Shallow Gas Accumulation Discipline in Heidimiao Layers of Daqing Changyuan in Northern Songliao Basin

Hailei Sun1,*

1 Exploration and Development Research Institute, Daqing Oilfield Company Limited, Daqing 163712, China
*E-mail: sunhailei@petrochina.com.cn

Abstract. Shallow gas has been a hotspot in present natural gas exploitation and development due to its shallow depth, low cost of exploitation and development, high production and good benefits. Combined data of core, log, 3D seismic and indoor analysis experiments have been studied. Results indicated: In northern region of Daqing Changyuan, shallow gas can be defined as oil type associated gas from underlying reservoir while in the southern region as mainly degradation gas of crude oil mixed with oil type gas of heavy hydrocarbon component from bacteria degradation in early stage. Main accumulation-affected factors of shallow gas in Daqing Changyuan contain: (1) accumulation of shallow gas was based on early large reservoir as source of gas while in the southern region as mainly degradation gas of crude oil mixed with oil type gas of heavy hydrocarbon component from bacteria degradation in early stage. (2) many reservoir cap combinations in prograded delta front sedimentary environment controlled accumulation location; (3) quaternary structural trap related with source reservoir fracture controlled horizontal distribution of shallow gas accumulation. Gas reservoir was defined as structural gas reservoir. Consequently, for degradation gas reservoir and associated gas reservoir of southern and northern Daqing Changyuan respectively, formation mechanism and accumulation model have been founded.

1. Introduction
Shallow gas was mostly buried under 1500m, mainly contain biogas, oil type associated gas, coalbed gas, and source mixed gas and other genetic types [1]. Shallow gas reservoir has advantages of shallow depth, low cost of exploitation and development, high production and good benefits and disadvantages of vertical vulnerable, strict storage condition and difficult dissert prediction [2]. In this paper, comprehensively analyzing genetic types, natural gas source, distribution law and reservoir forming main control factors, accumulation discipline of shallow gas has been indicated, which guide effectively shallow gas exploitation and development in this area and is also important for guiding exploitation of shallow gas in overlying formation above similar discovered large oil field and gas field.

2. Regional Geological Condition
Daqing Changyuan is located at central sag of Songliao basin which is near Qijia-Gulong sag in the west and Sanzhao sag in the east and is most oil and gas enriched secondary structural unit. 3 oil bearing series, bottom Fuyang oil layers and middle Sa, Pu, Gao oil layers and upper Heidimiao layers, have been discovered. The secondary structural unit consists of 7 tertiary positive structures, Lamadian, Saertu, Xingshugang, Taipingtun, Gaotaizi, Putaohua and Aobaota structure from north to south in turn. Shallow gas of Daqing Changyuan mainly distributes in Heidimiao layers of 2nd, 3rd and 4th member in Cretaceous Nenjiang formation. Nenjiang formation sedimentary period belongs to earlier stage of uplift of Songliao basin and massive lake regression. Whereas Daqing Changyuan is
located at the depocenter of lake basin, sedimentation kept relatively stable and a set of sand shale formation was developed by eastern provenance prograded delta deposit.

3. Genetic Type and Source of Shallow-buried Natural Gas

In shallow gas of Heidimiao layers in Punan area, methane has a lighter carbon isotope among -60 ~ -65‰ with a broken line in the plate (Figure 1). It was overlapped with the line of natural gas in the degraded oil of Heidimiao layers. Such features show natural gas of Heidimiao layers in Punan area is mainly degradation gas of crude oil mixed with small amount of oil type associated gas of heavy hydrocarbon components.

In shallow gas of Heidimiao layers in Aonan area, carbon isotope of methane is among -54 ~ -57‰ with a broken line in the plate (Figure 1). Carbon isotope of propane is inversed with butane and Carbon isotope of ethane and butane are overlapped with that in associated gas of underlying P oil formation. Such features show that natural gas of Heidimiao layers in Aonan area is mixed gas of degradation gas and oil type gas with secondary alteration. Shallow gas of Southern Changyuan is mainly from early Heidimiao layers of which crude oil was degraded and then shallow gas reservoir and heavy oil reservoir were formed.

![Figure 1. Chung genetic type plate of shallow gas of Heidimiao layers in Daqing Changyuan](image)

4. Accumulation Discipline of Shallow-buried Natural Gas

In Southern Changyuan, natural gas is mainly crude oil degradation biogas from early oil reservoir. Almost each well in Southern Changyuan can be seen oil and gas show in Heidimiao layers. In tertiary structural traps, 83% wells show oil bearing degree above oil immersion. It indicates that tertiary structural traps are almost full of oil reservoirs. Such large reservoirs supplied adequate oil and gas for secondary heavy oil reservoir and degradation biogas reservoir formed by damage of reservoir later.

