延长石油集团
陆相页岩气勘探开发新进展

The progress of Lacustrine Shale Gas E&D of Yanchang Petroleum Group

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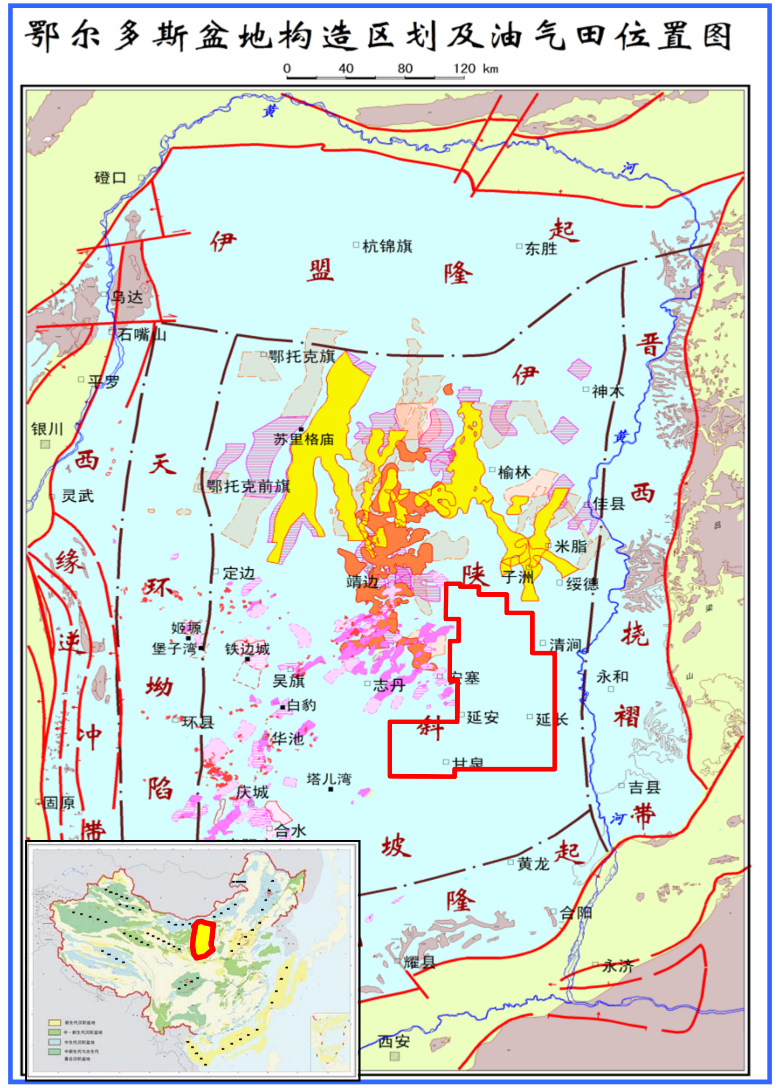
一、鄂尔多斯盆地概况 General Overview of Ordos Basin

鄂尔多斯盆地是中新生代大型叠合盆地，面积25万平方公里。页岩气探区属于黄土高原丘陵沟壑地貌。

Ordos Basin, a Mesozoic-Cenozoic superimposed basin, covers an area of 25×10^{4}km^2. Yanchang Shale Gas Exploration Area in the Shanbei Slope is characterized by the Plateau hilly topography.

延长石油页岩气探区地形地貌

Topographical features of shale gas exploration area



Tectonic map of Ordos Basin and oil field location

1905 延长石油 YANCHANG PETROLEUM

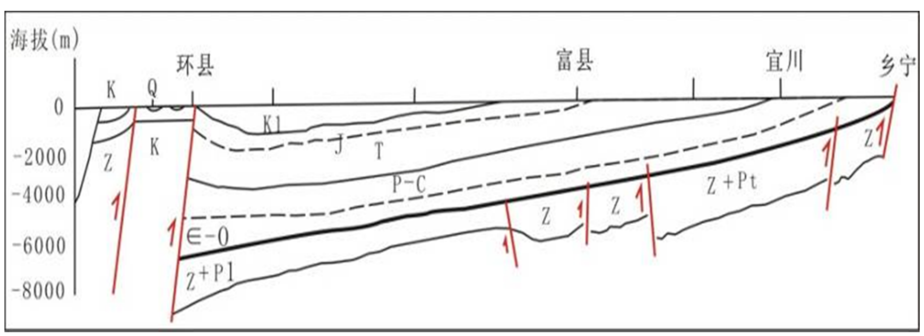
一、鄂尔多斯盆地概况 General Overview of Ordos Basin

☞ 鄂尔多斯盆地内部构造相对简单，西倾单斜构造。

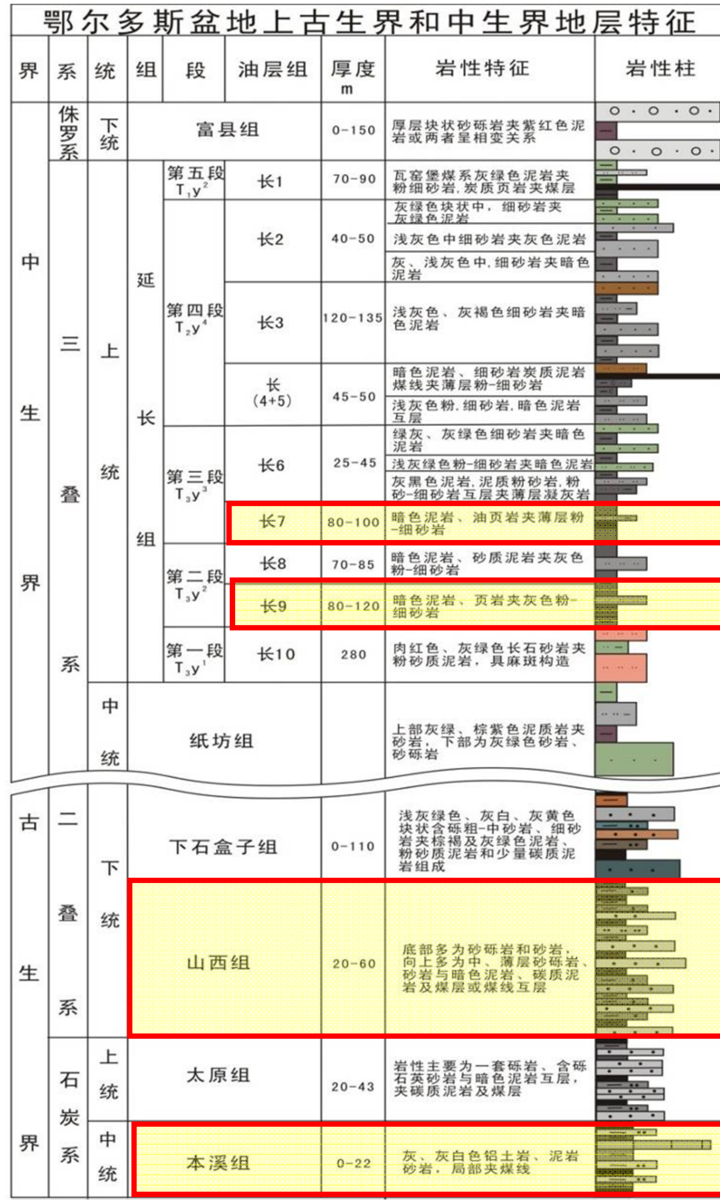
☞ 目标层系：上古生界本溪-山西组、中生界延长组。

☞ **The tectonic structure of Ordos Basin is relatively simple and characterized by a single western dipping monocline.**

