IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)
e-ISSN: 2321–0990, p-ISSN: 2321–0982.Volume 9, Issue 3 Ser. I (May – June 2021), PP 51-59
www.iosrjournals.org

Research on the Characteristic Differences of Ultra-deep Sub-salt Adjacent Gas Reservoirs in Kuqa Depression - Take Keshen 2 Gas Reservoir and Keshen 8 Gas Reservoir for Example

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Abstract*：Keshen 2 and Keshen 8 are the two gas reservoirs which locate in the adjacent hanging wall and footwall, belong to Keshen segment of Kelasu thrust belt in the middle of Kuqa depression, Tarim Basin. After Keshen 2 gas reservoir has gained the industrial gas flow, the drilling data from Keshen 8 gas reservoir which located in the footwall of Keshen 2, and buried deeper than Keshen 2 shows that, single well test of the highest daily production of natural gas are more than one million cubic meters, well above Keshen 2. Through the comprehensive study of the core, characteristics of reservoir, sedimentary phase, capacity, geometry, current stress, cracks and other data of the two gas reservoirs, show that there are no much difference between two gas reservoir in petrological characteristic, reservoir physical property, sedimentary environment and other aspects. The difference is mainly in the following three aspects: structural type, the development scale of cracks, the magnitude of stress. Relative to Keshen 2 structure, Keshen 8 structure in the footwall is pop-ups which formed on the basis of imbricate thrust structure, has more fractures, horizontal compression ability is relatively weak, vertical communicated reservoirs ability is strong, has high effectiveness of fractures. In order to verify the above opinions, we use the elastic displacement theory which bases on the mechanical mechanism, did some numerical simulation of the effectiveness of the cracks in Keshen 2 well block and Keshen 8 well block. The simulation results show that when the maximum Columbo shear stress is larger, the broken degree of rock is higher, the effectiveness of cracks is better. The results show that, the distribution of maximum Columbo shear stress in Keshen 8 well block is better than Keshen 2 well block, has a banding distribution, and gradually decreased to the south, the distribution area of maximum Columbo shear stress of prolific wells in Keshen 2 and Keshen 8 well block is 80-100Mpa, is well coincident with actual drilling.*

Keywords*：Keshen 2 Gas Reservoir, Keshen 8 Gas Reservoir, Kelasu Thrust Belt, Fracture Effectiveness, Geostress*

Date of Submission: 01-06-2021 Date of Acceptance: 14-06-2021

I. Introduction

Keshen area in Kuqa foreland thrust belt is the most abundant area of tectonic oil and gas reservoirs in Tarim Basin, which has the dual characteristics of oil and gas enrichment and complex structure. According to the structural deformation characteristics of Kuqa depression, from north to south it can be divided into the northern monocline belt, Kelasu thrust belt, Yiqiklike thrust belt, Yangxia sag, Baicheng sag, Wushi sag, Qiulitage thrust belt and southern slope belt (Fig. 1). In recent years, the study of crassus thrust belt[1-5], deep zone degree deepening, is generally believed that in kuqa foreland thrust belt is affected by intense tectonic movement, especially after the late Miocene, under the strong compression from the Tianshan mountains, forming a complex thrust tectonic belt, in a typical Mesozoic detachment fault and the steps of thrust faults and their associated characteristics of the imbricate fault combination[6-8], the existence of the halite layer slows down the vertical compaction, release some of the extrusion stress, protect the reservoir under the salt, form effective traps[9-11].

Real drilling data shows that it is located in the middle of Crassus thrust belt of deep well Keshen 2 blocks in single well because of the difference of tectonic position, test yield difference is bigger, single-well daily production gas quantity generally between 0.2 - 80 x 10^4 cubic meters, which is located in the footwall of Keshen 8 well, deep buried depth is greater, but from the current single well test data of 10 wells, under the same working system, single well test daily gas production are more than 100 x 10^4 cubic meters. The two gas reservoirs are close to each other and located in the same sedimentary facies zone. What is the reason for the gas production of Keshen 8 gas reservoir located in the footwall of thrust fault to be better than that of Keshen 2 gas reservoir? Based on the comparison of sedimentary, reservoir, structure and stress characteristics of two adjacent gas reservoirs, Keshen 2 and Keshen 8, and combined with the comprehensive study of numerical simulation technology, the reasons for the difference between the two adjacent gas reservoirs are discussed.

