CORE AND PETROPHYSICAL ANALYSIS TO DESIGN A PROPER PERFORATION TECHNIQUE FOR PRODUCTION ENHANCEMENT A CASE STUDY, HASSI MESSAOUD FIELD

MENAPS-11-16

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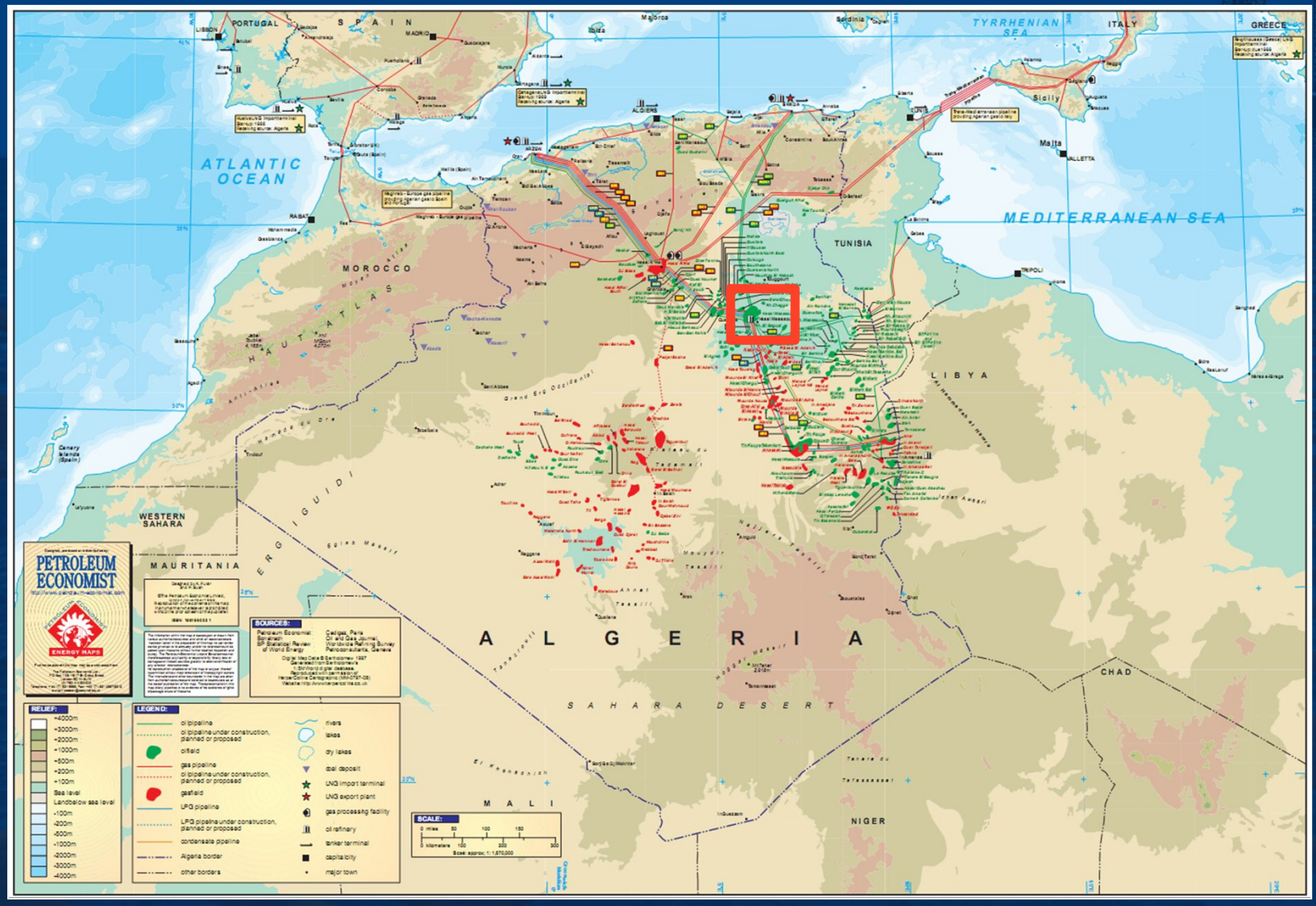
Outline

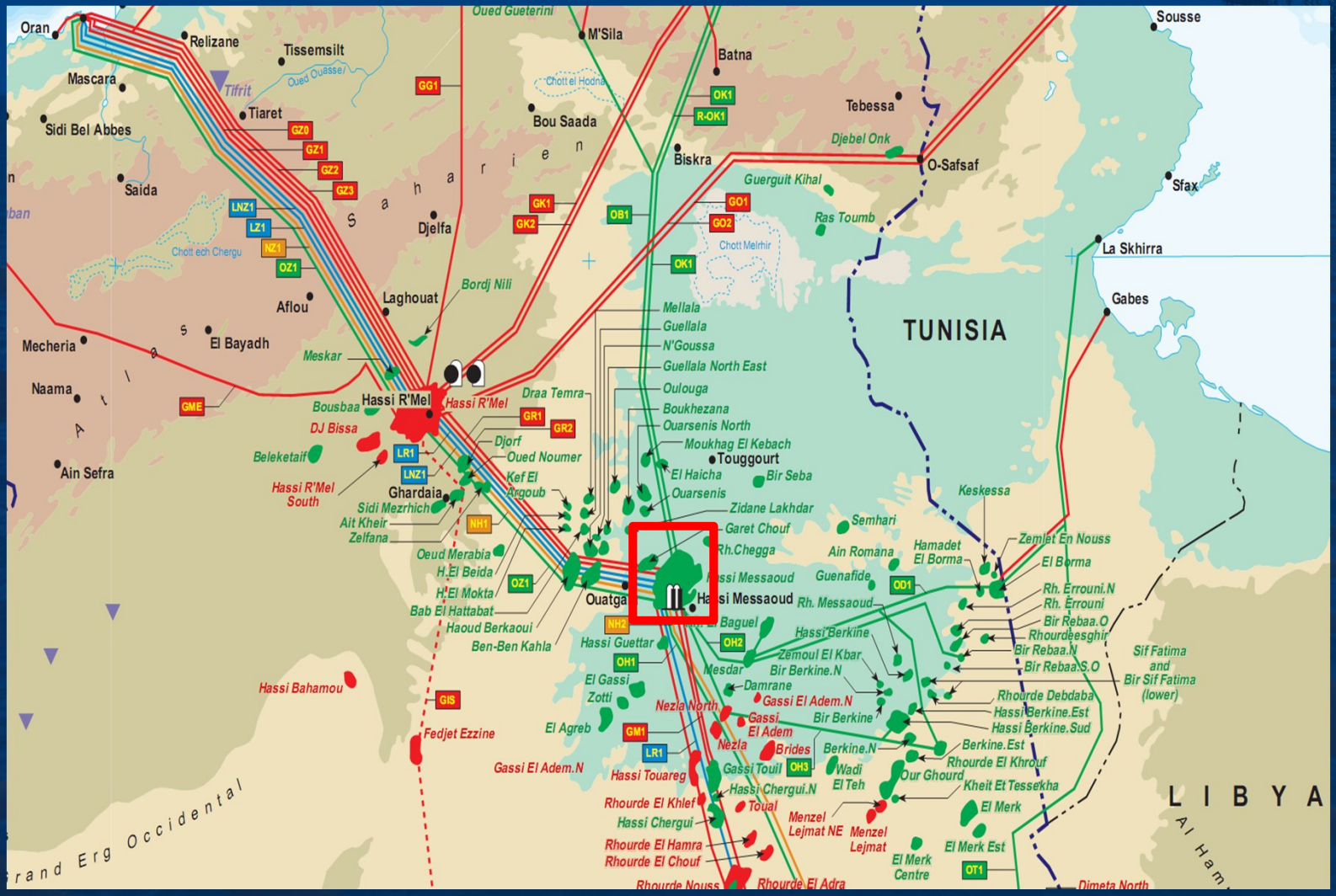
- Overview of Hassi-Messaoud field
- Core analysis
- Perforation strategy & Case Study
- Conclusions

