6 wells



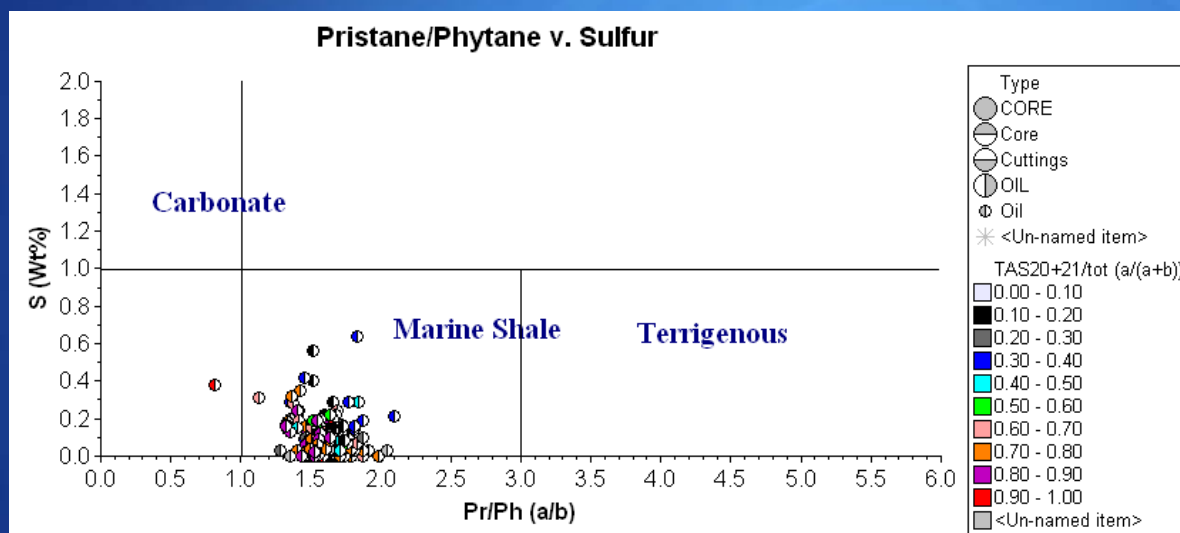
Bakken Oils: Marine, low S kerogen

Variability in bulk parameters is limited



Limited source rock variability

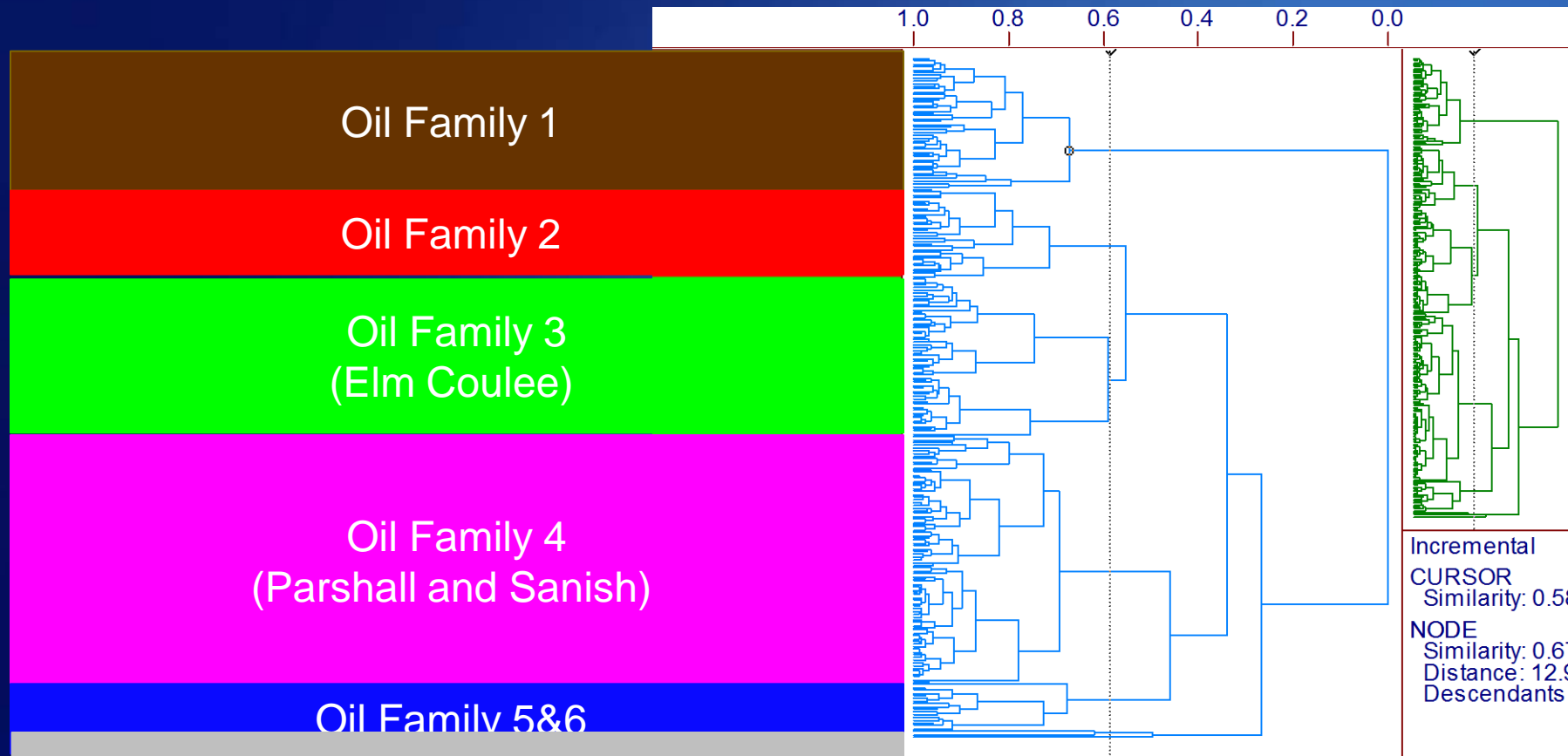
Limited secondary alteration



Two Bakken Oil Families Recognized



Oil families support multiple
