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Study on the Migration Direction of Mesozoic Oil/gas in Zhenjing Region of Erdos Basin

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Oil/gas migration in the Zhenjing region of Ordos basin had been studied through geochemical tracing based on analysis of saturated hydrocarbon, aromatic hydrocarbon, nitrogen compounds. Results revealed that hydrocarbon migrated from the north to the southeast in the research area. The reservoirs in the research area were of low porosity and low permeability, and under-compaction ubiquitously existed between the Chang-6 and Chang-8 reservoir groups, leading to the existence of abnormally high over-pressure in the Chang-7 reservoir group, which provided the main driving force for the oil/gas migration. Meanwhile, the sand body in the underwater distributary channel, the local nose structures, the faults and fractures in the region largely controlled the migration direction of the oil/gas. They were all developed in the southeast part of the region, providing advantageous delivery conditions for the oil/gas to migrate to the southeast part of the region.

1. Source rocks and geological background

Ordos basin in Mesozoic-Cenozoic was a large asymmetric depression developed on old stable block in north-to-south direction whose west wing was steep and narrow while the east one was wide and flat. It was reported by Li (2004, 2011) that the fold was developed at the edge of the basin, the internal structure was relatively simple. The Upper Triassic Yanchang formation deposited in the basin had experienced a whole geological evolution stage of lake occurrence, development and demise, so a complete set of sandstone sequence with progradation-vertical accretion-retrogradation and 10 oil groups including Chang-10 to Chang-1 from the bottom to the top had developed. The sandstone was all of low-permeability, with porosity between 6%~16% and permeability between 0.1×10^{-3}~2×10^{-3} μm^2.The Zhenjing region was located in the south of the Tianhuan syncline of Ordos basin and to the southeast of Qingyang city (Fig. 1). Except for the complex structures developed at the edge, flat monoclinic structures composed the main part of the basin. As confirmed by Shi et al (2003) that stratigraphic and lithologic traps were developed in the Mesozoic formations. Yang and Zhang (2005) had figured out that Chang-7 mudstone and shale was the main source rock of this area.

2. Tracing oil/gas migration direction by geochemical parameters

2.1. Saturated hydrocarbon

2.1.1. n-alkanes

Later and Horstad (1992), Later and Bowler (1996) had confirmed that molecular could serve as indicators for secondary migration of oil. Curiale (1996) reported the chromatographic effect happened during oil/gas migration would enable the normal alkanes with relatively short chain and smaller molecular weight compounds to move faster than those with long chain and larger molecular weight, and the former would enrich following the migration direction, meaning that with increasing of migration distance, value of (C_{21}^{-}+ nC_{22}^{+})/ (nC_{28}+nC_{29}) and nC_{21}^{-}/nC_{22}^{+} would increase too. As it could be seen from figure 2, values of (C_{21}^{-}+ nC_{22}^{+})/ (nC_{28}+nC_{29}) and nC_{21}^{-}/nC_{22}^{+} increased in crude oil from north to southeast in Zhenjing region, indicating that the oil/gas might migrate from north to south in this area.

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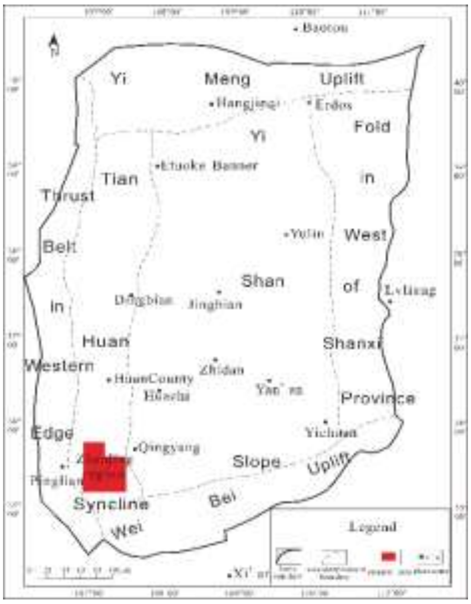


