HYDROGEOMORPHOLOGIC ARCHITECTURE AND DISTRIBUTION CHARACTERISTICS OF EARLIER EPIKARST CARBONATE RESERVOIRS IN MIDDLE-LOWER ORDOVICIAN IN TAZHONG OIL FILED, TARIM BASIN

ZHANG HENG, CAI ZHONGXIAN

China University of Geosciences, Wuhan

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Introduction

Carbonate Reservoir Model (C&C, 1998)

Vertical megakarst profile showing stages of evolution and their relationship to porosity-permeability

Epikarst development model, Flank control on development of karst porosity
Ellenburger Reservoir
Permian Basin
Loucks et al., 1999

Ordovician Reservoir in Tahe Oil Field
Tarim Basin
Jiao Fangzheng et al., 2008

Block diagram of a near-surface modern karst system

Karst caves distribution model in the early Hercynian period
What is the karst condition of Tazhong Oil field? Same?
What are the reservoir distribution characteristics?
Geological setting

Diagenetic stages in the evolution of a limestone and of its karst. Black dots indicate possible cave formation. (Choquette & Pray, 1970)

The Palaeo-structure high (T74) of Tazhong uplift (Chen Honghan, 2012)

It is a little different from the classic definition. The uplift and erosion returns the limestone to the surface immediately. Thus, its limestone is soft rock rather than hard rock.
Both the 2D and 3D seismic data indicate that the terrain of the whole Middle-Lower Ordovician is flat and the relief amplitude is small.
Amplitude difference of Landscape in Shunxin and Kal 1 blocks is 30-40ms
1) The erosion and collapse of landform is weak, 2) Fissure and karren develop well, 3) Fissure and karren are the main paleo-geomorphology category and extend along constant directions.
Hydrogeomorphologic architecture

1) Karren in Malham Cove, Yorkshire (left), 2) clint and crike (right) (Ford, 2006)

Clint in Northwest of Burren, Ireland (left)
Karren in Curacao Coastal zone, Netherlands (right)
The Karren assemblages vary a lot, but the angle of slope changes from small to medium.

<table>
<thead>
<tr>
<th>Karren assemblages</th>
<th>The bearing surface</th>
<th>Development environment</th>
<th>Denudation of rock</th>
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</thead>
<tbody>
<tr>
<td>Grikekarren–rinnenkarren</td>
<td>1,600–1,800</td>
<td>Under soil, or bedding plane surface, where is bordered by soil</td>
<td>Total bed</td>
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<tr>
<td>Rinnenkarren–grikekarren</td>
<td>1,600–2,100</td>
<td>Under soil, or bedding plane bordered by soil or at the boundary of beds</td>
<td>Surface of bedding planes, or total bed</td>
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<tr>
<td>Rinnenkarren–pit</td>
<td>1,800–2,100</td>
<td>Surface of bedding planes</td>
<td>Cavity development</td>
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<tr>
<td>Rinnenkarren–grike</td>
<td>1,800–2,100</td>
<td>Surface of bedding planes</td>
<td>Cavity development, surface of bedding planes</td>
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<td>Wall karren–schichtfugen-karren</td>
<td>1,600–2,100</td>
<td>Bed head</td>
<td>Regression of the surface of the bed heads</td>
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<td>Pit–grikekarren</td>
<td>1,600–2,100</td>
<td>At the lower margin of bedding planes surfaces</td>
<td>Shortening of bedding planes surfaces</td>
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</table>

(Veress, 2003)
Krubera Cave in connection with recent uplift of the Caucasus range. (Klimchouk et al., 2009.)

Map of karst regions of the 48 conterminous United States

Two karst landform types
REGIONS OF HIGH RELIEF
REGIONS OF MODERATE RELIEF

The karst landform type of Tazhong is identified to be later
Hydrogeomorphic architecture

**Without surface drainage pattern:** The surface flow pattern has been generally restricted to the paleo-geomorphic landform and tends to be diffuse, and it is really impossible to form the drainage system on the surface.
1. A set of vug and fissure is identified near the unconformity surface ($T_7^4$) by imaging logging, which is the broad reservoir category.

