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The Geological Characteristics of Chengkou Type Shale Gas of Lower Cambrian in Dabashan

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1 Introduction

After the successful implementation of large-scale shale gas exploration, development and utilization in United States, the domestic shale gas exploration and development is in a rapid development. However, the progress of exploration and understanding of the high-Evolution shale gas in the complex structure zone of the outer basin are relatively slow, the evaluation method and techniques are extremely lack of. The Chengkou block Located in the hinterland of Dabashan is typical and representative in high evolution marine shale of Paleozoic in mountains of China, the geological characteristics and rich-gas mechanism summarized have a important practical significance in the area of building the correct understanding of enrichment regularity of the high evolution shale gas in reconstruction region of China outer basin area and evaluating the prospect of the resources.

2 The Block Profile and Exploration Progress

The Chengkou block is located in the northeast of Chongqing City —Chengkou County, 400 kilometers away from Chongqing city. Geotectonic position is in the outer Basin of Dabashan arc thrust belt inner surface of northeastern Sichuan Basin, mountains overlap, ravines, the exposed stratum is dominated by Nanhua system of Middle Proterozoic era metamorphic rocks and the Paleozoic lower Cambrian mud shale and carbonate rocks. The dip is high, mainly with 60 degree and 70 degree, the fault is dense and the fold well develops. The block area is 1021km², the target stratum for shale gas exploration is shuijingtuo formation of lower Cambrian, Currently, three geological parameter well and one test well (vertical well) were drilled in the region for shuijingtuo formation of Lower Cambrian, a total footage of more than 6400

meters. four wells are located in chengba fault and xiuchi fault clip from Chengkou to Gao Guan thrust imbricate fragment tectonic belt between 20km² range, complex subsurface structures and great change of stratum were revealed in the drilling, mainly to steep (average dip is more than 60 degrees) and broken strata, fracture and fault breccia well developed. After drilling the surface of Quaternary regolith, the target stratum shuijingtuo formation was exposed, the whole well was drilled in the target stratum, no abnormal formation pressure and harmful gas. Stratigraphic can not be compared between drilled wells, but all with good hydrocarbon gas shows.

3 Shale Gas Shows and Gas Component

a long well segment was showed in the shale gas of upper shuijingtuo formation of lower Cambrian, the accumulative thickness of each well is more than 120 meters, Field desorption total gas ranges from 0.15m³/t to 5.3m³/t, general 1.2m³/t~2.2m³/t, the total hydrocarbon value of Gaslogging is generally more than 2%, up to 47.2%, and bubbles can be seen in the groove. it is different from other parts of the country's large outer Basins (baoding, Chongqing, Guizhou, Hunan Xiushan, Tongren, etc.) in Niutitang formation of lower Cambrian shale gas with containing large amounts of N₂, while in chengkou block the upper shuijingtuo formation of lower Cambrian shale gas is dominated by hydrocarbon gas, methane content ranges from 94.17% to 99.31%, an average of 97.17%, it is the typical dry gas, which contains only a small amount of N₂ and CO₂.

4 The Geological Features of Shale Gas

(1)containing gas is not affected by the faults: the drilled wells were located in imbricate thrust faults fragment belt, surface and subsurface faults are well developed, but rich gas was revealed in the drilling; the

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best gas segment of the well of chengtan yi (CT1) was cutted by two connectivity surface faults; the well of chengdi yi(CD1) showed continuous non-uniform gas from 620 meters to 1500 meters, which is 180 meters away from the well of chengtan yi (CT1),the highest desorption gas content was 4m³/t; tectonic fracture zone and fault breccia belt was drilled in the well of chengdisi (CD4) , the Cumulative depending on thickness was up to 713 meters, 51% of the total wells; the dip ranged from 46 degrees to 90 degrees, with an average of 67.2 degrees, but the well logging gas reservoir and gas reservoir revealed the apparent thickness of more than 400 meters, the maximum gas logging of relatively complete black mudstone Which was preserved in fault fracture zone is up to 14.4%,the core desorption gas content was 5m³/t, methane content was more than 90%. The well of yucan er (YC2) was drilled near large fault, the highest gas content was more than 2m³/t. In such intensive structural damage, lack of sealing and preservation conditions of the construction site, it is difficult to interpret to these wells still appearing good gas shows with existing shale gas accumulation theory

(2) poor correlation between containing gas and TOC: shale gas content was affected by the reservoir's TOC content. In general, commercial gasflow reservoir's TOC is equal to or more than 2%, gas content and total organic carbon were positively correlated, but in Chengkou area, this relationship is not obvious. According to the experimental analysis, organic matter of hydrocarbon generation can't be seen in the rich gas segment with the high organic carbon shale, mostly solid pitch and pitch coke carbon. by core observation, this kind of reservoir schistosity was well developed, it exhibited a metallic luster, thus causing the rock high free gas content.

(3) containing gas and clay, brittle mineral content irrelatd: due to small particles and specific surface area, clay minerals has good adsorption properties, the more clay mineral content, the more adsorption gas. So the containing gas is proportional to the content of clay minerals. Generally speaking, brittle mineral adsorption capacity is weak, so the content is higher, the higher content of free gas, but Chengkou shale gas content whether with clay minerals or brittle mineral content are irrelatd.

(4)There is no relevance between the gas content and reservoir microscopic pore structure: The isothermal physical adsorption and desorption of liquid nitrogen in the most enriched reservoir section of the well of CT1 were carried out, the results showed that shuijingtuo formation reservoir pore average aperture between 6nm ~ 20nm, specific surface area was about 1 ~ 2m²/g. there is no associated among amount of total hydrocarbon gas

with micro pore structure and specific surface area, which shows reservoir's micro-pore structure has little effect on hydrocarbon gas.

