**Diagenesis and Reservoir Quality of Lengdong Area, Qaidam Basin, China**

**Jie He\(^1\), Hua Wang\(^1\), and Detian Yan\(^1\)**

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\(^1\)Faculty of Earth Resources, China University of Geosciences (Wuhan), Wuhan, Hubei, China (jiehe19920402@163.com)

**Abstract**

Based on thin section observation and homogenization temperature of the fluid inclusions analysis, combining with reservoir modeling, the reservoir characteristics of Jurassic coal measure strata and neighboring sandstone and the evolution of pores in Lenghu Tectonic Zone of the North Margin of the Qaidam Basin has been studied. The analysis results indicated dissolution by organic acid fluid, together with sequence boundary and favorable sedimentary facies, is one of the main controlling factors on reservoir quality.

In the early diagenesis stage, the decaying plant decomposed quickly and then produced humic acid, resulting in an acid medium of pore water in the process of sedimentation. Therefore, in early diagenesis most reservoir of coal measure strata lacks calcite, gypsum and zeolite cement filling, etc. And the compaction decreased primary porosity, reducing throat thinning and thus permeability. The coal measure strata in this stage are commonly low porosity and permeability reservoir quality. In the middle diagenesis stage, a large amount of organic acid fluid formed and intensively dissolved the unstable components such as feldspar, debris, etc. As the rock in this stage has almost been consolidated and the compaction rate decreased, the secondary dissolution porosity was likely preserved and thus relatively high quality reservoir formed.

In addition, the acid fluid from coal bearing strata went into the neighboring reservoir along the fault in Lenghu Tectonic Zone. By reservoir modeling, the effects of acid fluid on porosity of reservoir were simulated. As the acid fluid migration distance increased, the quality of reservoir got better and then deteriorated before ameliorating. The diagenesis of acid fluid in different conditions can be modeled by changing the related parameters. Owing to the acid fluid in Jurassic coal measure strata, the Jurassic reservoir, neighboring Lulehe and Lower Ganchaigou Group is of high quality, despite the upper Lulehe Group. The experimental results fit well with testing data, so the simulation is a practical method in coal measure strata diagenesis. This study can provide references for prediction and exploration of petroleum in reservoir studies.
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Sep 2016
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  - Geological Settings
  - Methods
  - Reservoir lithologies
  - Diagenetic minerals
  - Reservoir properties
  - Discussion
  - Conclusions
Introduction

- **Qaidam Basin**
  - large inland lake sedimentary basin
  - abundant resources

- **Lengdong Area**
  - located in northwestern of North Qaidam
  - produced good industrial oil flows in shallow layer
  - has good gas show in deep Jurassic and basement rock

- **Reservoir Quality**
  - high quality reservoir
  - reservoir evaluation
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Geological Settings

Fig. 1 The tectonic map of Qaidam Basin

Fig. 2 The tectonic map of Lengdong area
# Geological Settings

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<th>Stratum System</th>
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<th>Code</th>
<th>Seismic Reflections</th>
<th>Tectonic Movements</th>
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<td>Q_{1+2}</td>
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<td>Xia Youbshashan</td>
<td>N_{2}^1</td>
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<td>Oligocene</td>
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<td>--T_3--</td>
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<td>Middle Caishiling</td>
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<td>Yanshan movement I</td>
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<td>Indosinian movement</td>
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</tbody>
</table>

**Figure 3** Synthetical Stratum Histogram
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  ● Reservoir lithologies
  ● Diagenetic minerals
  ● Reservoir properties
● Discussion
● Conclusions
Methods

- **Optical microscopy**
  - Processed: vacuum, blue resin, mixed Alizarin Red-S and Potassium Ferri Cyanide.

- **SEM (scanning electron microscopy)**
  - JSM-5500LV and energy dispersive X-ray spectroscopy (EDS), Petroleum geology analysis and test center, Research Institute of Exploration and Production of Sinopec Zhongyuan Oilfield Company, China.

