

Enhanced Oil Recovery



ptrc

Petroleum Technology
Research Centre

6 Research Dr.

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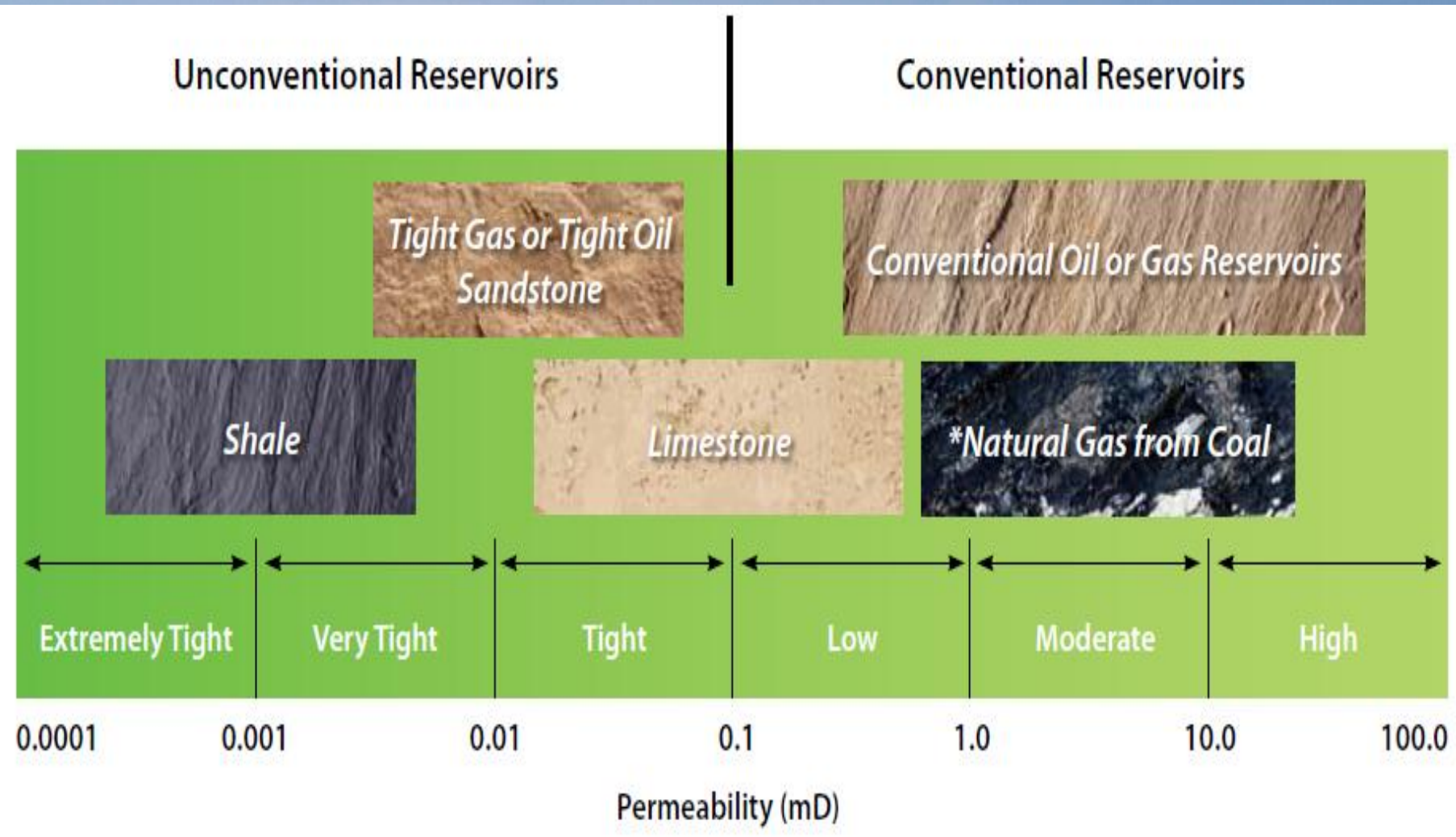
Director, Energy Innovation Hub

International Chair, ISO Technical Committee for CCS Standards

The Utopia of Underground lakes Of Oil



Petroleum is Hidden in Underground Rocks



Poor ← Quality of Reservoir → Good

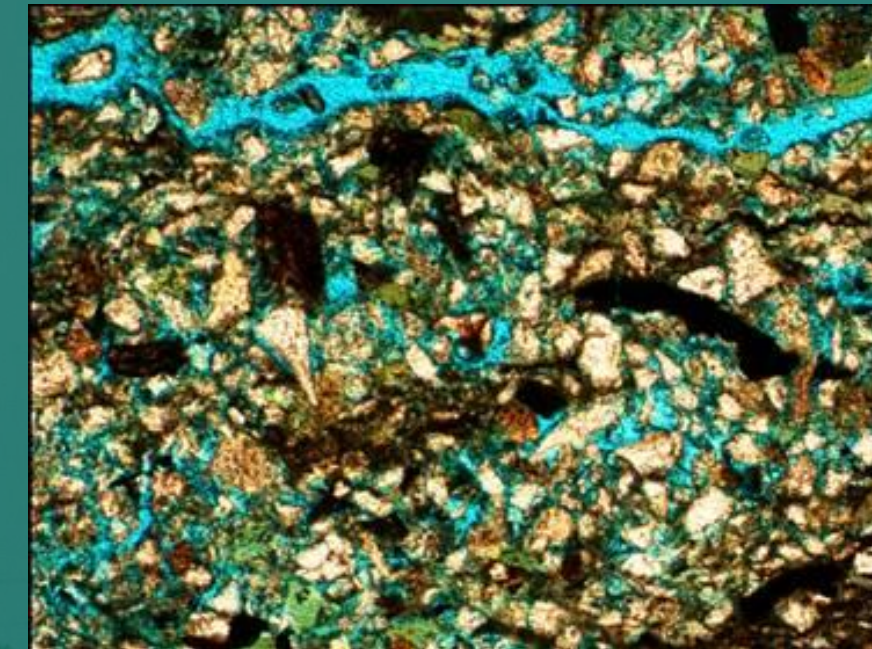
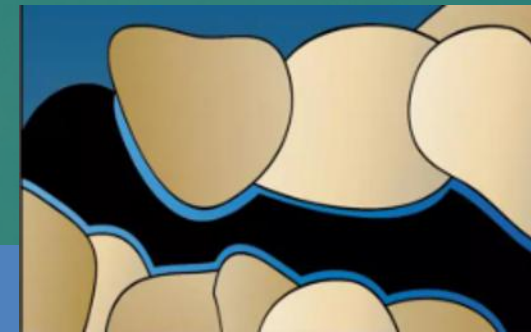


* Natural Gas from Coal reservoirs are classified as unconventional due to type of gas storage
 Source: Canadian Society of Unconventional Resources

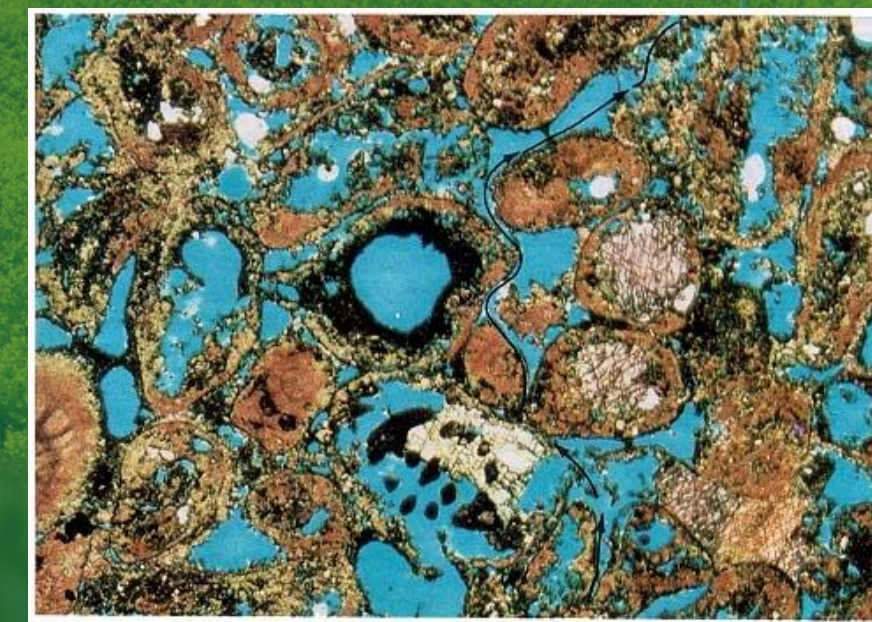


What is Oil Reservoir Rock?

A permeable subsurface rock that contains petroleum; must be both porous and permeable.