The max thickness of limestone is 80m.

Vug and fissure intervals

5349.5-5373.5m, 4.4 tons of oil is produced per day;
5432.5-5452.8m, 61786 cubic metres gas is produced per day.
<table>
<thead>
<tr>
<th>组段</th>
<th>GR (API)</th>
<th>海拔 (m)</th>
<th>岩性剖面</th>
<th>取芯段</th>
<th>RD (Ω·m)</th>
<th>岩层类型</th>
<th>储层类型</th>
<th>储层级别</th>
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<td>良里塔格组</td>
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Z15, 5455-5461m、5473-5482m, vug and fissure, vug develops along fissure in vertical direction

unconformity
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<tr>
<th>组段</th>
<th>海拔 (m)</th>
<th>岩性剖面</th>
<th>取芯段</th>
<th>岩溶层类型</th>
<th>岩溶段</th>
<th>预测类型</th>
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<td>组三</td>
<td>-5640</td>
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GR (API) 0 - 150
CAL (in) 4 - 10
RD (Ω·M) 2 - 20000
RS (Ω·M) 2 - 20000

岩溶层类型

岩溶段

预测类型

Z19, 5474-5476, 5483-5488m, vug and Fissure

Z19, 4_62/72, core, unconformity
2. Epikarst reservoir mainly develops in the region 0-120m away from unconformity.

Vertical distribution of epikarst reservoir in Yingshan Fm. (data from core and thin sections)
3. Horizontal distribution characteristics of epikarst reservoir

1) The distribution is universal
2) Horizontal distribution features vary in different regions
3) Epikarst reservoir develops better near the Pinchout line and the genesis of reservoir becomes complex when far away from Pinchout line

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The distribution of different genesis reservoir in Tazhong Oil field

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Reservoir distribution characteristics

4. "short plate" or "beaded" reflection are the primary seismic reflection characteristics. Average Absolute Amplitude Anomaly distributes as line in NEE direction.

Horizontal distribution prediction of cave in Yingshan Fm. in Kal 1 block (T₀-100ms Average Absolute Amplitude)
Reservoir distribution characteristics

5. The differentiation of reservoir distribution in different landform is not obvious, but the underlying reservoirs are intimately related to fissures and faults.

The overlay figure of cave, paleo-morphology and fault system in Shunxi Block

The overlay figure of cave, paleo-morphology and fault system in Kal 1 Block
Discussion

The difference between high and moderate relief regions

High relief regions

Krubera Cave in connection with recent uplift of the Caucasus range

Moderate relief regions

Cross-section through the karst area of southern Indiana

Idealized profile through the Mammoth Cave System, Kentucky
Discussion

The difference between high and moderate relief regions

Karst reservoir development model figure in moderate relief regions
## Discussion

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<th>Paleomorphology</th>
<th>Hydrology</th>
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<tr>
<td>Karren, channeling karren</td>
<td>Without surface drainage system; Without uniform water table</td>
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<tr>
<td>Clints、channeling karren、doline, sink hole</td>
<td>Obvious surface drainage system; Without uniform water table With the enlarge of fissure, isolate caves develop</td>
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<tr>
<td>Fengcong、fenglin、karst depression、sink hole、dry valley、blind valley</td>
<td>Integrated drive system Isolate caves ——Cave system Surface drainage system、Subsurface drainage system Collapse</td>
</tr>
</tbody>
</table>

### Karstification evolution stage

- **Initiation**
- **Youth**
- **Maturity**
Conclusion

1. The slope of karst terrain in research area is flat and the slope of surface is small, and surface drainage system does not form.

2. Karren is the most obvious geomorphic category, including cracks and fissures along some constant directions.

3. Fissures and vugs are the main reservoir categories, which controlled by the fault system distribution.

4. Fissure-Spose patter karst model is the product of the unique hydrogeomorphologic architecture (Without surface drainage pattern), which reflecting the feature in the initiation period.
Thank You Very Much!