Bakken shale facies



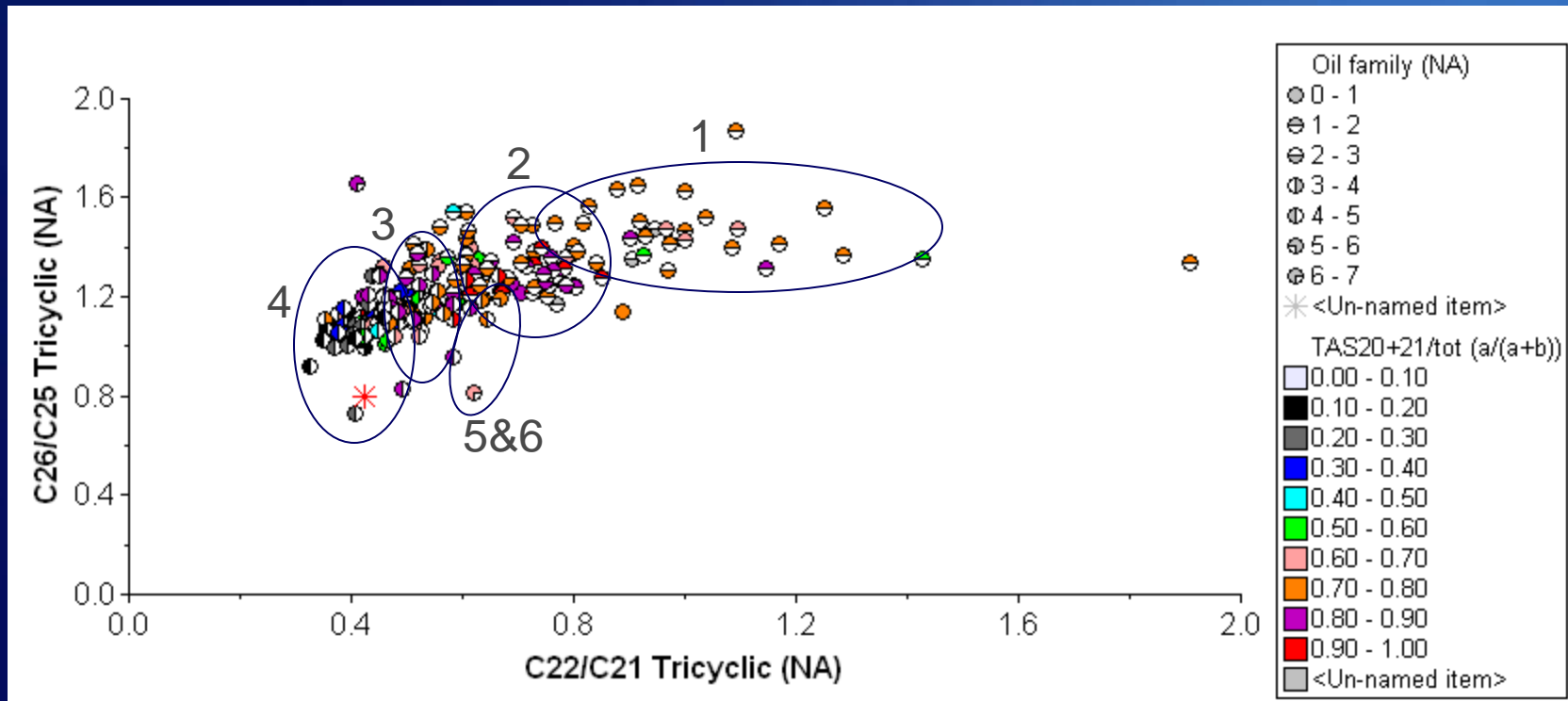
C_{19}/C_{23} , C_{24}/C_{23} , C_{26}/C_{25} , $C_{24}Tet/C_{23}$, % C_{27} , % C_{28} , % C_{29} Steranes,
 $C_{31}R/Hopane$, C_{35}/C_{34} , norhopane/hopane, $\delta^{13}C$ saturated HCs,
pristane/phytane, hopane/sterane

