

Natural Gas Geological Theory and Practice of China

Editor In-Chief: Wang Tao

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Natural Gas Geological Theory and Practice of China
by Wang Tao *et al.*

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Preface

Coal, petroleum and natural gas are three pillars of modern energy resources, among which natural gas is the cleanest and with greatest developing potential; therefore, it attracts more attention. Natural gas industry was developed later than coal and petroleum industries, and is now in the prosperous phase. C. Marchetti (1979) predicated that the peak of utilizing natural gas appear at the beginning of next century. The present work is published a little bit ahead of its appearance, and it is hoped that this book can contribute a bit to accelerate the appearance of the peak of natural gas utilization.

China is one of the countries which first discovered and utilized natural gas and has made brilliant achievements. At the beginning of the 13th century, China developed the first natural gas field in the world, the Ziliujing Gas Field, this adds a magnificent page in the history of science and technology of the world. In modern times, China was gradually reduced to a semi-colonial, semi-feudal country: petroleum industry, like other industries, was strongly hindered and behind the time. Since the foundation of the People's Republic of China in 1949, natural gas industry has gained much momentum and developed rapidly (except Taiwan province). The main symbols of the rapid development are (1) sharp increase of the number of gas fields, reserves and output, by the end of 1994, discovered gas fields, reserves and yearly output are respectively 39, 3147 and 2381 times of those before 1949; (2) sharp increase of the number of discovered gas-bearing basins, there was only one discovered gas-bearing basin, the Sichuan Basin, before 1949, 10 have been found since 1949; (3) sharp increase (from 0 to 30) of the number of large and medium-scale gas fields; (4) the team of natural gas geologists have been much strengthened, there were only 48 persons engaged in petroleum exploration before 1949, however, the natural gas geologists who participated in tackling key national natural gas scientific and technological problems were 3500 in the period of 1991 - 1995; (5) new achievement in theories of natural gas formation, theory which guides the exploration changes from monism, i.e. sapropelic type gas, to dualism, i.e. sapropelic and coal-formed gases. The present work is accomplished on basis of these changes. The authors are a group of key persons who have engaged in scientific research and exploration for a long time, they are familiar with new discoveries, laws and theories of natural gas geology of China.

The content of this work was discussed twice by major contributors organized by Wang Tao. The introduction of this work is written by Wang Tao and Dai Jinxing; Chapter 1 by Xu Yongchang, Fu Jiamo, Shen Ping, Chen Junhong and Liu Wenhui; Chapter 2 by Cheng Keming, Liu Dehan, Liu Wenhui and Dai Jinxing; Chapter 3 by Ying Fengxiang, Chen Lihua, Zhao Chenglin, Kong Jinxiang and Chen Zhangming; Chapter 4 by Hao Shisheng, Song Yan and Huang Zhilong; Chapter 5 by Dai Jinxing. Literary modification and unification of scientific terms is done by Dai Jinxing. Finally, Wang Tao reviewed and compiled the book.

Besides published literature, many unpublished data and reports of different oil and gas fields are consulted, here we express our gratitude.

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Introduction

The formation and development of geological theories of Chinese natural gas are, on the one hand, the product of the development of ancient and modern Chinese natural gas industry and, on the other hand, the result of close combination of theory and productive practice .

