[PS]Gas-Water Distribution and Development Strategy of Xujiahe Tight Gas Reservoir in Sichuan Basin, China*

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Abstract

The tight sandstone gas reservoir of Xujiahe Formation, Upper Triassic in central Sichuan basin has drawn increasing interest in China's unconventional gas research circle. For its low porosity, ultralow permeability and high original water saturation, the problem of water production and water flooding presents challenges to gas field development. Xujiahe reservoirs in central Sichuan basin are mainly of labyrinth structure, meaning the reservoirs are relatively high permeability sand lens, randomly distributed in the tight sandstone background which may or may not be interconnected. Meanwhile, the original water saturation of Xujiahe reservoir is quite high with an average of 50%. The gas-water distribution rules of Xujiahe reservoir were discussed in this paper. We conclude as a whole, the tectonic controls the gas-water distribution, and that on the local scale, some gas tops, or zones with relatively high gas saturation, exist in the structural high spots within the interconnected reservoirs. It's realized that to optimize perforation programs to avoid shooting the zones of high water saturation and to moderately enlarge pressure differentials to drain movable water in reservoirs are feasible. On the other hand, spatial drainage gas recovery techniques are utilized to protect gas wells with a certain amount water production from water flooding, which have meet with success in Sichuan basin.

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Introduction

Increasing numbers of tight gas were developed in China: Ordos, Sichuan, and Songliao basin. Meanwhile, water production hindered the TGS development. Gas wells producing more water enduring sharper production reduction, as well as general water flooding.

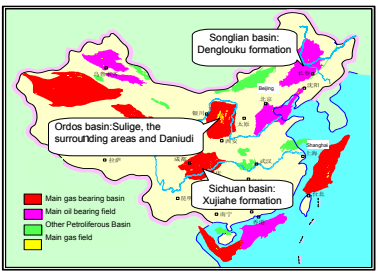


Fig.1 The distribution map of tight gas resources in China

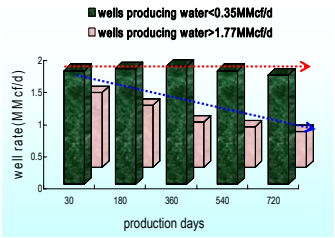


Fig.2 The production comparison of wells producing water

Reservoir characteristics of TGS

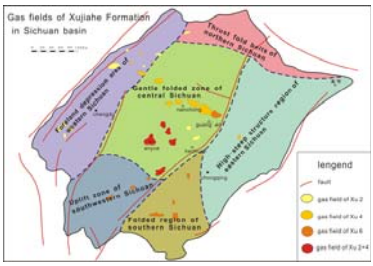


Fig.3 Gas fields of Xujiahe Formation in Sichuan basin

Large scale sand body:

- totally 300m thick of Xu6, Xu4, Xu2 sand sections;
- tens of thousand km^2 extension of Xujiahe formation.
- Dozens of gas fields of Xujiahe formation spreading in basin.

Tight sands:

- Tight gas sands with few mud interlayers
- Sedimentary facies: braided delta
- medium grained feldspar detritus sandstone
- Porosity: 6%-12% average 9.08,
- $K_{in\text{-}situ}$: 0.01mD-0.5mD, average 0.37mD

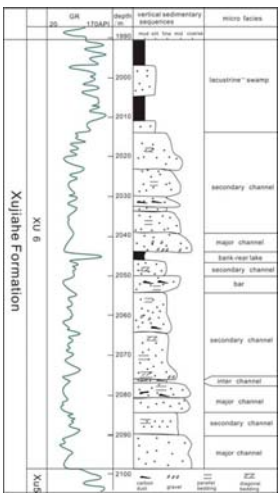
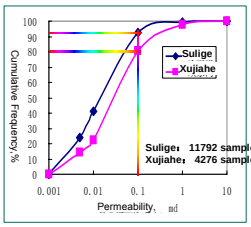


Fig.4 Vertical profile of Xu6 of Well Guang'an 101

Generally, “sweet spots” are limited, most sands are tight



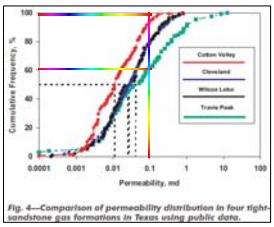


Fig.5 Reservoir $K_{in\text{-}situ}$ accumulation scatter chart

- Sulige, Xujiahe: percentage of samples with $K_{in\text{-}situ}$<0.1mD is 80~92％
- United States: percentage of samples with Kin-situ<0.1mD is 60~95％

Reservoir model:

reservoirs are relative high quality lenticular sands in low permeability background.

