Reservoir Quality of Brookian Sandstones, North Slope, Alaska

Kenneth P. Helmold, Alaska Division of Oil & Gas

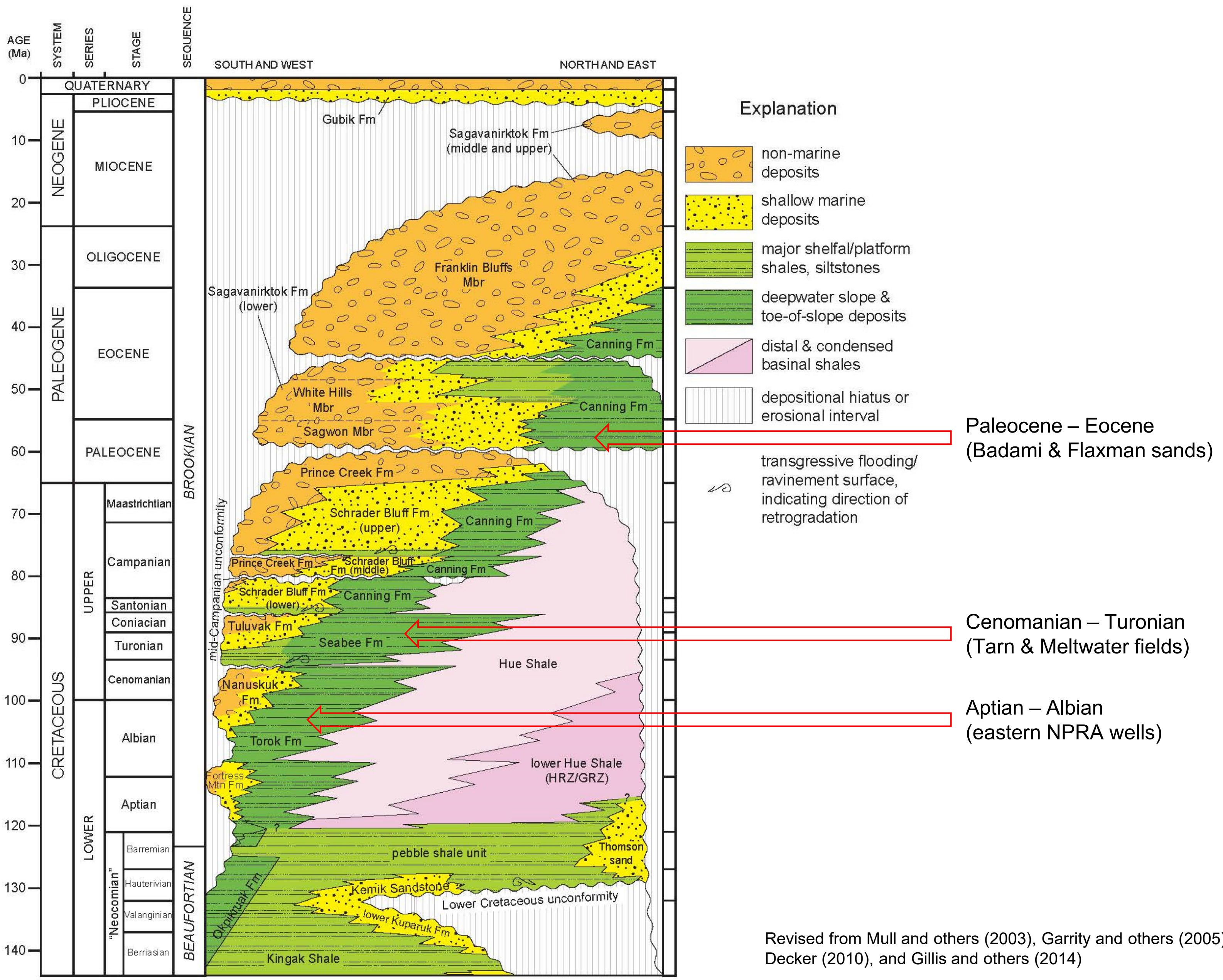
DGGS-DOG Videoconference
June 25, 2020

Alaska Department of Natural Resources

Outline

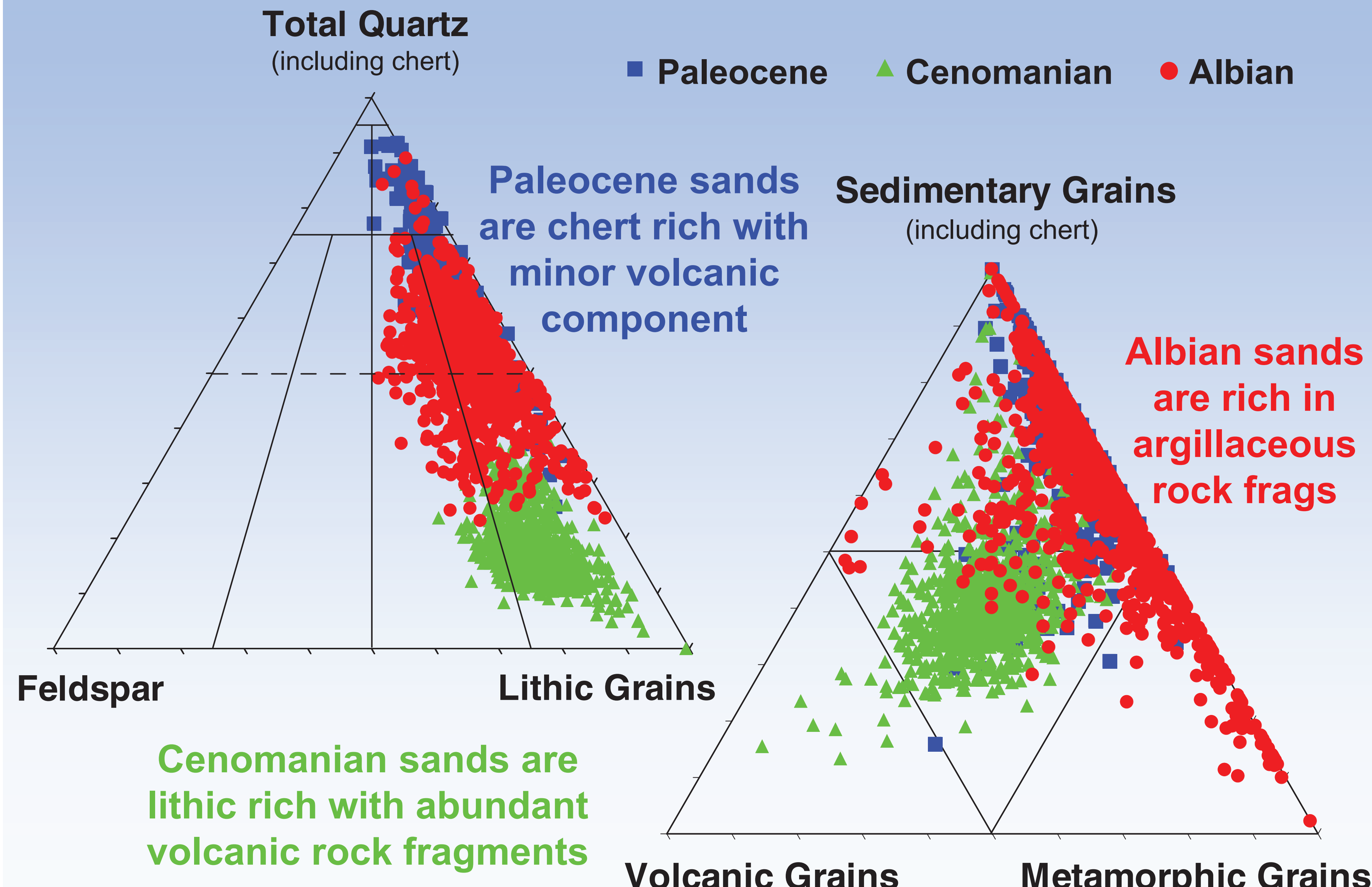
- **Stratigraphic setting**
- **Mineralogy of sandstones**
  - Paleocene - Flaxman, Badami (Canning Fm.)
  - Cenomanian - Tarn, Meltwater (Seabee Fm.)
  - Albian – eastern NPRA wells (Torok, Nanushuk Fms.)
- **Facies and reservoir quality** (Tarn)
- **Regional reservoir quality model**
- **Nanushuk specific model**
- **Way forward / Conclusions**

Stratigraphic Column of North Alaska



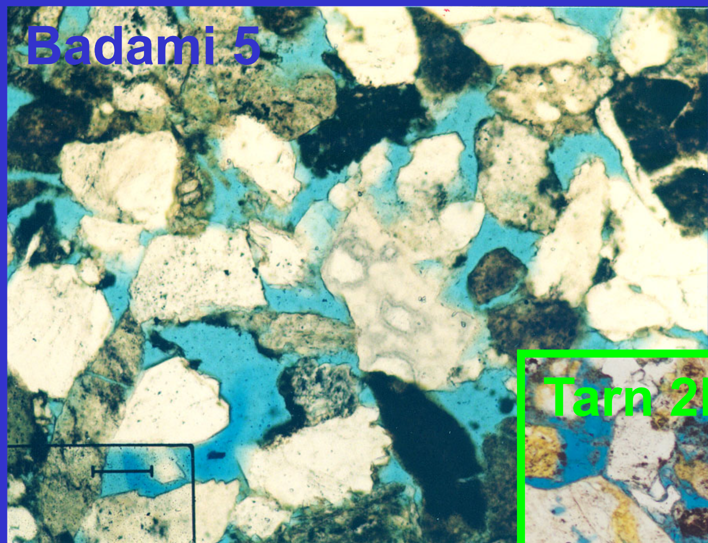
Revised from Mull and others (2003), Garrity and others (2005), Decker (2010), and Gillis and others (2014)

Brookian Sandstone Composition

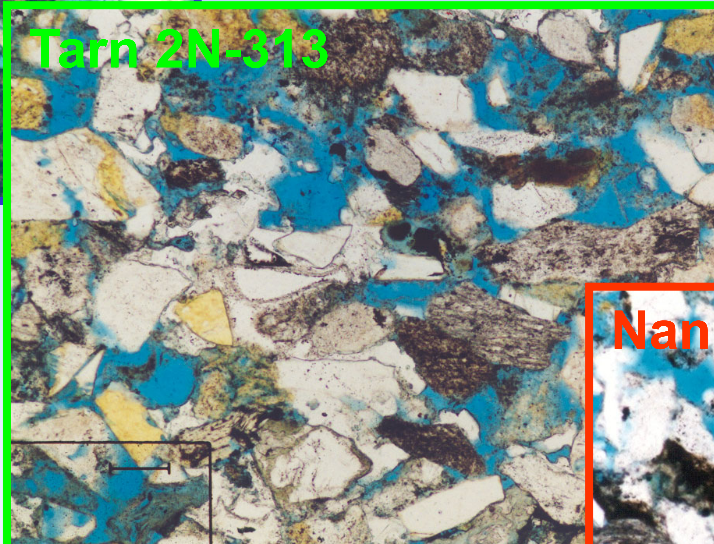


from Helmold and others (2006)