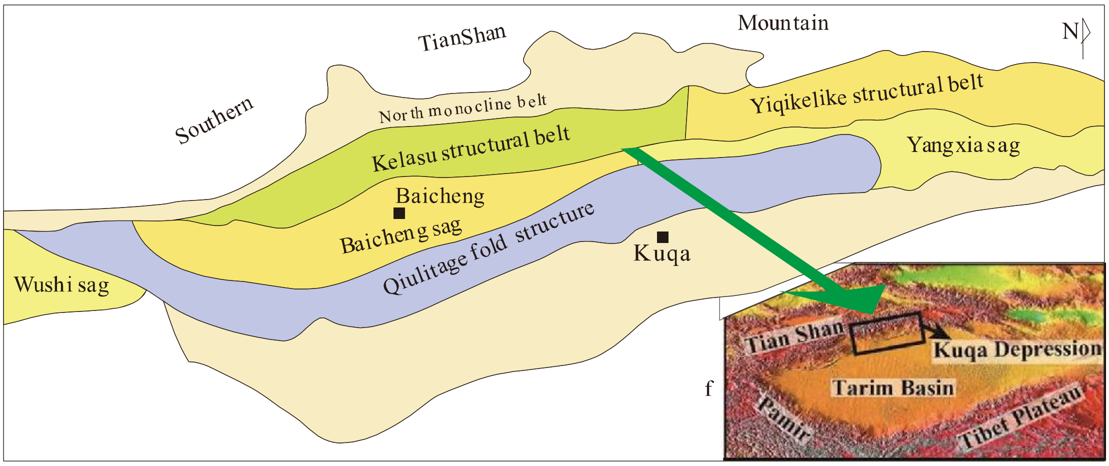

Fig1 Regional tectonic unit division and study area location of Kuqa depression

II. Comparison of regional geological features

Keshen 2 gas field and Keshen 8 gas field are found follow the Dina 2 gas field and Kela 2 gas field, after the production of the kuqa deep fractured low pore sandstone reservoir have been found in the two large gas fields, more than one hundred billion cubic meters, Keshen2 and Keshen 8 field of crassus structure with gas accumulation geological condition is superior, adjacent to Baicheng hydrocarbon-generating sag, and develop high quality reservoir, has a good prospect and potential of oil and gas exploration.

2.1 Stratigraphic characteristics

The strata of Keshen 2 gas reservoir and Keshen 8 gas reservoir are similar, and the drilling revealed the normal stratigraphic sequence, from top to bottom, the Quaternary, Neogene Kuqa Formation, Kangcun Formation, Jidike Formation, Paleogene Suweiyi Formation, Kumugeliemu Group, Cretaceous Bashijiqike Formation and Baxigai Formation, and the Upper Cretaceous is missing. The main gas producing zone is the Cretaceous Bashijiqike Formation. The first lithologic member of Bashijiqike Formation has different degrees of denudation in both gas reservoirs, while the second lithologic member and the third lithologic member are well preserved. According to the drilling data, the overall thickness of Keshen 2 gas reservoir is similar to that of Keshen 8 gas reservoir, and the reservoir thickness is about 300m, which is an ultra-deep and super-thick sandstone reservoir. The stratigraphic lithology of the two gas reservoirs is similar, which is dominated by fine sandstone, medium sandstone with a small amount of argillaceous siltstone, siltstone and thin layer mudstone.

2.2 Characteristics of sedimentary facies

Regional sedimentary facies study shows that Cretaceous kuqa foreland basin deposition, under a hot and dry climate, palaeocurrent are mainly from north to south, the north of south Tianshan mountains exports have more than one source, carrying a large amount of detrital material after the south pass, due to the slow terrain, water body energy is abate, clastic sedimentary of abundant material and quickly into the lake, so from north to south of sedimentary facies of alluvial fan, fan delta and braided river delta, littoral and shallow lake sedimentary system. The alluvial fan and fan delta appear as multi-phase fan bodies overlapping each other vertically, and the multi-phase fan bodies interconnecting with each other on the plane, forming a large scale Cretaceous sand body.

The sedimentary conditions of Keshen 2 gas reservoir and Keshen 8 gas reservoir are the same, the third lithologic member is in the fan delta front sedimentary environment, the first lithologic member and the second lithologic member are braided river delta front sedimentary environment.

2.3 Reservoir characteristics

The petrology characteristic is similar. Through the identification and analysis of 650 rock sections in Keshen 2 and Keshen 8 well areas, the results show that the rock type of Keshen 8 area is consistent with that of Keshen 2 area in the north, mainly composed of lithic feldspar sandstone with a small amount of feldspar lithic sandstone. Longitudinally, the composition of rock ore has little change and the quartz content is relatively stable.