☞ **The target Formations: The Benxi-Shanxi Formation of Upper Paleozoic, the Yanchang Formation of Mesozoic**



鄂尔多斯盆地剖面图
Profile Diagram of Ordos Basin



鄂尔多斯盆地上古生界和中生界地层特征

界	系	统	组	段	油层组	厚度 m	岩性特征	岩性柱
中生界	侏罗系	下统	富县组			0-150	厚层块状砂砾岩夹紫红色泥岩或两者呈相变关系	
	三叠系	上统	延长组	第五段 T_1y^2	长1	70-90	瓦窑堡煤系灰绿色泥岩夹粉细砂岩,炭质页岩夹煤层	
				第四段 T_2y^4	长2	40-50	灰绿色块状中，细砂岩夹灰绿色泥岩	
							浅灰色中细砂岩夹灰色泥岩	
							灰、浅灰色中,细砂岩夹暗色泥岩	
					长3	120-135	浅灰色、灰褐色细砂岩夹暗色泥岩	
					长(4+5)	45-50	暗色泥岩、细砂岩炭质泥岩煤线夹薄层粉-细砂岩	
							浅灰色粉,细砂岩,暗色泥岩互层	
				第三段 T_3y^3	长6	25-45	绿灰、灰绿色细砂岩夹暗色泥岩	
							浅灰绿色粉-细砂岩夹暗色泥岩	
							灰黑色泥岩,泥质粉砂岩,粉砂-细砂岩互层夹薄层凝灰岩	
					长7	80-100	暗色泥岩、油页岩夹薄层粉-细砂岩	
				第二段 T_3y^2	长8	70-85	暗色泥岩、砂质泥岩夹灰色粉-细砂岩	
					长9	80-120	暗色泥岩、页岩夹灰色粉-细砂岩	
				第一段 T_3y^1	长10	280	肉红色、灰绿色长石砂岩夹粉砂质泥岩，具麻斑构造	
		中统	纸坊组				上部灰绿、棕紫色泥质岩夹砂岩，下部为灰绿色砂岩、砂砾岩	
古生界	二叠系	下统	下石盒子组			0-110	浅灰绿色、灰白、灰黄色块状含砾粗-中砂岩、细砂岩夹棕褐及灰绿色泥岩、粉砂质泥岩和少量碳质泥岩组成	
			山西组			20-60	底部多为砂砾岩和砂岩，向上多为中、薄层砂砾岩、砂岩与暗色泥岩、碳质泥岩及煤层或煤线互层	
	石炭系	上统	太原组			20-43	岩性主要为一套砾岩、含砾石英砂岩与暗色泥岩互层，夹碳质泥岩及煤层	
		中统	本溪组			0-22	灰、灰白色铝土岩、泥岩砂岩，局部夹煤线	

陆相页岩
Lacustrine Shale

海陆过渡相页岩
Marine-lacustrine transitional facies shale

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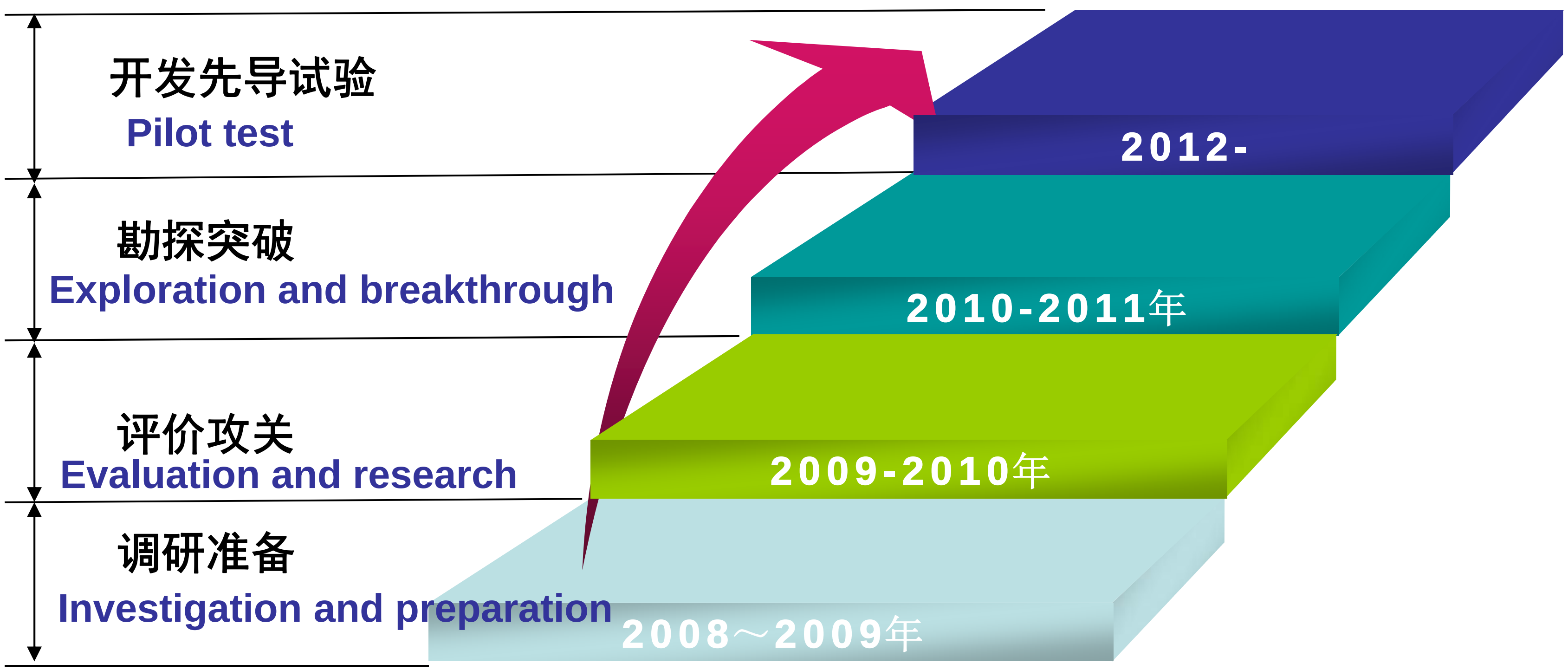
二、勘探开发历程 Exploration and Development Process

勘探开发历程：4个阶段

The exploration and development history can be divided into four stages



二、勘探开发历程 Exploration and Development Process

——2008～2009年调研准备阶段

2008 -- 2009: The investigation and preparation

- **开展前期调研、相关资料收集与技术交流；**
- **开展野外露头观察、老资料复查，认为鄂尔多斯盆地具有页岩气成藏的基本地质条件。**

- **Carried out the survey, collected data etc.**
- **Investigated the field outcrops and old data, confirmed that Ordos Basin has geological conditions for forming shale gas reservoirs.**

