# SYMPOSIUM ON PETROLEUM GEOLOGY OF TARIM BASIN IN CHINA AND SIBERIA PLATFORM IN RUSSIA

Jia Chengzao and N.V. Sennikov *et al.*

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# Preface

Based on the great success made in oil and gas exploration in Mesozoic and Cenozoic continental basins in the past decades, China produces 160 million tons of crude oil annually. However, to keep the country's oil production and reserves stable and rising steadily, China needs to step up the efforts for oil and gas exploration of Paleozoic marine carbonate rock that is extensively distributed in China. The purpose is to help the country obtain the strategic substitute areas for oil and gas resources. There are three characteristics extensively existing in China's marine carbonate rock tableland. 1. The era of the strata is very old, usually Lower Paleozoic and Proterozoic, with a long history. The period for hydrocarbon is very early. 2. Evolution of organic matter is extensively of high degree and usually under a stage from wet gas to dry gas. 3. The abundance of organic matter in carbonate rock is extensively low, formed mainly in shallow water and shallow water environment represented by epicontinental sea. For example, North China area (including Ordos basin) is an epicontinental sea environment at Cambrian–Early Ordovician era. The remaining organic carbon content of old carbonate rock is usually about 0.20 percent in China. This bears great influence on assessment of marine carbonate rock resources volume and principles for oil and gas exploration in the country.

On the contrary, Russia has made tremendous achievements in old marine carbonate rock oil and gas exploration. For example, the proven and controlled oil and gas resources volumes are currently 3.2 billion tons of equivalent oil and gas in Timan–Pechyora basin and the prospect resources volumes are 17 billion tons. West Siberia is a famous oil and gas basin in Russia. In addition to some large and giant oil and gas fields of Mesozoic-Cenozoic Jurassic and Cretaceous such as Qiuming Oil Field and Urengoy Gas Field, Paleozoic has become more and more important target horizons for exploration. A total of four Ordovician oil and gas reservoirs have been discovered. Kovikgin Condensate Gas Field and Verchon Gas Field have been discovered in the central southern part of the East Siberia platform. The producing layers of Koviktin Condensate Gas Field are of the second formation of Vendian. The oil and gas flow is found in 22 wells with the production reaching 300,000 $m^3$/d.

In 1999, Academician Dai Jin at China's Academy of Sciences sponsored a research project for cooperative comparison of "Chinese-Russian marine carbonate rock and oil and gas " in an attempt to promote bilateral academic exchange in this field and borrow each other's experience. It is important for the Chinese side to borrow experience from marine carbonate rock oil and gas exploration from the Russian side. In addition, the research project can promote exchange of samples of hydrocarbon source rock and crude oil for common analysis and study and solve some issues of mutual concerns.

Basedon the scheduleof Chinese-Russian marine carbinate rock and oil and gas project an eight-member delegation headed by Dr. Jia Chengzao visited Russia for technical exchange between December 10 and 29, 1999. The Chinese researchers visited Geophysical Chemistry & Analytical Chemistry Research Institute under Russia's Academy of Sciences (from December 10 to 18, 1999), VNIGRI (from December 19 to 22), GAZPROM (on December 21) and Petroleum Geological Research Institute of Russia's Academy of Sciences (from December 23 to 28). The bilateral sides exchanged geophysical chemical samples from Tarim basin and Timan–Pechyora basin as well as some preliminary research results on these two basins. During the course of technical discussion, the Chinese side briefed about the oil geological conditions of Tarim basin while the Russian side reciprocated by briefing about the oil geological conditions of Timan–Pechra basin, East Siberia tableland and West Siberia basin.

The Chinese researchers discussed in detail with their counterparts at Petroleum Geological Research Institute under Russia's Academy of Sciences about the oil geological conditions of Tarim basin and Siberia tableland. The two sides have highly evaluated each other's research fruit and shared an identical view on such scientific exchange. They proposed to publish the result of their academic exchange in English in China and in Russian in Russia.

This book is an English version of the theses submitted for Chinese-Russian academic exchange concerning the oil geological conditions of Tarim basin and Siberia platform. This book collects 19 academic papers in total, six ones from the Chinese side and 12 ones from the Russia side. Those papers cover the structure, sedimentation, oil generation and oil and gas reservoirs of Tarim basin, West Siberia basin and East Siberia tableland. Those papers are also focused on the comprehensive oil geological conditions and the oil economic conditions in Russian. Publication of this collection partially reflects the exchanged results of the "Chinese-Russian marine carbonate rock and oil and gas research project." Meanwhile, I hope that this collection of papers can help the Chinese and Russian researchers borrow each other's experience in oil and gas research and exploration.