The proportion of reservoir space is similar. The reservoir space in well blocks Keshen 2 and Keshen 8 is mainly intergranular pores, accounting for 60% - 83% of the total pore types, followed by intragranular dissolved pores, accounting for 5% - 20% of the total pore types.

The reservoir physical properties are similar. The Cretaceous Bashijiqike Formation reservoirs in the target member of Keshen 2 well area are generally buried between 6500 and 7000m, and the core matrix porosity is mainly distributed between 2% and 7% with an average of 4.1%, and the matrix permeability is mainly distributed between 0.05mD and 0.5mD with an average of 0.055mD. Keshen 8 gas reservoir is located in the footwall of Keshen 2 well area, 6600 - 7200 m buried depth, the reservoir physical property is the same as that of Keshen 2 area, but the porosity development degree is generally higher than that of Keshen 2 area, the core measurement matrix porosity is mainly distributed in 4.0% - 9.0%, average 5.4%, porosity matrix permeability distribution in 4.0% - 8.0%, and both gas reservoir belongs to low porosity, low permeability reservoir.

III. Contrast of structural development characteristics

The special stratigraphic conditions in Kuqa area make the pre-salt structure style very special, in other words, the pre-salt structural section is developed between two decollement beds, the strata of the Mesozoic Jurassic Kizilenur Formation are the main strata in the descalation, thickness can reach above 2000 m, is located in the bottom structure, and subject to the effect of ultra high temperature, super high pressure, liquidity is relatively high, the control of the structure development main had precursor effect and pushing the filling effect. The upper decollement bed is mainly composed of Paleogene gypsum salt rock with local gypsum mudstone. The thickness of the upper decollement bed is 300 - 2500m, which is the best cover rock in the region. The buffering effect of salt ensures the relative integrity of the structure and reduces the degree of fragmentation of the structure. Based on the flow, filling and supporting action of the plastic decollement layer, the structural development pattern of imbricate heaps was formed in the Kelasu structural belt. Under the strong compression action of the mountain, the plastic flow of sliding and delamination is the main factor for the development of the structure, and the structure develops continuously.

The tectonic evolution history shows that the Kelasu thrust belt was mainly formed after Kuqa Formation. During the Pliocene, influenced by the Himalayan movement, the southern Tianshan Mountains were gradually uplifted under the action of compression. The former palaeo-thrusting faults in the pre-salt Kelasu tectonic belt moved further and formed several "forward-spreading" thrusting faults developing southward in its footwall. Under the control of Kelasu fault and Keshen 8 fault, the Keshen 8 structure and Keshen 2 structure show a wedge-shaped thrust structural style, forming a large area anticline. In the Quaternary, the uplift of South Tianshan strengthened the compaction on the northern margin of Tarim Basin, and the tectonic deformation was complicated. The pre-salt faults in Kelasu structural belt were further active, and the new secondary thrust faults developed between the north of Keshen 8 structure and Keshen 2 structure, forming two independent anticlines, Keshen 8 and Keshen 2.

Keshen 8 structure had formed its embryonic form in the early stage of Kuqa Formation based on pre-existing faults. With the continuous strengthening of stress in the middle and late stage of Kuqa Formation, the structure continued to form southward in the process of formation. There is a strong correlation between the burst structure and imbricated structure, which is the result of the further development of imbricated structure.

Compared with the imbricate structure, the sudden structure has the lateral sealing ability and the larger fracture development scale. During the upward development of the burst structure, the top and both wings of the structure were wrapped by gypsum salt rock, which reduced the risk of "sand-sand" joint with the strata on the hanging wall. In addition, for a single faulted anticline, the "free space" was nearly generated at the top of the faulted anticline under the induction of the flow of the upper salt layer, so the "meso-plane effect" visible in the surface anticline can be formed in the ultra-deep pre-salt layer, which is called the "meso-plane model of faulted anticline". A large number of tensile fractures can be developed in the upper part of the middle and upper surface, which not only alleviates the lateral tectonic compression stress on the reservoir, but also communicates the low porosity and low permeability sandstone reservoir, improves the reservoir physical properties, and is conducive to natural gas production. Keshen 8 structure, as a burst structure, is bidirectional extrusion, with large arch rise amplitude and large fracture development scale, and the favorable reservoir thickness is 25% - 60% higher than that of Keshen 2 structure (Fig. 2).