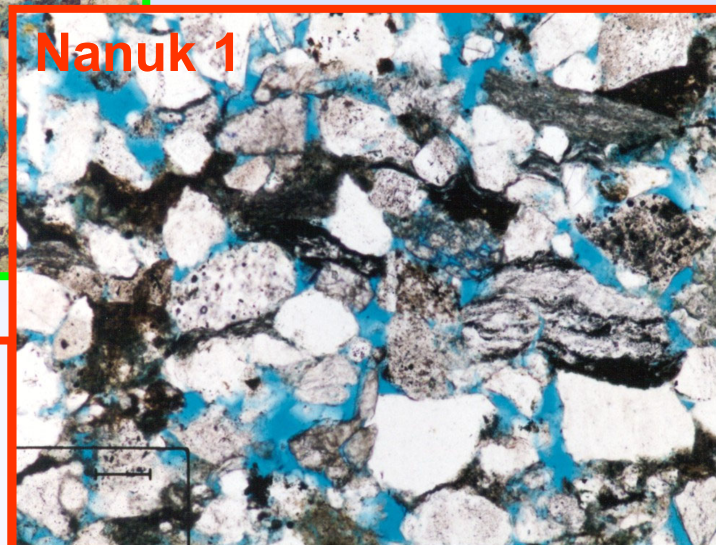
Typical Brookian Sandstones



Paleocene (Flaxman)
Chert rich
Medium-grain sand



Cenomanian (Tarn)
Volcanic glass rich
Analcime cement

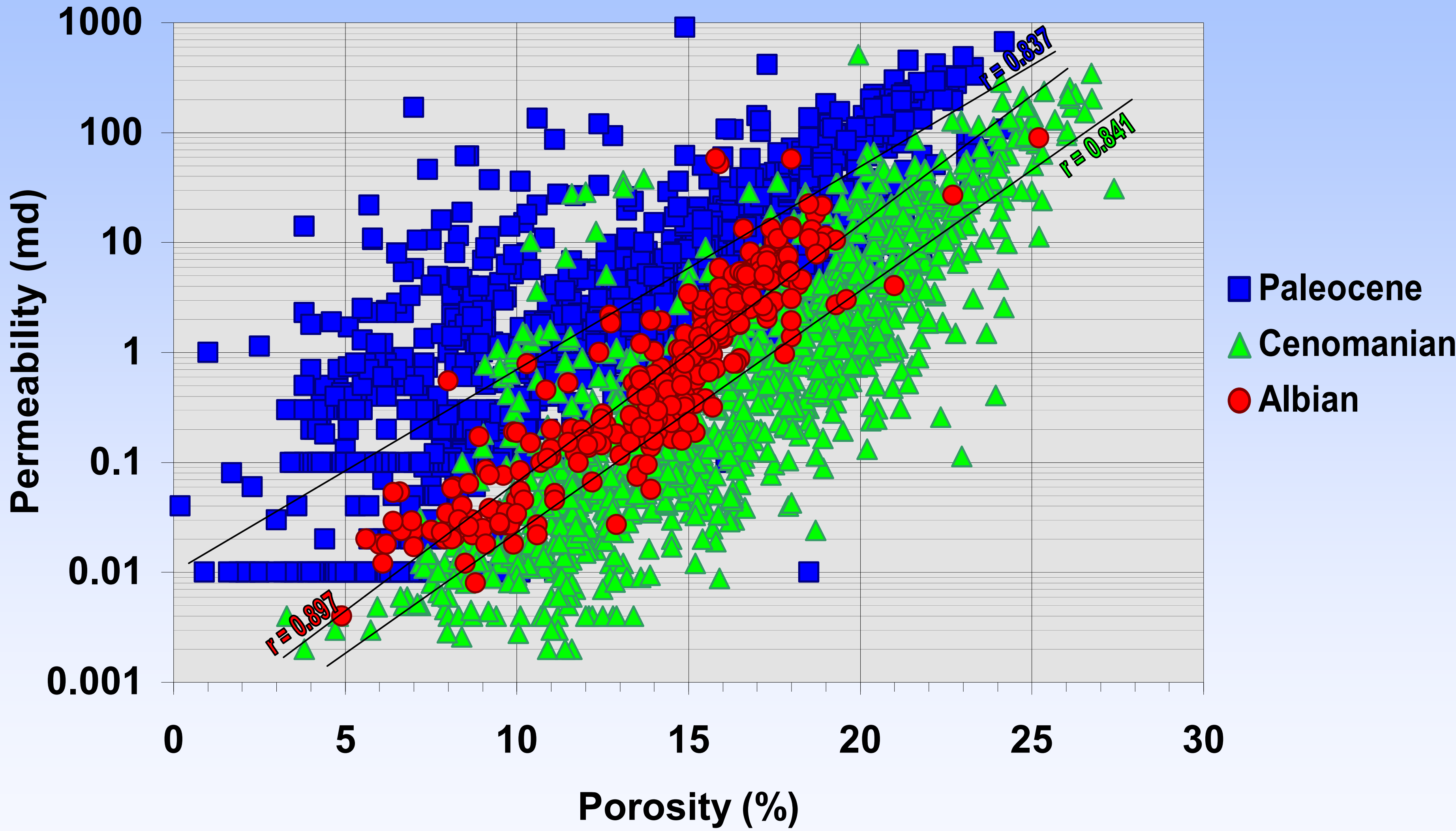


Albian (Torok/Nanushuk)
Argillaceous rich RF
Generally lack cement

100 µm

from Helmold and others (2006)

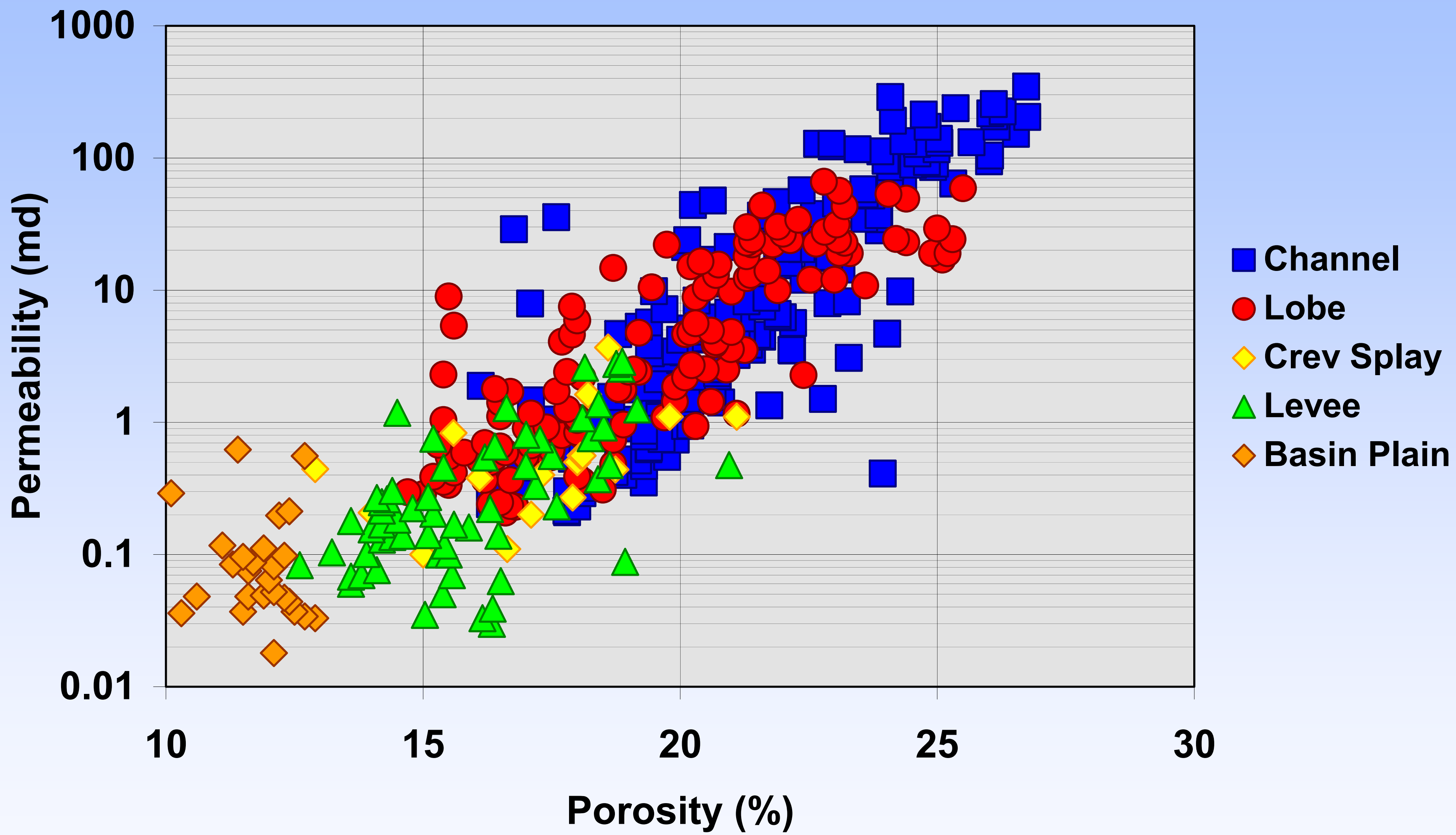
Brookian Sandstone Phi-K Trends



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

from Helmold and others (2006)

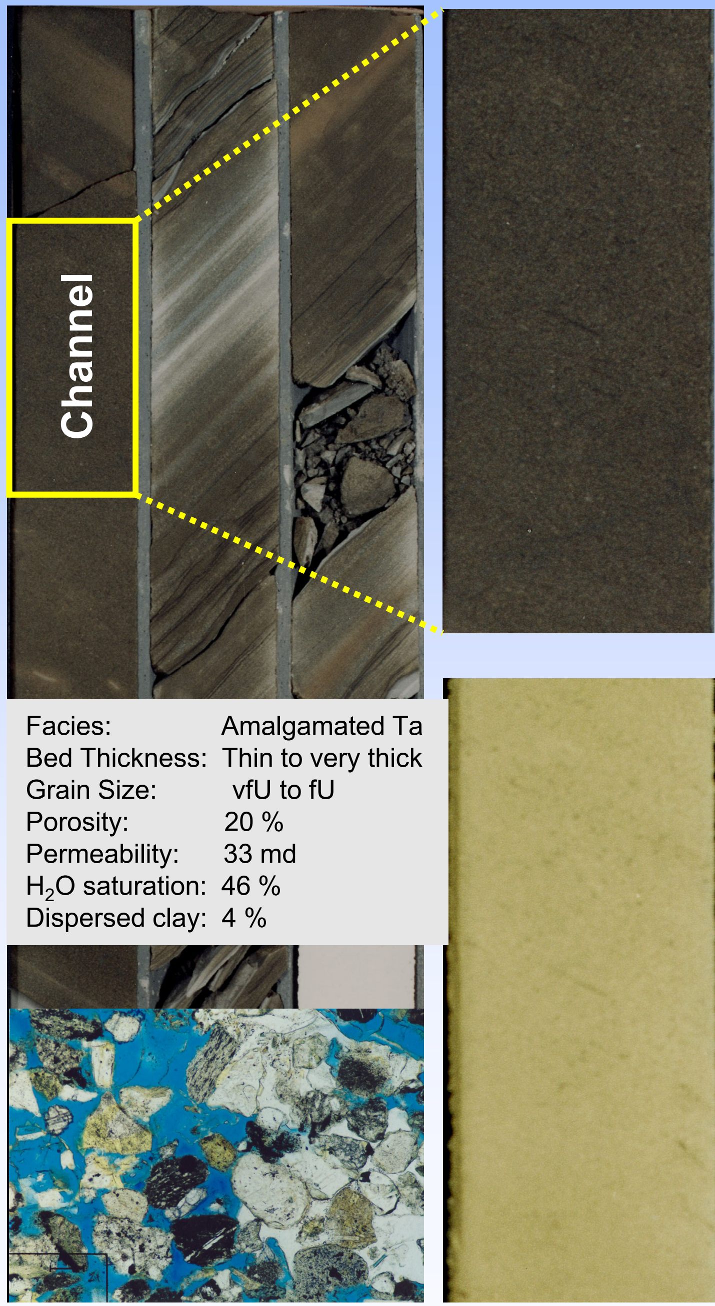
Depositional Control on Tarn Reservoir Quality



