Improved Permeability Measurement using T_2 Bin-Distribution and Bulk Volume Irreducible from Nuclear Magnetic Resonance Tools

Case Study: Granite Wash, Hemphill and Wheeler Counties, TX.

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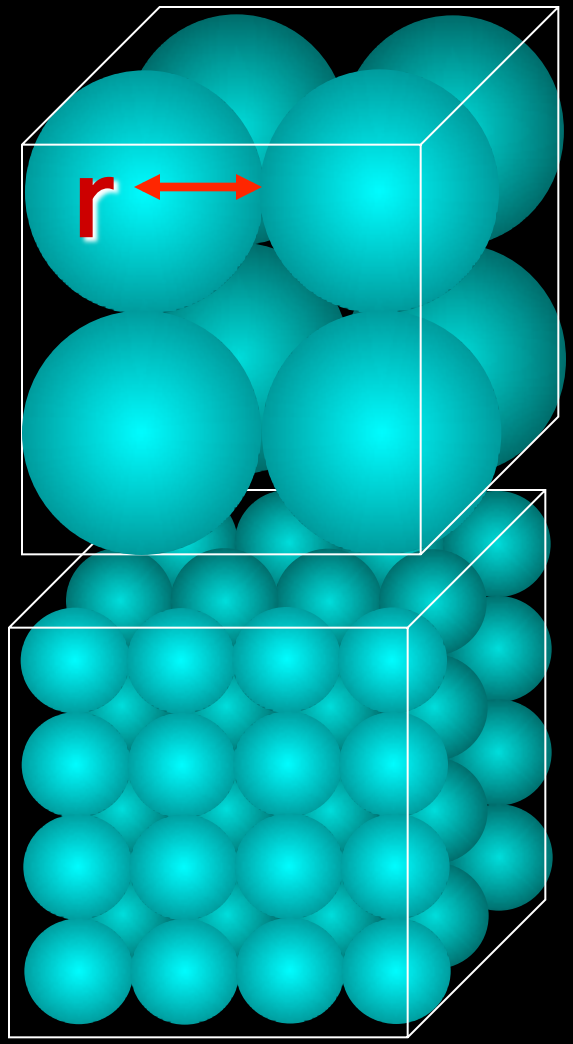
Standard porosity-based permeability measurements often do not indicate the best zones to perforate or reflect the ultimate hydrocarbon production potential.

Permeability measurements using Nuclear Magnetic Resonance (NMR) bin-distribution and bulk volume irreducible (BVI) data are compared to standard porosity-based permeability measurements as indicators of hydrocarbon production.

