Reservoir Quality and Petrophysical Model of the Tarn Deep-Water Slope-Apron System, North Slope, Alaska

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Pacific Section AAPG
May 8, 2006

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Natural
Resources

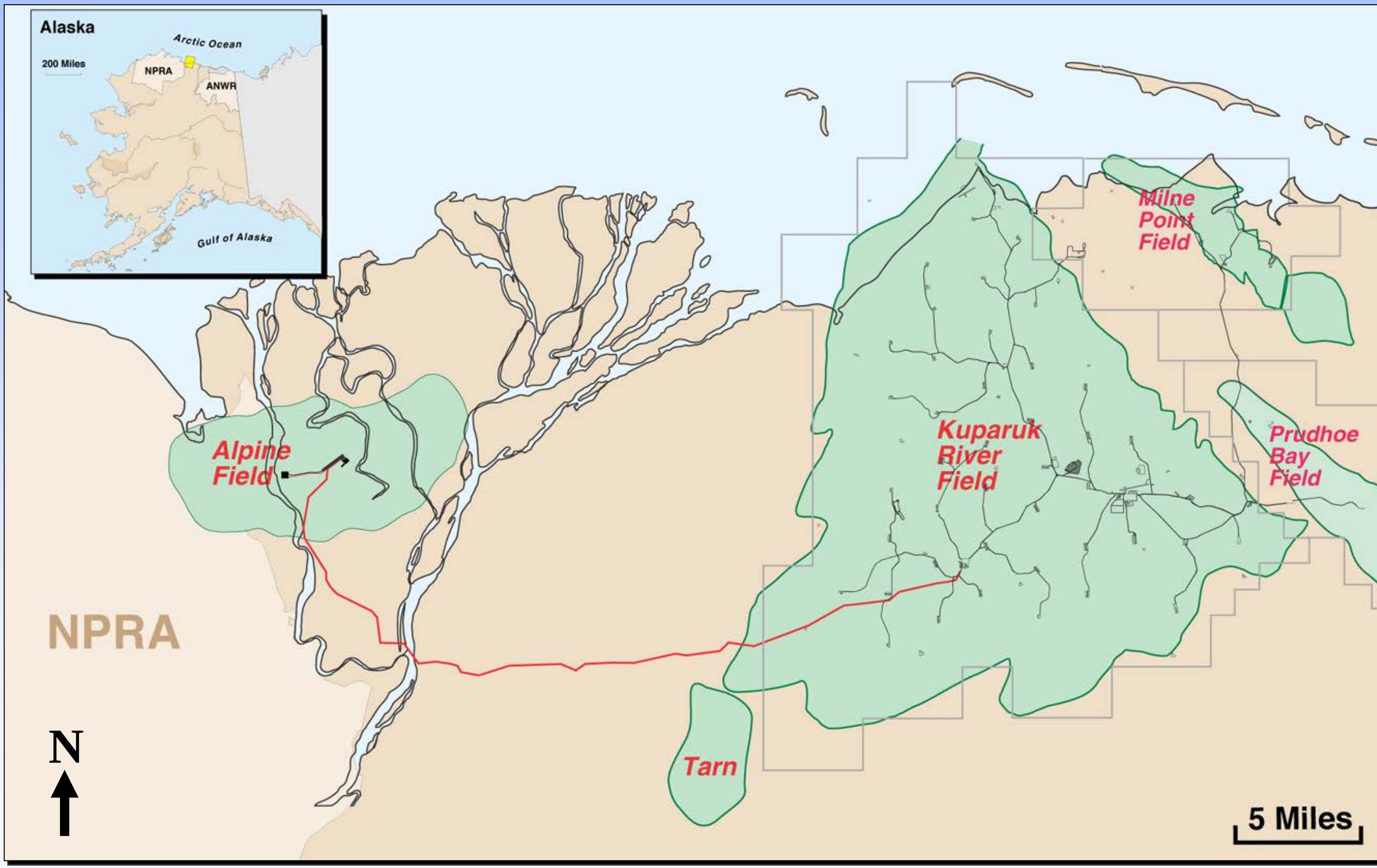
Outline

- Regional setting
- Petrology of sandstones
- Facies and reservoir quality
- Regional reservoir quality model
- Petrophysical model
- Conclusions

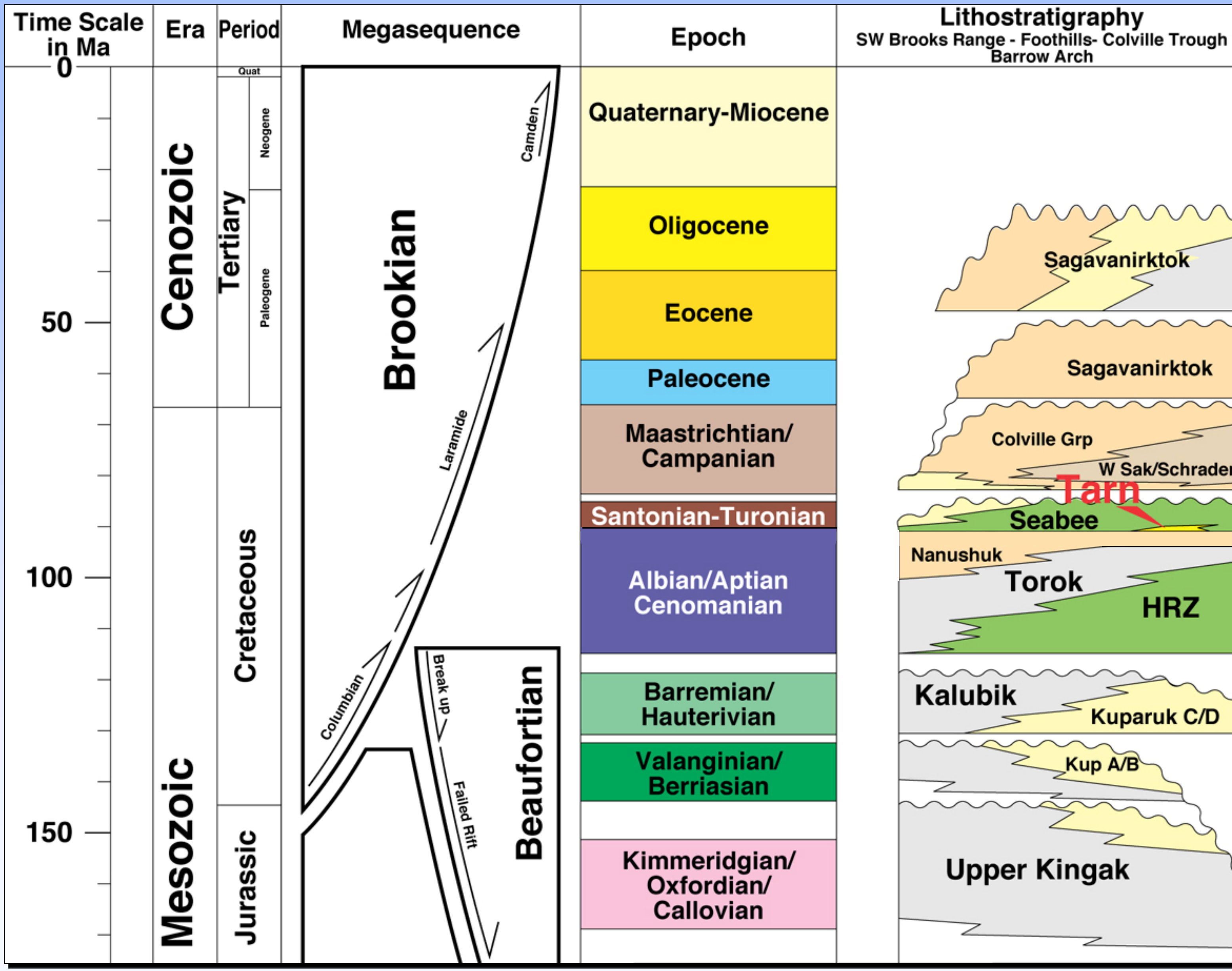
Conclusions

- **Reservoir quality is initially controlled by textural parameters related to turbidite elements**
- **Channels are the best reservoirs followed by lobes, crevasse splays and levees**
- **Mechanical compaction exerts a strong regional control on reservoir quality**
- **Reservoir quality of Brookian sandstones can be accurately predicted prior to drilling**
- **Petrophysical model is complicated by abundance of structural clay and low-density zeolite**

