The Challenges of Stimulation
In Sichuan Western Tight Sand Formation

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2. Demands of This Expert Visits of PPM China Case Study

2.1 Objective

When exploring and development $T_3X$ in west Sichuan, Southwest Petroleum Branch, SINOPEC have run into difficulty, in despite of obtaining, on a certain extent, some success on exploration and development in mid-shallow reservoir. The formation cannot be breakdown, or the treatment pressure is very high which do not satisfy hydraulic fracturing request.

The last expert visits of PPM China case study have discussed already some mentalities and methods, but also had the certain insufficiency in field trial. Therefore we will ask expert again to analyze solve our problems.
2. Demands of This Expert Visits of PPM China Case Study

• **Background**

    The tight sand gas reservoir in the Sichuan western is the important natural gas production base of SINOPEC, which already has achieved certain scale with the natural gas annual output $21 \times 10^8 m^3$ undergo many years exploration and development.
2. Demands of This Expert Visits of PPM China Case Study

Eight Explored Reserves Area

- Xincan
- Xiaoquan
- Dongtai
- Hexincan
- Luodai
- Shilongcan and Baiya
- Majin
- Xindu
2. Demands of This Expert Visits of PPM China Case Study

J3p Play: shallow layer;
J2s Play: mid-deep;
T3x Play: deep
2. Demands of This Expert Visits of PPM China Case Study

Exploratory development potential analyse

<table>
<thead>
<tr>
<th>Item</th>
<th>Shallow layer</th>
<th>Mid-deep layer</th>
<th>Deep layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proportion of total potential reserves</td>
<td>18.80%</td>
<td>38.70%</td>
<td>42.50%</td>
</tr>
<tr>
<td>Proportion of proved reserves</td>
<td>44.50%</td>
<td>51.90%</td>
<td>3.50%</td>
</tr>
<tr>
<td>Proportion of control reserves</td>
<td>20.80%</td>
<td>72.50%</td>
<td>6.70%</td>
</tr>
<tr>
<td>Ratio of explored reserves</td>
<td>52.08%</td>
<td>17.83%</td>
<td>0.58%</td>
</tr>
</tbody>
</table>

Remark: Total potential reserves is $10778 \times 10^8 m^3$
2. Plans of This Expert Visits of PPM China Case Study

- **Background**

  But, with the western greatly developing, gas transportation from west area to east area, and the grand strategy of Sichuan area natural gas outputing outside, the market to the natural gas demand fast growth, has at present been in the aspect which falls **short of demands**.

  The key technology of the exploration and development for tight sand gas reservoir is **hydraulic fracturing**, which has obtained the great achievement in Sichuan western, but **still have many technical difficult problems** restricts the natural gas further exploration and the development. For example, the proved reserves of deep gas reservoir TX group is $396.71 \times 10^8$ m$^3$, and the prognostic reserves is $1434.84 \times 10^8$m$^3$, but present the deep fracturing technology has not obtained break through.
2. Demands of This Expert Visits of PPM China Case Study

2.1 Objective

Because abundant gas natural resource cannot be exploited, and cannot obtain economic benefit.

So the objective of this expert visits of PPM China case study are:

(1) Make the deep fracturing technology break through, and take full advantage of the gas resource in deep reservoir in west Sichuan;

(2) Enhance the level of PPM;
2. Demands of This Expert Visits of PPM China Case Study

2.2 Topic
“The Stimulation for Deep Tight Sandstone Gas Reservoir”

2.3 What assist we demand
We hope to invite the expert with prolific practice experience on reservoir simulation in tight sandstone gas reservoir, to settle problems on reservoir simulation in west Sichuan, and get along with case study in west Sichuan, which will put into effect on case study of PPM.

what assist we demand (the detailed content sees behind):

(1) Deep Fracturing Technology;
(2) Multilayer Hydraulic Fracturing for Mid-shallow reservoir;
(3) Horizontal Well Stimulation.
3. Challenges of Stimulation at Present

3.1 Deep Fracturing Technology

3.1.1 Status Quo

- Commercial wells (five wells) are available, taking up to 9.6% of drilled 52 wells;
- Complex geologic characteristic, not known completely;
- Limit of current technology;
3.1 Deep Fracturing Technology

3.1.2 Geologic Characteristic of T₃x²

- Depth: 4300-5300 m;
- Lithology: sandstone is dominating with fine and moderate diameter;
- Clay composition: illite 44-85%, chlorite 15-56%;
- Reservoir property: $\phi$ is 2-4%, $K$ is $0.04-0.16 \times 10^{-3} \mu m^2$;
- Reservoir type: fracture-pore type and pore-fracture type;
- Reservoir pressure: 70-90 MPa, pressure coefficient 1.58-1.86;
- Reservoir temperature: 110-150°C;
3.1.2 Geologic Characteristic of \( T_3x^2 \)

- **Rock Mechanics:** Young's modulus of 50.7GPa, Possion’s ratio of 0.38;
- **Sensitivity:** Referring to the table for the sensitivity test result.