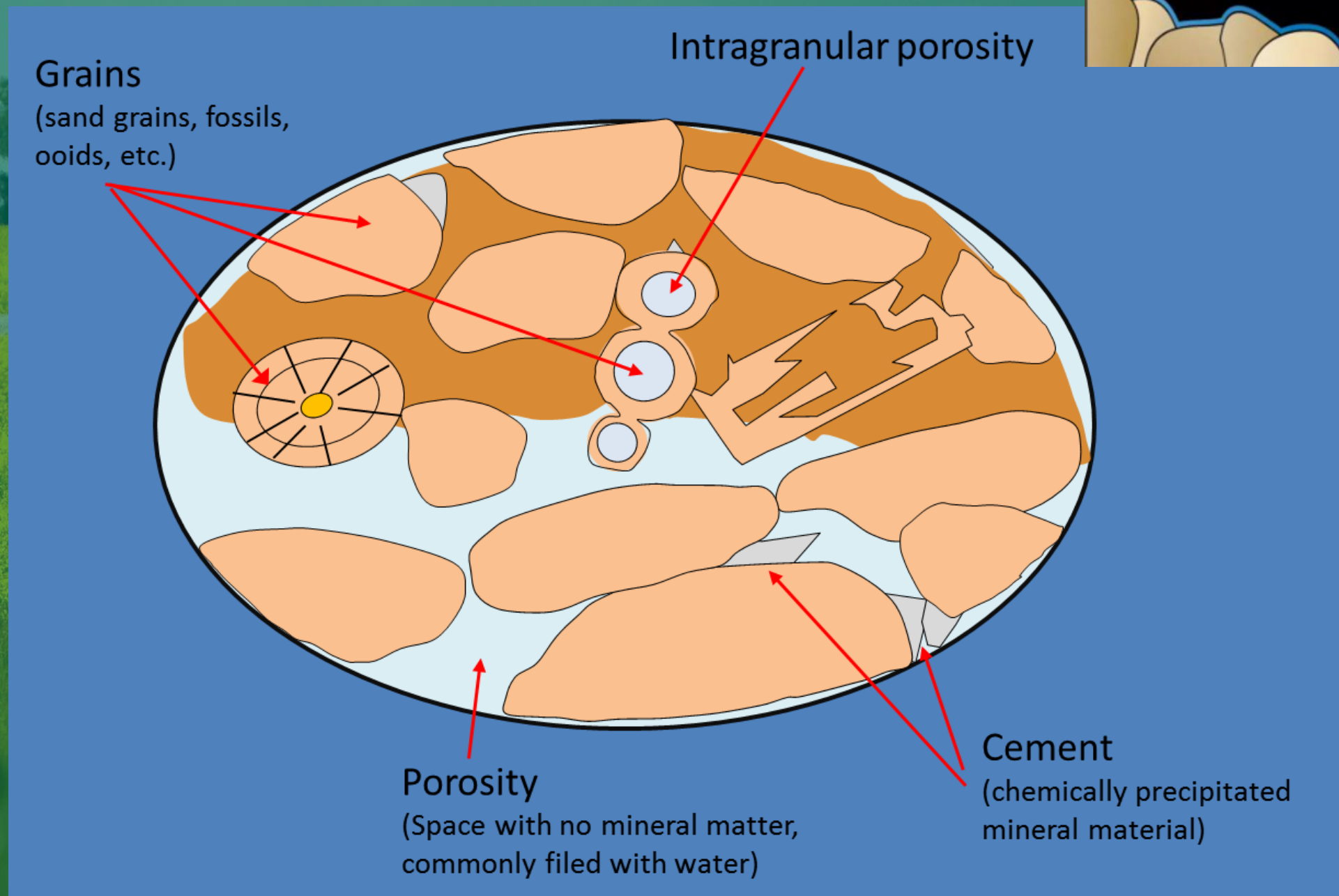


Argillaceous rock, Viking formation, Saskatchewan

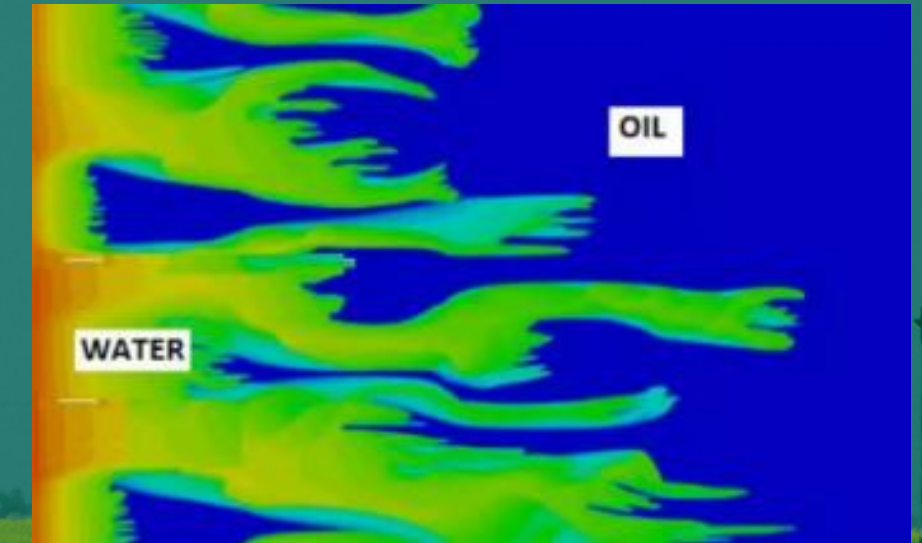
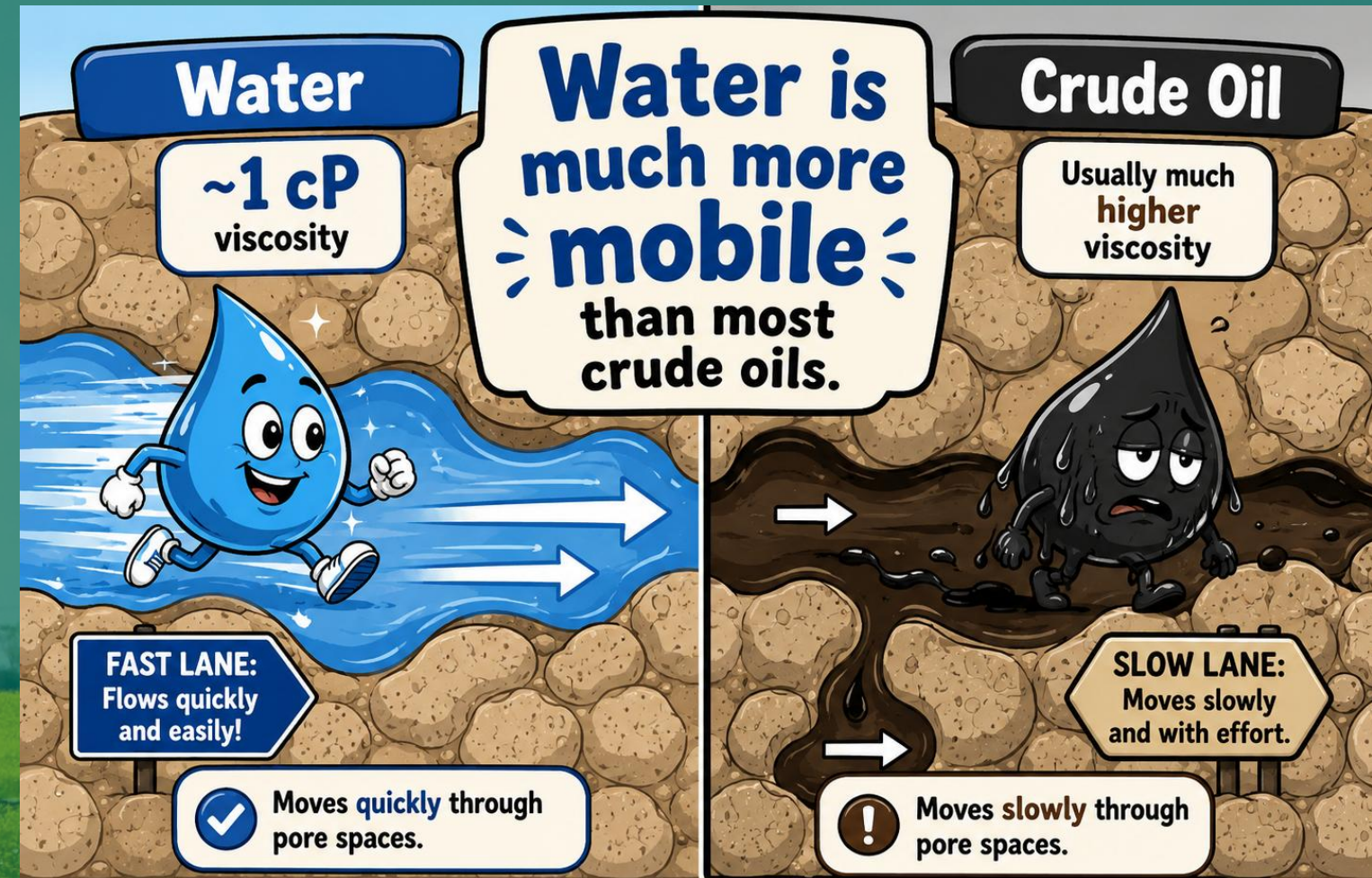


