Identification signs for sedimentary facies of complex carbonate oil reservoirs

—— the case study on North Tluwa Oilfield in the eastern margin of the Pre-Caspian Basin

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Abstract: In this paper, the method to confirm the sedimentary environments and microfacies of reservoirs of complex carbonate oil reservoirs was illustrated on the basis of cores and logging data. The sedimentary environments of reservoirs are petrographically confirmed on the basis of rock color, sedimentary structure, paleontology and rock types. Red rocks are the products of oxidation environments and grey rocks represent the sedimentation of reducing environments. Stable structures indicate lower energy of water bodies and cross bedding is deposited in the water bodies with high energy. From the aspect of electrofacies, shale content is higher in low-energy environments but lower in high-energy environments. Gamma ray is of low value. And dolomite content is higher in evaporative platforms and restricted platforms than in open platforms. And then, the case study was conducted on North Tluma Oilfield in the eastern margin of the Pre-Caspian Basin. And based on the cores and logging data, it is ascertained that KT-I reservoir is deposited in the environment of open platform-restrict platform-evaporative platform and KT-II reservoir is the product of open platform.

Regional Summary

The Pre-Caspian Basin is tectonically located in the southeast of Eastern Europe Platform, and to the east, it is bounded with Ural Hercynian folded mountain system. In the eastern margin of the Pre-Caspian Basin, multiple carbonate oil and gas fields have been discovered below saline formations and their hydrocarbon bearing series are acted by Visean-Upper Carboniferous carbonate reservoirs, which are divided into two platform carbonate reservoirs (i.e., KT-1 and KT-2) by the barrier of MKT clastics with higher shale content. Carbonate reservoirs were deposited in the environment of marine platform. At the late stage, they were uplifted and their lithology, physical properties and reservoir space types were quite diversified and complex. And consequently, this area becomes the study target of dual-medium large complex carbonate oil and gas reservoirs. During the Carboniferous, it was located in the eastern margin of Eastern Europe Platform, where it was the normal sea sedimentation environment in low-latitude tropical or subtropical humid climate with abundant marine creatures.

Lithofacies Identification Signs

When North Tluwa Oilfield was initially developed, multiple coring wells were drilled. According to core characteristics, the sedimentary environments of Carboniferous strata were preliminarily analyzed from the aspects of rock color, sedimentary structure, paleontology and rock types.

Rock color

The original colors of rocks play an important role in indicating sedimentary environments. The red class (e.g. red, yellow, brown, yellow red, purple, grey purple, brown red and red brown) represents oxidation environments, light color class (e.g. ligth grey, offwhite and white) for weak reducing environments and dark color class (e.g. grey, dark grey, black and grey black) for reducing environments.

Based on the description data of cores and cuttings, the rocks in this area appear in various colors as follows.

Limestones: brown grey, light brown gray, dark brown gray, grey brown, light grey brown, light grey, grey, dark grey, grey black, with light colors as the dominant, indicating weak oxidation-weak reducing environments (Fig.1).

Argillaceous limestones: brown grey, light brown grey, grey and dark grey, indicating reducing environemnts.

Dolomites: grey brown, indicating weak oxidation environments (Fig.2).

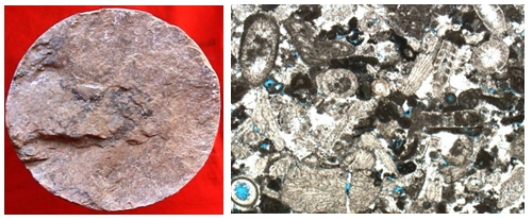

Fig.1 Intraplatform shoal of open platform

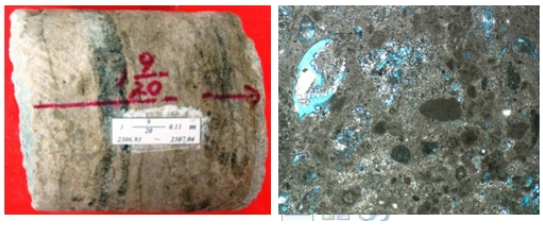

Fig.2 Dolomitic flat of restricted platform

Mudstones, limy mudstones and silty mudstones: brown grey, brown, black grey, red brown, yellow brown, grey brown, blue grey, light grey, dark grey, mauve, brown and brown red, diversified and complex colors indicating the diversity of the formation environments of mudstones, including oxidation, weak oxidation, weak reducing and reducing environnments.

