PS A Multidisciplinary Approach for Rock Typing Characterization in a Highly Heterogeneous Carbonate Reservoir in Abu Dhabi UAE*

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Abstract

Nowadays, there is a significant number of reservoir models that are purely constrained to numerical reservoir perception. Moreover, such models neglect the influence of geological events which are essential in characterizing and modeling carbonate reservoirs. This mentioned approach leads to conceptual errors because ideally, a reservoir model would enable heterogeneities predictability and mitigate reservoir-modeling uncertainty. The objective of this paper is to show the results obtained from an integrated reservoir rock-typing characterization process for its subsequent implementation into reservoir models.

This multi-disciplinary study emerged as the fundamental pillar to model the Lower Cretaceous Thamama Group in a major Oil Field in the Arabian Plate. This rock-typing approach intends to define rock types (referred as Static Rock Types (SRTs) in this paper) which result from the combination of two sub-processes, the Petrophysical Synthesis and the Geologic Synthesis. The latter aims to define Facies groups by relating depositional facies and their associated diagenetic processes. On the other hand, the Petrophysical Synthesis proposes to define petrophysical groups based on a combination of similar petrophysical characteristics. Ultimately, this rock-typing approach enables generating Static Rock Types defined by the reconciliation of related geologic and petrophysical patterns. The data inventory for this study includes detailed Core Description, RCA, SCAL, and Log data. Applying consistent data quality validation, which allows implementing a robust workflow combining deterministic methods and machine learning supported algorithms for data analysis.

Static Rock Types (SRT) were classified through distinctive sets of geologic and petrophysical groups. This classification resulted in four SRTs. SRT1 exhibiting enhanced reservoir properties product of early diagenesis, SRT2 is dominated by neutral diagenetic processes that preserve reservoir properties, SRT3 and SRT4 are both associated to late diagenetic property reducing processes that distort arrangement of minerals and pore structure. The major achievement of this rock-typing approach resumed in the integration of the Geology and Petrophysics. This integration enable finding significant evidence to understand reservoir properties at depositional stage, properties alteration product of diagenetic processes and reservoir dynamic behavior links to a geologic concept. This rock-typing approach changes the traditional practice,

formerly used to model this particular reservoir, which was limited only to the classification of petrophysical patterns; instead, this approach allows associating a particular petrophysical pattern to a singular geologic facies, feature or event.

Ultimately, via the integration of dynamic and static data, reservoir models become more predictive. Similarly, the basis of the rock-typing approach presented herein brings together a solid static understanding in order to delineate the origin of particular reservoir dynamic behaviors. This fit-for-purpose approach built from the premise of integration provides a complete basis for reservoir simulation, management, and forecasting; and at the same time contributes reducing reservoir uncertainties by means of enhancing heterogeneities predictability, dynamic flow understanding, which all combined yields organically into optimized field development strategies.

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ADNOC

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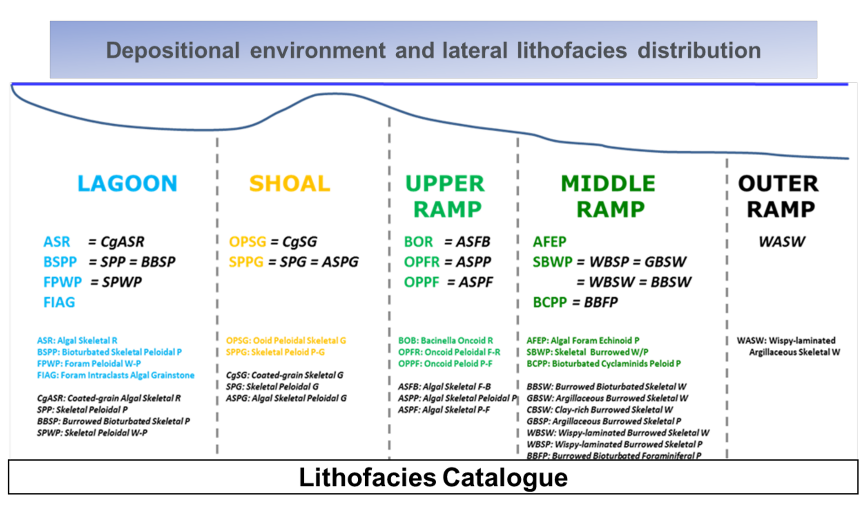
Geologic Synthesis

