# Current Status of $CO_2$ Injection Projects in Croatia

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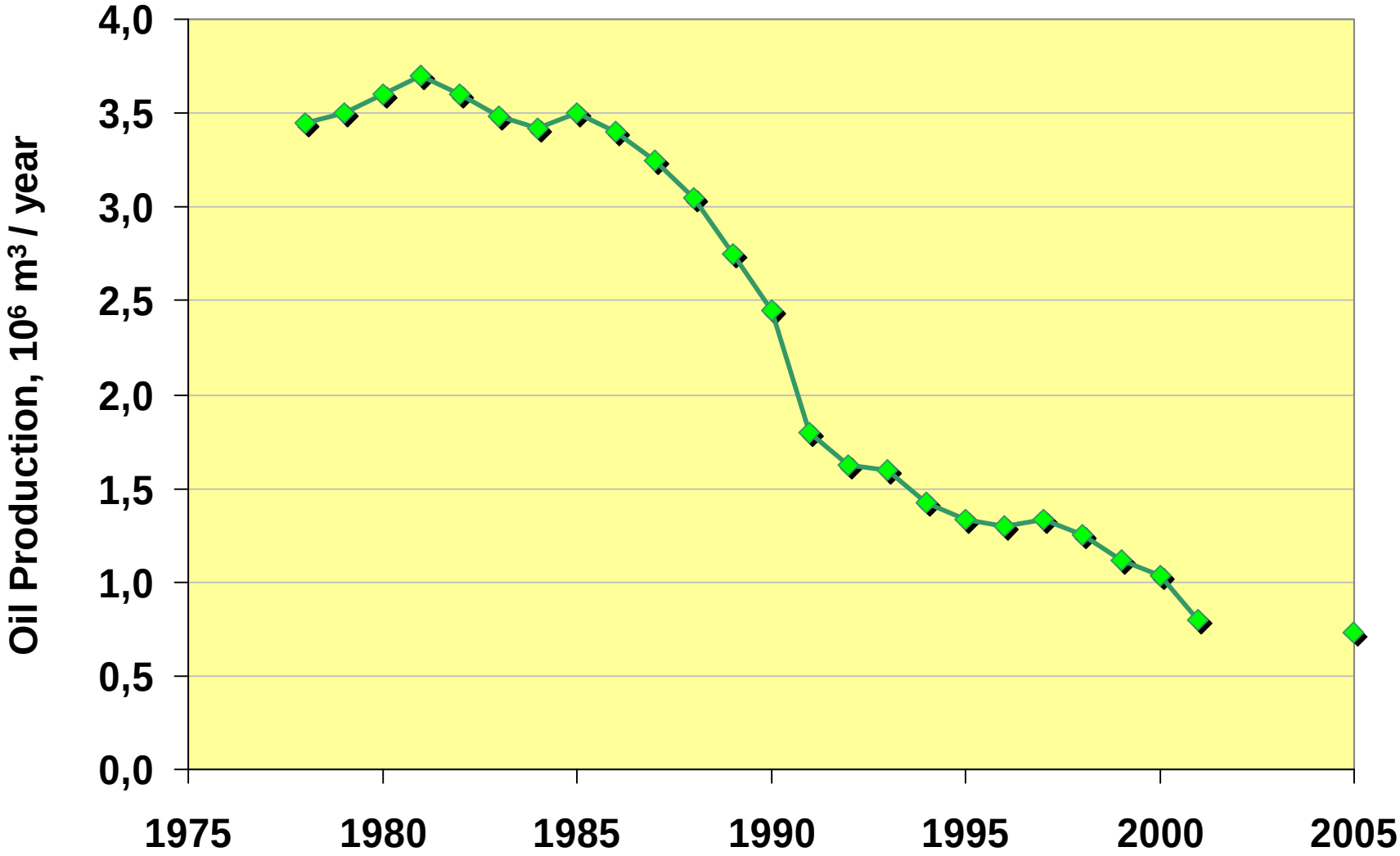
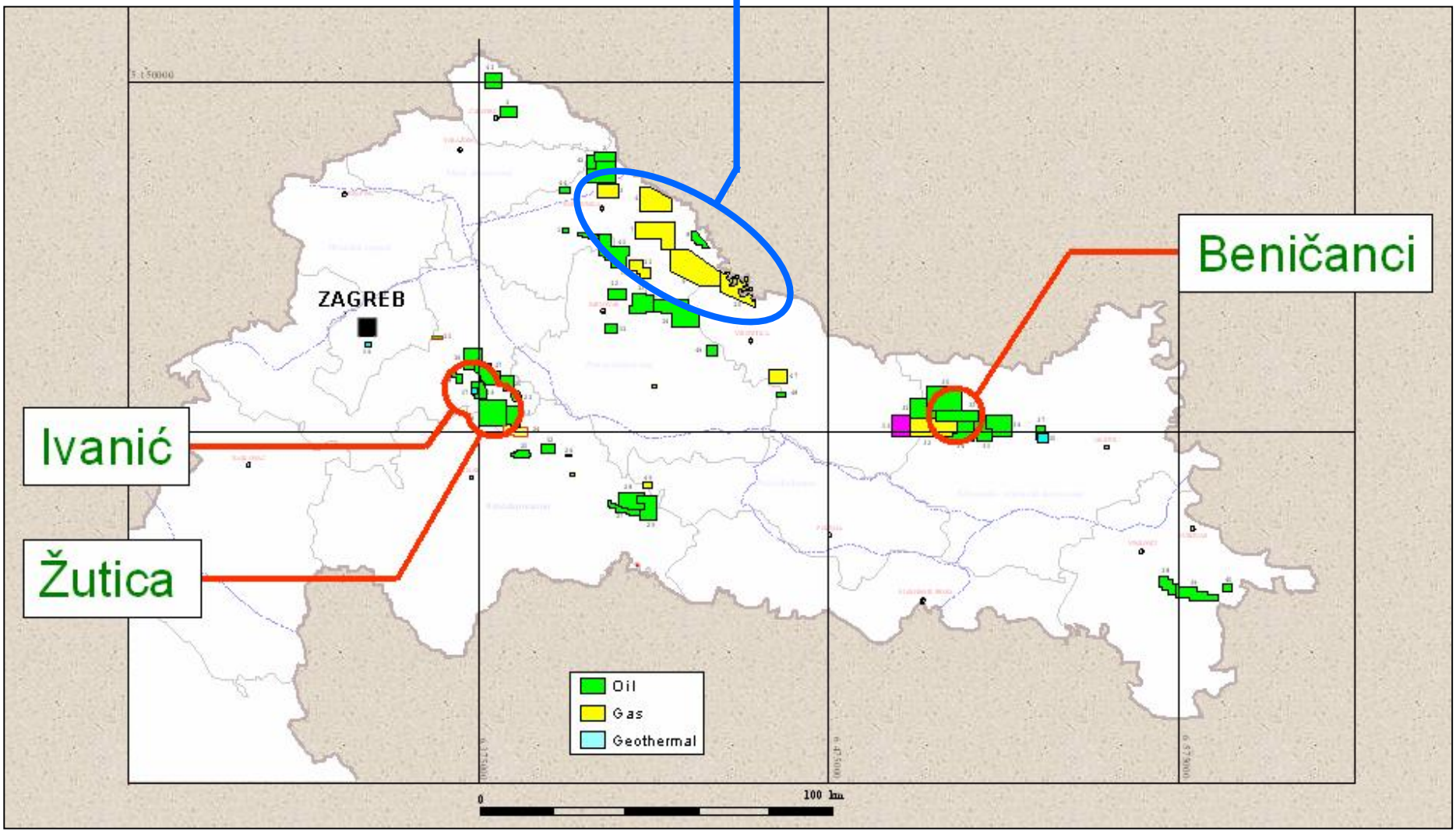
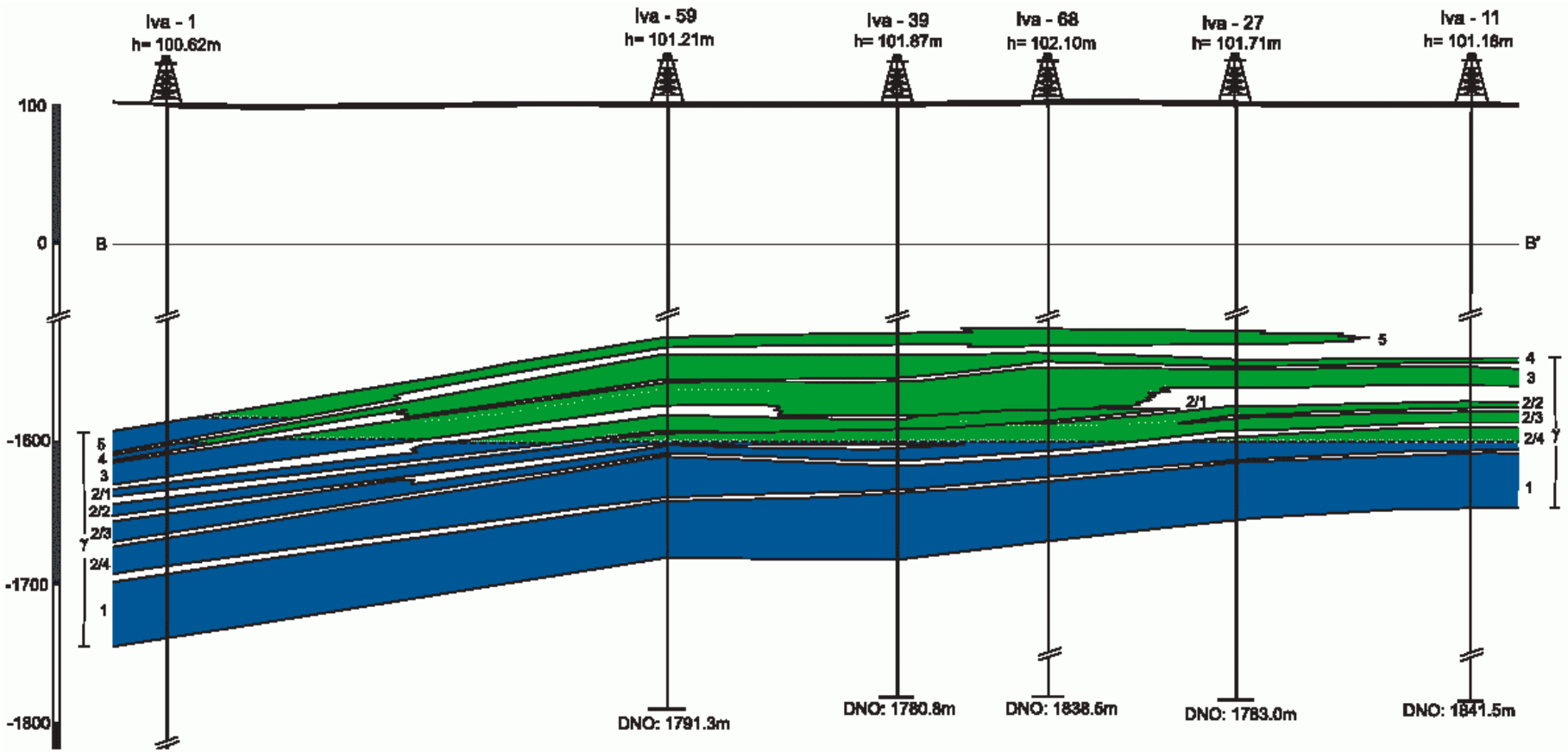
# Production Decline in Croatia