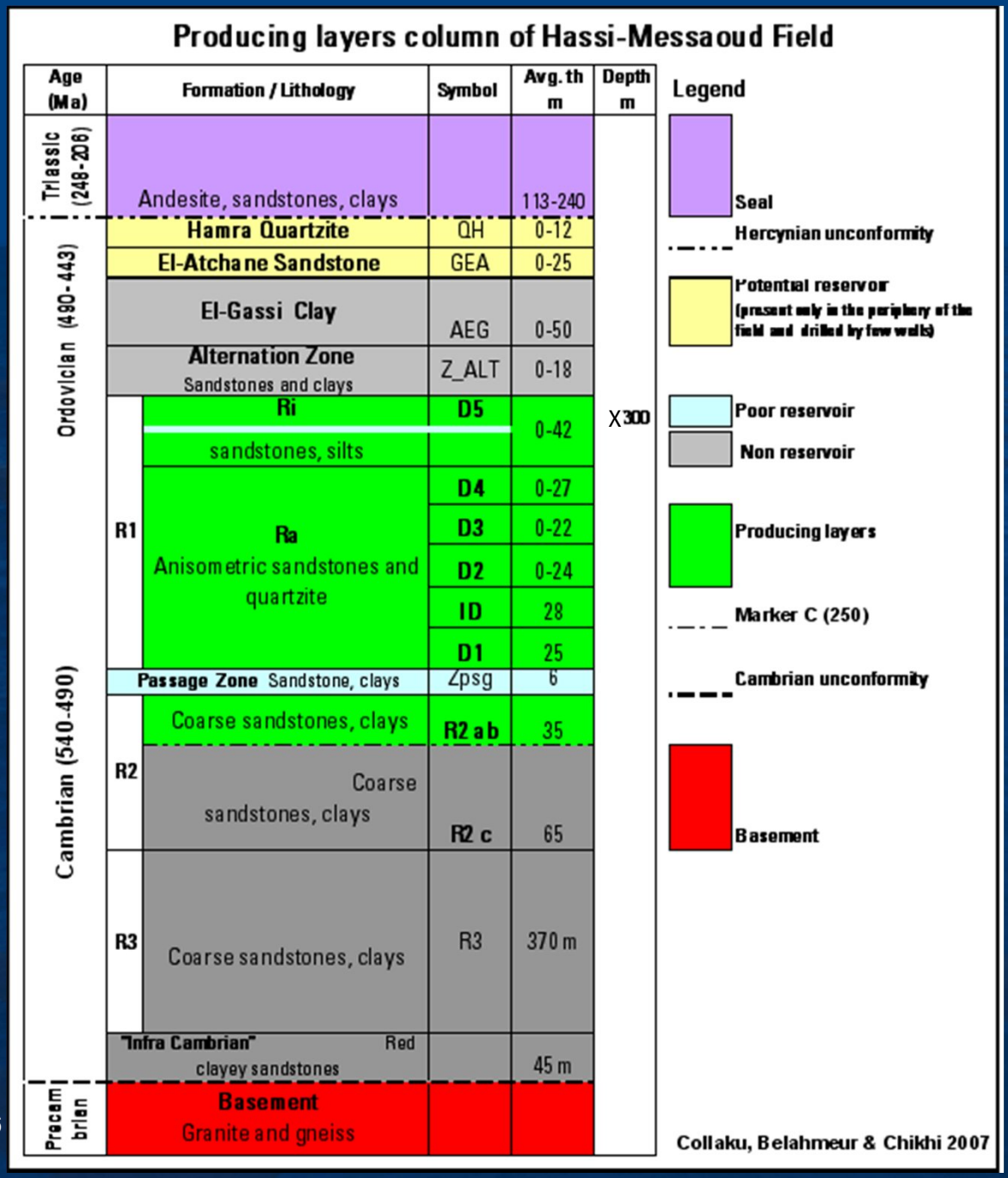
Overview of Hassi-Messaoud Field

Hassi Messaoud field



Hassi Messaoud field



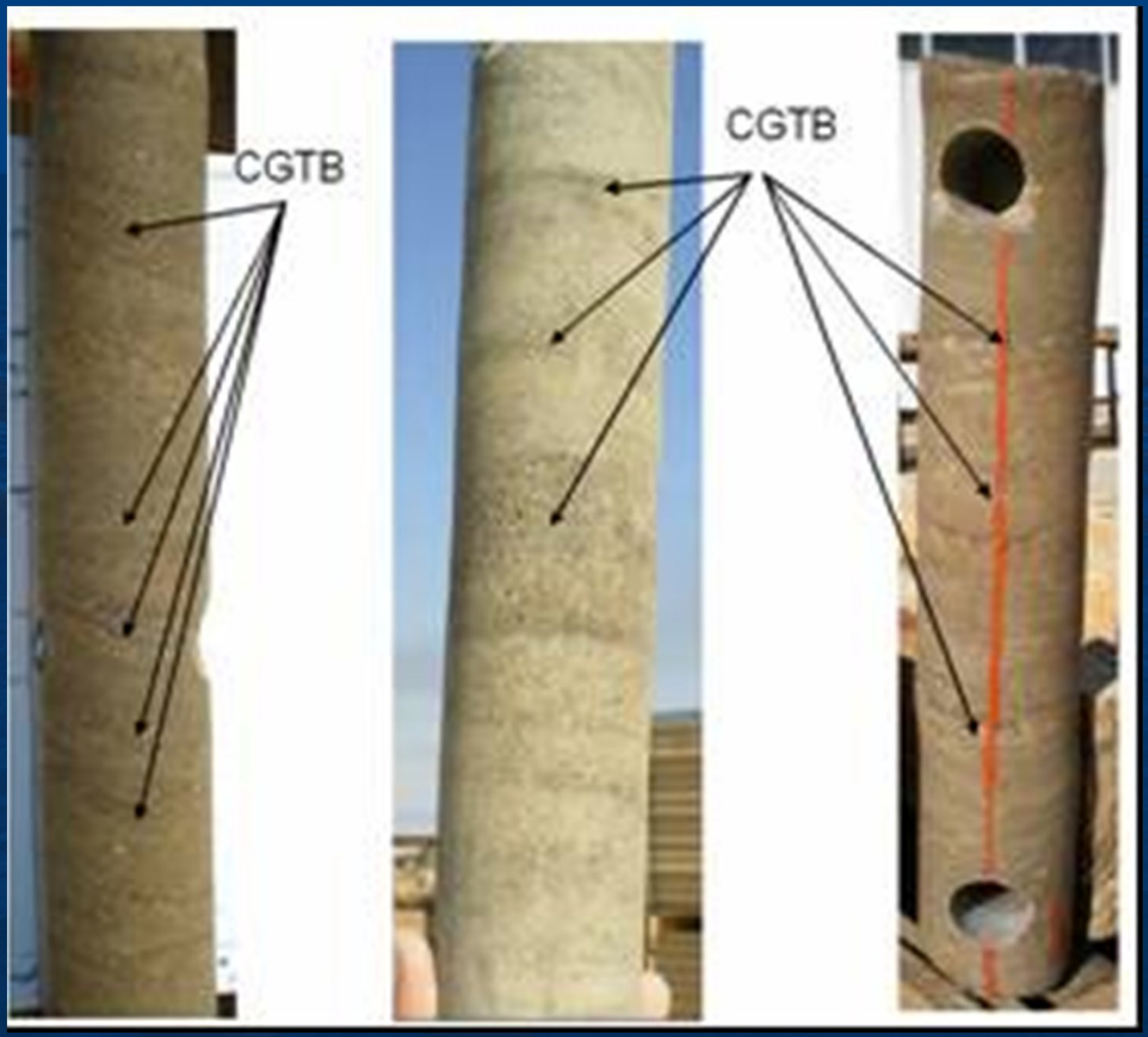

Producing layers column of Hassi-Messaoud Field
Age (Ma)
Formation / Lithology
Symbol
Avg. th m
Depth m
Legend
Triassic (248-206)
Andesite, sandstones, clays
113-240
Ordovician (490-443)
Hamra Quartzite
QH
0-12
El-Atchane Sandstone
GEA
0-25
El-Gassi Clay
AEG
0-50
Alternation Zone
Sandstones and clays
Z_ALT
0-18
R1
Ri
sandstones, silts
D5
0-42
X300
Ra
Anisometric sandstones and quartzite
D4
0-27
D3
0-22
D2
0-24
ID
28
D1
25
Passage Zone Sandstone, clays
Zpsg
6
Cambrian (540-490)
R2
Coarse sandstones, clays
R2 ab
35
Coarse sandstones, clays
R2 c
65
R3
Coarse sandstones, clays
R3
370 m
"Infra Cambrian" Red clayey sandstones
45 m
Precambrian
Basement
Granite and gneiss
Seal
Hercynian unconformity