The papers in this book have been examined and determined by Dr. Jia Chengzao and Dr. Sennikov N. V. Thank Academician A.E.Kontorovich for offering good conditions for academic exchange. Thank Academician Dai Jinxing and Academician A.E.Kontorovich for their instructions on publication of this book.

**Dr. Jia Chengzao and Dr. N.V.Sennikov**

April 20, 2000

# Contents

# The Exploration Achievements and the Prospect for Natural Gas in Tarim Basin, China

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**Abstract**: In recent years, a great progress has been made in the gas exploration by Tarim Oilfield Corporation. A total of 15 giant and medium-size oil and gas fields are proved, with the proven and probable geological reserves being $9.03\times10^8$ tons oil equivalence including proven geological gas reserves of $5050\times10^8m^3$, and a total $11010\times10^8m^3$ of proven, probable and predicted gas geological reserves. So this is the base switching on the project of "western natural gas delivered eastward". Kela-2 gas field is the largest sized gas field proved in China, with gas-bearing area 47.1 $km^2$ and proven gas geological reserves $2506.1\times10^8m^3$. Tarim Basin is a large superposed composite basin made by Palaeozoic cratonic basin and Meso-Cenozoic foreland basin, with the two types of gas resources of cracking gas from marine strata and pyrolysis gas from measure strata. The tectonic position of the Tarim Basin belongs to basin group at the north margin of Tethys and belongs to a part of gas-rich province of Middle Asian. The basin has good condition forming giant–medium sized gas fields, developed with 4 sets of source rocks including main gas source rocks of Cambro–Lower Ordovician and Trassic–Jurassic, and 5 good reservoir-seal assemblages for gas accumulation. Several petroleum systems such as Kuqa, Mangl. Awati, Southwestern Tarim, Tanggu, Southeastern Tarim and Yingjisu are composed of by the 4 sets of source rocks and 3 oil-gas regions can be classified obviously, which are Kuqa–Tabei gas region, Mangal oil-gas region and Bachu–Southwest Tarim gas region. At present, the focal exploration area is in Kuqa petroleum system. At the same time, seismic reconnaissance and comprehensive research are under way for Southwest Depression, which will be a very important strategic prepared area for gas exploration.

**Key words**: Gas-oil field, Petroleum system, Gas exploration, Tarim Basin

## 1 Introduction

Tarim Basin, surrounded by Tianshan Mountains and Kunlun Mountains, is located in the southern part of Xingjiang Uygur Autonomous Region and is the largest sedimentary basin in China, covering $56\times10^4km^2$. The central part of the basin is Taklamakan desert, the largest moving desert called "death Sea" in the world, is, with an extent of $33\times10^4km^2$.

From April 1989 to April 2000, 2D seismic survey of $19.4\times10^4$km and 3D seismic survey of 10460 $km^2$ were accomplished, 369 explosive wells were finished by Tarim Oilfield Corporation, with a total footage of $187.37\times10^4$m, and the commercial oil and gas flow came out in 151 of 369 explosive wells. The average success ratio for exploration well is 41% and the average success ratio for exploration trap is 34%. 15 giant–medium sized oil and gas fields were proved, which include 7 oil fields, i.e. Lunnan, Sangtamu, Jiefangqudong, Donghetang, Hade 4, Tazhong 4 and Tazhong 16, and 8 gas fields i.e. Kela-2, Yaha, Yingmai 7, Yangtake, Yudong 2, Jilake, Hetianhe and Tazhong 6[1]. Therefore, obviously, 3 oil-gas regions could be divided, i.e. Kuqa–Tabei gas region, Mangal oil-gas region and Bachu–Southwest Tarim gas region (Fig. 1).

