



技术进步引领中国石化天然气多样化发展

Technological progress — the engine behind
Sinopec's diversified natural gas development

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一、引言 Introduction

➤ 世界天然气资源丰富、开发潜力巨大

Significant natural gas potential in the world

根据剑桥能源的分析预测，到2050年全球天然气可采资源总量为789万亿立方米，目前已采出107万亿立方米，已探明未动用天然气可采储量187万亿立方米，常规天然气预测可采潜力217万亿立方米，非常规天然气预测可采潜力385万亿立方米。天然气资源丰富，可供全球长期使用。

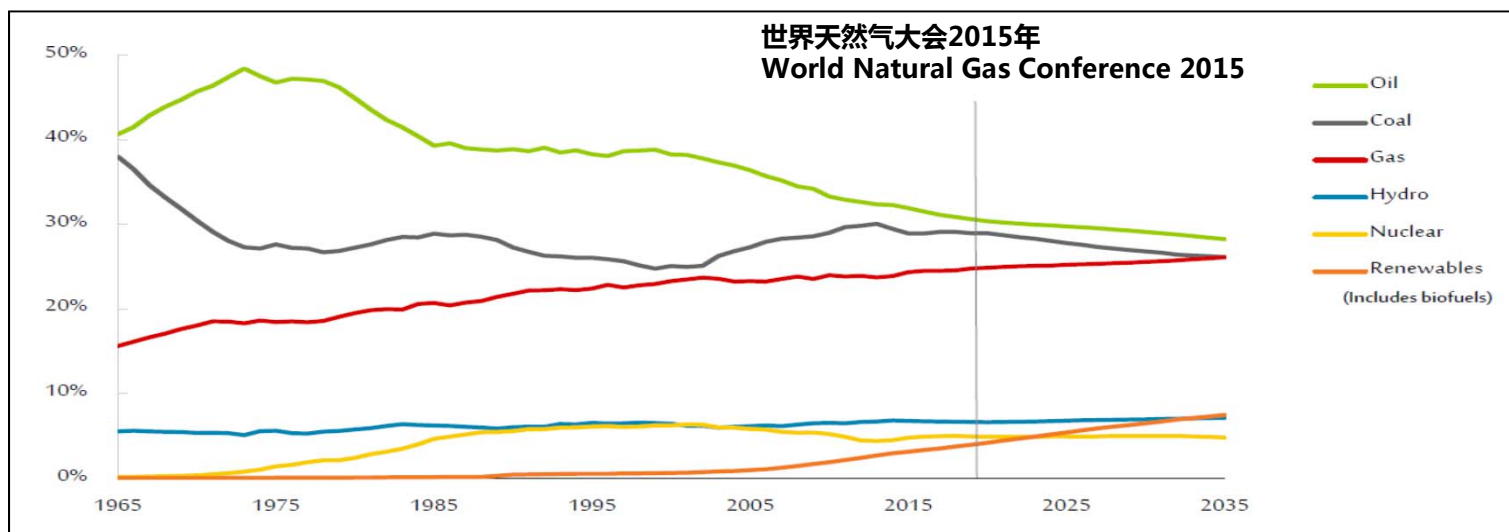
- **World technical recoverable gas resource: 789 TCM by 2050**
- **Gas production to date: 107 TCM**
- **Undeveloped recoverable gas reserves: 187 TCM**
- **Conventional gas potential: 217 TCM**
- **Unconventional gas potential: 385 TCM**

(Data source: CERA)

➤ 天然气作为主要能源资源战略地位不可动摇

Strategic importance of natural gas as primary energy

- ◆ 全球天然气生产增长迅速，目前天然气为三大主要能源资源之一；
- ◆ 到2035年天然气将成为第二大消费能源资源；
- ◆ 天然气在中国一次能源的消费比例由2010年的3.8%提高到2014年的6.3%。
- Natural gas as one of the three major energy resources;
- Natural gas will be the second largest energy resource in 2035;
- Gas consumption doubled in 2010 -2014 (3.8-6.3% in China's total primary energy consumption)



➤ 中国积极推动能源革命，天然气储量产量增长强劲

Reform in energy production and consumption in China yielded high growth rate in reserve and gas production

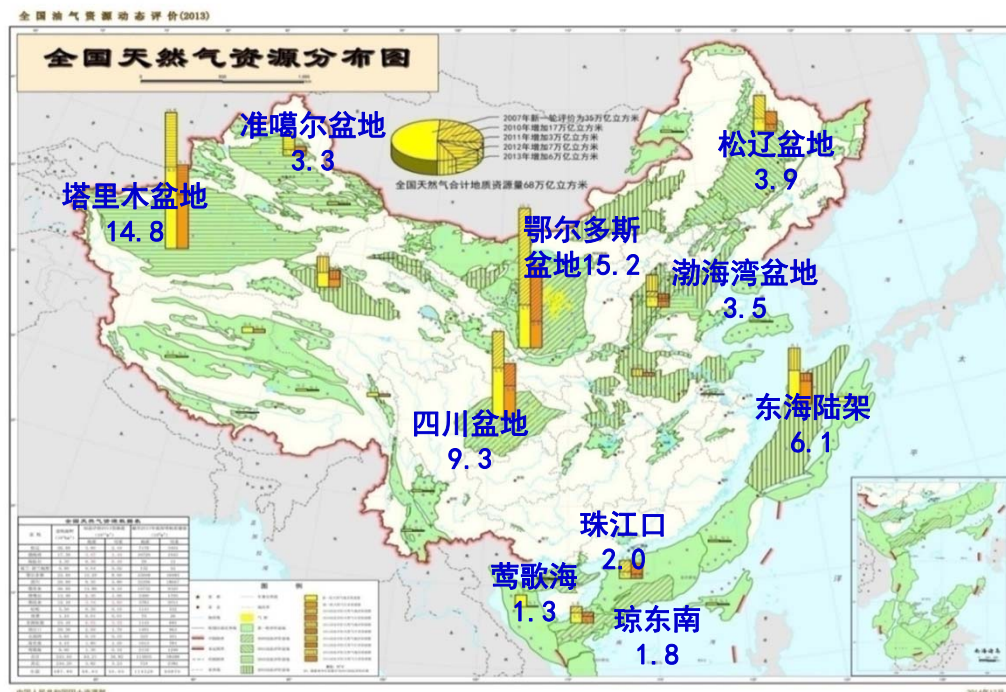
据国土部2015年公布数据，常规天然气地质资源量68万亿方、可采资源量**40万亿**立方米，主要分布在鄂尔多斯、塔里木、四川及东海等盆地。近十年年均探明地质储量**7344亿**立方米，处于储量快速发现阶段。

据中国工程院评价结果，页岩气、煤层气可采资源量**20万亿**立方米。

- China national oil & gas resources assessment in 2015: **40 TCM** of technologically recoverable resources of conventional natural gas (mainly distributed in Ordos, Tarim, Sichuan and East China Sea basins).