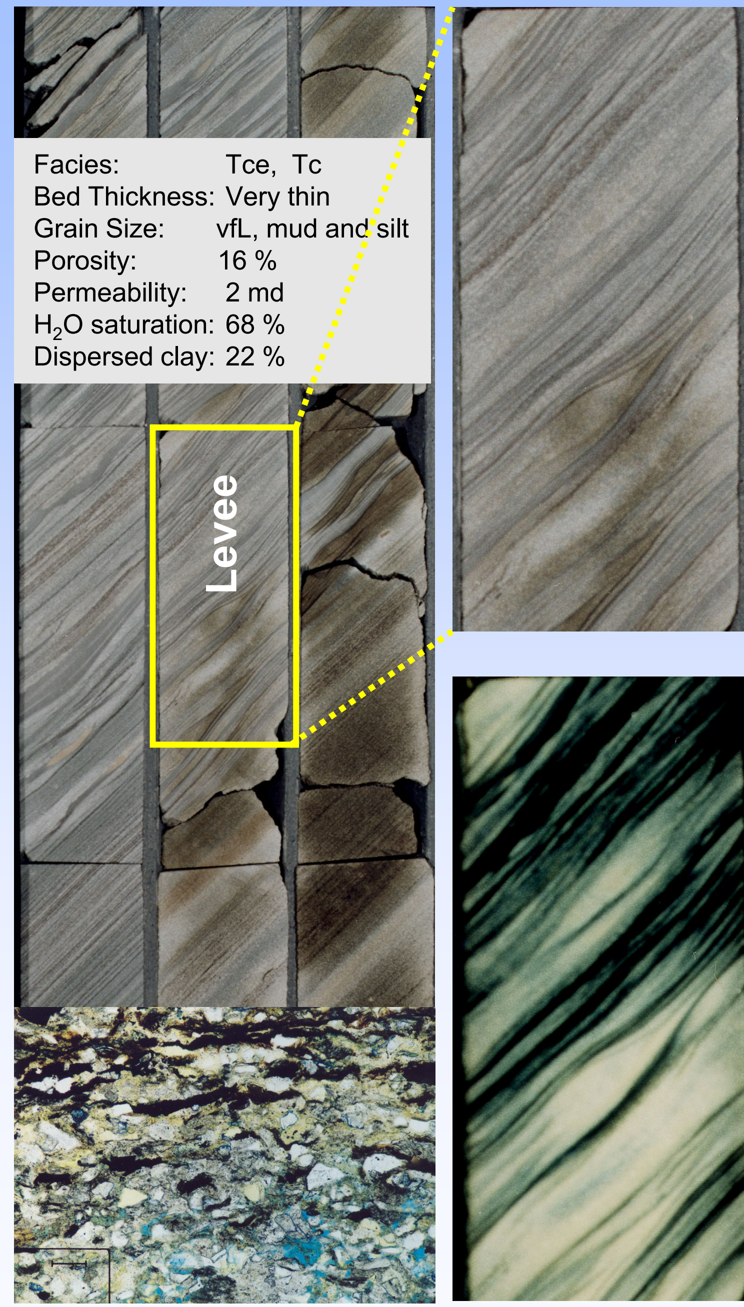
Best reservoirs in channels; poorest in levees and basin plain

from Helmold and others (2006)

Tarn Channel Facies

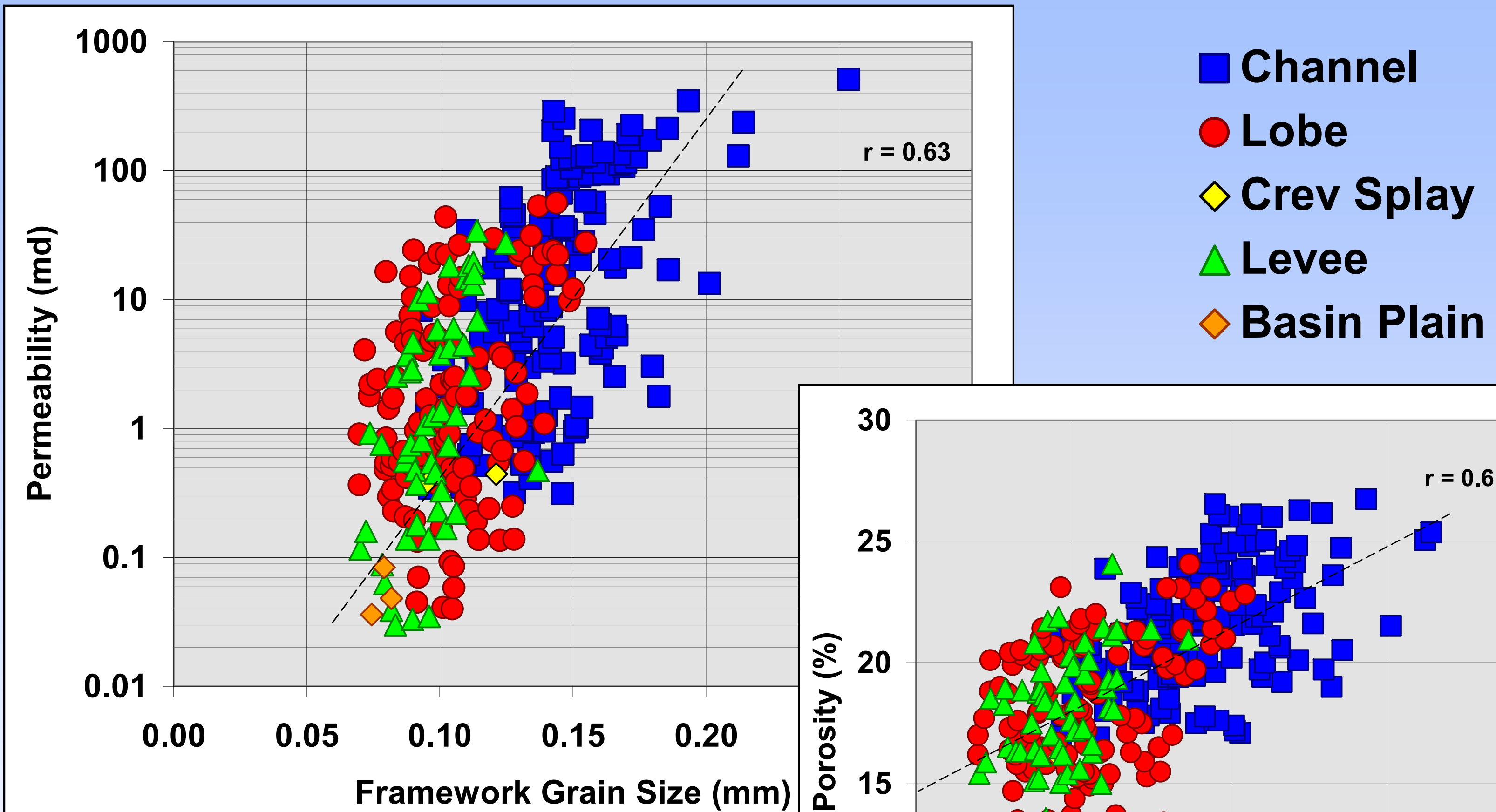


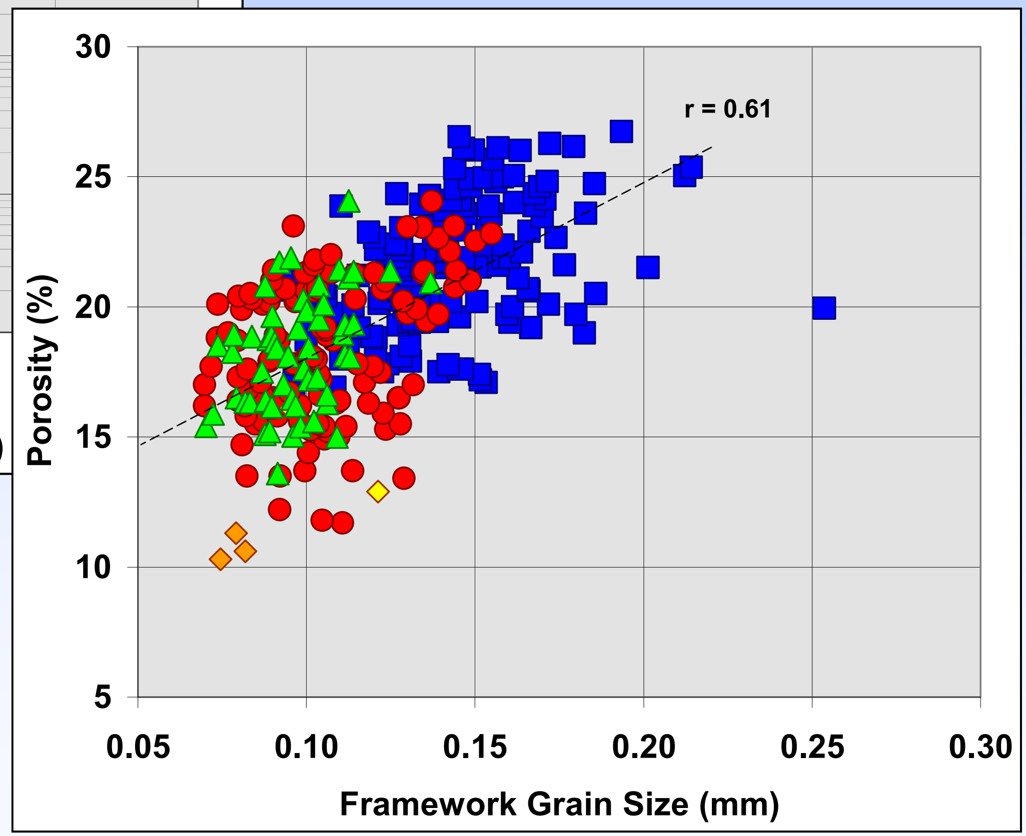
Tarn Levee Facies



modified from Helmold and others (2006)

Effect of Grain Size on Tarn Phi-K



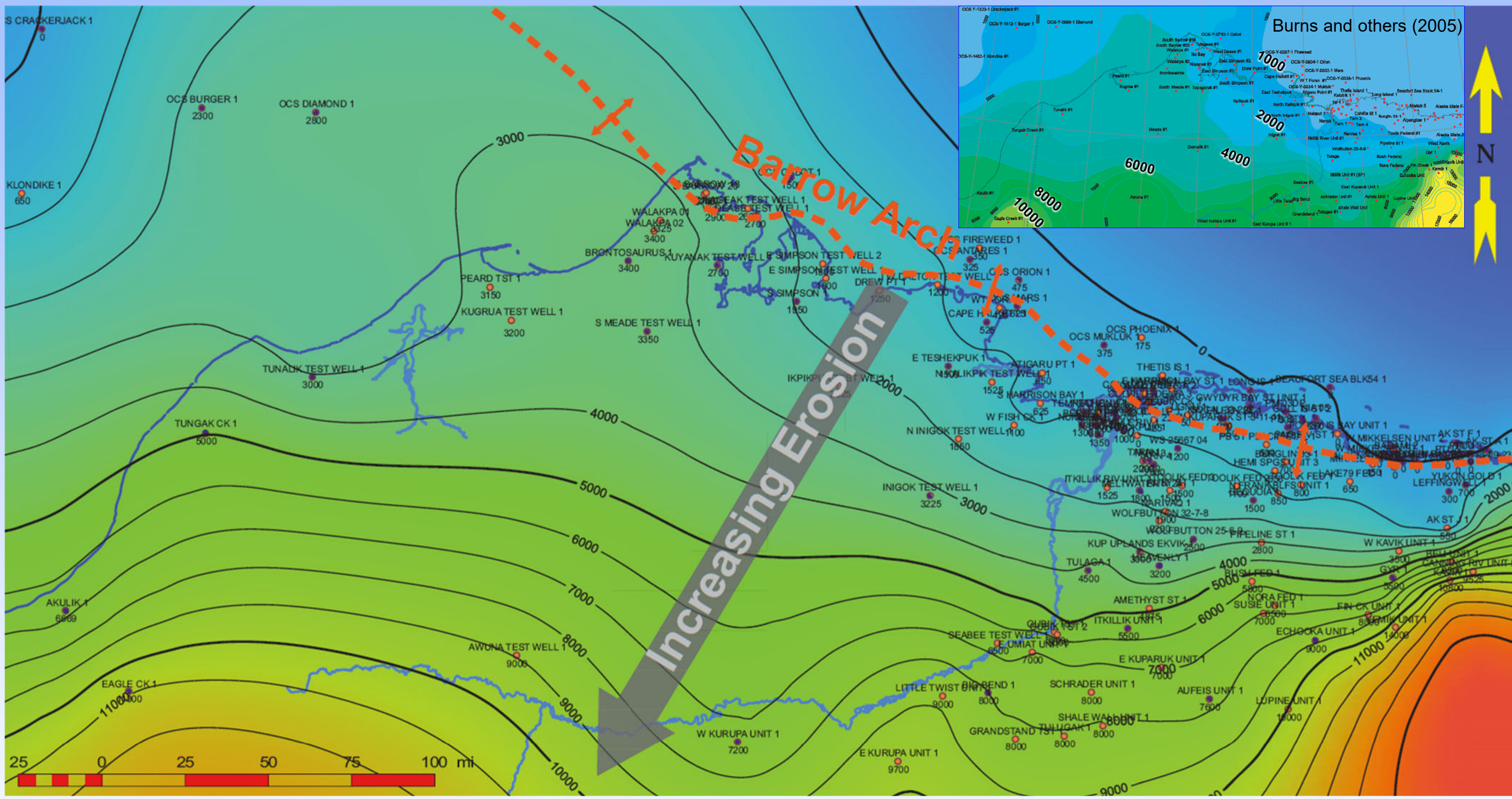


Facies control on grain size is largely responsible for reservoir quality variability

from Helmold and others (2006)