DEPOSITIONAL FACIES SCHEME



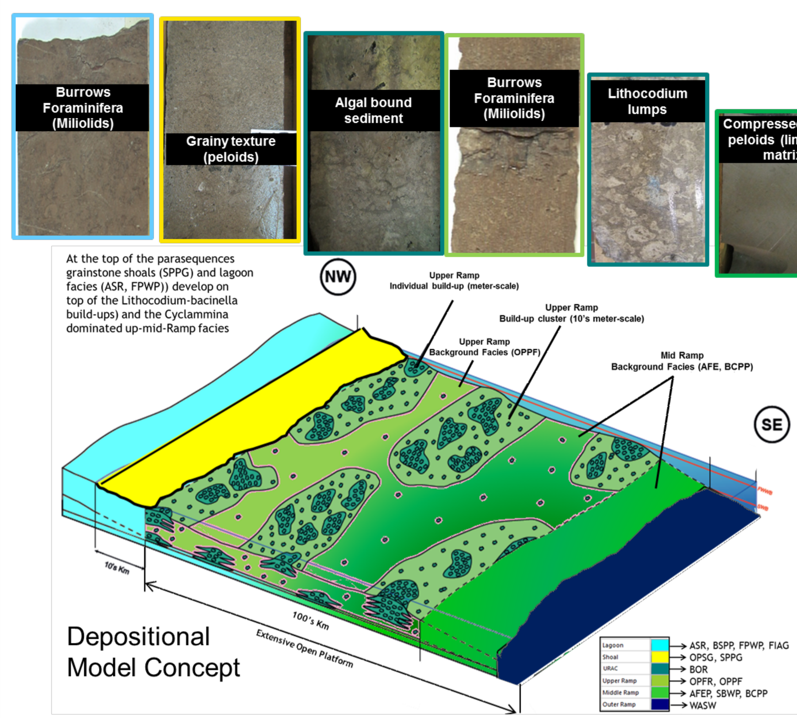
Different facies observed on reservoirs from grain-dominated to mud-dominated facies

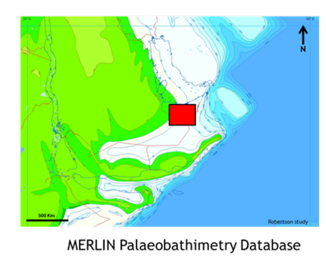
→ Facies Associations based on depositional environments