Bakken oil families



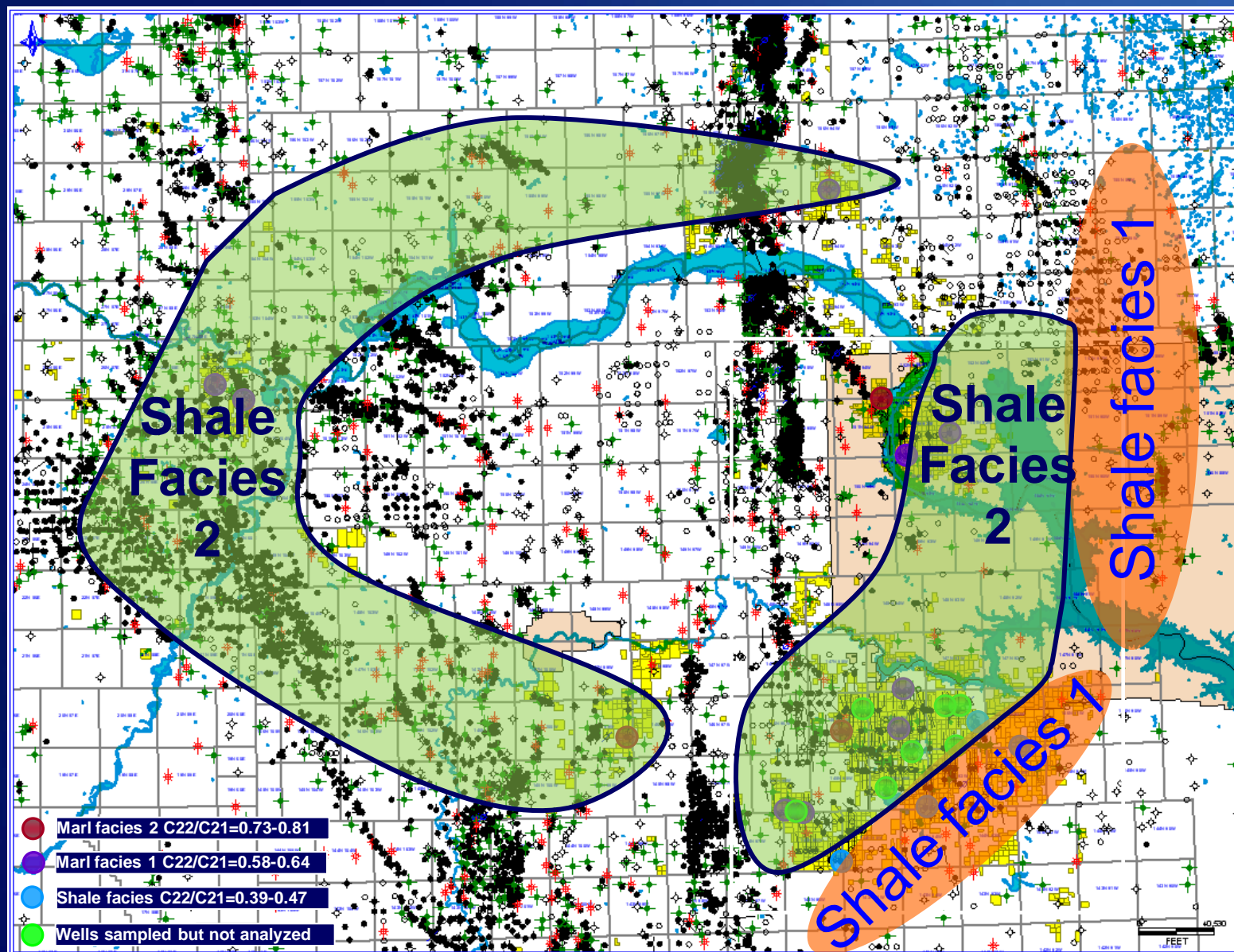
Tricyclic distribution suggests multiple Bakken facies

- Shale facies with low C_{22}/C_{21} and C_{26}/C_{25} ratio
- Shale facies with higher C_{22}/C_{21} and C_{26}/C_{25} ratio



Bakken Oil Family distribution

Oil migration a significant process



Modeling input variables with their influence on modeling results.