# EOR Candidates and $CO_2$ Sources



# Ivanić Oil Field




Miocene sandstones

$\phi$ = 21.5 - 23.6 %

k = 14.6 - 79.6 mD

OOIP = 21.62 × $10^6$ $m^3$

Maximum recovery = 44%

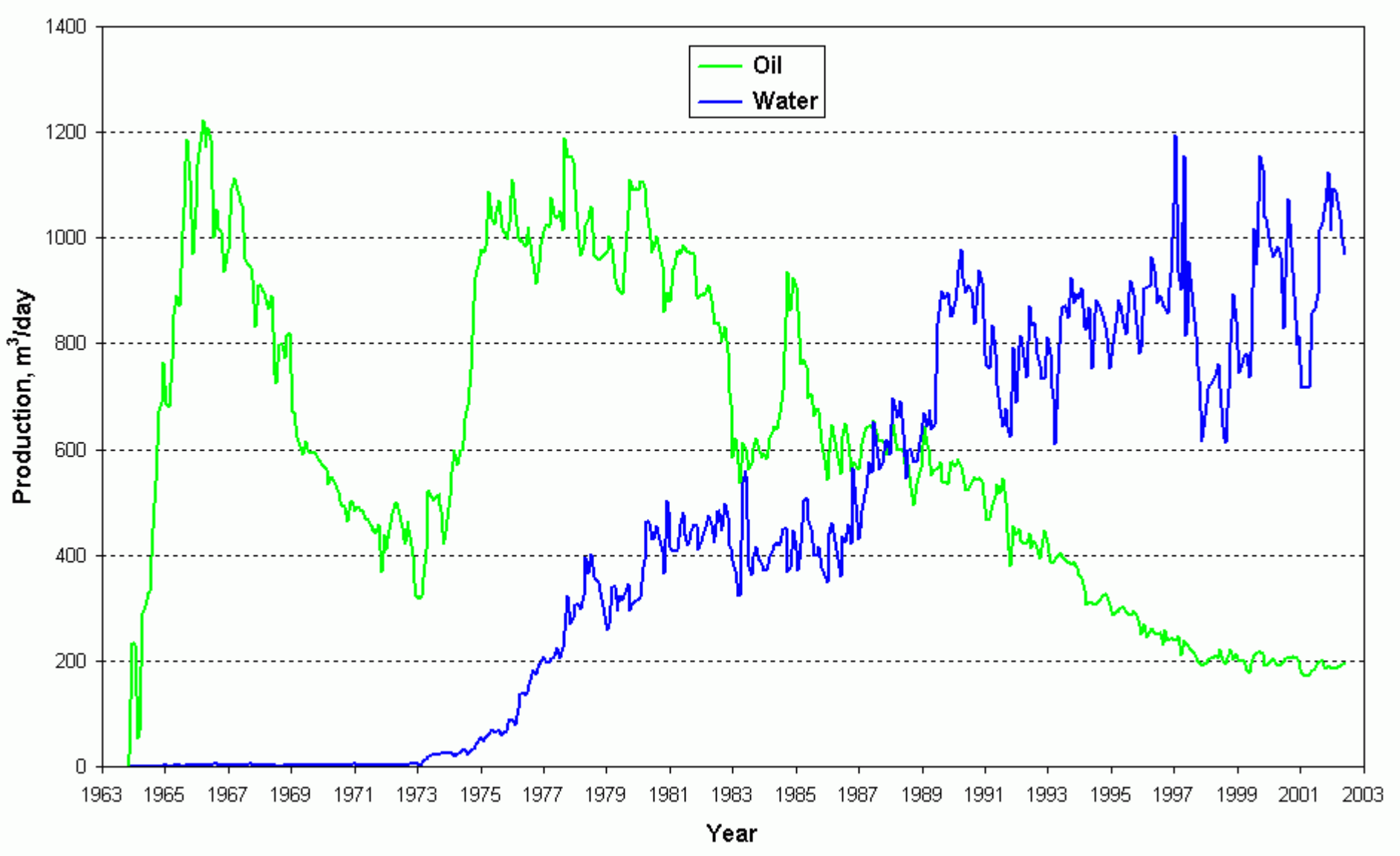
Remaining = 0.68 × $10^6$ $m^3$

T = 97.8°C

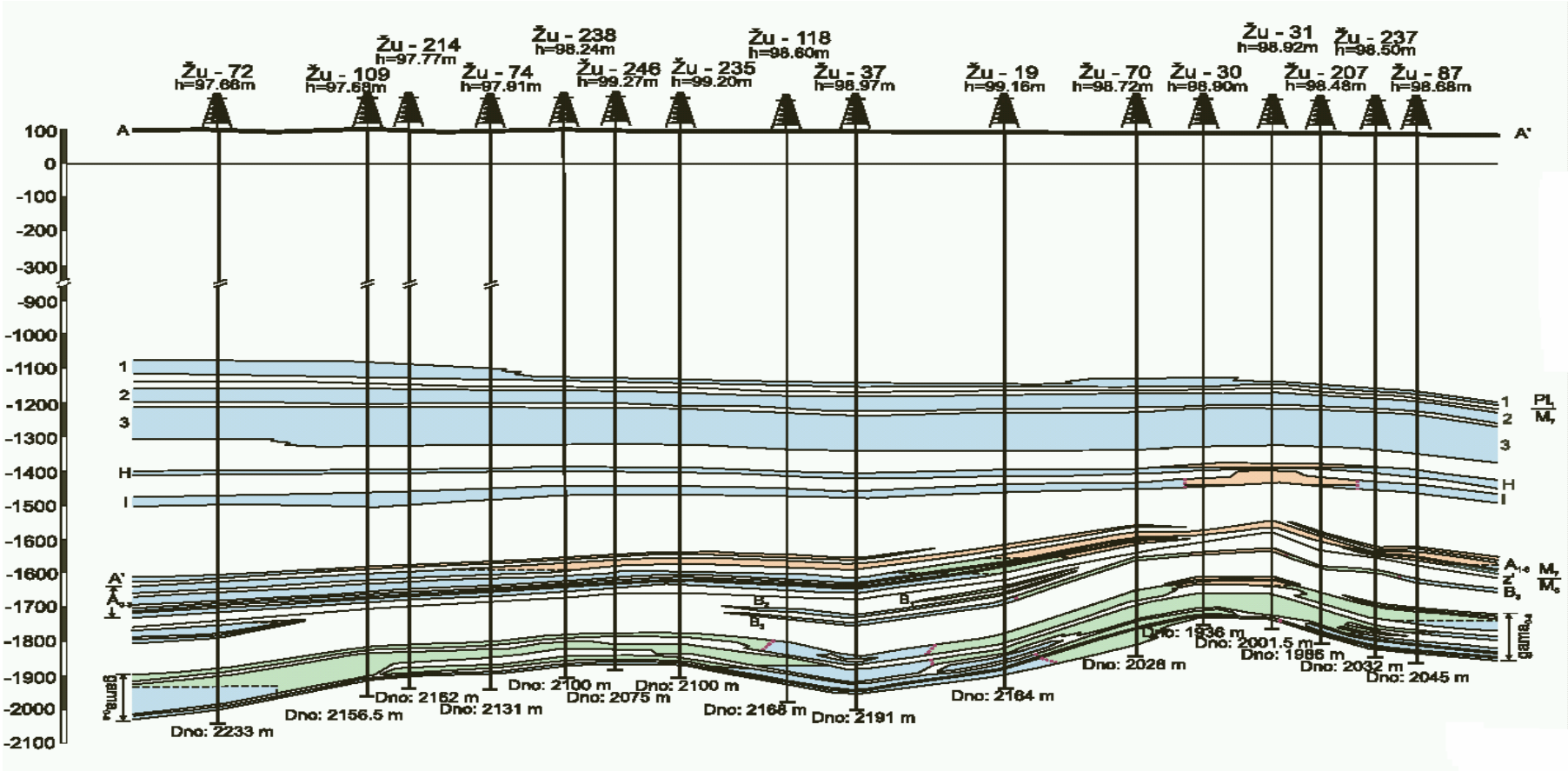
$P_i$ = 183 bar

33.4°API oil

# Ivanić Production History

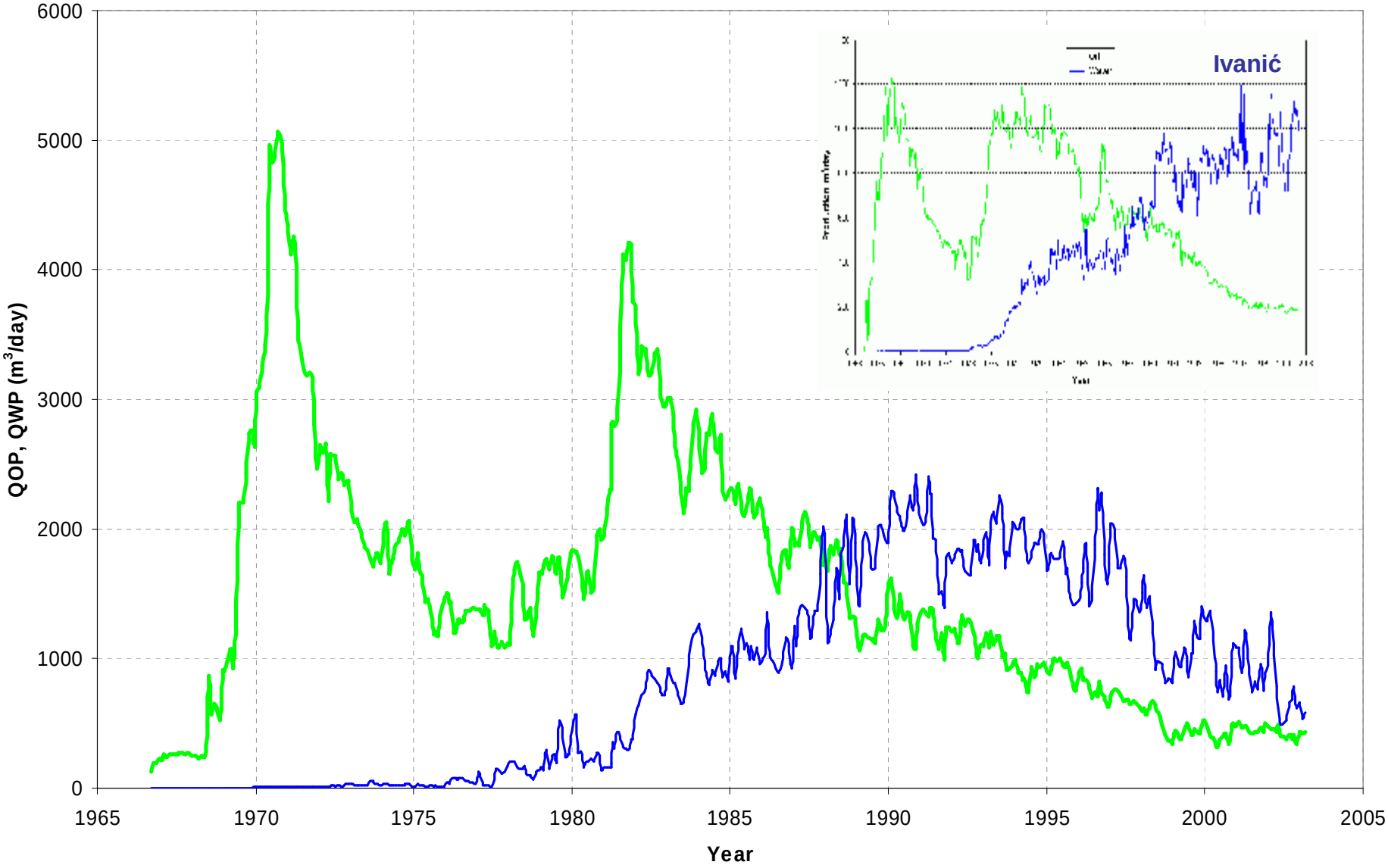


# Žutica Oil Field



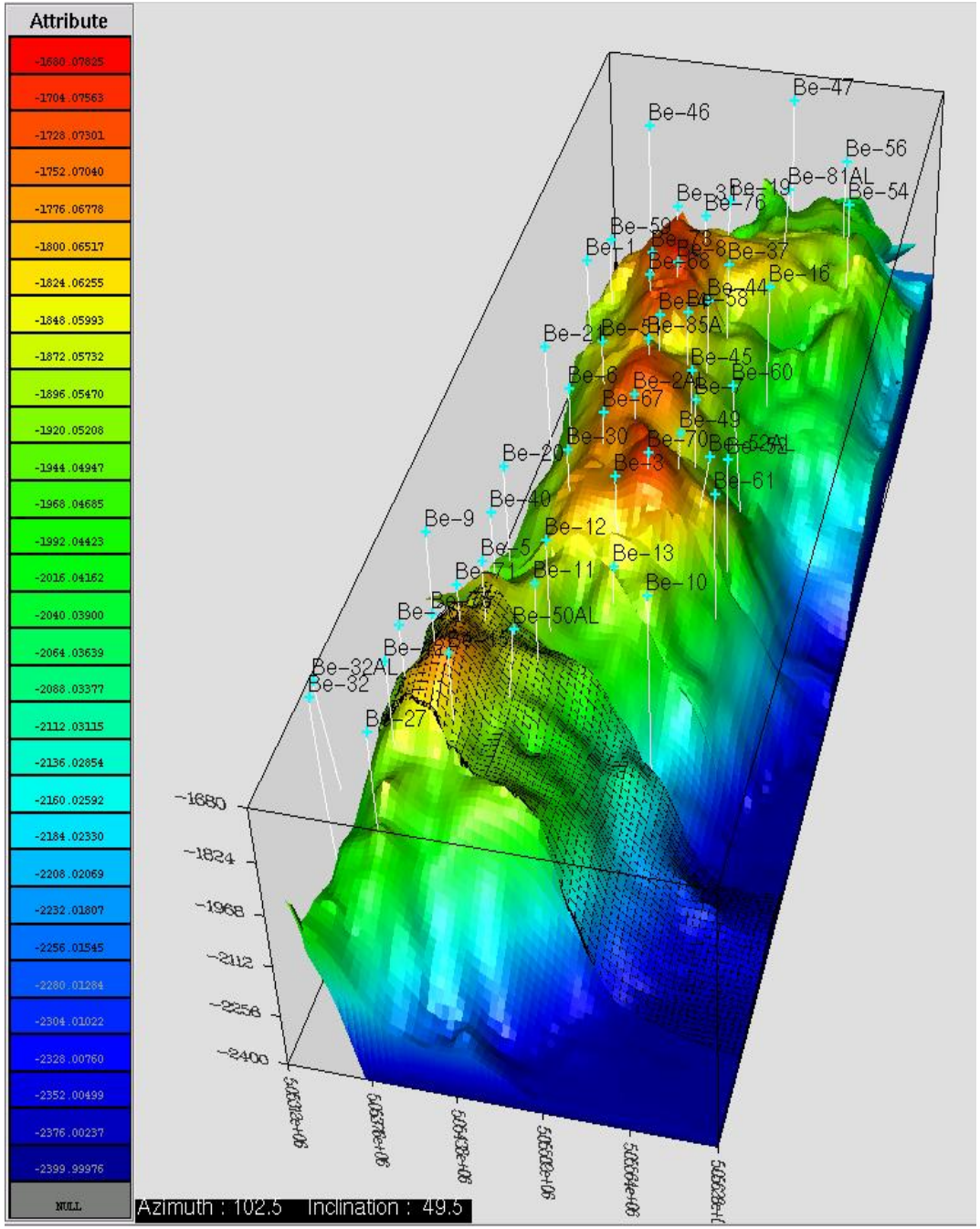

| | | |
|---|---|---|
| Miocene sandstones | OOIP = 52.37 × $10^6$ $m^3$ | T = 110.7°C |
| $\phi$ = 16-22% | Maximum recovery = 35% | $P_i$ = 211 bar |
| k = 5-90 mD | Remaining = 0.66 × $10^6$ $m^3$ | 33.8°API oil |

