Enhanced Coalbed Methane (ECBM) Field Test at South Qinshui Basin, Shanxi Province, China

Bill Gunter, Sam Wong, David Law, ARC
Feng Sanli,Ye Jianping, Fan Zhiqiang, CUCBM

GCEP workshop
August 22-23, 2005 Beijing

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ECBM Project in China

Micro Pilot

to Pilot

to Commercial Demonstration

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Micro-Pilot Test Goals

- To measure and evaluate data to obtain estimates of reservoir properties and sorption behavior
- To calibrate a simulation model for estimation of the enhancement of CBM recovery in a larger-scale pilot or full field development

Enhancement of CBM recovery can not be estimated directly from micro-pilot test data

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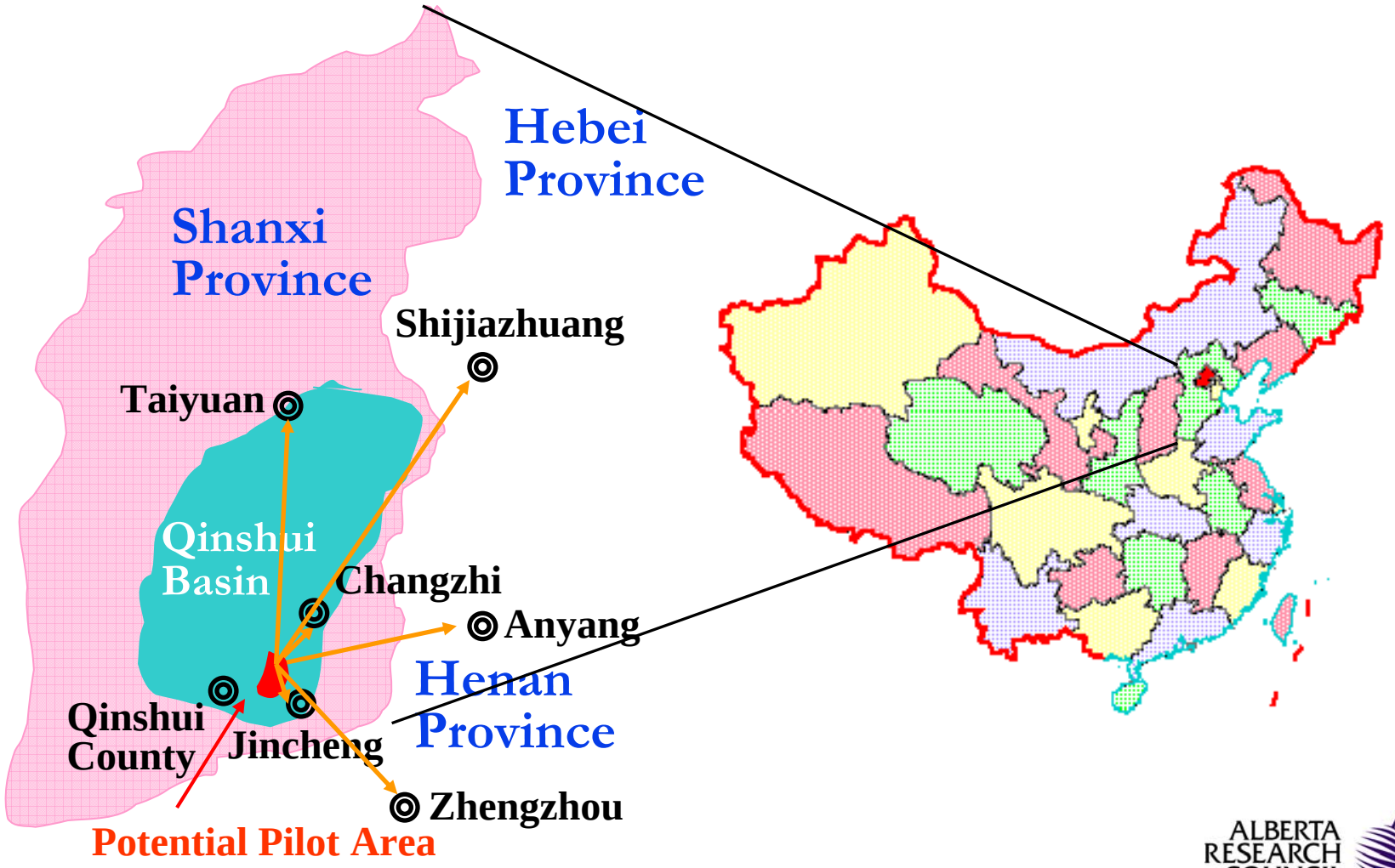
Demonstration Site Location



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Attractiveness of Qinshui Basin

- Large areal extent
- Thick, laterally continuous coal seams
- Highest gas contents measured in China
- Relatively shallow depths of coal seams
- Reasonable access to local and distant markets (West to East Pipeline is 30-90 km from south Qinhsui at Jincheng)
- Relatively more explored than other basins

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Coal Characteristics

- Qinshui Basin: 24,000 km^2
  - CBM Resource: 5.5 trillion sm^3
- Primary CBM recovery performance in South Qinshui Basin (CUCBM owned 20+ wells)
  - Peak rate: 5,000 – 16,000 sm^3/d
- High rank semi-Anthracite and Anthracite coal
  - Vitrinite reflectance: 2.7 – 4%

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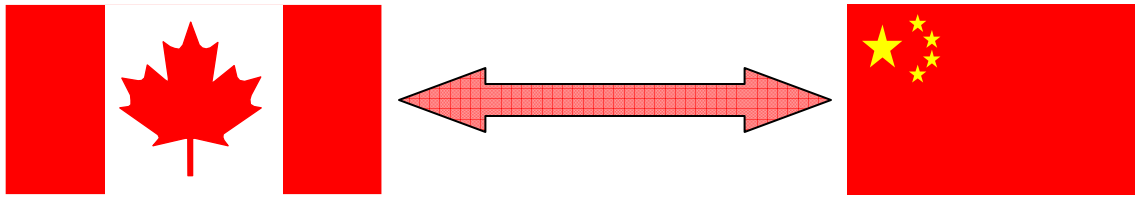
China ECBM Project



Canadian International Development Agency (CIDA)

Ministry of Commerce (MOFCOM)

Canadian Climate Change Development Fund (CCCDF) (CA $ 5 million)

China United Coalbed Methane Corporation Ltd. (CUCBM) (CA $ 5 million)

3.5 - year CA $ 10 million Project (Started March 2002)

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Major Tasks

- Potential pilot site selection
- Geological/engineering/environmental characterization and ranking of selected 3 pilot sites
- Design of micro-pilot field test procedures to evaluate CBM reservoir properties
- Carry out a single well micro-pilot field test at the best suitable site
  - Selection of existing wells or drilling new wells
  - Up to three micro-pilot tests will be performed if first two tests do not show commercial potential

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Major Tasks (Continued)

- Micro-pilot test evaluation and numerical model calibration and fine tuning
- Large-scale pilot design leading to commercial production
- Training and technology transfer to be conducted in Canada and China