Predicting permeability from porosity

Cubic Packing

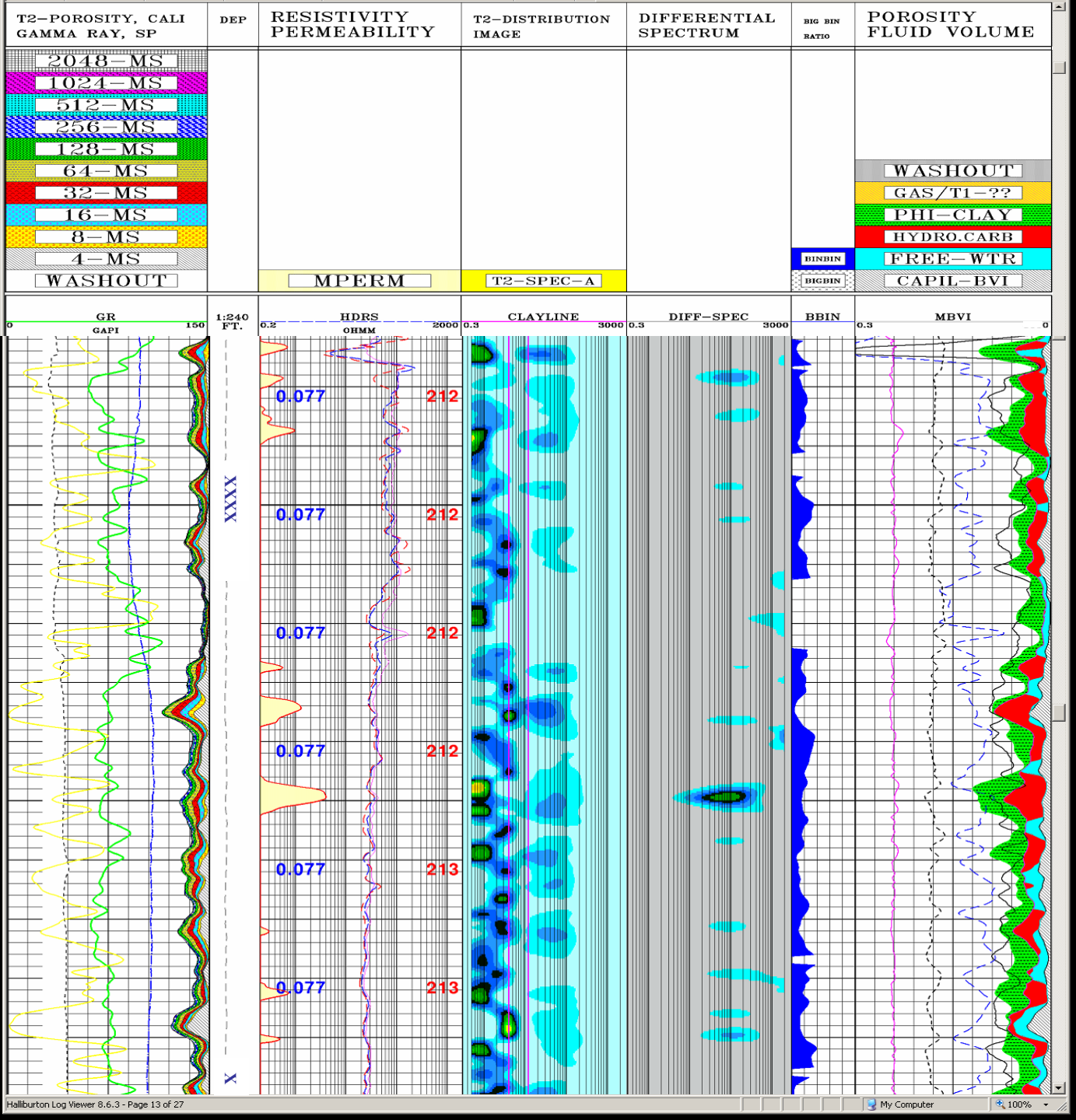


ϕ = 47.6 %
k = 5000 md
r = 2.0 μ

ϕ = 47.6 %
k = 5.00 md
r = 0.5 μ

- *Porosity is controlled by:*
  - ☒ Packing
  - ☒ Grain size distribution
- *Permeability is controlled by:*
  - ☒ Packing
  - ☒ Grain size distribution
  - ☒ Grain size