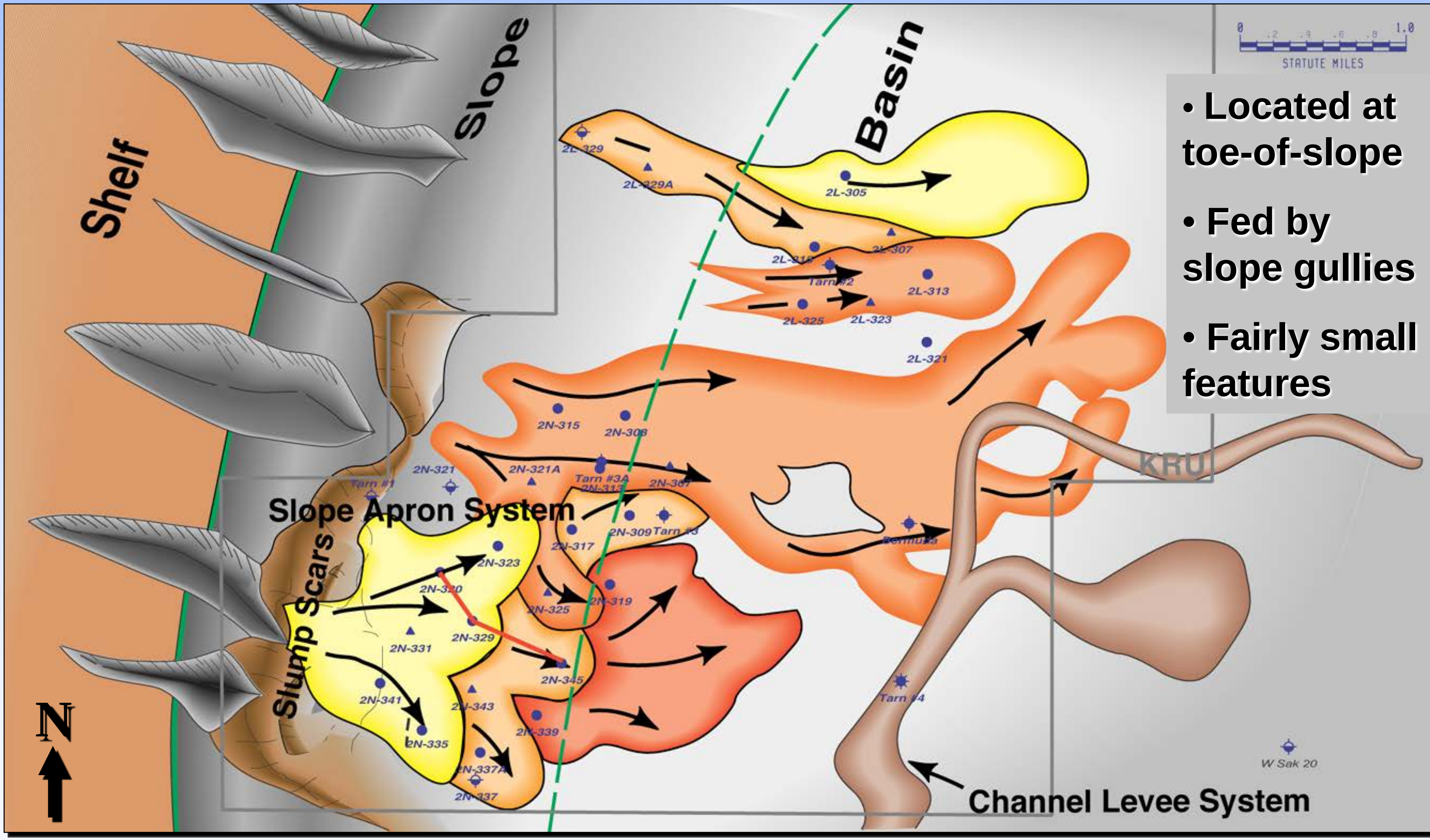
Location of Tarn Field



Stratigraphic Column of North Alaska



Tarn Slope-Apron Deposits



- Located at toe-of-slope
- Fed by slope gullies
- Fairly small features

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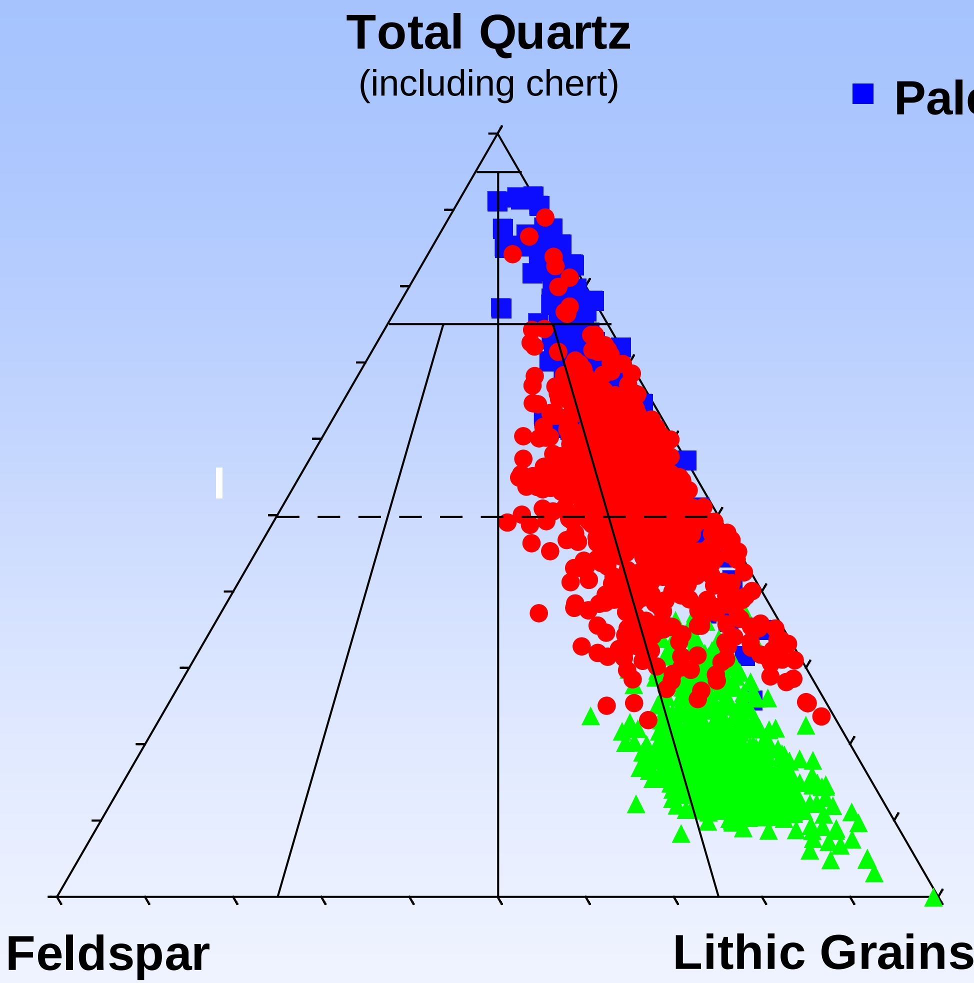
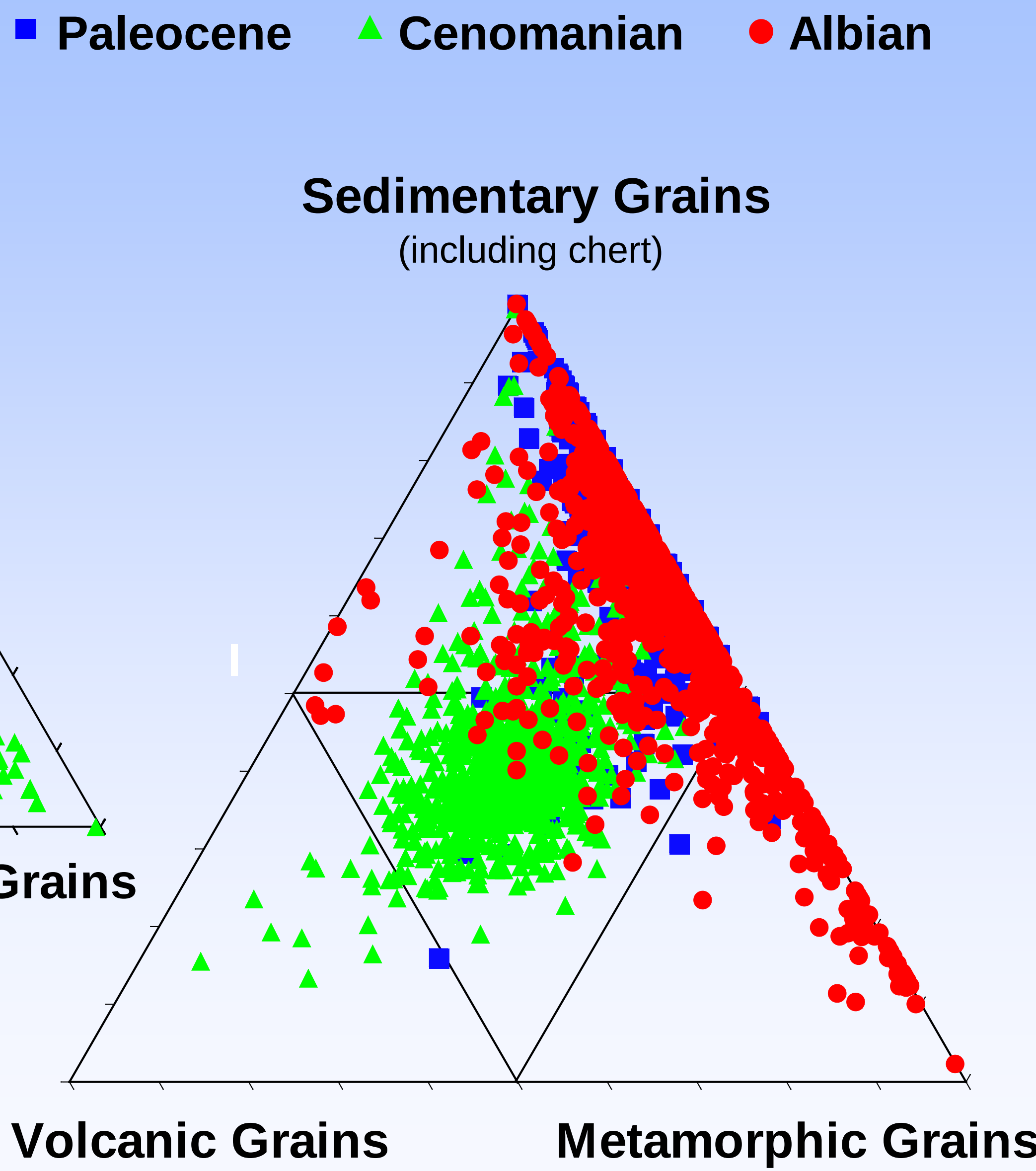
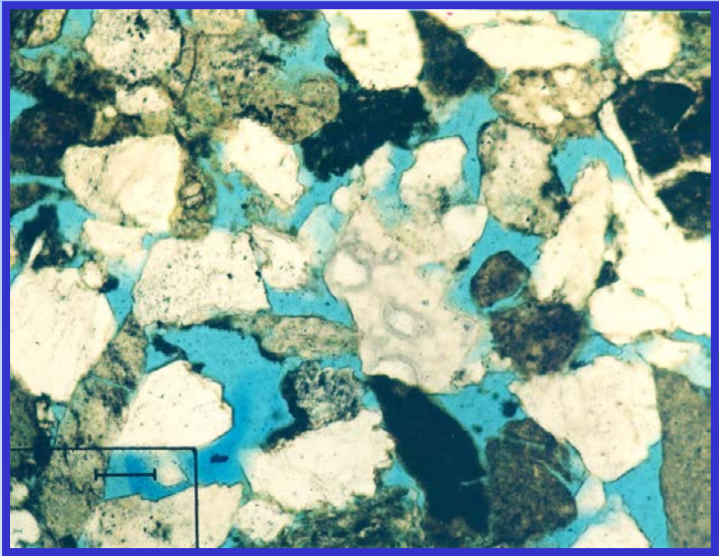
Brookian Sandstone Composition