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Site Visit

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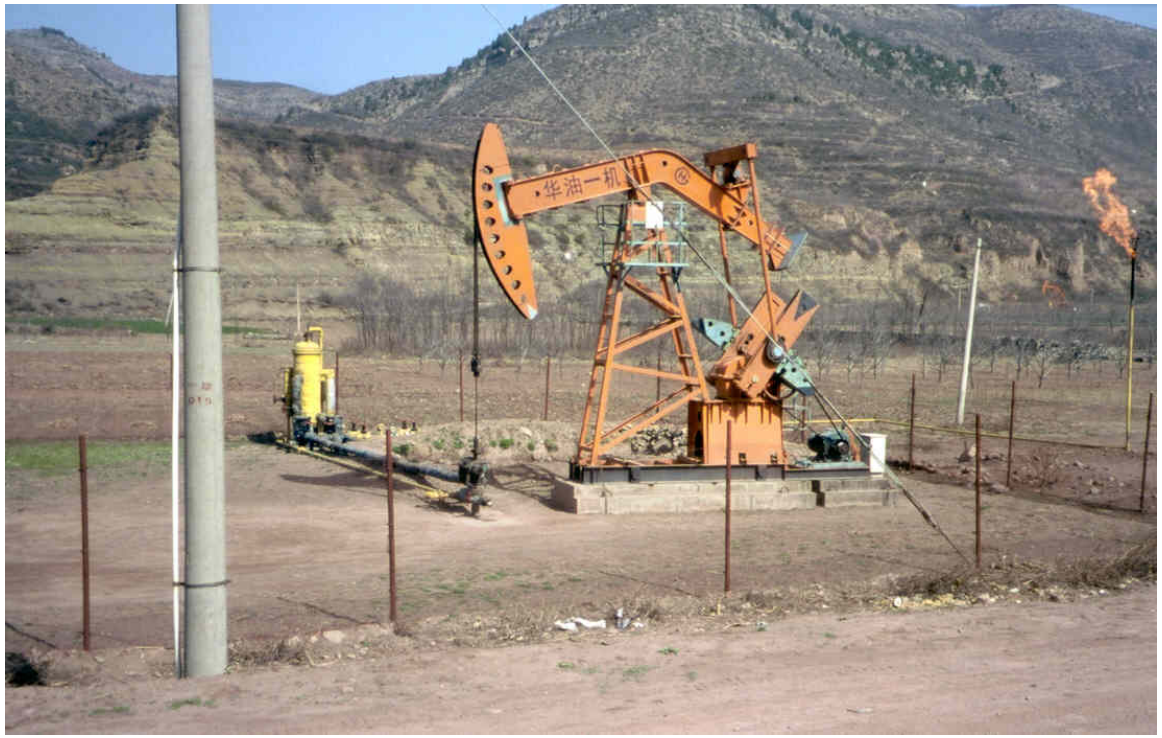
Primary CBM Recovery Operation

CBM Production Well



Gas / Water Separator

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Target Coal Seam Well for Field Test

- No. 3 seam – Shanxi Formation
  - Age: Carboniferous Permian coal
  - Depth: 478 meters
  - Average thickness: 6 meters
  - Reservoir temperature & pressure
    25C & 500 psi
- To isolate seam from lower No. 15 seam, a bridge plug set in TL003 well at 573 meters

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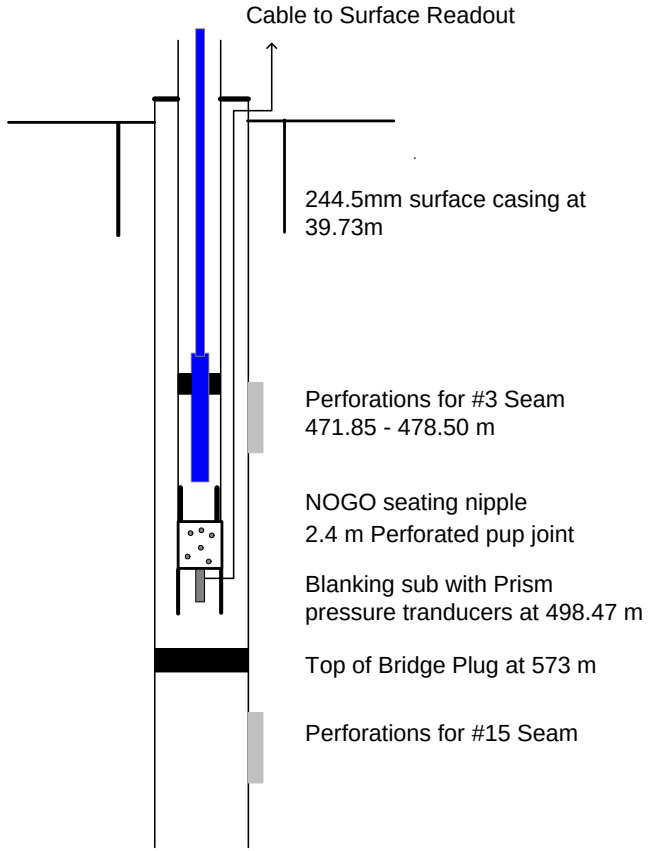
Well Configuration

- Downhole gauges
- Perforated pup
- Nogo seating nipple
- pump
- wellhead



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Downhole Gauge Installation

- Installed 2 sensors
  - 0 – 1500 psi range
  - 0.025% full scale accuracy
  - 0.0003% resolution
  - 120 C temperature
- Signals transmitted via multi-conductor electro-mechanical wireline cable
- Surface Readout
  - Live data readouts
  - 1M data points storage capacity

Gauge Carrier

Surface Readouts

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On-line Gas Chromatograph

- Capable of measuring produced gas composition "on-line"
- Separates and quantitates:
  - CO_2, CH_4, O_2, N_2, C_2-C_4, H_2S
- Analysis every 5 minutes initially & decreased to 1/ hr as pilot continues
- Baseline Composition: CH_4- 96.3%, CO_2 – 0.5%, N_2 – 3.67%, C_2 – 0.01%

Wang Guoqiang

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TLOO3 Wellsite & Wellhead

Instrument Trailer

Well head with Downhole gauge packoff

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CO_2 Injection Strategy

- Goal is to inject 200 tonnes into reservoir over a 12 day period. Each truck can transport 18 tonnes of CO_2
- Injection rate to be maintained below reservoir fracture pressure (1100 psi)
- Estimate average injection rate of 30L/min over 8-10 hr period

