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Geo-mechanical modeling and selection of suitable layer for hydraulic fracturing operation in an oil reservoir (south west of Iran)

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ABSTRACT

According to the growth of demands to oil resources, increasing the rate of oil production seems necessary. However, oil production declines with time as a result of pressure drop in reservoir as well as sealing of microscopic cracks and pores in the reservoir rock. Hydraulic fracturing is one of the common methods with high performance, which is widely applied to oil and gas reservoirs. In this study, wells in three sections of east, center, and west sides of a field are compared regarding the suitable layer for hydraulic fracturing operation. Firstly, elastic modulus were obtained in both dynamic and static conditions, then uniaxial compressive strength (UCS), type of shear and tensile failures, the most accurate model of failure in wells, safe and stable mud window, the best zone and layers, and finally reference pressures are determined as nominates for hydraulic fracturing. Types of shear failure in minimum, and maximum range of model and in tensile model were determined to be “Shear failure wide breakout (SWBO)”, “Shear narrow breakout (SNBO)”, and “Tensile vertical failure (TVER)”, respectively. The range of safe mud window (SMW) in the studied wells was almost in the same range as it was in every three spots of the field. This range was determined between 5200-8800psi and 5800-10100psi for Ilam and Sarvak zones, respectively. Initial fracture pressure ranges for selected layers were determined 11,759–14,722, 11,910–14,164, and 11,848–14,953psi for the eastern, central, and western wells. Thus, western wells have the best situation for Hydraulic fracturing operation. Finally, it was concluded that the operation is more economic in Sarvak zone and western wells.

1. Introduction

Hydraulic Fracturing is a well stimulation treatment and technical operation used to enhance production from oil and gas wells. This process involves the injection of various fluids into the formation at a pressure high enough to cause a tensile failure of the rock and propagate the fracture. Oil and gas reservoirs with a low capacity for the flow of fluids usually require hydraulic fracturing to make them commercially viable (Economides and Nolte, 2002; Hibbeler and Rac, 2005; Legarth et al., 2005; Pak and Chan, 2008; Queipo et al., 2002).

Bangestan reservoir in the Ahwaz oil field is a good candidate for a hydraulic fracturing operation Because of a sufficient amount of oil in place and the good quality of porosity with low permeability and flowing capacity in some of the production layers. For the mentioned reasons, at the beginning of a fracture reservoir study, it is necessary to conduct some important rock mechanics tests on different reservoir rock samples for obtaining more information on the physical and mechanical properties of the reservoir rock. Knowledge of the vertical profile of the minimum horizontal stress is one of the most important parameters in a hydraulic fracturing operation (Willis et al., 2005).

The uncertainty associates with the results of hydraulic fracturing conducted in different fields is due to the lack of accurate data to estimate a valid stress profile, which is one of the key problems in fracture treatment design.

The main goal of this work is to select the suitable layer for hydraulic fracturing operation in an oil reservoir as well as identifying the reference pressures, using geomehanical study. In this paper, elastic modulus are obtained in dynamic and static conditions, then the uniaxial compressive strength, type of the shear and tensile failure, the most accurate model of failure in wells, safe

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and stable mud window, the best zone and layers, and finally the reference pressures are determined as choices for hydraulic fracturing. For these purposes, six wells are selected randomly, from East (A1, A2), Center (B1, B2), and West (C1, C2) of the Bangestan reservoir layer.

1.1. Geological setting

Ahwaz oil field located in Khuzestan in southwest of Iran is one of the largest oil fields in Middle-East (Yeganeh et al., 2012). Bangestan is a carbonate reservoir in Iran and yields almost 5% of total produced oil in south of Iran (Figures 1 and 2) (Shadizadeh et al., 2009).

1.2. Prediction of geomechanical and mathematical earth modeling

To achieve our objectives, we constructed a 1D mechanical earth model, which includes the continuous logs of the formation's elastic properties and strength as well as induced stress and pore pressure (Chardac et al., 2005).

1.2.1. Determination of lithology and elastic modulus of reservoir rocks

Studied area is composed of a combination of limestone, sandstone, and less by dolomite. However, sandstone is mainly detected in this area. Average porosity and water saturation values of the wells are listed in Table 1.