Figure 1: Geographic position of the research area

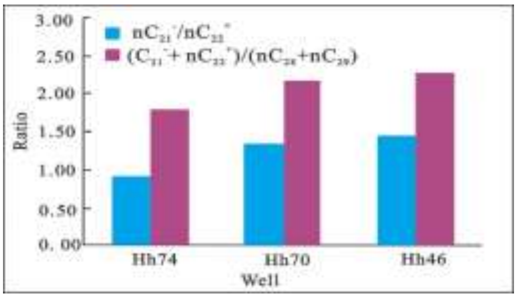


Figure 2: Distribution characteristics of C_{21}^{-}/C_{22}^{+} and $(C_{21}+ C_{22})/ (C_{28}+C_{29})$ of crude oil from north to south in Zhenjing region

2.1.2. Steroids and terpenoid compounds

As tricyclic terpene and pentacyclic terpane was resistant to biodegradation which was affected only when the oil encountered strong biodegradation. Tricyclic terpane had smaller molecular weight than pentacyclic terpane, so tricyclic terpane/pentacyclic terpane value increased gradually with the increase of oil/gas migration distance. The same happened to rearrangement sterane/regular sterane. As a result, the tricyclic terpane/pentacyclic terpane and rearrangement of terpane sterane/regular sterane values could be used to indicate oil/gas migration direction.

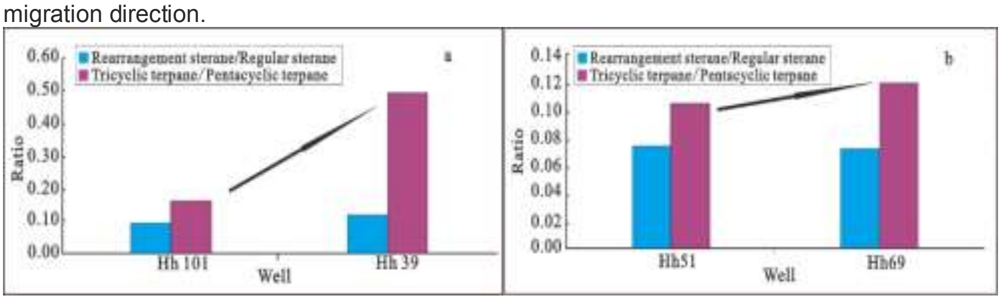


Figure 3: Distribution of steroid and terpenoid of crude oil from north to south in Zhenjing region

As shown in figure 3, the tricyclic terpane/pentacyclic terpane and rearranged sterane /regular sterane of the crude oil in the study area increased from north to south, indicating that the crude oil had a tendency to migrate from north to south. nC_{21}^{-}/nC_{22}^{+} also increased from the north to the southeast in the study area,

$(C_{21}^{-}+nC_{22}^{+})/(nC_{28}+nC_{29})$ and nC_{21}^{-}/nC_{22}^{+} presenting an increasing trend, showing the crude oil in Zhenjing region migrated from the north to the southeast.

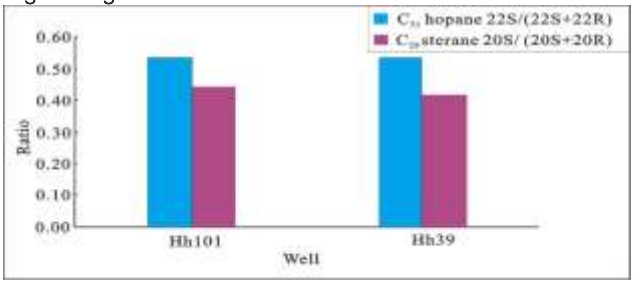


Figure 4: Distribution of maturity parameters of crude oil from north to south in Zhenjing region

According to sandstone reservoir filling simulation by England (1987): Maturity of the early filling oil was lower than that of the late filling oil within a reservoir. Oil with relatively higher maturity was always located at the closest part of the reservoir filling area, so the reducing direction of the oil maturity significantly indicated the way of oil filling [8]. It was also proved by Peters (1991) that homohopanes in petroleum could be used in tracing oil migration. It could be seen from figure 4 of maturity parameter C_{29} sterane 20S/ (20S+20R) and C_{31} hopane 22S/ (22S+22R) that oil maturity reduced from north to south in the research area.