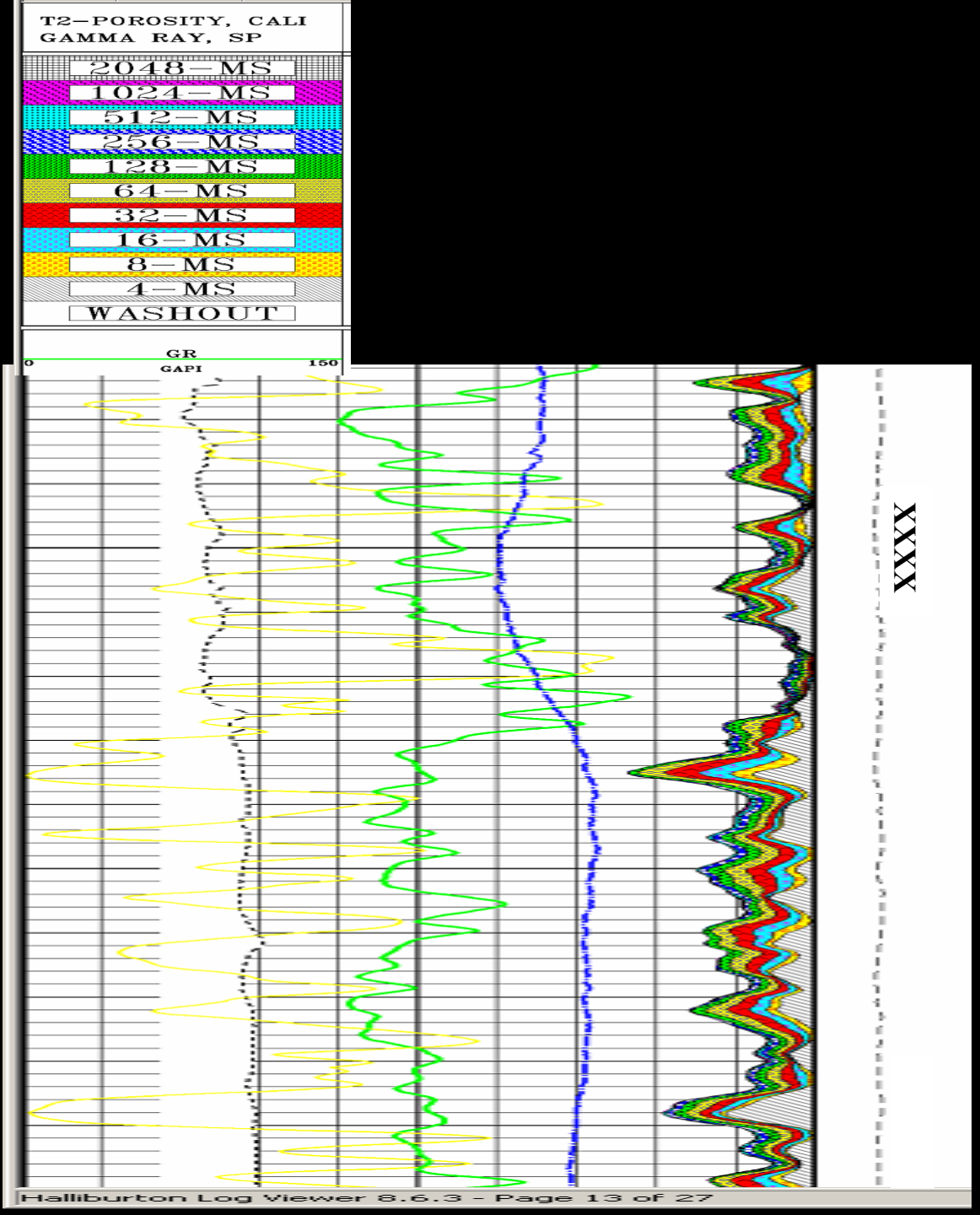
Porosity is independent of grain size



MRIAN

Magnetic Resonance Imaging Analysis

MRIL service



Bin Distribution is a function of:

Pore size
Fluid type

Case study

Seven wells were drilled in Hemphill and Wheeler Counties, TX

All were air drilled to avoid drilling problems and mud invasion into the formation

5 wells were loaded with fluid before logging
2 were logged with no fluid in the well

Client driven partnership between the operator and the service company.

Stimulation and wireline logging personnel met with client representatives to determine the best procedures and techniques for success.

Drilling, logging, and stimulation

Rotary cores from an offset well were used to aid in the petrophysical analysis.

Cores were characterized by NMR laboratory measurements to define BVI and SBVI relationships and permeability parameters.

Triple combo data was logged.

Sonic was not, but could have been used in the frac design.

NMR (Magnetic Resonance Imaging Log – MRIL) was recommended and run as a porosity, BVI, and permeability measurement.

Conventional rotary core and NMR analysis:
Porosity, permeability and grain density
NMR T2 analysis for BVI, SBVI and permeability coefficients

At the time, Coates IV was the preferred permeability equation:

$$MPERM = \left[(MPHI / C)^2 * (FFI / BVI) \right]^m$$

The Bin Perm Equation is based on the relationship of pore size to T_2 time. High porosity in the larger bin sizes increases bin permeability:

$$BPERM = \left[(MPHI / C)^2 * \left(\sum_{T2Bphi4ms}^{T2Bphi2048ms} wf * T_2 Bphi / BVI \right) \right]^m$$

T_2 time is highly influenced by pore size and fluid type.