Carbonate reservoir rock

<http://www.kgs.ku.edu/Publications/Oil/primer03.html>



Classification of Oils



Light oil (16.6 mPa·s or cP)



Heavy oil (8,800 mPa·s or cP)



Bitumen (64,800 mPa·s or cP)



Stages of Oil Production:



Initial production (using natural reservoir energy)

Oil flows naturally to the surface due to existing reservoir pressure

Recoveries of 6-30% OOIP (vary significantly among reservoirs)

Secondary Production (Waterflooding, gas injection for pressure maintenance)

Water is typically injected to boost the pressure to displace the oil

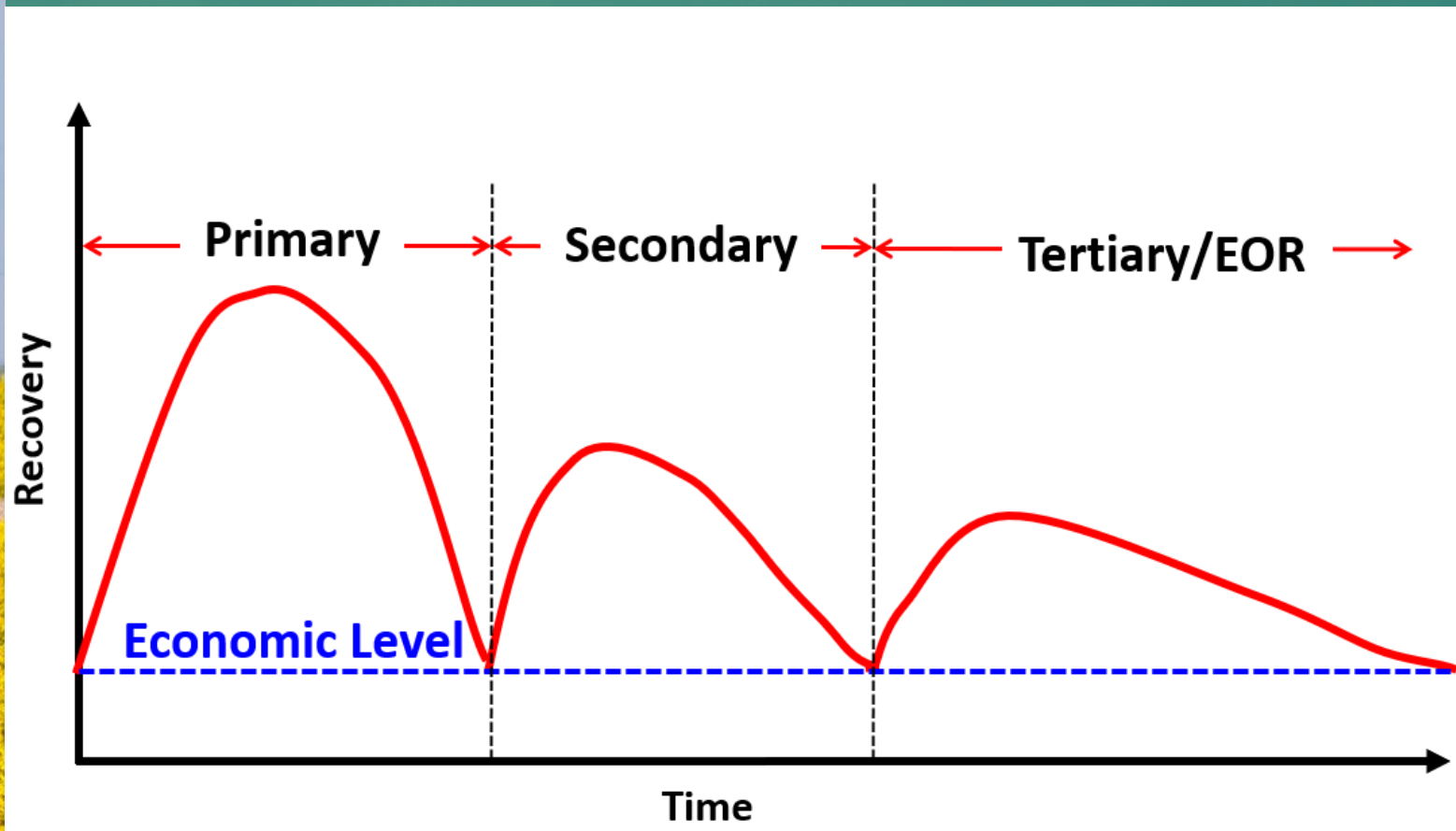
Recoveries of 10-20% OOIP (vary among reservoirs)

Remaining in the ground 50-84% OOIP

Tertiary Production (Enhanced Oil Recovery)

Use of different methods such as injection of CO₂, natural gas, chemicals, steam and other methods to recover more of the remaining oil

Stages of Oil Production



Mechanism

Primary

Secondary

Typical Recovery

6-30% OOIP

10-20% OOIP

50 to 84% of OOIP remaining in the ground

EOR Methods to recover more of the remaining oil:

- Thermal (steam and hot water injection)
- Chemical (polymer, surfactant)
- Miscible displacement, (injection of CO₂ and/or other hydrocarbon gases, or inert gas under high pressure)

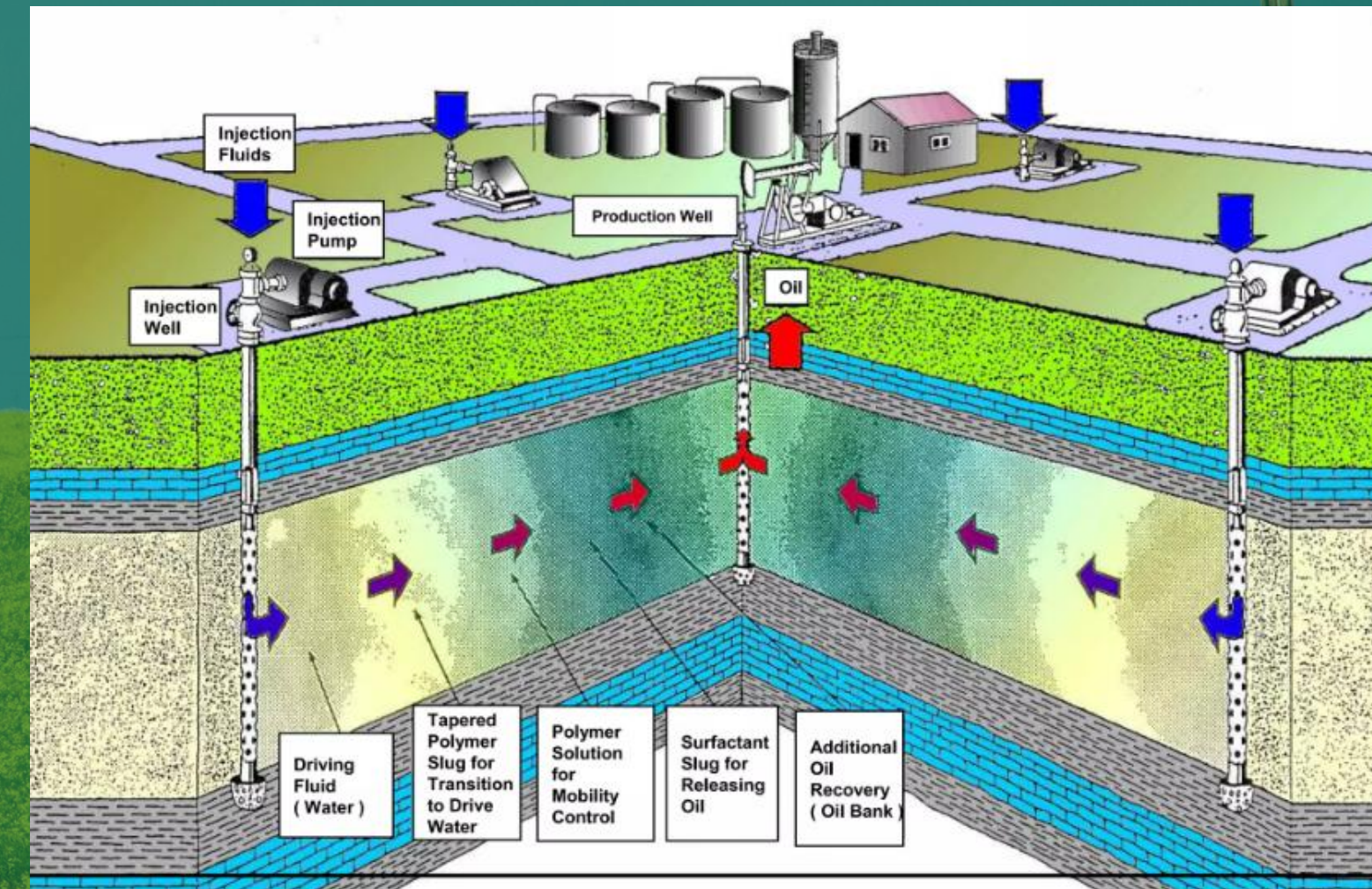
What is Enhanced Oil Recovery?