2.2. Aromatic hydrocarbon

According to the research by Radke(1988), Chakhmakhchev et al (1997) and Wang (2005), alkyl benzene and thiophene parameters such as 4-/1-MDBT, 2,4-/1,4-DMDBTand4,6-/1,4-DMDBT could serve as an effective tool to indicate the oil/gas migration path, which could be used not only for crude oil of different maturity, but also for biodegraded crude oil and the mixed crude oil from same source rock and different filling phases. With the increasing of oil/gas migration distance, the above parameters would reduce. On the overall performance, 2-/1-MDBT, 4-/1-MDBT, 2,4-/1,4DMDBT, 4-/1-MDBT, 2,4-/1,4DMDBT, 4,6-/1,4 DMDBT, 2,6-/1,4DMDBT and 4,6-/1,4 DMDBT values decreased from northwest to southeast (Fig. 5), reflecting the oil migrated from northwest to southeast in the study area.

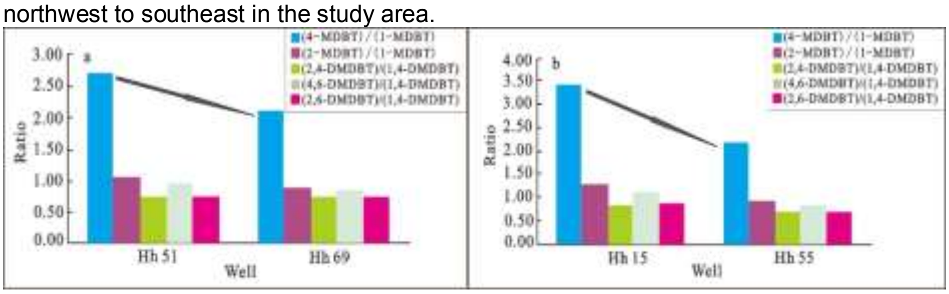
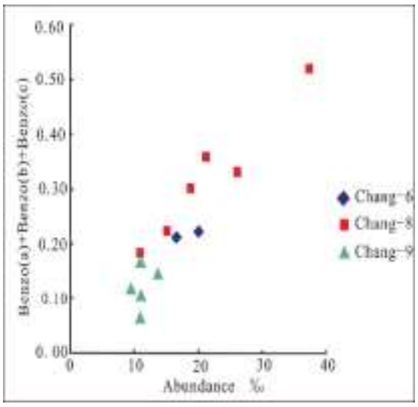


Figure 5: Alkyl benzene and thiophene (DBT) distribution characteristics in Zhenjing region

2.3. Nitrogen compound

Santamaria et al (1998) had reported that nitrogen compound was common non-hydrocarbon component in crude oil, which served as an important means for tracing oil/gas migration path. In the process of oil migration, as interaction should happen between polar nitrogen compounds and the surrounding rock surface, the concentration of the nitrogen compounds would decrease, and the ratio of different isomers would vary. Different structural isomers of styrene acrylic carbazole existed in Styrene acrylic carbazole, with the linear benzo [a] carbazole and semi-spherical benzo [c] carbazole isomers as the most common ones. Benzo [a] carbazole molecules moved faster than benzo [c] carbazole molecules, leading to the relative enrichment of benzo [a] carbazole molecules with the increasing of oil/gas migration distance, as confirmed by Dorbon (1984). Multiple samples of nitrogen compounds in the study area had been selected for this study, and it had been found that a good positive correlation existed between the nitrogen compound abundance and benzo [a] carbazole + benzene [b] carbazole + andbenzo [c] carbazole, which all decreased with the increasing of migration distance, and the same happened in the plane. Two kinds of the parameters on the whole showed a decreasing trend from north to the southeast indicating that the oil migrated from the north to the southeast in the study area (Fig. 6 and 7).