铜川金锁关长7张家滩页岩

Lacustrine shale of Yanchang Formation in Tongchuan

延川县长7张家滩页岩

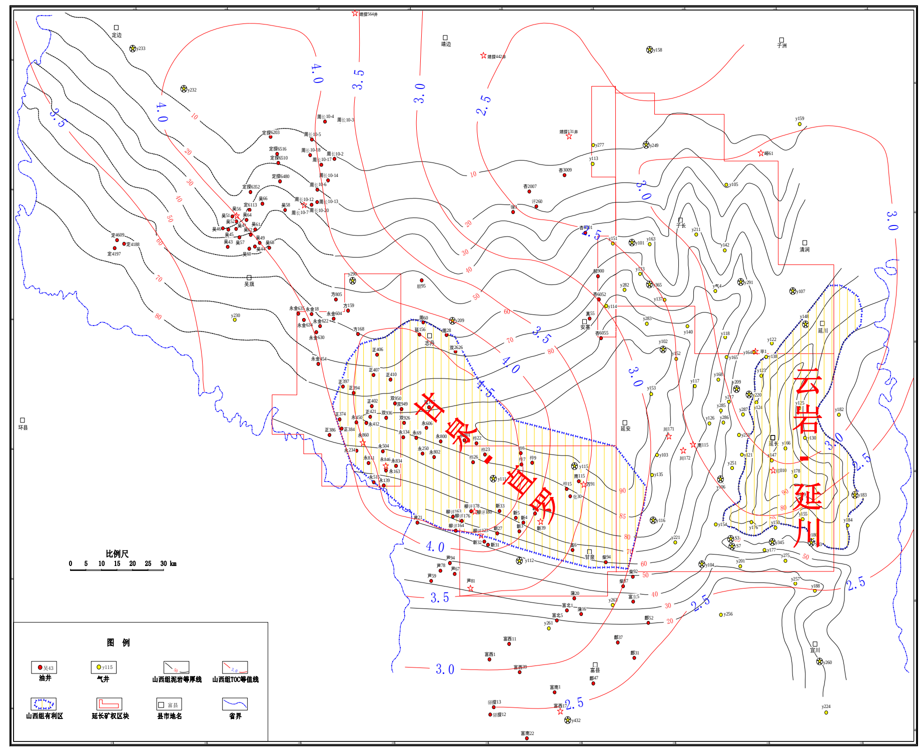
Lacustrine shale of Yanchang Formation in Yanchuan county

——2009～2010年评价攻关阶段

2009 -- 2010: The evaluation and research

- ◆ **开展页岩气成藏条件研究，探索钻完井关键技术；**
- ◆ **开展资源评价及有利目标区优选。**

- ◆ **Studied the reservoir-forming conditions, explored the drilling and completion techniques.**
- ◆ **Evaluated resource potential, selected favorable exploration target.**



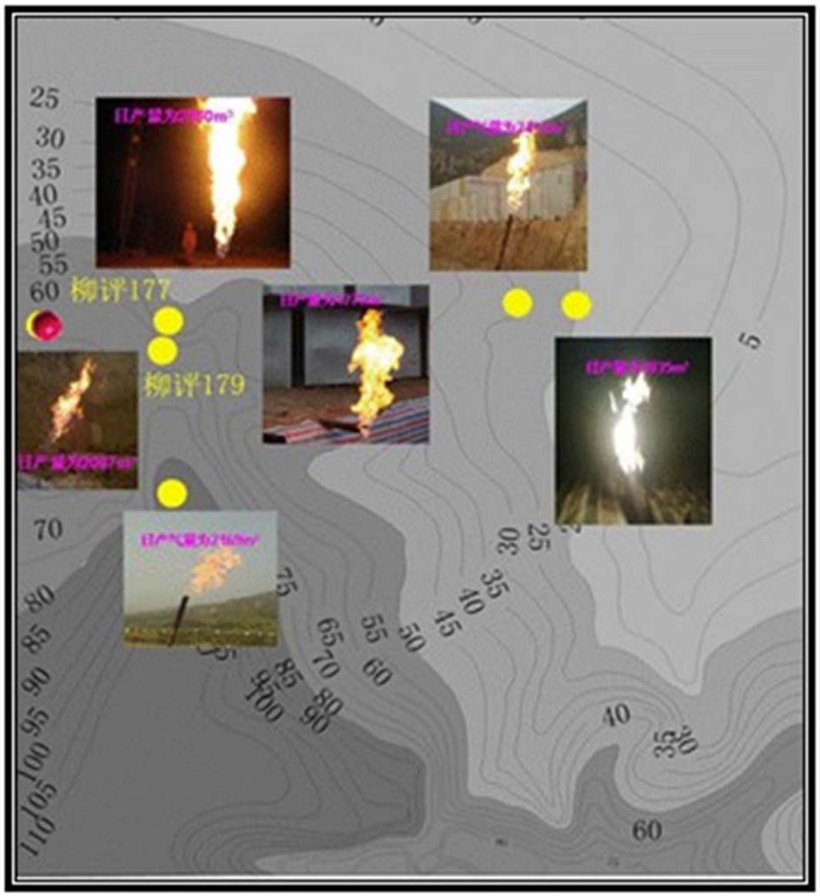
延长页岩气勘探有利区综合评价图

The comprehensive evaluation map of shale gas

二、勘探开发历程 Exploration and Development Process

——2010～2011年勘探突破阶段

2010 – 2011: The exploration and breakthrough



柳评177长7段泥页岩段压裂点火成功，成为中国第一口陆相页岩气井；

柳评179等多口井获页岩气流，拉开了延长石油陆相页岩气勘探开发序幕。

Well LP177, the first lacustrine shale gas well in China, was ignited successfully after fracturing.

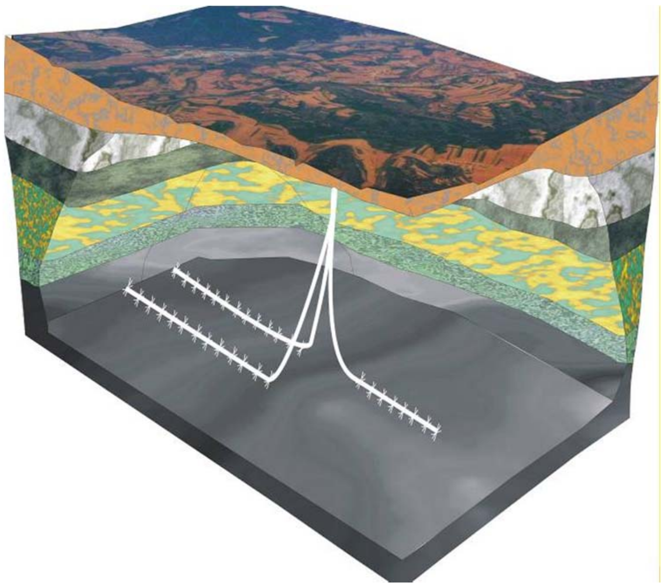
Several wells like LP179 got gas flow in the dark shale, which indicates the beginning of lacustrine shale gas exploration and development of Yanchang Formation.

二、勘探开发历程 Exploration and Development Process

——2012～ 开发先导阶段 2012- present: The pilot test

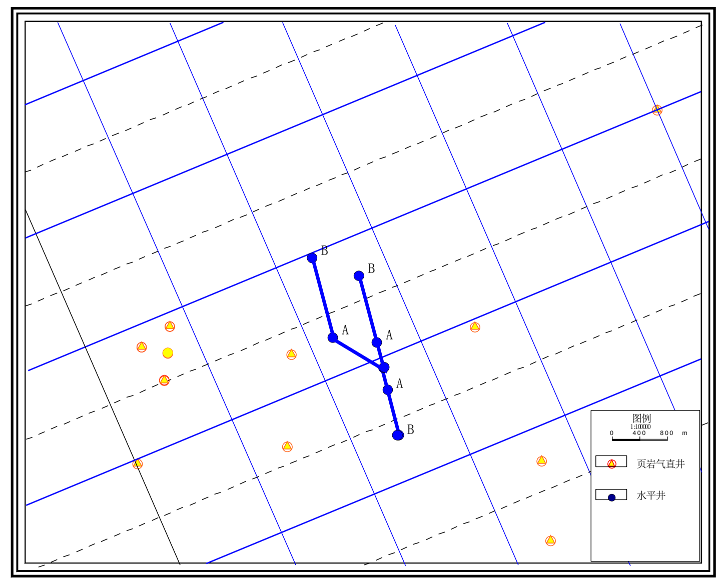
◆部署评价井，落实含气面积； Deployed appraisal wells, confirmed the gas-bearing areas