Potential reservoir
(present only in the periphery of the field and drilled by few wells)
Poor reservoir
Non reservoir
Producing layers
Marker C (250)
Cambrian unconformity
Basement
Collaku, Belahmeur & Chikhi 2007

Core analysis

- Coarse Grain Thin Beds (CGTB)
- Fractures

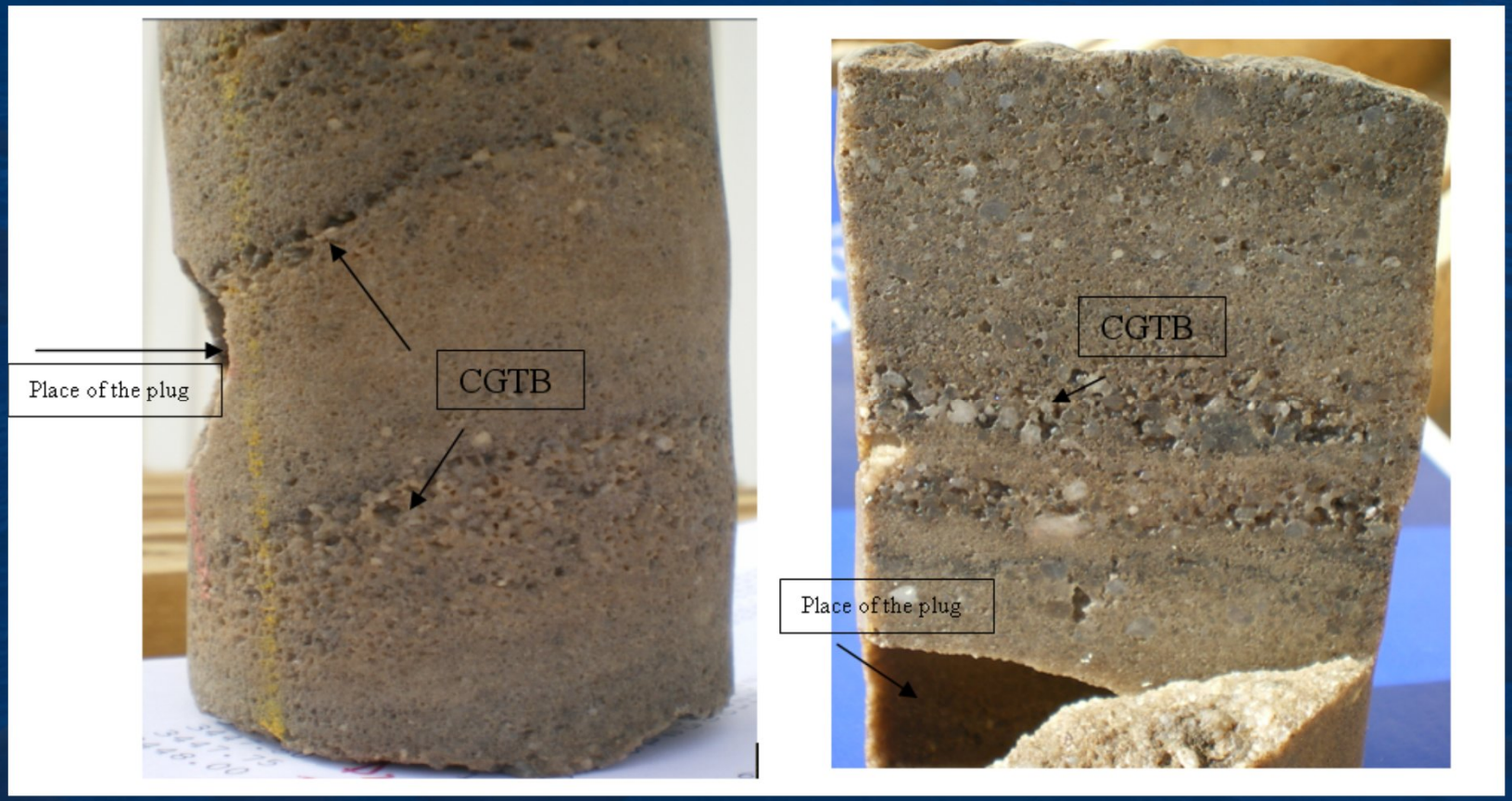
Coarse Grain Thin Beds (CGTB)

- Over all studied area where stacked fluvial or tidal channels the Coarse Grain Thin Beds are present (D4, D2, ID, D1)
- The Coarse Grain Thin Beds exhibits good porosity and permeability values and greatly contribute to the well potential
- CGTB in terms of flow might have the same behavior as fractures



Example of Coarse Grain Thin Beds (CGTB) with tight matrix from above and below

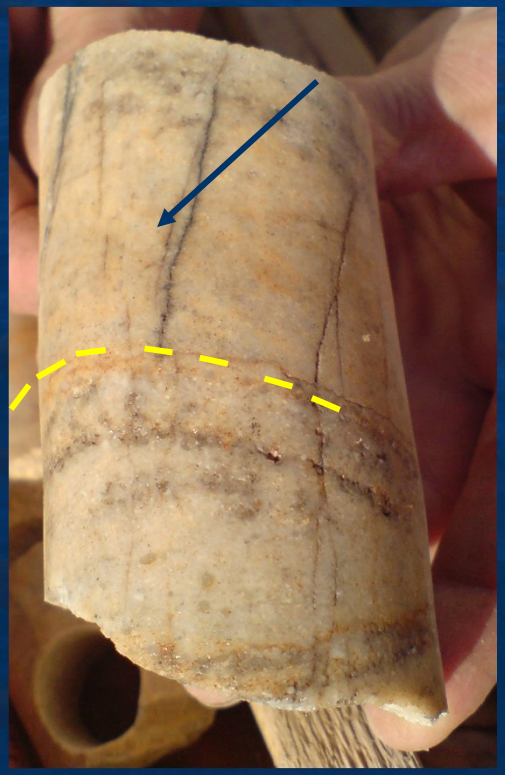
Photographs showing good examples of Coarse Grain Thin Beds separated by tight horizontal barrier.