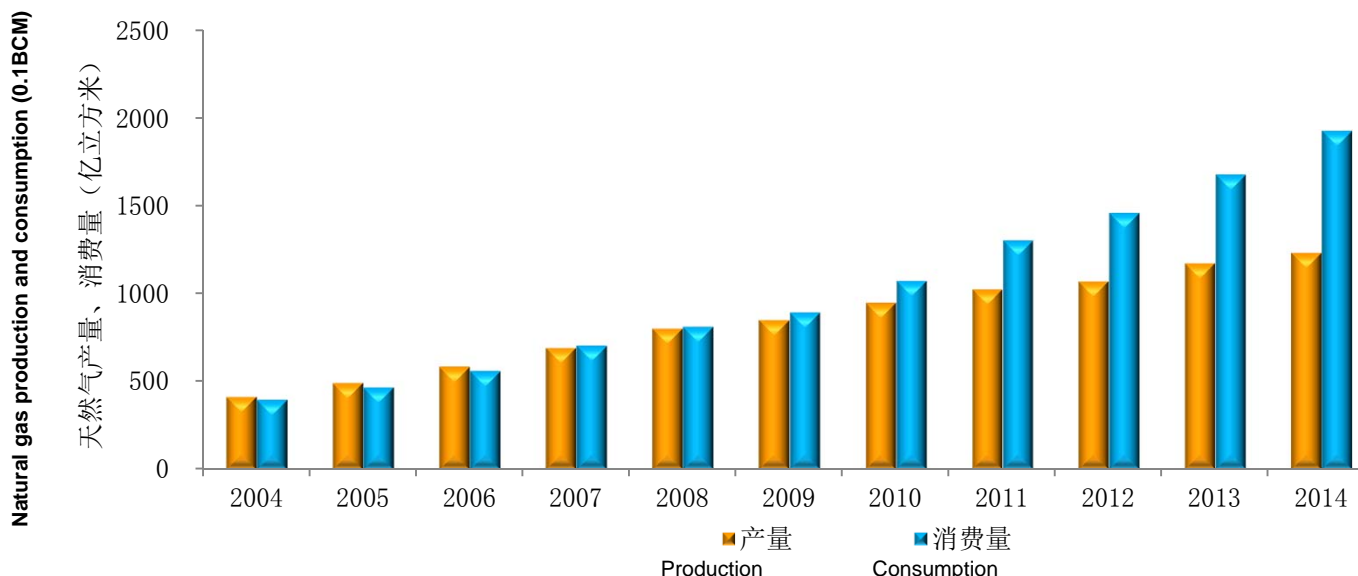
- Increasing measured in-place reserve of **734.4 BCM** per year in the last decade.

- Chinese Academy of Engineering: **20 TCM** of shale gas and coal-bed methane.



从2004到2014年，中国天然气产量从415亿立方米增长1234亿立方米，年均增速8.2%，天然气消费量2014年达到1930亿方，对调整能源消费结构、促进绿色低碳发展起到了重要作用。

Natural gas production in China had increased by 8.2% annually from 41.5 BCM in 2004 to 123.4 BCM in 2014. Gas consumption reached 193 BCM in 2014, making significant contribution to reshaping energy mix and facilitating a low-carbon economy in the country.



中国天然气产量及消费量变化曲线
Production and consumption of natural gas in China



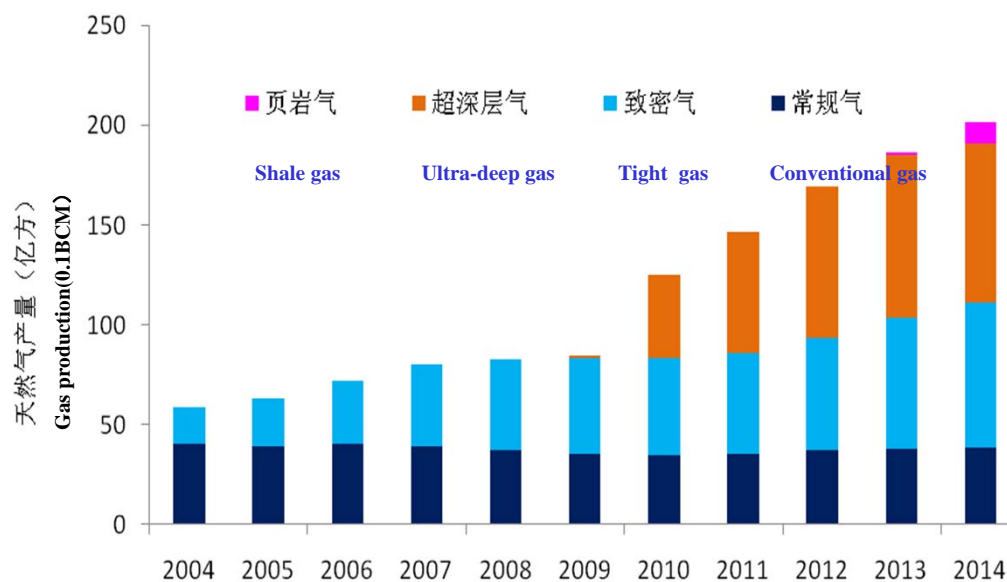
► 技术进步引领中国石化天然气多样化发展

Sinopec's diversification development of Natural Gas driven by technological Progress

2004年以来，中国石化推动储层及含气性预测、气藏精细描述及开发优化、超深层优快钻井、酸性气防腐、非常规气井工厂开发等技术的革命性进步，使低丰度致密气、超深层高含硫气藏、页岩气藏得到规模效益开发，2014年天然气产量突破200亿方，实现了天然气产量的跨越式增长。

● Since 2004, Sinopec has achieved technological advances in many aspects concerning natural gas, including gas content estimation and reservoir characterization, development optimization, ultra-deep drilling, anti-corrosion, and factory drilling.

● Large-scale commercial development of tight gas, ultra-deep sour gas and shale gas was based on these advancements, and by 2014, Sinopec's annual gas production surpassed 20 BCM, marking a giant leap in gas production growth.



