PS Reservoir Forming Mechanism and Main Controlling Factors of Different Types of Large Tight Sandstone Gas Fields in China*

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Abstract

Tight sandstone gas has become a hotspot of the natural gas industry in China. From the latest statistics of resource assessment, total reserves of tight sandstone gas is 300 trillion cubic meters, about 88 – 121 trillion of which could be recoverable. By 2012, China has found sixteen large tight sandstone gas fields such as Sulige, Daniudi and Anyue gas fields. Proved reserve of these gas fields accounts for 49.5% of the total proved natural gas resources in China. These gas fields can be divided into three types: large-area tight sandstone gas in cratonic basins, large-size structural-lithological tight sandstone gas in foreland basins, and structural-lithological tight sandstone (conglomerate) gas in deep rift basins. Tight sandstone gas in the upper Paleozoic of the Ordos Basin and the Xu Jiahe Formation of the lower Jurassic of the Sichuan Basin, the Jurassic tight sandstone gas in the Kuqa Depression and deep buried tight sandy conglomerate in the Songliao Basin are typical representatives of the three types, respectively. Based on components and isotopes of natural gas and maturity of source rocks, we suggest that, for the first type, gas mainly filled and accumulated in near-source reservoir rocks driven by overpressure resulting from hydrocarbon generation. Physical simulation shows that gas migrates in the way of low-velocity non-Darcy seepage and diffusion in tight sandstone. The gradient of overpressure is higher, the range of the trap would be larger, and hydrocarbon saturation would be higher. Fluid inclusions show a wide scope of homogenization temperature with a single peak, which reflects one-period accumulation. Calculated proportions of gas migrated and accumulated accounting for 5.2% of total gas generated. Accumulation and enrichment of these reservoirs are mainly controlled by four factors: structure controls migration direction and accumulation degree, reservoir rock controls scale of the gas pool, effective source rock controls the saturation of gas pool and fractures control enrichment and high yield. For the second type, development of micro-fractures is the key to improved storage space of tight reservoir rock. Therefore, tectonic movement controls accumulation and enrichment of gas pool. In addition, preservation conditions are equally important for this kind of gas reservoirs. As to the last type, natural gas accumulates in the near-source reservoir. Quality of reservoir rock controls accumulation and enrichment of natural gas.

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Introduction

— By 2012, China has found sixteen large tight sandstone gas fields such as Sulige, Daniudi and Anyue gas fields. Proved reserves of these gas fields account for 49.5% of total proved natural gas resource in China.

— These gas fields could be divided into **three** types:

(1) Type Ⅰ: large-area tight sandstone gas in a cratonic basin

(2) Type Ⅱ: large-size structural-lithological tight sandstone gas in foreland basin

(3) Type Ⅲ: structural-lithological tight sandstone (conglomerate) gas in deep rift basin

— Previous studies indicate that these large tight sandstone gas fields have different characteristics.

Goal: To make clear about reservoir forming mechanism and main controlling factors of different types of Large Tight Sandstone Gas Fields in China.

Research Progress

Key factors	Type Ⅰ	Type Ⅱ	Type Ⅲ
Geological background	Overlaying source and reservoir rock	Near-source reservoir	Near-source reservoir
Transporting mechanism	Net system of pores and fractures	Faults, pores and fractures	Faults and fractures
Sealing mechanism	Tight reservoir rock and cap rock	Mudstone barrier	Gypsum mudstone
Migration and accumulation mechanism	Dynamic trap	Faults and lithology	Structure and lithology
Enrichment conditions	Near-source high performance enrichment	Faults controlled high performance enrichment	Anticline controlled high performance enrichment
Distribution law	Near-source large tight sandstone	Around-sag tight conglomerate	Relatively high tight sandstone

a. Type Ⅰ

— **Near-source accumulation:** gas seldom moves long distance in tight sandstone from source rock due to high resistance and poor transportation conditions.

— **Overpressure charged**: overpressure generated from hydrocarbon-generation provide efficient driving force for gas charge.

— **Net transporting system of pores and fractures:** micropores and microfractures construct net-system for gas migration in tight sandstone(*Fig.1*).

