Introduction of Enhanced oil recovery technology

V-petrotek，LLC

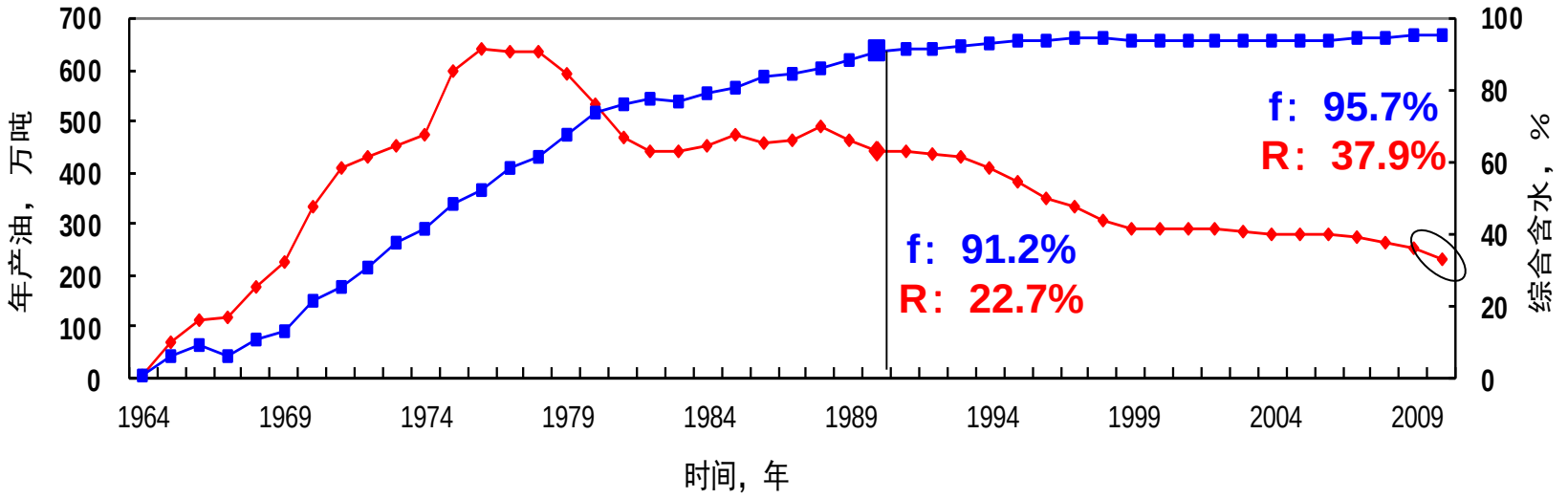
Enhanced oil recovery technology

Conventional water flooding	high water cut stage reservoir	Vector well pattern adjustment; Sand body pattern perfect
	complex fault block oil reservoir	Streamline pattern modification; development of the top horizontal well
	low permeability reservoir	Three-dimensional development of complex fault block; small well spacing waterflood development; CO2 miscible displacement
chemical flooding	Ⅰ、Ⅱ、Ⅲ、Ⅴ and Offshore oil reservoir	polymer flooding technology
	Ⅰ、Ⅱ and polymer flooding reservoir	Binary compound flooding
	Ⅳ and polymer flooding reservoir	foam combination flooding
	Ⅳ and polymer flooding reservoir	Heterogeneous composite flooding
steam flooding	Conventional water flooding of heavy oil reservoir	Conventional steam flooding water drive to steam flooding
	After stimulation of heavy oil reservoir	Chemical steam drive
microbial flooding	After high ooze water flooding and polymer flooding reservoir	microbial enhanced oil recovery

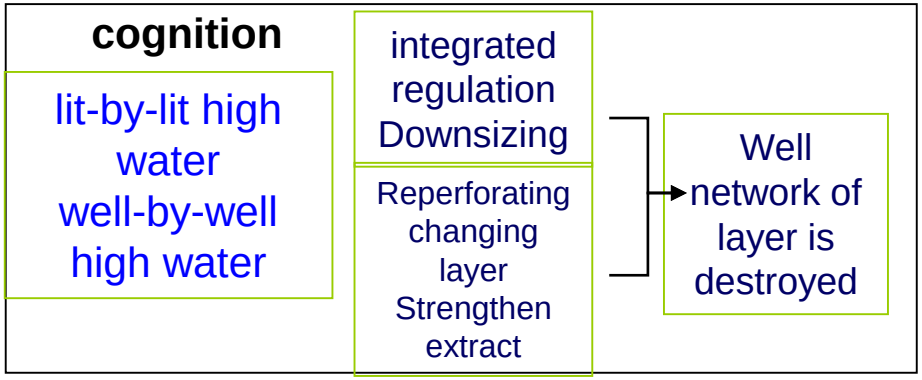
一、Conventional waterflood enhanced recovery technology

1、high water cut stage reservoir

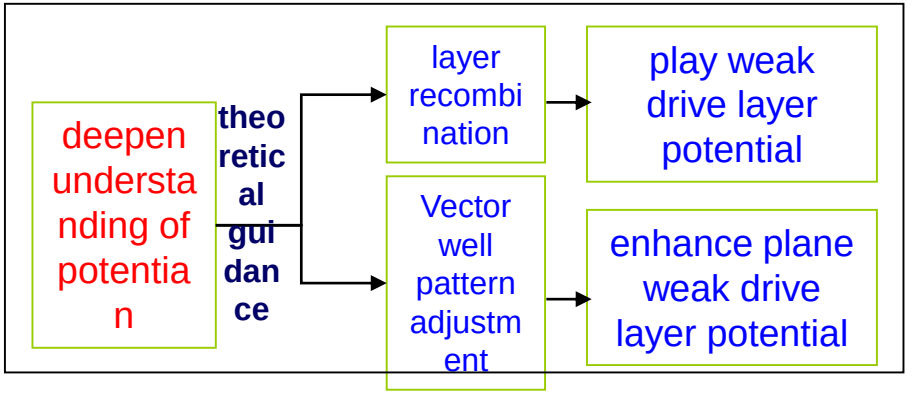
1、Vector well pattern adjustment



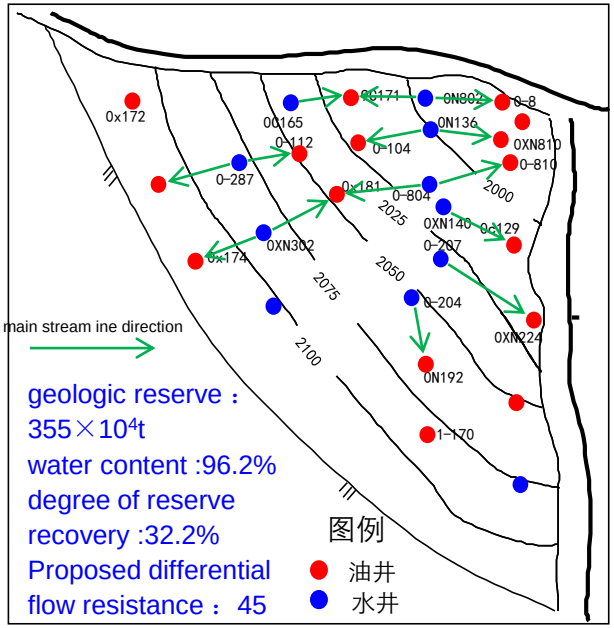
“Tenth Five-Year” the mid to late



Since the "twelfth five-year"



（1）9-10 layer recombination、Vector well pattern adjustment

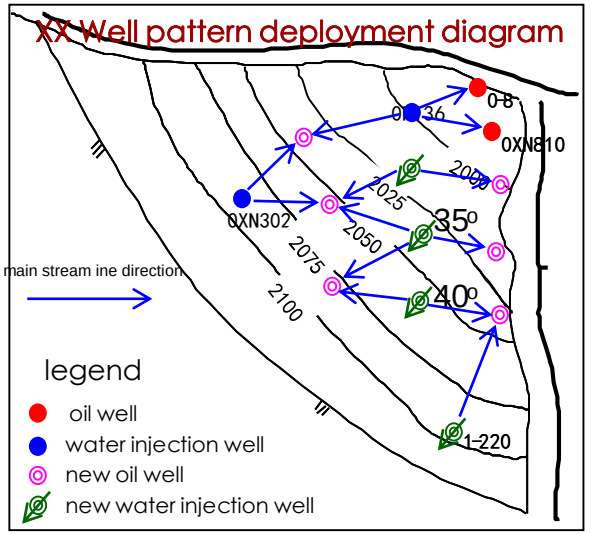


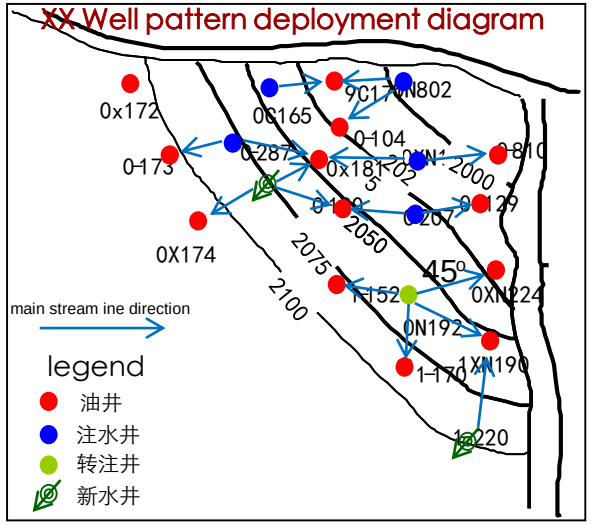
10 sands group 5 sublayer a layer，Proposed differential resistance 3.7

vacuate well pattern：
300*260m-380*300m；
change flowline： 35-40°
extract： 70t↑150t
recovery ratio： 41→45%

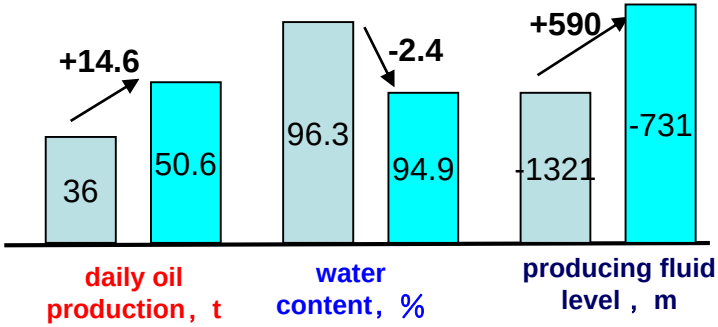
9 sands group 2 sublayer a layer，Proposed differential resistance 2.1

well pattern：
300*260m-200*250m；
change flowline： 30-45°
extract： 22t↑50t
recovery ratio：
28→36%





big well pattern nest small



decrease from 14.4% to 6.2%， degree of reserve recovery improve 5.7 percent36.3→42%）

一、Conventional waterflood enhanced recovery technology

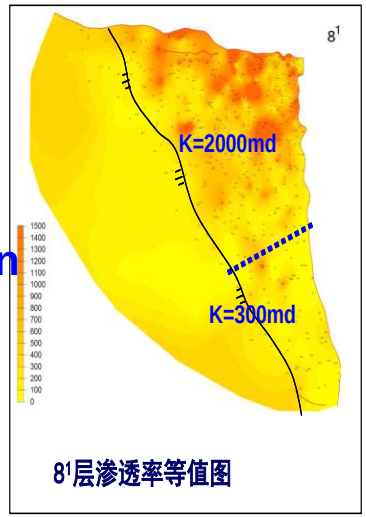
（2）8 layer system plane vector well pattern adjustment

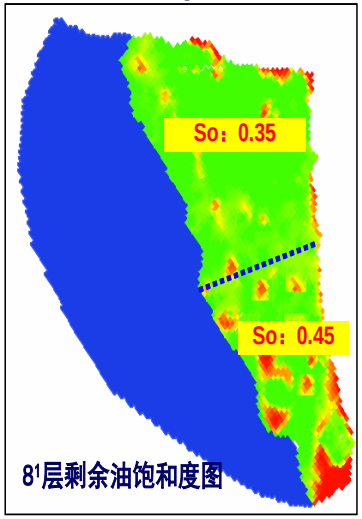
high permeability、extraction zone → big well pattern → Changing the flow direction

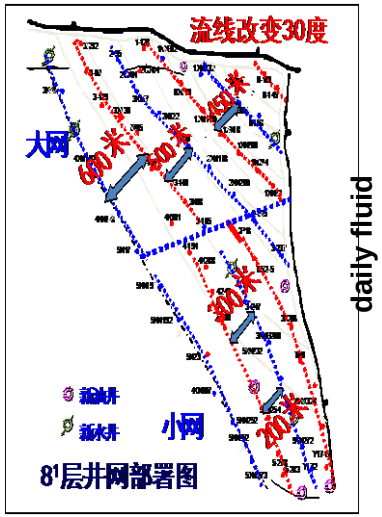
low permeability、extraction zone → Small well pattern → Improve multiple of injection、displacement pressure gradient

geologic reserve：1280万吨； water content ： 97.9%；
degree of reserve recovery ： 46.4%

big well pattern nest small



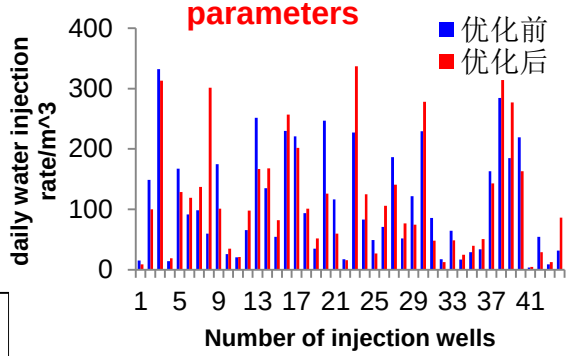


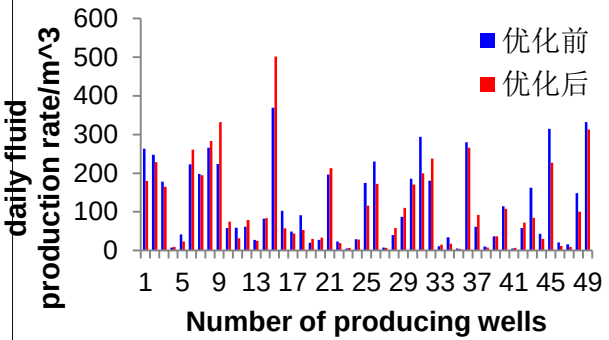


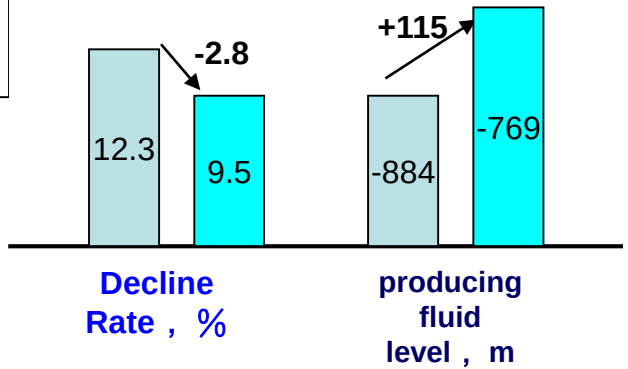
original well spacing ： 400m → big well pattern450-600m ， small well pattern200-300m

scheme recovery ratio improve from 48.4% to 52.85%，
Improved 4.45 percentage points

Optimize injection parameters



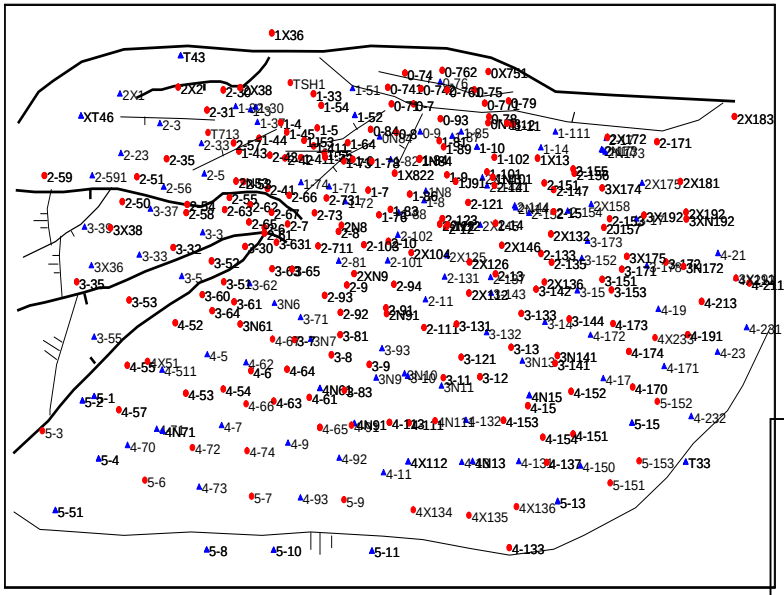




一、Conventional waterflood enhanced recovery technology

（3）1-3 Layer well network restructuring

1-3Layer well network



oil-bearing area：19.1km2

geologic reserve：3740万吨

sublayer： 17个

permeability： 0.5-2.8μm²

composite water cut： 95.6%

degree of reserve recovery： 32.8%

existing problem：

- **multiple sublayer in vertical， Serious interference between layers， Proposed differential flow resistance 25.4**
- **Well network improve poor， Low control degree of reserves （46%）**

Layer well network restructuring

- Layer restructuring → According to the proposed differential flow resistance restructuring boundary，restructuring 2 layers
- plane vector well pattern → Well network deployed by sand, river center deployment water wells, river side edge deployment oil wells
- vector water flooding regime → According to the distribution of remainder oil saturation, vector optimize injection parameters

Expected to increase recoverable reserves 191万吨， Recovery rate increased by 5.1 percentage points

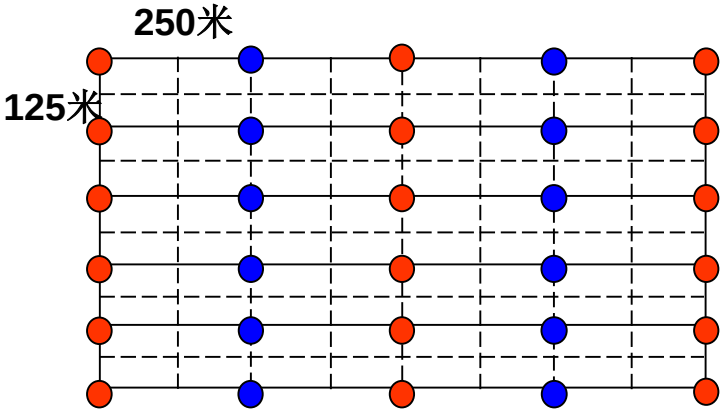
一、Conventional waterflood enhanced recovery technology

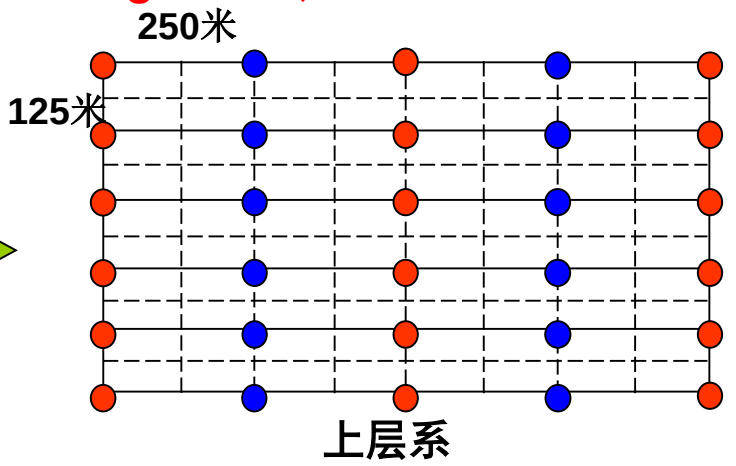
1、high water cut stage reservoir

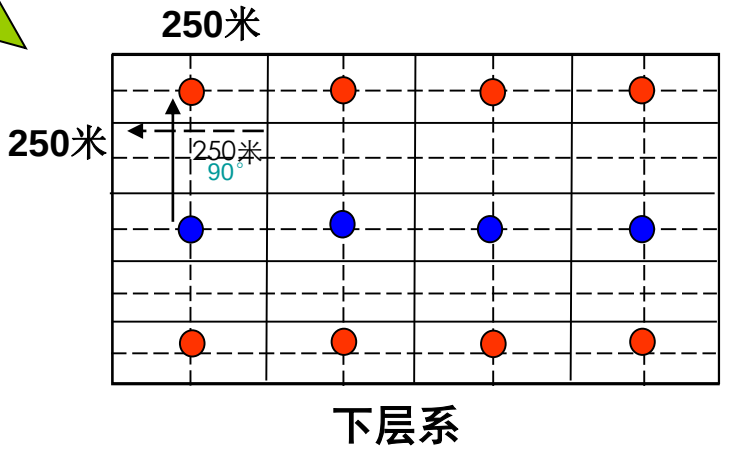
2、fluid diversion adjustment technology

（1）multilayer layer system：Strata subdivision， old well upper layer 、new well down layer （Streamline change 90°）

geologic reserve ： 430万吨； water content ： 95.2%；
degree of reserve recovery ： 37.8%





