WANG Ke, ZHANG Ronghu, DAI Junsheng, WANG Junpeng and YANG Xuejun, 2015. Genesis and Evolution of Structural Fracture in Tight Sandstone Reservoir of Keshen-2 Gas Field, Tarim Basin, NW China. *Acta Geologica Sinica* (English Edition), 89(supp.):85-88.

Genesis and Evolution of Structural Fracture in Tight Sandstone Reservoir of Keshen-2 Gas Field, Tarim Basin, NW China

WANG Ke[1*], ZHANG Ronghu[1], DAI Junsheng[2], WANG Junpeng[1] and YANG Xuejun[3]

1 *PetroChina Hangzhou Research Institute of Geology, Hangzhou, Zhejiang 310023*
2 *China University of Petroleum, Qingdao, Shandong 266580*
3 *Tarim Oilfield Company, CNPC, Korla, Xinjiang 841000*

1 Introduction

Keshen-2 gas field is located in the middle of Kelasu-Ichicklick Structural Belt, Kuqa Depression, Tarim Basin, NW China. The primary reservoir of Keshen-2 gas field is Bashijiqike Formation, Lower Cretaceous (K_1bs), buried -6500~-7600 m. Exploration in this area has shown that structural fracture is the primary factor that improving reservoir physical properties and enhancing gas production, therefore, the understanding of genesis and evolution of structural fracture and their relationship with petroleum accumulation has an significant theoretical meaning on guiding exploration and development of Keshen-2 gas field.

In this article, we take a research on genesis and evolution of structural fracture and their relationship with petroleum accumulation based on mechanical genetic classification of structural fracture in order to provide some suggestion to the exploration and development of Keshen-2 gas field.

2 Mechanical Genetic Classification of Structural Fracture

Mechanical genetic classification is the basis of research on genesis and evolution of structural fracture. Combining domestic and international research achievements (Nelson, 2001; Zeng et al, 2007, 2009, 2010; Zeng, 2008; Hou and Pan, 2013), mechanical genetic classification of reservoir structural fracture is carried out as Table 1 shows according to types of early dominant stress and late dominant stress.

3 Genesis of Structural Fracture in Keshen-2 Gas Field

Identification and mechanical classification of structural fracture in Keshen-2 gas field are carried out guiding with mechanical genetic classification above, and we found that shearing, tensile, extensile and transtension fractures develop with different extents. Structural fractures in Keshen-2 gas field are divided into 3 groups according to fracture strike derived from core fracture description and imaging logging fracture interpretation based on confirming mechanical types of core fracture.

The first group is EW group. Fractures mainly develop in some wells of the high spot and limbs of anticline with high angle and NWW-SEE or NEE-SWW strike, and mechanical types include tensile, extensile, shearing and transtensile.

The second group is NS group. Fractures are mainly shearing, also some extensile and transtensile, with NNW-SSE and NNE-SSW strikes which are the superior fracture orientations in this area.

The third group is NW-SE group. Fractures are mainly shearing with NW-SE strike, and have a small amount.

In addition, fault belts develop a mass of netlike fractures with various strikes, which formed by stress disturbance of faults.

Combing analysis above and results by rock acoustic emission experiment and C-O isotopes analysis of fracture fillings, we consider that structural fractures in Keshen-2 gas field should be formed under 3 different structural stress fields.

4 Evolution of Structural Fracture in Keshen-2 Gas Field

Tectonic analysis demonstrates that Keshen-2 gas field has went through 4 evolution stages: paleo-foreland basin stage (Late Permian-Triassic), depressed basin (Jurassic-Cretaceous), weak contracted flexural basin (Palaeogene-Miocene) and intracontinental basin (Pliocene-Quaternary)

* Corresponding author. E-mail: wangk_hz@petrochina.com.cn

Table 1 Mechanical genetic classification of reservoir structural fracture

Early dominant stress	Initial fracture type	Late dominant stress	
		Compressive (Shearing) stress	Tensile stress
Compressive (Shearing) stress	Shearing fracture	Shearing fracture/Transpression fracture	Shearing fracture with high aperture
	Extensile fracture	Extensile transtension fracture/Extensile fracture with lowaperture	Extensile fracture with high aperture
Tensile stress	Tensile fracture	Tensile transtension fracture/Tensile fracture with low aperture	Tensile fracture with high aperture

(He et al, 2003; Zhang and Wang, 2004; Zeng et al, 2004; Liu and Zeng, 2004; Neng et al, 2013). In the matter of tectonic stress field evolution, Keshen-2 gas field suffered extensile process with approximately NS direction from Early Cretaceous to the early period of Late Cretaceous, and compressive process with the same direction at the late period of Late Cretaceous. In most time of Palaeogene, Keshen-2 gas field suffered extensile process with approximately NS direction again, and started to suffer compressive process with the same direction one more time since the late period of Oligocene.