In Northern Changyuan, natural gas is original from super-saturated associated gas from underlying Saertu, Putaohua and Gaotaizi formations [3], which can supply adequate gas for Heidimiao layers with large oil bearing area and 300m oil column.

Heidimiao layers is eastern province prograded delta sedimentation with large distribution of sand bodies of dividing channels, estuary dams and far sand dams and others of delta front. Strata is buried shallow with 2~10m sand thickness and 10%~50% sand than and 300~700m buried depth. Reservoir owns good properties with mainly 22.9~35.0% of porosity and 10~1500 mD permeability. High quality reservoir space is provided for shallow gas accumulation.
In 2nd member of Nenjiang formation, no sandstone developed in Southern Changyuan but a set of 10-43m sandstone reservoir developed in Northern Changyuan with 70–90% mud than, above this reservoir, a set of 30-50m mudstone cap rock was developed and stable regional cap rock was formed. In 3rd member of Nenjiang formation with 50–90% mud than, due to degraded delta, inverse cycle characteristics of strata was formed with well top reservoir of a certain thickness of mudstone layers which formed barrier for bottom reservoir. Reservoir and cap assemblages have a stable distribution; In 4th member of Nenjiang formation with 50–70% mud than, due to long term water subsidence deposition, sand bodies like underwater distributary channels and estuary dams were developed in reservoir, no stable regional caprock existing.

In Heidimiao layers of Daqing Changyuan, shallow gas mainly from underlying source rock or reservoir and its distribution is mainly controlled by faults [4-5]. Faults of Daqing Changyuan cut through Nenjiang formation to Yaojia formation and even Qingshankou formation and effectively communicate source rock and reservoir which can be regarded as channel from deep to shallow of oil and gas. Daqing Changyuan is consisted by 7 tertiary positive structures which were complicated further due to the cut of faults. Then quaternary structural traps related with faults were formed like faulted anticlines, faulted noses and faulted blocks. Presently, gas reservoirs in 5 tertiary structural traps of Daqing Changyuan all distributed in quaternary structural traps related with source reservoir fracture. Such traps control horizontal distribution of shallow gas accumulation.

In Heidimiao layers of Daqing Changyuan, reservoir was developed. 2nd and 3rd members of Nenjiang formation features multiphase delta prograded sedimentation. Multiphase superimposed estuary dams were formed as stable reservoir and mudstone layers deposited between 2 stage estuary sedimentation as stable cap rock. The special depositional pattern decided the gas reservoir as layered structure gas reservoir (Figure 2); Reservoirs developed in 4th members of Nenjiang formation but with undeveloped regional cap rock. Thus, gas mostly enriched in high points of structure and well combination with local cap rocks formed in vertical.

In Northern Changyuan, shallow gas was from associated gas of underlying reservoir. Lamadian, Saertu and Xingshugang oilfields of Northern Changyuan have wide areas and thick oil bearing layers. In original high pressure of reservoir, a large amount of natural gas dissolved in oil. While faults cut through deep reservoirs, reservoir pressure dropped down suddenly. Pressure determines natural gas solubility and depressurization released dissolved gas [6]. Natural gas separated constantly from oil and migrated upwards along faults. At the bottom of reservoir, pure gas reservoir and gas trap formed. Part of gas released migrated further into shallow formation, light hydrocarbon gas; especially methane migrated fastest and longest, even with continuous flow. Shallow gas reservoir was formed in traps of Heidimiao layers with well accumulation and preserving condition (Figure 3).
6. Conclusions
In Northern Daqing Changyuan, shallow gas was oil type associated gas from underlying reservoir; in Southern Changyuan, shallow gas was mainly crude oil degradation gas mixed with heavy hydrocarbon gas derived from early crude oil bacteria degradation. Main factors for shallow gas accumulation of Daqing Changyuan: early large reservoirs supplied by many high quality source rocks as source of shallow gas are foundation of shallow gas accumulation; in prograded delta front sedimentary environment, shallow gas accumulation formations are controlled by many reservoir and cap combinations and 3 sets of gas bearing units were formed; horizontal distribution of shallow gas accumulation is controlled by quaternary structural trap connected with source reservoir fracture and gas reservoir type is structural gas reservoir. Accumulation mechanism and pattern were built for crude oil degradation gas reservoir and oil type associated gas reservoir in Southern and Northern Changyuan respectively.

7. Reference
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