Woody International Publish Limited
An Multidisciplinary Academic Journal Publisher

Journal of Theory and Practice in Engineering and Technology, Volume 2, Issue 2, 2025
https://www.woodyinternational.com/

The Controlling Effect of Diagenesis on Hydrocarbon Charging in the Upper 3rd Member of Eogene Shahejie Formation of the KL Oil Field, Laizhou Bay Sag, Bohai Bay Basin, China

Chao Li, Hanqing Zhao*

Tianjin Branch of CNOOC Ltd., Tianjin 300459, China
**Author to whom correspondence should be addressed.*

Abstract: ***By comprehensively utilizing various analysis and testing methods such as casting thin sections, scanning electron microscopy, and fluid inclusions, combined with drilling and logging data, burial history, sedimentary systems and other related research results, a detailed analysis was conducted on the diagenesis of the upper 3rd Member of Eogene Shahejie Formation(E2s3u) in KL oil filed and its control over hydrocarbon accumulation. The research results indicated that E2s3u in KL oil filed belongs to the "high porosity, medium-high permeability" reservoir, and the reservoir space are still mainly composed of intergranular pores, with secondary intergranular pores and mold pores visible, the overall diagenesis of the reservoir is in the middle diagenesis stage A, characterized by "medium compaction, strong dissolution, and weak cementation". The maturity of organic matter in E2s3u is in the semi mature to low mature stage, which is a stage of massive discharge of organic acids, the acidic dissolution and pore enlargement of feldspar and calcite provide space for the charging of hydrocarbon in Laizhou Bay Sag.The research results provide reference significance for hydrocarbon exploration on the southern slope of Laizhou Bay Sag.***

Keywords: Bohai Bay Basin; Laizhou Bay Sag; Storage space; Diagenesis; Hydrocarbon charging.

Cited as: Li, C., & Zhao, H. (2025). The Controlling Effect of Diagenesis on Hydrocarbon Charging in the Upper 3rd Member of Eogene Shahejie Formation of the KL Oil Field, Laizhou Bay Sag, Bohai Bay Basin, China. *Journal of Theory and Practice in Engineering and Technology*, *2*(2), 14–23. Retrieved from https://woodyinternational.com/index.php/jtpet/article/view/323

1. Introduction

The diagenesis and evolution of reservoirs are closely related to the migration and accumulation of oil and gas, and are the key research objects of petroleum geologists at home and abroad，many achievements have also been made [1-6]. One of the important target strata in the Bohai Bay Basin is the Eogene Shahejie Formation, which has abundant oil and gas resources and has discovered a large number of oil fileds, the KL oil filed on the southern slope of the Laizhou Bay Sag is one of them.The upper 3rd Member of Eogene Shahejie Formation in the KL oil filed is generally buried over 2000 meters and belongs to a typical offshore "mid to deep" oil field, the author used various analysis and testing methods such as casting thin sections, scanning electron microscopy, vitrinite reflectance, and fluid inclusions, combined with previous research results such as regional sedimentary systems and burial history, to analyze the diagenesis and hydrocarbon charging stages of the the upper 3rd Member of Eogene Shahejie Formation reservoir, clarify the formation mechanism and controlling effect to hydrocarbon charging in the oil filed, and have important significance for oil and gas exploration in the basin.

2. Regional Geological Overview

The Laizhou Bay Sag in the Bohai Bay Basin is a typical "north fault south super" basin (Figure 1). The KL oil field is located in the southern gentle slope zone of the Laizhou Bay sag, adjacent to the northern of the Laizhou

Bay Sag. The KL oil field is a flower shaped structure controlled by large east-west slip faults, and is a block and semi anticline structure formed by attaching to boundary faults, with a very favorable location for reservoir formation. The material source of KL oi lfield comes from the Kendong Uplift in the southwest direction, 20km away from the Kendong Uplift. The sedimentary range is controlled by the western boundary fault and advances to the sag, swinging north-south. The sedimentary environment is a near source braided river delta. The upper 3rd member of the Eogene Shahejie Formation is the main oil-bearing layer of KL oil field, and three subfacies are mainly developed within the oil field: braided river delta plain, braided river delta front, and pre braided river delta.

