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Integrated rock-typing approach considering petrophysics, geology and diagenesis

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Abstract

Development of oil and gas field with carbonate reservoirs is quite challenging due to its high heterogeneity (diagenesis, fractures, wetting, leaching, recrystallization etc.). There is no universal rock-typing methodology in order to define groups of rocks in petrophysics, geology and diagenesis. This work proposed integrated approach of rock-typing by using clustering algorithms. At the first stage three homogeneous groups were defined by using well logs. Then the groups were confirmed by lithological description of the core data and capillary pressure curves. For further development, it is better to try different clustering algorithms and use data from several wells simultaneously. This will help to construct geological model.

Keywords: Carbonates, rock typing, machine learning.

1. Introduction

It is said that a huge amount of the world's oil reserves are found in carbonate reservoirs. Many of these are located in the Middle East, Libya, Russia, Kazakhstan, and North America.

In contradiction to stable terrigenic rocks, carbonate reservoirs are exposed to diagenetic processes (recrystallization, dolomitisation, leaching etc.) and have complex depositional geometry. These processes alter carbonate rocks abruptly which lead to challenges in oil production. Such kind of reservoir may have high porosity values according to logs but in the same time, pores may not be interconnected. As a result, due to high heterogeneity there is a differentiation in reservoir properties and oil production between two neighbor wells. Heterogeneity at all the reservoir scales can make them a challenge to model, and it is not an easy task to make reliable predictions about their production performance.

For the last 15 years rock typing is the main trend among the geologists. Carbonate rock typing is critical in distribution of reservoir properties, such as permeability and water saturation, in the reservoir model. There are a lot of standard rock typing approaches such as FZI, Winland, Pittman, PGS, Cuddie, Lucia [1] etc. These approaches are based on empirical equations and have some limitations and gaps:

1) Standard rock typing methods do not take into account diagenesis;
2) Standard rock typing methods do not consider depositional features;
3) There is no ability to correlate rock types with well logging curves;
4) It is difficult to propagate rock types in geological model.

Therefore, it is demand in new rock typing approach, which will use synergy of geology, sedimentology, petrophysics and overcome limitations of standard rock typing algorithms [2].

In this work, a new rock typing approach is constructed and applied to real carbonate reservoir.

2. Materials and methods

The workflow of proposed methodology consists of several steps: 1) Clustering of well logging curves 2) Searching of correlation between defined clusters and petrophysical properties 3) Searching of geological meaningful of clusters 4) Searching of diagenetic meaningful of clusters.

Clustering algorithms applied to well logging curves may be effective tool in order to define groups of rocks with similar properties.

K-means clustering is a type of unsupervised learning, which can be applied to unlabeled data i.e. data without defined groups. The target is to detect categories in the data, with the number of groups represented by the variable K. K-means works iteratively to assign each data point to one of K groups based on the specific features that are presented. Data points are grouped based on the similarity of features (Figure 1). The results of the K-means clustering algorithm:

1. Centroids of clusters K, which can be used to denote new data;
2. Labels for training data (each data point is assigned to one cluster).

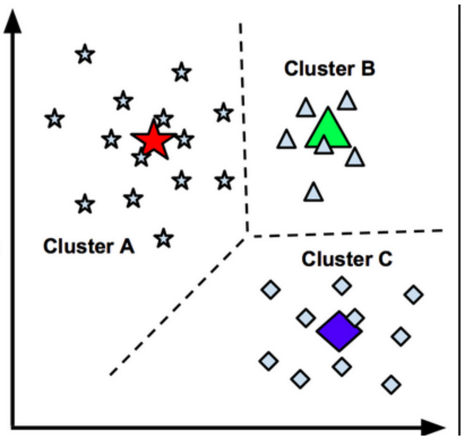

Fig. 1. Data points being clustered (https://medium.com/@dilekamadushan/introduction-to-k-means-clustering-7c0ebc997e00).

Optimal number of clusters is defined with the help of Silhouette score. As it can be seen from figure 2 three clusters are defined on the base of neutron, density, acoustic, resistivity and caliper well logs.

