SPE International
Northwest Russia Section

II STRATEGIC CONGRESS 2017

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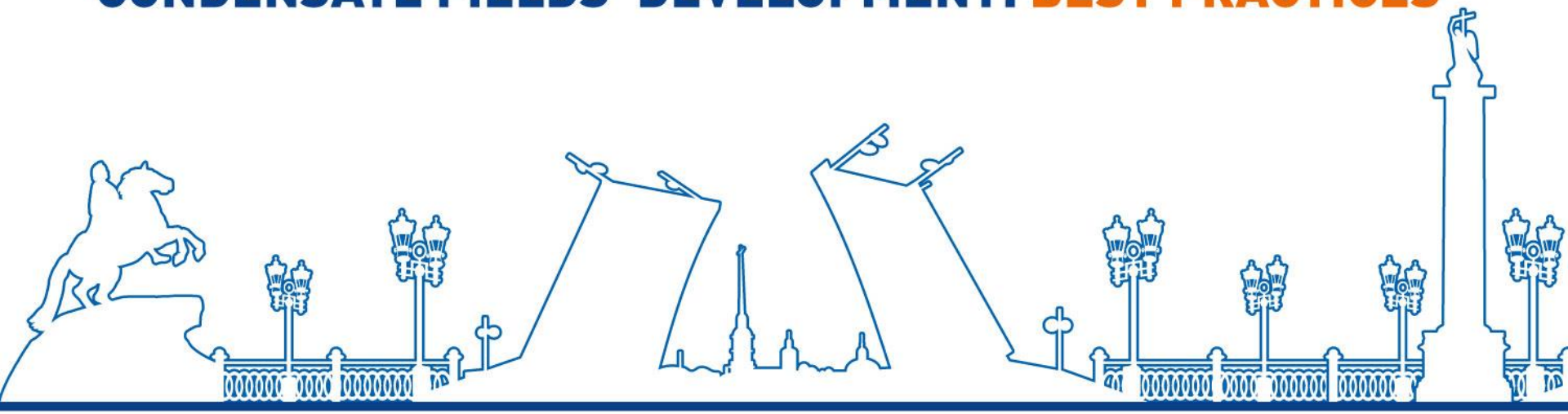
INTEGRATED MANAGEMENT OF OIL AND GAS CONDENSATE FIELDS' DEVELOPMENT: BEST PRACTICES



Development Technologies for Oil Deposits below the Gas Cap in Lamadian of Daqing

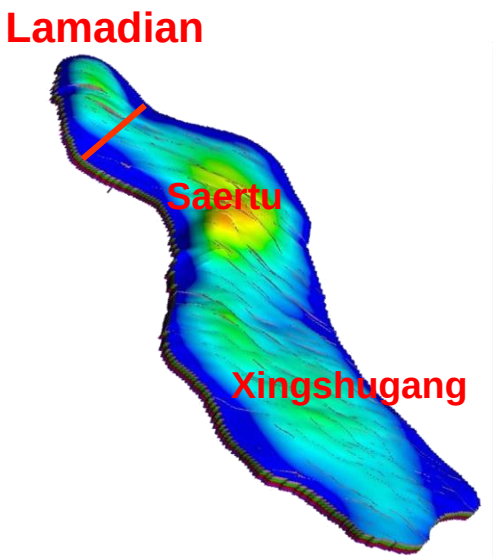
SEPTEMBER 26, 2017, ST. PETERSBURG, HOTEL ASTORIA

Outline

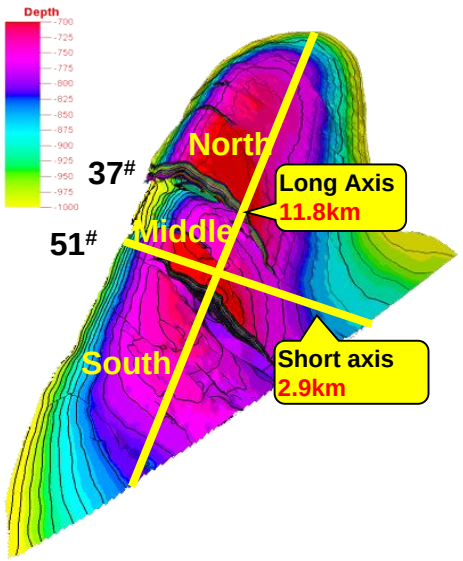
- Introduction to Lamadian Oilfield
- Development Principles
- Development Technologies
- Oil-gas Buffer Zone Development Technologies
- Summary

➢ Introduction to Lamadian Oilfield

- ♦ Oil-bearing area: 100km^2
- ♦ OOIP: 8.2 × 10^{8}t
- ♦ Gas-bearing area: 32.3km^2
- ♦ OGIP: 99.6 × 10^{8}m^3