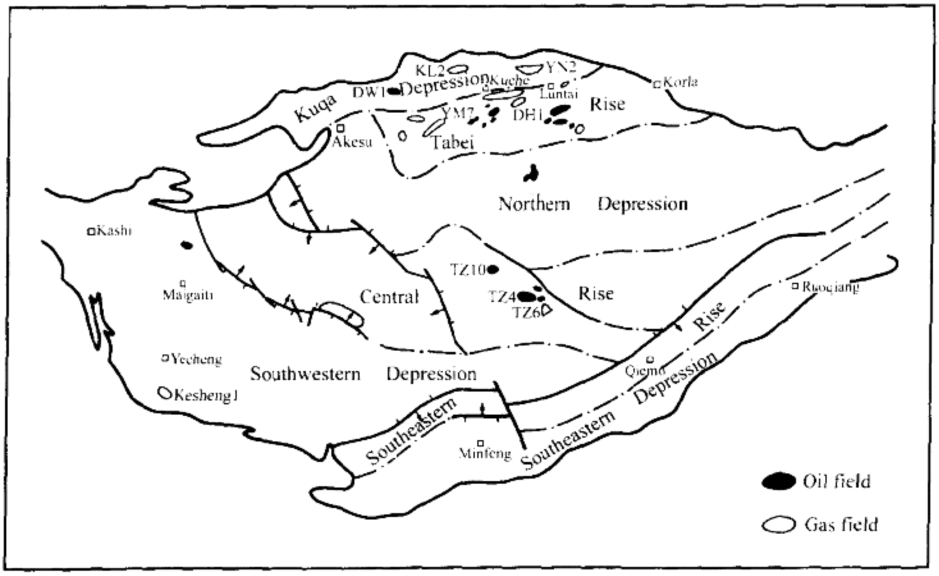


**Fig. 1 The oil and gas field distribution in Tarim basin.**

Till the end of the April 2000, the total geological reserves of proven $3.25\times10^8$ tons of oil ($0.95\times108$ tons recoverable) and $4700\times10^8m^3$ of gas ($3248\times10^8m^3$ of gas recoverable), probable $0.67\times10^8$ tons of oil and $760\times10^8m^3$ of gas and predicted $1.26\times10^8$ tons of oil and $4208\times10^8m^3$ of gas, had been obtained by Tarim Oilfield Corporation for the 11 years' exploration.

For 3 years from 1997 to 1999, a very important progress had been made in the gas exploration. Hetianhe gas field was discovered and proved in Mazatage structural belt of the south margin of Bachu Uplift, with proven reserves of $616\times10^8m^3$. Kela-2 gas field in Kelasu structural belt and Yinan-2 in Yiqikelike structural belt were discovered, and then several gas fields such as Dabei-1 and Tuzi-1 etc. had been found in Kuqa Depression. The proven gas geological reserves of Kela-2 was $2506\times10^8m^3$ and the total predicted gas geological reserves of Dabei-1, Tuzi-1, Ynan-2, Yishen-4 and Kela-3 gas fields was $3543\times10^8m^3$ (Fig. 2).

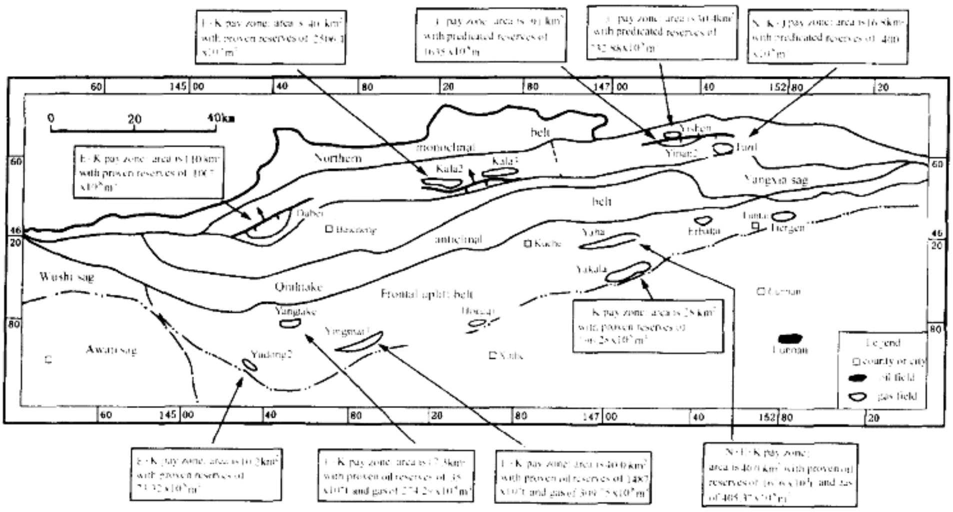


**Fig. 2 The distribution of the gas fields in Kuqa–Tabei gas region.**

Up to now, Tarim Oilfield Corporation has acquired $9.03\times10^8$ tons of oil equivalence of proven and probable geological reserves including $5050\times10^8 m^3$ of proven gas geological reserves, and a total $11010\times10^8 m^3$ of 3 grade gas geological reserves. So Tarim Basin has already been a basin with the largest remnant recoverable gas reserves. It costs 0.73 dollar for a recoverable barrel of oil equivalence lower than the average level of the oil companies in the world.

## 2 Petroleum Geology and Gas Resources

### 2.1 Tectonics

(1) Tarim Basin is a large superposed composite basin made from Palaeozoic cratonic basin and Meso–Cenozoic foreland basin, with the two types of gas resources of cracking gas from marine strata and pyrolysis gas from measure strata and with the two kinds of exploration targets in Palaeozoic cratonic basin and Meso–Cenozoic foreland basin[2].