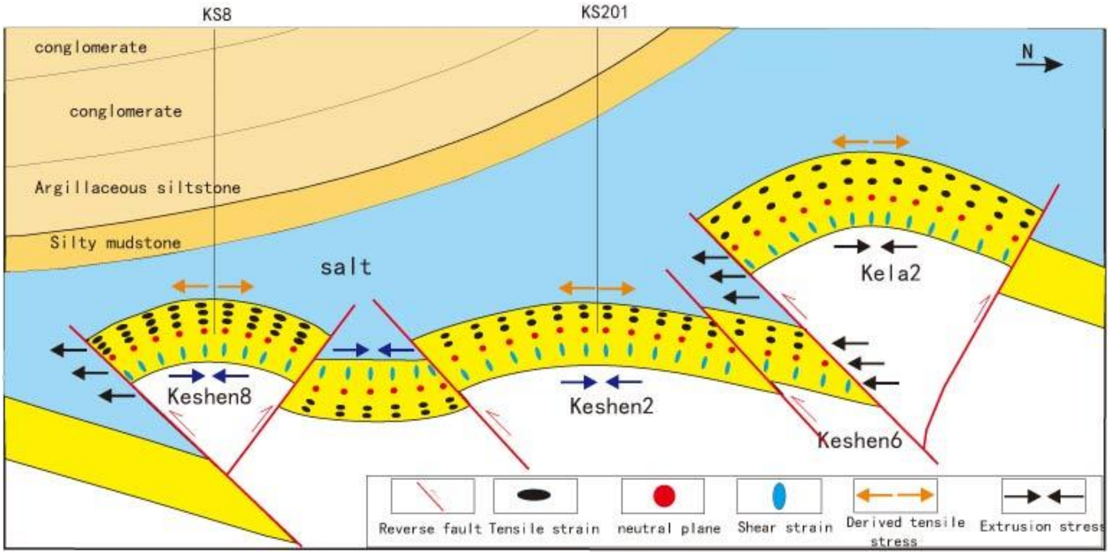

Fig 2 Tectonic-strain distribution model of keshen 8- Keshen 2 structures

IV. Fracture Development Characteristics

4.1 Comparison of microscopic fracture characteristics

Based on the observation of 246 cast thin sections in Keshen 2 and Keshen 8 wells, the micro-cast thin sections and laser confocal thin sections in the two wells all developed micron-scale fractures of cut particles generated by structural extrusion, micron-scale grain margin fractures with unconsolidated grain edges and nanoscale fractures within the particles (Fig. 3). The width of the grain margin fracture in Keshen 2 well area is between 1um and 10um, and the width of the nanoscale fracture in the grain is generally less than <1um. In comparison, the fracture width of Keshen 8 well area is slightly larger and the development frequency is higher. In the horizon of fracture development in Keshen 8 well area, it accounts for 13.3% of the total horizon. However, Keshen 2 well area only accounts for 4.2% of the total field of view.

4.2 Core and imaging fracture differences

Based on core fracture description and statistics, the wells in the same structural position (including structural axis, high point and wing) were selected, and the filling degree was mainly half-filled to unfilled calcite. However, a total of 361 fractures were identified in the 126.5m core of Keshen 2 well area, with a linear density of 2.85 lines /m and an apparent dip angle of 60-85°, the fractures with apparent length greater than 20cm accounted for 20.2%. A total of 317 fractures were identified in the 63.1m core of Keshen 8 well area, with a linear density of 5.02 lines/m, an apparent dip angle of 60-85°, and an apparent fracture length greater than 20cm accounting for 35%.

Fig3 Cast thin section and core in Keshen 2-8 well area

According to the statistical results of fracture identification by FMI imaging logging, the structural fracture development degree of Keshen 8 well area is generally better than that of Keshen 2 well area, which is mainly reflected in fracture opening, fracture porosity, fracture length and other parameters. Fractures in the two well areas are mainly high-angle vertical fractures. In the imaging of Keshen 2 well area, fractures show chaotic fracture inclination. Although there are many fractures, there are few dominant major fractures with large scale, and most of them are associated with the main fractures. In the imaging of Keshen 8 well area, the fracture occurrence is relatively single, which is manifested as high and steep echelon fractures. The fracture has strong depth ability, large opening and high effectiveness. The fracture opening of Keshen 2 well area is 0.05-0.3mm, and that of Keshen 8 well area is 0.05-0.6mm. Taking Wells Keshen8 and Keshen201 as examples, both of which are structural highs, the mud system is water-based mud. According to the imaging interpretation, the average maximum fracture length, average fracture width and average maximum apparent porosity of well Keshen 8 are 13.7m, 0.25mm and 0.218% respectively. As for Keshen 201 well, the maximum fracture length was 9.3m, the average fracture width was 0.15mm, and the average apparent fracture porosity was 0.086%.