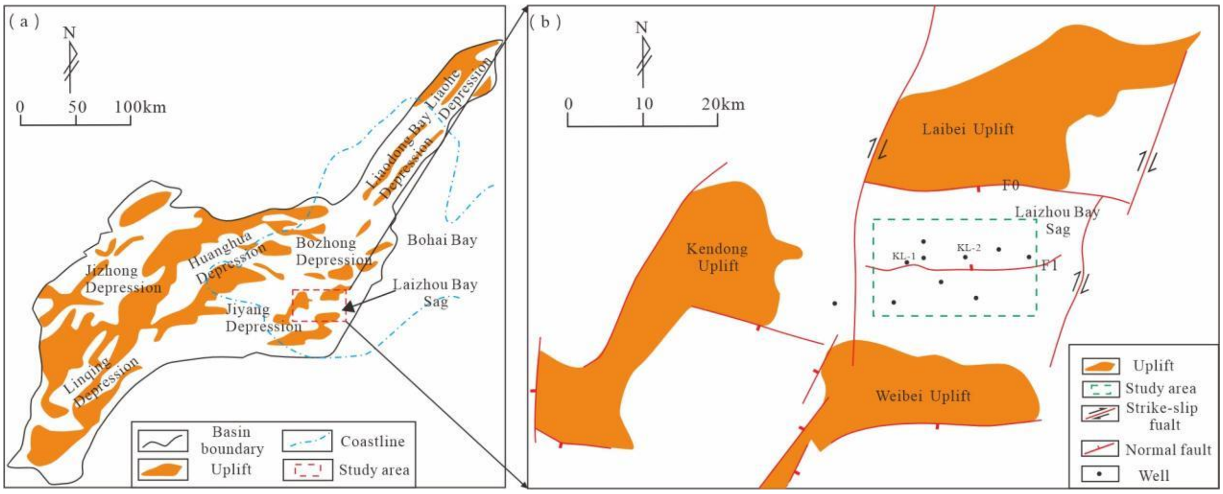


Figure 1: Geological Overview of KL oil filed

The sedimentary strata within the Sag directly cover the volcanic rock basement, sequentially filling the Eogene Shahejie Formation and Eogene Dongying Formation, the Neogene Guantao Formation, the Neogene Minghuazhen Formation, and the Quaternary Pingyuan Formation. The upper 3rd Member of Eogene Shahejie Formation is the main oil and gas bearing zone of KL oil filed, with the development of distributary channels and mouth bar sediments of the braided river delta.It can be divided into 13 small layers from top to bottom, including the I oil group, II oil group, and III oil group. The oil-bearing section is mainly located in the II oil group and III oil group.

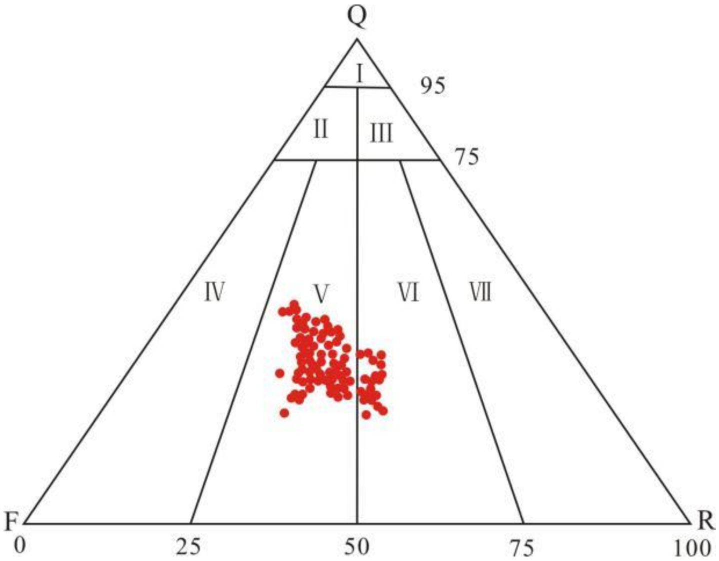


Figure 2: Triangulation of sandstone type of $E_2s_3^u$ in KL oil filed

The statistical analysis of the identification results of 138 sample thin sections shows that the reservoirs of the upper 3rd Member of Eogene Shahejie Formation in KL oil filed are mainly composed of lithic feldspar sandstone and feldspar lithic sandstone (Figure 2). The maturity of reservoir components is low, rich in feldspar and rock debris, with low quartz content. The volume fraction of quartz ranges from 23.0% to 45.0%, with an average of only 32.4%. The feldspar content is 29.0% to 48.0%, with an average of 37.2%, and the rock debris is 17.0% to

41.0%, with an average of 30.4%. The rock debris is mainly composed of granite and metamorphic rocks; the reservoir structure has a high degree of maturity, with good to medium particle sorting, moderate roundness, particle support, and an average content of less than 5% of mudstone interstitial material. It is mainly composed of medium fine sandstone, followed by medium coarse sandstone and fine siltstone.

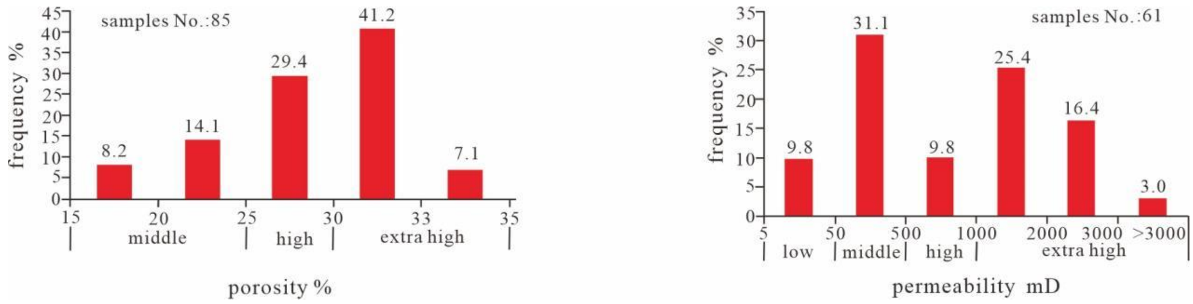
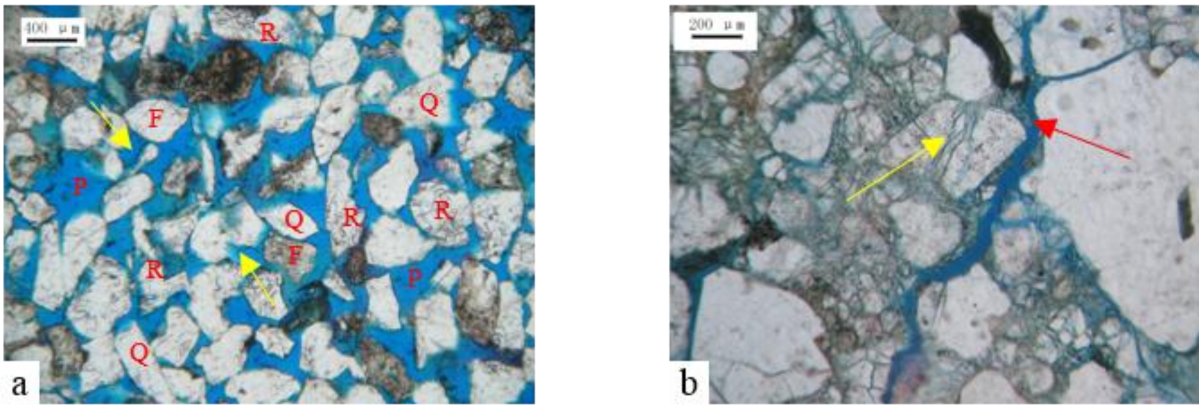


