

Conceptual Fracture Modelling For Carbonate Reservoir in Bai Hassan Oil Field Northern Iraq

Qays Mohammed Sadeq*, Swapan Kumar Bhattacharya and Wan Ismail

Department of Petroleum Geoscience, Universiti Teknologi Petronas, Malaysia

Abstract

The Bai Hassan field is fold structure in the foreland area of the Zagros Mountains of north-eastern Iraq. The structure have hydrocarbon accumulations in Tertiary and cretaceous reservoir strata. Fractures are thought to provide the most important permeability in the field, and the lack of oriented fracture data hampers the ability to model fracture permeability within the reservoirs. To west of Bai Hassan is the Qara Chauq structure. There are strong similarities between Qara Chauq and Bai Hassan, including

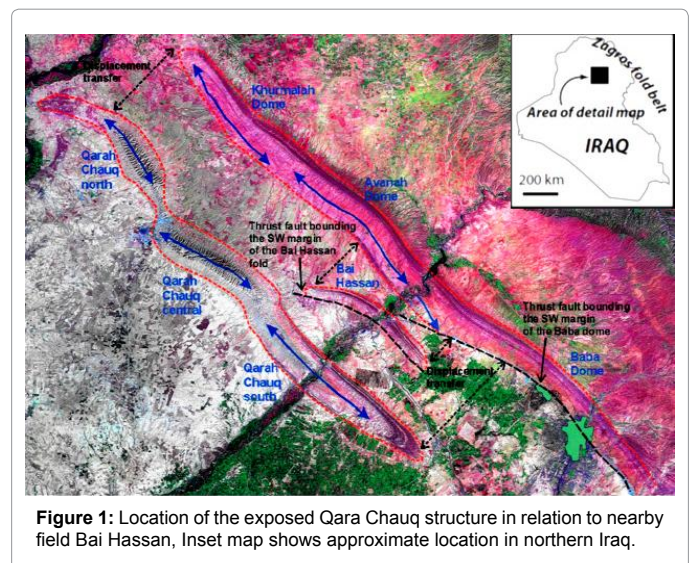
- (i) The exposed strata at Qara Chauq are thought to be the same as the reservoir units at Bai Hassan, and
- (ii) Both are elongate sigmoidal anticlines.

The lack of available subsurface data to constrain the fracture patterns at Bai Hassan led to the idea that analysis of the surface exposure of reservoir analog strata at Qara Chauq might provide insight into the fractures present at reservoir depths in Bai Hassan field. The purpose of the project described here is to generate a conceptual fracture model applicable to the Bai Hassan field using the most appropriate available data. Having generated this model, the goal is to provide a protocol for applying numerical results from the analysis to reservoir simulations of Bai Hassan field. Fieldwork and aerial photo data sets that been used as an interpretation base for fractures exposed around Qara Chauq. Although time constraints precluded mapping the entire visible fracture population, representative structural positions were targeted to produce an interpretable data set in a timely fashion.

Keywords: Bai Hassan; Qara Chauq; Foreland; Zagros; Sigmoidal anticlines; Fractures; Fracture permeability; Elongate