In KT-II reservoir, light colors are dominant without red colors. It is indicated that it was deposited in stable weak reducing-reducing environment. In KT-I reservoir, however, rocks colors are diversified and complex, indicating diversity and unstability of its sedimentary environments.

Sedimentary structure

The sedimenatary structure of carbonate rocks is a good facies sign. In general, it can be easily identified and characterized on field outcrop sections. At the scale of cores, however, the sedimentary structure information that could be identified and provided is rather limited. And in this project, fewer sedimentary structures were observed in the cores from the coring wells.

Massive structure: Limestones are mostly in the form of massive bedding perhaps due to two reasons. First, there is no bedding structure in the limestone itself. And second, the bedding structure can not emerge because of drilling mud .

Horizontal bedding: It indicates supratidal or subtidal low energy environments. It commonly appears in mudstones and dolomites, as well as micrites.

Cross bedding: It indicates intertidal-subtidal high energy environments with strong hydrodynamics. And it frequently appears in grain limestones in grain shoals and intraplatform shoals.

Exposed structure: It indicates the exposure environments. For example, mud crack, bird’eye, autobreccia, gypsum-salt pseudocrystal and tepee structure represent supratidal exposure environments.

Evaporation genetic structure: It includes chickenwire, ptygmatic, lumpy and nodular structures in gypsum rocks.

Paleontology

There are multipe types of creatures, including clastics of gastropod, deltidium, pelecypoda, crinoid, Fusulinida, foram, algae and coral (Fig.3). On the whole, it is the environment of open marine platform with open seawater, sufficient oxygen, abundant nutrition and oscillating water bodies which is suitable for the growth of various creatures.

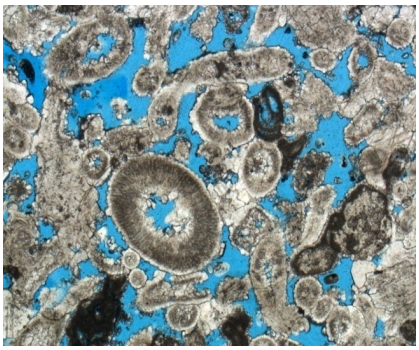

Fig.3 Calcsparite chloroalgal framestone

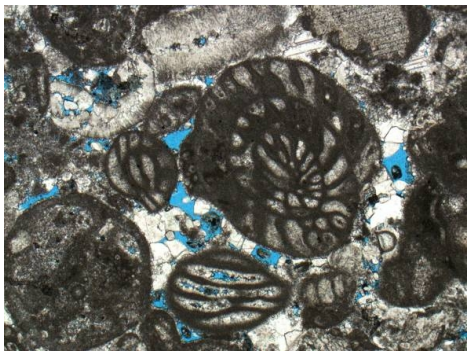

Fig.4 Calcspartie Fusulinida and foram limestones

Rock type

In general, there is no corresponding relation between single rock type and sedimentary environment. The same type of rocks can be formed in different sedimentary environments, and in the same sedimentary environment, different types of rocks can be formed. However, some special types of rocks can indicate sedimentary environments well.

Gpsum rock and salt rock: They indicate evaporation environments and represent evaporative platform facies. In this project, no gypsum rocks or salt rocks is discovered in the coring wells. Based on logging, however, gypsum rocks, salt rocks, gypsum bearing dolomites and gypsum bearing mudstones are developed in KT-I reservoir in some wells, so it is the sedimentary environment of evaporative platform.

