The application of advanced techniques of Formation Evaluation, integrated with core analysis: improve gas field R&D in the Pannonian Basin.

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INTRODUCTION

This presentation will show an example of best data optimization from a Deep well (***Case A***) drilled in unconventional reservoir part of Pannonian basin

All these informations can contribute to:

- Optimal well position
- Minimize environmental risks
- Identify best target for well completion
- Maximize production
- Field deployment

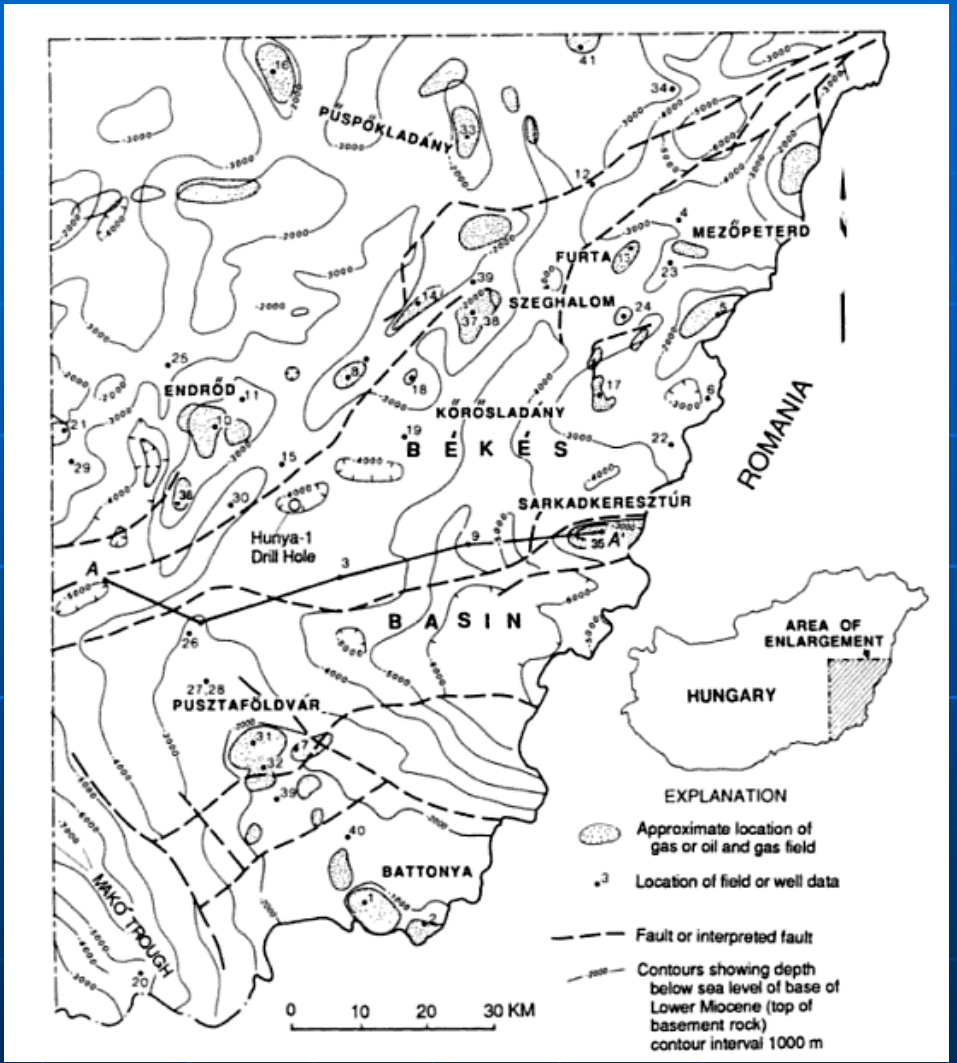
Integration with other data services like geological assistance and coring, validate and support all above FE data collected, processed and analyzed

SUMMARY

- Field history and geological description
- FE data available
  - WL logging
  - Geological Master Log
  - Core analysis data
- FE logging analysis and interpretation
- COMPOSITE PLOTS of integrated services
  - FE Logging
  - WL analysis comparison with CORE data
  - MREX fluid characterization and quantification
  - Acoustic and Image In-*Situ stress* analysis
  - RPM in OH : Inner vs. Standard Fe data / GasView^{tm}
- Conclusion: results on full integrated analysis

Field History and geological description

- Area is a depositional sequence at the base of the delta slope of lower pannonian turbiditic section (Bekes basin)
- Reservoir is clean Sandstone with good porosity range (22-28%) (Szalonta Fmt.) laying upon basal marl (Endrod Fmt.)
- Well is located to enter reservoir in its best structural position (conventional reservoir)
- Current Gas production is 78400 m3/day with 13.2 m3/day condensate (**from 2008 MOL Expl. & Dev. update report**)



*J.L.Clayton, I.Koncz – Geochemistry of natural gas and carbon dioxide in bekes basin..