◆部署开发井，评价产能。 Deployed developing wells, estimated the shale gas productivity



开发井型设计示意图

Designed sketch of developing well



已完钻水平井组分布

The distribution of completed horizontal wells

二、勘探开发历程 Exploration and Development Process

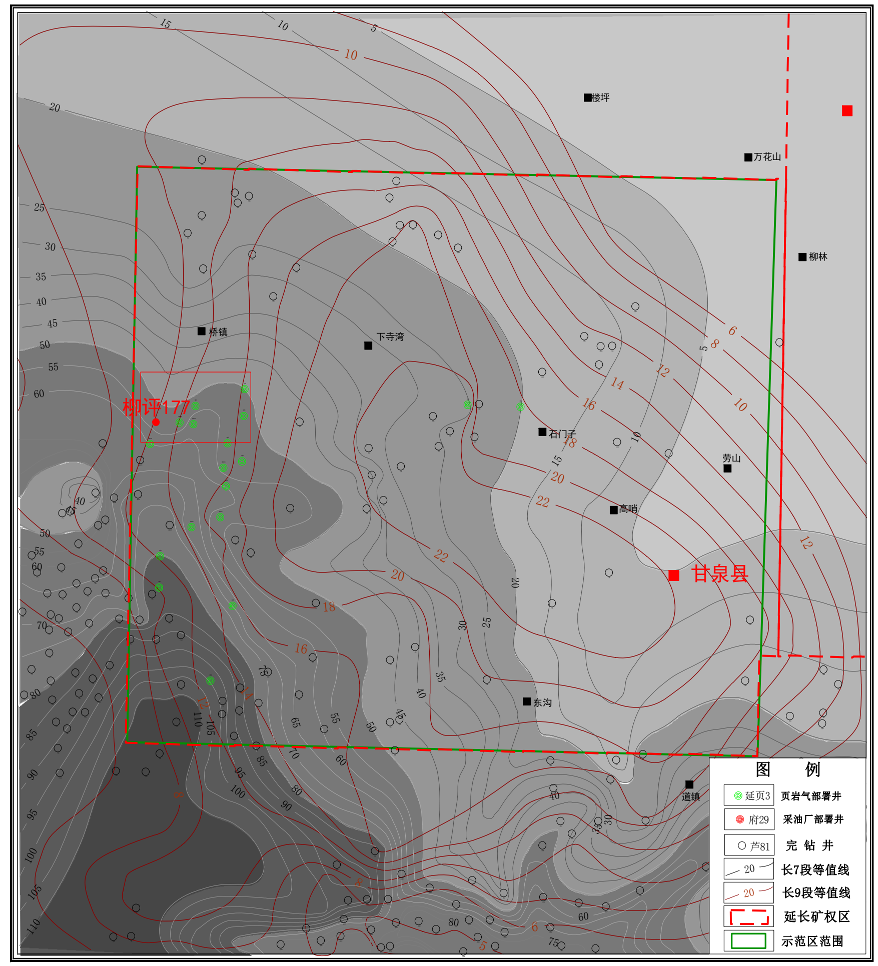
目前现状 Current Situation

完钻页岩气井51口，其中：直井47口、水平井4口。

完成页岩气井压裂42口，其中：直井38口、水平井4口，均获页岩气流。

☞ Drilled 51 shale gas wells including47 vertical wells and 4 horizontal wells

☞ Fractured 42 shale gas wells including 38 vertical wells and 4 horizontal wells. All the fractured wells have gotten the shale gas flow.



陆相页岩气勘探程度图

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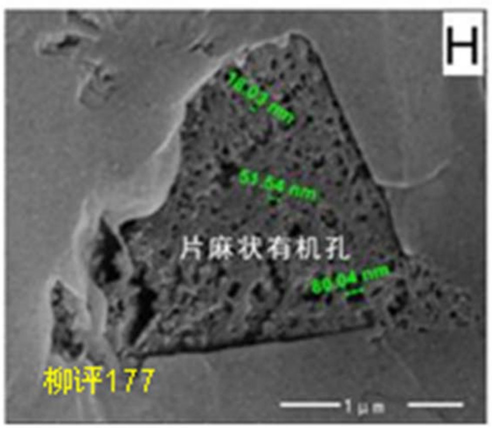
进展一：初步形成了地质评价选区技术

Progress 1: Initially developed the technologies of geological evaluation and optimization

确定地质评价选区关键参数，地质与工程相结合，优选了“甜点”富集区——云岩-延川、下寺湾-直罗。

Based on the combination of Geology and engineering, we determined the key parameters of geological evaluation and optimization, and then selected the two favorable areas (Yunyan-Yanchuan region and Xiasiwan-zhiluo region).



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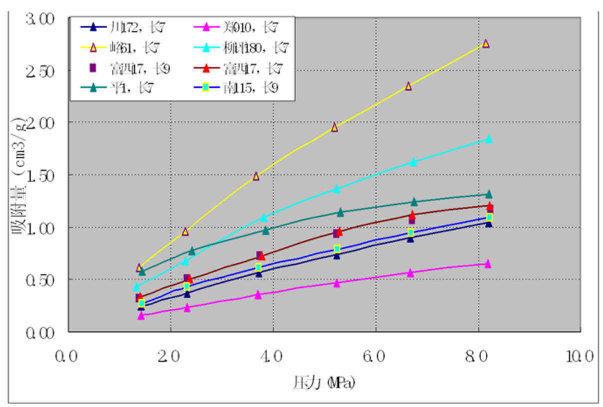
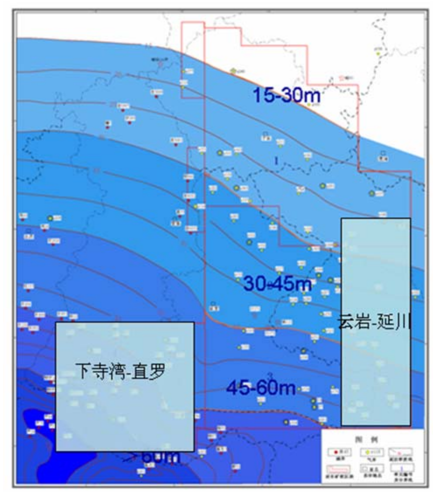


