

Anadarko Woodford Shale: How to Tie a Shoe*

Craig Caldwell¹

Search and Discovery Article #80408 (2014)**

Posted October 6, 2014

*Adapted from oral presentation given at AAPG Education Directorate Woodford Shale Forum, Oklahoma City, Oklahoma, May 29, 2014. Please refer to other articles on the Woodford by the author: Search and Discovery [Article #50518 \(2011\)](#), [Article #10425 \(2012\)](#), and [Article #80288 \(2013\)](#).

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Description of Presentation

A discussion of the Cana Woodford rock types and regional mechanical/lithostratigraphy and their effects on completion design and production.....What have we learned?

Outline

- Introduction
- Regional lithostratigraphy and depositional geometries of the Woodford- Cana area
- Lateral placement and lithostratigraphy
- Regional variations in clay content and porosity

Key Question

Is there a relationship between Woodford rock types, stratigraphy, completion design, and production?

Conclusions

- Changes in depositional patterns demonstrated by isopach maps of the Basal, Lower, Middle and Upper Woodford may be related to the Canadian Flexure.
- Quartz-rich mudrocks and clay-rich mudrocks have distinctively different mechanical properties. Frac stages in clay-rich mudrocks commonly treat at higher pressures, and proppant placement can be challenging.
- Embedment studies demonstrate lower fracture conductivity in more clay-rich lithologies compared to those observed in more silica-rich rock.

- An important part of any Woodford completion program should be a discussion of lateral placement....which can affect productivity.
- Regional variations in clay content (brittleness) and porosity are among the variables that appear to affect Woodford productivity.

References Cited

Johnson, K.S., R.A. Northcutt, and G.C. Hinshaw, 2000, Petroleum production from marine clastics in Oklahoma, *in* K.S. Johnson, ed., Marine Clastics in Southern Midcontinent, 1997 symposium: Oklahoma Geological Survey Circular 103, p. 1-17.

Kvale, E., and J. Bynum, 2014, Regional upwelling during Late Devonian Woodford deposition in Oklahoma and Its Influence on hydrocarbon production and well completion (abstract): Woodford Shale Forum, Program Booklet, Oklahoma City, May 29, 2014, p. 8-10.

Rottman, K., 2000, Defining the role of Woodford-Hunton Depositional relationships in Hunton stratigraphic traps of western Oklahoma, *in* K.S. Johnson, ed., Platform Carbonates of the Southern Midcontinent: Oklahoma Geological Survey Circular 101, p. 139-146.

Sondergeld, C.H., R.J. Ambrose, C.S. Rai, and J. Moncrieff, 2010, Micro-Structural Studies of Gas Shales: SPE Paper 131771, SPE Unconventional Gas Conference, Pittsburgh, Pennsylvania, 17 p.

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AAPG Woodford Shale Forum
May 29, 2014 Oklahoma City, OK





ACKNOWLEDGEMENTS

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Devon Energy Corp.

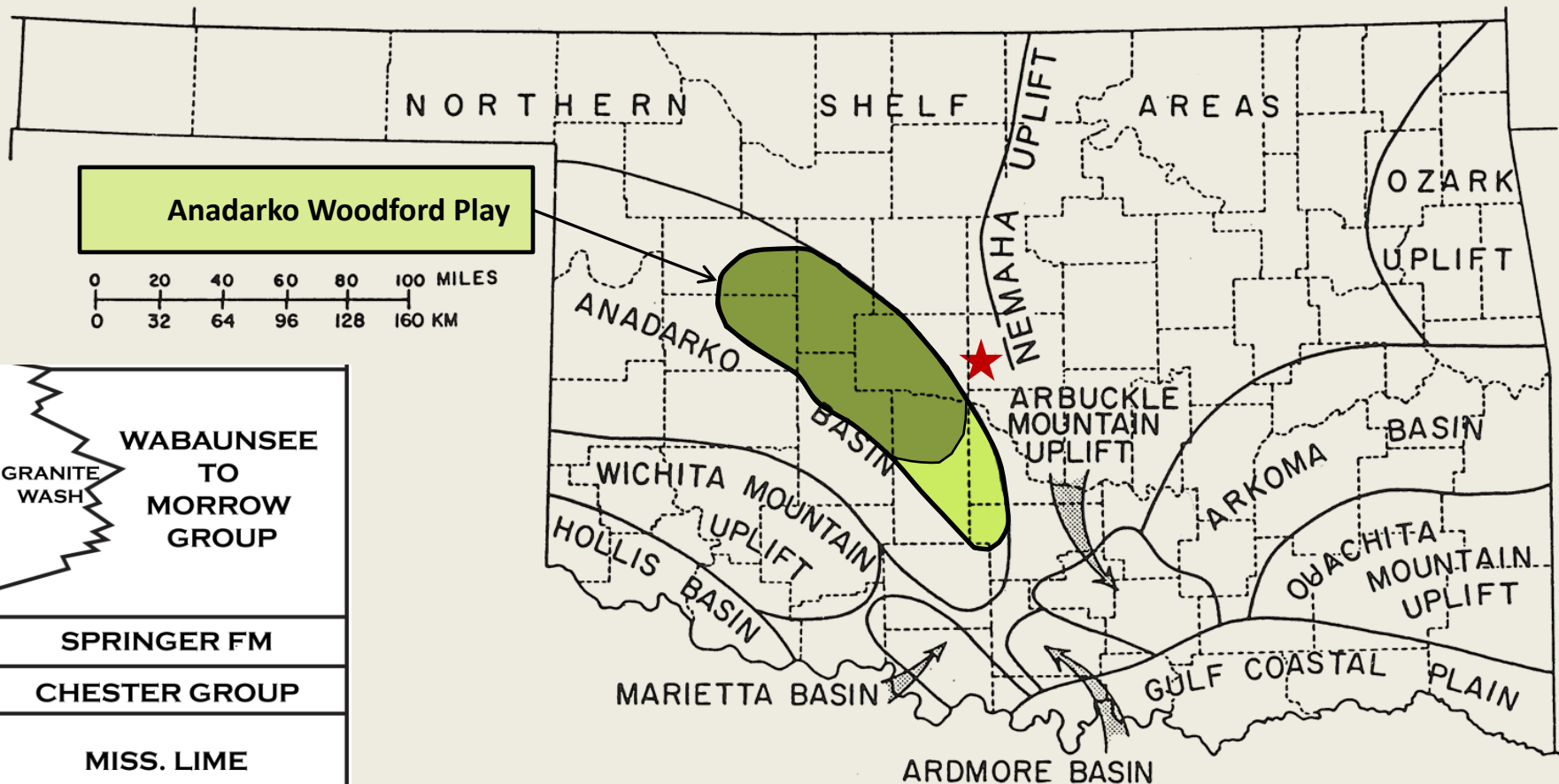
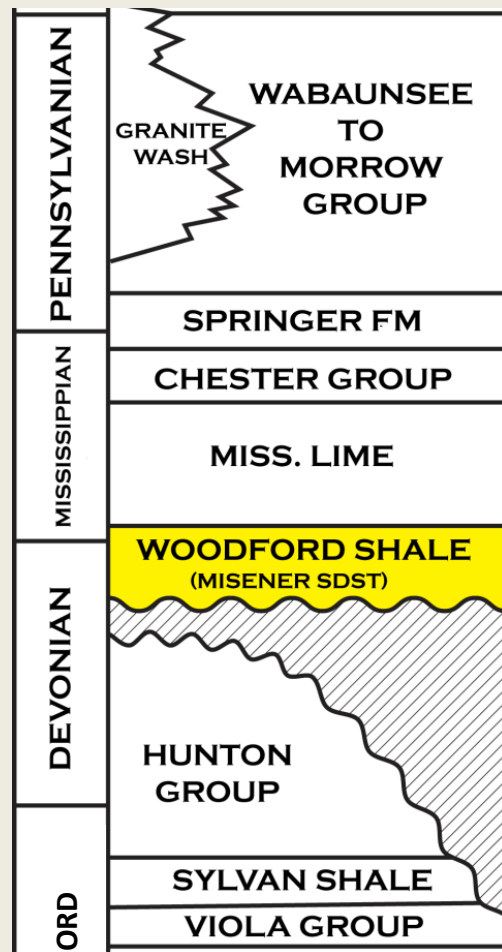
Terra Tek Inc.

&

Weatherford

- 
- **Introduction**
 - **Regional Lithostratigraphy and Depositional Geometries of the Woodford- Cana Area**
 - **Lateral Placement and Lithostratigraphy**
 - **Regional variations in clay content and porosity**

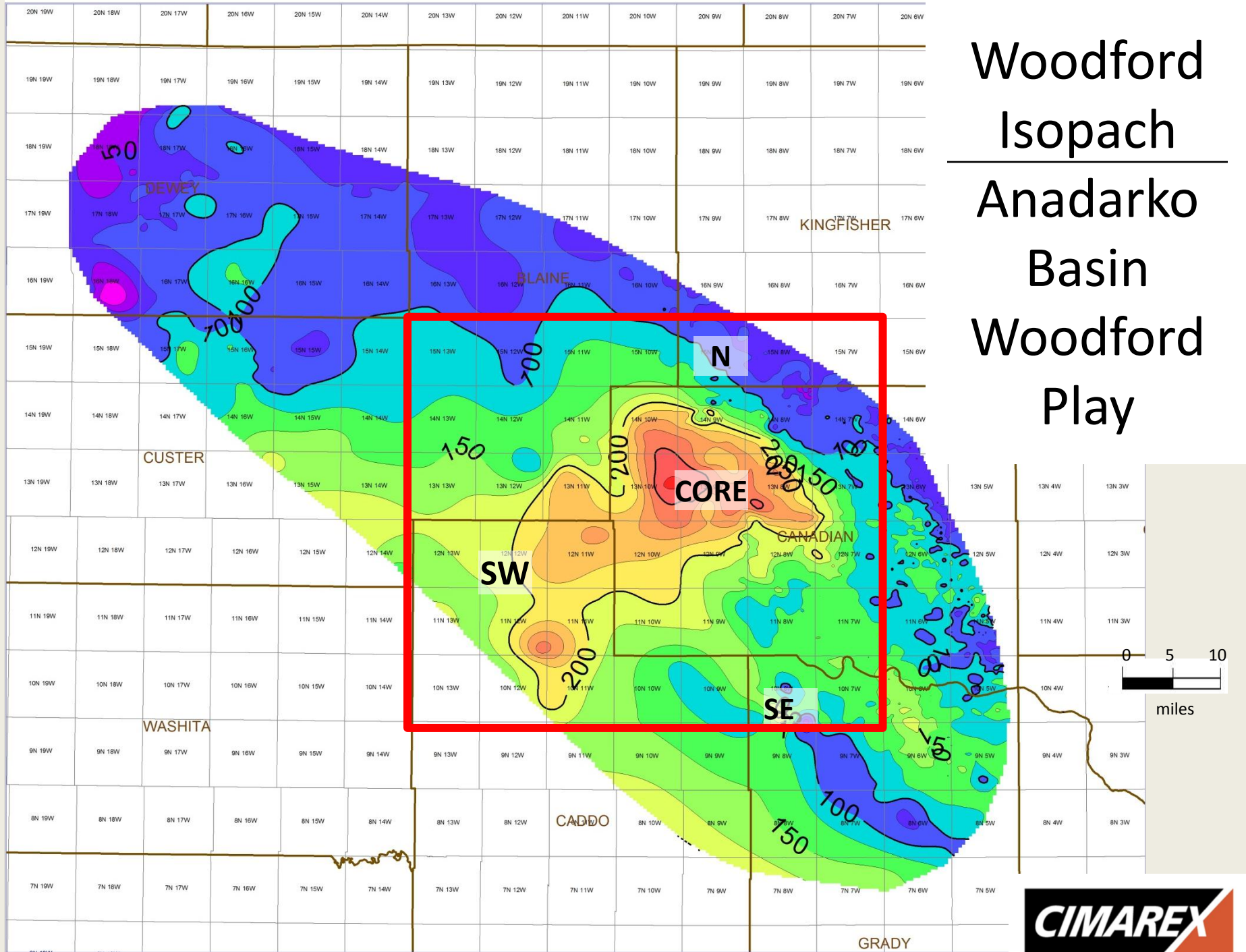
Is there a relationship between Woodford rock types, stratigraphy, completion design, and production?



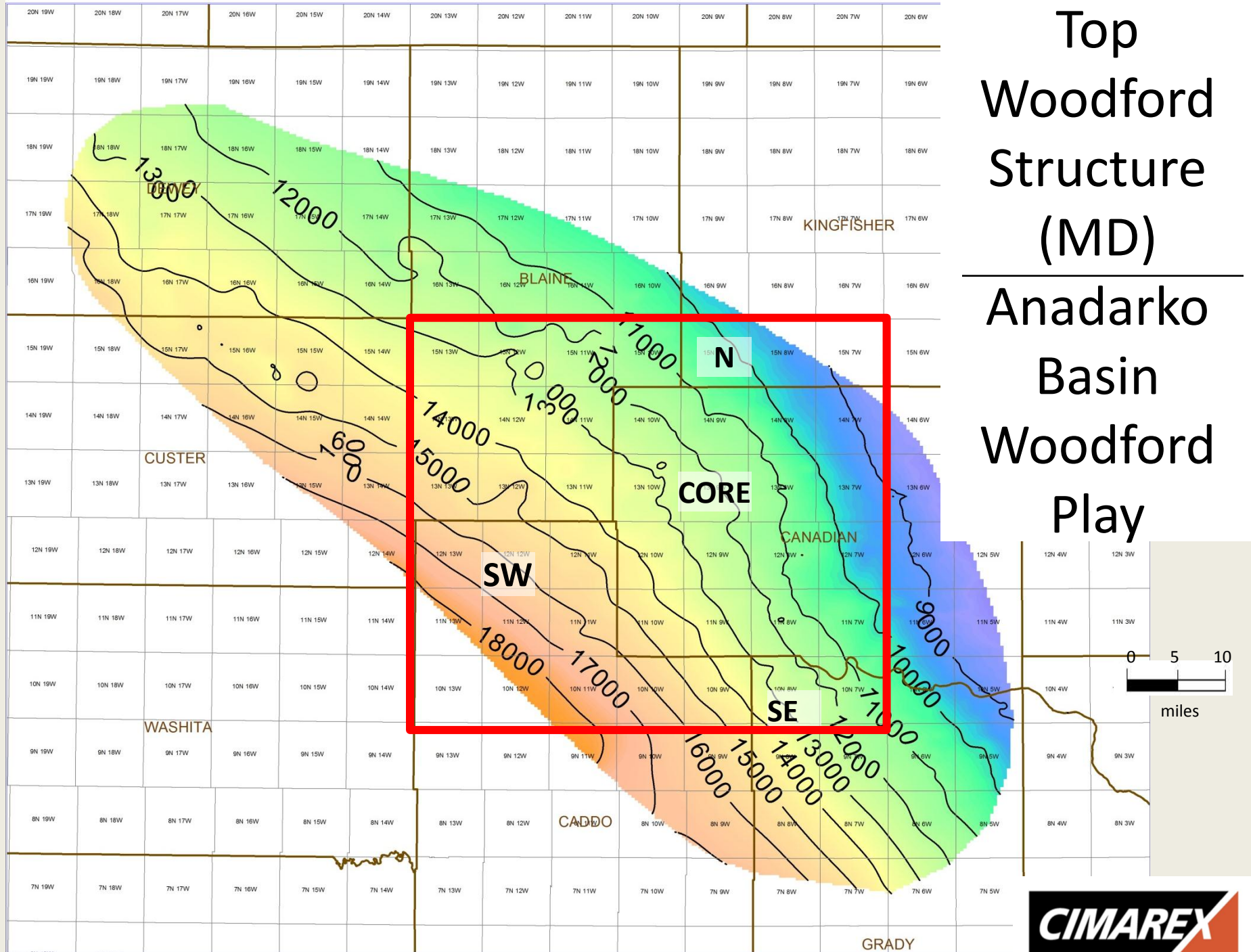
STRAT COLUMN AND MAJOR GEOLOGIC PROVINCES OF OKLAHOMA

*After Johnson et al (2000)

Woodford Isopach Anadarko Basin Woodford Play



Top Woodford Structure (MD) Anadarko Basin Woodford Play



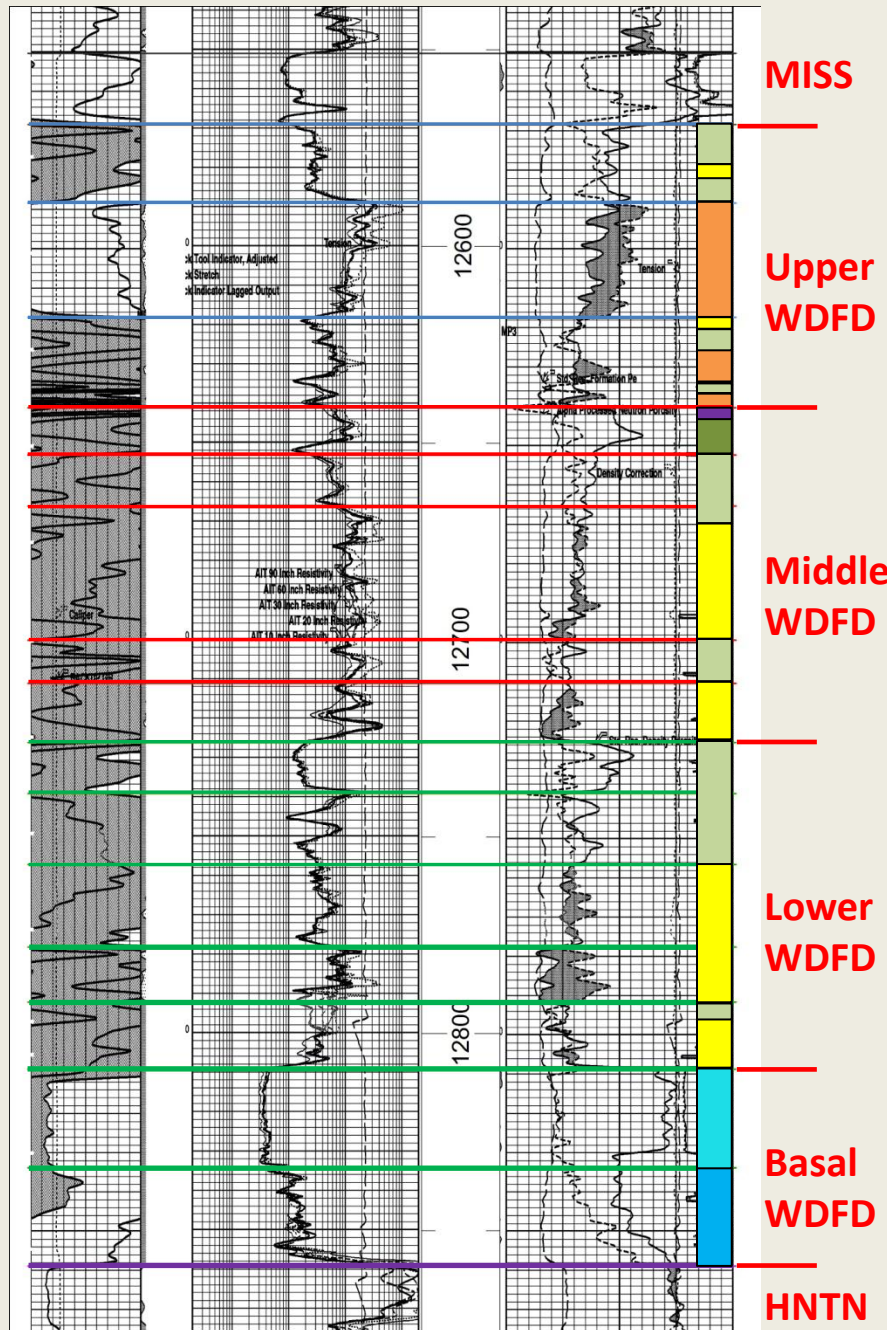
Woodford Lithostratigraphy Anadarko Basin Woodford Play Core Area

