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Application of integrated rock typing and flow units identification methods for an Iranian carbonate reservoir

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ABSTRACT

During the exploration phase of any oil and gas field, recognition of borehole type, its completion approach, and understanding of the future reservoir performance are directly interrelated to identification of the reservoir's rock types and flow units. Identifying different geological events, lithofacies characteristics, diagenetic processes, and level of heterogeneity can be the first step for knowing rock types and consequently flow units in its reservoir layers. These result in an acceptable dynamic model of a field development and relatively reliable production forecasts.

Focus of this paper is on rock typing and flow unit classification for a carbonate reservoir of a green field. Four petrophysical methods including Rock Fabric Number (RFN), Winland porosity-permeability plot (R35), Reservoir Quality Index/Flow Zone Indicator (RQI/FZI), and Bulk Volume Water (BVW) were implemented on four exploration wells. At the next step graphical tools (Stratigraphic Modified Lorenz Plot (SMLP), Modified Lorenz Plot (MLP) and Stratigraphic Flow Profile (SFP) were used to locate established flow units and rock types within the reservoir column. Lastly, variation and frequency of defined flow units have been used to achieve a satisfactory understanding of the level of heterogeneity and the possible effect on well production.

Integration of defined flow units by different methods inferred a high level of heterogeneity in the studied reservoir and the BVW was chosen as the best method of rock typing for feeding to the static model. The BVW method assists in considering main variation of reservoir properties meanwhile avoid complexity of models. During modelling, choosing an optimum number of rock types for fine-grid model with small dimensions cells (50 m*50 m*1 m) can help to separate different layers vertically without necessity of dividing them to many distinct subzones. Usually, groping numerous subzones during up scaling is confusing and complicate; likewise, in a coarse grid may omit or mix some frequency of thin seal and productive subintervals in reservoir zones. Comparing achieved flow unit classification with outcomes of production test showed in this reservoir with high level of heterogeneity an adequate type of well is vertical and highly deviated ones, moreover, dual completion can be the best type of production which separate high and low productive zones.

1. Introduction

Rock typing and flow unit identification in carbonates usually have been challenging due to the complexity of pore networks which are the results of facies changes and digenetic processes. However, these rock type classifications are inevitable for knowing reservoir and predicting its production performance against any operation. The first step for rock typing and flow unit identification is facies analysis based on core examinations and thin section studies. This study can end up to the electrofacies definition when petrophysical studies are correlated with log data. Diagenetic processes such as cementation, dissolution and compaction significantly overprint facies properties. Therefore, it was tried to apply different methods of rock typing for getting the most reliable one.

Totally, varieties of approaches are used during identification of the reservoir rock typing and flow unit. Amaefule et al. (1993) proposed RQI/FZI method for characterization of hydraulic units and the correlation between the combination of log data and FZI had been used for permeability predictions in cored and uncored intervals of wells. Kharrat et al. (2009) used RQI/FZI method for rock typing in a real case but used Artificial Neural Network (ANN) for estimating permeability via logs and FZI. Francescoin et al. (2009) have used integration of petrophysical data, porosity, permeability and Mercury Injection Capillary Pressure (MICP), with sedimentological, diagenetica and petrographical data in an

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isolated carbonate platform field. Gunter et al. (1997) introduced a graphical method for easily quantifying reservoir flow units based on the geological framework, petrophysical rock/pore types flow capacity, storage capacity and reservoir process speed. Stolz et al., 2003, compared seven methods for flow unit definition with using numerical simulation and final results showed the predicting flow performance varies depending on the flow unit method which had been used. Skalinski et al., 2006, used integrated approach by applying MICP in conjunction with depositional facies and stratigraphy. Holmes et al., 2009 applied a constant product of porosity and irreducible water saturation (SWi) as a base for categorizing rock quality un some cases and the final results illustrated higher quality rocks have a steeper slope than the lower quality rocks on the log permeability versus linear porosity plot. In this article, the RFN, RQI/FZI, Lorenz Plot and BVW were applied on core and log data of four wells. After verification of outcomes, they were considered in Stratigraphic Flow Profile and tried to correlate with flow units resulted from Lorenz Plot. Satisfactory correlation between rock types and identified flow units provided valuable hints for understanding reservoir performance and chose the most applicable method of rock typing for inserting in static and dynamic models. A summary of the workflow is illustrated in Fig. 1.

2. Background

The studied green field, which its information is confidential at this stage, with a N-S trending was discovered in 1999 by a few exploration wells in the south-west of Iran. The Sarvak, a shallow marine carbonates deposited in Cenomanian age has been confirmed as a substantial oil-bearing interval in this field. Sarvak is composed of limestone to argillaceous limestone and is known as an age-equivalent of the Mishrif and Natih formations.