陆相页岩等温吸附曲线

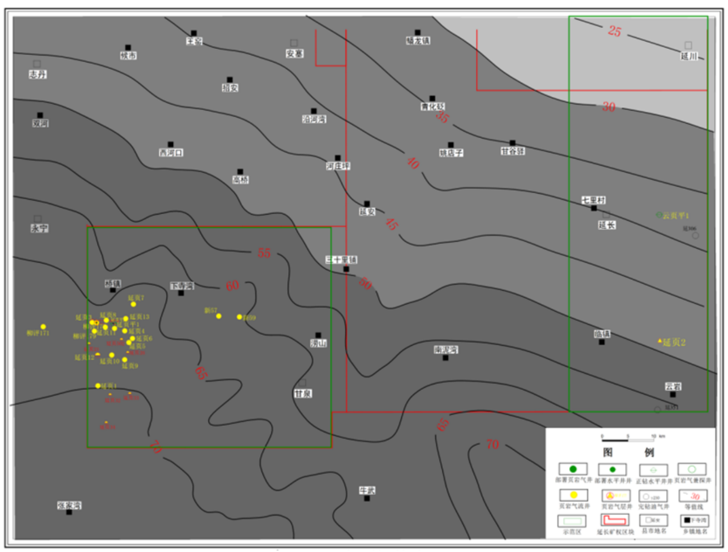


三、主要技术进展 Progress of Key Technologies

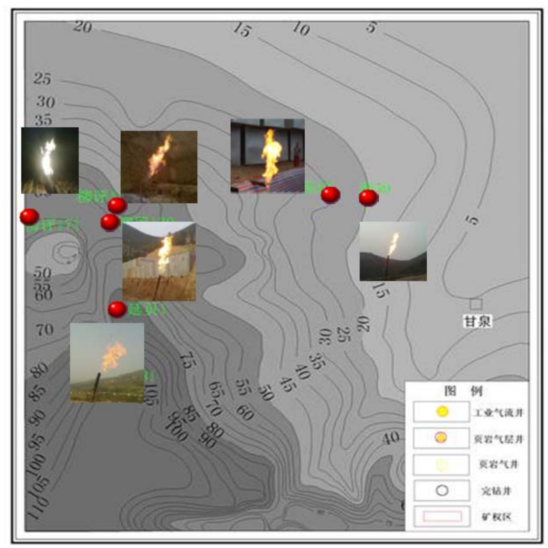
- 系统评价资源潜力，估算研究区页岩气资源量5630×10^8m^3。
- 进行精细勘探，探明地质储量96×10^8m^3，发现了中国第一个陆相页岩气田。

☞ Made a systematic evaluation for the resource potential of study area. The amount of geological resources is 5630×10^8m^3.

☞ Performed precise exploration, and discovered the first lacustrine shale gas field of China with a proven geological reserves of 96×10^8m^3.



页岩气勘探程度图
The map of exploration degree



页岩气勘探成果图
The map of exploration results

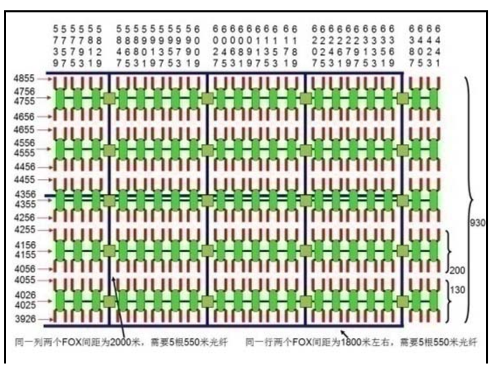
三、主要技术进展 Progress of Key Technologies

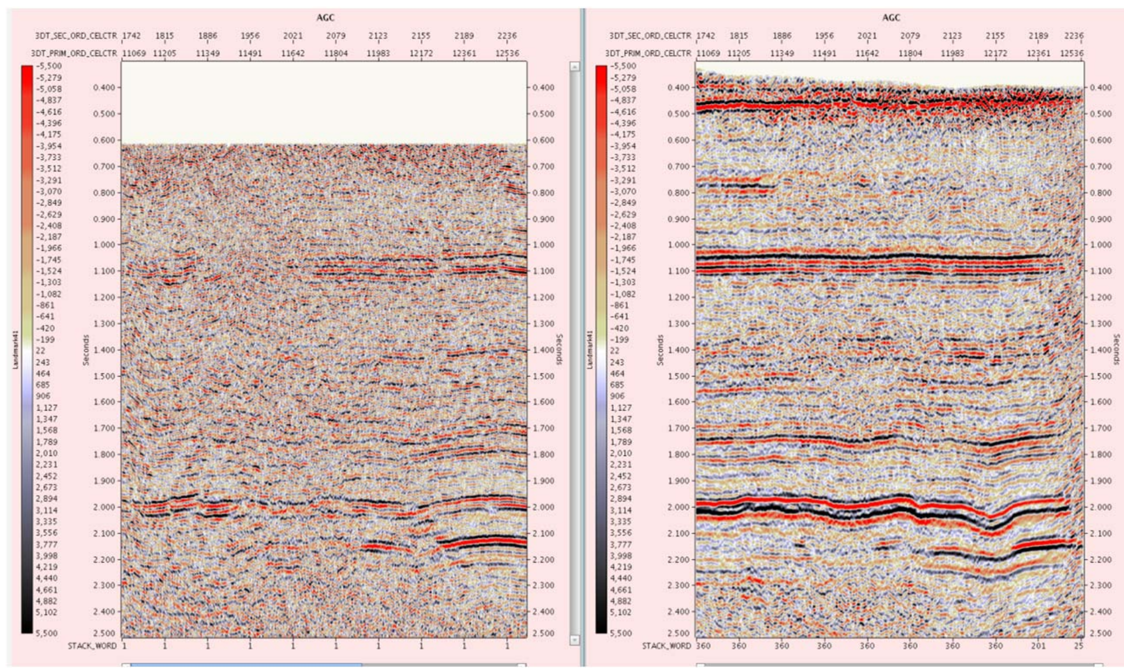
进展二：开展高密度单检三维地震勘探

Progress 2: Carried out 3D Seismic Exploration by UniQ Technology.

首次针对页岩气开展了三维地震勘探，采用了斯伦贝谢西方地球物理公司的UniQ技术，满覆盖次数360次，资料品质显著提高，为后期甜点预测奠定了基础。

Yanchang petroleum acquired the first 3D seismic data with UniQ technology of SLB ,the ultimate fold reaches 360 times and the quality was enhanced obviously.





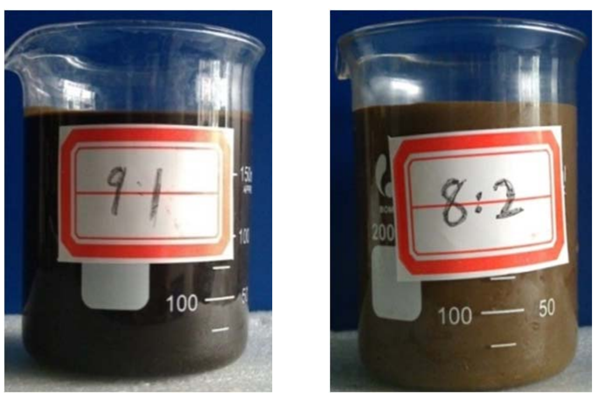
三、主要技术进展 Progress of Key Technologies

进展三：初步形成陆相页岩气水平井钻完井技术

Progress 2: Initially developed the drilling and completion technologies of horizontal wells in lacustrine shale

- 研究页岩气水平井裸眼井壁稳定机理，研发全油基钻井液技术
- 优选钻头、优化钻井参数，研发页岩气水平井钻井提速技术
- 研发低密度高强度固井水泥浆、高效清洗隔离液体系，形成水平井固井技术

- Developed the technology of applicable oil-based drilling fluids .
- Optimized bit and drilling parameters, formed the speed-raised technology in horizontal well drilling.
- Developed the cementing technologies of horizontal well, such as the cement paste with low density and high performance and efficient spacer fluids.