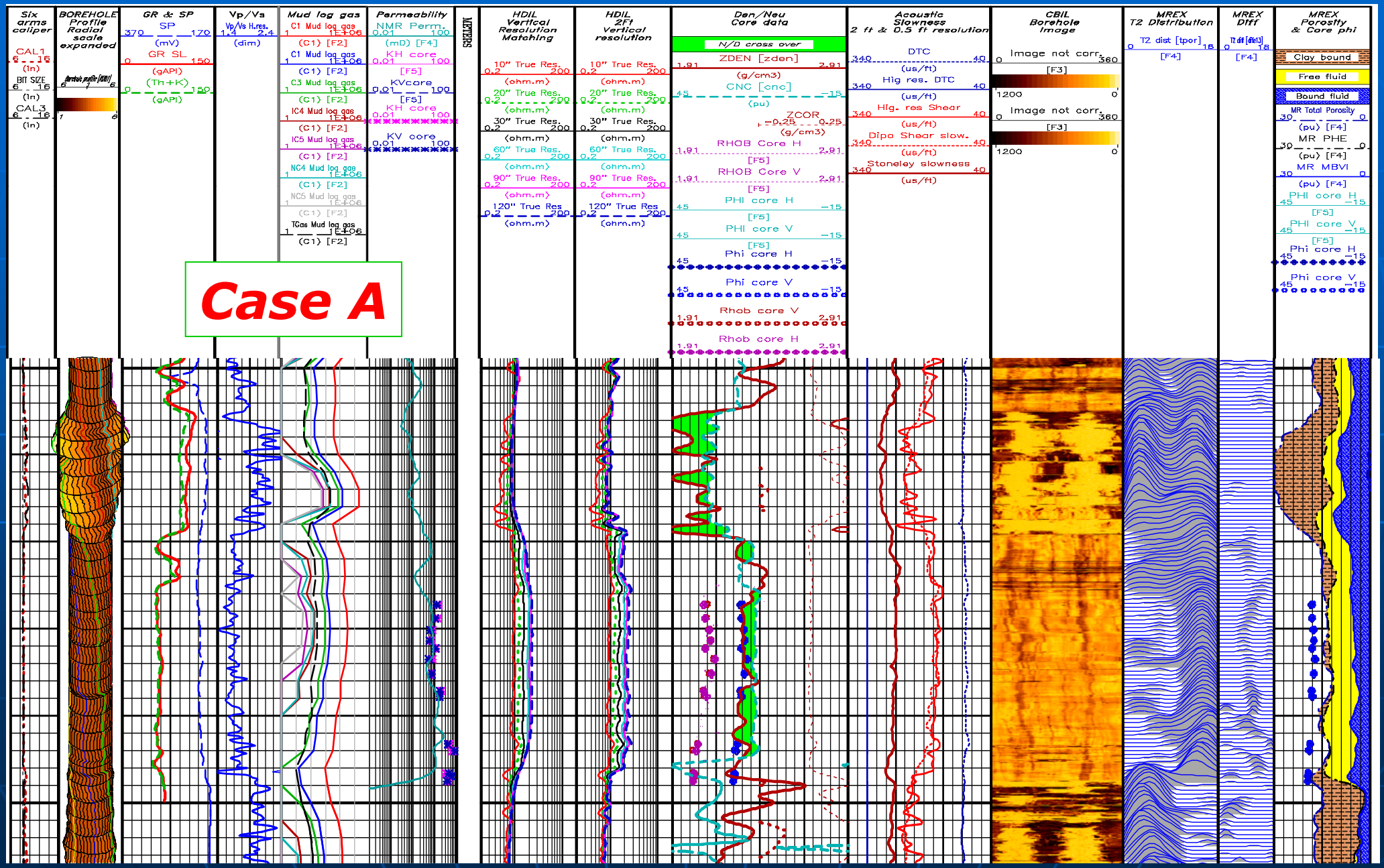
FE logging data

- TARGET: Lower Pannonian Formation (Szalonta/Endrod Fmt.)
- General Well Information:
  - Max. Inc.: 1.9°
  - Max Temp: 105.6° C downhole
  - Mud Prop.: WBM, MW: 10 ppg, Salinity: 41.8 g/l Cl^-
  - Rm @ BHT: 0.065 Ω/m @ 104.5° C
- BHI WL Logging program:
  1. HDIL/XMac-F1/WGI (Resistivity/Acoustic/Borehole profile)
  2. ZDL/CN/DCBIL (Density/Neutron/Circumferential Image log
  3. MREX/DSL (NMR/Digital Spectralog gamma ray)
  4. RPM/GR (Pulsed Neutron/ Gamma ray) in open hole
- Local Geological services
- CORING data

FE logging analysis & interpretation

- FE evaluation
  - Composite plot importing core and mudlog gas shows
  - Comparison with core data
    - Porosity
    - Permeability
  - MREX fluid characterization and quantification
  - XMAC
    - Slowness determination (high resolution 0.5 ft)
    - Cross waveform (Acoustic anisotropy)
  - CBIL Image analysis
    - Comparison anisotropy and in situ stress
  - RPM in open hole (gasview analysis and porosity)