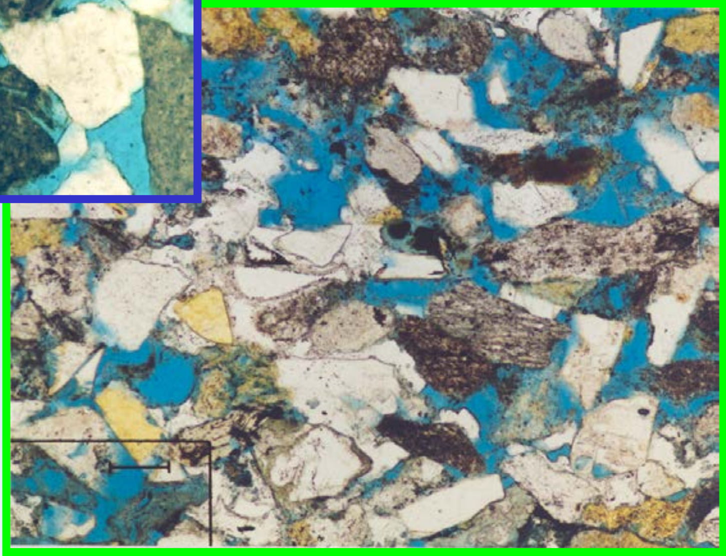


Cenomanian sands are lithic rich with abundant volcanic rock fragments

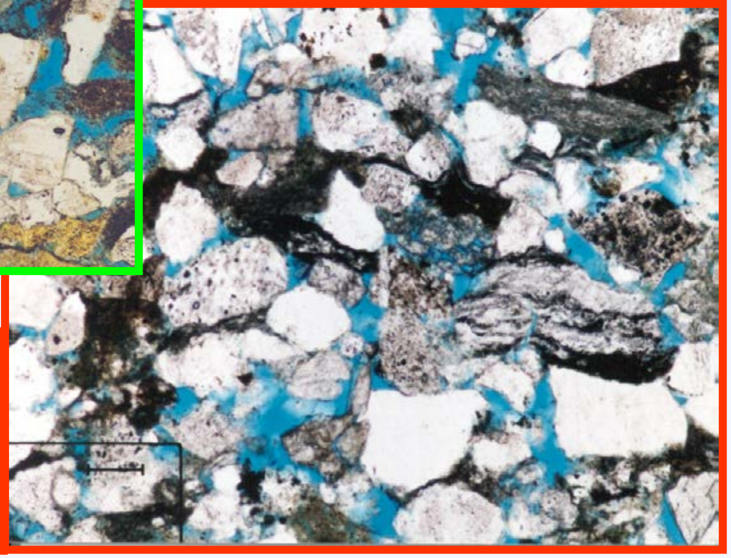
Typical Brookian Sandstones



Paleocene (Flaxman)
Chert rich
Medium-grain sand



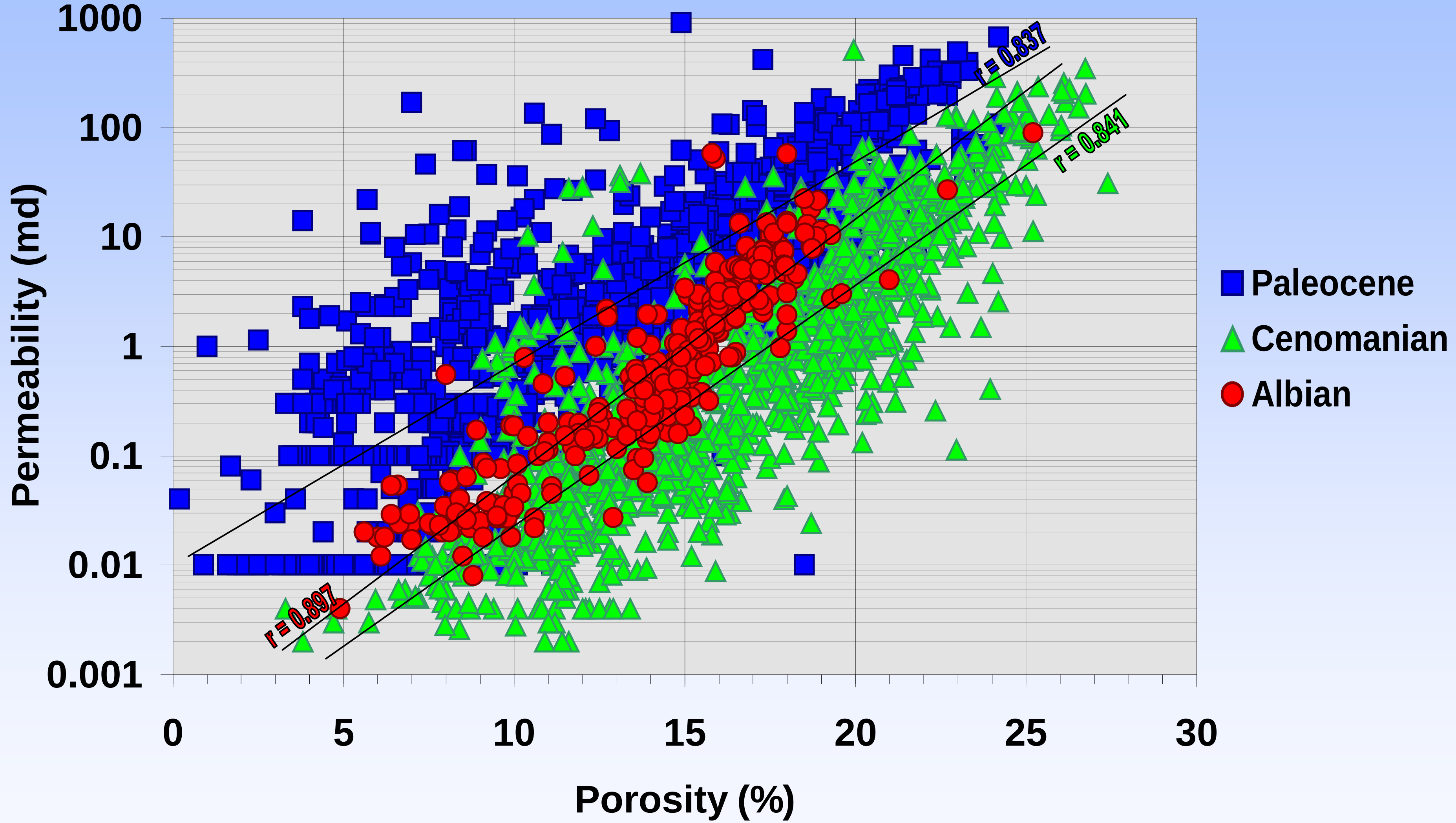
Cenomanian (Tarn)
Volcanic glass rich
Analcime cement



Albian (Torok)
Argillaceous rich RF
Generally lack cement

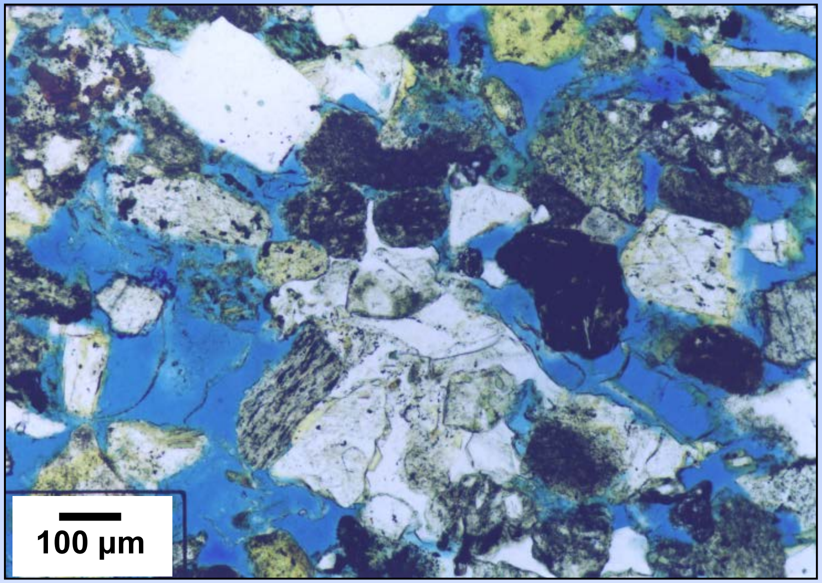
100 µm

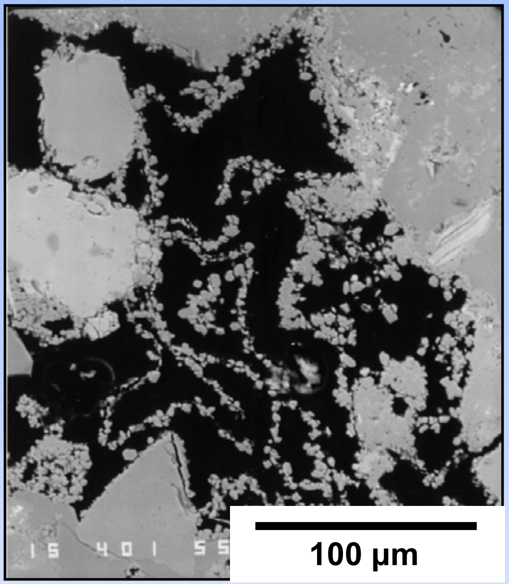
Brookian Sandstone Phi-K Trends

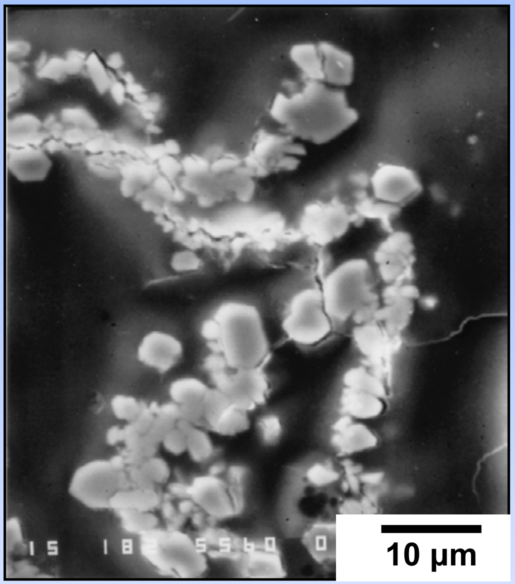


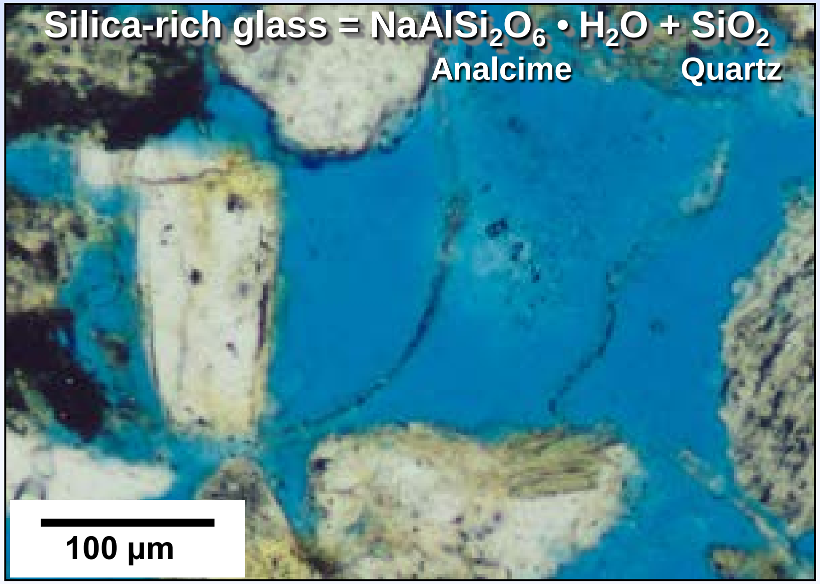
1 md K cutoff = Phi of 12% Paleocene, 15% Albian, 17% Cenomanian

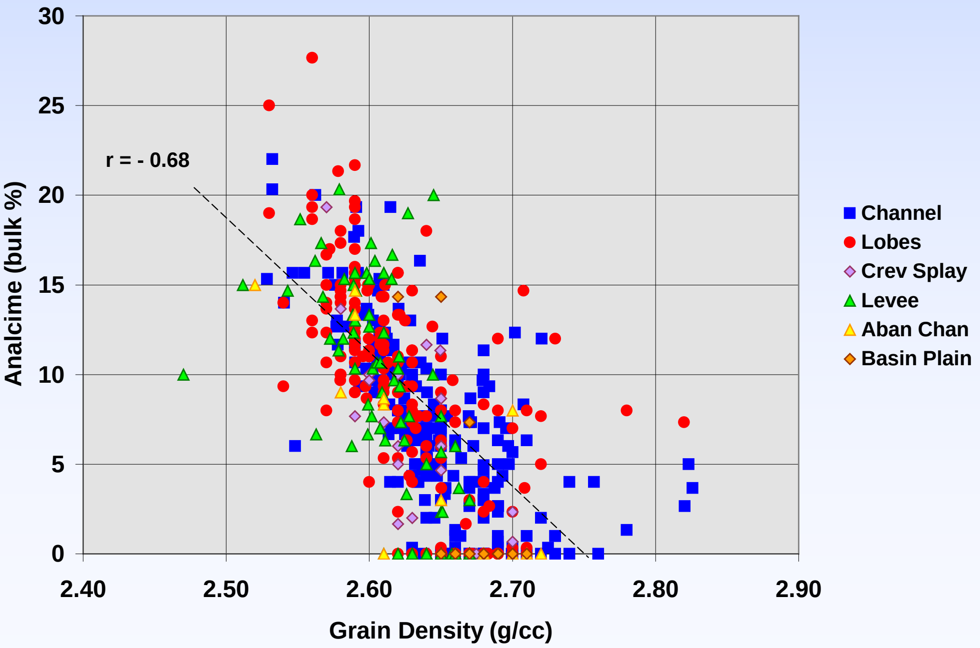
Analcime and Microcrystalline Rims











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- Petrology of sandstones
- **Facies and reservoir quality**
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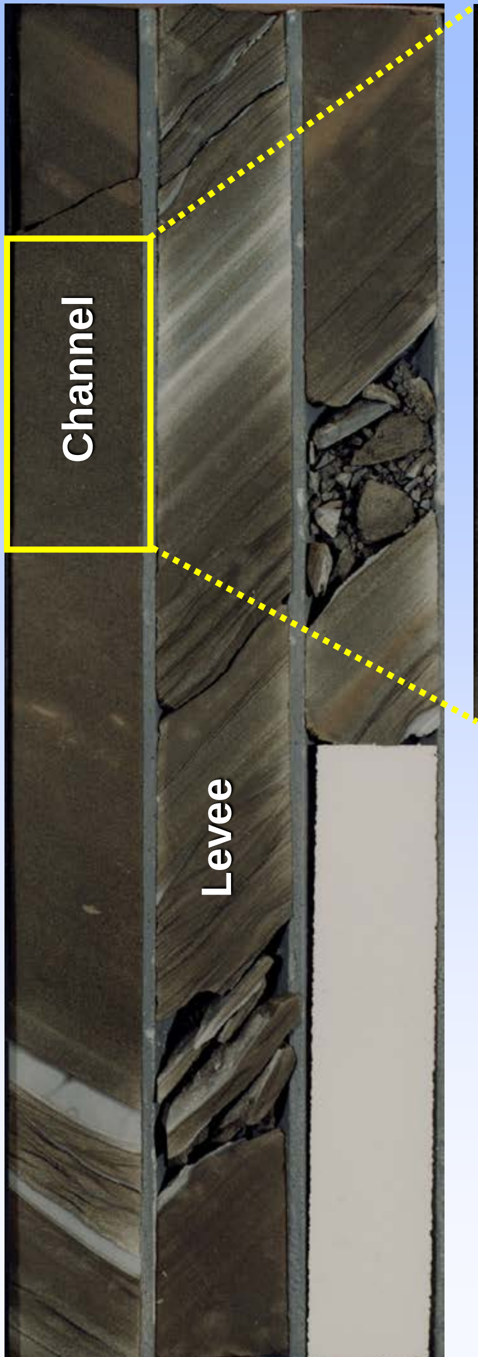
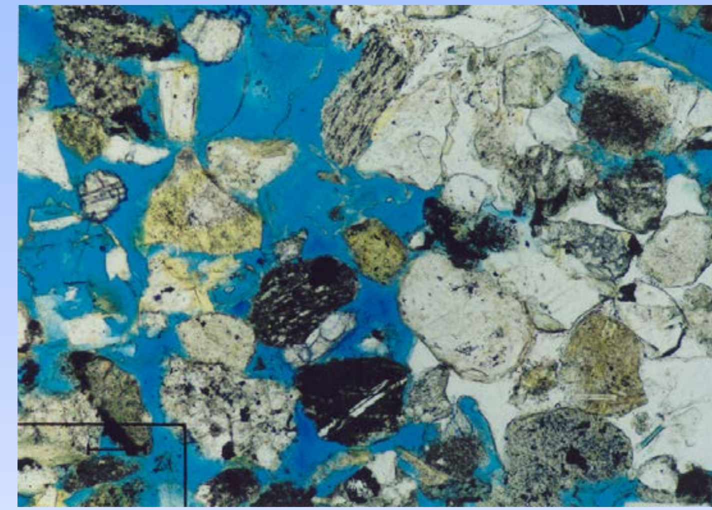
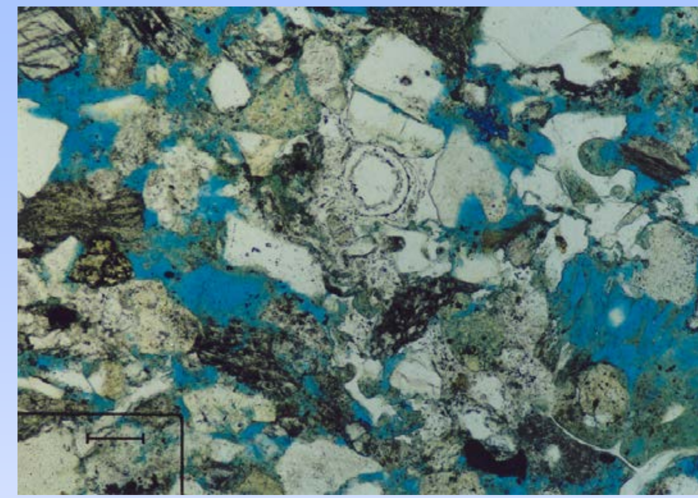
Channel Facies