EOR:

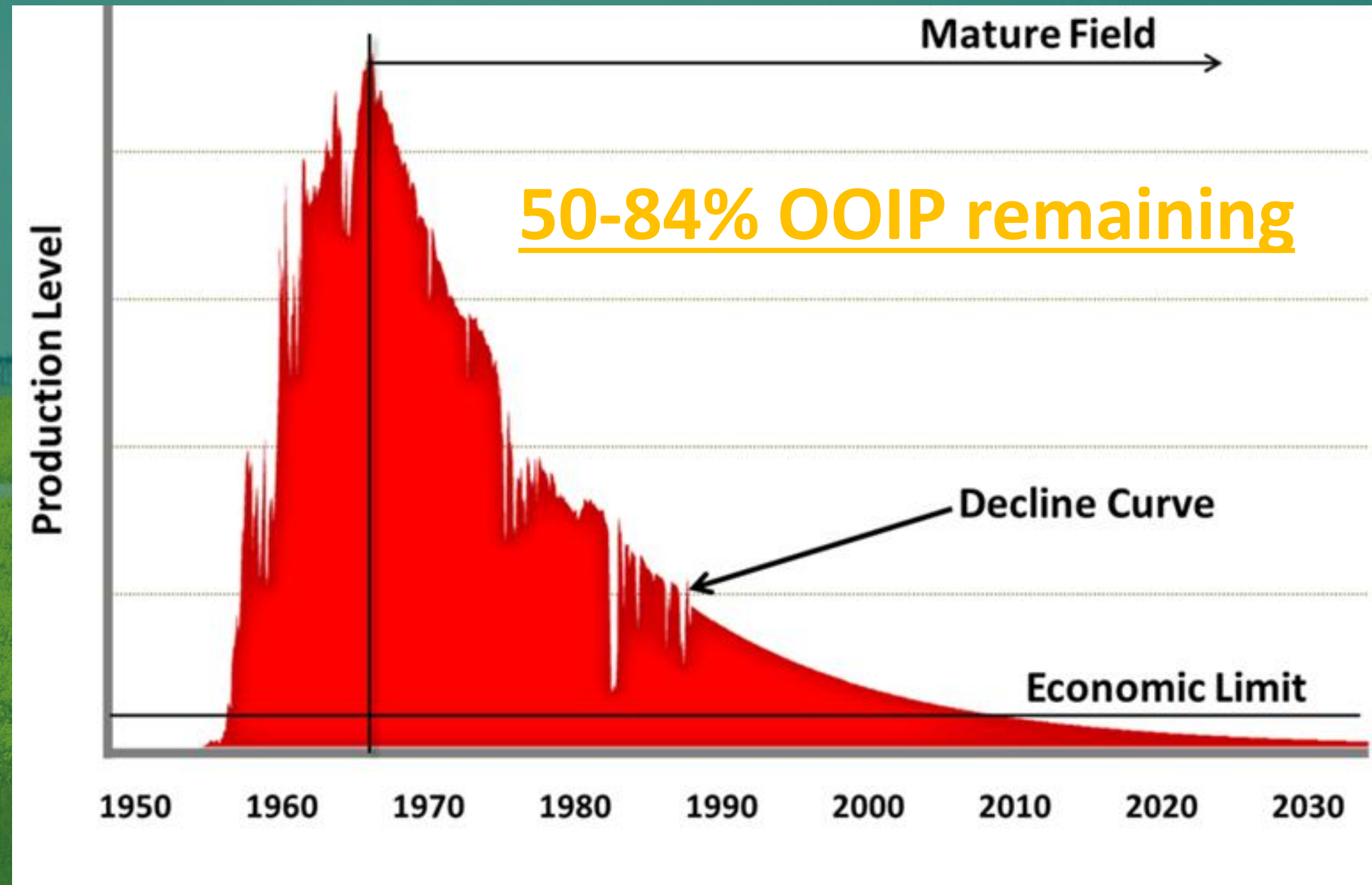
Techniques used to increase production beyond primary and secondary recovery methods.

Objectives:

- Restoring formation Energy
- Improving oil and/or reservoir conditions
- Enhancing oil displacement in the reservoir
- Improve economic recovery



Mature Oil Fields

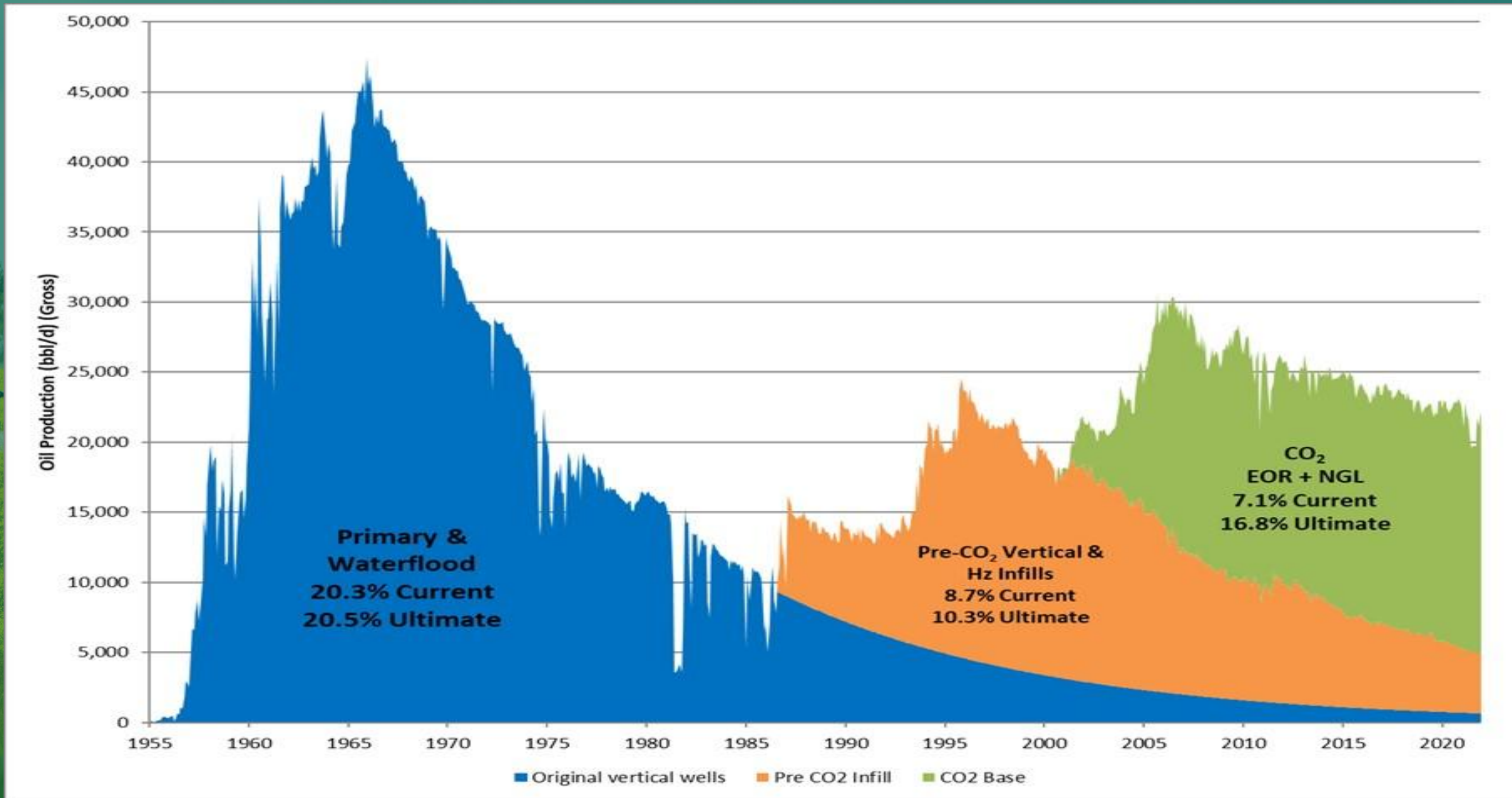


“A mature oil field is one that has come off plateau, that then has oil processing capacity where finding the right technology can unleash those barrels into the facilities.”