→ Higher K contrast is controlled by grainstone shoals

→ Best reservoir facies are identified at sequence boundaries

CONCEPTUAL MODEL; DEPOSITIONAL ENVIRONMENTS





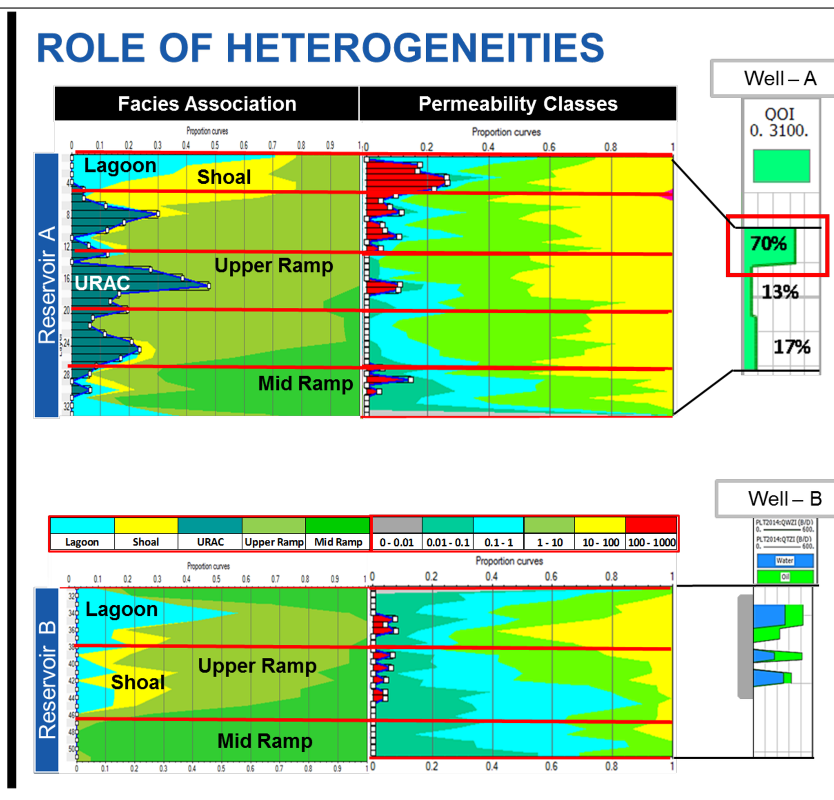
- Valanginian age map.
- Open sea → Eastward direction.

→ Reservoir A: distal echinoid dominated facies, development of in-situ algal clusters within the mid-ramp, transition into shoals.

→ Reservoir B: algal clusters disappeared from mid ramp, lesser grain supported lithofacies capped by lagoonal lithofacies.

→ Outer ramp lithofacies not present in reservoir intervals

ROLE OF HETEROGENEITIES



Reservoir A
Observation data shows highest contribution linked to higher Permeability contrast (100-1000Md) and mostly Skeletal Peloidal Packstone Grainstone.

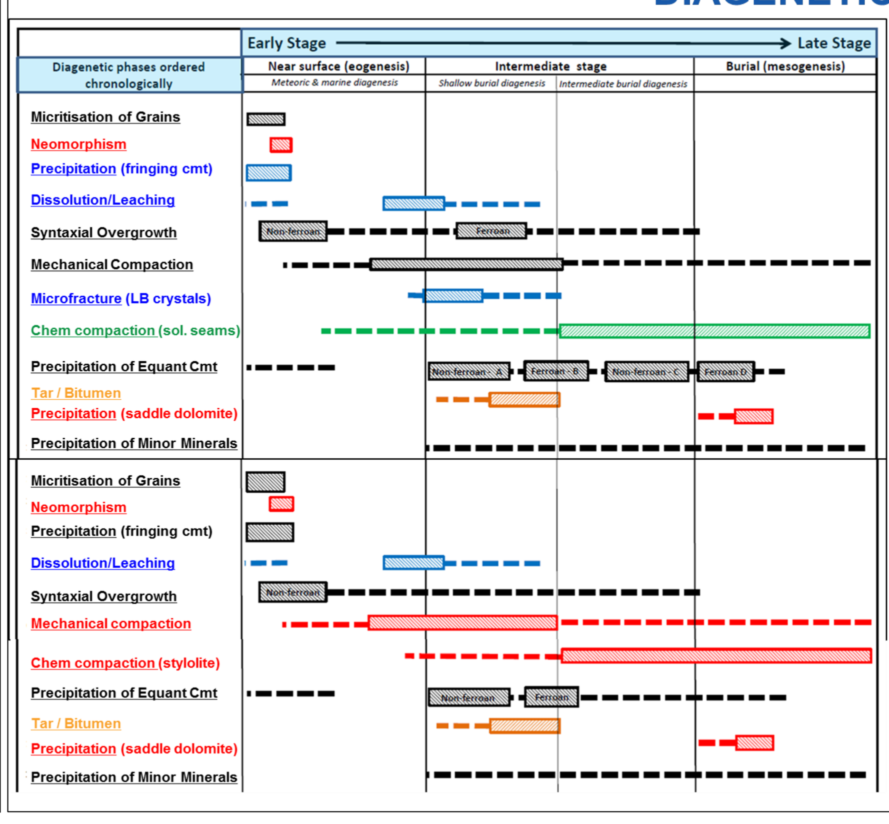
→ Grainy facies: highest contribution to flow

Reservoir B
Not as heterogeneous as Reservoir A, similarly higher Permeability contrast is associated to the grainy facies.