The main body of the Tarim Basin is Palaeozoic cratonic basin developed upon the old continental crust and basement, superposed by the two Meso–Cenozoic foreland basins in the northern part and in the southern part of the basin in late period. These two basins have their own sediments, tectonic characters and petroleum accumulation regularities (Fig.3). The hydrocarbon accumulation is under the control of paleo-uplift and its slope in Palaeozoic cratonic basin and thrust belt of Himalayan orogeny in Meso–Cenozoic foreland basin[2]. The natural gas in Palaeozoic cratonic basin is mainly the cracking gas from Cambro–Ordovician and the natural gas in Meso–Cenozoic foreland basin is mainly the pyrolysis gas from meas-

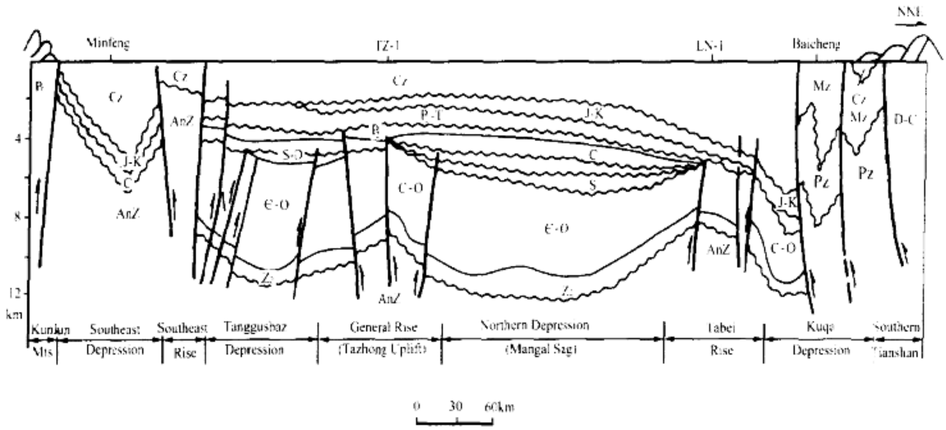


**Fig. 3 Structural cross section of Tarim Basin.**

ure strata of Triassic and Jurassic.

The Palaeozoic cratonic basin has a huge thickness of carbonate and clastic sediments, involving cratonic marginal aulacogen stage from Sinian to Ordovician, marginal foreland basin stage from Silurian to Devonian and cratonic margin and intracratonic rift stages from Carboniferous to Permian[2]. The paleo uplifts are the main hydrocarbon accumulation area and can be divided into 3 types or 5 kinds, including Tazhong stable paleo uplift, Tabei and Tadong residual paleo uplifts and Bachu and Tanan active paleo uplifts. In Palaeozoic cratonic basin, Hetianhe gas field has been discovered at the south margin of Bachu paleo uplift.

Kuqa Depression and Southwest Depression are marine sediment depression from Mesozoic to Cenozoic in the front of Tianshan Mountains and Kunlun Mountains, respectively. In the two depressions, Lacustrine to swamp deposit was developed in Triassic and Jurassic with coal-bearing strata, and fluvial--delta deposit was mainly developed in Creataceous and Tertiary with shallow sea facies and lagoon facies developed in the western part of the basin. Thus, the good source–reservoir–seal assemblages were formed. At the end of the Tertiary, the strong thrust belts, being the most favorable gas accumulation area, were taken shape in Kuqa Depression and Southwest Depression, caused by Himalayan orogeny and formed a lot of fault-folded local structures and traps. Some giant to supergiant anticlinal gas fields such as Kela-2, etc., had been found in the foreland basins.

Therefore, there are two types of gas resources of the cracking gas from marine strata and the phyrolysis gas from measure strata and two kinds of exploration targets in Palaeozoic cratonic and Meso–Cenozoic foreland of the large superposed composite basin.

（2） The tectonic position of the Tarim Basin is situtated in the basin group at the north margin of Tethys and belongs to a part of gas-rich province of Middle Asian

The basin group is located at the northern margin of paleo Tethys structural belt, including Tarim Basin, Fergana Basin, Sirduya

Basin, Kala–Kum Basin and Tadzhikistan–Afghanistan Basin etc. These basins are always under the active continental marginal tectonic setting of the north side of paleo Tethys Sea and neo Tethys Sea from Mesozoic Era, and involved retroarc foreland basin from Permian to Triassic, retoarc expanding rift-subsidence basin from Jurassic to Palaeogene and regenerative foreland basin (Fig.4).