Zhongyuan Oilfield CO_2 Truck Fleet

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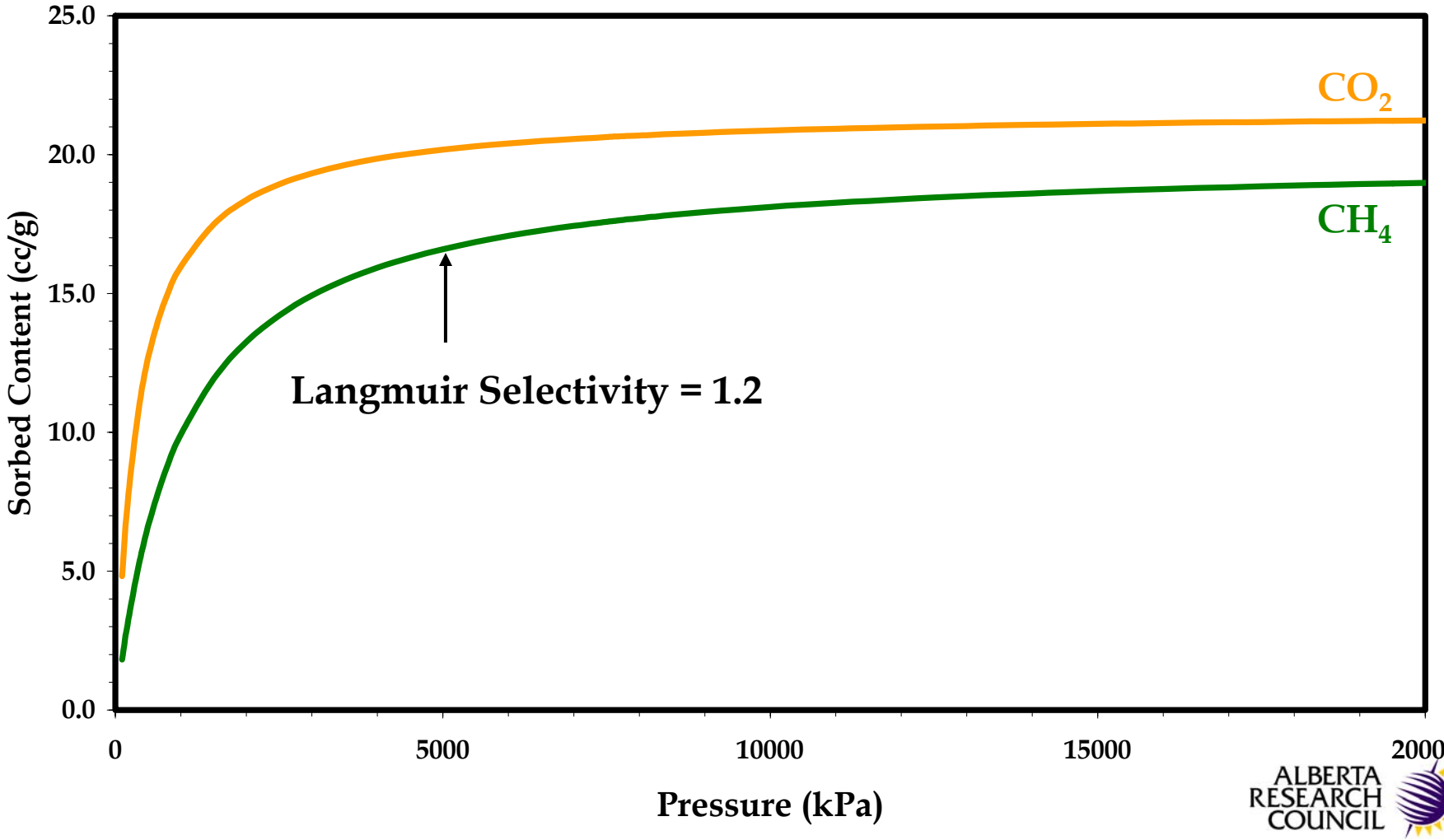
Injecting Liquid CO_2

Adsorption Isotherms

Qinshui Basin



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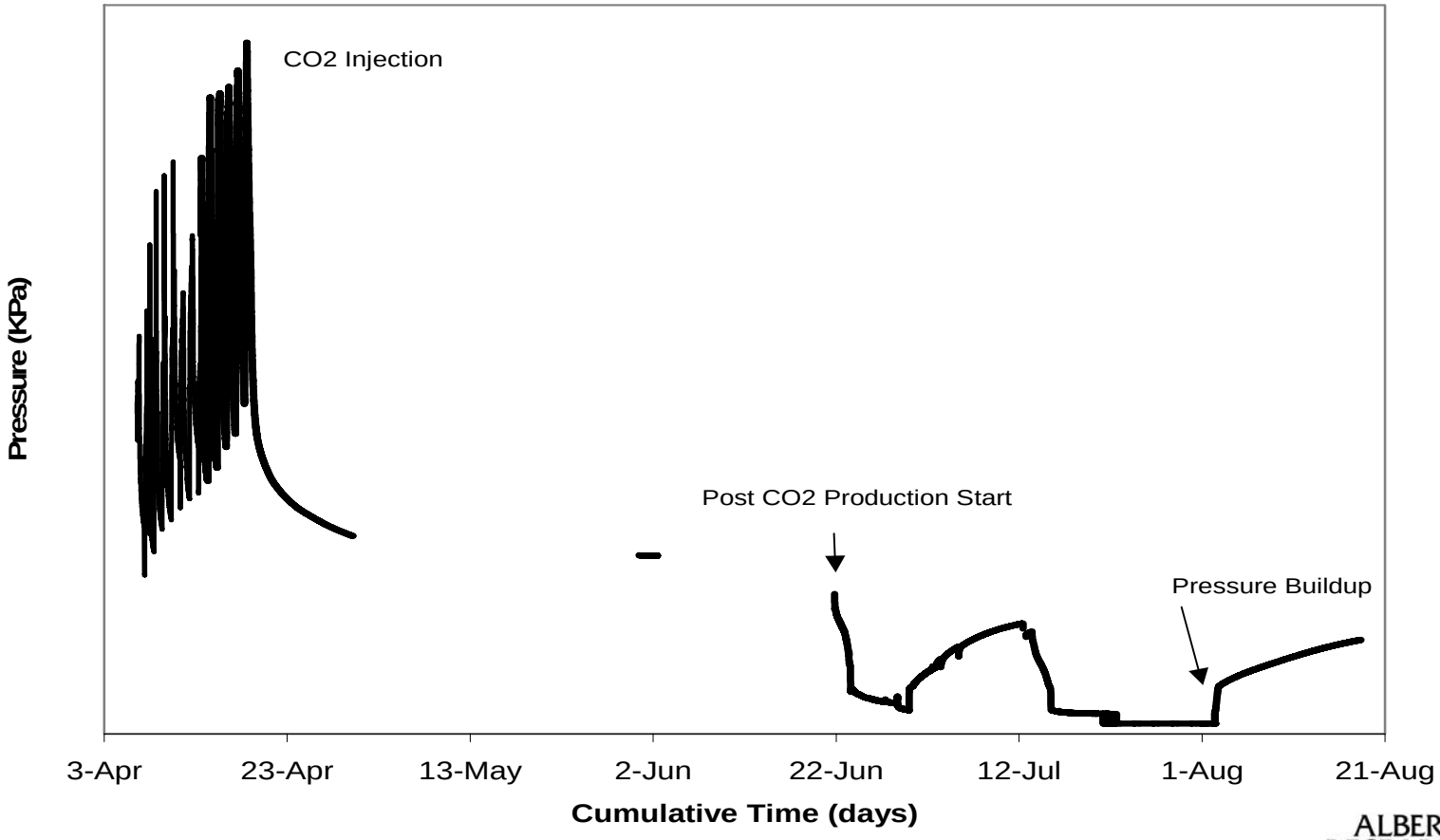
Bottom-hole Pressure During Final Production Test



