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SHALE GAS IN CHINA：NEW IMPORTANT ROLE OF ENERGY IN 21ST CENTURY

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ABSTRACT

In terms of the shale gas occurring characteristic in china basin, four big provinces could be divided, including SouthChina, NorthChina, Northeastern China, and Northwestern China. It was estimated that the total shale gas resource ranged from 21.5 to 45 trillion m^3, the average value is 30.7 trillion m^3 .In SouthChina province, black shale occurred in upper simian, lower Cambrian, upper Ordovician-lower Silurian, middle Devonian, lower carboniferous, lower Permian, upper Permian, lower Triassic etc. 8 set of formations. Study on TOC, maturity of source rocks proved that that black shale had huge potential in shale gas. In weiyuan anticline of Sichuan Basin, Wei-5 well finished in 1966 had found gas influx and blowout, and acquired 24.6 thousand cubic meter production rate. In Northchina province, upper Paleozoic formation has widely occurred marine-terrigenous facies coal and dark shale layers. Organic matter in dark mudstone ranged from 2 to 5 percent. Thickness ranged from 70 to 200 meter. This is primary condition for shale gas. In western of Ordos basin, many area with high mature coal and mudstone, high hydrocarbon generation rate and developed fractures were favorable places for shale gas exploring. In Songliao basin in Northeastern and Northwestern Province, thick dark mudstone and shale also occurred with high organic matter content and certain maturity is favorable for shale gas. In Cai-3 well of Zhungaer Basin, good gas show has been detected in shale layer.

INTRODUCTION

Shale, an abundant sedimentary rock of extremely low permeability, is often considered a natural barrier to the migration of oil and gas. During the past several decades, ten thousands of oil or gas wells drilled that have penetrated substantial intervals of shale before reaching their target depths. Shale gas is produced only under certain conditions. In gas shale, the gas is generated in place; the shale acts as both the source rock and the reservoir. This gas can be stored interstitially within the pore spaces between rock grains or fractures in the shale, or it can be adsorbed to the surface of organic components contained within the shale. Contrast this to conventional gas reservoirs, in which gas migrates from its source rock into a sandstone or carbonate formation where it accumulates in a structural or stratigraphic trap, often underlain by a gas/water contact. It should come as no surprise, therefore, that gas shales are considered unconventional reservoirs.

It is estimated that the total shale gas resource was over 456 Tcm, mainly located in North America, Latin America, central asia, north Africa and former soviet Union. North America has the largest amount of shale gas in the world and has gotten commercial production in Michigan and Indiana and so on. The gas Produced from shale has over 40 bcm, accounting for 8 percent of all the gas production. In china, shale formed in marine facies and continental facies have a large distributive area over 1 million cubic merters. High shale maturity and TOC showed that it has a huge potential in most basin. China yet has not carried out symmetrical study on shale gas till now. In some china gas basin, like sicuan, zhungaer basin, has acquired industrial gas production in history. In this paper, the authors had analysized the china shale basin characteristics and evaluated the potential of the production potential.

SHALE GAS GEOLOGICAL CONDITION AND RESERVOIR CHARACTERISTICS

The Hydrocarbon Source

Shale comprises clay and silt-sized particles that have been consolidated into rock layers of ultra-low permeability. Clearly, this description offers little to commend shale as a target for exploration and development. However, some shales are known to contain enough organic matter and it doesn't take much to generate hydrocarbons. Whether these shales are actually capable of generating hydrocarbons, and whether they generate oil or gas, depends largely on the amount and type of organic material they contain; the presence of trace elements that might enhance chemogenesis; and the magnitude and duration of heating to which they have been subjected.

Organic matter, the remains of animals or plants, can be thermally altered to produce oil or gas. Before this transformation can take place, however, those remains must first be preserved to some degree. The degree of preservation will have an effect on the type of hydrocarbons the organic matter will eventually produce.