油基钻井液配方研究
oil-based drilling fluids

油基钻井液堵漏剂YDLJ-1样品
Plugging agent

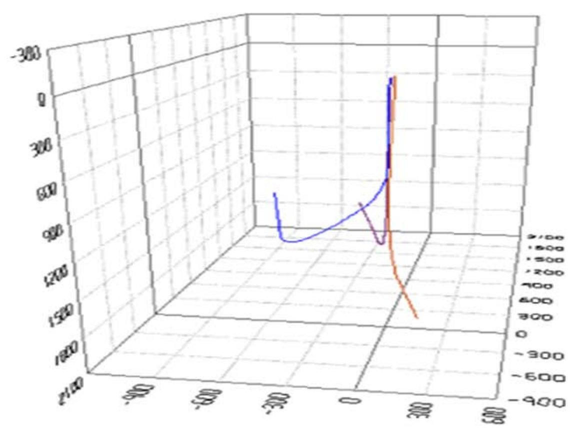
高效除油剂
Degreasing agent

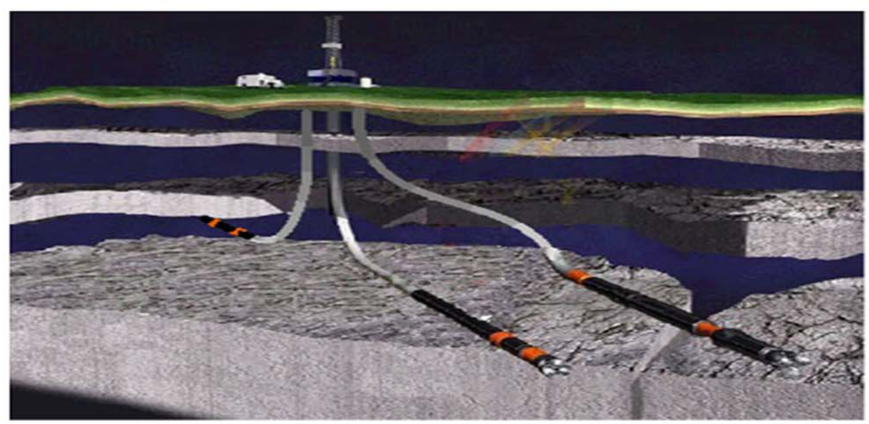
应用该项技术

- 水平井钻井周期从65天缩短至54天
- 平均机械钻速从4.26m/h提高到6.05m/h
- 固井质量合格率100%

Based on this technology

- The drilling time is shortened from 65 days to 54 days.
- The drilling speed is increased from 4.26m/h to 6.05m/h.
- The qualification rate is 100%.





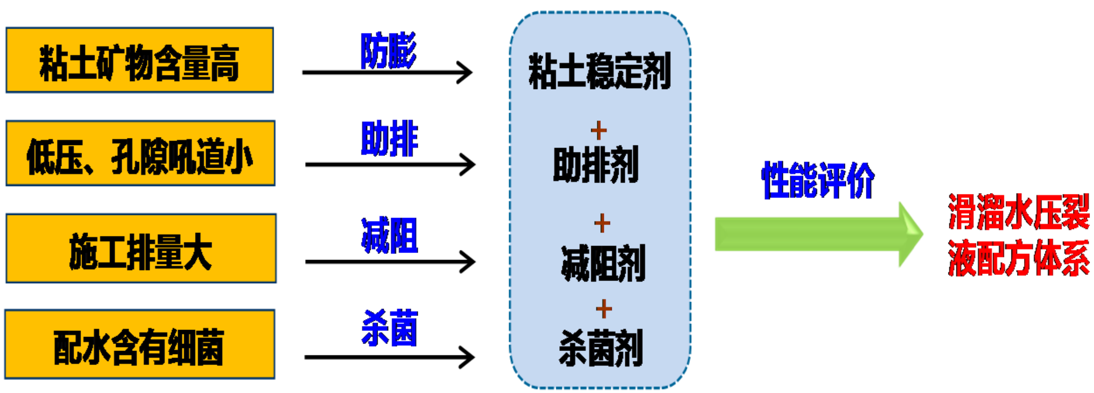
三、主要技术进展 Progress of Key Technologies

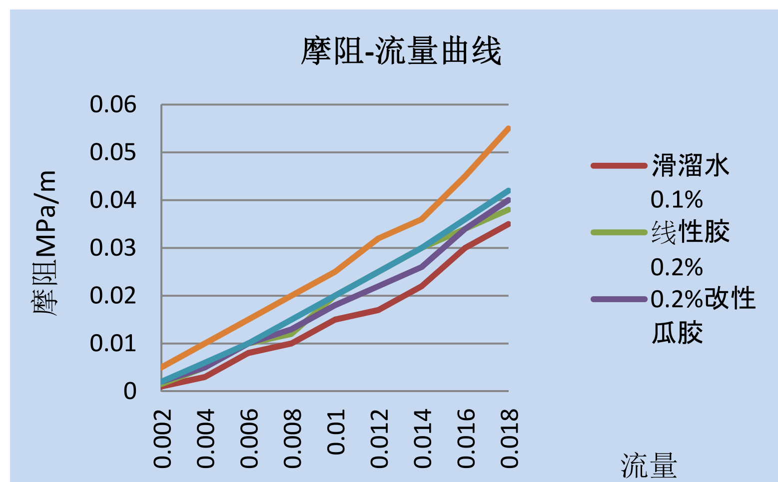
进展四：初步形成页岩气大型缝网压裂工艺技术

Progress 3: Initially developed the Volume fracturing technology

（1）研制出减阻剂等核心材料，开发出适合陆相页岩的低伤害、低摩阻滑溜水压裂液体系。

(1) Developed the key materials like friction-reducing additive, and the fracturing liquid with low harm and friction like slick water.





三、主要技术进展 Progress of Key Technologies

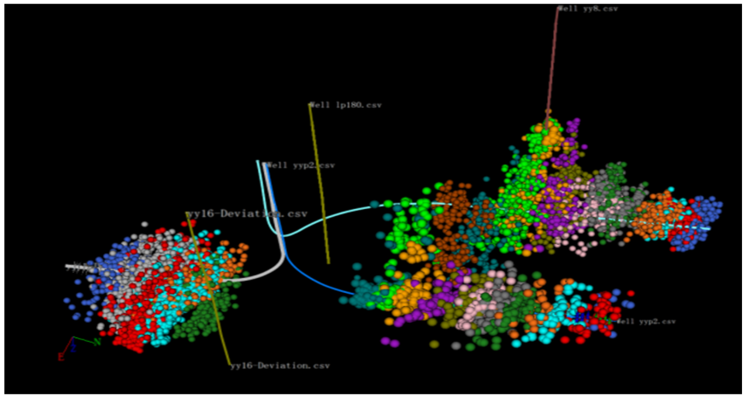
（2）集成应用多项配套工艺技术，初步形成陆相页岩气水平井多级分段压裂工艺技术，压裂直井38口，压裂水平井4口。

(2) Developed the multi-staged fracturing technology suitable for the lacustrine shale exploration by using its supporting technologies, fractured 38 vertical wells and 4 horizontal.

- 射孔桥塞联作分级压裂工艺
- 前置酸降破压技术
- 连续混配供液技术
- 井下微地震压裂实时监测技术

- Staged fracturing technology by combining tech of perforation with bridge plug
- Pressure-decreasing technology for pad acid
- Liquid supply technology by using continuous mixing method
- Monitoring technology of downhole fractures by using micro-seismic

大型压裂现场
Fracturing Site



微地震监测
Micro-seismic Monitoring

进展五：创新性开展了页岩气井CO_2压裂技术实践

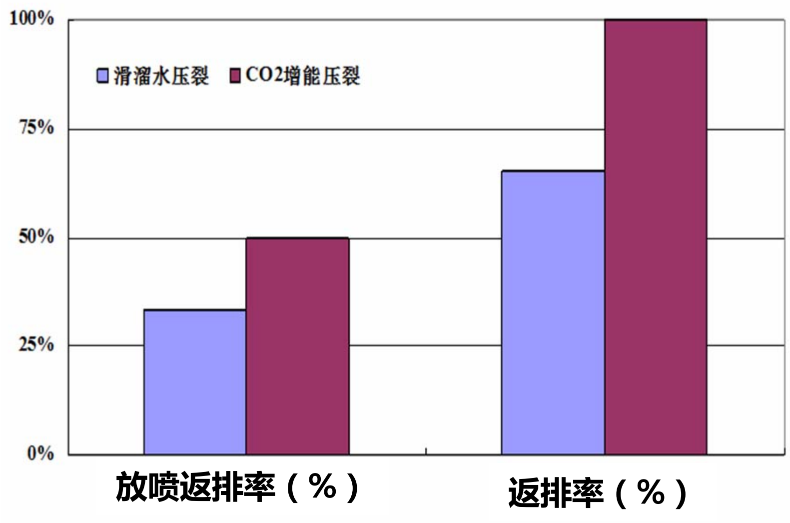
Progress 4：Innovatively used the CO_2 fracturing technology