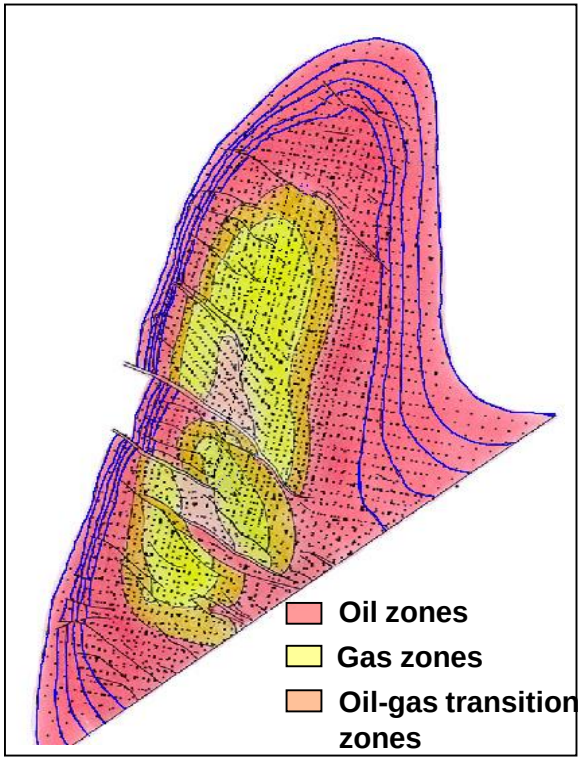


Daqing Placanticline

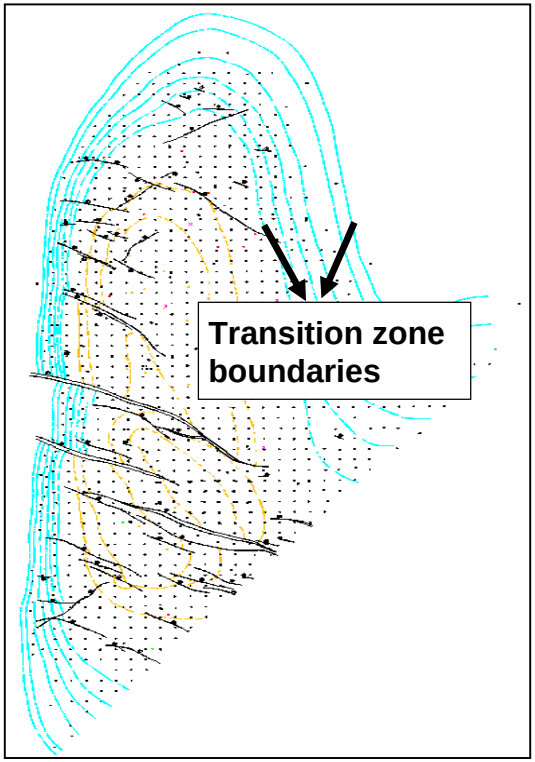


Lamadian Oilfield

- **Oil, gas and water distribute in circularity zones**
- **5 zones: pure gas, oil-gas transition, pure oil, oil-water transition and water**

