IOR/EOR Methods for Gulf of Mexico Deepwater Reservoirs

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RPSEA Project Objectives

- Identify IOR Processes for Deepwater GoM which could add substantial reserves and which are relatively close to technical feasibility.
- Identify the "technical gaps" preventing application of those IOR processes.
- Recommend future R&D programs to bridge those technical gaps & identify potential partners for RPSEA.

LSU's Role Phase I

IOR/EOR literature review and identification: started out with exhaustive list of possible methods (see vignette to the far right) and identified some priority processes at this stage.

Large Target for IOR/EOR

Remaining proved reserves ~ 8.8 BBOE
Undiscovered technically recoverable (MMS, 2006) ~ 86.3 BBOE

Big Challenge

Small reservoirs -- 50% have 20 Million Bbl OOIP or less
High well costs => Few wells per reservoir; mostly subsea wells

Prioritized IOR/EOR Methods

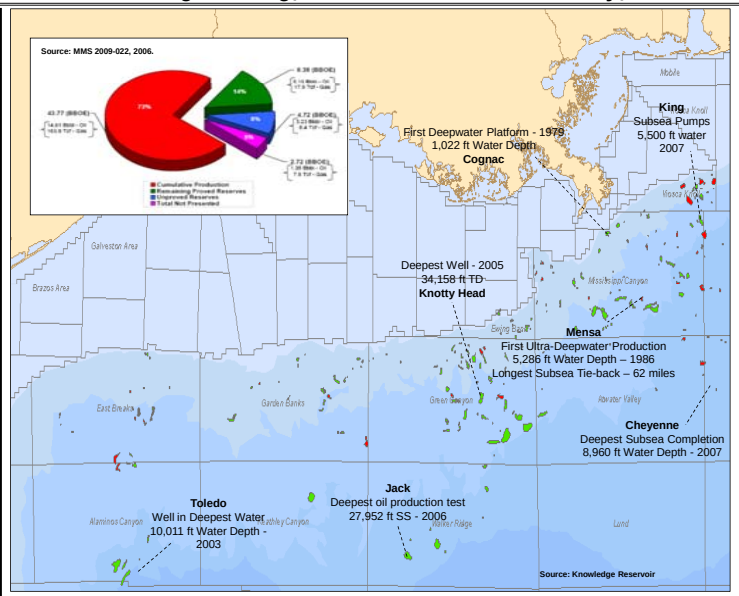
The prioritized methods are low-cost variations of classic IOR/EOR processes:

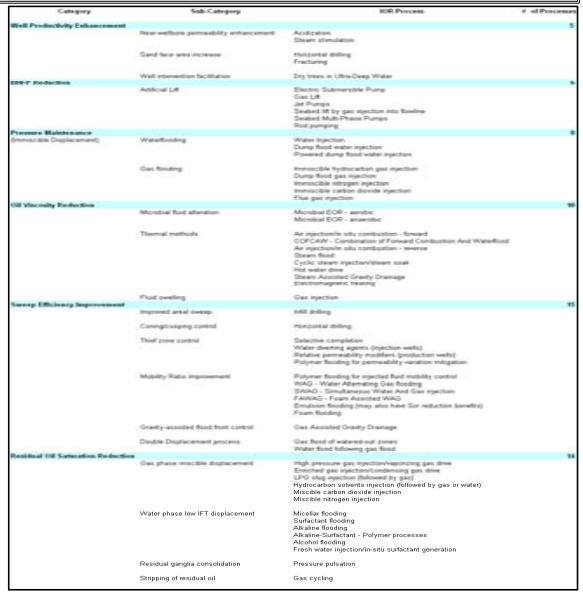
1. ***Air injection (low-temperature oxidation)***
2. ***Hydrocarbon gas injection***
3. ***Dump flooding***
4. ***Sea-floor injection***
5. Single well injection/production: simultaneous & huff 'n' puff
6. Smart well technology
7. Casing drilling

This list is only indicative of the work in progress and is by no means the final list of IOR/EOR methods that can potentially be applied in deepwater GoM reservoirs.

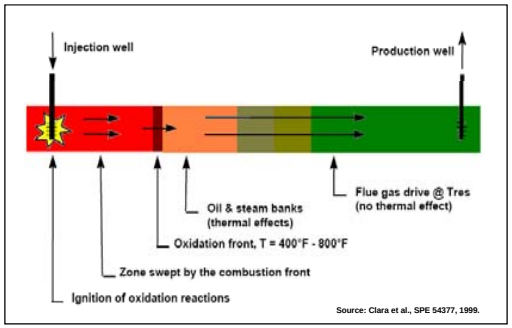
Future Work

Numerical simulation will be used to assess the incremental recovery of selected IOR/EOR processes using actual GoM deepwater reservoir characteristics.