针对储层压力低、水敏性强、用水量大、压裂液返排慢等问题 ❯ "CO_2增能+缝网压裂" "纯液态CO_2压裂" ❯ 提高了压裂液返排速度和返排率；抑制页岩膨胀，减少压裂用水量。

For reservoir with low pressure, high water sensitivity and water consuming as well as the slow flowback of fracturing liquids problems. ❯ "Energy Increasing by CO_2 + Fractures Network Fracturing" and " Pure Liquefied CO_2 Fracturing" experiments. ❯ Increased the flowback speed and rate, restrained shale expansion and reduced the quantity of fracturing water.

二氧化碳压裂现场

CO_2 Fracturing site



Flowback rate （%）

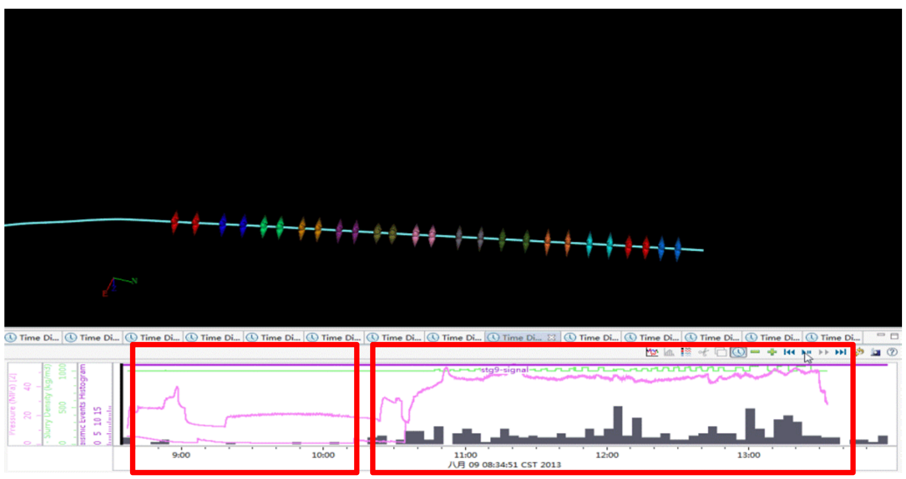
三、主要技术进展 Progress of Key Technologies

进展五：创新性开展了页岩气井CO_2压裂技术实践

Progress 4： Innovatively used the CO_2 fracturing technology

延页平x井采用射孔桥塞联作分级13段前置CO_2复合压裂，泵入CO_2 767吨、加砂728方、压裂液28787方，压后返排快，良好见气显示。

The well YYP X was fractured by bridge plug and clustering perforation in 13 different parts. After pumping CO2 of 767 tons and adding sands of 728 Cubit feets and fracturing fluid of 28787 Cubit feets, the well shows fine air and quick flowback.



CO_2压裂阶段
Part of Co2 fracturing

滑溜水压裂阶段
Part of Slide water fracturing

进展六：初步形成压裂返排液无害化处理与回收利用技术

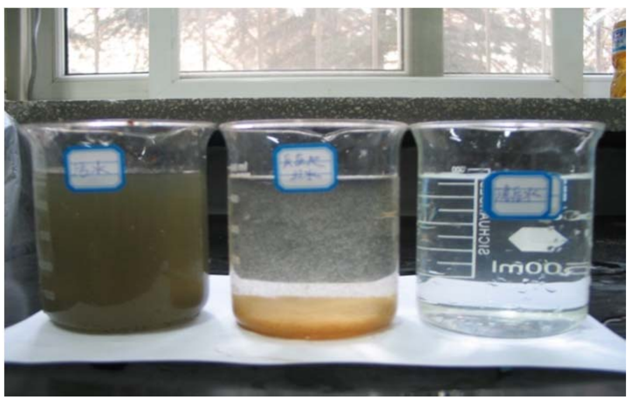
Progress 5：Developed the technologies of non-harm processing and recycling for the fracturing flowback liquids

- **自行设计并研制了压裂废液处理装置**
- **自主研发了压裂废液处理工艺技术**
- **探索了循环利用技术**

- **Designed and developed equipment for fracturing liquids processing (FLP)**
- **Developed technology of FLP**
- **Developed the technologies of fracturing liquids recycling and utilizing**

在水平井开展压裂返排液处理，日处理能力600m^3，用于压裂配液或回注。

The processing equipment can dispose 600 m^3 fracturing liquids per day, and the fracturing flowback liquids are being recycled for producing new fracturing liquids.



延页平1井压裂返排液处理前后样品
Samples before and after recycling and utilizing

延页平1井压裂返排液处理装置及处理现场
The site of recycling and utilizing

进展七：开展了页岩气综合利用

Progress 6：comprehensively utilize the shale gas

在页岩气井场配置燃气发电机组进行发电，实现了为井场电潜泵排液、污水处理装置及抽油机平稳供电。

The gas-fired generating units were allocated in the well fields to generate electricity, which can meet the power demand of electrical pumps, sewage treatment equipments and pumping units.

新57井场发电机组
The gas-fired generating units

新59井场发电机组
The gas-fired generating units

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四、国际交流与合作 International Exchange and Cooperation

国际交流 International Exchange

Energy Roundtable Meeting
for European and Asian Countries

12th US-China Oil and Gas
Industry Forum

AAPG Annual Convention
at Pittsburgh in 2013

Field Trip for AAPG Convention in 2013

US-China Shale Gas Round Table
meeting in 2013

Columbia University in 2013

四、国际交流与合作 International Exchange and Cooperation

国际合作 International Cooperation

与斯伦贝谢战略协议

The agreement signed with Schlumberger

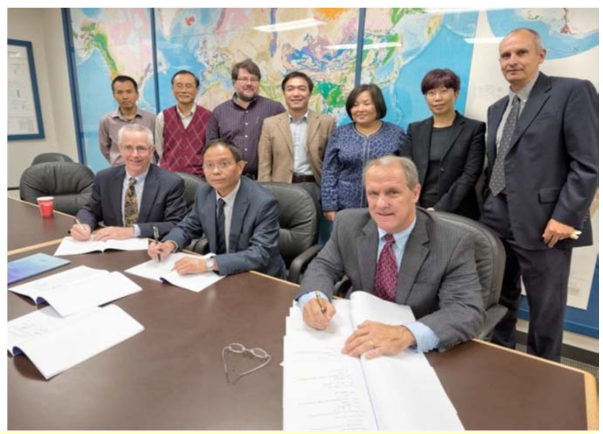
澳大利亚全球碳捕集与封存研究院

Institute of Globe CCUS at Australia

美国德克萨斯大学奥斯丁分校、犹他大学、澳大利亚全球碳捕集与封存研究院、斯伦贝谢盐湖城TerraTek实验室及波士顿Doll Research (SDR)研发中心等世界知名高校和研发机构积极合作，开展攻关研究。

犹他大学EGI

With University of Utah



与德州大学奥斯汀分校签署研究协议

The agreement signed with BEG of UT Austin

Yanchang Petroleum cooperated with many international institutions and Universities to develop shale gas such as UT Austin, Australian Globe CCUS Institute, Schlumberger TerraTek Laboratory at Salt Lake City, and so forth.

