Establishing Petrophysical Benchmark for the Burgan Field in Kuwait. A Case Study*

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Abstract

A field-wide petrophysical re-evaluation project was carried out for the Greater Burgan field of Kuwait. The evaluation covered Early Cretaceous Burgan Sands and the platform carbonates of Mauddud as well as Late Cretaceous Wara and Ahmadi sequences. The aim of the project was four fold. First, a comprehensive open hole well log database was constructed to serve as the foundation for the subsequent work. Second, standardized and auditable log processing and normalization procedures were prepared to facilitate the petrophysical interpretation. Third, a core calibrated petrophysical model was generated for each reservoir in the analyzed interval. Finally, a consistent process was implemented to evaluate new wells in the field. The 1000 wells processed in the study were divided based on old and modern vintages. The old vintage of wells (nearly 400 wells) in the Burgan field was processed to derive shale volume, porosity and water saturation estimates. A consistent Neutron counts to porosity index conversion algorithm was implemented for the old vintage Neutron tools. The petrophysical properties distribution in the old vintage wells was validated against modern well data in offset wells. A Potassium Chloride correction workflow was introduced in the processing of the modern wells that included quantitatively estimating and then removing the borehole effect. For consistency, complete set of environmental corrections were performed on Gamma Ray, Neutron Porosity and Bulk Density logs. The key well study was performed on 46 wells in the field, incorporating all core and advanced log data. Thorough examination of XRD and integration with thin-section data revealed formation complexity and heterogeneity, which was studied in detail. Other core data including core grain density, porosity, permeability and critical saturation from SCAL data in addition to advanced logs including capture spectroscopy and magnetic resonance log data was used for model validation. The validation process was implemented at each step of the workflow to reduce the results uncertainties. The modern wells that were processed using defined workflows from the study showed consistent results when integrated with new core and dynamic data such as production logs. The results of the new and improved petrophysical analysis would fulfill the first ever reservoir rock typing and the next generation full field static model requirements for the Greater Burgan field.

Reference Cited

Bateman, R.M., and C.E. Konen, 1978, The Log Analyst and the Programmable Pocket Calculator: Part IV, Dual Induction-Late-Rolog 8": The Log Analyst, May-June, 1978.

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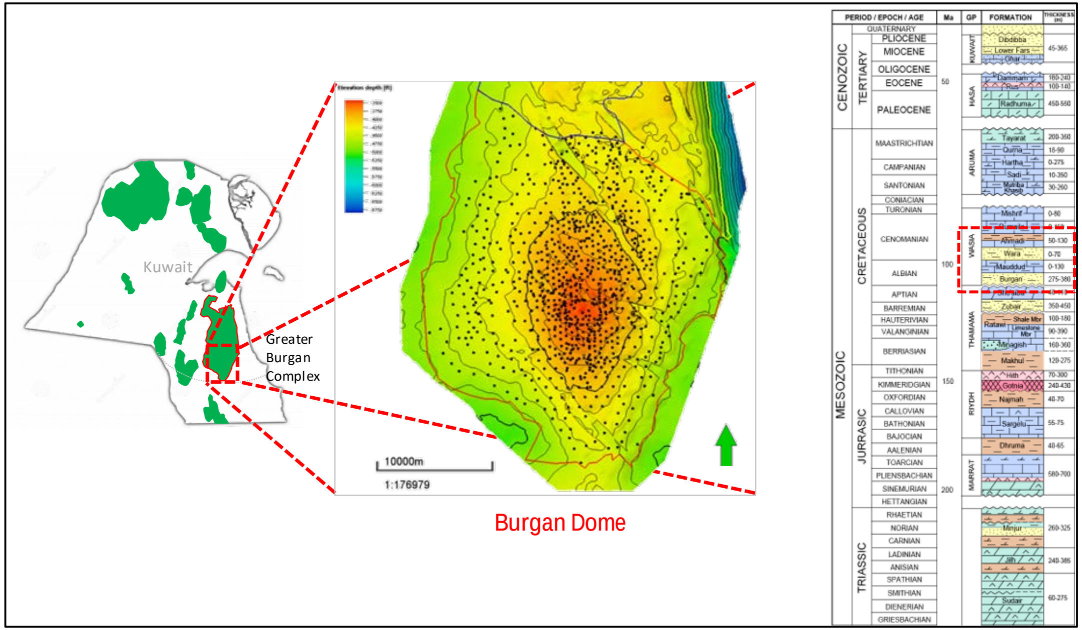
Kuwait Oil Company
A Subsidiary of Kuwait Petroleum Corporation