Category	Sub-Category	IOR Process	# of Processes
Well Productivity Enhancement			5
	Near-wellbore permeability enhancement	Acidization Steam stimulation	
	Sand face area increase	Horizontal drilling Fracturing	
	Well intervention facilitation	Dry trees in Ultra-Deep Water	
ESP-F Reduction			4
	Artificial Lift	Electric Submersible Pump Gas Lift Jet Pumps Seabed lift by gas injection into flowline Seabed Multi-Phase Pumps Rod pumping	
Pressure Maintenance (Immiscible Displacement)			8
	Waterflooding	Water injection Dump flood water injection Powered dump flood water injection	
	Gas flooding	Immiscible hydrocarbon gas injection Dump flood gas injection Immiscible nitrogen injection Immiscible carbon dioxide injection Flue gas injection	
Oil Viscosity Reduction			10
	Microbial fluid alteration	Microbial EOR - aerobic Microbial EOR - anaerobic	
	Thermal methods	Air injection/in situ combustion - forward COFCAW - Combination of Forward Combustion And Waterflood Air injection/in situ combustion - reverse Steam flood Cyclic steam injection/steam soak Hot water drive Steam Assisted Gravity Drainage Electromagnetic heating	
	Fluid swelling	Gas injection	
Sweep Efficiency Improvement			11
	Improved areal sweep	Infill drilling	
	Coning/cusping control	Horizontal drilling	
	Thief zone control	Selective completion Water diverting agents (injection wells) Relative permeability modifiers (production wells) Polymer flooding for permeability variation mitigation	
	Mobility Ratio improvement	Polymer flooding for injected fluid mobility control WAG - Water Alternating Gas flooding SWAG - Simultaneous Water And Gas injection FAWAG - Foam Assisted WAG Emulsion flooding (may also have Sor reduction benefits) Foam flooding	
	Gravity-assisted fluid front control	Gas Assisted Gravity Drainage	
	Double Displacement process	Gas flood of watered-out zones Water flood following gas flood	
Residual Oil Saturation Reduction			11
	Gas phase miscible displacement	High pressure gas injection/vaporizing gas drive Enriched gas injection/condensing gas drive LPG slug injection (followed by gas) Hydrocarbon solvents injection (followed by gas or water) Miscible carbon dioxide injection Miscible nitrogen injection	
	Water phase low IFT displacement	Micellar flooding Surfactant flooding Alkaline flooding Alkaline-Surfactant - Polymer processes Alcohol flooding Fresh water injection/in situ surfactant generation	
	Residual ganglia consolidation	Pressure pulsation	
	Stripping of residual oil	Gas cycling	



Air injection – low temperature oxidation

Oxygen in the injected air stream reacts with reservoir oil through low temperature oxidation reactions (400-800°F), thus generating flue gases that aide in recovery process.

Benefits

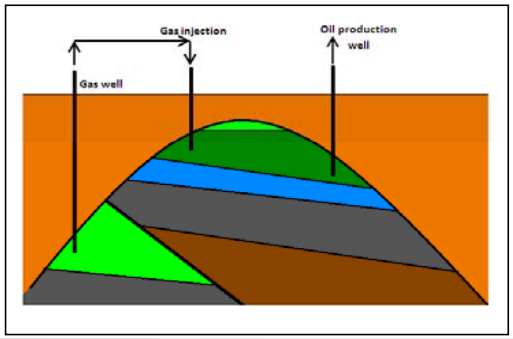
- Low cost:
  - Abundant and easily accessible gas source.
  - Comparable to nitrogen injection.
- Estimated incremental recovery 5%OOIP.

Challenges

- Limited offshore experience.
- Large well spacing necessary (advantage?).

World-wide experience

- North Sea (Ekofisk feasibility study).



Hydrocarbon gas injection

Injected hydrocarbon gas recovers oil by way of viscous displacement, oil swelling & stripping and pressure support. Has been applied as EOR method and/or because of operational constraints.

Benefits

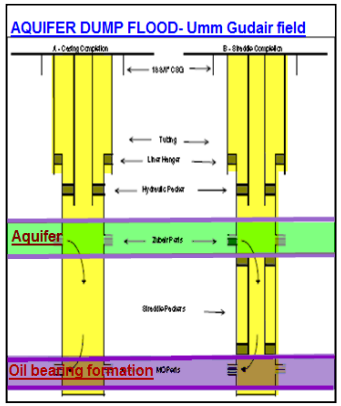
- Low cost:
  - Gas can be sourced from formation within same or nearby field.
  - Reduced gas flaring.
- Incremental recovery: 3%OOIP.

Challenges

- Market demand for gas.
- Mobility ratio issues.
- GoM GOR too low?

World-wide experience

- North Sea (Ekofisk), Gulf of Arabia (Abu Al Bukhoosh).



Dump flooding

It is the allowance of fluid to move from one formation to another in the same well in order to maintain pressure.

Benefits

- Low cost:
  - Eliminates the need for water treatment.
- Reduces environmental impact.

Challenges

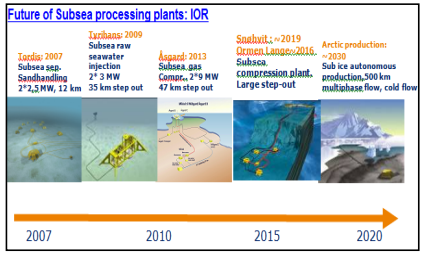
- Traditional dumpflooding is uncontrolled, hence, inability to monitor or control injection rates.

Opportunities

- Combining it with smart well technology.

World-wide experience

- Kuwait, Egypt, Saudi Arabia.



Subsea water injection or subsea separation and injection facility

Benefits

- Low cost:
  - Makes water injection feasible where there are restrictions to install or upgrade a conventional system.
  - Reduced environmental impact.

Challenges

- Reliability.
- Seawater compatibility.

World-wide experience

- North Sea, Brazil, GOM, Angola.