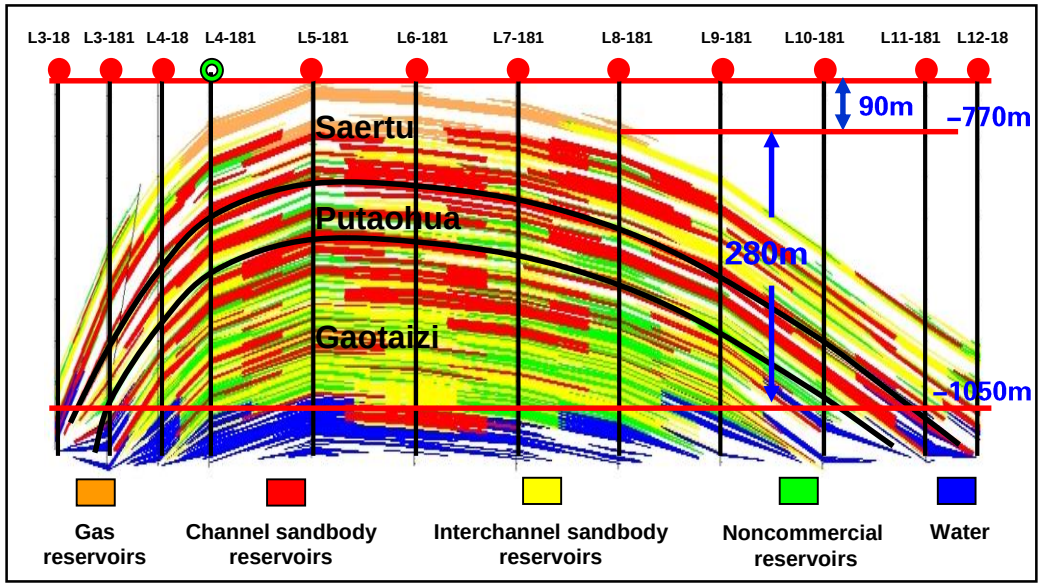


Oil and gas distribution



Oil-water transition zone boundaries

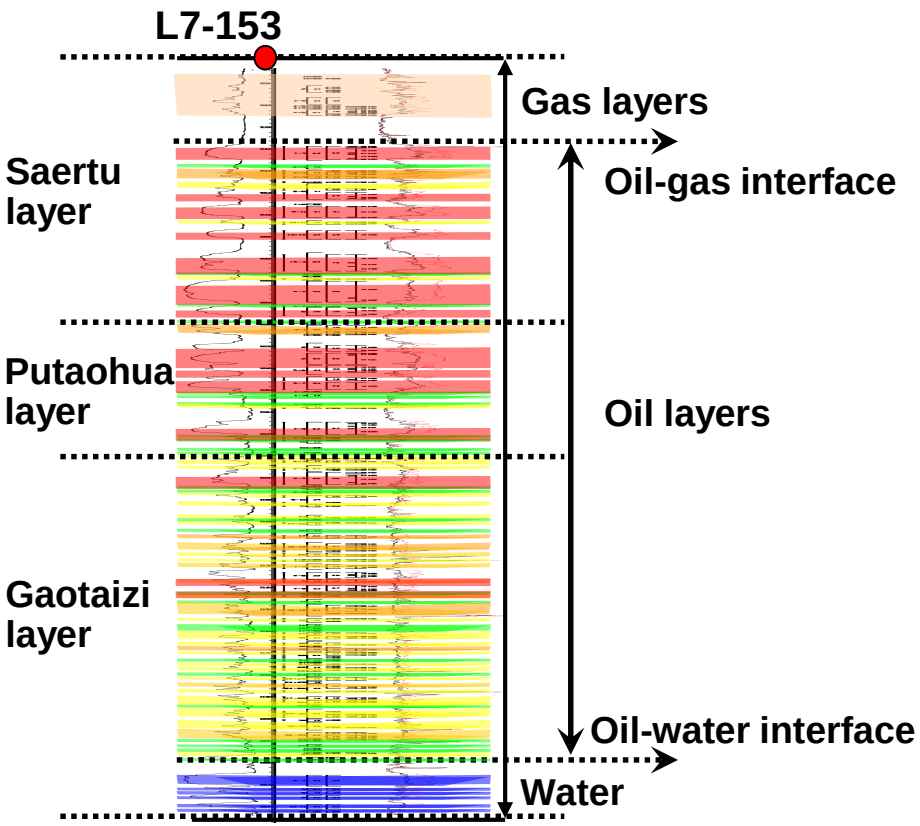
- Height of the gas cap: 90m
- Height of the oil reservoirs: 280m
- Depth of oil-gas interface: -770m
- Depth of oil-water interface: -1050m



Section drawing of the gas and the oil reservoirs

♦ Reservoir type: river-delta deposit

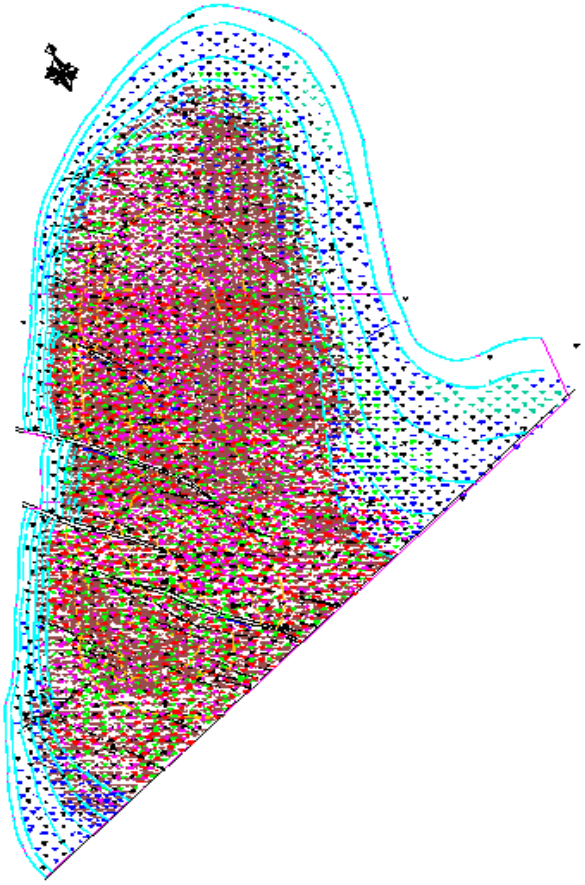
- 3 layer series
- 8 layer groups
- 37 sandstone groups
- 97 sub layers
- 115 sedimentation units



