Shaanxi Yanchang Petroleum (Group) Co., Ltd is one of four qualified enterprises for oil and gas exploration and production in China, and also a large integrated energy chemical company aiming at the high–efficiency use of coal, oil and gas. In 2015, Yanchang became No.380 of Fortune Globe top 500 companies.
Carbon Emission Reduction is a global Issue

In 2014, China released “China’s National Plan on Climate Change (2014-2020)”, has pledged to reduce carbon emission by 45% for per unit GDP by 2020 from the 2005 level.

In 2015, China signed “U.S.-China Joint Presidential Statement on Climate Change”

In 2016, China signed the “Paris Agreement on Climate Change”
Social Responsibility Development Need

Yanchang Petroleum is the largest provincial state-owned enterprises in north-west China. It’s our responsibility to fight against climate change.
Advantages of Yanchang CCUS Project

- **Coal Chemical Industry**
  - Abundant CO₂ Source
  - Low Cost, High Purity CO₂

- **CO₂-EOR and Storage**
  - Good Geological Conditions for Safety Storage
  - Huge storage capacity in oil reservoir and saline aquifer
  - CO₂-EOR

**Advantages**

- Abundant CO₂ Source
- Good Geological Conditions for Safety Storage
- Huge storage capacity in oil reservoir and saline aquifer
- CO₂-EOR
1、Abundant Carbon Dioxide Sources and Huge Storage Space in Ordos Basin

(1) Abundent CO₂ Emission Source
More than 100 mtpa CO₂ emission in Ordos Basin

(2) Storage Capacity
1.2 billion tonnes of oil reserve is suitable for CO₂-EOR,
0.4 billion tonnes of CO₂ can be safely sequestrated.

(3) Saline Aquifer
Huge Storage capacity in Saline Aquifer (>1 billion tonnes)
2、Yanchang’s Unique Source-Sink Advantages

Yanchang’s business is including multiple coal chemical plants and oil & gas fields, which is unique source-sink conditions for CCUS project.
1. Low Cost CO₂ Capture Technology in Coal Chemical Industry

**Project Highlights**

- CO₂ Source: Coal Gasification Process
- High Purity: CO₂ = 99.6%
- Low Capture Cost: <120 Yuan ($19)
- Low Transportation Cost
1. Low Cost CO₂ Capture Technology in Coal Chemical Industry

In November 2012, a 50,000 t/a CO₂ capture facility has been built at Yulin Coal-chemical Plant. 99.6% purity of CO₂ is captured using a Rectisol process, then delivered to injection sites for CO₂-EOR and storage.

50,000 t/a CO₂ Capture Project Operated by Yulin Coal Chemical Company
2. CO₂-EOR Experiment Assessment

Establishing a CO₂-EOR assessment system based on physical simulation experiment in formation conditions.

**Test:**
- Minimum Miscibility Pressure (MMP) Test
- CO₂-Oil Phase Behavior Test
- Influence of CO₂ Injection on Reservoir
- Influence on CO₂-EOR Efficiency
- Channeling and Sealing system

PROGRESS

- Modified starch gelatum system
- Flowing gelatum
- Fracture sealing
3. Injection-production Casing String Design and Anti-corrosion Technology

- Injection-production casing string design has been optimized,
- Anti-corrosion technology has been determined as “ordinary steel+ inhibiter”
### 4. CO₂ geological Storage Capacity Assessment System

A new CO₂ geological Storage Capacity Assessment System has been established in consideration of interaction between CO₂-EOR and Storage. The result shows the effective CO₂ storage capacity could be 0.4 billion tonnes in Yanchang oilfield.

<table>
<thead>
<tr>
<th>No.</th>
<th>Reservoir</th>
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<td>5</td>
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<td>0.56</td>
</tr>
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5. “Underground—Surface—Atmosphere” CO₂ Storage Monitoring System

- Casing string Monitoring
- Soil Gas Monitoring
- Online Monitoring System
- 3D-Seismic Monitoring
- Vegetation Physiological & Biochemical Analysis
- Sample Analysis
6. CO₂-EOR and Storage Pilot Test

1、Jingbian CCS Pilot Site

- Pay-zone Depth: 1300m-1600m
- Injection Pressure: 8.3Mpa
- Reservoir Temperature: 44℃
- Liquid Production/well: 0.53m³/d — 1.05m³/d
- Oil Production/well: 0.17 t/d — 0.33 t/d
- Water-cut: 64%

Since September 2012, the total amount of CO₂ injection is 87,300 tons.
6. CO$_2$-EOR and Storage Pilot Test

2、Wuqi CCS Pilot Site

- Pay-zone Depth: 2000m
- Injection Pressure: 9.5Mpa
- Reservoir Temperature: 60℃
- Liquid Production/well: 2.88 m$^3$/d — 3.07 m$^3$/d
- Oil Production/well: 1.91 t/d — 2.23 t/d
- Water-cut decrease: 6.5%

Since September 2014, the total amount of CO$_2$ injection is **380,000** tons.
7. Yanchang 360,000 t/a Integrated CCUS Demonstration Project

The feasibility study of 360,000 t/a CCUS Demonstration Project has been approved, the project is now in the construction scheme design phase.