Introduction

Historically productive oil fields in the Zagros Mountains frontal zone, specifically Bai Hassan field (Figure 1), have been exploited by production from wells drilled at or near the oil/water contact. Detailed simulation and planning of future production is dependent upon reliable permeability models of the reservoir so that hydrocarbons can be efficiently swept. Bai Hassan field is fold structure with hydrocarbon accumulations in Tertiary and Cretaceous reservoir strata [1,2]. Both reservoirs are suspected to be fractured and fractures are thought to provide the most important permeability in the fields [1]. The lack of long-term, high-quality production data and oriented fracture data hampers the ability to model fracture permeability within the reservoirs. Fortunately, Qara Chauq is a structural and stratigraphic analog exposed west of Bai Hassan [1]. Qara Chauq consists of Tertiary strata thought to be correlative with the reservoir interval at Bai Hassan in a 16-18 km long sigmoidal fold. Remote sensing data from Qara Chauq provides a wealth of fracture data from suspected carbonate lithologies that may be directly analogous to reservoir rocks at Bai Hassan. The lack of available subsurface data to constrain the fracture patterns led to the idea that analysis of the surface exposure of reservoir analogy strata at Qara Chauq might provide insight into the fractures present at reservoir depths in Bai Hassan field. In this project, field work and aerial photo data from Qara Chauq are analysed in detail as the basis for determining fracture sets and deriving usable relationships between fracture intensity and structural position that can be applied to subsurface hydrocarbon fields. The purpose of this study is to improve the general understanding of fracture permeability in hydrocarbon fields of the frontal Zagros zone by generating conceptual fracture models for Bai Hassan field. Once formulated, these fracture models provide quantitative or semi-quantitative guidelines for incorporating fracture data into reservoir models of existing field with the goal of improving the predictive quality of this mode [3-9].



*Corresponding author: Qays Mohammed Sadeq, Department of Petroleum Geoscience, Universiti Teknologi PETRONAS, Malaysia, Tel: 9647701244627; E-mail: qase1967@yahoo.com

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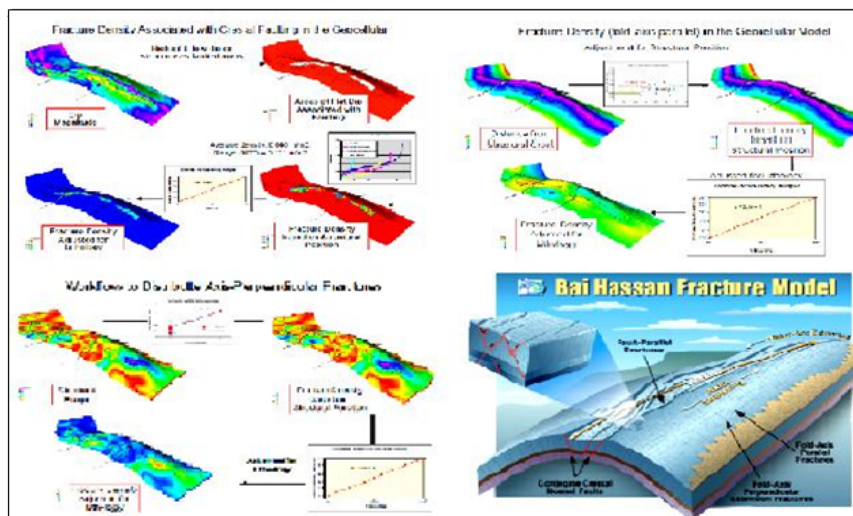


Figure 2: Conceptual fracture model developed for Bai Hassan.

Methodology

Prior to the commencement of this study, it was not clear which datasets would provide the most useful information to achieve the study's goal. Various data analysed to determine the best approach, including Field survey, Geologic map of Qara Chauq anticline. Aerial photo were determined to be the most useful about characterizing the fracture populations of structures analogous to Bai Hassan because they provide fracture data within the context of both structural geometry and stratigraphic position. The data quality permits detailed fracture mapping, cross-section construction, and development of three-dimensional models of deformed stratigraphic horizons. These results are essential ingredients in the development of a Qara Chauq fracture model that can then be applied by direct analogy to Bai Hassan. Bedding planes, faults, and fractures were mapped. Bedding planes appear as either exposed edges of pavements or as contacts between Lithologic layers observed on the ground surface. No direct Lithologic information was available for the exposed beds; however, published geologic mapping inferred fracture-bearing limestones that are essentially time equivalent to the Bajawan and Baba formations at Bai Hassan. Faults picked where the beds appeared discontinuous. Fault-line scarps noted on the crest of Qara Chauq, also lead to the interpretation of normal displacement faults sub-parallel to the fold-axis. These faults are mainly limited to the axial region, but a few of them move down the limb. None of the faults extends beyond the edges of the structure indicating that (1) they are not regional faults, and (2) they formed in response to folding. The effect of the axial normal faults if present at Bai Hassan is to create an effective vertical and lateral fracture network, which may be representative of the significant drilling losses experienced by these crestal wells. Fractures are evident where large bedding pavements have been disclosed during erosion. They show up due to the contrast between the lighter colored limestone host rock and darker lineaments believed to be sediment or vegetation growing in the fractures. Fracture interpreted at several locations (pavements) across the structure including the limb, the crest and the structural nose.