Regional Brookian
RQ Model

Brookian Erosion Map

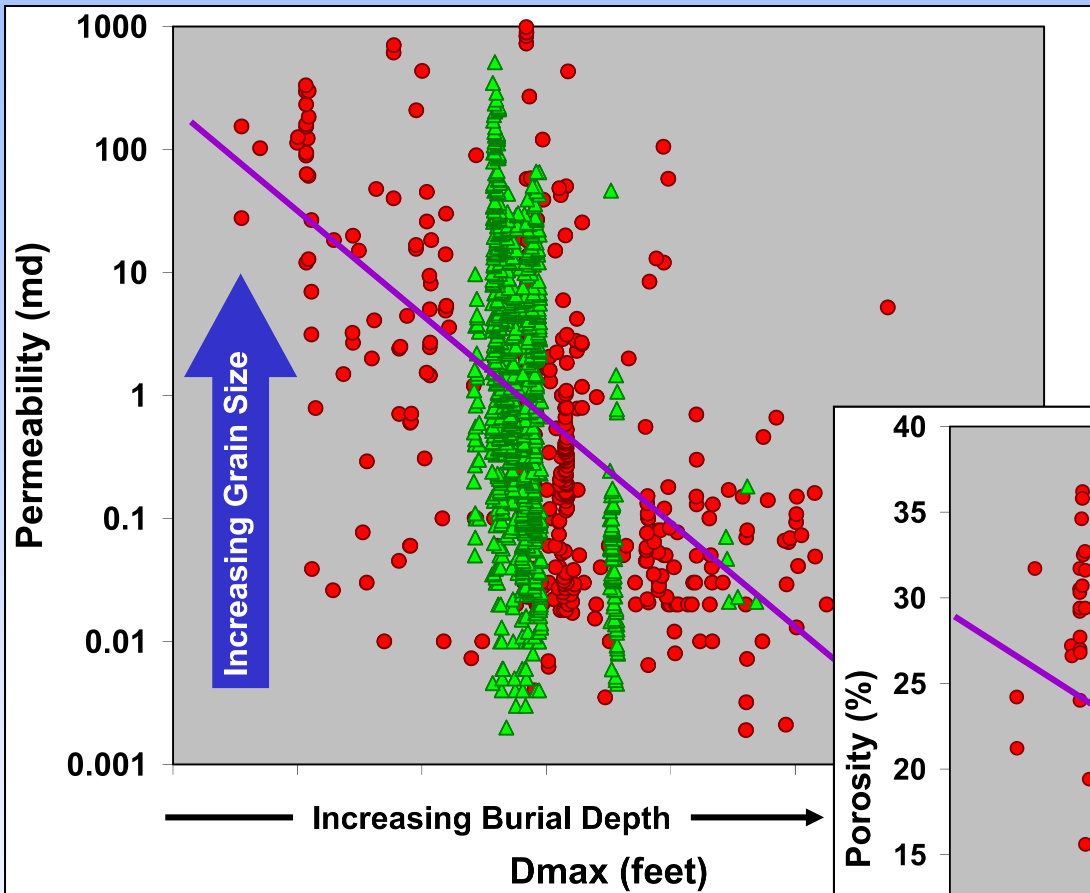


Erosion estimates for 145 wells derived from sonic compaction curves (Burns and others, 2005)
Contours generated using GeoAtlas mapping module of GeoGraphix

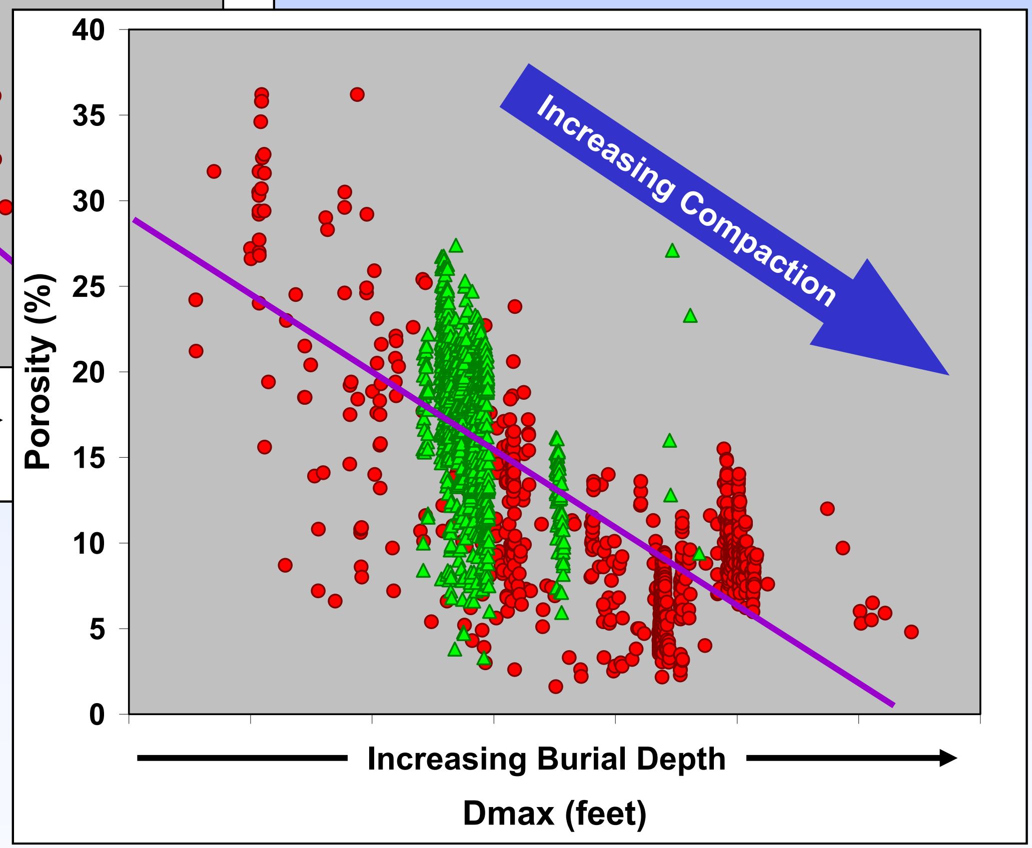
Maximum Burial Depth (Dmax) = Present Depth (ft) + Brookian Erosion (ft)

modified from Helmold (2016)

Brookian Phi-K vs. Dmax



- Locally, reservoir quality is controlled by grain texture related depositional energy
- Regionally, reservoir quality is controlled by compaction



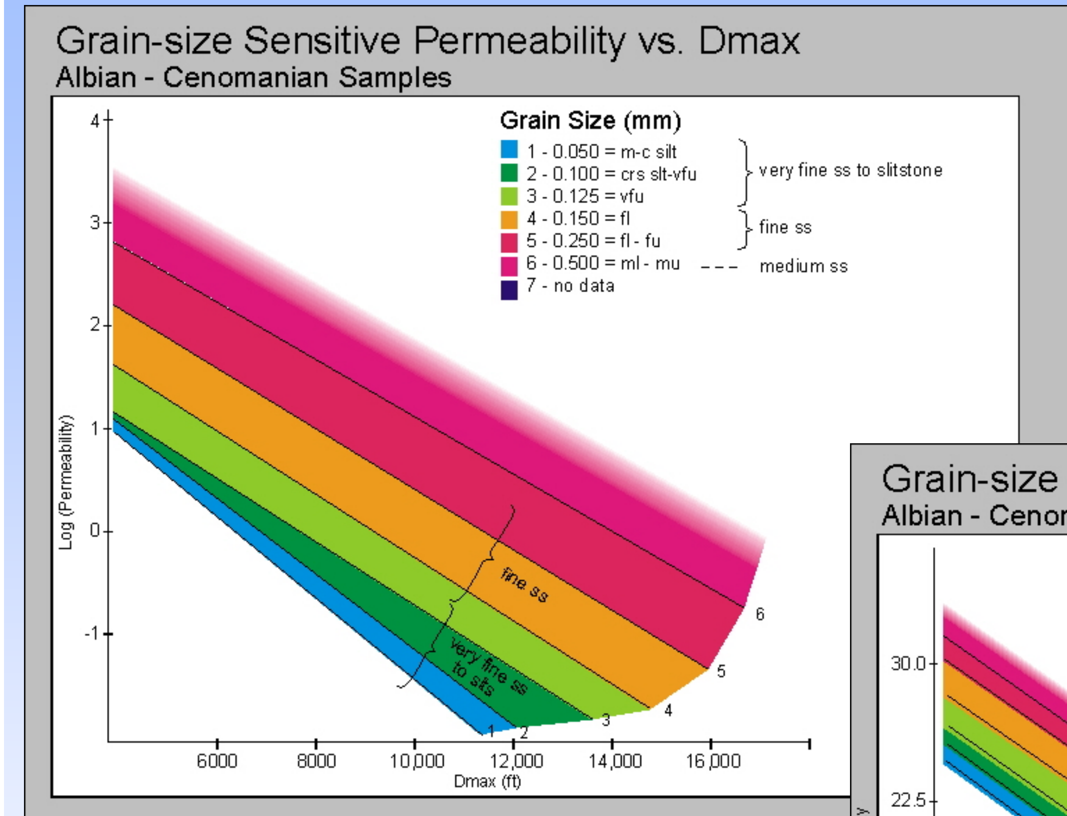
Cenomanian

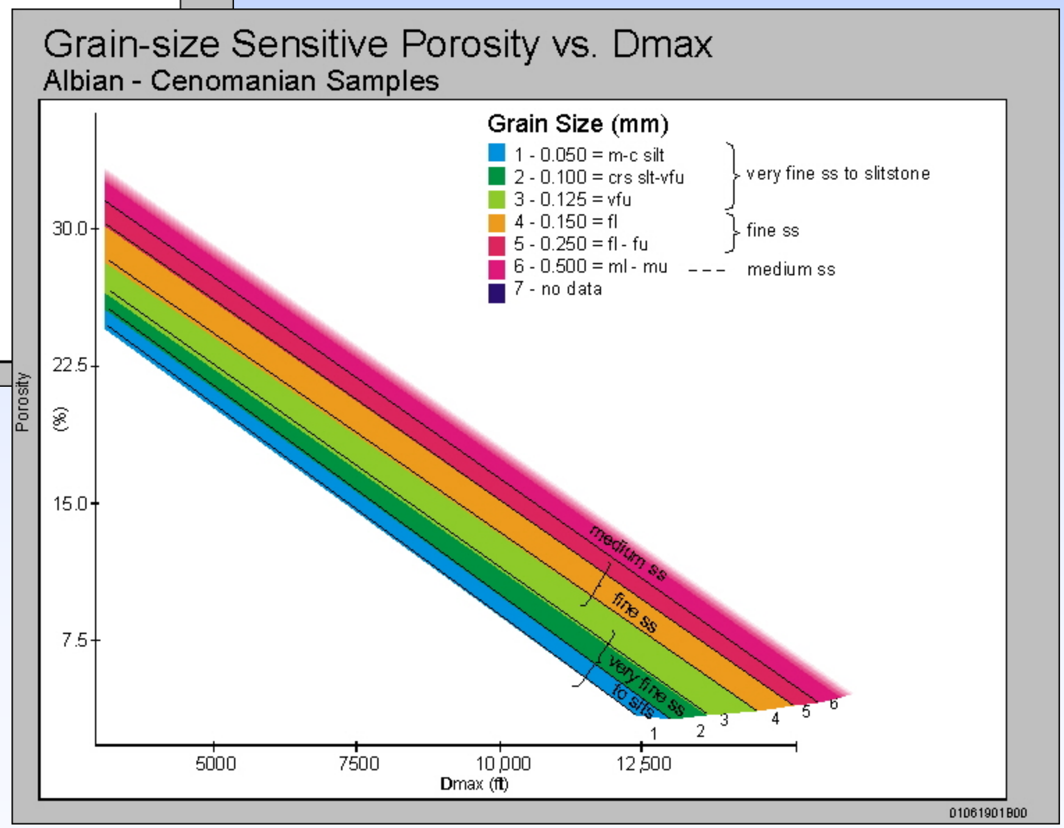
Albian

Model regression

from Helmold and others (2006)