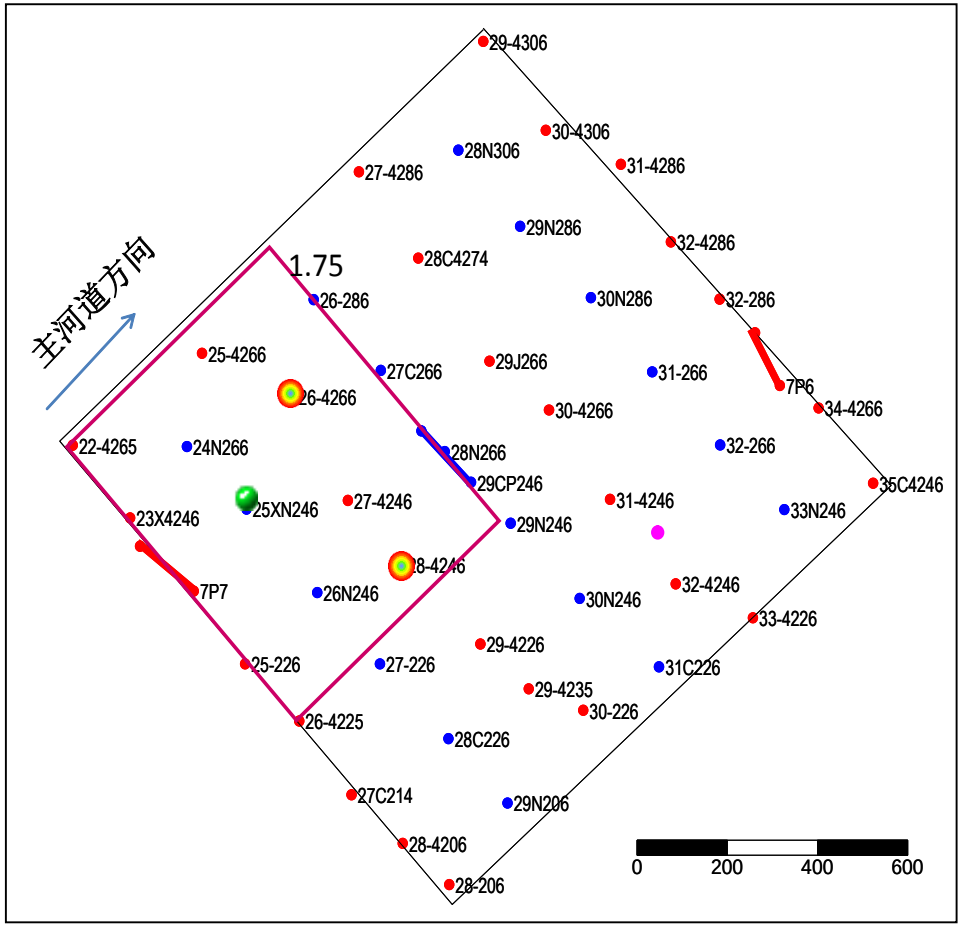


Subdivided into two strata, the upper level is the use of old wells network development wells, down level drilling new wells form 250 * 250m ranks well pattern (90 ° change streamline)

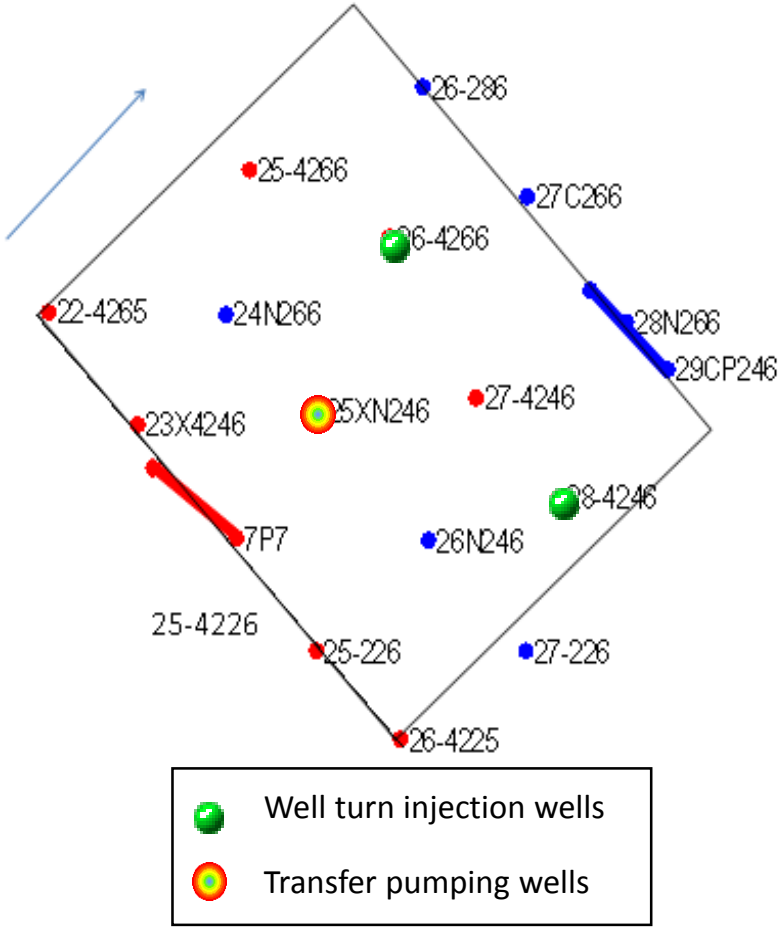
Being further optimization program, ready to implement

一、Conventional waterflood enhanced recovery technology

（2） Single-layer system： Converting some oil wells and water wells, changing the flow direction



Changing the flow direction of 60 degrees



一、Conventional waterflood enhanced recovery technology

1、high water cut stage reservoir

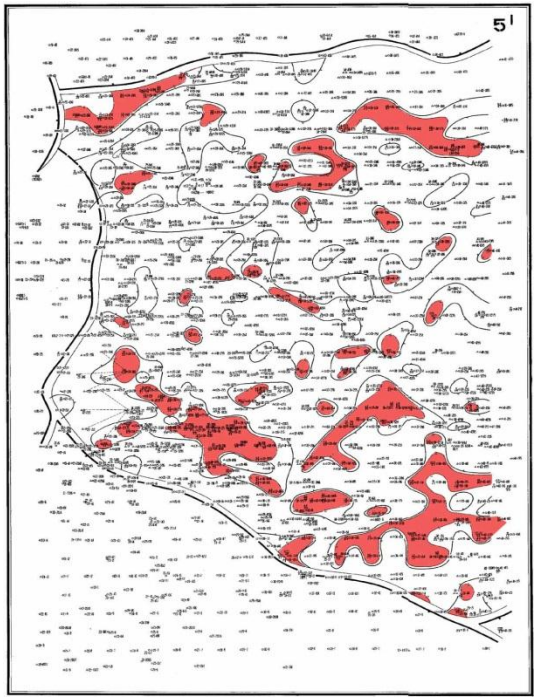
3、Single sand body injection technology

xxOilfield overall water content ratio> 92%, the main sand body injection patterns better, small sand with low level of well network control.

xxStatistics of utilized small oil sands condition

分类	砂体个数	地质储量 104t	采出程度%
砂体动用状况《0.02	13	8.67	15.25
砂体动用状况0.02-0.04	22	40.44	20.84
砂体动用状况0.04-0.1	9	32.12	17.14
合计	44	81.23	18.78

Small floor plan



xx Oil sands unused small tables sands

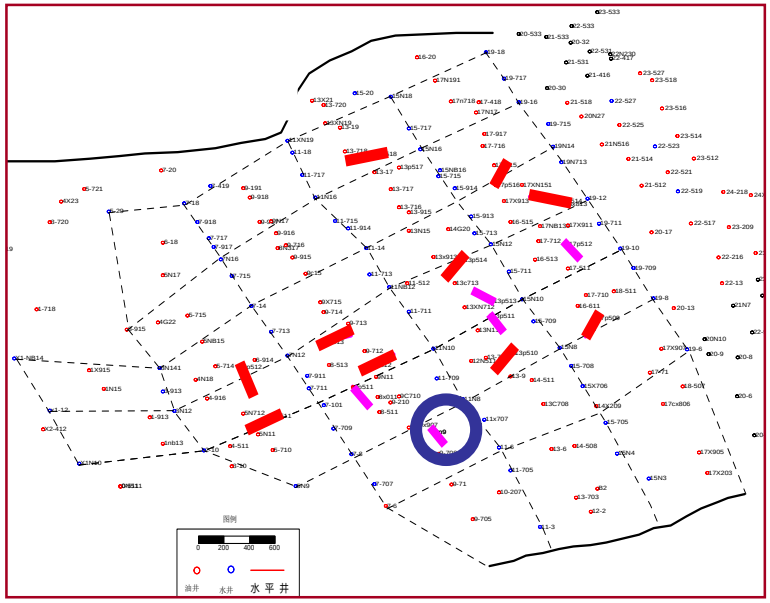
分类	≤1.0×10⁴t		1.0-2.0×10⁴t		2.0-5.0×10⁴t		>5.0×10⁴t		小计		
	个数	地质储量 10⁴t	个数	地质储量 10⁴t	个数	地质储量 10⁴t	个数	地质储量 10⁴t	个数	地质储量 10⁴t	比例
面积≤0.02km²的砂体	260	96.9	8	9.7	1	2.2			269	108.8	71.25
面积0.02-0.04km2的砂体	17	10.2	24	35.9	10	27.8			51	73.8	55.33
面积0.04-0.1km2的砂体	2	2.8	4	6.0	12	38.7	3.0	17.8	21	65.4	32.42
合计	279	109.9	36	51.6	23	68.73	3	17.82	341	248.0	50.84

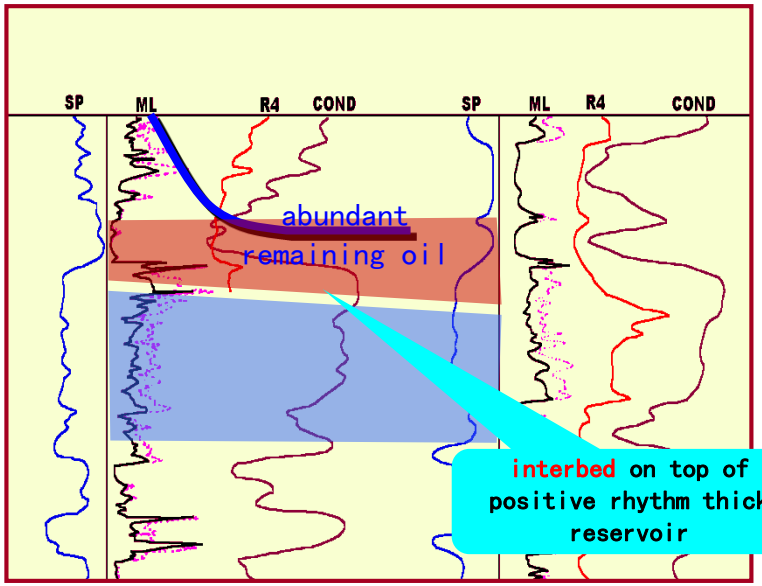
To 2010, drilled 13, put into production 11 ， old well turn injection wells 6, enhanced oil recovery of 15.7%.

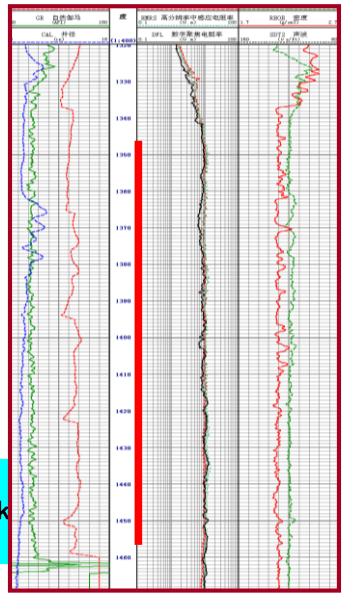
一、Conventional waterflood enhanced recovery technology

1、high water cut stage reservoir

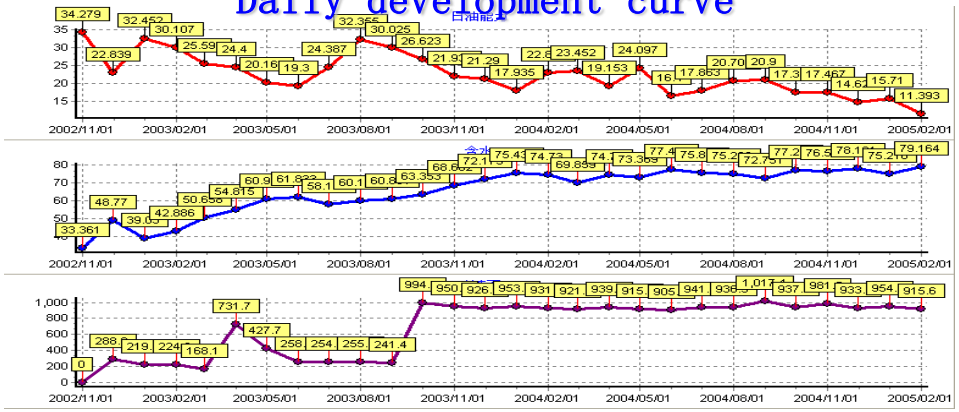
4、Thick oil layer at the top horizontal wells tapping technique







Daily development curve



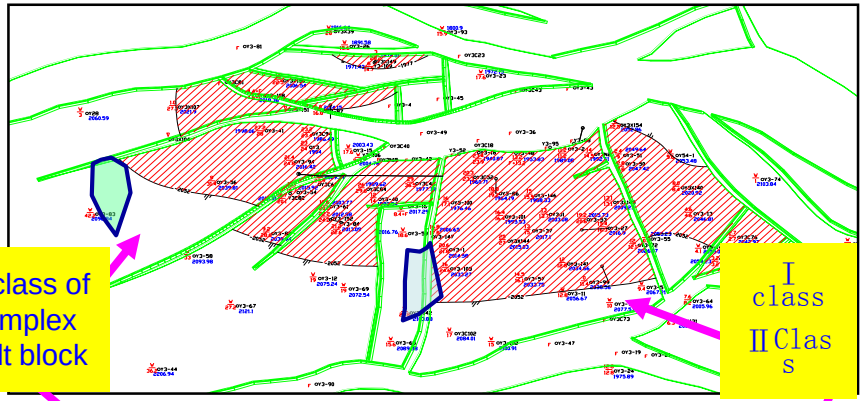
After the operation has accumulated oil production 22,200 tons.

一、Conventional waterflood enhanced recovery technology

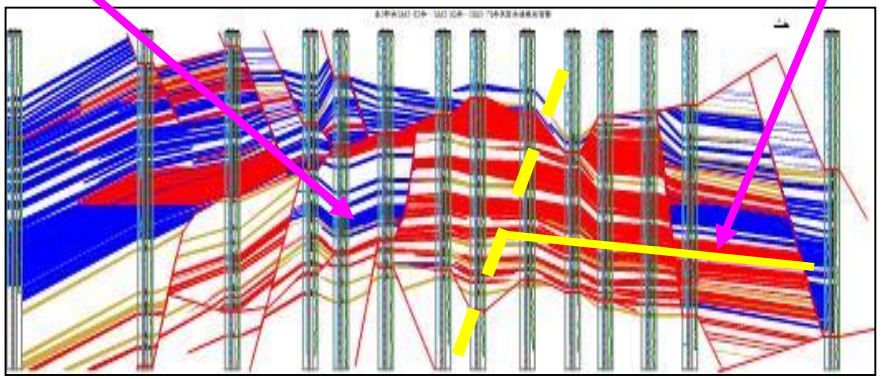
2、complex fault block oil reservoir

Three-dimensional adjustment techniques

Geological reserves of 4.39 million tons, 92.3% water cut; degree of recovery of 38.2%, 42.5% recovery



Xx fault block reservoir EW cross-sectional view



Ⅰ class. Thick layer of simple block：

The degree of recovery of 48.8%, 97.8% water cut, open wells 2, state is basically technology abandoned.

Class Ⅱ. Multiple thin simple block The degree of recovery of 30.1%,water content 89.8% , the obvious contradiction between layers.

Ⅲ class. Complex fault block

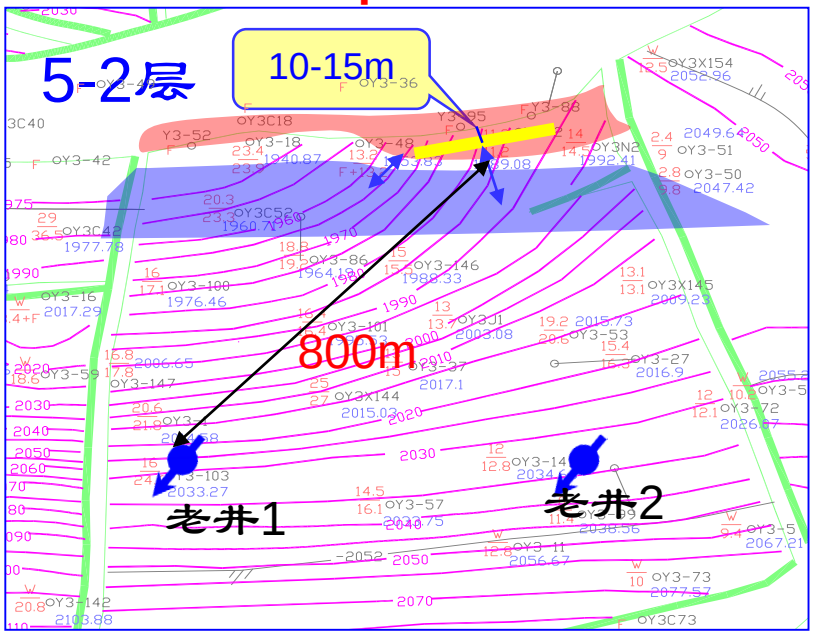
The degree of recovery of 27.9%, 78.6% water cut, open wells 2, many small non-well control.

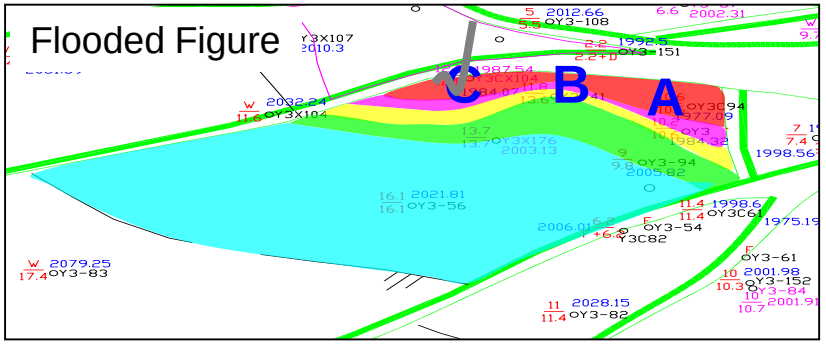
Between layers, the inter-block potential overal analysis, three-dimensional optimization

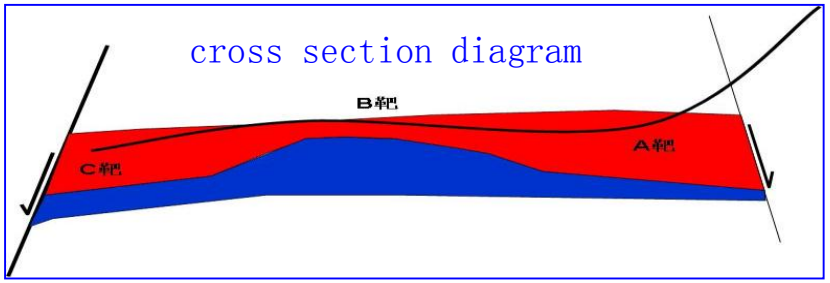
一、Conventional waterflood enhanced recovery technology

(1) Class Ⅰ thick layer of simple block - horizontal wells near fault + high strength injection wells

single layer development







horizontal wells near fault - put into production from the spray 24 tons/d, 12.2% water content

Curved around the water cone horizontal wells

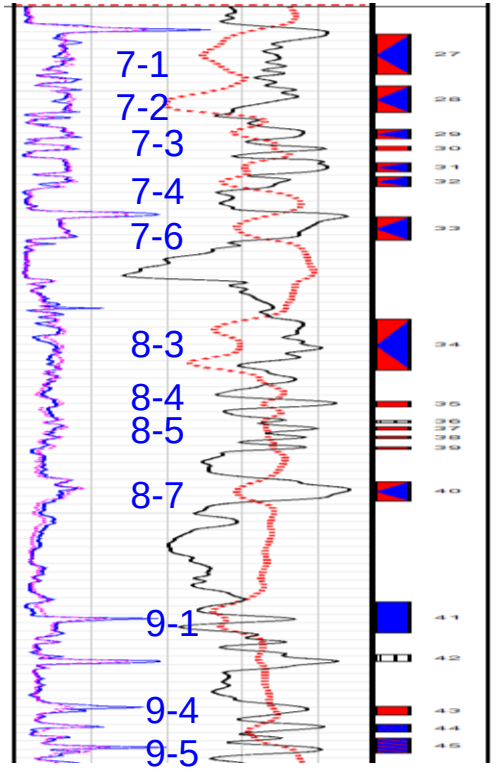
Day 13 tons of oil production, water content 36%, has accumulated 8,777 tons of oil

一、Conventional waterflood enhanced recovery technology

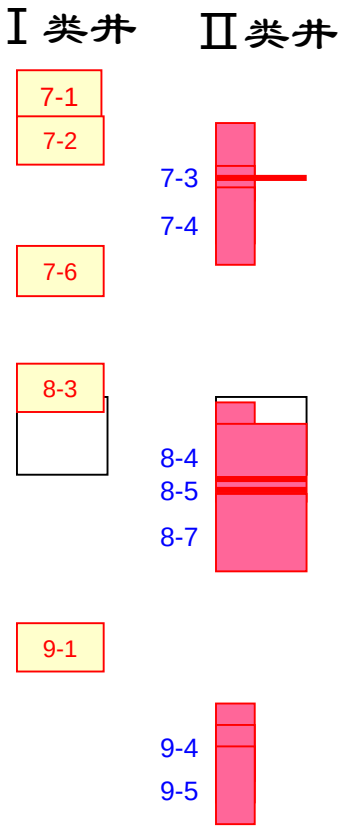
（2） II class multiple thin layers- layer recombination 、vector network of wells

Three segments: Layer recombination, selective mining separate injection, variable density perforation