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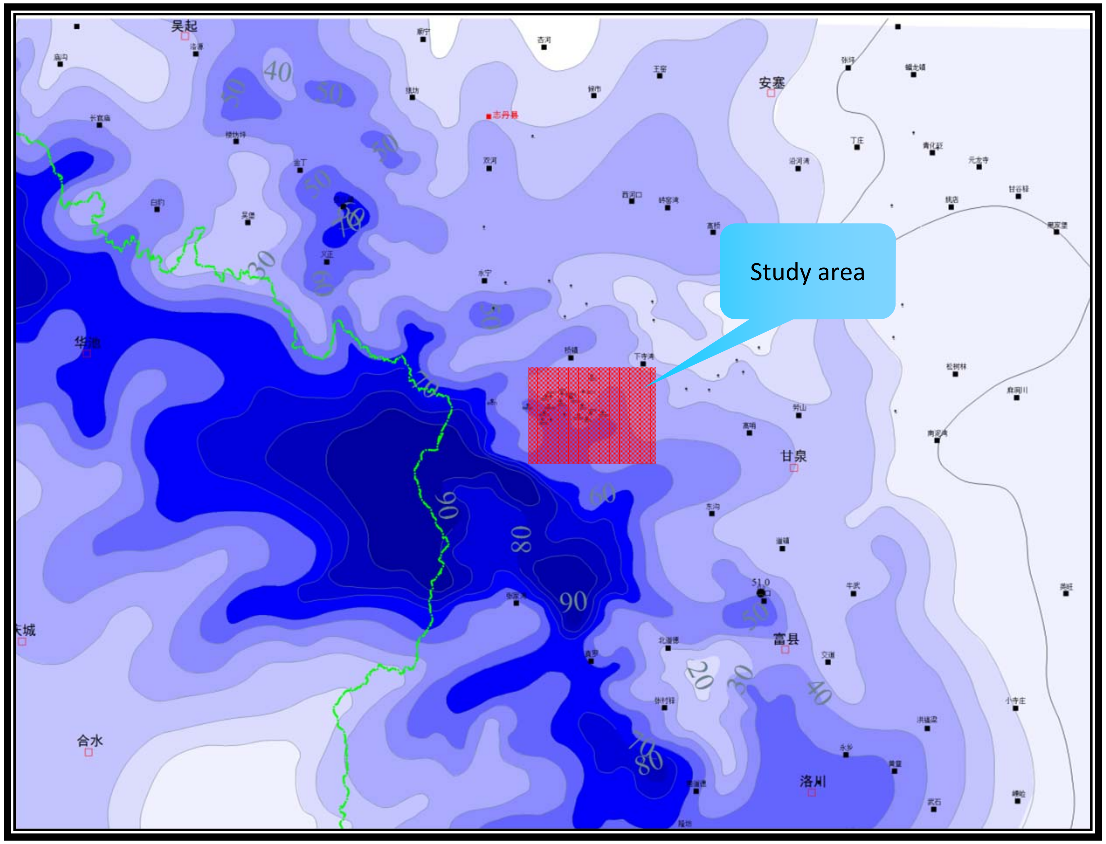
五、面临的挑战 Major Challenges

挑战一：资源落实程度偏低

Challenge 1： Lower degree of resources proven

勘探程度较低，资源及地质储量落实程度差。

The exploration degree is low, which leads to poorer definite degrees of resources and reserves.



鄂尔多斯盆地东南部长7段页岩气分布趋势图

The distribution of shale gas of Chang 7 Member

五、面临的挑战 Major Challenges

挑战二：水平井钻完井及压裂技术有待提高

Challenge 2： The drilling and fracturing technologies for horizontal well need to be improved

Lacustrine shale gas of china

钻井施工

压裂施工

Marine shale gas of north America

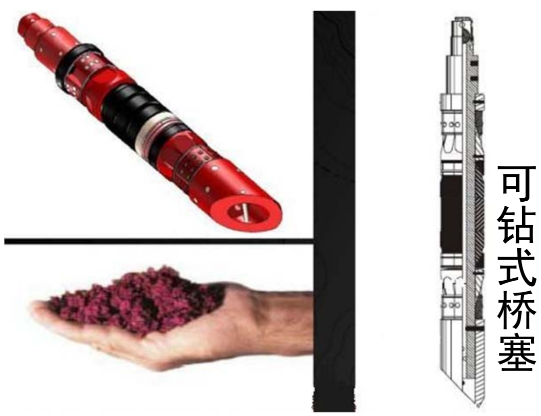
五、面临的挑战 Major Challenges

挑战三：某些井下工具及设备需要攻关或引进

Challenge 3：Improvement or import of some down-hole equipments

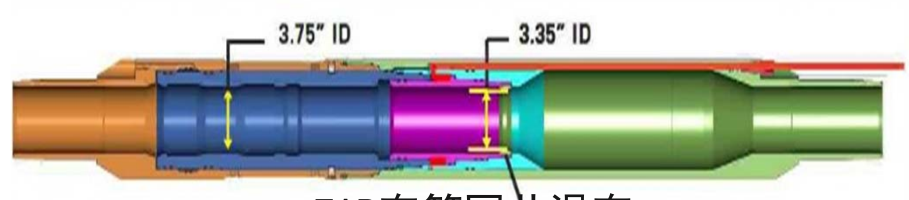
在某些关键设备，特别是井下设备，比如随钻测井仪器、桥塞、滑套等，还有待改进。

Some of the key equipments, especially the apparatus of logging while drilling, bridge plugs and sliding sleeve in down-hole equipments need to be improved.



bridge plug with drilling ability

地质导向钻井：随钻测量+自然伽马测井
Geo-Steering Drilling : logging while drilling and GR logging



TAP套管固井滑套

五、面临的挑战 Major Challenges

挑战四：环境保护对页岩气开采提出更高要求

Challenge 4： Environmental protection

页岩气压裂用水量大、压裂返排液可能污染环境等，陕北地区生态环境保护对页岩气勘探开发技术提出了更高的要求。

More research on technology of exploration and development should be met the needs of the environmental protection in Shanbei, for a large quantity of fractured fluids will be discharged.

违规排放造成的环境影响

Environmental pollution

大规模压裂用水量大

A large amount of Water used in fracturing

五、面临的挑战 Major Challenges

挑战五：勘探开发成本较高

Challenge 5： High-cost exploration and development

一是勘探开发初期，工作效率相对较低，作业成本高；
二是地形地貌复杂，勘探难度大，成本高；

Firstly, the relatively lower working efficiency leads to the high cost in the initial stage of exploration and exploitation.

Secondly, the complex topography gives rise to high difficulty and high cost in exploration.

延长石油页岩气探区地形地貌

The topography of Yanchang Petroleum

结束语 Conclusion

针对中国页岩气勘查开发初期，投入大、资源落实程度差、勘探开发关键技术不完善等问题。需要借鉴美国页岩气勘探开发的经验，建议中美两国加强不同层次的交流和合作，积极推进中国页岩气产业的发展 。

Facing the problems such as high cost, low proven degree, imperfect technologies, shale gas exploration of China is still in the early stage. Thus, exploration experience of America should be used for reference. We suggest that China and America could reinforce the technical exchange, in order to promote the development of shale gas industry in both countries.


Thanks for Your Attention!