Schlumberger

Introduction

- Discovered in 1938, the Burgan field is dominated by Albian to Cenomanian siliciclastic intervals (Burgan and Wara Formations) with an interbedded carbonate sequence (Mauddud Formation) constitute the stratigraphy
- Traceable and Auditable workflows of formation evaluation within a consistent framework was imperative for over 1000 wells drilled in the field over 7 decades



Objectives

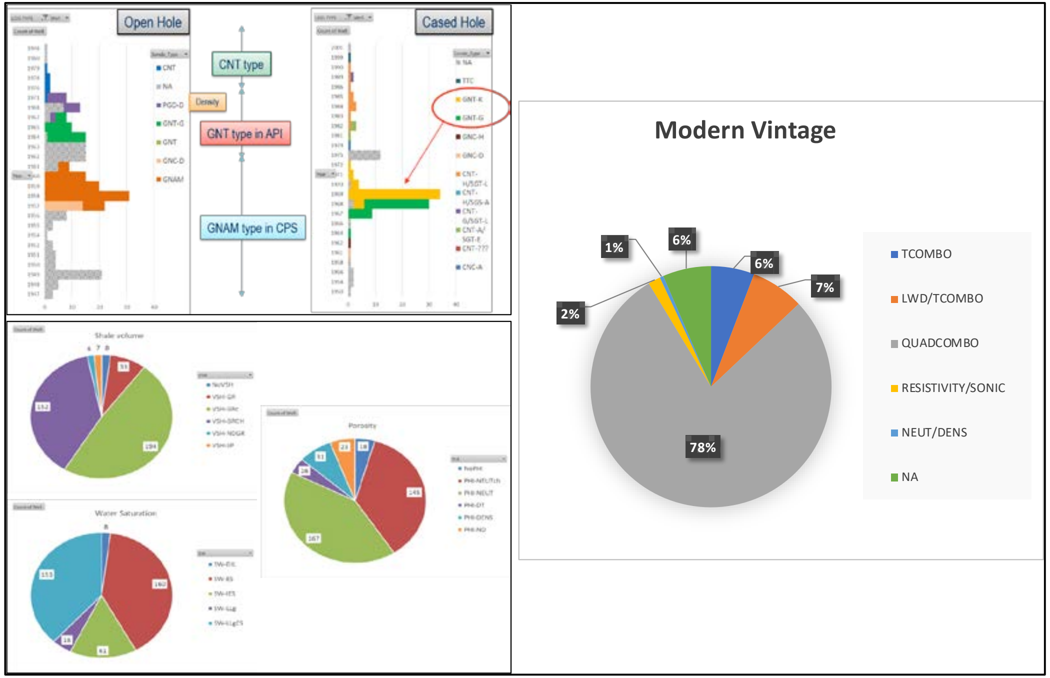
- Establish a comprehensive well log database for the Greater Burgan field
- Standardized and auditable log processing and normalization procedures
- Core calibrated formation evaluation for multiple reservoirs (Ahmadi – Shuaiba)
- Propose a consistent process/workflow to evaluate new wells in the field

Phases

- Phase 1: Database creation and Key Well Study
- Phase 2: Data processing (modern wells) and Vintage Well Study
- Phase 3: Normalization and Evaluation