Division of layer series in Lamadian oilfield

By the end of 2016

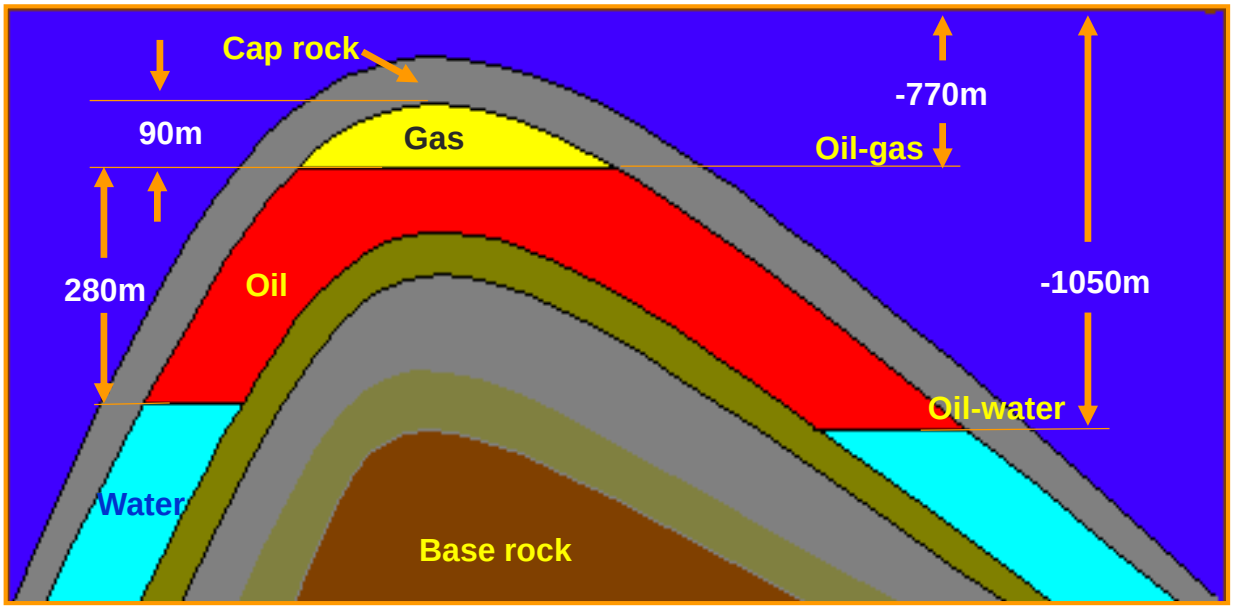
- Total number of production wells : 9770
- Total number of injection wells: 4315
- Cumulative oil production: 3.36×10^8t
- Recovery of geological reserves: 41.18%
- Recovery of recoverable reserves: 96.07%
- Residual recoverable reserves: 1374.0×10^4t
- Cumulative water injection: $32.48 \times 10^8 m^3$
- Cumulative injection-production ratio: 1.08



Develop well position map

➢ Development Principles

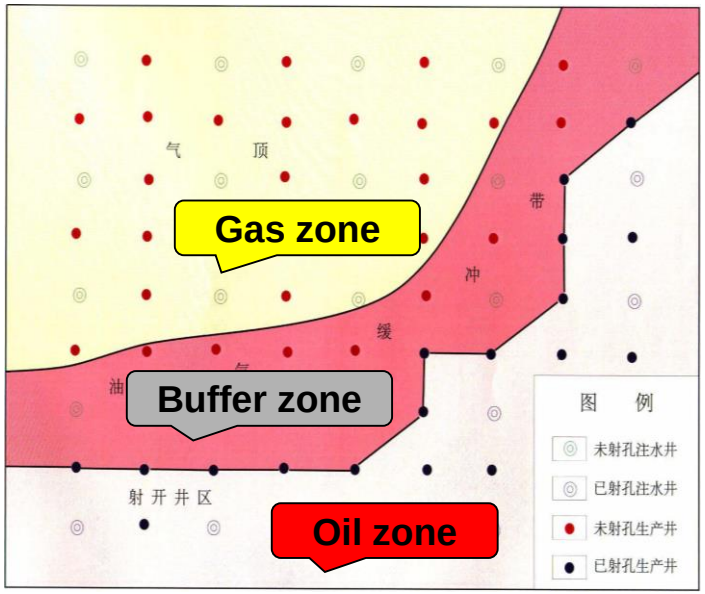
- ♦ **Development strategy: keep oil-gas interface steady**
- ♦ **General Principle: two-step development**
  - **Step 1: oil reservoirs development in priority**
  - **Step 2: gas cap development when needed**



