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石犬通訊

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Shale Gas

Shale gas is natural gas that is found trapped within shale formations. Shale is a fine-grained sedimentary rock formed by the compaction of silt, clay or sand that accumulates in deltas and on lake and ocean bottoms. It is the most abundant of all sedimentary rocks and can be a rich source of petroleum and natural gas.

Composition of shale gas is similar to that of natural gas in conventional reservoirs. Shale gas contains 75-95% methane, which is the most valuable component for extraction. Other components include nitrogen, ethane, propane, oxygen, carbon dioxide and the noble gases. Shale gas is used for generating electricity, heating and cooking, and as such is no different from other natural gas.

Shale gas is classified as an 'unconventional' natural gas. The term unconventional relates to the technology needed to extract the shale gas. This is different from the technology used to extract 'conventional' natural gas. Shale gas is considered as a safe, reliable and clean energy source, emits 50% less carbon dioxide than coal, and has a relatively low sulphur content. It was first extracted as a resource in the US in the early 1800s, but was never extracted economically until 1980's. At present, the US and Canada are recognized as the only two countries that can utilize shale gas resources efficiently and economically.

Extraction of Shale Gas

Unlike most natural gas, shale gas is held in rock pores up to 20,000 times finer than a human hair and for this reason will not flow freely into a well. Special technology has to be employed to extract shale gas safely and economically, and the method is known as hydraulic fracturing or 'fracking'. Almost all shale gas wells drilled in the US at present are using this method of extraction.

The principle of fracking is to create small fissures in the shale formation near the wellbore to release the natural gas inside the rock. The process involves pumping a fluid into a borehole at a constant rate and at high pressure to fracture or open discontinuities. As the existing pathways within the shale formation are connected, natural gas can flow more easily from the formation to the wellbore. Water and sand make up 98% of the fracking fluid; water is used to open the pores in the rock and inject sand into it, while the sand is used to keep the fissures open. The remaining 2% of fracking fluid consists of different kinds of additives like acid and antibacterial agents. Waste water that comes back out of a shale gas well is called flowback fluid, which amounts to 20% to 40% of the original fracking fluid.

Fracking is used together with horizontal drilling. In horizontal drilling, a well is drilled from the surface downward to a point where the borehole is turned and the well drilled along a horizontal plane. Although the cost of horizontal drilling can be 3 times more than that of a vertical well used in the extraction of conventional natural gas, a horizontally drilled well allows greater

頁岩氣

頁岩氣是指藏於頁岩內的天然氣。頁岩是細粒沉積岩的一種，由積聚於三角洲、湖泊或海底的粉土、黏土及砂土經壓縮作用而生成。頁岩是地球上最豐富的一種沉積岩，岩內更可能蘊藏豐富的石油及天然氣資源。

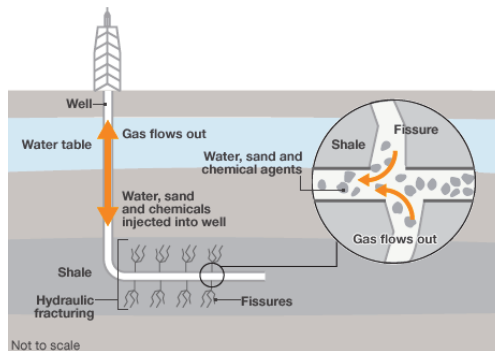
頁岩氣的成份與常規天然氣藏內的天然氣十分接近。頁岩氣有 75-95% 的成份為甲烷，此成份是其開採的主要目的。其他成份包括氮氣、乙烷、丙烷、氧氣、二氧化碳及貴氣體。頁岩氣的用途與其他天然氣並沒有甚麼不同，都可以用於發電、加熱及煮食。