0 .1 General Information

0 .1 .1 The Meaning of Natural Gas

Gas formed naturally in the nature is called natural gas . Natural gas is mostly a mixture of compounds and elements which are in gaseous state under standard condition; only in special case, it is formed by a single gaseous component . Gaseous compounds and elements which are normally seen in natural gas are hydrocarbons ($C_1 - 4$), carbon dioxide, nitrogen, hydrogen sulphide, mercury and rare gases (helium, neon, argon, krypton, xenon) . At the moment, there are two opinions about the definition of natural gas, one thinks that natural gas (broad sense) includes all the gases in the nature (Sokolov, 1971), i . e . the gases in the atmosphere, hydrosphere, lithosphere and even the mantle and core of the earth; another thinks that natural gas (narrow sense) refers to the hydrocarbon dominated (sometimes carbon dioxide and occasionally hydrogen sulphide dominated) gas in lithosphere, hydrosphere and even the mantle and core of the earth (Dai Jinxing et al ., 1992) . In ancient Chinese literature, natural gas was often called “ fire well ”, “ well fire ”, “ coal gas ”, “ negative gas ”, “ poison gas ”, “ fire pond ”, “ ground fire ”, “ holy lamp ”, “ fire dragon ” and “ fire fountain ” (Dai Jinxing, 1981) .

Natural gas geology deals with the formation, origin, geochemistry, isotope, migration, accumulation, seepage, and distribution of natural gas (narrow sense), as well as the relations with other geological processes .

0 .1 .2 The Birth of Natural Gas Geology

Natural gas, especially the oil type gas, has close relationship with oil . This determines that the predecessor of natural gas geology was attached to petroleum geology . Natural gas, especially the coal-formed gas, has also many differences from oil; this determines that natural gas geology must become an independent branch of science . The independence of natural gas geology from petroleum geology was achieved after the oil/ gas industry had developed to a certain stage, i . e ., new theories of natural gas had appeared . The publishing of “ Natural gas geology ” by I . V . Vesotski of Russia in 1979 can be considered as a symbol that natural gas geology had become a mature and independent branch of science . In the 40s of this century, German scientists first proposed the theory of coal-formed gas (Shi Xunzhi et al ., 1985), and it was successful in guiding natural gas assessment and exploration in west Europe and central Asia (the Kara-Kum and west Siberian basins) . This broke the tradition that coal-bearing basin or formation was not treated as the target of natural gas exploration and research in petroleum geology, and opened a new field in coal-formed gas exploration . Thereafter, the theory directing natural gas exploration developed from monism (only sapropelic organic matter of oil-bearing basins can form natural gas, or called oil type gas theory) to dualism (humic organic matter of coal-bearing basins can also form natural gas, or called coal-formed gas theory) . From the 50s to 70s of this century, oil/ gas industry of the world was rapidly developed, but the natural gas industry was developed more faster, this is indicated by the comparison between productivity and reserves of oil and gas . In this period, the ratio of productivity and reserves of natural gas to productivity and reserves of oil changed respectively from $1/3$ to $3/5$, and from $1/3$ to $4/5$, showing the that natural gas constitutes a larger and larger portion of energy resources . The rapid rise of natural gas industry paved the way for the birth of natural gas geology in 1979 .

0 2 A Brief History of Natural Gas Exploration and Research in China

0 2 .1 China is one of the countries which first discovered and used natural gas in the world

The discovery, exploitation and application of natural gas in ancient China (from 1600 B .C . to the Opium War) form a brilliant part in the world history of science and technology .

In *Yijing* written in early years of the Western Zhou Dynasty (1066 - 771 B .C .) the sentence“ there is fire on the pond ”describes the natural phenomenon of burning on water surface . There are two causes for the burning on water surface, one is oil, another is gas, and the latter is much more possible than the former, because the sediments on the bottom of a pond or lake are the favourable place to produce biogas, and the flammability of gas is lower than that of oil .

Chang Qu of the Jin Dynasty depicted in *Annals of the State Huayang* the grand sight of natural gas well and the scene of cooking salt with gas in Qionglai, Sichuan in the times of Qin Shihuang (221 - 210 B .C .) . Yang Xiong (53 B .C - 18 A .D .) of the Western Han Dynasty recorded“ fire well ”in his *Rhapsody of the capital of Shu* . We can see that natural gas had already drawn much attention . Two pieces of brick relief of the Han Dynasty found in Qionglai county (Figure 0 - 1) and Chengdu (Figure 0 - 2) after 1949 well demonstrate the situation of exploiting and using natural gas by the people of Sichuan in the Qin and Han dynasties . According to incomplete statistics, 20 counties in the Sichuan Basin were mentioned discovering and using natural gas in ancient Chinese literature (Dai Jinxing, 1981) . This indicates that the people in ancient China had already noticed the rich natural gas resource in the Sichuan Basin .