# Žutica Production History



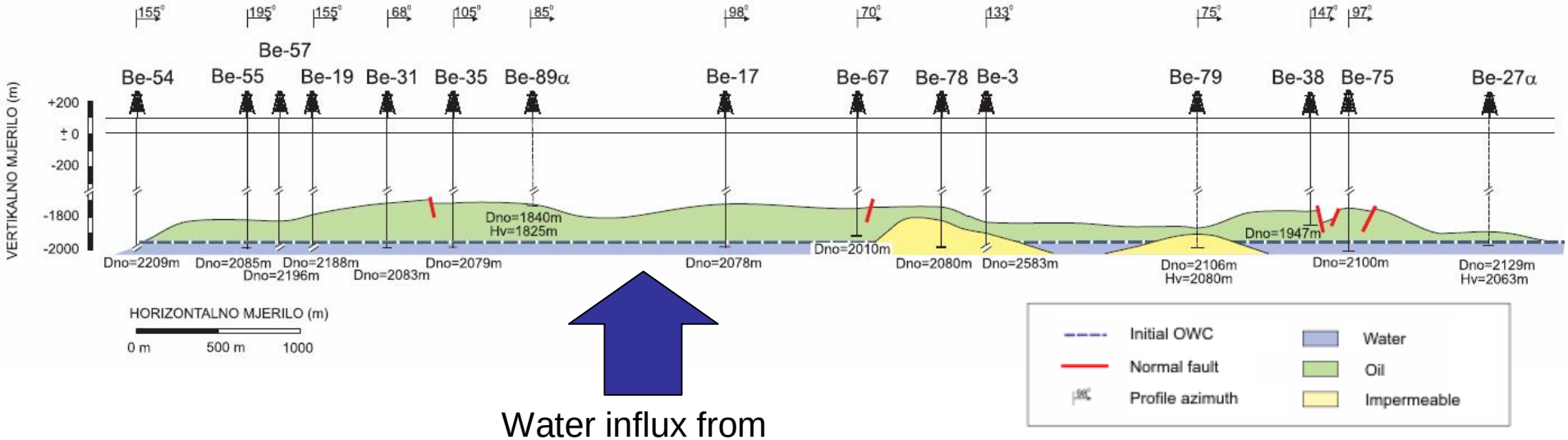
# Beničanci

- Massive structure
- Structural / stratigraphical trap
- Miocene breccias (limestone/dolomite)
- OWC = 1955 m ssl
- Closure = 266 m
- $\Phi_{average}$ = 8%
- $k_{average}$ = 200 mD



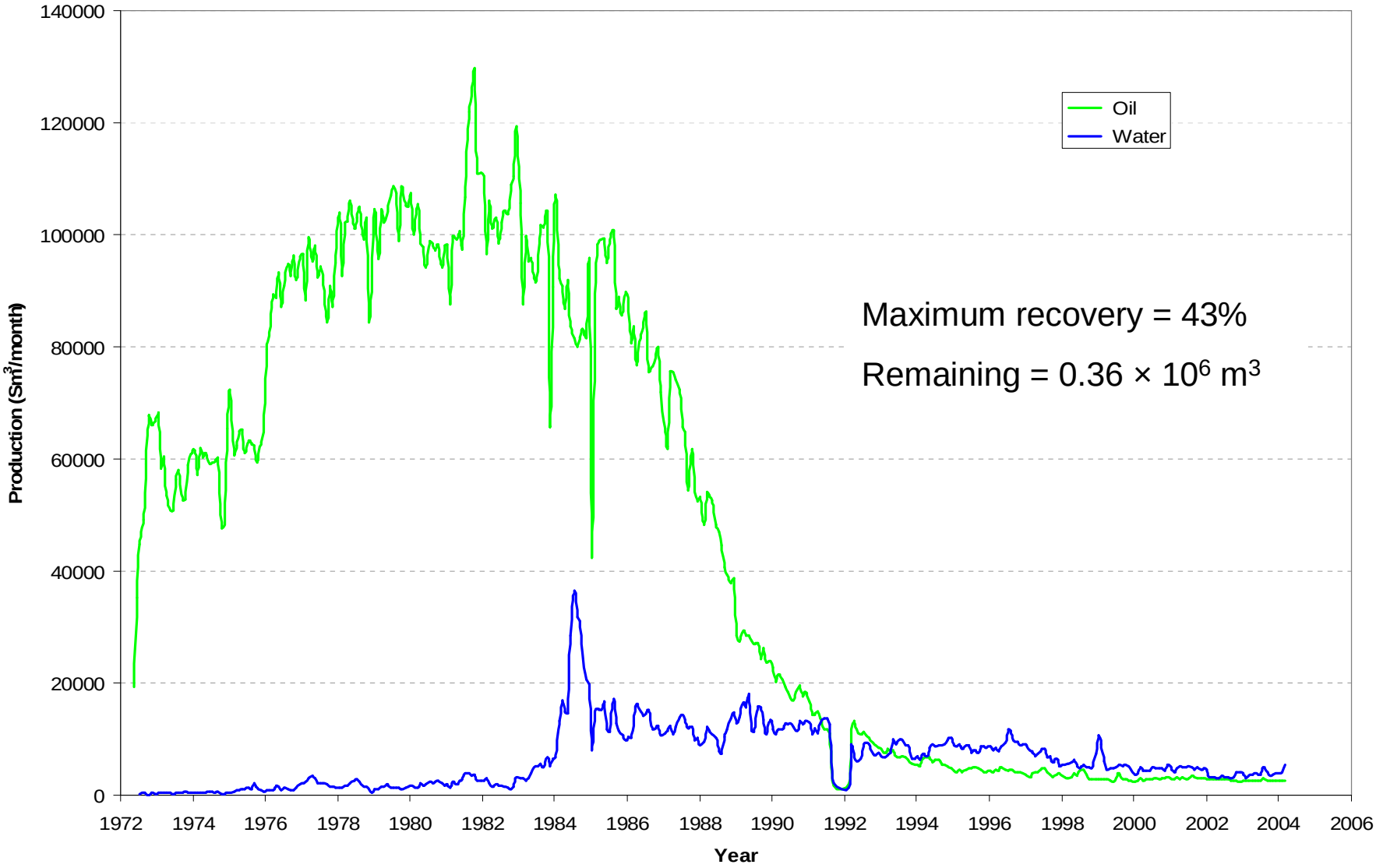
# Beničanci Engineering Data

| | |
|---|---|
| Temperature: | 123.3°C |
| Initial $P_{res}$ : | 191.0 bar ($P_b$ = 147.1 bar) |
| Actual $P_{res}$ : | ≈ 165 bar |
| Energy regime: | water drive (+ pressure maintenance by water injection into aquifer) |
| OOIP: | 41.8 × $10^6$ $m^3$ |
| Production: | since 1972 |
| Water injection: | started 1975 (at $P_{res}$ = 167 bar, recovery = 4.9%) |




Water influx from bottom aquifer

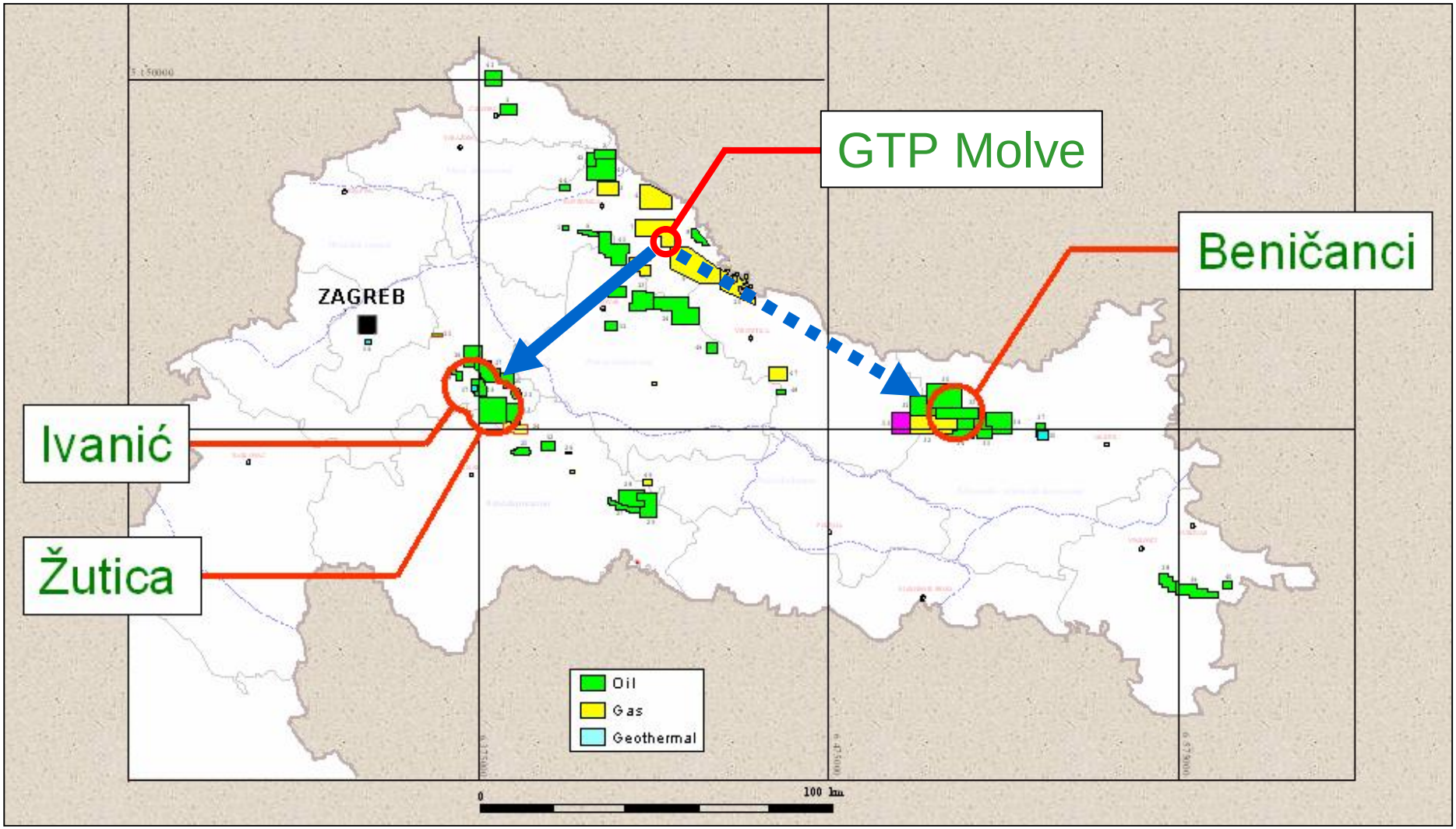
# Beničanci Production History



# Initial EOR Concept

- $CO_2$ injection in all three fields
  - → Near-miscible WAG: Ivanić, Žutica
  - → Immiscible crestal injection: Beničanci
- $CO_2$ captured at GTP Molve, transported by pipelines