This done to capture any variability in fracture development related to structural position. Each fracture digitized as a series of nodes to enable the determination of fracture orientation and fracture length. Three different, independent fracture sets recognized based on their

orientation namely, fold axis-parallel fractures, fold axis-perpendicular fractures, and crestal fractures associated with the crestal graben faults. The quantification of fractures (fracture density) calculated as the total length of fractures for a given orientation (in meters) per unit area of pavement (in square meters). Aerial photo were determined to be the most useful about characterizing the fracture populations of structures analogous to Bai Hassan because they provide fracture data within the context of both structural geometry and stratigraphic position. The data quality permits detailed fracture mapping, cross-section construction, and development of three-dimensional models of deformed stratigraphic horizons. These results are essential ingredients in the development of a Qara Chauq fracture model that can then be applied by direct analogy to Bai Hassan.

Results

In this paper, we present a conceptual model for fracture development in carbonate strata in Zagros folds of northeastern Iraq. Based on detailed mapping from remotely sensed data (aerial photos) and fieldwork for fracture modelling from the Qara Chauq anticline, three dominant fracture sets are identified:

- (1) Set 1, fold-axis-parallel fractures;
- (2) Set 2, fold-axis-perpendicular fractures; and
- (3) Set 3, normal-fault-parallel fractures.

Fracture sets 1 and 2 are dominantly strata-bound extension fractures, and therefore influence transmissivity and lateral anisotropy within reservoir layers. In contrast, Set 3 may include small-scale normal faults that cut multiple layers and systems of related smaller faults and extension fractures that form an interconnected fracture network that can provide reservoir communication vertically between layers. Because of this vertical reservoir connectivity, reservoir simulations for Bai Hassan should include Set 3 fractures in addition to sets 1 and 2 even in areas where Set 3 fracture traces are likely to parallel Set 1 fracture traces.

The conceptual fracture model (Figure 2) relates the presence and densities of fractures in these sets to structural position throughout an anticlinal structure. Structural position information and stratigraphic parameters (lithology and bed thickness) can then be used with a set

of quantitative predictors and modifiers presented in this paper to populate reservoir models with fracture sets and densities on a cell-by-cell basis. The approach is laid out in a workflow that is flexible and easily refined as new and improved structural, lithologic, and bed thickness constraints on fracture sets and densities become available.

Conclusion

Conceptualization of fracture formation based on the Qara Chauq analysis used to develop a systematic approach to populating reservoir models of Bai Hassan field. A set of baseline fracture information in terms of fracture orientations and areal fracture densities (length per unit pavement area) developed based on the analysis of Qara Chauq and the three fracture sets defined. These data provide the basis for populating fracture sets (orientations and densities) according to structural position in the Bai Hassan field for a stratigraphic unit that is lithologically similar to our assessment of the lithology (limestone) of the key bed at Qara Chauq from which most data were derived. Relating fracture sets to their structural origin enables them to be placed in geologically reasonable structural locations – each cell in the reservoir model can be characterized according to structural position and then populated with fractures according to the relationships derived in the structural analysis. Using this approach, reservoir models of Bai Hassan can be populated with orientations and densities for the three fracture sets based on the structural position and lithology of the cell throughout the model in three dimensions. Further refinement of the

fracture model is possible using lithological data, of which known to influence fracture intensity.

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