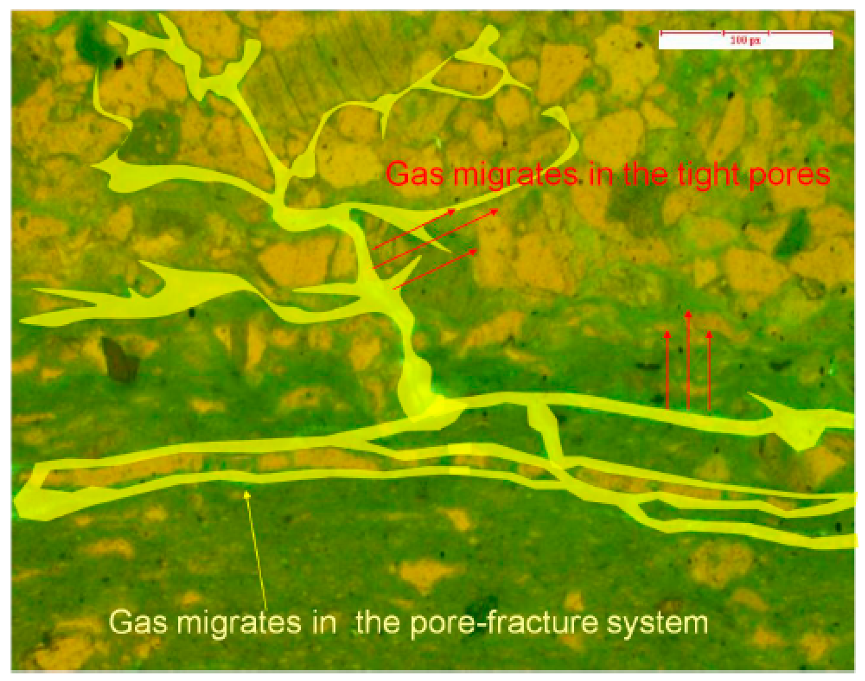

Fig.1 Net transporting system of pore and fracture

— **Non-Darcy seepage migration of low velocity**: migration of natural gas in low-permeability sandstone is non-Darcy seepage migration of low velocity(*Fig.2*).

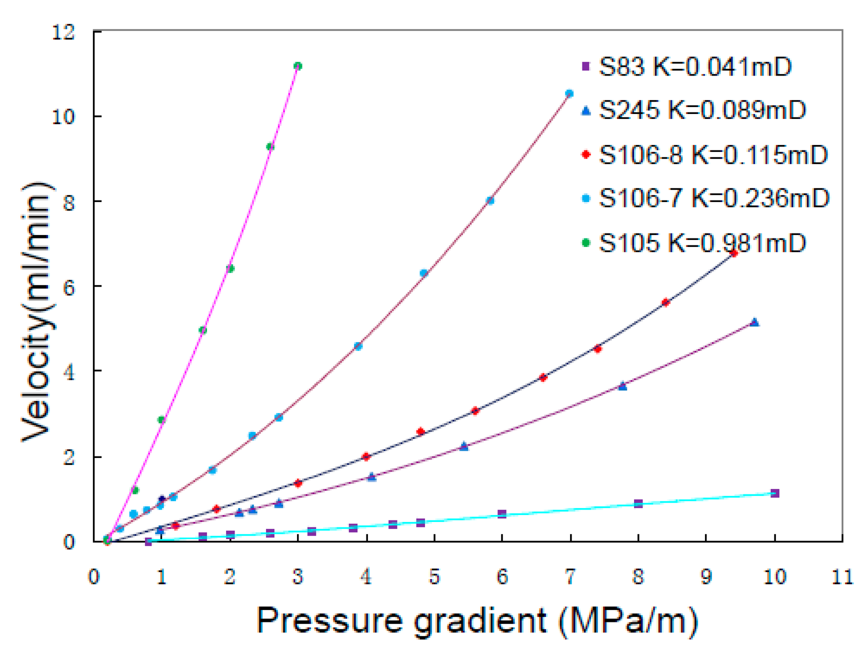

Fig.2 Relationship between flow velocity and pressure gradient

— The lower the permeability of sandstone is the higher pressure gradient is needed for natural gas to migrate in it(*Fig.3*).