Figure 3: Physical property distribution histogram of sandstone reservoir of $E_2s_3^u$ in KL oil filed

The lithic feldspar sandstone and feldspar lithic sandstone, with good to medium particle sorting, the particle size is mainly medium to fine sand, followed by medium coarse sand and fine silt. Based on the statistical analysis of 85 conventional thin sections of core samples from 2 exploration wells, the average porosity and permeability of the sandstone reservoir of the upper 3rd Member of Eogene Shahejie Formation are 29.1% and 1117.7mD (Figure 3), indicating a high porosity to medium high permeability reservoir.

The casting thin section shows that the pore types are still mainly primary intergranular pores (Figure 4a), including secondary intergranular pores, intragranular dissolution pores, and mold pores; The cracks are relatively developed (Figure 4b), indicating intergranular and intragranular cracks around the particles, which are the main reason for the reservoir's ultra-high permeability and a reflection of strong tectonic movements. According to the analysis of core mercury injection data, the capillary pressure curve of the reservoir is mainly characterized by coarse skewness, with a displacement pressure of 0.02~0.114 MPa, a median saturation pressure of 0.07~1.834 MPa, and an average pore throat radius of 1.577~11.7 μm, belonging to the pore throat structure of large, medium, and fine pores. The pore morphology is mostly irregular, and the throats are mostly small pores with reduced size. The cracks are in the form of plate-like throats, which provide large plate-like flow channels for fluid migration.



a. Well KL-2, blue cast body, 2176.11m, fine sandstone, with abundant development of primary intergranular pores, particle point line contact, visible intragranular dissolution pores (yellow arrows); b.Well KL-1, blue cast body, 2254.82m, medium coarse sandstone, with developed cracks, visible intergranular cracks (red arrows) and intragranular cracks (yellow arrows) around the particles.Q-quartz; F-feldspar; R-rock fragments; P-pore.

Figure 4: Reservoir space of sandstone of Es_3^U in KL oil field

3. Diagenesis

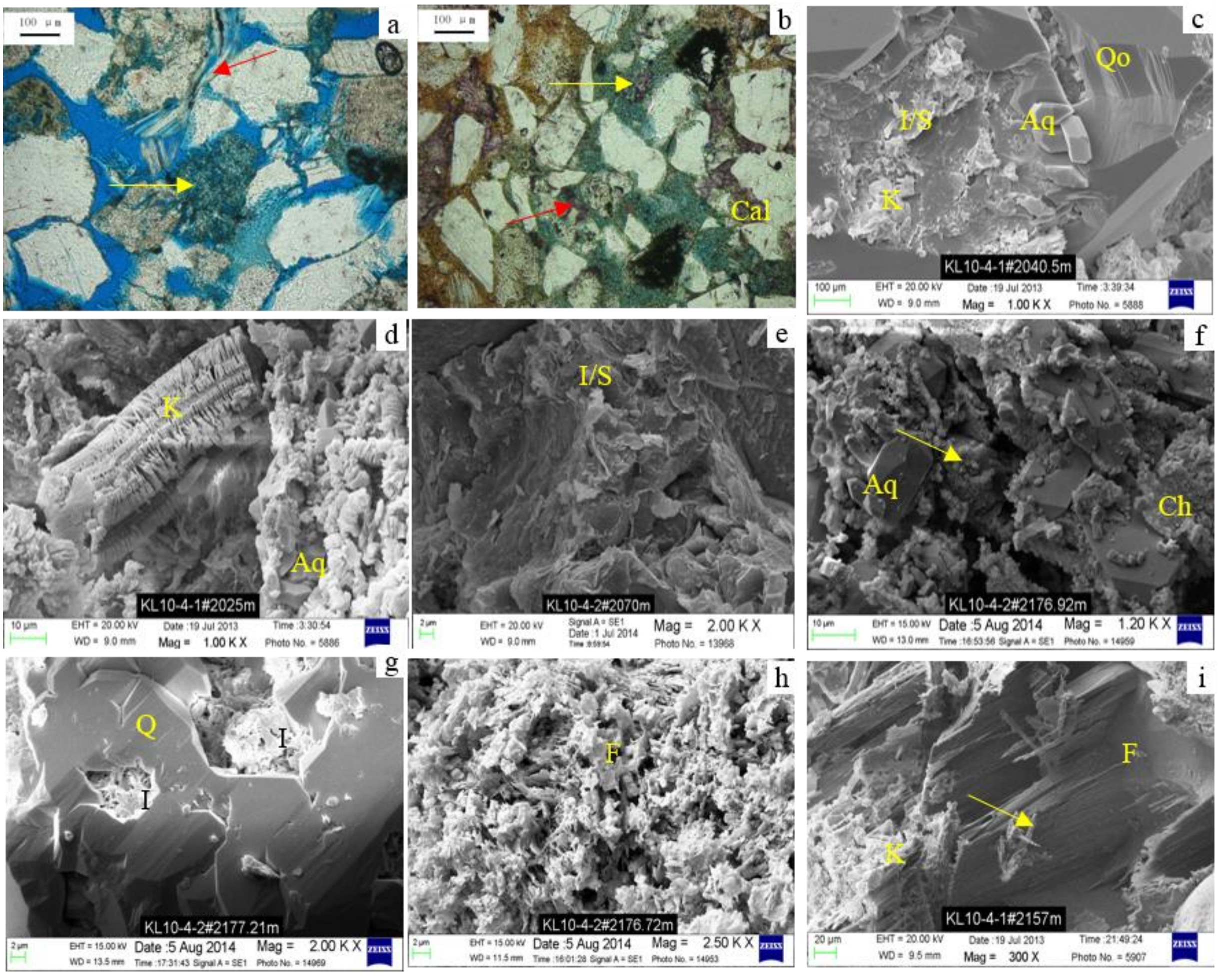
Through comprehensive analysis of cast thin sections and scanning electron microscopy, the diagenetic stage of the upper 3rd Member of Eogene Shahejie Formation in KL oil filed is in the middle diagenetic stage A. The main diagenetic processes include compaction, cementation, and dissolution.