Composite Plots: core & gas data integration

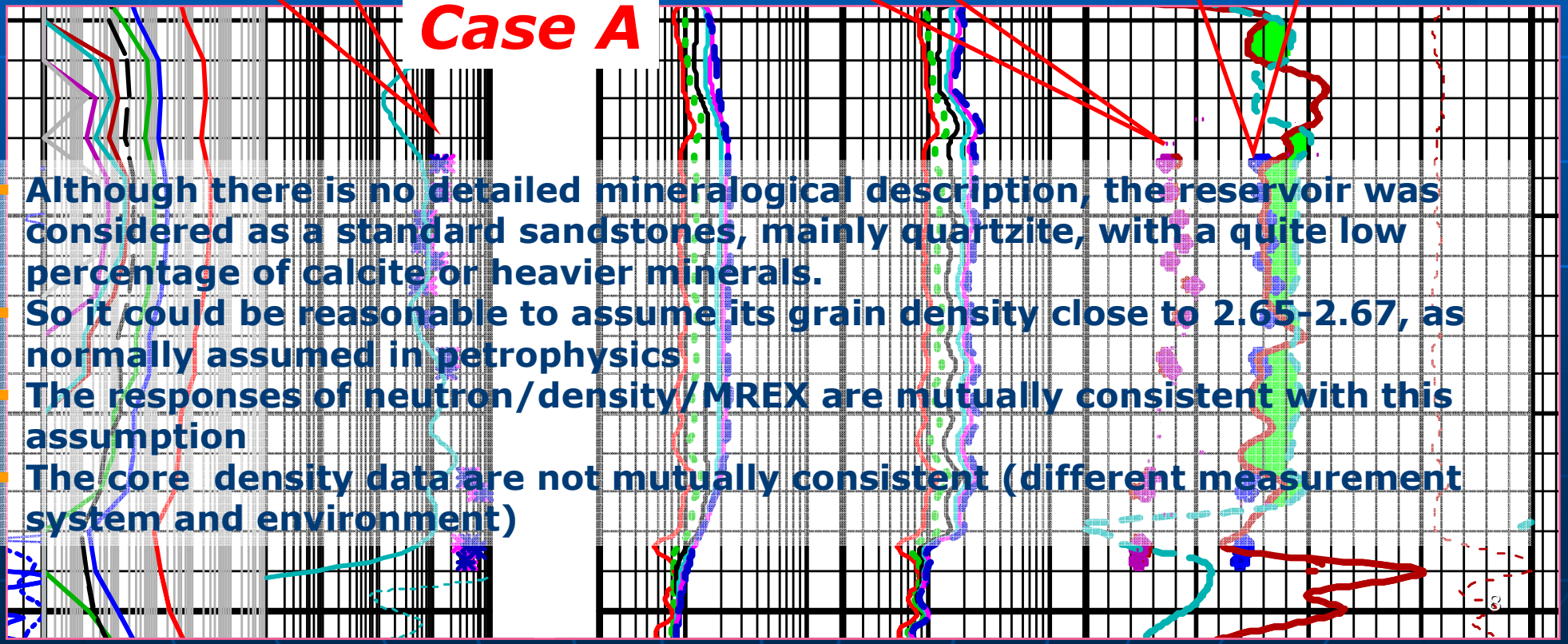


Comparison with core data: Φ and K

Good agreement between MREX permeability and core permeability

Discrepancy between rhob from densilog and rhob from core analysis

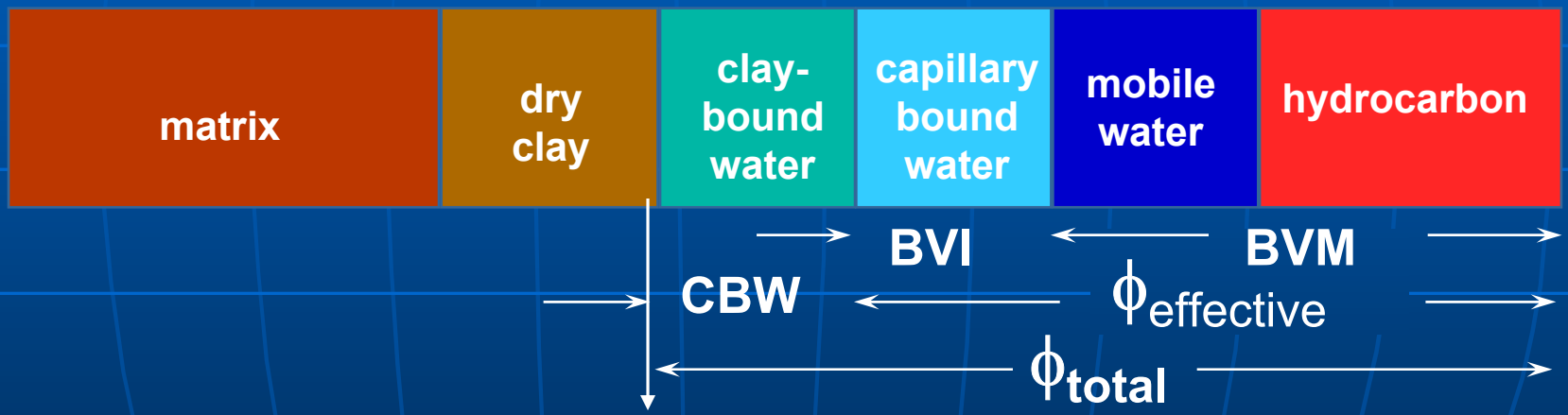
Good agreement between Neutron/Density porosity and core porosity



- Although there is no detailed mineralogical description, the reservoir was considered as a standard sandstones, mainly quartzite, with a quite low percentage of calcite or heavier minerals.
- So it could be reasonable to assume its grain density close to 2.65-2.67, as normally assumed in petrophysics
- The responses of neutron/density/MREX are mutually consistent with this assumption
- The core density data are not mutually consistent (different measurement system and environment)

MREX: fluid characterization and quantification

- MR porosity measurement is
  - A direct measurement that is sensitive only to the fluids present in the rock pores
  - Independent of rock matrix and mineralogy
- NMR – Porosity Model



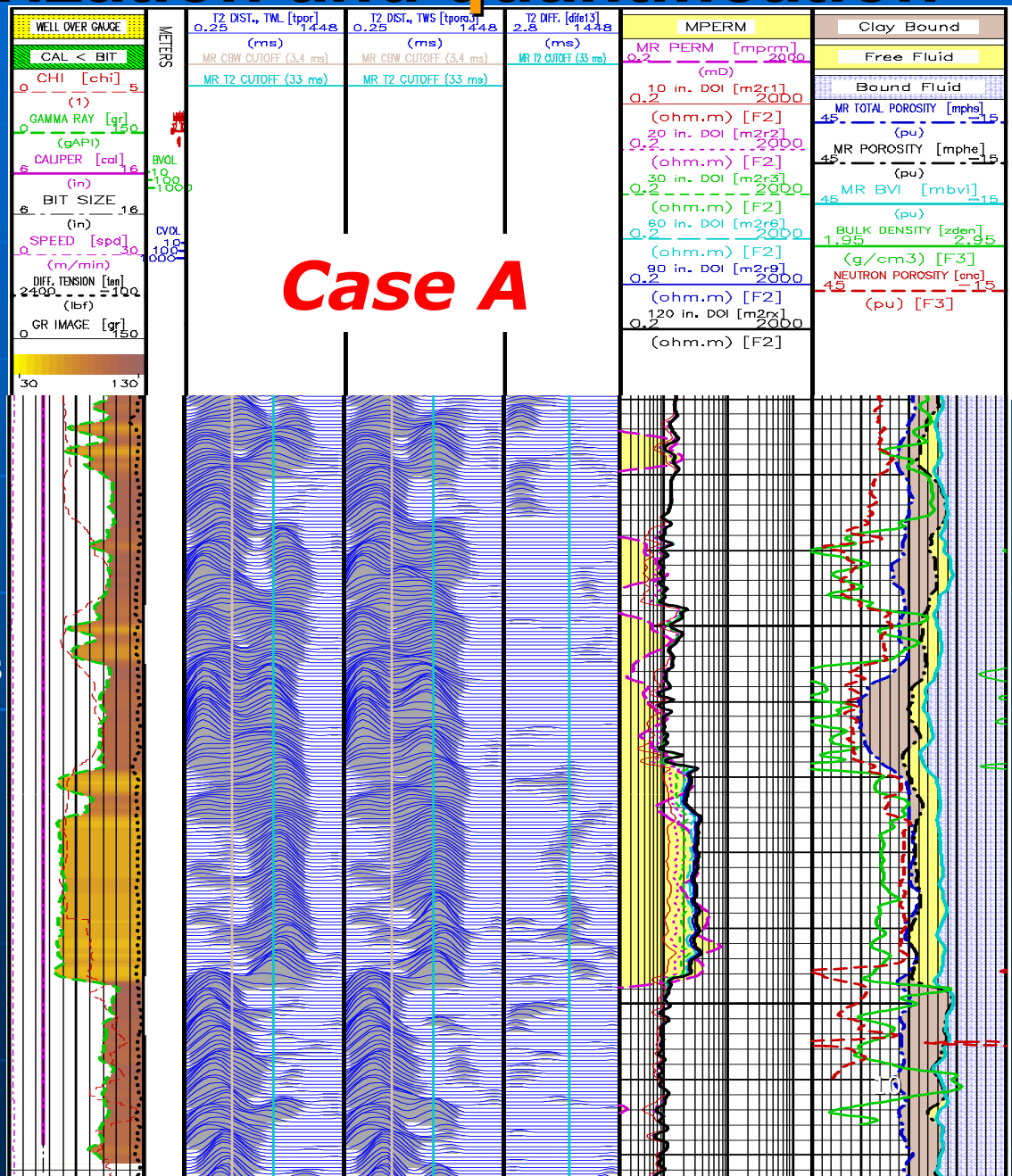
- Oriented Object Acquisition mode (OOA)

PoroPerm + Gas	▪***Porosity*** ▪***Permeability*** ▪***Quantify & characterize gas & light oil (< 1 cp)***	▪ϕ_t, ϕ_e, CBW, BVI, BVM, k_{NMR} ▪T_2, T_1, D ▪HI_g, ρ_g, $S_{g,xo}$, 2DNMR imaging