Siliceous
mudrock

Clayey,
siliceous
mudrock

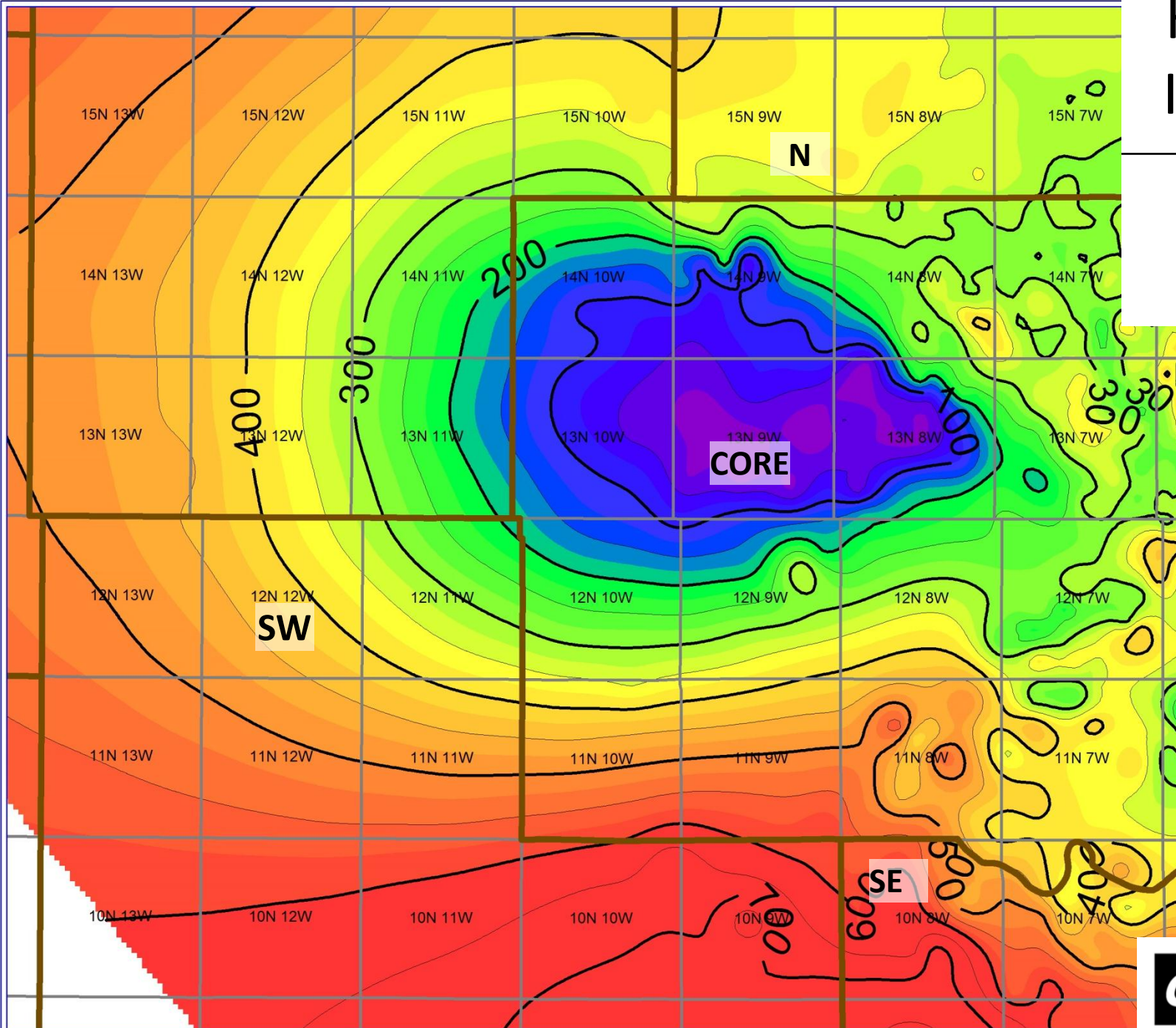
Clayey
mudrock

Organic-
poor
clayey
mudrock



Hunton Isopach (in feet)

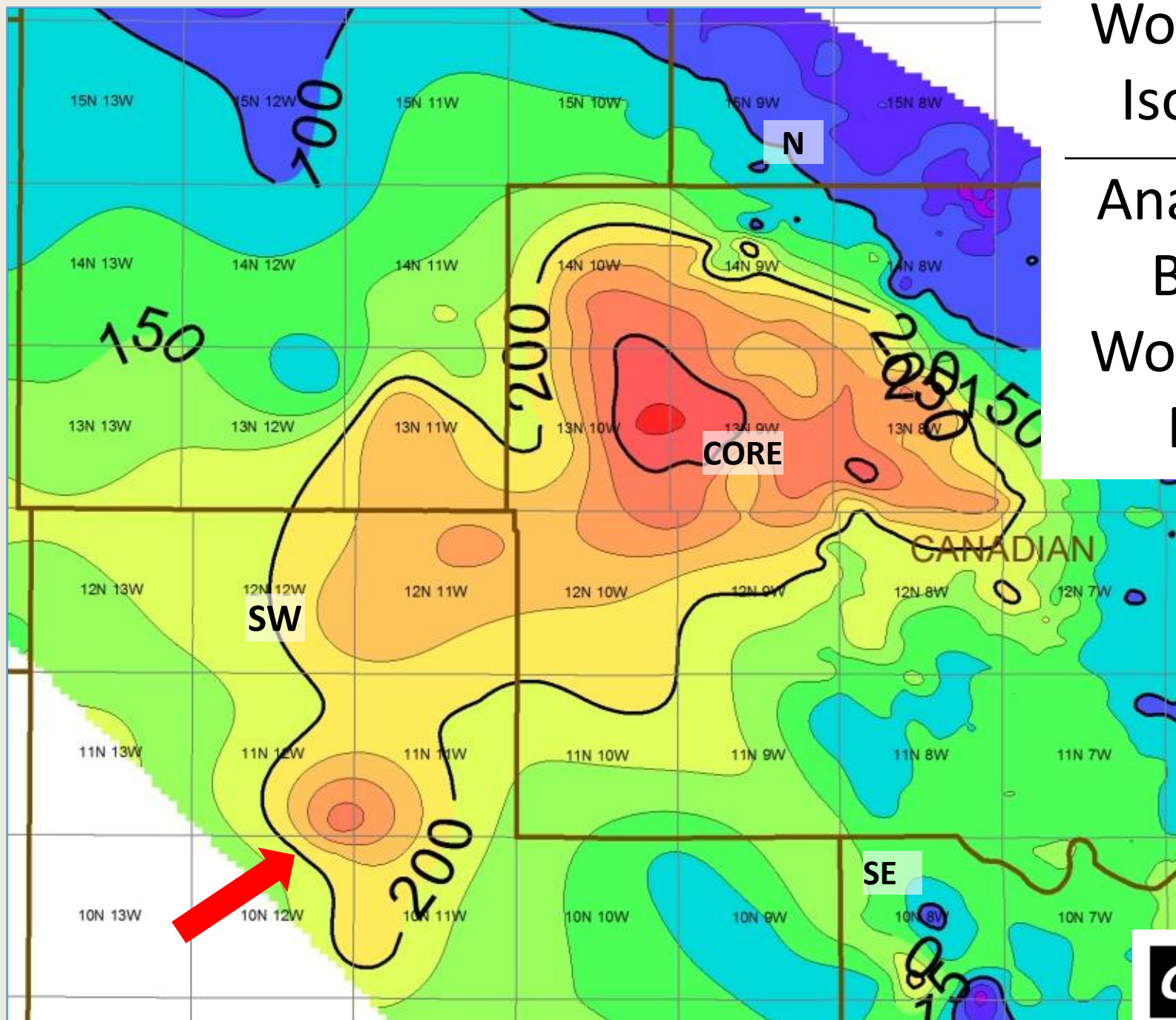
Cana Area



Woodford Isopach

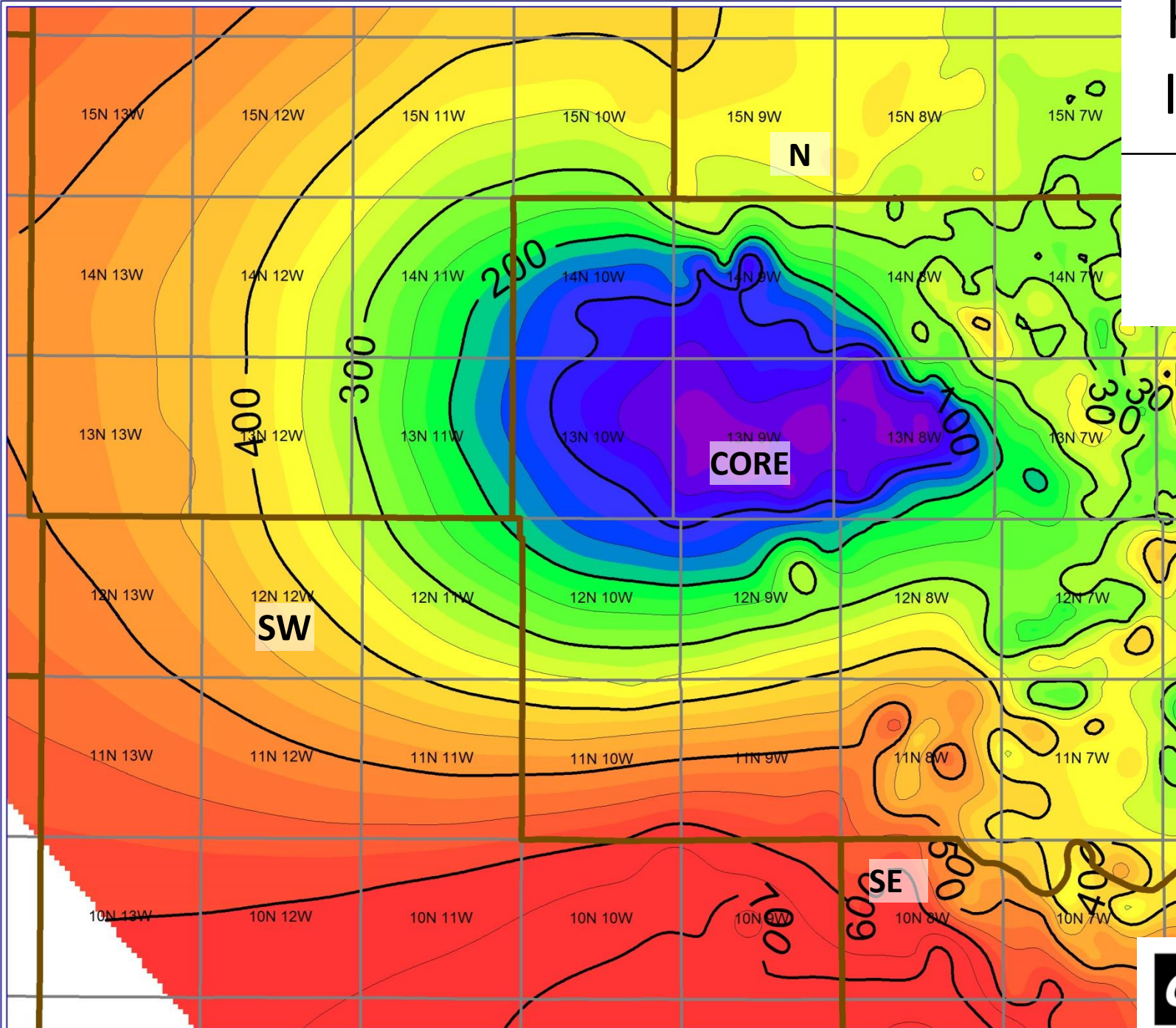
(in feet)

Anadarko Basin Woodford Play



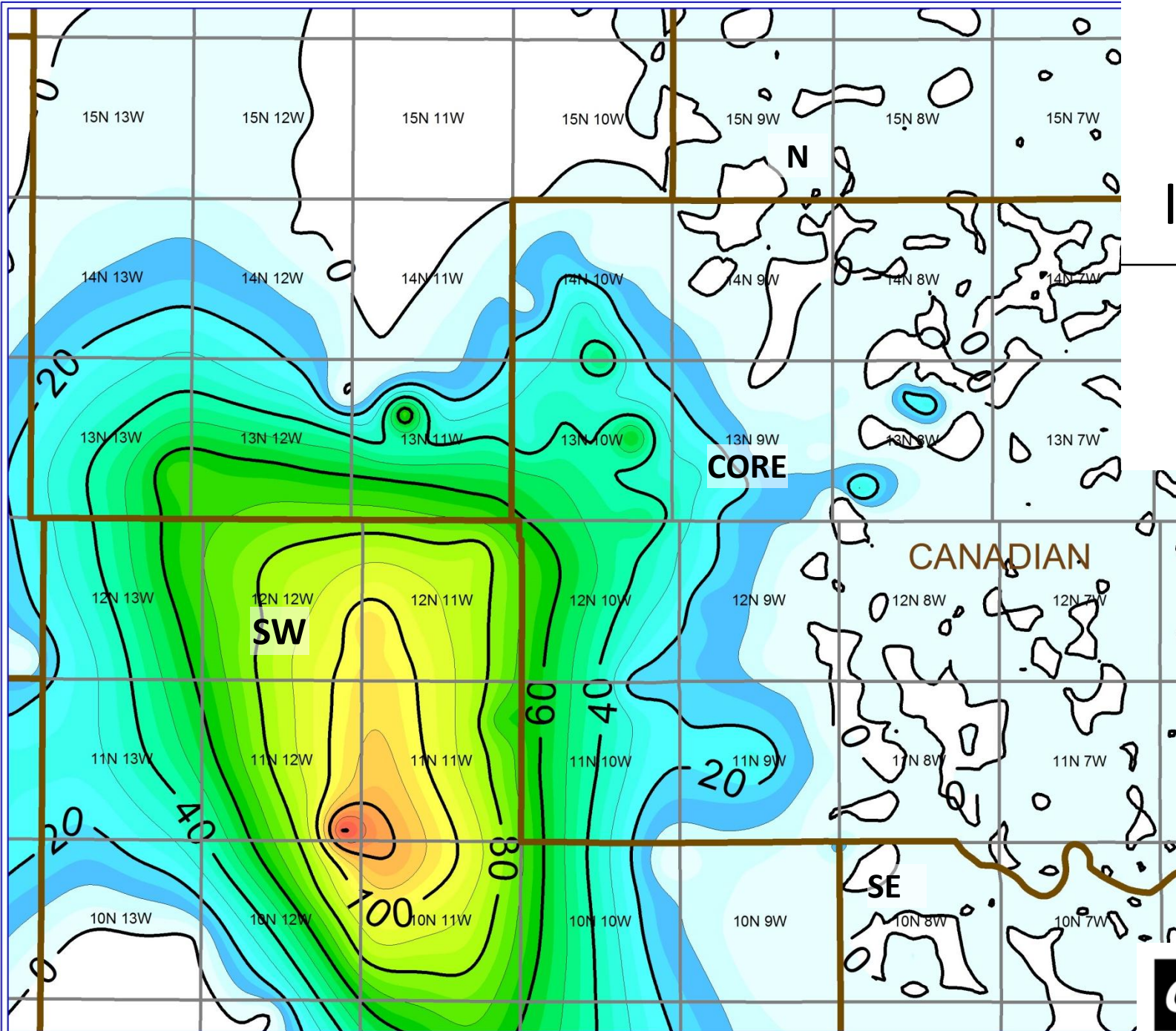
Hunton Isopach (in feet)

Cana Area



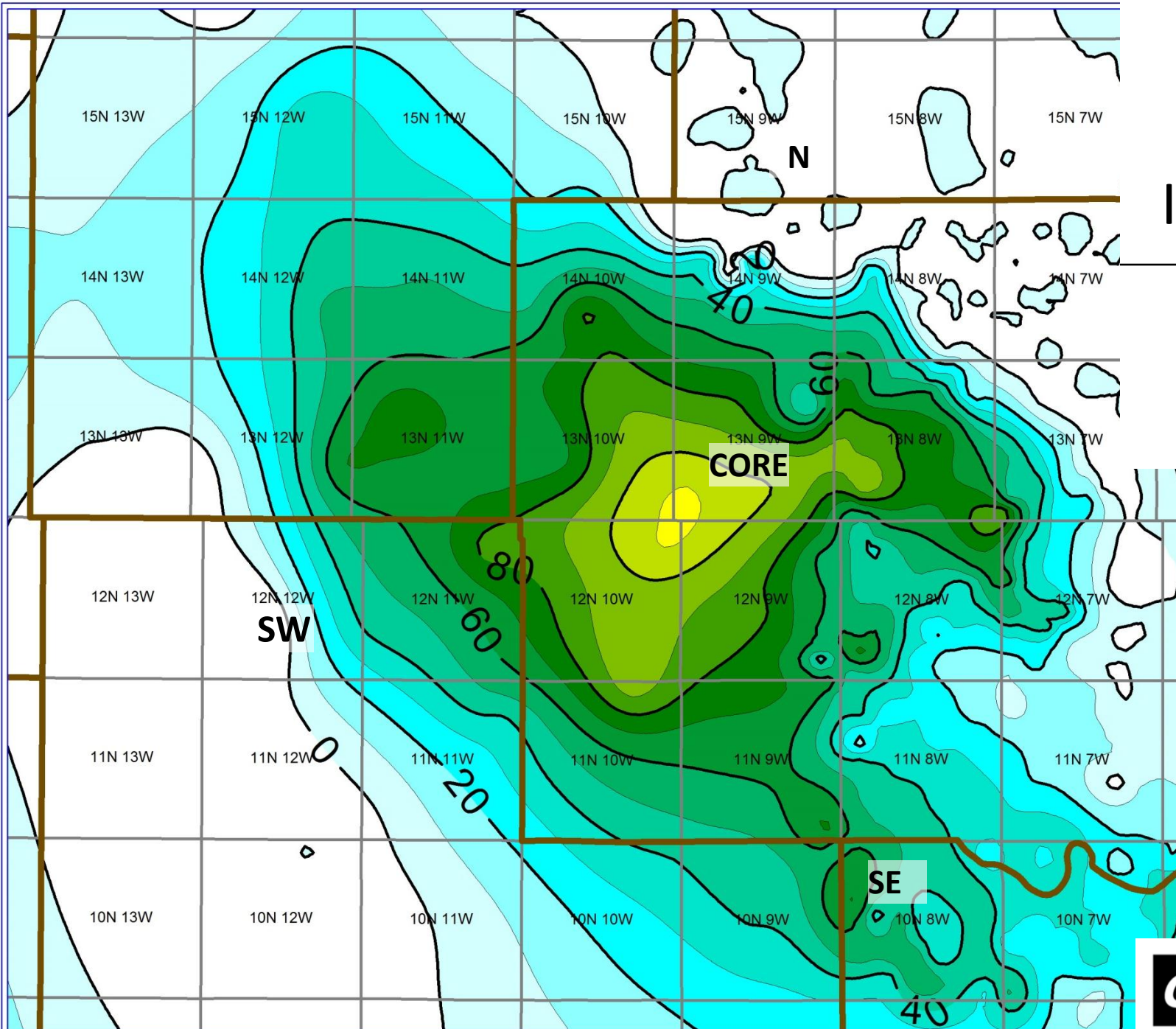
Basal WDFD Isopach (in feet)

