Spatial Diagenetic Heterogeneity of Lenticular Sandbody in Shahejie Formation, Bohai Bay Basin, China, and Its Implications for Sandstone Diagenesis*

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Abstract

The entity of diagenesis which refers to the physical and chemical processes that affected sedimentary materials after deposition and weathering was always an outstanding issue. We try to figure out its complicated process by studying a whole diagenetic system, which are composed of the deeply buried (3,100~3,300 m) lenticular sandbodies and the surrounded shales. The lenticular sandbodies of five diverse distribution patterns were lying at Shahejie Formation in the rift basin of eastern China. 141 core samples, including sandstones and shales, were acquired within sandbody and near the sand/shale contact (SSC) by densely sampling. Based on analysis of thin section, X-Ray Diffraction, Scanning Electron Microscopy and Cathodoluminescence Micrography, those samples’ diagenesis and its differences between the exterior and the interior of lenticular sandbody were analyzed.

We found the lenticular sandstones got high porosity (20%) at the interior and low porosity (4%) at the SSC. The reason for low porosity was the present of carbonate cements. The quantity and sorts of carbonate cements formed during increasing burial depth is much more in the external (>15%) than in the interior of lenticular sandbody (<3%). Shale supplied the source for a portion of the diagenetic cements near the SSC in the whole diagenetic system. Based on analysis of thin section, X-Ray Diffraction, Scanning Electron Microscopy and Cathodoluminescence Micrography, those samples’ diagenesis and its differences between the exterior and the interior of lenticular sandbody were analyzed.
sand and shale would dominate episodic diffusion gradients and the direction and velocity of the transfer mass. The whole diagenesis evolution result proved shales play an important role in the process and must be considered in to sandstone diagenesis.

Reference

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12th, April, 2011
OUTLINE

- INTRODUCTION & BACKGROUND
- SAMPLES AND METHODS
- DIAGENETIC HENTEROGENEITY
- ORIGIN DISCUSSION
- CONCLUSIONS
Why do we study the sandstone diagenesis

- Turbidite
- Fan
- Sandbody

Background

- Faulted basin
- Faulted depression
- Turbidite fan
Samples and Methods

- Nine lenticular sandbodies and around mudstone

Column of well Y3-7-7

- Mudstone 3220.61m
- 3273.7m
- 3146.64m
- Sandstones 3147.44m
- 3150.44m
- 3147.94m
Select five sandbodies and dense sampling

<table>
<thead>
<tr>
<th>Burial depth</th>
<th>sandstone</th>
<th>VS</th>
<th>mudstone</th>
</tr>
</thead>
<tbody>
<tr>
<td>3250 ~ 3252m</td>
<td>1.00</td>
<td></td>
<td>5.00</td>
</tr>
<tr>
<td>3199 ~ 3202m</td>
<td>2.20</td>
<td></td>
<td>15.00</td>
</tr>
<tr>
<td>3272 ~ 3280m</td>
<td>7.60</td>
<td></td>
<td>21.00</td>
</tr>
<tr>
<td>3220 ~ 3230m</td>
<td>10.00</td>
<td></td>
<td>17.00</td>
</tr>
<tr>
<td>3230 ~ 3237m</td>
<td>5.00</td>
<td></td>
<td>1.00</td>
</tr>
</tbody>
</table>

Burial depths and scale of sandbody and around mudstone
Samples and Methods

- Multi analysis methods

- Section
- CL
- SEM
- X-RD

- 3250.9m (+)
- 3250.54m (SEM)
- 3280.5m (CL)
Diagenetic Heterogeneity

- Sandstone types according to Fork’s classification and porosity differences
Sandstone diagenetic stage

- I/S mixed layer ratio = 20%
- Ro 0.8 ~ 1.3%
- T > 105°C

![Diagenetic Heterogeneity](image)

