Flow Units in Conventional and Unconventional Petroleum Reservoirs

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(Based mostly on SPE 165360-PA and SPE 178619-PA)

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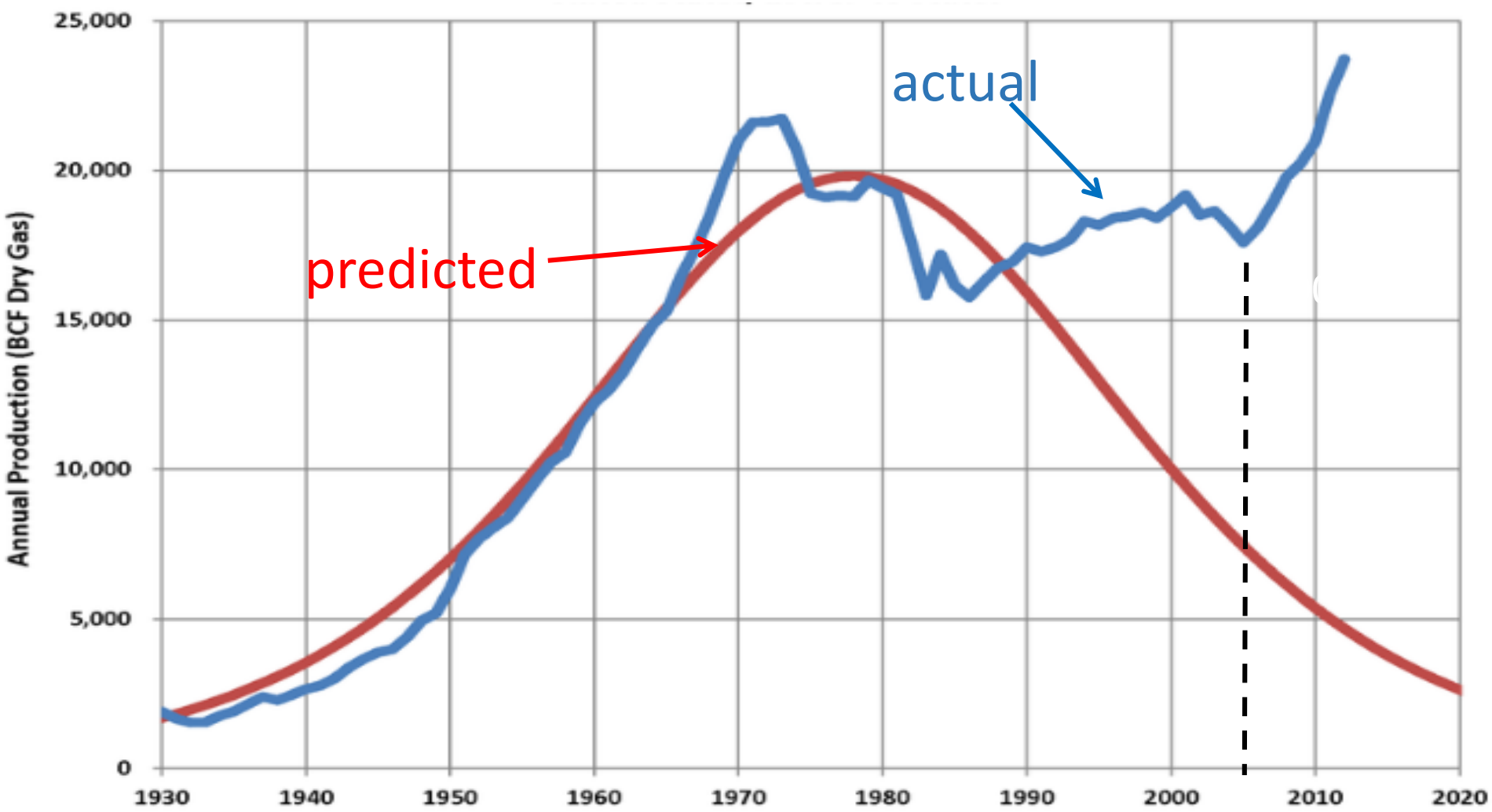
OUTLINE

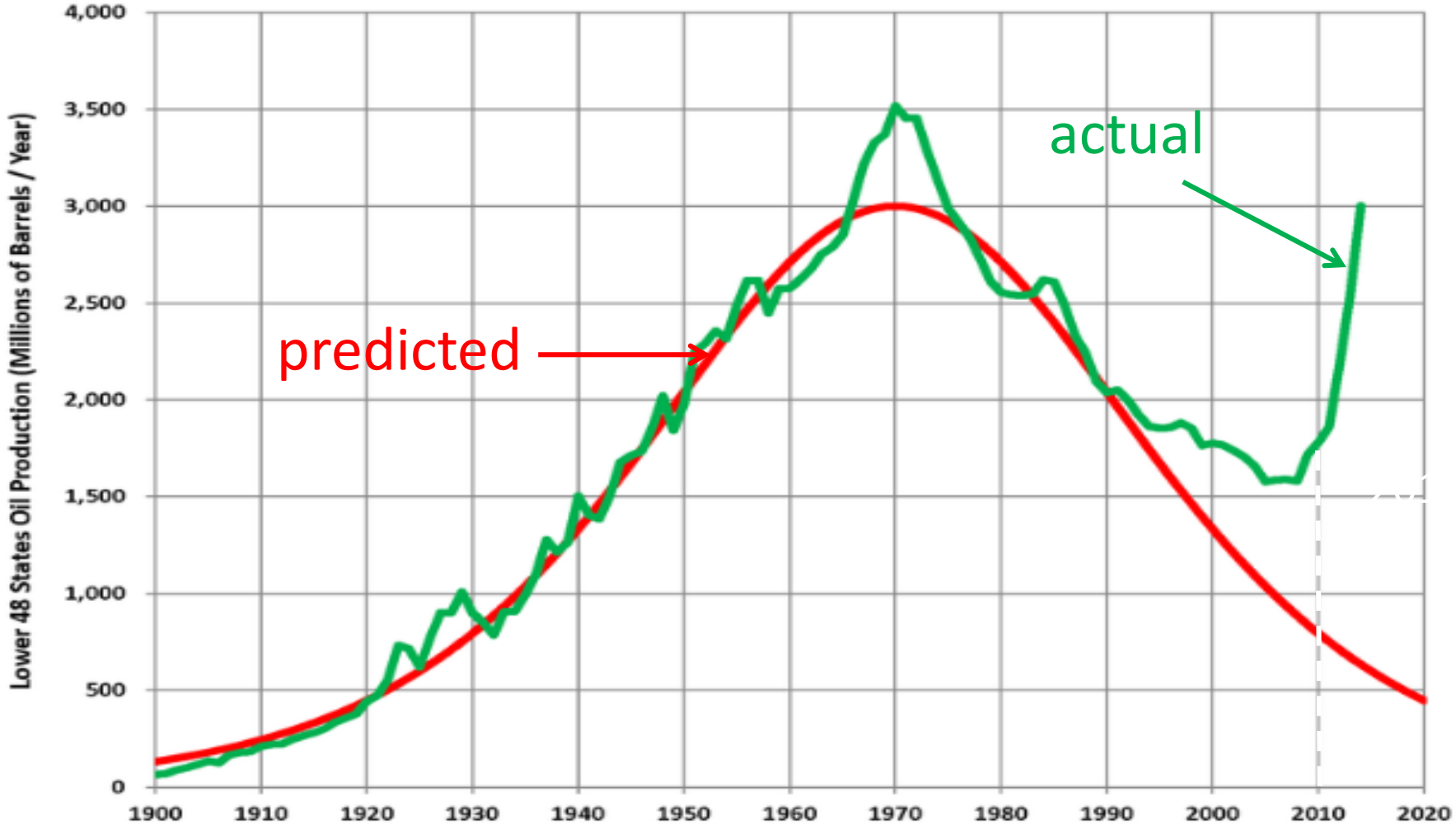
- The ‘unconventionals’ role
- Discuss petroleum flow units in conventional, tight and shale reservoirs within the context of a total petroleum system.
- Relate pore throat apertures to oil and gas rates in vertical and horizontal wells.
- Make the work tractable by using geoscience an petroleum engineering published data
- Role of pore size on recovery of liquids

Hubbert's prediction vs. actual gas production: US lower 48 states



(from Hubbert, 1964; Intl. Energy Outlook, 2014, Moslow, 2015)

Hubbert's prediction vs. actual oil production: US lower 48 states



(from Hubbert, 1956; Intl. Energy Outlook, 2014, Moslow, 2015)

FLOW UNIT

A flow unit is defined as a stratigraphically continuous reservoir subdivision characterized by a similar pore type (Hartmann and Beaumont, 1999), for example r_{p35}

PETROLEUM SYSTEM

The Petroleum System is a unifying concept that encompasses all of the disparate elements and processes of petroleum geology including a pod of active source rock and all genetically related oil and gas accumulations (Magoon and Beaumont, 1999)

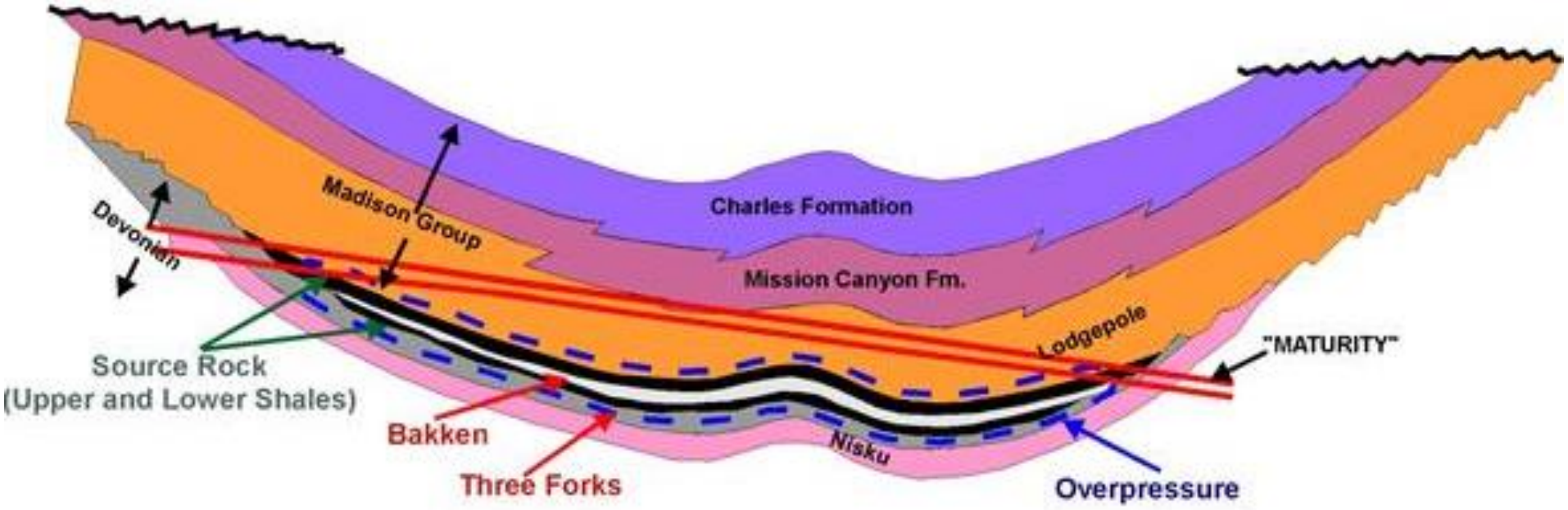
PETROLEUM
(in conventional
& unconventional
reservoirs)