wf is a weighting factor based on NMR Bin distribution

Typical Well Stimulation Program

Job Procedure Granite Wash A

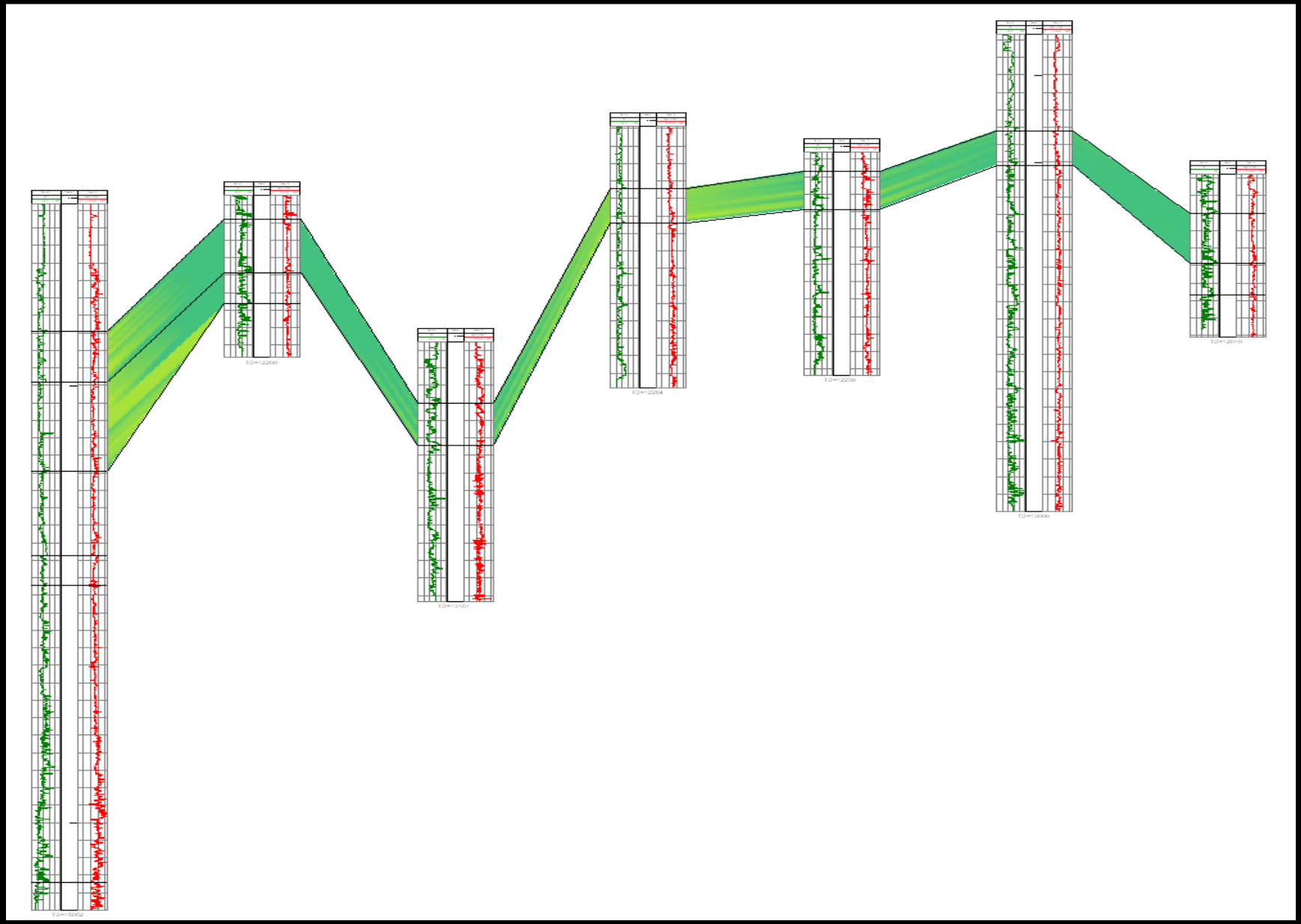
Proposal for the Waterfrac of the Granite Wash A interval at 130bpm and ±3100psi down the casing.

Job Summary

7.5%_Hydrochloric Acid	4,000	Gal	
Treated Water	336,923	Gal	
Premium White-20/40		180,000	lbm
Total Job Volume	340,923	Gal	
Total HES Supplied Water	3,240	Gal	
Total Water Required		340,163	Gal
Total Proppant Quantity	180,000	lbm	
Pad Percentage	50.90	%	
Job Rate	130	bbl/min	
Total Customer Supplied **			
Fresh Water **	336,923	Gal	

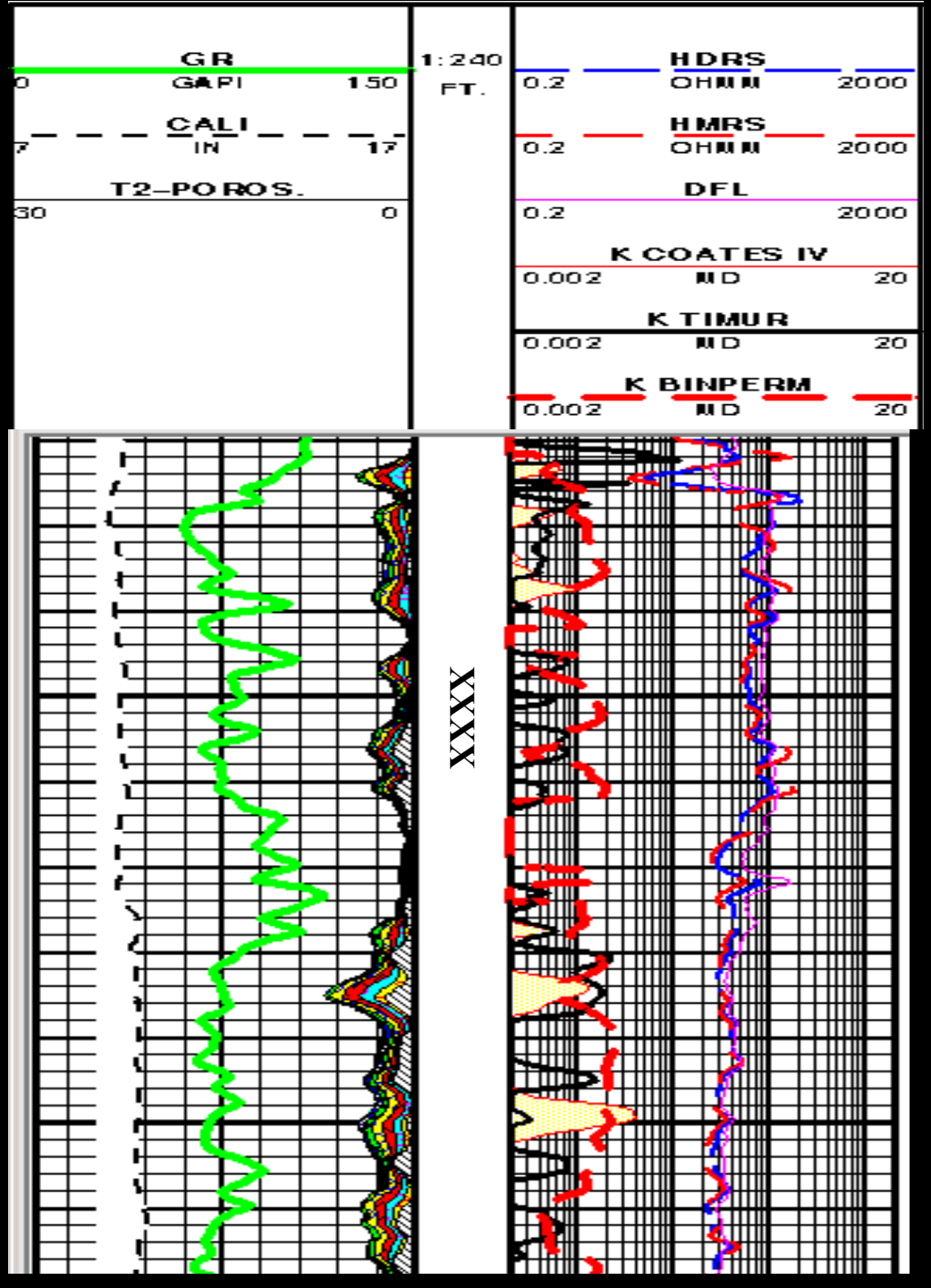
Drilling, logging, and stimulation procedures were fairly uniform across all seven wells