<table>
<thead>
<tr>
<th>Stage Diagenesis</th>
<th>Early diagenesis</th>
<th>Moderate diagenesis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>T°C</td>
<td>05</td>
<td>05</td>
</tr>
<tr>
<td>R%,%</td>
<td>0.3</td>
<td>0.5</td>
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<tr>
<td>Compaction</td>
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<tr>
<td>Clay mineral</td>
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<tr>
<td>Calcite cement</td>
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<tr>
<td>Quartz overgrowth</td>
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<td>Chlorite</td>
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<td>Illite</td>
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<td>Ferrocarnite</td>
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<td>Anskerite</td>
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<tr>
<td>Calcite dissolution</td>
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<tr>
<td>Feldspar dissolution</td>
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<tr>
<td>Primary Pore</td>
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<tr>
<td>Secondary pore</td>
<td></td>
<td></td>
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<tr>
<td>Oil charge</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Pore vs. Age

Pore evolution vs. Age

Depth vs. Temperature

3199.6m (-)

3272.9m (+)
Diagenetic Heterogeneity

- Porosity differences

- Low porosity near the SSC
- High porosity interior sandbody

SSC: sandstone / shales contact
Cementation heterogeneity was the main reason

- High percent near the SSC
- Low percent interior sandbody
Diagenetic Heterogeneity

- Same characteristics of ankerite
  - High percent near the SSC
  - Low percent interior sandbody

```
岩性
白云石
```

```
深度 / m
3196
```

```
lithology
ankerite
```

```
3199.5/3%
```

```
3199.66/1%
```

```
3199.7/1%
```

```
3200.5/<1%
```

```
3200
```

```
3201
```

```
3202
```

```
3203
```

```
3204
```

```
3205
```

```
3206
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```
3207
```

```
3199.5
```

```
3199.66
```

```
3199.7
```

```
3200.5
```

```
3201
```

```
3202
```

```
3203
```

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3204
```

```
3205
```

```
3206
```

```
3207
```

```
3199.5
```

```
3199.66
```

```
3199.7
```

```
3200.5
```
Three sandbodies have the same characteristics

why?

Diagenetic Heterogeneity
Origin Discussion

 ➢ Carbonate cements formation

How?

\[ (\text{Mg}, \text{Fe}, \text{Ca}) \cdot n\text{CO}_3 \]

\[ (\text{Fe}, \text{Ca}) \cdot n\text{CO}_3 \]
Diagenesis material come from around mudstone

- Illitization → Cations
- Organic material maturation → Acid root

\[
CaCO_3 + 2H^+ = Ca^{2+} + H_2O + CO_2
\]

\[
(\text{Na}_{0.7}\text{Ca}_{0.3})\text{Al}_{1.3}\text{Si}_{2.7}\text{O}_8 + 5.2H^+ + 2.8H_2O = 0.7\text{Na}^+ 0.3\text{Ca}^{2+} + 1.3\text{Al}^{3+} + 2.7H_4\text{SiO}_4
\]

\[
K_{0.12}\text{Na}_{0.25}(\text{Al}_{1.41}\text{Fe}_{0.22}\text{Mg}_{0.41})(\text{Si}_{3.88}\text{Al}_{0.12})\text{O}_{10}(\text{OH})_2 + 9.96H_2O = 0.12\text{K}^+ + 0.25\text{Na}^+ + 0.22\text{Fe}^{3+} + 0.41\text{Mg}^{2+} + 1.53\text{Al}^{3+} + 3.88H_4\text{SiO}_4 + 6.44\text{OH}^-
\]

\[
CH_2O + H_2O \rightarrow CO_2 + 4H^+
\]

\[
Ca(Sr)CO_3 + HAC \rightarrow Ca(Sr)^{2+} + HCO_3^- + AC^-
\]
Origin Discussion

- Material can be transported to sandstones

The transportation experiment

(Thyne 2001)
Sandstone evolution model according to the lenticular sandbody diagenetic heterogeneities

different stage, different diagenesis, different porosity

- Primary stage
- Shallow burial depth
- Moderate burial depth
- Deep burial depth
Conclusions

- Lenticular sandstones got high porosity (20%) at the interior and low porosity (4%) at the sandstones/shales contact (SSC).
- The reason for low porosity was the presence of carbonate cements.
- Shale supplied the source for a portion of the diagenetic cements near the SSC in the whole diagenetic system, the diffusive mass transport process was formed in the whole diagenetic system.
- Sufficient burial depth could afford the temperature threshold to the formation of chemical gradient. The scale of lenticular sandbody and shales would influence the cement extent and cement distribution. Sorts and quantity of composition in both sand and shale would dominate episodic diffusion gradients and the direction and velocity of the transfer mass.
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