Rock Typing Characterization Using Artificial Neural Network Methods

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Agenda

- Self Presentation
  - Education, Experience and achievement.
- Challenge and Solution
- Geological Context
  - Depot environment, HQ subdivision.
- Methodology and Data
  - Petrofacies Characterization Workflow;
  - HFU approach (definition, clustering methods, HFU estimation in uncored wells).
- Results and Discussion
  - HFU Classification and FZI Estimation in Cored Well;
  - HFU Combined with Lithofacies to define RRT;
  - FZI/RRT Estimation in Uncored Key Wells Using NN;
  - Permeability Estimation in Uncored Key Wells Using NN;
  - Permeability and RRT Prediction in Uncored Wells Using SOM;
  - Validation of the Results (RRT distribution, PLT)
- Conclusion
Self Presentation
Self Presentation

Education:
- Master degree in Geosciences from the Algerian Petroleum Institute (2015);
- Master degree in Applied Geophysics at the Houari Boumediene University of Sciences and Technology (2011);
- Graduated in Applied Geophysics Engineering at the Houari Boumediene University of Sciences and Technology (2007).

Experience:
- 4 years of experience in the Oil and Gas industry, particularly specialized in petrophysics and reservoir characterization;
- Employed with Sonatrach as a petrophyscist in 2015;
- Head of Wireline Logging Operations and Data Management Service in 2019;
- Involving in Petrophysical Engineer with specialties including reservoir characterization, log database setup and management, neural net solutions, rock typing, saturation height modeling, formation pressure gradient analysis, deterministic petrophysical analysis and integration of petrophysical results with reservoir models;
- Working most on Hassi Messaoud and Ahnet Fields in Algeria.
Self Presentation

- Achievement:
  - Performing some papers on AAPG, SEG, and EGU:
    » Conducting Integrated Reservoir Studies in the Quartzite Hamra Reservoir-Tight Oil, Southern Periphery of Hassi-Messaoud Field, Algeria AAPG Annual Convention and Exhibition. April 2017;
  - Preparing a PHD degree (Reservoir Characterization Using Artificial Neural Network Methods).
Challenge / Solution
Challenge

- Failure of previous geological model of Hamra Quartzites (HQ):
  - Fail to accurately classify and make an estimation of the reservoirs petrophysical properties;
  - Facies defined based on conventional methods (cut-off);
  - Properties were distributed randomly;
  - Results were not consistent with the underlying geologic controls on reservoir properties.
Solution

- Refine the previous definition of Facies:
  - Characterization should be approached from a dynamic aspect;
  - Re-characterize the HQ formation using Artificial Neural Network methods;
  - Application of the Flow Zone Indicator (FZI) method in HQ reservoir using HFU module from **DSP Landmark Software**;
  - Application of the Neural Network combined with SOM module from **DSP Landmark Software** to predict FZI, RRT and permeability for the uncored interval in the same well, and well without core data.
Geological Context
In most of well studies, the HQ is recognized as clean, blocky sandstone, intensively bioturbated (Skolithos, pipes-rock);

- The average thickness is around 63 - 65m;

- The HQ reservoir is deposited in shore face environment;

- HQ have a range of porosity from 2-15% and permeability from 0.002 to 200 mD;

- HQ reservoir was divided into 3 layers:
  - HQ-1 (best reservoir quality);
  - HQ-2 and HQ-3 (poor reservoir zone).
Methodology and Data
Petrofacies Characterization Workflow

Data preparation

- FZI, RQI Approach
  - Calculation (RQI, PHIZ, FZI)

- OH Log data (GR, RHOB, NPHI, DT)

Classify HFU from core data

Core data (K, PHI)

Core Data check
- (Depth shift, Data correction & filtering)

Build the NN model between HFU and log data

Lithofacies SCAL

SOM Algorithm

Generate HFU for the uncored wells

Validation with PLT, MDT and PI

No

OH Log data (GR, RHOB, NPHI, DT)

Yes

RRT
Permeability Profile

Validate with PLT, MDT and PI
Hydraulic Flow Unit (HFU) Determination in Cored Wells

- The expression HFU was defined by Amfaeul et al 1993 as "a portion of reservoir with some specific hydraulic characteristics which control the fluid flow in the reservoir";
- Each HFU is characterized by a single flow zone indicator (FZI), which also depends on Reservoir Quality Index (RQI) and void ratio ($\phi_z$):
  
  $\text{RQI} = 0.0314 \sqrt{\frac{K}{\phi_e}}; \quad \phi_z = \frac{\phi}{1-\phi}; \quad \text{FZI} = \frac{\text{RQI}}{\phi_z}$

  $K = 1014 \times FZI_{\text{Mean}}^2 \times \frac{\phi_e^2}{(1-\phi_e)^2}$

- Several clustering methods can be applied for FZI zoning. The most popular are Log-Log plot of RQI vs $\phi_z$, Histogram analysis of FZI distribution and the probability plot of FZI distribution;
HFU Estimation in Uncored Wells Using NN

- Use The NN algorithm to predict the FZI in the key cored wells for the uncored intervals. Based on range of FZI from core to defined RRT;
- Key wells chosen on the basis of their stratigraphic and geographic coverage and the quality and reliability of their measurements.
- In un-cored wells, the HFUs can be estimated using a Neural Network (NN) approach, a computation mathematical model is built between input and output data. The used inputs to train the NN system are: NPHI, GR, RHOB. The calculated FZI values are used as an output.
Results and Discussion
HFU Classification and FZI Estimation in Cored Well