3.1 Compaction

The mechanical compaction effect of the upper 3rd Member of the Eogene Shahejie Formation mainly manifests as particle deformation, such as the bending and rupture of mica (Figure 5a), as well as the formation of pseudo matrix by mud deformation. The overall contact between particles is mainly point line contact, and no concave convex contact or suture line contact is observed. The compaction strength belongs to the medium compaction degree, and the weak compaction degree preserves the original intergranular pores.

3.2 Cementation

The overall cementation effect of the upper 3rd Member of Eogene Shahejie Formation is weak, but the types of cementation are diverse. According to microscopic observations and statistics, the proportion of cement in the upper 3rd Member of Eogene Shahejie Formation does not exceed 10%, and the main types of cement are carbonate cement, siliceous cement, and authigenic clay mineral cement.



a. Well KL-1,blue cast,2178.32m, medium-fine grained sandstone,Mica compression deformation (red arrow),visible feldspar alteration kaolinite (yellow arrow); b. Well KL-2,blue cast,2179.32m,fine sandstone,calcite alizarin red stained purple-red, partial dissolution of calcite (red arrow), strongly dissolved calcite residue appears floating (yellow arrow); c. Well KL-1, 2040.5m, secondary enlargement of quartz and self generated quartz microcrystals, the surface is coated with I/S mixed layers and kaolinite; d. Well KL-1, 2025m, worm shaped kaolinite and authigenic quartz microcrystals; e. Well KL10-2, 2070m, filamentous I/S mixed layers; f. Well KL-2, 2176.92m, pompon shaped authigenic chlorite (yellow arrow) fills pores, self generated quartz microcrystals and surface developed self generated chlorite crust; g. Well KL-2, 2177.21m, quartz is dissolved to form dissolution pores, fill the hole with filamentous illite; h. Well KL-2, 2176.72m, feldspar is strongly dissolved to form a skeletal structure; i. Well KL-1, 2157m, sodium feldspar is dissolved to produce mold pores (yellow arrows) and self generated kaolinite. Cal-calcite; Q-quartz; F-feldspar; Aq-Self generated quartz microcrystals; Qo- Quartz secondary enlargement; K-kaolinite; I/S-illite / montmorillonite mixed layer; I-illite; Ch-chlorite; Py-pyrite; Ha-halite.

Figure 5: Diagenetic Characteristics of Sandstone Reservoir of $E_2s_3^u$ in KL oil filed

The carbonate cement in the reservoir mainly develops calcite. Under the blue cast, calcite is dyed purple red with Alizarin Red (Figure 5b). Calcite contains iron, indicating that the diagenetic stage has entered the middle diagenetic stage.The main type of calcite cementation is porous cementation, and the cementation site is mainly located inside small pores with poor physical properties. Calcite cementation has a significant effect on the early anti compaction of the reservoir and the later dissolution and pore enlargement.

The siliceous cement in the reservoir is mainly composed of self generated quartz microcrystals, and the secondary enlargement of quartz is not obvious (Figure 5c). The integrity of the crystal structure of self generated quartz microcrystals depends on the growth space, and typical hexagonal columns can be seen. Overall, the development degree of siliceous cementation is relatively low, and the self generated quartz microcrystals are small and not extensively connected. The secondary enlargement edge is not obvious, and the secondary enlargement level of quartz in the upper part of the upper 3rd Member of Eogene Shahejie Formation generally belongs to grade I to II.

The content of impurities in the reservoir is low, and the clay minerals inside the reservoir are mainly self generated by diagenetic. The scanning electron microscopy analysis results indicate that the self generated clay minerals in the reservoir are characterized by "rich kaolinite and poor chlorite", containing a certain amount of illite / montmorillonite mixed layer and illite. Kaolinite is mainly filled in pores (Figure 5d), with a proportion of over 60% in authigenic clay minerals. Single crystals are mainly pseudo hexagonal and plate-like, while aggregates are mainly in the form of book pages and worms. Under scanning electron microscopy, kaolinite has a high degree of crystallization, complete crystals, and relatively abundant content. The main source of kaolinite in the reservoir is the dissolution product of feldspar under acidic conditions[9-11].·The illite / montmorillonite mixed layer and illite mainly appear in a pore filling state (Figure 5e), with the illite / montmorillonite mixed layer being the main one, with an average volume fraction generally not exceeding 30%. Illite is in the form of filamentous flakes, and the morphology of the illite / montmorillonite mixed layer is between montmorillonite and illite, which is a typical self generated formation. Chlorite is almost undeveloped, with an average content of less than 10%, appearing in the form of pore filling and particle shell (Figure 5f). Self generated single crystals of chlorite are mostly produced in needle leaf or needle sheet shapes, and aggregates are filled in the pores in a fluffy ball shape, mostly developed around self generated quartz.

