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Fractured reservoir modeling: From well data to dynamic flow. Methodology and application to a real case study in Illizi Basin (Algeria)

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ABSTRACT

Fault arrays and natural fractures distribution strongly influence subsurface fluids migration, trapping and production. It is critical to develop methodologies that can be used to accurately characterize reservoir volumes as present-day exploration and appraisal campaigns become increasingly focused on tight or low porosity reservoirs.
A common method used to model the distribution and intensity of subsurface fracture sets is the Discrete Fracture Network (DFN) technique. Shortcomings of the DFN technique include the evaluation of fracture attributes, computational aspects in the case of large fields, and most importantly issues related to upscaling.
Thus, the aim of this work is to present a simplified methodology for fractured reservoir characterization based on the distribution of fracture intensity as a continuous property. Fracture intensity was calculated from image well-logs data and then distributed in the reservoir according to specific fracture drivers.
The case study is related to a large appraisal gas field located in the Illizi Basin, Southern Algeria, where Late Ordovician glacial deposits are the primary reservoir levels, in which the presence of faults and fractures strongly enhance well performances.
The final fracture intensity model was obtained by implementing a workflow in a commonly used commercial geomodeling software and calibrated by means of well test data analysis.
The implemented methodology is a useful tool for large fractured reservoir characterization when DFN technique is hardly applicable for computational reasons or the level of uncertainty does not support a performing discrete analysis.

1. Introduction

Fault arrays and natural fractures distribution exert an important influence on subsurface fluids migration, trapping and production mechanism since they may play a key role in changing the original petrophysical properties -such as porosity and permeability- of reservoir rocks (Caine et al., 1996; Aydin, 2000; Agosta et al., 2007). This becomes even more critical in present-day exploration and appraisal campaigns that are increasingly focused on tight or low (primary) porosity reservoirs and for which the knowledge of the fracture distribution represents a major step in the production forecast.

The characteristics of natural fractures sets are related to tectonic events (Abul Khair et al., 2015; Madritsch, 2015; Zazoun, 2008), diagenesis processes (Laubach et al., 2010) and lithologic variations (Rustichelli et al., 2013). All of these factors control intensity, orientation, spatial distribution, spacing, length, abutting relations, connectivity, and aperture of different fracture sets.

The most common method to model subsurface fractures is the Discrete Fracture Network (DFN) that represents fractures as planar features with specific geometrical and spatial properties. The DFN is based on the creation of a robust conceptual model by integrating well data (wireline logs, image logs, core data), inter-well data (geo-mechanical analysis, seismic attribute analysis, outcrops analogues), and dynamic analyses. The DFN is then used in the models by upscaling fracture properties to reservoir static model cells together with dynamic calibration. However, some difficulties in implementing DFN need to be considered, such as the evaluation of the fractures characteristics themselves (mainly length and aperture), upscaling related issues (Ahmed Elfeel and Geiger, 2012; Ahmed Elfeel et al., 2013) and computational aspects in case of large fields.

The aim of the study is to present an alternative and simplified methodology based on the distribution of fracture intensity as a continuous instead of a discrete property. It has to be noted that some previous

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works had already focused on the characterization of fractured reservoir by using a continuous property distribution known as continuous fracture modeling technique (CFM; Jenkins et al., 2009). CFM uses a neural network approach to integrate all the available static and dynamic field data (Ouenes et al., 1998; Ouenes, 2000).

In this paper a different workflow is proposed: fracture intensity has been calculated from wells image logs and then distributed in the static model considering (1) fault zones width, (2) fracture intensity decay from fault zones to the host rock, and (3) facies distribution as main fracture drivers. The proposed methodology is a useful tool for subsurface fracture characterization of large reservoirs and it is easily implementable when a 3D static model of the field is available. Moreover the final fracture model integrates important information coming from outcropping fractured reservoir analogues (fault damage zones width and fracture intensity decay) and subsurface data (seismic faults, facies distribution and fracture intensity from wells).

The workflow is applied to an appraisal field located in Illizi Basin, Southern Algeria, where nine wells have been recently drilled. The reservoir is characterized by Late Ordovician glacial deposits that show strong vertical and lateral heterogeneities in terms of facies distribution and related mechanical properties.

Several studies have focused on surface and subsurface fractures characterization in Algeria encompassing different methodologies and approaches (Gauthier et al., 2002; Guehria et al., 2005; Zazoun, 2008; Panien et al., 2010). The increasing interest in fractured reservoir modeling in Algeria is mainly due to the observations that well performances are strongly influenced by the presence of faults and fractures in the subsurface.

2. Geological setting and tectonic evolution

The study area is located in the Saharan platform (Central-Eastern Algeria), close to the Libyan border (Fig. 1). The appraised gas accumulation was discovered in the well-known hydrocarbon Province of Illizi, which has been one of the most prolific sites for hydrocarbon exploitation since the 1950s with continuous exploration and development efforts until today.