MREX: fluid characterization and quantification

Field Deliverable

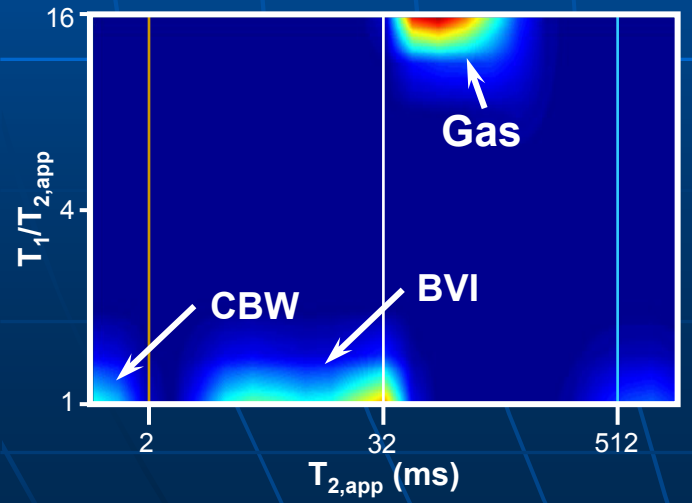
- CBW, BVI, BVM, fe, ft, and kNMR
- Porosity distribution based on chosen cutoffs such as: CBW 3 ms and BVI 33 ms
- kNMR based on Coates equation with chosen C, m, and n
- Underestimation of BVM, fe, ft and kNMR in gas zones if HI effect is significant
- T2 spectra for long and short TW and the differential spectrum
- Highlights intervals with gas in the flushed zone due to insufficient polarization of gas with short TW



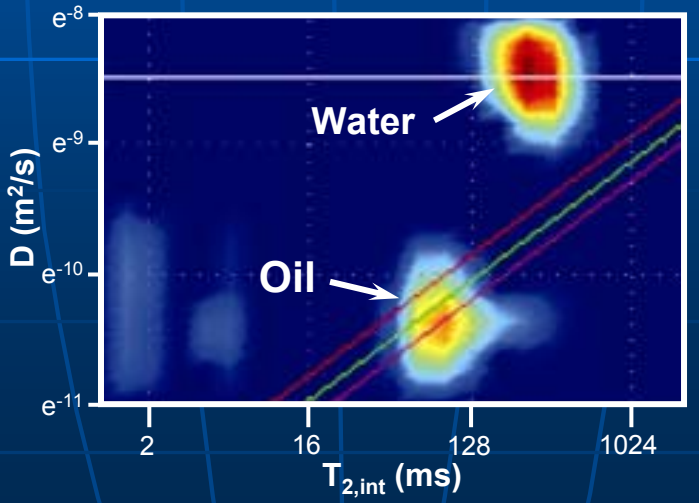
MREX: fluid characterization and quantification

MREX: Superior hydrocarbon typing

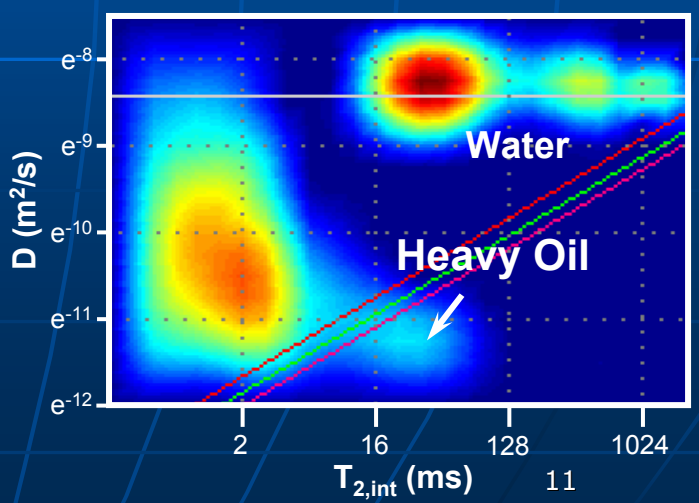
- Innovative NMR acquisition (OOA) techniques provide comprehensive NMR data for thorough fluids analysis
  - T_1, T_2 & Diffusion data acquired simultaneously while logging
- 2D NMR plots identify and quantify hydrocarbons
  - Available from all hydrocarbon typing Objective Oriented Acquisitions
  - Acquired as continuous logs (NOT stationary measurements!)
  - T1/T2 contrast used as Gas indicator (R_T2 method)