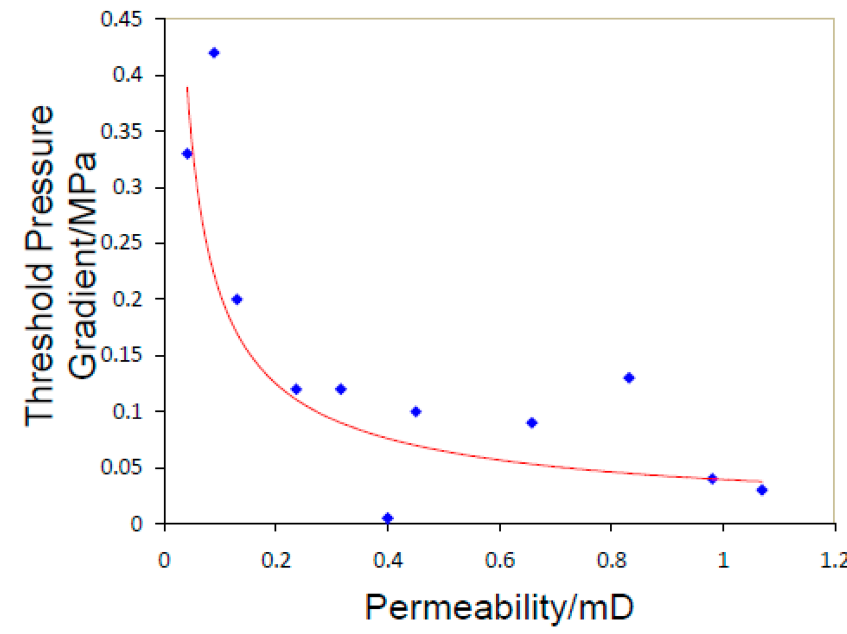

Fig.3 Relation between threshold pressure gradient and permeability

— **Dynamic trap:** overpressure and reservoir rock control the scale of reservoir (*Fig.4*).

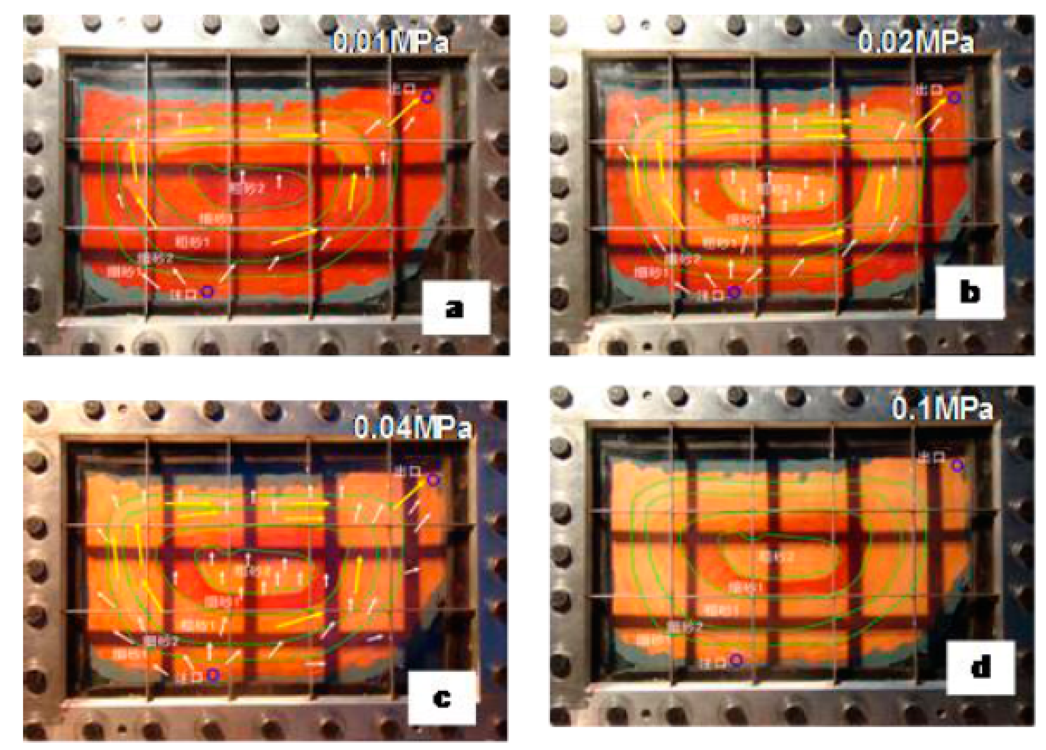

Fig.4 2-D reservoir simulation experiment result of sandstone reservoir

(a. charging pressure 0.01MPa, charging time 382 min b. charging pressure 0.02MPa, charging time 533 min c. charging pressure 0.04MPa, charging time 353 min d. charging pressure 0.1MPa, charging time 247 min)

— **Diffusion is an important migration mechanism:** experiment shows that diffusion could contribute much to tight gas accumulation

— **Continuous charge:** fluid inclusion data shows a wide scope of homogenization temperature with a single peak.