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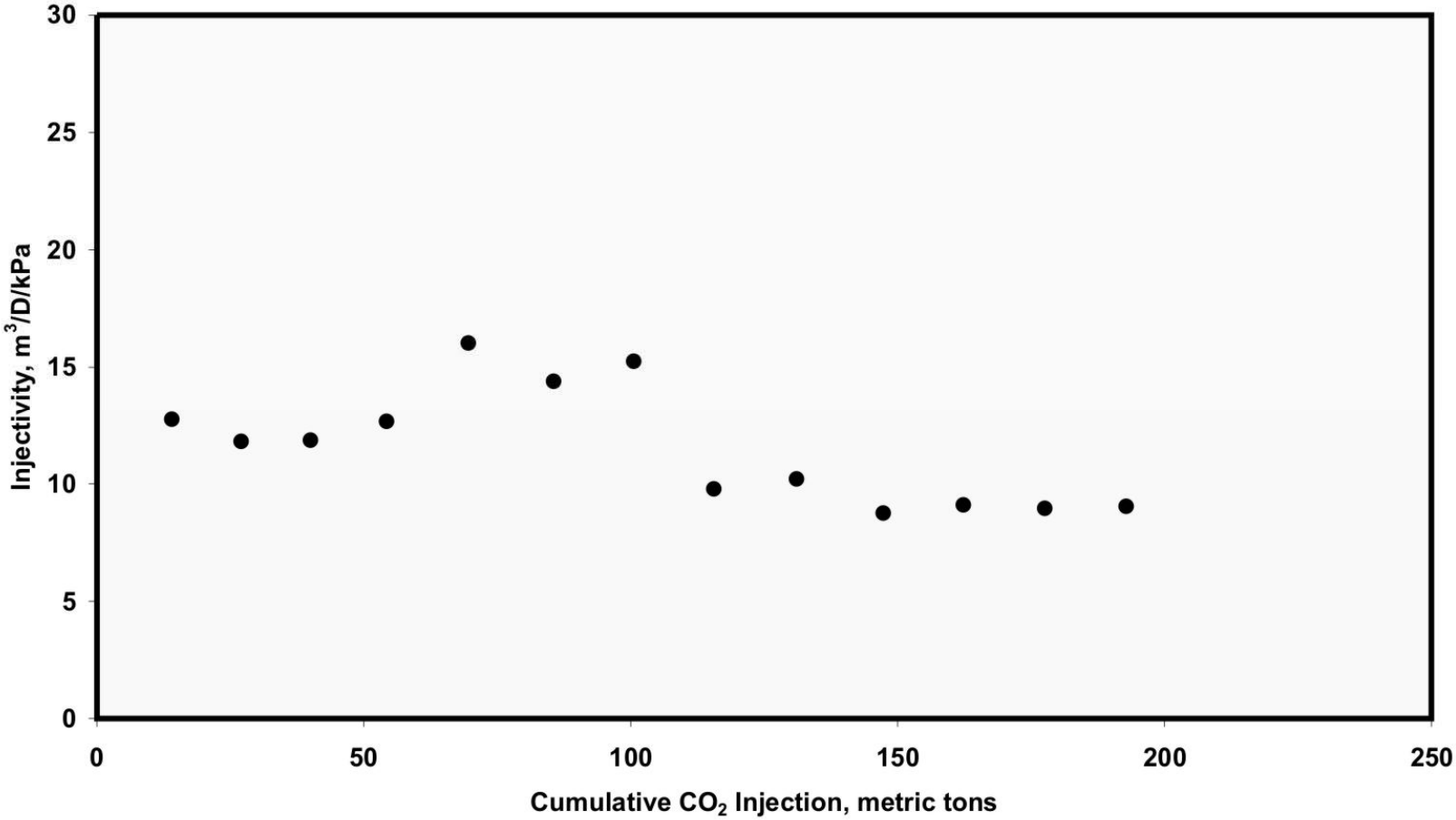
Injectivity versus Cumulative CO_2



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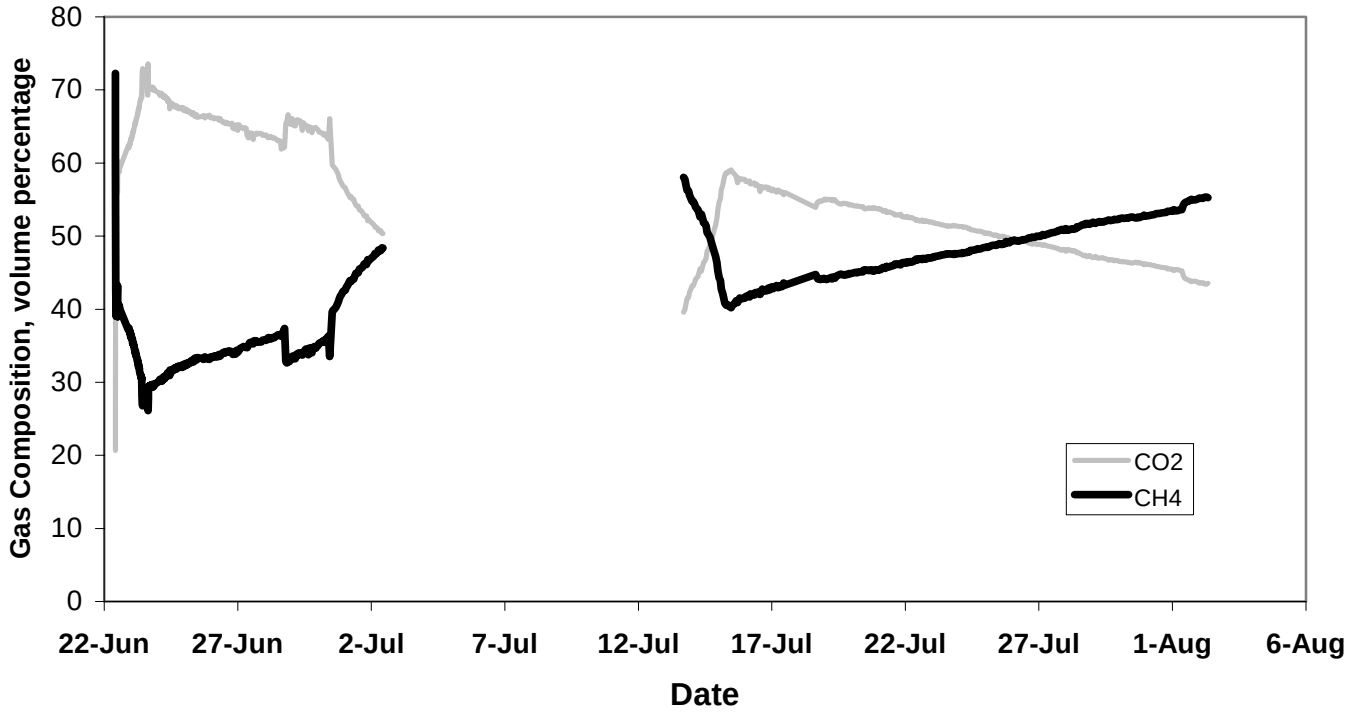
Gas Composition During Final Production Test



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Results

- The average pressure of seam #3 is 1,241 kPa at a depth of 472 m
- Absolute permeability of the coal seam prior to CO_2 injection was 12 md, which was based on an effective permeability of gas of 2 md and a gas saturation of 40.8%
- 192 metric tonnes of CO_2 was injected
- Injectivity decreased during injection but permeability rebounded after an extended production period of 1 month

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Summary

- **The micro-pilot test as conducted in the South Qinshui TL-003 well has been completed successfully and has met all the technical objectives of the micro-pilot test.**

- **The history matching of the dataset from the micro-pilot and the simulation prediction for the multi-well pilot indicated a significant production enhancement compared to primary production, and that substantial CO_2 storage in the coal seam is feasible in a multi-well project.**