頁岩氣被分類為非常規天然氣，是因為開採其所需的技術與開採常規天然氣有著明顯不同。它被視為一種安全、可靠及潔淨的能源，燃燒時所釋出的二氧化碳比煤少 50%，而且其硫含量亦較低。在十九世紀初期，頁岩氣率先在美國作為天然資源進行開採。不過，直到上世紀八十年代以前，開採的方式都不符合經濟原則。而現時，只有美國及加拿大這兩個國家有能力以符合經濟效益的方式有效率地應用頁岩氣資源。

頁岩氣的開採

與大部份天然氣不同，頁岩氣藏於岩石的細孔內。由於細孔的大小要比人類的頭髮還要細小二萬倍，所以頁岩氣不能自由流進氣井之內。要以安全及符合經濟效益的方式開採頁岩氣需要用上特別的技術，而這種技術稱為‘水壓致裂’或‘壓裂’。現時差不多所有位於美國的頁岩氣井都是以這種技術進行開採。

Shale gas extraction



Source: BBC

資料來源: BBC

注入液體以打開或破裂頁岩內本來不是互相連貫的氣孔。當本來存在於頁岩內的路徑連接在一起，頁岩內的天然氣就可以更容易流入井孔。壓裂液大部份成份(98%)是水及砂。水用於打開岩石內的氣孔，而砂則可以令岩石內的裂痕保持持續打開的狀態。壓裂液剩下的 2%成份為不同種類的添加劑，例如酸及抗細菌劑等。由頁岩氣井流出來的廢水稱為返排水，容量為原來壓裂液的 20%至 40%。

開採頁岩氣時，壓裂技術會與水平鑽井一併使用。使用水平鑽井時，氣井由地面向下延伸，當達到一定深度後，鑽孔的方面會改變，令氣井可以以水平方向進行鑽探。雖然成本比開採常規天然氣時使用的垂直鑽井高三倍以上，使用水平鑽井可以增加鑽井與頁岩的接觸範圍，令更多的

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exposure to the shale reservoir which then allows more natural gas to migrate into the wellbore. This largely solves the problem of the low permeability of shale formations.

Fracking is a highly sophisticated and complex technological operation with a high cost.

Social and Environmental Issues

Although shale gas is considered as a clean and green energy, the extraction of shale gas raises social and environmental concerns in relation to:

Groundwater contamination - Groundwater could potentially be contaminated during the extraction by the shale gas itself, the fracking fluid and the flowback fluid released. A recent study has identified 65 chemicals that are probable components of fracking fluids. These include benzene, glycol-ethers, toluene, 2-(2-methoxyethoxy) ethanol and nonyl-phenols. Also, large amounts of flowback fluids have to be stored, disposed and treated to minimize their negative impacts to the environment. Groundwater that is contaminated is likely to have severe effects on the quality of surface water and drinking water, and may affect natural habitat.

Leakage of Methane - During the extraction of shale gas by fracking, there is a possible risk from the leakage of methane into the atmosphere. Methane is estimated to be 72 times more potent than carbon dioxide as a greenhouse gas on climate change. The leakage of methane may offset the benefit of shale gas as a green energy.

Land and community - The development of shale gas can significantly change landscapes and the character of rural and residential areas.

Seismic Activity - There has long been a concern that fracking could induce seismicity, although it is currently believed that there are no significant effect.

US Shale Gas Boom

The US shale gas industry has experienced an extraordinary boom in the past decade. Shale gas made up just 1.6% of the country's total natural gas production in 2000, but this increased significantly to 23.1% in 2010. Starting in the late 1970s, the US government implemented a series of policies to promote the development of shale gas and other unconventional natural gas. These policies included incentive pricing, tax credits, R&D programs for unconventional natural gas and policies promoting industry restructuring.

Another factor that triggered the rapid development of shale gas was high natural gas prices in the early 2000s. The increased profit margin attracted existing firms and new entrants to invest into existing or new shale gas projects. Eventually, the increase in supply of shale gas has driven down natural gas prices.