Fractures

- In the analyzed wells, most of the vertical and sub-vertical fractures are very thin with aperture much less than 1 mm and very often cemented

- The wells where the thin layers and vertical fractures meet together they could provide good rates of production



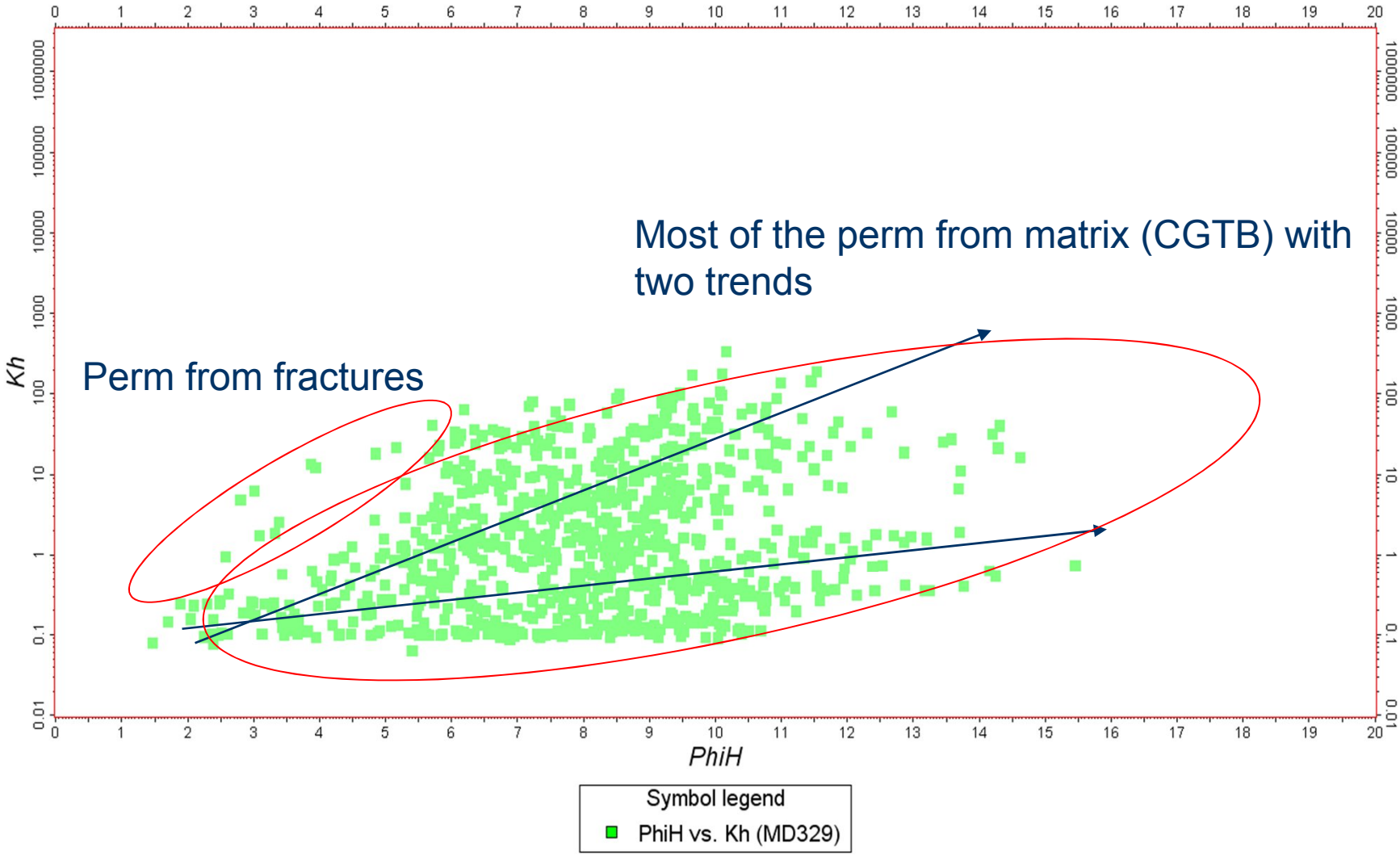
Core samples of D2 drain of Hassi-Messaoud field

Fractures partly cemented by quartz and asphalt cutting across cross-beds

Example of CGTB's connected with vertical fracture.

Many CGTBs connecteb by Vertical fracture

K-Phi Plot


Most of the perm from matrix (CGTB) with two trends
Perm from fractures
Kh
PhiH
Symbol legend
PhiH vs. Kh (MD329)

Perforation strategy & Case Study

- Perforations Conventions
- Dynamic underbalance (PURE)
- Multiple Shooting
- Coarse Grain Thin Beds & Multiple PURE Shooting
- Case Study – MD4XX

Perforation Conventions

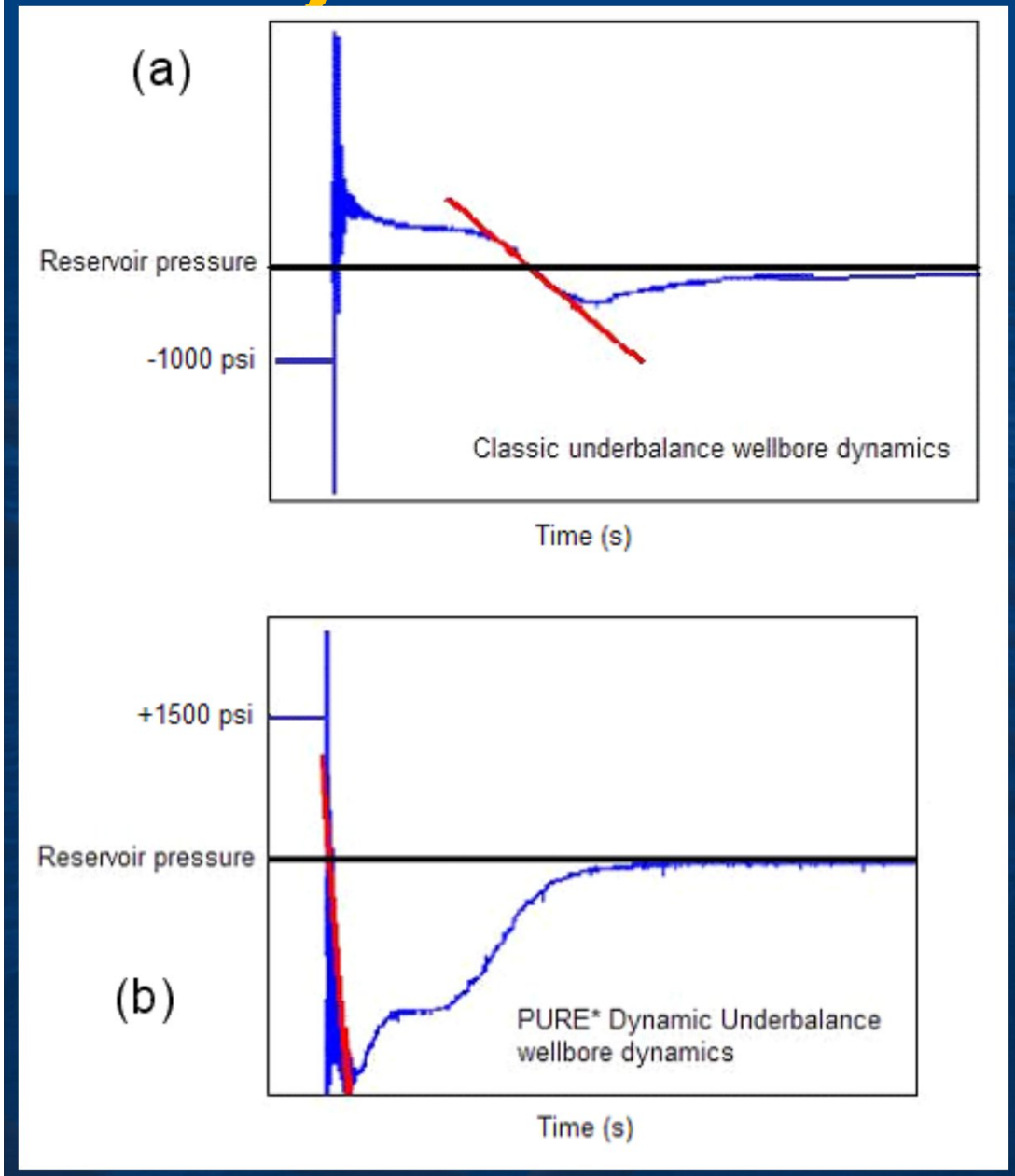
- **Static Conditions**
  - Overbalance, Ph>Pr
  - Balance, Ph=Pr
  - Underbalance, Ph<Pr