Conceptual Model: Rerservoir A is made up of facies dominated by Lithocodium-Bacinella algae in an array of coarse grained floatstones and rudstone and finer grained but similar composition packstones and grainstone textures with peloidal 'matrix', lastly Wackestones are rare; nevertheless when found they are inferred to be the results of compacted peloidal packstone/grainstone. The concept model shows sequential evolution of distal echinoid dominated facies at the bottom of the sequence, followed by the development of in-situ algal clusters mostly with in the mid-ramp, then transitioning into high energy grain supported lithofacies capped by lagoonal lithofacies. Reservoir B is dominated mainly by Cyclammina, it is particular to be higher in textural variability of the sediments (from wackestone to grainstone) when compared to Reservoir A, and Algal Skeletal Rudstone is the same facies in both reservoirs in terms of texture. The concept for this reservoir differ from the upper reservoir as in this case the algal clusters disappear from the mid-ramp and high energy grain supported lithofacies are capped by lagoonal lithofacies (green algae). Observation data from both reservoirs provides early evidences for the association of lithofacies to particular permeability contract and consequently related to preferred dynamic contribution intervals. Both reservoirs exhibit a distinctive link of the highest permeability contract to Skeletal Peloidal Grain dominated facies, even when Reservoir B is less heterogeneous than Reservoir A.

