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Artificial Intelligence Technique in earth sciences for porosity prediction in shaly petroleum reservoir from geophysical well-logs data. Application to Hassi R'mel field, Algeria

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Abstract. . Machine learning techniques are becoming very popular in earth sciences, mainly in petroleum exploration and exploitation. Reservoir characterization using geophysical well-logs data analysis is commonly conducted and plays a central role in formation evaluation in petroleum domain. The most petrophysical parameters that describe the reservoir are the porosity, the permeability and the water saturation where the porosity is the main key. Using conventional methods, the estimation of the porosity is very difficult, mainly in shaly reservoirs where the presence of clay affects considerably, the porosity and the permeability. For that, we propose to accurately predict the porosity from geophysical recordings crossed the formation of wells using machine learning methods such as multi-layer neural network. The input layer are constituted by the petrophysical well-logs data and the output layer presented by one neuron corresponding to the predicted porosity. The training step of neural network machine (NNM) is processed using core data (CORPOR) by minimizing the root mean square error using Radial Basis Function algorithm (RBF). Once trained, the model is then applied to the target wells to predict porosity (PORRBF). The predicted porosity match the core values with good accuracy. This approach provides significantly a robust computation method and reduces dependency on prior domain knowledge

Keywords: Machine learning, Earth sciences, Porosity prediction, geophysical well-logs.

Introduction

In recent years, the Artificial intelligence (AI) techniques became popular methods in earth sciences and geosciences such as in seismology and earthquakes study [1], in hydrogeology [2] and in geothermal exploration [3]. In petroleum domain, many authors have applied artificial intelligence techniques [4, 5], mainly in reservoir characterization where machine learning has been used for petrophysical prediction and lithofacies classification [6, 7].

The porosity is a key parameter in formation evaluation from geophysical well-logs data and in some cases, it is very difficult to estimate it by conventional methods, mainly in shaly reservoirs where the presence of clays affects considerably the reservoir parameters such as porosity, permeability and water saturation [8]. For that, we suggest the use of machine learning neural network to predict the porosity in shaly reservoirs.

Many authors have applied different kind of artificial Intelligence to predict the porosity, Sridi and his collaborators [9], (2023) have used fuzzy logic technique to predict the porosity and the permeability in a reservoir. Aliouane et al (2018) [4], have implemented a Multilayer Perceptron neural network with back propagation and Hidden weight optimization (HWO) algorithms to predict the permeability in shaly sand where the HWO has shown the good performance. In this study, the Radial Basis Function (RBF) neural network has been suggested to estimate the porosity where RBF is a particular type of neural network that uses radial basis function as activation function. An application to Hassi R'mel field located in Algerian Sahara has been implemented where the geophysical recordings crossed shaly reservoirs of two wells have been exploited for training and generalization steps. The obtained results are presented and compared to core porosity data from laboratory measurements to show the efficiency of RBF neural network machine in reservoir characterization.

1 Geophysical well-logs data analysis

Hassi R'Mel field, which covers an area of around 3700 km², is producing condensate gas that at a rate of 235 grams per cubic meter, with the presence of a large oil ring on its eastern and southern periphery (fig. 1) . Geophysical recording crossed shaly reservoirs are exploited to predict porosity by conventional and machine learning methods. These are gamma ray (GR), Resistivity deep (LLD) and shallow (MSFL), bulk density (RHOB), neutron porosity (NPHI) and transit time of P wave (DT) (Fig. 2)