Most animal or plant material is consumed by other animals, bacteria or decay, so preservation usually requires quick burial in an anoxic environment that will inhibit most biological or chemical scavengers. This requirement is met in lake or ocean settings that have restricted water circulation, where biological demand for oxygen exceeds supply, which occurs in waters containing less than 0.5 milliliters of oxygen per liter of water.4 Even in these settings, however, anaerobic microorganisms can feed off the buried organic matter, producing biogenic methane in the process. Further sedimentation increases the depth of burial over time. The organic matter slowly cooks as pressure and temperature increase in concert with greater burial depths. With such heating, the organic matter—primarily lipids from animal tissue and plant matter, or lignin from plant cells—is transformed into kerogen.5 Depending on the type of kerogen produced, further increases in temperature, pressure and time may yield oil, wet gas or dry gas.

Kerogen Maturity

Geological processes for converting organic material to hydrocarbons require heat and time. Heat gradually increases over time as the organic matter continues to be buried deeper under increasing sediment load; time is measured over millions of years. Through increasing temper - mature and pressure during burial, and possibly accelerated by the presence of catalyzing minerals, organic materials give off oil and gas.

This process is complicated and not fully understood; however, the conceptual model is fairly straightforward. Microbial activity converts some of the organic material into biogenic methane gas. With burial and heating, the remaining organic materials are transformed into kerogen. Further burial and heat transform the kerogen to yield bitumen, then liquid hydrocarbons, and finally thermogenic gas, starting with wet gas and ending at dry gas.

The process of burial, conversion of organic matter and generation of hydrocarbons can generally be summed up in three broad steps (above right). Diagenesis begins the process. It is often characterized by low-temperature alteration of organic matter, typically at temperatures below about 50°C [122°F].12 During this stage, oxidation and other chemical processes begin to break down the material. Biological processes will also alter the amount and composition of organic material before it is preserved. At this point, bacterial decay may produce biogenic methane. With increasing temperatures and changes in pH, the organic matter is gradually converted to kerogen and lesser amounts of bitumen.

Catagenesis generally occurs as further burial causes more pressure, thereby increasing heat in the range of approximately 50° to 150°C [122° to 302°F], causing chemical bonds to break down within the shale and the kerogen.

Hydrocarbons are generated during this process, with oil produced by Type I kerogens, waxy oil produced by Type II kerogens, and gas produced by Type III kerogens. Further increases in temperature and pressure cause secondary cracking of the oil molecules, resulting in production of additional gas molecules.

Metagenesis is the last stage, in which additional heat and chemical changes result in almost total transformation of kerogen into carbon. During this stage, late methane, or dry gas is evolved, along with nonhydrocarbon gases such as CO2, N2 and H2S.

The preservation and maturation of organic matter are not unique to gas shales. The model for generating oil and gas is actually the same for conventional and unconventional resources. The difference, however, is location. In conventional reservoirs, oil and gas migrate from the source rock to the sandstone or carbonate trap. In unconventional shale-gas reservoirs, hydrocarbons must be produced straight from the source rock.

Shale gas reservoir characteristics

Form the experience of America, Geologists evaluate heterogeneity at a wellbore scale by analyzing cores and well logs. Shale typing by petrological analysis of drill cuttings, complemented by TOC measurements and log analysis from multiple wells, allows preliminary evaluation of reservoir potential within a basin. Through analysis of these measured data, geoscientists can determine gas in place, reservoir potential, and its variability as a function of depth. These data form the basis for estimating the potential for economic production, identifying reservoir units to be targeted for completion, and developing cost-benefit assess - ments of lateral and vertical completions. The greatest limit to gas production from shale may lie in the pore throats of the rock. TerraTek researchers have compared well productivity to matrix-permeability values over a variety of shale types and basins. Empirical evidence from these studies suggests that permeabilities below 100 nanodarcies define a lower limit to economic production of shale-gas plays. This limit appears to be independent of completion quality and gas content. Ultimately, the key to finding gas shale reservoirs lies in pinpointing the concurrence of favorable geologic parameters such as thermal history, gas content, reservoir thickness, matrix rock properties and fractures.