In addition,under scanning electron microscopy, berry shaped pyrite, octahedral pyrite single crystal aggregates, and cubic rock salt single crystal aggregates were also observed, existing in the form of filling intergranular pores with relatively low content. It is generally believed that pyrite is a product of weak alkaline reducing environment in the early diagenetic stage, while rock salt crystals are often formed in environments rich in alkaline cations such as Na^+, thus having indicative significance for diagenetic environment.

3.3 Dissolution

The dissolution was developed in the reservoir, and it had a significant improvement effect on the physical properties of the reservoir. The dissolution process of the upper 3rd Member of Eogene Shahejie Formation reservoir can be divided into two categories: early alkaline dissolution and late acidic dissolution. The later acidic dissolution transformation and pore enhancement have a significant effect on improving the physical properties of the reservoir,which beneficial for hydrocarbon charging.

Through the use of cast thin sections and scanning electron microscopy observation, it was found that there was significant dissolution of quartz particles in the reservoir. The quartz particles were locally dissolved to form internal pores of the crystal, which were filled with illite mixed layers (Fig.5g). Quartz generally developped stably, and it is generally believed that significant dissolution occurs only in alkaline environments with a pH value greater than 8.5[12-14]. The dissolution of quartz mainly occurs in the early stage of diagenesis, and alkaline fluids mainly release a large amount of alkaline cations such as $Na^+$and K^+ due to the alteration of magmatic rock debris during early diagenesis, gradually transforming the fluid into alkaline fluid and leading to the dissolution of siliceous materials such as quartz.

Table 1: Values of Ro and Tmax in the upper section of $E_2s_3^u$ in KL oil filed

Well name	Sample depth/m	No.of measurement points	Ro/%	Tmax/°C
KL-1	1960	28	0.45	434.00
KL-1	2010	24	0.48	432.00
KL-1	2050	23	0.46	438.00
KL-1	2100	23	0.46	443.00
KL-1	2140	22	0.47	441.00
KL-1	2240	22	0.49	445.00
KL-1	2290	23	0.49	443.00
KL-1	2330	21	0.47	438.00
KL-1	2380	26	0.51	447.00

KL-2	2140	36	0.50	441.00
KL-2	2260	21	0.48	442.00
KL-2	2320	21	0.52	445.00
KL-2	2360	29	0.51	444.00
KL-2	2390	25	0.55	449.00

The acidic dissolution process has a stronger effect on the transformation of physical properties, and the acidic dissolution of the upper 3rd Member of Eogene Shahejie Formation reservoir was mainly the dissolution of carbonate cement and feldspar. After the dissolution of carbonate cement, the pore space was partially restored. After dissolution, feldspar particles become irregular, and under scanning electron microscopy, feldspar is dissolved by acidic fluids to form a skeletal structure (Figure 5h) or mold pores (Figure 5i).The acidic diagenetic environment within the reservoir generally originates from the discharge of organic acids before the maturation of organic matter[15-18], the measured values of organic matter vitrinite reflectance Ro and Tmax pyrolysis peak temperature (Table 1) in the upper 3rd Member of Eogene Shahejie Formation indicate that the organic matter vitrinite reflectance ranges from 0.4% to 0.6%, and the pyrolysis peak temperature is between 432 and 449. The organic matter is still in the semi mature to low mature stage, which is a stage where a large amount of organic acids were excreted.

3.4 Reservoir Diagenetic Evolution Sequence

The vitrinite reflectance of the upper 3rd Member of Eogene Shahejie Formation reservoir in KL oil field is 0.45~0.55%, and the montmorillonite mass fraction in the illite / montmorillonite mixed layer is between 30~50%, indicating that the diagenetic stage of the upper 3rd Member of Eogene Shahejie Formation reservoir has evolved to the middle diagenetic A1 sub stage, and the diagenetic processes experienced are compaction early carbonate cementation / alkaline dissolution illite / montmorillonite mixed layer transformation acidic dissolution / kaolinite cementation. Through comprehensive analysis of its diagenetic characteristics, the diagenetic evolution sequence has been restored.

In the early diagenetic stage A, the volcanic rocks in the upper 3rd member of the Eogene Shahejie Formation released a large amount of alkaline cations such as Na^+ and K^+ through weathering, and the diagenetic environment changed to alkaline. At the same time, the released cations such as Fe^{2+} and Mg^{2+} provided the material basis for chlorite and pyrite. The siliceous particles and cement were dissolved by alkaline dissolution, and some were enveloped by clay minerals; in the early diagenetic stage B, the increase in temperature causes Ca^{2+} precipitation to form calcite and fill the intergranular pores. Although it resists compaction to some extent, the physical property loss reaches its maximum at this time. Entering the A1 sub stage of diagenesis, as organic matter releases organic acids, the diagenetic environment gradually becomes acidic, and feldspar and carbonate cement undergo significant dissolution, only carbonate residues remain in pores with poor physical prop.