PoroPerm + Gas



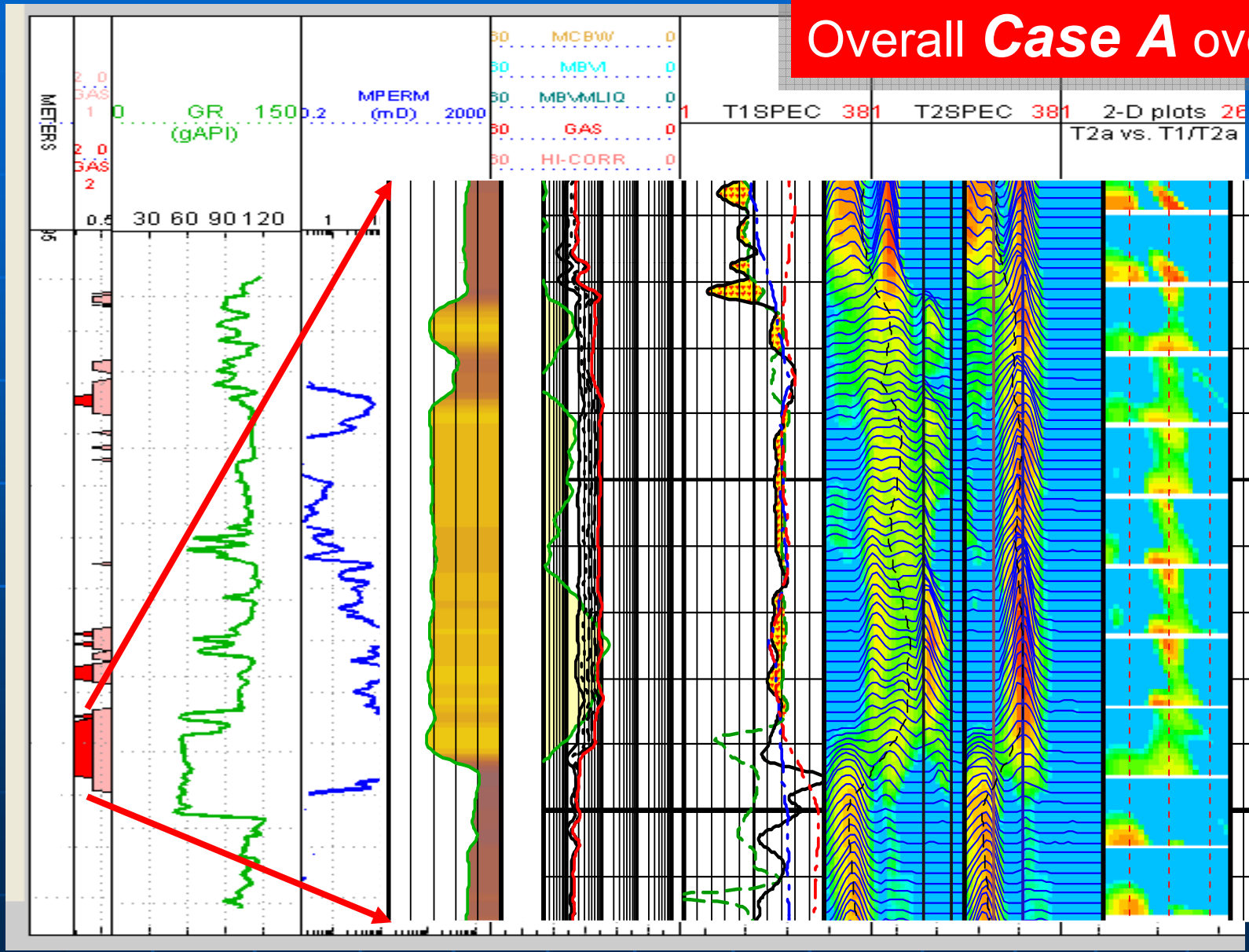
PoroPerm + Oil



PoroPerm + Heavy Oil

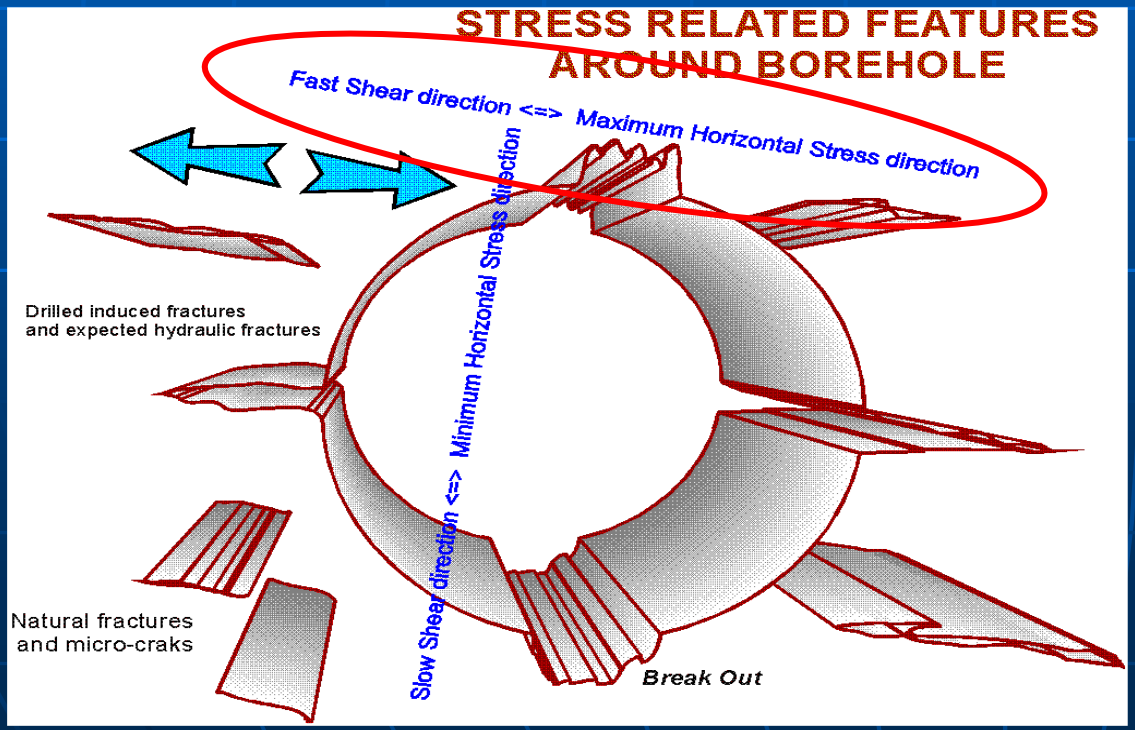
MREX: fluid characterization and quantification