- **Dynamic Conditions**
  - A combination of reservoir and well information and knowledge put together to calculate for a dynamic underbalance for optimal perforation tunnels cleaning under all the above static conditions

Dynamic Underbalance PURE*

- A technique to obtain a dynamic underbalance during the perforation process
- Can be performed in one or several runs
- Applies for oil, gas, water, in vertical, slanted, and horizontal wells.
- PURE perforation can also be oriented.
- Increases productivity or injectivity by maximizing perforation cleanup
- Is not an alternative for other means of formation stimulation

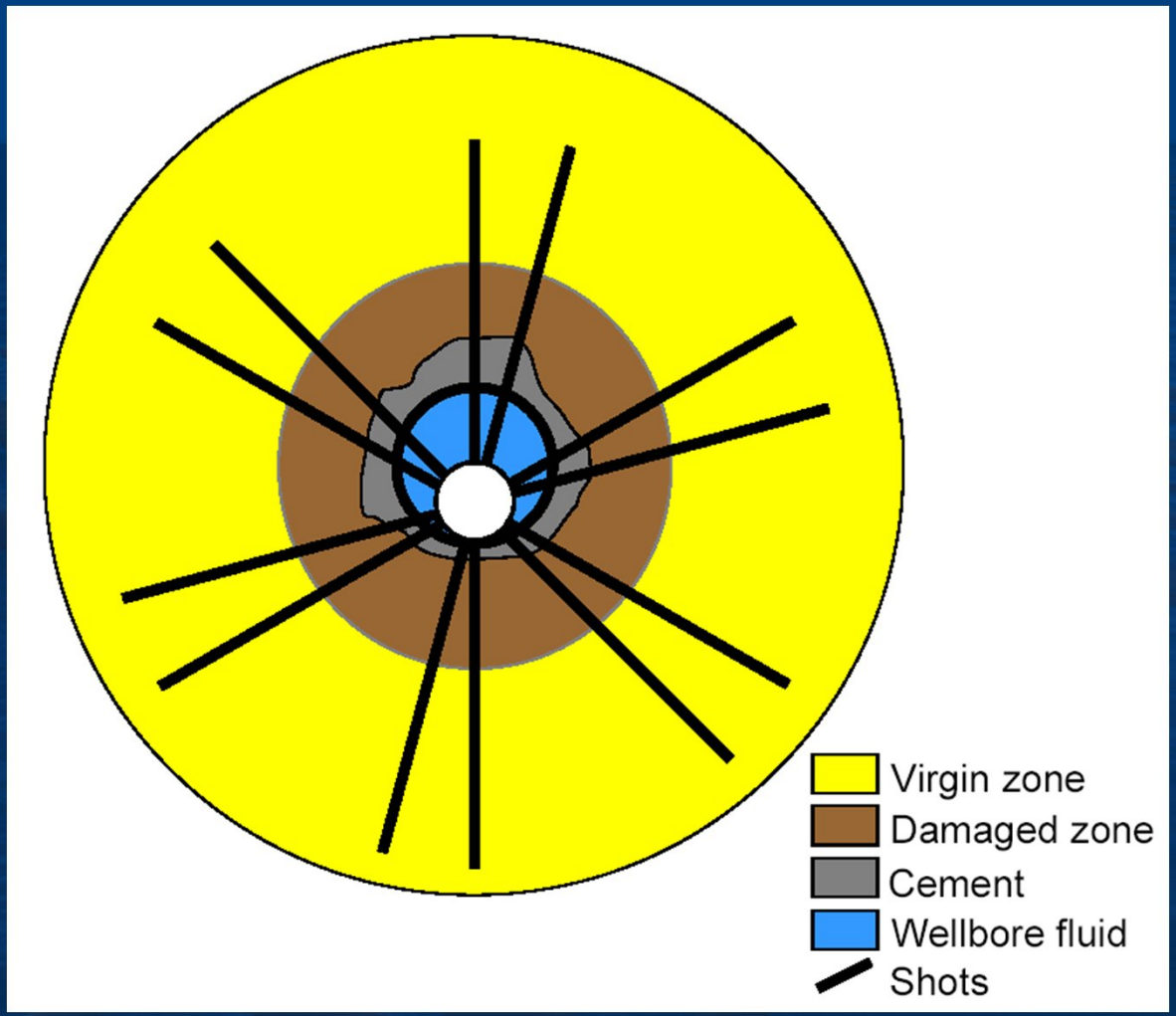
Dynamic Versus Classical



Classical Underbalance

Dynamic Underbalance
PURE

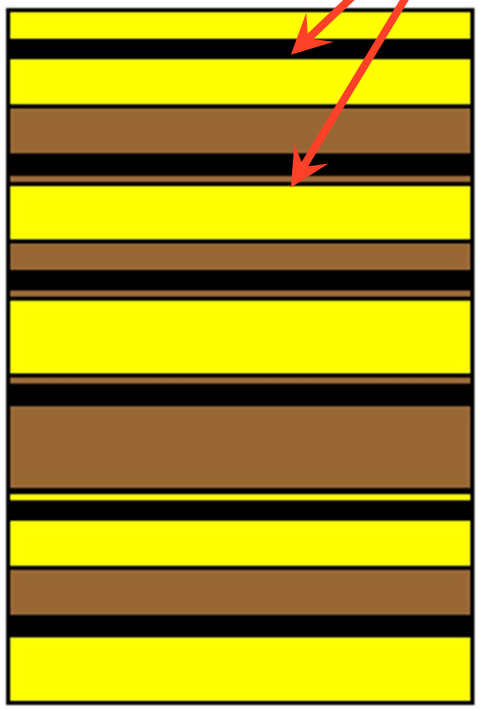
Multiple Shooting



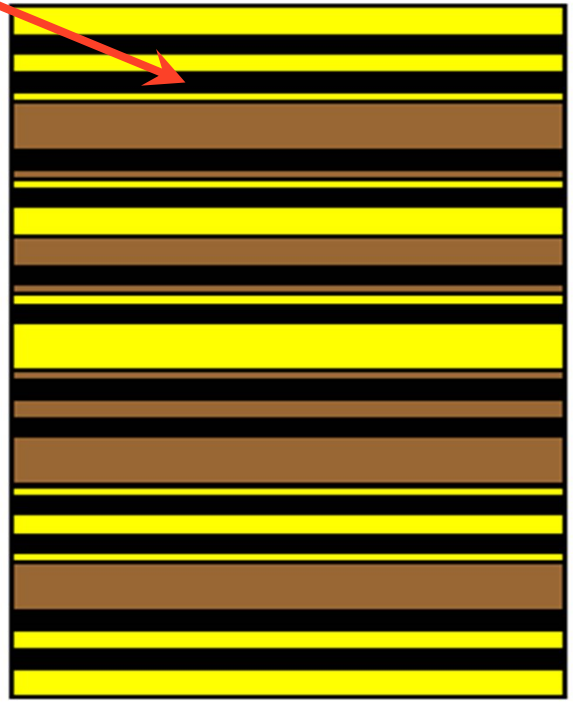
The objective of multiple shooting Is to obtain more SPF in a small Size casing (as of case 4 ½") In order to expose more of CGTB to The wellbore for enhancing well Productivity.

