Fracture Patterns and Petrophysical Properties in the Kuqa Depression, Tarim Basin, and Their Relationship with Regional Folding

Zhao Wang¹ and Xiuxiang Lv¹

Search and Discovery Article #11259 (2019)**

Posted September 23, 2019

*Adapted from poster presentation given at AAPG 2019 Annual Convention & Exhibition, San Antonio, Texas, May 19-22, 2019

**Datapages © 2019. Serial rights given by author. For all other rights contact author directly. DOI:10.1306/11259Wang2019

¹State Key Laboratory of Petroleum Resources and Prospecting, China University of Petroleum (Beijing), Beijing 102249, China (Wz0531024@163.com)

Abstract

The Kuqa Depression of the Tarim Basin hosts a prolific hydrocarbon system. The main reservoirs are characterized by tight sandstone with low-porosity and low-permeability, buried at more than 5000 m depth. In the Bashijiqike Formation, hydrocarbon production mainly comes from secondary porosity created by dissolution and fracturing. The Bashijiqike formation have undergone multiple phases of deformation associated with burial, uplift, folding, thrusting and rapid subsidence. With the aim of evaluating the reservoir quality, we studied fracture patterns and petrophysical properties of the Bashijiqike formation with data collected from Dabei and Kelasu anticlines. We document four fracture systems whose distribution is related to regional stress field, thrusting and local folding. In the Kelasu Anticline, the North-South system is parallel to the maximum horizontal principle stress, showing higher intensity closed to the ridge. Calcite veins filled in the fractures show a characteristic of bending, indicating they form earlier than folding or during folding. The East-West system is parallel to the fold axis, showing a trend of decreasing fracture intensity from limbs to hinge end to crest. Fractures observed on the cores show existence of E-W shearing. Crosscutting relationships suggest that the shearing fractures formed earlier than the tension fractures that due to the local outer arc extension. The Northeast-Southwest and Northwest-Southeast systems are symmetrical with respect to the fold. In the Dabei Anticline, the Northwest-Southeast system parallels to the maximum horizontal principle stress, showing higher fracture intensity than other systems. The Northeast-Southwest system parallels to the fold axis, showing lower fracture intensity at crest with local increments at the limbs. In addition, we analyzed petrophysical properties include porosity and permeability of the Bashijiqike formation in relation to their structural position within folds. The higher porosity and permeability are recorded in the hinges and forelimbs of the both anticlines. It is indicated the best reservoir quality is associated with dissolution and fracturing. The results show how fracture distribution and petrophysical properties depends on structural position and fold evolution. Our work illustrates the folding serve as controls on the fracture patterns and petrophysical properties, providing favorable reservoir targets for prospecting in the compressional basin.
Fracture Patterns and Petrophysical Properties in the Kuqa Depression, Tarim Basin and their Relationship with Regional Folding

Zhao Wang, Xinjiang Lu
State Key Laboratory of Petroleum Resources and Prospecting, China University of Petroleum (Beijing), Beijing 102249, China

Abstract

The Kuqa Depression of the Tarim Basin hosts a prolific hydrocarbon system. The main reservoirs are characterized by high porosity with low permeability, typically in the range of 10-20%. In the Baohushan Formation, hydrocarbon production results mainly from secondary porosity caused by dissolution and fracturing. The Baohushan Formation has undergone multiple phases of deformation associated with挤压, strike-slip, folding, and rapid subsidence. With the aim of evaluating the reservoir quality, we studied fracture patterns and petrophysical properties of the Baohushan Formation with data retrieved from Dabei and Keshen wells. We document four fracture systems whose distribution is related to regional stress fields, thrusting and folding and locally left-lateral strike-slip. In the Keshen structure, the northeast-southwest fracture system is parallel to the maximum horizontal principal stress, showing higher intensity closed to the ridge. The west-east fracture systems are parallel to the fold, showing a trend of decreasing fracture intensity from limbs to hinge. In the Keshen well, the moderate-dipping fractures along with the vertical fracture have an impact on the distribution of primary porosity and permeability of the Baohushan Formation. In the Keshen structure, the main axis and conjugate faults have higher permeability for a given porosity (4-5) than Baohushan and wellbore. In the Dabei structure, fold lag generally has higher permeability, followed by backbone.

Conclusions

We have characterized the fracture systems at Dabei and Keshen structures within the central Kuqa Depression of Tarim Basin.

(1) Regional stress field, thrusting, folding and locally strike-slip play an important role in fracture development.

(2) The moderate-dipping set of Strike-parallel fractures is possibly forced due to thrusting. However, the vertical set may have been formed due to other stresses in the folds.

(3) A comparison between the Dabei and Keshen fracture systems shows that the distribution of fracture systems are scale-variable.

(4) Fractures intensity may be controlled by regional stress field, strain, and folding. The presence of Strike can make local inversion of fracture intensities in the general trend. Field evaluation may have an impact on the north-southwest fracture system in the Dabei structure, because for the fracture intensity of this system increases from limbs to fold hinge.

(5) The structural positions have a potential impact on the petrophysical distribution.