# $CO_2$ Transport

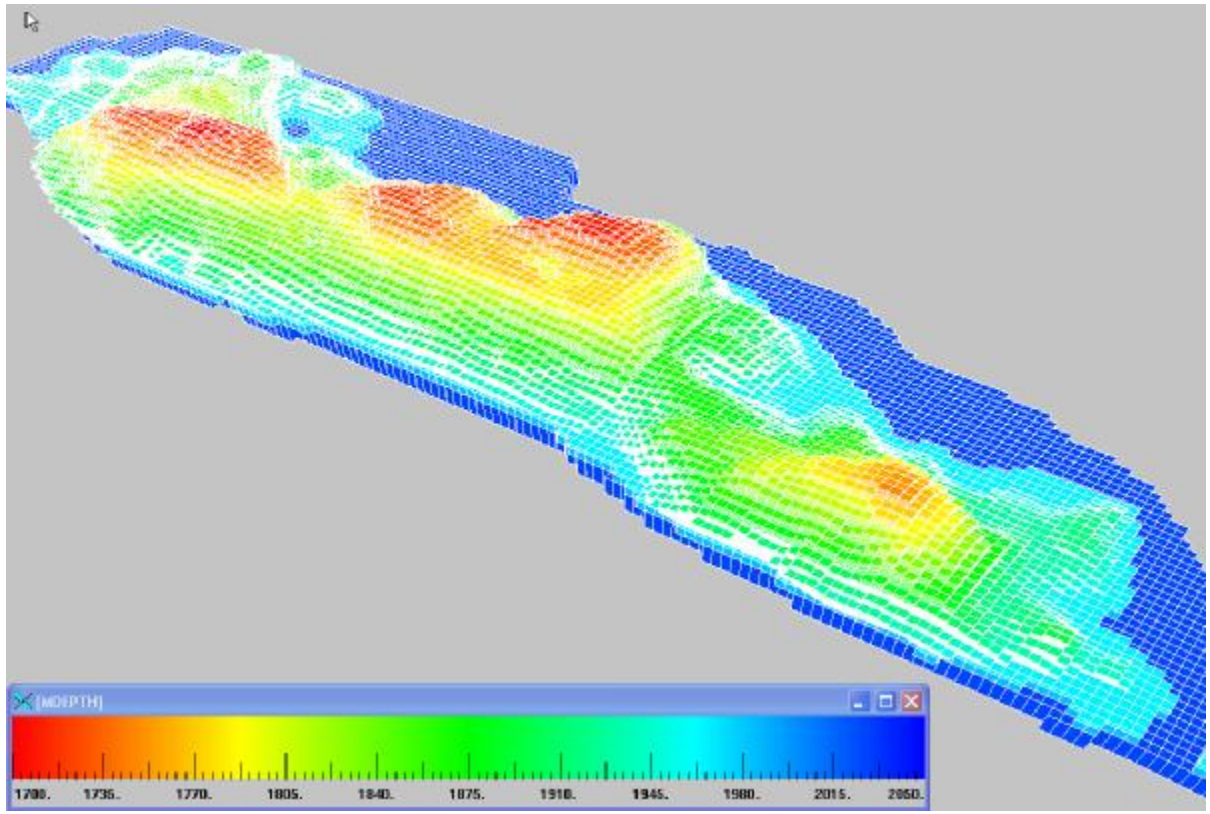


# New Concept for Beničanci

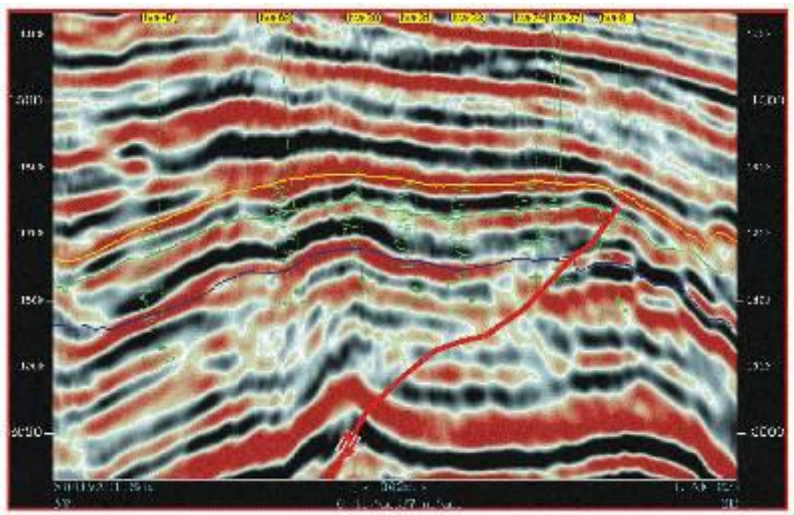
- Natural gas injection
  - → Locally generated $N_2$ too expensive for the volume needed
  - → Vicinity of current and future gas supply
- Important: UGS potential
  - → Operating volume 400 × $10^6$ $m^3$, scalable

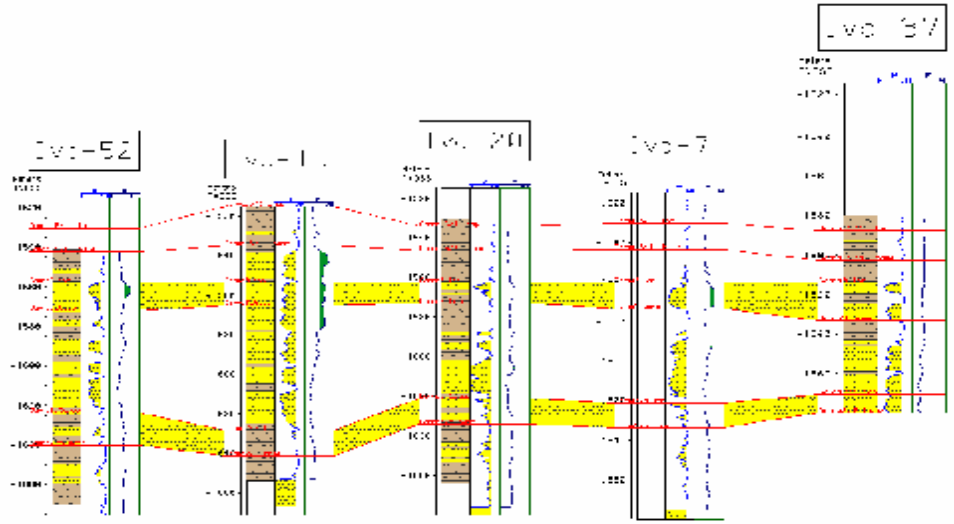
# Beničanci: Further Activities

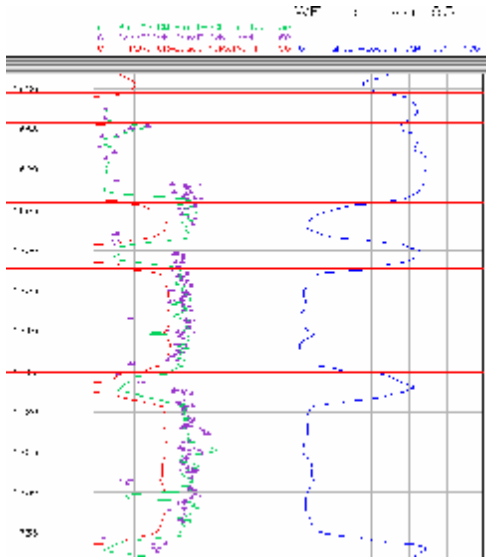
- Numerical simulation
- Pilot natural gas injection