Natural gas was found in many places in ancient China . Ban Gu described in his *Hanshu* a“ fire well ” in a military horse raising yard of Hongmen (61 B .C .) . Hongmen is located southwest to the present Shenmu county in the Ordos Basin . According to the research of Zhang Kang (1987), the“ fire well ”described by Ban Gu is coal - formed gas . Wei Shou noted in his *Weishu* the self burning of a pond in Shanxi in May of 223 . Shen Yue noted in *Songshu* that the fire in the pond to the east of the town of Liangzhou (present Wuwei) in February of 359, and the fire in a pond of Guzang (in present Wuwei county) in 360 . Ouyang Xiu wrote in *New history of Five Generations* that in the winter of 912, there was gas out of water which can burn in Linjiang (present Hexian county of Anhui) . In *Weishu* there is such a description that in 526 the ground of Qiuxian (present Laishui county of Hebei) was burning . Tuo Tuo noted in his *History of Jin* that there was fire coming out of the ditch in front of Zhou Xiuwu 's residence in Beijing and burned up the

Figure 0 - 1 A Han Dynasty Brick relief of “ fire - wells ” in Qionglai county, Sichuan

Figure 0 - 2 A Han Dynasty Brick relief of “ fire - wells ” in Chengdu, Sichuan

wood bridge . Zhu Guozhen of the Ming Dynasty wrote that there was a fire well in Azhu (present Zi meng county of Yunnan), smoke came out with water, if bamboo or wood was put in, it would be burned up . Liu Xun described in his book that on 26 June 1723 there was great fire in Chishan (present Gaoxiong county of Taiwan), black muddy water erupted out of two openings, grasses and trees around which were all burned up into ash . In ancient China, natural gas was not only found in continent, the burning of natural gas over the East China Sea was also noted . In the *Annals of Shanghai* written by Ye Ting chun of the Qing Dynasty, the fire over the East China Sea in November of 1512 was recorded . Shi Hongbao recorded in his *Notes of Fujian* the fire over shallow sea of middle Fujian . According to incomplete statistics (Dai Jinxing, 1981), at least 58 counties of 19 provinces, cities and autonomous regions (Beijing, Shanghai, Tianjin, Sichuan, Shaanxi, Hebei, Shanxi, Anhui, Zhejiang, Fujian, Guangdong, Guangxi, Hunan, Hubei, Yunnan, Gansu, Xinjiang, Heilongjiang and Taiwan) discovered natural gas in ancient China . In terms either of time, or geographic range, or number of discovery, China is prominent in the world .

Exploiting and using natural gas in the Sichuan Basin has a long history in ancient China and made great success, the most typical instance is the Ziliujing gas field . During the period from 11th to 15th century, people of the Sichuan Basin began to use natural gas to cook salt in great scale (Hu Lishan, 1957) . Large - scale exploitation of natural gas relies first on shaft sinking, by the time of 1129, 30 prefectures of Sichuan had sunk wells (Shen Lisheng, 1980), this indicates that natural gas exploitation was widely carried out in Sichuan . China developed the first gas field in the world, the Ziliujing gas field (You Qi, 1977; Shen Lisheng, 1980; Meyerhoff, 1970), which was discovered in the Han Dynasty . The development of the Ziliujing gas field can be divided into three periods . Before the 13th century, the activity was dominated by salt well sinking . During the Tang and Song dynasties, nearly 100 salt wells were sunk in the Ziliujing structure, with a depth of 300 - 400 chi (1 chi is about 0 . 3 m) . From 13th century to 15th century, shallow gas of the Ziliujing structure was exploited in large scale, it was used to cook salt . Since the 19th century, deep gas has been exploited . In 1835, the first well over 1000 m deep (1001 . 4m) in the world, the Xinghai well, was sunk using the “ Zhuotongjing ” (cable tool - slim hole) techniques (Figure 0 - 3), it had a productivity of 5000 - 8000 m³ per day . After 1840, the Mozi well with a depth of 1200 m was finished,