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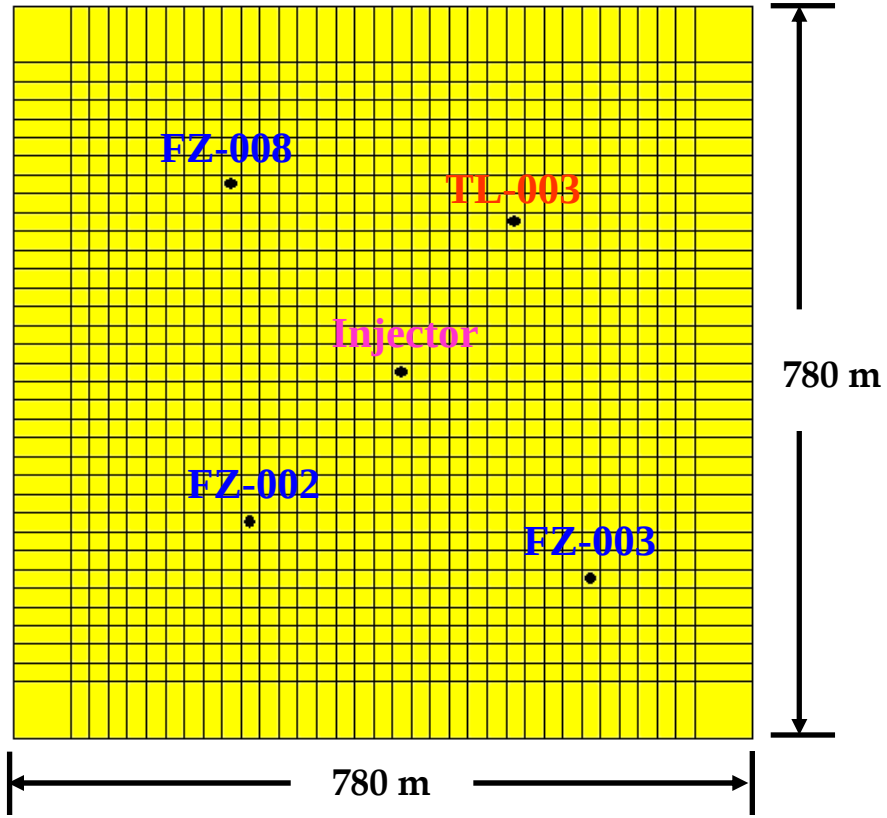
5-Spot Field Pilot Test

Numerical Grid System

Region of Investigation:



Rectangular Grid:

35 × 35 × 3

(Seam #3, Water zone, Seam #15)

Grid Block Size:

20 m × 20 m

(except boundary grid blocks)

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Design of 5-Spot Field Pilot Test

Numerical Simulation Scenario

- Continue after history matching run (November 19, 2003)
- Start CO_2 injection at new injector at a constant rate of 22,653 m^3/d (0.8 MMscf/d)
  - Inject CO_2 at coal seam #3 only
- Continuous production at all four Wells FZ-002, FZ-003, FZ-008 and TL-003 at 1,560, 2,400, 1,400 and 1,450 kPa, respectively)

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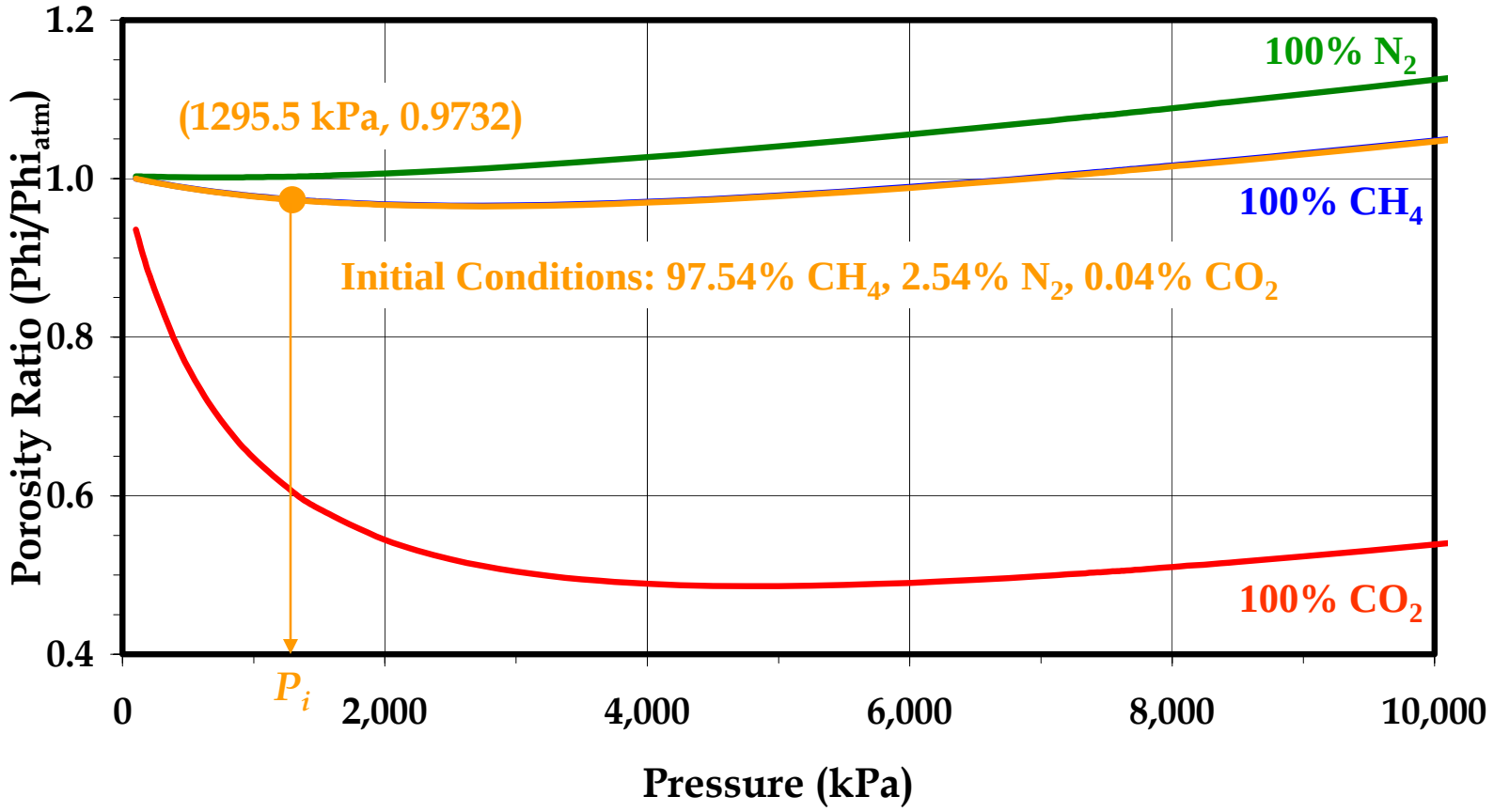
ARC Permeability Theory