Fig.3 Histogram analysis of FZI distribution

Fig.4 Lorenz plot

Fig.5 Horizontal Porosity-Permeability cross plot of QH1, QH2 and QH3

Tab.1 Equation of core permeability Vs core porosity Vs FZI

<table>
<thead>
<tr>
<th>Type</th>
<th>Name</th>
<th>Equation</th>
<th>R²</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>HFU1</td>
<td>Perm = Phi^3 * (0.219 / (0.0314 * (1.0 - Phi)))^2</td>
<td>-0.2824</td>
<td></td>
</tr>
<tr>
<td>Regression</td>
<td>HFU2</td>
<td>Perm = Phi^3 * (0.656 / (0.0314 * (1.0 - Phi)))^2</td>
<td>0.7697</td>
<td></td>
</tr>
<tr>
<td>Regression</td>
<td>HFU3</td>
<td>Perm = Phi^3 * (1.515 / (0.0314 * (1.0 - Phi)))^2</td>
<td>0.8026</td>
<td></td>
</tr>
<tr>
<td>Regression</td>
<td>HFU4</td>
<td>Perm = Phi^3 * (3.248 / (0.0314 * (1.0 - Phi)))^2</td>
<td>0.8718</td>
<td></td>
</tr>
<tr>
<td>Regression</td>
<td>HFU5</td>
<td>Perm = Phi^3 * (6.973 / (0.0314 * (1.0 - Phi)))^2</td>
<td>0.7938</td>
<td></td>
</tr>
</tbody>
</table>
HFU Combined with Lithofacies to define Reservoir Rock Type (RRT)

- **RRT1**: shale, silicified sand, poorly connected, poor rock type;
- **RRT 2**: silicified sand, poor sorting, cemented sometimes by clay, poor rock type;
- **RRT 3**: cemented sandstone, pores sometimes connected, medium rock type;
- **RRT4**: sandstones with intergranular porosity, sometimes connected, good rock type;
- **RRT5**: sandstones with intergranular porosity, good connected, good rock type.

<table>
<thead>
<tr>
<th>RRT</th>
<th>Porosity range (%)</th>
<th>Permeability range (mD)</th>
<th>FZI range (µm)</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>RRT1</td>
<td>4-14</td>
<td>0.004-0.2</td>
<td>0.05-0.43</td>
<td>blue</td>
</tr>
<tr>
<td>RRT2</td>
<td>2-10</td>
<td>0.005-1</td>
<td>0.43-1.06</td>
<td>blue</td>
</tr>
<tr>
<td>RRT3</td>
<td>3-9</td>
<td>0.05-3</td>
<td>1.06-2.26</td>
<td>blue</td>
</tr>
<tr>
<td>RRT4</td>
<td>4-11</td>
<td>0.4-40</td>
<td>2.26-4.88</td>
<td>blue</td>
</tr>
<tr>
<td>RRT5</td>
<td>6-12</td>
<td>10-200</td>
<td>4.88-12</td>
<td>blue</td>
</tr>
</tbody>
</table>

Tab.2 Porosity, permeability and FZI range of each RRT
The RRT distribution is depicting the overall depositional environment showing the sand rich, shallow marine high energy more pronounced in the upper part of the HQ reservoir to the calmer, wavy/tidal influence at the lower part of HQ reservoir.
FZI RRT Estimation in Cored and Uncored Key Wells Using NN

- Track 06:
  - Black dots: FZI identify from core interval;
  - Purple curve: FZI prediction in uncored interval after modification.

- Track 07: RRT distribution.
  - Good Match between FZI-Core & FZI-Predict.
Permeability Estimation in Cored and Uncored Key Wells Using NN

- Track 07:
  - Purple curve: Permeability from RRT;
  - Black dots: Permeability from core data;
  - Good Match between the K-RRT & K-core.
Permeability Validation in Cored Key Wells Using PLT

- Good agreement obtained between core permeability and calculated permeability K-NN ($R^2 > 0.6$).
- Comparison results of predicted permeability with PLT at cored well are quite matching.
Permeability and RRT Prediction in Uncored Wells Using SOM

- Use **SOM** classification methodology to extend RRT to uncored wells, using key wells as training samples.
Comparison results of predicted permeability with PLT at uncored well are quite matching.
Conclusion

- The results show that RRT 5 and RRT 4 are the best reservoirs quality to flow, which commonly found in zone 1 (HQ-1);
- The Formation HQ Zone 2 and Zone 3 (HQ-2, HQ-3) are commonly presented by RRT 1 and RRT 2 with poor quality reservoir rocks;
- RRT results are in complete agreement with the geological and sedimentary study;
- For each Rock-Type, a linear regression law is provided, allowing the calculation of a synthetic permeability from porosity curves;
- Combination method NN and SOM method for predict RRT at well without core data;
- Permeability determined from NN is correlated to core permeability with a good correlation coefficient of 0.6 which clearly indicates the accuracy of NN approach;
- This work proves that rock typing using FZI approach combined with NN can be very efficient in building coherent and reliable permeability being necessary for reservoir characterization;
- Validation with lithofacies and PLT for fine tuning RRT.
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