Dolomite: It is mostly the product of metasomasis. Gypsum-salt bearing pseudocrystals and nodular muddy powder crystal dolomites are formed in the environment of supratidal sabakha of evaproative platform. And powder, fine, medium and coarse crystal dolomites are deposited in multiple diagenetic environments, such as return permeability, mixed water and buried dolomitization. In this area, dolomites are developed at the upper part of KT-I reservoir with micrite as the dominant and partially powder crystal, and residual bioclastic structures occur. In several particular samples, there is a small amount of gypsum pseudocrystal. To sum up, it is fine, medium and coarse crystal dolomite, indicating the sedimentary environments of evaprotive platform and restricted platform at the upper part of KT-I reservoir (Fig.5).

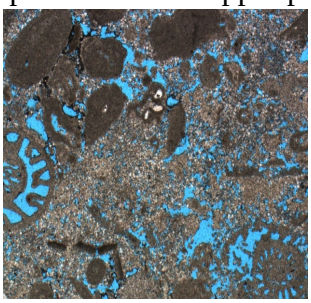

Fig.5 Powder-crystal residual foram dolomite

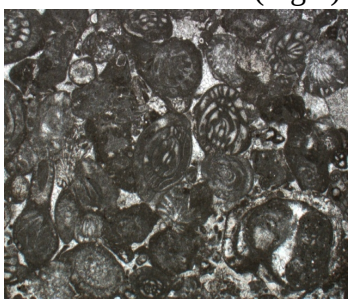

Fig.6 Fusulinida sparite

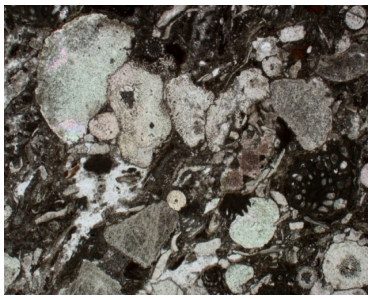

Fig.7 Echinate micrite

Grain limestone: The limestones with grain patterns (grain content＞50%) are deposited in the environment of shoal, with calcsparite cementation indicating the high energy and micrtiic filling indicating the low energy (Fig.6).

Micrite: The limestones with micritte structures (grain content＞50%) are mainly developed in

low-energy environments which are lack of strong hydrodynamic, such as shallow lagoon, tidal flat or deeper slope of restricted platform and basin (Fig.7).

Mudstone: It is composed of fine clay minerals and respresents low-energy environments with weak hydrodynamics. In this area, the mudstones are presented in multiple colors and it is indicated that they are deposited in differente environments, such as the low-energy environments of subtidal lagoon, tidal flat, interbank sea and continetal shelf.

Electrofacies Identification Signs

Logging is one effective approach to identify sedimentary facies of carbonates. And especially when there are fewer coring wells and coring data, it is necessary to study and analyze sedimentary microfacies by means of electrofacies. In this project, sedimentary microfacies are studied by using shale content (VSH), gamma ray (GR), interval transit time (AC), deep lateral resistivity (RD), litho density (ZDEN), calcite content (Calcite), dolomite content (Dolomite) and quartz content (Quartz).

Argillaceous-limy continental shelf: It is lithologically composed of interbeds of mudstones, silty mudstones, sandstones and micrites. VSH, GR and AC logs fluctuate in the shape of saw with small amplitude. Calcite and quartz contents are higher, but no dolomite occurs.

Intraplatform shoal of open platform: It is mainly composed of pure calcites, so its calcite content is high in the form of box. The argillaceous is hardly identified, so VSH and GR are low. And there is no domomite or terrigenous quartz (Fig.1).

Platform algal reef of open platform: In lithology, it is biogenic limestone with organic frameworks as the dominant. It is mainly composed of pure calcites, so its calcite content is high in the form of box. The argillaceous is hardly identified, so VSH and GR are low. And furthermore, AC is high and RD is low.

Interbank sea of open platform: Its VSH and GR are higher than those of intraplatform shoal but lower than those of lagoon. And AC is low and RD is high.

Grain shoal of restricted platform: Its shale content is higher than that of intraplatform shoal of open platform, so its VSH and GR are higher. Its calcite content is high in the form of box. Dolomitization occurs locally, so dolomite content is lower.

