Rock-Typing: An Integrated Reservoir Characterization Tool for Tight Jurassic Carbonates, West Kuwait*

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Abstract

Middle Jurassic tight fractured Najmah-Sargelu Formation is spread across whole of Kuwait. It is often vertically and laterally heterogeneous because of depositional variability and diagenetic alteration through space and time. Understanding the distribution of hydrocarbons in relation with porosity / permeability heterogeneities is thus of major importance in effective field development and production. Rock-typing is then an essential step in Carbonate reservoir characterization and geological model building for reservoir simulation and predicting fluid flows through time in order to support development scenarios. A static rock-type is defined as "a rock unit characterized by similar depositional and diagenetic processes resulting in a typical and unique Ø-K relationship and capillary pressure curve at given wettability". This paper establishes a deterministic rock-type scheme in Najmah-Sargelu reservoir and presents a methodology to distribute these rock types vertically and laterally in the 3D geological model. In the present study, 27 wells were analyzed. The rock-types are based on core observation of the main sedimentary facies, dynamic properties measured in special and conventional core analyses and logs. This approach reconciles sedimentology, petrophysics and dynamic characteristics of rocks. This also allows identifying the rock-types in non-cored intervals. During the electrofacies analysis, both non-supervised and supervised approaches were carried out successively, the first one to characterize electrofacies on reference-cored wells, and the second one to propagate this signature to other wells once the comparison with lithofacies is positive. Once the electrofacies were interpreted and propagated, they were tied to available petrophysical information, in order to build the rock-types. A rock-type can gather several electrofacies if their dynamic behavior is similar; conversely, electrofacies must be refined if it appears that their group points have no consistent petrophysical characteristics. In this study, Najmah and Sargelu formations were treated separately due to strong impact of bitumen in the formation, which reduces the weight of other facies, and 10 rock-types (5 in Najmah and 5 in Sargelu) have been defined. These rock-type results have been used to refine stratigraphy and static 3D geological modelling of the reservoir.

Introduction

Najmah-Sargelu Formation of Middle Jurassic is tight, fractured Carbonate reservoirs, spreading across whole Kuwait deposited in a flat inner to outer carbonate ramp and a basinal environment. These reservoirs are often vertically and laterally heterogeneous because of depositional variability and diagenetic alteration through space and time. Understanding the distribution of hydrocarbons in relation with porosity / permeability heterogeneities is thus of major importance in effective field development and production. Rock-typing is then an essential step in Carbonate reservoir characterization through seismic facies characterization and geological model building for reservoir simulation and predicting fluid flows through time in order to support development scenarios.

A static rock-type is defined as "a rock unit characterized by similar depositional and diagenetic processes resulting in a typical and unique Ø-K relationship and capillary pressure curve at given wettability". Representative reservoir rock-types lead to a better understanding of reservoir fluid movement and oil recovery. This paper establishes a deterministic rock-type scheme in Najmah-Sargelu reservoir of Abduliyah and Dharif Fields and presents a methodology to distribute these rock types vertically and laterally in the 3D geological model.

General Principles and Methodology

The rock-typing analysis is based on core observation of the main sedimentary facies, dynamic properties measured in special and conventional core analyses and logs. The principles of electrofacies analysis are based on cluster analysis in the log space (Figure 1).

First, the depth points at the reservoir level corresponding to the log sampling are extracted and plunged in a multivariate space. Usually the depth points are considered from a subset of wells honoring most available and quality data on cores and logs in terms of consistent sampling of the main geological variations encountered across the field.

In the second step, cluster analyses are carried out in the log space in order to group depth points, which are close to this space and therefore define a similar electrofacies response. Cluster analyses can be performed with classification methods based either on probabilistic approaches, or on optimization schemes such as neural network approaches.

In the present study, 27 wells were analyzed with logs and nine wells of core data. EasyTrace™ software was used for cluster analysis with probabilistic approaches. An unsupervised classification scheme is based on the computation and interpretation of the multivariate probability density function estimated in the multivariate space of logs. The supervised scheme is based on discriminant analysis.