In reservoir interval, the sedimentological investigation of cores unravels the dominant depositional environments containing tidal flat, platform interior, rudist mound, and open platform environment. Geologically, sea level fluctuations, diagenesis, and paleo-topography have strongly affected the vertical and lateral variation of facies of this reservoir. Moreover, some tectonic events, like Zagros Orogeny, have created micro-fractures in some directions. However, fractures are rarely obvious in the image logs but are clear in core slabs. It is presumed high deliverability of some wells (productivity index equal to 84bbl/day/psia) is because of fine connectivity between vugs that form by the micro-fractures in some part of the field. This study covers reservoir characterization of northern part of this giant culmination.

The Sarvak formation in this field is divided into 13 subzones with definite geological-reservoir characteristics which only the first eight zones represent hydrocarbon shows. The first zone is mainly composed of skeletal wackstone to packstone. Zone-2 is made from intraformational conglomerate/sub-tidal channel deposit with pervasive stylolitization and cementation. The third zone is comprised of coarse-grained echinoid-algae wackstone to packstone. Benthic Foraminifera and milliolid wackstone to packstone show most frequent facies in zone-4 to7. Coarse-grained echinoid-algae wackstone to packstone repeats in zone-8.

Zone-1 &2 have very poor reservoir quality due to muddy content and occurrence of shaly layers. Zone-3 with high porosity and medium permeability limestones has the best reservoir quality. Zone-4 represents another porous subunit in some points but it has a weaker reservoir quality in comparison with zone-3. Zone-5 is a fossiliferous limestone subunit which represents hydrocarbon show on the petrophysical evaluation logs. Zone-6 &7 are mainly composed from argillaceous sand chalky limestone. The amount of water saturation increases toward Sarvak-7 and middle of Sarvak-8. Sarvak-9 to Sarvak-12 are completely water bearing zones which are composed of white cream and light cream soft limestone. The lower most part of Sarvak is zone-13. This is massive limestone with about 230-m thickness and contains some green and dark grey shales in the upper and lower part.

3. Methodology for rock typing

According to the classical definition, rock typing is classifying reservoir rocks into distinct units. These units are deposited under similar conditions and they have experienced the similar diagenetic processes. This results in a unique porosity-permeability relationship, similar capillary pressure profile and the same water saturation for a given height above the free water level for each rock type (Archie, 1950). Different quantitative methods can be applied for describing rock-typing and their corresponding petrophysical properties. In this study based on the available data the following methods were followed:

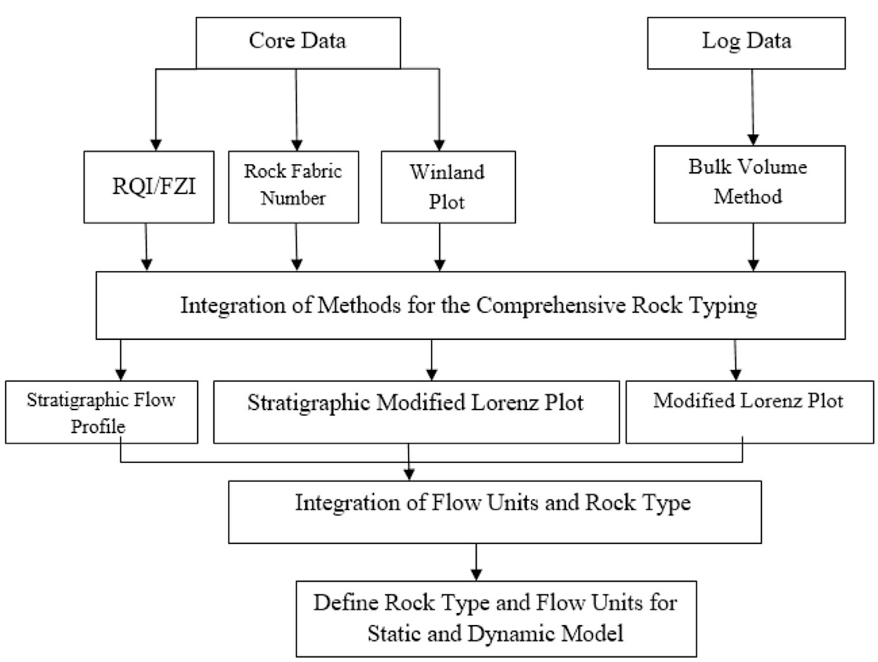

Fig. 1. Rock typing and flow units identification workflow.