(1) Thermal and biological hydrocarbon gas
(2) Condensates
(3) Crude oils
(4) Natural bitumen

SYSTEM

The word ‘system’ describes the interdependent elements and processes that form the functional unit that creates hydrocarbon accumulations.
(Magoon and Beaumont, 1999)

Bakken Total Petroleum System
(Used Mostly to Explain Tight Oil)
(Sonnenberg, 2011)

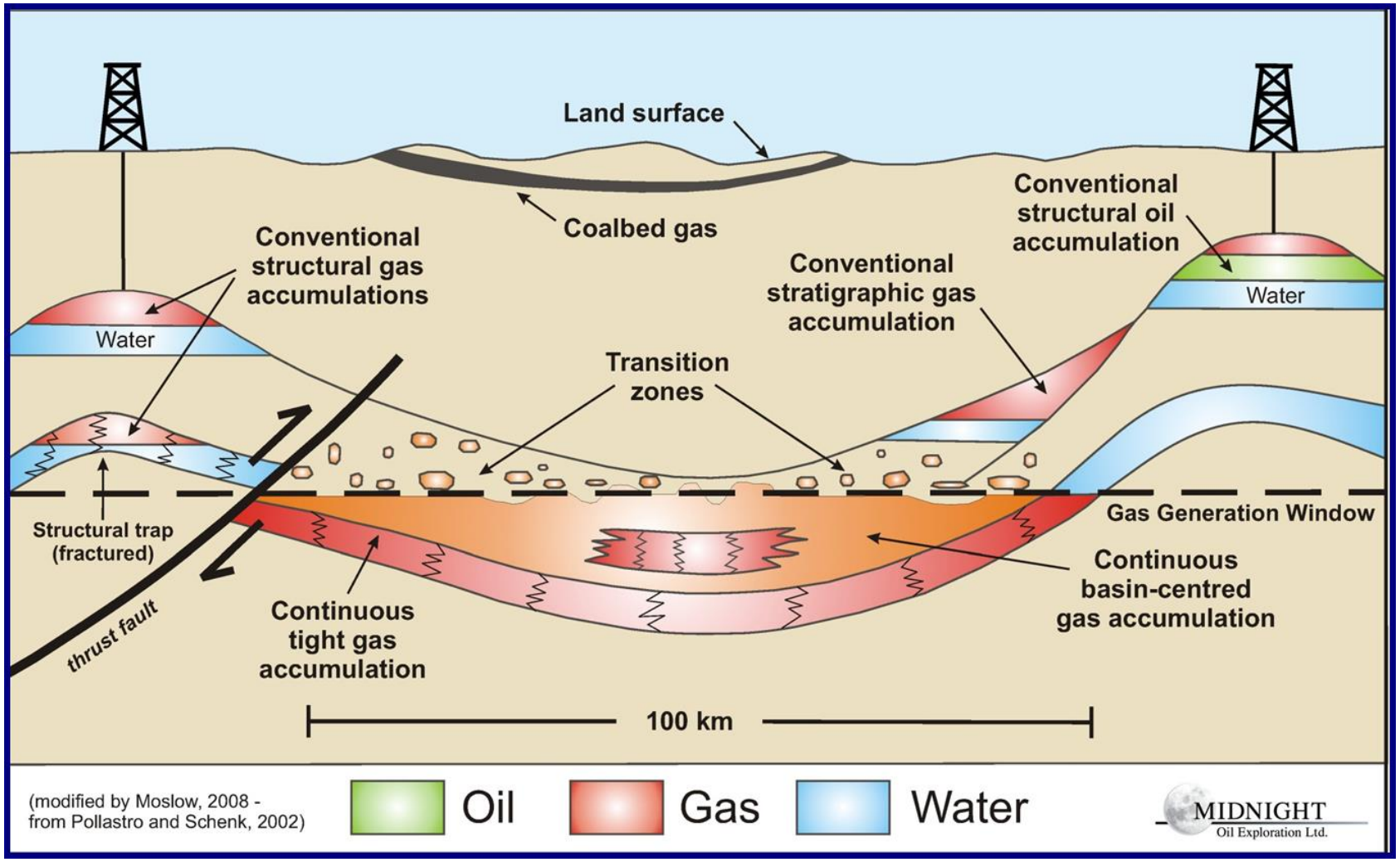


Reservoirs:
Middle Bakken & Three Forks

Source Beds:
Upper & Lower Bakken Shales

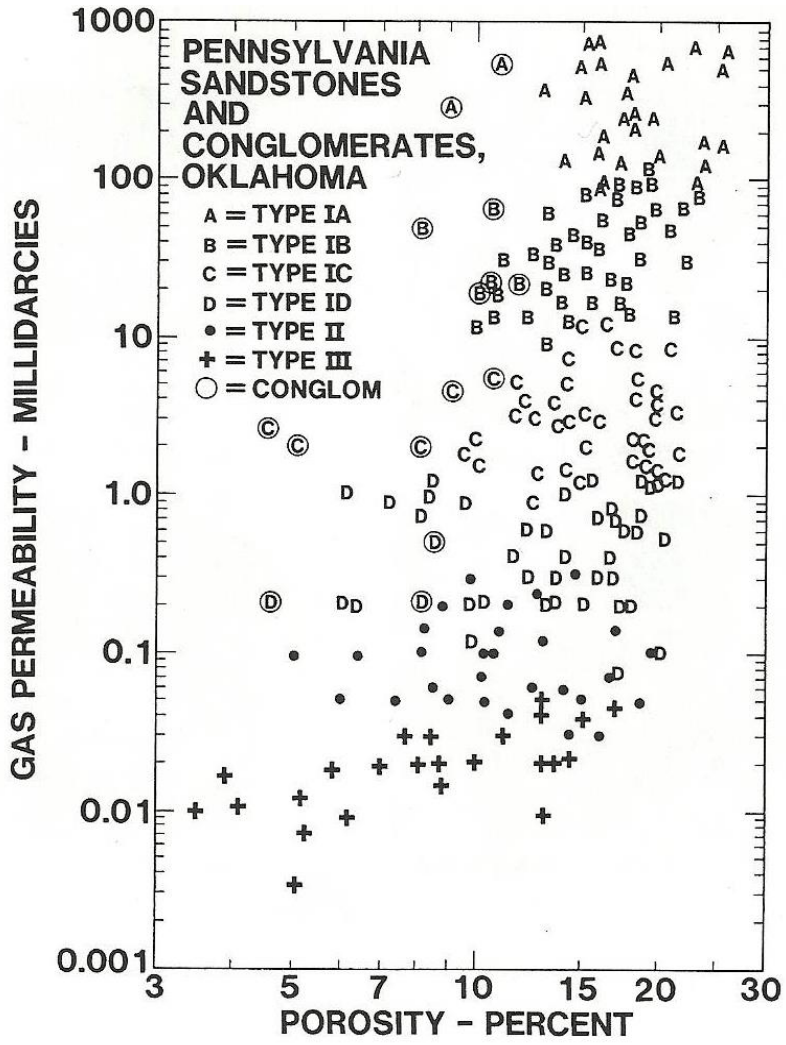
"what was made in the Bakken, stayed in the Bakken PS"

Conventional vs. Continuous Type Accumulations (Used mostly to Explain Tight Gas) (Pollastro and Schenk; 2002, Moslow, 2008)

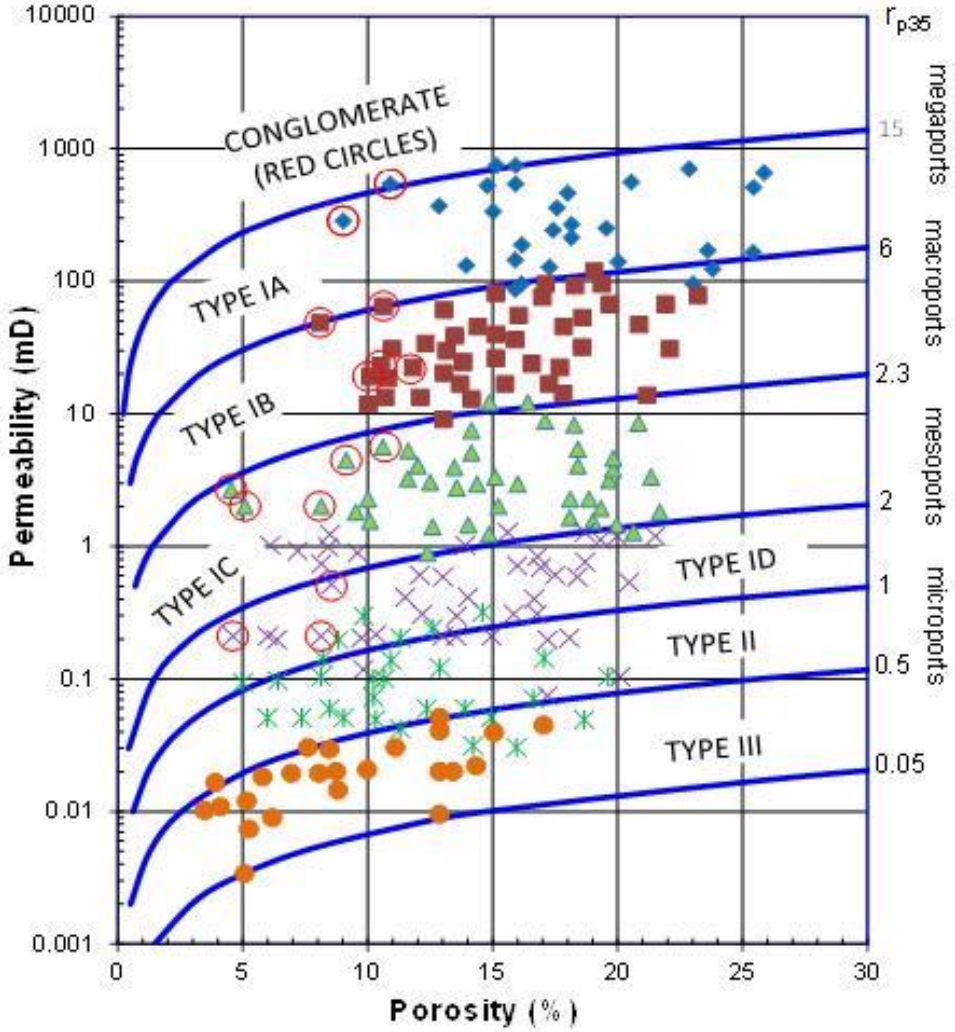


Real Data
Conventional and
Low Permeability Rocks

Elk City Oil Field (Sneider et al., 1983)