Combining with tectonic evolution and tectonic stress field evolution, we consider that reservoir of Bashijiqike Formation (K_1bs) in Keshen-2 gas field contains 3 stages of structural fractures which are corresponding to primary tectonic events.

The first stage of structural fracture: At most time of Cretaceous, Keshen-2 gas field was suffering extensile process with approximately NS direction, while gravity was the maximum principal stress and tensile stress with NNW-SSE or approximately NS direction was the minimum principal stress. In the condition above, some tensile fractures with NEE-SWW or approximately EW strike formed on the high position of the anticline.

In the late periods of Cretaceous and Palaeogene, Keshen-2 gas field suffered short compressive stress. The maximum principal stress was approximately NS or NNW-SSE direction, and the value of average maximum effective principal stress was 35.2~59.9 MPa. Affected by this stress condition, a few shearing, extensile, extensile transtension fractures with approximately NS or NNW-SSE strike, and shearing fractures with NNE-SSW strike, formed on the limbs of the anticline. Besides, in the conversion period which the stress converted from extensile to compressive at the late periods of Cretaceous and Palaeogene, some shearing, extensile and tensile transtension fractures could be formed.

Extensile process at Palaeogene, bending effect of anticline under latter compressive stress condition, and the effect of formation fluid with high pressure, would increase the aperture of fractures with approximately EW strike formed at Cretaceous at latter time, which would make wells that have these fractures to have higher production. Cores show that aperture of fractures with approximately EW strike in Well A2-1 and Well A2-2 distributes between 0.2~1.5 mm, and 4.0 mm for the maximum, while that with other strikes in other wells is just 0.1~1.0 mm, only a little can reach 2.0 mm.

The second stage of structural fracture: At the late period of Miocene, Keshen-2 gas field suffered strong compressive stress. The direction of maximum principal stress is NNW-SSE or approximately NS, and the value of average maximum effective principal stress is about 74.8 MPa. In this condition, a mass of extensile and shearing fractures with NNW-SSE or approximately NS strike, and some shearing fractures with NNE-SSW strike formed on the limbs of anticline. As the tensile stress component derived from uplifting and bending of anticline reduce the compressive stress, few structural fractures develop on the top of anticline.

The thrid stage of structural fracture: At the late period of Pliocene, Keshen-2 gas field suffered stronger compressive stress. The maximum principal stress is NNW-SSE or approximately NS direction, and the average maximum principal stress is about 80.9 MPa. Under this kind of tectonic stress environment, a mount of shearing fractures with NNW-SSE and NNE-SSW strikes, extensile and extensile transtension fractures with NNW-SSE or approximately NS strike, formed over the whole anticline. Straight splitting fractures with approximately NS strike in Well A2-4 are the very extensile fractures formed by this stage of tectonic stress field. Besides, in this period, the direction of maximum compressive stress of the whole Kuqa area is NW-SE, which is a little different with Keshen-2 gas field. Therefore in this period, the maximum compressive stress might deflected from approximately NS to NW-SE, and some NW-SE strike shearing fractures formed, but the amount is rare. Furthermore, some shearing fractures with low dip angle derived from faults with approximately EW and NEE-SWW directions would form around faults.

The second and third stages of structural fracture are the most important to Keshen-2 gas field. The second stage of structural fracture is Kangcun Period of Neogene. In this period, Keshen-2 gas field started to transform from weak contracted flexural basin to intracontinental basin, with the stress status transformed from previous tensile to latter compressive, and therefore, shearing and extensile fractures with approximately NS direction formed. In the late of this period, horizontal tectonic stress enhanced constantly. As the shallow depth of strata, the gravity might be small enough to be the minimum principal stress in some areas, which lead to the forming of a few low dip angle shearing fractures with approximately EW strike. Because faults did not develop at this time, most of these fractures with low dip angle should be ordinary shearing fractures, which can differ from fractures derived by thrust faults in the third stage of structural fracture.

The periods of the third stage of structural fracture are Kuqa Period of Neogene and Xiyu Period of Quaternary, and have a strong tectonic stress. In Kuqa Period, strata began to bend and deform as the effect of compressive stress, the Paleo-Kelasu Fault revived, a mass of new faults formed, and the rudiments of the Kasangtuokai Anticline and Kumugeliemu Anticline appeared. To Xiyu Period, the compressive tectonic stress was stronger, and thus strong deformation of strata came up. As the strong horizontal tectonic stress and the uplifting of strata of Cretaceous by the thrusting effect of previous faults, the overlying gravity reduced to be the minimum principal stress. According to Anderson's fault formation mode, in this kind of stress condition, the previous thrust faults extended and new ones generated constantly, which finally form the current tectonic framework of foreland imbricate type. And meanwhile, a mount of low dip angle shearing fractures derived by or associated with faults generated, which mostly developed around faults, and also a few on the top and limbs of anticline. These low dip angle fractures formed horizontal seepage system in reservoirs, and enhanced the horizontal permeability of fractures.