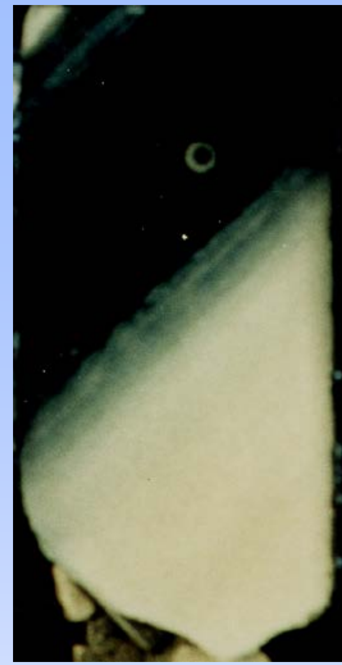


Sedimentary Facies:	Amalgamated Ta, some Tb, Tabc, Tc (climbing at margins)
Bed Thickness:	Thin to very thick
Grain Size:	Very fine to fine-grain sand
Avg. Porosity:	20 %
Avg. Permeability:	33 md
Avg. H_2O saturation:	46 %
Avg. Dispersed clay:	4 %

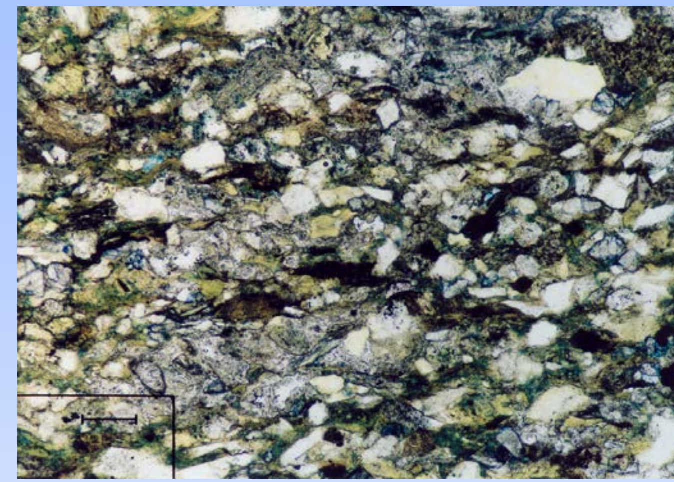
Lobe Facies



Sedimentary Facies:	**Tace, Tabe, Tabce, Tbce, occasional Tae, Tbe**
Bed Thickness:	**Thin to very thick, rare very thin**
Grain Size:	**Very fine- to fine-grain sand, rare mud**
Avg. Porosity:	**18 %**
Avg. Permeability:	**7 md**
Avg. H_2O saturation:	**61 %**
Avg. Dispersed clay:	**8 %**