Petrophysical Properties and Petrologic Analyses

There are evidences of the pore-eyes also both in the Keshen and the Dabei structure. The permeability values range over five orders of magnitude due to the innate fractures. Even though the Baohushan Formation has low porosity with low permeability, it provides the essential reservoir permeability and some permeability. Besides, our results suggest the structural position on regional fold may control the distribution of primary and permeability of the Baohushan Formation. In the Keshen structure, the main axis and conjugate faults have higher permeability for a given porosity (4-5) than Baohushan and wellbore. In the Dabei structure, fold lag generally has higher permeability, followed by backbone. InThe northeast-southwest and stress. Overall, this study has contributed to the maximim horizontal stress. Fracture intensities shows good correlation with the maximum horizontal stress. Fracture intensities is also sensitive to the hinge zone. In the hinge region, the fracture intensities are high. This is probably related to the folding mechanisms. Crosscutting relationships suggest a first event developed the hinge-perpendicular fracture sets, followed by a second event developed the moderate-dipping set of the strike-parallel fractures. The early set of fractures were formed due to the emplacement of the Indian plate, whereas, the later set of fractures have possibly an impact on the distribution of the primary porosity. The fracture systems are proposed to be related to the stress inversion during each stage.

Fracture System

Dabei structure: The northeast-southwest fractures propped in the main area of the horizontal principal stress. Overall, this system presents very high fracture intensities, with a decreasing trend from limbs (0.05-0.1) to the fold (0.02-0.03). The northeast-southwest fractures probably to the fold. Fracture intensities of the northeast-southwest fracture systems increase from hinge (0.05-0.1) to the fold (0.02-0.03). It consists of the moderate-dipping fracture set and the vertical fracture set. The northeast-southwest fractures is parallel to the maximum horizontal principal stress. The west-east fracture systems is parallel to the fold axis. Fracture intensity shows a decrease from the limb (0.05-0.1) to the fold (0.02-0.03). It includes the moderate-dipping fracture set and the vertical fracture set. The northeast-southwest and northeast-southwest fracture systems show existing intensity and strength. The strength increases from west to east, and is consistent with the trend of the Keshen fold (Dabei, Keshen). A comparison between the Keshen and Dabei structures shows that the formation of fracture systems was controlled by: The northeast-southwest fracture systems was observed very high intensity in all structural positions and shows increasing trend of fracture intensity from hinge to fold in the Dabei structure, whereas, in the Keshen structure, the high intensities are almost restricted near the fold axis. In a similar way, the ground distribution of intensity shows that in the hinge region of the Keshen anticline the intensity shows low values, whereas in Dabei, the values are high. This is probably related to the folding mechanisms.

Keshen structure: The north-south fracture systems is parallel to the maximum horizontal principal stress. The west-east fracture systems is parallel to the fold axis. Fracture intensity shows a decrease from the limb (0.05-0.1) to the fold (0.02-0.03). It includes the moderate-dipping fracture set and the vertical fracture set. The northeast-southwest and northeast-southwest fracture systems show existing intensity and strength. The strength increases from west to east, and is consistent with the trend of the Keshen fold (Dabei, Keshen). A comparison between the Keshen and Dabei structures shows that the formation of fracture systems was controlled by: The northeast-southwest fracture systems was observed very high intensity in all structural positions and shows increasing trend of fracture intensity from hinge to fold in the Dabei structure, whereas, in the Keshen structure, the high intensities are almost restricted near the fold axis. In a similar way, the ground distribution of intensity shows that in the hinge region of the Keshen anticline the intensity shows low values, whereas in Dabei, the values are high. This is probably related to the folding mechanisms.
Geological Setting

The Kuqa Depression developed in the northern Tarim basin near the foothill of the southern Mt. Tianshan. Due to the dual-action of vertical shear-force and extrusion induced by the strong uplift of the southern Mt. Tianshan, a series of fault-related folds have developed in the basin. Current contractional structural deformation in the Kuqa Depression is mainly due to the most intense tectonic deformation caused by Himalayan orogeny during Neogene-Quaternary. The stratigraphic units involved in the structures range in age from Triassic to Oligocene. The Cretaceous Bashijiqike Formation sandstones is buried at more than 6000 m depth and is the most important reservoir that has been explored in the past decade, despite its low matrix porosity (<9%) and ultra-low permeability (as little as 0.001 mD). The Bashijiqike Formation is overlain by the Palaeogene Kumugeliemu Group (E1-2km), an excellent regional seal with salt and gypsum unit. Natural fracture systems have a significant impact on reservoir performance.

Methods

Subsurface data, including Formation Micro Imager (FMI) logs (31 wells), 3D core-images (7 wells), core pictures (15 wells) and contour map. Using stereographic technique, we document the subsurface fracture system. Bedding dip is restored to the horizontal. Fracture intensity (the number of fractures per meter) within sandstones was analyzed. Stereographic projections are used with different colors to represent fracture intensities. 3D core-images are compared with FMI data to orient them through markers. Cross-cutting relationships and fracture wall morphologies, kinematic indicators, and crosscutting relationships. The 3D core-images are compared with FMI data to orient them through markers such as mudstone interlayer, bedding plane and fracture geometry. Thus, orientation and dip azimuth of each fracture on the 3D core-image is obtained. Then, the relative timing between the various fracture sets were established based on cross-cutting relationships, and subsequently related it to the regional structural context. The surface textures and fillings that could be diagnostic of relative displacements are used to determine the history of open fracture formation and fracture modes.