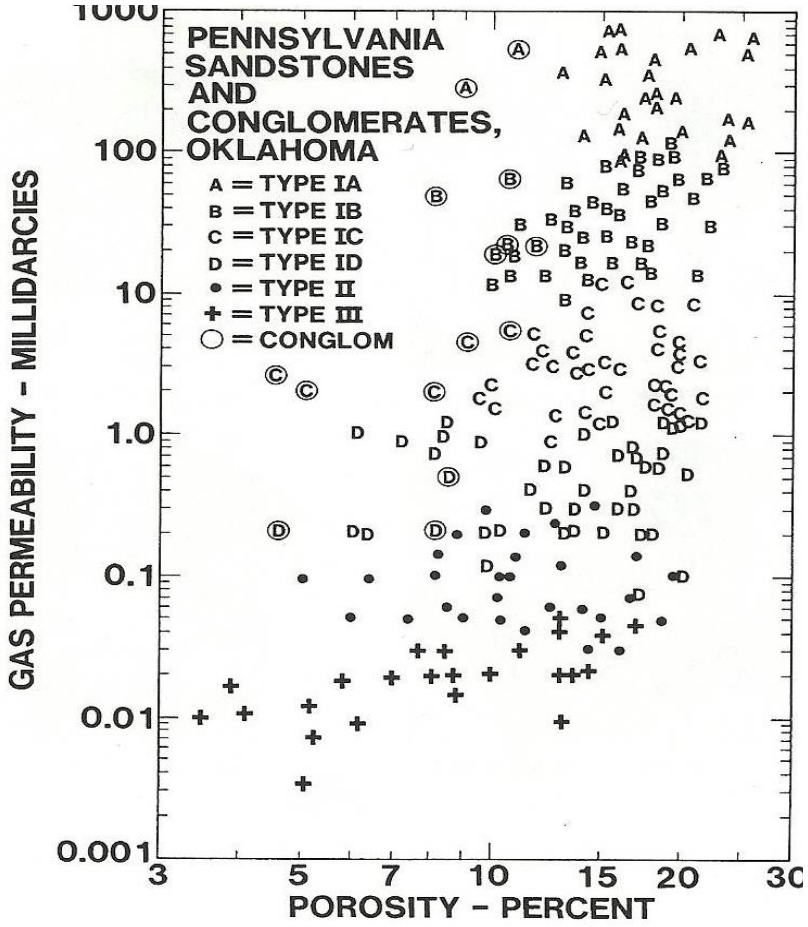


Flow Units, Elk City Oil Field (SPE 165350, 2013)
Data from Sneider et al., 1983

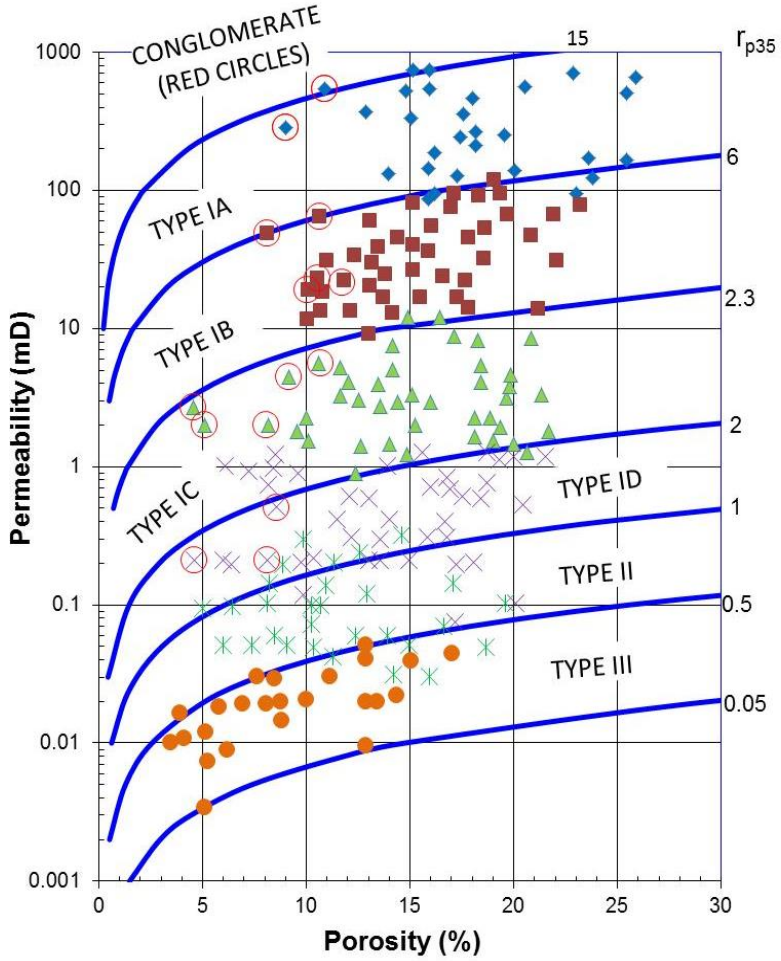


Flow Units (Elk City Oil Field)

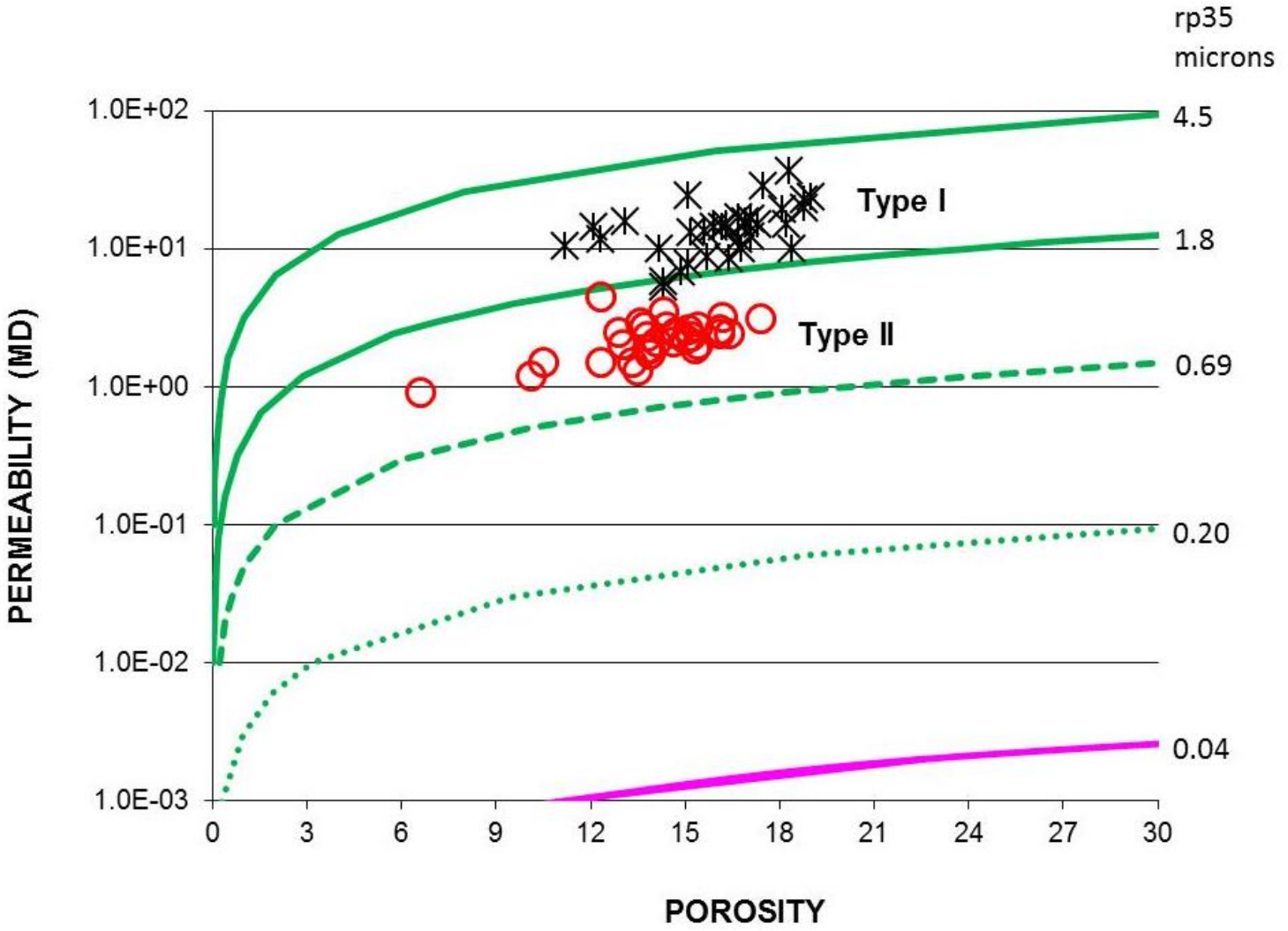
Sneider et al, 1983



SPE 165360

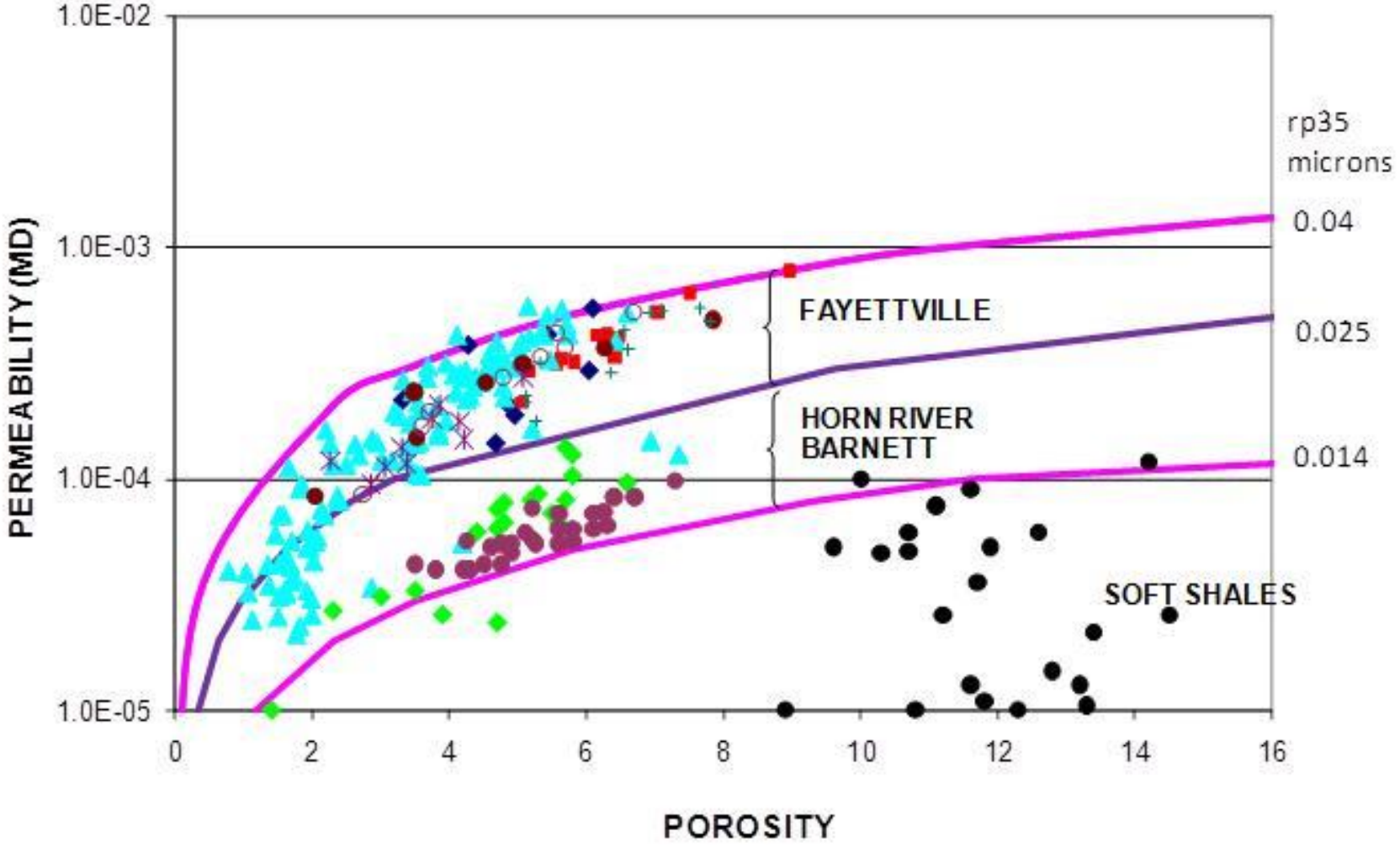


Flow Units, Cardium SS, Pembina Oil Field (Source of Data: MacKenzie, 1975; Hamm and Struyk, 2011)