3.5 Factors Controlling Reservoir Diagenesis

3.5.1 Structure background

The KL oil field is located on the southern slope of the Laizhou Bay Sag, controlled by the boundary slip fault F1 (Figure 1). The current structural deformation is mainly controlled by tensile stress, and the fault properties are mainly tensile normal faults. From Figure 6, it can be seen that the KL oil field is located in the area with the strongest F1 fault activity. After sedimentation in the upper 3rd member of the Eogene Shahejie Formation, the fault displacement can reach up to 600m. Furthermore, through geological testing, the average temperature of the upper 3rd member of the Eogene Shahejie Formation is currently 83.9 ℃, and there are samples with fluid inclusion homogenization temperatures exceeding 90 ℃ (Figure 7), indicating that the process of oil and gas injection is accompanied by the flow of deep-seated hydrothermal fluids. The strong tectonic movement promotes the development of fractures and provides convenient conditions for the later entry of organic acids into the reservoir space to improve physical properties, oil and gas injection, and the flow of hot fluids to carry away dissolved substances.

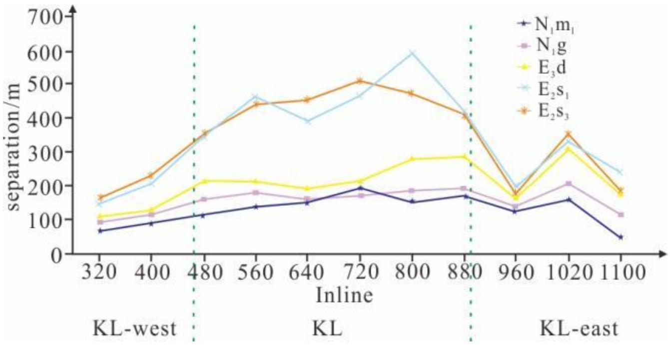


Figure 6: Break distance spider diagram of boundary fault F1 in KL oil field

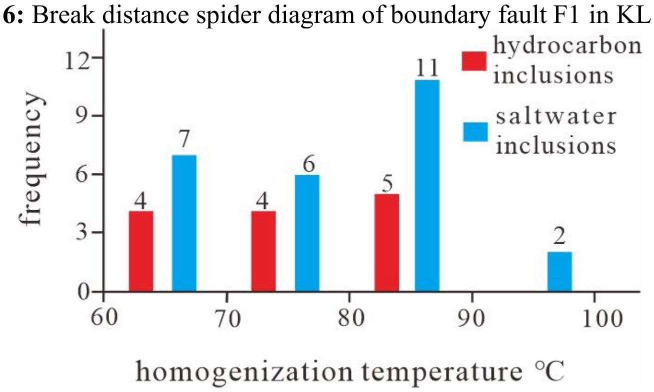


Figure 7: Uniform temperature distribution histogram of fluid inclusions of $E_2s_3^u$ in KL oil filed

3.5.2 Sedimentary environment and hydrodynamics

By comparing Table 2, it can be found that the transgressive systems tract in the upper 3rd Member of the Eogene Shahejie Formation has the highest sand to land ratio, and the average porosity and permeability interpreted by well logging are the highest. The content of interstitial material is also very low, indicating that the sedimentary properties of the reservoir in the upper 3rd Member of the Eogene Shahejie Formation are the best. The control of physical properties by sedimentation mainly includes two aspects: one is near source sedimentation, where feldspar content is relatively high, and feldspar improves reservoir properties through later dissolution and pore enlargement; the second is the near source braided river delta front developed in the upper 3rd Member of the Eogene Shahejie Formation, under the dual hydrodynamic effects of lake waves and rivers, the sandstone structure has high maturity, low matrix content, and good initial physical properties of the reservoir.

Table 2: Physical properties table of reservoirs in different formations of KL oil field

Formation	Sequence unit		sand to land ratio/%	porosity/%	permeability/mD	contents of matrix/%
	third-order sequence	System tract				
E_3s_1	I	RST	16.5	26.8	402.2	10.5
E_3s_2		TST	25.6	27.1	303.5	9.9
$E_2s_3^u$	II	RST	18.8	25.9	301.6	13.3
		TST	47.5	27.4	428.8	9.5
$E_2s_3^m$	III	RST	27.4	22.0	122.9	8.7

3.5.3 Abnormal formation pressure

There are many causes of abnormal pressure formation, and formation overpressure is generally manifested in the form of high pore fluid pressure, which reduces the acoustic velocity of sandstone and mudstone. When entering the overpressure zone, there will be abnormal logging responses with high acoustic time difference. Taking the KL-1 well as an example (Figure 8), the acoustic time difference curve shows a normal trend above an altitude of -1800m, but begins to deviate below an altitude of -1800m, causing an increase in acoustic time difference and entering the formation overpressure zone. The upper 3rd Member of the Eogene Shahejie Formation is located within the overpressure zone.

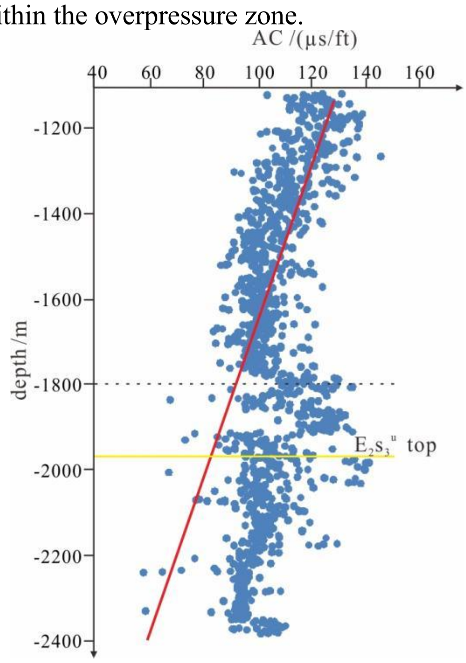
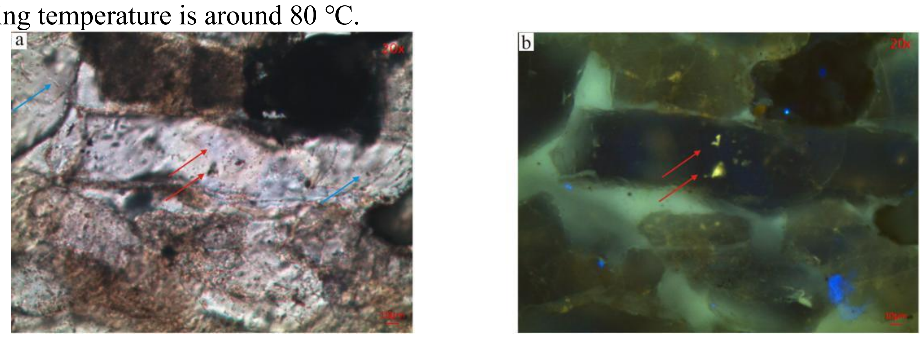