中国石化天然气产量构成和变化图
Sinopec's natural gas production



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二、超深层高含硫气田安全高效开发技术

Safety- and efficiency-oriented technologies for the development of Puguang Gas field

普光高含 H_2S (15.2%)，元坝气田埋藏深 (7200m)、高温 (164°C)、高压 (70MPa)，储层分布、安全高效开发难度大。

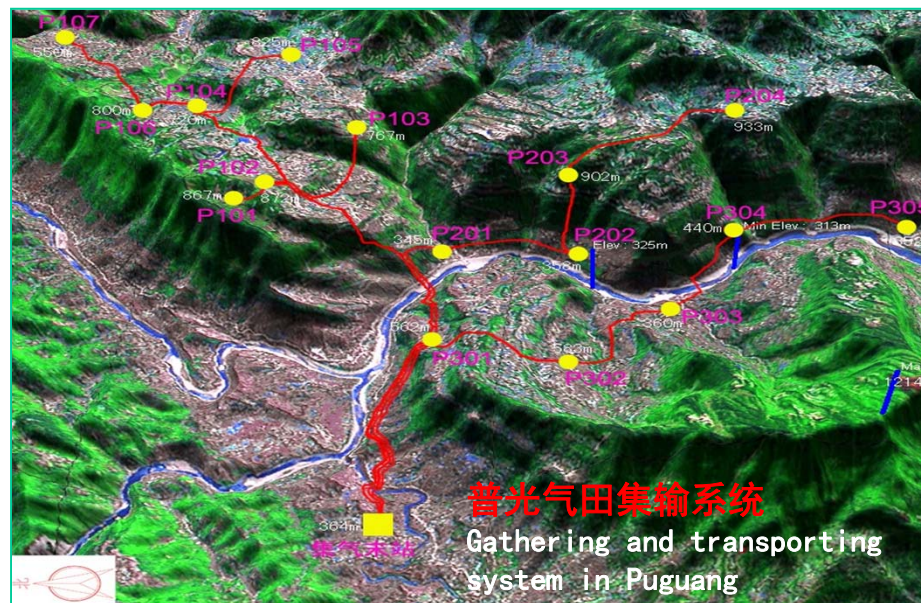
Gas production from Puguang and Yuba fields has many challenging issues:

- Puguang: high H_2S (15.2%)
- Yuanba: HTHP (164°C and 70MPa), deep burial (7200m), and complex reservoir and water-gas distribution.

形成的开发技术系列：

Technology Series for gas development

- ◆ 超深层礁滩相储层精细刻画技术
- ◆ 超深薄层水平井优快钻井技术
- ◆ 特大型高含硫气田腐蚀防护技术
- ◆ 高含硫天然气超大规模深度净化技术
- ◆ Fine characterization of ultra-deep reef-flat facies reservoirs
- ◆ Rapid drilling for horizontal wells in thin ultra-deep layers
- ◆ Anti-corrosion in sour gas development
- ◆ Advanced sour gas purification system



普光气田已建成110亿方/年生产能力，元坝气田今年底建成40亿方/年生产能力。

普光安全高效开发技术获国家科技进步特等奖。

Puguang gas field: annual gas productivity of 11BCM; Yuanba gas field: annual gas productivity of 4BCM

Technologies for Puguang gas field development won the Special Prize of National Science and Technology Award



1、超深层礁滩体精细刻画技术

Fine characterization of ultra-deep reef-flat facies reservoirs

创新形成了超深层礁滩体精细刻画技术，新井储层钻遇符合率85%以上，新井测试无阻流量 $149-634 \times 10^4 \text{m}^3/\text{d}$ 。

Fine characterization of ultra-deep reef-flat reservoirs with more than 85% accuracy in terms of drilling data and open flow rate for newly drilled wells being $149-634 \times 10^4 \text{m}^3/\text{d}$).

◆波阻抗反演、古地貌分析技术刻画礁滩体剖面及平面分布

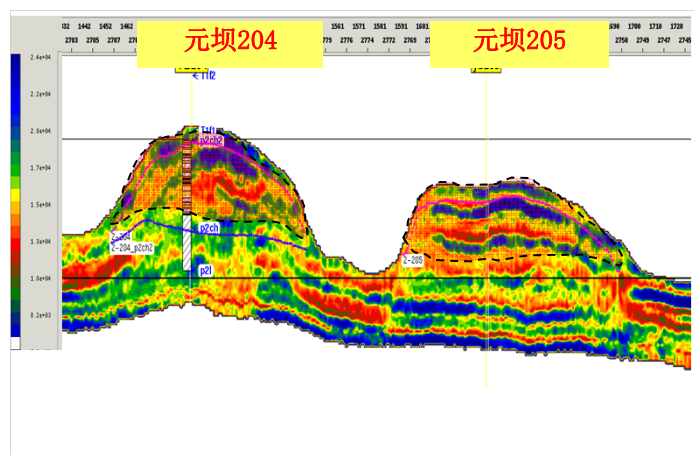
Impedance inversion and paleogeography analysis for profile and planar distribution characterization;

◆三维可视化技术和多属性体融合技术，雕刻礁滩体空间分布

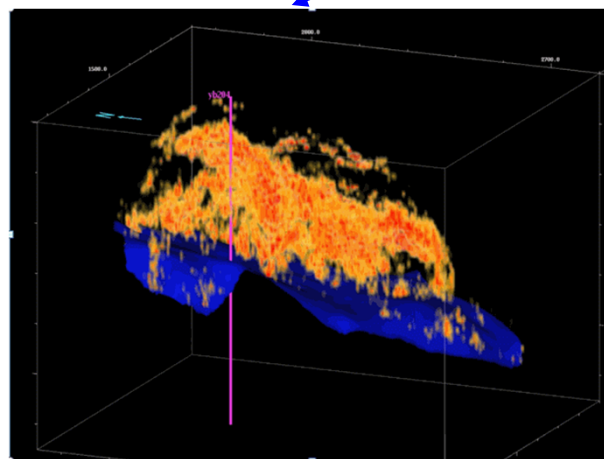
3D visualized and multi-attribute fusion technique for spatial distribution characterization;

◆三维地质建模精细表征生物礁滩储层展布

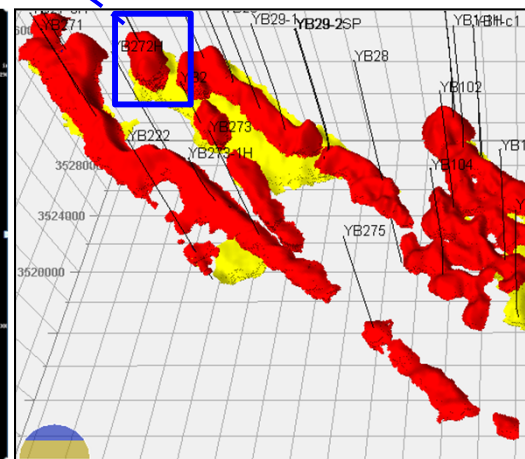
3D geological modeling of reservoir distribution in reef-flat bodies



波阻抗反演分析技术
Wave impedance inversion



三维可视化技术
3D visualization



礁滩储集体模型
Reef-flat reservoir models 10



2、超深薄层长水平井优快钻井技术 Speed drilling for horizontal wells in thin ultra-deep layers

形成了三项核心技术，实现“十个月完钻一口超深水平井”的突破，创造了高含硫气藏超深水平井钻井3项世界纪录和2项国内纪录。

Application of the following three technologies refreshed 3 world records and 2 domestic records in ultra-deep horizontal well drilling of high sulfur gas reservoirs.