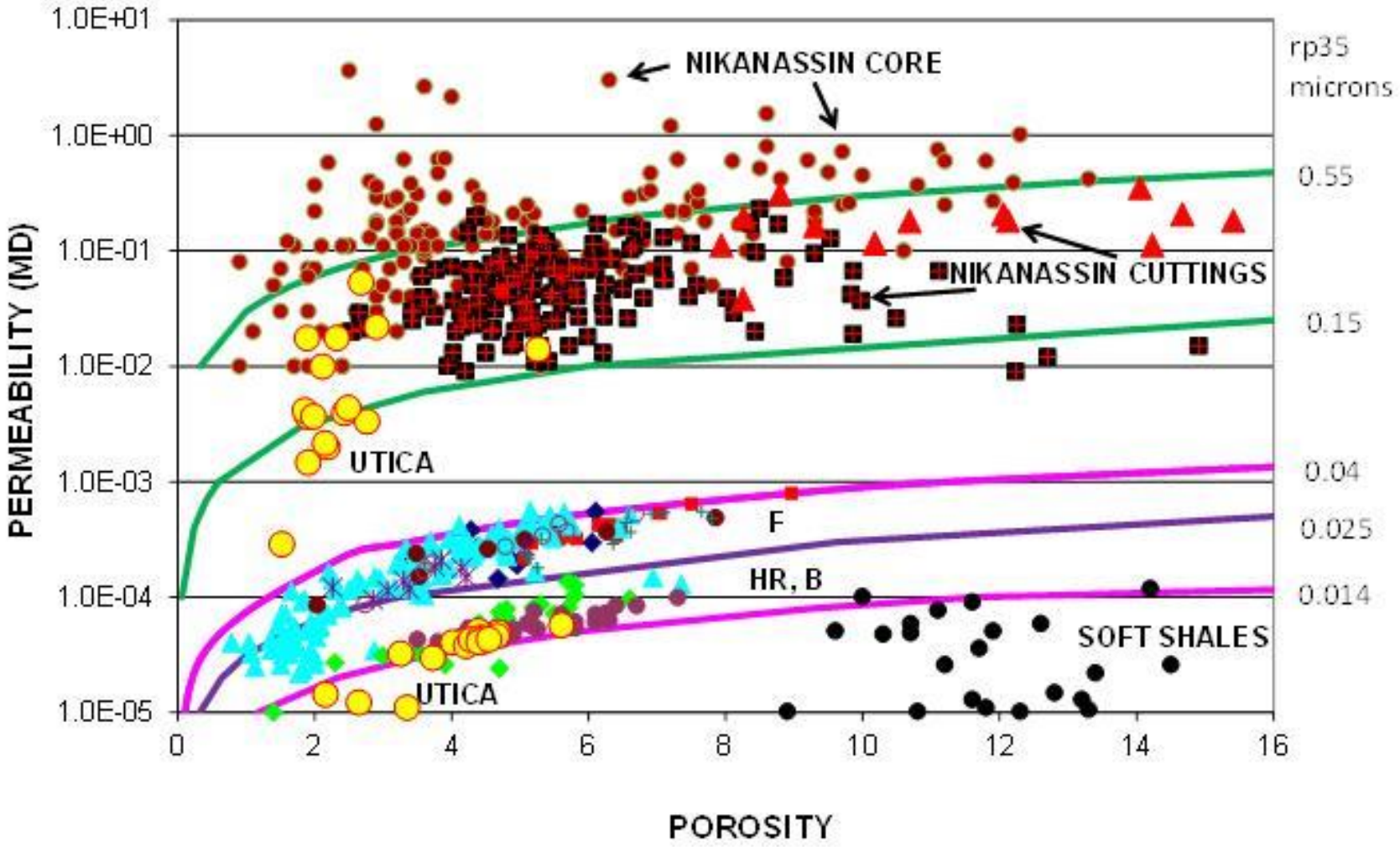
Real Data
Shale Gas

Flow Units: Shale Gas (SPE 132845)



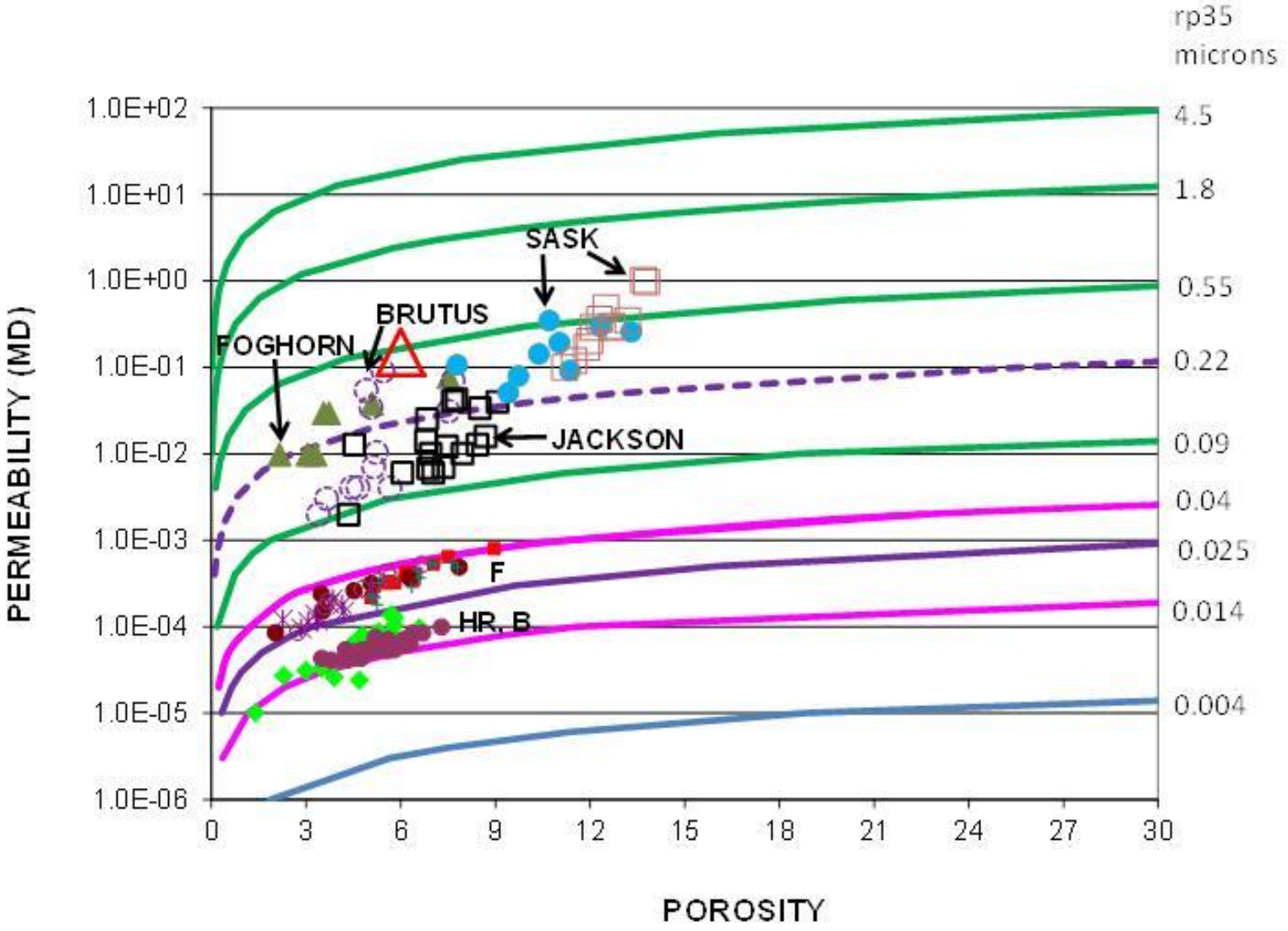
Real Data
Shale Gas and Tight Gas

Flow Units: Shale Gas and Tight Gas (SPE 132845)