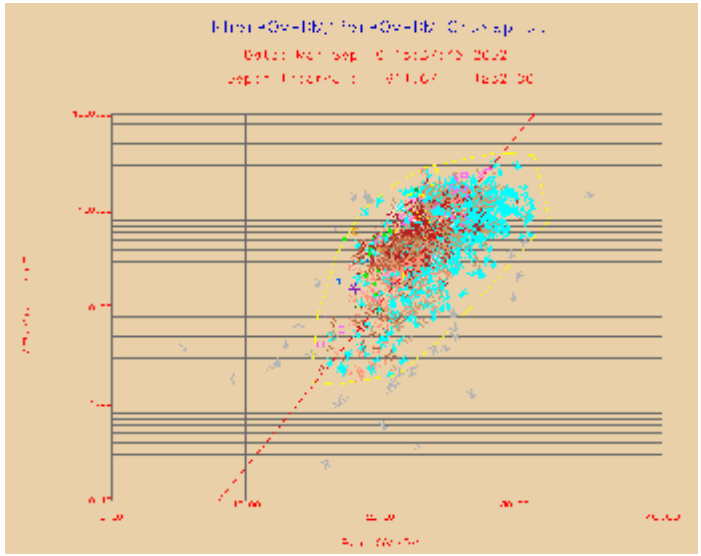


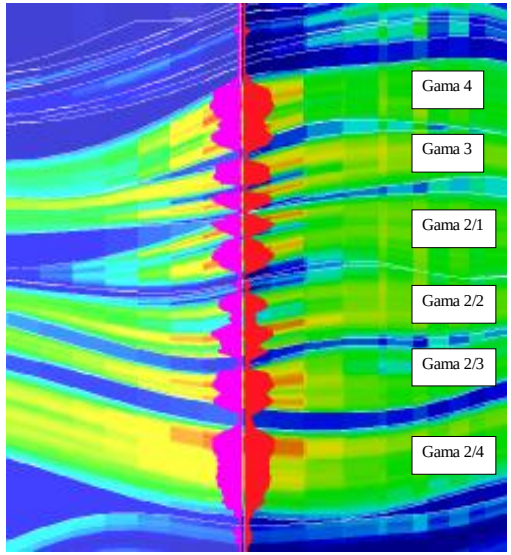
# Ivanić: 3D Geological Model



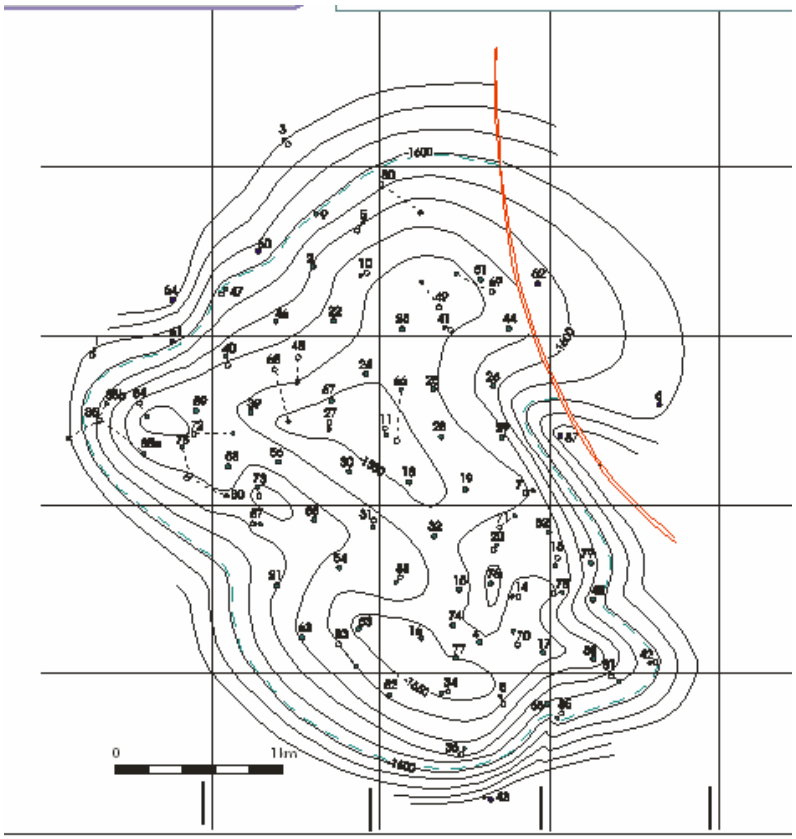




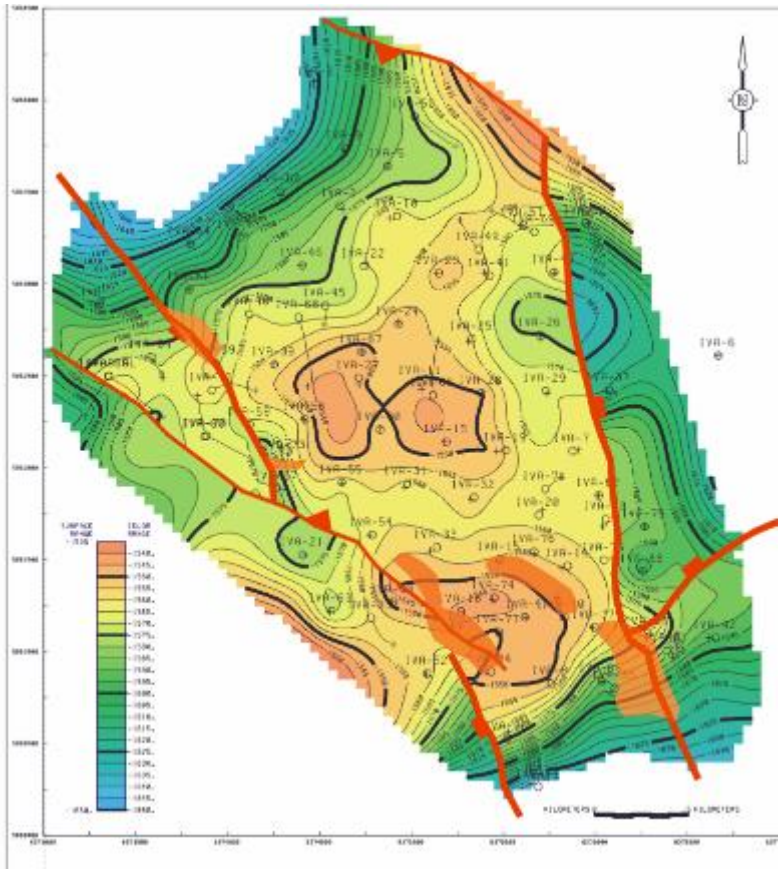




# Geological Setting

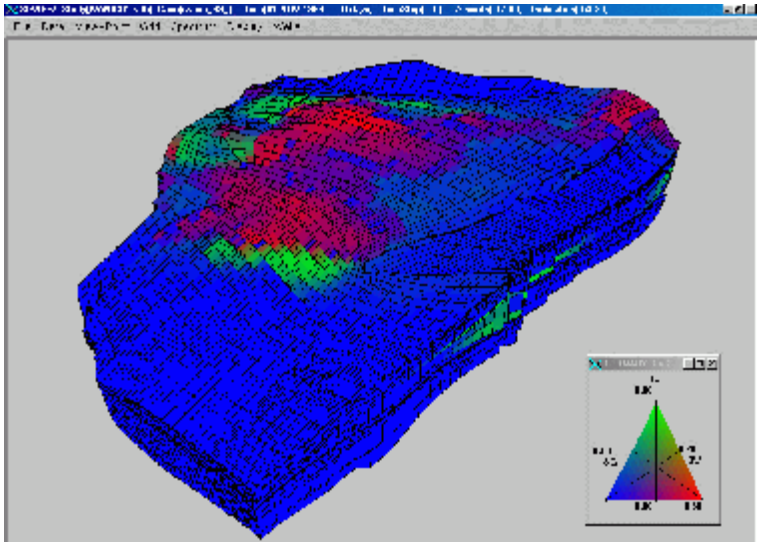


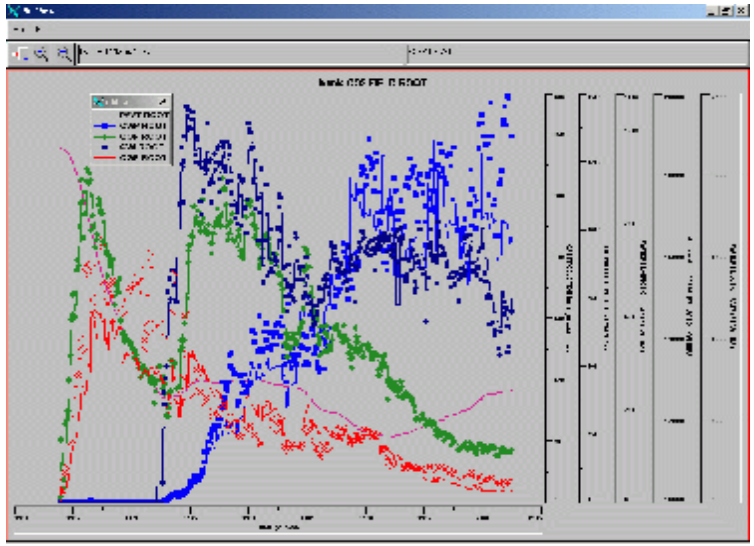

Old

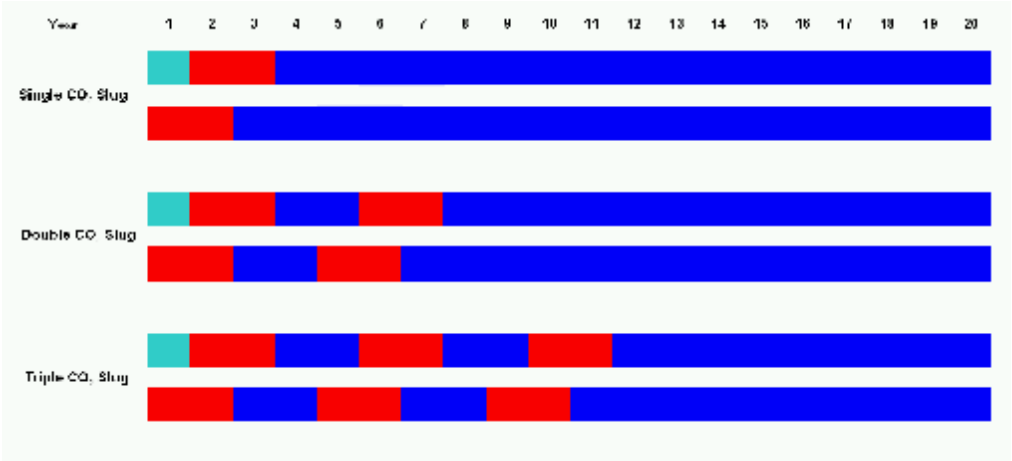


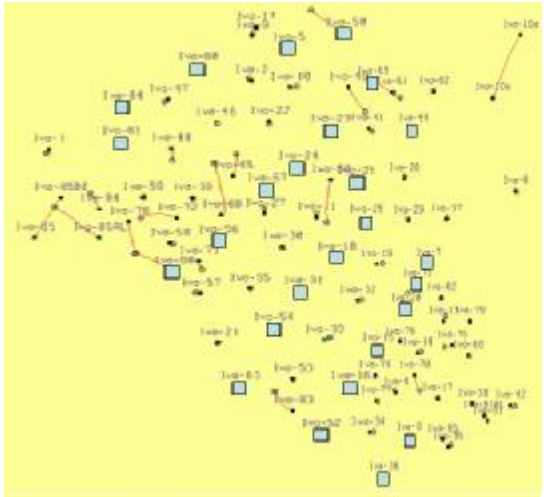
New

# Numerical Simulation (2003)



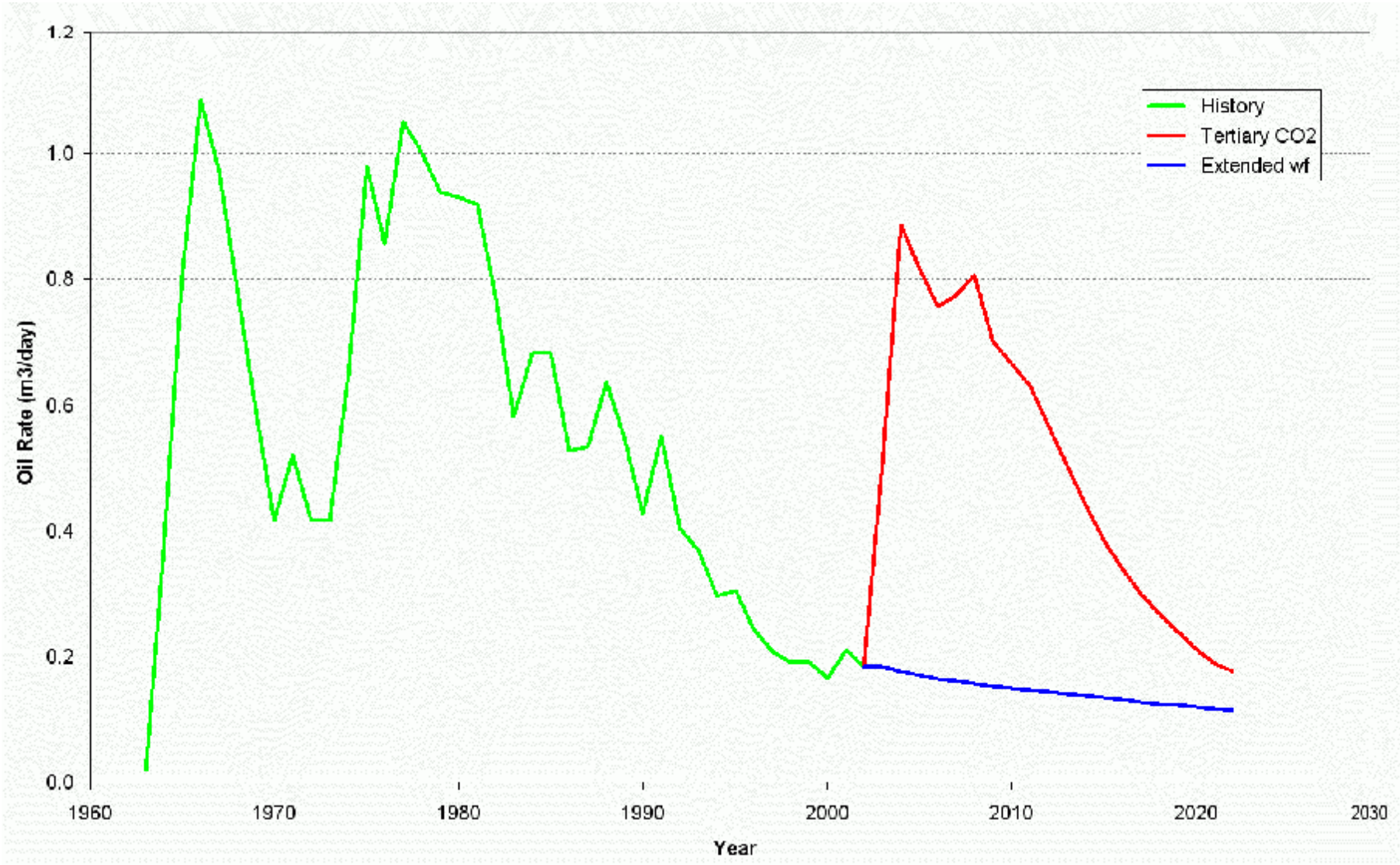




**SPE 89361, Tulsa 2004**

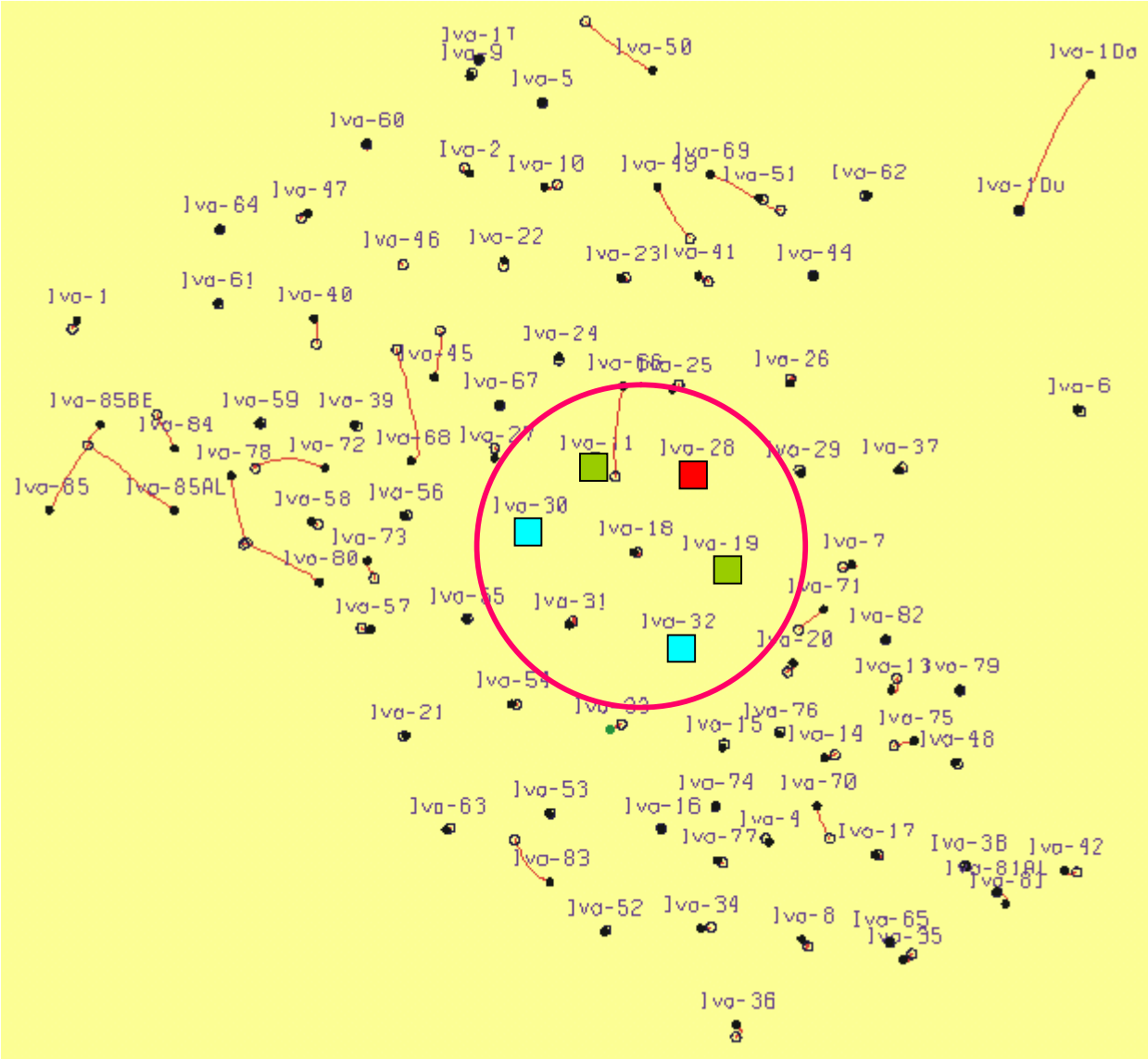
# Tertiary Oil Production (2003)



# Incremental Oil & $CO_2$ Utilisation

| | **IncrmOil** ($10^6$ $m^3$) | **$CO_2$ UtRatio** ($m^3$ / $m^3$) |
|---|---|---|
| Repressuring<br>2 slugs<br>2 additional rows | 2.55 | 278 |
| No repressuring<br>3 slugs<br>Existing injectors | 2.24 | 658 |