Crevasse Splay Facies



Sedimentary Facies: Tce (climbing), Tb, Tabe, Tace, rare Tbe, Tbce

Bed Thickness: Very thin to thick

Grain Size: Very fine- to lower fine-grain sand, mud and silt

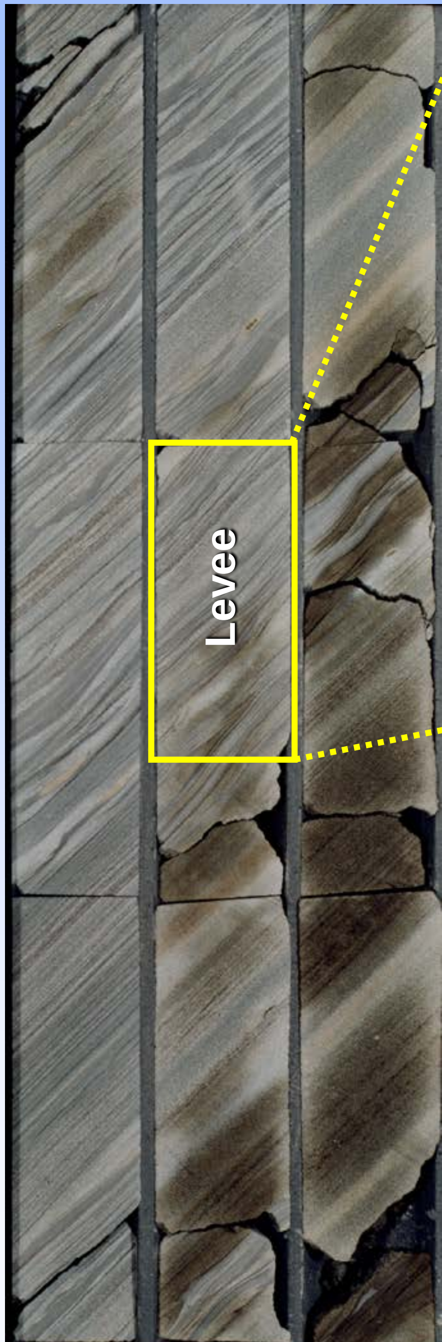
Avg. Porosity: 17 %

Avg. Permeability: 3 md

Avg. H_2O saturation: 64 %

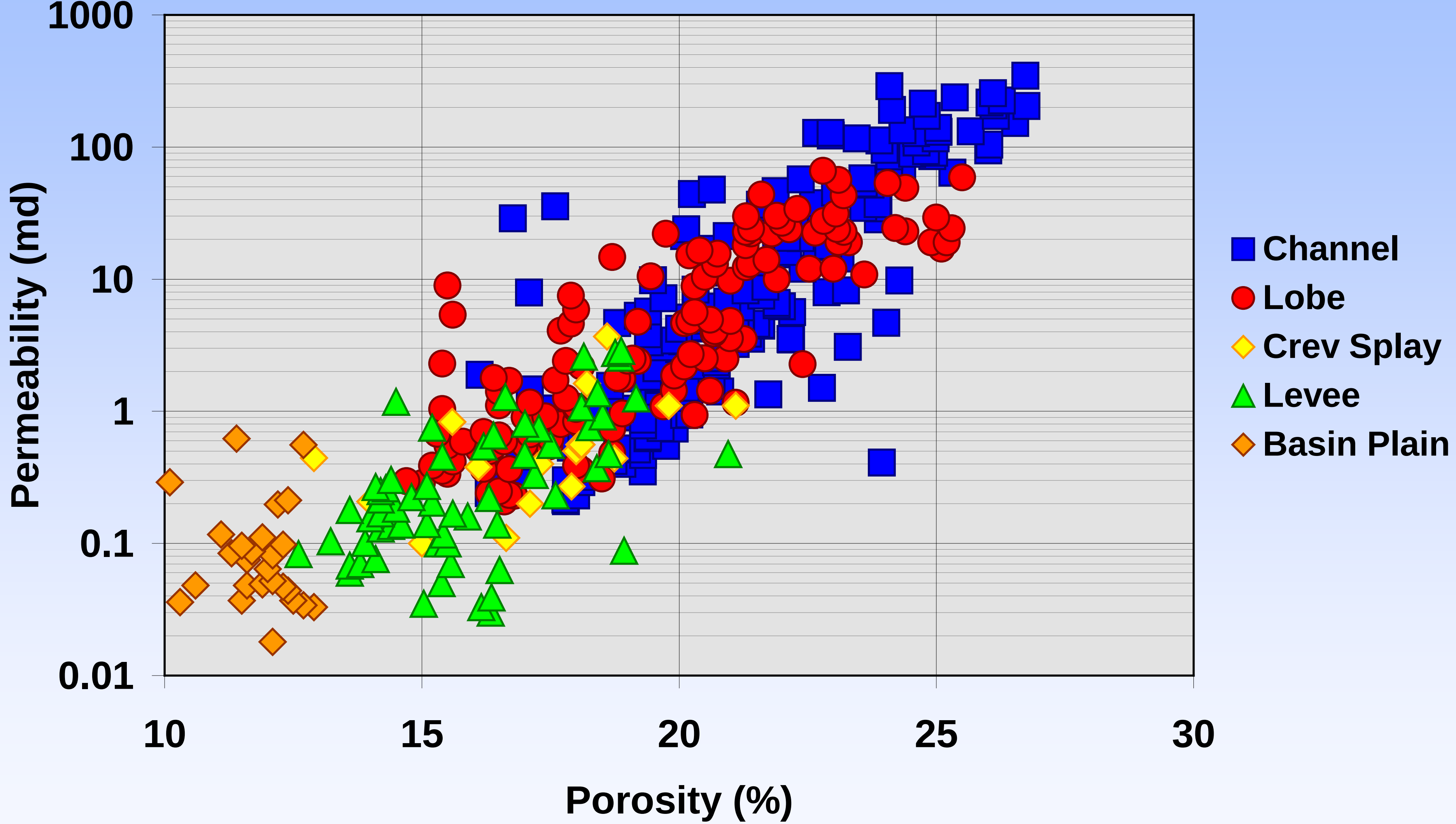
Avg. Dispersed clay: 13 %

Levee Facies



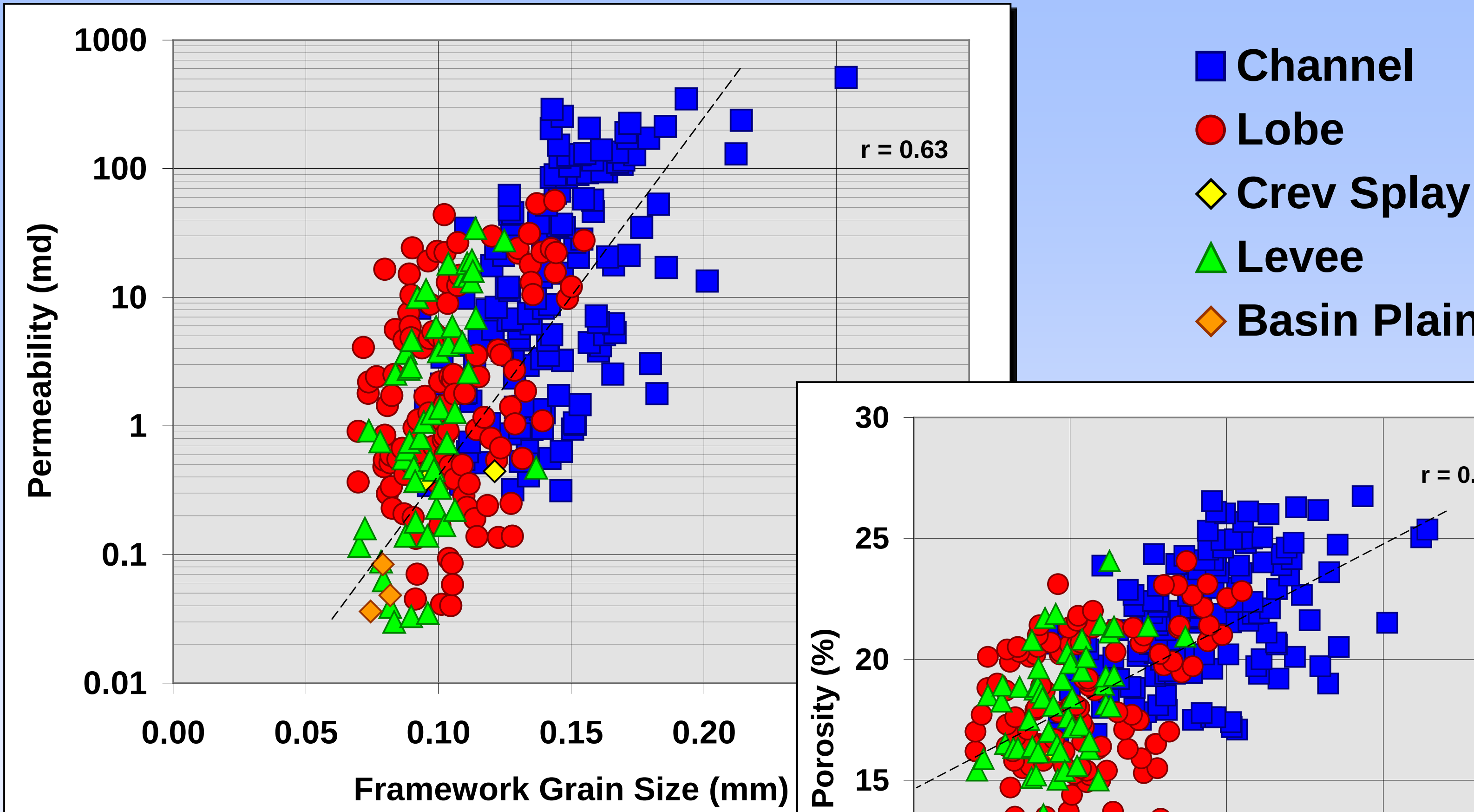
Sedimentary Facies:	Tce, Tc
Bed Thickness:	Very thin, rare thin
Grain Size:	Very fine-grain sand, mud and silt
Avg. Porosity:	16 %
Avg. Permeability:	2 md
Avg. H_2O saturation:	68 %
Avg. Dispersed clay:	22 %

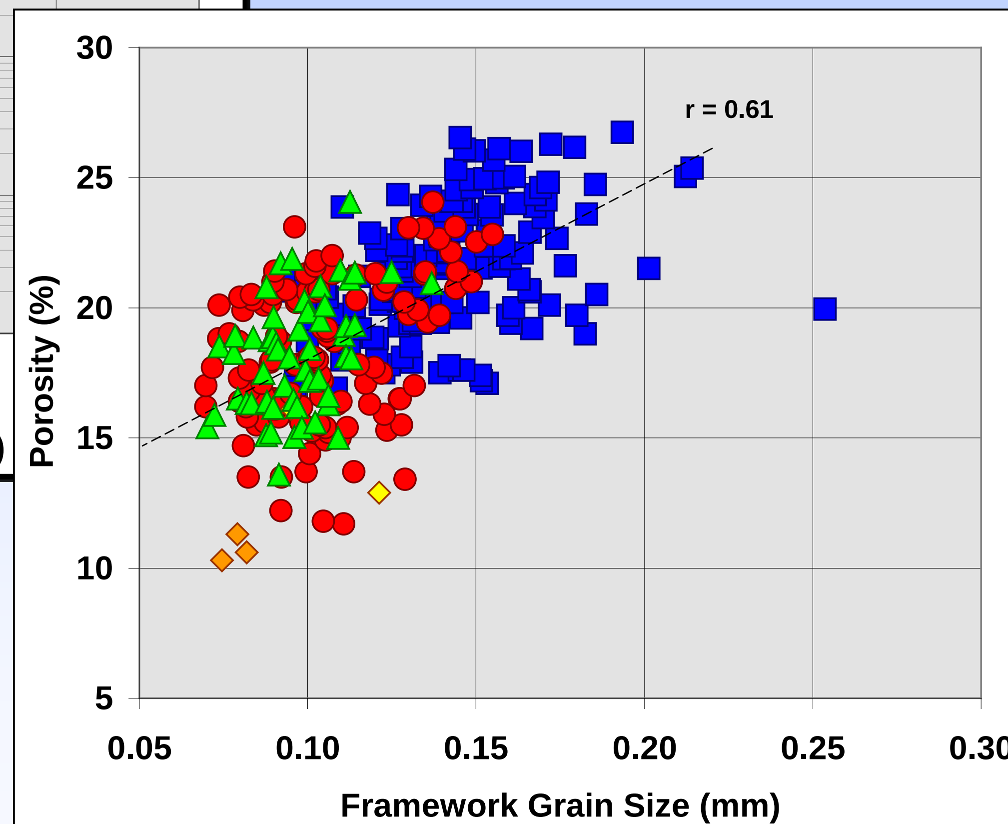
Depositional Control on Reservoir Quality



Best reservoirs in channels; poorest in levees and basin plain

Effect of Grain Size on Phi-K





Facies control on grain size is largely responsible for reservoir quality variability

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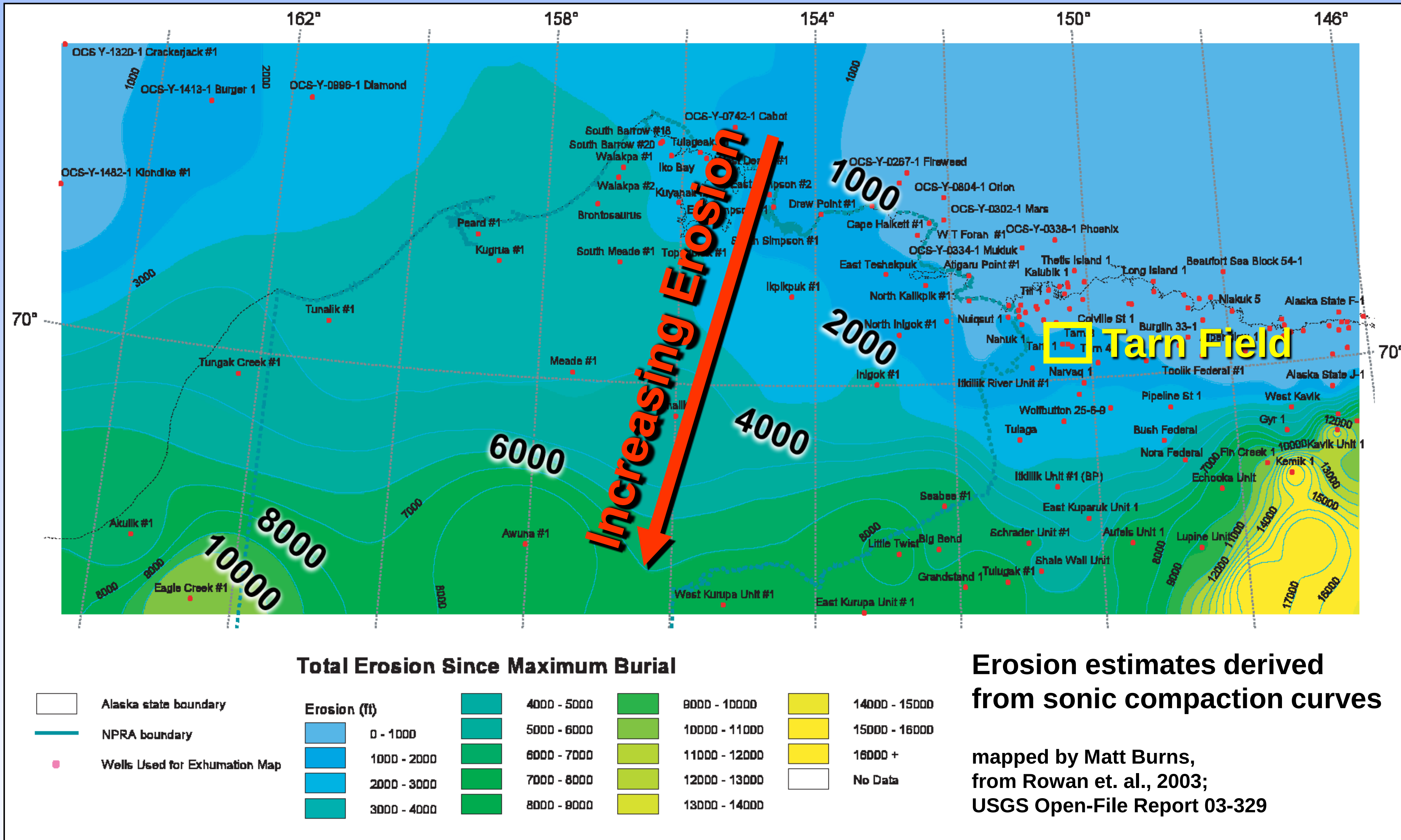
Brookian Erosion Map

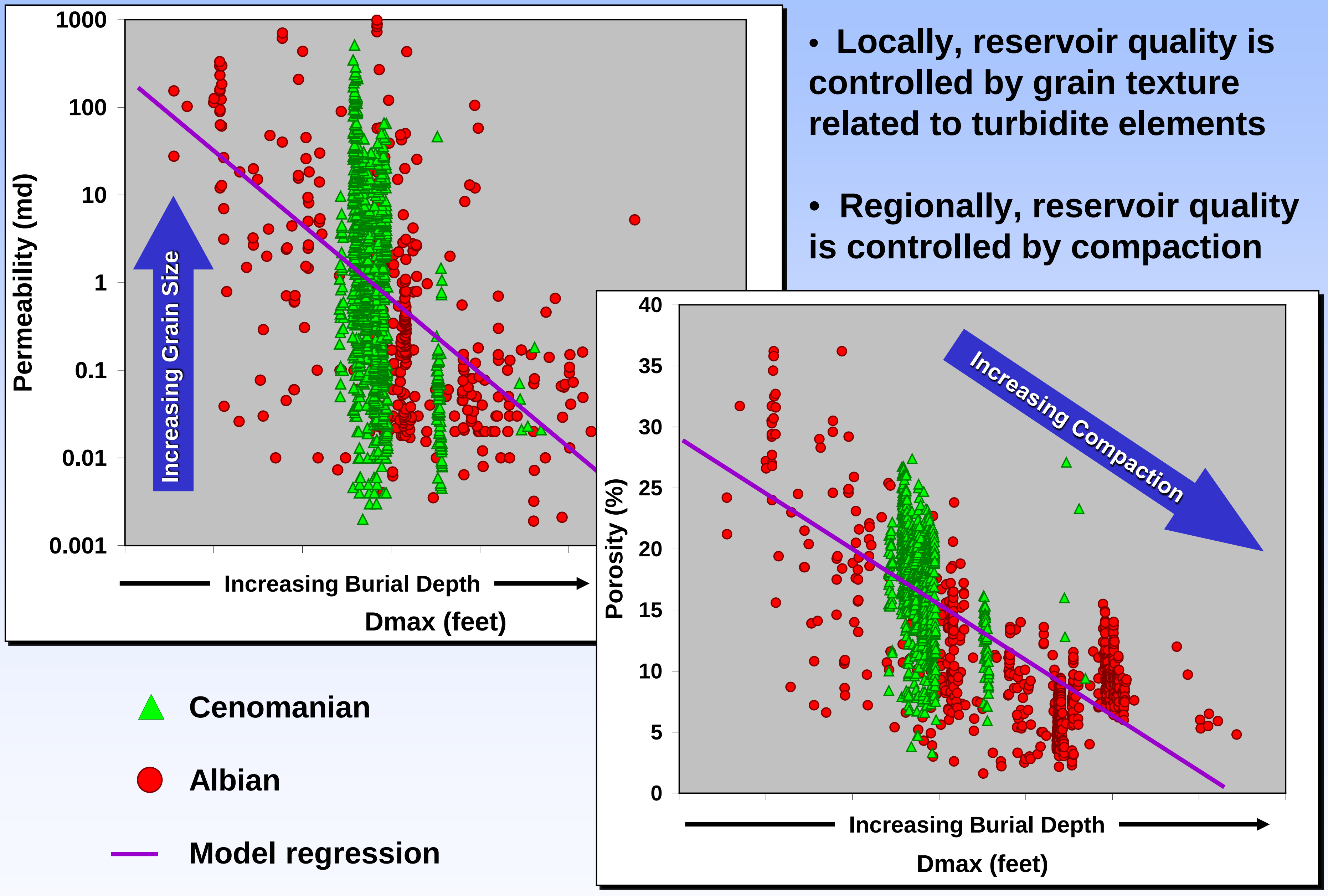


Erosion estimates derived from sonic compaction curves

mapped by Matt Burns,
from Rowan et. al., 2003;
USGS Open-File Report 03-329

Maximum Burial Depth (Dmax) = Present Depth (ft) + Brookian Erosion (ft)