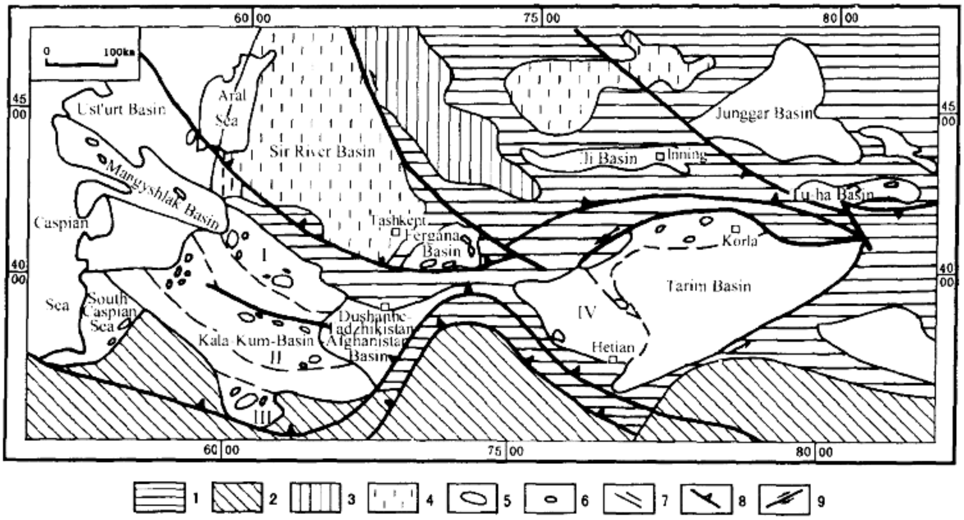


**Fig. 4 The gas field distribution of Jurassic basin in the northern Tethys.**

1. Fold belt of Palaeozic; 2. Fold belt of Meso–Cenozoic; 3. Sedimentary basin of Palaeozoic; 4. Sedimentary basin of Meso–Cenozoic; 5. Jurassic basin; 6. Gas field; 7. Fault; 8. Plate stylolitic structural belt or subductition orogenic belt; 9. Strike-slip fault; I. Buhar–Karzov Step Block, II. Kala Uplift, III. Budhzi–Kalar Uplift, IV. The Cresent Zone of Western Tarim.

The tectonic setting of the northern margin of Tethys determines that the organic matters in the basins are mainly humic type (the kerogen of type II and III) generating mainly natural gas. It is well known that these basins are much rich in gas, for example, Kala–Kum basin with gas reserves of $67000x10^8$.

The hydrocarbon-bearing basins of the north margin of Tethys are much similar in the conditions of petroleum geology as follows.

Tectonic setting: All basins were always under the active continental marginal tectonic setting of the north side of paleo-Tethys and neo-Tethys from Mesozoic Era.

Evolution history: These basins involved the basement developing stage in Triassic, the subsidence stage from Jurassic to the end of Paleccene and the molasse developing stage from the end of Eogene.

Organic matter: The main hydrocarbon source rock is Jurassic coal-bearing strata, in which the organic matter is humic type (type III) or humic sapropellic type (type II) and humic organic matter is dominant, which mainly generates natural gas.

The trap formation is closely related with the fold thrust belt of the foreland, and the dynamic background is related with continued impingement between Indian plate and Eurassian plate.

So the conclusions can be obtained as follows through the analysis of tectonic setting and petroleum geological conditions of the Tarim Basin.

(1) Tarim Basin is one part of the gas-rich province of Middle Asia and has probably been an entirty with Kala–Kum Basin and Tadzhikistan–Afghanistan Basin, which were separated by Pamir Arch developed in Miocene and formed the present tectonic framework.

(2) Tarim Basin has the petroleum geological conditions to form huge sized natural gas fields. especially in the western Tarim Basin where stratigraphic sequences are much similar to the basins of Middle Asia and also the main gas-enriched area.

## 2.2 Source Petroleum System

4 sets of main source rocks including Cambro–Lower Ordovician, Middle and Upper Ordovician, Carboniferous and Trassic–Jurassic, are developed in Tarim Basin. But the gas source rocks are mainly Cambro–Lower Ordovician and Triassic–Jurassic. Analysing by sedimentary facies and organic matter source, the source rocks of Palaeozoic are marine strata developed in cratonic basin and the ones of Mesozoic are terrestrial strata developed in foreland basins. The 4 sets of source rocks grouped seven petroleum systems, such as Kuqa petroleum system, Mange petroleum system, Awati petroleum system, Southwestern Tarim petroleum system, Tanggu petroleum system, Southeastern Tarim petroleum system and Yingjisu petroleum leum system (Fig.5).

*2.2.1 Gas source rock of Cambro–Lower Ordovician*

The source rock of Cambro–Lower Ordovician is distributed most widely, with higher organic abundance, the largest amount of resources composed and the multiple stages of thermal evolution and hydrocarbon generating. According to sedimentary environment, the source rock can be divided into 2 types of starved basin facies of margional cratonic and endogenous platform facies of inner cratonic.