Phi, K, Grain Size & Dmax

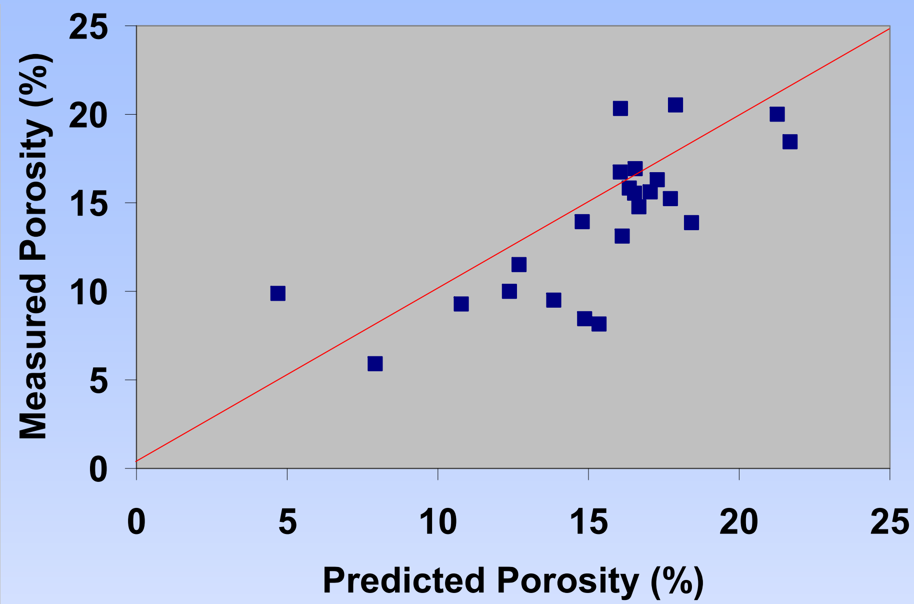


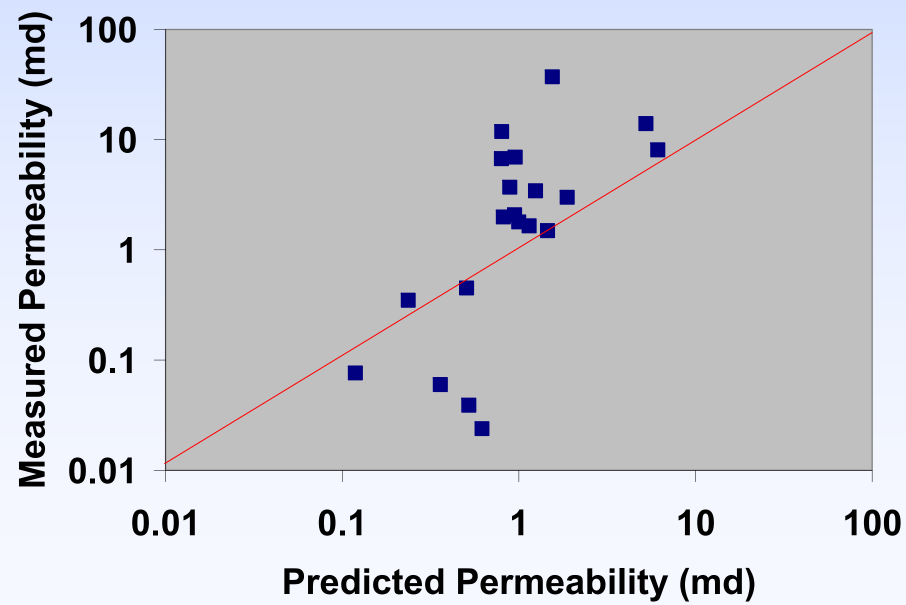


unpublished

Brookian Reservoir Quality Model

		MEAN Ø		MEAN K	
Well	Dmax	$Ø_{predict}$	$Ø_{actual}$	$K_{predict}$	K_{actual}
Kalubik 2	5,814	21.7	18.4	6.12	8.08
Kalubik 1	5,969	21.3	20.0	5.24	13.97
Bergschrund 1	7,002	18.4	13.9	1.88	3.00
Tarn 2N-313	7,198	17.9	20.5	1.55	37.11
Tarn 3	7,259	17.7	15.2	1.45	1.49
Tarn 2	7,417	17.3	16.3	1.24	3.43
Tarn 4	7,502	17.0	15.6	1.14	1.65
Cirque 3	7,638	16.7	14.8	1.00	1.79
Meltwater N. 2A	7,683	16.5	16.9	0.95	6.94
Nanuk 1	7,691	16.5	15.5	0.95	2.08
Nanuk 2	7,754	16.4	15.8	0.89	3.70
Meltwater N. 2	7,839	16.1	13.1	0.82	1.99
Bermuda 1	7,860	16.1	20.3	0.80	11.83
Meltwater N. 1	7,864	16.1	16.7	0.80	6.72
Trailblazer A1	8,119	15.4	8.2	0.62	0.02
Trailblazer H1	8,293	14.9	8.4	0.52	0.04
Atlas 1	8,320	14.8	13.9	0.51	0.45
Kokoda 1	8,666	13.8	9.5	0.36	0.06
Meltwater S. 1	9,086	12.7	11.5	0.24	0.35
Cronus 1	9,200	12.4	10.0	0.21	
Hunter A	9,781	10.8	9.3	0.12	0.08
Grizzly 1	10,820	7.9	5.9	0.04	
Heavenly 1	11,995	4.7	9.9	0.01	

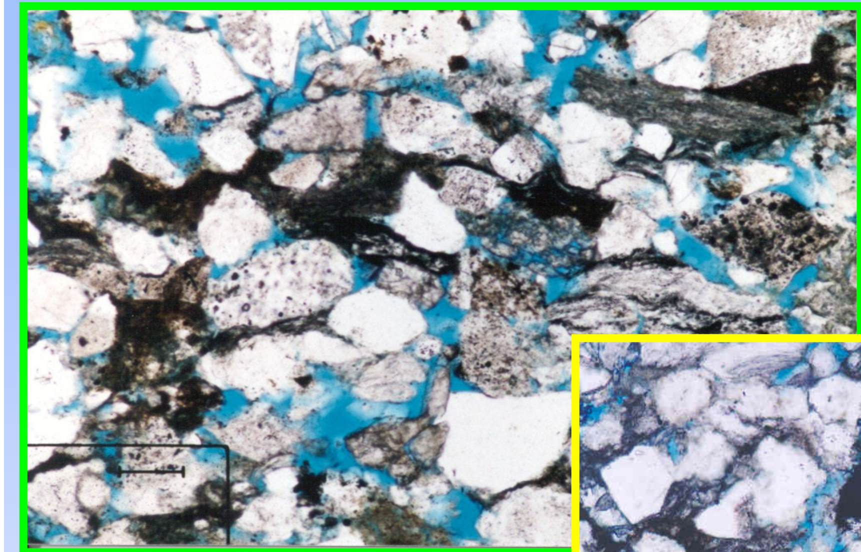




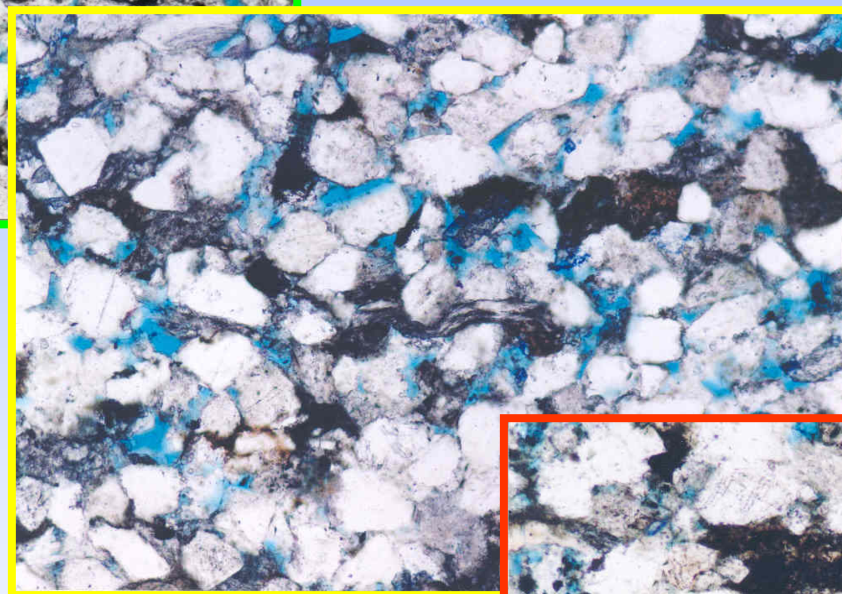
Albian Prospects **Cenomanian Prospects**

from Helmold and others (2006)

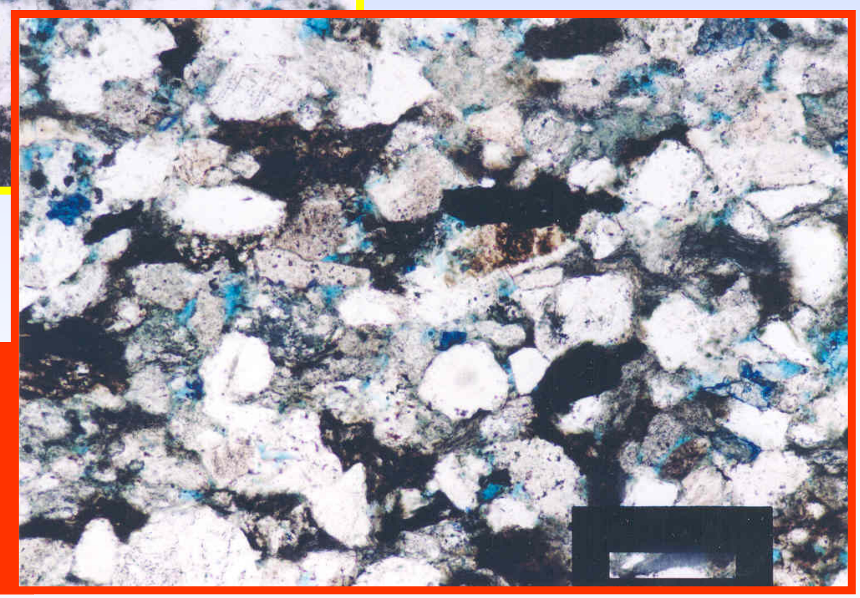
Compaction of Brookian (Torok) Reservoirs



Nanuk 1
7665′ Dmax
ø = 17.6 %
k = 10.9 md



Atlas 1
8331′ Dmax
ø = 16.0 %
k = 3.1 md



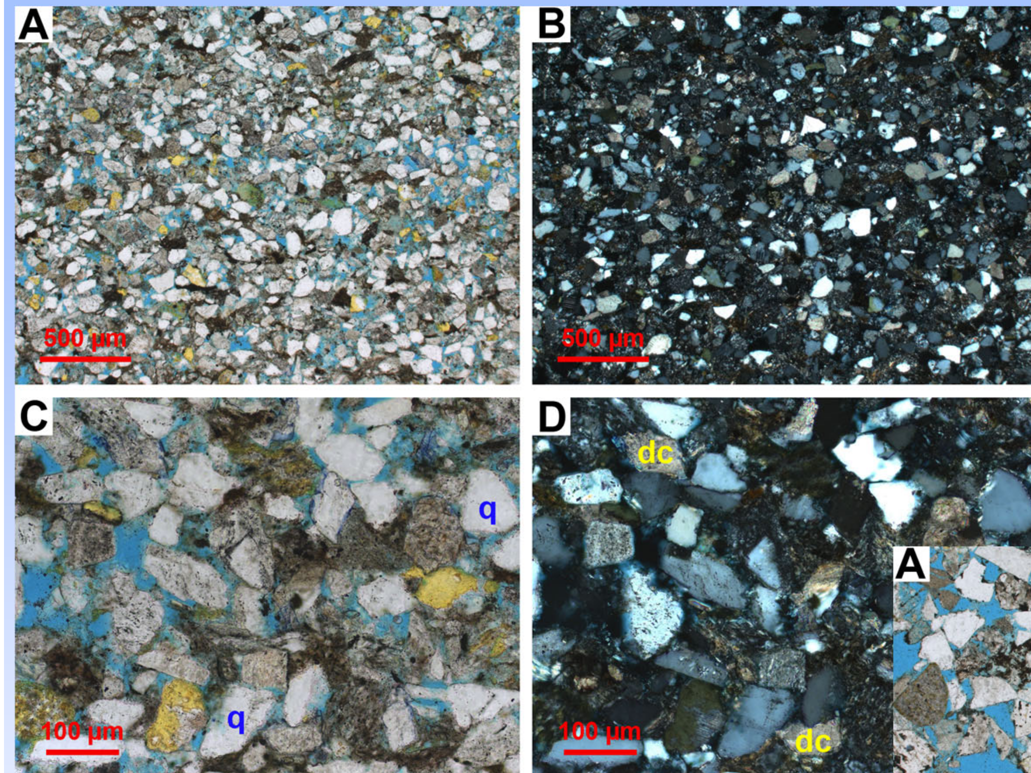
Hunter A
9627′ Dmax
ø = 11.5 %
k = 0.15 md