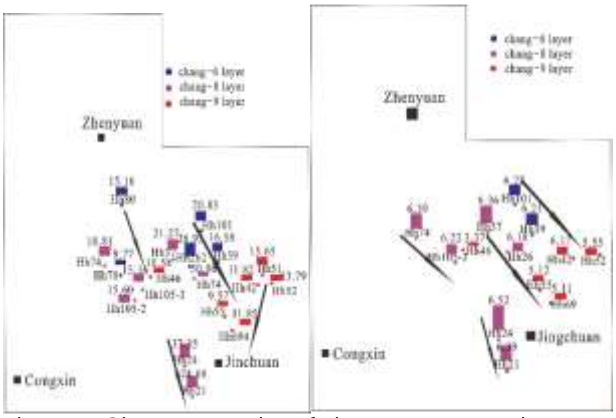


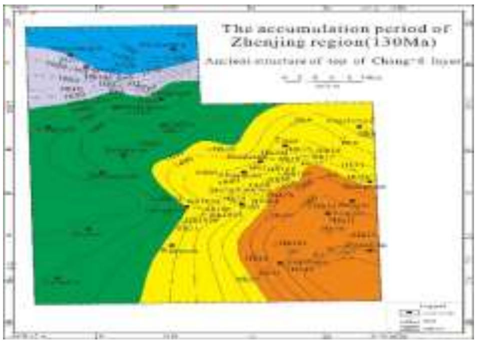
Figure 6: Correlation between nitrogen abundance(left) compound abundance and benzo [a] carbazole + benzene [b] carbazole + andbenzo [c] carbazole

Figure 7: Characterwastics of nitrogen compound and benzo [a] carbazole + benzene [b] carbazole + andbenzo [c] carbazole (right) in Zhenjing region

The chromatographic effect indicated by saturated hydrocarbon, sulfur compound and nitrogen compound had obviously and clearly shown the pathway of oil-gas migration. Considered the characteristic of structural section of reservoir formation period in Zhenjing region (Fig. 8), it was found that the southeast was higher than the northwest, the moving direction of the oil/gas was from the higher to the lower part (Fig. 9). The source rock of Yanchang formation of Chang-7 layer in the study area, without water washing, oxidation or biodegradation were in good condition, combined with good preservation condition, so the crude oil properties were affected by the oil/gas migration. It migrated in vertical direction with short distance.

3. Migration dynamics of oil/gas in low permeability reservoirs

Research showed that there were big differences in liquid dynamics system in basins with different nature or in the same basin at different evolution stages. For basin with fault, the fault imposed great influence on the process of oil migration and reservation, and the dynamics of oil migration was often connected with tectonic stress. For depression basin, especially for those with tight sandstone reservoirs, the main pathways of oil migration were sand body, unconformable surface and fractures, and the main dynamics of oil migration came from over-pressure. The fluid pressure was the main dynamics of oil migration in the low-permeability reservoir of Erdos Basin. Under-compaction was quite popular between the Chang-6 and Chang-8 layers inthe Erdos basin. The over-pressure in Chang-7 layer was abnormally high and it decreased upward and downward, so the over-pressure generated during the high peak of hydrocarbon generation and expulsion had an important influence on the process of oil migration and reservation. The distribution of the high values of over-pressure matched well with the center of sedimentation which was high in the center of the basin and low at the edge.



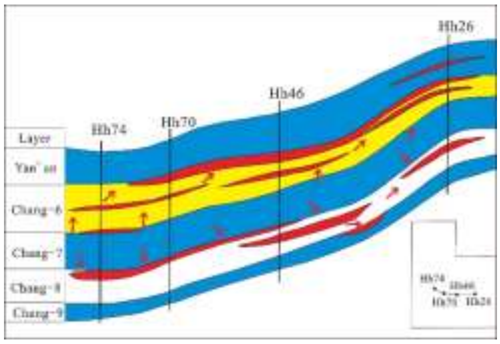


Figure 8: Ancient structure of top of Chang-6 laye regionin its accumulation period (130Ma) in Zhenjing Region（according to internal information from North China Branch, Sinopec，2010, with little change）

Figure 9: Oil/gas migration direction in Zhenjing

The fluid over-pressure of Chang-6 layer mainly appeared in the south of Wuqi and Zhidan area. The over-pressure of Chang-7 layer was common and it was higher in the south than in the north. Deng (2011) once pointed out the fluid over-pressure of Chang-6 and Chang-7 layers was distributed in Zhidan and Fuxian area (Fig. 10). Considering the dynamics of oil migration in the low permeability reservoir and the distribution characteristic of over-pressure in Yanchang formation of Erdos, an important conclusion could be drawn that the direction of oil migration was from north to southeast and the northeast of the study area was favorable area of oil reservation.