it was a high - yielding well of deep gas, productivity $200 \times 10^3 \text{ m}^3$ per day, and was called“ the king of fire well ”. By 1850, there were more than 10 gas producing wells, yearly output about $1 \times 10^8 \text{ m}^3$. By the end of 1949, the gas exploiting history of the Ziliujing gas field was more than 300 years, an estimated cumulative natural gas output is about $30 \times 10^9 \text{ m}^3$. The Ziliujing gas field is the first gas field in China, also the first in the world, its exploitation can be considered as the beginning period of natural gas exploitation in China .

0 2 2 Brief Information About the Natural Gas Industry of China in Modern Times

From the Opium War to the founding of the People 's Republic of China, China was gradually reduced to a semi - feudal, semi - colonial country . Like the other industries, oil/ gas industry was strongly hindered and ruined, it developed very slowly .

Personnel engaged in oil/ gas exploration in modern times was very limited . According to the statistics of Chinese Petroleum Company, there were only 48 persons of geological exploration, including oil geo-physical exploration . These persons were mainly engaged for oil exploration, there was no special natural gas personnel . Natural gas exploration was only carried out in Shiyougou of Baxian county and Shengdengshan of Longchang county, Sichuan (Shen Lisheng, 1988) . According to *Summary of Sichuan salt*, there were still 746 fire wells drilled by old style cable tool in Pengxi, Suining, Xichong, Yanting, Zhongjiang, Ziliujing and Gongjing of Sichuan in operation by the end of the Qing Dynasty, their distribution is shown in Table 0 - 1 . From 1878 to 1949, only 134 wells were drilled by new style drilling machine in Taiwan, Shaanxi, Sichuan, Xinjiang and Gansu, with a total drilling depth of 64000 m .

Table 0 - 1 Distribution of natural gas wells in Sichuan at the end of the Qing Dynasty
(from Shen Lisheng, 1988)

Area	Number of fire wells	Zhongjiang	300
Pengsui (Pengxi, Suining)	8	Furong (Ziliujing, Gongjing)	199
Xiyan (Xichong, Yanting)	239	Total	746

Figure 0 - 3 Drilling a deep well in Sichuan(from Ding Baozhen, 1882)

From 1878, when China began to use modern drilling techniques in oil/ gas exploration, to 1949, only 6 gas fields were found. The Jinshui gas field, Zhudong gas field and Niushan gas field. Liuchongxi gas field in Taiwan were found respectively in 1913, 1934 and 1937; the Ba - 1 well in Shiyougou, Baxian county, Sichuan was finished in 1939, Triassic limestone below the 1100 m depth yielded gas, $14150 \text{ m}^3/\text{d}$, this well is the discovery well of the Shiyougou gas field; the Shengdengshan gas field in Longchang county, Sichuan was found in December of 1943, gas productivity of the discovery well was $14 \times 10^4 \text{ m}^3/\text{d}$. 7 gas fields exploited in modern times in China (Ziliujing, Jinshui, Zhudong, Niushan, Liuchongxi, Shiyougou and Shengdengshan) produced $1.17217 \times 10^9 \text{ m}^3$ of gas (Shen Lisheng, 1988). By 1949, China has discovered only 7 gas fields (4 of them in Taiwan), the yearly gas output of China (Taiwan not included) was only $7 \times 10^6 \text{ m}^3$, proven natural gas reserves were $3.85 \times 10^8 \text{ m}^3$.