■超深薄层长水平段轨迹调整及控制技术

Horizontal well trajectory adjustment and control in thin ultra-deep layers

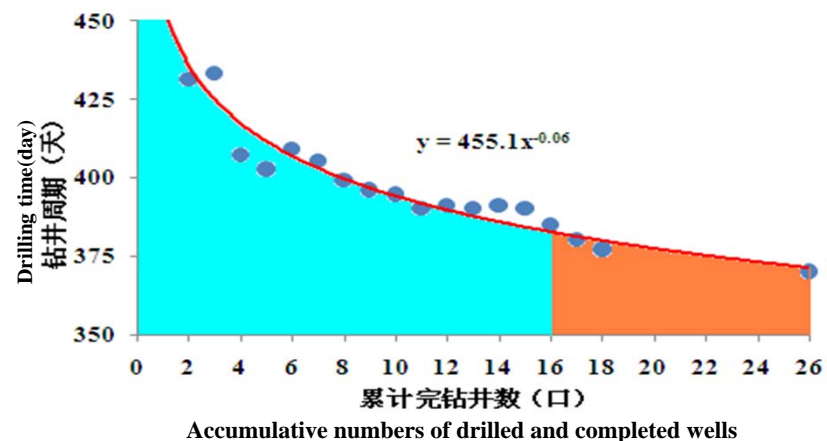
■多压力系统井身结构设计技术

Multi-pressure system well design

■超深水平井优快钻井技术

Speed drilling for ultra-deep horizontal wells

Accumulative drilled and completed wells



名称 (Items)	指标 (Records)	井号 (Well)	级别 (Record Level)
垂深最深 (Vertical depth)	6991. 1m	元坝121H (Yuanba121H)	世界 (World)
井深最深 (Well depth)	7971m	元坝101-1H (Yuanba101-1H)	世界 (World)
水平段最长 (Lateral length)	1073. 3m	元坝272-1H (Yuanba272-1H)	世界 (World)
井底压力最高 (Bottom pressure)	140MPa	元坝272H (Yuanba272H)	中国 (China)
钻井周期最短 (Drilling time)	282d	元坝102-3H (Yuanba102-3H)	中国 (China)



3、特大型高含硫气田腐蚀防护技术

Anti-corrosion in sour gas development

创新了特大型高含硫气田腐蚀防护技术，腐蚀速率控制在0.059毫米/年以下，实现了年产百亿立方米高含硫湿气输送，节约了土地，减少了污染源，降低投资20%。

Innovations in sour gas anti-corrosion technologies has helped keeping facility corrosion rate well below 0.059mm/year and realized direct pipeline transportation of several 10 BCM of sour and wet gas. It saves land and money and is environmental friendly.

●抗硫管材的腐蚀评价与优选技术

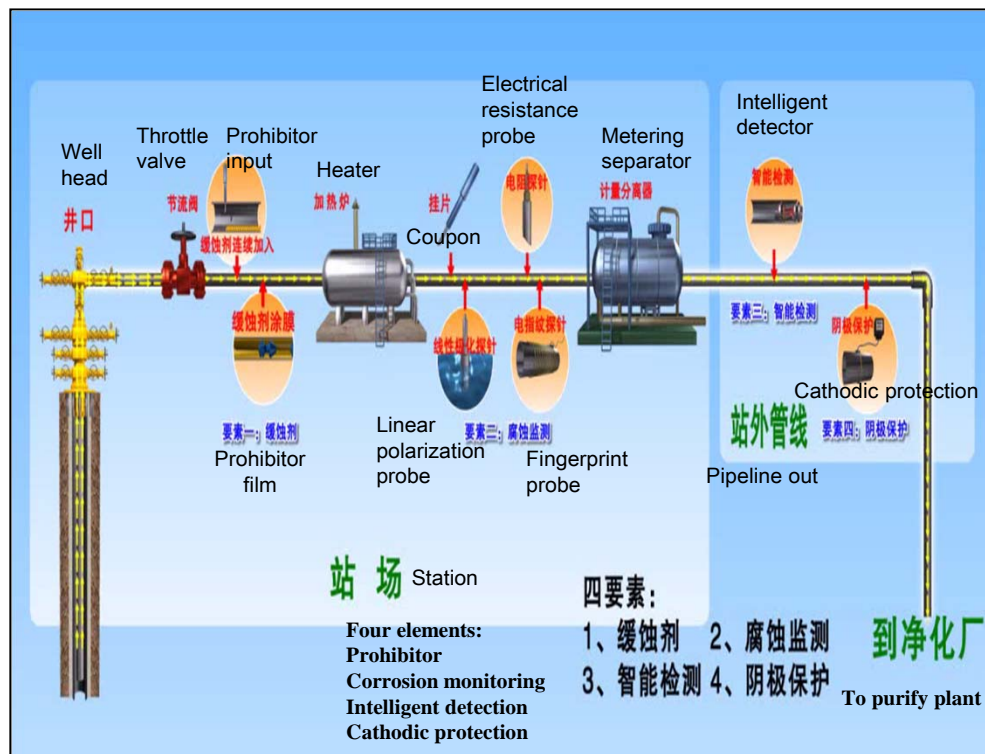
Sulfur resistant pipe material evaluation and selection

●高含硫天然气集输管道焊接技术

Pipe welding

●高含硫气田湿气集输腐蚀监测、缓蚀剂、阴极保护、智能检测等综合防腐技术

The “four elements” anti-corrosion method consisting of corrosion monitoring, prohibitors, cathodic protection, intelligent detection



普光气田集输系统“四要素”综合防腐工艺
“Four elements” anti-corrosion method



4、高含硫天然气超大规模深度净化技术

Advanced sour gas purification system

◆研发了固定床低温催化水解有机硫技术，发展了两级吸收、级间冷却深度净化技术，天然气净化率达99.99%，优于一类气标准；

Fixed bed low-temperature catalytic hydrolysis system with two-stage absorption and intra-stage cooling and purifying technologies integrated for treatment of high sulfur gas (purifying rate = 99.99% and > requirement of type I gas standard in China)

◆研发了特大型克劳斯炉、建成了20万吨级单列硫磺回收装置，年生产硫磺210万吨，总硫回收率达99.9%，硫磺产品纯度99.9%，优于一等品标准。

Super-huge Klaus sulfur recovery system with 200 000-ton single sulfur recovery unit capable of producing 2.1 million tons of sulfur per year, with both sulfur recovery rate and sulfur purity reaching 99.9%, higher than national standard of first class product