The key activities included are:

1. Detailed quality control on data (raw logs cleaning, core depth shift...);
2. Rough unsupervised clustering approach to determine the reference logs and thus the reference well set;
3. Unsupervised approach based on the reference wells to perform the electrofacies definition. Results on Sarjelu formation illustrated in Figure 2. Each electrofacies corresponds to a distinct peak on the multivariate probability density function. The corresponding points

are displayed in the cross-plots of the logs involved in the classification showing correspondence to clearly stable and distinct log responses, i.e. to different areas or clusters in the log space.
4. Conformance between electrofacies and core descriptions in the cored wells;
5. Integration of CCAL/SCAL data in order to determine rock-types from electrofacies;
6. Extension of rock-types in the wells with missing logs using a supervised approach guided by the electrofacies previously determined at the reference wells.

Based on the testing phase this methodology has been applied separately for both reservoir units (Najmah and Sargelu) to respect the depositional model breakdowns. As an example, the workflow outputs and results are shown in Table 1 and Table 2 for Najmah Formation. Ten rock-types have been identified (5 rock-types per reservoir). The main characteristics of each rock-type are shown in the following Table 3.

Conclusions

1. The multivariate probability density function (PDF) allowed for honouring the two reservoirs separately and defining electrofacies, which correspond to natural clusters in the log space, therefore, which are stable and highly predictable.
2. The supervised analysis allowed the extension of electrofacies and associated rock-types to all wells involved in the study.
3. The rock typing exercise led to geologically segregating the various composite facies into quantifiable reservoir types.
4. The workflow integrated and considered lithofacies, electrofacies and petrophysical properties to generate clusters on reference wells, which could then be probabilistically transformed for the entire area of the study effectively in the geological model.
5. Highest potential for hydrocarbon resource has been attributed to Low Porous Limestones (RRT1) and Bioturbated Limestone (RRT3) for Najmah and Tight to Low Porous Limestone (RRT12) and Low Porous Limestone (RRT13) for Sargelu reservoir units.

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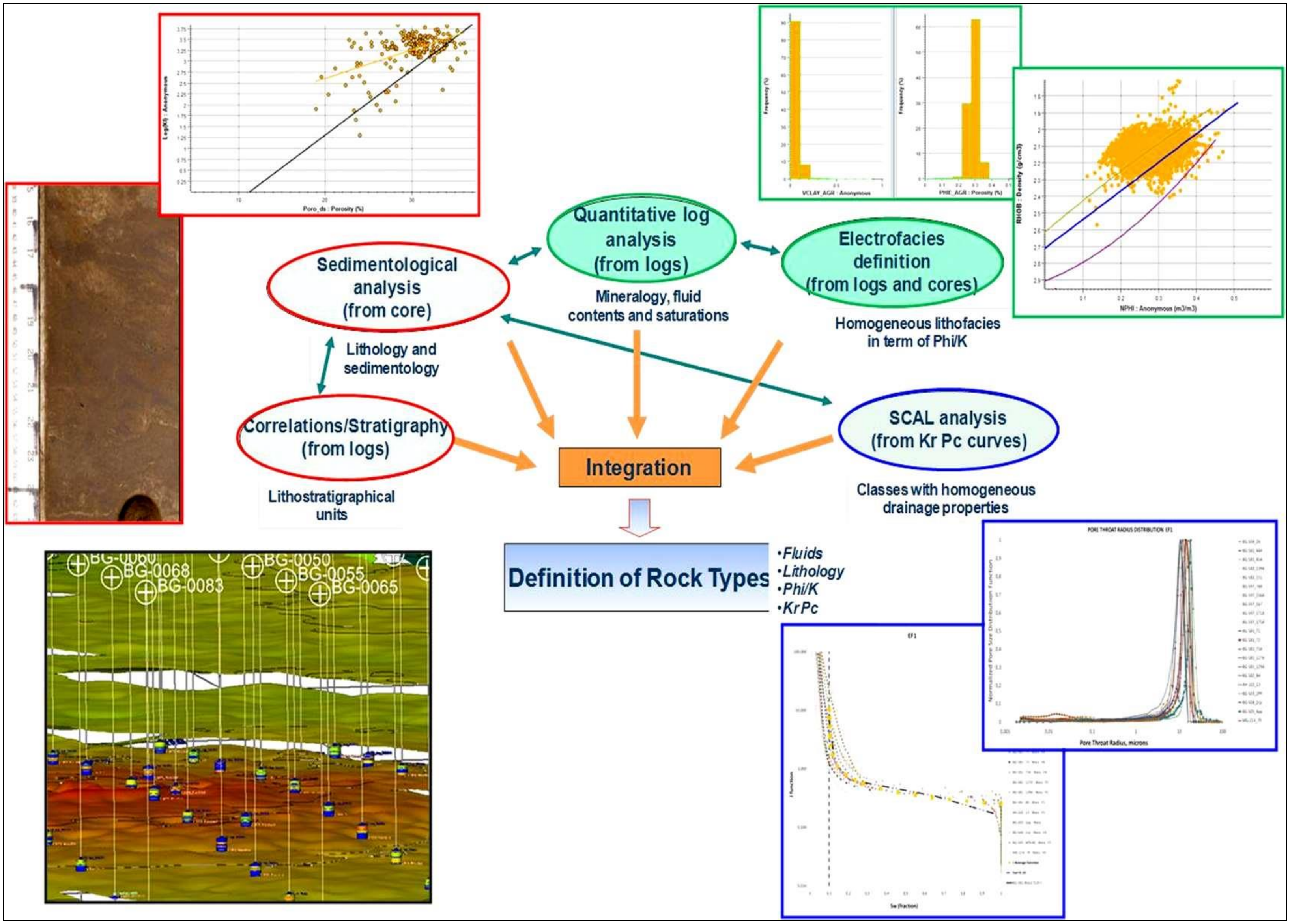