The US had already fulfilled two prerequisite conditions before the boom of the shale gas industry. First, sufficient water is generally available for fracking. Second, the network of pipelines to transport natural gas to the markets had been extensively developed before the rapid development of shale gas. Countries new to shale gas should look at the American success story for generating attractive policies (and a favorable market environment).

Shale Gas Resources

According to the US Energy Information Administration (EIA), China has the largest shale gas resources in the world (1275 t.c.f.), followed by the US (862 t.c.f.), Argentina (774 t.c.f.), Mexico (681 t.c.f.) and South Africa (485 t.c.f.). - Note t.c.f. is trillion cubic feet.

The Sichuan and the Tarim are two large sedimentary basins in China that contain shales with excellent potential for shale gas development.

天然氣可以流入井孔內，這樣將可以大幅改善頁岩內的低滲透性問題。

壓裂是一種十分精密及複雜的開採技術，而且成本高昂。

社會及環境問題

雖然頁岩氣被視為一潔淨及環保的能源，開採頁岩氣時會引起以下的社會及環境問題：

地下水污染- 開採頁岩氣時，地下水有機會被頁岩氣本身、壓裂液及流出的返排水污染。近期一份研究報告指出壓裂液的 65 種可能化學成份，當中包括苯、乙二醇醚、甲苯、2-(2-甲氧基乙氧基)乙醇及任基酚等。另外，大量的返排水需要作儲存、處理及棄置，才可以盡量減低對環境造成的壞影響。地下水污染可令地表水及食用的水質嚴重下降，亦可能影響天然生境。

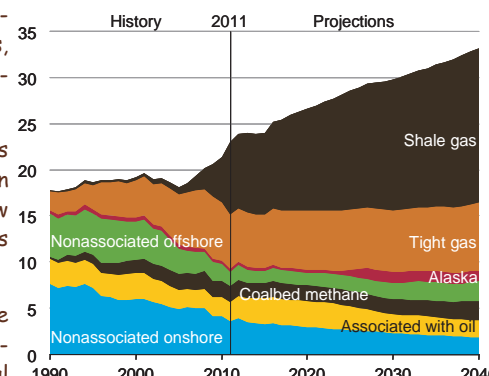
甲烷的洩漏- 當以壓裂開採頁岩氣時，甲烷有機會洩漏並進入大氣層。甲烷作為溫室氣體的影響要比二氧化碳大 72 倍以上。因此，甲烷洩漏帶來的負面影響可能會抵銷頁岩氣作為環保能源所帶來的好處。

土地及社區- 發展頁岩氣會大幅影響當地風景，以及郊區及住宅區的環境。

地震性活動- 長久以來，壓裂會否觸發地震一直令人關注。但一般相信，壓裂不是大地震的主要成因。

美國頁岩氣的迅速發展

過去十年間，美國頁岩氣行業發展非常迅速。在 2000 年，頁岩氣只佔其國家天然氣生產量的 1.6%，但到 2010 年卻激增至 23.1%。自七十年代後期起，美國政府實施了一連串的政策，以配合頁岩氣及其他非常規天然氣的發展。這些政策包括鼓勵性定價、稅額減免、非常規天然氣的研究發展計劃及促進行業重組的政策。



U.S. dry natural gas production by source, 1990-2040 (trillion cubic feet) (Source: EIA)
美國不同來源的乾天然氣產量, 1990-2040 (t. c. f.) (資料來源: EIA)

另一引發頁岩氣急速發展的因素為廿一世紀初期的高天然氣價。由於氣價高企，利潤率得以提高，吸引了很多天然氣公司或新的投資者投資頁岩氣項目。終於，激增的天然氣供應令氣價大幅下跌。