Jonathan Williams, BP

- Significant amounts of residual oils are left behind in mature fields.
- Excellent opportunities to test new EOR schemes, drilling methods, and other innovative technologies to maximize production.

Weyburn Southern Saskatchewan

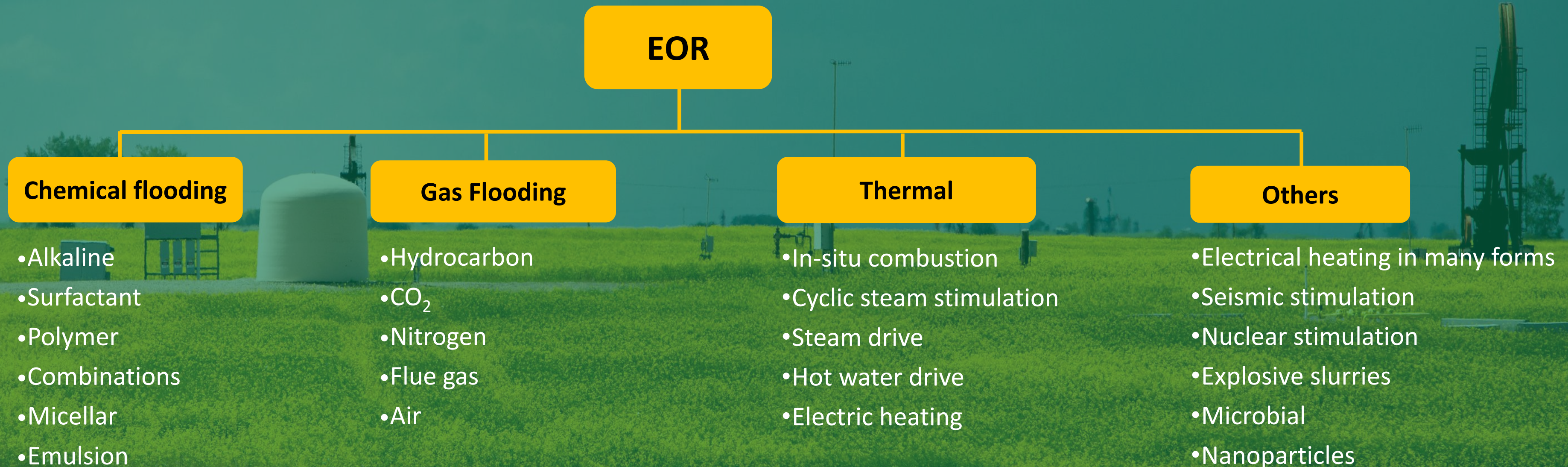


Production history of the Weyburn oil field



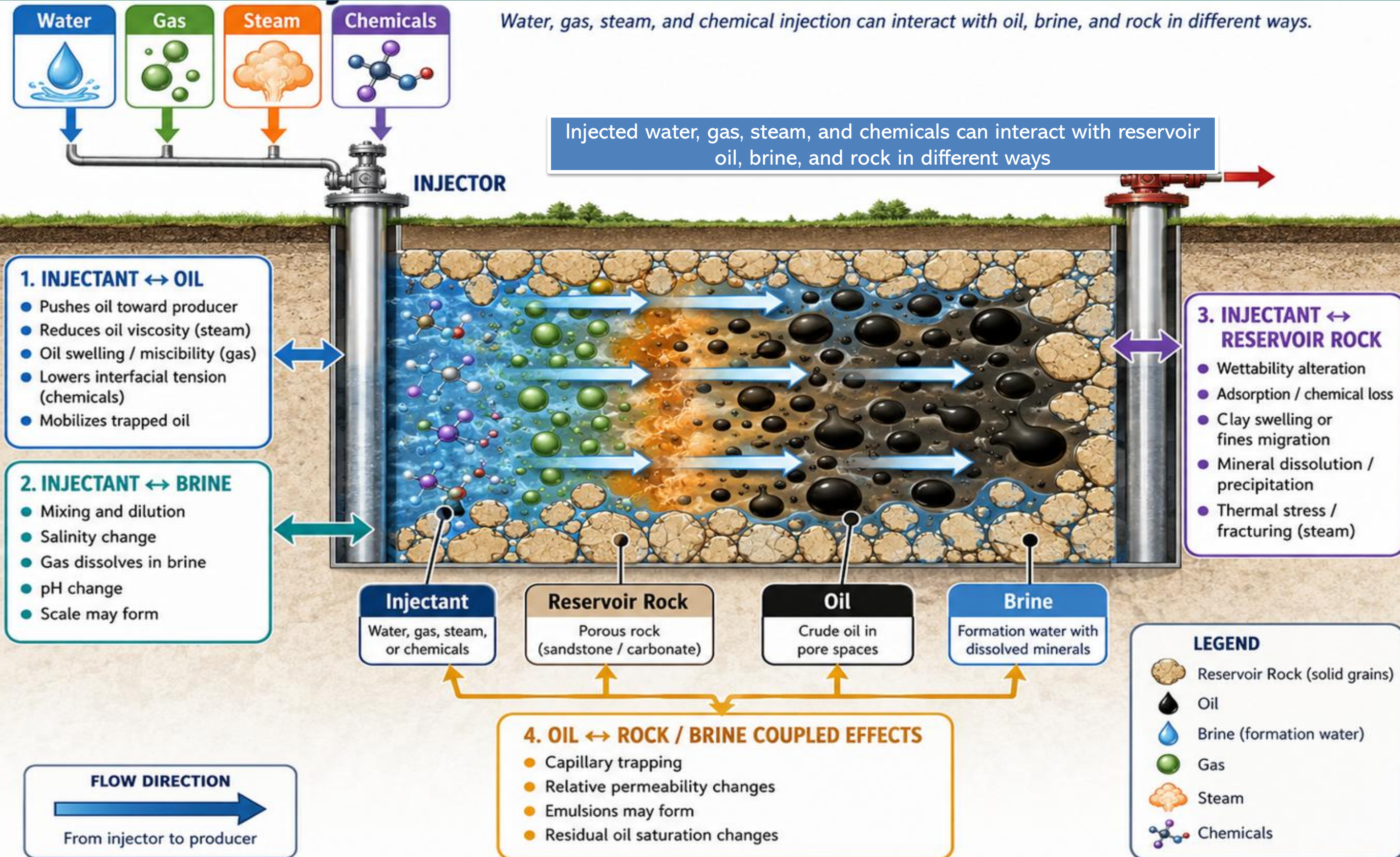
Classification of EOR Methods

EOR is not one technology. It is a toolbox for specific reservoirs



EOR Changes the reservoir condition

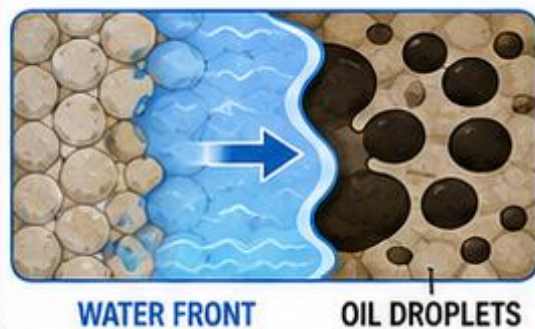
Water, gas, steam, and chemical injection can interact with oil, brine, and rock in different ways.



How Does EOR Get The Oil Out?