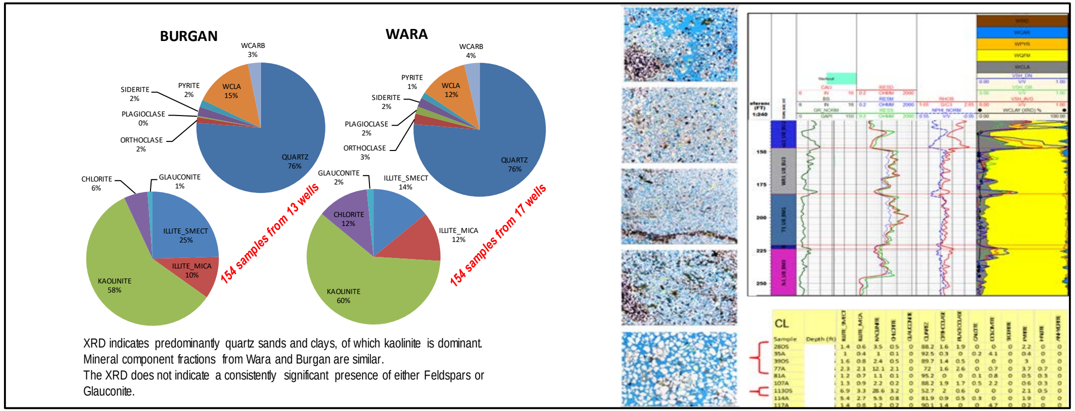
Phase 1(a): Data Inventory

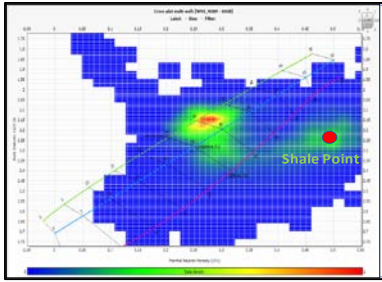
- Database was divided into vintage and modern wells
- Old vintage wells comprised of first 400 wells drilled prior to 1971
  - Typical logs included SP, GR (OH/CH), Neutron (majority with count rates) and Resistivity logs (majority with ES and Induction)
- 602 modern wells in the field revealed logging services ranging from:
  - Simple Resistivity/Sonic to Triple Combo and Quad Combo services.
  - 47 wells in the modern vintage had Quad Combo, Spectroscopy, NMR and core data.
  - These 47 wells were hence selected as the key wells.

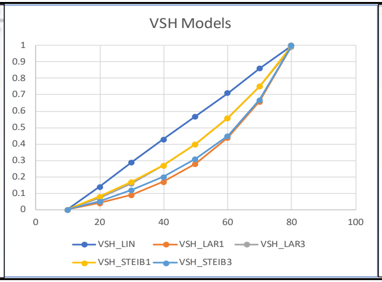


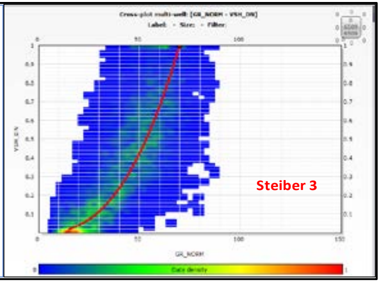
Phase 1(b): Key Well Study

- A key well study was performed to serve two purposes:
    1. Establish the correct workflow, parameters and ascertain the uncertainties related to interpretation &
    2. Establish the basis for performing log EC and normalization
- Key well selection process was based on:
    1. Presence of core data
    2. Presence of advanced logs
    3. Spatial distribution of wells
- Core data (XRD/Thin-sections) was reviewed to determine most prevalent minerology
- Stieber3 shale model was found to be matching the data best