Cana Area



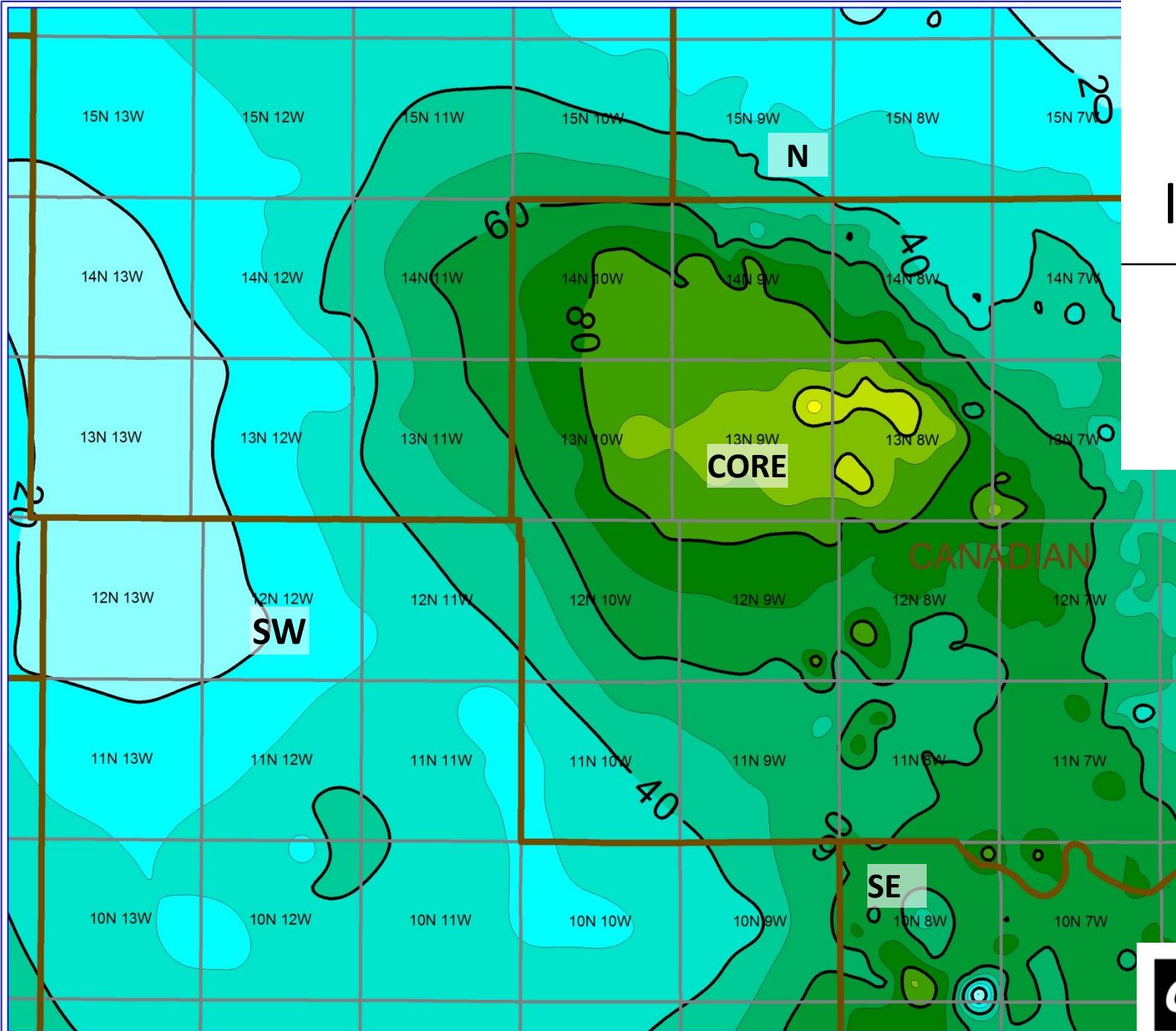
Lower WDFD Isopach (in feet)

Cana Area



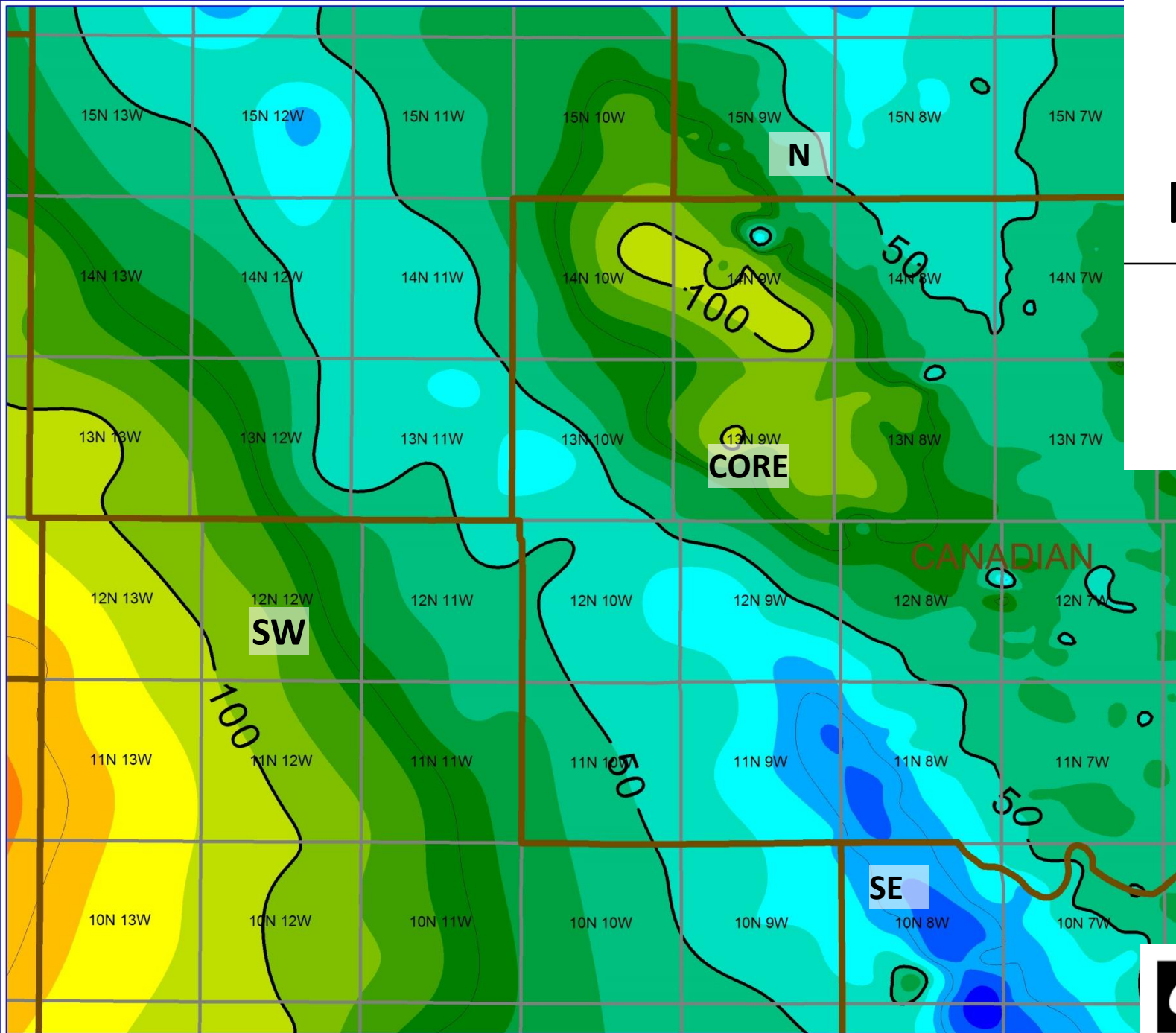
Middle WDFD Isopach (in feet)

Cana Area



Upper WDFD Isopach (in feet)

Cana Area

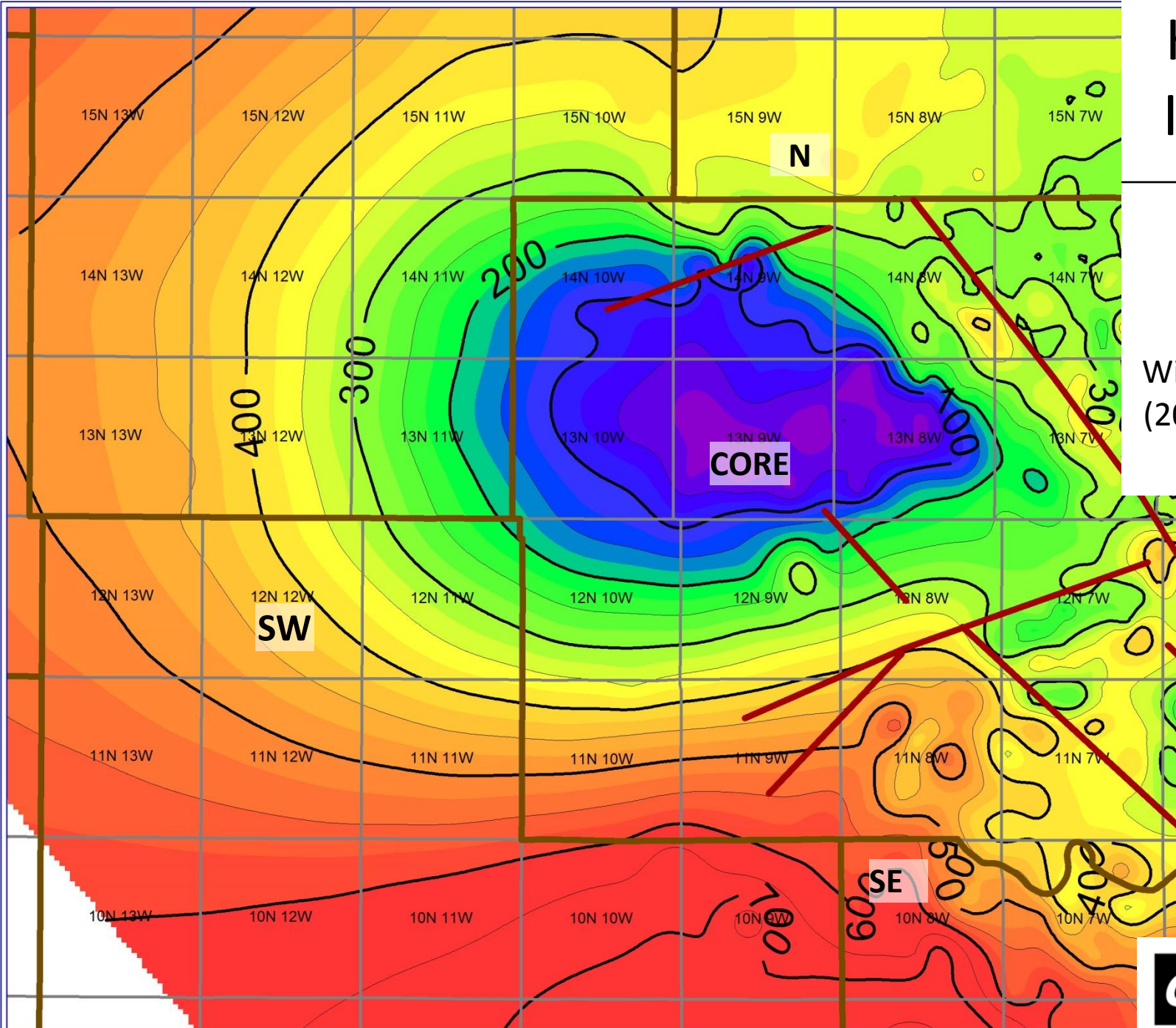


Hunton Isopach

(in feet)

Cana Area

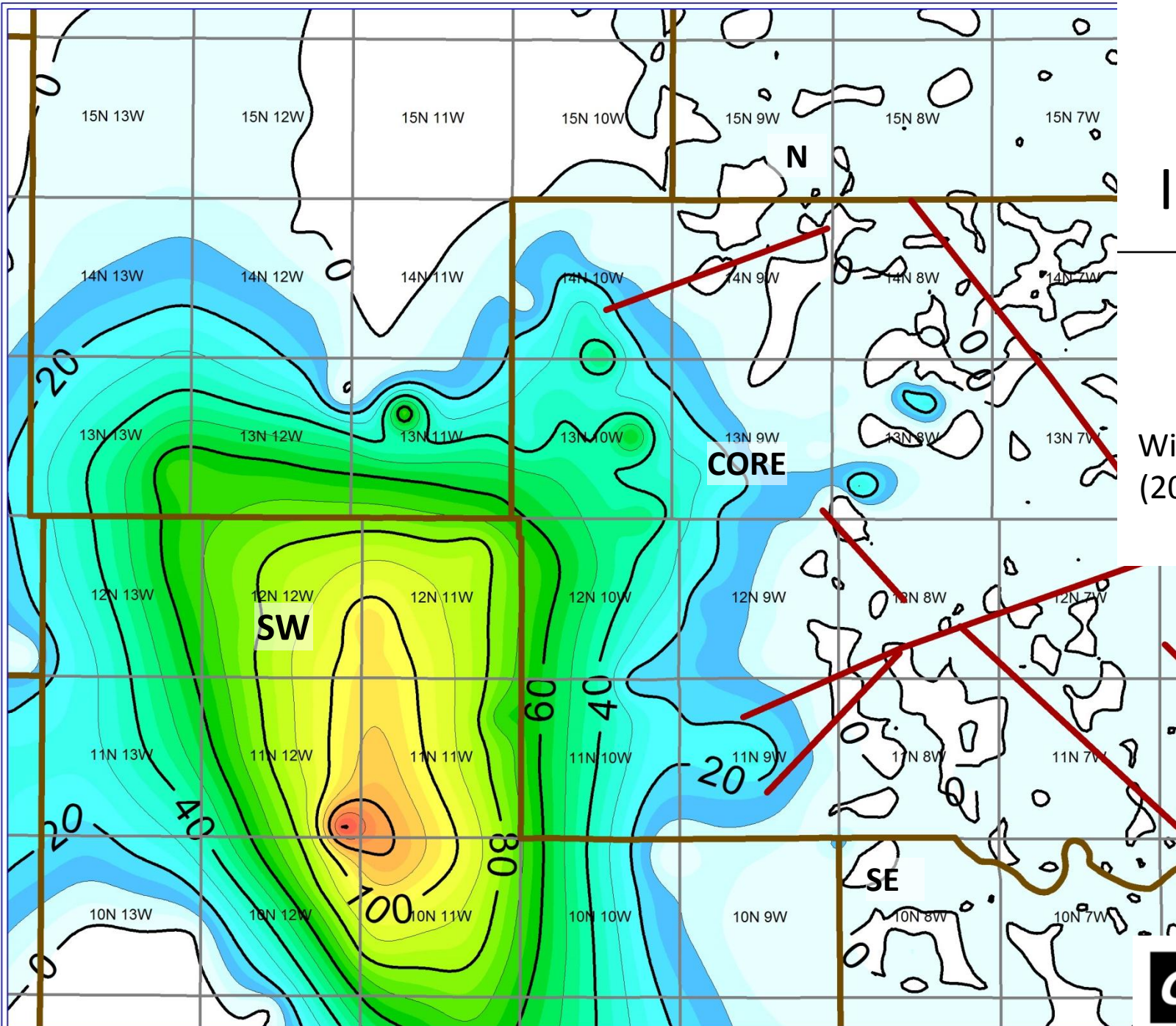
With K. Rottman
(2000) Canadian
Flexure



Basal WDFD Isopach (in feet)

Cana Area

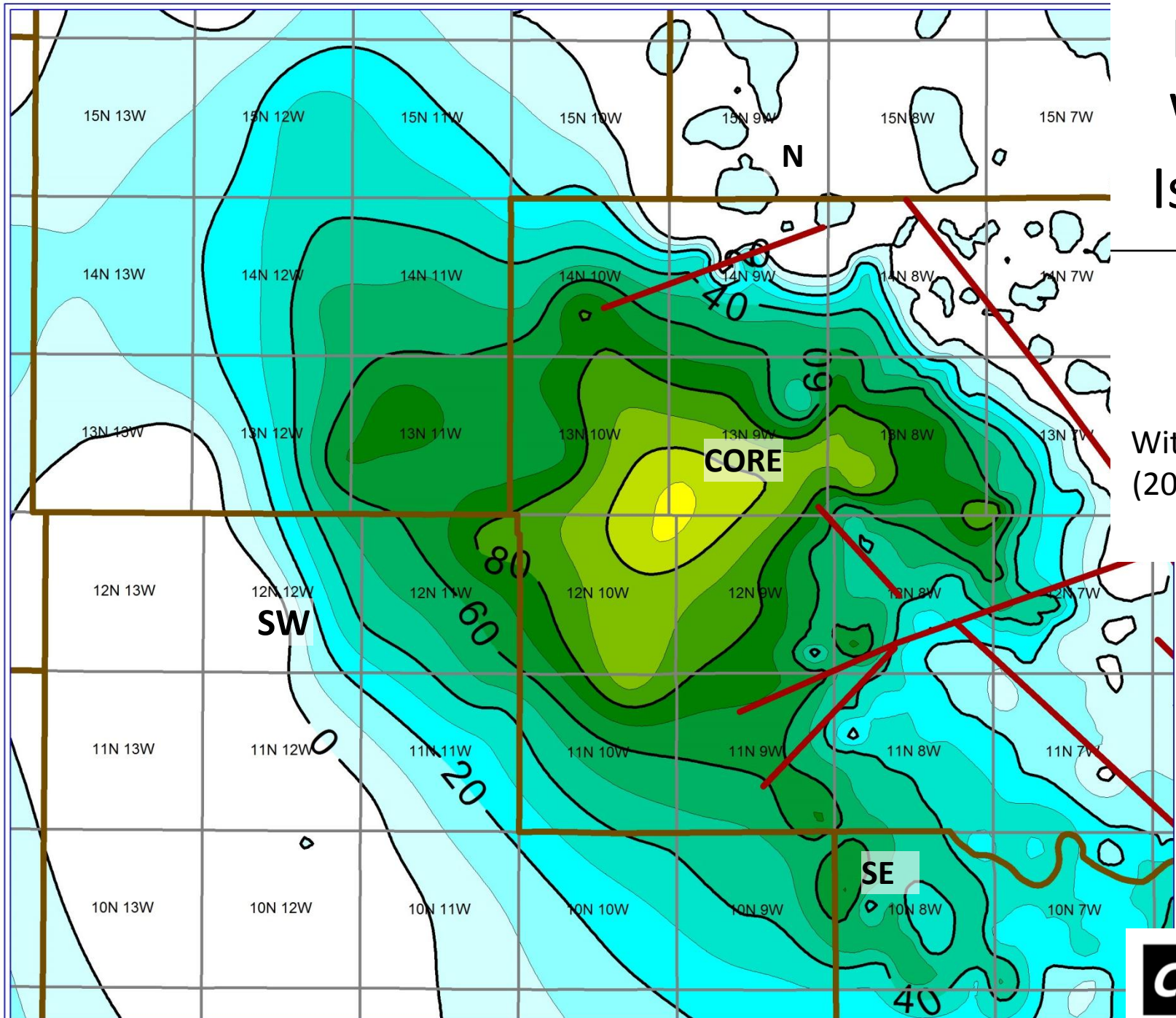
With K. Rottman
(2000) Canadian
Flexure



Lower WDFD Isopach (in feet)

