

Towards Geological Storage of CO₂ in the Czech Republic – TOGEOS

Activity 3 Evaluation/Screening of CO₂ Storage in Czech Oil & Gas Fields with Optional CO₂-EOR

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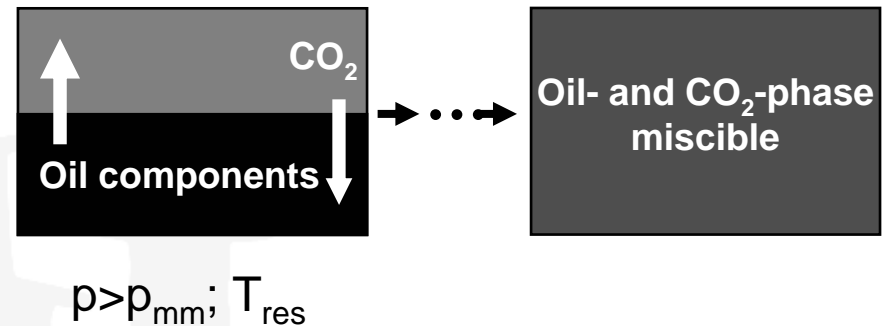
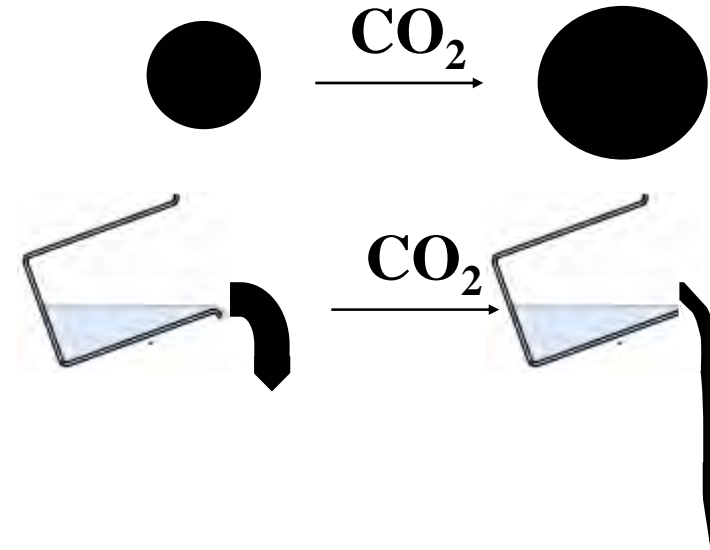
Outline

- Introduction - CO₂-flooding mechanisms
- Activity description
- CO₂ EOR evaluations
- Current conclusions



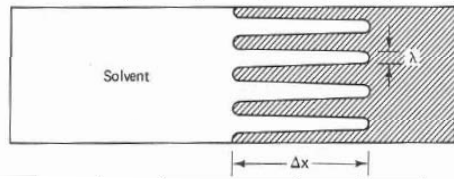
CO₂ Flooding - Oil Recovery Mechanisms

- Oil Swelling
 - Greatest effect on lighter oils
- Reduction of oil viscosity
 - Greatest effect on high viscous oils
- Mass transfer CO₂- and oil-phase
 - Can develop miscibility
- Depend on temperature, pressure and oil composition

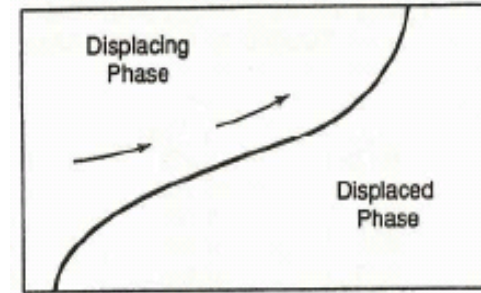


Macroscopic Formation Sweep Efficiency

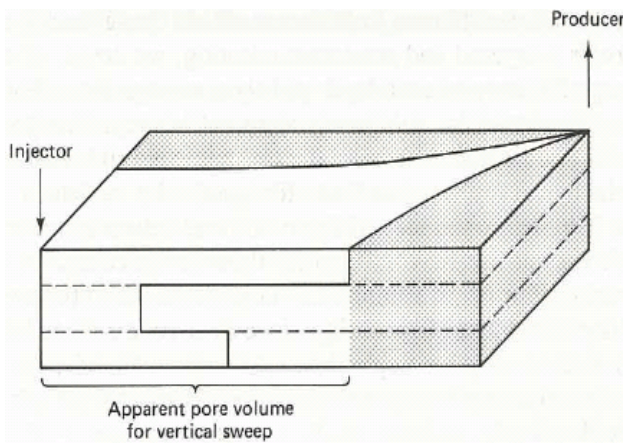
Fraction of reservoir area contacted by EOR-fluid