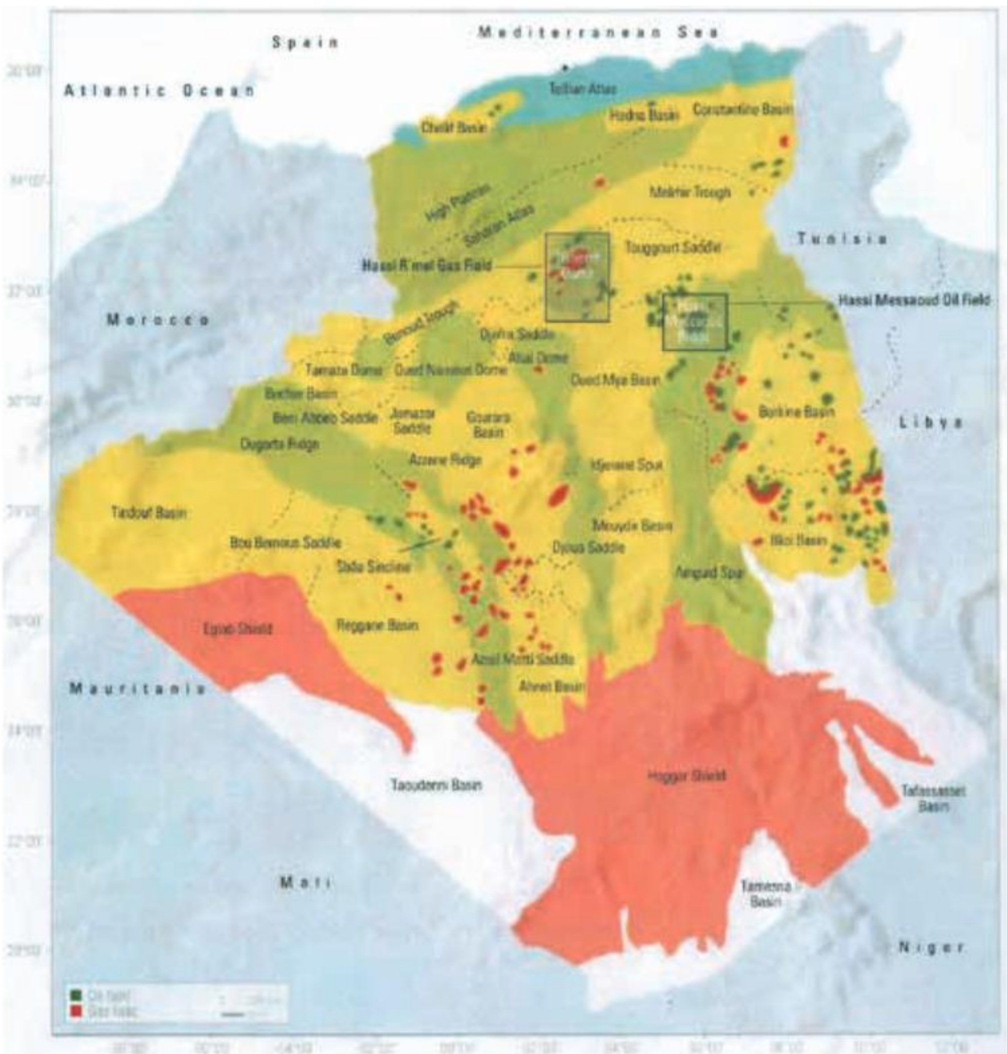

Fig.1Geogrphic location of Hassi R'Mel field [10]