0.3 Increasingly Prosperous Natural Gas Industry of New China

After Liberation, natural gas industry of China has developed rapidly. The main symbols of the rapid development are (a) sharp increase of the number of gas field, reserves and output; (b) sharp increase of the number of gas-bearing basins discovered; (c) sharp increase of the number of large and medium-scale gas field; (d) the team of natural gas geologists have been much strengthened; (e) new achievement in theories of natural gas formation.

By 1994, China (Taiwan is not counted, same in the following) had discovered 116 gas fields and proven natural gas reserves about $1211.6 \times 10^9 \text{ m}^3$, the yearly natural gas output was $16.67 \times 10^9 \text{ m}^3$. Gas fields discovered, proven reserves and yearly natural gas output are respectively 39 times, 3147 times and 2381 times of that shortly before Liberation. Although gas fields, reserves and output have increased sharply, they cannot yet meet the needs of national economy development, more work should be done in the future.

Before Liberation, China discovered natural gas fields only in the Sichuan Basin. Now, natural gas fields have been found in the Sichuan, Ordos, Tarim, Turpan-Hami, Qaidam, Bohai Bay, Songliao, Qiongdongnan, Yinggehai and East China Sea basins. Gas producing formations changes from one (Triassic) before the liberation to 12 (Quaternary, Tertiary, Cretaceous, Jurassic, Triassic, Permian, Carboniferous, Silurian, Ordovician, Cambrian, Sinian and Presinian). Gas fields and gas producing formations expands vertically and horizontally.

Before Liberation, there was no gas field in China with proven reserves of more than $10 \times 10^9 \text{ m}^3$, by 1994 there were 30 gas fields with proven reserves of more than $10 \times 10^9 \text{ m}^3$ (Figure 0 - 4), among which there are two large - scale gas fields, the central gas field of the Ordos Basin (Figure 0 - 5) and the Ya - 13 - 1 gas field of the Qiongdongnan Basin. Operation of large and medium-scale gas fields sharply increased the natural gas output of China, for example, the Ya - 13 - 1 gas field (Figure 0 - 6), which was in operation in January 1996, has a yearly output of $3.4 \times 10^9 \text{ m}^3$, this made the natural gas output of China in 1996 increasing 20% on the basis of 1995.

Before Liberation, there were only 48 persons engaged in petroleum exploration, there was no special research personnel for natural gas geology. After Liberation, the team of natural gas geologists has rapidly developed. Only the natural gas geologists who participated in tackling key national natural gas scientific and technological problems were 800 in the period of 1981 - 1985, 1400 in the period of 1986 - 1990, and 3509 in the period of 1991 - 1995. Increasingly strengthened team of natural gas geologists has accomplished a lot of work of natural gas assessment, target selection and scientific research, worth mentioning is the assessment of natural gas reserves of China. There was no monograph or special issue of natural gas geology, by 1995, 28 monographs of natural gas geology had been published. The achievement in natural gas research in China has enriched and developed the theory of natural gas geology of the world, at the same time, it guided the natural gas exploration in China.

From the modern times to 1980, the oil type gas theory was mainly prevailed in China to explain the origin of natural gas and to guide natural gas exploration. Due to the limitation and one-sidedness of natural gas formation theory, i.e. only oil type gas theory, China had lost a lot of favourable target areas and formations of coal-bearing basins. The establishment of coal-formed gas theory at the end of 1970s (Dai Jinxing, 1979) opened a new territory of natural gas exploration in China. Improvement and development of

Figure 0 - 4 Distribution of large - medium - scale gas fields in China

Figure 0 - 7 Relationship between Chinese gas - forming theories and the increase of gas reserves in China

natural gas formation theory greatly increased the proven natural gas reserves, and greatly increased the effectiveness of natural gas exploration compared with oil exploration .