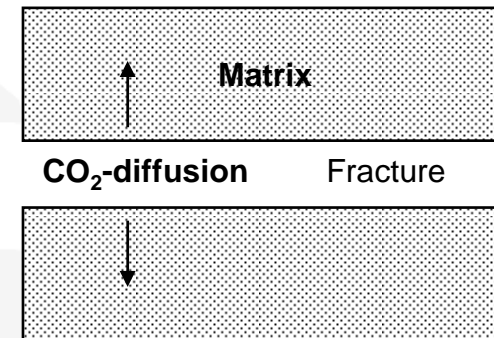
CO₂ fingering effects in homogeneous systems (core scale)



CO₂ overriding of oil due to density difference - homogeneous reservoir



CO₂ areal and vertical sweep efficiency - layered reservoir



CO₂ diffusion in naturally fractured reservoirs

Activity 3

- Sub-activities
 - 3.1 Primary screening
 - 3.2 Secondary screening
 - 3.3 Storage potential evaluations



3.1 Primary Screening

- Potentials for CO₂-flooding of oilfields are evaluated based on primary screening criteria:
 - Reservoir description
 - Formation type, average depth, thickness, dip angle, heterogeneity, length, width, average permeability, average porosity, average remaining oil saturation, presence of gas-cap gas, etc.
 - Oil Characteristics
 - PVT-report, e.g. composition, specific gravity and viscosity
 - Reservoir conditions
 - Temperature and pressure

3.2 Secondary Screening

- Oilfields found to have a potential for CO₂-flooding in primary screening are further evaluated by comparing them with oil fields where CO₂-flooding has been reported to increase the recovery
- Input to this evaluation
 - Reservoir description
 - Oil properties
 - Reservoir conditions



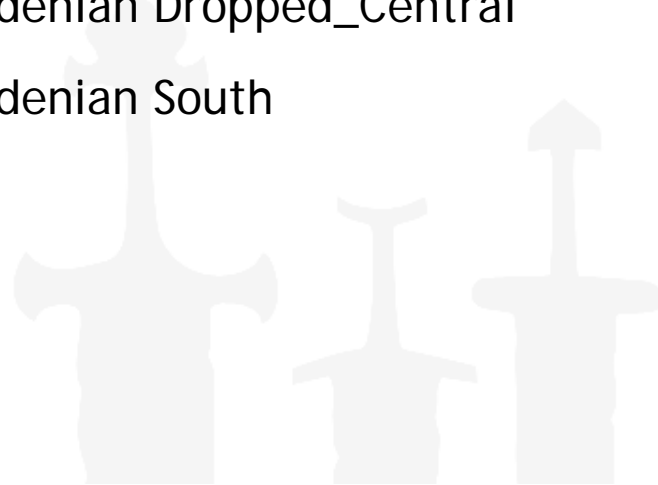
3.3 Storage Potential Evaluations

- CO₂ storage potential for promising reservoirs are estimated from:
 - Simplified reservoir model
 - EOR software SWORD



Input Data

- Received data for the following reservoirs:
 - ZDANICE - MIOCEN
 - KORYCANY
 - HRUSKY-7th Badenian Dropped_North
 - HRUSKY-7th Badenian Dropped_Central
 - HRUSKY-6th Badenian South



ZDANICE – MIOCEN

- Reservoir
 - Sandstone rock with some heterogeneity due to limestone, average 150mD
- Remaining oil saturation 55%
- Depth 880m
 - CO₂-flooding potential if pressure and oil composition are favorable
- Pressure (P)
 - 6.36MPa < 7MPa min. screening P miscible CO₂-flooding
 - 6.36MPa ≈ 6MPa min. screening P partially CO₂-flooding for oil viscosity reduction
- Oil composition/properties
 - Heavy oil with high asphaltene concentration
 - Specific gravity higher and °API lower than recommended
 - Properties outside recommended range
- No potential miscible CO₂-flooding, but oil viscosity may be reduced

KORYCANY

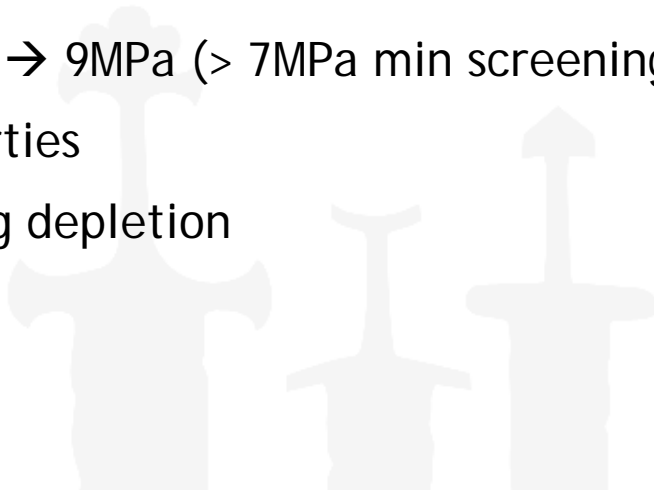
- Reservoir
 - Sandstone with underbed naturally fractured granite
 - Average permeability 150mD sandstone and 0-50mD granite
- Remaining oil saturation 58%
- Depth 1800m
 - CO₂-flooding potential if pressure typical and oil composition are favorable
- Pressure (P)
 - Minor depletion 15.55MPa → 14.51MPa (> 7MPa min screening P miscible CO₂)
- Oil composition/properties
 - Not much depletion
 - Composition of remaining oil probably similar to original oil
 - Wax problem in production
- Interesting reservoir