Geologic Grouping

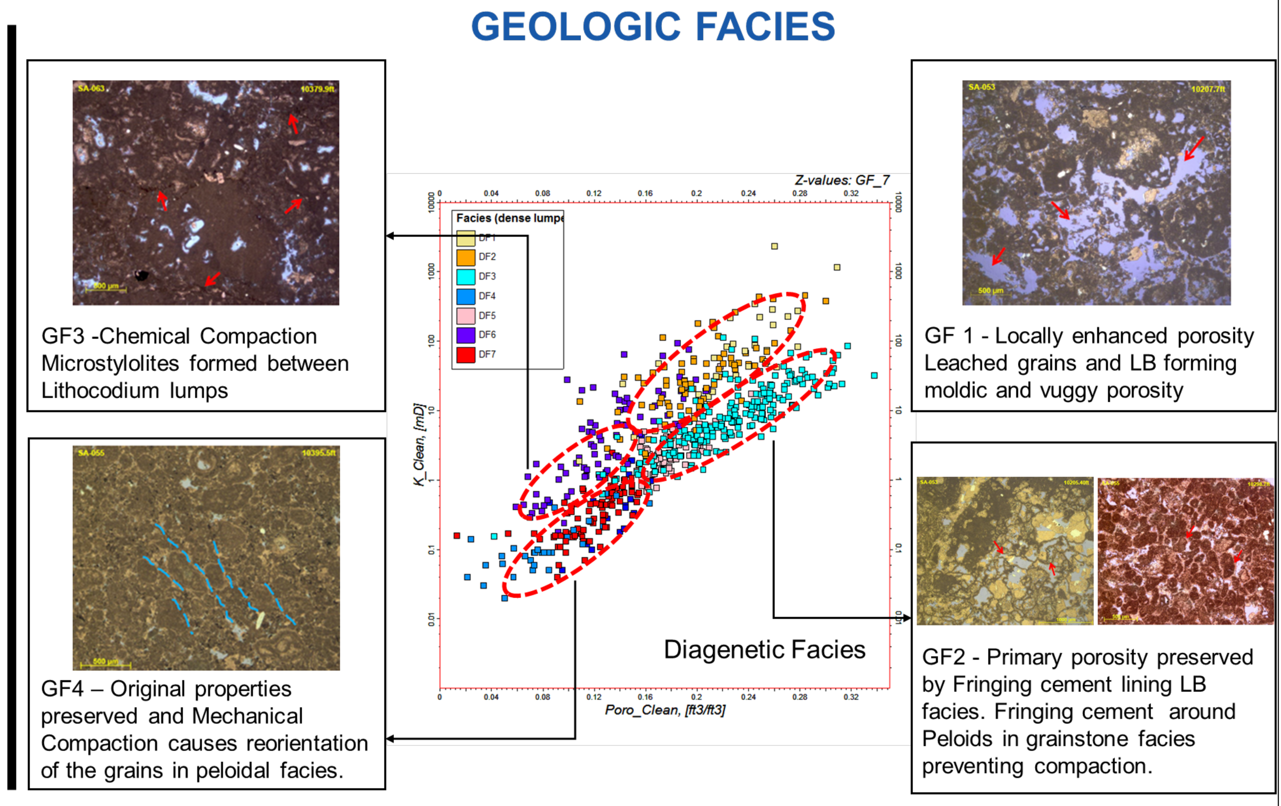
DIAGENETIC FACIES WORKFLOW



Diagenetic Facies	Texture	Visual Porosity	Diagenesis: Cement	Diagenesis: Compaction	Diagenesis: Leaching	Properties (mean): Poro (pu)	Properties (mean): Perm (mD)
DF1	Grainstone	Mod-Good intergranular / intragranular	Rare	Absent	Moldic/ Vuggy grains	0.21	118
DF2	Packstone	Mod-Good intergranular / intragranular	Rare	Absent	Intraclast	0.19	50
DF3	Packstone	Mod-Good intergranular	Lining cement (Prsp)	Absent	-	0.21	16
DF4	Grainstone / W / P	Poor	Equant calcite (Chem compaction)	Abundant-Common	-	0.11	0.8
DF5	Grainstone/P			Absent	-	0.17	4
DF6	Packstone	Poor-Mod intergranular	Rare	Absent	-	0.13	11
DF7	Grainstone/P	Poor-Mod intergranular / intragranular	Common-abundant	Abundant-Common	-	0.11	0.7

→ Diagenesi Facies Matrix: Lithofacies / diagenesis overprint / Poro | Perm

GEOLOGIC FACIES



GF3 -Chemical Compaction Microstylolites formed between Lithocodium lumps

GF4 – Original properties preserved and Mechanical Compaction causes reorientation of the grains in peloidal facies.

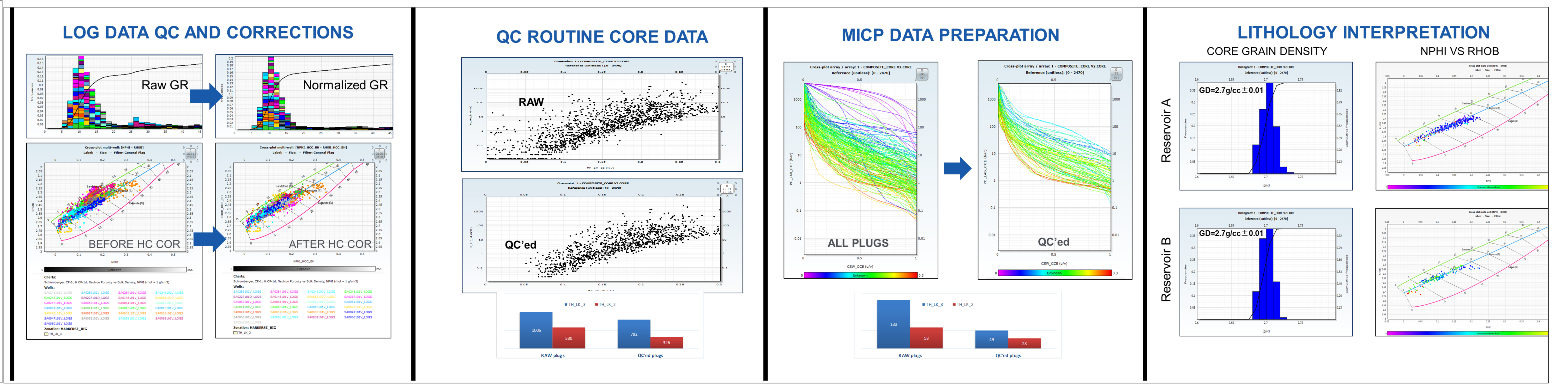
GF 1 - Locally enhanced porosity Leached grains and LB forming moldic and vuggy porosity