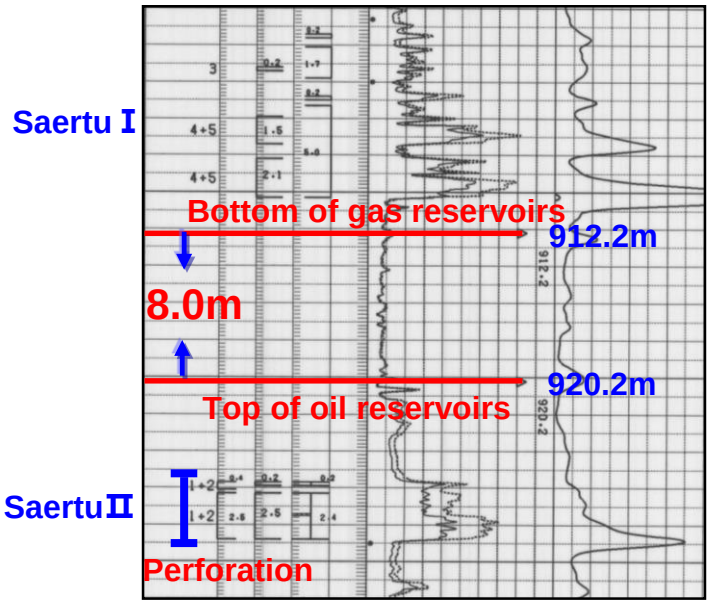
➢ Development Technologies

♦ Establishment of a buffer zone between oil and gas zones

- 450m-600m
- Reserves: 3117 × 10^4t



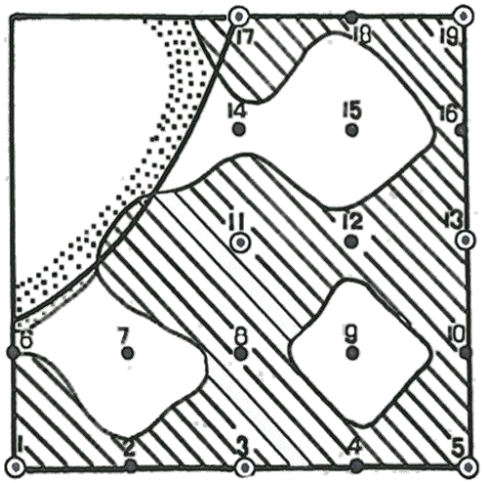
A diagram of the buffer zone



Section drawing of L7-163

♦ Research on rational oil and gas zone pressure difference

• Early calculation results by electrical network analogy method

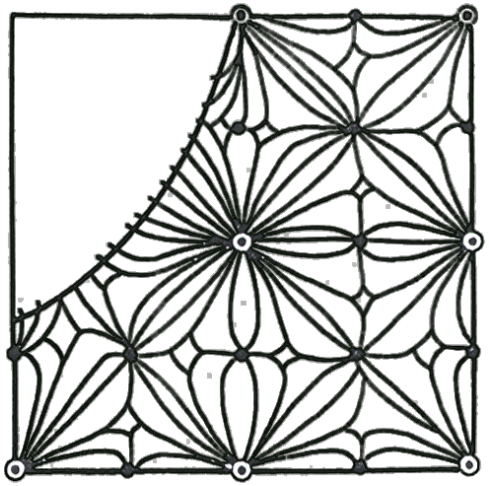


Saturation distribution

Gas saturation＞5%

Water saturation＞5%

Oil zone

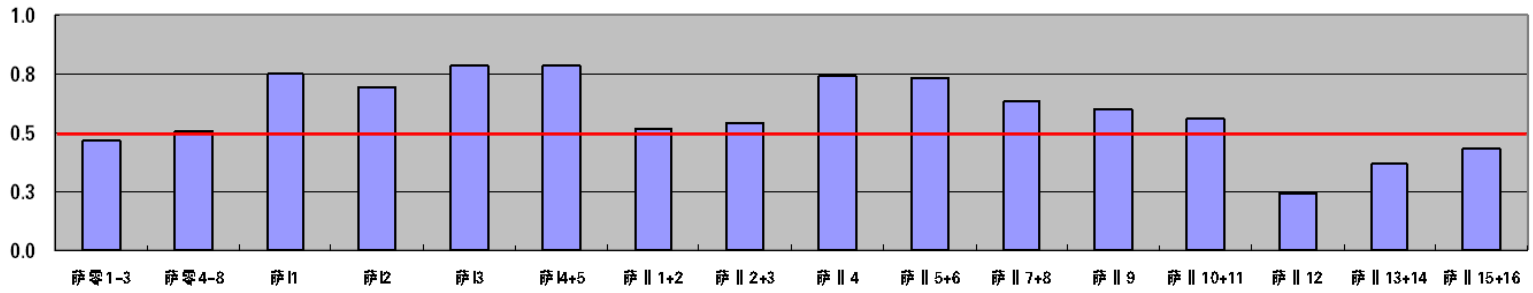


Streamline distribution