- **XRD (X-ray diffraction)**

- **CL (cathode luminescence)**
  - CITL Cold Cathode Luminescence 8200mk3, excitation energy 20 kV and 400mA, Cameca SX100 electron microprobe, 15 kV, 10 nA, 5mm.
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Reservoir lithologies

Figure 4  Lithologic Classification

Particle characteristic: subangular to subrounded, medium to fine grain, medium to well-sorted, line, point-line and line-point contacts.

Component: 35.21% quartz, 27.16% lithic fragment, 19.32% feldspar.

Heavy mineral : magnetite, garnet, epidote and zircon ,ZTR 20.51%.
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Diagenetic minerals

I. Calcite

Well Saixin 1

1320.75m, 1.23mm (-)

1560.50m, 4x8

1560.50m, 550x

1186.11m, 330x

1186.11m, 330x
Diagenetic minerals

1. Calcite

Figure 5  Energy Spectrum Analysis of Well Saixin 1, 1174.30m, 430×
Diagenetic minerals

I. Calcite

Figure 6 Energy Spectrum Analysis of Well Saixin 1, 1186.11m, 330×
Diagenetic minerals

Ⅰ. Calcite

Figure 7  Energy Spectrum Analysis of Well Saixin 1, 1310.50m, 330×
Diagenetic minerals

1. Calcite

Figure 8 Energy Spectrum Analysis of Well Saixin 1, 1466.50m, 230×
Diagenetic minerals

II. Illite and illite/smectite

- 1275.00m, 650x
- 1423.70m, 1100x
- 1310.50m, 1200x
- 1466.50m, 2000x
Diagenetic minerals

Ⅲ. Quartz

1310.50m, 1.23mm (-)

1469.00m, 1.23mm (-)

1454.00m, 2700x

3632.62.00m, 4x8
Diagenetic minerals

IV. Feldspar

Well Saixin 1
Diagenetic minerals

V. Laumontite
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Reservoir properties

Lulehe and Shangganchaigou Formation. The average porosity is 10.24%, with 6.7% (E1+2), 10.52% (E3) and 17.48% (N1). Main pore types: primary pore (54.68%), secondary pore (42.47%) secondary intergranular pore and a small amount of intragranular pore, moldic pore and matrix pore, micro fracture (2.84%).
The relationship between lithology and physical property

Porosity (%) vs. Permeability ($10^{-3} \mu m$)

- Polotaic sandstone
- Siltstone
- Fine sandstone
- Medium sandstone
- Conglomerate
- Conglomeratic sandstone
Reservoir properties

The relationship between physical property and oil-gas possibility

- Porosity (%)
- Permeability ($10^{-3} \mu m$)

- Blue dots: no hydrocarbon show
- Orange dots: fluorescence
- Gray dots: oil patch
- Yellow dots: oil trace
## Reservoir properties

Table 1  Statistical table of relationship between physical parameters and microfacies

<table>
<thead>
<tr>
<th>Microfacies types</th>
<th>Physical parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Porosity (%)</td>
</tr>
<tr>
<td>Underwater distributary channel</td>
<td></td>
</tr>
<tr>
<td>Distributary channel</td>
<td></td>
</tr>
<tr>
<td>Mouth bar</td>
<td></td>
</tr>
<tr>
<td>Channel bar</td>
<td></td>
</tr>
<tr>
<td>Flood fan</td>
<td></td>
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<tr>
<td>Underwater distributary interchannel</td>
<td></td>
</tr>
<tr>
<td>Distributary interchannel</td>
<td></td>
</tr>
<tr>
<td>Sand flat</td>
<td></td>
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<tr>
<td>Mud flat</td>
<td></td>
</tr>
</tbody>
</table>
Figure 9  The relationship between physical parameters and microfacies
Reservoir properties

From 0.03 to 82 mD with an average of 30.54 mD. The average permeability of Lulehe (E_{1+2}), Xiaganchaigou (E_3) and Shangganchaigou (N_1) Formation is 0.82, 40.31 and 21.57 mD respectively.