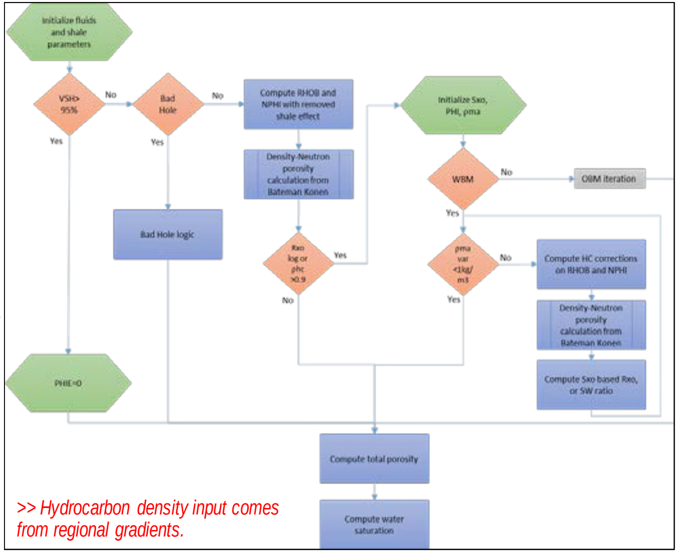




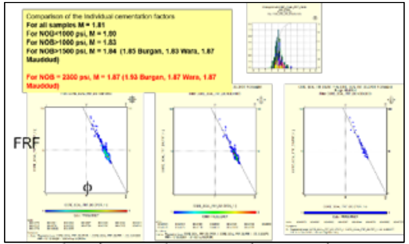


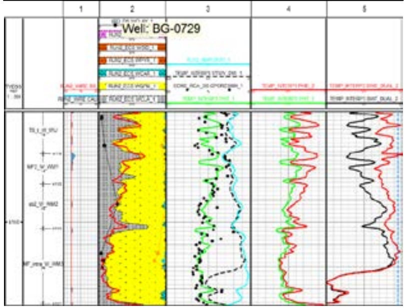
Phase 1 (b): Key Well Study

- Porosity estimation workflow was designed on Bateman-Konen algorithm (Bateman 1978)
- Workflow calculates a shale and Hydrocarbon corrected density-neutron porosity
- Overburden corrected core porosity was compared with the log derived porosity for validation
- All SCAL data for electrical parameters (FRF/RI) was analyzed per reservoir to ascertain Archie's parameters
- Several Sw models were tested, with dual water model yielded the best results when compared to SCAL data and available NMR results

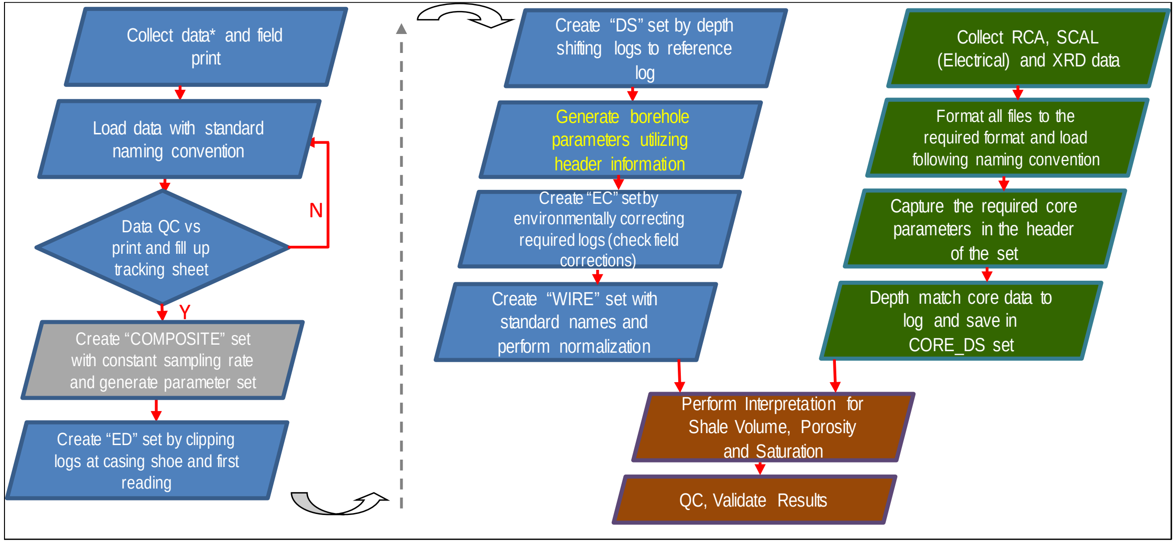


>> Hydrocarbon density input comes from regional gradients.