Dolomitic flat of restricted platform: It is mainly composed of dolomites and partially calcites, so its dolomite content is high in the shape of tooth and calcite content is low. VSH is low and GR is medium-high, but lower than that of lagoon microfacies (Fig.2).

Limestone flat of restricted platform: Its VSH and GR are slightly higher than those of grain shoal, but lower than those of lagoon. Its calcite content is high in the form of tooth like box. Dolomitization occurs locally, so dolomite content is lower.

Lagoon of restricted platform: There is more argillacoues and calcareous, so its VSH and GR are very high. AC varies in a large range. Calcite content is medium-high and domomite content is lower.

Gypsum-salt lacustrine of evaporative platform: It is mainly composed of gypsum rocks and salt rocks, so its ZDEN and RD are high in the form of box or tooth like box. There is no or few dolomites and calcites, so its calcite content and dolomite content are lower. And there is no or scarce shale, so its VSH and GR is lower.

Gypsum-dolomite flat of evaporative platform: It is mainly composed of gypsum bearing dolomites and dolomites. Its dolomite content is higher, but lower than that of dolomitic flat. There is more shale, so its VSH and GR are higher.

Distribution of Sedimentary Facies

Based on lithofacies and electrofacies analysis, it is confirmed that KT-I reservoir in North Tluwa Oilfield in the eastern margin of the Pre-Caspian Basin is deposited in the environments of open platform-restricted platform-evaporative platform, where the sedimentary microfacies of dolomitic flat, limestone flat, grain shoal and lagoon are mainly developed (Fig.8). And in KT-II reservoir, it is open platform facies where algal reef, intraplatform shoal and interbank microfacies are mainly developed (Fig.9).

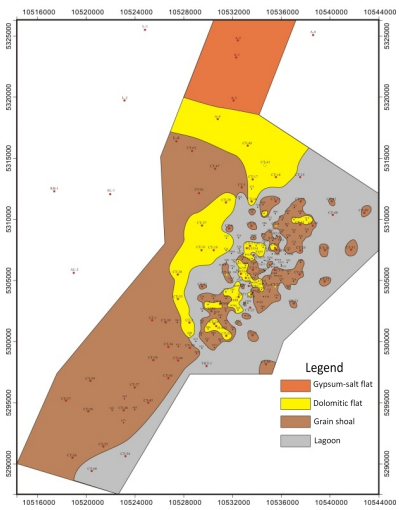

Fig.8 Sedimentary microfacies in KT-I reservoir

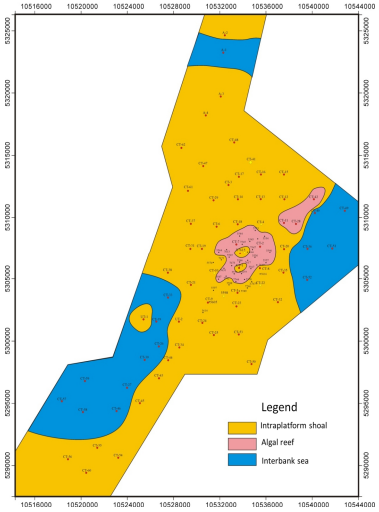

Fig.9 Sedimentary microfacies in KT-II reservoir

Conclusion

Lithofacies and electrofaices are two key factors for the discrimination of sedimentary environments. In lithofacies, the sedimentary environments of reservoirs are confirmed on the basis of rock color, sedimentary structure, paleontology and rock types. From the aspect of electrofacies, shale content is higher in low-energy environments but lower in high-energy environments. Gamma ray is of low value. And dolomite content is higher in evaporative platforms and restricted platforms than in open platforms. The sedimentary environments of Carboniferous carbonate reservoirs in North Tluma Oilfield are confirmed by analyzing cores and logging data. And it is ascertained that KT-I reservoir is deposited in the environment of open platform-restrict platform-evaporative platform and KT-II reservoir is the product of open platform.

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