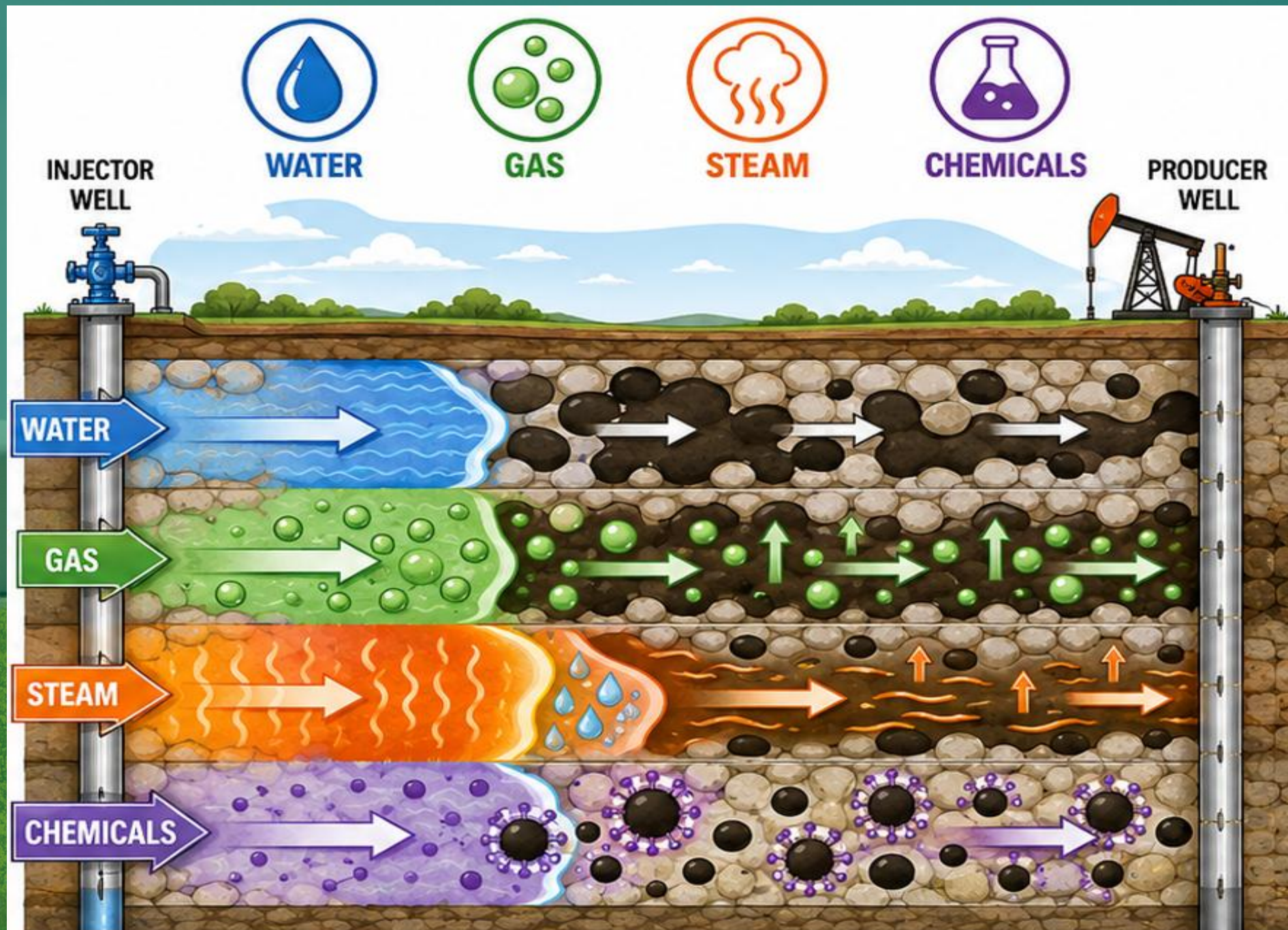
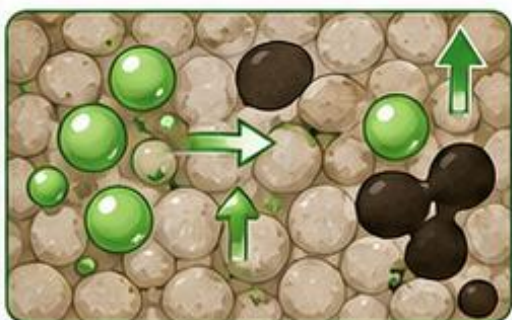
1 WATER INJECTION

- Maintains reservoir pressure
- Pushes oil toward producer (displacement / sweep)
- Improves volumetric sweep
- Can trap some residual oil behind water front



2 GAS INJECTION

- Pressure maintenance
- Oil swelling
- Oil viscosity reduction
- Miscible or near-miscible displacement
- Gas-drive and gravity drainage



MAIN RECOVERY MECHANISMS



Pressure support

Keeps the reservoir energy strong



Oil mobilization

Frees oil droplets and moves them



Viscosity reduction

Makes oil flow more easily

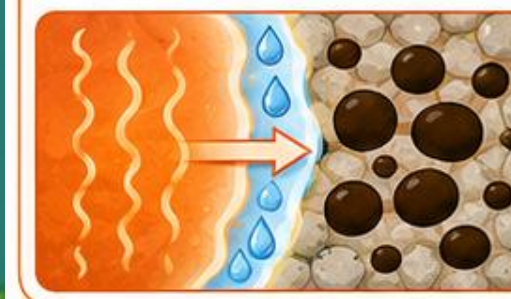


Better sweep efficiency

Reaches more oil, leaves less behind

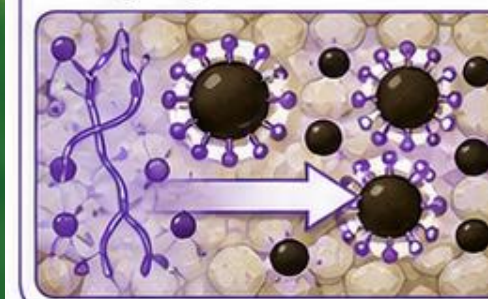
3 STEAM INJECTION

- Heats reservoir and oil
- Strongly reduces heavy-oil viscosity
- Improves oil mobility
- Steam condensation helps displace oil
- Can cause thermal expansion and some gravity drainage



4 CHEMICAL INJECTION

- Lowers interfacial tension (surfactant)
- Improves sweep efficiency (polymer mobility control)
- Changes wettability
- Mobilizes trapped oil
- Can reduce channeling / fingering