Single and multiple Shooting with thin layers

Black Lines are Perforation Tunnels

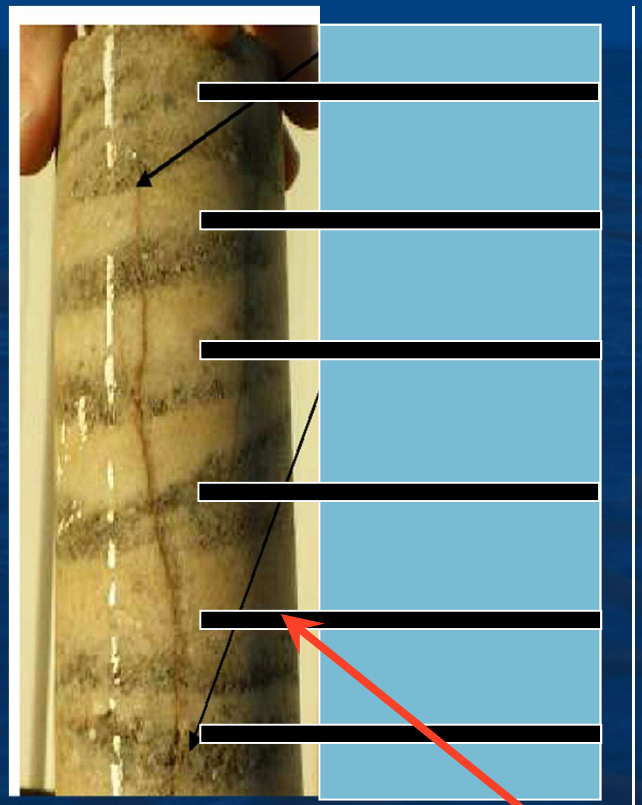


1 ft, 6

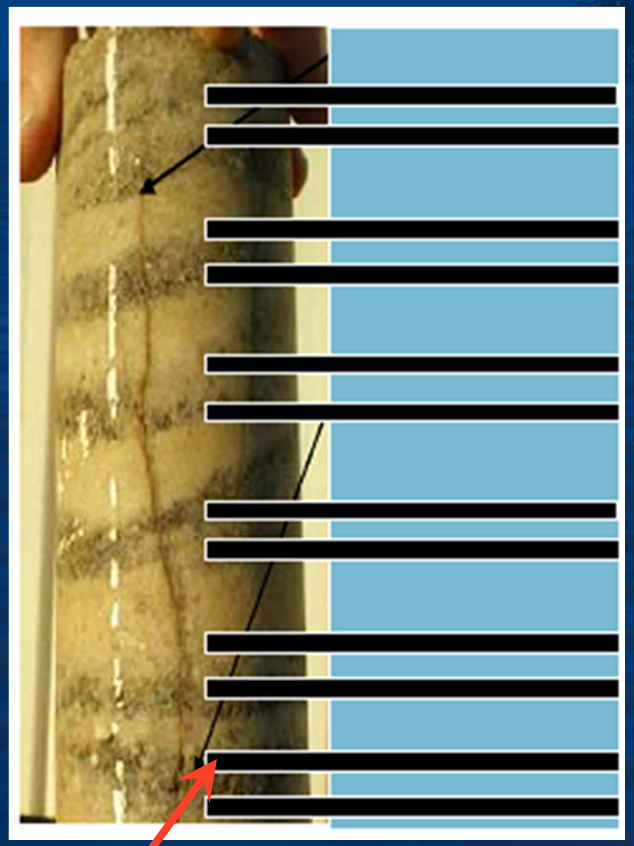


1 ft, 12 spf

Single and multiple Shooting with CGTB's



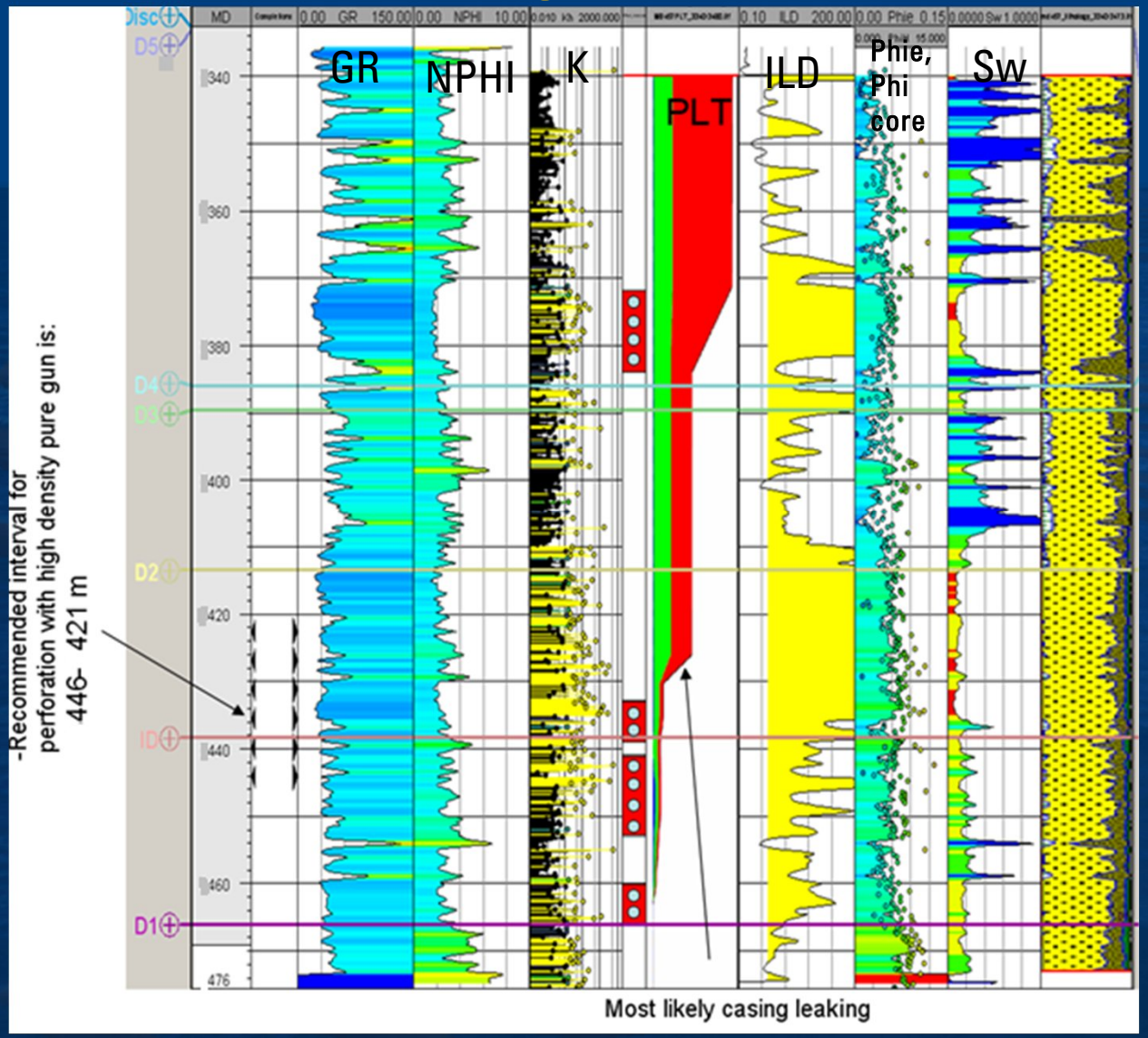
6 SPF



12 SPF

Black Lines are Perforation Tunnels

OLD PLT

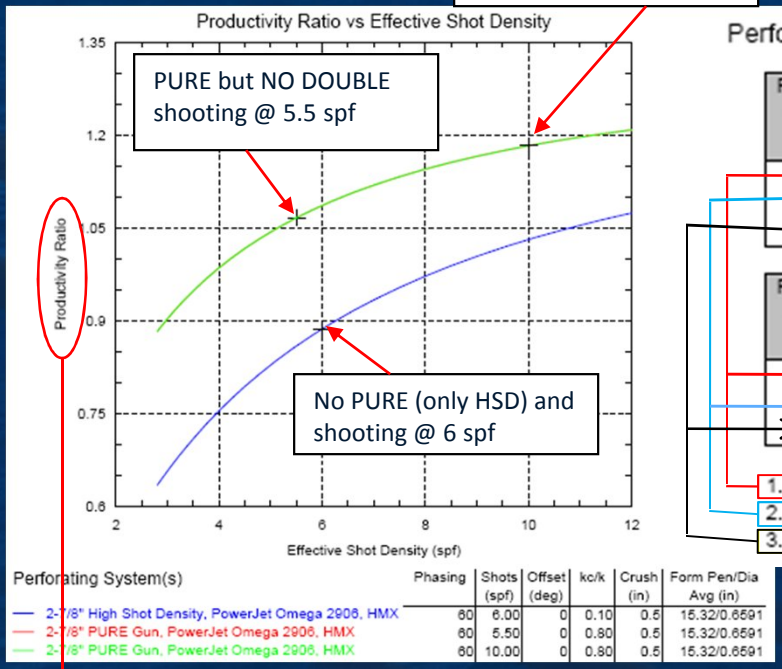


MD4XX Petrel Composite Log

Completion
4 ½" LCP

SPAN MD-4XX

PURE and FOUR Times shooting (10 spf)