Figure 1. A typical integration of data that provides the backbone for a Rock-typing exercise in a reservoir.

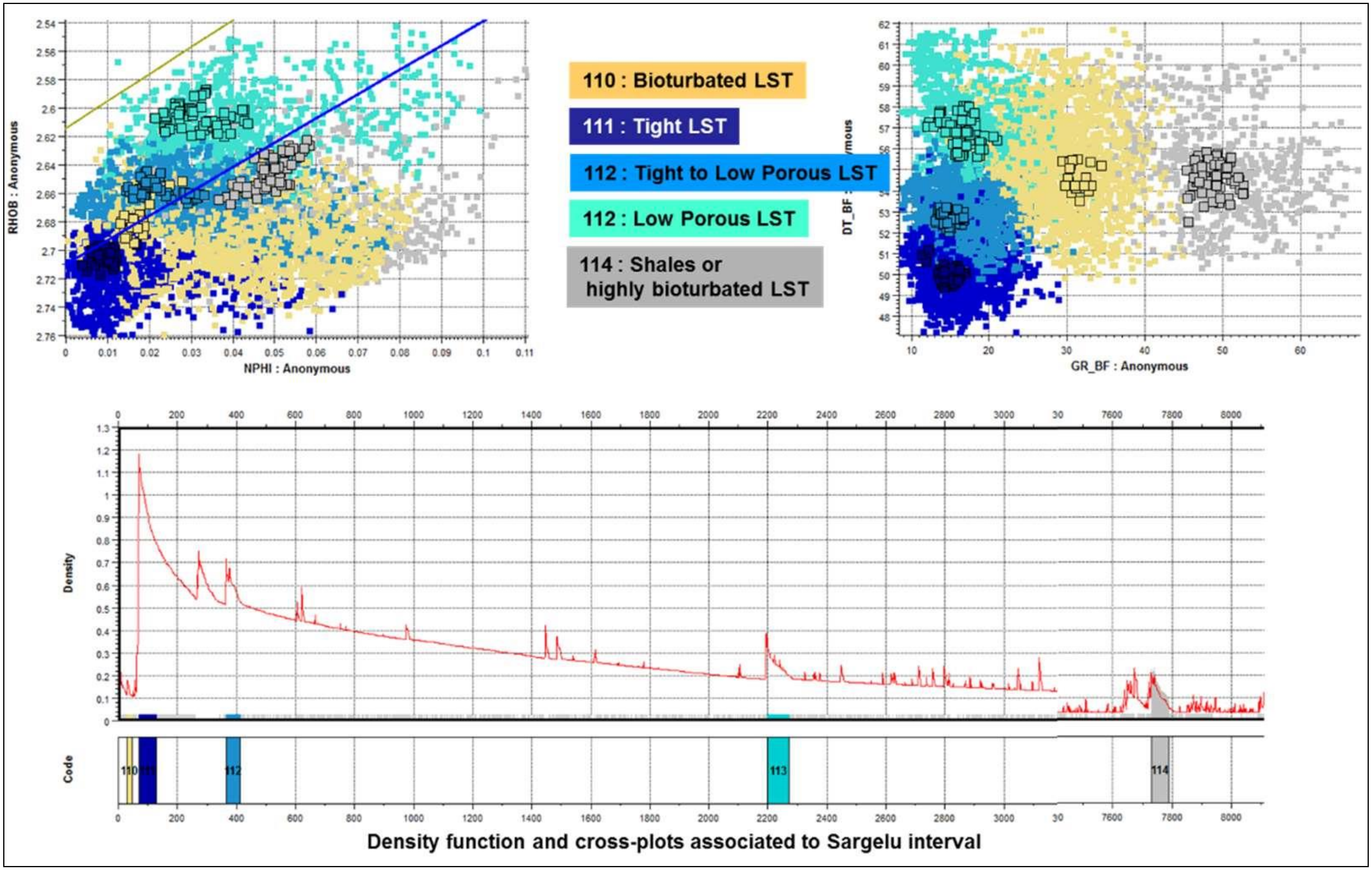

Figure 2. Unsupervised classification for the reference wells, showing the electrofacies from the probability density function, and their representation in the cross-plots of the logs involved in the classification.

Electrofacies code	Preliminary description	Lithofacies description	Lithofacies code
100	Tight Limestones	Limestone (Mudstone/Wackestone)	F1 -F7
101	Low porous Limestones	Limestone (Packstone to Grainstone)	F2-F3
102	Bitumen	Bioturbated Limestone	F4-F5-F6
103	Bioturbated Limestones	Laminated calcareous shale	F8-F9-F10
104	Shales or calcareous shales	Bitumen+Shale	F11

Table 1. Preliminary electrofacies characterization based on cross-plots analysis in Najmah interval and grouping of described lithofacies into simplified lithofacies.

		100	101	102	103	104
VCL (%)	**Q10**	0	0	0	0	0
	Median	**0**	**0**	**11**	**8.5**	**21.8**
	Q90	2.6	2	2.0	14.6	45.2
PHIeff (%)	**Q10**	1	3.7	0	0	0