The Illizi basin is a deep intracratonic depression filled by a thick succession of Paleozoic and Mesozoic sediments deposited over a high-grade metamorphic and igneous pre-Cambrian basement. Furthermore, it is bounded by the Amguid and Tihemboka basement highs to the West and East respectively (Fig. 1), while the northern boundary is defined by the Ahara high, marking the transition to the northernmost Ghadames basin. The southern rim corresponds to the outcrops of the Palaeozoic successions (Hoggar Massif) that onlap above the pre-Cambrian basement (Fig. 1).

The stratigraphic column (Fig. 1) shows the following succession (internal reports and Craig et al., 2008):

- Cambrian to middle Ordovician sandstones and shales deposited in a continental to shallow marine environment.
- Upper Ordovician glacial deposits related to the Ashgillian glacial phase (Hirst et al., 2002; Deschamps et al., 2013) that show a strong vertical and lateral heterogeneity due to a complex depositional environment from transitional marine to glacial. Thick packages of sandstones have been preserved with poor to medium reservoir properties (porosity and/or permeability) that are usually enhanced by the presence of fractures. These glacial-related deposits are the object of the present study.

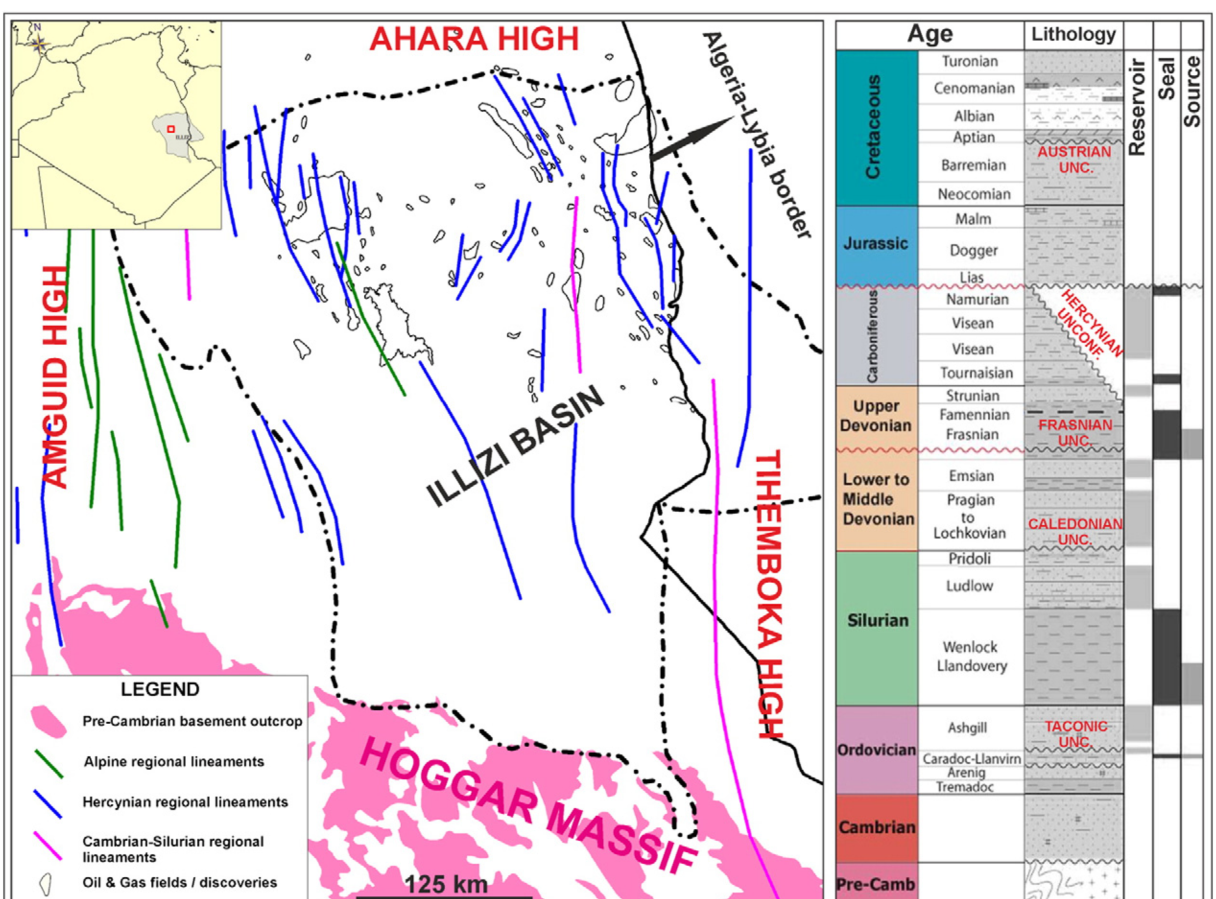

Fig. 1. Location map of the area, Illizi basin regional lineaments, basin stratigraphy and petroleum system elements. Regional lineaments from Craig et al. (2008)