# $CO_2$ Pilot Injection Ivanić




- injector
- producer
- observation

Target: reservoir $\gamma_{2/4}$

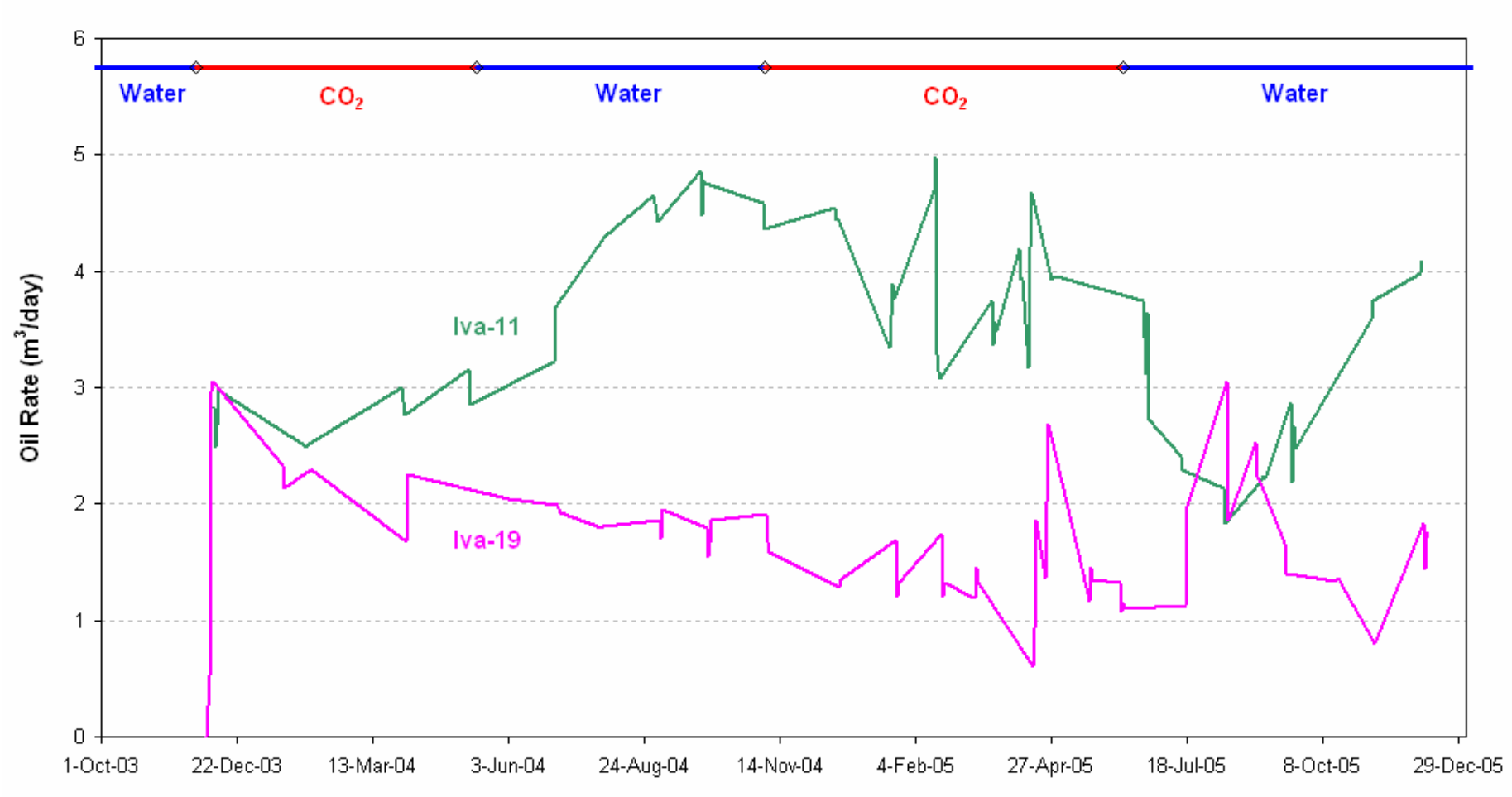
Estimated ROIP:
$683 \times 10^3$ m$^3$

# $CO_2$ Injection Site: Iva-28

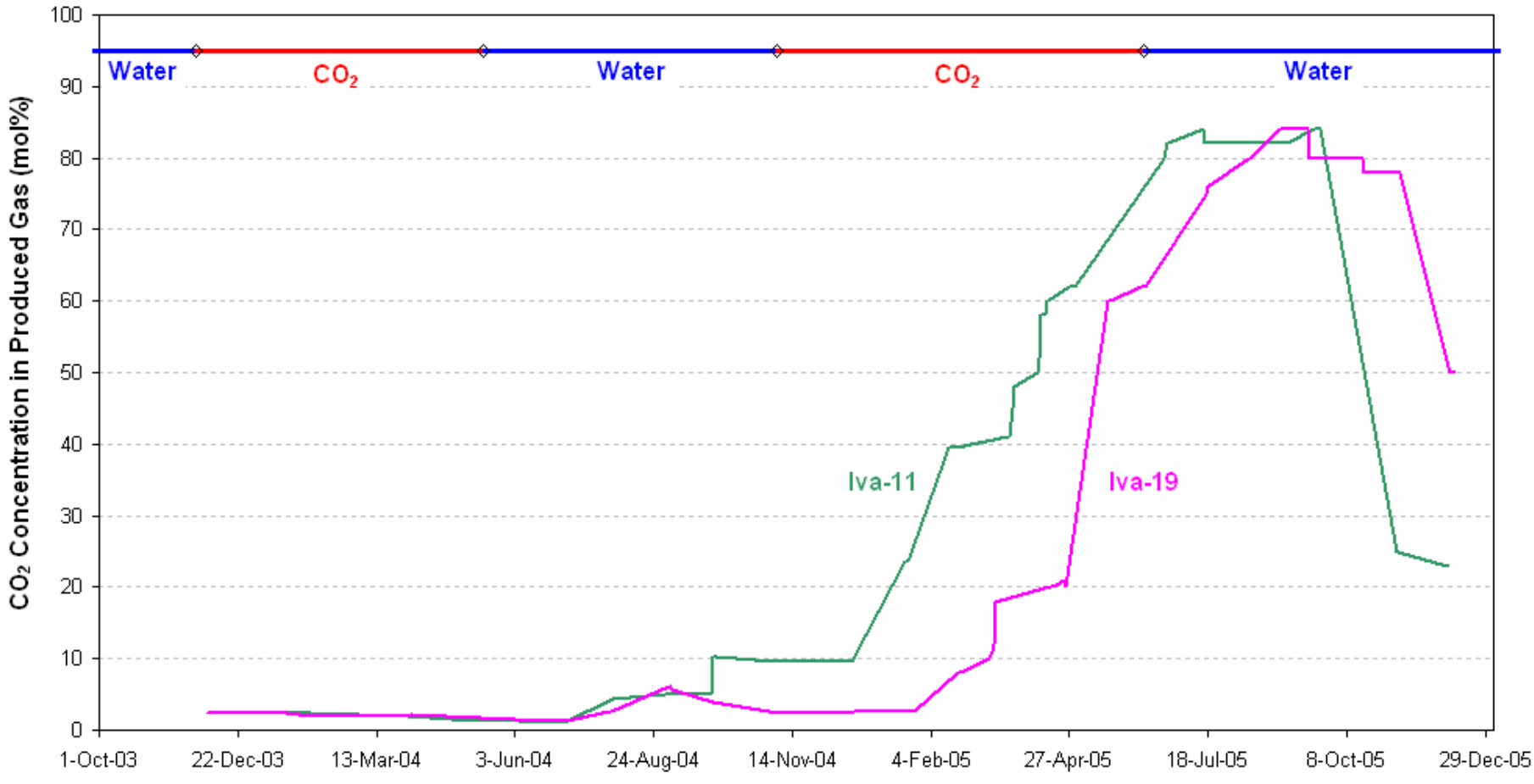
# $CO_2$ Injection Data

- Two slugs
  - è Nov 2003 - May 2004
  - è Nov 2004 - June 2005
- Injection rate: 45,000 $Sm^3$/day (88 t/day)
- Wellhead:  p = 55 bar, T = -20°C
- Downhole:  p = 193 bar, T = 60°C
- Slug size: $8.2 \times 10^6$ $Sm^3$ (16,000 t)
- No operational problems

# $CO_2$ Pilot – Oil Rate



# $CO_2$ Pilot – $CO_2$ in Produced Gas

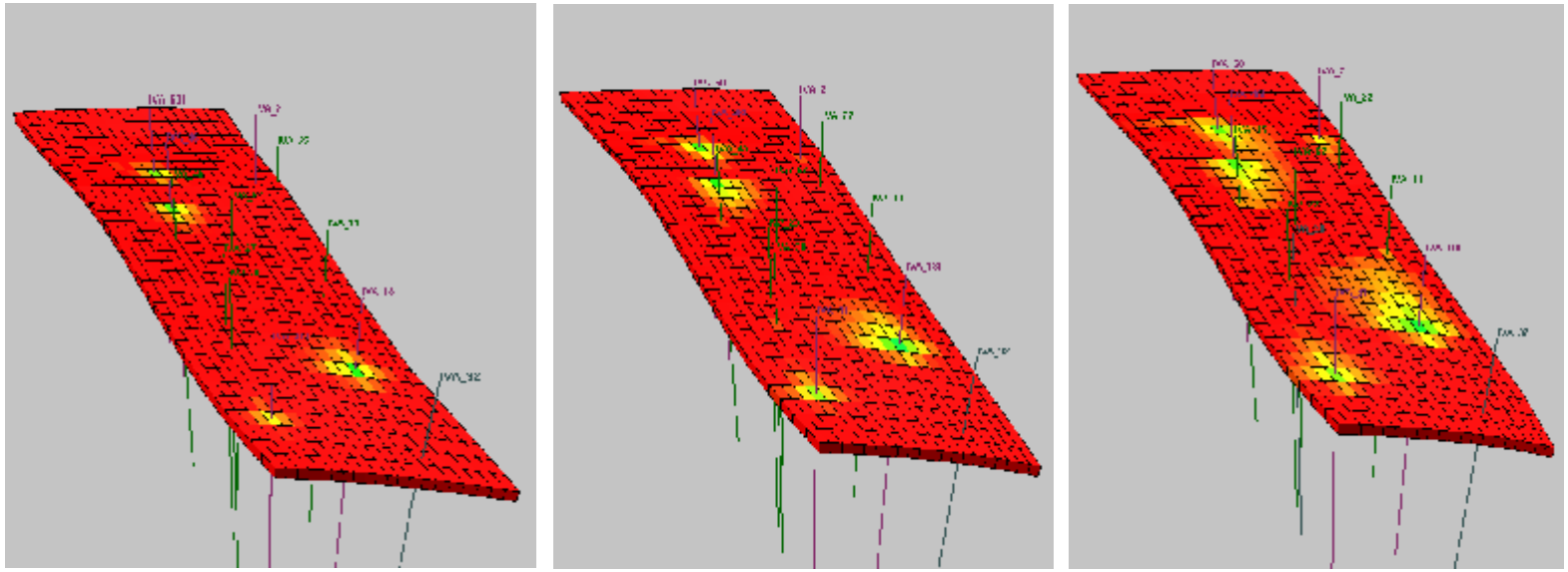


# Obtained from $CO_2$ Pilot

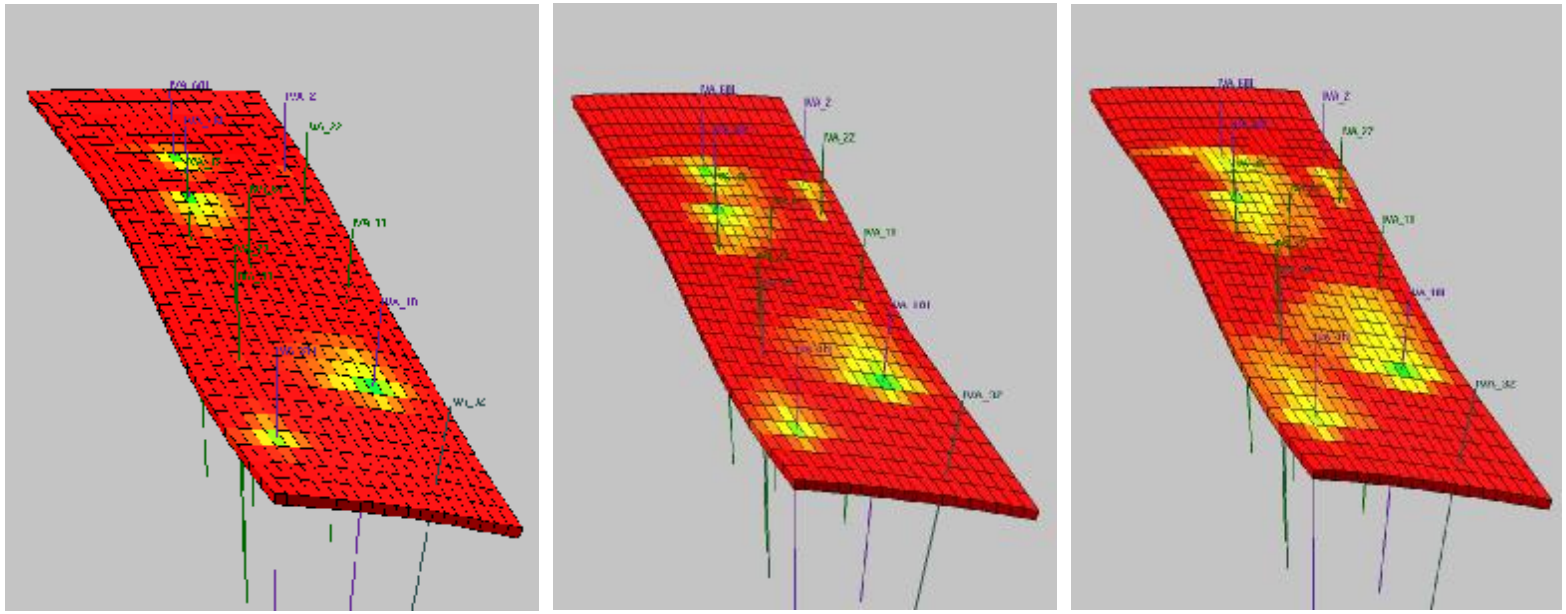
- Confirmation of oil displacement by $CO_2$ in real reservoir environment
- Source of data for fine tuning of simulation models: pilot area and full field
- Practical experience with:
  - $CO_2$ injection (including safety systems)
  - Oil production after $CO_2$ breakthrough