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Zone</th>
<th>Test result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stress-</td>
<td>( T_3x^2 )</td>
<td>moderate</td>
</tr>
<tr>
<td>Velocity-</td>
<td>( T_3x^2 )</td>
<td>poor</td>
</tr>
<tr>
<td>Water-</td>
<td>( T_3x^2 )</td>
<td>poor</td>
</tr>
<tr>
<td>Acid-</td>
<td>( T_3x^2 )</td>
<td>no or poor</td>
</tr>
<tr>
<td>Alkali-</td>
<td>( T_3x^2 )</td>
<td>poor - moderate</td>
</tr>
<tr>
<td>Salinity-</td>
<td>( T_3x^2 )</td>
<td>Moderate - severity</td>
</tr>
<tr>
<td>Water-locking</td>
<td>( T_3x^2 )</td>
<td>serious</td>
</tr>
</tbody>
</table>
3.1 Deep Fracturing Technology

<table>
<thead>
<tr>
<th>Well</th>
<th>Horizon</th>
<th>Depth</th>
<th>Type</th>
<th>Maximum pressure (MPa)</th>
<th>Maximum flow rate (m³/min)</th>
<th>Scale (m³)</th>
<th>Pre-production (m³/d)</th>
<th>After-production (m³/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CF563</td>
<td>T₃x²</td>
<td>4672-4744</td>
<td>Acidizing</td>
<td>86</td>
<td>1.87</td>
<td>60</td>
<td>1238</td>
<td>43100</td>
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<tr>
<td>CG561</td>
<td>T₃x²</td>
<td>4921-4943</td>
<td>Breakdown</td>
<td>92</td>
<td>NO Breakdown</td>
<td>12000</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Weighted acidizing</td>
<td>92</td>
<td>0.63</td>
<td>20</td>
<td>12000</td>
<td>27000</td>
</tr>
<tr>
<td>CL562</td>
<td>T₃x²</td>
<td>5090-5125</td>
<td></td>
<td>92</td>
<td>NO Breakdown</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

We can’t breakdown the formation even if the pressure is very high during the in site job!
3.1.3 Difficulty of stimulation of $T_3x^2$

**Challenge:**

The formation is of great plasticity for the high clay content and of high fracturing pressure gradient. Fracturing pressure is very high, under the existing technical method and the equipment, the formation cannot be fractured.

**What assist we demands:**

1. The reasons for the high Fracturing pressure;
2. How to reduces the Fracturing pressure?
3. How to ensure the success of hydraulic fracturing under present equipment ability?
3.1 Deep Fracturing Technology

3.1.4 Geologic Characteristic of T₃x₄

- Depth: 3300-4100m;
- Lithology: sandstone is dominating with fine and moderate diameter;
- Clay composition: illite 28-73%, chlorite 13-72%, kaolinite 0-59%;
- Reservoir property: $\phi < 10\%$, $K$ is $0.025-0.16 \times 10^{-3} \mu m^2$;
- Reservoir type: pore type;
- Reservoir pressure: 60-80 MPa, pressure coefficient 1.72-2.15;
- Reservoir temperature: 80-110 °C;
3.1 Deep Fracturing Technology

3.1.4 Geologic Characteristic of $T_3x^4$

- **Rock Mechanics**: Young's modulus of 24-36 GPa, Possion’s ratio of 0.15-0.21;
- **Sensitivity**: Referring to the table for the sensitivity test result.

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Zone</th>
<th>Test result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stress</td>
<td>$T_3x^4$</td>
<td>moderate</td>
</tr>
<tr>
<td>Velocity</td>
<td>$T_3x^4$</td>
<td>Moderate - severity</td>
</tr>
<tr>
<td>Water</td>
<td>$T_3x^4$</td>
<td>Moderate - severity</td>
</tr>
<tr>
<td>Acid</td>
<td>$T_3x^4$</td>
<td>no or poor</td>
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<tr>
<td>Alkali</td>
<td>$T_3x^4$</td>
<td>poor - moderate</td>
</tr>
<tr>
<td>Salinity</td>
<td>$T_3x^4$</td>
<td>Moderate - severity</td>
</tr>
<tr>
<td>Water-locking</td>
<td>$T_3x^4$</td>
<td>serious</td>
</tr>
</tbody>
</table>
3.1 Deep Fracturing Technology

3.1.5 Challenge for Reservoir Simulation in $T_3x^4$

1. Abnormally high fracturing pressure
   - fracturing pressure: 100 ~ 150MPa;
   - fracturing pressure gradient: 2.7MPa/100m ~ 3.3MPa/100m;

2. High stress and high Young’s Module
   - Fracture width is limited and sand plug is often came across as the high Young’s Module.
3.1 Deep Fracturing Technology

FRACTURE SIMULATION TUTORIAL CH148 WELL

The CH148 well treatment curve

The treatment is very high
3.1 Deep Fracturing Technology

3.1.5 Challenge for Reservoir Simulation in T₃x₄

(3) High leakage and multifracture

With natural fractures and serious leakoff, multiple fractures will be created during simulating.

(4) Fracturing fluid requirement

For the low porosity and low permeability, fracturing fluid must be of less damage.