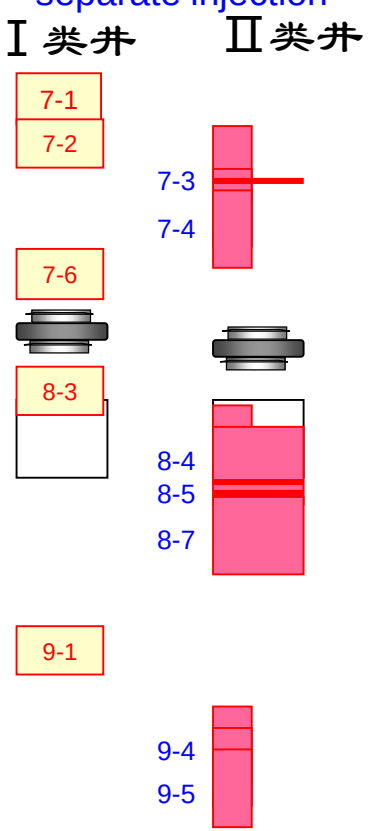
inductive/SP



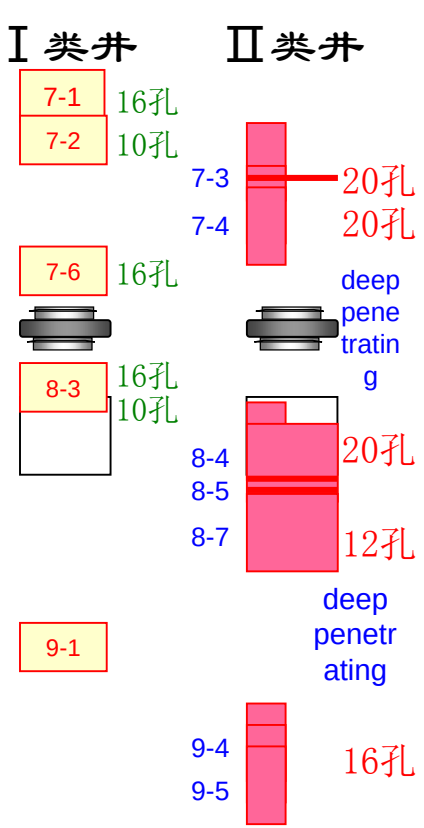
Old Well based New Well based



selective mining separate injection



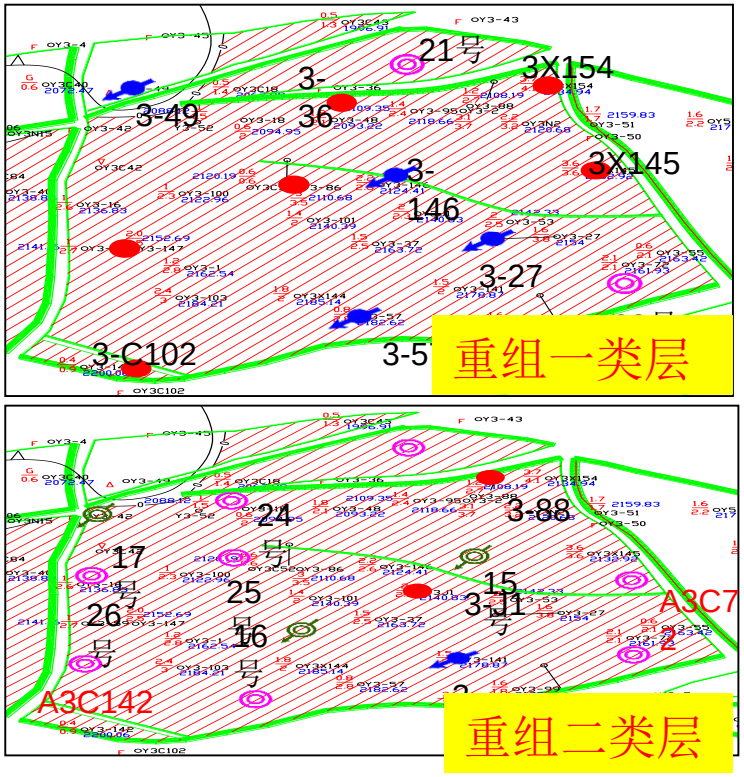
variable density perforation

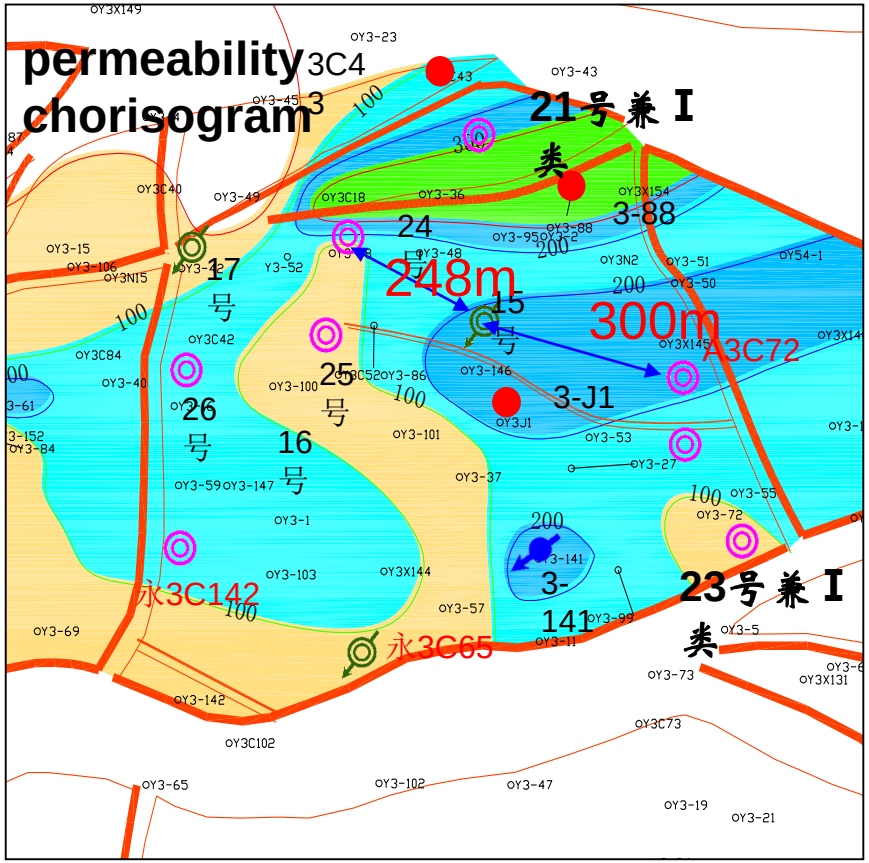


一、Conventional waterflood enhanced recovery technology

（2） II class multiple thin layers- layer recombination 、vector network of wells

vector network of wells





I class layers injection well spacing 280m ,

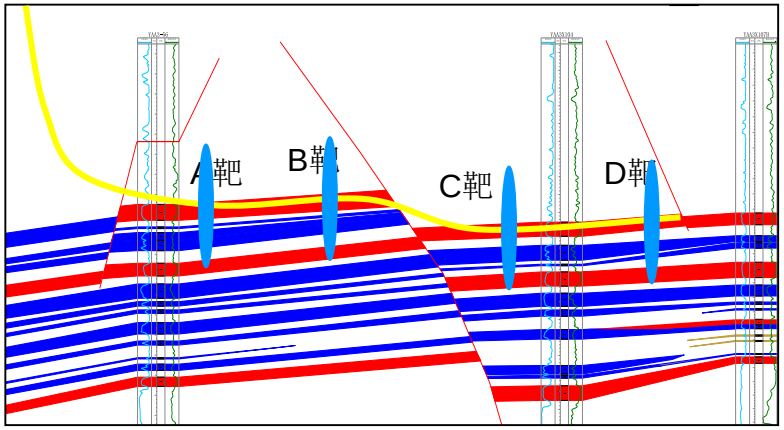
II class layers injection well spacing 200m

Consider permeability, formation dip, to determine the specific well spacing

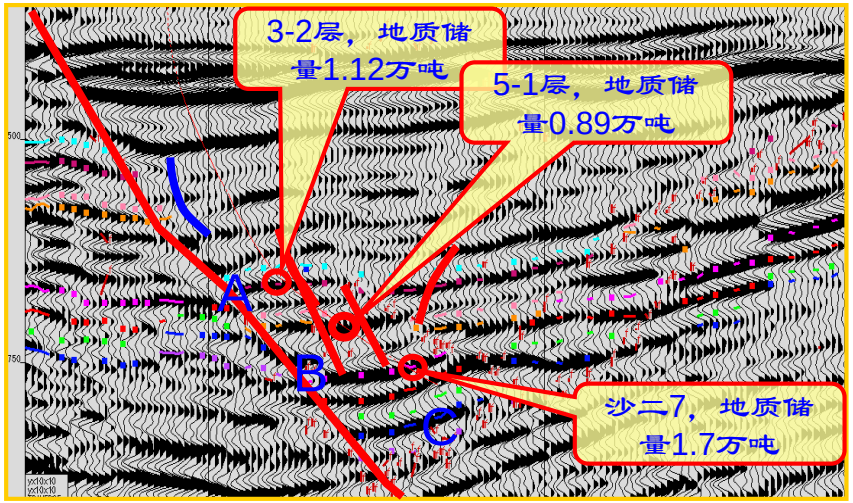
一、Conventional waterflood enhanced recovery technology

（3） Ⅲclass Complex fault block - use a combination development of multi-target multi-block

Horizontal wells across the block



Three target directional well



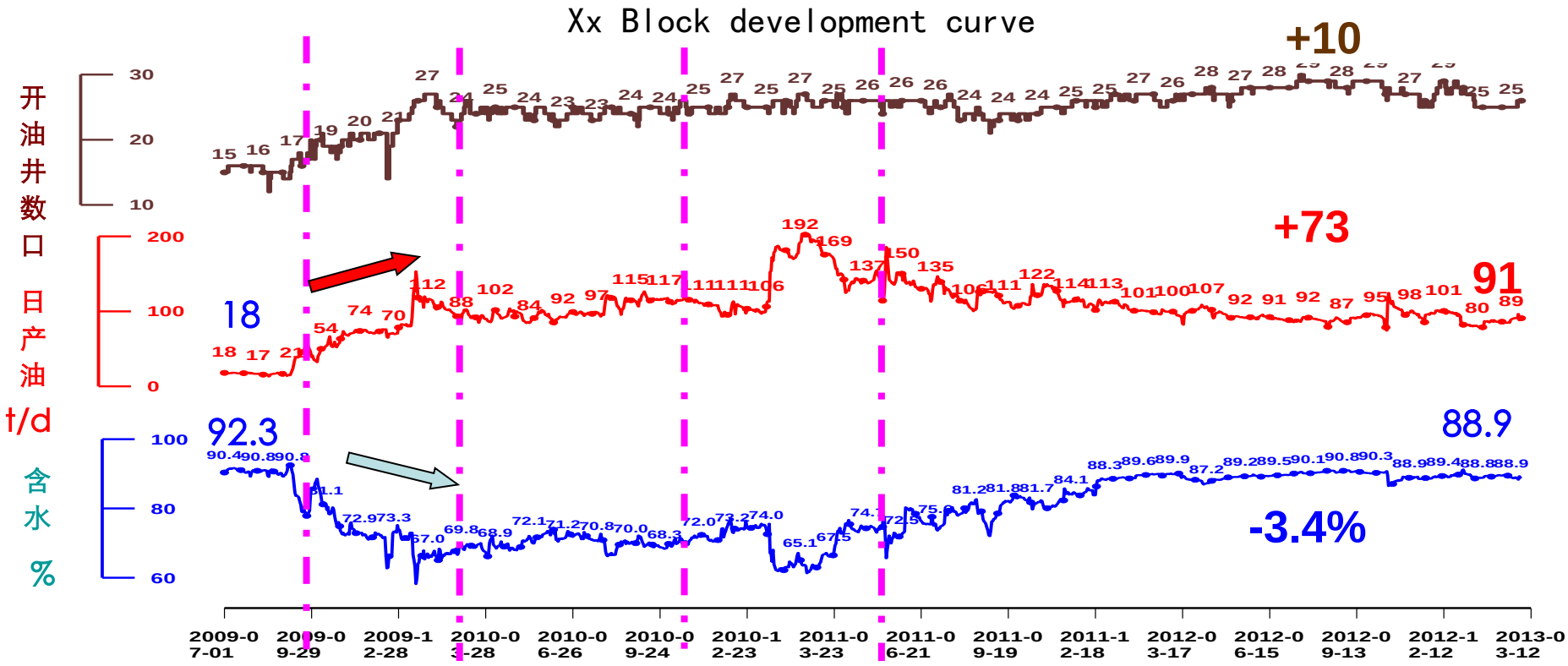
Oil drilling 317m. Initial daily oil production 60t / d, excluding water. The current production of AB segment, 12.4 tons daily oil production, water 82.9%, has accumulated 15,295 tons of crude oil.

Initial daily output of 10t / d, water 3.9%. Currently oil production 3.0t / d, 85% of water, tired produced 7,625 tons of crude oil

一、Conventional waterflood enhanced recovery technology

The overall effect of the test area

Daily oil production increased from 18t to 192t, water rate from 92.3% down to 65.1%. Has accumulated increase of oil 118,000 tons, recovery from the 42.5% increase to 53%.



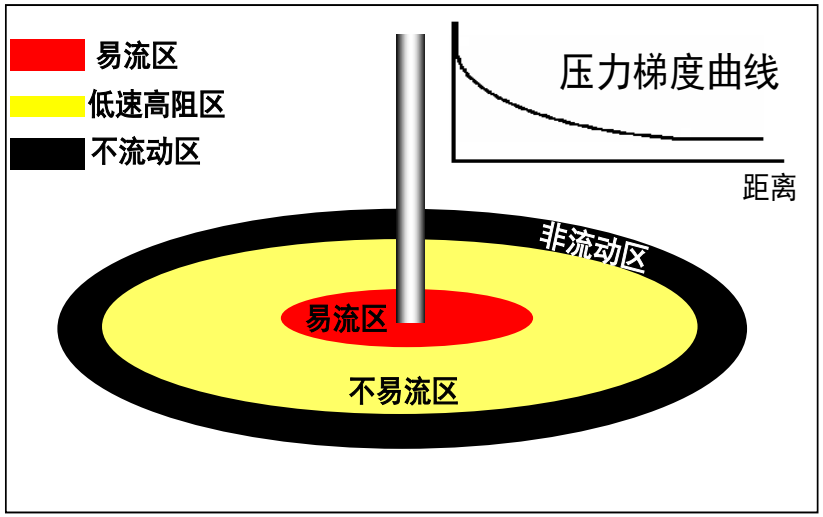
一、Conventional waterflood enhanced recovery technology

3、low permeability reservoir

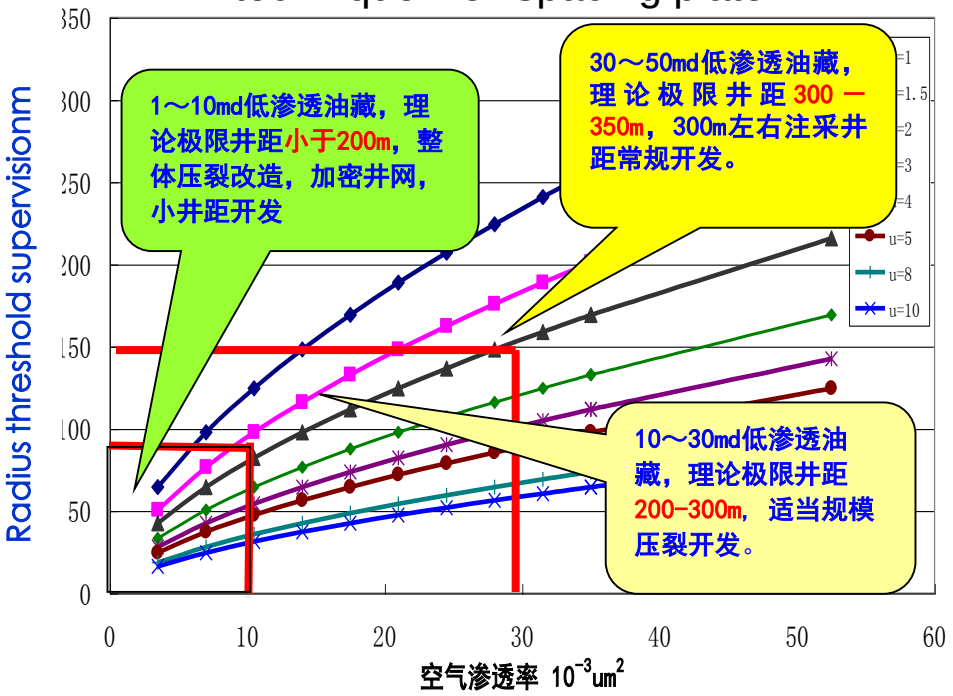
1、small well spacing waterflood

Under the guidance of low permeability reservoir percolation mechanism established technology critical spacing plates.

Low permeability reservoir flow state distribution area



technique well spacing plate

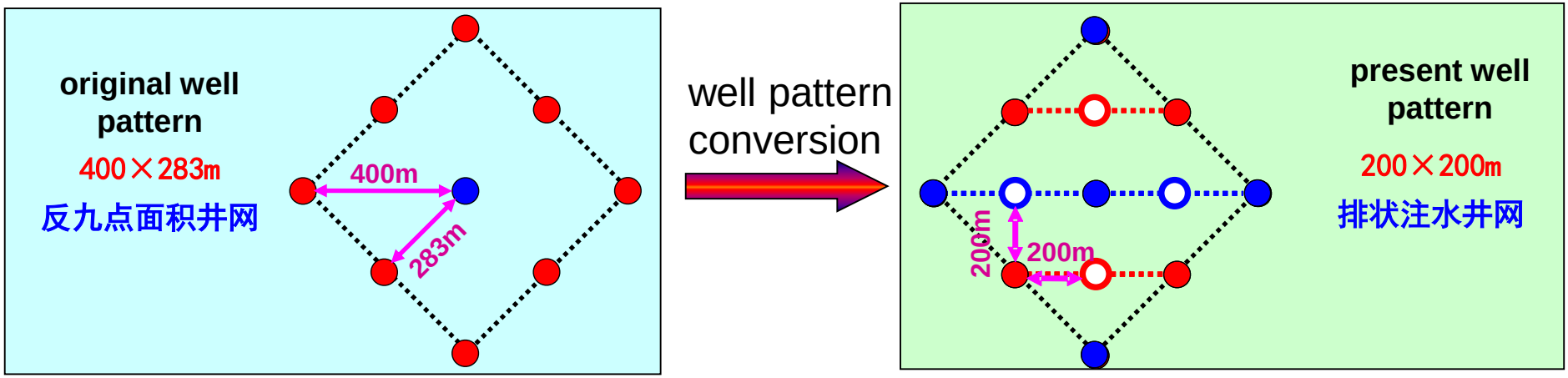


$$r_{极限}=3.226(P_e-P_w)\left(\frac{K}{\mu}\right)^{0.5992}$$

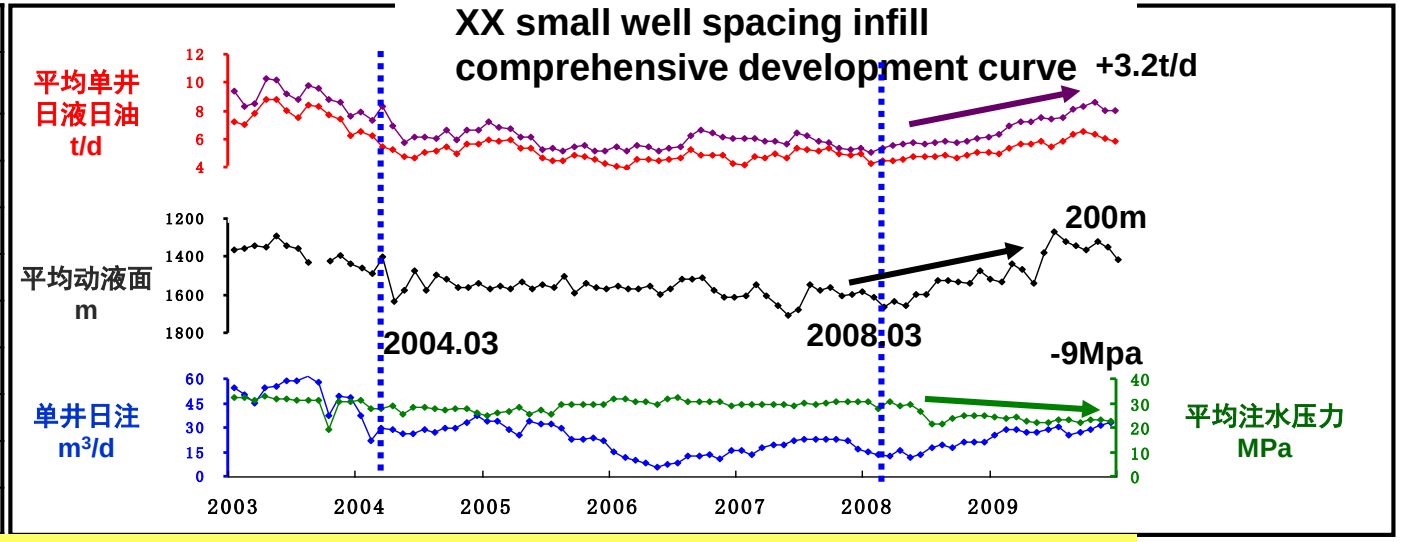
To determine the reasonable well spacing to achieve cost-effective development of the reservoir to provide theoretical guidance

一、Conventional waterflood enhanced recovery technology

small well spacing infill achieved remarkable results



xx井区基本情况	
含油面积，Km^2	1.8
地质储量，10^4t	286
油藏埋深，m	3250
空气渗透率，mD	15.2
见效前生产状况	
油水井数比	4：1
单井日液，m^3/d	5.2
单井日油，t/d	4
吸水指数，$m^3/d/MPa$	0.58
注水压力 MPa	34.0