The high quality source rock of starved basin facies of marginal cratonic is mainly distributed in the eastern part of the Mangl Sag. The lithology of the source rock is black shaly micritic marl and siliceous or calcareous mudstone, with average TOC from 1.24% to 2.28% and the maximum TOC 5.52%. The organic precursor of the source rock is mainly planktonic algae, constituting type I organic matter. The source organic matter of the starved basins facies are at the stage of over-maturation, with converted Ro from 1.91% to 3.61% for Middle and Lower Cambrian strata, from 1.88% to 2.13% for Upper Cambrian strata.

The source rock of endogenous platform facies was developed in Middle and Lower Cambrian strata and was distributed in the western part of the basin with average TOC from 0.91% to 1.24%. The organic matter of the source rock belonged to type I and is at higher thermal evolution, equivalent to vitrinite reflectance Ro from 1.44% to 2.06%, showing the source rock being at the stage of high maturation to over-maturation.

The distribution of the oil and gas derived from the source rock is very complicated because of multiple thermal evolution stages. The dstribution of gas field in cratonic area is under the control of the source rock. The dry gas in Hetinhe gas field and in Jilake gas field found at present were derived from high-quality and effective source kitchen of Cambrian in Southwest Depression and in the eastern part of Mangl Sag, respectively. Moreover, the central and western part of Awati Sag is a potential dry gas-rich area generating from Cambrian. The Cambro–Lower Ordovician petroleum system can be regionally classified into 2 confirmed petroleum systems and a guessed petroleum system, which are Mangl, Southwest Tarim and Awati petroleum systems.

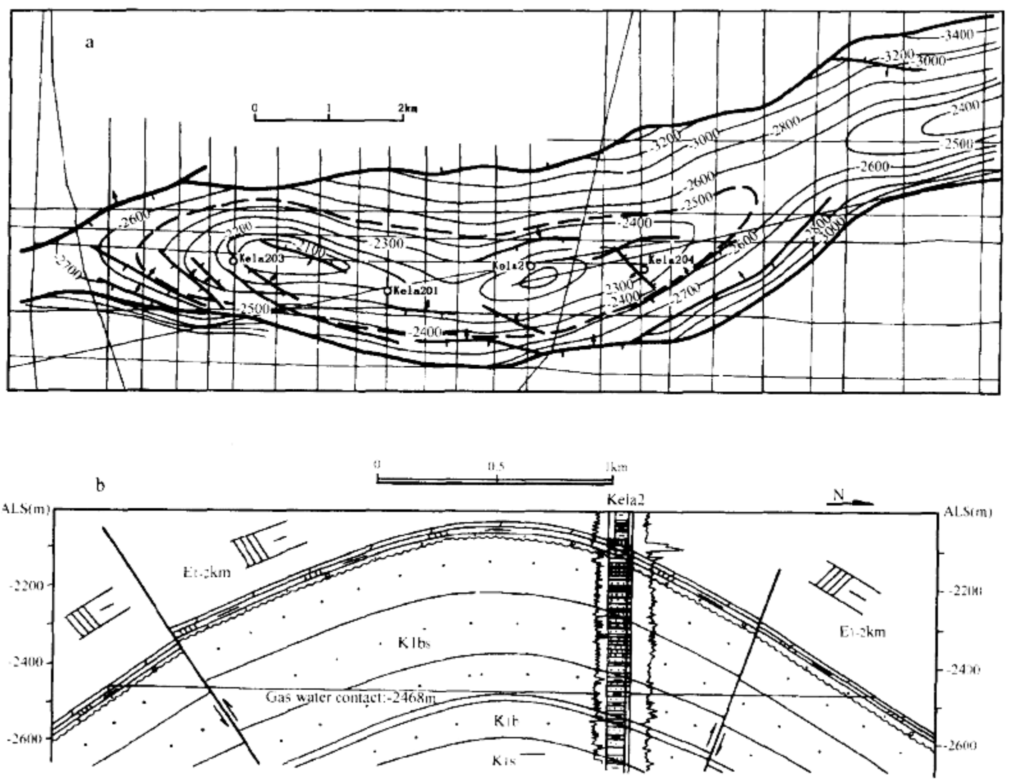


**Fig. 5 (a) The gas bearing area of Kela-2 gas field;**
**(b) The cross section of Kela2 gas field along BC95-230 line through well Kela-2.**

*2.2.2 Middle–Upper Ordovician source rock*

The high-quality Middle–Upper Ordovician source rock is mainly distributed in Tazhong Uplift, Tabei Uplift and its south slope and the central and western part of Awati Sag.

The source rock in Tazhong area is widely distributed in the main uplift and its northern slope. with average thickness of 80m, TOC from 0.5% to 5.54%. The organic matter of the source rock is type I or mixed type $II_2$ to III, and is at the peak of hydrocarbon generation of oil prone, with organic maturation $R_o$ from 0.81% to 1.30%.