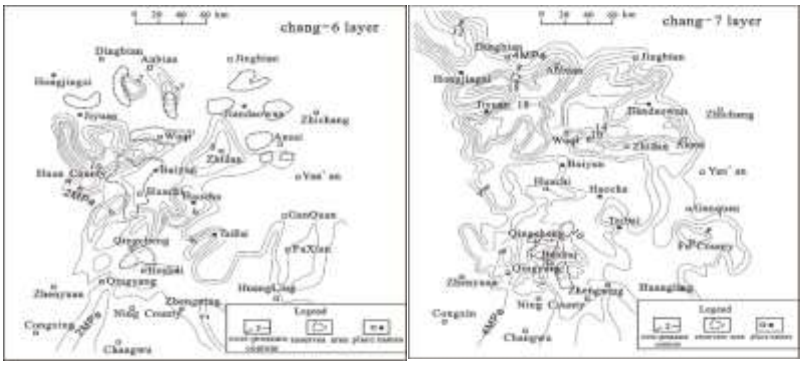


Figure 10: Distribution characteristics of over-pressure and reservoirs of Yanchang formation in Ordos basin (according to Deng, 2011)

4. Migration pathway of oil/gas in low permeability reservoirs of Zhenjing Region

Researchers had pointed out Yanchang formation in Zhenjing region was mainly developed in the front of braided river delta (Fig. 11) and lithologic traps were the main reservoirs, so the oil/gas distribution was controlled by favorable face belt. The channel sand body on the delta front was the main part where the reservoirs were formed and distributed of Yanchang formation. As it had been stated above, the structures in Zhenjing region was a simple and flat monoclinic structure featured with local nasal structure. The nasal structure, which skewed with the north-to-east main channel, controlled the oil/gas enrichment, and oil/gas mainly distributed on the higher part. The main characteristic of low permeability reservoirs was the highly developed faults and fractures, and for Zhenjing region it was no exception. Zhang (2008) and Yin (2012) had proved that structural fractures greatly developed in Yanchang formation, playing an important role for the improvement of the reservoir performance and controlled the oil/gas enrichment effectively.

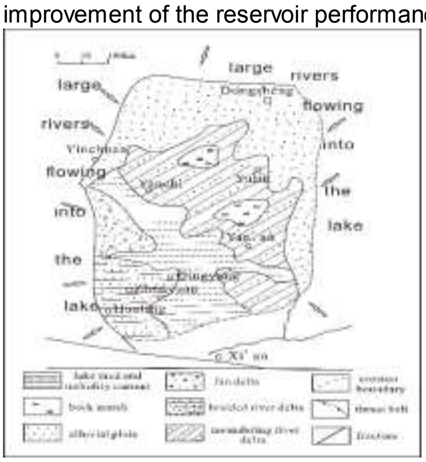


Figure 11: The sedimentary system of Upper Triassic Yanchang formation in Ordos basin (according to Liu, 2006)

Comprehensively, it could be seen that the channel sand body of the delta front, local nasal structure as well as faults and fractures developing in the southeast of the Zhenjing region, greatly controlled the oil/gas migration direction, which further confirmed the fact that the oil/gas migrated from the north to the south.

5. Conclusions

Study by geochemical characteristics of saturated hydrocarbon, aromatic hydrocarbon, nitrogen compounds of the crude oil samples of Zhenjing region in Erdos basin to track the oil/gas migration direction. It was found that the oil/gas migrated from the north to the south in the area. Moreover, the migration dynamics and pathways greatly matched with the tracing results, which, on the other hand, further proved the north-to-south migration direction of the oil/gas in the research area.

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References

Chakhmakhchev A., Suzuki M., Takayama K., 1997, Distribution of alkylated dibenzothiophenes in petroleum as a tool for maturity assessments, Organic Geochemistry, 26(7), 483~490, S0146-6380 (97) 00022-3.

Curiale J.A., Bromley B.W., 1996, Migration induced compositional change in oils and condensates of a single field, Organic Geochemistry, 24(12), 1097-1113, DOI: 10.1016/S0146-6380(96)00099-X.

Deng X.Q,, Yao J.L., Hu X.F., et al, 2011, Characteristics and Geological Significouldce of Hydrodynamic System on ultra-low Permeability Reservoir of Yanchang Formation in Ordos Basin, Journal of Northwest University (Natural Science Edition), 41(6), 1044-1050, DOI: 10.16152/j.cnki.xdxbzr.2011.06.018.