Surfaces

- 1) Greenhorn
- 2) Swift
- 3) Spearfish
- 4) Opeche
- 5) Charles-Salt
- 6) Lodgepole
- 7) Bakken
- 8) Three Forks Formation
- 9) basement

Porosity

- Upper and Lower Bakken: 3.6 %
- Middle Bakken: 5%
- Lodgepole: 1.5%

Permeability

- Upper and Lower Bakken: 0.001nD
- Middle Bakken: 1.0nD
- Lodgepole: 0.5nD

Thermal calibration of Williston Basin Model

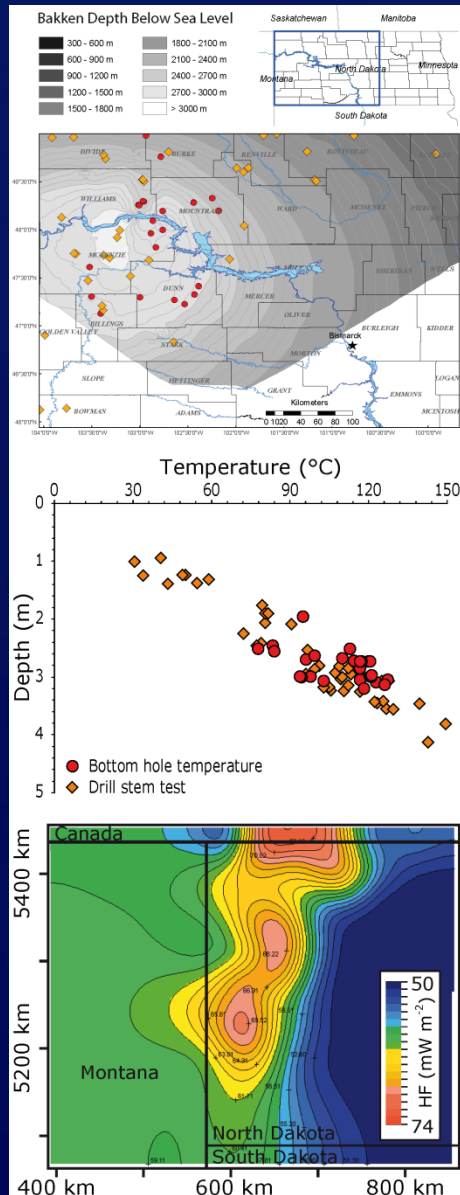


Bottom-hole temperature, Rock Eval Tmax, biomarker maturity parameters

Spatial distribution of wells with bottom-hole temperatures and drill-stem tests