Fracture Porosity used in Reservoir Simulation



$$\phi_{atm} = 0.00822 \Rightarrow \phi_i = 0.008$$

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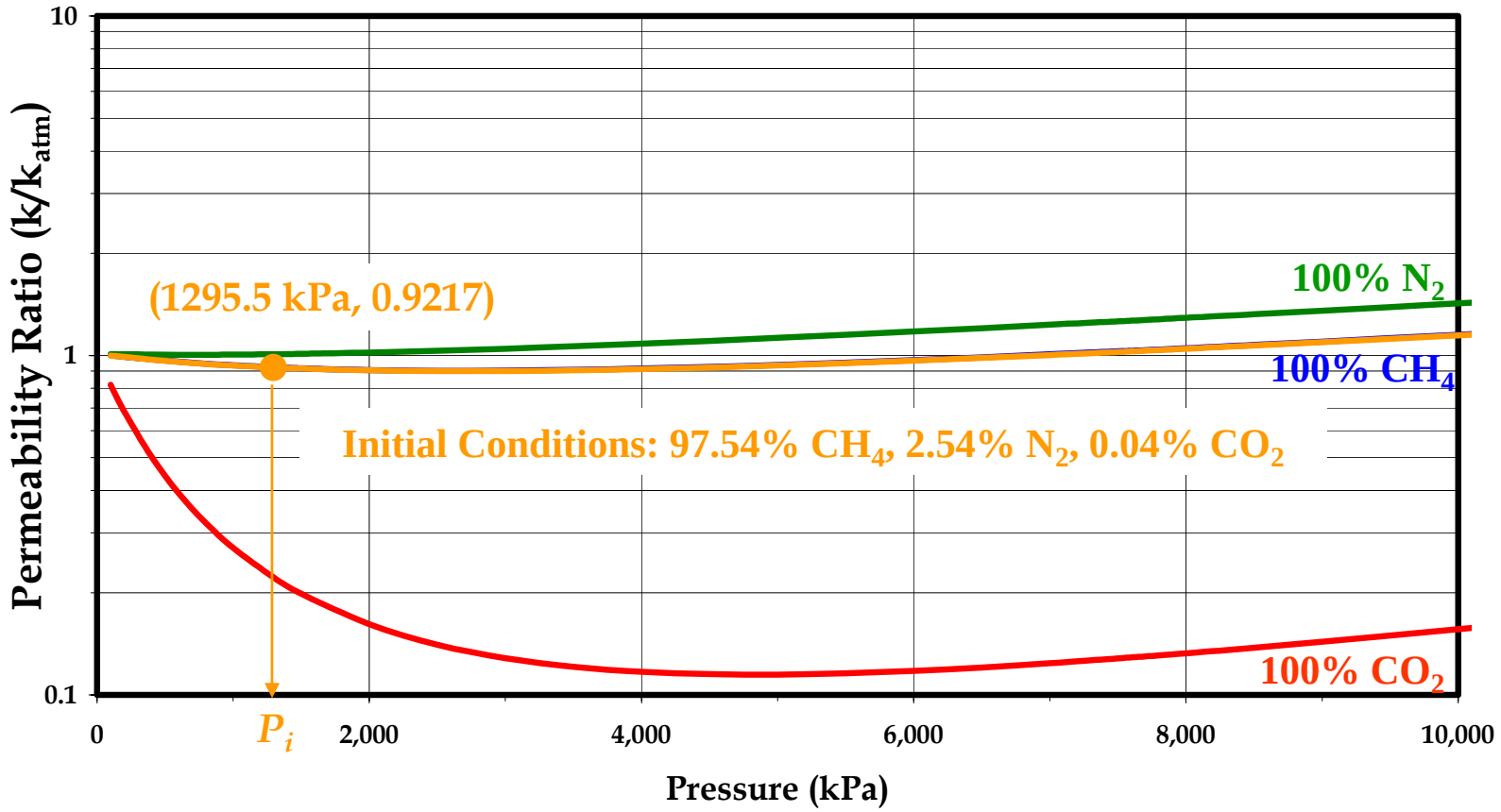
ARC Permeability Theory

Fracture Permeability used in Reservoir Simulation



k_{atm} = 13.67 md $\Rightarrow$ k_i = 12.6 md

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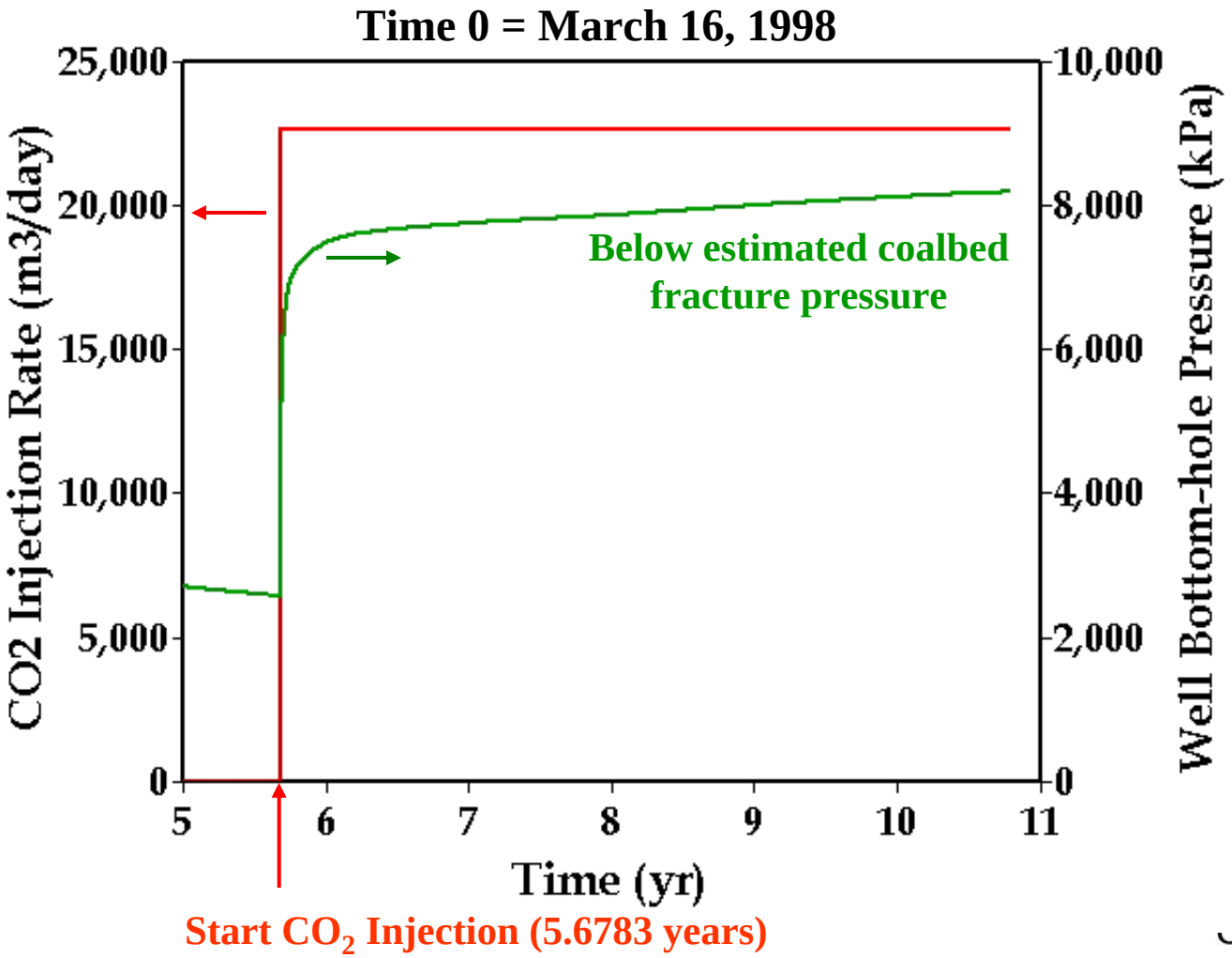
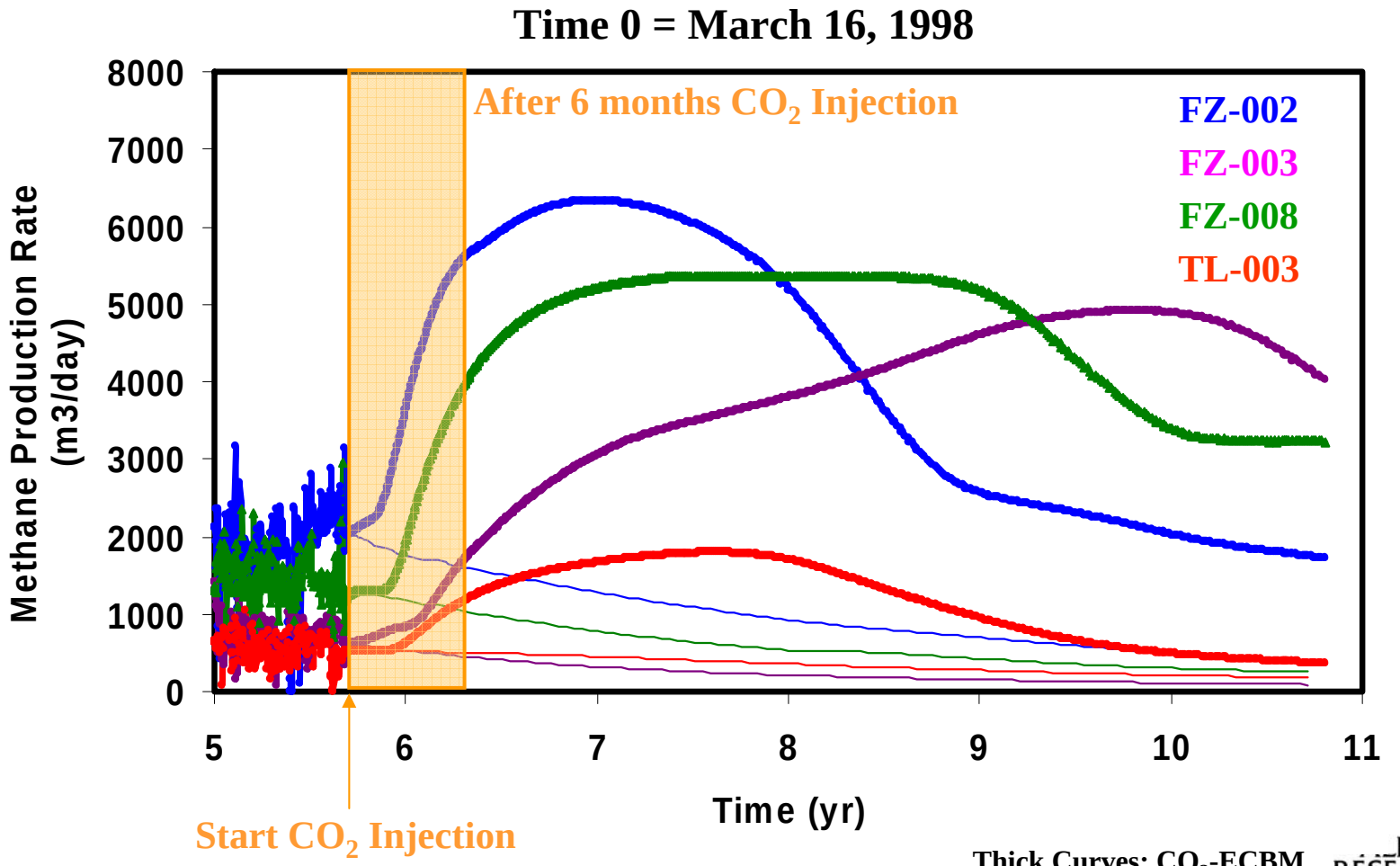
5-Spot Field Pilot Test