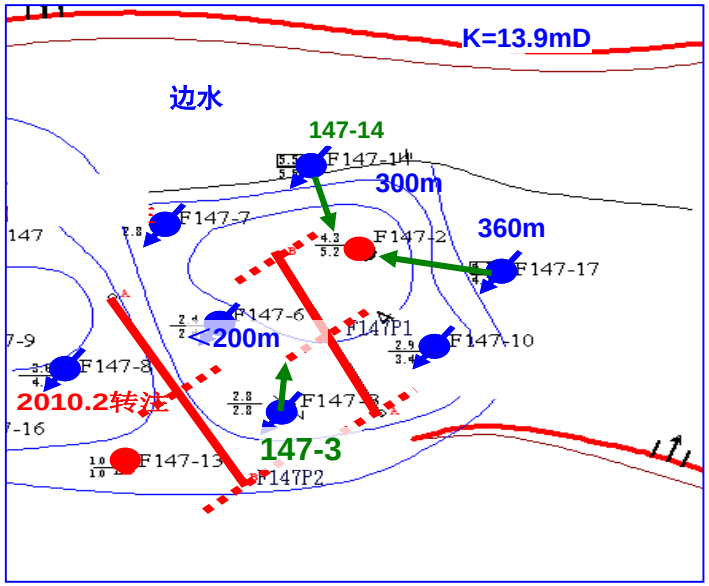
Recovery increased from 17.7% to 24.5%, 6.8%, enhanced oil recovery

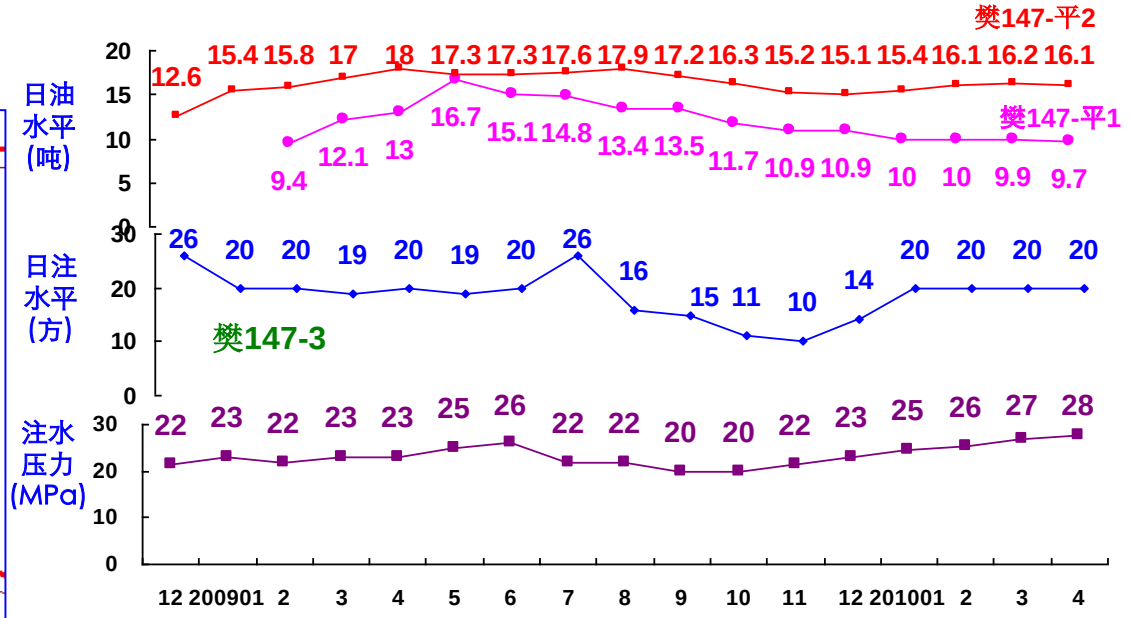
一、Conventional waterflood enhanced recovery technology

3、low permeability reservoir　2、horizontal well fractured completions waterflooding

Using a horizontal well fracturing by fragment oil well completion, matching small well spacing injection supplement energy wells network mode

Xxblock Well network deployment diagram





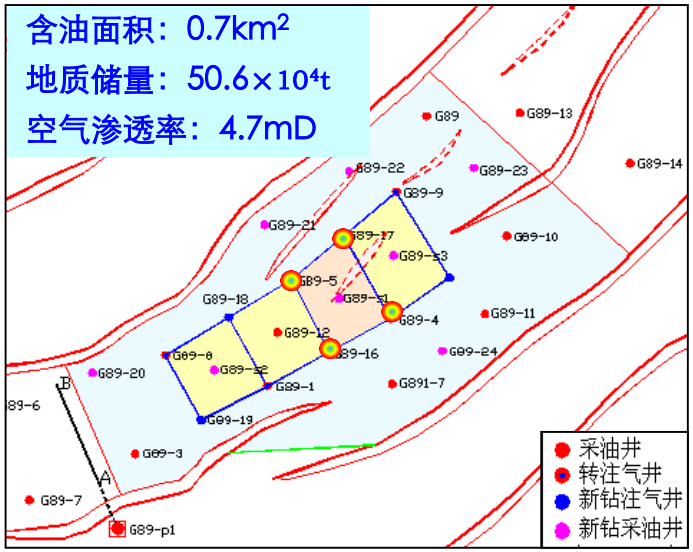
Cumulative oil production 1.38万吨。

4 horizontal wells into production, cumulative oil production 4030 tons of single well, injection wells injecting normal recovery reached 26%.

一、Conventional waterflood enhanced recovery technology

3、low permeability reservoir

Xx well array well location map



Expected recovery from 8.9% to 26.1%, improved by 17.2%.

3、CO2 miscible flooding pilot test

✓injection test stage

20,400 tons of accumulated injection injection pressure 6MPa, day water injection 63.6 tons; meters depending on the suction index 1.55t / (d ·MPa ·m)

✓Gas injection phase

Well Group 4 gas injection wells, as the current total amount of 31,300 tons injection

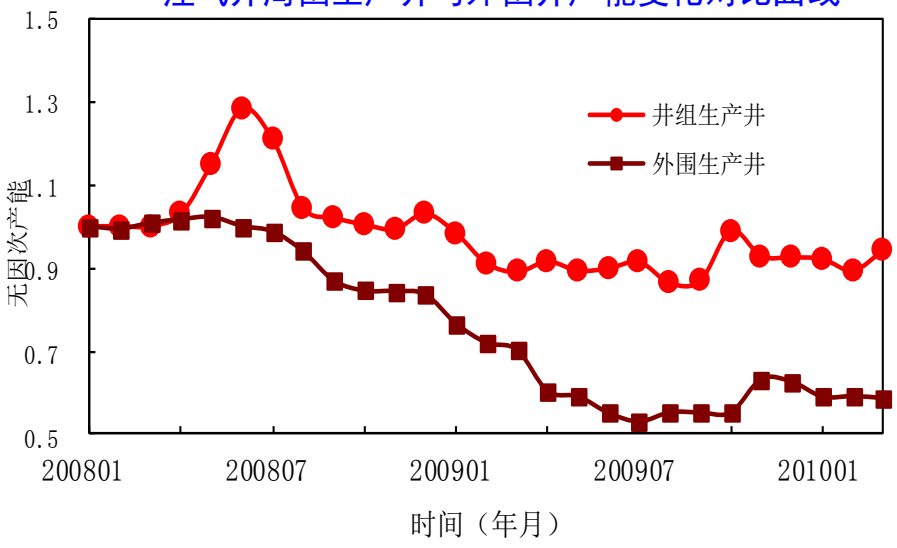
Xx Well group gas injection basic statistics

井号		注入压力（MPa）	日注（t）	累注（t）
高89-4	初期	3	35	23076
	目前	7.6	15.9	
高89-16	初期	12	16.6	2150
	目前	7	30.3	
高89-5	初期	12	16.6	2695
	目前	7	18	
高89-17	初期	8	29	3386
	目前	17.1	35.8	
小计	目前			31307

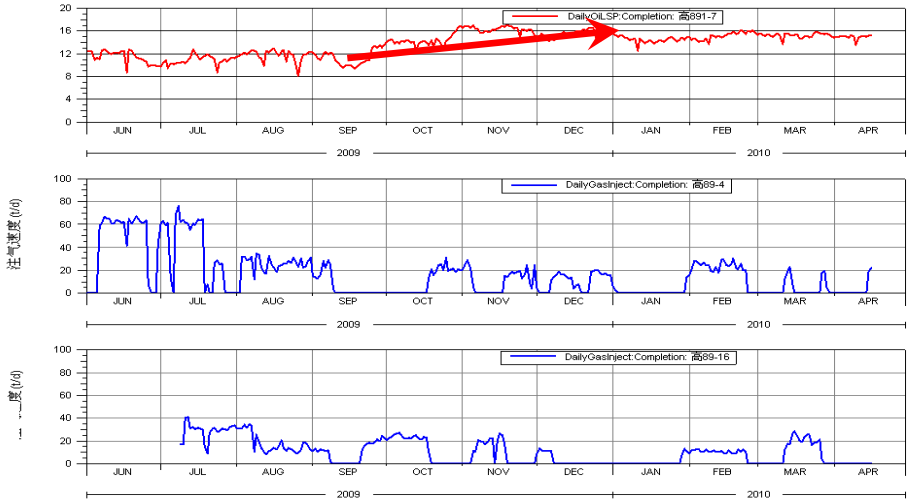
一、Conventional waterflood enhanced recovery technology

Well Group cumulative incremental oil 7430 tons. Peripheral production wells yield showed a decreasing trend

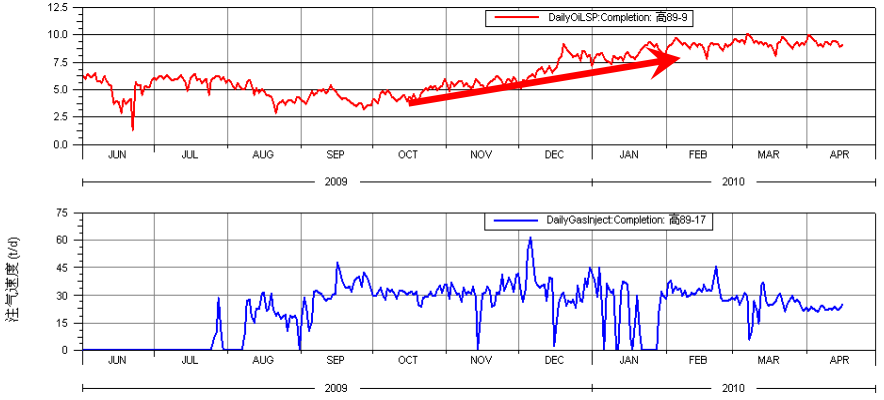
注气井周围生产井与外围井产能变化对比曲线



well 1 Yield curve changes after gas injection



well 2 Yield curve changes after gas



二、Chemical flooding technology

Chemical flooding Resource Evaluation Criteria

Chemical flooding Resource Evaluation Criteria

类别	空气渗透率 $10^{-3}\ \mu m^2$	原始地层温度 ℃	目前地层水矿化度 mg/L	$Ca^{2+}+Mg^{2+}$ mg/L
Ⅰ类	＞500	≤70	＜10000	＜200
Ⅱ类		＜80	＜30000	＜400
Ⅲ类	＞100	＜95	＜100000	>400
Ⅳ类	大孔道严重			
Ⅴ类	温度：95-120℃；渗透率：$50\sim100\times10^{-3}\ \mu m^2$			
海上	海上油田			

二、Chemical flooding technology

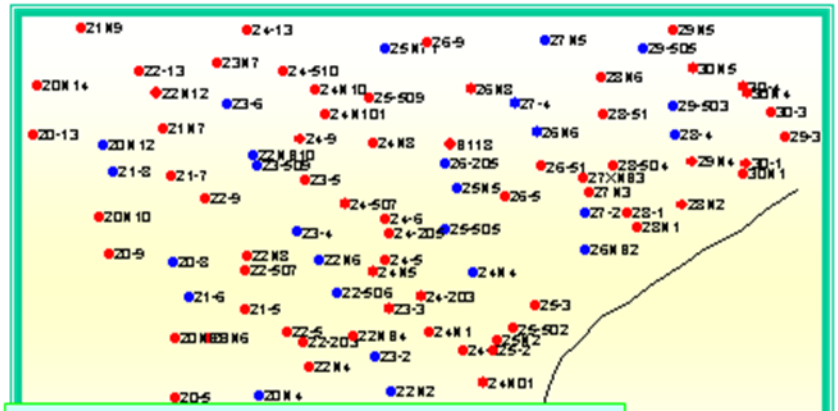
Different types of reservoirs suitable for chemical flooding methods

Reservoir classification		polymer flooding	dualistic flooding	Heterogeneous combination flooding	foam flooding	notes
I		√	√	√	√	mature
II		√	√	√	√	
III		√				pilot tracey
IV				√	√	
V	Special high temperature (95-120℃)	√			√	reserve
	Low permeability(50-100md)	√				
Maritime		√	√	√	√	pilot tracey
After polymer flooding				√	√	

(一) Polymer flooding technology

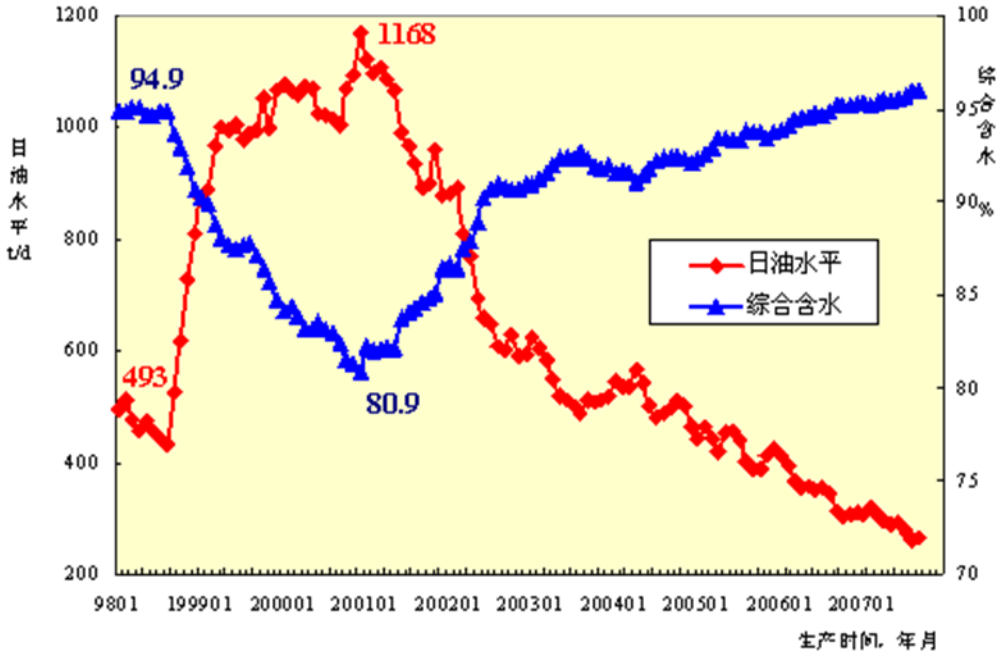
●Class Ⅰ reservoir the effect of the implementation of polymer flooding

XX Well deployment diagram



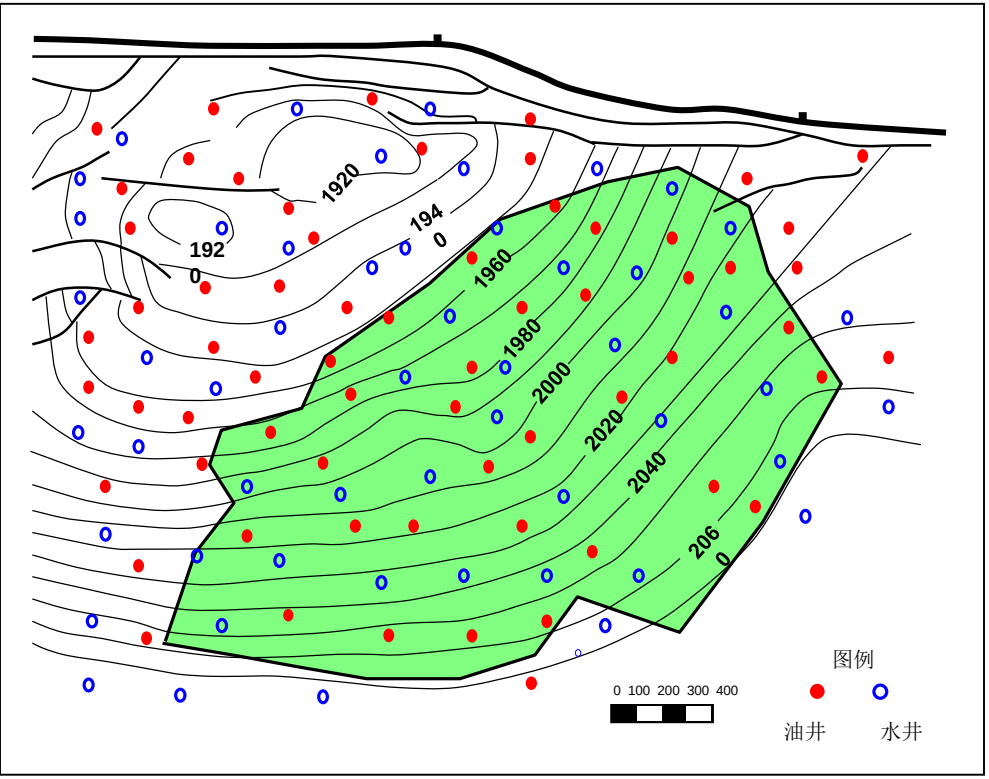
- ●面积1.8km², 地质储量1185万吨
- ●温度70.5 ℃, 矿化度5797mg/L
- ●原油粘度85mPa.s
- ●注入井38口, 生产井90口
- ●注采井距250m
- ●采出程度38.0%, 综合含水95.0%

XX Production curve

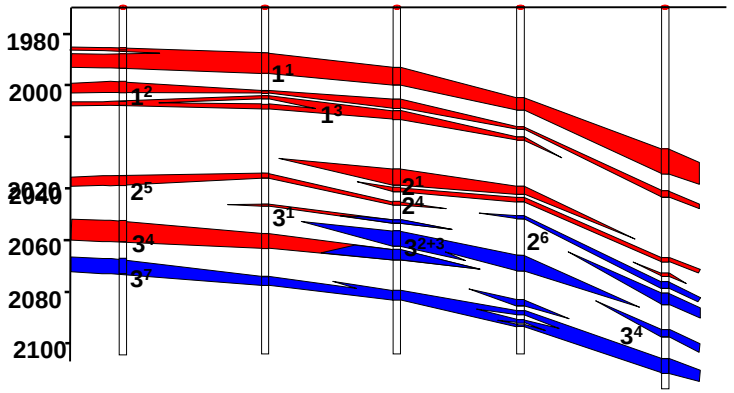


- ●已累积增油120.6万吨
- ●提高采收率10.2%
- ●吨聚增油84.6t/t
- ●采出程度59.4%

●Class Ⅱ reservoir high temperature and salinity polymer flooding pilot test



xx field xx area constructed Figure

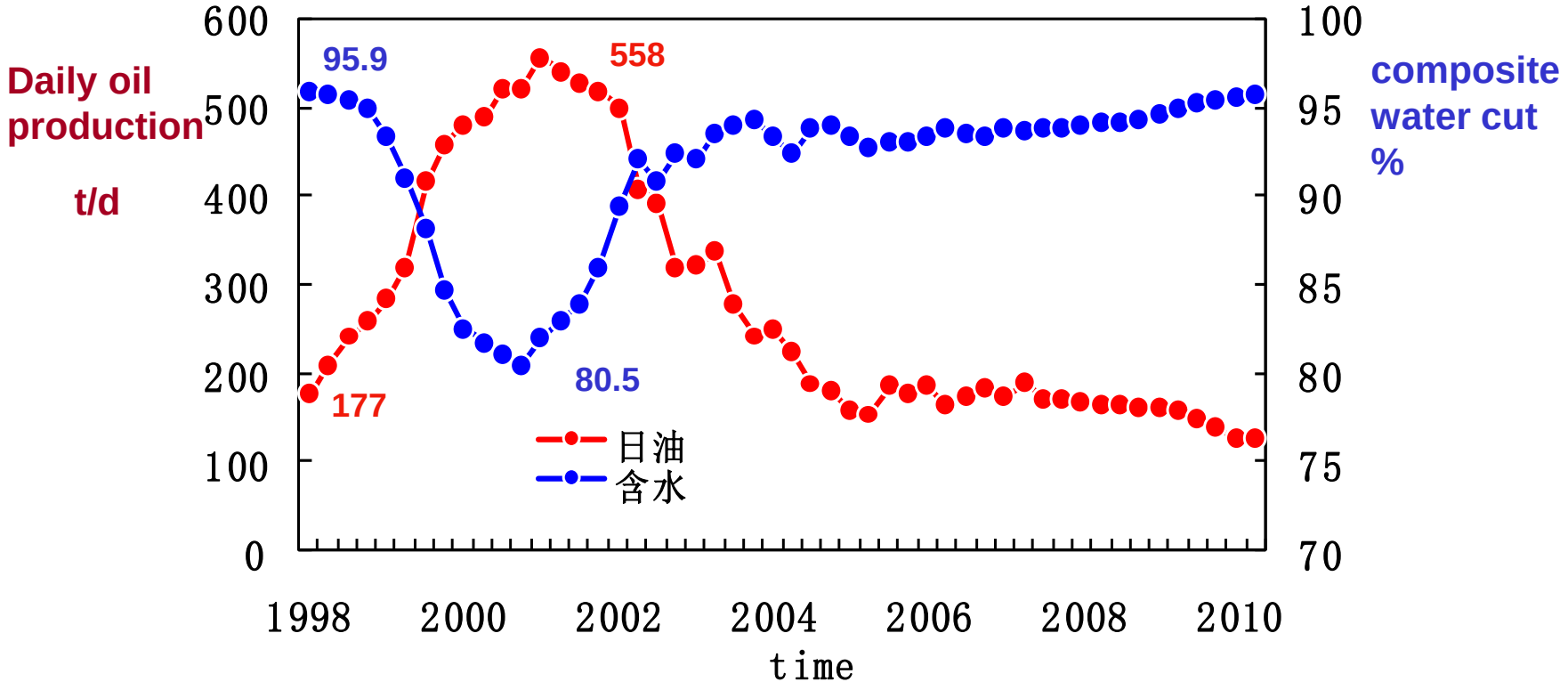


xxSectional view of the reservoir

- geologic reserve : 1089×10⁴t
- Injection wells: 32 production wells: 58
- Formation temperature : 80℃
- formation water salinity : 21000mg/L
- Calcium and magnesium content : 311mg/L