# RelPerms vs $CO_2$ Propagation

**Old**



**New**



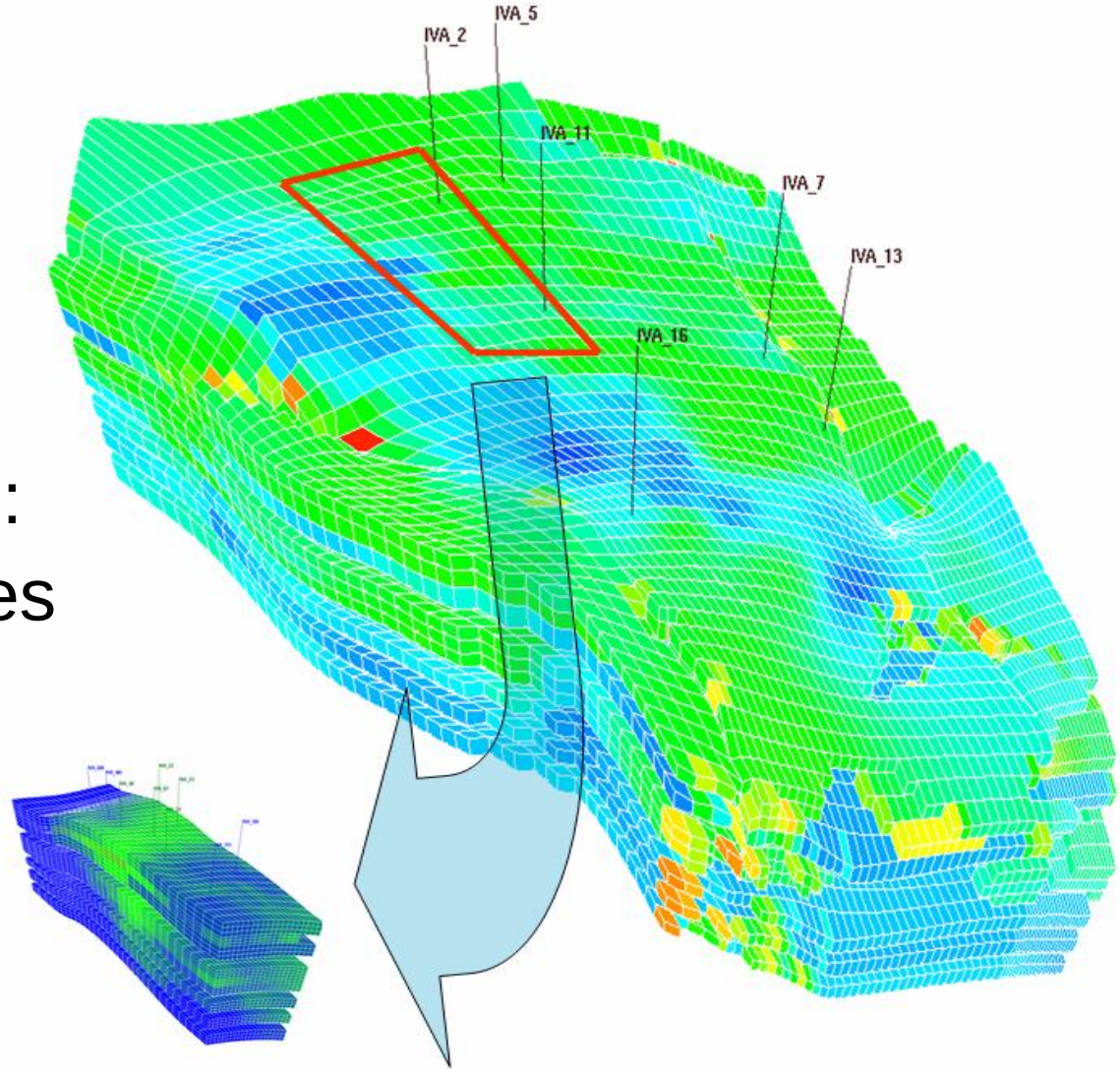
# Ivanić Pattern Model (2005)

Refined:

- gridding
- layering

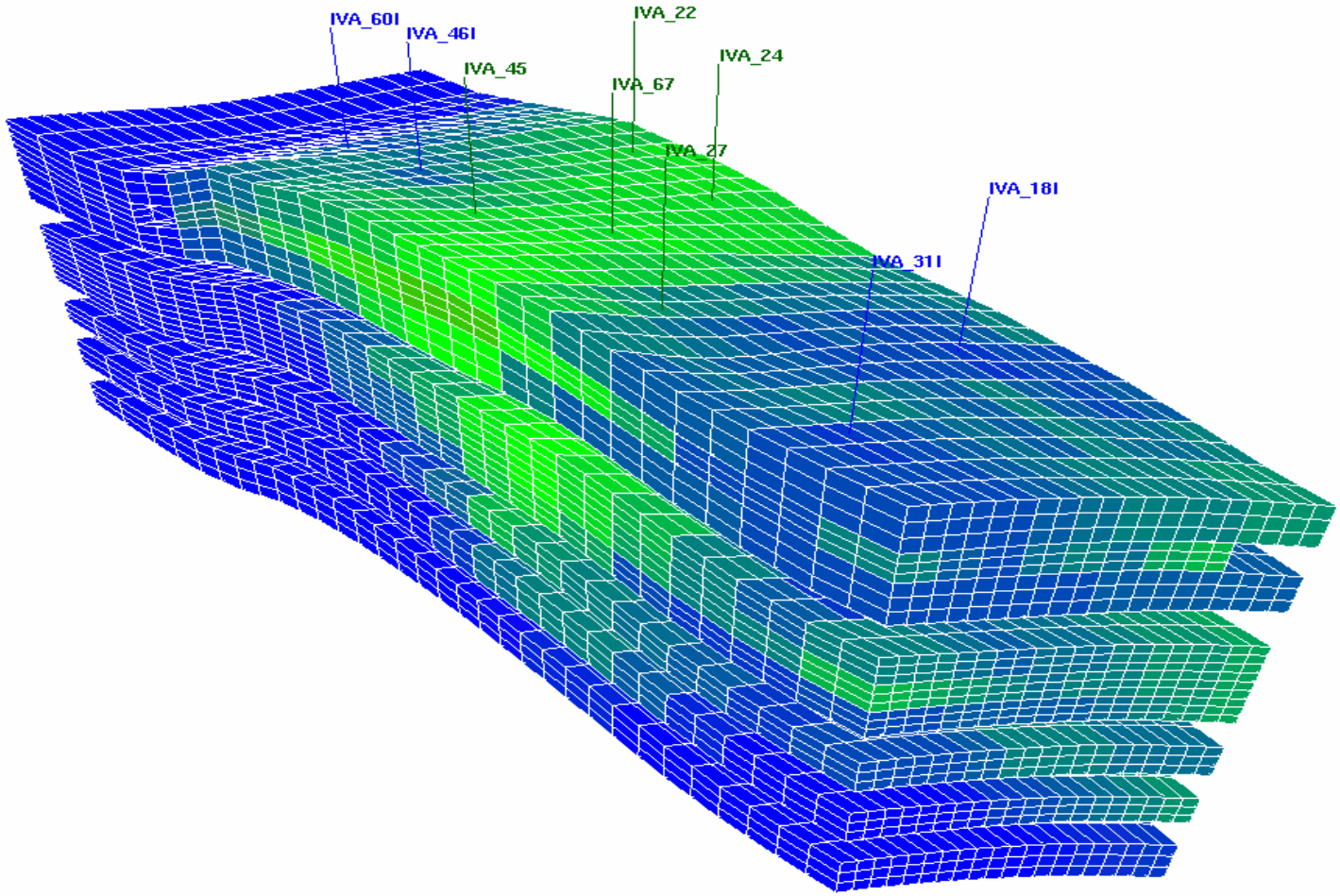
Representativeness:

- reservoir properties
- history match
- wf recovery
  - field: 33%
  - pattern: 36%