在頁岩氣迅速發展以前，美國已經達成了行業發展的兩個必要條件。其一為壓裂所

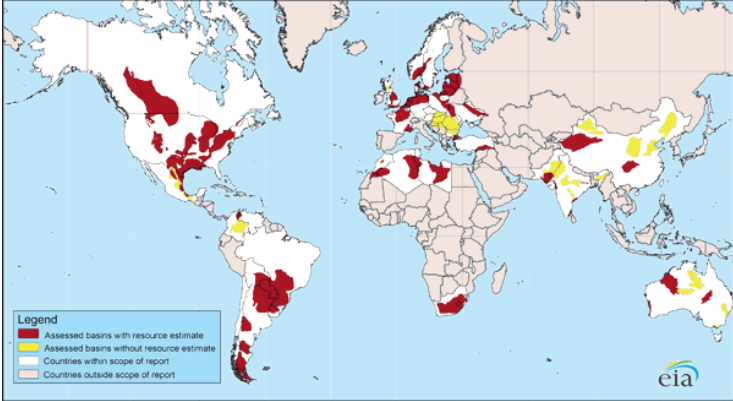
用的水源充足；其二為有一個可以傳輸天然氣到市場的完善及覆蓋範圍廣大的天然氣網絡。

任何想發展頁岩氣的國家都應參考美國的成功故事，以制定有利行業發展的政策及提供一個理想的營商環境。

頁岩氣資源

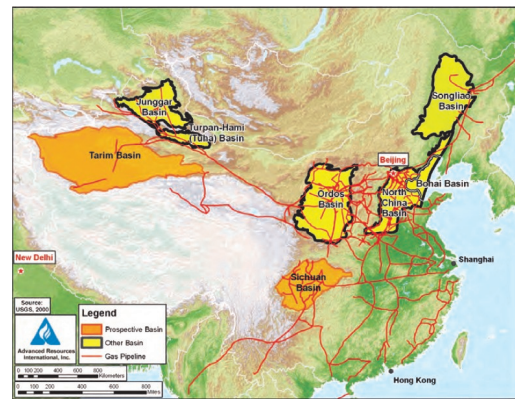
China also has other five sizeable but less prospective shale gas basins.

The Sichuan Basin is located in south-central China and covers a large area of 211,000 km². The structure of Sichuan Basin is quite complex with extensive folding and faulting, which increases the difficulty in drilling the horizontal wells needed to extract shale gas.



根據美國能源信息署(EIA)的資料，中國擁有世界上最豐富的頁岩氣資源(1275 t.c.f.)，緊隨其後的國家依次為美國(862 t.c.f.)、阿根廷(774 t.c.f.)、墨西哥(681 t.c.f.)及南非(485 t.c.f.)。

四川盆地及塔里木盆地是中國兩個大型沉積岩盆地，此兩盆地藏有



大量可用於頁岩氣開發的頁岩。另外，中國亦有其他五個大型的頁岩氣盆地，但發展前景不及此兩盆地。

四川盆地位於中國的中南地區，覆蓋面積達 211,000 平方公里。四川盆地的結構比較複雜，有很多折疊及斷層，這增加了開

採頁岩氣時使用水平鑽井的難度。

塔里木盆地位於中國西部的新疆維吾爾自治區，面積為 607,000 平方公里。開採的主要問題在於大部份位於塔里木的頁岩都位處地底較深處 (>450m)，令開採的難度提高。

中國現時的頁岩氣發展

中國政府相信發展頁岩氣可以顯著改善居住環境。相對於現時國家的主要能源—煤，天然氣是一種較潔淨的能源。如果頁岩氣的生產可以達到國家定下的 2015 年的目標，每年的碳排放量將可降低一千萬噸。

於 2012 年 3 月出台的十二五規劃定出國家由 2011 至 2015 年的發展計劃，當中包括定下一個目標及四個發展里程碑，此為：

- * 完成全國性的頁岩氣調查及評估。
- * 全國生產量在 2015 年達到 65 億立方米。
- * 為中國頁岩氣行業的調查、評估、勘探及生產發展出合適的方法、技術及器材。
- * 規範中國頁岩氣發展而制定技術標準、規則及政策。規範活動包括儲量調查、評估及驗證、測試及分析、勘探及生產和環境測量。

2012 年 11 月 1 日，中國財政部及國家能源局聯合發表由 2012 至

The Tarim basin is located in Xinjiang Uyghur Autonomous Region in western China, and covers a total area of 607,000 km². The main challenge for extraction is that much of the shale is relatively deep for shale gas development (>450 m).