SHALE IN CHINA OIL AND GAS BASIN

Mesozoic and paleozoic shale formation developed in South china gas province

Yangtze platform belong to eastern Tethys region, very thick meso-paleozoic sedimentary has formed in cetral-lower Yangtze platform. Several series of hydrocarbon resource has developed in this area and has several sets of originating, reservoir and cap rock assemblage. Upper Sinian-silurian assemblage and Silurian-central Triassic assemblage are two important assemblages with thick shale layers as hydrocarbon resource.

Eastern china shale gas province with continental shale occurring

In Bohai bay basin, songliao basin, Mesozoic and Cenozoic shale is the important hydrocarbon source with high organic content, high maturity and great thickness, stable distribution. In some area of basins, gas show and intrusion, blow out occurred during drilling in history. Shale or mudstone has an amount of calcite content and brittle, easily to be fractured. In Dongpu depress, shaheji formation is main hydrocarbon source with thickness over 900 meters. In central uplift area of depress, the strata pressure coefficient varied form 1.2 to 1.5 MPa per 100 meter. This geological condition is favorable for shale gas.

Western china shale gas province

In zhungaer basin, there has seven hydrocarbon including carboniferous system, upper Permian system,upper Triassic system, middle-lower Jurassic system, lower Cretaceous system and lower Eocene. Till now, oil founded come from Permian system and middle-lower Jurassic system. In carboniferous system, dark shale occurred in formation usually with thickness 50 meter and TOC ranged form 2 to 8 percent. In Badaowan formation, dark mudstone thickness varies from 50 to 80 meter. Mudstone maturity varies from 0.6 to 2.0 percent favorable for shale originating.

North china shale gas province

Upper Mesozoic hydrocarbon source mainly occurred in Benxi formation, Taiyuan formation and shanxi formation, particularly in lower shihezhi formation. The hydrocarbon lithotype is dark mudstone and carboniferous mudstone and coal seam. Coal measures distribute in Taiyuan formation and shanxi formation. The former is mainly coastal marsh facies sedimentary, the latter delta plain and river facies coal measure sedimentary.

In Huanghua depress and central hebei, the thickness of hydrocarbon source distribute with central thicker than surrounding area. Coal measure and shale thickness varies from 20 to 30 meter in North to south direction and 5 to 15 meter in center area. The TOC of shale is very high ranged form 2 to 8 percent. In QInshui basin, Gas show abnormal occurred in many well, it is shown in table 1, that Qinshui basin has a potential for shale gas.

Table 1. Gas show abnormal in Paleozoic strata in Qinshui Basin

well	period	formation	Upper depth（m）	Bottom depth（m）	thickness（m）	Gas show Abnormal depth（m）	Gas show abnormal depth（m）

Qin 4	Carboniferous system	Shanxi	539	619.5	80.5	539～619.5	80.5
		Taiyuan	619.5	687	67.5	619.5～687	67.5
Cang 1	permian	Shangshihezi	552	645	93	336.5～348.5	12
	permian	Xiashihezhi	348.5	449	100.5	348.5～360.5	12
Lao 1	Carboniferous system	Shanxi	350.5	450.5	100	350.5～450.5	100
Qin 2	Carboniferous system	Shanxi	1236	1316.7	80.7	1255.7～1286.7	31
Qin 1	Carboniferous system	Shanxi	1190	1281	91	1241.6～1242.8	1.2
		Taiyuan	1281	1358	77	1334～1339	5
Yang 2	Carboniferous system	Benxi	164.5	218	53.5	169～218	50

CHINA SHALE GAS RESOURCE IN PLACE

Compared with shale gas in America, China has the primary geological conditons in many basins. In order to calculated the shale gas resource, in this paper, the analogical method has been used to estimate the gas in place of china basins. South china basin has a high maturity similar to Appalachian basin, Rocky mountain basin similar to zhungaer and tuha basin and Michigan basin is similar to Qadam and Eastern china basin. From three kinds of basin , Probability distribution of GIP abundance curve has acquired in the below ,shown in fig.1. From the fig.1, we can calculated the shale gas in different type basin in china. It is shown that shale gas in main oil bearing basin in china ranged from 21 to 45 Tcm, median value is 30.7 Tcm, is shown in table 2.