普光天然气净化厂

Puguang gas purification plant for gas



特大规模硫磺高效回收技术

Super-scale sulphur recovery facility



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三、致密砂岩气藏开发技术

Development technologies for tight gas

大牛地气田储层厚度小、非均质性强、储层物性差、储量丰度低、直井产量低，经济有效开发难度大。

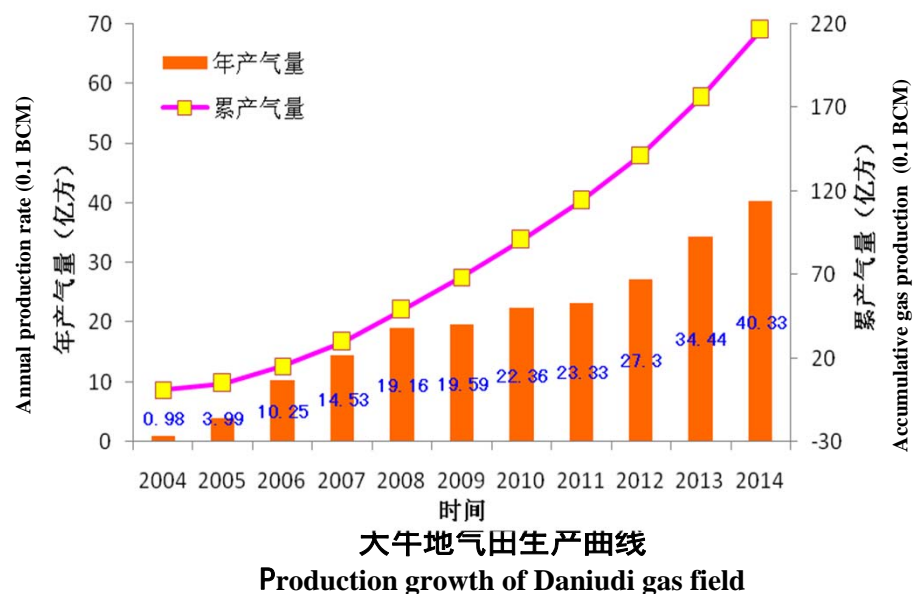
Daniudi gas field: difficult to develop economically due to its thin layers, strong heterogeneity, unfavorable reservoir features, low abundance of organic matter, and low production from vertical wells

形成的开发技术系列：

- ◆煤系薄储层及含气性预测技术
- ◆致密砂岩气藏定量选区评价技术
- ◆致密气藏有效开发方案优化技术

Development Technology Series :

- ◆Prediction of thin coal formations and their gas content
- ◆Quantitative block assessment
- ◆Development optimization Accumulative gas production rate (0.1 BCM)



实现了大牛地气田规模开发，获国家科技进步二等奖

Large-scale development of the field was the 2nd prize winner of the National Science and Technology Award

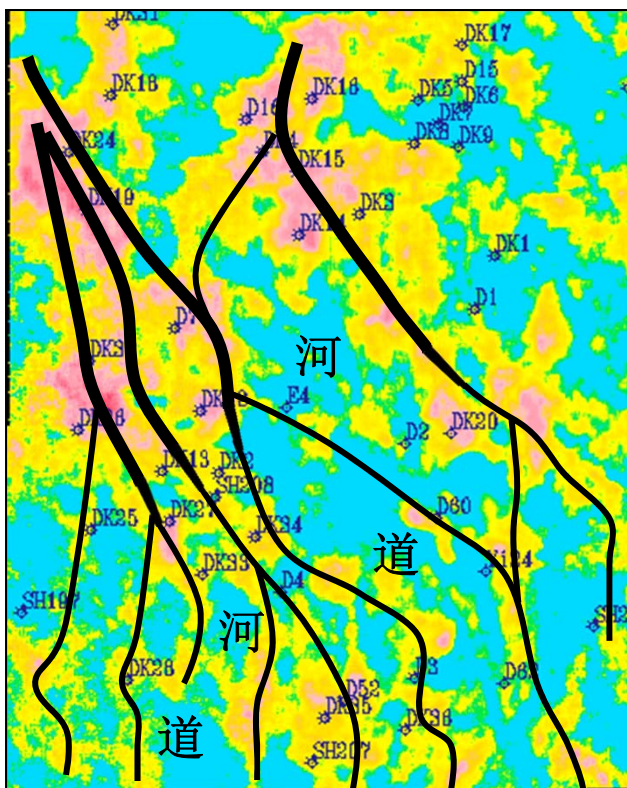


1、煤系薄储层预测技术

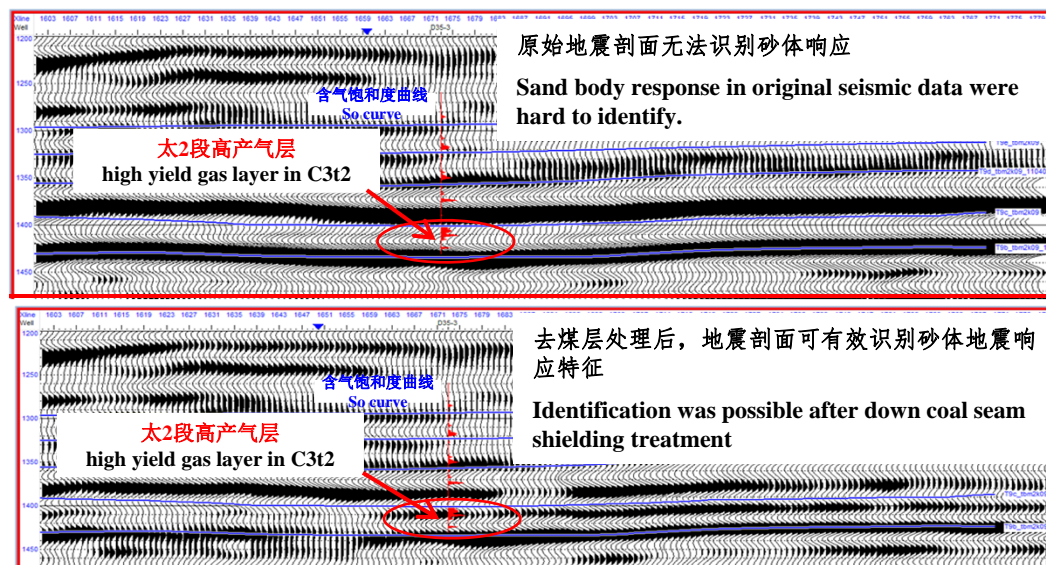
Seismic prediction of thin tight sand layer