Figure 8: Sonic log response of formation overpressure of $E_2s_3^u$ in KL oil field

The occurrence of formation overpressure will reduce the compaction degree of the reservoir of the upper 3rd Member of the Eogene Shahejie Formation, allowing for the preservation of intergranular pores. Based on the burial history map of the study area, it can be seen that the burial in the study area can be divided into three stages: rapid burial, slow burial, and rapid burial. This may be the reason for the formation of geological overpressure: the rapid deposition of thick mudstone at the top of the upper 3rd Member of the Eogene Shahejie Formation, as well as the first and second members of the Shahejie Formation, makes it difficult for geological water to be quickly discharged, and geological pressure gradually increases with burial depth. The geological overpressure that may exist in the early stage of burial of the upper 3rd Member of the Eogene Shahejie Formation plays a role in delaying the deterioration of reservoir properties.

4. Hydrocarbon Charging Characteristics

Through microscopic observation of fluid inclusions in the reservoir of the upper 3rd Member of Eogene Shahejie Formation (Figure 9), it was found that fluid inclusions generally develop in quartz particle cracks and are fluid inclusions captured by quartz enlargement or formation of microcrystals in acidic fluid environments[19-21]. They are mainly saltwater inclusions and visible hydrocarbon inclusions. By analyzing the statistical data of uniform temperature of fluid inclusions (Figure 7), the temperature of hydrocarbon charging in the upper 3rd Member of Eogene Shahejie Formation ranges from 61 to 85 ℃, the temperature of saltwater inclusions ranges from 61 to 93 ℃, the initial filling temperature of hydrocarbon is 60 ℃, and the peak filling temperature is around 80 ℃.



KL-1, 2126m,fine sandstone,A is a transmitted light photo, b is a fluorescence photo, and a small amount of oil inclusions are seen in the cracks of quartz particles. It appears brown under transmitted light and yellow under fluorescence (red arrow); saltwater package (blue arrow).

Figure 9: Development characteristics of fluid inclusions of $E_2s_3^u$ in KL oil filed

5. Control of Acid Dissolution on Hydrocarbon Charging

Based on the characteristics of organic matter evolution, pore development, homogeneous temperature of fluid inclusions, and burial history map of the study area (Figure 10), it can be seen that in the KL oil filed, reservoir diagenesis has a controlling effect on hydrocarbon charging. Acidic dissolution of carbonate cement and feldspar effectively increases the pore space of the reservoir. At this time, the mature source rocks in the center of the basin sag begin to expel a large amount of hydrocarbons and reach the peak of oil generation in the late Neogene Minghuazhen Formation. Timely dissolution and pore enlargement of diagenesis provide a large amount of high-quality storage space for oil migrating from the basin.

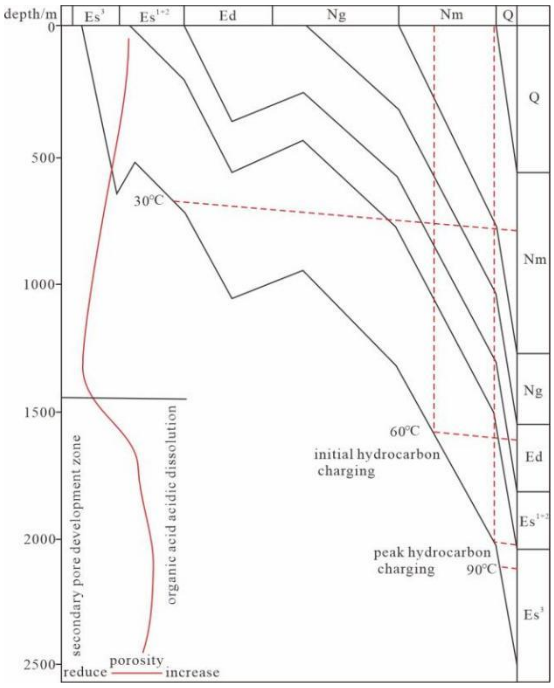


Figure 10: The control of acid dissolution on hydrocarbon charging in KL oil filed

6. Conclusion

1) The reservoir of the upper 3rd Member of Eogene Shahejie Formation in KL oil filed belongs to high porosity to medium high permeability reservoirs, the diagenesis stage is in the middle diagenesis stage A, characterized by "medium compaction, strong dissolution, and weak cementation". The particles are mainly in point line contact, and the dissolution process is divided into early alkaline dissolution and later acidic dissolution. The cementation process is weak but diverse, including carbonate cementation, siliceous cementation, and authigenic clay mineral cementation.

2) The organic matter in the mudstone of KL oil filed is still in the semi mature to low mature stage, which is a stage where a large amount of organic acids are discharged. This causes the fluid properties of the upper 3rd Member of Eogene Shahejie Formation to become acidic, and a large amount of carbonate cement and feldspar are dissolved, effectively increasing the storage space of the reservoir.