Granite Wash A & B



Permeability Comparisons

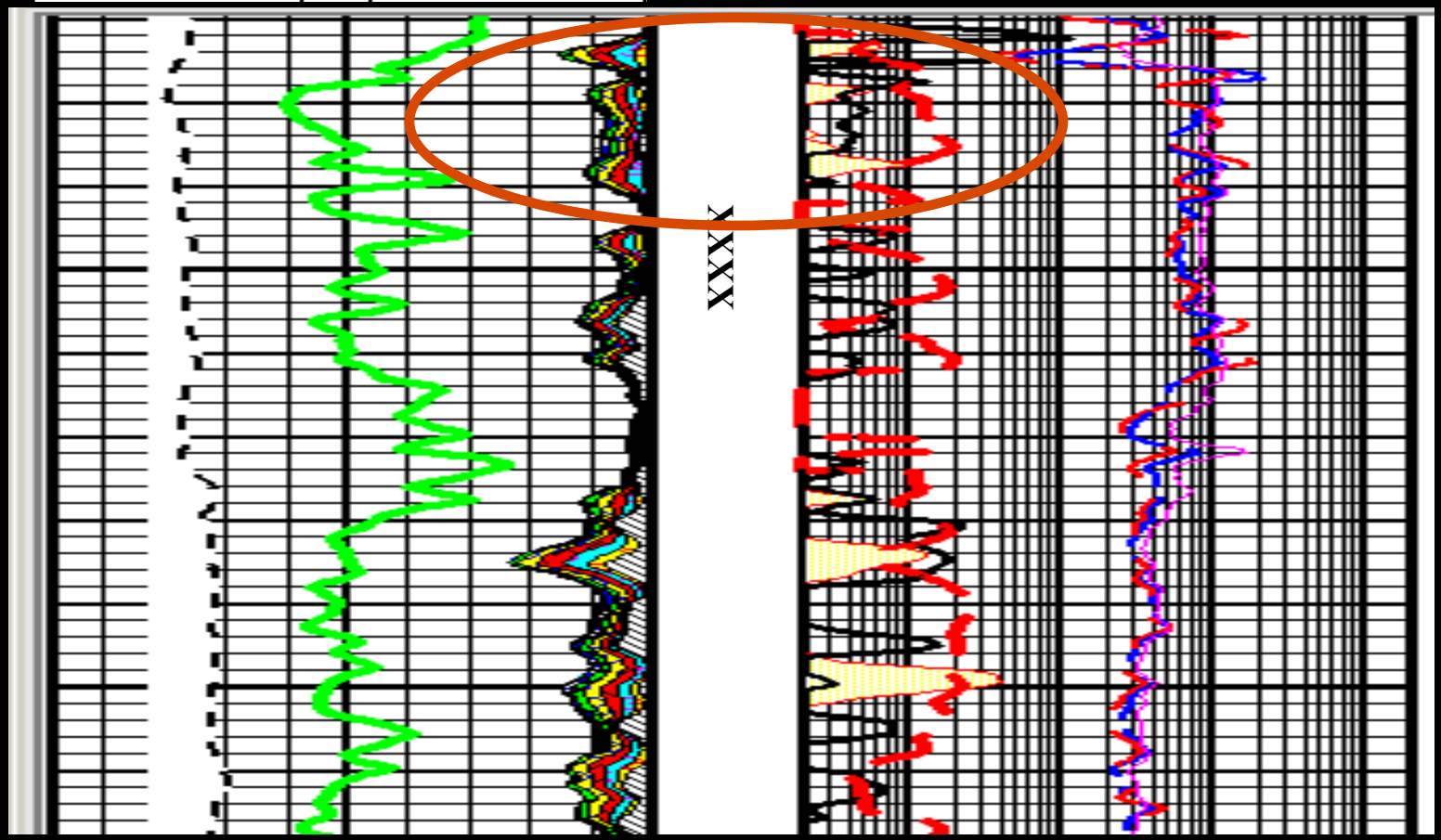
Perfs	Perf Interval	Gas Cum MCF	Prod Life Months	MCF / Month	MCF / Day	HCPV	HCPV / FT	Timur kh	Timur k Avg md/ft	Coates VI kh	Coates IV Avg md/ft	MRIL BigBin kh	MRIL BigBin Avg md/ft
11186-12100	914	480152	47	10216	340	16.43	0.0180	2.742	0.0030	13.18	0.0144	7.295	0.00798
12786-13123	337	308179	30	10272	342	3.987	0.0118	3.086	0.0092	0.4	0.0012	3.026	0.00898
11950-13123	1173	31858	11	2896	96	17.324	0.0148	8.475	0.0072	1.04	0.0009	10.01	0.00853
11298-12117	819	383655	37	10369	345	21.471	0.0262	8.282	0.0101	4.675	0.0057	7.463	0.00911
11182-11941	759	266106	44	6047	201	17.959	0.0237	1.193	0.0016	10.561	0.0139	4.01	0.00528
11187-11998	811	282902	40	7072	235	14.927	0.0184	14.455	0.0178	3.765	0.0046	6.354	0.00783
11049-12261	1212	342223	36	9506	318	43.042	0.0239	16.216	0.0134	12.604	0.0104	8.971	0.00740