(5) Equipment requirement

Deep zone and high friction increase the risk of treatment as well as more requirements for the equipment.
3.1 Deep Fracturing Technology

3.1.6 What Assist We Demands About $T_3x^4$

(1) Reasons for the high fracturing pressure;
(2) How to reduce the fracturing pressure and the treatment pressure;
(3) Some advice for fracturing fluid requirement;
(4) How to overcome the influence by high leakage and multifracture;
3.2 Multilayer Hydraulic Fracturing for Mid-shallow Reservoir

Reservoir is a heterogeneity reservoir with the characters of multilayers, multi sandstone container rocks lap over and monolayer sandstone container rock is very thin. One of the most key techniques of effectively exploiting the reservoir is multiplayer fracturing.
3.2 Multilayer Hydraulic Fracturing for Mid-shallow

3.2.1 Status Quo

- There are more than 10 layers, interlayer spacing varies from several meters to hectometre;
- 212 wells for multilayer hydraulic fractures, where 110 wells for combine-fracturing, 102 wells for fracturing of separate layers;
- Mainly 2-layer hydraulic fractures, not 3-layer hydraulic.
3.2 Multilayer Hydraulic Fracturing for Mid-shallow

3.2.2 Challenges of multilayer hydraulic fracturing

(1) The choosing standards of candidate layer for multiplayer fracturing:
   The reasonable space between two layers is worth studied.

(2) The techniques of multiplayer fracturing are simplex:
   Within one fracturing pipe string, the technique of multiplayer fracturing 3 or more than 3 layers are not mature.
3.2 Multilayer Hydraulic Fracturing for Mid-shallow

3.2.2 Challenges of multilayer hydraulic fracturing

(3) Absence of tools of multiplayer fracturing:
the tools of multiplayer fracturing are not fit to the reservoir conditions.

(4) The problem between multiplayer fracturing and exploration and evaluating:
nowadays, most multiplayer fracturing is separate fracturing by tubing or casing, the separate layers' test and exploiting is not available after fracturing.
3.3 Reservoir Horizontal Well Stimulation

3.3.1 Purpose of horizontal well

- The reserves which is difficulty to development of Southwest Petroleum Company reaches 43.82% in the JS$_2^1$ and JS$_2^3$ reservoir of Xincan gas field;
- Improving individual well production;
- Increasing the probability of drilling the reservoir intrinsic fracture;
3.3.2 Geologic Characteristic of JS$_2^1$ and JS$_2^3$

- **Depth**: 2100-2550m;
- **Lithology**: mostly fine and moderate diameter; feldspathic arenite sandstone, with quartz of 34%-62%, feldspar of 17.5%-38% and clay of 20%;
- **Average $\Phi$**: 9.05% (JS$_2^1$), 9.44% (JS$_2^3$);
- **Average $K$**: $0.150 \times 10^{-3} \mu m^2$ (JS$_2^1$), $0.131 \times 10^{-3} \mu m^2$ (JS$_2^3$);
- **Pressure**: 43-48MPa, Pressure coefficient 2.05±;
- **Temperature**: 61-70°C;
### 3.3.2 Geologic Characteristic of JS$_2^1$ and JS$_2^3$

#### Sensitivity of JS$_2^1$ and JS$_2^3$

<table>
<thead>
<tr>
<th>Item</th>
<th>Test result</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>JS$_2^1$</td>
</tr>
<tr>
<td>Speed sensitive</td>
<td>Middling~ strong</td>
</tr>
<tr>
<td>Water sensitive</td>
<td>Middling~ strong</td>
</tr>
<tr>
<td>Salt sensitive</td>
<td>Middling</td>
</tr>
<tr>
<td>Acid Sensitive</td>
<td>HCl</td>
</tr>
<tr>
<td></td>
<td>Mud</td>
</tr>
<tr>
<td>Alcali sensitive</td>
<td>Middling</td>
</tr>
</tbody>
</table>
3.3 Reservoir Horizontal Well Stimulation

3.3.3 Difficulty of stimulation

- Lack of pertinence stimulation technology because of the poor physical property;
- Looks from the existing research achievement, except of the poor physical property, also has some other factors direct influence fracture effect:
  ① throat is thinner, and the correlativity of porosity-infiltrates is poor;
  ② the chlorite content in clay mineral is higher, and water sensitivity is strong;
3.3 Reservoir Horizontal Well Stimulation

3.3.3 Difficulty of stimulation

- With major gas reservoir JS₂² and JS₂⁴ compared, the aquifer yield of the reservoir JS₂¹ and JS₂³ is higher, gas-water ratio is lower, and gas condensate production is higher;
- Fracture distribution is not clear, which brings the enormous difficulty to seek for the oil-gas high production area.
3.3 Reservoir Horizontal Well Stimulation

3.3.4 How to realize the horizontal well staged fracturing

(1) Low permeability layer, flowback?
(2) Coiled tubing with packer to achieve staged fracturing;
(3) Water jet & fracturing technology;
(4) Limited entry fracture treatment by casing;
(5) Staged fracturing with two packer;
(6) Others?

Keys: Performance of packer.