How to Determine Which EOR Works

Selection depends on reservoir rock and fluid properties, and economics

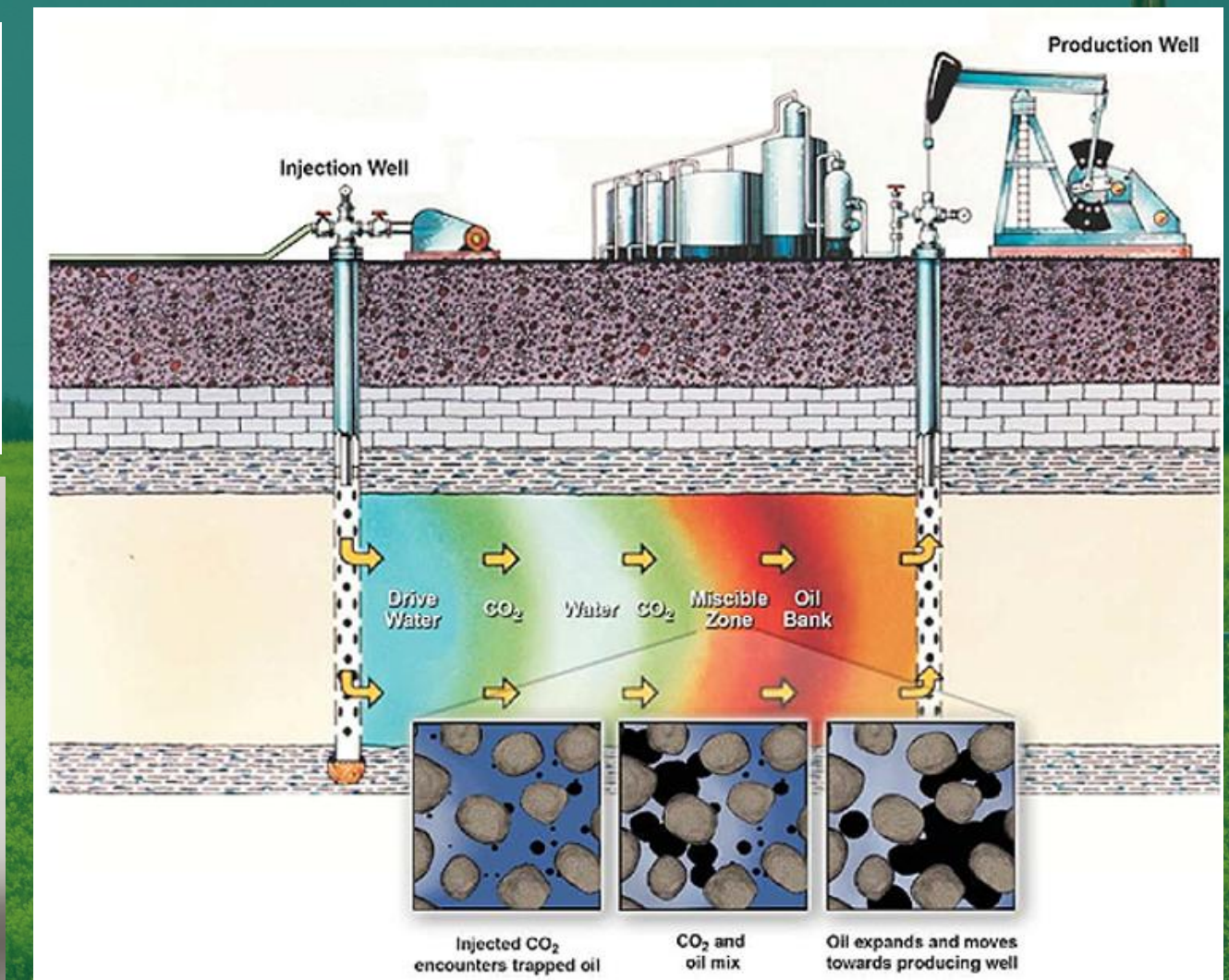
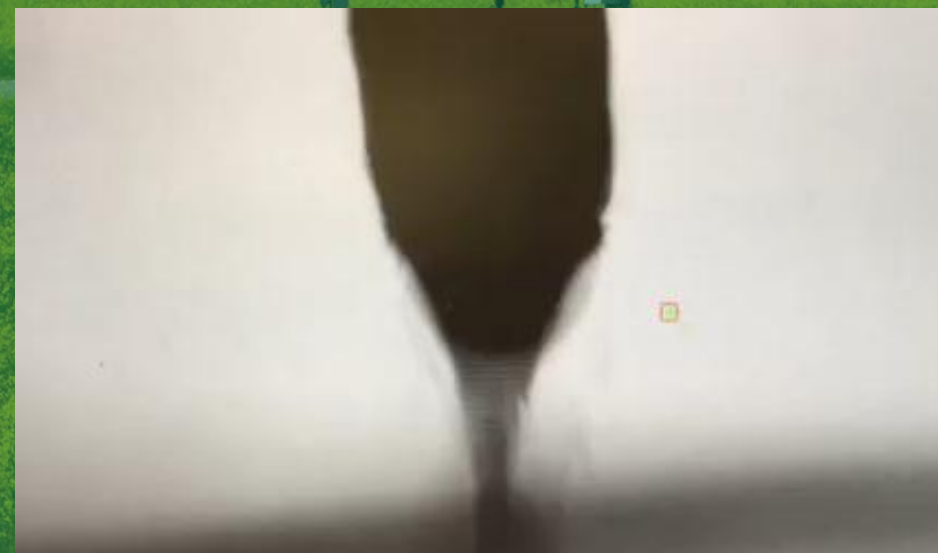
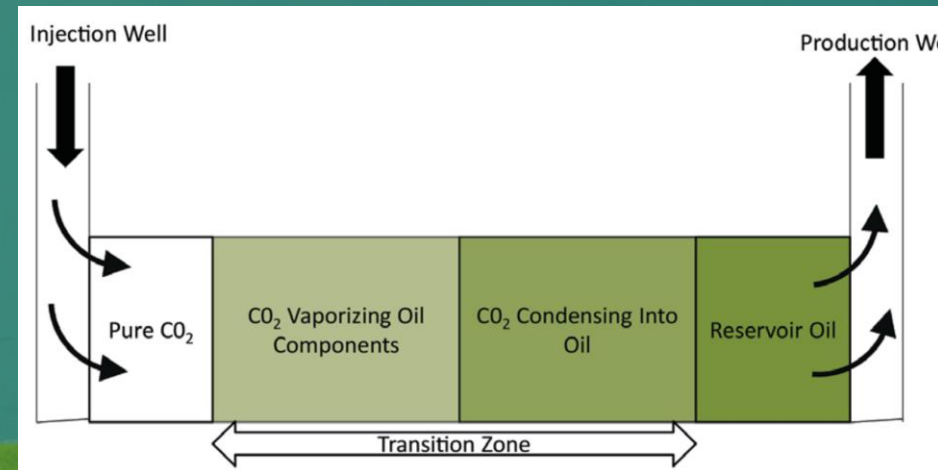
- ✓ **Oil type:** light, medium, heavy, or extra-heavy.
- ✓ **Rock type:** sandstone or carbonate; connected or fractured.
- ✓ **Other technical factors:** water chemistry, temperature, pressure, existing wells, and production history.
- ✓ **Sources:** Access to CO₂, steam fuel, chemicals, power, and water treatment.
- ✓ **Non-technical factors:** economic and market conditions, regulatory and policy frameworks, environmental considerations, social impact.



CO₂-EOR

CO₂ Miscible Displacement:

- Reservoir Temperature
- Reservoir Pressure
- Oil Composition
- Oil API Gravity
- CO₂ Availability
- CO₂ Stream Composition



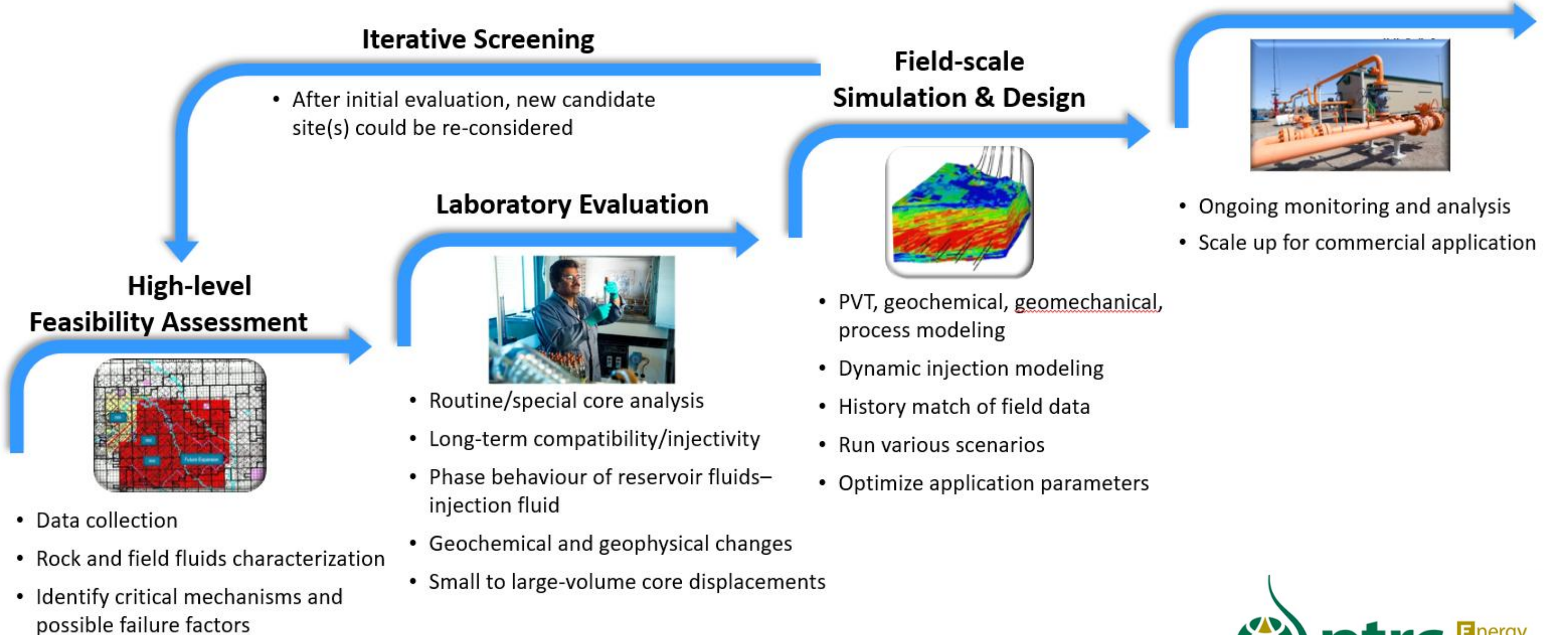
Multi-contact miscibility in CO₂-EOR miscible flooding

Preferred Oil Viscosity Range

EOR Methods	Oil Viscosity (mPa·s) at Reservoir Conditions					
	1	10	100	1,000	10,000	>100,000
Hydrocarbon Miscible	Very good	Good	Difficult	Uneconomic		
Nitrogen, Flue Gas	Good		Difficult	Uneconomic		
CO ₂ Flooding	Very good	Good	Difficult			Uneconomic
Surfactant/Polymer	Good		Fair	Difficult	Uneconomic	
Polymer	Good			Fair		Uneconomic
Alkaline	Good	Fair	Very difficult	Uneconomic		
Fire Flood	May not be possible		Good		Uneconomic	
Steam	Uneconomic			Very Good	Good	
Special Thermal	Not commonly applied			Various techniques possible		