Cana Area

With K. Rottman
(2000) Canadian
Flexure

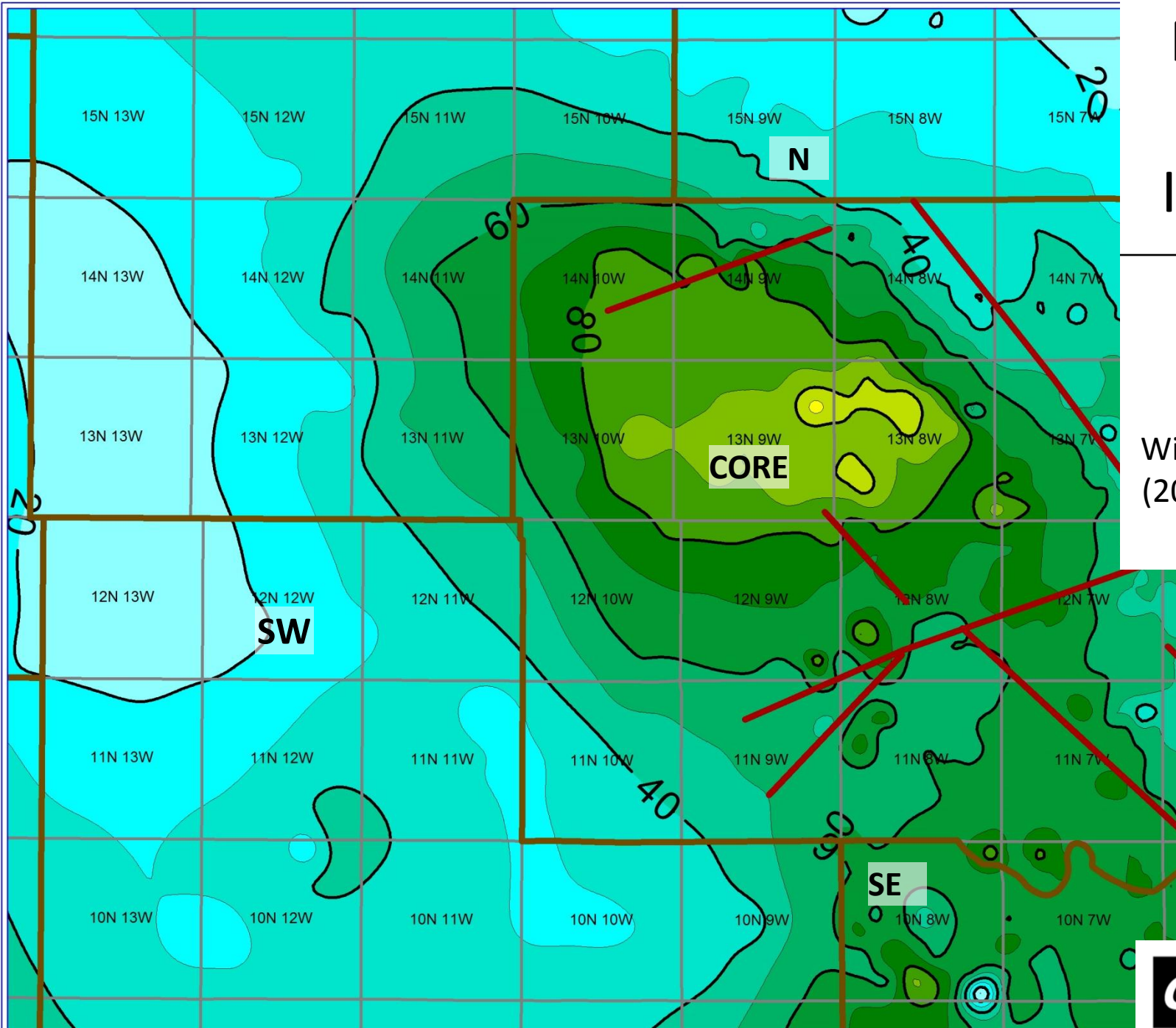


Middle WDFD Isopach

(in feet)

Cana Area

With K. Rottman
(2000) Canadian
Flexure



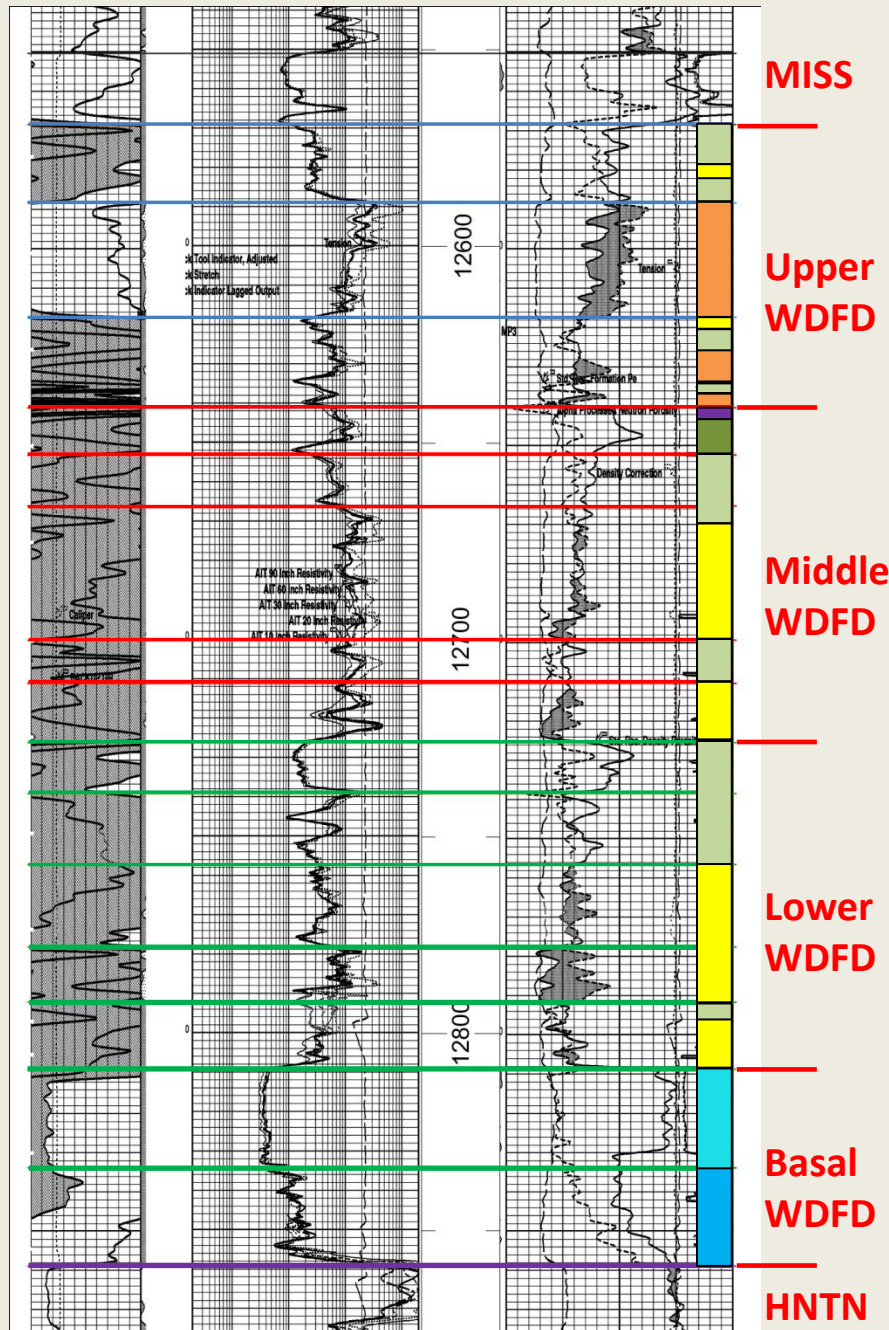
Woodford Lithostratigraphy Anadarko Basin Woodford Play Core Area

Siliceous
mudrock

Clayey,
siliceous
mudrock

Clayey
mudrock

Organic-
poor
clayey
mudrock



WDFD Thk. 290'



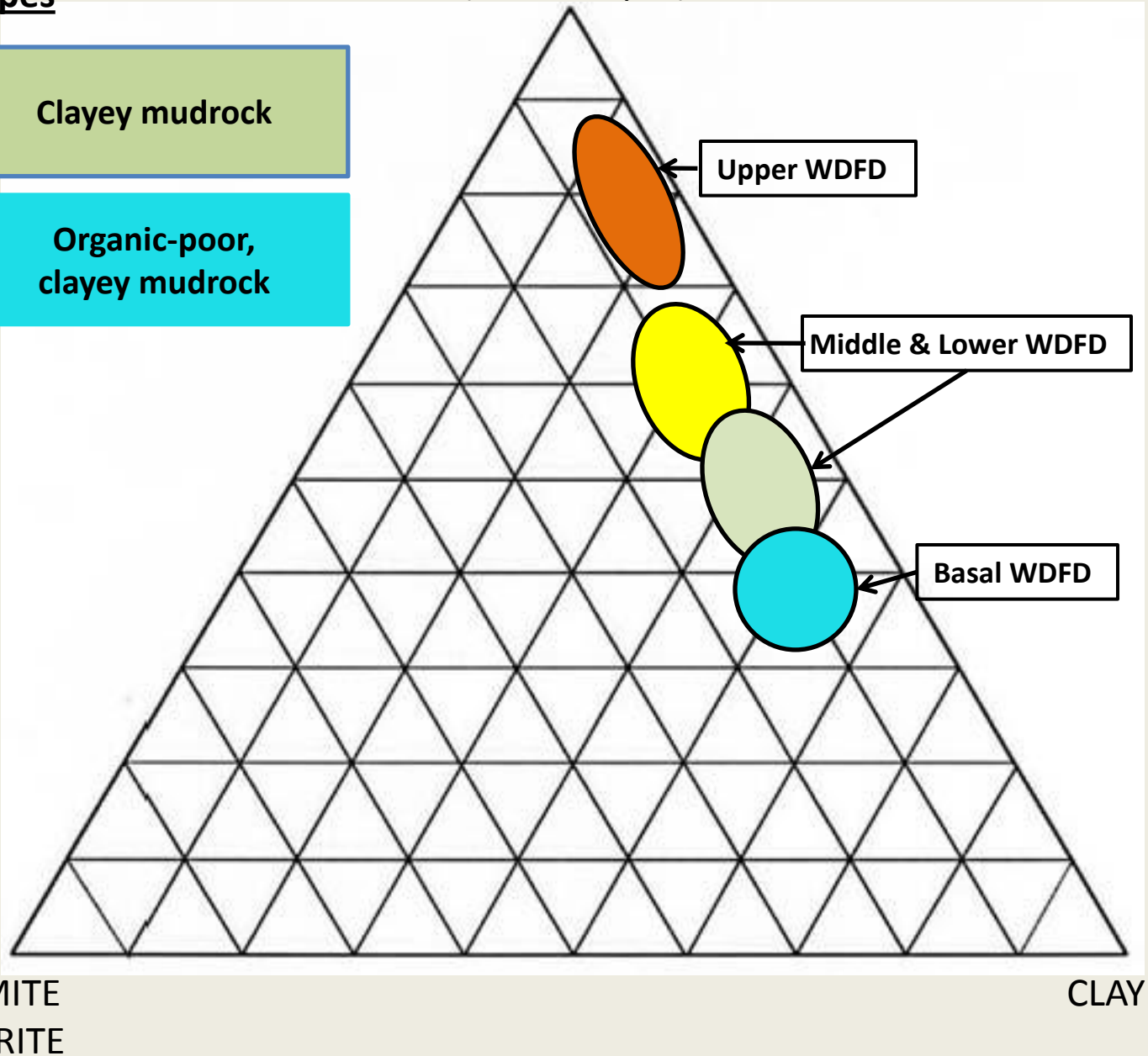
Anadarko Woodford Mineralogy (XRD)
and Rock Types

Siliceous mudrock

Clayey mudrock

**Clayey, siliceous
mudrock**

**Organic-poor,
clayey mudrock**



Woodford Rock Types

Anadarko Basin Woodford Play

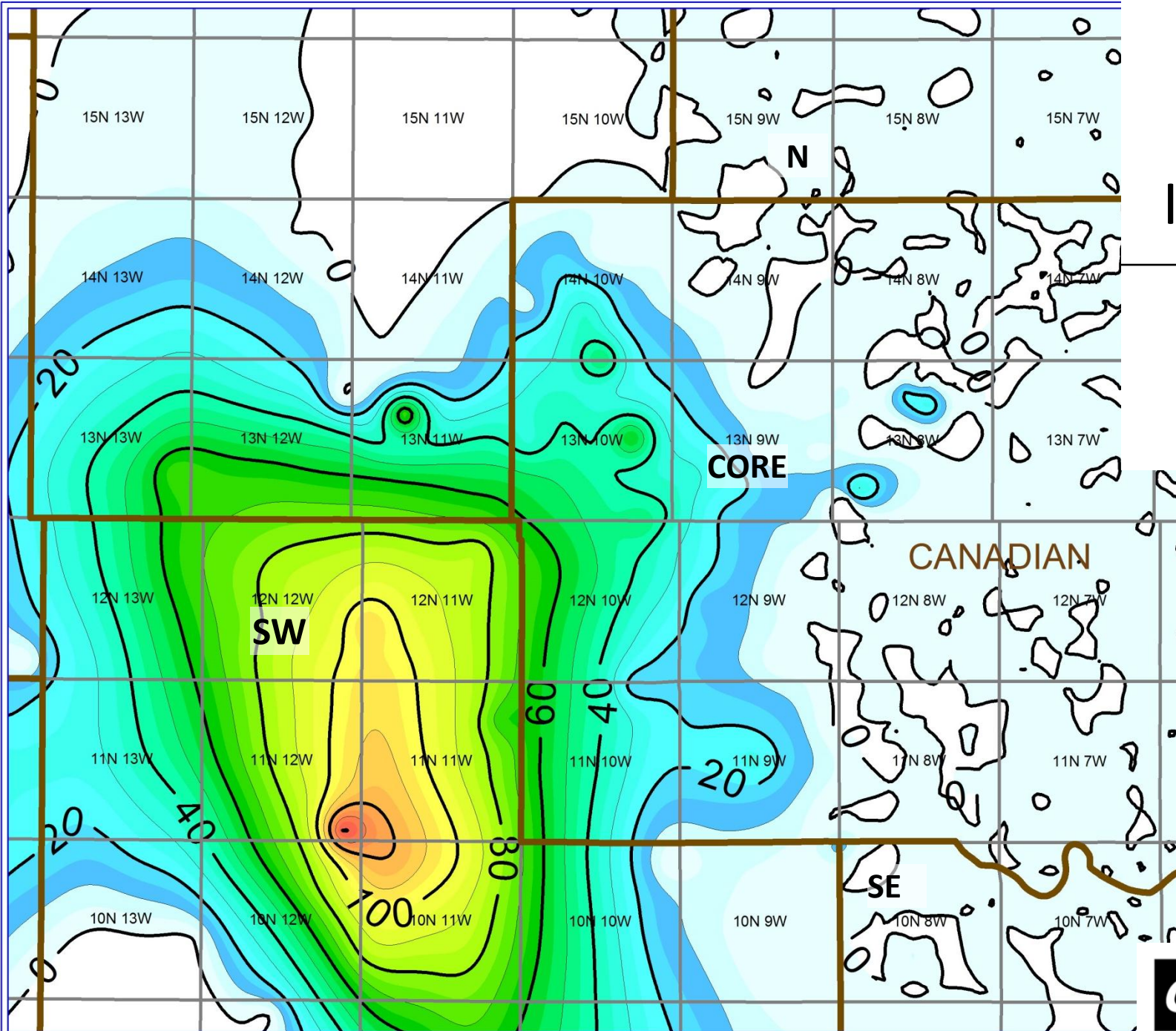
ROCK TYPE	% QUARTZ	% CLAY	% TOC	% GAS-FILLED POROSITY	PR _v	Brittleness Index*
Siliceous mudrock	75.2	14.5	4.86	5.4	0.155	0.75
Clayey, siliceous mudrock	54.8	27.4	6.43	6.8	0.164	0.55
Clayey mudrock	40.6	38	5.97	5.6	0.192	0.41
Organic-poor, clayey mudrock	27.3	52.4	0.6	1.8	0.25	0.27

*B.I.=Quartz/Qtz+Carbonates+Clay

(Sondergeld et. al., 2010)

Basal WDFD Isopach (in feet)