形成弱化煤层强反射屏蔽技术、振幅属性优化技术，以及井震联合地质统计学反演技术，准确预测厚度在5米以下薄砂体。

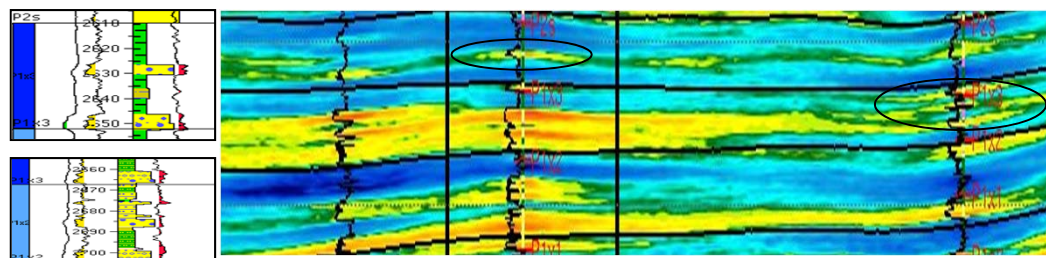
Innovations: sand body with thickness < 5 m can be accurately predicted through **coal seam reflection shielding technology**, **amplitude attribute optimization**, and **well-seismic tie geostatistical inversion**



优化振幅属性定性预测辫状河道
Braided river channel qualitatively predicted by
optimized amplitude attribute analyses



弱化煤层强反射屏蔽技术 Strong reflection of coal seam shielding technology



薄储层岩性反演技术 Thin reservoir lithology inversion technique 16

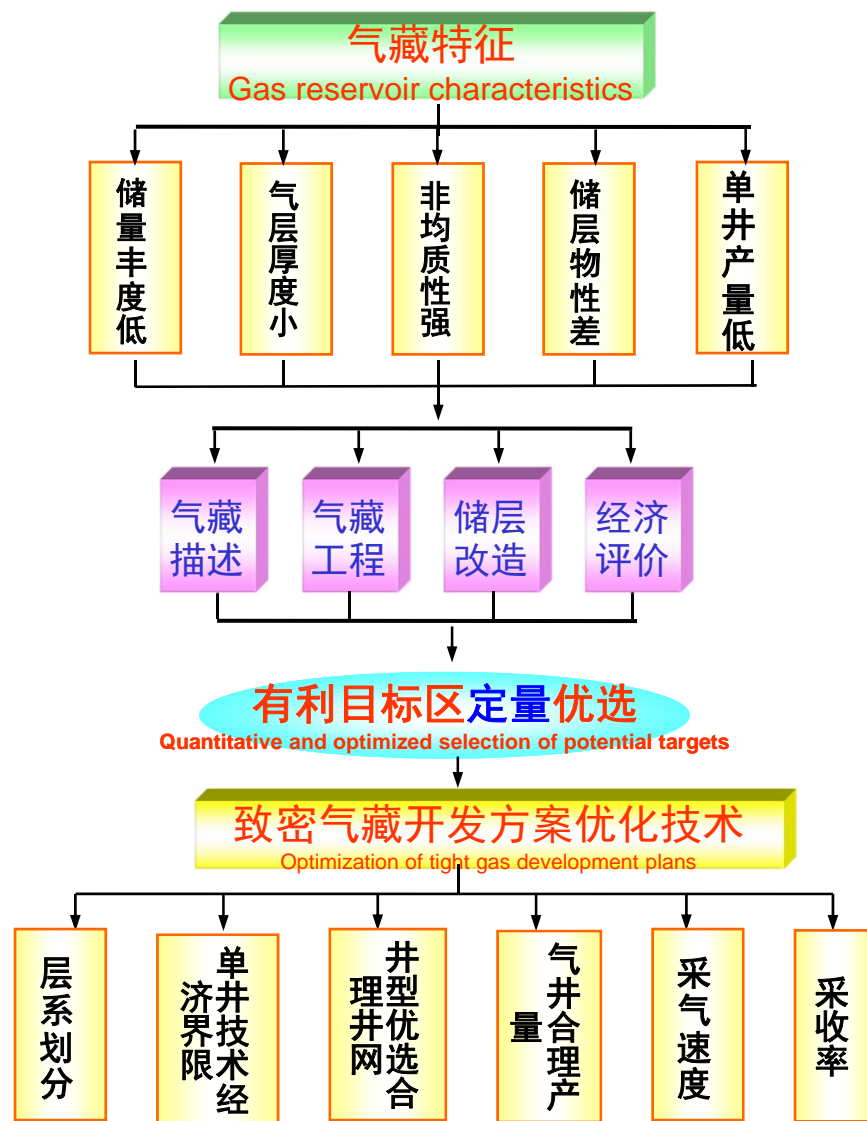
2、致密气藏有效开发方案优化技术

Development optimization of tight gas reservoirs

集储层预测、地质建模、气藏工程、改造工艺和经济评价于一体，形成了以无阻流量为主要指标的定量选区评价技术和致密气藏有效开发方案优化技术。

Quantitative block screening and development optimization of tight gas reservoirs:

- ✓ Formation evaluation
- ✓ Geological modeling
- ✓ Reservoir engineering
- ✓ Reservoir stimulation
- ✓ Economic evaluation





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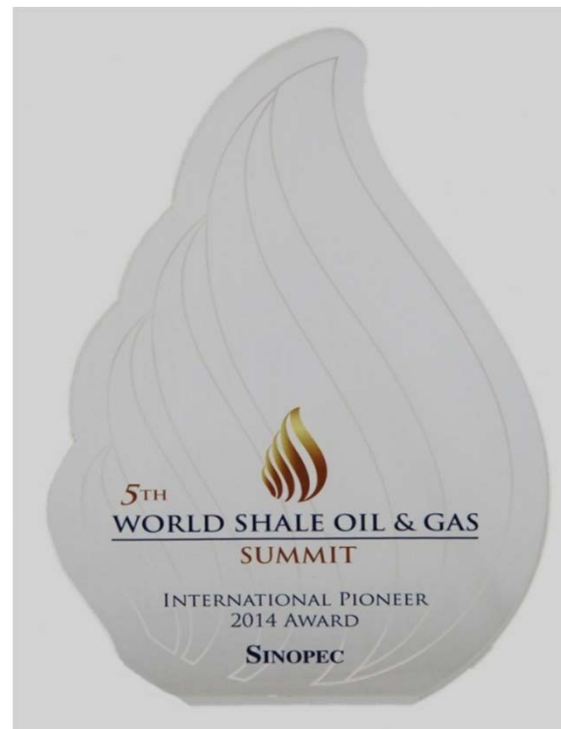


四、页岩气开发技术 Shale gas development technology

我国页岩气发育条件、地质特征、地表条件与北美差异较大，通过引进集成和理论技术创新，实现了涪陵页岩气勘探突破和规模绿色开发。目前试气158口井，达产率100%，累计产气26亿方；预计年底建成产能50亿方/年。

●Comparing with North America, shale gas reservoirs in China differs greatly in field, geological and surface conditions. Technological and theoretic innovations based on previous studies helped to achieve an exploration breakthrough and green exploitation of Fuling shale gas.

●All 158 wells drilled and tested in the area turned into production wells. By now, the field has produced accumulatively 2.6 bcm and a productivity of 5 bcm/year will be achieved later this year.