Bottom-hole temperatures and drill-stem test temperatures as a function of depth

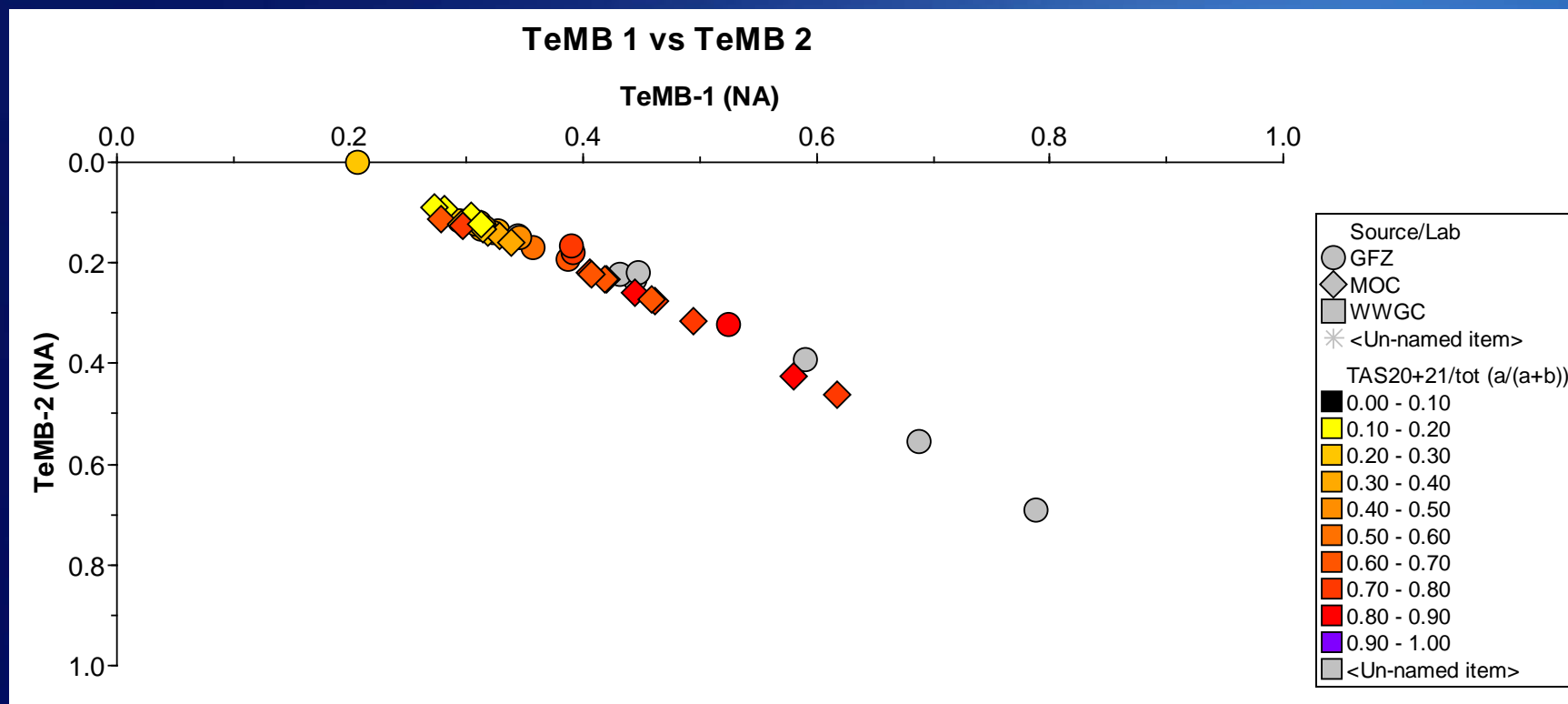
Heat flow map, range of 50 – 74 mW m⁻²



Range of Bakken oil maturities



Early oil window to late oil window oil maturities represented in study and also used in basin modeling calibration effort

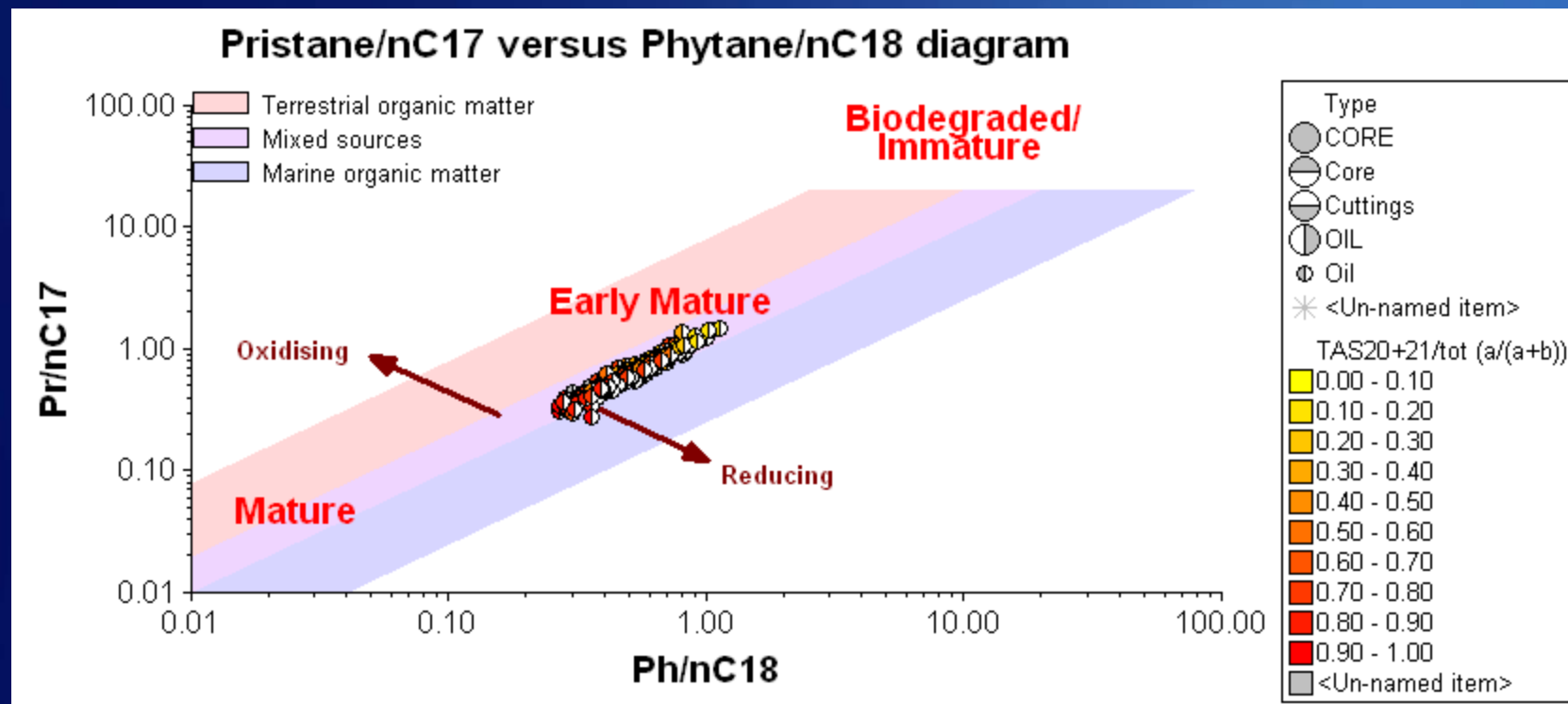


Plot of tetramethylbenzene (TeMB) maturity indicators with triaromatic sterane maturity indicator superimposed via color variation.