Real Data
Tight Oil

Flow Units: Bakken Tight Oil



Flow Units, Cardium SS, Pembina Oil Field
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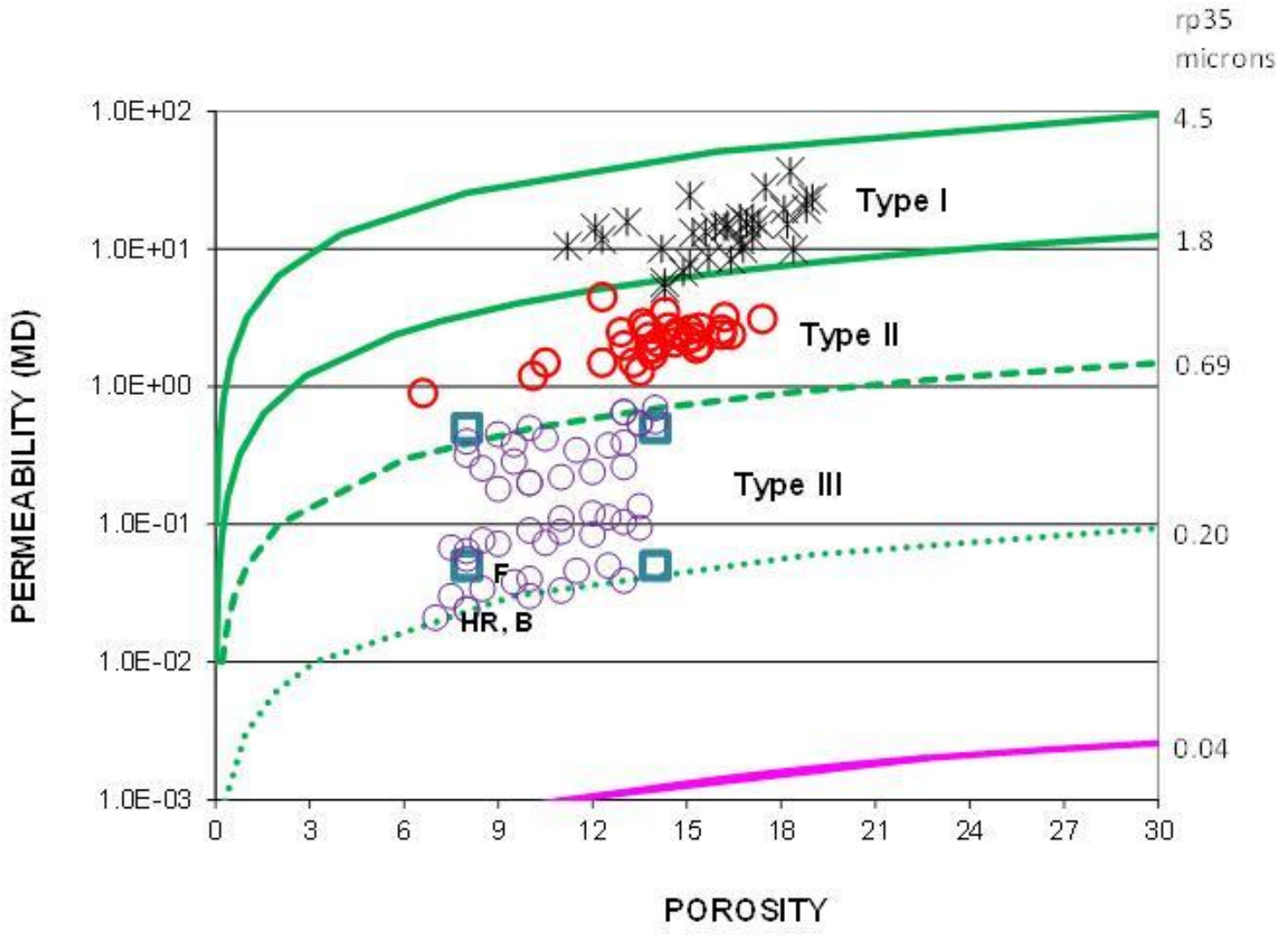
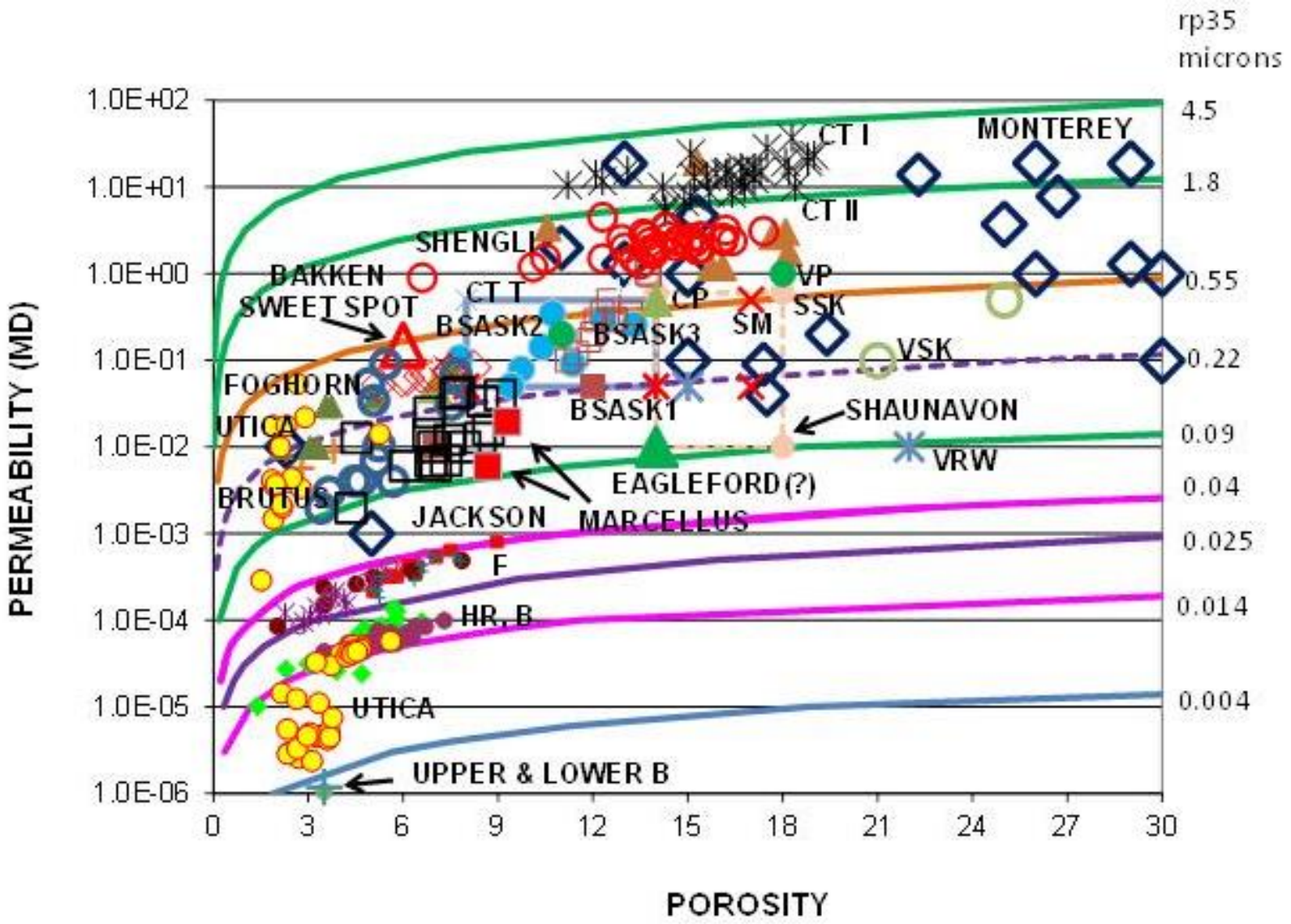


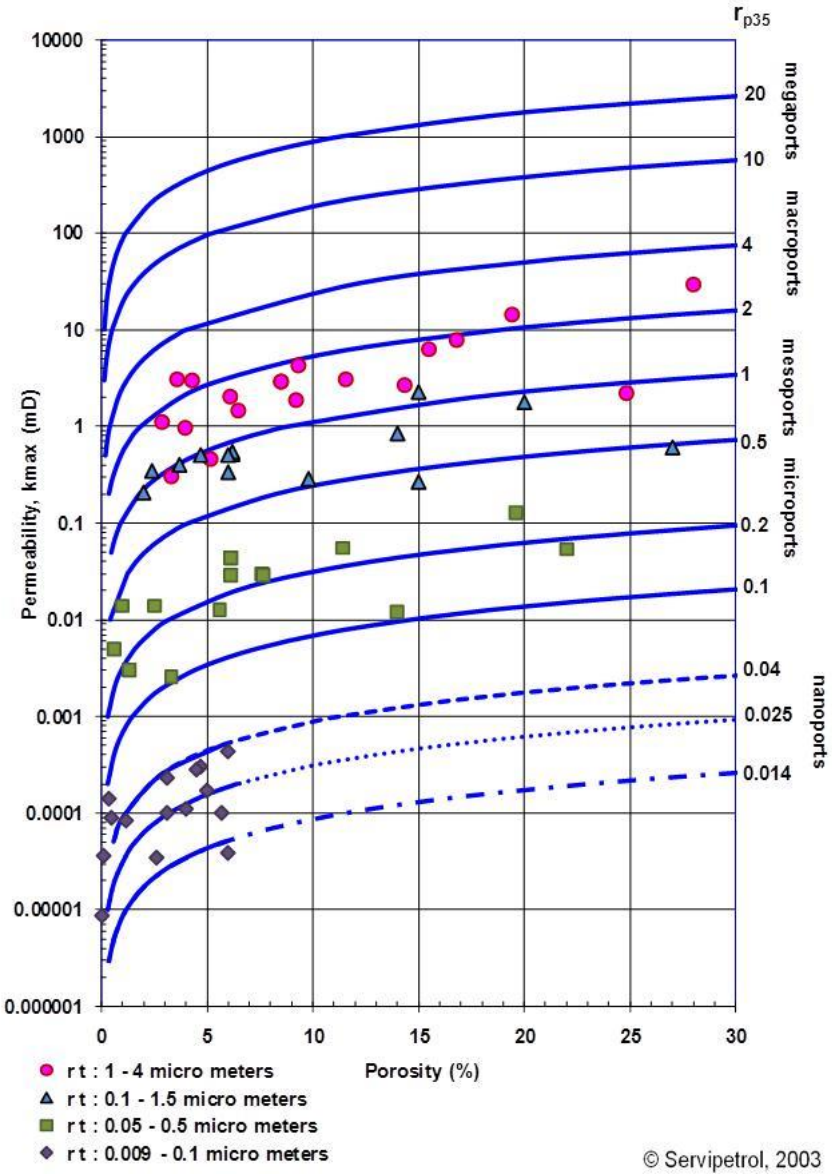
Flow Units: Tight and Shale



Theoretical Data
Pore Scale Modeling

Flow Units: Pore Scale Modeling

(Rahmanian et al., 2010)



Sleeping Giants

GFREE Management Style

G = geoscience

F = formation evaluation

R = reservoir drilling, completion & stimulation

RE = reservoir engineering

EE = economics and externalities

Utica Shale

Ryder (USGS, 2008) indicates that “based on black shale reservoirs in the Utica shale of the St. Lawrence Lowlands of Quebec (Aguilera, 1978), a hypothetical Utica shale reservoir is proposed in his report for the United States parts of the Appalachian basin.”

Utica (Quebec)* $\phi 2$ = 1.4%

Barnett** $\phi 2$ =1.5%

Marcellus** $\phi 2$ = 1.7%

Haynesville** $\phi 2$ = 1.2%

Utica (Quebec)* potential rec per well = 2.5 Bscf

Barnett*** potential rec per well = 2.65 Bscf

* Aguilera (SPE 7445, 1978)