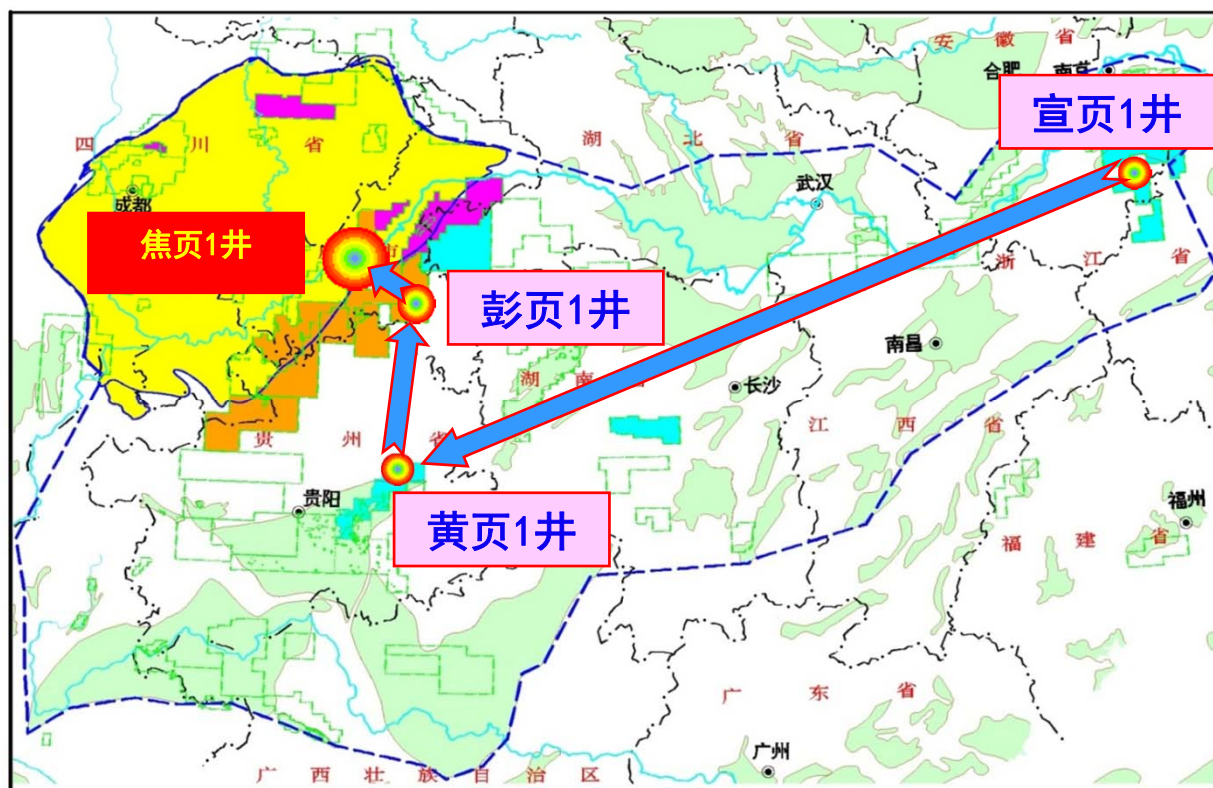


2014年第五届世界页岩油气峰会上获“页岩油气国际先锋奖”

1、曲折发现历程

Discovery history of Fuling gas field

通过2009-2012年10余口井钻探和跟踪研究，逐步认识到保存条件是我国页岩气富集主要控制因素，并将钻探逐步向四川盆地海相层系聚焦，最终取得焦页1井重大发现。



Analyses of drilling data from more than 10 wells drilled between 2009 and 2012 led to an understanding of preservation condition being one of the key factors for shale gas accumulations and a focusing on marine formations in Sichuan basin. The important discovery of shale gas well Jiaoye-1 was drilled in Fuling region.



2、山地“井工厂” 优快钻井技术 “Factory” drilling for mountainous areas

形成了山地“井工厂”水平井优快钻井技术系列，钻井周期缩短53%，钻井成本下降了35%。

Factory drilling technology customized for mountainous areas, which shortened drilling time by 53% and cut down drilling cost by 35%

■山地交错式井网优化布井技术

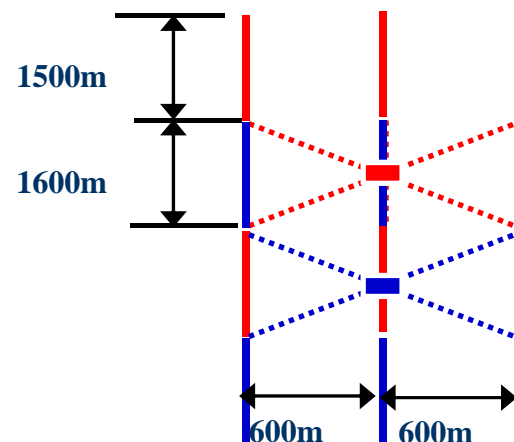
Well spacing optimization

■山地“井工厂”钻井施工技术：步进式、轨道式

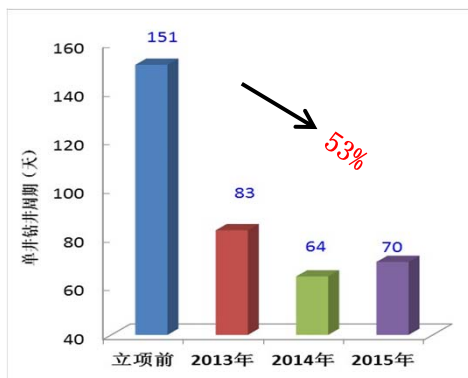
Factory drilling for mountainous areas with step style/slide rail drill rigs

■长水平段水平井快速钻井技术

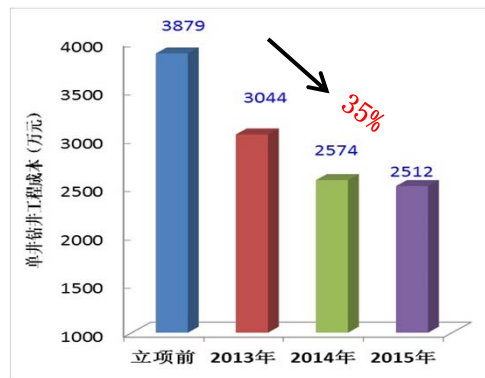
Rapid drilling for horizontal wells with long laterals