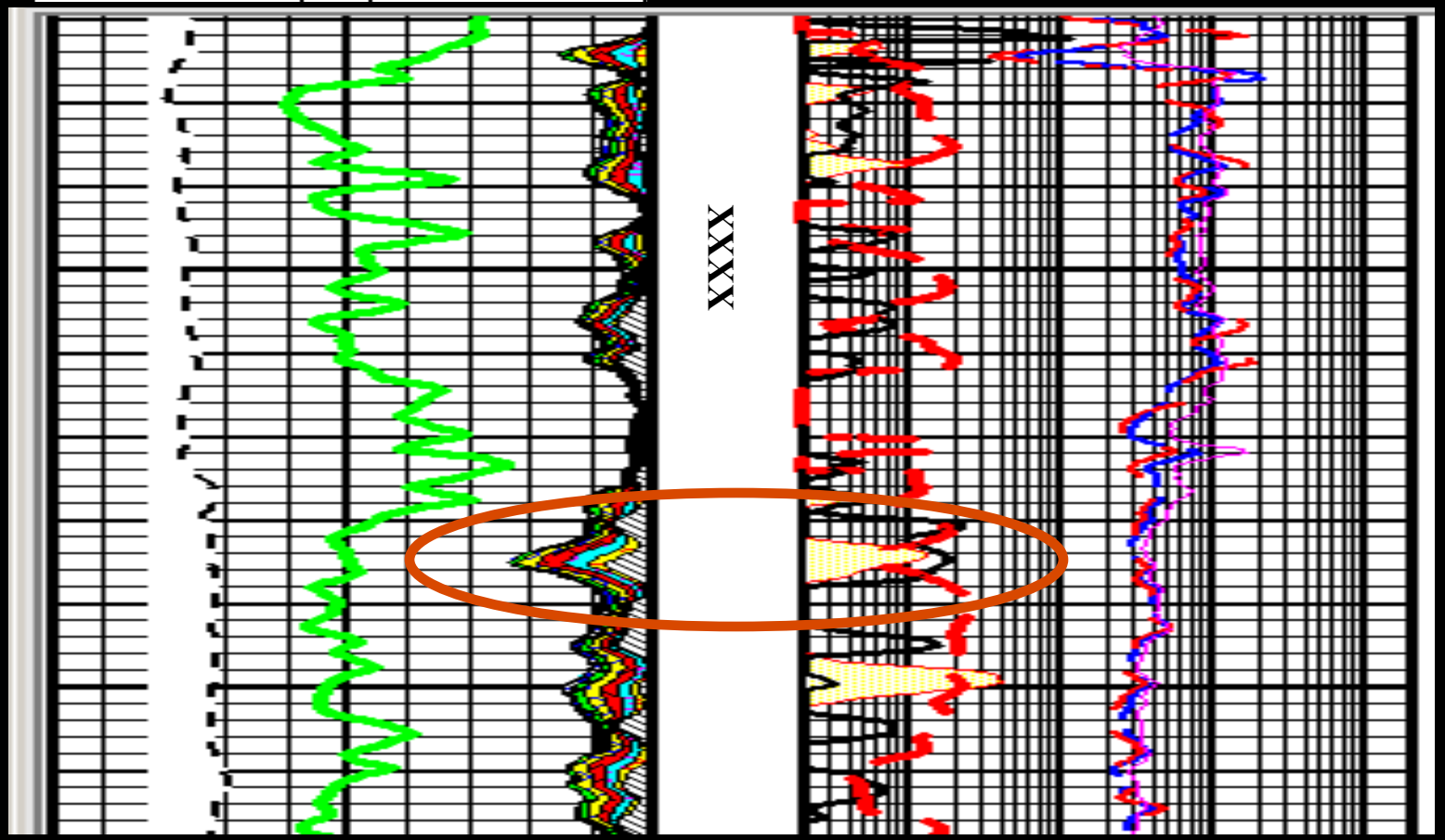
Comparison of Permeability equations:

Timur
Coates IV
BinPerm

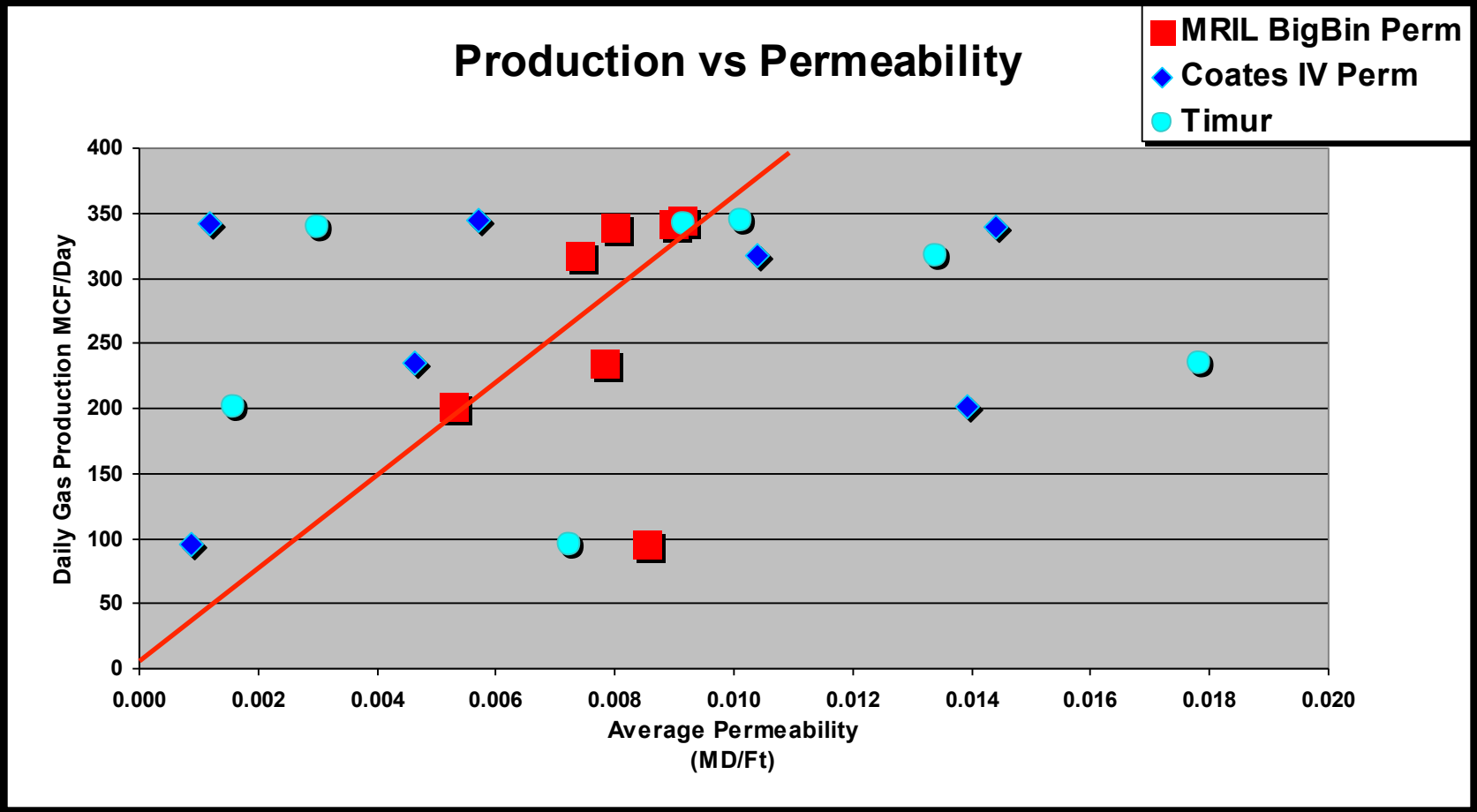
BinPerm response in relatively high permeability