Phase 2: Data Processing

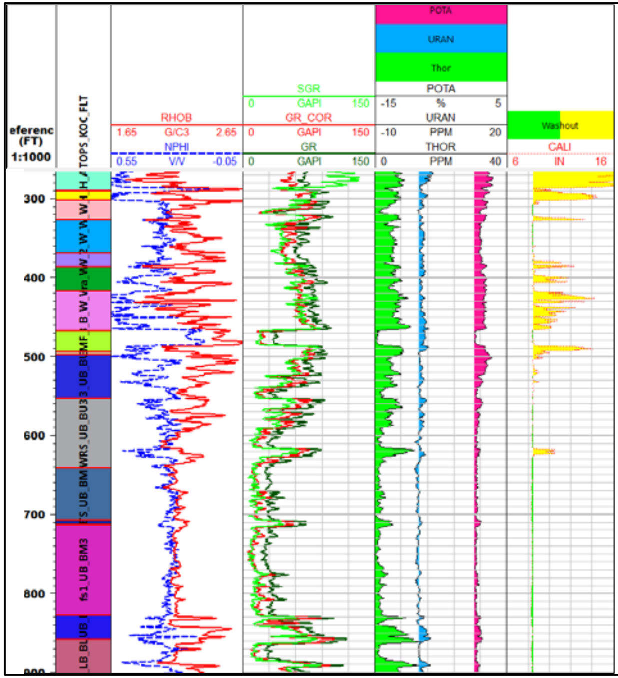


Well Name:	BG-XXXX		
Mandatory Sets	Present (Y/N)	QC	Y/N
WELL_HEADER		Well Name, Location (X,Y), Elevations	
AUDIT_TRAIL		Check that it is not deleted	
TOPS		Petrel classification	
UNITS		Combined tops	
DIRECTIONAL		As provided from Petrel	
REFERENCE			
MOBILITY		Should have the mobility	
RUN2_RAW*			
RUN2_COMPOSITE		All logs at constant sampling rate of 0.25 ft, capture parameters	
RUN2*ED		logs clipped at casing shoe and first reading, carry forward constants	
RUN2*DM		check depth matching, constants	
RUN2*EC		Should have GR and NPHI corrected curves with temperature and mud properties (GR_COR, NPHI_COR, FTEMP, BTEM, RM, RMF, RMC etc)	
RUN2_WIRE		Should contain curves with harmonized names, normalized logs, badhole, coal flags and confidence logs	
RUN2_INTERP		Should contain the final interpreted logs (VSH_FINAL, PHIT_FINAL, PHIE_FINAL, SWT_FINAL, SWE_FINAL)	

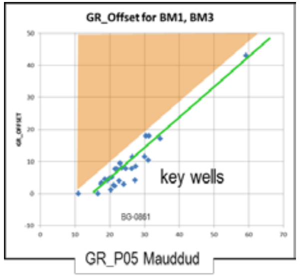
*Depth Shift tables		Only if depth shifting performed	
Special Sets			
CORE_RCA_RAW		Check for harmonic names	
CORE_RCA_DS		Check for depth shift tables	
CORE_SCAL_RAW		Check for harmonic names	
CORE_SCAL_DS		Check for depth shift tables	
RUN2_ECS		Check for harmonic names	
RUN2_NMR		Check for harmonic names	

Phase 2: Environmental Corrections

- Environmental Corrections were applied on GR and NPHI
- GR Correction was performed in two steps:
  - First step was to removed background radioactivity due to KCL muds
  - Second step aims at applying mud weight/hole-size corrections
- To remove background radioactivity, P05 (5th percentile) was stored for BM1/BM3 & MDD intervals
- This P05 value was then compared with reference GR values across same formations in “non KCL” wells
- The GR with KCL effect removed was then corrected for hole size and mud weight effects
- The impact of not implementing Neutron corrections would yield a spread of ~3.5 p.u across typical “wet sands”.
- Hole size, TEMP, PRESS, BH Salinity, mud weight and standoff EC’s were implemented