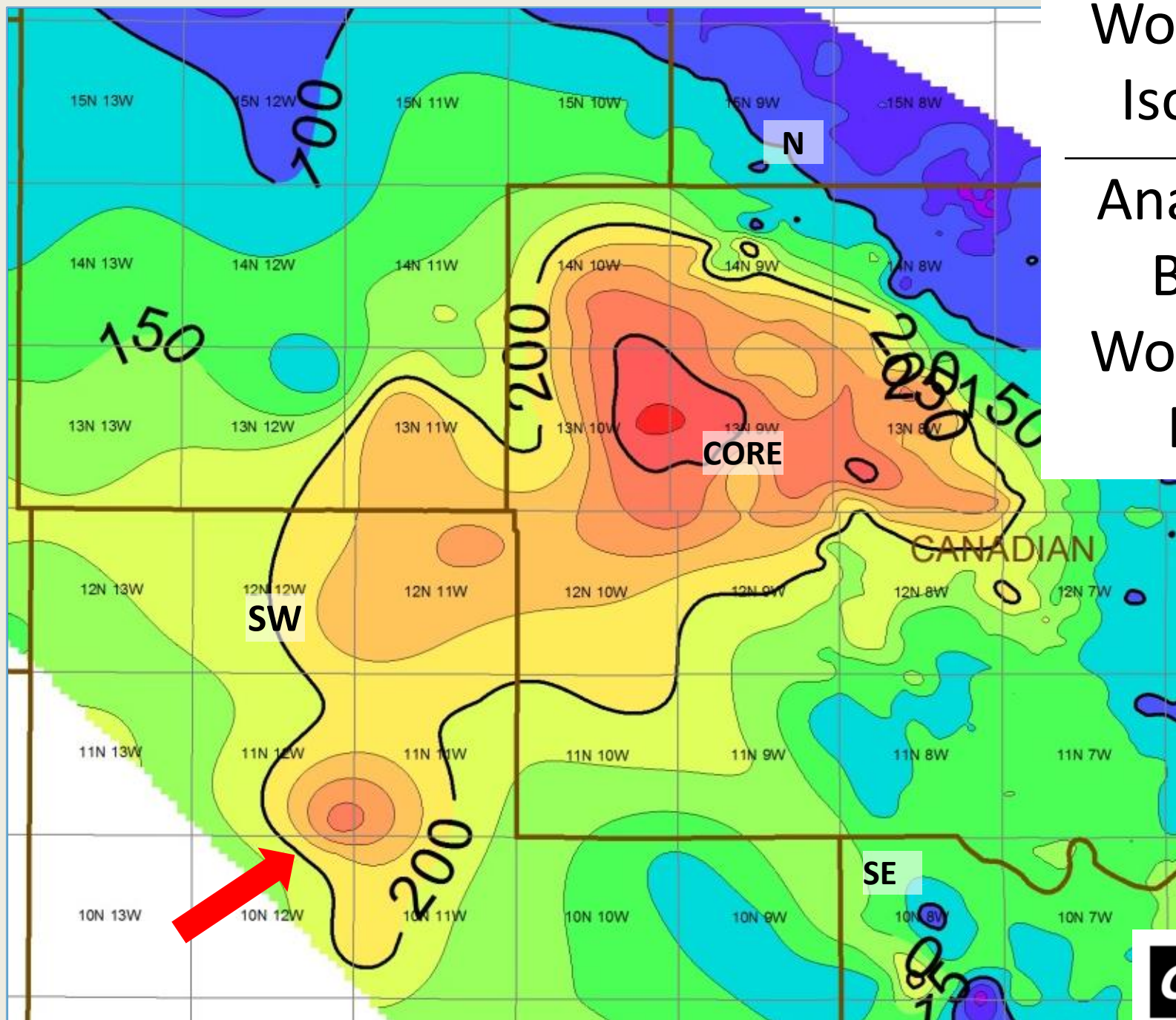
Cana Area



Woodford Isopach

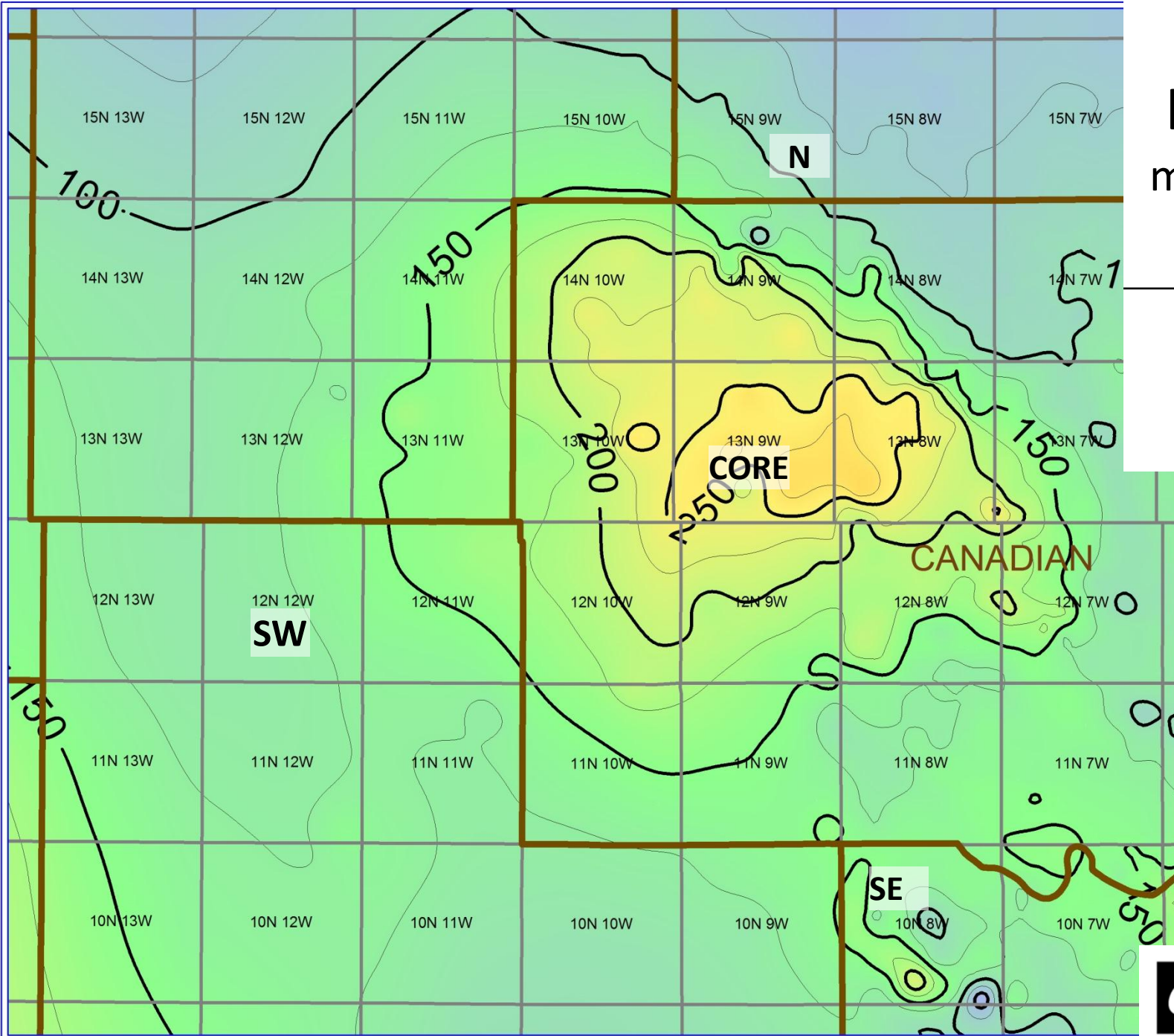
(in feet)

Anadarko Basin Woodford Play



WDFD
Isopach
minus Basal
WDFD
(in feet)

Cana
Area



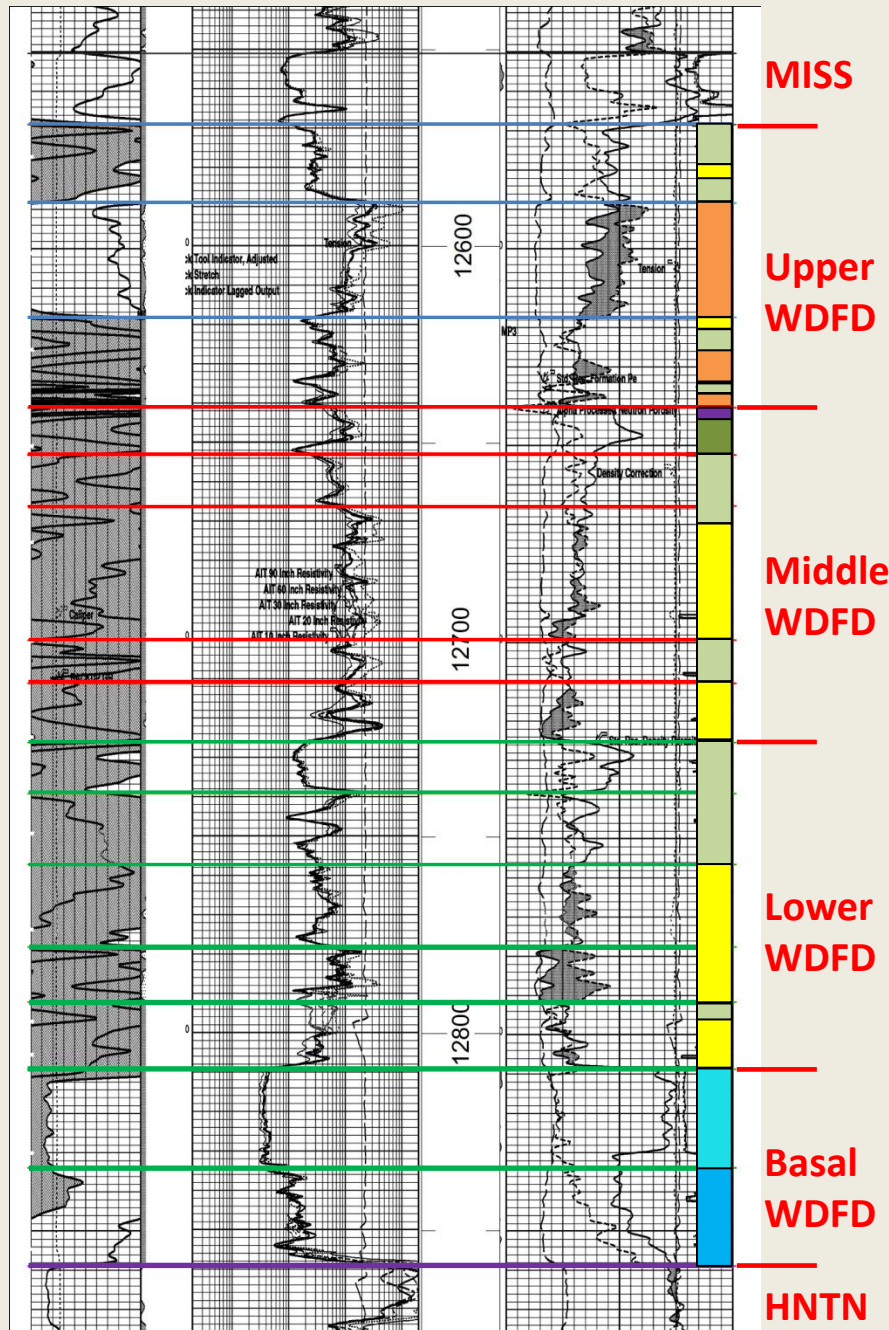
Woodford Lithostratigraphy Anadarko Basin Woodford Play Core Area

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Clayey
mudrock

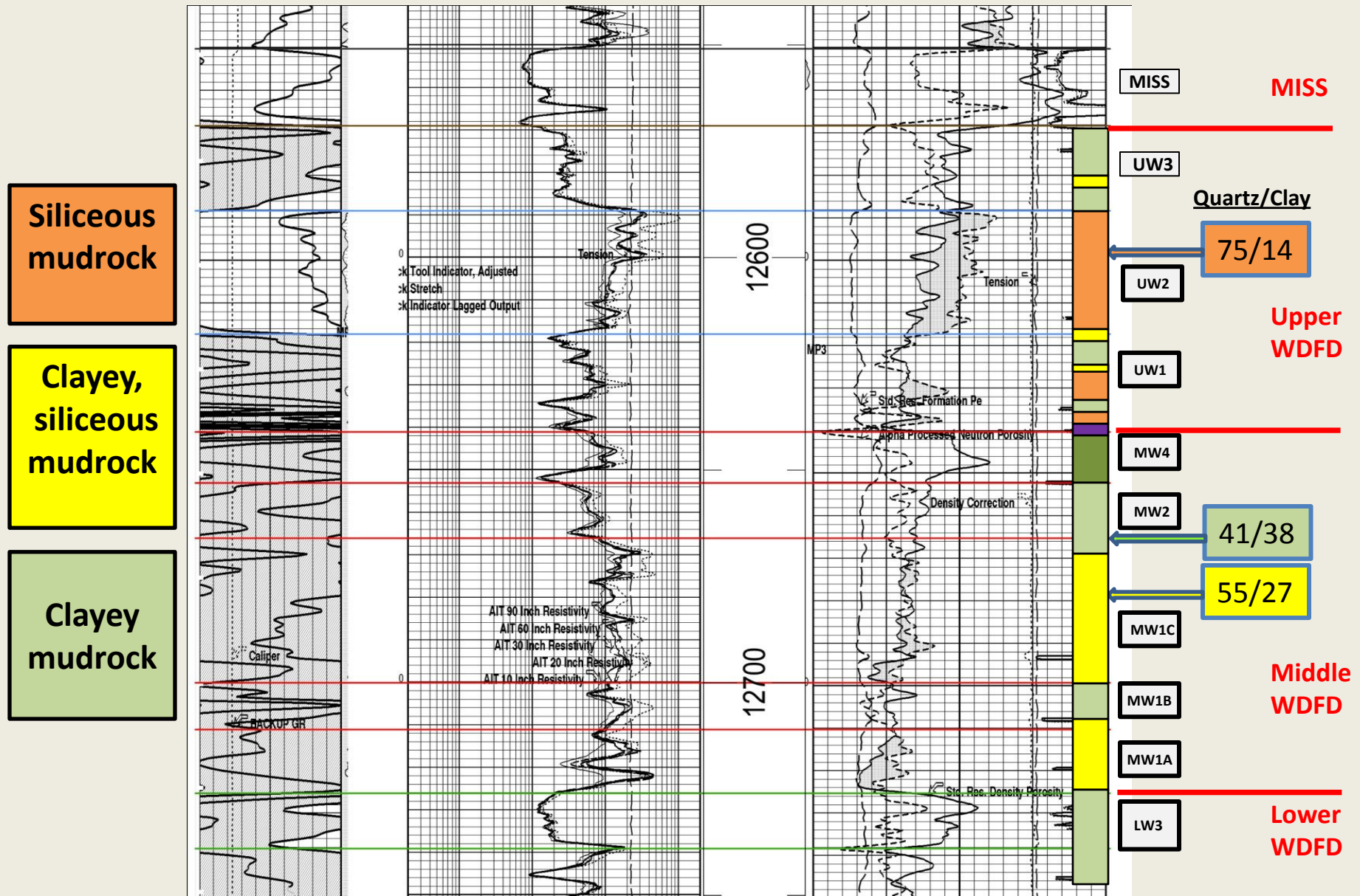
Organic-
poor
clayey
mudrock



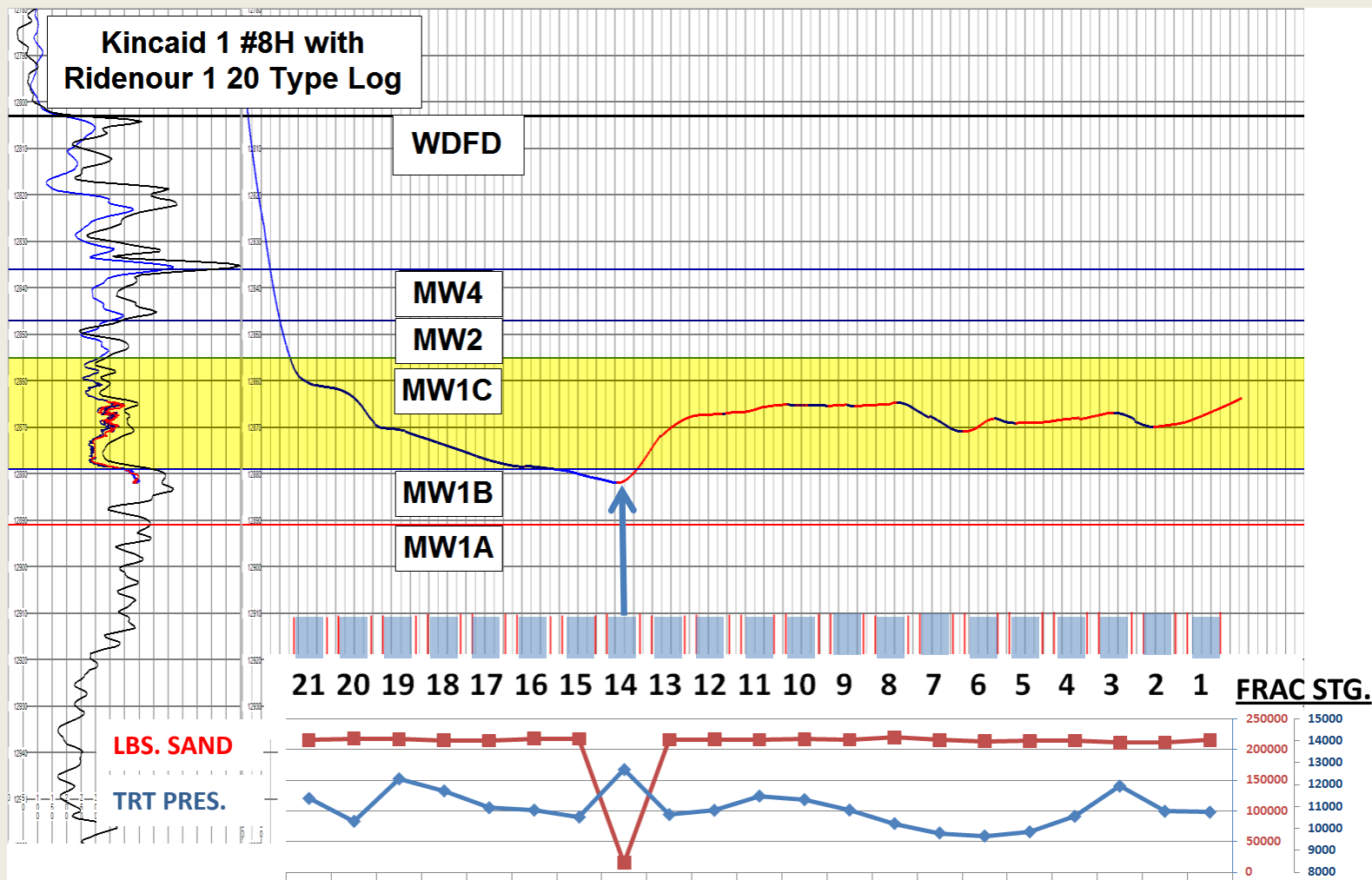
WDFD Thk. 290'



Middle and Upper Woodford Lithostratigraphy, Anadarko Woodford Play – Core Area



Well Path Showing Woodford Lithostratigraphy and Lateral Placement



Frac' Success and Woodford Rock Types

ROCK TYPE	% QUARTZ	% CLAY	% SUCCESS
Siliceous mudrock	75.2	14.5	100
Clayey, siliceous mudrock	54.8	27.4	86
Clayey mudrock	40.6	38	53

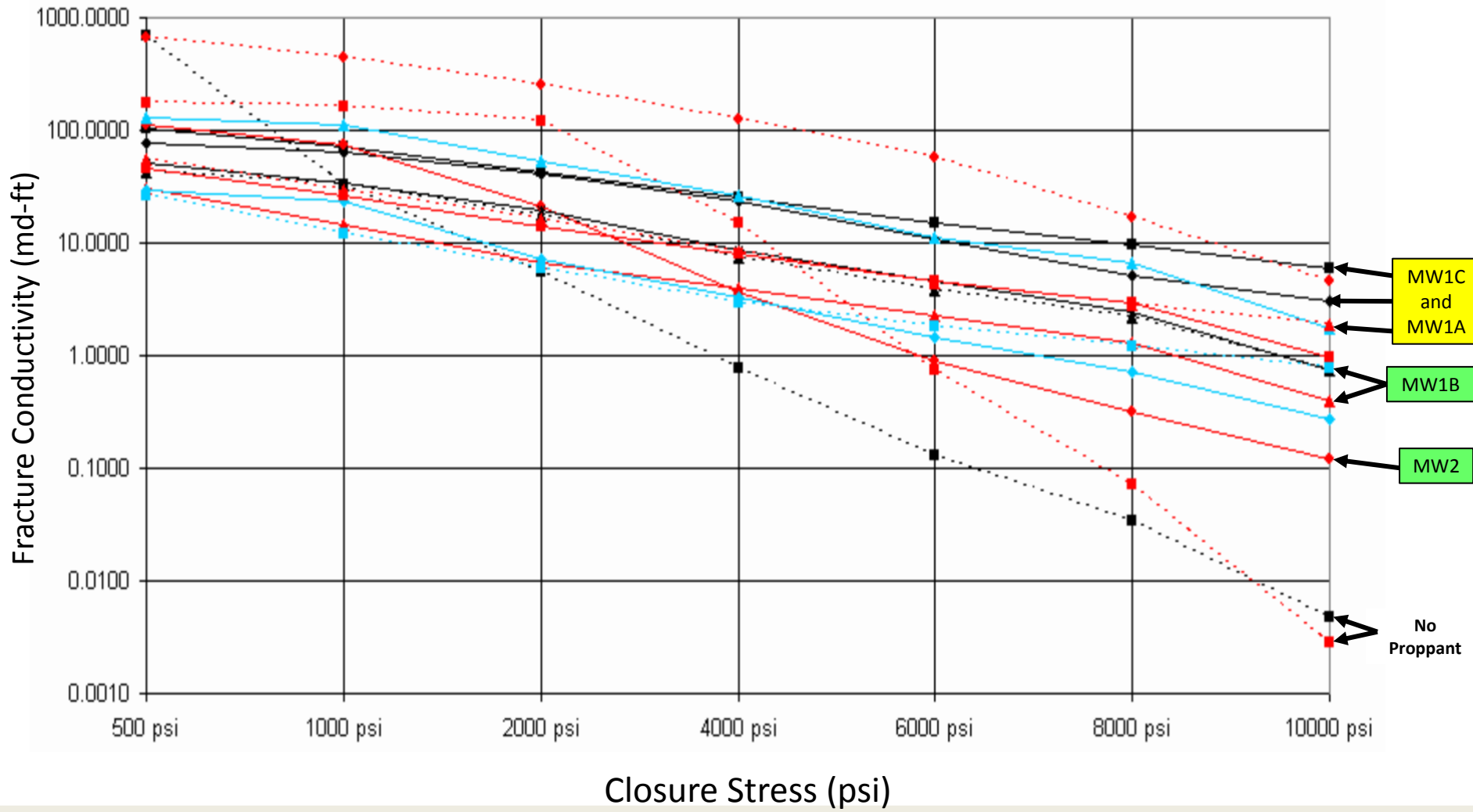
Successful frac' defined as one in which >75% of planned proppant amount was placed.