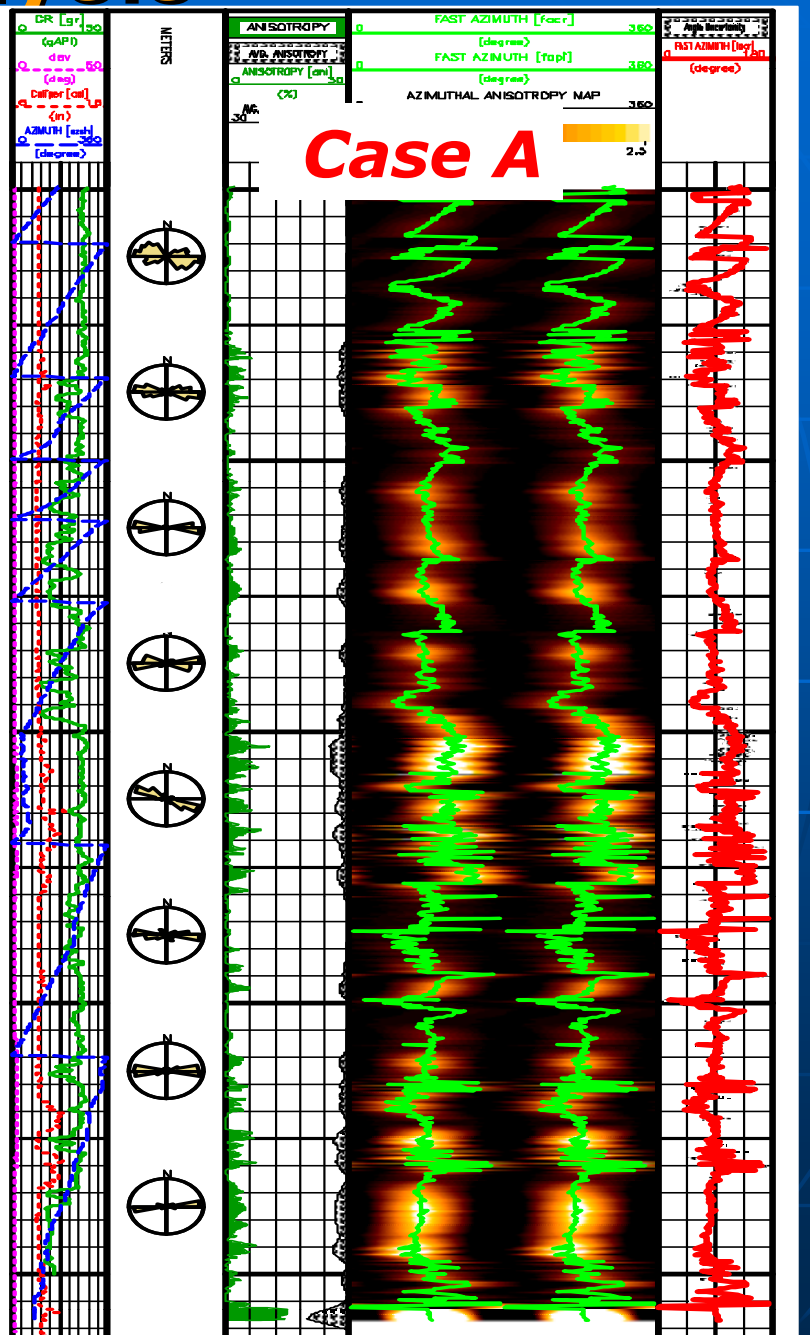
Overall ***Case A*** overview



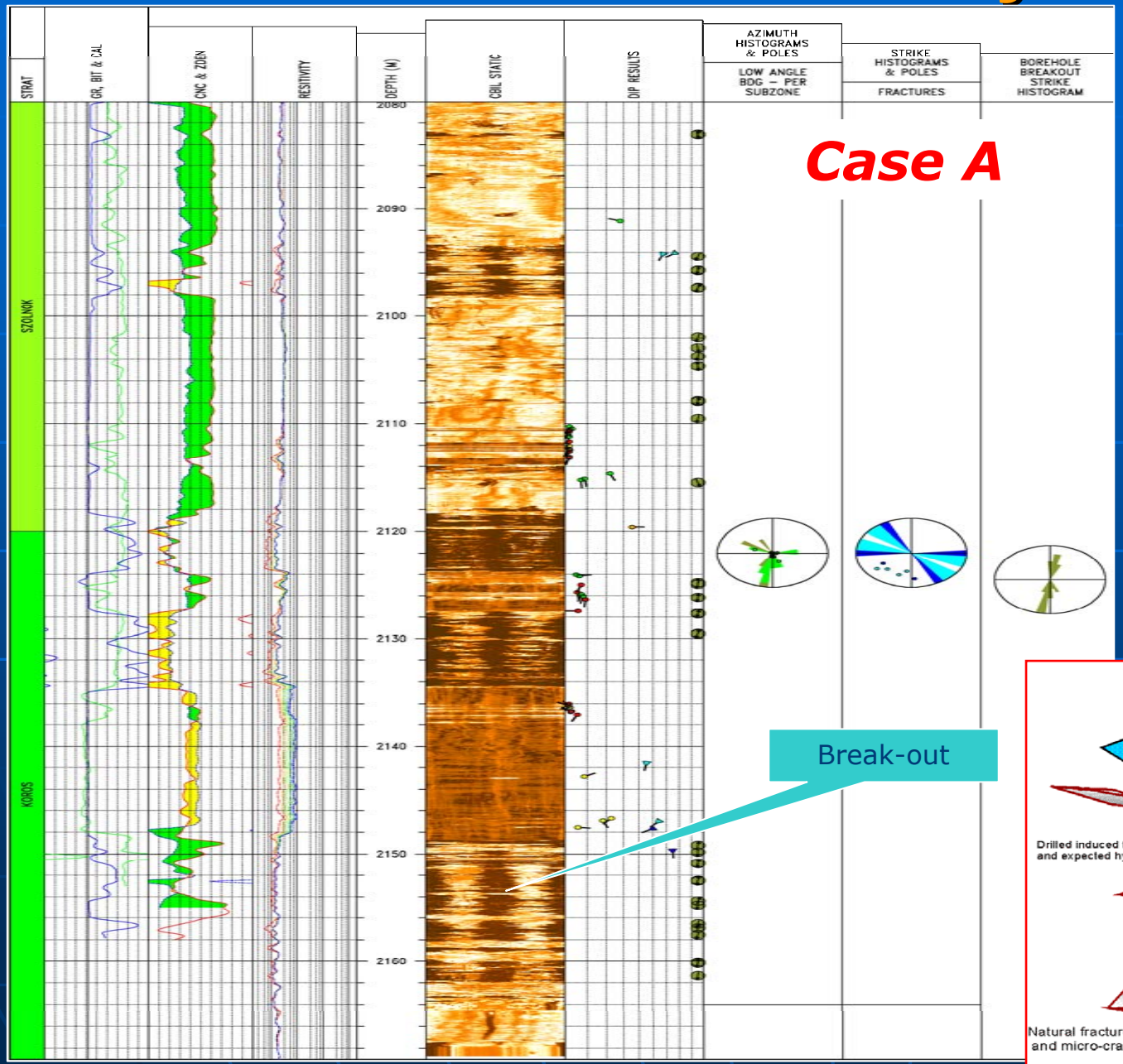
XMAC: In-situ stress analysis

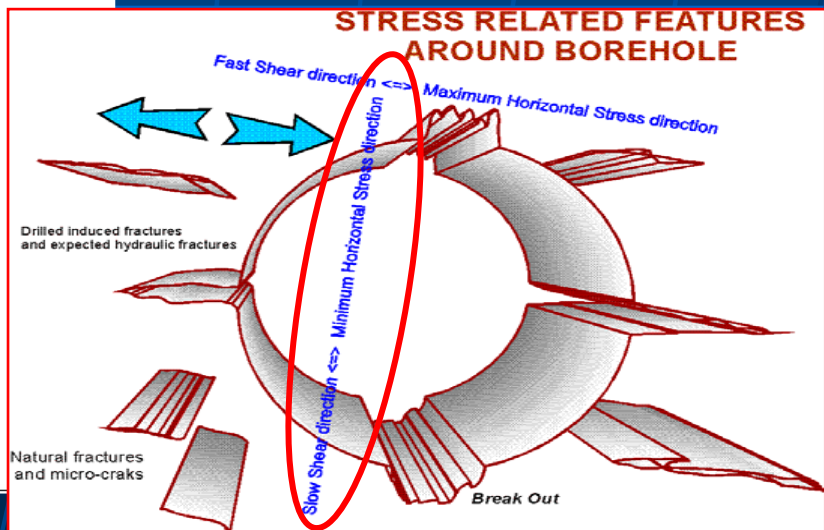
- High resolution slowness derived
- Well/reservoir direct options
  - Acoustic shear anisotropy
  - Borehole image log
- The Best option
  - Combining Imager & shear anisotropy!