0 3 1 Monism and Chinese Natural Gas Industry

Before 1980, Chinese petroleum geologists believed that natural gas was formed by sapropelic source rocks, i e . natural gas was the product of marine carbonates, mudstones and shales, and lacustrine mudstones and shales, and is called oil type gas . At the same time, the monism was used to guide natural gas exploration, great potential and prospect of coal measures and similar sequences were ignored, coal measures were not considered as gas source rocks and target beds . Therefore, natural gas exploration progressed slowly, proven reserves increased insignificantly . From 1950 to 1980, only $288.3 \times 10^9 \text{ m}^3$ of reserves were proven, about $8.5 \times 10^9 \text{ m}^3$ per year .

0 3 2 Dualism Improved the Development of Natural Gas Industry of China

In 1979, Dai Jinxing first proposed in China that coal measures and similar formations were good gas source rocks, and pointed out that the Sichuan, Ordos, Bohai Bay and Tarim basins were favourable regions to explore coal-formed gas . This makes the guiding theory of natural gas research and exploration changing from monism (oil type gas theory) to dualism (oil type gas theory and coal-formed gas theory) . Coal-formed gas theory received attention and support immediately after its appearance from Ministry of Petroleum Industry, Ministry of Geology and Mineral Resources and Ministry of Coal Industry . In 1983, the State Commission of Planning set " Development and research of coal-formed gas " as a national key project of the 6th Five-year Plan (1981 - 1985), this accelerated the combination of theory and practice and

strengthened natural gas research and exploration in China . In the past , exploration and research of natural gas in China guided by the oil type gas theory were mainly concentrated in the Sichuan Basin , and the target was mainly carbonates . Since the 1980s , natural gas exploration in China has been guided by dualism , exploring territory has been much enlarged , and the exploration has become more efficient , proven gas reserves have increased sharply . In the period when exploration was guided by monism , $288.3 \times 10^9 \text{ m}^3$ of gas reserves were proven in China , about $8.5 \times 10^9 \text{ m}^3$ per year . In the period of dualism (until end of 1994) , $919.8 \times 10^9 \text{ m}^3$ of reserves were proven , about $54.1 \times 10^9 \text{ m}^3$ per year (Figure 0 - 7) , these are respectively 3.2 times and 6.4 times of that of the monism period . We can see in Figure 0 - 7 that the proven gas reserves increased sharply in the period of dualism , this is mainly due to the sharp increase of coal-formed gas reserves . Proven coal-formed gas reserves in 1978 was 9% of the total proven reserves , this number changed into 38% in 1994 . The discovering rate of large and medium-scale gas field has also been accelerated . In the period of monism , 6 medium-scale gas fields were discovered , about five year a field . In the period of dualism , 24 large and medium-scale gas fields were discovered , about one year a field .

Natural gas industry of China is both old and young . China is one of the countries which first discovered , exploited and used natural gas , has made brilliant success , and has a brilliant position in the technological history of the world . But in modern times , the development of Chinese natural gas industry was slowed down . After Liberation , especially since the 1980s , proven natural gas reserves in China have sharply increased , but the production remains low , rank only the 20th in the world list , natural gas constitutes only 2% of energy resources , being far from the needs of national economic development . China is rich in natural gas resource , but the proven rate remains low , only 30% . Therefore , natural gas research and exploration should be further strengthened in the future , in order to make a great development in the near future .

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1 Geochemical Characteristics of Natural Gas

Natural gas Geochemistry deals with mainly the geochemical process of formation, evolution, migration, accumulation and destruction of gases in the crust of the earth. Its concrete content includes: types of parent rocks, sedimentary environment, process of gas generation, mechanism of gas generation, law of accumulation and the characteristics of distribution of organic genetic natural gas; components and isotopic composition of natural gas and their indicating function in gas generating process and comprehensive distinguishing natural gases of different genetic types. Exploration of gas of inorganic origin (including atmospheric methane trapped in the early days of the earth and the gas generated by rocks and minerals during the geochemical evolution process of the earth) was one of the hot topics of scientific exploration in the 1980s. The results show that methane of inorganic origin is widely distributed and the reserve is enormous. But to the point whether it can accumulate into industrial resources, there are different opinions.