(一) Polymer flooding technology

- The recovery ratio has been increased by 7.4%(OOIP), tons of poly oil increase by 101t/t, which is expected eventually can be achieved 109t/t,

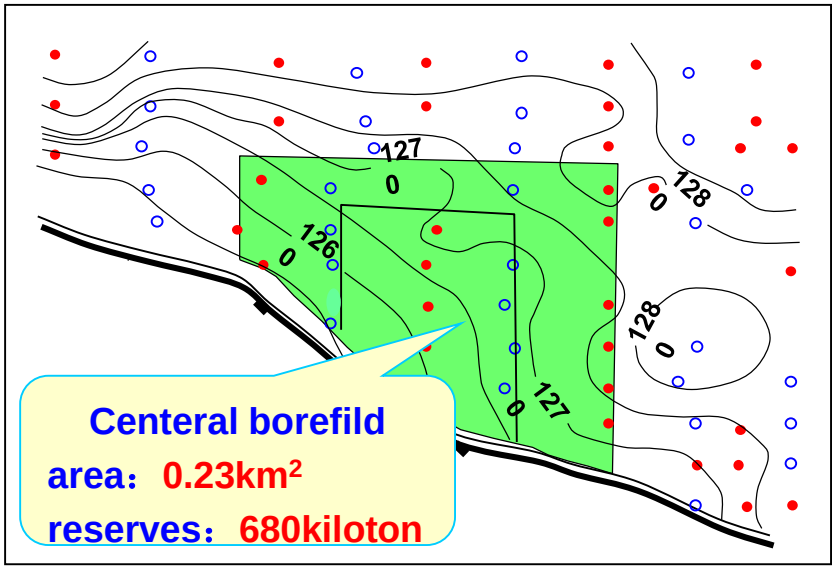


production curve of central well in pilot site

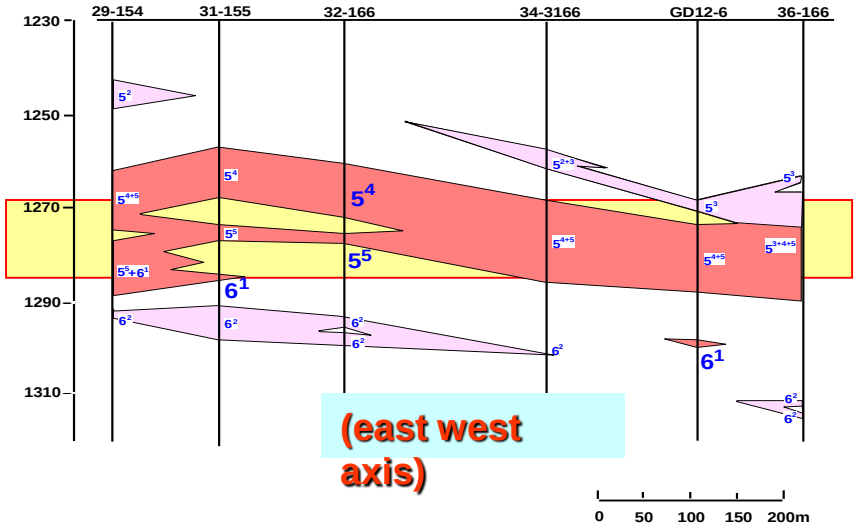
2.2 The binary system flooding technology

● The pilot test of surfactant/polymer(SP) flooding

well location map of pilot site



Reservoir Profile



- ◆Reservior temperature 68℃
- ◆Reservoir water salinity8207mg/L
- ◆$Ca^{2+}+Mg^{2+}$ 231mg/L
- ◆Geologic reserve： 277 0kiloton
- ◆Injection well :10， producing well:16
- ◆Injection producer distance： 300m

- ◆the composite water cut before combination flooding: 98.0%
- ◆The degree of reserve recovery before combination flooding: 35.2%

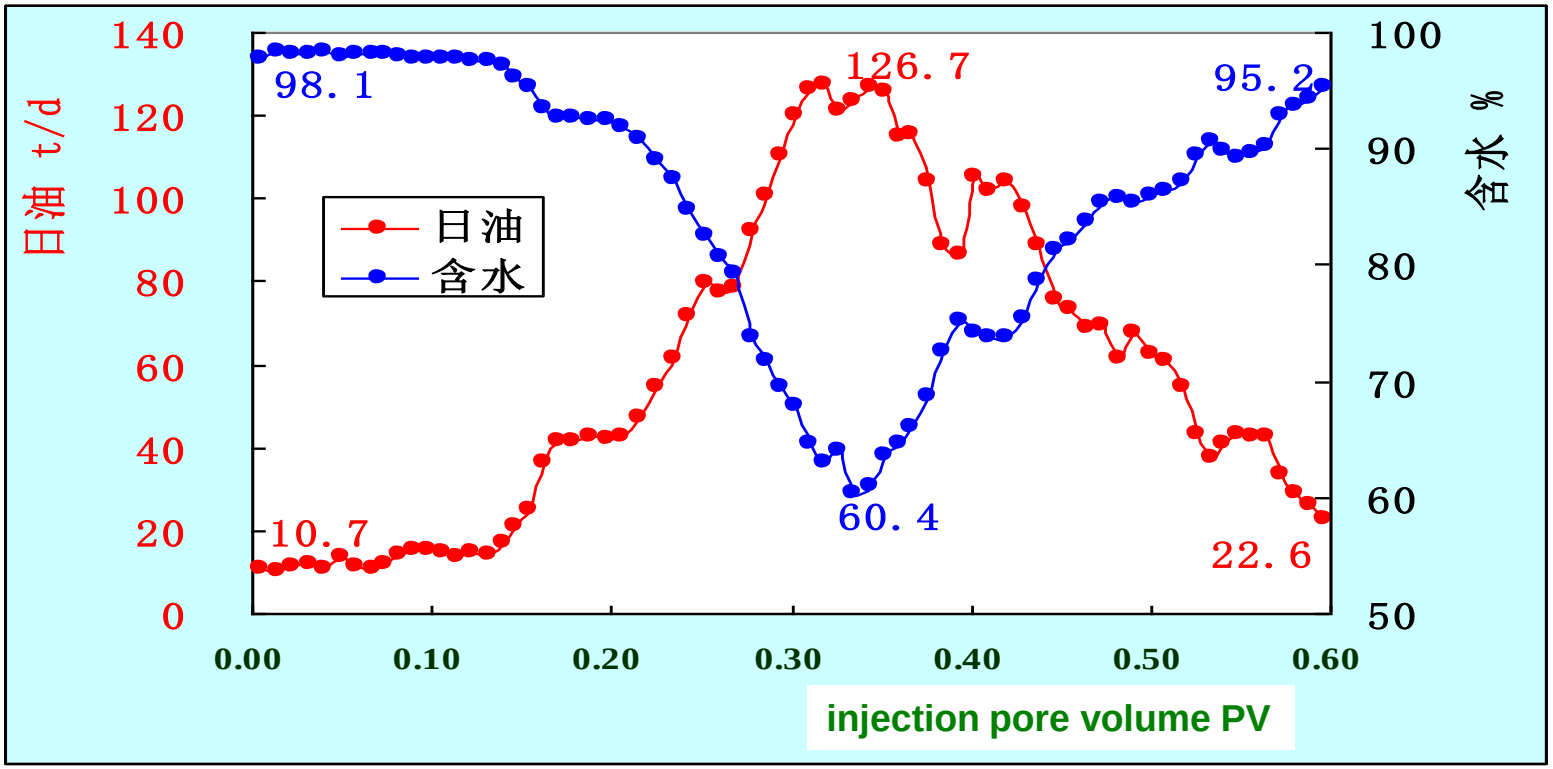
2.2 The binary system flooding technology

implementation effect

(2) Production performance-The daily oil production is improved and water content is lower

- The recovery ratio has been increased by 16.8%

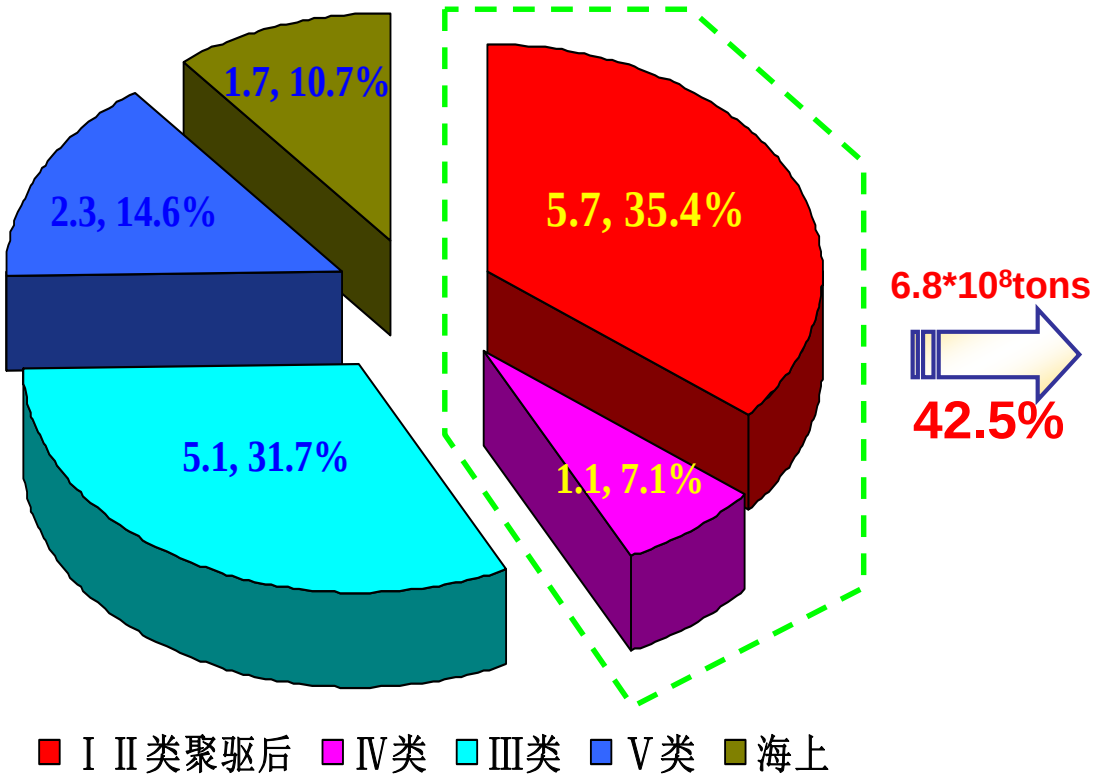
The production curve of pilot site



2.3 The Foam Flooding Technology

It enhanced oil recovery of class Ⅳ high capacity channel and class Ⅰ and Ⅱ reservoir(after polymer flooding)

Diagram of chemical resources in Shengli Oilfield



Development feature

(serious dynamic heterogeneity and severe development situation)

- Composite water cut: >95%
- Water injection multiple: >2PV
- Cumulative water/oil ratio: >7

Reservoir feature

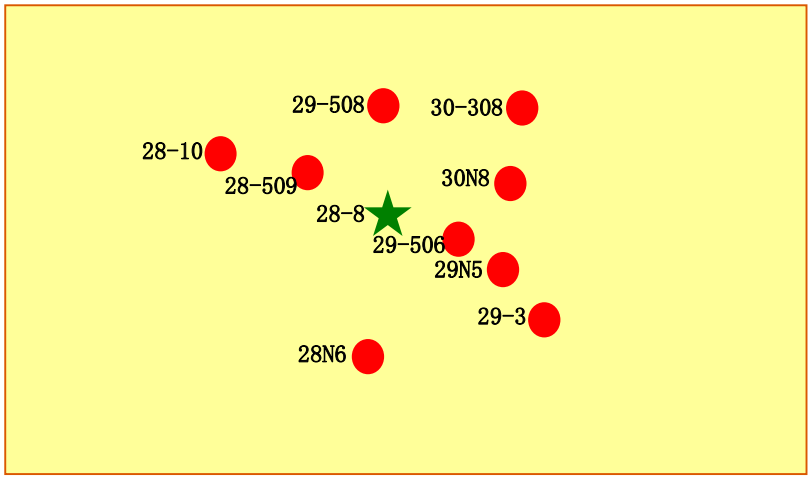
(high temperature and high salinity)

- Reservoir temperature:60-80 ℃
- Total salinity: 6000-20000mg/L
- Ca and Mg content:100-400mg/L

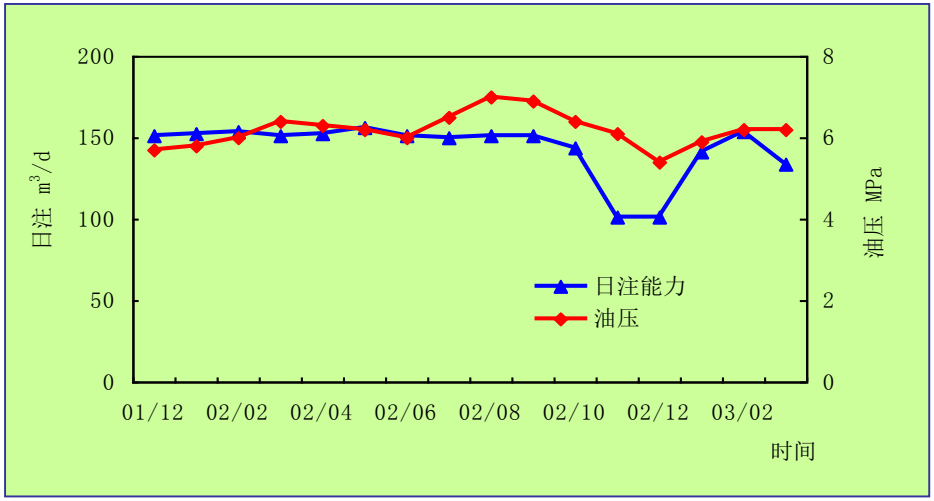
2.3 The Foam Flooding Technology

1.The pilot test of reservoir enhanced foam flooding after polymer flooding

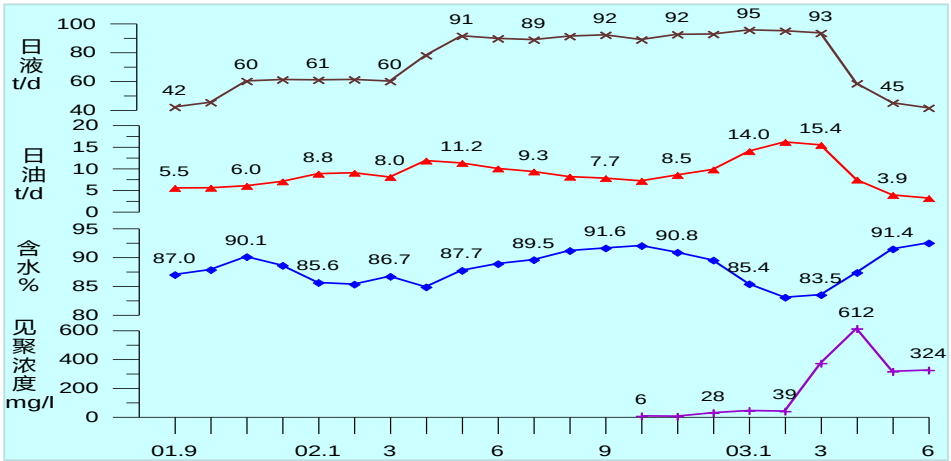
the pilot test of enhanced foam flooding after polymer flooding



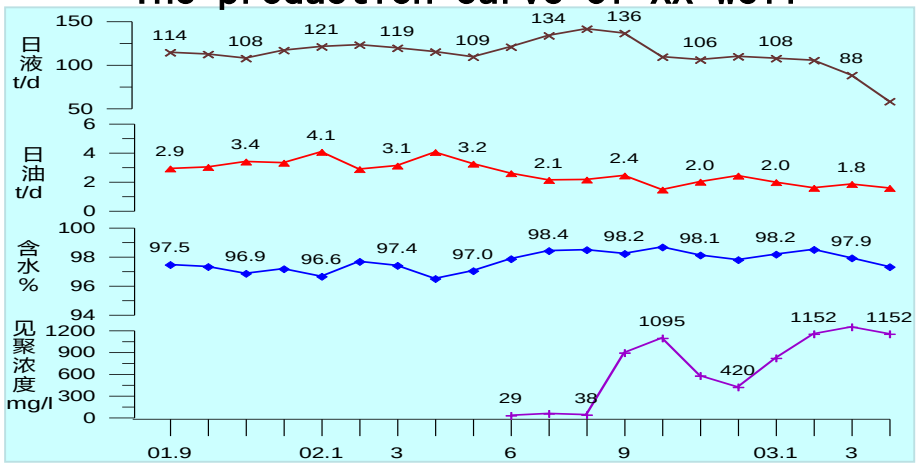
The injection curve of polymer



The production curve of XX well



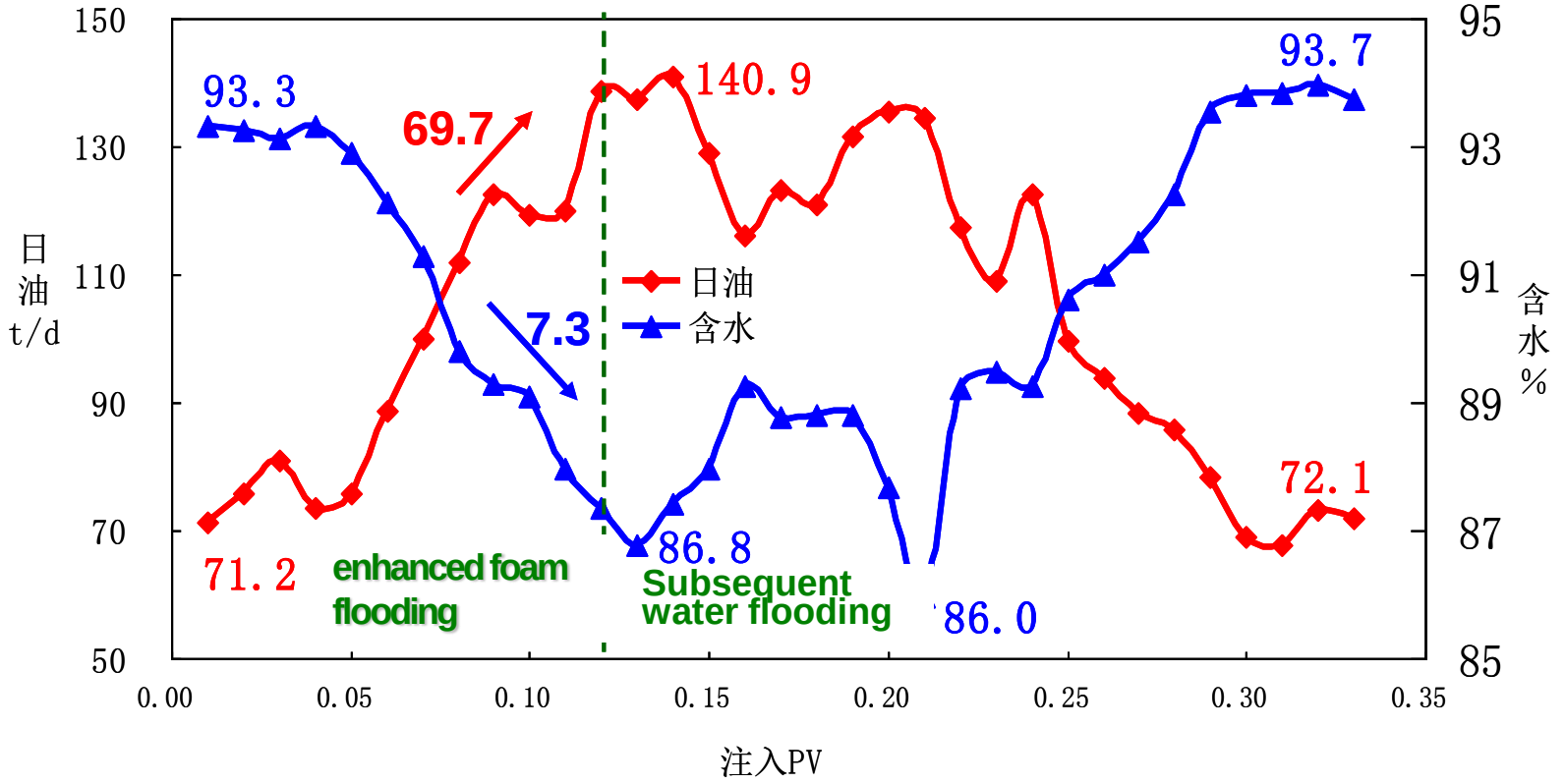
The production curve of XX well



2.3 The Foam Flooding Technology

◆**The obvious of decreasing water and increasing oil are achieved.**

The production curve of pilot site

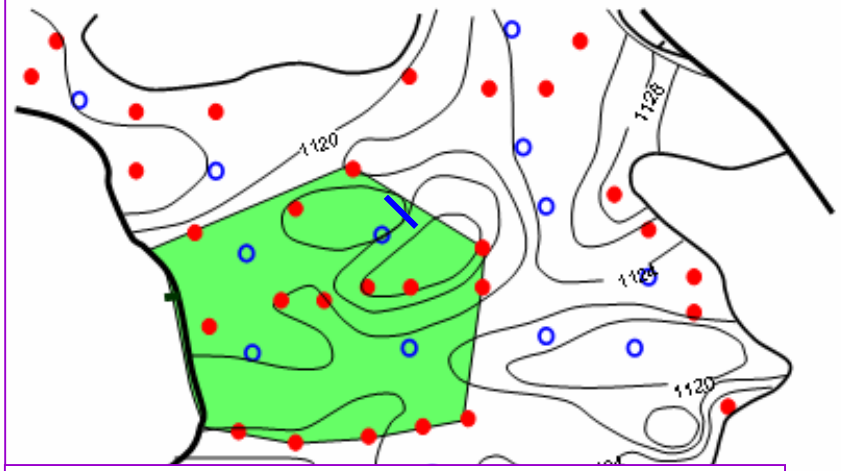


- **6 wells are response producer, and the total increased oil production is 11,000tons.**