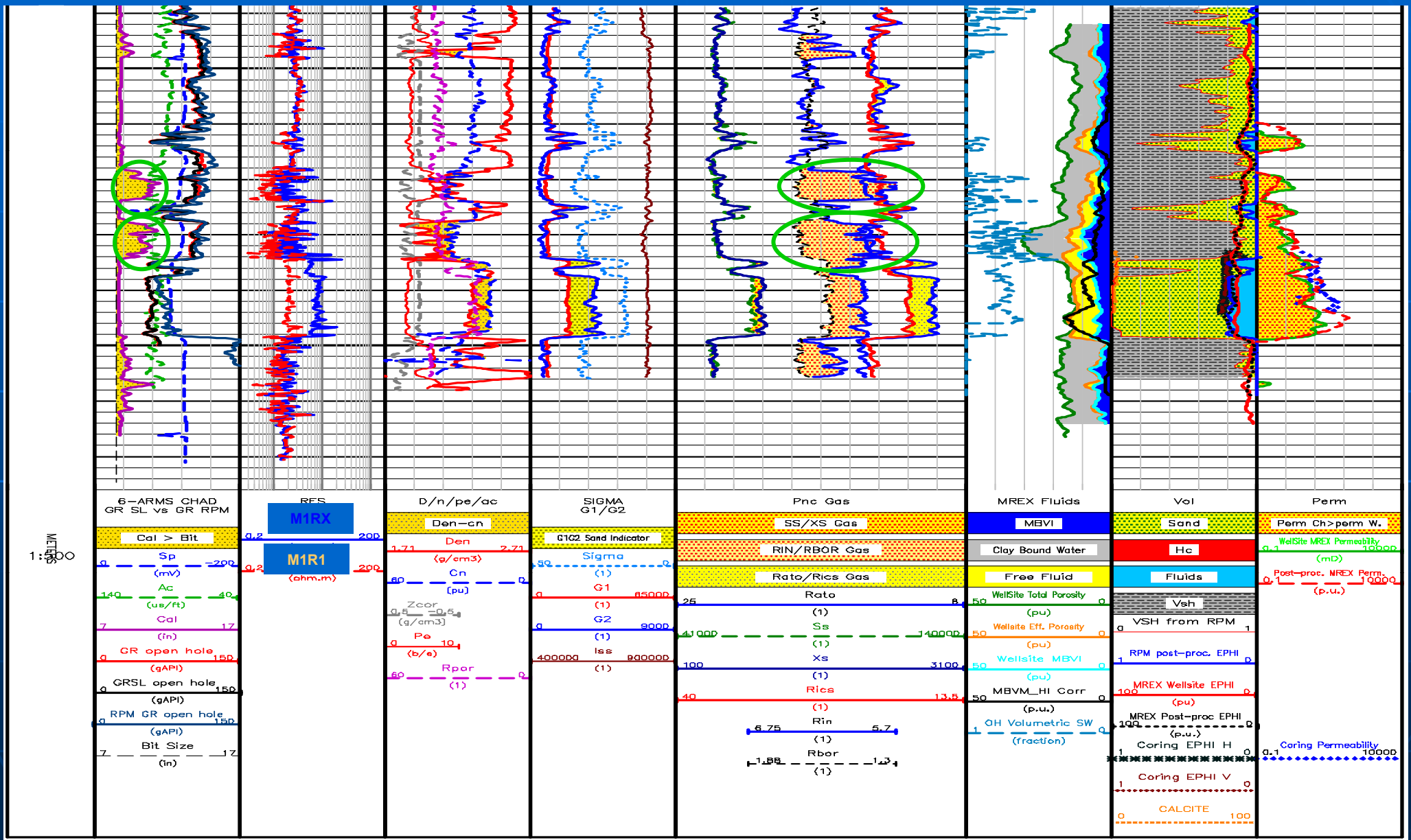


CBIL: In-situ stress analysis



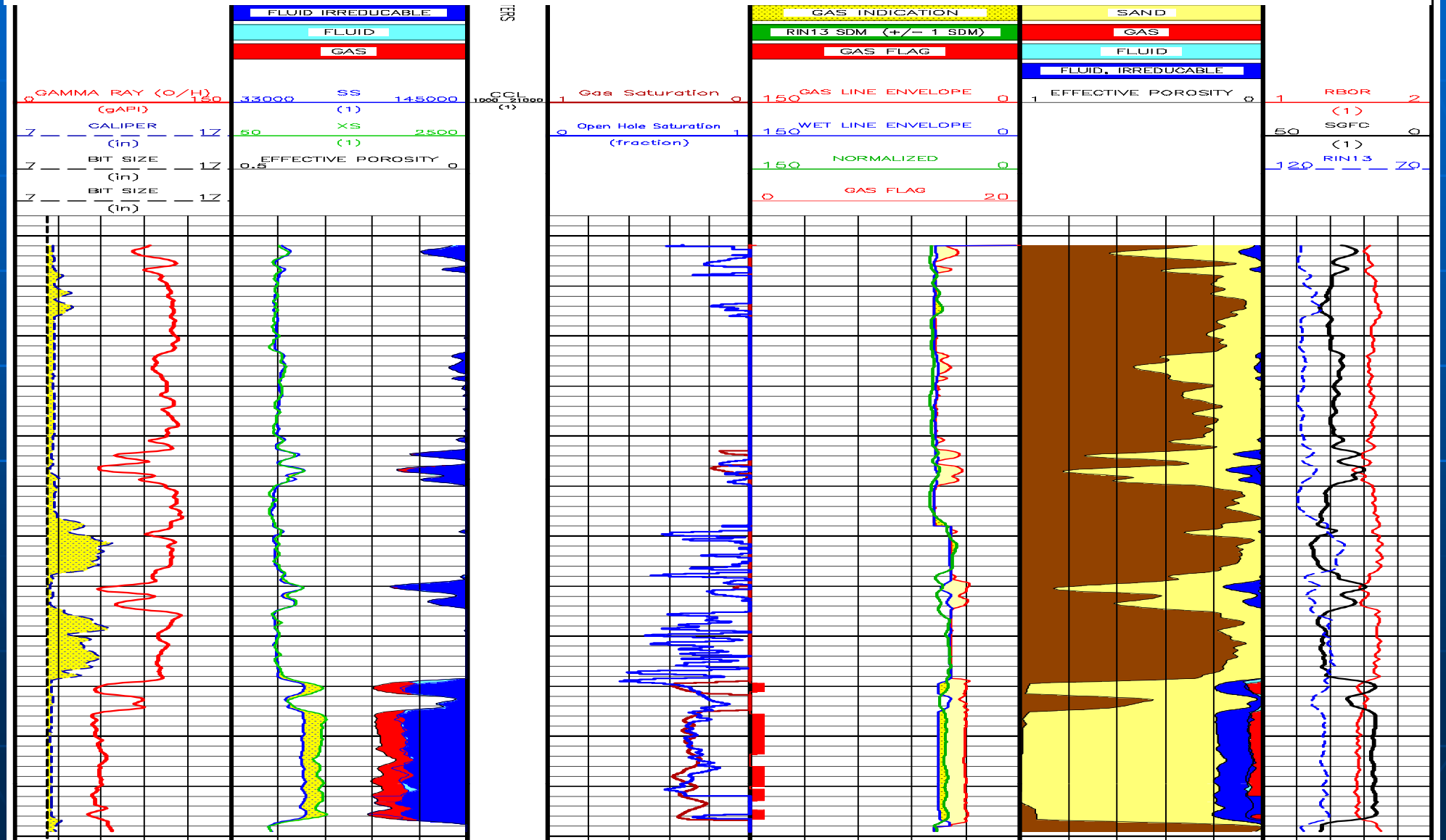


OH RPM logging: FE & Vol. data comparison

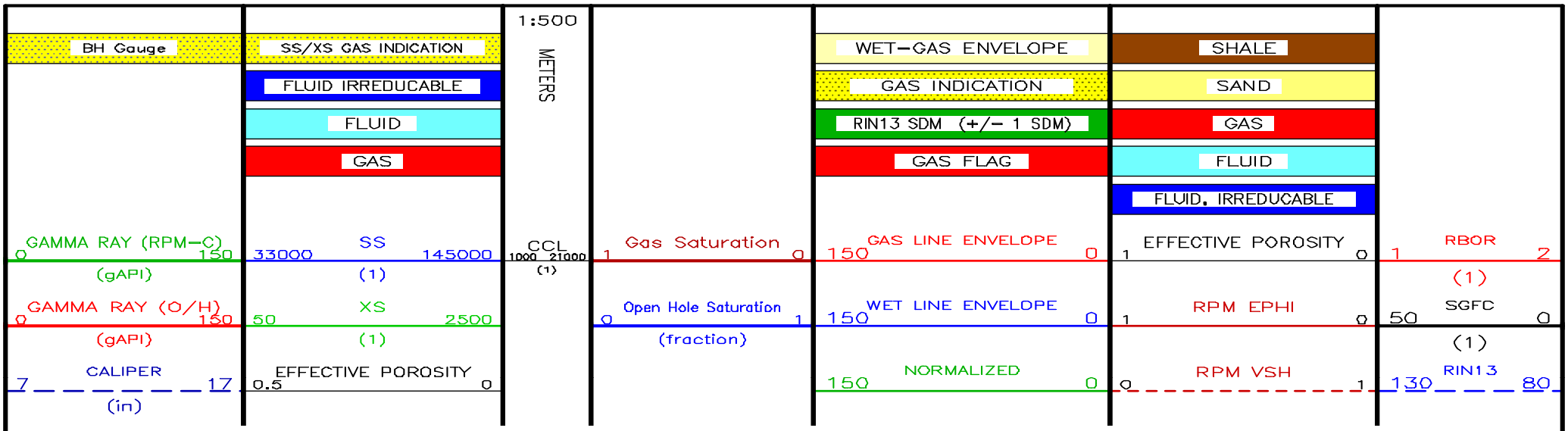


OH RPM logging: GasView^{tm} quantification

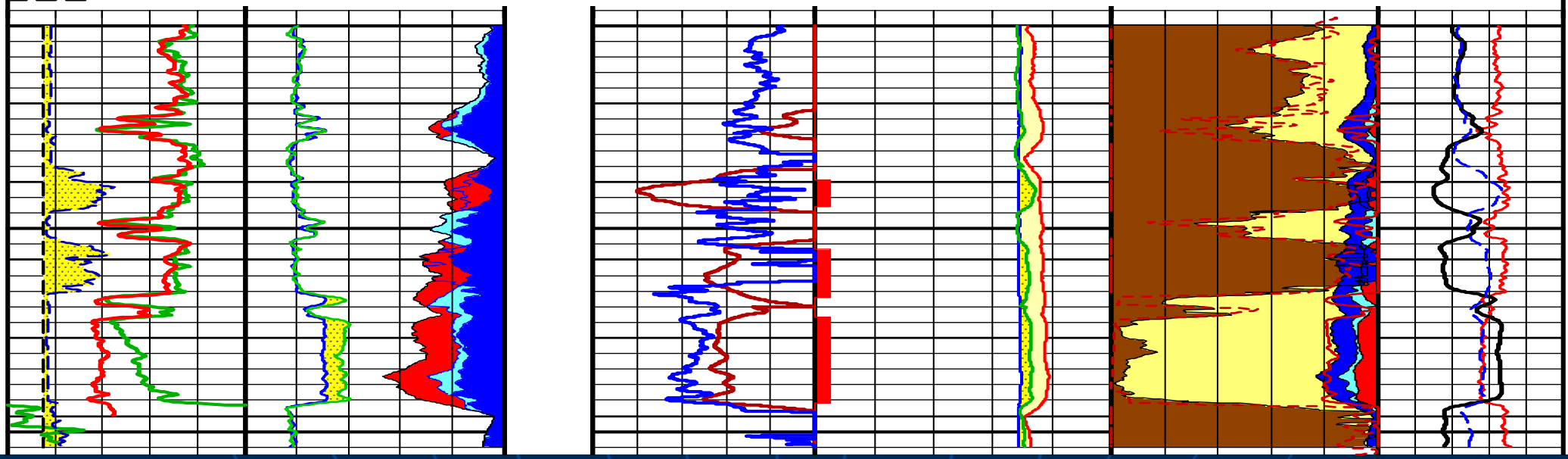
Case A: Gas evaluation using RPM FE data



OH RPM logging: GasView^{tm} quantification



Case A: Gas evaluation using WL tool FE data



Conclusion: results on full integrated analysis

- FE basic logging might not be enough to characterize fluids and optimize completion program (ex. borehole shape, geomechanics, free fluid saturation)
- Core data generally still as reference for porosity/permeability
- N/A or invalid core data might be replaced by high tech tool and petrophysics in short or longer time, depending on service
- NMR advanced technique can help identify:
  - Gas Saturation
  - Correct Total / Effective porosity by gas effect and be alternative to Neutron Porosity
  - Establish Gas diffusion also in water filled pore spaces
- In-*situ* stress and rock mechanical analysis from acoustic might help preventing incorrect well planning and other effects (es. Sand production, borehole stability)
- In-*situ* stress and mechanical analysis from IMAGE logging integrates with acoustic geomechanical analysis to highlight stress directions (es. Break-outs)
- RPM-C in Open Hole logging
  - Data QC showed good response in good hole condition but generally borehole washouts compromised correlation
  - Verification on porosity emulation was based with core, post-processed data as offsets
  - Vshale from RPM in good correlation with Vshale from petrophysical analysis
  - Preferable, in case of open hole application, to run it again in CH to check Sg validity and others (ex. invasion profiles)
  - RPM does not replace OH tools but can be an option (very slim holes, no radioactive uses etc. etc.) to provide fluid saturation analysis
- Well is completed in 2 intervals and producing 78400 m3/day gas + 13.2 m3/day cond.

We thank the operators for the data release
&
the audience for your participation !