1.1 Genetic Types of Natural Gas

This section discusses the genetic classification of natural gas, mainly hydrocarbons, based on material source, formation mechanism, and exogenic agents of gas generation.

1.1.1 Organic Genetic Gas and Inorganic Genetic Gas

Materials in the nature are divided into organic and inorganic types according to whether they are related to living things. Judging from the source materials, natural gas can also be divided into organic and inorganic types.

Organic genetic gas was tended to be called biogenic gas (Schoell, 1988). It refers to gas generated by bacteria action, chemical action and physical action during the diagenetic process in scattered or concentrated organic matter in sediments. It is the major objective of natural gas geology.

Inorganic genetic gas, also called abiogenic gas, refers mainly to primary methane trapped in the mantle when the planet was formed and the hydrocarbon gas produced by rocks under high-pressure and high-temperature condition through Fisher-Tropsch process as well as non-hydrocarbon gas produced by inorganic reaction in rocks.

1.1.1.1 Two subtypes of organic genesis: oil - type gas and coal - formed gas

Organic genetic gas is the major source of most hydrocarbon gas reservoirs of industrial value. Therefore, it has been well studied and systematically classified. Based on elemental composition and maceral composition, the original organic matter and kerogen can be divided into sapropelic type (type I), humic type (type III) and the transitional type: humic-sapropelic type (type II₁) and sapropelic-humic type (type II₂). Considering the succinct generality of classification principles, and based on the characteristics of mother materials, organic genetic gas is divided into two subtypes: oil-type gas and coal-formed gas (see 1.2).

1.1.1.2 Inorganic genetic gas

The theory of inorganic origin of oil and gas has been hold by a school for a long time, it is an important point of view. Since the 19th century, many workers have explored in this area (M. Berthelot, 1866; A. Biasson, 1871; D. L. Mendeleev, 1877 - 1897). In the 50s of this century, Kugriachev of the former Soviet Union was a representative of the theory of inorganic origin of oil. In the early 80s, American astronomer Gold (1980, 1982) of Connel University proposed the opinion that major gas reservoirs in the world are of inorganic origin.

Inorganic genetic gas is considered to be mainly primary hydrocarbon gas in mantle of the earth. Gold (1980, 1982), as a representative, believed that there are large quantities of hydrocarbon gas dominated by methane in the deep part of the earth, and that gaseous hydrocarbon reservoirs are genetically related to this

kind of inorganic methane .

In the atmosphere of planets there is usually hydrocarbon gas of varied content dominated by methane, e .g . the earth 1.4×10^{-6} , the Jupiter 6×10^{-4} , and 99% of the atmosphere of the sixth satellite of the Saturn is methane . A general tendency is that the atmosphere of terrestrial planets has lower content of methane dominated hydrocarbon gas and the content increases with the distance from the sun, and finally methane becomes a major component of the atmosphere of planets far away from the sun .

Hydrocarbon compounds contained in meteorites were already discovered in 1806 in the Alais carbonaceous chondrite . More than 60 hydrocarbons have been found so far, e .g . aliphatic hydrocarbon, aromatic hydrocarbon, amino acid, porphyrin, isoprenoid, alkane, purine, pyrimidine . Research results show that these hydrocarbons are of inorganic origin . They are primary pre-life materials not the traces of extraterrestrial life . These hydrocarbons can be formed by inorganic material through inorganic physical and chemical processes . For example, the Vrey-Muller experiment shows that CH_4 , H_2O and NH_3 can form amino acids through electric sparks; by means of Fisher-Trosch reaction hydrocarbons from methane through to $\text{C}_{20}\text{H}_{42}$ can be formed .