	Median	**2.4**	**4.9**	**0**	**2.4**	**0**
	Q90	3.3	6.9	0	4.2	0

Table 2. Petrophysical properties of electrofacies in Najmah interval- the results observed in this table confirm the lithological description of electrofacies preliminary done and the simplified merging of lithofacies.

	Electrofacies	Rock-types		PHIeff (%)	VCL (%)
Najmah	EF100	RRT0	Tight limestones	2.0	2
	EF101	**RRT1**	**Low porous limestones**	**4.4**	**0.6**
	EF102	RRT2	Bitumen	0.0	10.0
	EF103	**RRT3**	**Bioturbated limestones**	**4.54**	**6.5**
	EF104	RRT4	Shales or calcareous shales	0.0	28.0
Sargelu	EF110	RRT10	Bioturbated limestones	1.7	5.8
	EF111	RRT11	Tight limestones	0.9	0.4
	EF112	**RRT12**	**Tight to low porous limestones**	**2.3**	**1.1**
	EF113	**RRT13**	**Low porous limestones**	**2.75**	**5.7**
	EF114	RRT14	Shales, calcareous shales or highly bioturbated limestones	1.5	16.0

Table 3. Characteristics of each rock-type with corresponding Electrofacies & Lithofacies for both reservoirs, which clearly brought out the rock types having better potential shown here in **bold**.