2.3 The Foam Flooding Technology

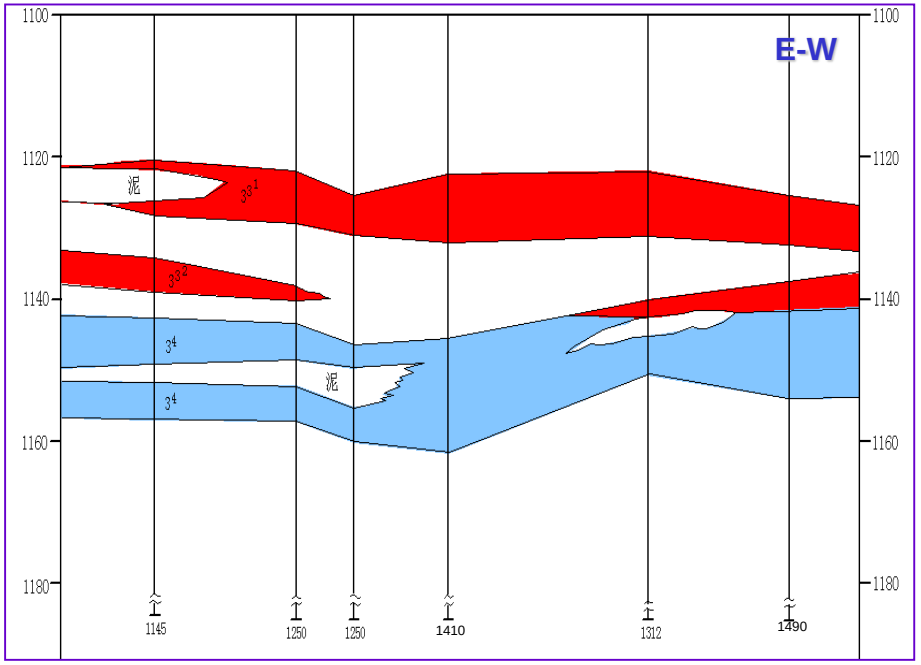
2.The pilot test of enhanced foam flooding in class Ⅳ reservoir

The well location map of the enhanced foam flooding in XX site



- Reserves of pilot site: 119×10^4t
- Injection well:4
- Producing well:15
- Reserves of central well region:42×10^4t
- Central well :3

Reservoir profile in XX site



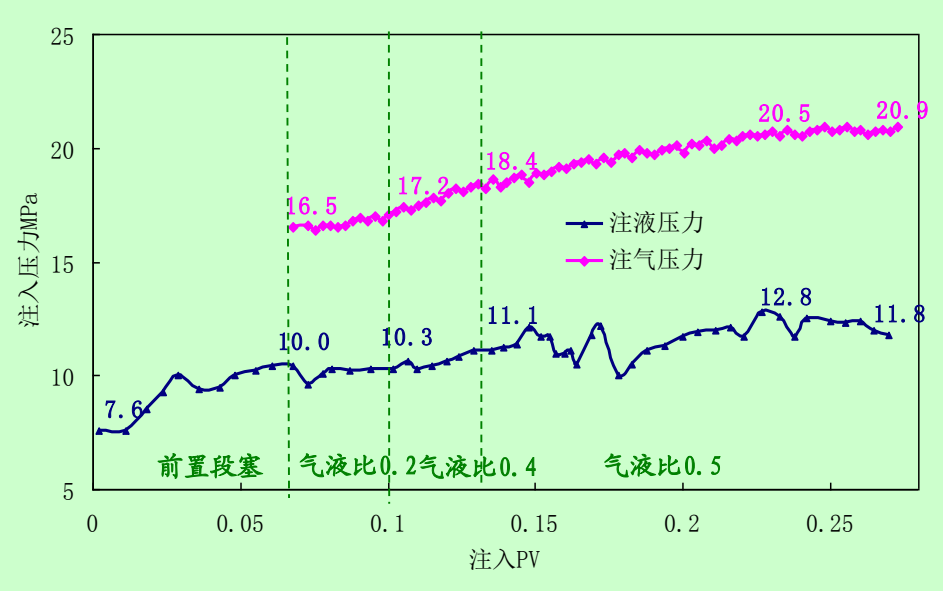
Typical representative of Ⅳ reservoir

- Composite water cut: 97.1%
- degree of reserve recovery:40%
- Water injection rate: 0.3PV/a
- cumulative water-injected multiple: 2.8 PV

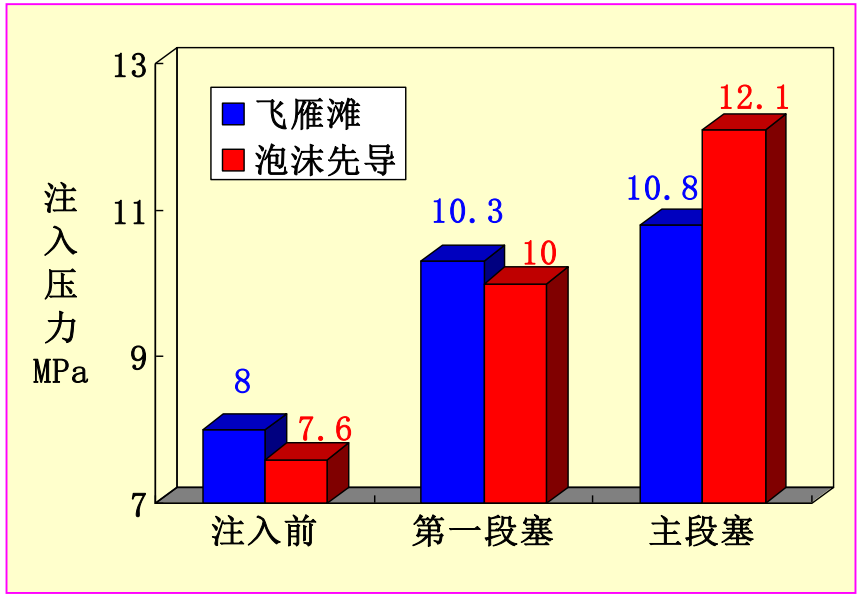
2.3 The Foam Flooding Technology

◆A large range of injection pressure increasing

The injection curve of injection well



The injection pressure

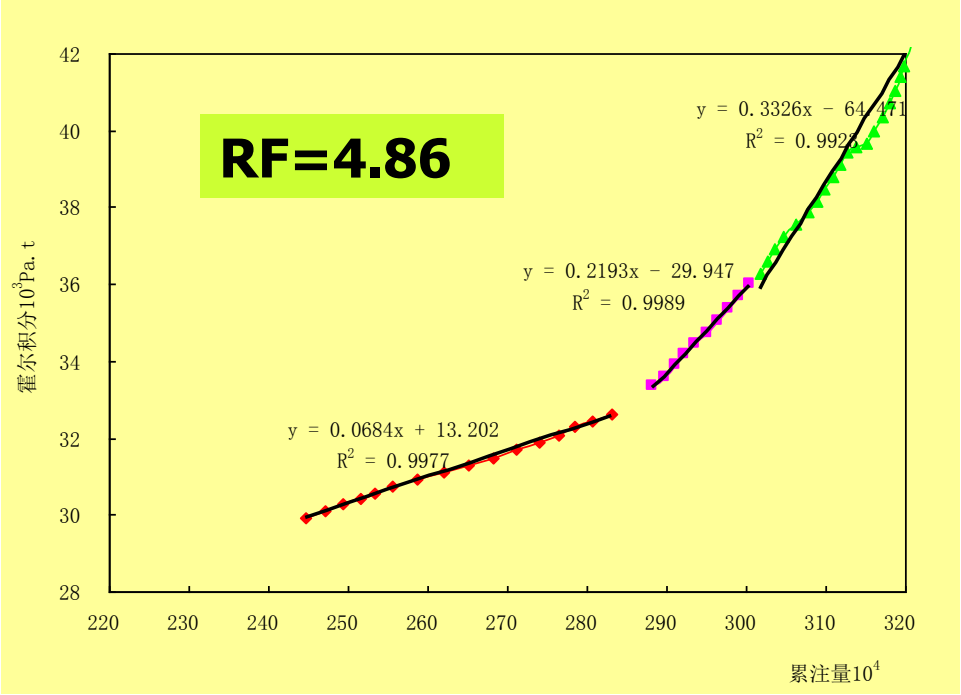


●The main slug pressure has increased significantly, proved that the shut off capacity is stronger than polymer.

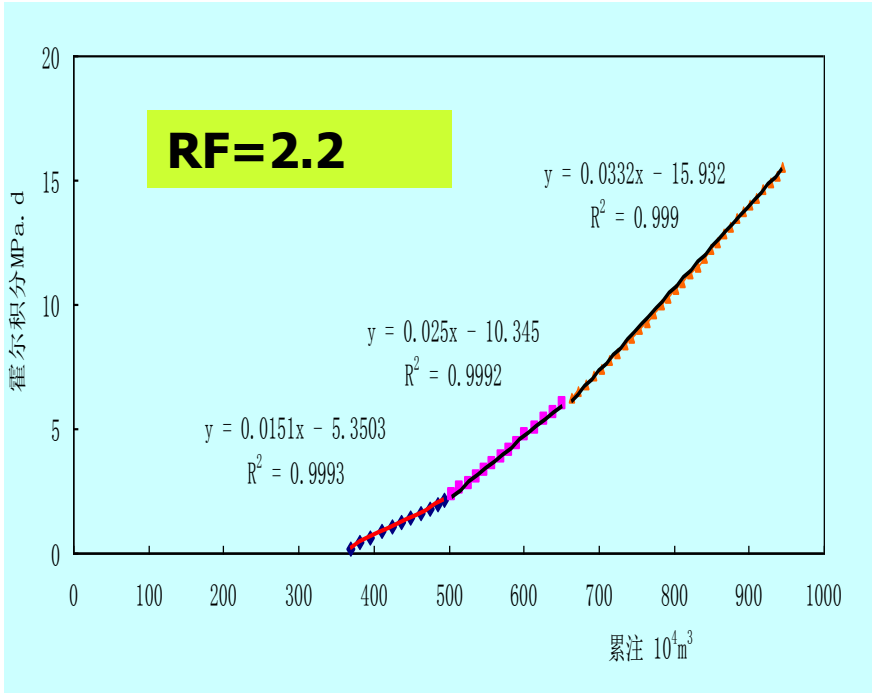
2.3 The Foam Flooding Technology

◆The resistance coefficient is larger significantly.

Hall curve in pilot site



Hall curve in XX polymer-flooding block

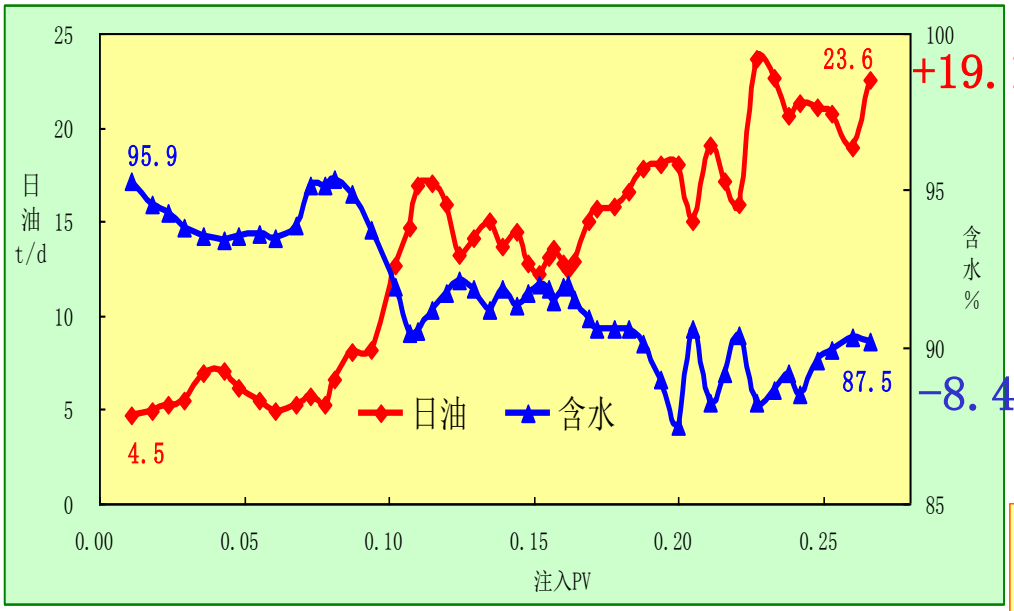


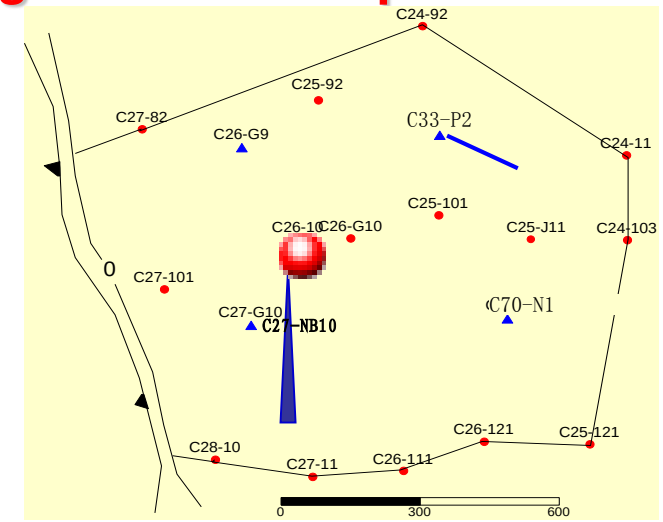
- It is significantly higher than the resistance coefficient of polymer, the filtrational resistance of the enhanced foam system is greater and has stronger shut off capacity

2.3 The Foam Flooding Technology

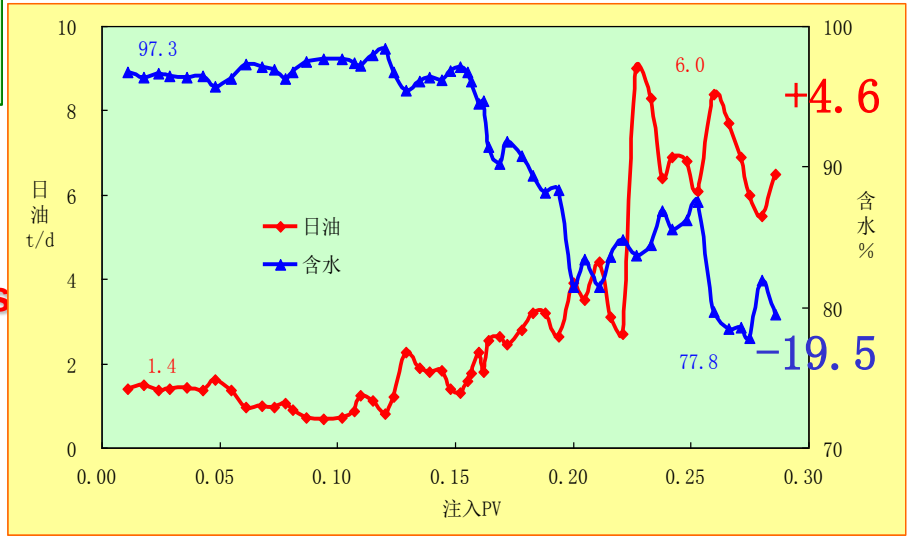
- The obvious of decreasing water and increasing oil achieved in pilot site.

The development curve in pilot site





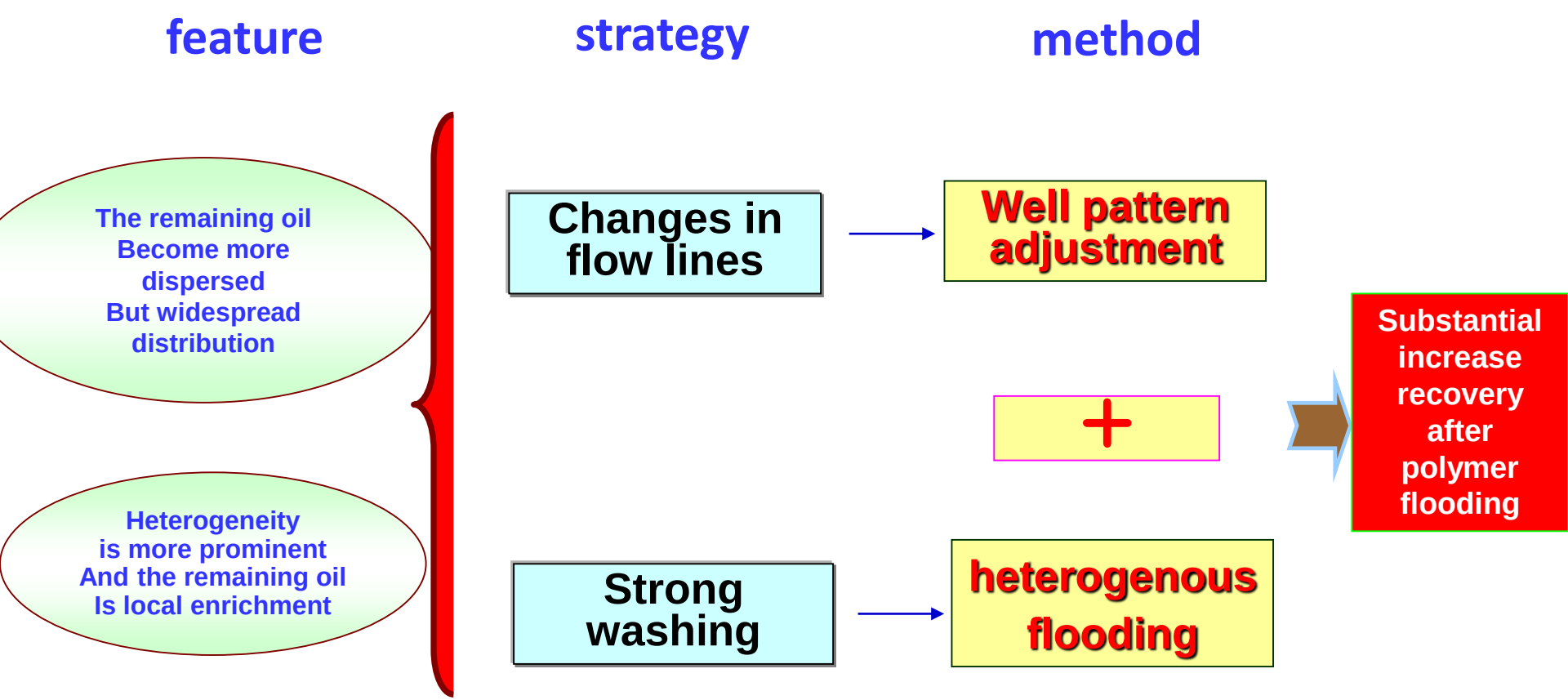
The production curve of XX well



- The daily oil production is 5.2 times before injection.
- The total increased oil production is 19,000tons
- The oil recovery has been enhanced by 4.5%
- The forecast oil recovery will be enhanced by 12.7%

2.4 The heterogenous flooding technology

◆After polymer flooding by "well network adjusted heterogeneous flooding" to improve oil recovery

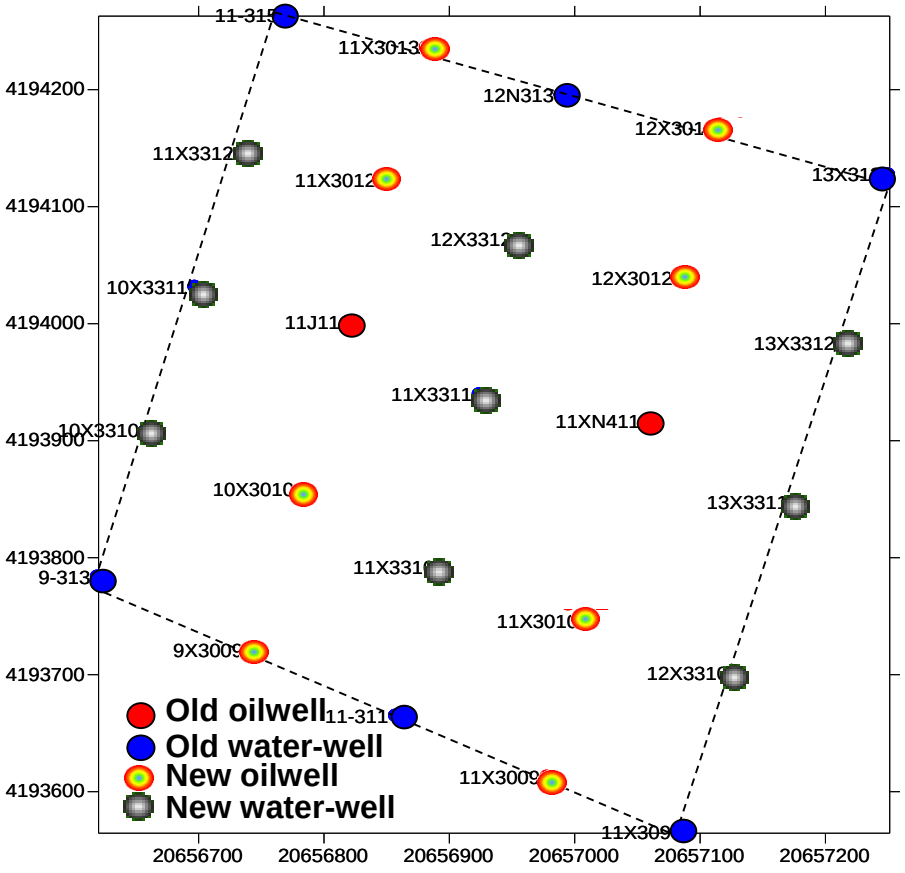


2.4 The heterogenous flooding technology

Carry out pilot test of hetergenous flooding by well pattern adjustment after polymer flooding in class Ⅰ reservoir.