Dorbon M., Schmitter J.M., Garrigues P., et al, 1984, Distribution of carbazole derivatives in petroleum, Organic Geochemistry, 7(2), 111-120, DOI: 10.1016/0146-6380 (84) 90124-4.

England W.A., Mackenzie A.S., Mann D.M., et al, 1987, The movement and entrapment of petroleum fluids in the subsurface, J Geological Society, 144(2), 327~347, DOI: 10.1144/gsigs.144.2.0327.

Larter S.R., Bowler B.F.J., Li M., Chen M., Brincat D., Bennett B., Noke K., Donohoe P., Simmons D., Kohnen M., Allan J., Telnaes N., Horstad I., 1996, Molecular indicators of secondary oil migration distance, Nature, 383(6601), 593-971, DOI: 10.1038/383593a0.

Larter S.R., Horstad I., 1992, Migration of petroleum into Brent Group reservoirs, some observations from the Gullfaks Fields, Tampen SpurArea North Sea, Geological Society London Special Publications, 61(1), 441-452, DOI: 10.1144/GSL.SP.1992.061.01.22.

Li D.S., 2004, Return to Petroleum Geology of Ordos Basin, Petroleum Exploration and Development, 31(6), 1-7, DOI: 10.3321/j.issn:1000-0747. 2004. 06. 001.

Li R.X., Duan L.Z., Zhang S.N., et al, 2011, Review on Oil/gas Accumulation with Low Permeability in Ordos Basin, Journal of Earth Sciences and Environment, 33(4), 364-372, DOI: 10.3969/j.issn.1672-6561.2011.04.006.

Moldowan J.M., 1991, Effects of source, thermal maturity, and biodegradation on the distribution and isomerization of homohopanes in petroleum, Organic Geochemistry, 17(1), 47-61, DOI: 10.1016/0146-6380 (91) 90039-M.

Radke M., 1988, Application of aromatic compounds as maturity indicators in source rocks and crude oils, Marine and Petroleum Geology, 5(3), 224~236, DOI: 10.1016/0264-8172(88)90003-7.

Santamaria-Orozco D., Horsfield B., di Primio R., et al, 1998, Influence of maturity on distributions of benzo- and dibenzothiophenes in Tithonian source rocks and crude oils, Sonda de Campeche, Mexico. Organic Geochemistry, 28(7-8), 423~439, DOI: 10.1016/S0146-6380 (98) 00009-6.

Shi J.A., Wang J.P., Mao M.L., et al, 2003, Reservoir Sandstone Diageneswas of Member 6 to 8 in Yanchang Formation (Triassic), Xifeng Oilfield, Ordos Basin, Acta Sedimentologica Sinica, 21(3), 373-380, DOI: 10.14027/j.cnki.cjxb.2003.03.002

Wang T.G., Li S.M., and Zhang A.L., et al, 2000, A discussion on Petroleum Migration in the Lunnan Oilfield of Xinjiang Based on Nitrogen Compounds, Acta Geologica Sinica, 74(1), 85~93, DOI: 10.3321/j.issn:0001-5717.2000.01.009.

Yang H., Zhang W.Z., 2005, Leading Effect of the Seventh Member High-quality Source Rock of Yanchang Formation in Ordos Basin during the Enrichment of Low-penetrating oil-gas Accumulation: geology and geochemwastry, Geochimica, 34(2), 147-154, DOI: 10.3321/j.issn:0379-1726.2005.02.007.

Yin W., Zheng H.R., Hu Z.Q., et al, 2012, Main Factors Controlling Hydrocarbon Accumulation and Favorable Exploration Targets for the Yanchang Formation in Zhenjing Werea, south Ordos Basin, Oil and Gas Geology, 33(2), 159-165, DOI: 10.11743/ogg20120201.

Zhang Z.L., Zhou W., Su F.Y., 2008, Research on the Relationship between Dwastributions of Fluvial Facies Sandbody and the Formatiom of Trap, the Yanchang Formation in Zhenjing Region, J Mineral Petrol, 28(4), 95 -99, DOI: 10.3969/j.issn.1001-6872.2008.04.016 .