100 µm

from Helmold and others (2006)

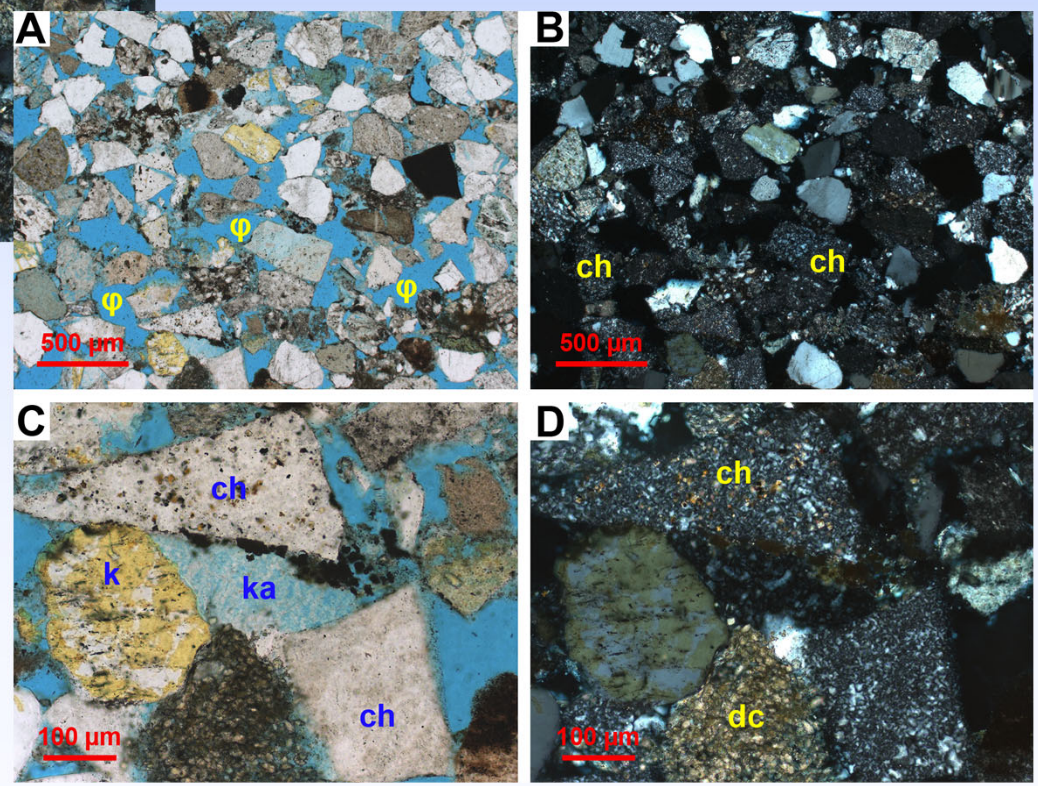
Nanushuk Specific RQ Model

Very-fine and Medium Grained Nanushuk Sandstone



Wainwright #1, 1,072.1’ MD
Dmax = 3834’
grain size = 0.063 mm (vfL)
Qm = 24.6 %
chert = 6.9 %
φ = 19.7 %
k = 20.7 md

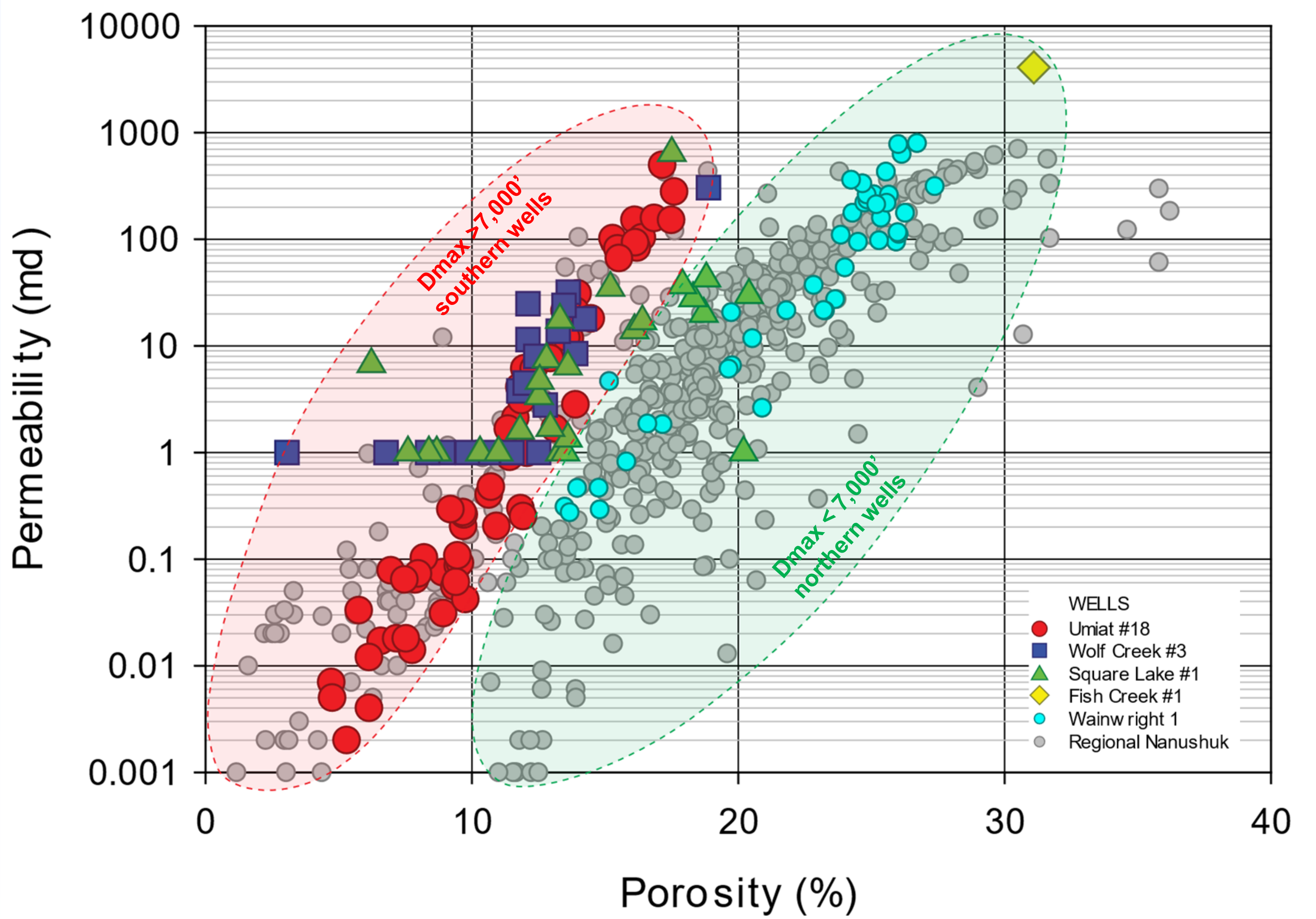
Wainwright #1, 1,128.1’ MD
Dmax = 3890’
grain size = 0.269 mm (mL)
Qm = 11.5 %
chert = 38.5 %
φ = 26.7 %
k = 796 md



q = momocrystalline quartz
k = potassium-feldspar
ch = chert
dc = detrital carbonate
ka = kaolinite (pore-filling)
φ = intergranular pore

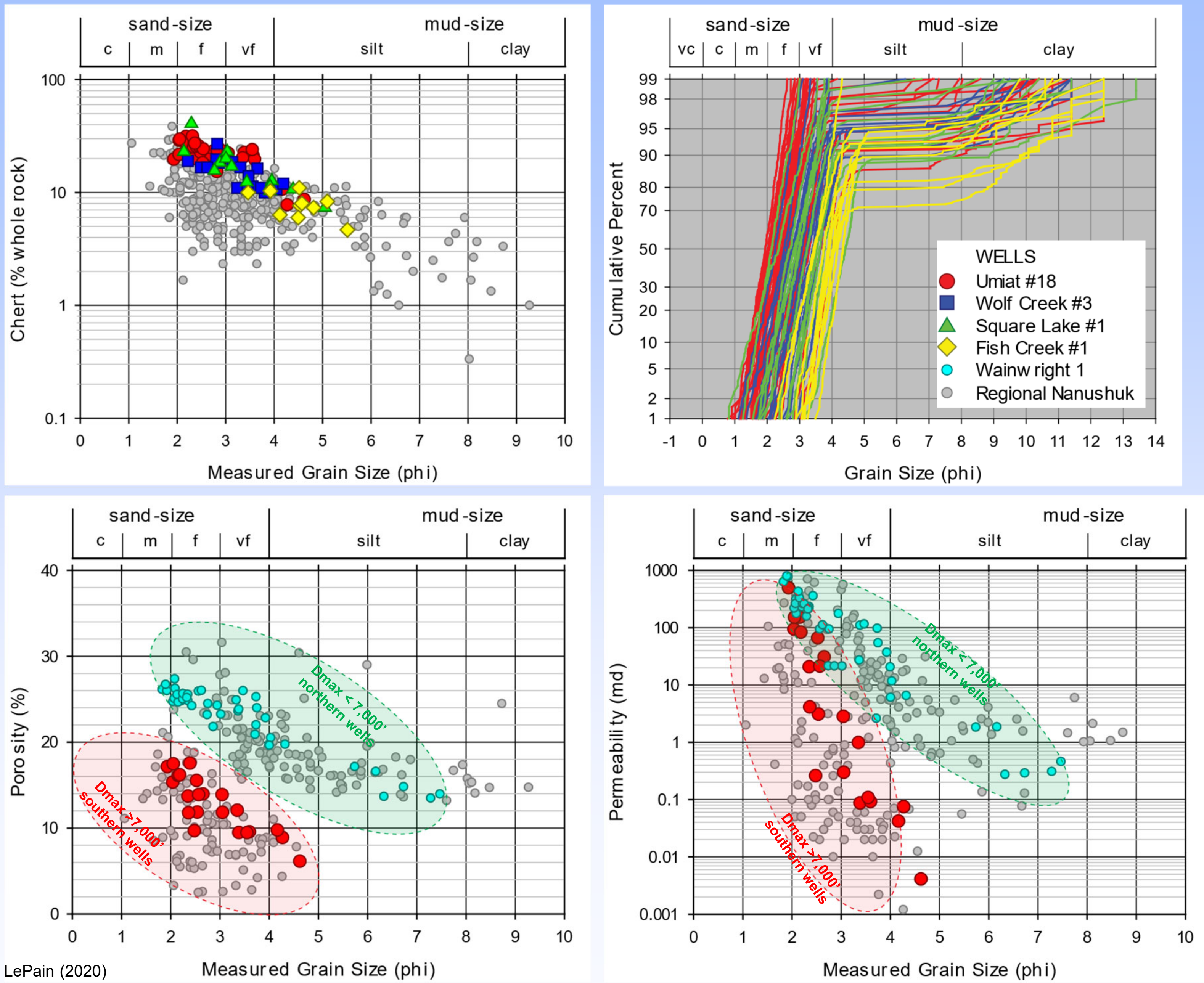
from Helmold (2016)