The dynamic and static elastic modulus are shown in Table 2. According to the equations of Table 2, the average values of Young's modulus (E) in dynamic condition for studied wells, are 53.2, 51.9, and 50.6 MPa for the east, central, and west side wells, respectively. The average value of Poisson's ratios for all the wells is 0.3 MPa. All of the mentioned parameters are measured in dynamic condition. Due to the fact that these parameters should be used in a static condition, empirical correlations are introduced to convert them into desired static model (Gaeger and Cook, 1969.). It should be mentioned that $v_{Dynamic} = v_{Static}$. Therefore, the average value of static modulus, as an instance, in Young's modulus is 20.99, 20.44, and 19.92 MPa for the east, central, and west side wells, respectively. Figure 3 shows an example of the difference between static and dynamic Young's modulus in one of the studied wells which is:

$$10 < E_{Static} < 30, \quad 35 < E_{Dynamic} < 70$$

1.2.2. Determination of in-situ stresses, induced stresses and safe and stable mud window design

Generally, stresses are divided into two groups: (1) in-situ stresses and (2) induced stresses (stresses resulted after drilling operation). Stresses are just three types of in-situ stresses in deep beds, including vertical stress (σ_v), main maximum horizontal stress ($\sigma_{H\,max}$), and minimum horizontal stresses ($\sigma_{h\min}$). This assumption has negligible effects on the final results as it is proved by several authors (Brady, 1995; Lund and Zoback, 1999; Zoback, 1992; Zoback and Zoback, 1991; Zoback and Zoback, 1980). In addition, induced stresses that are developed after drilling

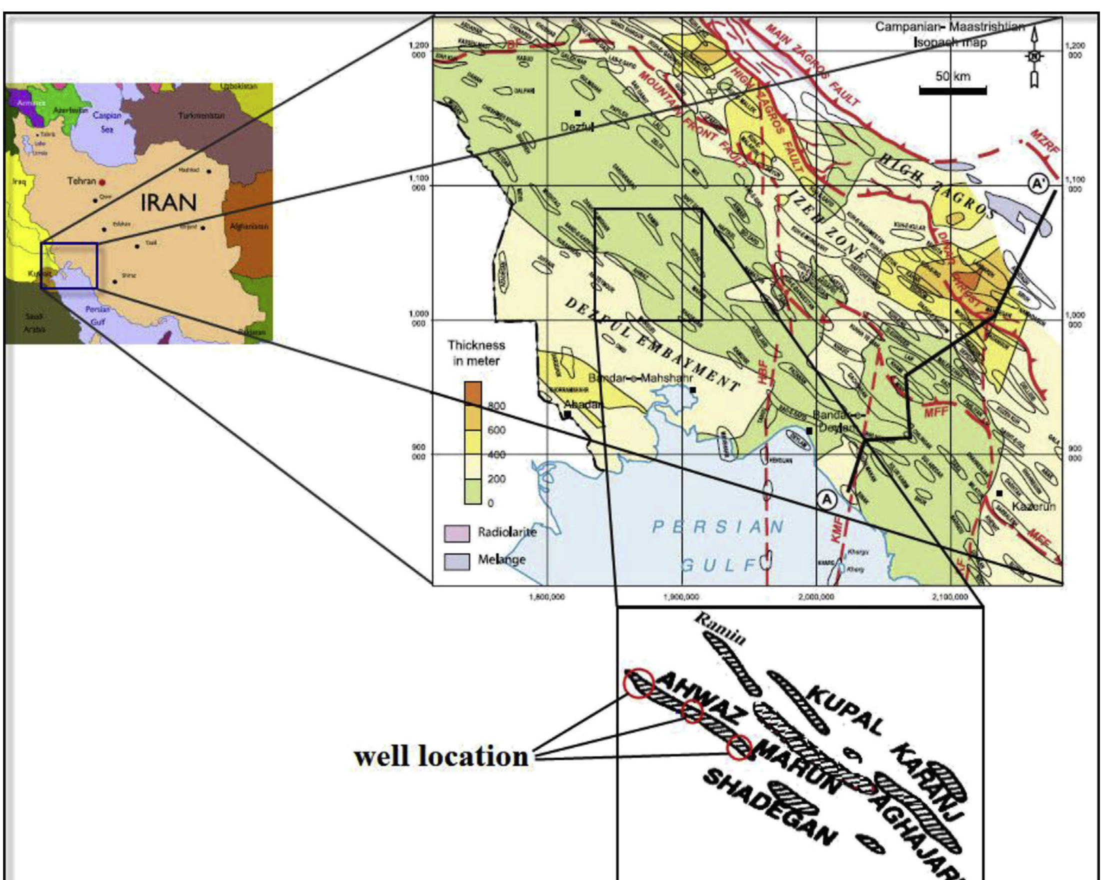

Fig. 1. Location of Ahwaz oil field in southwest of Iran.