GF2 - Primary porosity preserved by Fringing cement lining LB facies. Fringing cement around Peloids in grainstone facies preventing compaction.

Methodology: This is the main geologic component of the rocktyping approach. This session entails the outcome from reservoir characterization and preliminary evidence found from data analysis. The output from this exercise are groups of rocks associated by depositional lithofacies and diagenetic overprint. The initial stage in this process concentrates in looking into the depositional facies concepts, diagenetic processes, and reservoir properties to define initial groups designated as "Depositional Facies". Depositional concepts have already been designated for each reservoir, having in common a smooth transition from mid-ramp deposits to high energy shoals ending in lagoon environment. Paragenetic sequence were observed to define whether reservoir properties were affected by different diagenetic phases. As per in Reservoir A, the most important factors are specific to early stage near surface eogenesis and intermediate burrial stage. The first is characterized by precipitation of fringing cement, dissolution and leaching of grains, and microfracturing of Lithocodium-Bacinella crystals leading to porosity enhancement. And the second is related mostly to chemical compaction resulting in solution seams leading into reduction of permeability. The heterogeneity in this reservoir makes it more likely to be impacted by diagenesis, yet primary reservoir properties are preserved overall. Reservoir B is also mainly impacted by early stage near surface eogenesis and intermediate burrial stage, and also late stage mesogenesis. An at early stage porosity is enhanced by the dissolution of crystals and leaching of cement. Other intermediate to late processes including mechanical compaction and precipitation of saddle dolomites together reduced porosity. Reservoir B primary reservoir properties are mostly impacted by reducing processes as most of this reservoir in partially in the transition zone.

Petrophysical Synthesis

LOG DATA QC AND CORRECTIONS · QC ROUTINE CORE DATA · MICP DATA PREPARATION · LITHOLOGY INTERPRETATION



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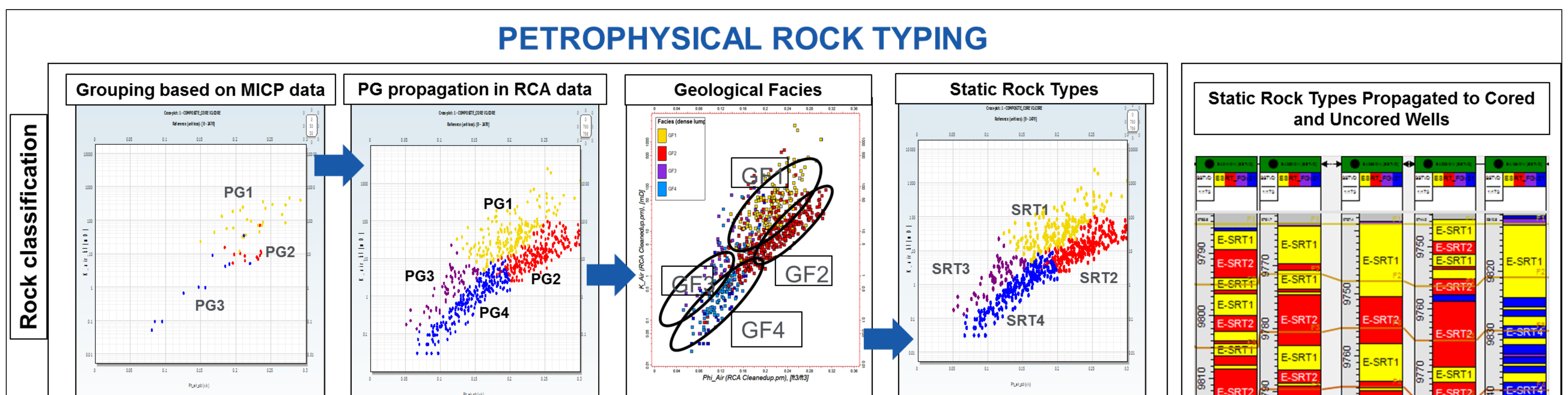
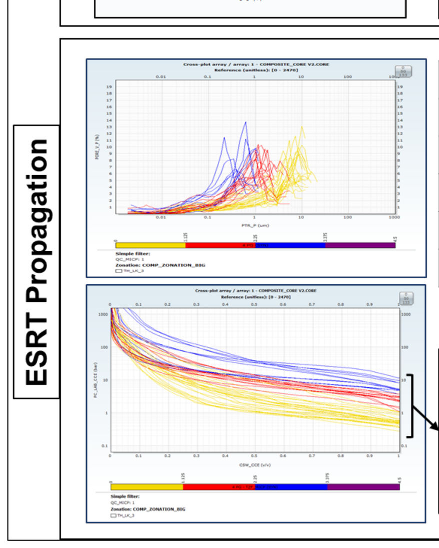
Static Rocktypes

