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Application of artificial intelligence to characterize naturally fractured zones in Hassi Messaoud Oil Field, Algeria ☆

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Abstract

In highly heterogeneous reservoirs classical characterization methods often fail to detect the location and orientation of the fractures. Recent applications of Artificial Intelligence to the area of reservoir characterization have made this challenge a possible practice. Such a practice consists of seeking the complex relationship between the fracture index and some geological and geomechanical drivers (facies, porosity, permeability, bed thickness, proximity to faults, slopes and curvatures of the structure) in order to obtain a fracture intensity map using Fuzzy Logic and Neural Network.

This paper shows the successful application of Artificial Intelligence tools such as Artificial Neural Network and Fuzzy Logic to characterize naturally fractured reservoirs. A 2D fracture intensity map and fracture network map in a large block of Hassi Messaoud field have been developed using Artificial Neural Network and Fuzzy Logic.

This was achieved by first building the geological model of the permeability, porosity and shale volume using stochastic conditional simulation. Then by applying some geomechanical concepts first and second structure directional derivatives, distance to the nearest fault, and bed thickness were calculated throughout the entire area of interest. Two methods were then used to select the appropriate fracture intensity index. In the first method well performance was used as a fracture index. In the second method a Fuzzy Inference System (FIS) was built. Using this FIS, static and dynamic data were coupled to reduce the uncertainty, which resulted in a more reliable Fracture Index. The different geological and geomechanical drivers were ranked with the corresponding fracture index for both methods using a Fuzzy Ranking algorithm. Only important and measurable data were selected to be mapped with the appropriate fracture index using a feed forward Back Propagation Neural Network (BPNN). The neural network was then used to obtain a fracture intensity maps throughout the entire area of interest. A mathematical model based on "the weighting method" was then applied to obtain fracture network maps, which led to a better description of the major fracture trends.

The obtained maps were compared and the results show that the proposed approach is a feasible and practical methodology to map the fracture network.

Keywords: Artificial intelligence; Reservoir characterization; Naturally fractured reservoir; Fuzzy logic; Neural networks; Hassi Messaoud

1. Introduction

Naturally fractured reservoirs represent a significant percentage of oil reservoirs throughout the world and have been given considerable attention. According to

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our current understanding, such reservoirs behave like two media of different porosity: the matrix and the fracture network. The productivity of the wells in these low permeability reservoirs is attributed to fracture network. Naturally fractured reservoirs were initially homogeneous and became fractured under certain circumstance of rock deformation and/or physical diagenesis. A thorough description of fracture connectivity, orientation and location is a key point to fractured reservoir characterization.

Researchers have attempted to model natural fractures with idealized approaches such as the sugar cube and the slab models (Eduardo et al., 2001). Classical geostatistics methods often fail to predict the distribution of the fractures. Recent trends in reservoir characterization tend to use more sophisticated tools such as artificial intelligence. A key element of using such a technique is that reservoir characterization is more complex to model with traditional methods. Artificial intelligence has the ability of combining several tools from several sources thereby, reducing the uncertainty. The most common known artificial intelligence techniques are Artificial Neural Network (ANN) and Fuzzy Logic.

Neural Networks are systems constructed to use some organizational principles resembling those of the human brain. They are composed of simple elements operating in parallel employing a set of linear and non-linear activation functions that do not require a prior selection of a mathematical model. A network can be trained to perform a particular function by adjusting the values of the connection's weights between the elements (Demuth and Beale, 2000). Usually neural networks are adjusted or trained so that a particular input leads to a specific target output.

Fuzzy logic uses the benefit of fuzzy reasoning. Under this type of reasoning, decisions are made on the basis of fuzzy linguistic variables such as low, good and high, with fuzzy set operators such as 'AND' and 'OR'. This process simulates the human expert reasoning process much more realistically than do the conventional systems (Soto et al., 2001). Fuzzy set theory is an efficient tool for modeling the kind of uncertainty associated with vagueness, imprecision and/or a lack of information regarding a particular element of the problem at the hand.

This study aims to apply the above discussed techniques to characterize naturally fractured reservoirs. Hassi Messaoud oil field (Algeria) is used as a case study.

2. Literature review

The application of Artificial Intelligence (AI) tools such as Fuzzy Logic and Neural Network is evolving as an oilfield technology. During the last few years several studies have been conducted in the field of petroleum engineering by applying artificial intelligence. The major applications are seismic data processing and interpretation, well logging, reservoir mapping and engineering.

Recent applications of artificial intelligence tend to focus on reservoir characterization. Considerable efforts have been devoted to the area of naturally fractured reservoirs. Balch et al. (1998) used the well data set consisting of traditional logs and tuned-to-core estimates of secondary porosity from FMI image to train an artificial neural system to predict the secondary porosity. Neural network has also been used to provide porosity and permeability estimates across a study area by training on seismic amplitude information. Sadiq and Nashawi (2000) presented a neural network model to predict fracture gradient pressure; the results indicated that neural network is not only feasible but yields quite accurate results.

Richardson and Weiss (1995), Ouenes et al. (1998), Ouenes (2000), Zellou et al. (1995), and Barman et al. (2000), introduced a collection of artificial Intelligence tools to model the interwell region of fractured reservoirs. Assuming that fractures can be represented by well performance at grid block scale, Ouenes et al. used AI tools to map between different geological and geomechanical drivers and the well performance. Eduardo et al. (2001) proposed a Fuzzy algorithm for fracture detection using conventional well logs and drilling information. He also suggested the use of Fuzzy Curvature Index for application to naturally fractured reservoirs.

Ouenes and Hartley (2000) presented an integrated fractured reservoir model using both discrete and continuum approach. Gauthier et al. (2000) applied successfully such Integrated Fractured Reservoir Characterization to a case study in North Africa.

3. Hassi Messaoud field description

Hassi Messaoud (HMD) field is situated in southeast Algeria and was discovered in 1956. With its reserves (OOIP) of several billion m^3 in place. The productive formation is a Cambrian sandstone, 3400 m deep with an average thickness of 300 m and three productive layers (R2, Ra, and Ri from bottom to top). HMD is mainly produced by solution gas drive.

The R2 and Ri layers are characterized by poor petrophysical properties. The important layer is Ra and is characterized as being extremely heterogeneous with an average porosity of 8% and a permeability of 5