Perforating System(s)

	Phasing	Shots (spf)	Offset (deg)	kc/k	Crush (in)	Form Pen/Dia Avg (in)
2-7/8" High Shot Density, PowerJet Omega 2906, HMX	60	6.00	0	0.10	0.5	15.32/0.6591
2-7/8" PURE Gun, PowerJet Omega 2906, HMX	60	5.50	0	0.80	0.5	15.32/0.6591
2-7/8" PURE Gun, PowerJet Omega 2906, HMX	60	10.00	0	0.80	0.5	15.32/0.6591

Perforating System(s)

Perf #	Phasing Angle (deg)	Shot Density /Open Perfs (spf/%)	Eff Shot Density (spf)	PURE Density spf	Crush Zone kc/k	Crush Zone (in)	Form Pen Avg (in)	Form Dia Avg (in)	EH Dia Avg (in)
1	60	6.00/100	6.00		0.10	0.5	15.32	0.66	0.36
2	60	5.50/100	5.50	0.50	0.80	0.5	15.32	0.66	0.36
3	60	10.00/100	10.00	0.50	0.80	0.5	15.32	0.66	0.36

Perf #	Skin Eff	Darcy Coef	Non-Darcy Coef (1/m3/day)	PR	PI (m3/day) (/psi)	Flow Rate (m3/day)
1	0.91	0.91	5.996e-4	0.89	0.61	111.1
2	-0.44	-0.44	4.101e-4	1.07	0.73	133.6
3	-1.10	-1.10	3.962e-4	1.18	0.81	148.2

1. 2-7/8" High Shot Density, PowerJet Omega 2906, HMX
2. 2-7/8" PURE Gun, PowerJet Omega 2906, HMX
3. 2-7/8" PURE Gun, PowerJet Omega 2906, HMX

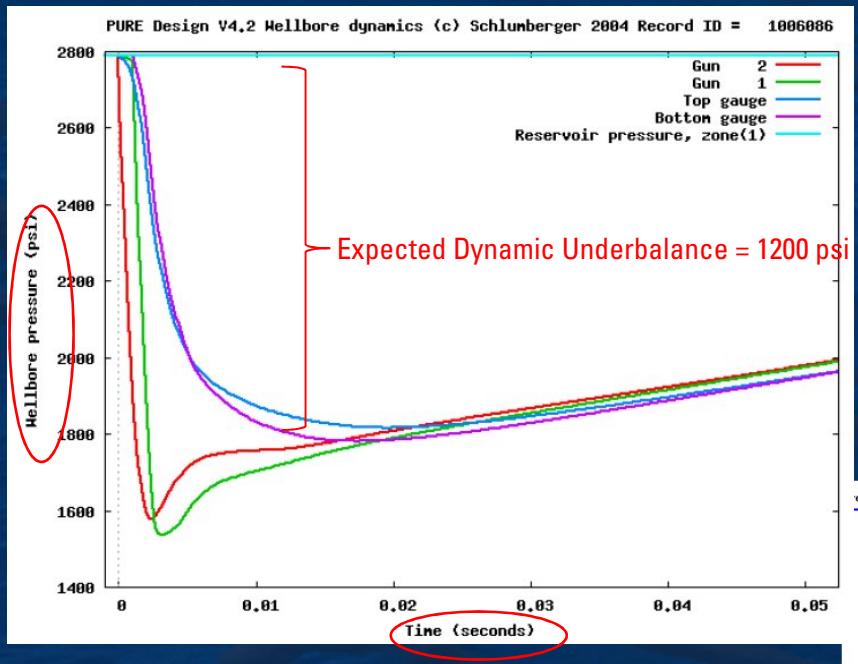
$$PR = \frac{q_p}{q_o} = \frac{\text{Perforated Well Flow}}{\text{Undamaged Open Hole Flow}}$$

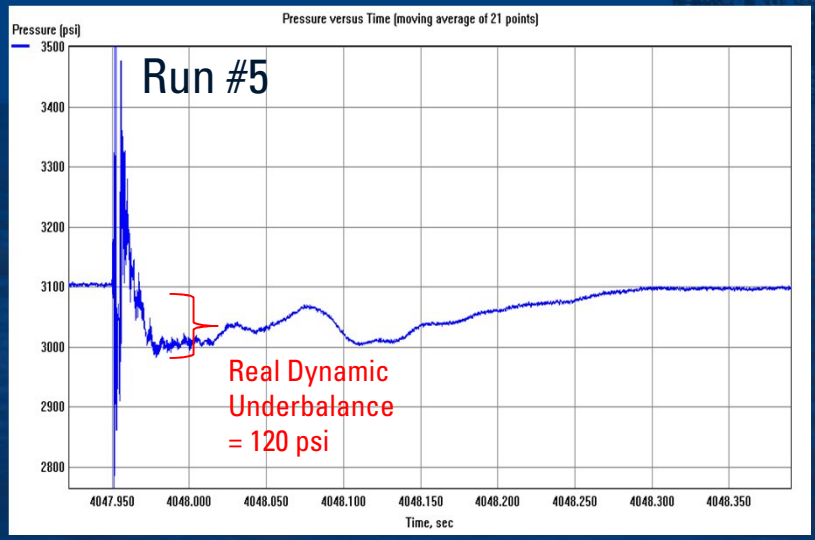
MD-4XX

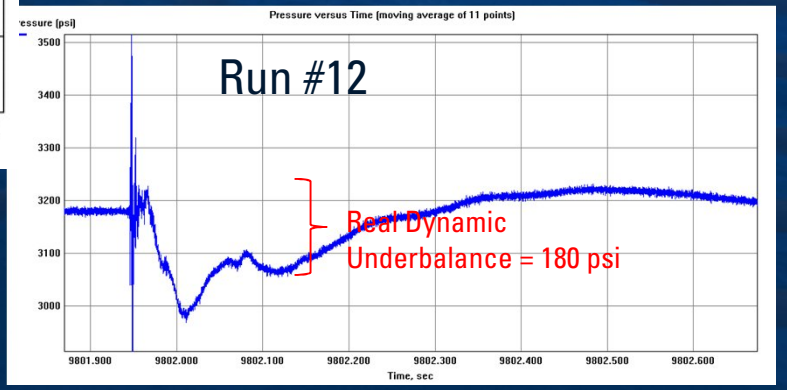
- MD-4XX
  - Drilled by Sonatrach in Hassi Messaoud field in 1994
  - Formation pressure @ 2008 = 2800 psi
- Proposed intervals for perforating – Jun-2008

GUN SUMMARY				
Run	PowerJet Omega, 2906 HMX			PURE Punchers
	Top Loaded (m)	Bottom Loaded (m)	Shot Density (spf)	Shot Density (spf)
1	X421	X429	2.50	0.50
2	X421	X429	2.50	0.50
3	X421	X429	2.50	0.50
4	X421	X429	2.50	0.50
5	X429	X437	2.50	0.50
6	X429	X437	2.50	0.50
7	X429	X437	2.50	0.50
8	X429	X437	2.50	0.50
9	X437	X445	2.50	0.50
10	X437	X445	2.50	0.50
11	X437	X445	2.50	0.50
12	X437	X445	2.50	0.50
Intervals in ligth blue used Fast Gauges				