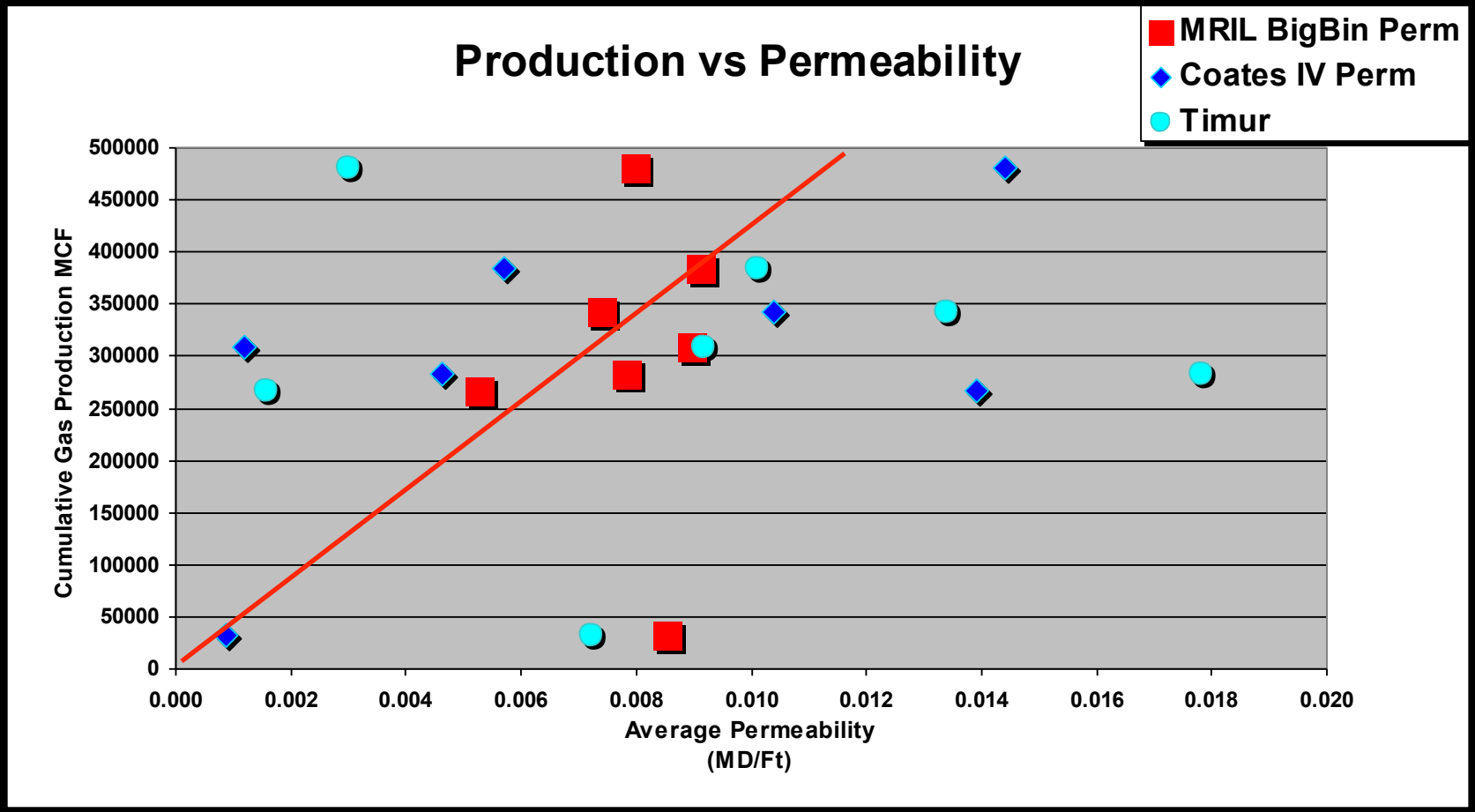
BinPerm response in relatively low permeability



Permeability Comparisons



Permeability Comparisons



Conclusions

Permeability measurements using NMR bin-porosity and BVI data provide a good indicator of ultimate hydrocarbon production, at least in this Granite Wash field study.

More comparisons are suggested to determine if this method can be applied to other fields and formation types.