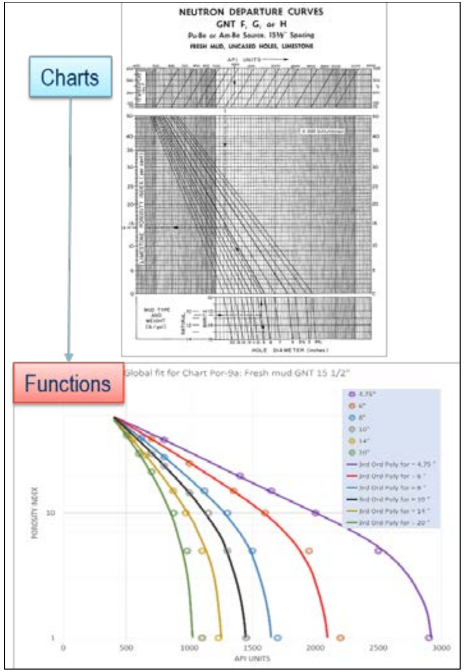


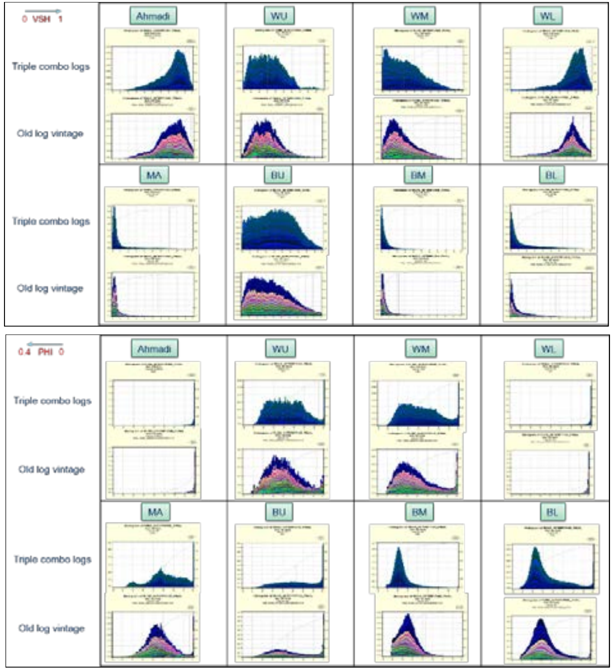
Formation	GR_ref (API) 12 ¼” BS	GR_ref (API) 8 ½” BS	GR_ref (API) 16” BS
Mauddud	18.5	20	16
BM1	7	10	8
BM3	7	10	8



Phase 2: Vintage Wells

- Challenges for vintage well log evaluation falls in 2 categories:
  - Log preparation related to:
    - Depth matching
    - Parameters setting
    - SP baseline shift
    - Neutron conversion from counts to Porosity
  - Formation evaluation of:
    - Shale volume SSP
    - Neutron porosity transformation using historical charts
- Porosity calculated at each vintage well was validated against a nearby modern well
- A confidence log was produced for each well to highlight the overall confidence in the petrophysical interpretation