Brookian Phi-K vs. Dmax

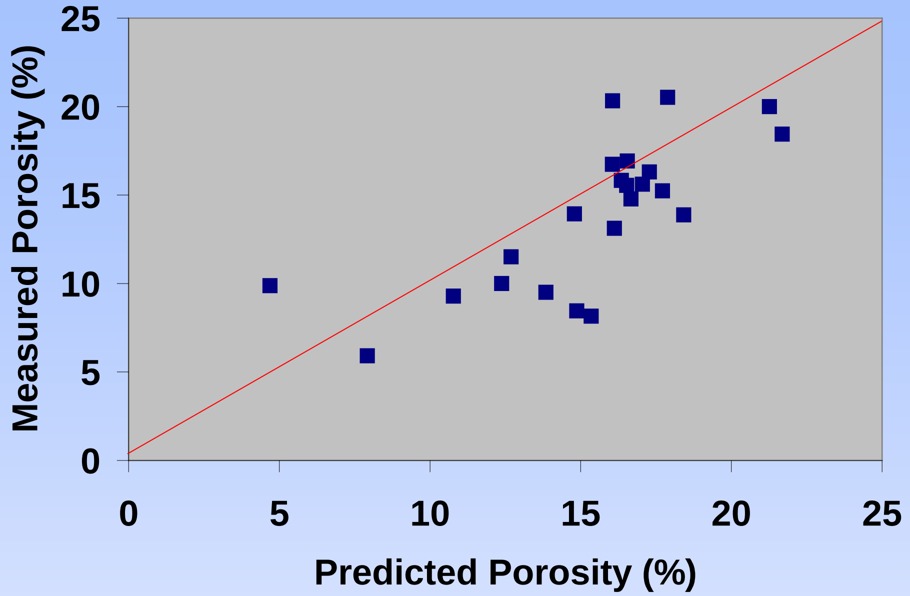


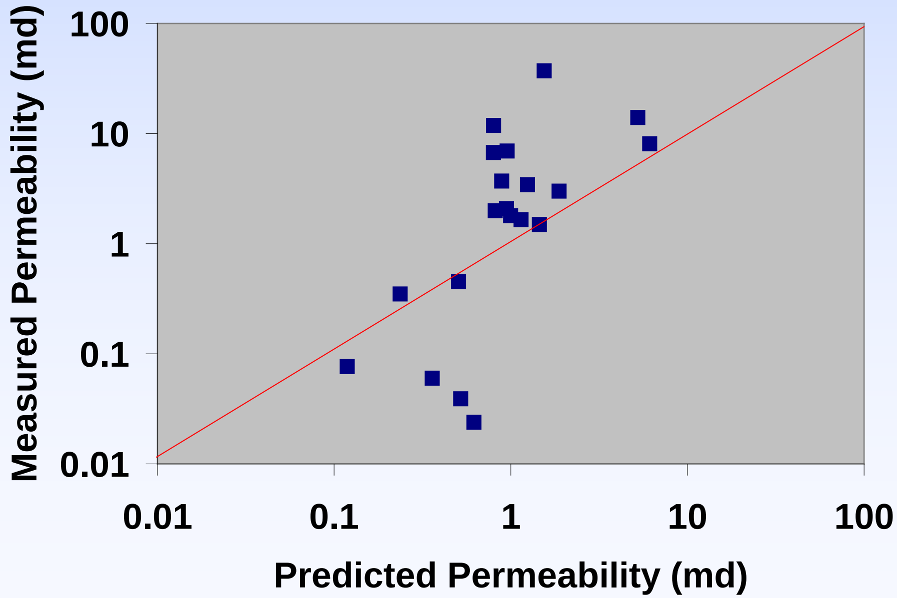
- Locally, reservoir quality is controlled by grain texture related to turbidite elements
- Regionally, reservoir quality is controlled by compaction

Brookian Reservoir Quality Model

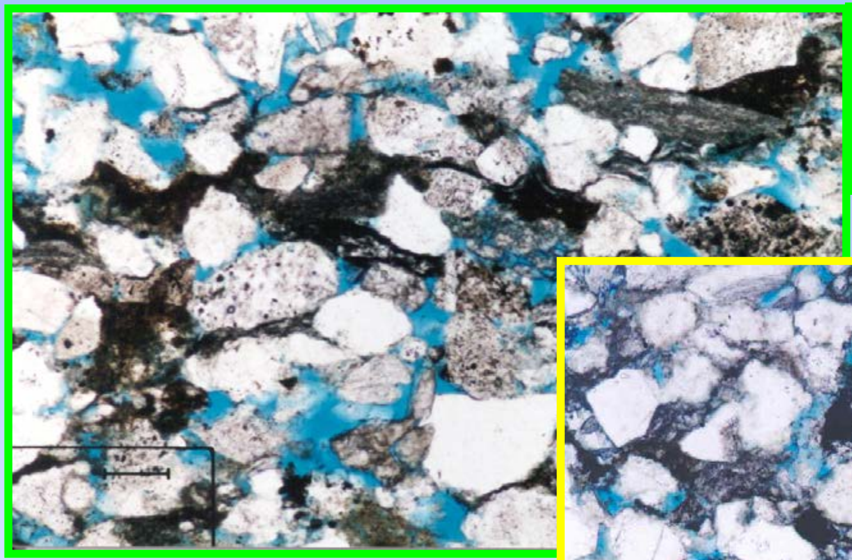
		MEAN Ø		MEAN K	
Well	Dmax	$Ø_{predict}$	$Ø_{actual}$	$K_{predict}$	K_{actual}
Well A	Increasing Burial Depth	21.7	18.4	6.12	8.08
Well B		21.3	20.0	5.24	13.97
Well C		18.4	13.9	1.88	3.00
Tarn D		17.9	20.5	1.55	37.11
Tarn E		17.7	15.2	1.45	1.49
Tarn F		17.3	16.3	1.24	3.43
Tarn G		17.0	15.6	1.14	1.65
Well H		16.7	14.8	1.00	1.79
Well I		16.5	16.9	0.95	6.94
Well J		16.5	15.5	0.95	2.08
Well K		16.4	15.8	0.89	3.70
Well L		16.1	13.1	0.82	1.99
Well M		16.1	20.3	0.80	11.83
Well N		16.1	16.7	0.80	6.72
Well O		15.4	8.2	0.62	0.02
Well P		14.9	8.4	0.52	0.04
Well Q		14.8	13.9	0.51	0.45
Well R		13.8	9.5	0.36	0.06
Well S		12.7	11.5	0.24	0.35
Well T		12.4	10.0	0.21	
Well U		10.8	9.3	0.12	0.08
Well V		7.9	5.9	0.04	
Well W		4.7	9.9	0.01	