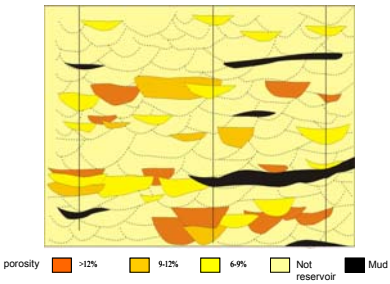


Fig.6 Reservoir model of Xujiahe tight gas sandstone

Gas-water distribution

Original water saturation of Xujiahe reservoirs are generally high, even to 50-65%. It’s because of the insufficient gas displacement of the original formation water through the pool forming process.

Gas tended to occupy the sandstone with higher porosity, while residual formation water occupying the pore throats of relatively poor reservoirs, and mainly were irreducible water.

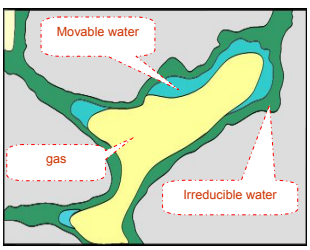


Fig.7 sketch map of gas-water distribution in microscopic scale

For the floatage, gas frequently migrated to the structural high spots, and the lower zones retained the water. That is, structure and property co-control the gas-water distribution.

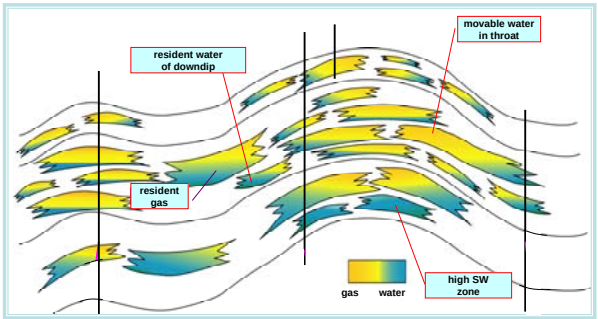


Fig.8 Gas-water distribution profile

Development strategies

(1) To avoid perforating high water saturation zones of well profile with low resistivity, which can prevent from water flooding.

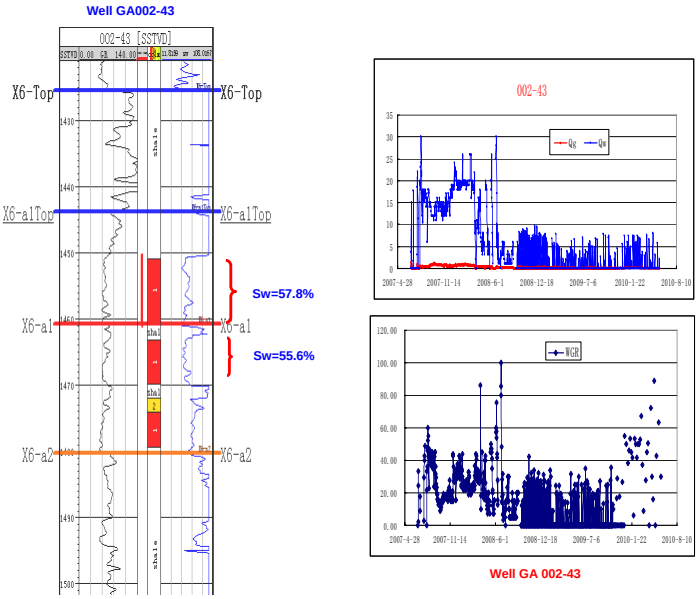


Fig.9 Water saturation profile and production curve of Well GA002-43

For Guang'an gas field, reservoirs of por>12%, Sw＞55% results in water flood

(2) To appropriately magnify the differential pressure, which can extract part of movable water in the reservoirs and avoid water locking.

(3) Water drainage to reduce the water body in a local scale, which had met with success in Sichuan basin.

Xujiahe reservoir of Guang'an gasfield:

- 55 gas well, 53 wells in produce water.
  Water production: highest 200 cubic ft/d, average 30 cubic ft/d
  WGR: average 87 cubic ft/ MMcf;
- 8 water flood wells;
- 17 intermittent production wells(May, 2010), with low hour ratio-3.9 day/month.
  Since 2008, Guang'an gasfield optimized foam drainage as main technique.

Tab.1 Water drainage techniques in Guang'an gas field

techniques		Wells applied	effects
Water drainage	Air lift	GA5	Water flood again soon
	Optimized pipe size	GA126、GA113、GA141、GA002-X53、	Mostly production recovered and enhanced, but bad follow-up production
	Coiling tube	GA002-H1-2	Good enhancement
	Plunger air lift	GA111	Good enhancement at initial stage
	Foam drainage	GA5、GA126	No effect
	Foam drainage（new medicament）	GA107、GA128、GA002-X76、GA002-X78, etc.	Good enhancement

Conclusions

- Gas-water distribution controlled by both structure and reservoir property for TGS with high water saturation.
- Avoid perforating high water saturation zones of well profile with low resistivity, and perforating the structural higher spots and good quality reservoir with low water saturation.
- Insist water drainage.

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