**Wang and Reed, U of Texas (SPE 124253, 2009)

***Chesapeake (2010)

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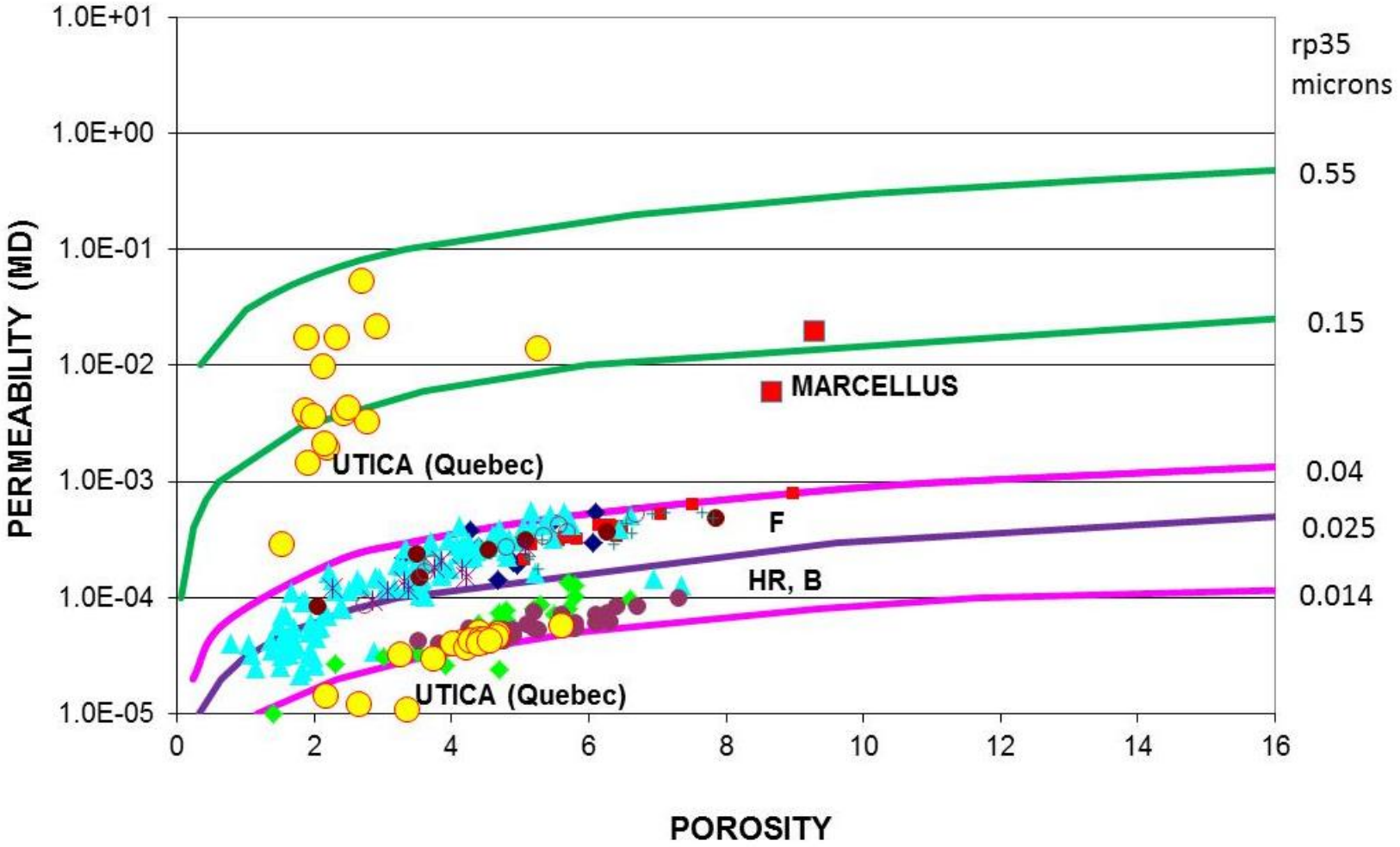
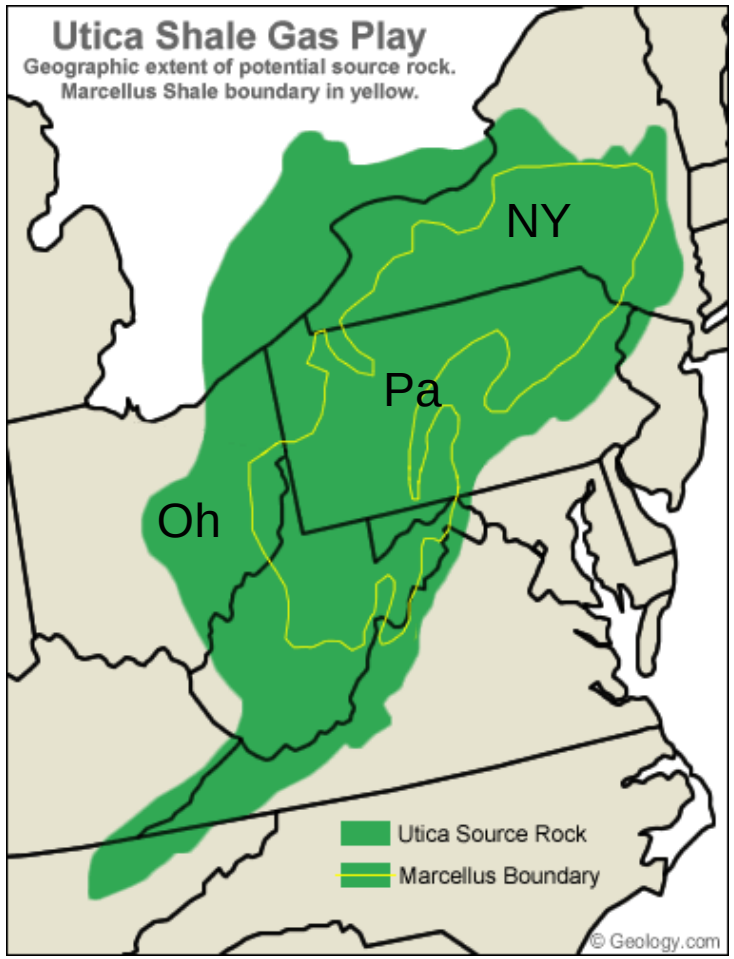
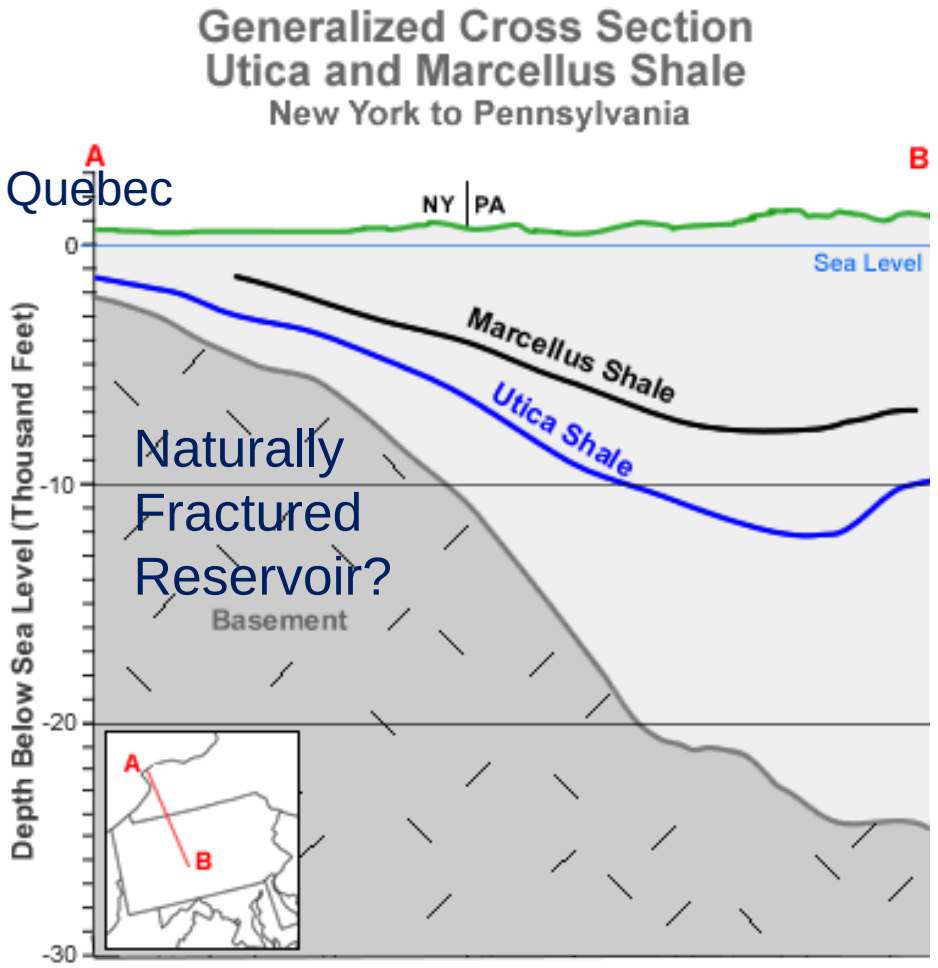


Utica Shale - The Natural Gas Giant Below the Marcellus?
(Adapted from Geology.com, 2010)