PETROPHYSICAL ROCK TYPING

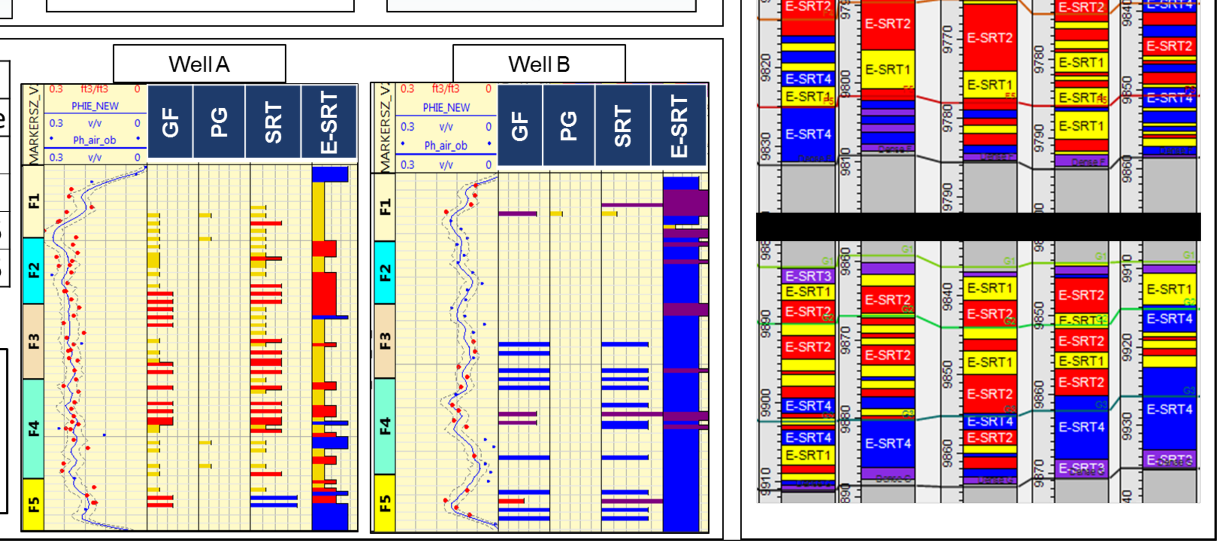




Pore Throat Size

SRT	Category	Port Size
SRT1	Macro	2 -10
SRT2	Meso	0.5 - 2
SRT3	Micro	0.1 - 0.5
SRT4	Micro	0.1 - 0.5

Pce (entry pressure) SRT1<SRT2<SRT3 <SRT4



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