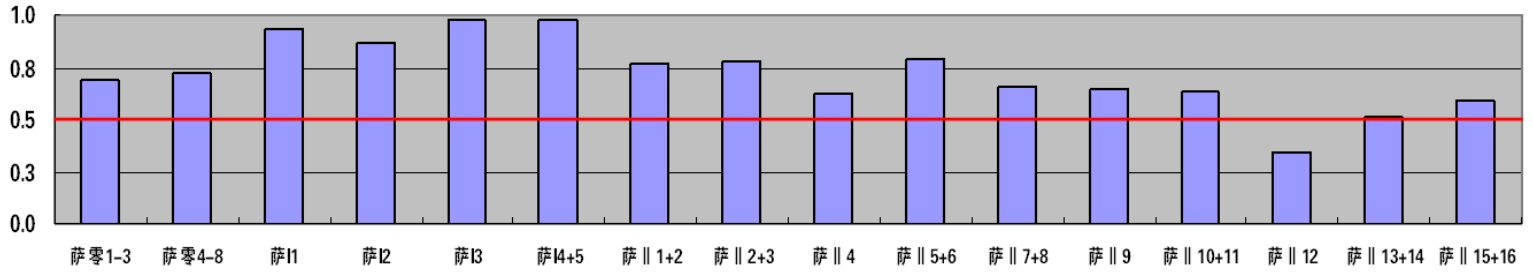
$P_{oil} - P_{gas} > +0.5MPa$: oil breakthrough

$P_{oil} - P_{gas} < -0.5MPa$: gas breakthrough

- **Computer simulation results**



Oil and gas zone pressure differences in some sub layers when gas breakthrough (MPa)

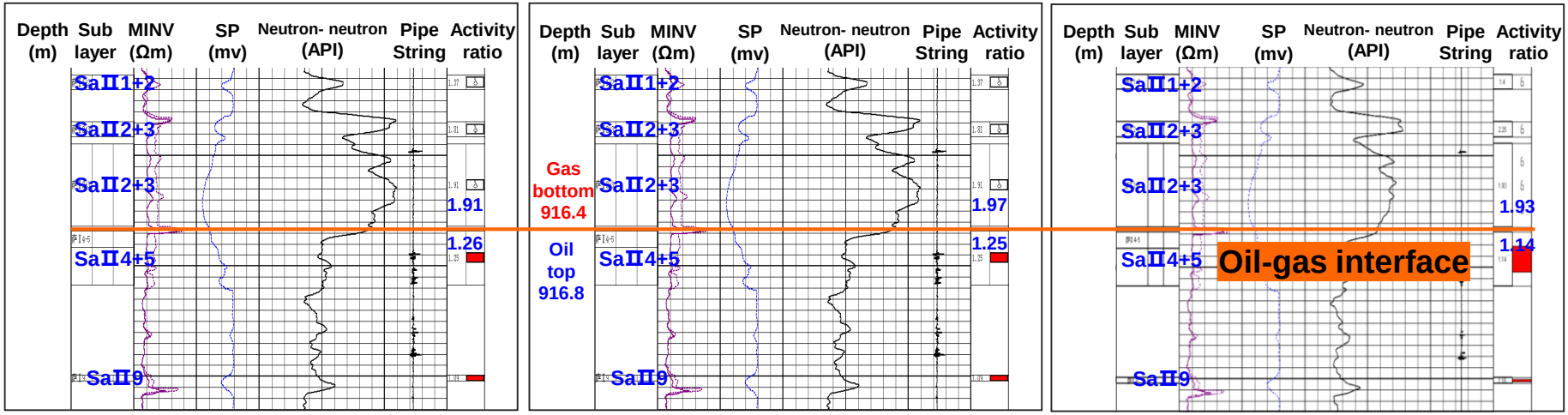


Oil and gas zone pressure differences in some sub layers when oil breakthrough (MPa)

✓ $P_{oil} - P_{gas} = \pm 0.5MPa$

♦ Proper well-point arrangement for monitoring

- Total number of monitoring wells: 246 (oil zone 50, gas zone 50, produced GOR 64, oil-gas interface 82)
- 2 times per year