HRUSKY-7th Badenian Dropped_North

- Reservoir
 - Homogeneous sandstone with average permeability 230mD
 - Favorable formation dip
- Remaining oil saturation 68%
- Depth 1560m
 - CO₂-flooding potential if pressure typical and oil composition are favorable
- Pressure (P)
 - Depletion 15.79MPa → 10.10MPa (> 7MPa min screening P miscible CO₂)
- Oil composition/properties
 - Loss of C₅-C₁₂ during depletion
- Interesting reservoir

HRUSKY-7th Badenian Dropped_Central

- Reservoir
 - Homogeneous sandstone with average permeability 200mD
 - Favorable formation dip
- Remaining oil saturation 68%
- Depth 1560m
 - CO₂-flooding potential if pressure typical and oil composition are favorable
- Pressure (P)
 - Depletion 15.79MPa → 9MPa (> 7MPa min screening P miscible CO₂)
- Oil composition/properties
 - Loss of C₅-C₁₂ during depletion
- Interesting reservoir



HRUSKY-6th Badenian South

- Reservoir
 - Homogeneous sandstone with average permeability 95mD
 - Favorable reservoir dip
- Remaining oil saturation 68%
- Depth 1420m
 - CO₂-flooding potential if pressure typical and oil composition are favorable
- Pressure
 - Depletion 15.79MPa → 7MPa equal to min screening P miscible CO₂
- Oil composition/properties
 - Loss of C₅-C₁₂ during depletion
- Interesting reservoir, but pressure close to min P miscible CO₂-flooding

Reservoir Size and Remaining Oil

Parameter	Unit	ZDANICE - MIOCEN	KORYCANY	HRUSKY-7th Badenian North	HRUSKY-7th Badenian Central	HRUSKY-6th Badenian South
Length	Km	2	3.5	1.5	3	1.4
Width	Km	1.5	1.9	0.6	0.7	0.6
Thickness	m	30	0-120	6	6	6
OOIP	m ³			540·10 ³	1280·10 ³	570·10 ³
Total oil production	m ³			230·10 ³	480·10 ³	190·10 ³
Remaining oil	m ³			310·10 ³	800·10 ³	380·10 ³

Miscible CO₂-flooding - Reservoir Ranking

- Interesting reservoirs
 - KORYCANY
 - HRUSKY-7th Badenian Dropped_North
 - HRUSKY-7th Badenian Dropped_Central
- Less interesting reservoir
 - HRUSKY-6th Badenian South
- No potential miscible CO₂-flooding
 - ZDANICE - MIOCEN

Binary Screening - Miscible CO₂

Parameter	Literature examples	Zdanice Miocene	Korycany	Hrusky Badenian Dropped North	Hrusky Badenian Dropped Central	Hrusky Badenian South
Viscosity [cP] reservoir conditions	<15	59-410 (20°C, 1atm)	2.4-3.4 (20°C, 1atm)	7.5 (20°C, 1atm) 1.5 (in-situ)	7.5 (20°C, 1atm) 1.5 (in-situ)	7.6 (20°C, 1atm) 1.15 (in-situ)
Gravity [°API]	>26	18-21	40-43	32	32	36
Remaining oil interesting area [%]	>25	55 Log 70-80	55 Log/core 45-70	58	68	68
Depth [m]	>600	800	1800	1560	1560	1420
Temperature [°C]	<121	29	50	60	60	60
Original reservoir pressure [psia]	>1100	922	2255 Reduced to 2104	2290 Reduced to 1465	2290 Reduced to 1305	2290 Reduced to 1015
Permeability [mD]	>1	Average 150	Sandstone 150 Granite 0-50	Average 230	Average 200	Average 95
REMARKS		Not miscible, but may be immiscible	Interesting Reservoir	Interesting Reservoir	Interesting Reservoir	Not miscible, but may be immiscible

Oil properties remaining oil or original oil?

Conclusions Primary and Secondary Screening

Reservoir	Miscible CO ₂ -flooding potential	Comments
HRUSKY-7th Badenian Dropped_North	Interesting	Homogeneous Pressure after depletion > min screening pressure Rather light oil
HRUSKY-7th Badenian Dropped_Central	Interesting	Homogeneous Pressure after depletion slightly higher than min screening pressure Rather light oil More oil left than in HRUSKY-7th Badenian North
KORYCANY	Interesting, but wax	Heterogeneous Highest pressure and minor depletion Wax problem in production
HRUSKY-6th Badenian South	Low	Homogeneous Pressure after depletion equal to min screening pressure
ZDANICE - MIOCEN	No	Heavy oil with high asphaltene concentration Heterogeneous, low pressure

Limitations:

Oil properties for original or remaining oil?

Crude oil composition not known