Further enhanced oil recovery after exploring polymer flooding

well location map in pilot site



Oil area: 0.54 km^2

Geologic reserve: 221×10^4t

Reservoir temperature: 70^{0}C

Water salinity: 7373mg/L

Divalent ion content: 92mg/L

Injection well: 15

Production well: 10

The composite water cut before water injection:98.3%

Degree of reserve recovery: 52.3%

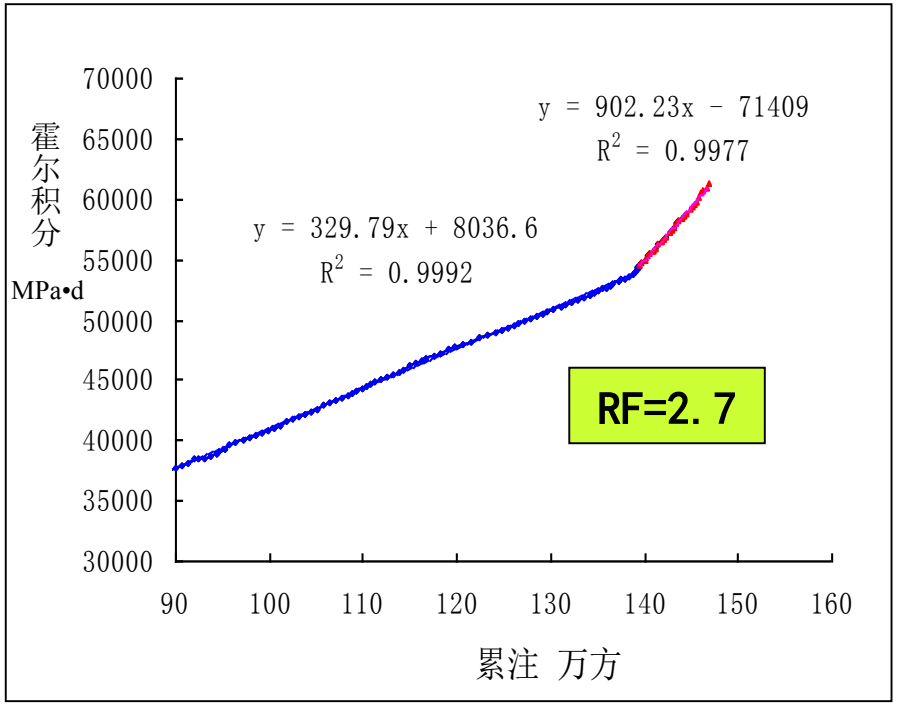
The forecast enhanced recovery is 8.5%

2.4 The heterogenous flooding technology

◆The effect of pilot test

● **Significant effect in mine application-The filtrational resistance is significantly increased.**

Hall curve in XX well



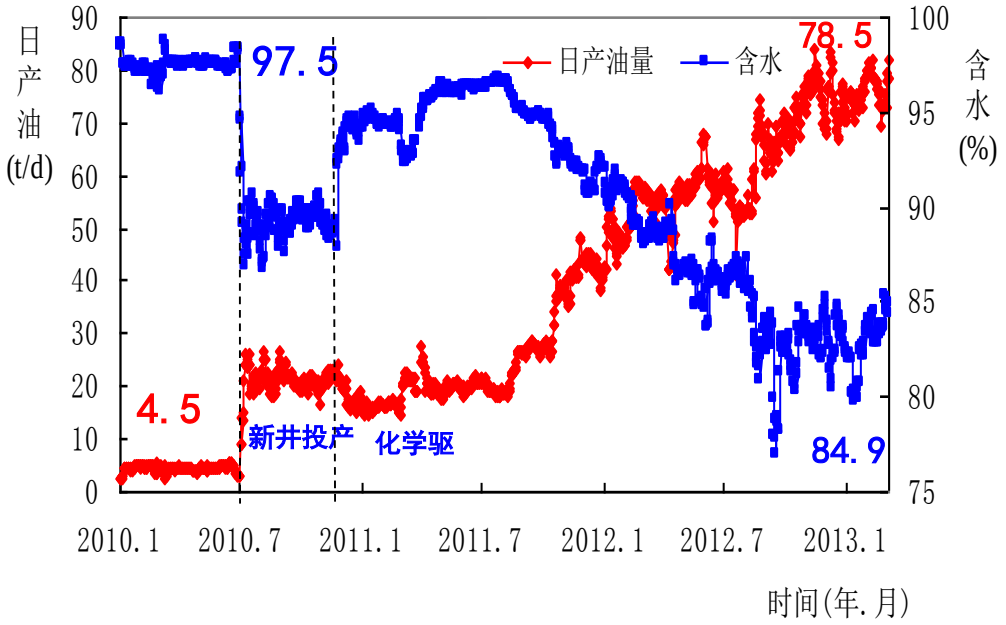
The comparison of resistance coefficient with different chemical flooding

Block	Resistance coefficient
Polymer flooding	1.43
Binary flooding	1.79
heterogenous flooding	2.20

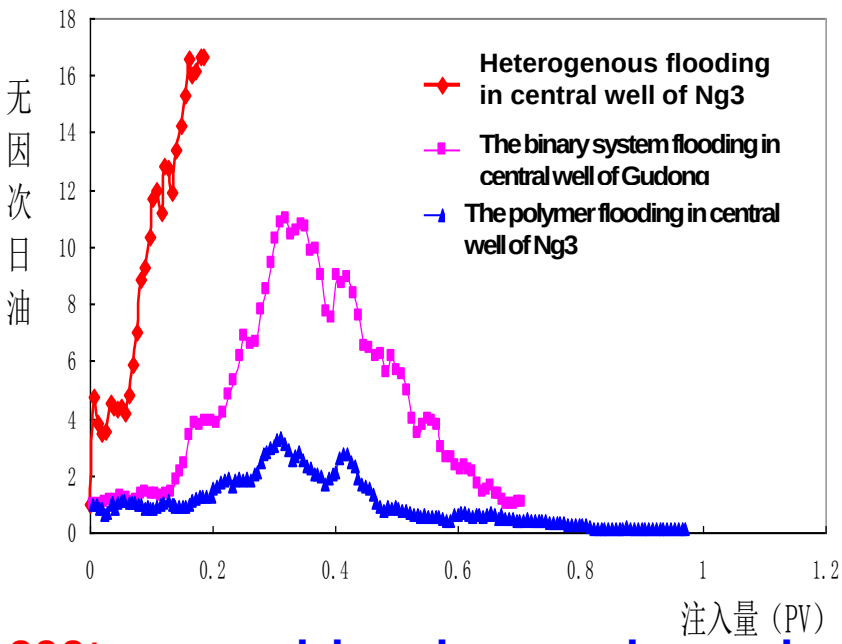
2.4 The heterogenous flooding technology

- **Significant effect in mine application-the significant effect of decreasing water and increasing oil in oil well**

The production data in central test area



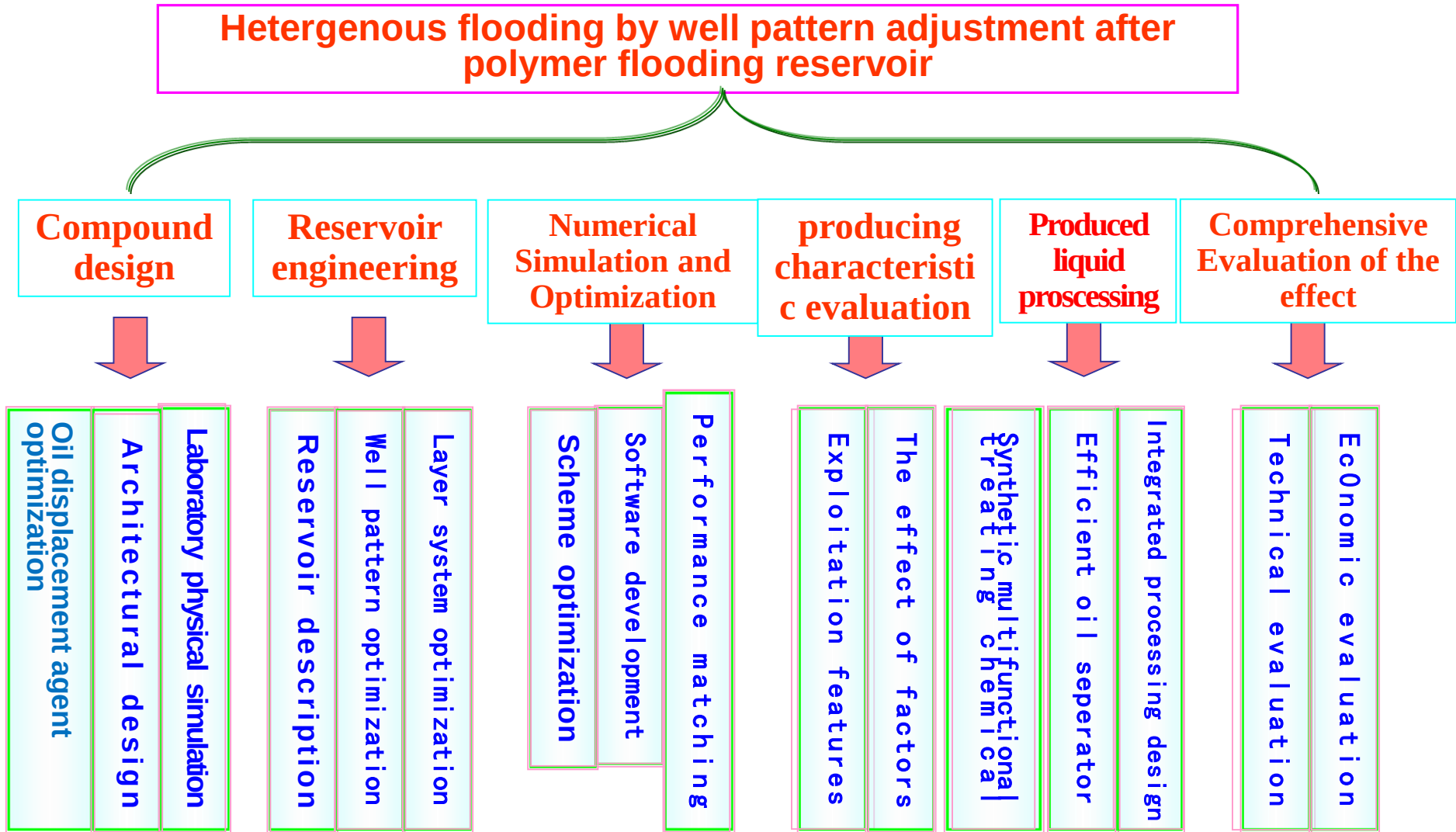
The dimensionless daily oil comparison with different chemical flooding



- **10 central well has increased oil 38,600tons, and has been enhanced recovery by3.14%**
- **The daily oil production of central well by the 4.5t/d increased to 78.5t/d**
- **The composite water cut from the 97.5% drop to 80.6%, a decrease of 16.9%**

2.4 The heterogenous flooding technology

◆Form the reservoir after polymer flooding and improve the recovery supporting technology



3.The steam flooding technology

The heavy oil classification standard in Shengli Oilfield

Type	surface viscosity mPa.s	Suitable methods
Ⅰ ordinary heavy oil	100～3000	conversion development ways after waterflooding
Ⅱ ordinary heavy oil	3000～10000	thermal recovery by steam injection
extra heavy oil	10000～50000	thermal recovery by steam injection
super heavy oil	>50000	improved thermal recovery technology

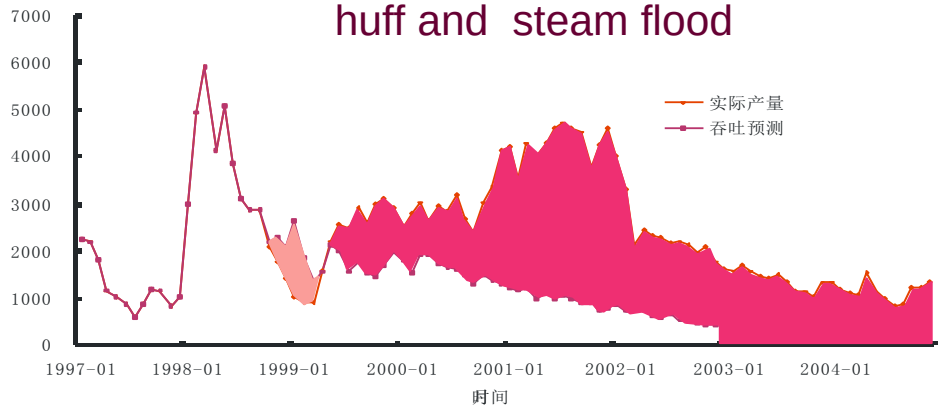
3.1 The stream flooding technique of conventional heavy oil

1、The mine application shows that the enhanced recovery of steam flood is about 20% higher than huff flooding.

Key technique

- improve steam ratio
- decrease borehole heat loss
- Effectively reduce the formation pressure

The production comparison of steam huff and steam flood



The effect comparison of steam flooding after cyclic steam stimulation

type	block	well spacing m	reserves 10^4t	oil viscosity mPa. s	steam stimulation recovery %	steam flood recovery %	Increase rate %
domestic	Le'an Oilfield	141×200	151	20000	32. 3	51. 7	19. 4
	Region 9 of Gudong Oilfield	180~220	375	4000	15. 6	36. 5	20. 9
	Qinqian 10 of Gucheng oilfield in Henan	70×100	17	54000	24. 5	52. 0	27. 5
	Qi40 block of Liaohe	70×70	86	4800	24. 8	48. 6	23. 8
abroad	American Kern River oil field			4000		62. 0	
	Duri oilfield of Indonesia			330		55. 0	
average						51. 0	22. 9

2. Forming a series of steam flooding technology

- The steam flooding reservoir screening technique
- The steam flooding reservoir engineering technique
- The steam flooding economic evaluation technique
- The steam flooding supporting technology

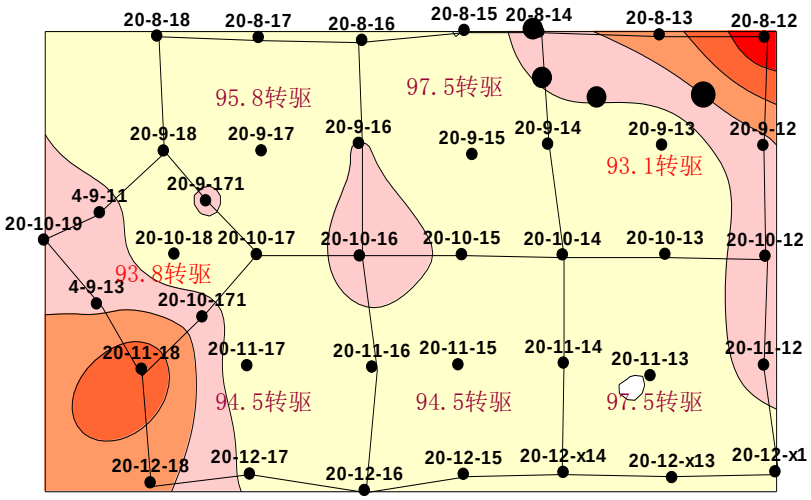
- The remaining oil description technique
- The numerical simulation techniques of thermal recovery
- The scheme optimization and preparatio technique
- The dynamic tracking evaluation techniques
- The injection parameter adjustment technique

3.Application results

（1） active edge and bottom water glutenite extra-viscous oil reservoir

- The pilot test of stream flooding

well location map of stream flooding



The stream flooding effect Statistics table

well group	well spacing m	beginning time a.mon	huff and puff recovery percent %	stream flooding recovery percent	total recovery percent %	notes
test well group	200×141	93.8	19.3	35.04	54.34	2002.2停驱
	200×283	93.1	13.4	28.09	41.49	2002.4停驱
Expanding test well group	200×283	94.5	16.76	11.74	28.5	00.3停驱
	200×283	94.5	19.85	19.02	38.87	02.5停驱
the well of transfer to stream flooding	200×283	95.8	8.89	7.21	16.1	99.2停驱
	200×283	97.5	9.77	2.5	12.27	01.9停驱
	200×283	97.5	20.36	5.95	26.31	99.12停驱

Active edge and bottom thickness: 12～20m
Viscosity:20000～30000mPa.s。

The area of well group is 1.0km^2,reserve is 219×10^{4}t，there are 1 small well group and 6 big well group, the stream flooding, the stream flooding enhance recovery of 16.6%; And the degree of recovery of small well group reached 54.34%

3.Application results

（1） active edge and bottom water glutenite extra-viscous oil reservoir

●the stream flooding evaluation of area Ⅰ and Ⅱ

It has active edge and bottom water and the thickness is 10-15m, Viscosity is 20000～40000mPa.s

Area Ⅰ
Reserves:151×10⁴t
Well spacing:141×200m
Well group: 9

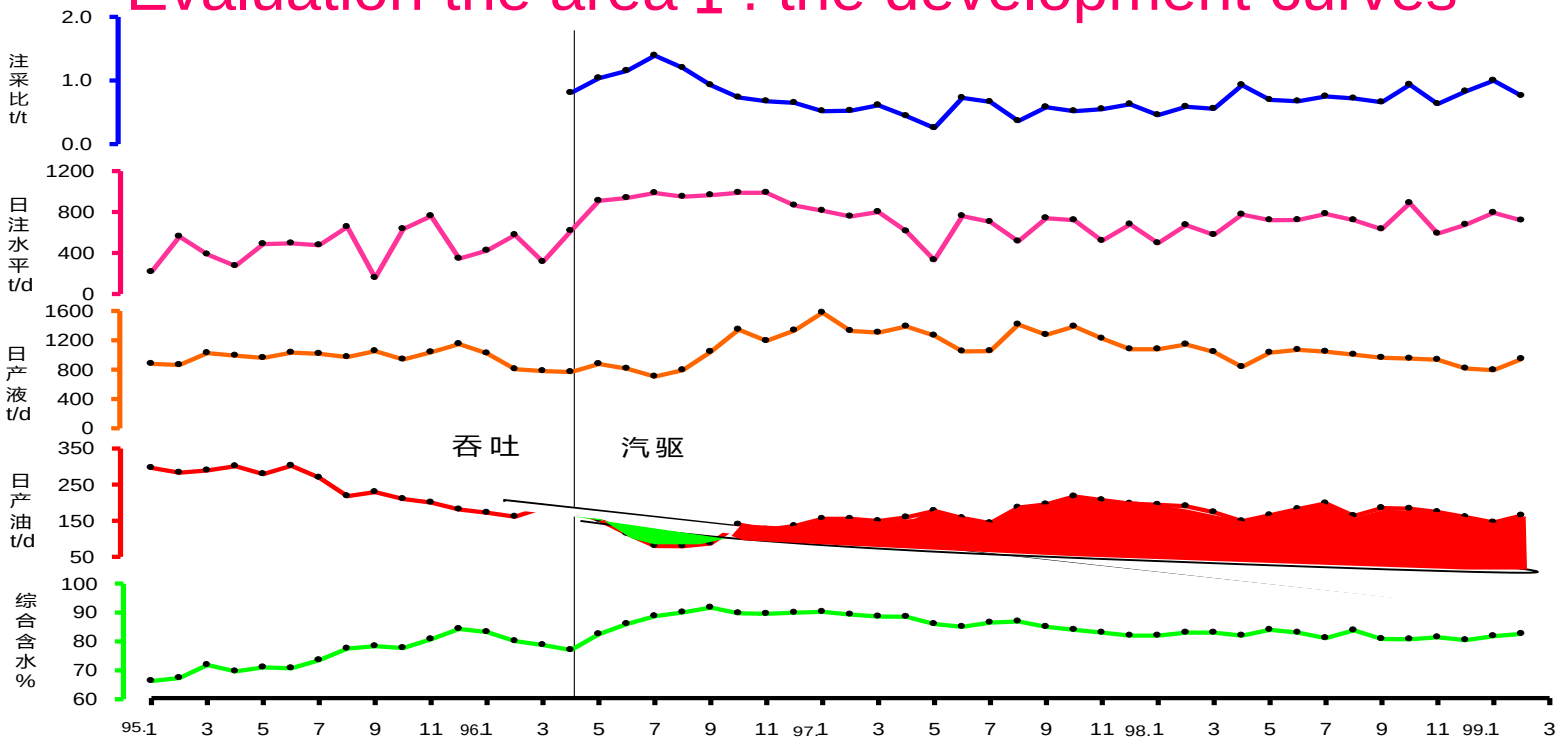
Area Ⅱ
Reserves:312×10⁴t
Well spacing:200×283m
Well group:10个

3.1 The stream flooding technique of conventional heavy oil

（1） active edge and bottom water glutenite extra-viscous oil reservoir

- the stream flooding evaluation of area Ⅰ and Ⅱ

Evaluation the area Ⅰ: the development curves

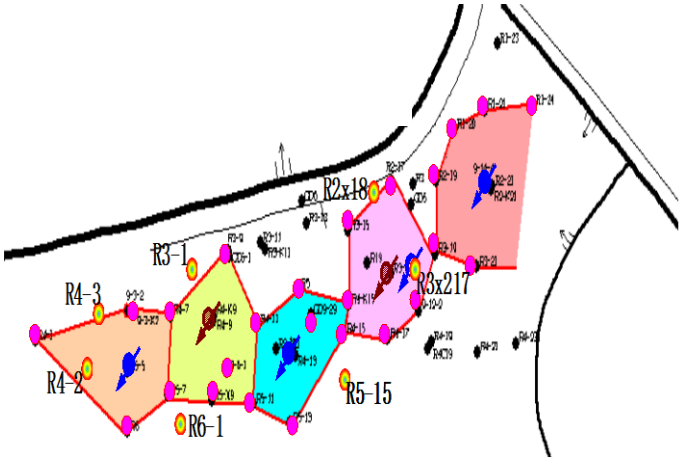


In area Ⅰ The steam injection is 123.6×104t, oil increment is 20.8×104t， cumulative oil steam ratio is 0.17t/t， the recovery of huff and puff and stream flooding is 51.7%,the enhanced recovery is 19.4% 。In area Ⅱ, the enhanced recovery is 3.2%， cumulative oil steam ratio is 0.16t/t。