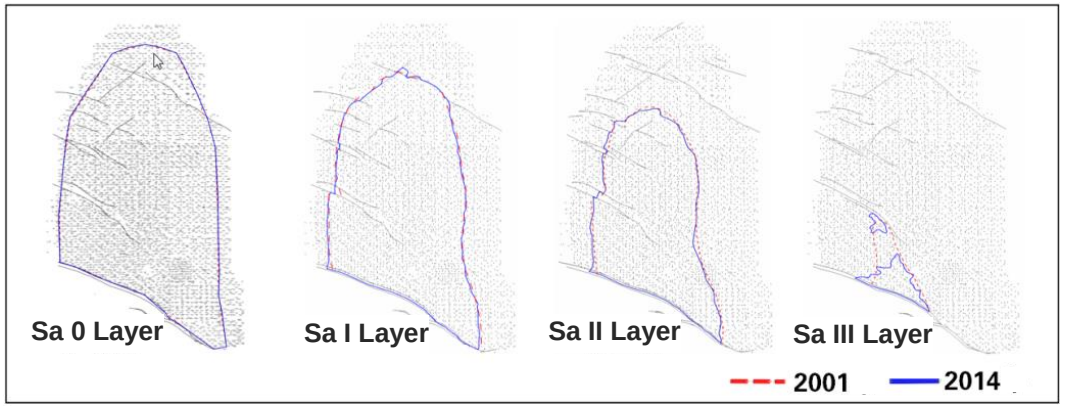


October, 2006 | October, 2011 | October, 2016

Well logging interpretation (L7-232)

♦ Control of oil and gas zone pressure system

- **Adjustment basis**
  - **Pressure difference**
  - **Neutron-neutron logging**
  - **Associated gas in production wells**
- **Adjustment methods**
  - **Oil breakthrough: production ↗, i-p ratio ↘, oil zone pressure ↘**
  - **Gas breakthrough: production ↘, i-p ratio ↗, oil zone pressure ↗**

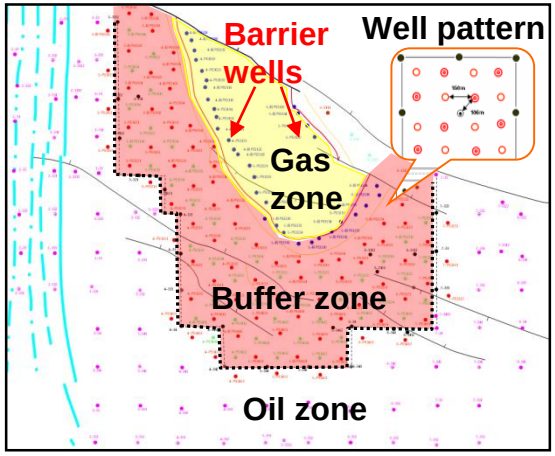


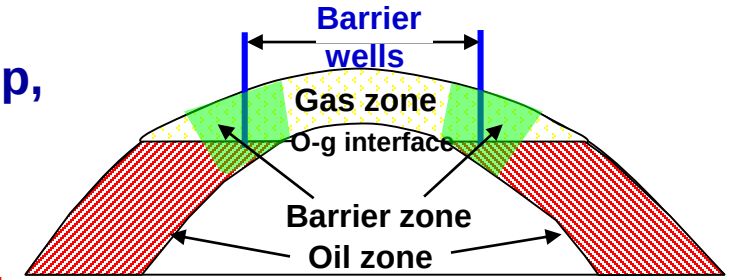
Oil-gas interfaces of different layers in the north block

➢ Oil-gas Buffer Zone Development Technologies

♦ Basic information

- Target layer: Sa II2+3
- Buffer zone area: 2.9km^2
- Buffer zone reserves: 179.8 × 10^{4}t
- Well pattern: 150m five-spot
- Number of wells: 163 (34 polymer barrier wells, 45 polymer injection wells, 84 oil production wells)
- Start of injection of polymer barrier wells: Sep, 2007
- Start of production in buffer zone: May, 2008
- Start of subsequent waterflooding: Jan, 2017

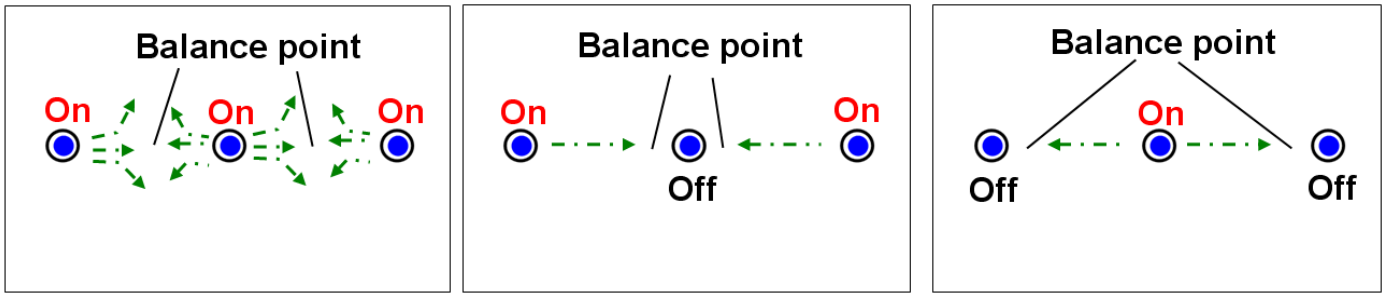




Test area

♦ Establishment of barrier

- Using high-concentration polymer (2000mg/L)
- Parameter optimization
  - Distance between polymer injection barrier wells and oil-gas boundary: 100m
  - Polymer injection barrier well spacing: 75m
- Interval well-opening and alternating injection