4.3 Differences in drilling fluid loss characteristics

As a dynamic index of fracture development in drilling process, drilling fluid loss can reflect the scale of fracture development to a certain extent. The pressure coefficient of Kuqa depression gas field is generally greater than 1.9, leading to high risk of well control, requiring the use of high-density drilling fluid (generally greater than 1.9g/cm3), and the existence of fractures is easy to cause well loss, resulting in the frequent occurrence of well loss. In other words, the more developed the fracture is, the more serious the leak is, which indicates that the effectiveness of the fracture is higher. Through the statistics of the leak characteristics of 20 wells in Keshen 2 and 8 well areas, the number of drilling fluid loss in a single well in Keshen 2 well area is 1-9 times, the average number of single well loss is 4 times, and the average amount of loss in a single well is 219 cubic meter. The loss in well Keshen 8 area is far more than that in well Keshen 2 area, the average loss in a single well is 1000 cubic meter, and the number of losses ranges from 5 to 20 times, the average number of losses in a single well is 9 times (Fig. 4).

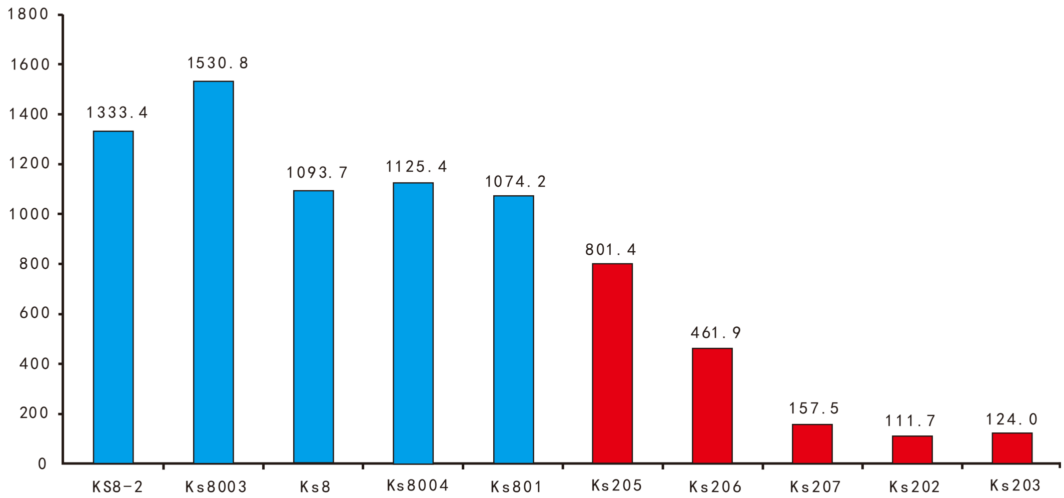

Fig4 Drilling fluid loss in Keshen 2 and Keshen 8

4.4 Production capacity characteristic comparison

The existence of structural fractures can form a high seepage gas transportation system in the low permeability reservoir and promote the discharge of natural gas. Therefore, the unimpeded flow of natural gas in a single well can reflect the development of structural fractures to some extent. Taking well Keshen201 in the high part of the structure as an example, the reservoir test section at the bottom of well Keshen201 ranges from 6735 to 6755m, with an open flow of 85×104 m3/d, and 6505 to 6700m in the middle and upper part with an open flow of 275×104 m3/d. The initial test of well Keshen 8 only opened 6860-693m at the bottom of the reservoir, with an open flow of 290.34×104 cubic meter. After combination test, 6717-6795m and 6860-6903m were selected for the test section, under the same working system, the open flow was 295×104 m3.

Test results of 43m and 121m at the bottom of well Keshen 8 are comparable. In Keshen 2 well area of multi-port layered testing appraisal wells, located at the bottom of the reservoir production of test section between 0.2 - 2 x 104 cubic meter, reservoir in the upper part of the test period of production is generally larger than 50 x 104 cubic meter, yield difference is bigger, it shows that the vertical communication ability of the reservoir in Keshen 2 well area is relatively poor, the size and communication ability of the fracture are much smaller than that in Keshen 8 well area.