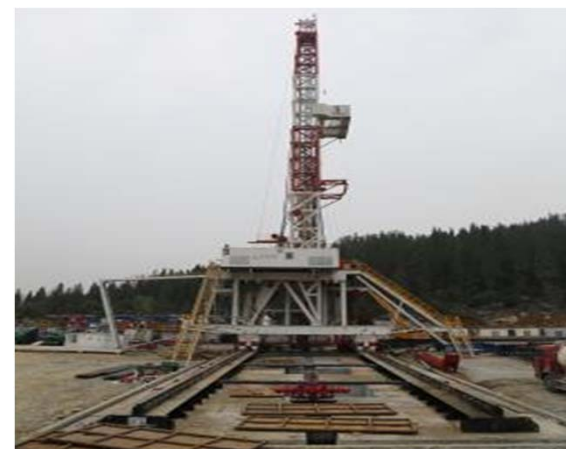
山地交错式布井方式
Staggered well spacing



2012-2015年平均钻井周期
Average drilling time
between 2012 and 2015



2012-2015年钻井工程成本
Drilling cost between 2012
and 2015



滑轨式钻机
Slide rail drill rig



3、水平井缝网压裂技术 Fracturing in horizontal wells

■水平井网络压裂参数优化设计技术

Optimized design of multistage hydraulic fracturing in horizontal wells

■研制了世界首台3000型压裂车

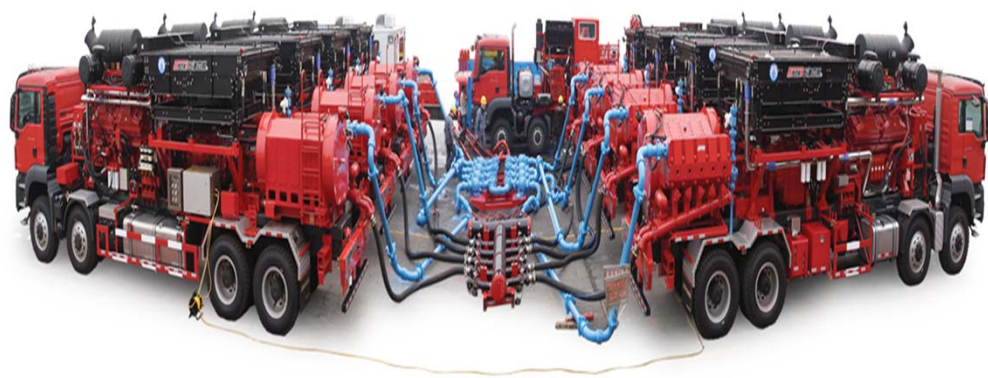
Built world's first 3000-model fracturing truck

■低成本高效压裂液体系：低摩阻、低伤害、携砂性能好

Promoted low-cost and high-efficient fracturing fluid: low friction, less formation damage and excellent proppant carrying capacity

■“井工厂”压裂施工优化，一日压裂施工6-8段。

6 to 8 stages of fracturing per day through optimization of fracturing procedure.



3000型压裂车组

3000-model fracturing truck



焦页9-1HF、9-3HF压裂现场

Fracturing of Jiaoye 9-1HF and Jiaoye 9-3HF wells

4、环境保护技术

Environmental protection technologies

发展和形成了环境保护技术，实现了页岩气经济开发、绿色发展。

Environmental friendly technologies developed and applied to realize a “green” and economic development of natural gas

■ **集约型施工和集气技术**：井工厂和集气站集中，单井土地征用面积缩减30%以上
Concentrated factory drilling facilities and gas gathering stations: to cut down land area by 30% per well.

■ **水资源利用与保护技术**：乌江取水，不与居民争水；浅表层清水钻进，保护水源
Water utilization and protection: to ensure local industrial/agricultural and residential use

■ **废液处理利用技术**：钻屑无害化处理、采出水及返排液处理后重复利用
Waste fluid recycling: to treat all bit cuttings and recycle produced water or flow back fluids



Before and after treatment



油基钻屑
cuttings





报告提纲

Outline

一、引言

Introduction

二、超深层高含硫气田开发技术

Development technologies for deep sour gas

三、致密砂岩气藏开发技术

Development technologies for tight gas

四、页岩气开发技术

Development technologies for shale gas

五、展望

Outlook

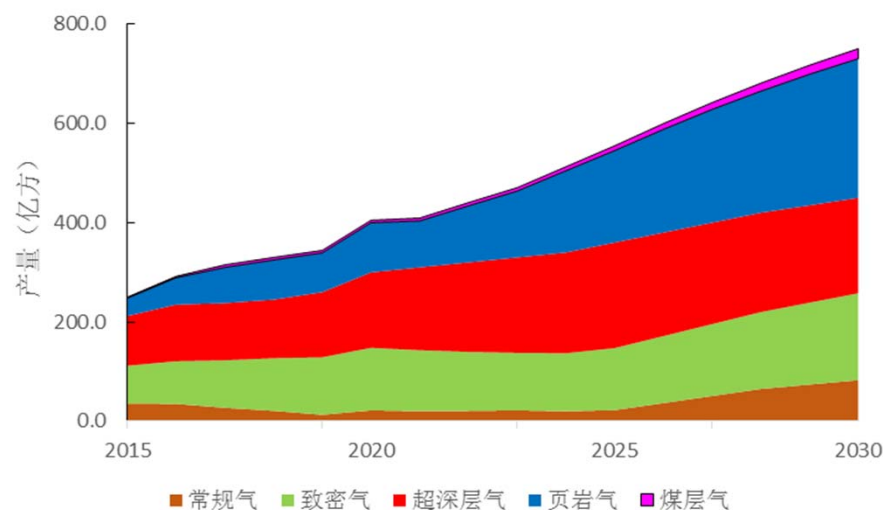


五、展望 Outlook

过去十年中国石化依靠革命性技术进步使低丰度、深层高含硫、页岩气等复杂气藏得到有效开发，实现了天然气产量快速增长。今后中石化将实施“原油可持续，天然气快上产，非常规再跨越”的资源发展战略，通过科技创新、管理创新、商业模式创新，实现天然气产量持续快速增长，为生态文明建设做出更大贡献。

Sinopec relied on technologic innovations to develop once uneconomic shale gas and realize a fast production growth of natural gas in the past decade. In future, Sinopec will implement the strategy of “maintaining a sustained development of crude oil, accelerating natural gas production growth, and achieving breakthrough in unconventional resources development, and make a great contribution to the ecological civilization construction through technology, management and business model innovations.

- **2020年：**总产量400-500亿方，常规气300-370亿方、非常规气100-130亿方。
- **2030年：**总产量800-1000亿方，常规气500-600亿方、非常规气300-400亿方。
- **2020:** annual gas production of 40-50 BCM (conventional 30-37 BCM and unconventional 10-13 BCM)
- **2030 :** annual gas production 80-100 BCM (conventional 50-60 BCM and unconventional 30-40 BCM)



中石化天然气产量远景规划
Sinopec natural gas production growth

A scenic landscape featuring a bright blue sky with scattered white clouds. In the background, there are rolling green hills. A dense forest of green trees lines the shore of a calm lake. The foreground is a vibrant green grassy field. The text "谢谢!" is overlaid in the center of the image.

谢谢!

Thanks for your
attention!