Range of Bakken oil maturities

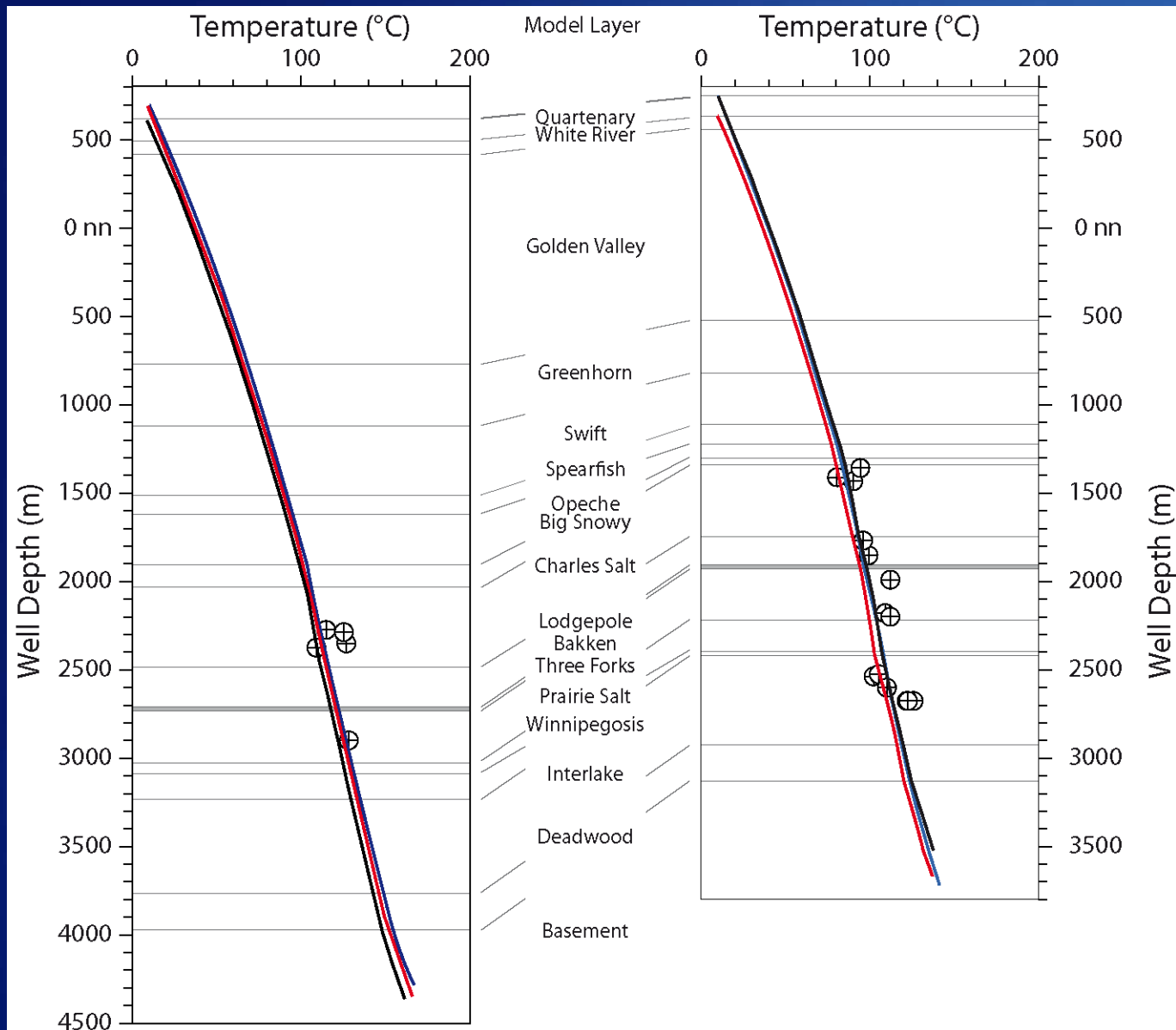


Early oil window to late oil window oil maturities represented in saturated hydrocarbon maturity indicators