Although the Keshen 2 gas reservoir and Keshen 8 gas reservoir are adjacent to each other, there are great differences in fractures from micro to macro and from static to dynamic. Belongs to the sudden structure of Keshen 8 is the result of imbricated structure further development, one of the most main characteristics of the fracture development is constructed the two wings and the core cracks are very development, and the core development more tensional fractures, it is good for the modification of the reservoir, the high proportion of productive wells also confirms the advantage of sudden structural fracture development.

V. Comparison of geostress distribution characteristics

The difference of structural morphology and the scale of fracture can not be separated from the influence of geostress, so it is indispensable to determine the distribution characteristics of geostress for gas reservoir analysis. The geostress testing is the most direct means to obtain the geostress. Theoretically, it has higher accuracy than other methods, but it has the difficulties of limited measurement data and high test cost. Therefore, the main method to obtain the present-day geostress is to calculate the present-day geostress by using logging data.

In the 1980s, Huang Rongzun et al. put forward Huang's model for geostress calculation, which accuracy is high, but it is difficult to determine the coefficient of relevant calculation parameters in the calculation model, so the flexibility of operation is limited in practice, in 2005, Xie Gang proposed a new model for calculating geostress profile using logging data, the parameters are easier to determine, so it is a commonly used method for calculating geostress:

$$\sigma_{min} = \sigma_x + \frac{\mu}{1-\mu}\sigma_v + \frac{1-2\mu}{1-\mu}\alpha P_p \quad (1)$$

$$\sigma_v = \int_0^z \rho\ (z)\ gdz \quad (2)$$

$$\sigma_{max} = \sigma_y + \frac{\mu}{1-\mu}\sigma_v + \frac{1-2\mu}{1-\mu}\alpha P_p \quad (3)$$

where：

σmin，σmax，σv are horizontal minimum principal stress, horizontal maximum principal stress and vertical principal stress respectively，MPa

σx and σy are tectonic stress components in x direction and y direction respectively，MPa

μis the formation Poisson's ratio, and is the parameter with dimension 1 ；

αis Biot coefficient, and is the parameter with dimension 1 ；

Logging data show that for the Keshen gas field，α=0.38，Pp is formation pressure，MPa

Z is depth，m

ρ（Z）is the density of overlying strata, and is a function related to formation depth Z，g/cm3

g is gravitational acceleration，m/S2

Combined with drilling induced fractures, borehole wall collapse, acoustic logging and other relevant data, various intermediate parameters in the equation can be solved, and then the three-way principal stress can be obtained. Based on the geostress logging calculation of 30 key wells in two gas reservoirs, the geostress trend is generally the same, mainly NS and NNW-SSE, but the geostress magnitude is obviously different. The average maximum principal stress in well Keshen 2 is about 176MPa, the average minimum principal stress is about 142MPa, and the average horizontal stress difference is about 33MPa. There is a large difference of geostress between structural positions. The average maximum and minimum principal stress of the high structural positions is about 170MPa, and the average minimum principal stress is about 137MPa, and the average stress difference is about 28MPa. The structural saddle and the structural east flank of the low-yielding wells, the average maximum principal stress is about 182MPa, the average minimum principal stress is 142MPa, and the average horizontal stress difference is 40MPa. The average horizontal maximum principal stress of 10 single wells in Keshen 8 well area is about 166 MPa, the horizontal minimum principal stress is about 138.5MPa, and the horizontal stress difference is only 24.6MPa.

Due to the special stress background, Keshen area has strong reservoir stress sensitivity, according to the stress study of the fractured low-porosity sandstone reservoir of Cretaceous Bashijiqike Formation in Keshen area conducted by the laboratory of American Core Company (Fig. 5), with the increase of stress difference, the reservoir porosity and permeability loss are 2.0% - 9.0% and 1.0% - 85%, respectively. Wang Ke et al. calculated the relationship between horizontal stress difference and fracture porosity and permeability in Keshen area based on finite element numerical simulation, the study showed that the larger the stress difference, the lower the fracture porosity and permeability, and the loss of reservoir porosity and permeability was 3%-45% and 9%-78%, respectively. The overall horizontal stress difference of well Keshen 2 is 8 - 16MPa larger than that of well Shen 8, and the loss of fracture porosity and permeability is 3.0% - 5% and 28% - 50%, respectively. A small horizontal stress difference means a weak compression stress, which improves fracture effectiveness and vertical connectivity of the reservoir, laying the foundation for higher and more stable production.