— **Controlling factors:** reservoir property source rock, fracture and structure (*Fig.5*).

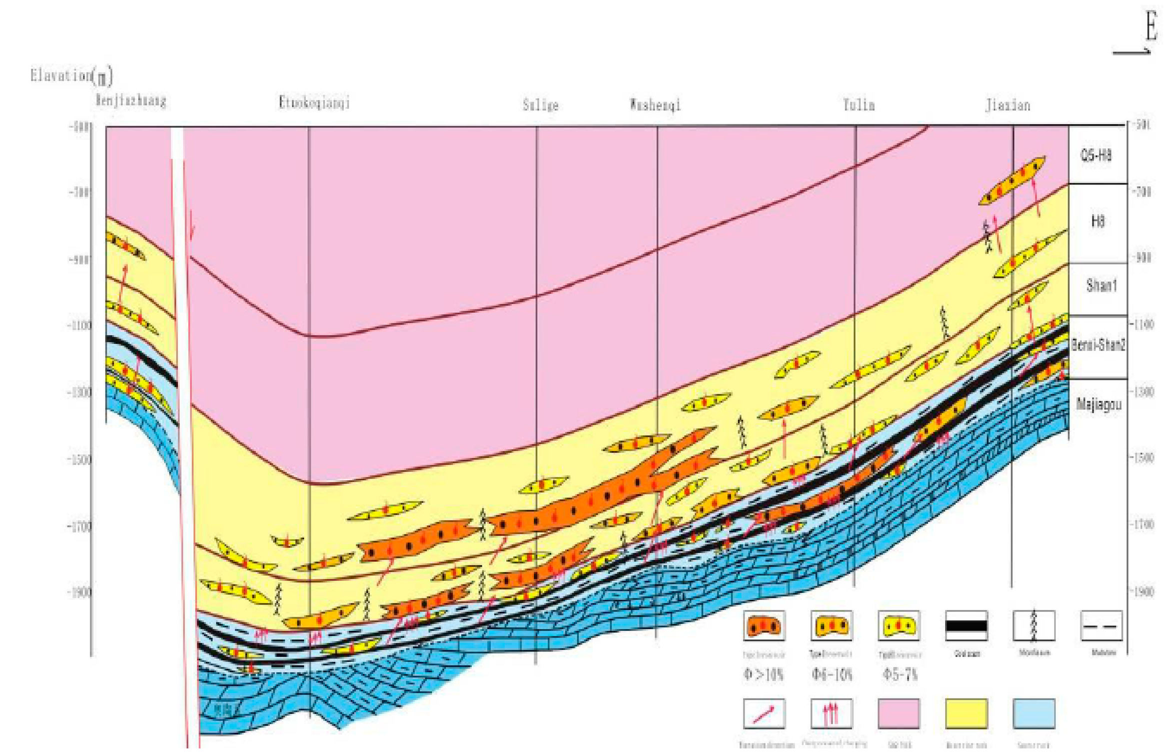

Fig.5 Accumulation model of tight sandstone gas field in upper Paleozoic of Ordos basin

b. Type Ⅱ

— Reservoir rock: reservoir spaces are dissolution pore, intergranular pore and slot around grvel.

— Transporting system of faults and fractures develop well.

— High quality reservoir rock controls accumulation.

— Near-source fan controls distribution of gas play.

c. Type Ⅲ

— Intergranular micropores (Argillaceous microporous and intercrystalline pore) and dissolution pores develop(*Fig.6*).

— Development of the micro-fracture is the key to improve tight reservoir quality.

— Micro-fractures can enhance accumulation efficiency.

— Well kept gypsum and mudstone guarantees gas preservation.

— Relatively high structure-lithology trap is helpful accumulation site.

Discussion

— These three types of tight sandstone gas fields have something in common. Such as poor reservoir rock, near-source accumulation, non-Darcy seepage and diffusion . They are all affected by fractures. But, effect of fractures on them varies. Fractures have much more effect on Type Ⅱ and Type Ⅲ compared with Type Ⅰ. More research is needed for the latter two types.

First author

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