Frac' Success and Woodford Rock Types

ROCK TYPE	% QUARTZ	% CLAY	% DOLOMITE	% Success, Pre-HF	% Success, w/ HF
Siliceous mudrock	75.2	14.5	2.8	100	100
Clayey, siliceous mudrock	54.8	27.4	3.6	86	94
Clayey mudrock	40.6	38	5.0	53	80

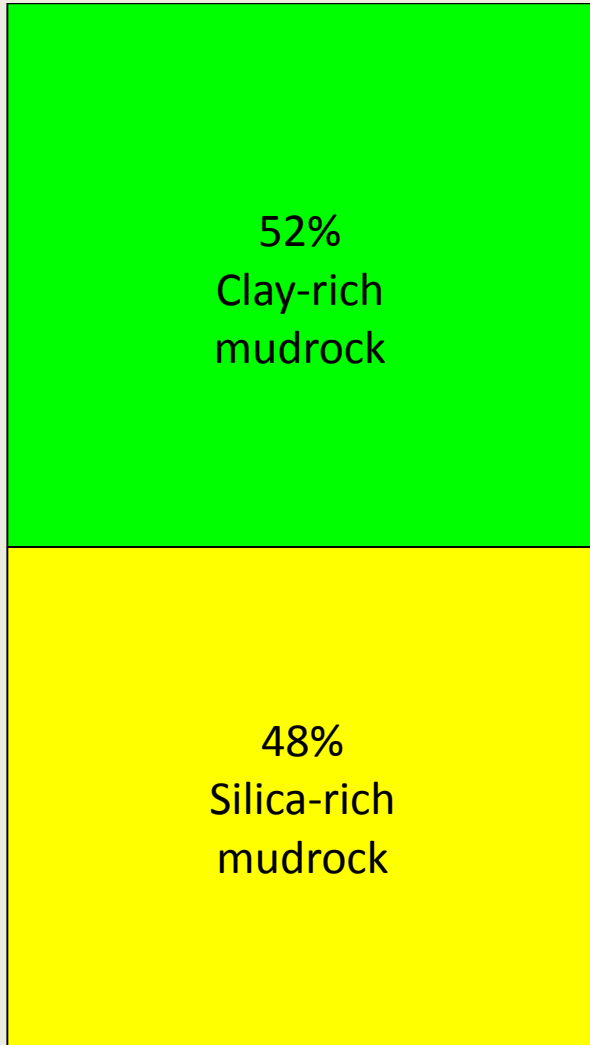
Successful frac' defined as one in which >75% of planned proppant amount was placed.
Table drawn from 906 frac stages.

Fracture Conductivity versus increasing Closure Stress – 40/70 PRC Proppant



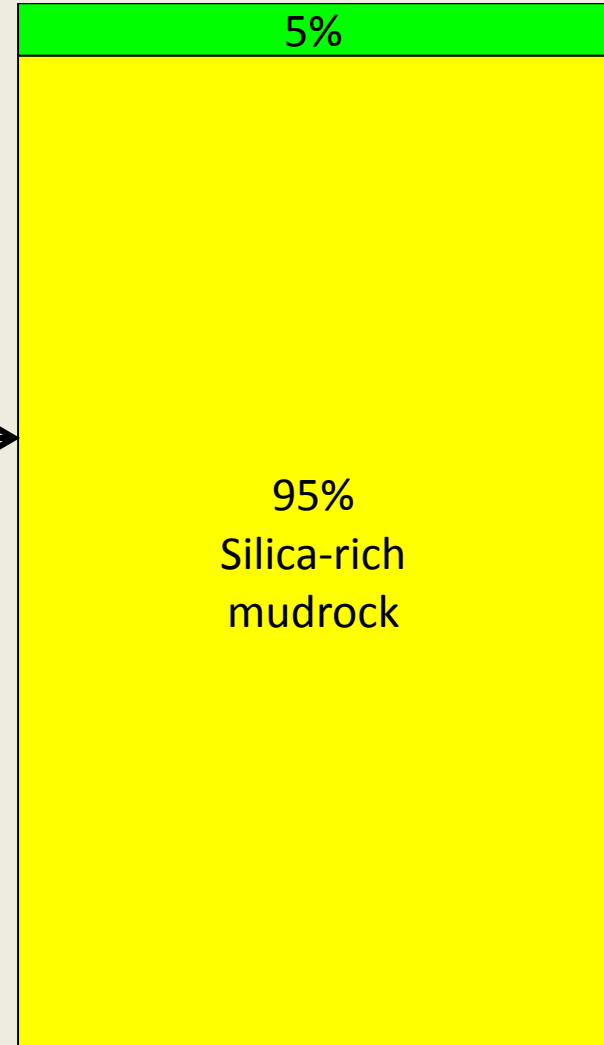
Lateral Placement and Productivity

WELL 1-4H
EUR 6.4 BCF



187 MB SW
1.5 MM#
4128'/9 stgs

WELL 1-3H
EUR 8.83 BCF



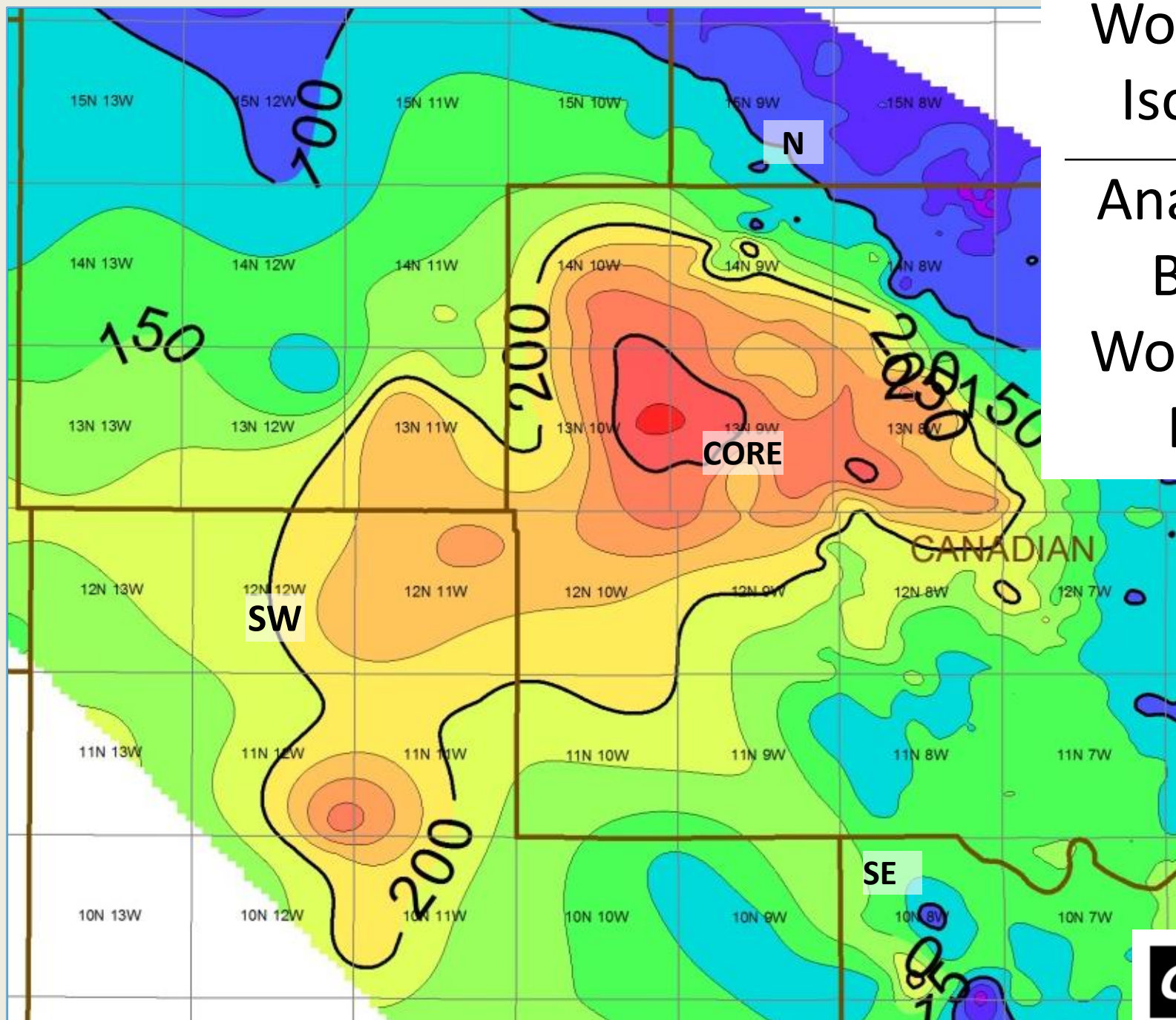
186 MB SW
1.5 MM#
4087'/9 stgs

~2200'

Woodford Isopach

(in feet)

Anadarko Basin Woodford Play



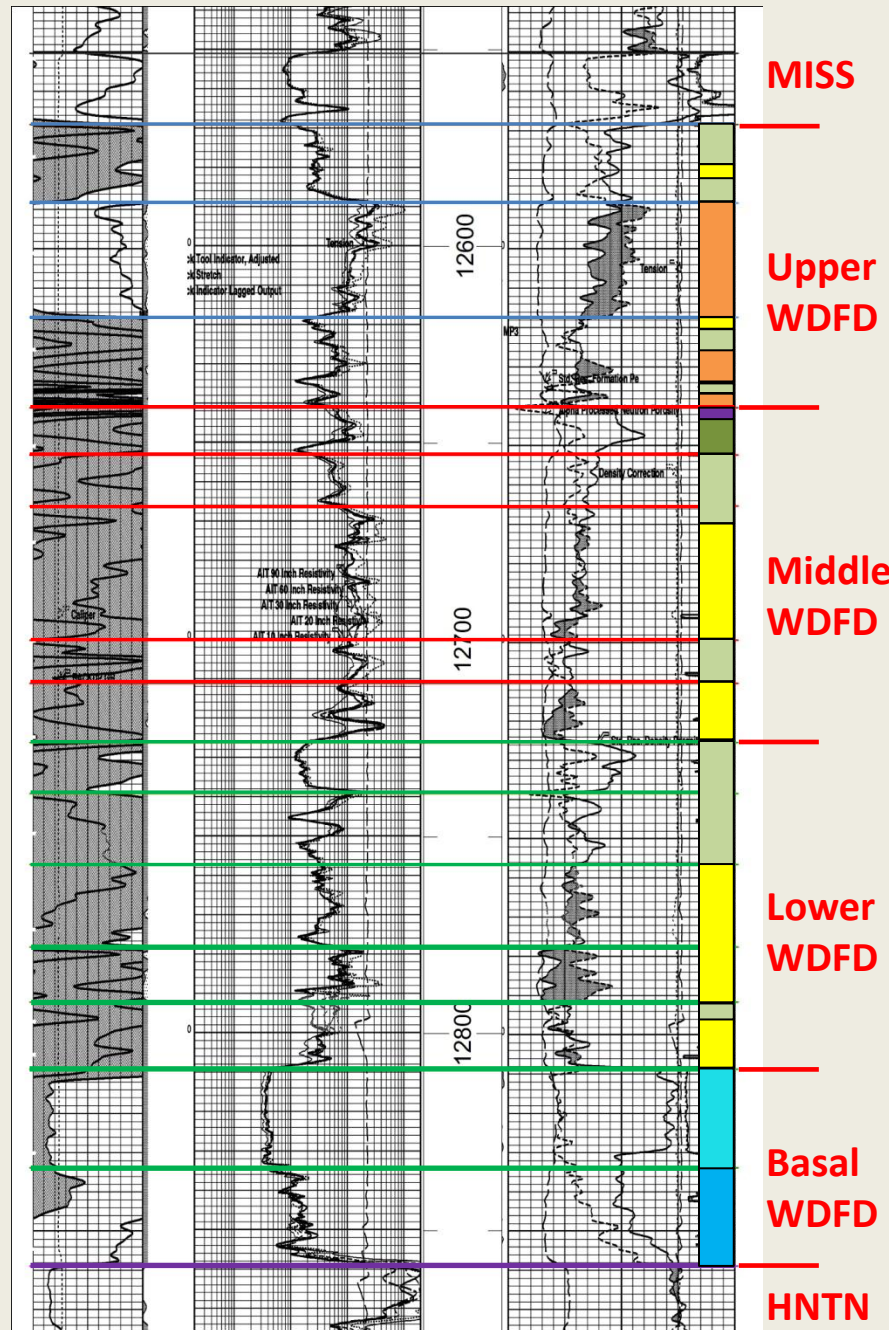
Woodford Lithostratigraphy Anadarko Basin Woodford Play Core Area

Siliceous
mudrock

Clayey,
siliceous
mudrock

Clayey
mudrock

Organic-
poor
clayey
mudrock



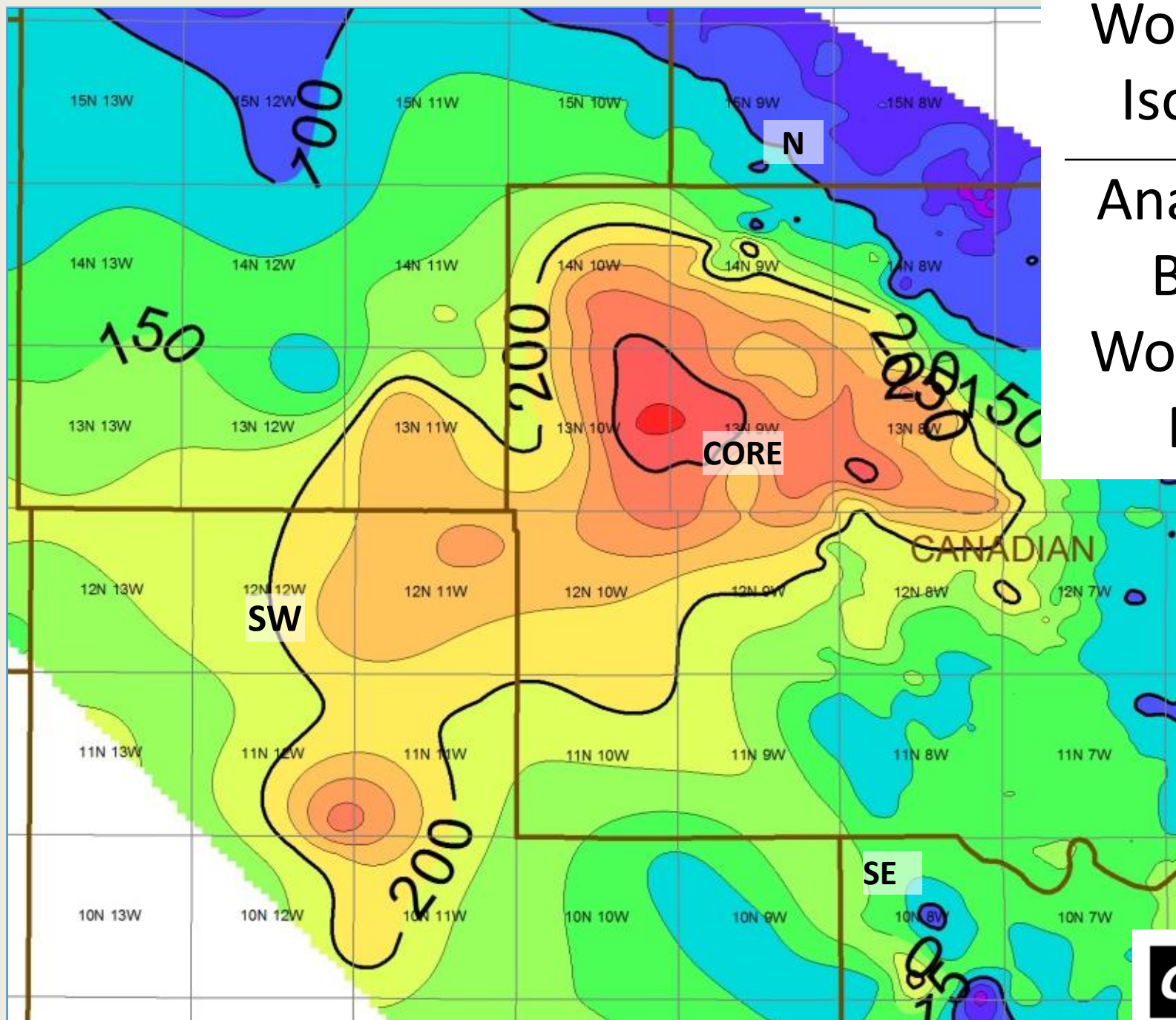
WDFD Thk. 290'



Woodford Isopach

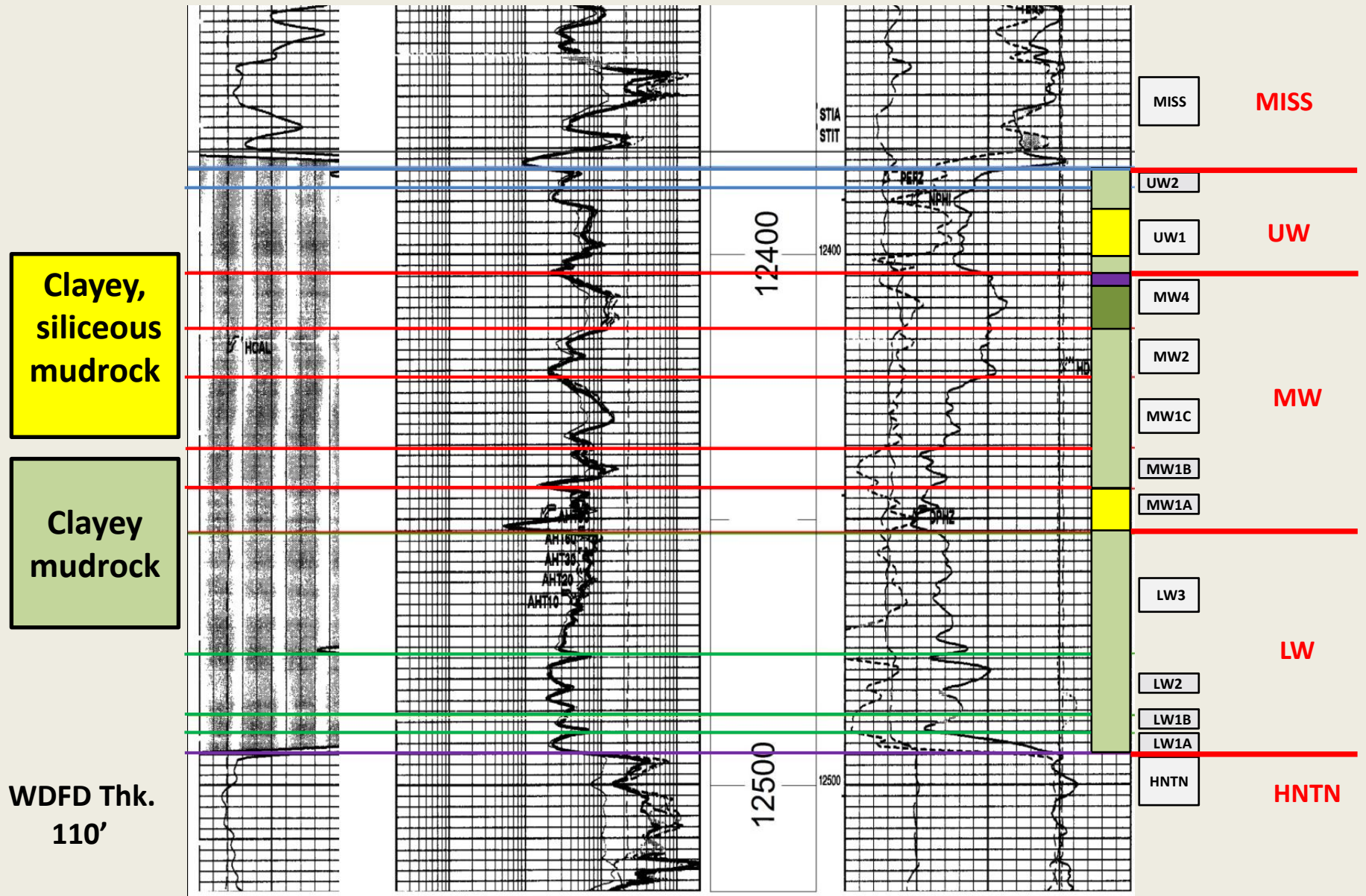
(in feet)