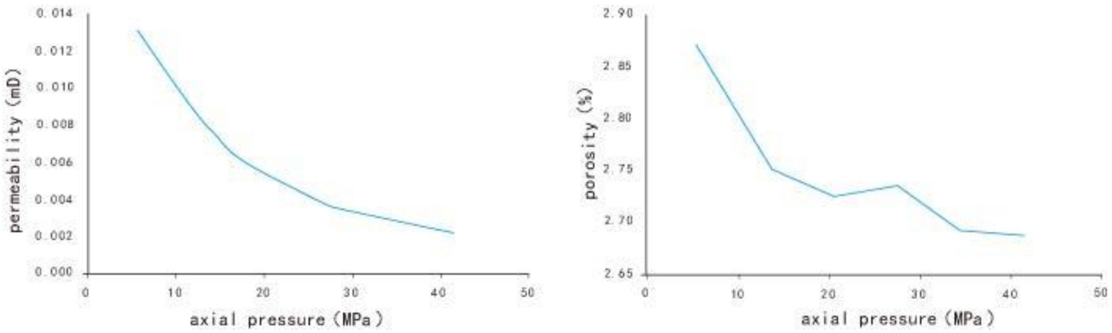

Fig5 Variation of core porosity permeability with effective stress

VI. Numerical simulation of fracture effectiveness based on elastic displacement theory

Keshen 2 gas reservoir and Keshen 8 gas reservoir have great differences in structural morphology, fracture development scale and geostress. In order to verify the above viewpoints, it is necessary to evaluate the effectiveness of fracture numerical simulation based on structural and stress mechanism research method. There have been many achievements in the study of fractures in Keshen area at home and abroad, such as structural curvature method, fractal dimension method, finite element numerical simulation method, etc. However, there is no method that can satisfy the above three conditions in one model at the same time. Therefore, the evaluation method of fracture effectiveness based on elastic displacement theory is introduced.

Elastic Dislocation theory is on the basis of the resolution of seismic data, according to the seismic data to determine the fault form and the accumulative sliding fault surface morphology and formation level of stress and strain data such as mechanics, which predicted based on seismic data can identify the fault characteristics of surrounding rock mass stress field distribution, and then to evaluate the effectiveness of the cracks.

The results of numerical simulation of elastic displacement theory show the maximum Columbus shear stress and strain distribution.

The calculation formula of the maximum Columbus shear stress：

$$MCSS = \left[\tau_{max} \cdot \sqrt{(1+\mu^2)}\right] - (\mu \cdot \sigma_{mean}) \qquad (4)$$

where：$\tau_{\max} = (\sigma_{\max} - \sigma_{min})/2$, Mpa , is the maximum shear stress

$\sigma_{\text{mean}} = (\sigma_{max} + \sigma_{min})/2$, Mpa , is the average stress

μ , the coefficient of internal friction；

σ_{max} , Mpa , maximum principal stress

σ_{min} , Mpa , minimum principal stress

According to the elastic displacement theory, the maximum Columbus shear stress is the maximum shear stress in the most favorable fracture plane direction in any stress system. Therefore, regions with high values of the maximum Columbus shear stress are highly effective in fracture development.

The numerical simulation results (Fig. 6) show that the distribution range of the maximum Columbus shear stress in Keshen 2 presents a certain regularity, and the simulated maximum Columbus shear stress in the western and central areas of the structure is relatively high, high stress values are mainly distributed in wells Kes 3-1, Ks3, Ks301 and Ks205, the simulated stress value is generally distributed in the range of 70-90MPa, the simulated stress values of Kes 2-1-14, Kes 2-2-18, Ks202, Kes 2-2-14, Kes 2-2-12 wells located in the middle of the structure are relatively inferior, the simulated stress value is generally distributed in the range of 30-60MPa. However, low-yield wells such as KES 2-2-1, KS208, KS207, KES 2-1-1 and KES 2-1-5 located in the east are located in the lower simulated stress range, and the simulated stress value is generally distributed at 30MPa.

According to the analysis of the actual drilling test data, the production of five wells in the low simulated stress area is all low, and the daily gas production of a single well is generally less than 10×104 cubic meter.

Well area Keshen 8 is better than well area Keshen 2, and it is distributed in a zonal pattern. The simulation results show that the most effective fracture development area is located in Wells KES 8-1 - KES 8-2 - KS 802 - KS 8003, the simulated stress value is generally distributed in the range of 80-100MPa, and it was followed by wells KS 807 - KS 8004 - KES 8-1 - KS 8, the simulated stress value is distributed in the range of 60 - 80MPa, the degree of fracture development in the area between wells KS 805 and KS 806 is relatively poor, and the simulated stress value is distributed in the range of 40 - 60MPa. Through the actual drilling and testing data, the highest daily production of a single well in Keshen 8 area is more than 100×104 cubic meter, and KES 805 and KES 806 wells have obtained high production flow after proper modification, which is consistent with the actual drilling test results.