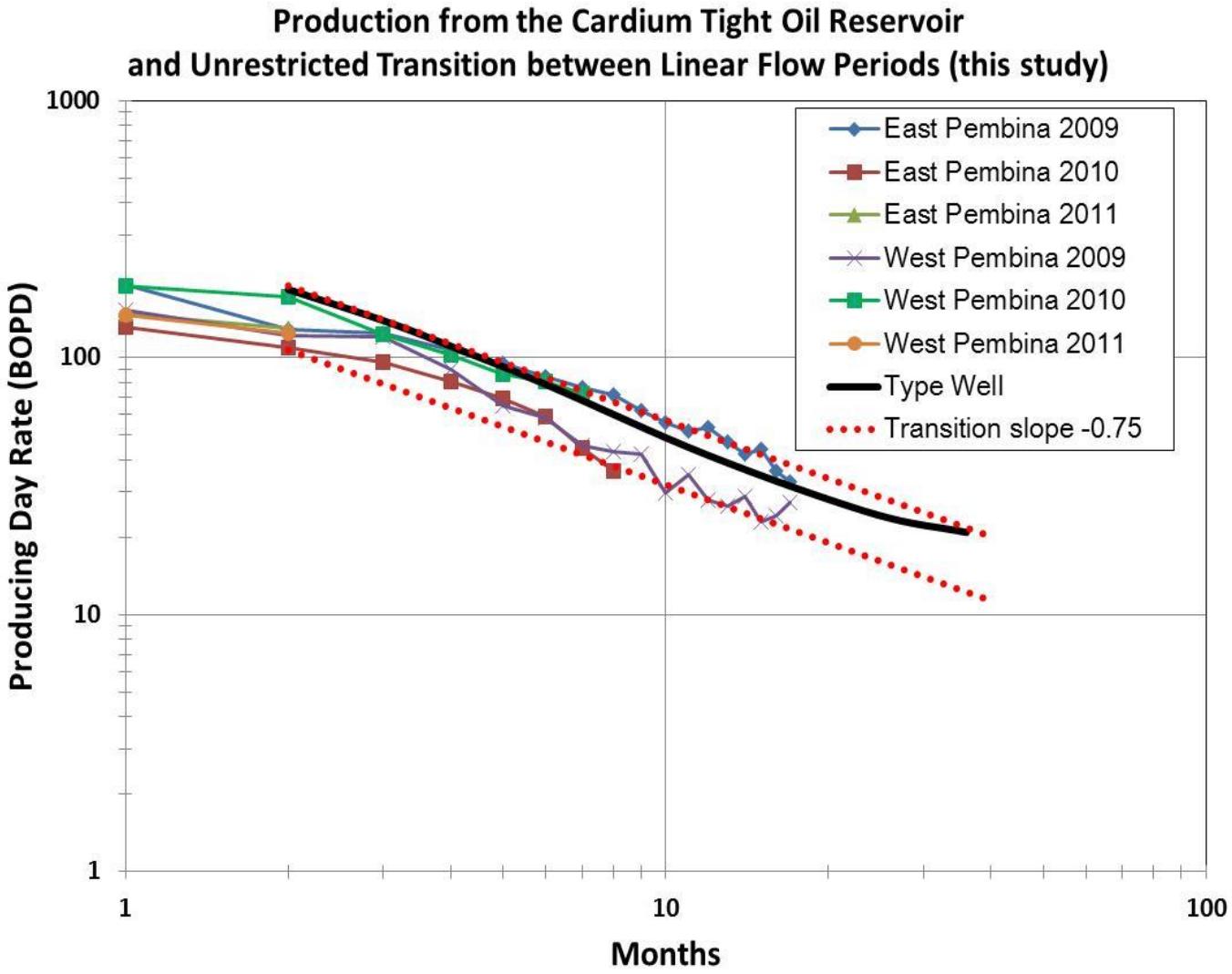




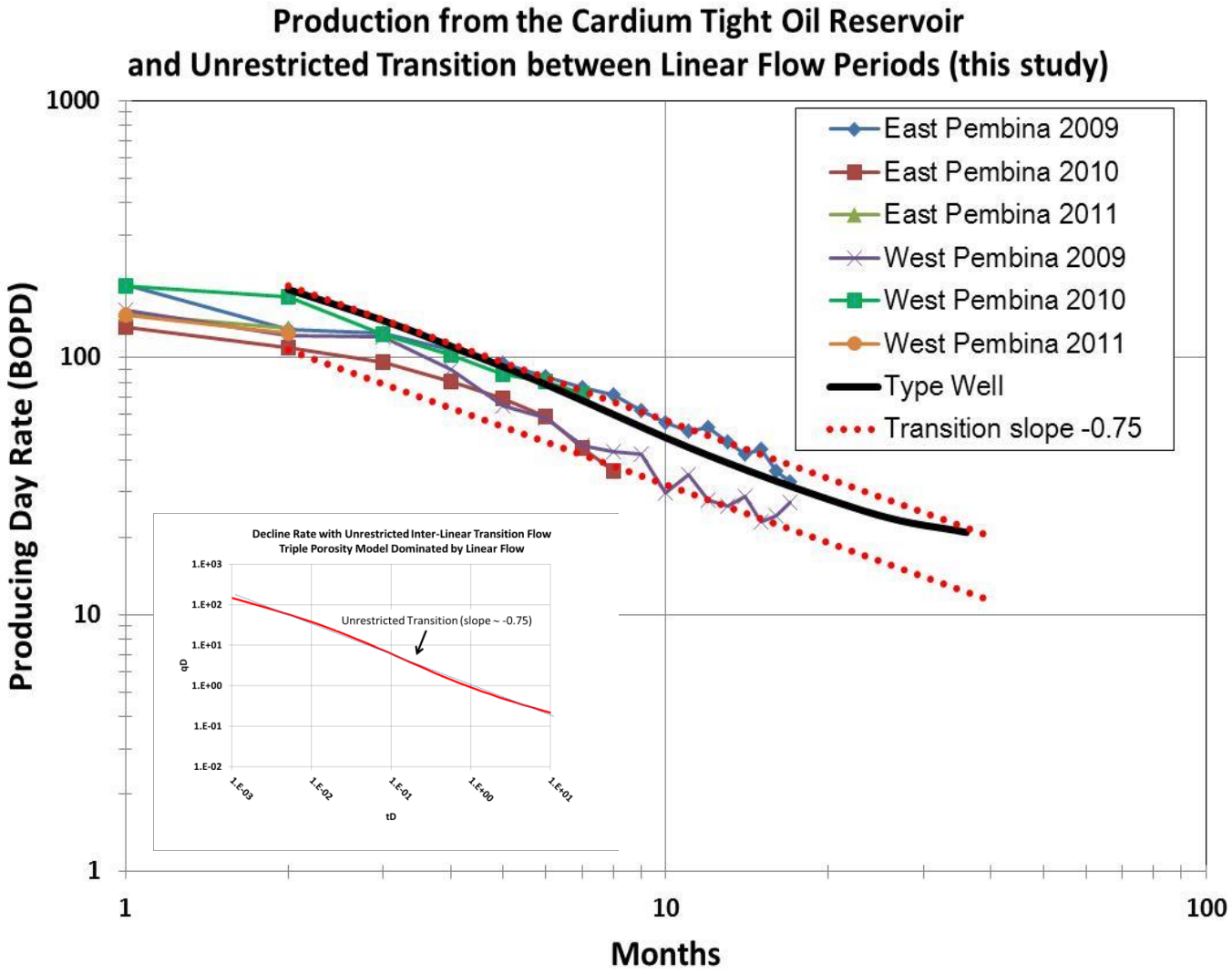
GFREE Research Team

Inter-linear Flow Period

Slope – 0.75


Production from the Cardium Tight Oil Reservoir
and Unrestricted Transition between Linear Flow Periods (this study)
Producing Day Rate (BOPD)
1000
100
10
1
1
10
100
Months
East Pembina 2009
East Pembina 2010
East Pembina 2011
West Pembina 2009
West Pembina 2010
West Pembina 2011
Type Well
Transition slope -0.75

Slope – 0.75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1000
100
10
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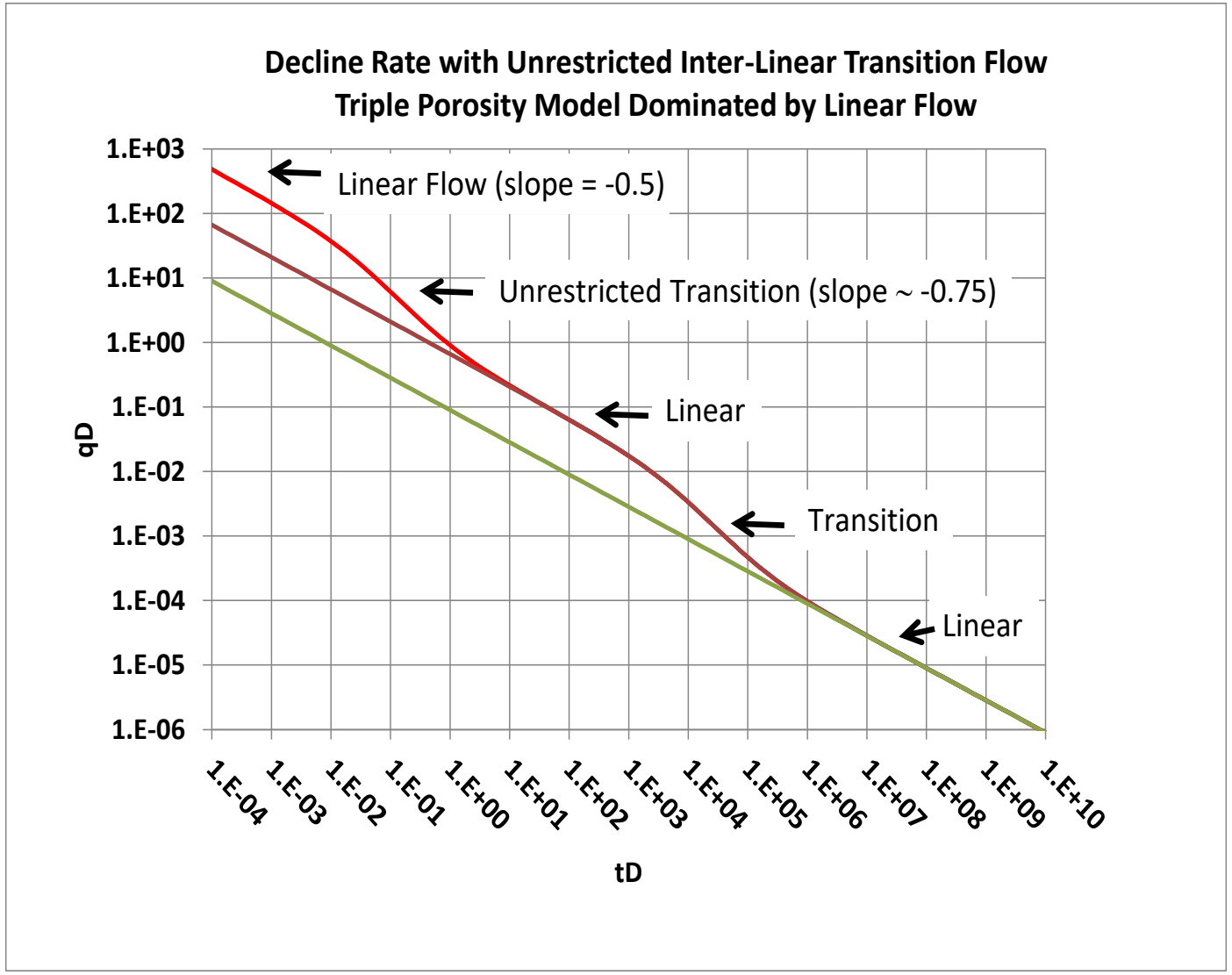
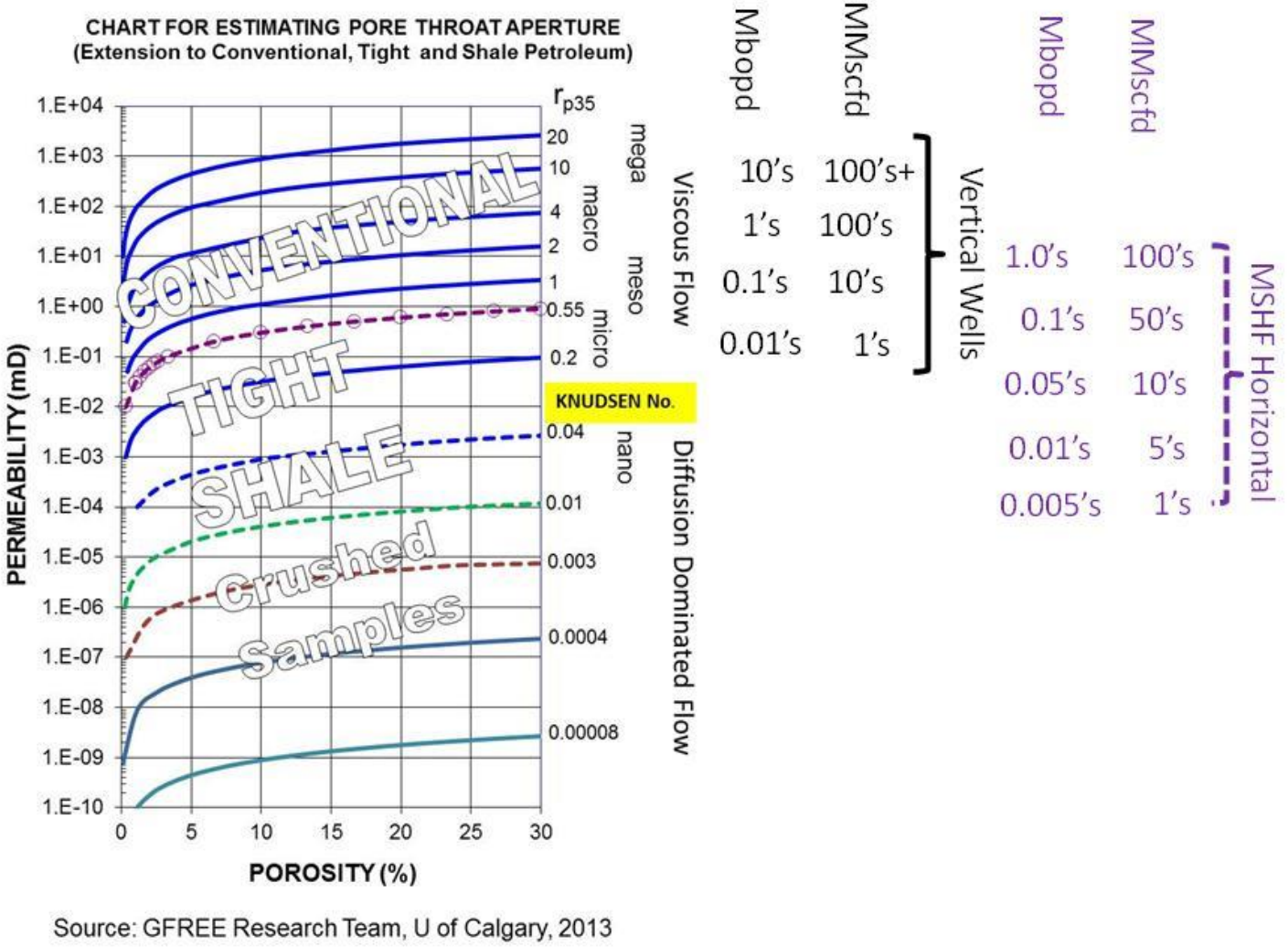
1
10
100
Months
East Pembina 2009
East Pembina 2010
East Pembina 2011
West Pembina 2009
West Pembina 2010
West Pembina 2011
Type Well
Transition slope -0.75
Decline Rate with Unrestricted Inter-Linear Transition Flow
Triple Porosity Model Dominated by Linear Flow
Unrestricted Transition (slope ~ -0.75)
qD
tD
1.E+03
1.E+02
1.E+01
1.E+00
1.E-01
1.E-02
1.E-03
1.E-02
1.E-01
1.E+00
1.E+01