Nanushuk Phi-K Trends



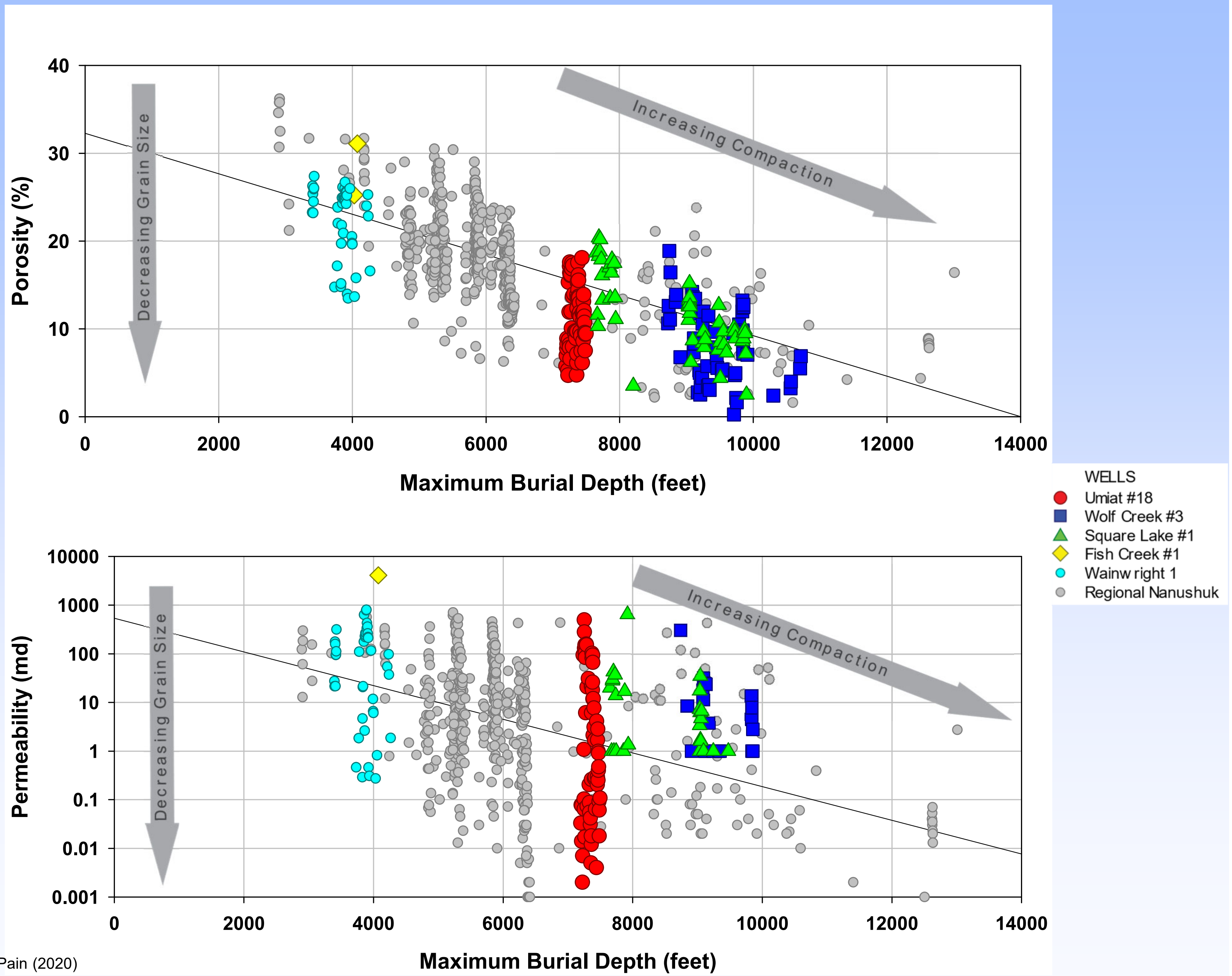
from Helmold and LePain (2020)

Nanushuk Grain Size Trends



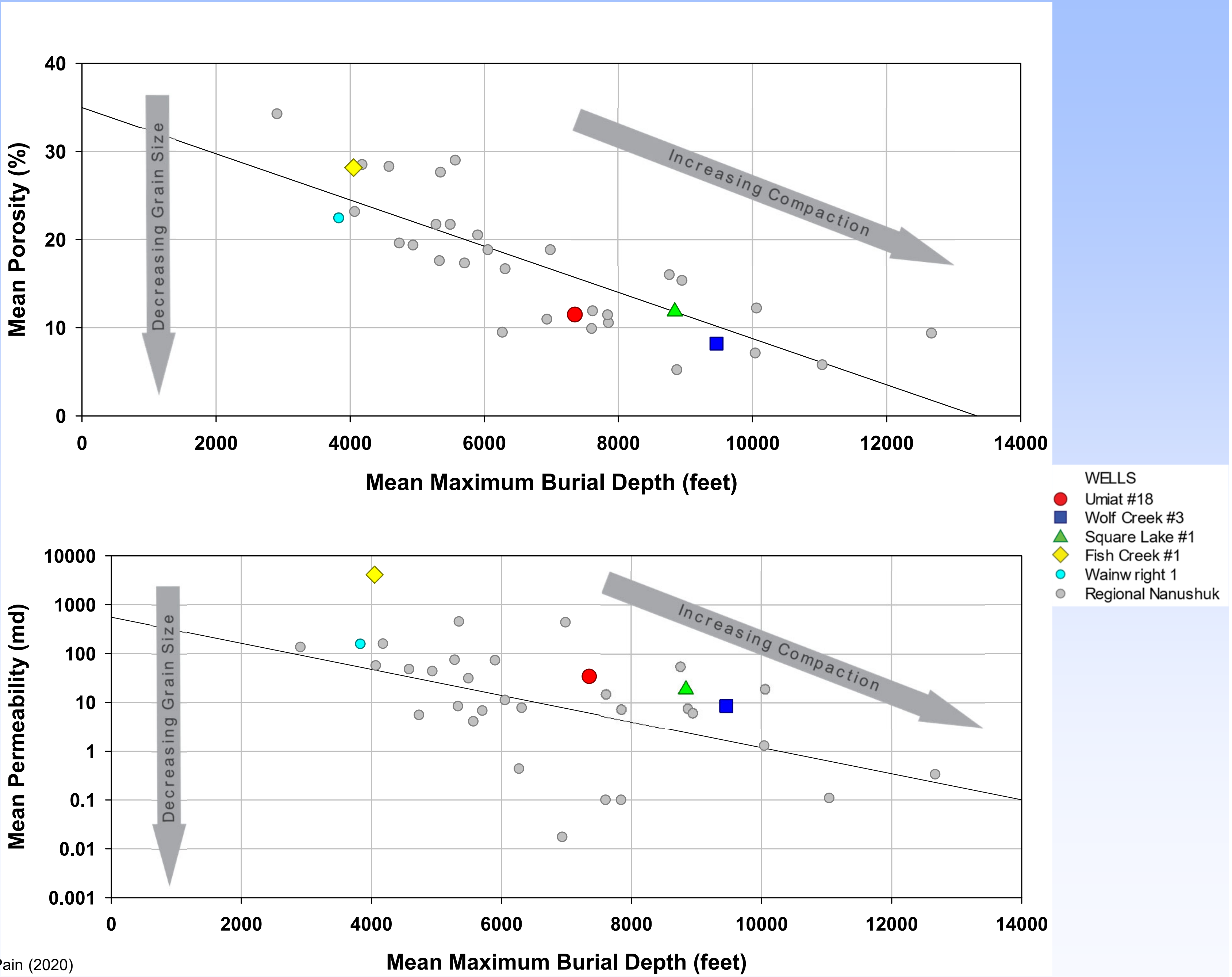
from Helmold and LePain (2020)

Nanushuk Phi-K vs. Dmax



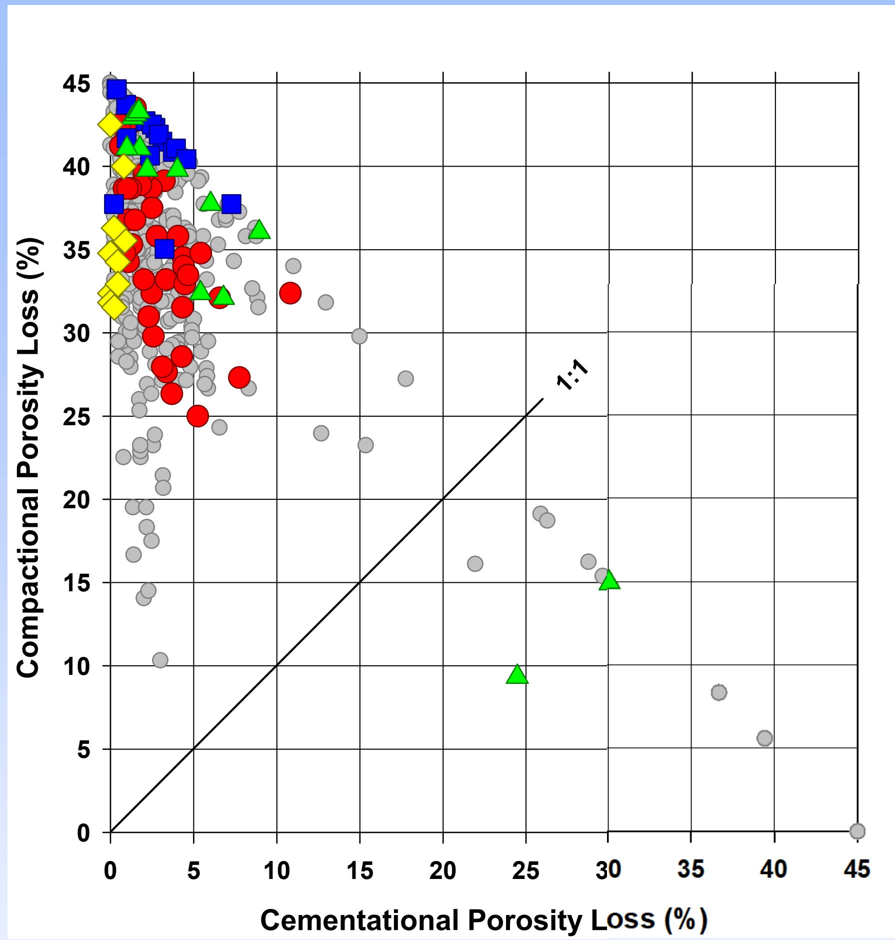
from Helmold and LePain (2020)

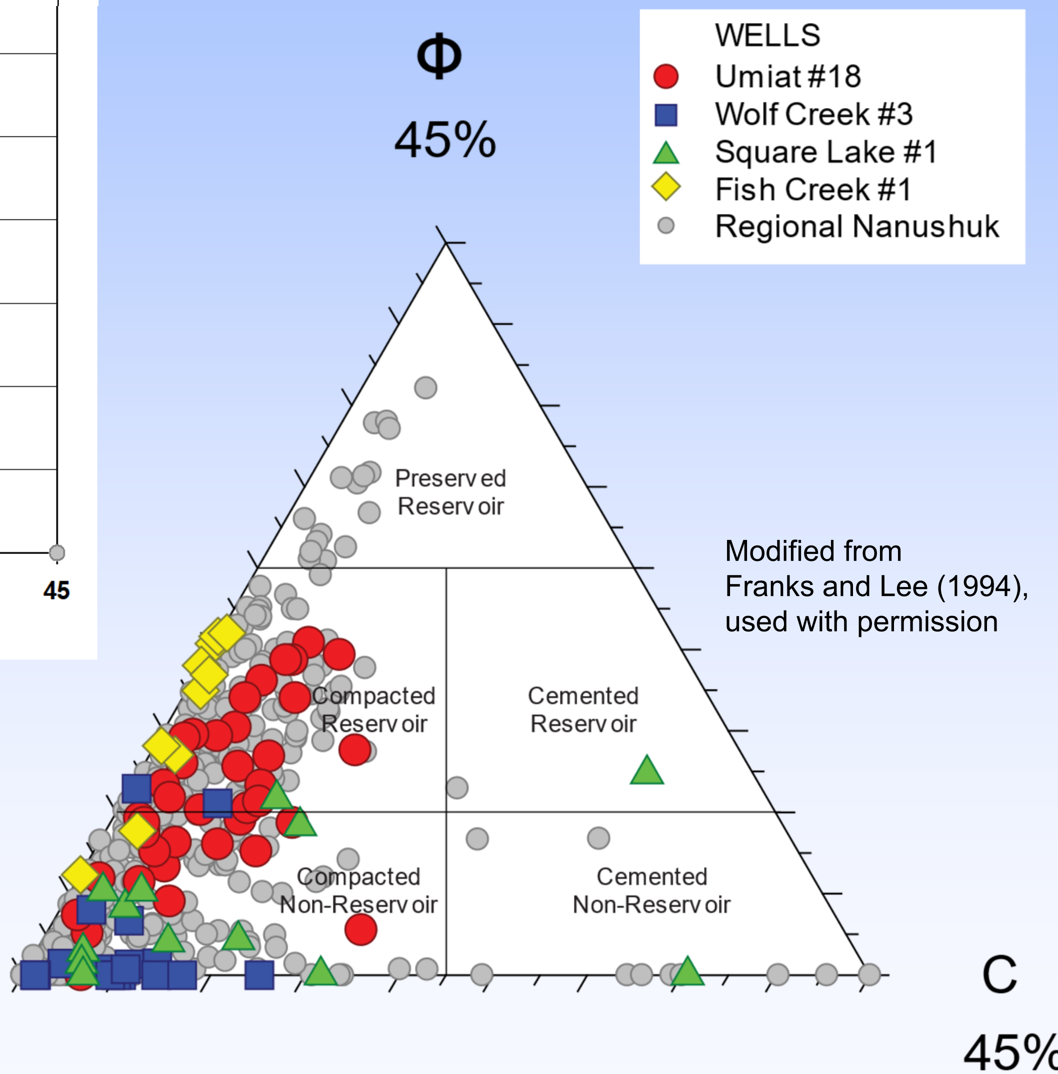
Nanushuk Phi-K vs. Dmax



from Helmold and LePain (2020)