(5) the main reservoir storage space is dominated by the inorganic pore and micro fracture: according to argon ion polishing SEM analysis , it showed that in Chengkou District rich-gas shale reservoir developed a lot of fragmentation porosity and micro cracks caused by tectonic extrusion in shuijingtuo formation of lower Cambrian, step and dissolved pores were formed by extrusion slip dislocation in silty mudstone. Hole, slit minor axis diameter general ranged from 100nm to 500nm. These inorganic hole with tectonic and diagenetic dissolution related seam constitute the main reservoir space in chengkou shale gas.

5 Genesis of Chengkou Type Shale Gas

good hydrocarbon show was seen in shuijingtuo formation shale of lower Cambrian in Chengkou district under the condition of dabashan complex tectonic belt , the gas index reached the standard of commercial gas field, which came as a surprise to most of domestic oil and gas exploration experts, scholars and which also draw the departments of land and resources of relevant research institution's great attention. Because of the different geological characteristics of shale gas highlighted in this area from the other regions of China, this paper named it as the "chengkou type" shale gas, the alternative of geological features showed in table one. It is difficult to explain its origin with the general theory and general enrichment rule of the evaluation of shale gas, Although the understanding is unclear, there is a special mechanism in Chengkou shale gas formation and preservation, it is speculated that the shale gas formation and preservation in chengkou is closely related with specific tectonic evolution history of hydrocarbon generation history , the reasons of shale with good gas shows may be as follows:

(1) The fracture cracks close together, no destructive effect: Dabshan is in the northeastern Sichuan Basin border mountains. Since the Indosian, it has experienced multi-stage subsidence uplift - nappe compression effect, the strongest squeezing movement occurred in the Yanshanian period. With the tectonic evolution process, the rich-organic shale of lower Cambrian has also experienced multi-stage Structure transformation and hydrocarbon generation. the stratum experienced early deformation and reclosed again ,then changed into dense rock belt under the later effect of tectonic compression and diagenetic transformation, cracks were filled with quartz, calcite and clay, which were changed into invalidated seam, In the latter part of the settlement

process, the lower Cambrian mudstone continued hydrocarbon generation, it was preserved in the strong squeeze tight formations. Although the Himalayan period is the most strong tectonic movement in Sichuan basin, in Dabashan it may be mainly for the overall uplift, the destructive effects of shale gas is weak.

(2) Shale innate with strong hydrocarbon generation capacity, rich residue; the shuijingtuo formation is formed in deep shelf environment, with good Primitive organic matter type (I - II₁ type), high abundance (TOC is more than 2%), a high degree of thermal evolution (RO is more than 2%), hydrocarbon generation capacity. densification and open action happened one after another formed by multi-stage difference tectonic compression movement, during large amount of hydrocarbon generated in the shale of shuijingtuo formation, dissipation and preservation existed at the same time. The ultimate result of dynamic destruction and squeezing densification is that a lot of hydrocarbon gases were still in the formation. The compressive mechanical crushing nano-grade pore and crack generated by the reservoir is constructed by Strong tectonic compression pressure, which not only increased the free gas reservoir space, but also reduced the diffusion rate. Therefore, in Chengkou area the shuijingtuo formation shale reservoirs are exposed to surface. but rich hydrocarbon gas are still preserved after 600 meters deep .

(3) the lithology of the highest abundance containing gas is mudstone and shale, with frequent interbedding of dense siliceous rocks and carbonate rocks constitute local seals of the mud shale. the cumulative effect of local seals is not only in reducing shale gas diffusion loss ,but also forming continuous multiple heterogeneous lithologic gas bearing features in shuijingtuo formation.

6 The Further Research Direction of Chengkou Type Shale Gas

(1) the Chengkou type shale gas showed rich gas and with high gas index, but whether the commercial gas flow can be formed by fracturing needs to be proved

(2) the preservation mechanism of shale gas is only qualitative inference, has yet to be carried out in-depth scientific research.

(3) evaluation index and the method of exploration technology for shale gas in chengkou urgent research, such as: resource evaluation method, complex surface of underground high and steep seismic imaging technology, high steep complex lithology anti oblique playing fast and low cost drilling technology, formation of high and steep fault lithology changing shale gas reservoir fracturing technology development and so on.

Table 1 the geological characteristics difference between Chengkou type shale gas and known shale gas

Characteristic	known shale gas	Chengkou type shale gas	
Gas controlling factor	TOC is proportional to containing gas (TOC≥2%)	The relationship is not obvious	
shale Gas type	Containing gas is proportional to the clay mineral content; inversely proportional to the brittle mineral content	Irrelevant	
Enrichment condition	Influence of reservoir pore structure on micro gas content significantly	no effect	
Reservoir characteristics	Shale ground pressure	Atmospheric pressure ~ ultra pressure - over-pressure	Atmospheric pressure
	Seal condition	Good sealing layer	No cap is needed
	Sweet point dip	Stay away from fracture	Unaffected by fault
	Reservoir space	Usually less than 30 °	More than30°~90°
	Occurrence	Organic matter and clay minerals interlayer hole hole based, multi-aperture is less than50nm	Tectonic compression fracture hole, slit the main aperture General ranged from 100nm to 500nm
	Fracturing test gas	Free gas mainly (jiaoshiba, Barnett Adsorption gas mainly (Lewis, Antrim)	Free gas mainly
		Industrial gas flow	Unknown, waiting for fracturing gas test reveals