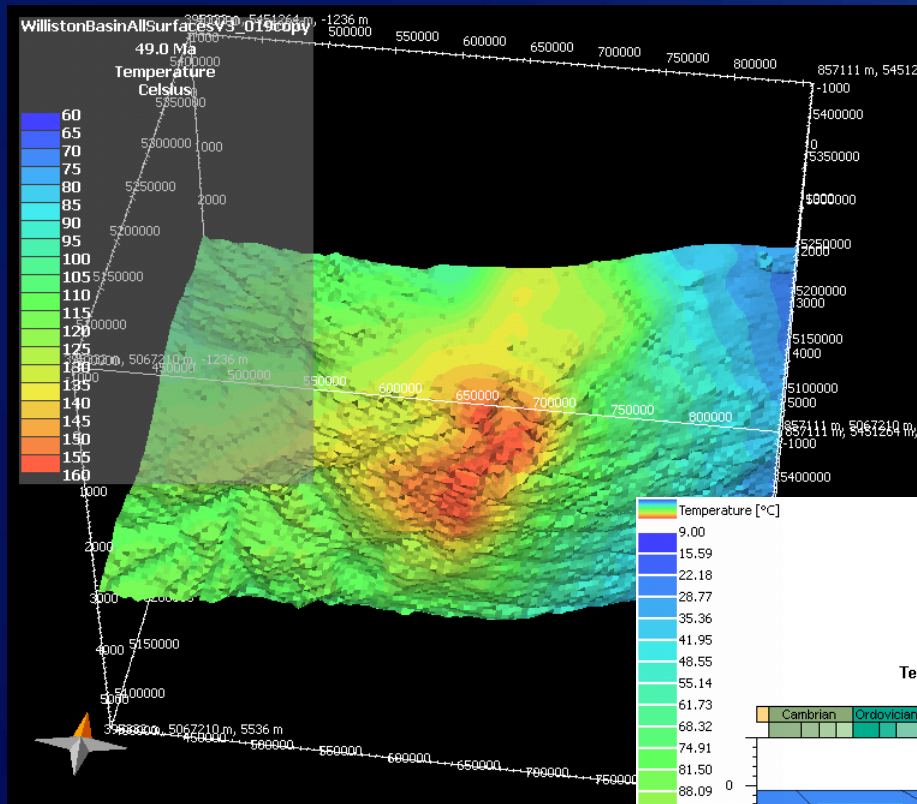


Plot of pristane/n-C₁₇ v. phytane/n-C₁₈ maturity indicators with triaromatic sterane maturity indicator superimposed via color variation.

Model calibration: Temperature



Bakken Basin Model

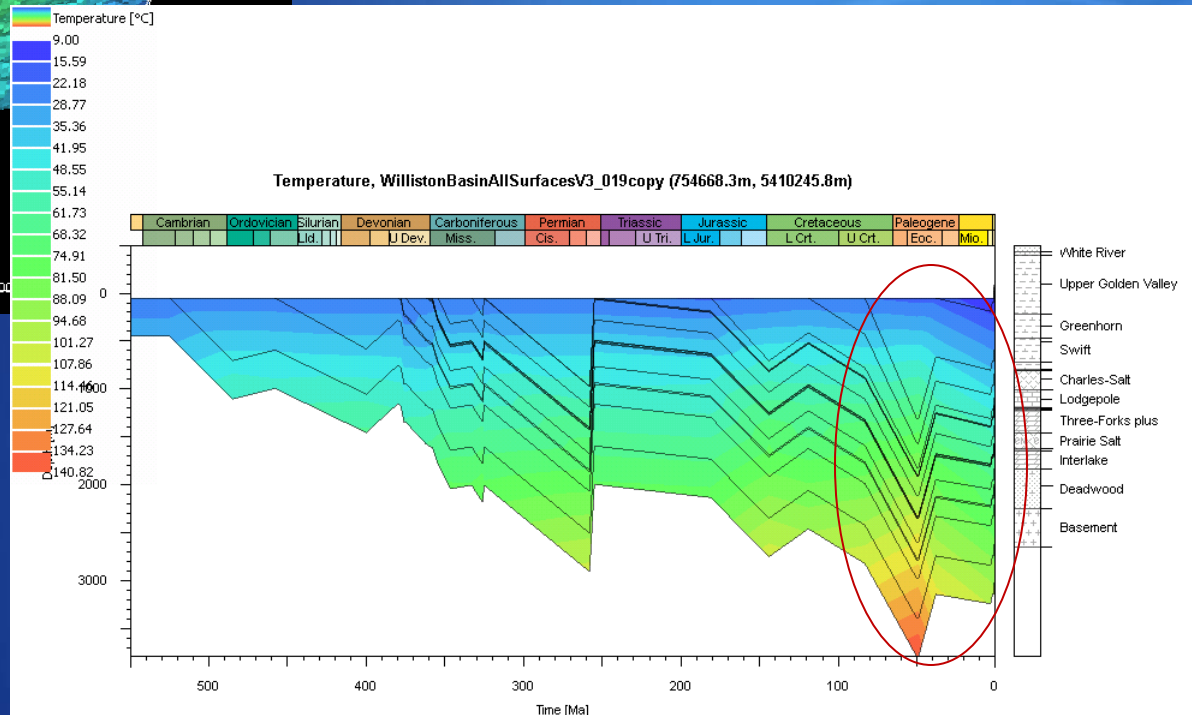


Oil Migration

- From kitchens to basin margin

Bakken Overpressure

- Petroleum Generation
- Uplift (550-700m)