Albian Prospects   Cenomanian Prospects

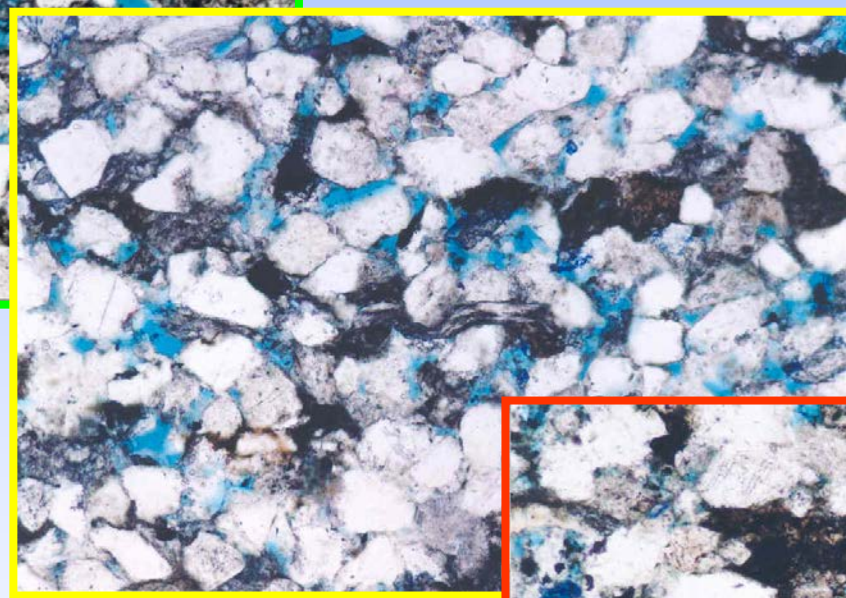




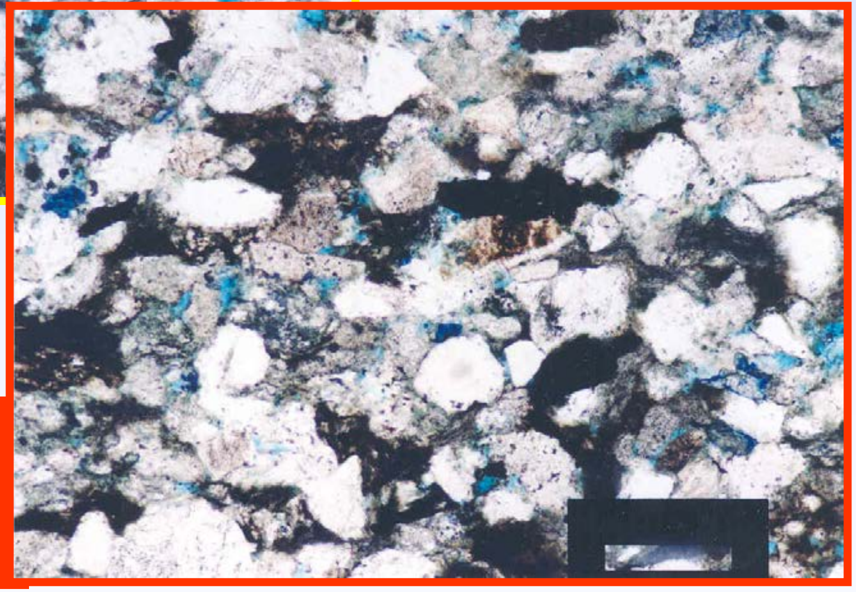
Compaction of Brookian Reservoirs



< 7000’ Dmax
ø = 18 %
k = 12 md



7000-9000’ Dmax
ø = 15 %
k = 3 md



> 9000’ Dmax
ø = 11 %
k = 0.1 md

100 µm

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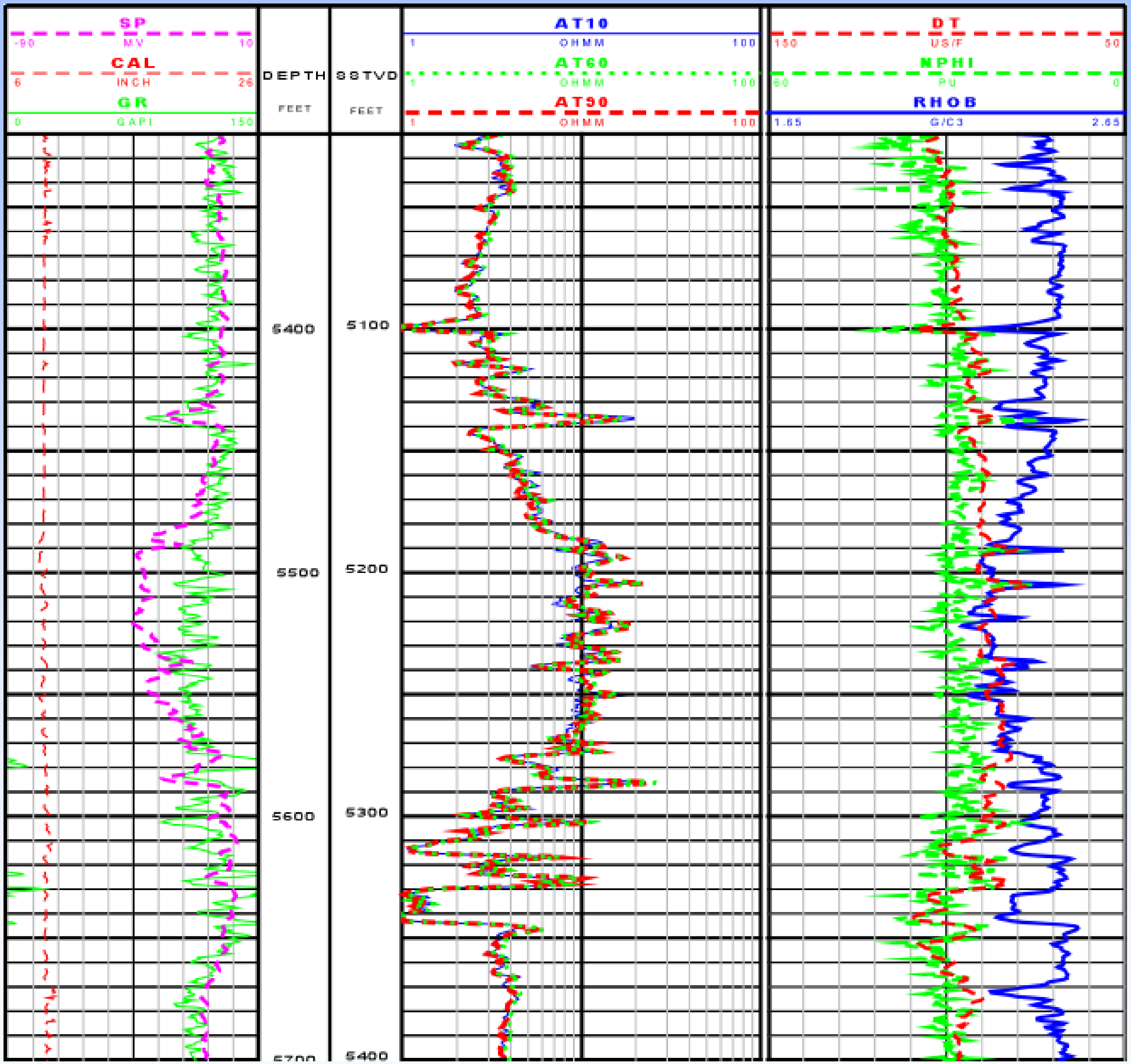
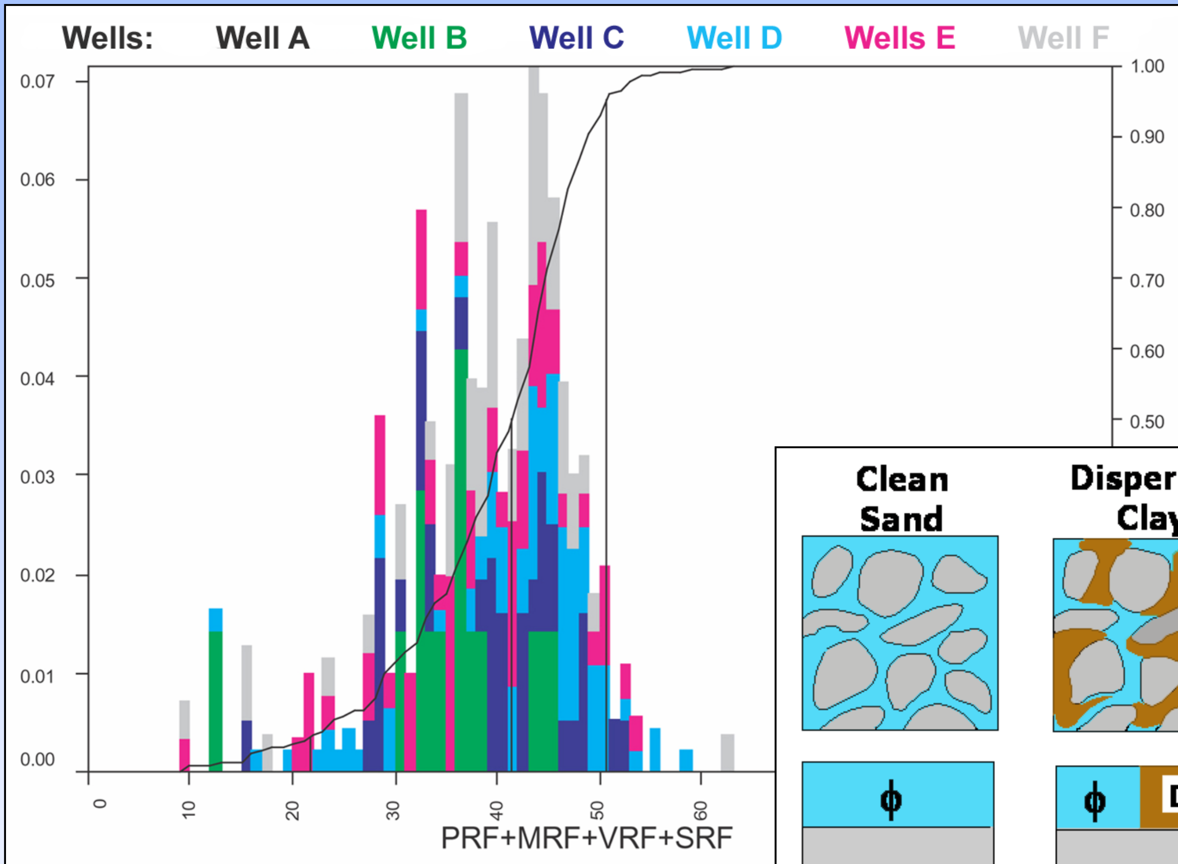
Petrophysics: Overview of the Problem

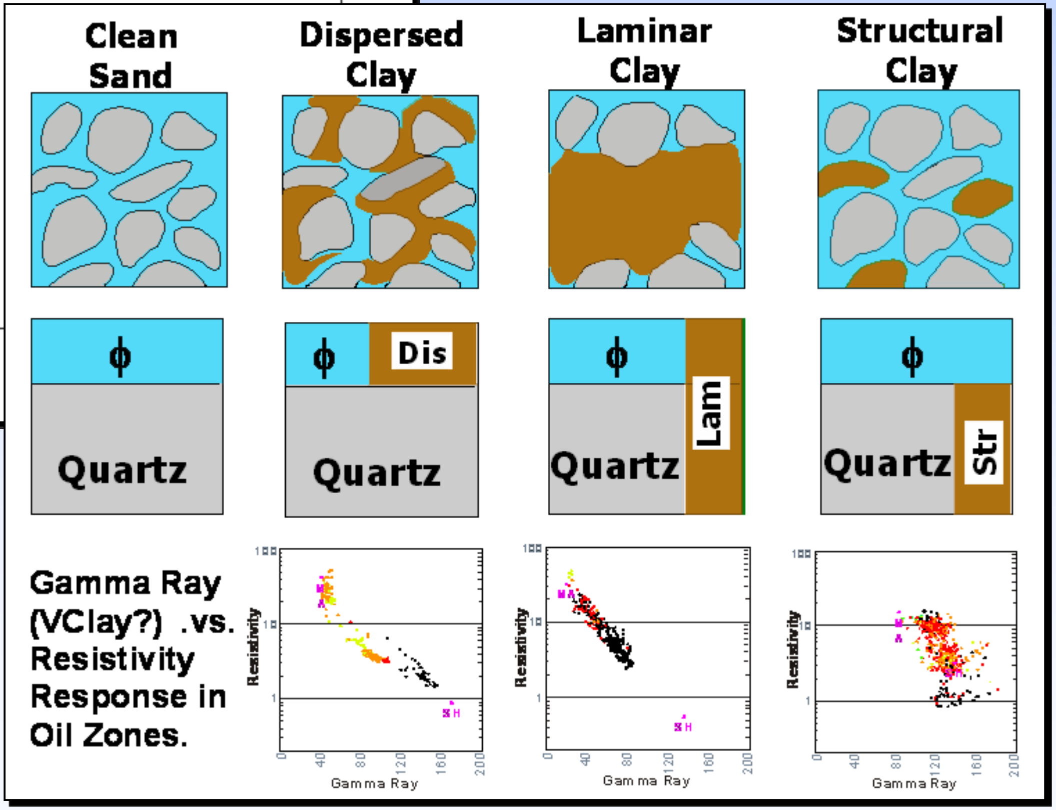


- GR log does not distinguish sand
- RT and RHOB logs do show sand character
- Problem results from presence of analcime and structural clay
- Standard shaly-sand log model is not appropriate

Effect of Clay on Log Model

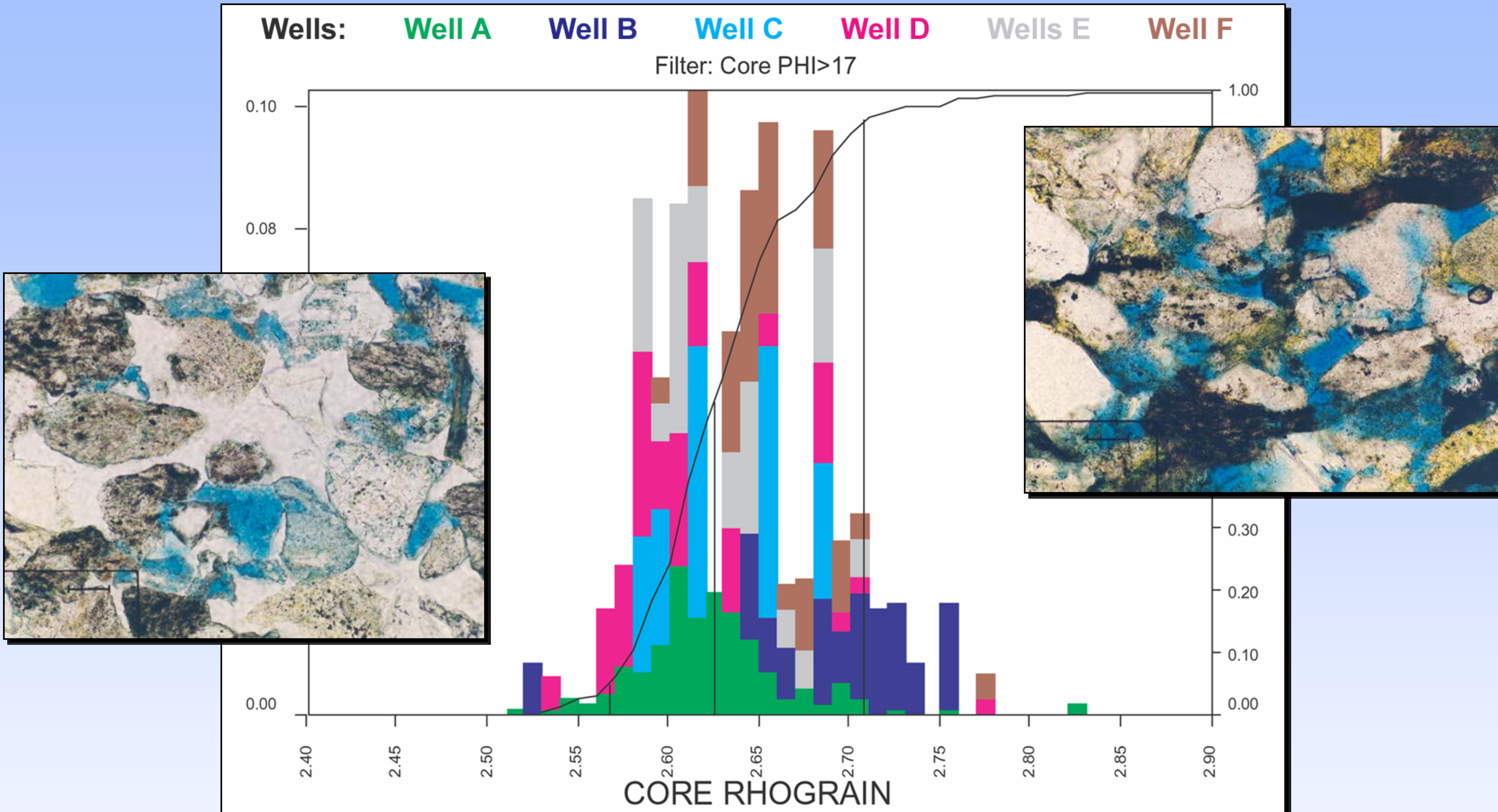


- Reservoir contains 30-50% argillaceous rock fragments
- Lithics are older and more compacted than surrounding shales