360,000 t/a CO₂ Capture Project in Yulin Energy and Chemical Company
- Phase 1: 360,000 tons/year CCUS demonstration project.
- Phase 2: 1 million tons/year CCUS industrial application project.
- Phase 3: 4 million tons/year CCUS推广应用 project.
Well Testing in Yanchang oilfield
Wuqi reservoir

Date: 27th June 2018

Vahab Honari
Acknowledgements

Professor Andrew Garnett; Professor Jim Underschultz; Professor Xingjin Wang

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ACA Low Emissions Technology Pty Ltd (ACALET).

Disclosure

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Disclaimer

The information, opinions and views expressed here do not necessarily represent those of The University of Queensland, the Australian Government or ACALET. Researchers within or working with the UQ-SDAAP are bound by the same policies and procedures as other researchers within The University of Queensland, which are designed to ensure the integrity of research. The Australian Code for the Responsible Conduct of Research outlines expectations and responsibilities of researchers to further ensure independent and rigorous investigations.
Research Collaborators:
China University of Mining Technology Beijing, Yanchang Petroleum Company,

Thanks also to APLNG, Bridgeport Energy, Shell/QGC and Armour Energy for provision of proprietary data and models for the wider Surat Deep Aquifer Appraisal Project.

Acknowledgements to Schlumberger, Computer Modelling Group and IHS Markit for provision of modelling software
Yanchang oilfield map

Location of CO₂ Capture and Injection Sites
## CO₂ geological Storage Capacity Assessment System

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Wuqi CCUS Pilot Site

- Pay-zone Depth: 2000m
- Injection Pressure: 9.5MPa
- Reservoir Temperature: 60°C
- Liquid Production/well: 2.88m³/d — 3.07m³/d
- Oil Production/well: 1.91 t/d — 2.23 t/d
- Water-cut decrease: 6.5%

Since September 2014, the total amount of CO₂ injection is 380,000 tons.
Project objectives

- Design and implement a long pumping test in Wuqi reservoir (tight reservoir with average permeability of 2mD).
- Achieve a relatively large radius of investigation.
- Quantify any existing heterogeneity/fracture in the reservoir.
- Use dynamic reservoir pressure response acquired from this test to de-risk the prediction of carbon storage capacity and injectivity.
Static and History matched dynamic model

- Wireline logs were interpreted and grid properties were upscaled/distributed across the model.
- Experimental data for Wuqi fluid and rock properties were incorporated into the model.
- 4 water injection wells (blue stars) were in the selected area of interest for this study.
- The monthly historical water injection rates were used in conjunction with history production rates to calibrate the sub-sector model.
Interference test design trial using two monitoring wells

- Well 106 (blue star) was considered as injection well and 101 (located 270 m apart from 106) and 103 (located 325 m apart from 106) (green stars) as the monitoring wells.
- Only well 101, 103 and 106 were shut-in in the model during the test.
- The initial shut-in period of at least 60 days (for base case K=2mD) would be essential to acquire interpretable data at the observation well.
- This needs to follow up with 120 days of injection and 30 days of FO.
- The flow rate needed to be 7 m$^3$/day (44 bbl/day).
60 days Initial shut-in relaxation (101 and 103), 120 days INJ at rate of 44 STB/day (7m³/day) and 30 days FO (210 days total)

- The ROI at injecting well was about 140 m. This is just at the outer edge of water flooded zone. Calculated permeability at the injection well was 0.29 mD.
The INJ data at observation well was matched with the type-curve, resulting in $K = 0.45\, \text{mD}$ and $0.51\, \text{mD}$ at well 101 and 103, respectively.

60 days Initial shut-in relaxation (101 and 103), 120 days INJ at rate of 44 STB/day ($7\, \text{m}^3/\text{day}$) and 30 days FO (210 days total)

Interpretation of INJ pressure response at observation wells (101 and 103) using type-curve matching described by Earlougher (1977).
60 days Initial shut-in relaxation (101 and 103), 120 days INJ at rate of 44 STB/day (7m³/day) and 30 days FO (210 days total) followed by 60 days of CO₂ injection (4000 sm³/day) and 90 days of shutin (BHP<=200bar)

The log-log plot derived from the CO₂ injection into the water flooded oil reservoir would potentially predict the gas front and water front as well as the formation (relative) permeability change when CO₂ is introduced to the reservoir.
Summary

- This is a low permeability reservoir. Thus, any new disturbance to the reservoir system causes long lasting effects that make the data collection/interpretation challenging.

- The interference test with two monitoring wells sequence with a follow-up CO$_2$ injection test is the most favourable, achieving the test objectives of establishing the reservoir characteristics and constraining dynamic CO$_2$ storage capacity within a reasonable testing time.

- The largest current uncertainty remains to be the bulk reservoir permeability.
Summary (2)

- Based on assumptions about permeability the best test options are:

  **Phase 1**  Interference test: “A” days initial shut-in relaxation at the monitoring (101 and 103) wells, “B” days INJ at the injection (106) well at rate of 44 STB/day and “C” days FO;

  **Phase 2**  The INJ-FO test will be followed by CO₂ INJ and FO with the period of “D” and “E”, respectively.

- Note*: As the test is being run and real time P/T readout is observed, we will be able to determine which permeability scenario is most likely and make decisions on test segment duration accordingly.

<table>
<thead>
<tr>
<th>Average permeability (mD)</th>
<th>Initial shutin time (day)</th>
<th>Injection period (day)</th>
<th>Fall off period (day)</th>
<th>CO₂ injection (day)</th>
<th>CO₂ falloff period (day)</th>
<th>Total testing period (day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>60</td>
<td>120</td>
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<td>30</td>
<td>60</td>
<td>90</td>
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Thank you