CO_2 Injection



5-Spot Field Pilot Test

Methane Production Rate



Thick Curves: CO_2-ECBM
Thin Curves: Primary CBM

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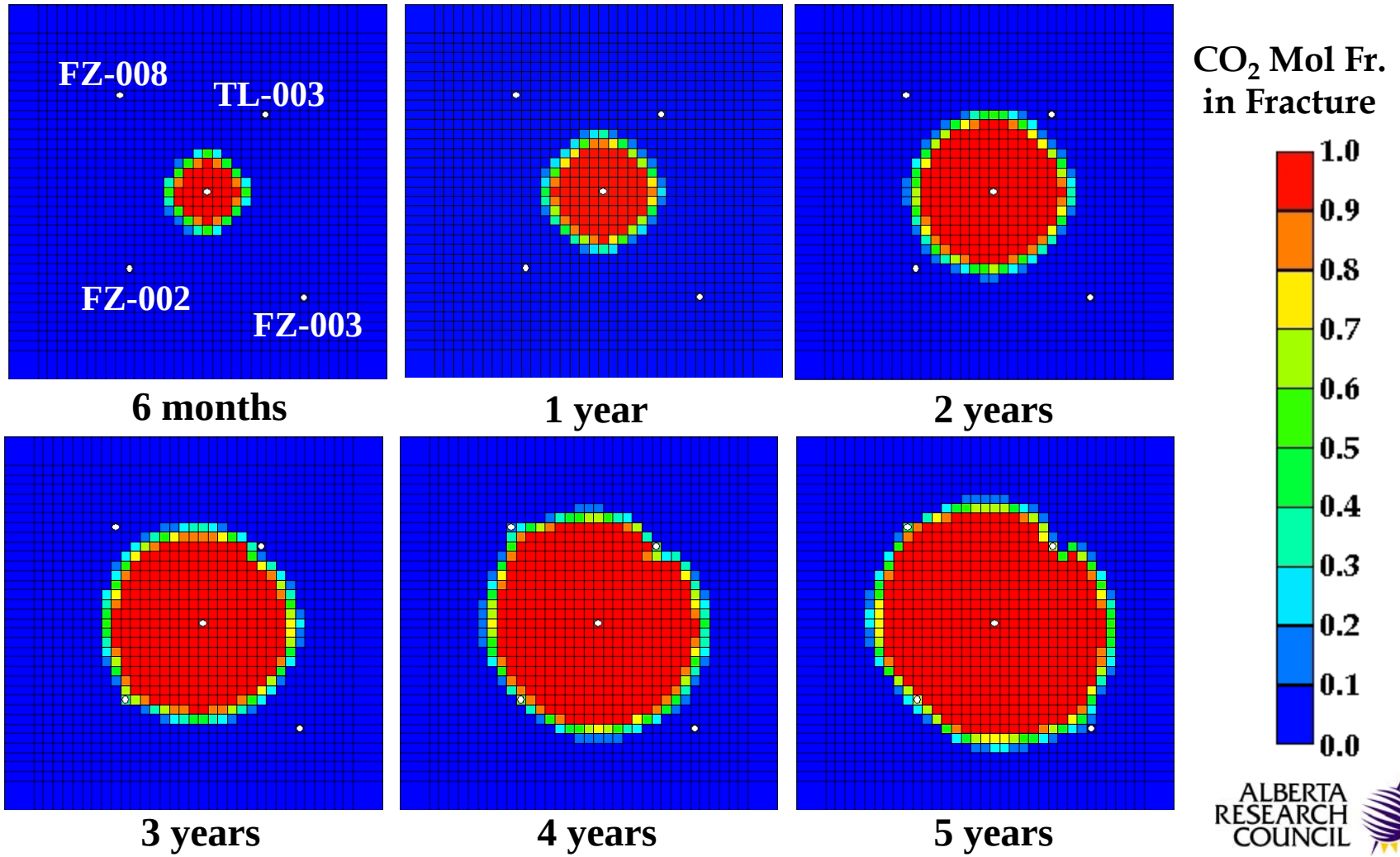
5-Spot Field Pilot Test