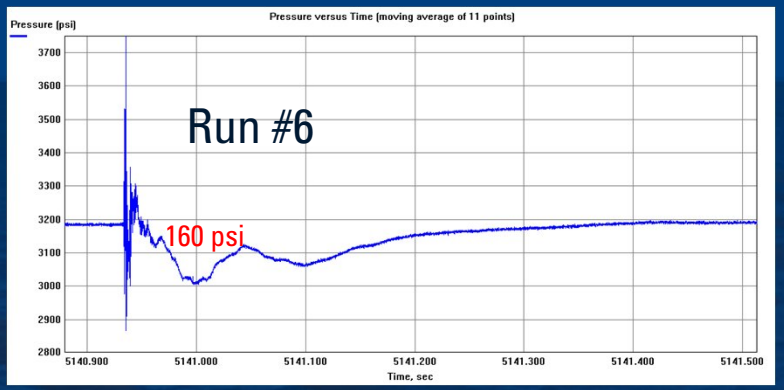
Run 1 to 12: X421-X445 m (4 Times Shooting)

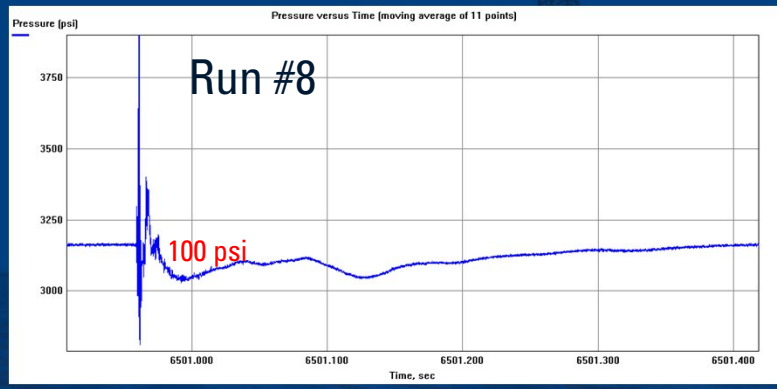


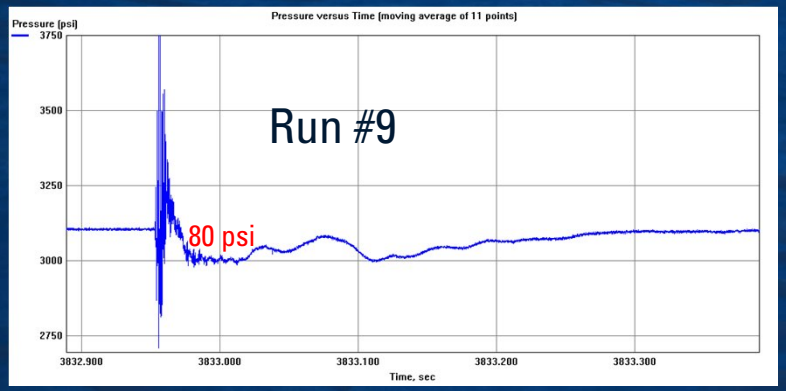


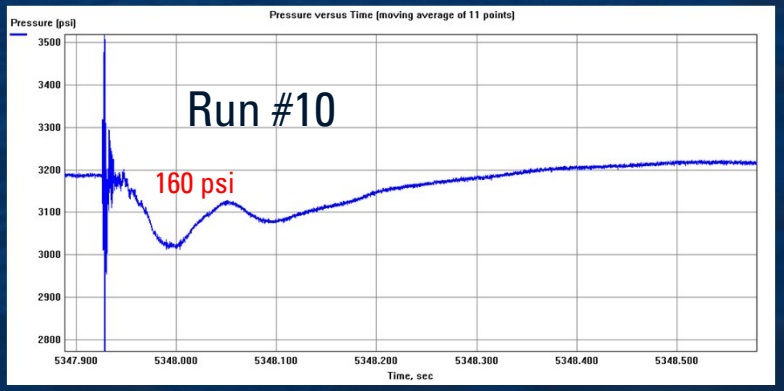


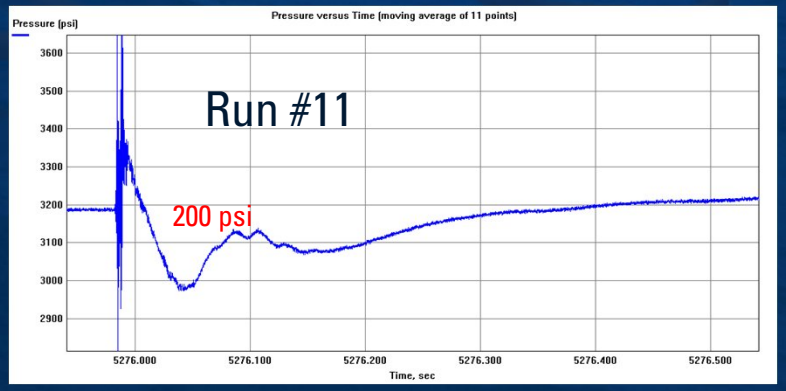
Pulse Responses





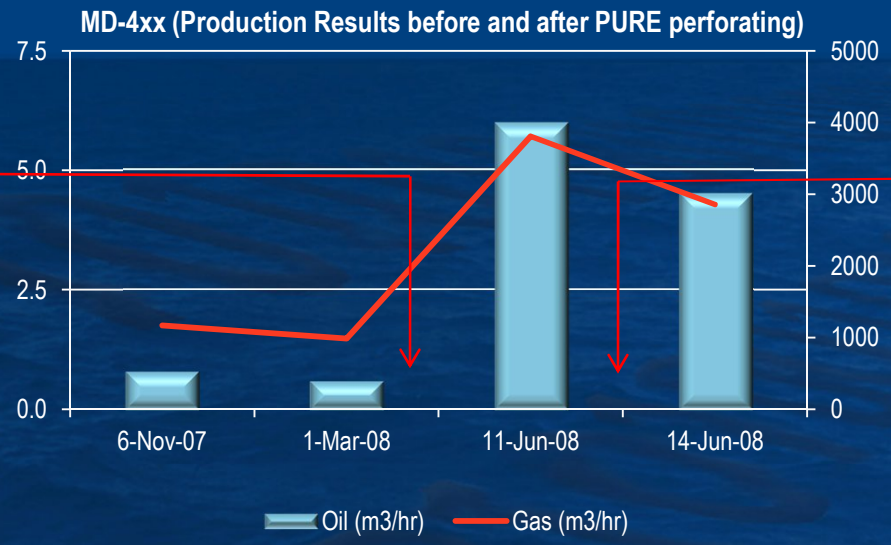






Results MD-4XX – Before and After PURE

PURE and PowerJet Omega job



Choke reduced from 15 mm to 12 mm

Testing Data	Choke Size	Flow Rates (m3/h)		GOR	Pressure (kg/cm2)			Oil Temperature (degC)	Water flowrates (l/h)	
	mm	Oil	Gas		WHP	Flowline	Separator		Produced	Injected
Testing Data Before Re-Perforation										
6-Nov-07	15	0.80	1170.5	1,469	19.2	12.5	3.98	19	620	720
1-Mar-08	15	0.60	986.91	1,637	19	15	2.16	10	0	
Testing Data After Re-Perforation										
11-Jun-08	15	5.99	3807.2	636	34	15.5	5.4	34	200	
14-Jun-08	12	4.52	2856.4	632	47.8	16.8	6.42	33	240	

Conclusions

- The well completion design to allow of all or majority of the Coarse Grain Thin Beds and the fractures to contribute in well production is a key of success of production enhancement.

- In the case of tight reservoir with CGTB's and fractures, the best way is to complete open hole (bare foot completion) or to perforate with the highest shot density and deep penetration of a feasible gun technology.

- In the MD 4XX case, Multiple Dynamic underbalance perforation technology is used with very good results.


THANK YOU