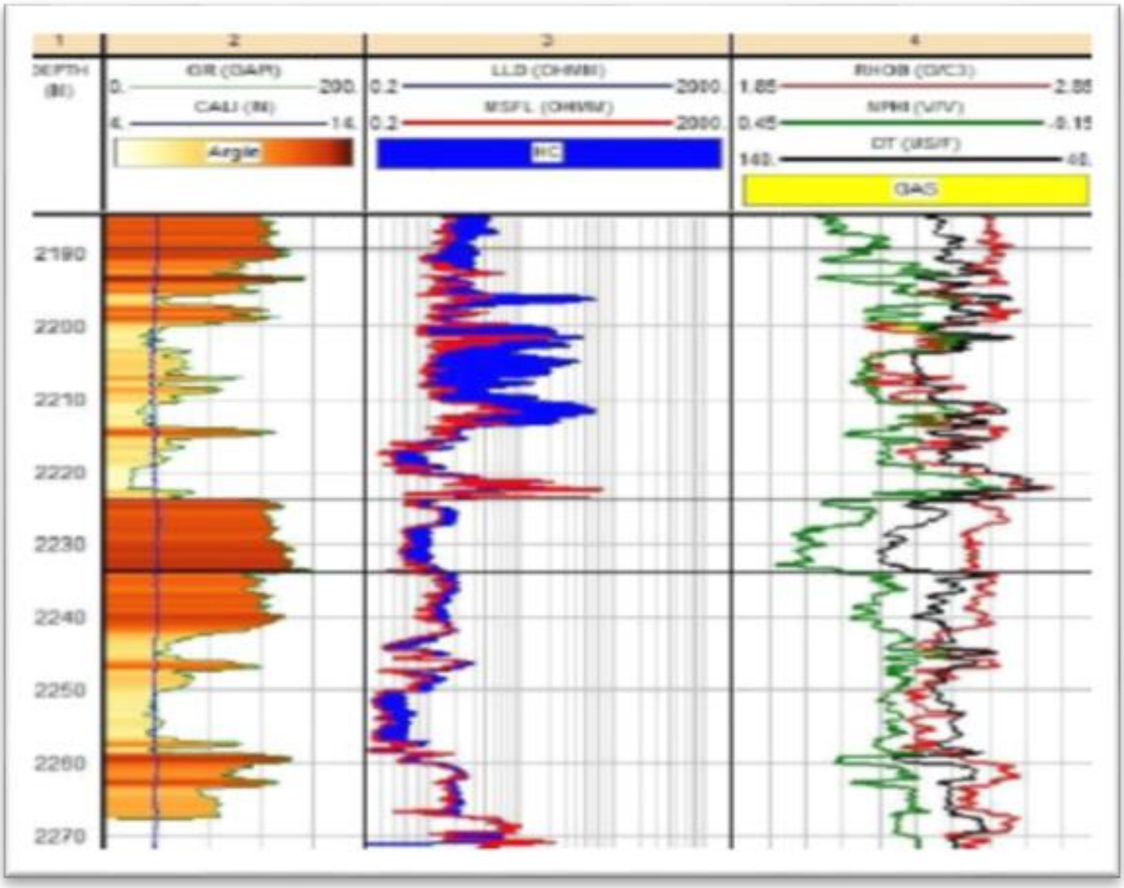

Fig.2 Well-logs data of well-1 crossed the shay sand reservoir of Hassi R'mel field where track1: Depth (m); track 2: Gamma ray; track 3: resistivity deep (LLD) and Resistivity shallow (MSFL); track 4 : Density (RHOB), Neutron porosity (NPHI) and Transit Porosity estimation by conventional methods time (DT)

2. Porosity prediction par Radial Basis Function Neural network

Radial Basis Function is one of neural network machines. Powell (1985) [11] surveyed the early work on RBF neural networks, which presently is one of the main fields of research in numerical analysis. Learning is equivalent to finding a surface in a multidimensional space that provides a best fit to the learning data. A structure of neural network has been established in order to predict the porosity presented in Fig.4 where input layer has 06 neurons corresponding to the 6 raw logs data: GR, RHOB, NPHI, DT, LLD and MSFL. The output layer presents only one neuron for CORPOR and one hidden layer. In training and generalization steps, the core data are exploited as desired output. The obtained result of the implemented neural network machine are presented in Fig. 5