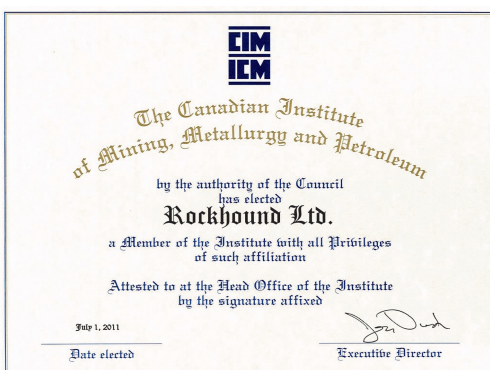
Current Development of Shale Gas in China

The Chinese government believes that the development of shale gas will greatly benefit the environment. Natural gas is a cleaner source of energy than coal, which is the main energy source of the country at present. If shale gas production can meet its 2015 targets, annual carbon emissions will be reduced by 10 million tonnes.

The 12th Five-year Plan issued in March 2012 sets out a development plan which lays out an overall target and four milestones to be achieved during 2011 to 2015. These include:

- * Completion of a nationwide shale gas survey and appraisal
- * Production output to reach 6.5 billion cubic metres by 2015
- * Development of suitable methods, technologies and equipment for China's shale gas survey, appraisal, exploration and production
- * Establishment of technical standards, rules and policies regulating the following activities in relation to China's shale gas development, such as reserve survey, appraisal and certification, test and analysis, exploration and production, and environmental measurements

On 1 November 2012, the Ministry of Finance and the National Energy Administration jointly announced that a subsidy of RMB 0.4 / cubic metre will be granted for shale gas produced in China during 2012 to 2015.



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Although China has held two rounds of auction of exploration rights which include 23 exploitable shale gas blocks in total, at present the country is producing no commercial quantities of shale gas.

Risks of Investing in Shale Gas in China

China's shale gas industry is still in its infancy stage and there are several risks that need to be taken into account for an investor. These are as follow:

Lack of extraction technology - Lack of drilling technology and domestic expertise are key obstacles to China to exploit its shale gas resources, although the government would like to introduce foreign technology by encouraging domestic firms to cooperate with foreign firms.

Geology challenges - The geology of most US shale basins is rigid, making the fracking technology for the extraction more effective and efficient. On the other hand, Chinese shale formations are deep and have much higher clay content. Such geology is less susceptible to the existing fracking technologies. The cost of drilling a single shale gas well in China is estimated to be US\$ 5 - 12 million, while that in the US is US\$ 3 - 5 million.

Water shortages - Most shale gas basins are located in regions that are facing problems of water shortages. Lack of water greatly restricts the size of production since fracking requires vast quantities of water. Chesapeake Energy states that depending on the depth of the well, 65,000 to 600,000 gallons of water is required for drilling of a typical shale gas well.

Natural gas pipeline system - China lacks a widespread pipeline infrastructure to transport the shale gas produced across the country efficiently. The gas pipeline network of China is 50,000 km, while that of the US is 400,000 km.

Lack of clear policy - There is still no clear policy on technological and environmental requirements for shale gas exploration and extraction, which poses high uncertainties in shale gas projects' profitability.

Lack of incentives - The current level of subsidy at RMB 0.4 / cubic metre may not be attractive. Also, natural gas prices are partially set by the government, and can dissuade shale gas investments.