Figure 10 The capillary pressure curve graph of Well Qian 4 Hole
Reservoir properties

**Permeability**

- Maximum advance mercury saturability (%): 
  \[ y = 1.2328 \ln(x) + 80.352 \]
  \[ R^2 = 0.0284 \]

- Porosity \((10^{-3} \mu m^2)\): 
  \[ y = 0.7892x - 0.674 \]
  \[ R^2 = 0.6089 \]

- Displacement pressure (Mpa): 
  \[ y = 0.7892x^{0.674} \]
  \[ R^2 = 0.6089 \]

- Maximum throat radius (μm): 
  \[ y = 0.541 \ln(x) + 1.7138 \]
  \[ R^2 = 0.5603 \]

- Average throat radius (μm²): 
  \[ R^2 = 0.0161 \]

**Figure 11** The relationship between permeability and pore structure parameter in Lengdong area.
Figure 12 The diagenesis stage of Lengdong Area
## Discussions

### Compaction

Influent factors on reservoir quality

<table>
<thead>
<tr>
<th></th>
<th>Average porosity of original pore</th>
<th>Numbers of samples</th>
<th>Average porosity of extant pore</th>
<th>Numbers of samples</th>
<th>Average loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shangganchaigou formation (N1)</td>
<td>27.40%</td>
<td>35</td>
<td>14.23%</td>
<td>532</td>
<td>13.17%</td>
</tr>
<tr>
<td>Xiangganchaigou formation (E32)</td>
<td>30.40%</td>
<td>30</td>
<td>12.18%</td>
<td>483</td>
<td>18.22%</td>
</tr>
<tr>
<td>Xiangganchaigou formation (E31)</td>
<td>31.09%</td>
<td>160</td>
<td>9.58%</td>
<td>168</td>
<td>22.51%</td>
</tr>
<tr>
<td>Lulehe formation (E1+2)</td>
<td>27.89%</td>
<td>60</td>
<td>7.07%</td>
<td>291</td>
<td>20.82%</td>
</tr>
</tbody>
</table>

Table 2: The porosity loss by compaction
Discussions

Influential factors on reservoir quality

Cementation

- Calcite cements
  Two-side effect on reservoir: decrease pore space, porosity and permeability—weaken the effects of compaction and provide with the material foundation for late dissolution.

- Authigenic clay minerals like illite and illite-smectite mixed-layer
  Two-side effect on reservoir: prevent overgrowth of mineral—severely reduced throat connectivity and permeability.

- Siliceous cement
  Quartz and feldspar overgrowth.
Discussions

Influential factors on reservoir quality

Dissolution

Figure 13  Flow diagram combining aspects of organic and inorganic diagenesis (modified from Surdam et al. 1984)
Discussions

Influential factors on reservoir quality

Modeling

Figure 14  Schematic representation of system modeled with starting compositions along right side and model grid on left. Note scale, total length of the system is 5m and grid spacing in 5cm.

Figure 15  The final distribution of illite for fast and slow precipitation.
Discussions

Influential factors on reservoir quality

Overpressure

Figure 16  The relationship between surface porosity and carbonate cement content

Figure 17  The relationship between surface porosity and calcite cement content
Discussions

Overpressure

Figure 18 The relationship between carbonate cement content and pressure coefficient

Figure 19 The relationship between porosity and pressure coefficient
Conclusions

1) The Lengdong sandstones are mainly feldspathic lithic sandstone with lithic feldspar sandstone and lithic sandstones.

2) Diagenetic minerals of study area are dominated by calcite, illite and illite/semctite, quartz, feldspar, laumontite. They have different effects on the reservoir quality.

3) The diagenesis stage from Paleogene to Neogene in Lengdong area is from A sub-period of eogenetic to A sub-period of mesogenetic stage. The eogenetic stage can be divided into stage A and B and sediments are poorly consolidated. In Lengdong area, only A sub-period of mesogenetic stage is developed.
4) The mostly developed diagenesis in Lengdong area is compaction, cementation and dissolution. The acid fluid formed in coalification transferred in adjacent sandstones and changed the minerals distribution near the boundary.

5) Overpressure have an good impact on reservoir quality in some degree.

6) The best reservoir in Lengdong area is Xiaganchaigou (E3), with a porosity of 10.52% and permeability of 40.31 mD.