Anadarko Basin Woodford Play

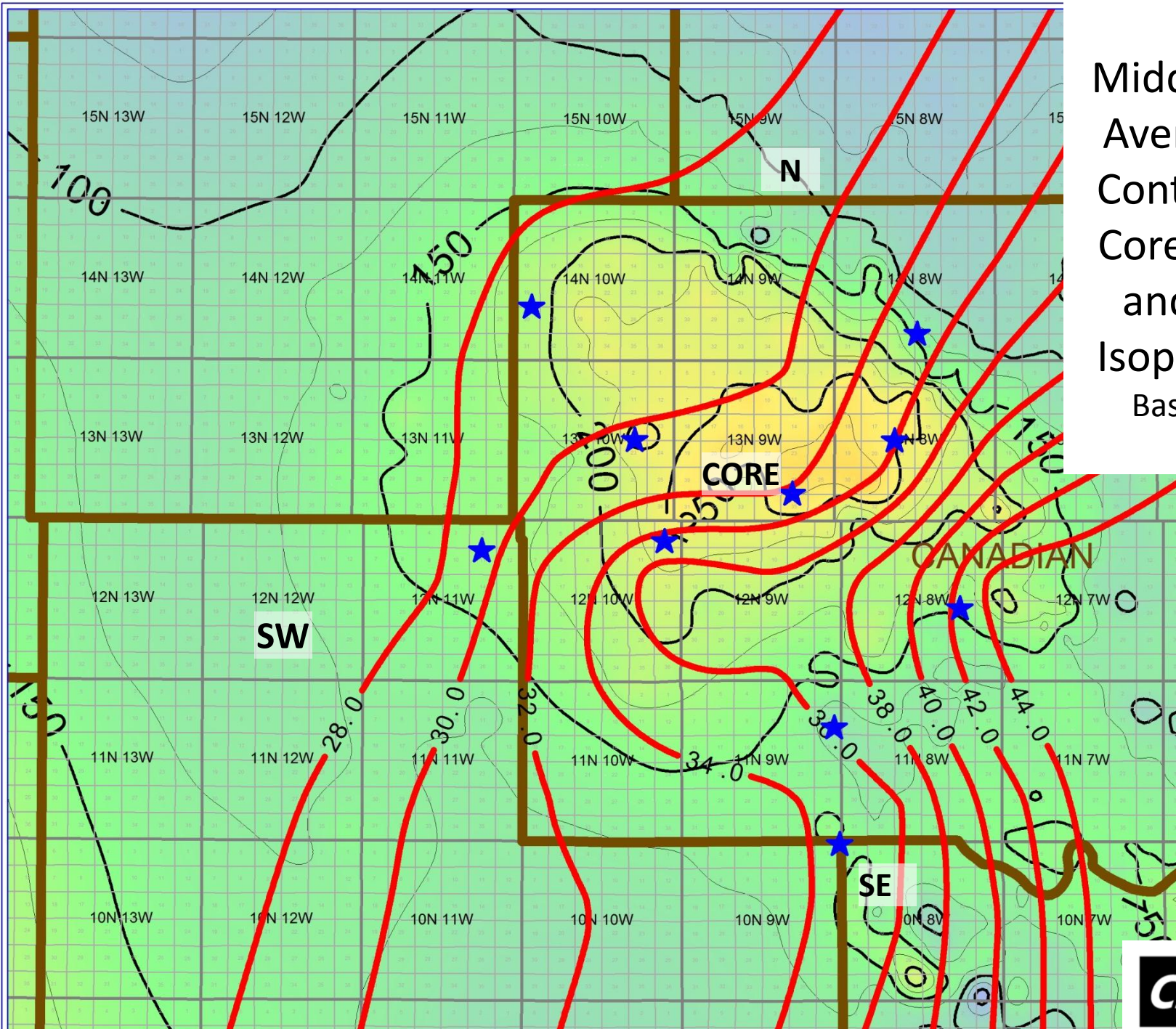


Woodford Lithostratigraphy Anadarko Basin

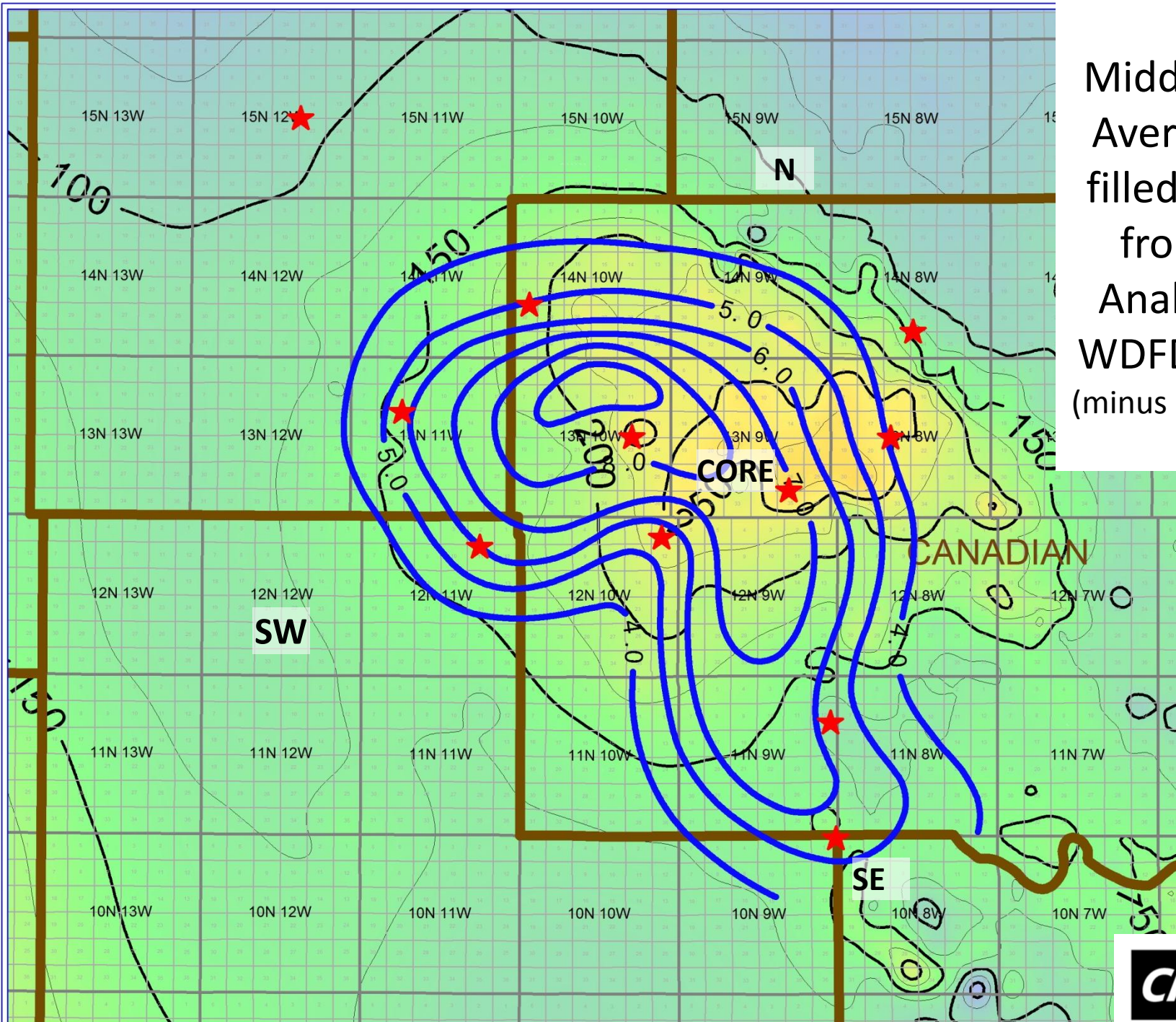
Woodford Play - SE Area



Middle WDFD
Average Clay
Content from
Core Analysis
and WDFD
Isopach (minus
Basal WDFD)



Middle WDFD
Average Gas-
filled Porosity
from Core
Analysis and
WDFD Isopach
(minus Basal WDFD)



CONCLUSIONS:

Changes in depositional patterns demonstrated by isopach maps of the Basal, Lower, Middle and Upper Woodford may be related to the Canadian Flexure.

Quartz-rich mudrocks and clay-rich mudrocks have distinctively different mechanical properties. Frac stages in clay-rich mudrocks commonly treat at higher pressures, and proppant placement can be challenging.

Embedment studies demonstrate lower fracture conductivity in more clay-rich lithologies compared to those observed in more silica-rich rock.

An important part of any Woodford completion program should be a discussion of lateral placement....which can affect productivity.

Regional variations in clay content (brittleness) and porosity are among the variables that appear to affect Woodford productivity.

QUESTIONS

Can a well designed and executed completion overwhelm a relatively poor reservoir rock?

Are engineers smarter than rocks?

Additional Slides

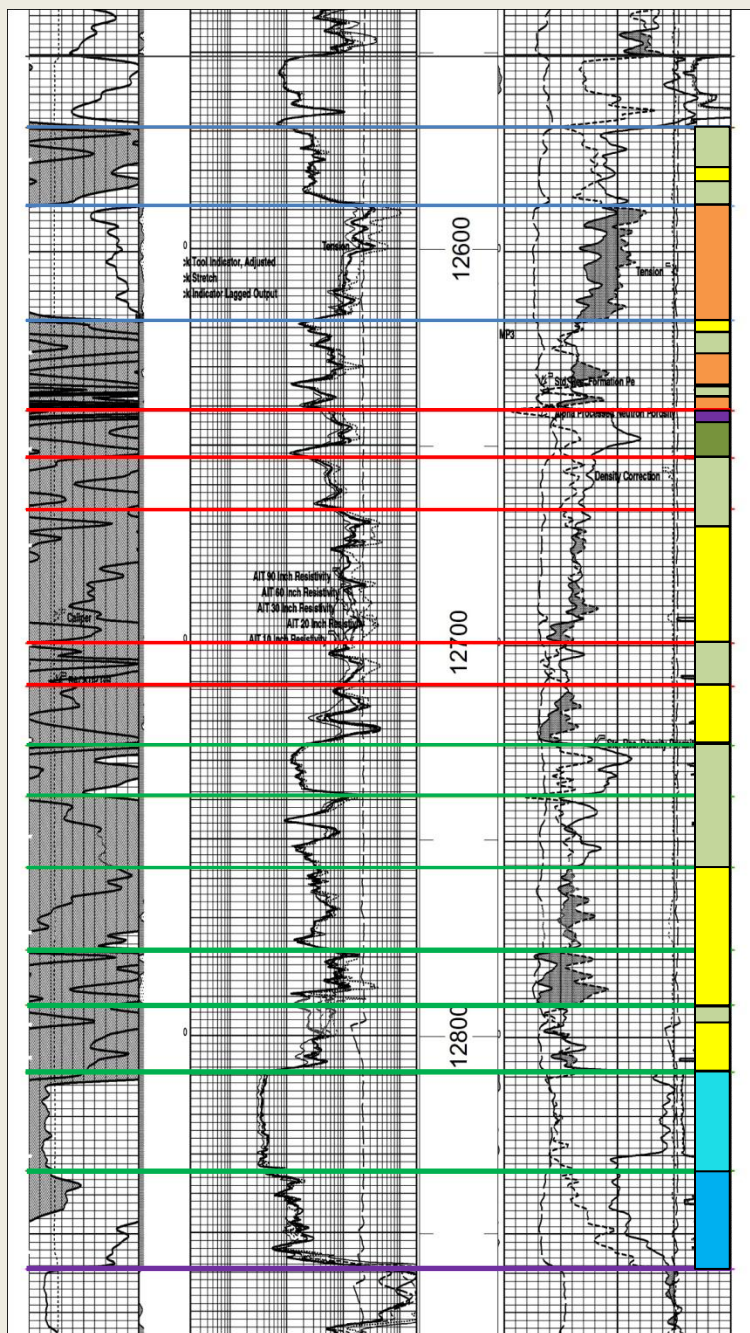
Woodford Strat. Kvale and Bynum (2014)

**Siliceous
mudrock**

**Clayey,
siliceous
mudrock**

**Clayey
mudrock**

**Organic-
poor
clayey
mudrock**



MISS

**Upper
WDFD**

A and B

**Middle
WDFD**

C and D

**Lower
WDFD**

E and F

**Basal
WDFD**

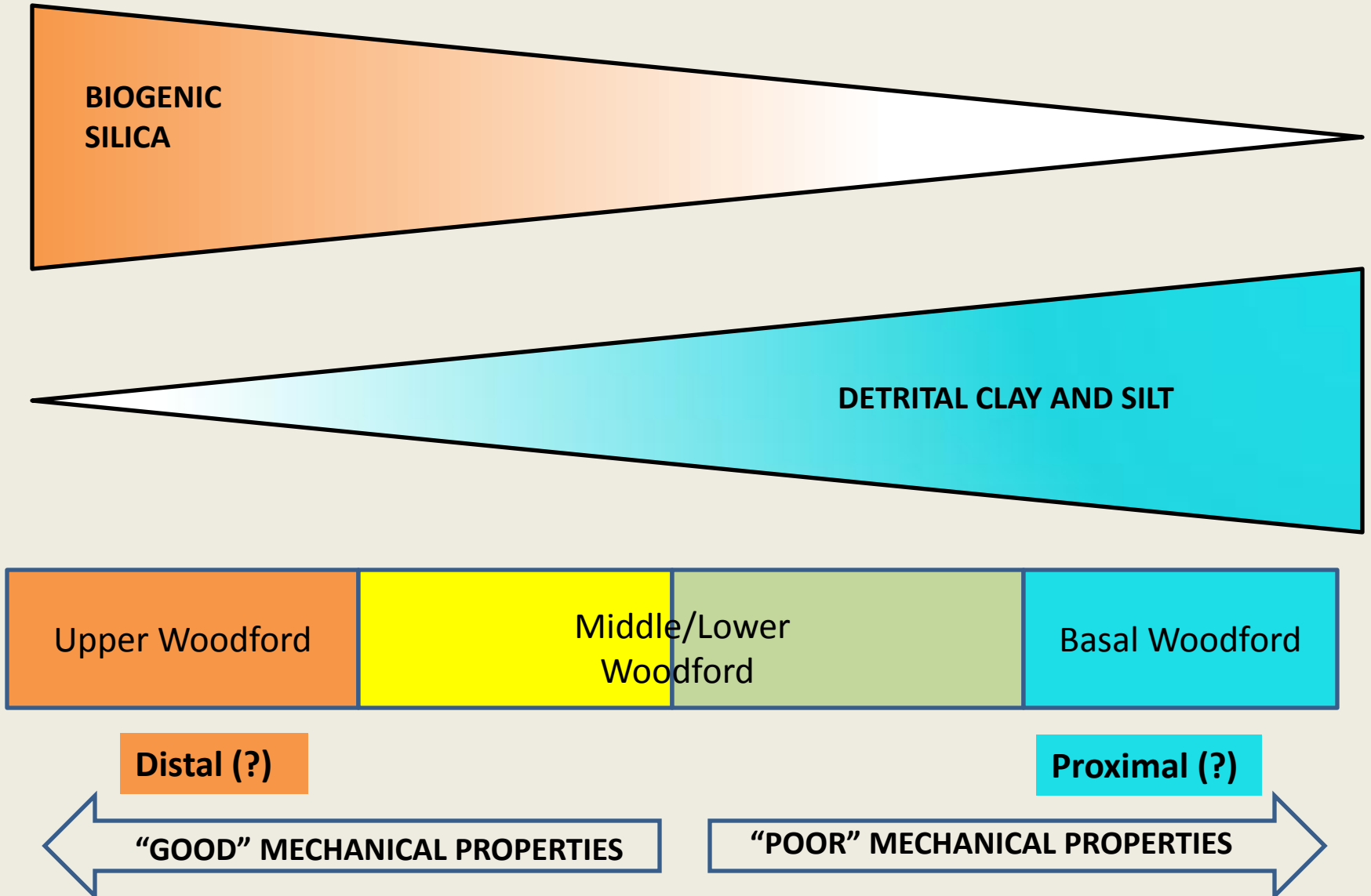
G and H


HNTN

WDFD Thk. 290'



Woodford Lithofacies

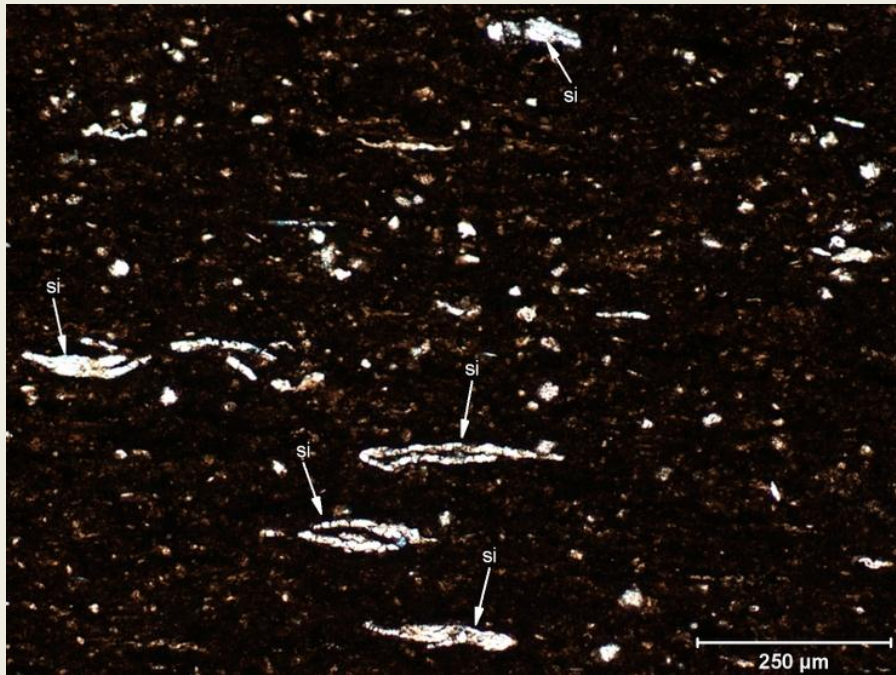




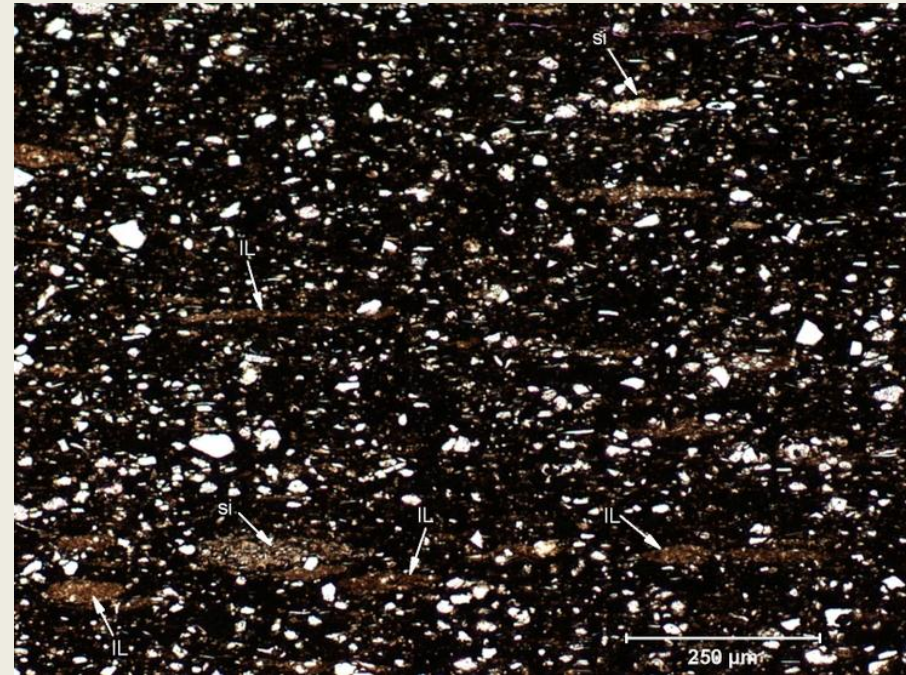
**Bed-limited
dolomite-cemented
fractures in thin
silicic layers**
**Siliceous mudrock
lithology**