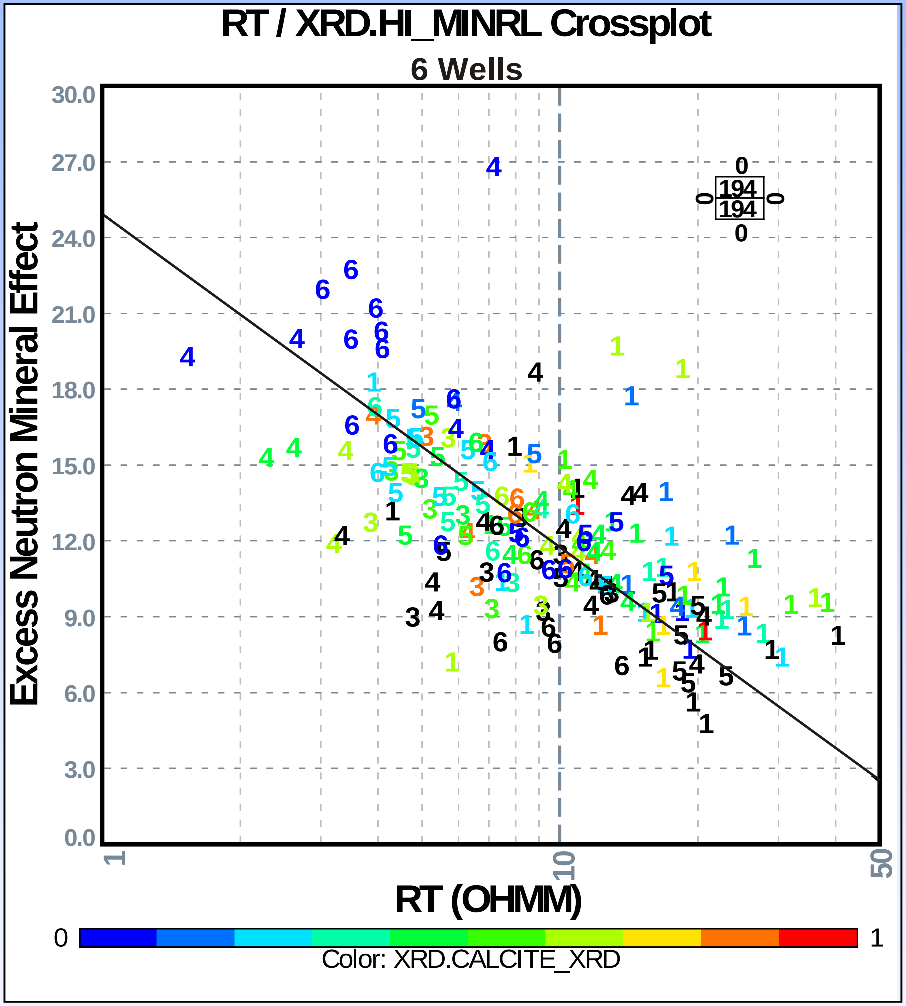
- Lithics are "pinpoints" of conductivity that are not connected
- Structural clay has little impact on reservoir quality

Effect of Analcime on Log Model

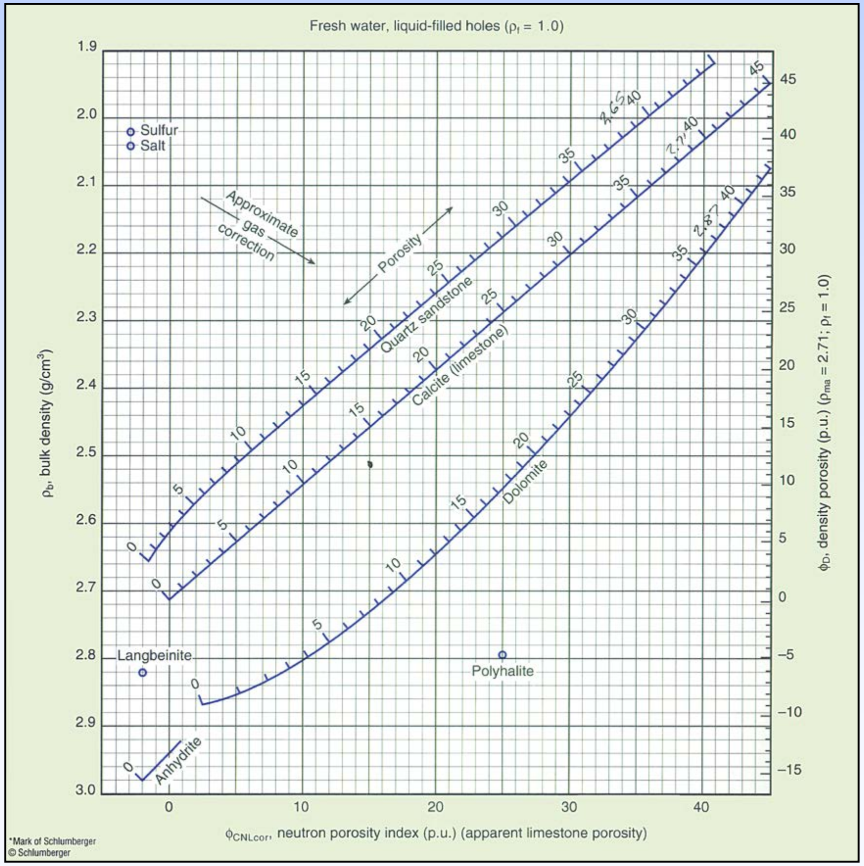


- Grain densities vary over a wide range from 2.52 – 2.78
- A single lithology model would yield poor results
- Solve for Φ and grain density allowing for mineralogical variation
- Model must use more than one porosity tool

Resistivity – Mineral Effect Cross Plot

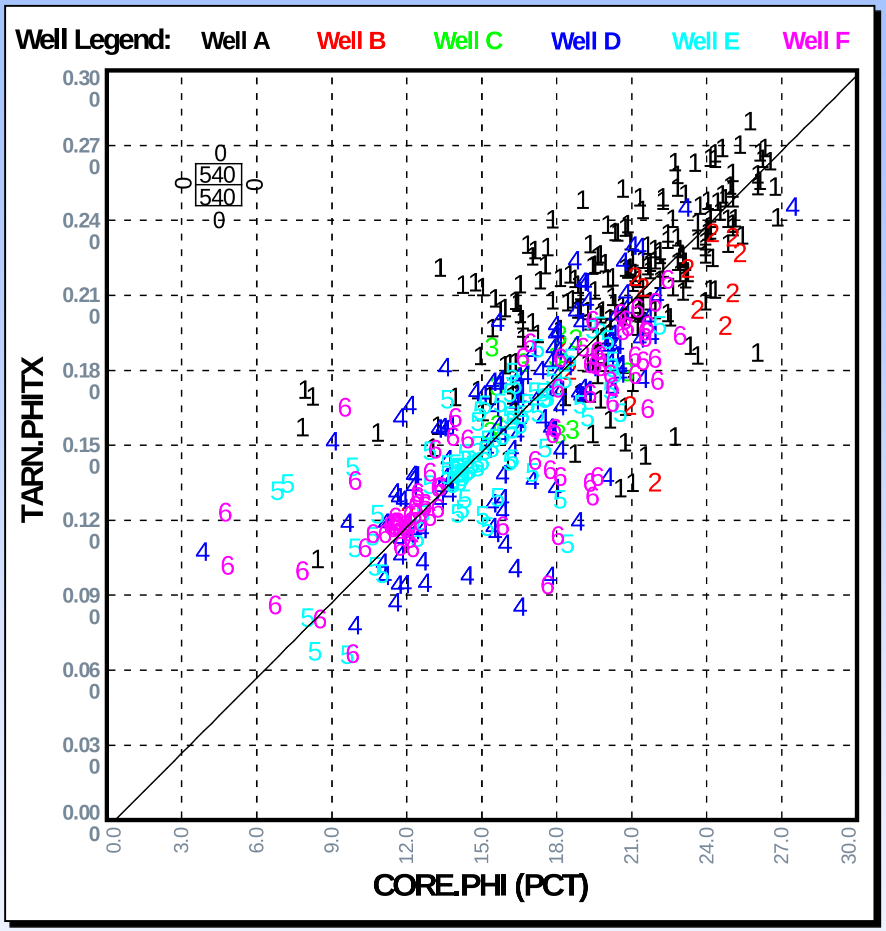


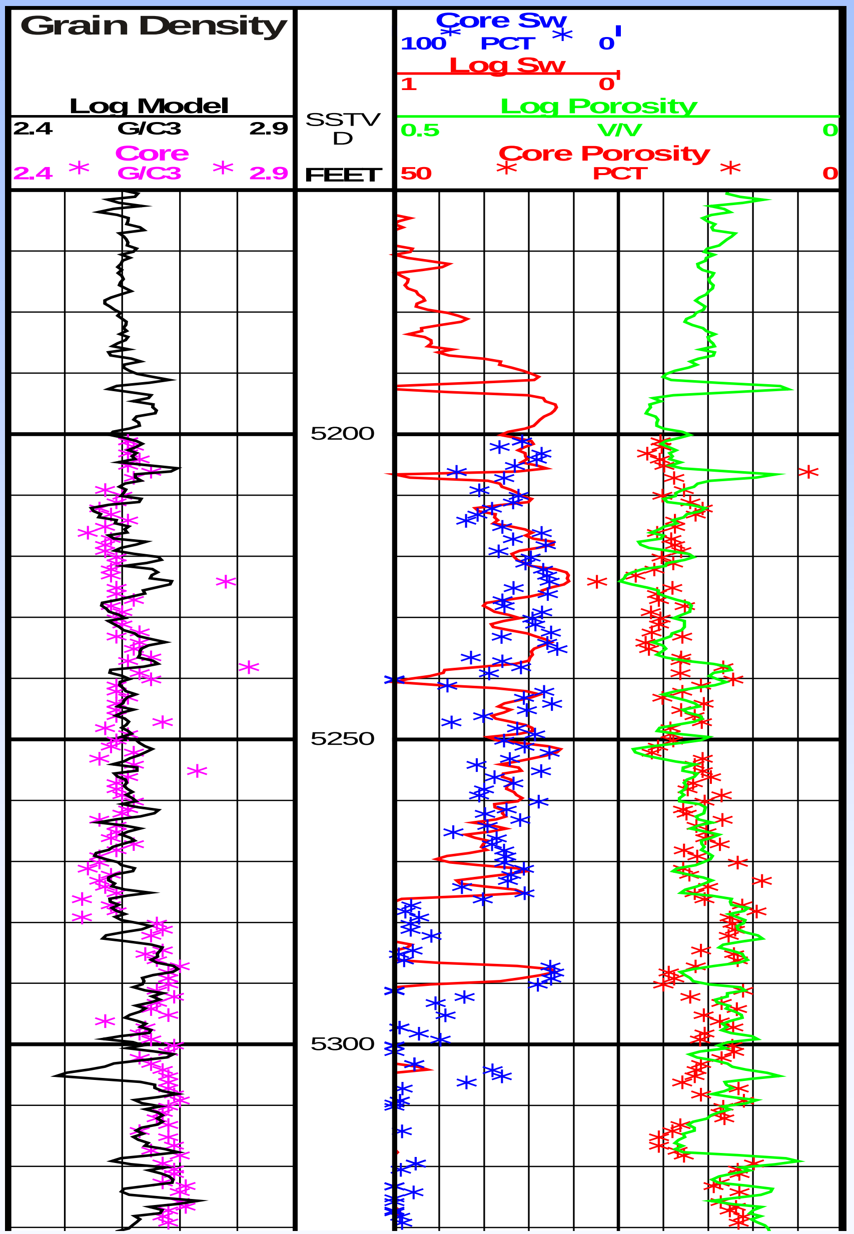
- Calculate mineral effect on Neutron log from mineral abundances (TS & XRD) and Log Parameter Table
- Plot mineral effect against raw logs to determine "best fit"
- Deep resistivity has best correlation



- Neutron correction is developed from the resistivity log
- Calculate phi and grain density from standard Neutron/Density cross plot

Model Results





- Results are for multiple wells
- No log normalization or individual customization

Conclusions

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The End