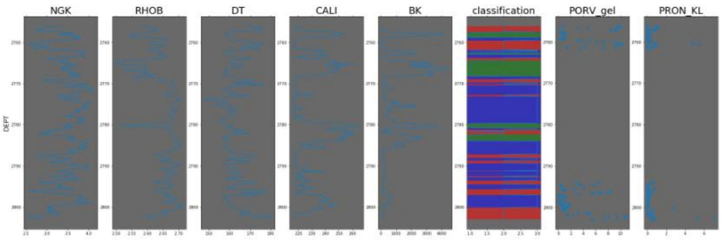

Fig. 2. Clusters defined on the base of well logging curves

The next stage of the workflow is correlation of defined clusters with petrophysical data (routine and special core analysis). It is important to note that clusters defined on the previous step is a result of mathematical algorithm which does not take into account geological features and properties of the reservoir and rely only on curve values. That is why it is necessary to justify clusters in terms of geology. In this case there is porosity-permeability cross plot which will help to understand the homogeneity of clusters. It is better to see segregation of porosity-permeability points into clouds (Figure 3). This means that defined clusters are homogeneous in terms of reservoir properties. Another feature of correct clustering is homogeneity of clusters in dynamic properties. Capillary pressure curves are good indicator of fluid movement in porous media and position of curves with similar color (Figure 3) indicates correctness of clustering.

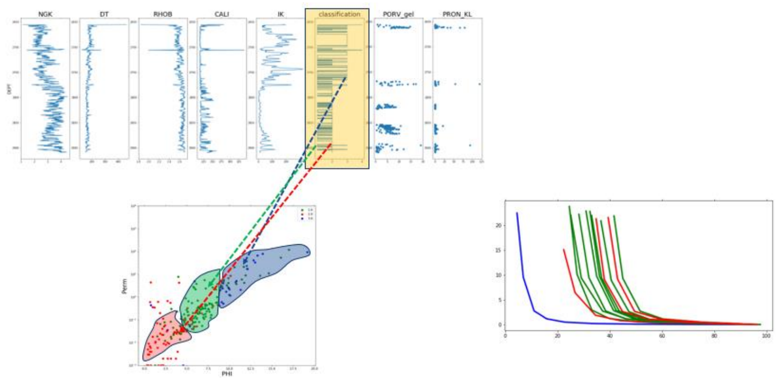

Fig. 3. Determination of petrophysical properties for each cluster

The next step is determination of geological meaningful of each cluster. Since the identified rock types are further needed to build a geological model, it is necessary to understand how the identified clusters propagate in the interwell space. For this, it is necessary to understand what lithology controls each cluster. This analysis can be done using pie charts for each cluster. These charts show the percentage of lithology in the clusters. Pie charts also show which process each cluster controls (dolomitization, recrystallization, leaching) (Figure 4).

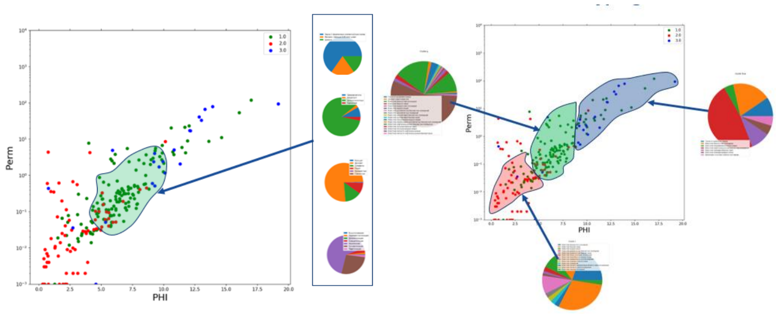

Fig. 4. Determination of geological meaningful of each cluster (left – diagenesis, right – lithology)

3. Conclusions

Proposed workflow shows good results in terms of clustering of well logs. Three groups of rocks are defined with homogeneous petrophysical properties and groups are geologically meaningful. These clusters can be called as rock types and geologist could use them in construction of geological model. It is recommended to perform further investigations using logs from several wells as input data for clustering.

References

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