3) The fluid inclusion data of KL oil filed shows that the hydrocarbon charging occurred during the Neogene Minghuazhen Formation, and the organic acid dissolution provided storage space for hydrocarbon charging.

References

[1] Niu Chengmin, Tectonic evolution and hydrocarbon accumulation of Laizhouwan depression in southern Bohai Sea[J]. OIL&GAS GEOLOGY, 2012, 33(3):424-431.

[2] Sun Hefeng, Zhou Xinhuai, Peng Wenxu, et al. Characteristics of salt-related structures in the eastern strike-slip zone of Laizhou Bay Sag[J]. Journal of Earth Sciences and Environment, 2008, 30(4) : 380-384.
[3] Cai Dongsheng, Luo Yuhui, Yao Changhua.Strike-slip and pull-part structure study and its significance to petroleum exploration on Laizhouwan Sag Bohai Area[J].Acta Petrolei Sinica, 2001, 22(2) : 19-25.
[4] Zhao Hanqing, Chen Cunliang, Chen Xiaoming, et al. Coupling relationship between diagenesis and hydrocarbon charging in the upper 3rd member of Eogene Shahejie Formation of the Kenli 10-4 oil filed[J]. Fault-Block Oil &Gas Field, 2018, 25(4):435-439.
[5] Zhao Hanqing, Liu Zhaojun, Yao Shuqing, et al.Quantitative Division of Sequence Stratigraphic Units Based on the Wavelet Inversion of Logging Curve[J]. Global Geology, 2013, 32(2):372-378.
[6] Wang Liang, Niu Chengmin, Yang Bo, et al.Petroleum system and favorable exploration targets of the third member of Shahejie formation in Laizhouwan depression[J].Fault-Block Oil & Gas Field, 2011, 18(5) : 545-548.
[7] Ma Benben, KENNETH A. Eriksson, CAO Yingchang, et al. Fluid flow and related diagenetic processes in a rift basin: Evidence from the fourth member of the Eocene Shahejie Formation interval, Dongying depression, Bohai Bay Basin, China[J].AAPG Bulletin, 2016, 100(11):1633-1662.
[8] Saturnina Henares, Luca Caracciolo, C´esar Viseras, et al. Diagenetic constraints on heterogeneous reservoir quality assessment: A Triassic outcrop analog of meandering fluvial reservoirs[J].AAPG Bulletin, 2016, 100(9): 1377–1398.
[9] Rowland S J, Alexander R, Kagi R I. Analysis of trimethylnaphthalenes in petroleum by capillary gas chromatography [J]. J Chromatogr A, 1984, 294: 407–412.
[10] Goldstein R H. Fluid inclusions in sedimentary and diagenetic systems [J]. Lithos, 2001, 55(1–4): 159–193.
[11] Volk H, Dutkiewicz A, George S, et al. Oil migration in the Middle Proterozoic Roper Superbasin, Australia: Evidence from oil inclusions and their geochemistries [J]. J Geochem Explor, 2003, 78/79(3): 437–441.
[12] Cai Maotang, Fang Xiaomin, Wu Fuli, et al.Pliocene-Pleistocene stepwise drying of Central Asia:Evidence from paleomagnetism and sporopollen record of the deep borehole SG-3 in the western Qaidam Basin, NE Tibetan Plateau[J].Global and Planetary Change, 2012, 94:72-81.
[13] Hao Fang, Zhou Xinhuai, Zhu Yangming,, et al. Lacustrine source rock deposition in response to co-evolution of environments and organisms controlled by tectonic subsidence and climate, Bohai Bay Basin, China [J]. Org Geochem, 2012, 42(4): 323–339.
[14] Gui Lili, Zhao Mengjun, Liu Keyu, et al.Reservoir fluid evolution and hydrocarbon charge history of the Gasi E13 oil filed, southwestern Qaidam Basin[J].Natural Gas Geoscience, 2016, 27(2):289-297, 319.
[15] Meng Qingyang, Gui Lili，Chen Yan，et al.Hydrocarbon charge history of typical oil fileds in southwestern Qaidam Basin[J].Natural Gas Geoscience, 2015, 26(2):252-260.
[16] Yu Bingsong, Lai Xingyun.Carbonic acid syetem of groundwater and the soubility of calcite during diagensis[J].Acta Sedmentological Sinica, 2006, 24(5):627-635.
[17] Lasaga A C, Luttge A.Variation of crystal dissolution rate based on a dissolution stepwave model[J].Science, 2001, 291(5512):2400-2404.
[18] Marchand A M E，Smalley P C, Haszeldine R S, et al.Note on the importance of hydrocarbon fill for reservoir quality prediction in sandstones[J].AAPG Bulletin, 2002, 86(9):1561-1571.
[19] Fall A, Eichhubl P, Cumella S P, et al.Testing the basin-centered gas accumulation model using fluid inclusion observations:Southern Piceance Basin, Colorado[J].AAPG Bulletin, 2012, 96(12):2297-2318.
[20] Burruss R, Cercone K, Harris P.Fluid inclusion petrography and tectonic-burial history of the Al Ali No.2 well:Evidence for the timing of diagenesis and oil migration, northern Oman Foredeep[J].Geology, 1983, 11(10):567-570.
[21] Rossi C, Goldstein R H, Ceriani A, et al.Fluid inclusions record thermal and fluid evolution in reservoir sandstones, Khatatba Formation, Western Desert, Egypt:A case for fluid injection[J].AAPG Bulletin, 2002, 86(10):1773-1799.