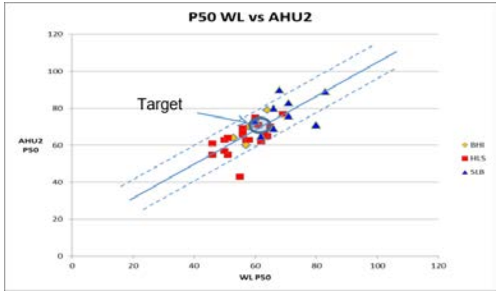




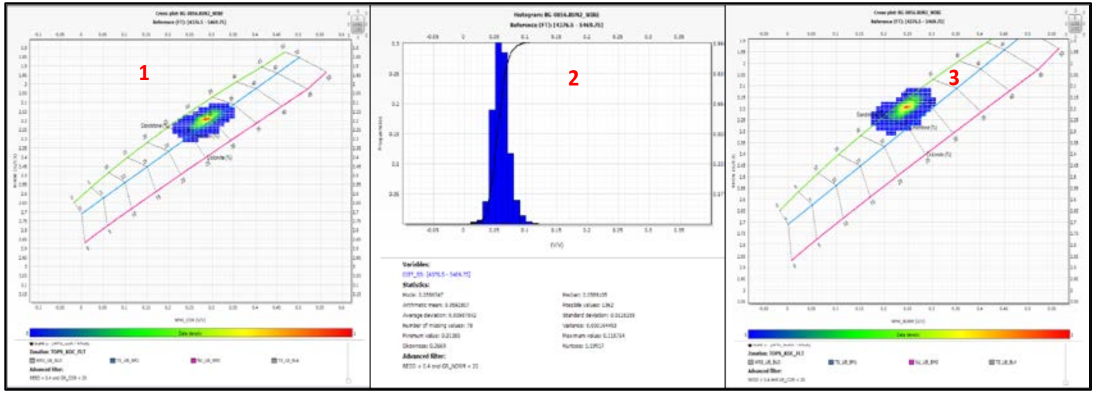
Phase 3: Normalization

Target	WL	AHU2	Top Ahmadi/AHU1
RMAX	60	70	77

- GR normalization was done using a 2-point method to get consistent response at both low and high ends
- The KCL correction helped in getting the low end of the distribution handled well. The high end was characterized by getting reference values across shale markers in the key wells:
    - Capture the P50 values for each of the 3 shale marker zones from histograms
    - Plot the WL_P50 against AHU2_P50
- NPHI normalization was based on an offset that considers density and neutron porosities equal in good hole, clean and wet sands. 3-step process was:
    - ND response across clean sands
    - Estimate mean of the difference between DPHI and NPHI for the same zone to determine the offset
    - Apply the offset on NPHI to get normalized log response

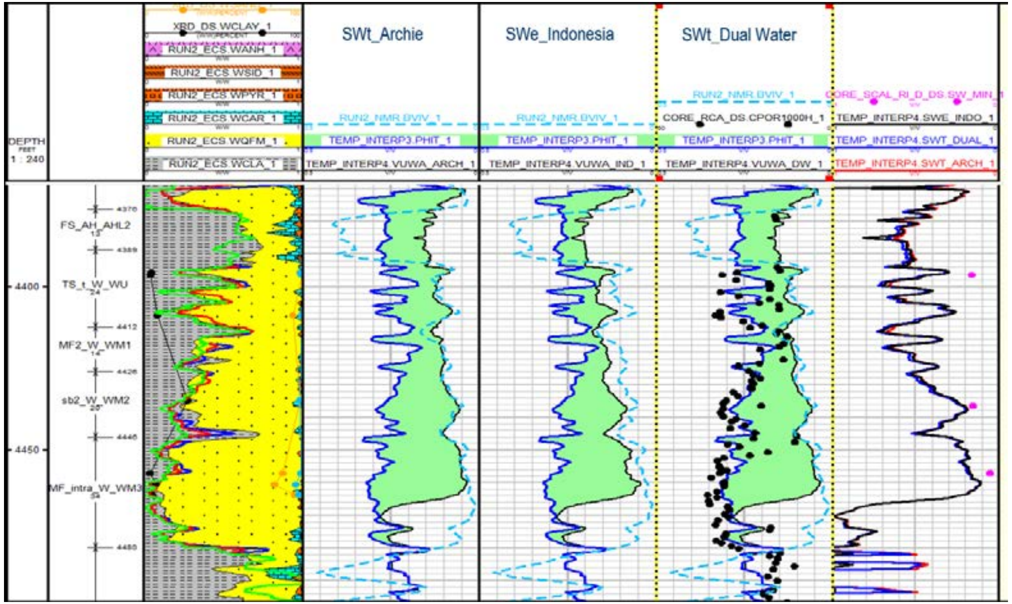


If the trend is consistent it indicates that both shale markers are equally displaced from the target values (see table on top)



Validation

- Validation of final petrophysical results was carried by selecting cored wells for blind testing.
- VSH methods were compared with various references including: Core permeability, WCLA from spectral data, XRD clay fractions.
- Computed porosity was validated against core porosity. Porosity model showed consistent results compared to core porosity.
- Some variability was observed related to:
  - Vertical resolution in thin beds
  - Under correction for light hydrocarbon effect in gas zones and
  - Some porosity deficit compared to core but matching NMR porosity
- Comparison of Water Volume from Saturation equations was made with NMR (Clay and capillary bound water) and SCAL_Swc (from RI, PC (Oil-Brine or MICP) and Kr core tests).



Conclusion

- A consistent and auditable database followed by a standardized petrophysical evaluation workflow was developed through the project
- A thorough review, utilization and integration of log and core data was done to yield the best formation evaluation methodology
- Petrophysical workflows adopted in the study were based on “industry accepted” criterion for formation evaluation
- Necessary validation steps were deployed at each sub-stage of the evaluation life-cycle
- Established workflows have become the new “gold standard” for the asset, being utilized by the asset studies as well as the operations team

Acknowledgement

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