The results of fracture prediction based on elastic displacement theory show that the effectiveness of fracture is the highest when the stress distribution of numerical simulation is between 80 MPa and 100 MPa in the Keshen area. When the stress distribution of numerical simulation is in the range of 0 - 30MPa, the effectiveness of fracture is relatively poor, and the yield is relatively low. Therefore, to understand the distribution of stress in the region is the premise of evaluating the effectiveness of fractures.

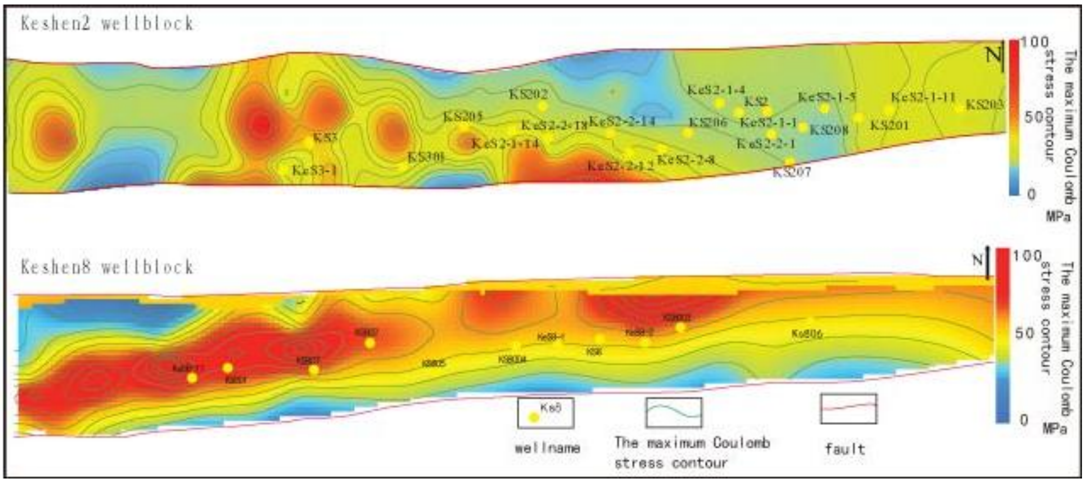

Fig6 Maximum Columbian shear stress distribution of Cretaceous Bashijiqike Formation in well Keshen 2 and Keshen 8 area

VII. Conclusion

a) Keshen 2 gas field is close to Keshen 8 gas field, and the main reservoir is Cretaceous Bashijiqike Formation, which is located on the Kelasu fault zone structurally, and has the same provenance, stratigraphic framework, sedimentary facies, petrologic characteristics and huge reservoir thickness.

b) The main differences between Keshen 2 gas reservoir and Keshen 8 gas reservoir are structural type, geostress, and fracture development scale. Compared with the Keshen 2 structure, the Keshen 8 structure is a burst structure formed on the basis of the thrust imbricate structure, with small horizontal compression stress and high fracture development degree.

c) Horizontal compression stress has a great influence on the effectiveness of fracture, and the average horizontal stress difference in Keshen 2 well area is about 33MPa. The horizontal stress difference in Keshen 8 well area is about 24.6MPa. When horizontal compression stress increases by 8 - 16MPa, the loss of fracture porosity and permeability is 3.0% - 5% and 28% - 50%, respectively. Small horizontal stress difference means weak compression stress, which improves fracture effectiveness and vertical reservoir connectivity, which is the main reason for the difference in vertical reservoir production between single wells in Keshen 2 gas reservoir and Keshen 8 gas reservoir.

d) Fracture effectiveness based on the theory of the elastic displacement numerical simulation experiment results show that the fracture effectiveness of well Keshen 8 is better than that of well Keshen 2, the effectiveness of fractures in Keshen 2 well area is relatively high in the high part of the structure, and poor in the saddle part of the structure, in the Keshen area, the maximum Columbus shear stress distribution of numerical simulation is 80 - 100 MPa, and the effectiveness of fracture is the highest. When the stress distribution of numerical simulation is in the range of 0 - 30MPa, the effectiveness of the fracture is poor, and the simulation results are in good agreement with the actual drilling.

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