The Middle–Upper Ordovician source rock in Tabei Uplift is distributed in the central and eastern part of the Uplift, with TOC from 0.2% to 0.96% and *Ro* from 0.89% to 1.45% being at the peak of hydrocarbon generation and the end of oil-generating window.

The Middle–Upper Ordovician source rock distributed in cratonic area, with higher organic abundance, moderate maturation and oil-prone mixed organic type, is a reality and effective marine oil source rock. Now, the distribution of marine oil field is under the control of the source rock in cratonic area, and most of the marine oil is derived from the Middle–Upper Ordovician source rock.

*2.2.3 Carboniferous source rock*

The Carboniferous source rock of high organic abundance is mainly distributed in the western part of the basin, and developed vertically in Kalashayi Formation and Bachu Formation.

The mudstone of Kalashayi Formation belongs to littoral lagoon facies and offshore fluvial–paludal facies with maximum thickness 97m, maximum TOC=7.09% and hydrocarbon source potential 37.78mg/g of the coal-bearing source rock. The organic matter of the source rock is mainly from type $II_2$ to III, being at the lower mature stage with *Ro* generally less than 0.7%.

The biomicritite of Bachu Formation belongs to the sediment in marginal platform slope with the thickness 30m, average TOC =0.62% and the maximum TOC=1.93% of the source rock. The mixed type is characteristic of the organic matter of the source rock , with *Ro* 0.80% or so. The Carboniferous petroleum system is distributed in Southwest Depression, in which the oil and gas commercial flow from Carboniferous has not been found except oil and gas indications and low oil flow in Well.Qun-4 and Well.Qu-1, and Well.Ma-4 in Mazatage structural belt.

*2.2.4 Triassic and Jurassic source rock*

The source rock of Triassic and Jurassic source rock, being mainly lacustrine mudstone and coal-bearing mudstone, is distributed in Kuqa Depression and Sothwest Depression.

(1) Triassic and Jurassic source rock in Kuqa Depression.

Triassic and Jurassic source rock in Kuqa Depression includes coal-bearing mudstone and lacustrine mudstone, with their sedimentary facies belonging to palludal facies and lacustrine facies, respectively. The coal-bearing source rock is widely distributed in the whole depression and vertically distributed mainly in Middle–Lower Jurassic and secondly in Upper Triassic. The lacustrine source rock is distributed in Jurassic and Triassic and is mainly developed in Qiakemake Formation of Jurassic and in the main body of Triassic.

Five source beds can be distinguished. They are Qiakemake Formation, Kezilenuer Formation and Yangxia Formation of Jurassic and Taliqike Formation and Huangshanjie Formation of Triassic, with the source thickness of Jurassic ranging from 0 to 1704m and the source thickness of Triassic from 0 to 980m. The maximum thickness of Jurassic and Triassic is located in Baicheng Sag, and the source rock of Jurassic is wider in distribution than that of Triassic because of overlying measure in Mesozoic. Some known structural belts such as Kelasu, Yiqikelike, Qiulitake and Gumuzibieke etc are in or near the hydrocarbon-generating center.

The source rock in Kuqa Depression has higher organic abundance with TOC from 0.01% to 39.98% and averages 3.68% for Jurassic mudstone and carbargillite, and from 0.01% to 24.52% and averages 3.68% for Triassic mudstone and carbargillite.

The source rock of Jurassic and Triassic is enrichment in vitrinite with the average content 52.07% and lower hydrogen index in a large pyrolysis data. The terrigeneous source kerogen in the whole depression is from −19.43‰ to −28.10‰ with main body from −22.8‰ to −28.1‰ showing terrigeneous plants for the organic precusor.

The vitrinite flectance of the Mesozoic source rock is generally more than 0.7%. In the direction from north to south, the main body of the depression, Baicheng Sag and Yangxia Sag of the central part of the depression, is higher in source maturation, while the northern part and the southern part of the depression are in lower mature stage. The bottom of Jurassic is at over-maturation stage with Ro more than 2.0%, in Baicheng Sag and at high-maturation stage with Ro 1.5% or so in Yangxia Sag. So, Kuqa foreland area is rich in gas because of the organic matter and maturation of Mesozoic source rock.

The peak of gas generation occurred in late Himalaya and the main period of gas accumulation began from 5 Ma, matched with the formation of traps and all these things were favorable for oil and gas accumulation with main dry gas and condensate gas phase.

(2) Jurassic source rock in Southwest Depression.