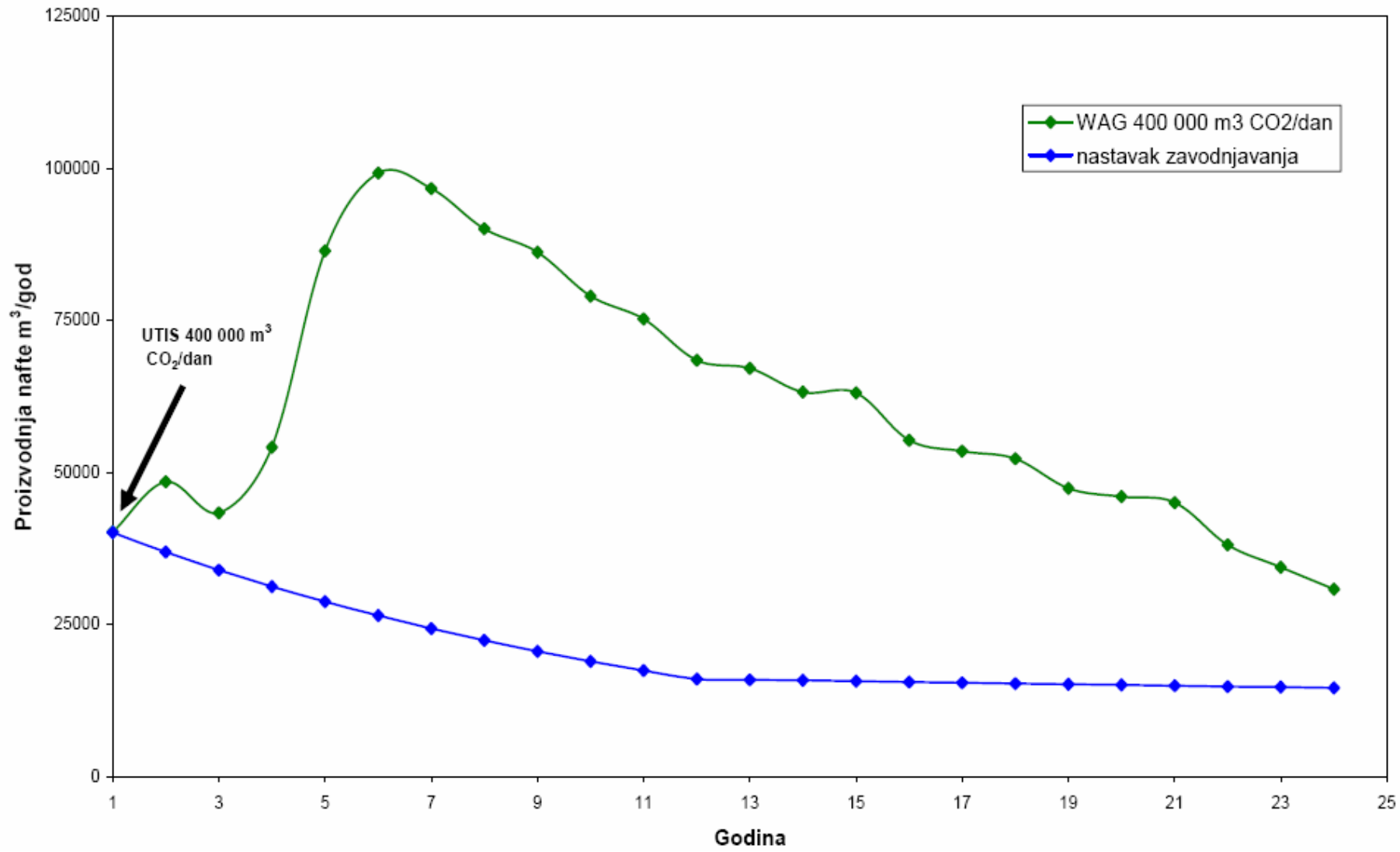

**SPE 100198, Europec, Vienna 2006**

# Ivanić Pattern Model

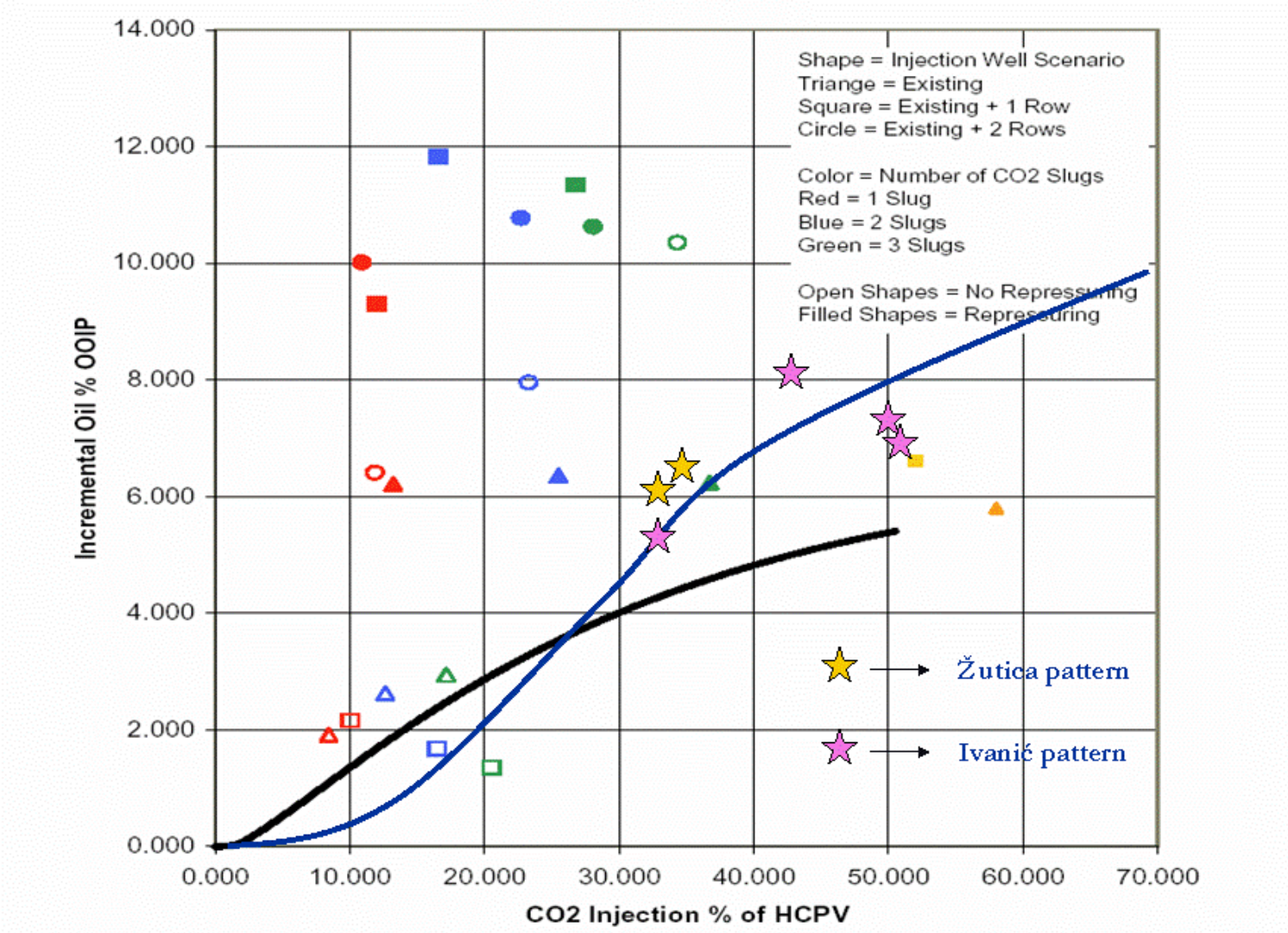



- Compositional simulation of history and predictions
- Upscaling prediction results to full field

# Production Prediction: Ivanić

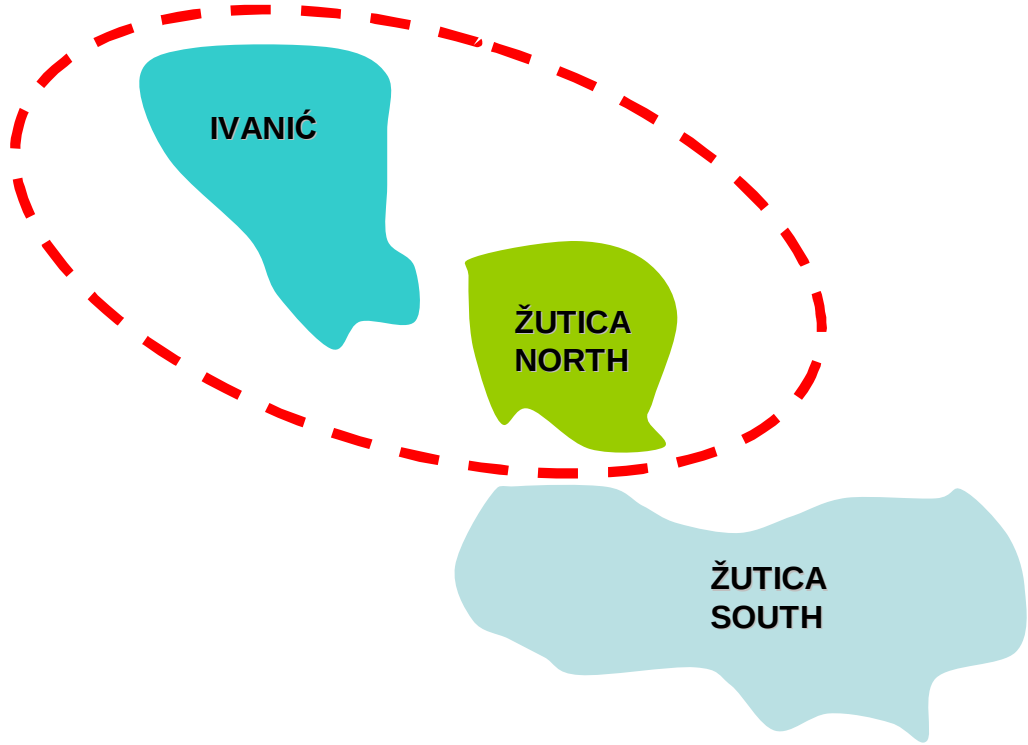


# Incremental Oil Predictions



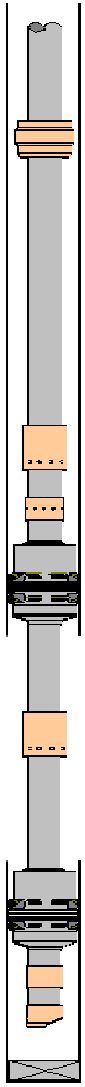
# Project Outline

- Two EOR objects
  - → Ivanić + Žutica North: $CO_2$ start in 2008
  - → Žutica South: $CO_2$ start in 2010

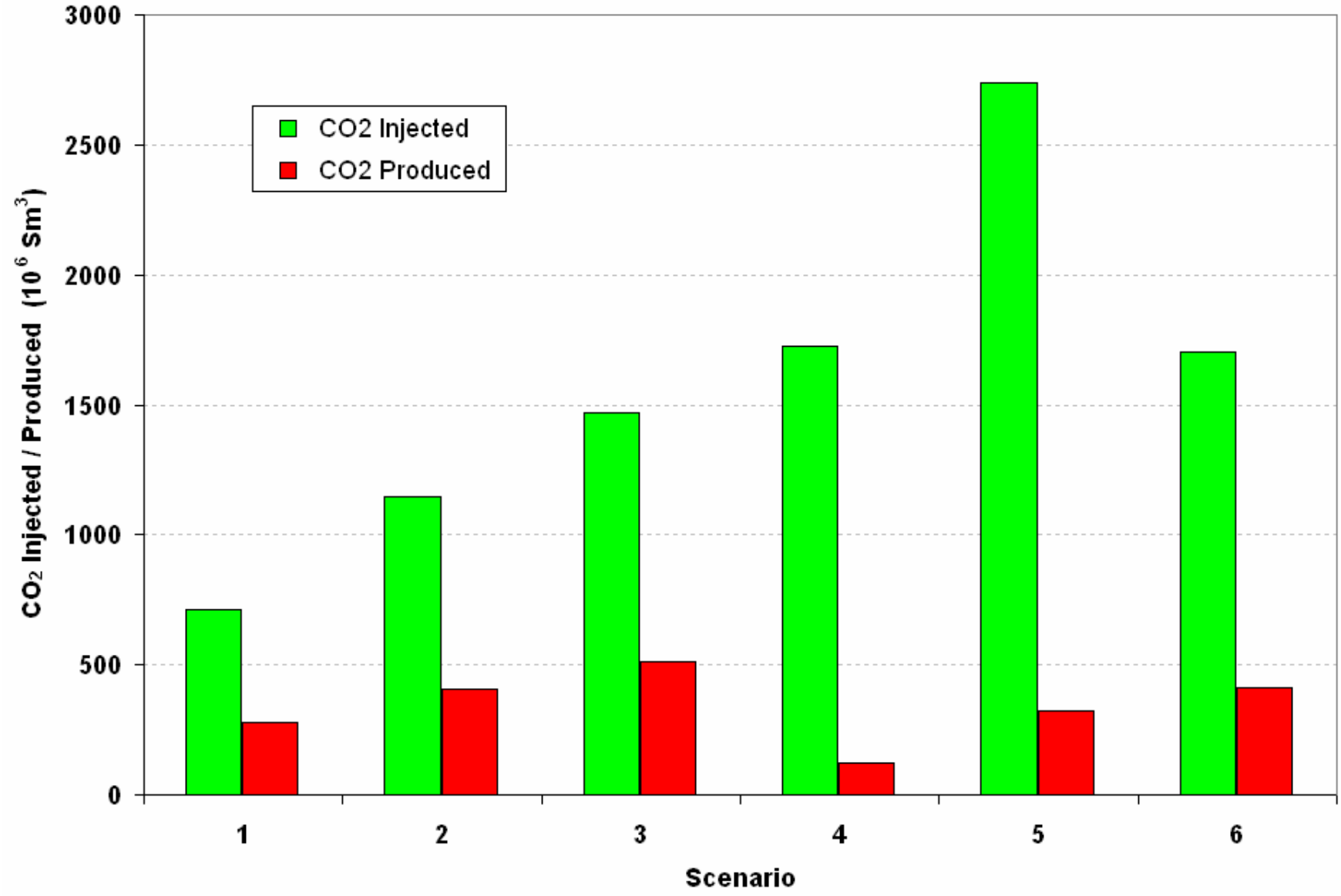


# Current Activities

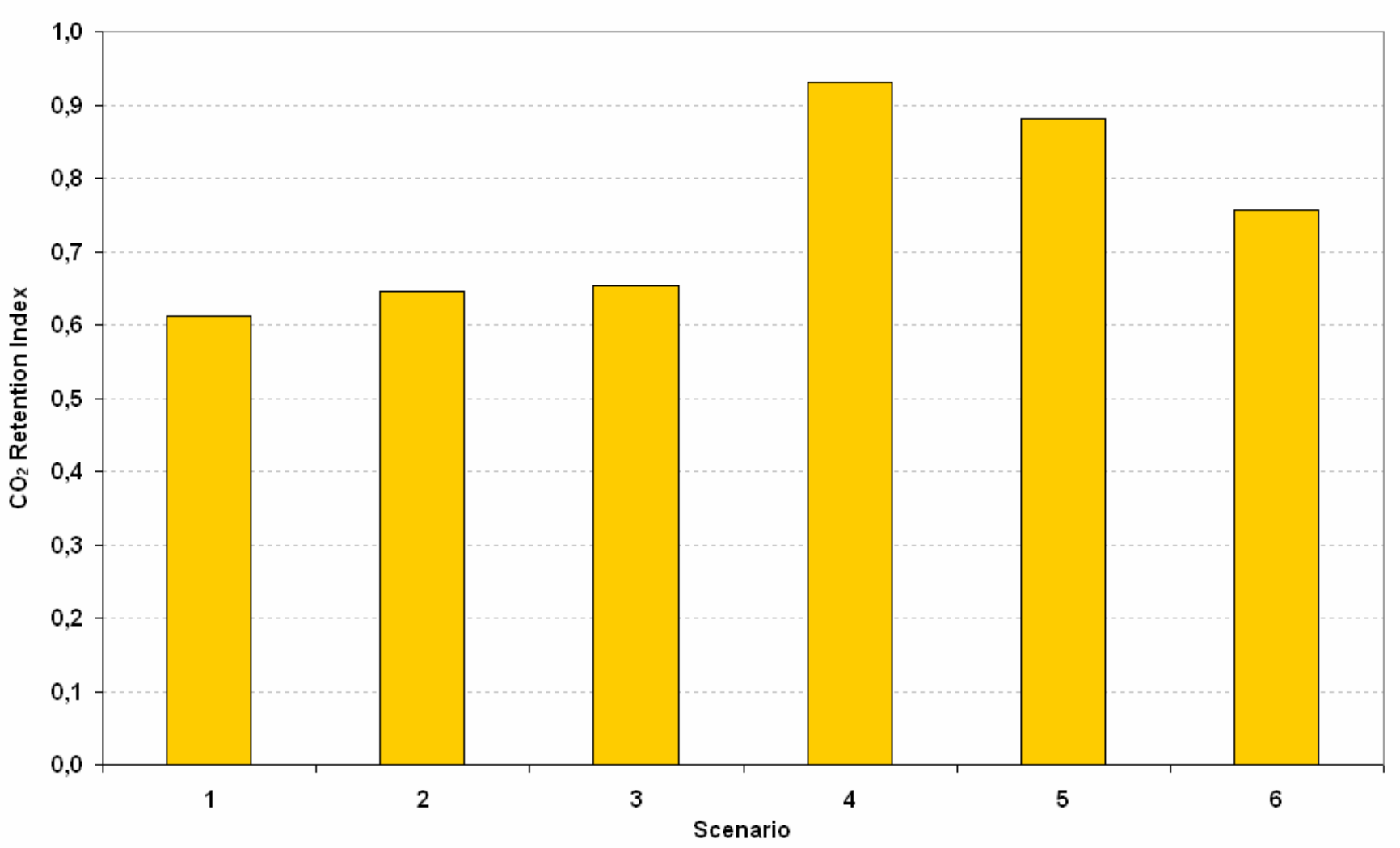
- Detailed engineering
  - → final choice of injection wells
  - → designing well completions
    - choice of materials
    - flow control options
  - → planning water/$CO_2$ delivery network
  - → surface facilities: Molve, Ivanić, Žutica
- Investment optimisation
  - → scheduling costs



# $CO_2$ Total Volumes - Simulation



# $CO_2$ Retention Index - Simulation



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