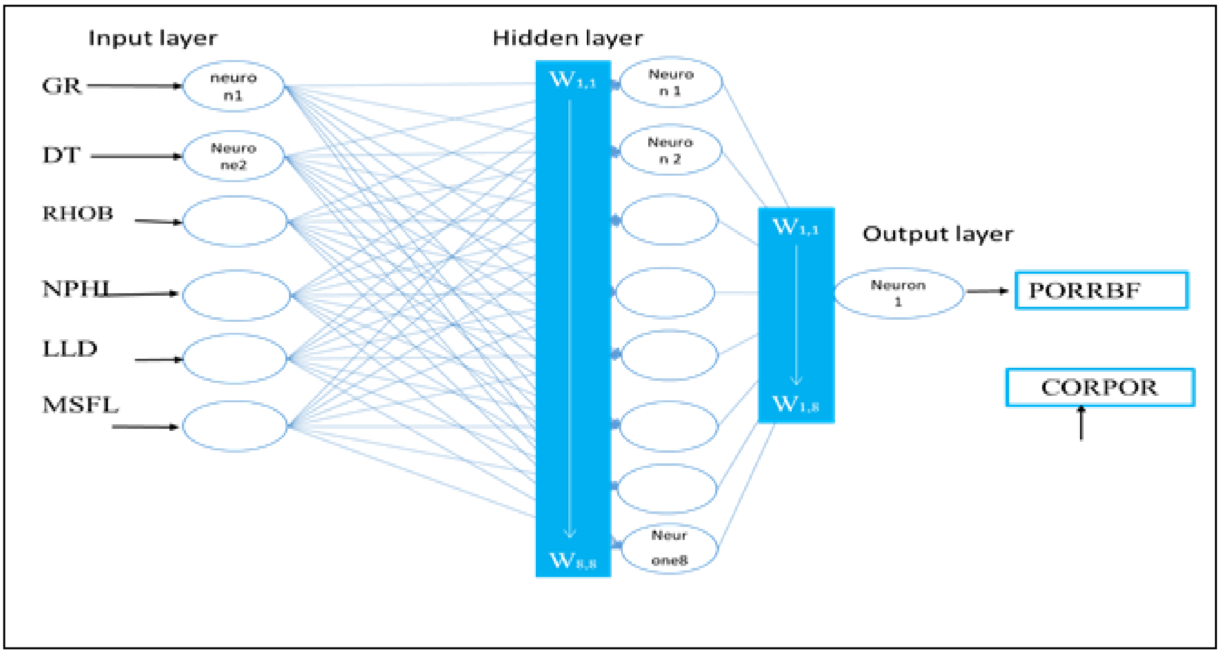

Fig.4. Neural Network machine structure for porosity prediction where in the input layer have 06 neurons corresponding to 06 physical parameters recordings and the output layer with 01 neuron for predicted porosity

3. Results analysis

The predicted porosities by the supervised neural network approach in shaly reservoirs in HassiR'Mel field are presented in Fig.5 where the Radial Basis Function neural network machine has been implemented. To evaluate the performance of the machine model, the values ofthe Root mean squared errors (RMS) have been used, and indicate the values of 6.0788 and 6.4287, respectively for training and generalization at the number of iteration equal to30. Obtained results show that the predicted porosities match the core values with good accuracy.

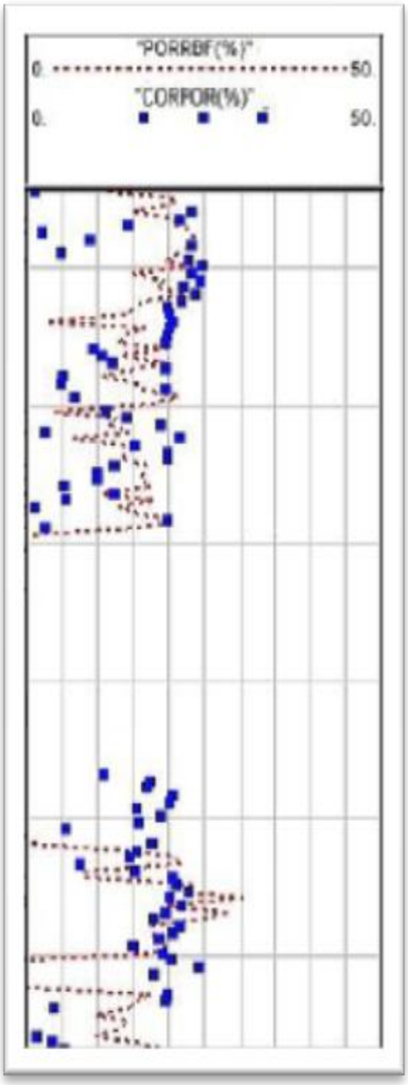

Fig.5. Predicted porosity PORRBF compared to core porosity CORPOR in shaly reservoir of well-1 of HassiR'mel field

Conclusion

In this study, we have applied neural network approach in earth sciences, mainly, in reservoir characterization to estimate the porosity in shaly reservoirs in HassiR'Mel field (Algerian Sahara). It has been shown that this kind of artificial intelligence can solve many problems in formation evaluation where the estimation of the porosity can be difficult to compute by conventional methods due to the facies change in the geological formations. Using neural network machine, we need just a kind of structure to be trained such as Radial Basis Function where the input are the recordings of the physical parameters (well-logs data) and the output are the predicted porosities compared core porosities from laboratory measurements as a desired output . Obtained results have shown that the predicted porosity match the core values with good accuracy

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