Decline Rate with Unrestricted Inter-Linear Transition Flow
Triple Porosity Model Dominated by Linear Flow
Linear Flow (slope = -0.5)
Unrestricted Transition (slope ~ -0.75)
Linear
Transition
Linear
qD
1.E+03
1.E+02
1.E+01
1.E+00
1.E-01
1.E-02
1.E-03
1.E-04
1.E-05
1.E-06
1.E-04
1.E-03
1.E-02
1.E-01
1.E+00
1.E+01
1.E+02
1.E+03
1.E+04
1.E+05
1.E+06
1.E+07
1.E+08
1.E+09
1.E+10
tD

Flow Units and Potential Oil and Gas Rates

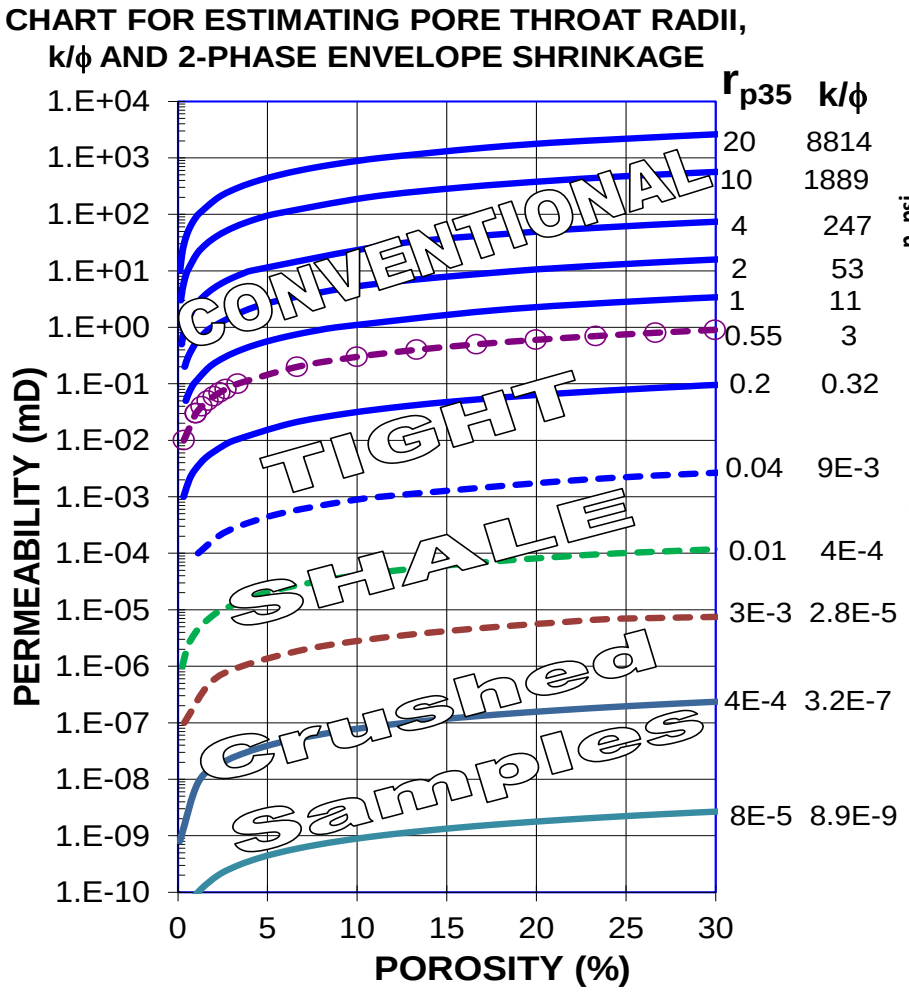
Microsimulation at the pore throat level will supplement results of r_p, k, phi, rel perms, cap pressures, electrical properties, rock mechanics

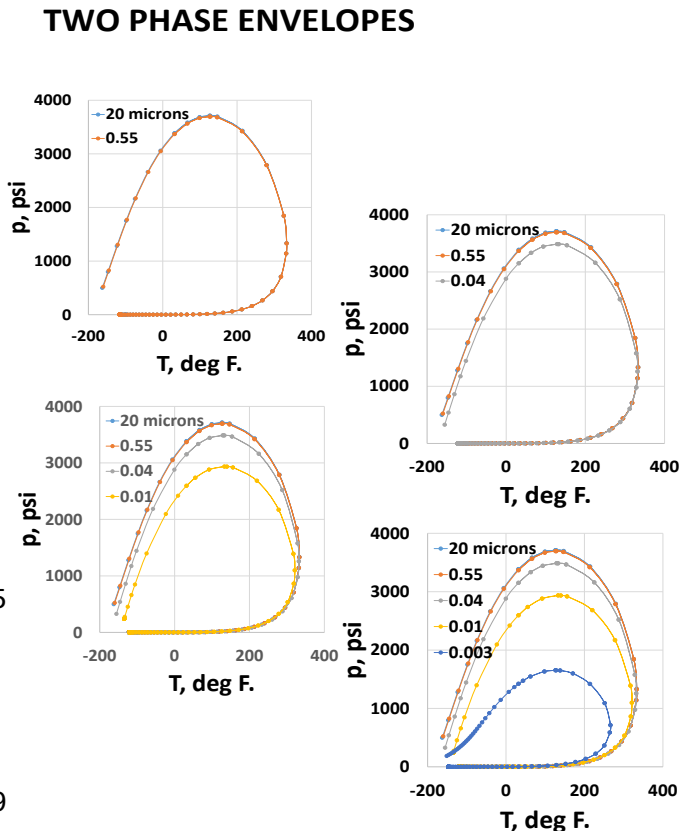
Brittle?
Ductile?
Type of Stimulation?
Effect of Sw, mud
Filtrate, leak-off on embedment?



Source: GFREE Research Team, U of Calgary, 2013

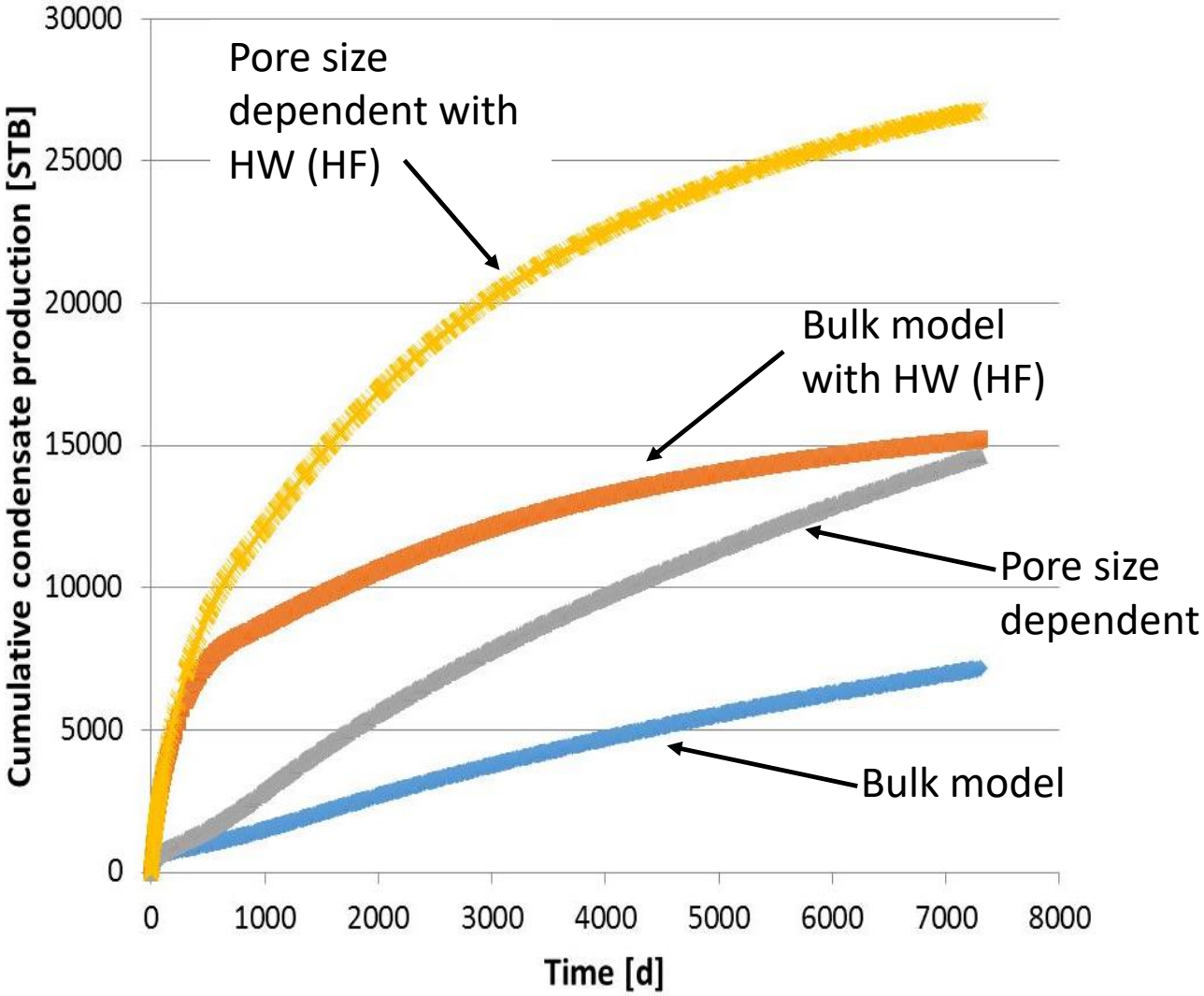
Flow Units and Critical Properties Shift





Source: GFREE Research Team, U of Calgary, 2015

Cumulative Production



CONCLUSIONS

1. Process (or delivery) speed, i.e., the ratio of permeability and porosity, provides a continuum between conventional, tight gas, shale gas, tight oil and shale oil reservoirs.
2. There are distinctive flow units for each type of reservoir penetrated by vertical and horizontal multi-stage hydraulically fractured wells that can be linked empirically to possible gas and oil rates and under favorable conditions to the type of production decline.

CONCLUSIONS

3. A new unrestricted transition flow period in tight oil reservoirs has been recognized by considering a triple porosity model that leads to a straight line with a negative slope equal to 1.00 on log-log coordinates. This straight line occurs as a transition between 2 linear flow periods.
4. To make the work tractable the bulk of the data presented in this paper have been extracted from published geologic and petroleum engineering literature
5. Pore size plays an important role on recovery of liquids in condensate reservoirs.

Acknowledgements

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CNOOC - NEXEN
NSERC
AIEES
GFREE Research Team
Schulich School of Engineering at U of C
Servipetrol Ltd.

Thank You