2015年，國家將為頁岩氣提供每立方米 0.4 元人民幣的補貼。

雖然中國曾經兩次拍賣，合共出售 23 塊可供發展的頁岩氣區塊，但國家現時仍未能生產商用性質的頁岩氣。

投資中國頁岩氣的風險

中國的頁岩氣行業仍處於發展初期，投資者需要考慮幾個重要的風險因素。重點風險如下：

欠缺開採技術 - 缺乏鑽探技術及本土專業技術是中國發展其頁岩氣資源的一大障礙。雖然中國政府正積極鼓勵本土公司與外國公司合作以獲取他們的開採技術，但成果如何仍是未知之數。

地質上的難題 - 大部份美國頁岩盆地的地質相對堅硬令開採時使用的壓裂技術更有效。但中國的頁岩位於地底深處，而且黏土含量很高。此類地質不大適合現時的壓裂技術。在中國建造一個頁岩氣井的成本估計為 500 至 1200 萬美元，高於美國的 300 至 500 萬美元。

水資源不足 - 大部份的頁岩氣盆地都位處水資源不足的地區上。由於壓裂需要大量的水，水源不足將限制了生產的規模。切薩皮克能源公司指出隨氣井深度而定，一般來說要開採一個頁岩氣井，將需要 65,000 至 600,000 加侖的水。

天然氣管道系統 - 中國現時尚缺乏一個分佈廣泛的天然氣管道基礎設施，將生產的頁岩氣有效地傳送到全國不同地區。中國的天然氣管道網絡為 50,000 公里，遠遜於美國的 400,000 公里。

缺乏明確政策 - 現時中國對於頁岩氣勘探及開採時的技術及環境要求，仍缺乏清晰的政策，這會增加投資者投資頁岩氣項目時盈利的不確定性。

鼓勵不足 - 現時對於行業的補貼為每立方米 0.4 元人民幣，此水平的補貼吸引力可能不足。另外，現時中國的天然氣價格部份受政府干預，可能會減低投資者投資頁岩氣項目的意欲。

Some Notable Shale Gas Companies in the World

ExxonMobil is an American multinational oil and gas company headquartered in Texas, US. It is the largest publicly traded oil company in the world and is considering buying a stake in the Bowland shale gas project in Lancashire, UK.

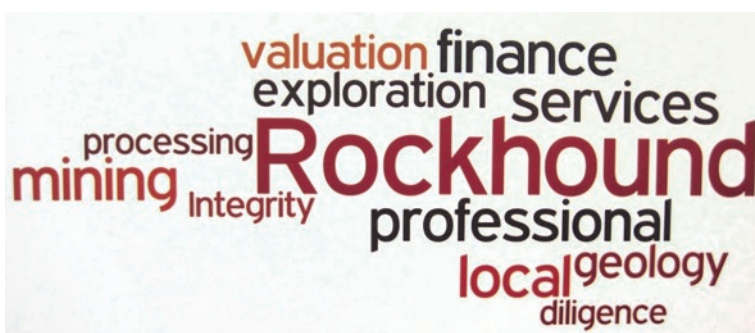
Royal Dutch Shell is an Anglo-Dutch multinational oil and gas company headquartered in the Hague, Netherlands. It has signed a production sharing contract with China Nation Petroleum Corp, the largest oil gas company in China, and will spend at least US\$ 1 billion to explore, develop and produce shale gas in the Fushun-Yongchuan block in the Sichuan Basin.

Chesapeake Energy is an Oklahoma-based oil and natural gas company and is the second-largest producer of natural gas in the US. It is one of the major shale gas players in the US.

Encana Corporation is headquartered in Calgary, Canada and is focused on growing its portfolio of diverse resource plays producing natural gas, oil and natural gas liquids. It has partnered with foreigner companies such as Mitsubishi and PetroChina to develop shale gas projects in Canada.

BP PLC is a British multinational oil and natural gas company headquartered in London, UK. In 2010, it teamed up with a Sinopec subsidiary to explore shale gas in Guizhou Province, China.

PKN is a major Polish oil refiner and petrol retailer. It has 10 shale gas exploration licenses in Poland.



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