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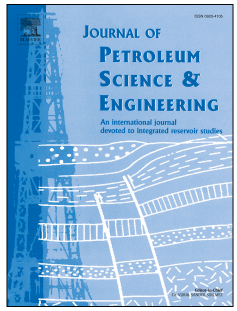

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Quantitative prediction of sub-seismic faults and their impact on waterflood performance: Bozhong 34 oilfield case study

Lei Gong[a], Bo Liu[b, *], Xiaofei Fu[a, b, *], Hadi Jabbari[c], Shuai Gao[a, *], Wenting Yue[c, d], Hongqi Yuan[a], Rongzhi Fu[a], Zijie Wang[c, e]
[a] College of Geosciences, Northeast Petroleum University, Daqing 163318, Heilongjiang, China
[b] Institute of Unconventional Oil & Gas, Northeast Petroleum University, Daqing 163318, Heilongjiang, China
[c] Petroleum Engineering Department, University of North Dakota, Grand Forks 58202, North Dakota, USA
[d] Research Institute of Petroleum Exploration & Development, PetroChina, Beijing 100083, China
[e] College of Petroleum Engineering, China University of Petroleum (East China), Qingdao 266580, Shandong, China

ABSTRACT

Sub-seismic faults are the key factors that control the reservoir quality, hydrocarbon accumulation, and water injection development. In this paper, we developed a method to predict the number, size, orientation and location of sub-seismic faults based on the analysis of fault fractal growth patterns and three-dimensional (3-D) geo-mechanical simulation. This work also discussed the influence of sub-seismic faults on water injection development and remaining oil distribution from analyzing the dynamic oilfield development data. In the methodology developed in this study, the geometrical features of large-scale seismic faults were thoroughly explained based on 3-D seismic data. Based on fractal geometry theory, the number, length and throw of the sub-seismic faults were predicted by extrapolating the power law distribution of seismic fault parameters. According to the distribution of seismic faults, we established the 3-D geo-mechanical model and simulated the disturbed stress field near the seismic fault zone during faulting. By combining the simulation results with the failure criterion, the preferred failure orientation grids and maximum Coulomb shear stress grids were then established. Using these two grids and the parameters of sub-seismic faults constrained by the power-law distribution, we determined the stochastic model to predict the distribution of sub-seismic faults. This work shows that the distribution of sub-seismic faults can be effectively predicted by the combination of fractal theory and 3-D geo-mechanical simulation. Both key parameters in a typical waterflood process, namely the residual oil saturation and the performance of water injection, can be impacted by the size (throw) and the orientation of sub-seismic faults.

Keywords: Sub-seismic faults; Fractal geometry theory; 3-D geo-mechanical simulation; Quantitative prediction; Remaining oil

1. Introduction

Faults are one of the significant characteristics of a sedimentary basin which usually control the formation and evolution of the basin, the migration and accumulation of hydrocarbons as well as the quality of the reservoirs (Kim et al., 2004; Gudmundsson et al., 2010; Zeng and Liu, 2010; Ferrill et al., 2014; Peacock et al., 2017). Faults can be categorized based on their size and the identification methods into large-scale, medium-scale, and small-scale faults (Fig. 1) (Gauthier and Lake, 1993; Casini et al., 2011; Rotevatn and Fossen, 2011; Laubach et al., 2014). Large-scale faults can be identified by two- or three-dimensional seismic data, i.e. seismic faults (Maerten et al., 2006; Lohr et al., 2008; Rotevatn and Fossen, 2011). Small-scale faults usually refer to shear fractures that can be identified through cores or imaging logs (Zeng et al., 2013; Sanderson and Nixon 2015). On the other hand, medium-scale faults may not be identified from seismic or logging data, and they are often referred to as sub-seismic faults (Gauthier and Lake, 1993; Damsleth et al., 1998; Casini et al., 2011; Rotevatn and Fossen, 2011). The boundary between seismic faults and sub-seismic faults is difficult to identify because the depth and lithology may affect the resolution of seismic and logging data (Gauthier and Lake, 1993; Ackermann and Schlische, 1997; Walsh et al., 1998; Steen and Arild, 1999; Fossen and Jonny, 2000; Maerten et al., 2006; Lohr et al., 2008).