5 Relationship between Structural Fracture and Petroleum Accumulation

The forming stages of reservoir structural fractures have a good matching relationship with petroleum accumulation. According to Zhao and Dai (2002) and Wang (2014), the petroleum system of Kuqa Depression has 3 primary stages of petroleum accumulation: the early and medium periods of Late Tertiary (17~10 Ma), Late Kangcun Period to Early and Medium Kuqa Period (10~3 Ma), and Late Kuqa Period to Xiyu Period of Quaternary (3~1 Ma).

The first stage is mainly oil accumulation. As in this period, the fracture system of Keshen-2 gas field had not formed completely, and therefore just a little oil accumulated. Furthermore, the latter tectonic destruction and natural gas accumulation made the accumulated oil overflow in quantity, which lead to that an oil pool could not formed. And meanwhile, oil-bearing inclusions and residual asphalt are not found in reservoir also verifies that early oil accumulation might not exist in Keshen-2 gas field.

The second stage is mainly condensate gas accumulation, combining with little oil accumulation. The time of this stage is approximately the same to the second stage of structural fracture.

The third stage is dominated by natural gas accumulation. Saline inclusions associated with natural gas are found in core samples of Well A2-1 and Well A2-2, and the experiment analysis demonstrates the natural gas is mainly high-over mature. In addition, the time of this stage is exactly the same to the third stage of structural fracture, thus it is the most important petroleum migration and accumulation of Kuqa Depression. In this condition, the gas pool of Keshen-2 gas field finally formed, and reached an industrial scale.

References

He Guangyu, Lu Huafu, Wang Liangshu, Jia Dong, Li Shuxin, Wang Shengli and Yin Donghao. 2003. Evidence for Paleogene extensive Kuqa Basin, Tarim. Journal of Nanjing University (Natural Sciences), 39(1): 40-45 (in Chinese with English abstract).

Hou Guiting and Pan Wenqing. 2013. Geological Modeling and Mechanical Mechanism of Fractures. Beijing: Science Press, 1-4 (in Chinese).

Liu Hongtao and Zeng Lianbo. 2004. Expression of the Himalayan orogeny in the Kuqa depression, Tarim Basin-evidence from the rock acoustic emission experiment. Geological Bulletin of China, 23(7): 676-679 (in Chinese with English abstract).

Nelson R A. 2001. Geologic Analysis of Naturally Fractured Reservoirs (Second Edition). Houston: Gulf Professional Publishing, 7-32.

Neng Yuan, Xie Huiwen, Sun Tairong, Lei Ganglin and Xu Lili. 2013. Structural characteristics of Keshen-2 segmentation in Kelasu Structural Belt and its petroleum geological significance. China Petroleum Exploration, 18(2): 1-6 (in Chinese with English abstract).

Wang Zhaoming. 2014. Formation mechanism and enrichment regularities of Kelasu subsalt deep large gas field in Kuqa Depression, Tarim Basin. Natural Gas Geoscience, 25(2): 153-166 (in Chinese with English abstract).

Zeng Lianbo. 2008. Formation and Distribution of Reservoir Fractures in Low-Permeability Sandstones. Beijing: Science Press, 18-22, 122-124 (in Chinese).

Zeng Lianbo, Ke Shizhen and Liu Yang. 2010. Study Methods of Fractures in Low-Permeability Oil-Gas Reservoirs. Beijing: Petroleum Industry Press, 1-6, 131-136 (in Chinese).

Zeng Lianbo, Qi Jiafu and Wang Yongxiu. 2007. Origin type of tectonic fractures and geological conditions in low-permeability reservoir. Acta Petrolei Sinica, 28(4): 52-56 (in Chinese with English abstract).

Zeng Lianbo, Tan Chengxuan and Zhang Mingli. 2004. Tectonic stress field and its effect on hydrocarbon migration and accumulation in Mesozoic and Cenozoic in the Kuqa Depression, Tarim Basin. Science in China Series D: Earth Science, 34(Suppl. 1): 98-106 (in Chinese).

Zeng Lianbo, Wang Zhengguo, Xiao Shurong and Zhang Guibin. 2009. The origin and geological significance of low dip angle fractures in the thrust zones of the western basins of China. Acta Petrolei Sinica, 30(1): 56-60 (in Chinese with English abstract).

Zhang Zhongpei and Wang Qingchen. 2004. Development of joints and shear fractures in Kuqa Depression and its implication to regional stress field switching. Science in China Series D: Earth Science, 34(Suppl. 1): 63-73 (in Chinese).

Zhao Jingzhou and Dai Jinxing. 2002. Accumulation timing and history of Kuche petroleum system, Tarim Basin. Acta Sedimentologica Sinica, 20(2): 315-319 (in Chinese with English abstract)