Thin-Section Photomicrographs of Woodford Rock Types

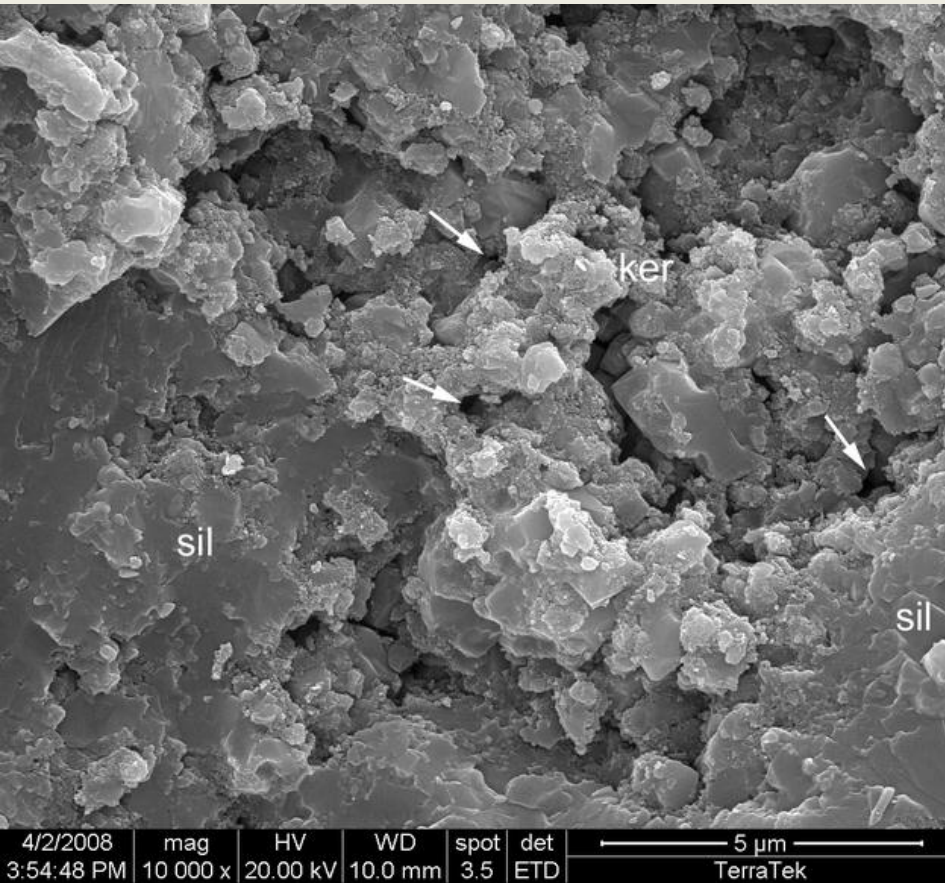


UW1 sample showing silicified Tasmanites;
sample is 64% quartz and 21% clay.
Siliceous mudrock lithology.

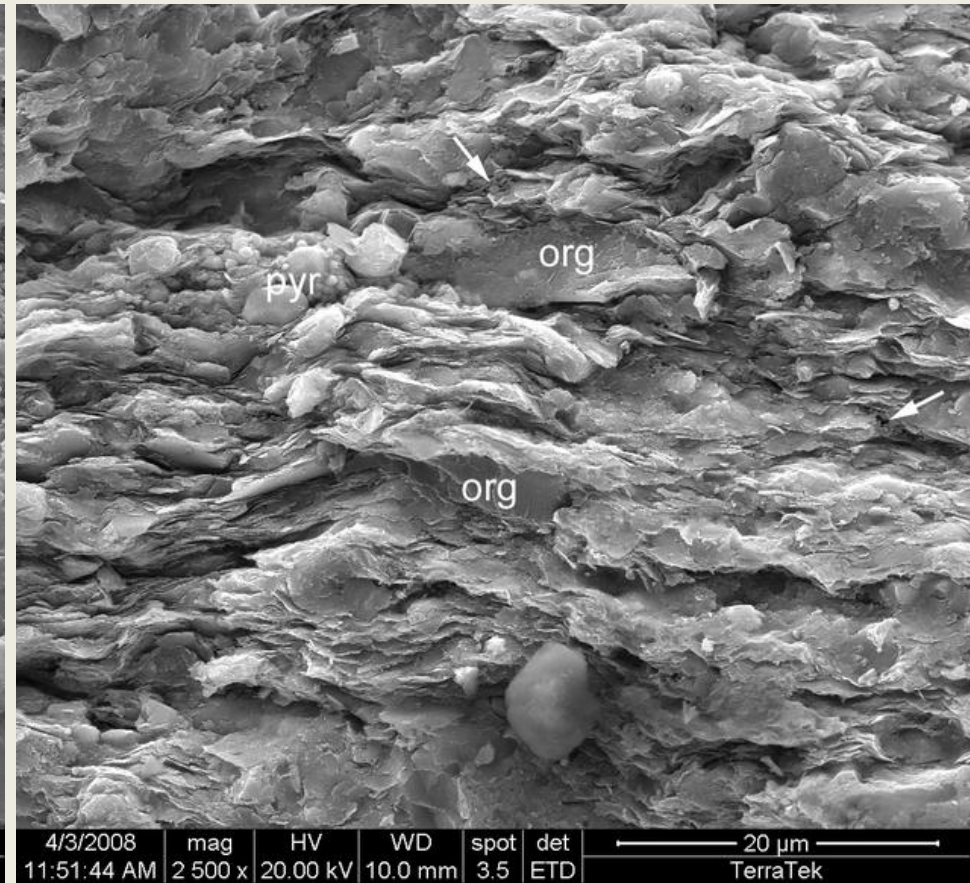


MW1B sample showing detrital silt;
sample is 34% quartz and 38% clay.
Clayey mudrock lithology.

SEM Photomicrographs of Woodford Microfabrics



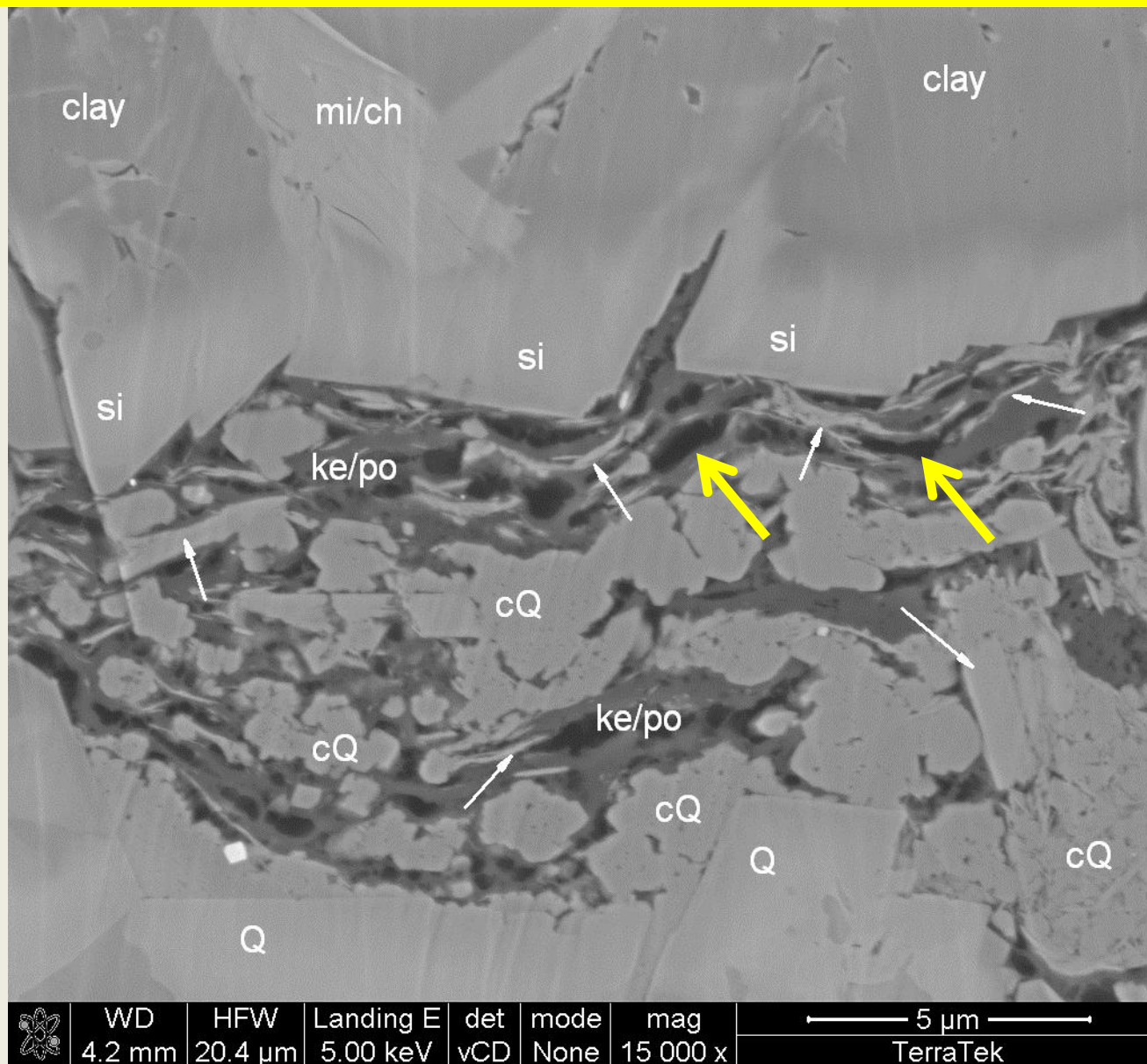
UW2 sample showing microcrystalline silica with intercrystalline porosity; sample is 76% quartz and 18% clay. Siliceous mudrock lithology.



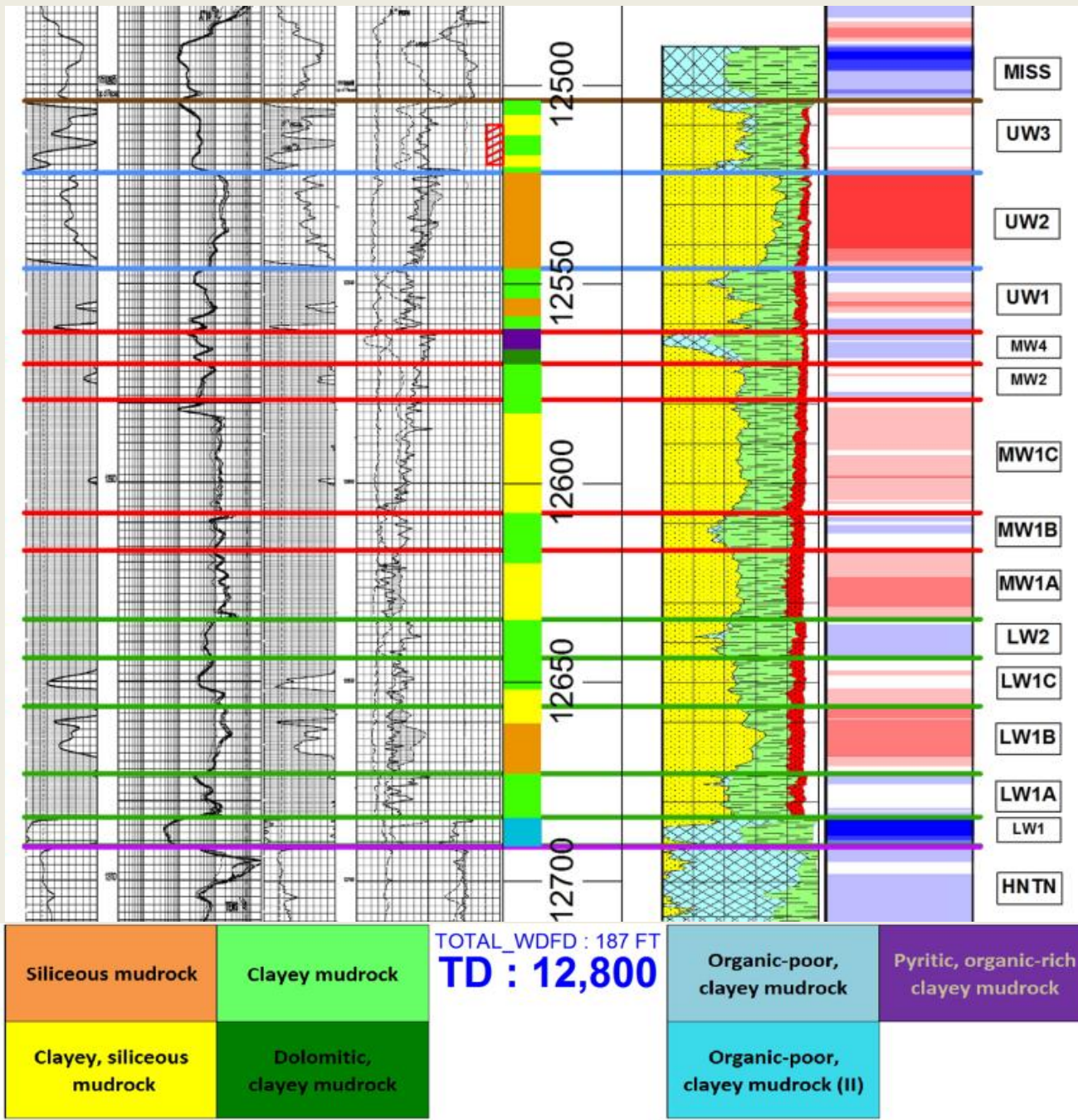
MW4 sample showing parallel alignment of illite clay; sample is 26% quartz and 44% clay. Clayey mudrock lithology.

Porosity in organic laminae

Clayey siliceous mudrock



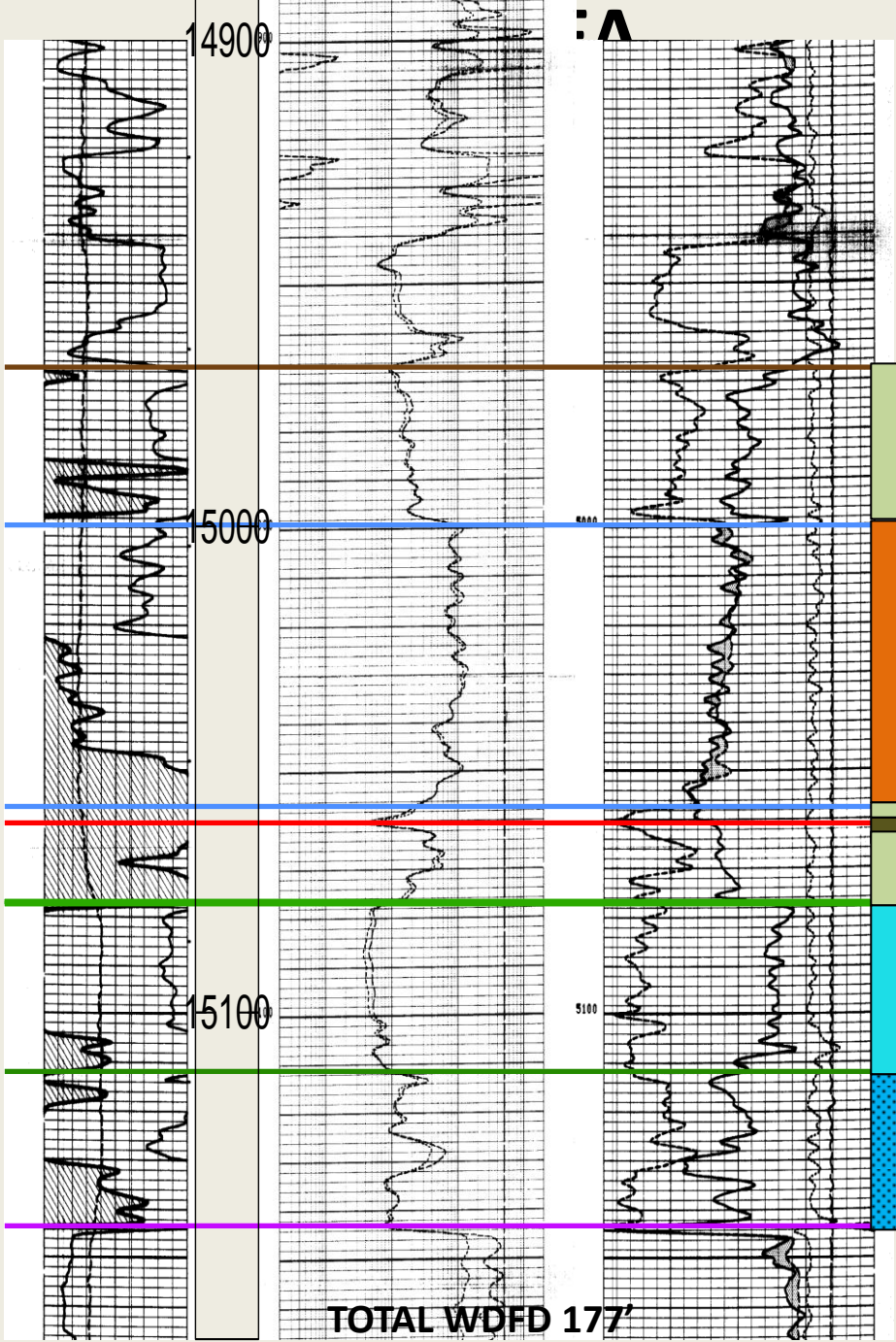
Woodford Lithostratigraphy With Sonic Scanner Data



**Siliceous
mudrock**

**Organic-
poor,
clayey
mudrock**

**Clayey
mudrock**



MISS

UW3

UW

UW2

MW/LW

LW1

BW

LW0

HNTN

TOTAL WDFD 177'

11/1981 WDFD minus BW 111'