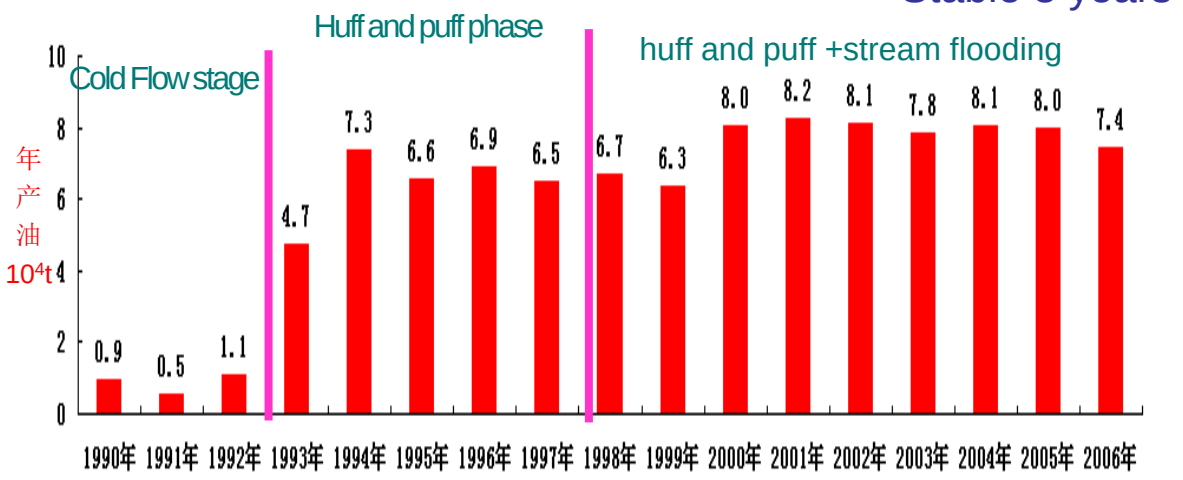
3.Application results

(2)The thin edge water common heavy oil sandstone reservoir.

the stream flooding well group location of west block in XX site



The histogram of heavy oil-producing over the years

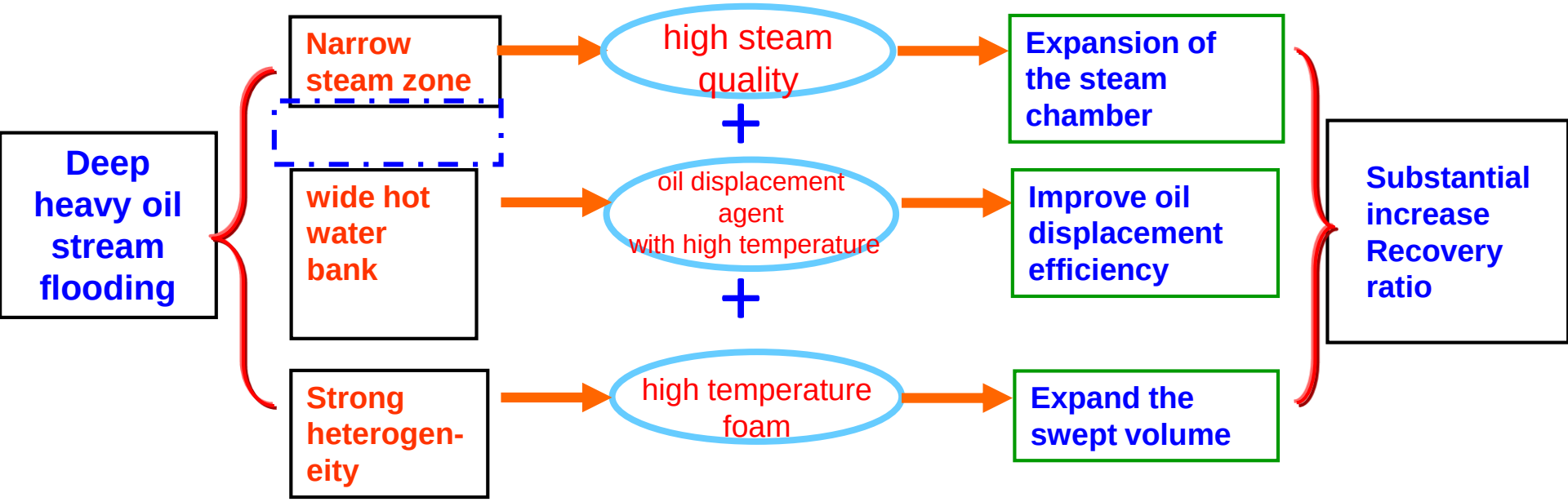


Area:2km^2， reserves:375×10^{4}t
reservoir depth :1320～1400m
crude viscosity :2000～5000mPa.s
Thickness:11～18m
permeability :2000×10^{-3}μm^2
Oil/water volume ratio:<1.5

the 5 well groups are intermittent stream flooding ,the cumulative oil/stream is 0.77t/t. The recovery of huff and puff and stream flooding is 36.5%， the stream flooding improved 20.9%。

3.2 The heavy oil chemical stream flooding technique

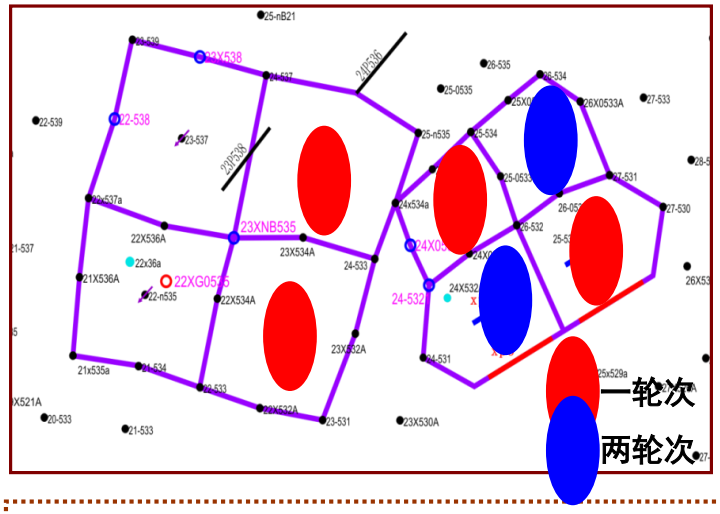
- **the technique of heavy oil chemical stream flooding to improve recovery**



After years of research and deepen scientific research, it has made a breakthrough.

3.2 The heavy oil chemical stream flooding technique

the pilot test of heavy oil chemical stream flooding



Well spacing:141×200m /100×141m

Reservers:184×10⁴t

formation of interest :Ng5³

effective thickness :10.2m

The recovery has been improved by18.1%;

Which: big well group improved by 6.2%t

small well group improved by 21.8%.

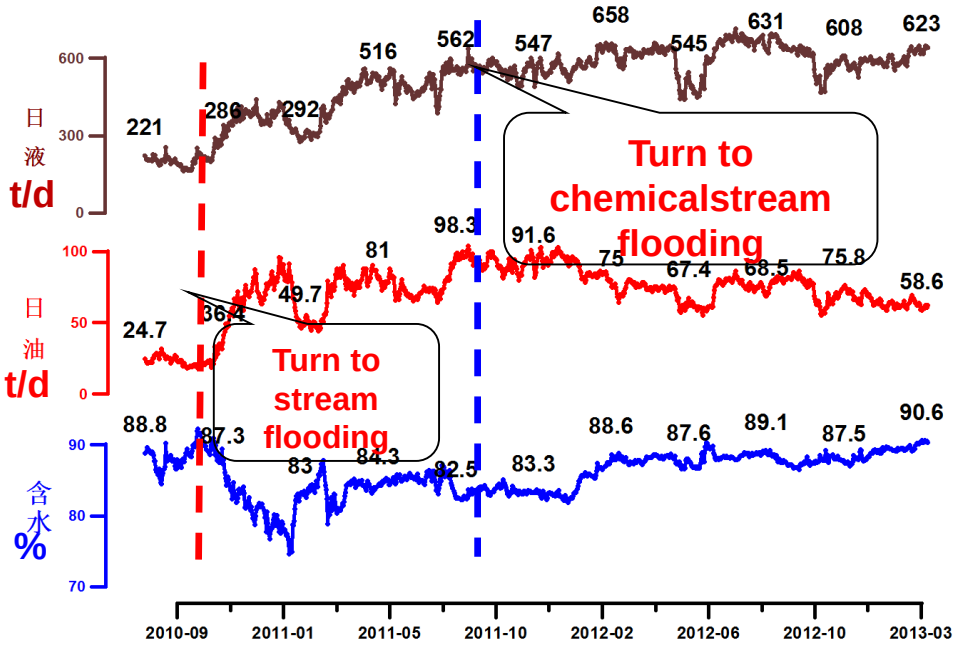
2009.10 **Improve well network、huff and putt decompression**

- **Well groups with small spacing**
  - **well groups turned to stream flooding**
    - **Two wells in the first round turned to chemical stream flooding**
      - **xx well group turn in the first round**
        - **xxx well group turn in the second round**
          - **xx well group turn in the second round**
            - **xxx well group turn in the first round**
- **Well groups with big spacing**
  - **4 well groups turned to stream flooding**
    - **xx well in the first round turned to chemical stream flooding**
      - **xxx well in the first round turned to chemical stream flooding**

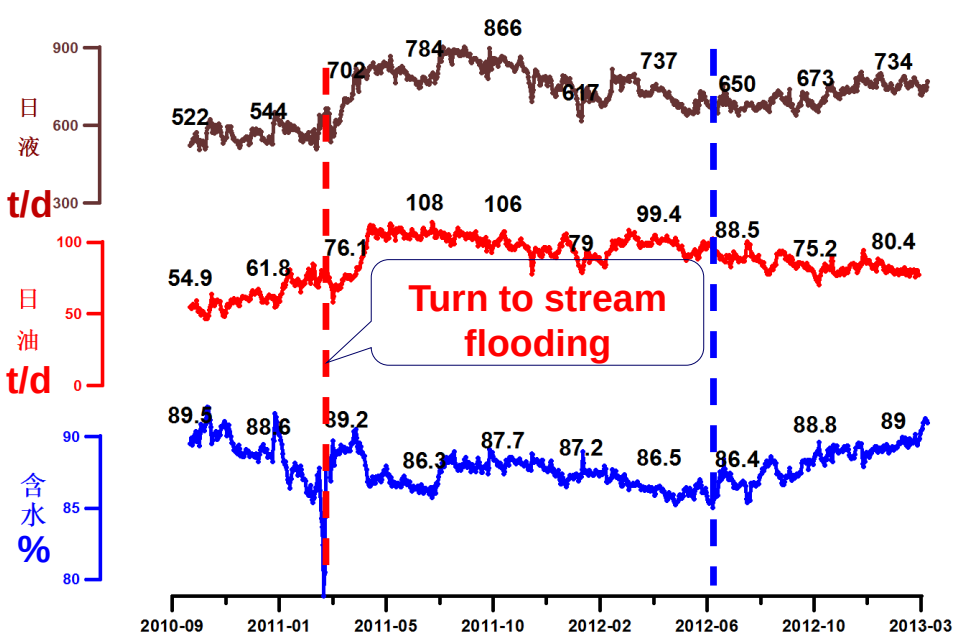
3.2 The heavy oil chemical stream flooding technique

◆The overall effect of the test area was significantly

The production curve of well groups with small spacing



The production curve of well groups with big spacing



production is from 20.2t/d increased to 104t/d, and currently is 70t/d.
Cumulative oil production: 65,500 tons
cumulative incremental oil :58,5000tons（the degree of recovery is improved of 9.3%）
Oil/stream ration： 0.17t/t

The production is from 68t/d increased to113t/d, and currently is 80t/d.
Cumulative oil production: 66,000tons
cumulative incremental oil : 38,000tons（ the degree of recovery is improved of 3.1%）
Oil/stream ration: 0.16t/t

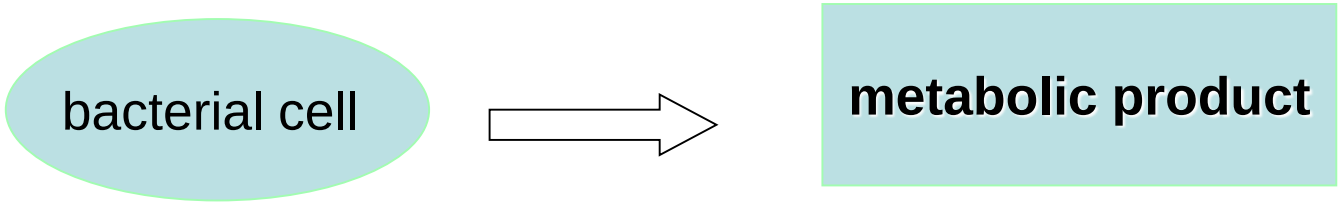
Microbial Enhanced Oil Recovery

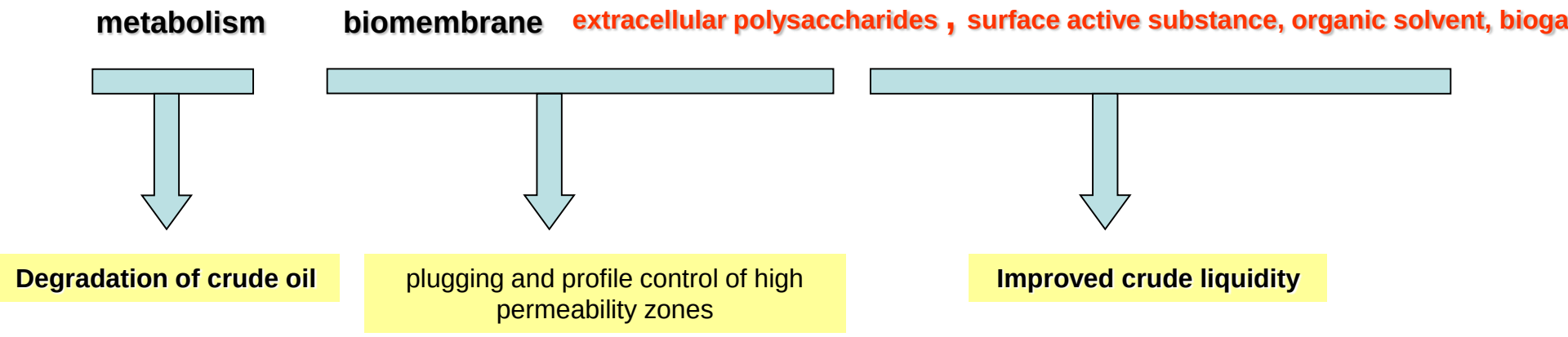
Refers to the use of a variety of microorganisms (mainly bacteria) and its metabolites to increase oil production and recovery.

Existing processes

- **Single-well Microbial Soak**
- **Microbial Waxing Control**
- **Microbial oil displacement**
- **Microbial plugging**

The mechanism of microbial enhanced oil recovery





Range of application

Adaptation reservoir conditions

	exogenous microbial enhanced oil recovery		endogenousmicrobial enhanced oil recovery	
guideline	Range of application	Optimum range	Range of application	Optimum range
reservoir Temperature(℃)	＜80	＜65	＜100	＜75
water salinity （mg/L）	＜100，000	＜50，000	＜150，000	＜50，000
reservoir permeability ($10^{-3}\mu m^2$）	＞100	＞200	＞100	＞200
Crude oil surface viscosity （mPa.s）	＜3000	＜1000	＜5000	＜1000
Remarks	The well network is basically completeness, the correspondence between the oil and water wells is clear, and the block has stable production.			

Range of application

The positioning of the microbial enhanced oil recovery technology

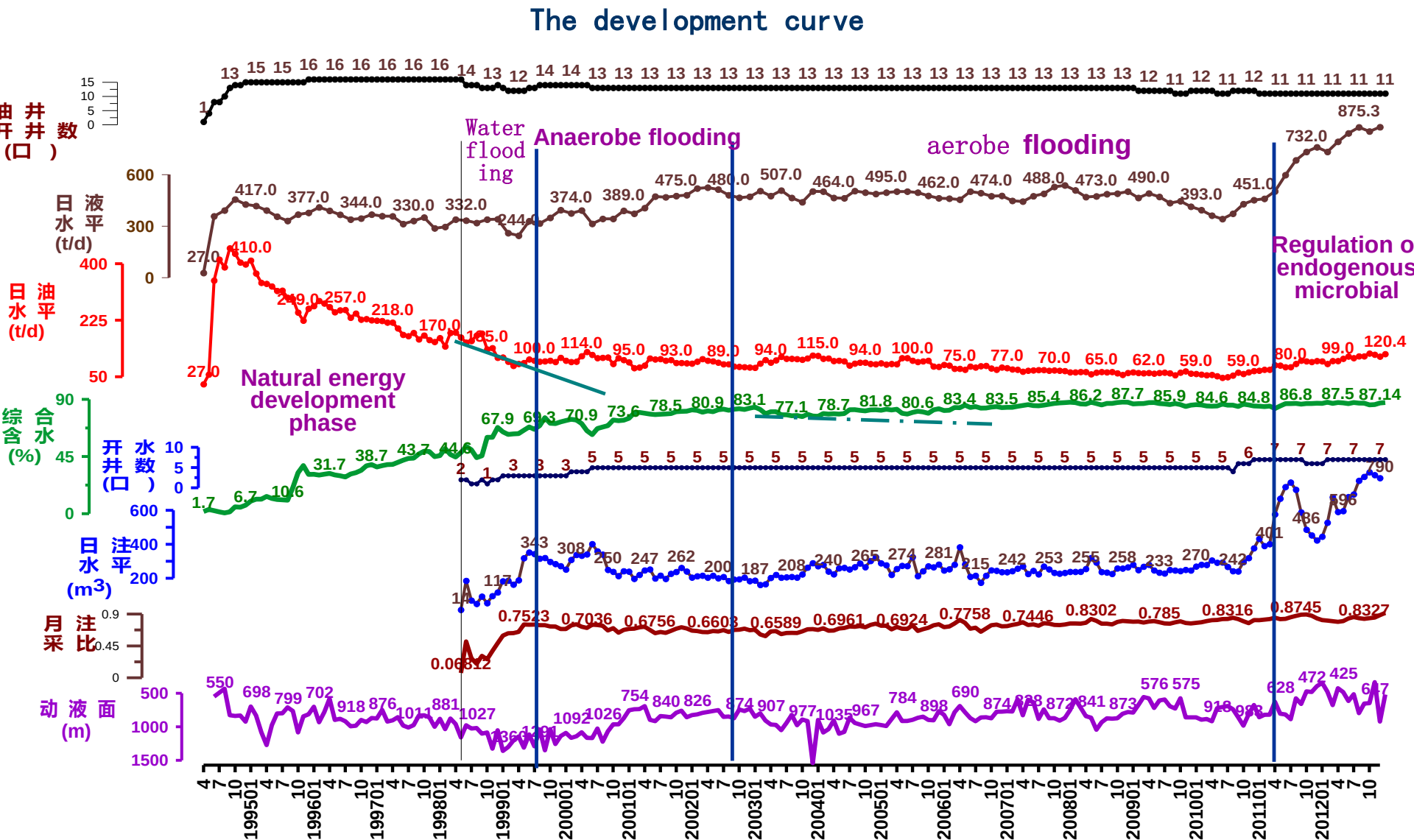
permeability > $100 \times 10^{-3} \mu m^2$

temperature < 75℃

salinity< 5万mg/L

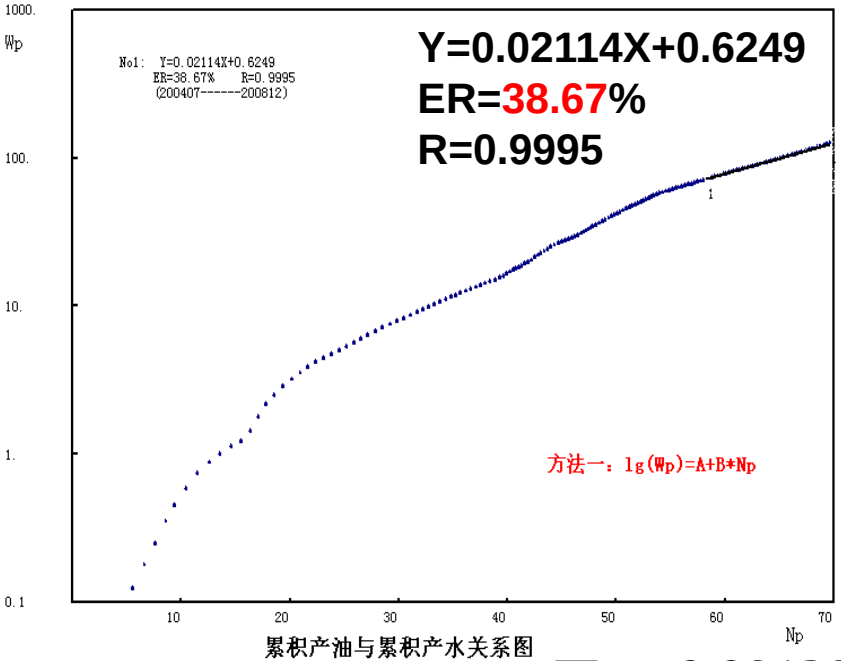
- Mid high permeability fault block reservoir
- integrity reservoir after water flooding
- reservoir after chemical flooding

●Mine implementation effect



4. The Microbial Enhanced Oil Recovery technology

●Improve development effectiveness



累积产油与累积产水关系图

Actual production forecast recovery: 38.67%

Elastic recovery :18.5%

$$E_R = 0.2126\left[\frac{\phi(1-S_{wi})}{B_{ob}}\right]^{+0.1611} \times \left(\frac{\bar{k}}{\mu_{ob}}\right) \times (S_{wi})^{+0.3722} \times \left(\frac{P_b}{P_a}\right)^{+0.1741}$$

Water flooding recovery:28.5%

$$E_R = 0.09129 + 0.08892\lg(k/\mu o) + 0.18966\phi + 0.002814 f$$

◆Through microbial enhanced oil recovery, the ultimately forecast improved water flooding recovery is 10.17%, recoverable reserves are increased 29.6×10^4t.

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Thank you