- Establishing a monitoring system
  - Logging, microseismic, testing, calculation…

♦ Development of the buffer zone

- **Well pattern: 150m five-spot**

Comparison of different development effects

Well pattern	Recovery by water flooding (%)	EOR by polymer flooding (%)	Ultimate recovery (%)
Five-spot	42.0	13.1	57.8
Seven-spot	41.5	12.3	56.2
Inverted nine-spot	41.2	11.6	54.8

- **High-concentration polymer flooding**
  - Lab experiment and numerical simulation
  - Direct polymer injection
  - Polymer concentration: 2000mg/L

♦ 3-zone pressure regulating and control

Pressure control

Gas cap

✓Control the injection rate in polymer barrier wells

Buffer zone

✓Control injection-production ratio

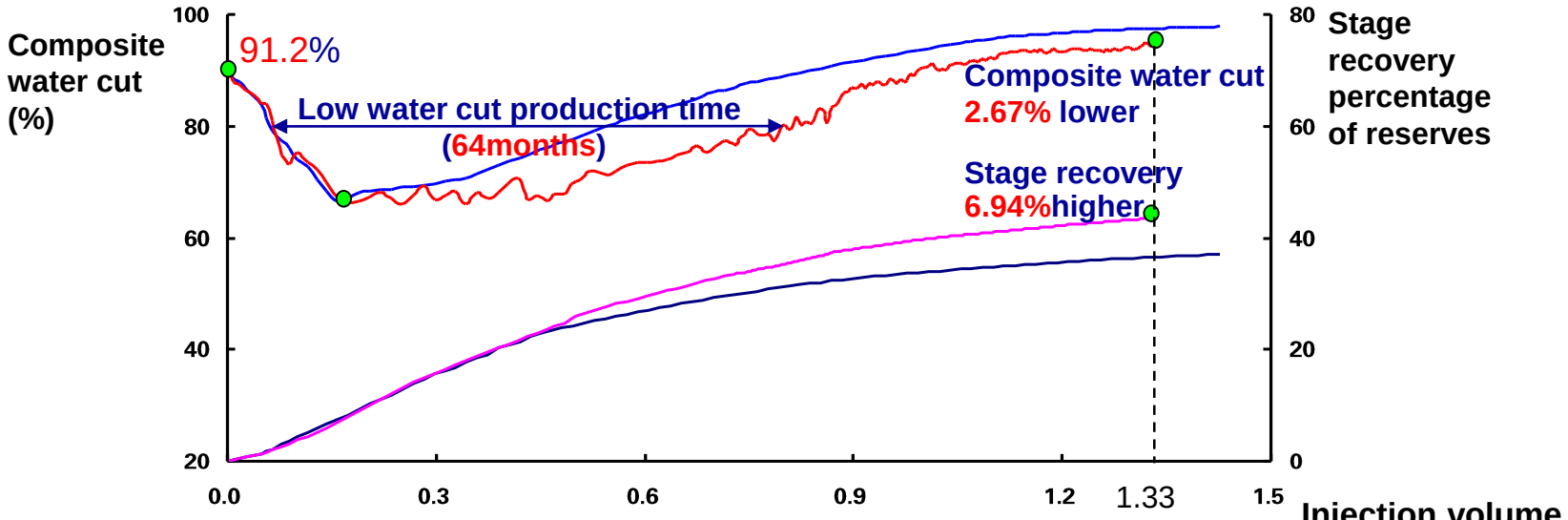
✓Control production parameters of the wells outside the gas cap

Oil zone

✓Control injection rates in the target layers

♦ Development effect

- Cumulative polymer injection pore volume: 1.33PV
- Cumulative stage oil production: 78.3 × 10^4t
- Enhanced stage recovery: 26.71%
- Recovery of reserves: 66.47%



Comparison of actual production with simulation

➢ Summary

♦ **DEVELOP a set of technologies for development of oil reservoirs below the gas cap, especially for efficient control of oil-gas interface**

♦ **EXPLORE efficient development methods for buffer zone**

♦ **CREATE 14-year stable production (1000×10^4t/a) record, even 400×10^4t/a for now**

Thank you!