CO_2 Distribution in Coal Seam #3



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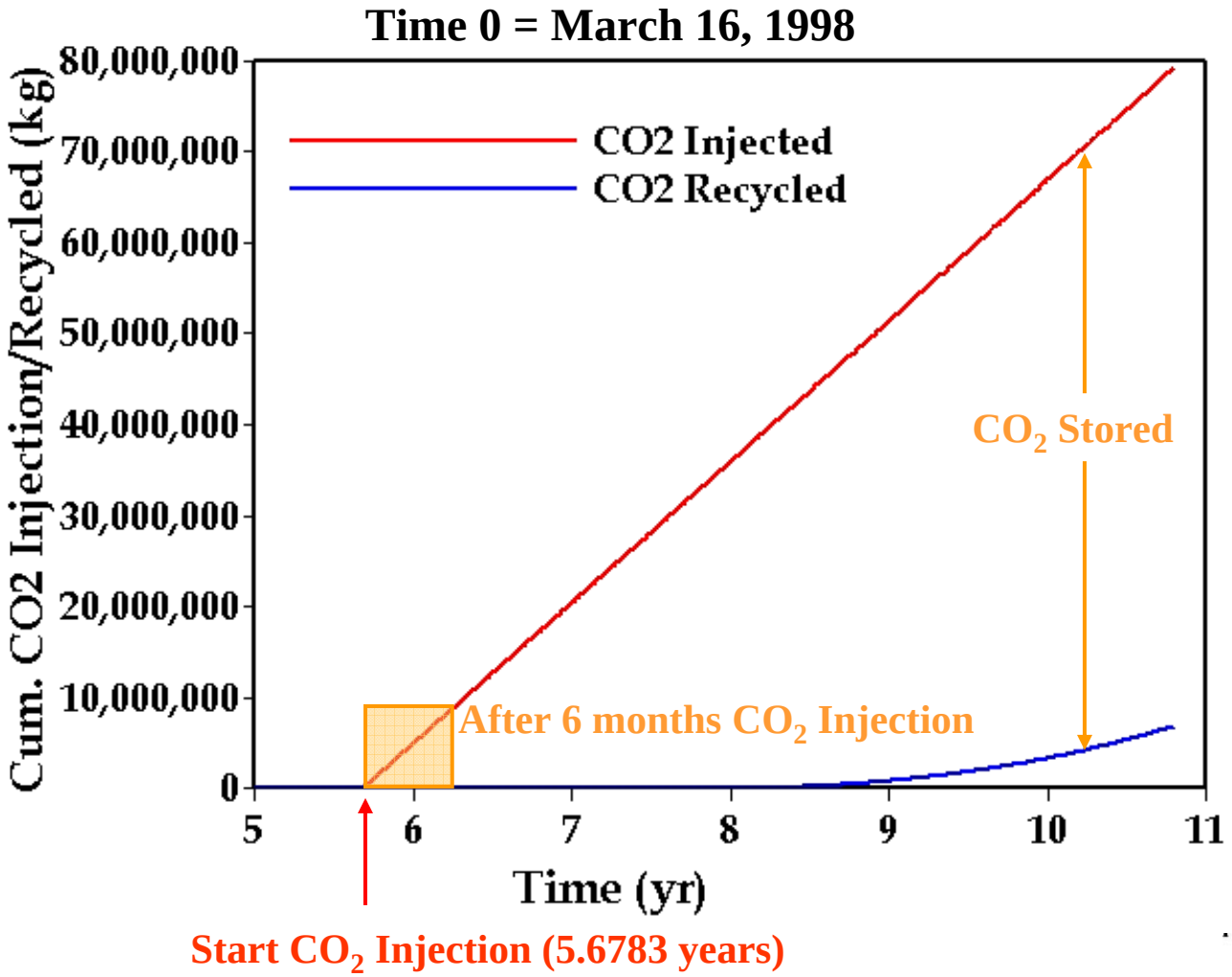
5-Spot Field Pilot Test

CO_2 Inventory



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5-Spot Field Pilot Test

Performance Prediction

Well	FZ-002	FZ-003	FZ-008	TL-003
CO_2 Breakthrough Time* (year after CO_2 injection)	2.6822	5.1233	3.8274	3.1205
Average CH_4 Production Rate before CO_2 breakthrough (m^3/day)	5,275	3,600	4,657	1,394
	1,883	240	718	405
Peak CH_4 Production Rate before CO_2 breakthrough (m^3/day)	6,319	4,901	5,355	1,789
	2,036	627	1,305	520
Enhancement Factor**	2.80	15.00	6.49	3.44

* Time after CO_2 injection when 10% CO_2 occurred in production gas stream

** Ratio of average CH_4 production rate: (CO_2-ECBM) / (Primary CBM)

CO_2-ECBM | Primary CBM

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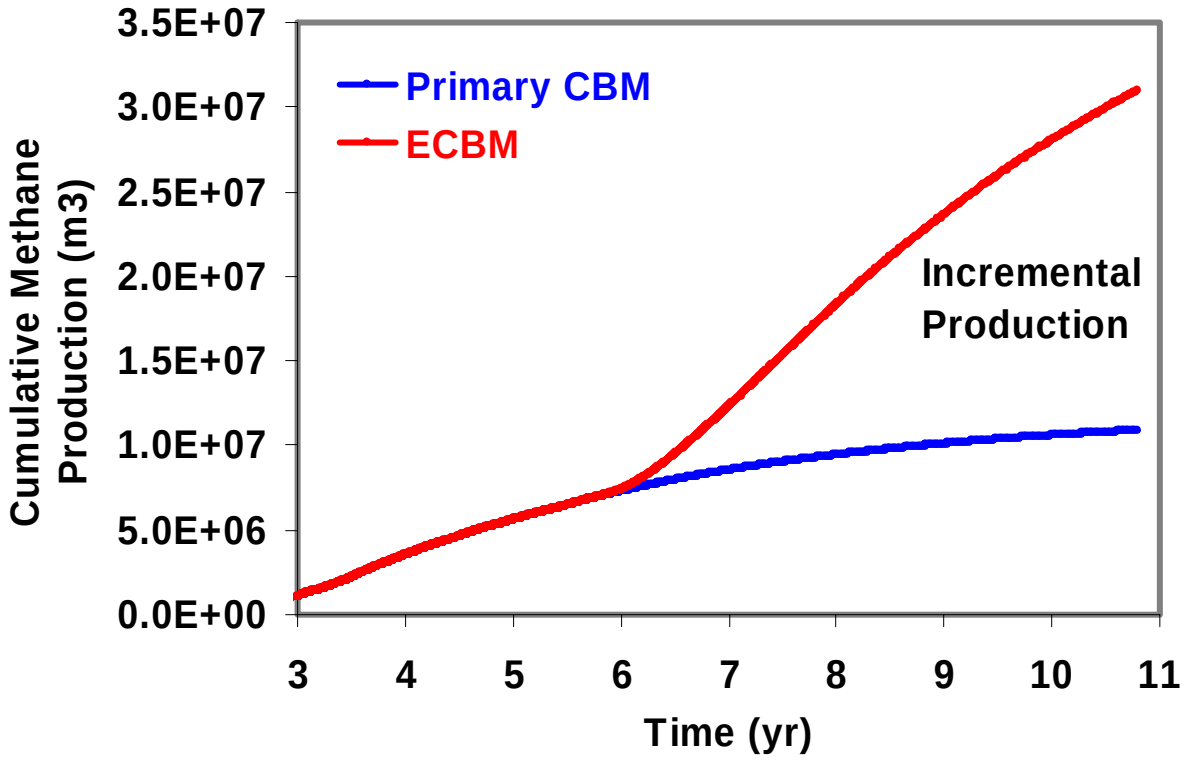
5-Spot Field Pilot Test

Cumulative CBM Production



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5-Spot Field Pilot Test

Recommendation

- 20-acre 5-spot field pilot:
  - Four corner producers are existing CBM Wells FZ-002, FZ-003, FZ-008 and TL-003
  - Drill one new injector located approximately at the center of the pattern
- Inject CO_2 continuously at new injector at a constant rate of 22,653 m^3/d (0.8 MMscf/d) for 6 months
  - Enhancement of CH_4 production should be observed at all producers even though no CO_2 breakthrough should be observed at all producers

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