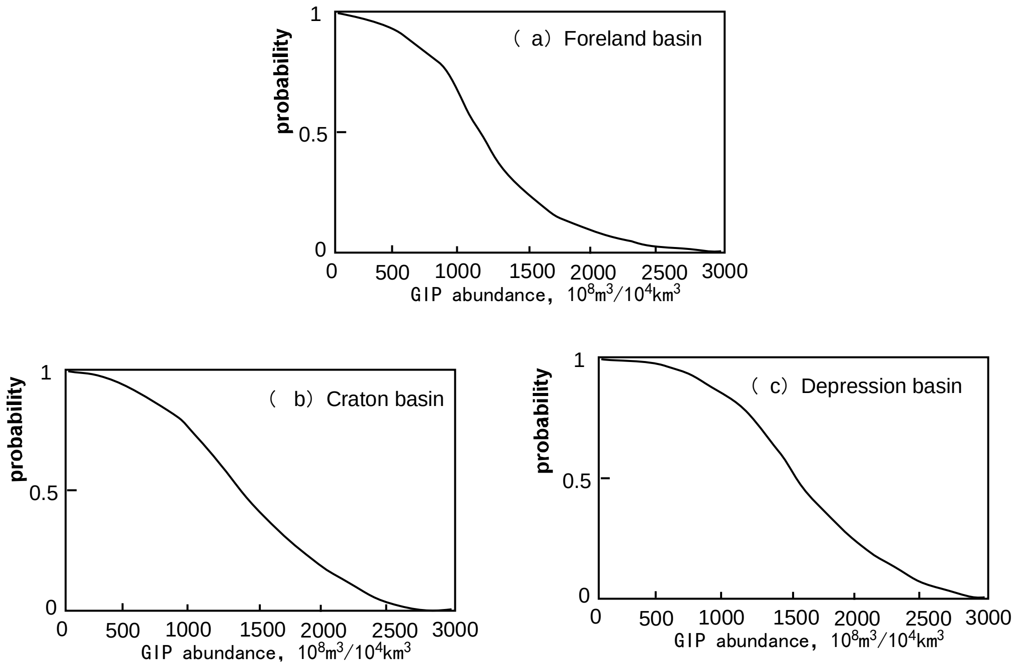

Fig.1 Probability GIP abundance of main intra-continental basin in the world

Table 2. The comparison between China main basin and American shale gas basin

Basin	Basin type	Basin area(10^4Km^2)	Period	GIP（10^6m^3）	GIP abundance（$10^8m^3/10^4m^3t$）
Appalachian basin	Craton basin	28	D	15120	540
Southchina province	Craton basin	90	S、D	135000	1500
Northchina province	Craton basin	60	C、P	54000	900
Suan Juan basin	Foreland basin	5.2	K	7280	1400
Wester china province	Foreland basin	70	P、J	58310	833
Eastern china province	Depression basin	50	K、N	60000	1200
Michigan basin	Depression basin	8.5	D	10200	1200

CONCLUSIONS

Indeed, China shale-gas industry is in its infancy, and innovative approaches to reservoir characterization and development are required to unlock the full potential that lies in such a geologically varied array of prospects. Shale gas forming and accumulating has itself characteristics, distributed in a large area and commercial production in some limited area. In many china basin, it has potential to develop shale gas in shale formations. It is estimated that china has 30.7 Tcm GIP shale gas.

As shale-gas production increases in the USA, operators in other countries will find analog basins that pave the way for increasing shale-gas reserves. Outside the USA, basin studies are being conducted to look for similar potential. In southchina, geologists are taking a closer look at the shale-gas potential of the Sinian and silurian formations of sicuan basin. Geochemical studies of these formations show potential for future development. Currently, the scarcity of shale gas plays outside of the USA may be due to uneconomical flow rates and extended well payouts rather than to an actual absence of productive shale-gas basins. However, the experience gained in US basins will inevitably help operators around the world exploit shale resources as production from conventional resources reaches maturity.

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