The source rock of Mesozoic in Southwest Depression is mainly measure strata of Middle–Lower Jurassic with fluvial, palludal and lacustrine facies, and is mainly distributed along Kashi Sag and Yecheng Sag near range-front. A total thickness of the source rock is more than 300m and the maximum 700m in Kashi Sag with dark laucstrine mudstone over 80m. The oil and gas in Kekeya gas field were generated by the source rock.

The organic abundance of the source rock of Middle–Lower Jurassic is higher than the other in the southwest of Tarim Basin. The value is TOC from 1.10% to 3.73% and hydrocarbon content from 539 ppm to 2789 ppm in Kashi Sag, and TOC from 0.70% to 1.10%, hydrocarbon content from 37 ppm to 285 ppm in Yecheng Sag. The organic matter of the source rock is mainly type $II_2$ or type III, with maturation from premature and early mature stage near Maigaiti Slope to mature and highly mature stage in central part of Yecheng Sag and Kashi Sag. The source rock of Jurassic entered the threshold of hydrocarbon generation in Miocene and was at the peak of oil generation or even at the stage of condensate gas and wet gas generation at present.

According to the analysis above, there are 2 sets of important gas source rocks, which are Cambro–Lower Ordovician source rock and Triassic–Jurassic source rock respectively. The natural gas generated by the former is the cracking gas from old oil reservoir with an example of Hetianhe gas field, and the one generated by the latter is pyrolysis gas from kerogen of type III with an example of Kela-2 gas field.

### 2.3 Reservoir–seal Assemblages

Five good reservoir–seal assemblages for gas accumulation are developed in Tarim Basin as follows:

(1) The assemblage of Cretaceous sandstone and Eogene saltay and gypseous mudstone is the best assemblage of the basin, of which Kela-2 gas field has been found, and is distributed in Kelasu and Qiulitake structural belts and Tabei area.

(2) The assemblage of Jurassic coal-bearing mudstone and its underlying sandstone, of which Yinan 2 gas field has been found, is distributed in monocline zone in the northern part of Kuqa Depression and Yiqikelike structural belt.

(3) The assemblage of interbeds of limestone and sandstone–shale of Carboniferous and buried hill in Ordovician weathering crust, of which Hetianhe gas field has been found, is mainly distributed from Selibuya to Mazatage structural belt.

(4) The assemblages of sandstone and mudstone in Neogene and gypseous mudstone and dolomite, sandstone in Eogene and Cretaceous, of which Kekeya gas field has been found, is distributed on the south margin of Southwest Depression.

(5) The assemblage of Cambrian salty and gypseous strata and the underlying dolomite are to be exploded further.

Moreover, the gypseous mudstone and gypseous salty mudstone of Jidike Formation and its underlying sandstone at bottom together construct composed of another high-quality assemblage.

## 2.4 The Resources of Natural Gas

(1) According to resource assessment of the whole nation in 1994, the resources of natural gas is $8.39\times10^{12}m^3$ in Tarim Basin, which is one of the richest basins in China.

(2) The resources of natural gas in Kuqa Depression

The range of Kuqa petroleum system is equivalent to Kuqa–Tabei gas region including its main body of Kuqa Depression and the northern part of Tabei Uplift, with a total area of 42700 $km^2$.

The reassessment of hydrocarbon resources to Kuqa Depression shows that the hydrocarbon resources is $26.5\times10^8$ tons of oil equivalents including $4.1\times10^8$ tons of oil and $2.23\times10^{12}m^3$ of gas. The oil and gas abundance reaches $9.43\times10^4$ tons of oil equivalents per square kilometers and gas to oil ratio is 5.4:1, indicating Kuqa petroleum system is rich in gas. The gas resources in the known structural belts is above $2\times10^{12}m^3$ in Kuqa petroleum system.

Comparing it with gas-rich province of Middle Asia, we anticipate that the big-sized gas field with gas reserves from $3000\times10^8m^3$ to $4000\times10^8m^3$ could be possibly found. According to G.P.Zipf rule explaining a relationship of power function between the rank and the size of oil and gas reservoir, 6–8 gas fields with gas reserves from $500\times10^8m^3$ to $1500\times10^8m^3$ and a total gas reserves near $7000\times10^8m^3$ could be found later.

(3) The resources of natural gas in Southwest petroleum system.

The resources of natural gas in Southwest petroleum system is $2.089\times10^{12}m^3$, and 2 gas fields of Hetianhe and Kekeya has been found, with proven geological reserves $967\times10^8m^3$ and probable geological reserves $436\times10^8m^3$. The petroleum system, with very poor exploration at present, is an important strategic prepared area for gas exploration in Tarim Basin.

(4) The cresent gas-rich zone in the western part of Tarim Basin.

The cresent gas-rich zone in the western part of Tarim Basin, composed of Kuqa, Southwest Tarim and Awati petroleum sys-