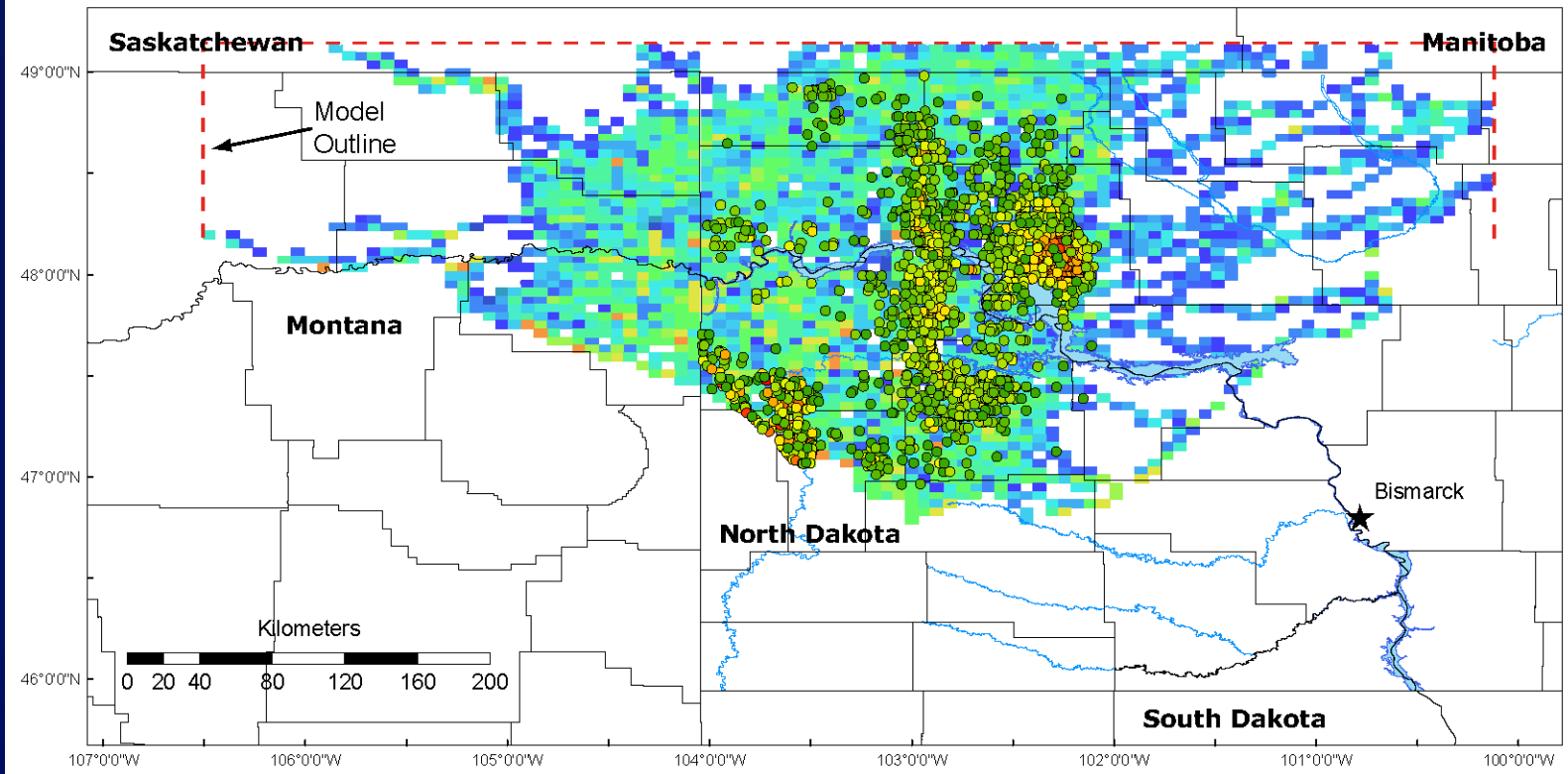
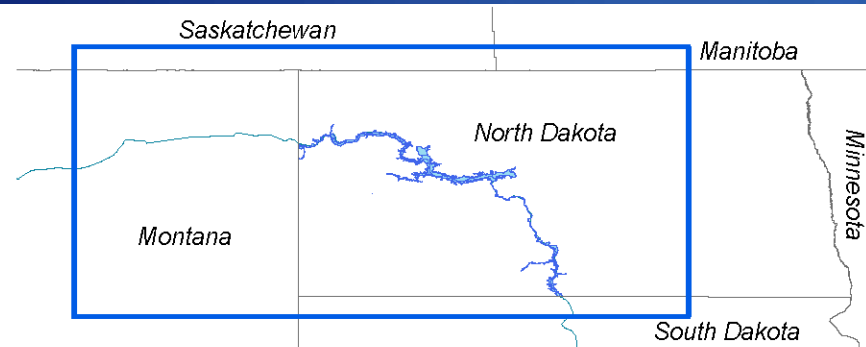
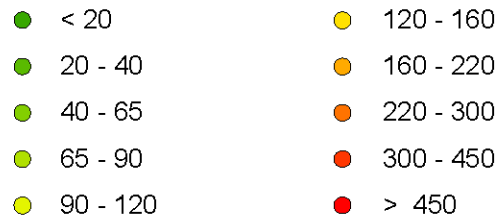


Model simulates known oil accumulations



Bakken Production per Well

Cum. sum in 1000 bbl (October 2010)



Summary and Future work



- ♦ Oil geochemistry demonstrates different facies (shale and shale/marl) of Bakken contributing to petroleum system.
- ♦ Migration in the Bakken system is a significant process as interpreted from oil data.
- ♦ Modeling supports presence of thermal anomaly in area of Nesson anticline.
- ♦ The Bakken petroleum system is conventional; the reservoir is the challenge.