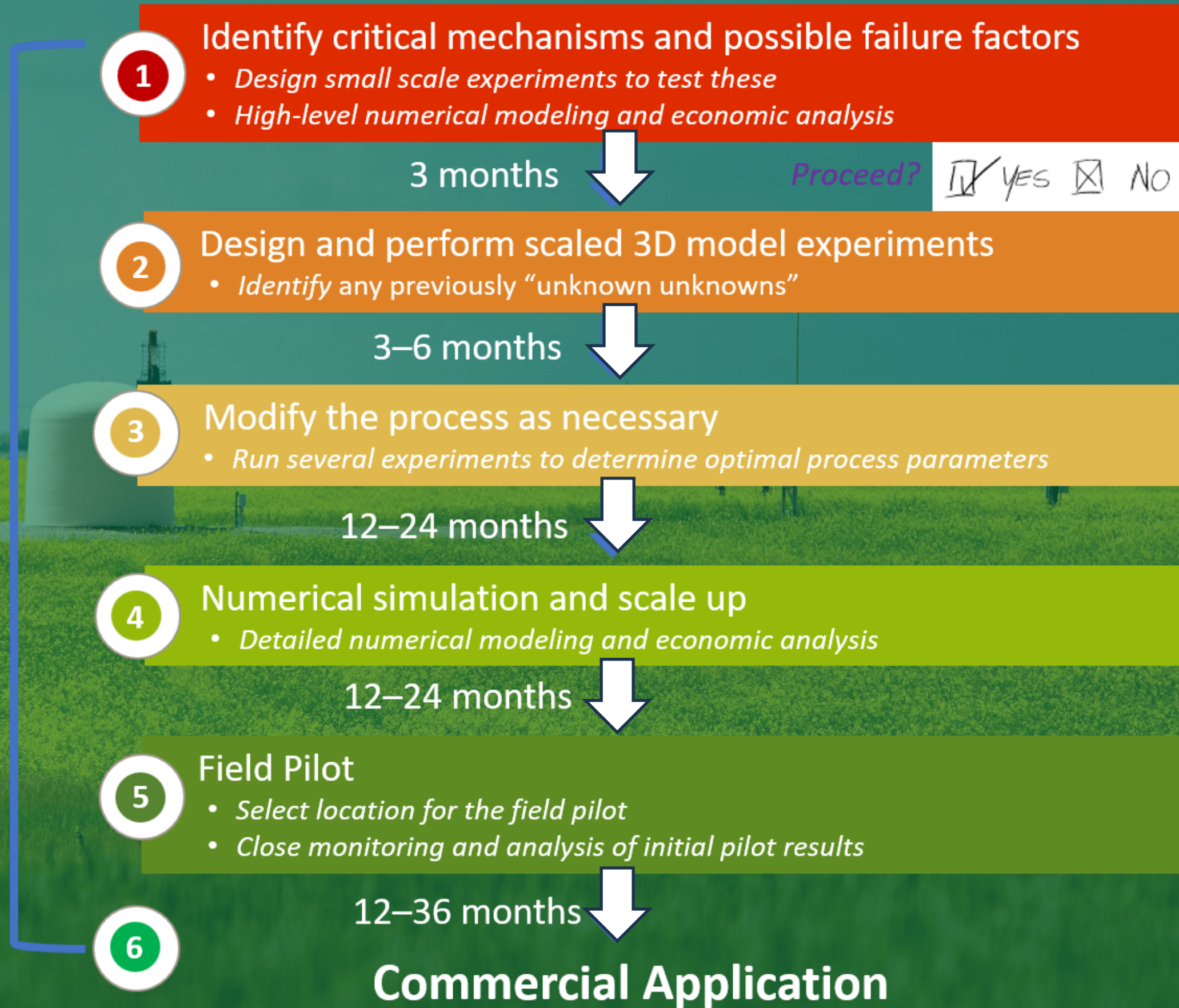
From Lab Evaluation/Validation to Field Application

— A practical decision workflow



EOR Project Design and Implementation

4-8 years



Lab Evaluation/Validation



- Physical Testing: Fluid and Rock analysis, Core flooding, PVT, IFT, wettability, HPHT conditions.

- Modeling and Simulation
- Integrated data acquisition and analysis systems.

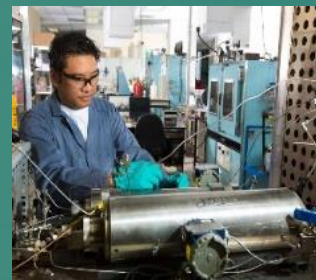
Fluid-Fluid Compatibility

- Scaling/precipitation/waxing
- Room conditions and reservoir P&T



Relative Permeability

- Unsteady State
- Steady state
- History match



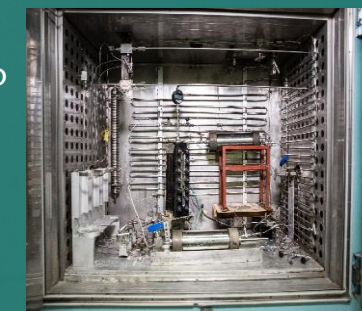
Slim Tube

- MMP



Custom PVT system

- Conventional light/medium/heavy oils
- High-T bitumen thermal tests
- Specialized tests, e.g., new phase detection, non-equilibrium kinetics, chemical treatment



Gas and High-Performance Liquid Chromatograph

- Chemical characterization
- Effluent analysis during chemical flooding
- Liquid hydrocarbon
- Field sampled gas
- Coreflood produced gas



Radial Coreflood & Large Physical 3-D Models

- Radial flow to evaluate sweep efficiency
- Large-scale EOR tests to evaluate blocking and conformance agents



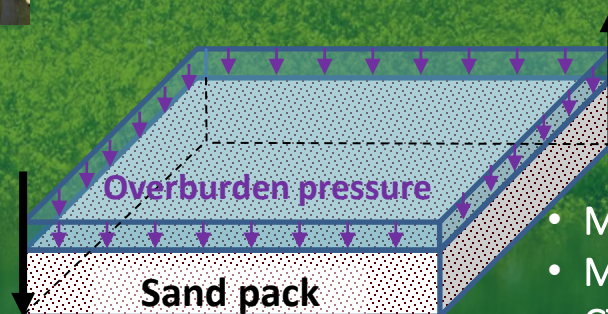
Industrial CT Scanning

- Dual micro- & mini-x-ray tube
- Walk-in chamber for large model/sample
- Digital core analysis
- Production QC/QA

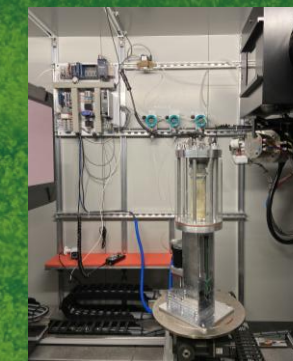


Linear Coreflood Apparatus

- Different diameter and length of coreholders with pore volume up to 10L
- Interim pressure and temperature ports
- Different configurations, e.g., parallel, series



- Multiple injection/production wells
- Multiple pressure points
- CT imaging capability

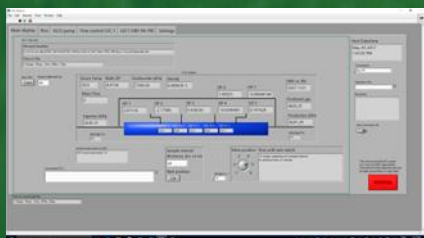


CT-aided Triaxial Cell

- Real-time see-through tests
- Core/tailing sands integrity
- Salt precipitation in CCS/geothermal

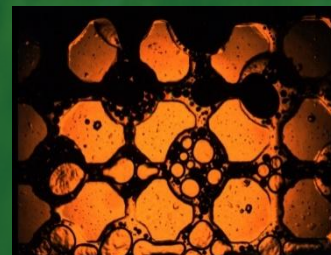
Custom Data Acquisition and Control

- LabView Coded GUI
- 24/7 Logging and Control



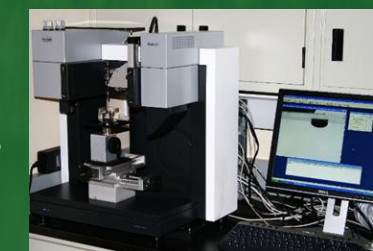
Micromodel

- Microscopic recovery mechanisms
- Chemical EOR
- Foamy oil flow



Contact angle & IFT meter

- HPHT measurements
- Minimum miscibility test
- Wettability in CCS and gas flooding



Innovation Through Collaboration



- Partnerships with global operators and R&D institutions
- Successful JIPs and public-private partnerships.
- Interface with funding agencies and regulatory bodies



PTRC brings together public and industry funders and research experts to design and approve the research that will best address the challenges



EOR CAN CREATE VALUE FROM EXISTING FIELDS, BUT ONLY WHEN TECHNOLOGY, GEOLOGY, ECONOMICS AND PUBLIC SAFEGUARDS LINE UP

Sustainable Energy System

- Reliable,
- Affordable, and
- Environmentally Acceptable

Thank You

We welcome visits, proposal discussions, and technical briefings



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