Petrographic Assessment of Nanushuk Reservoir Quality





Modified from Franks and Lee (1994), used with permission

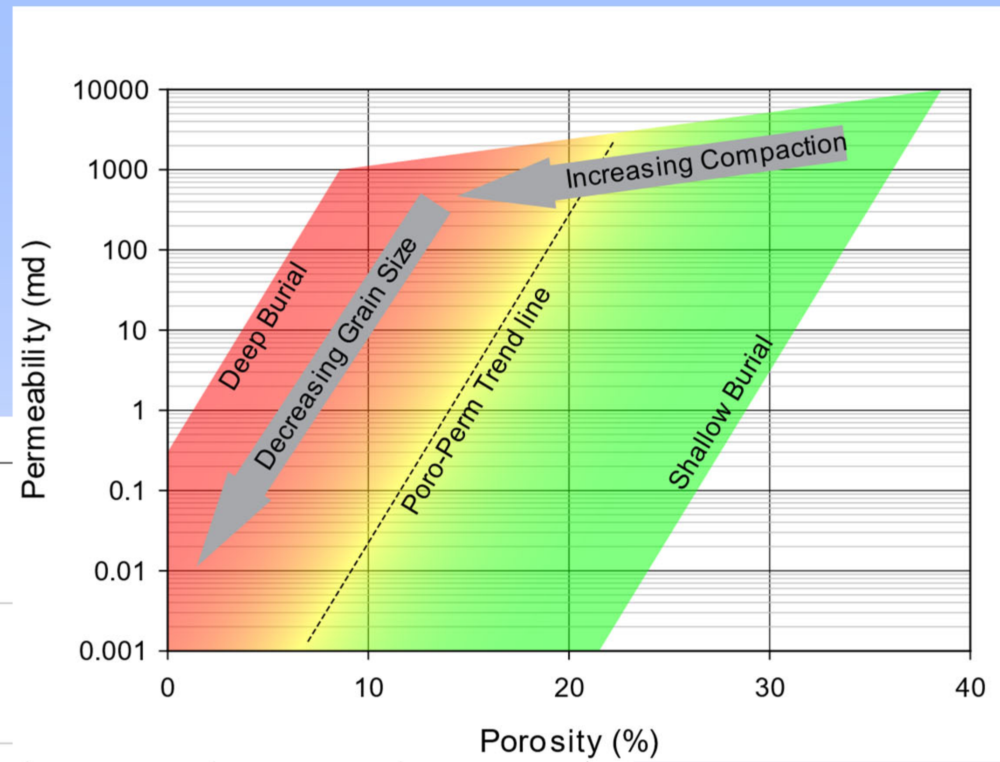
$COPL = P_i - (((100 - P_i) \times P_{mc}) / (100 - P_{mc}))$
$CEPL = (P_i - COPL) \times (C/P_{mc})$

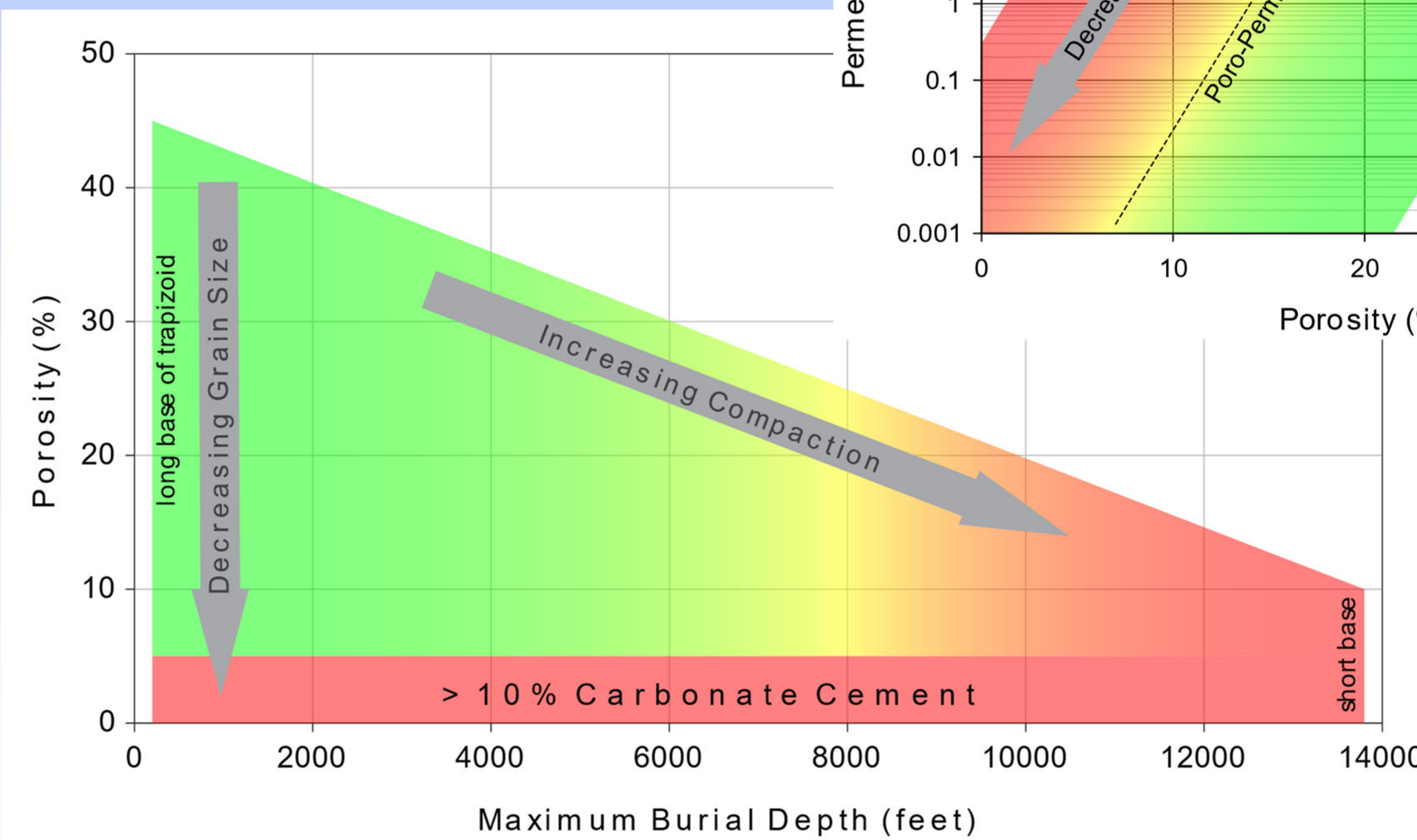
P_i = Initial (depositional) porosity
P_{mc} = Minus-cement porosity (P_o + C)
P_o = Optical (point-count) porosity
C = Pore-filling cement (volume %)

from Lundegard, 1992

from Helmold and LePain (2020)

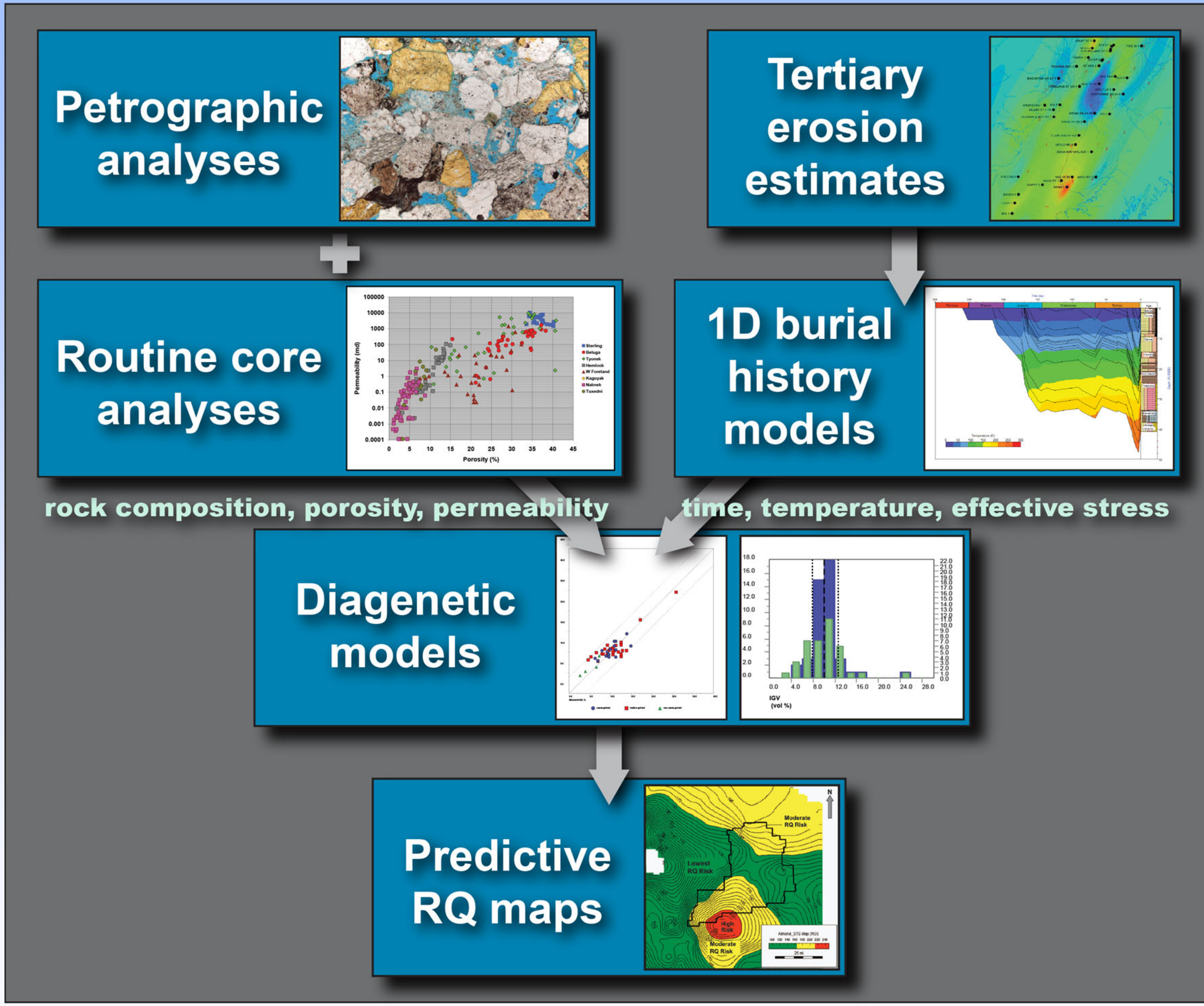
Theoretical Phi-Dmax & Phi-K Trends





from Helmold and LePain (2020)

Future Work – Diagenetic Modeling (Touchstone)



Conclusions

- Reservoir quality is initially controlled by textural parameters related to depositional energy (local control)
- High-energy facies (e.g., channels) are the best reservoirs; low-energy facies (e.g., levees) have minimal reservoir potential
- Mechanical compaction exerts a strong regional control on reservoir quality
- Cementation has minimal effect on RQ in most samples (highly cemented zones are local)
- Reservoir quality of Brookian sandstones can be accurately predicted prior to drilling (old school)
- Diagenetic models may be the wave of the future


The End