The presence of methane in the primary earth has been testified by different researches . The primary methane of the earth refers to the methane dominated gas trapped from the space when the earth was formed, which comes through various fracture system to the surfacial layer during the degassing process of the earth . Greatly enriched helium has been found in the high-temperature fluid (350 °C) at 20 °N of the East Pacific Rise, several times higher than the helium content of the sea-water nearby . The $^3\text{He}/^4\text{He}$ ratio is $(1 - 1.4) \times 10^{-5}$, being higher than that of terrestrial materials . Large quantities of hydrogen and methane have also been found in the hot fluid . The content of H_2 is $2 \times 10^{-6} \text{ cm}^3/\text{g}(\text{STP})$, and that of CH_4 is $1.1 \times 10^{-5} \text{ cm}^3/\text{g}(\text{STP})$. Sediments are lacking there, therefore, the possibility that the methane comes from the organisms in the sediments is excluded . The helium excess (He - excess) of this area is obtained by subtracting the helium concentration in surrounding sea-water from the helium concentration of this area . In this area $\text{H}_2/\text{He - excess} = 700$, $\text{CH}_4/\text{He - excess} = 9$. These results indicate that the methane of this area comes from the inorganic genetic methane in the deep part of the earth . Based on the ratios of H_2 and CH_4 to ^3He and the discharge of ^3He , the discharges of H_2 and CH_4 of the mid-ocean ridge can be calculated . The results are $1.3 \times 10^9 \text{ m}^3/\text{a}$ for H_2 and $1.6 \times 10^8 \text{ m}^3/\text{a}$ for CH_4 .

On the continents primary methane occurs mainly with the aquathermal system related to profound faults, e .g . the natural gas in the warm water of Kamcatka, Russia; the methane in the hot spring of the Yellow Stone park of the United States; the methane in the aquathermal systems of Tictere and Brolans, New Zealand ; and the methane in the aquathermal system related to volcanic activities in Tengchong , China .

The symbol of inorganic genetic methane is represented by the geochemical characteristics of methane and helium in the area where hot fluid erupting on the East Pacific Rise . The widely accepted diagnostic criteria are $^{13}\text{C}_1 > -20\text{‰}$, the ratio of $^3\text{He}/^4\text{He}$ of coexisted Helium is about the order of 10^{-6} , $\text{CH}_4/^3\text{He}$ is about 5×10^6 to 5×10^7 , the homologue of the methane possesses the $^{13}\text{C}_1 > ^{13}\text{C}_2 > ^{13}\text{C}_3 \dots$ series . Dai Jinxing et al . (1992) used $^{13}\text{C}_1 > -30\text{‰}$ as a diagnostic criteria for inorganic genetic methane with the precondition that there is no coal-bearing stratum in the region .

The largest scientific activity destined to the research on primary mantle methane reservoir is naturally the Siljan deep-drilling in Sweden . The well is located in a meteorite crater on a Precambrian granite basement . Seffrey and Kaplan (1988) systematically studied the deep-drilling, they found that the concentration of hydrocarbon gas from the granite section was relatively lower, and was rich in unsaturated hydrocarbons . This is possibly the result of abiotic synthesis of inorganic carbon in the granite, but this can also be resulted from the transformation of organic matter in the drilling fluid . The methane of highest concentration is rich in ^{13}C , $^{13}\text{C}_1 > -26\text{‰}$ According to the purpose of this well, it should admit that it is not successful .

China has also made meaningful exploration of inorganic genetic natural gas . The emphasis here is on the reservoirs of inorganic genetic natural gas . The methane of industrial gas well of China has heavier carbon isotope . The inversion series of carbon isotope was first reported by Zhang Yigang (1990, Gas source rock and geochemical characteristics of natural gas and the gas-forming mechanism): " Mixed deep-seated gas and humic gas was found during analysing two gas samples from the Tianwaitian - 1 well in the East China Sea, the carbon isotope value (PDB) of the samples from two horizons are the following: -17‰ for