Enhanced Oil Recovery

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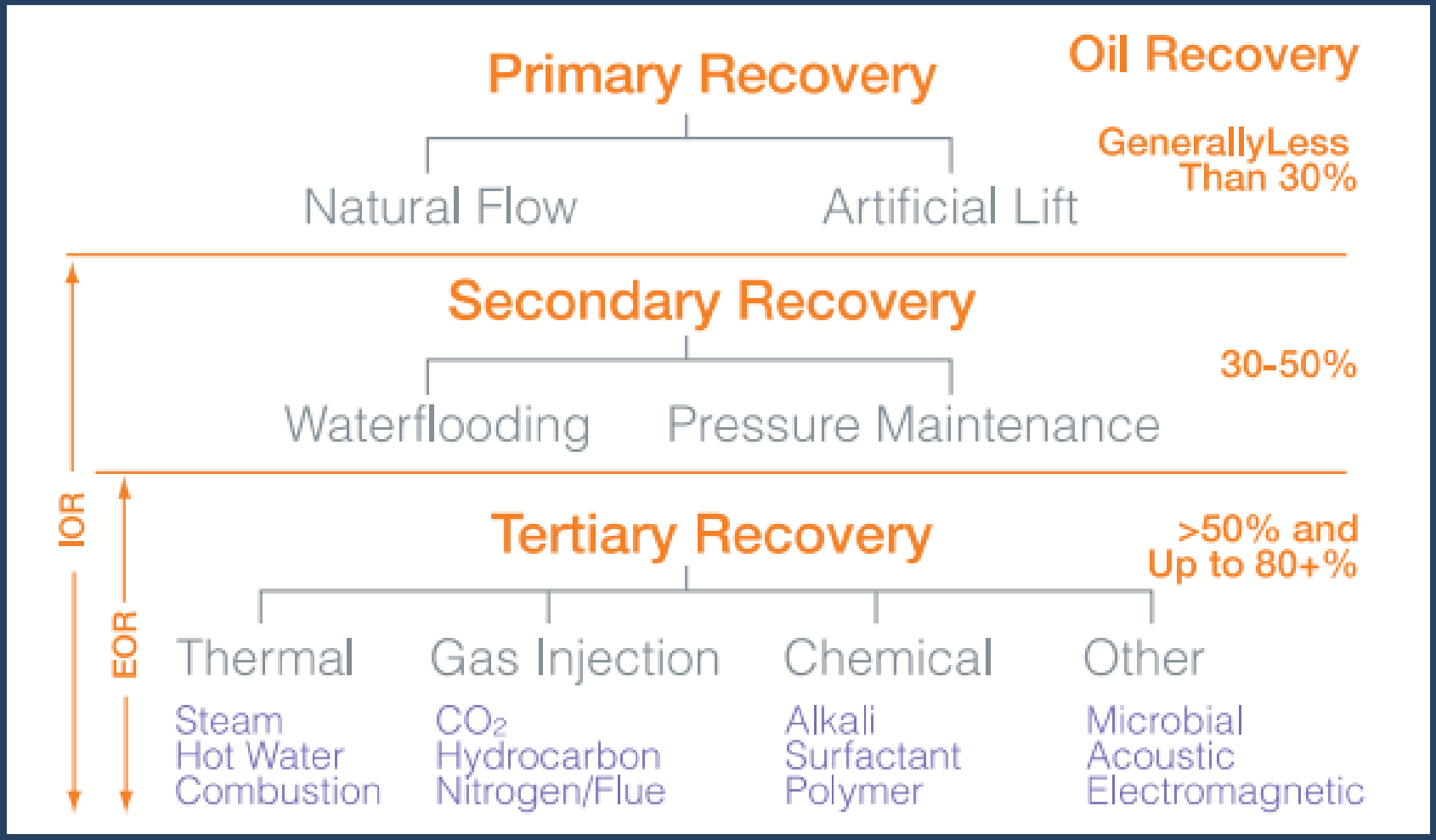
Oil Recovery



Kokal and Al-Kaabi, 2012

Oil Recovery

US EOR PRODUCTION

Table 1

	1992	1994	1996	1998	2000	2002	2004	2006	2008	2010	2012	2014
Thermal												
Steam	454,009	415,801	419,349	439,010	417,675	365,717	340,253	286,668	275,192	273,448	300,762	284,725
Cumbustion												
in situ	4,702	2,520	4,485	4,760	2,781	2,384	1,901	13,260	17,025	16,868	20,590	20,590
Hot water	1,980	250	250	2,200	306	3,360	3,360	4,370	1,776	1,676	1,703	1,703
Total thermal	**460,691**	**418,571**	**424,084**	**445,970**	**417,675**	**371,461**	**345,514**	**304,298**	**293,993**	**291,992**	**323,055**	**307,018**
Chemical												
Micellar–polymer	254	64								70		
Polymer	1,940	1,828	139	139	1,598							
Caustic/alkaline												
Surfactant					60	60	60					
Total chemical	**2,194**	**1,892**	**139**	**139**	**1,658**	**60**	**60**	—	—	**70**	—	—
Gas												
Hydrocarbon miscible/ immiscible	113,072	99,693	96,263	102,053	124,500	95,300	97,300	95,800	81,000	81,100	81,100	127,500
CO_2 miscible	144,973	161,486	170,715	179,024	189,493	187,410	205,775	235,344	240,313	272,109	308,564	292,735
CO_2 immiscible	95				66	66	102	2,698	9,350	9,160	43,657	42,795
Nitrogen	22,580	23,050	28,017	28,117	14,700	14,700	14,700	14,700	19,700	9,000	8,000	8,000
Flue gas (miscible and immiscible)	11,000											
Other	6,300	4,400	4,350	4,350								
Total gas	**298,020**	**288,629**	**299,345**	**313,544**	**328,759**	**297,476**	**317,877**	**348,542**	**350,363**	**371,369**	**441,321**	**471,030**
Other												
Microbial	2	2										
Total other	**2**	**2**										
Grand total	**760,907**	**709,094**	**723,568**	**759,653**	**748,092**	**668,997**	**663,451**	**652,840**	**644,356**	**663,431**	**764,376**	**778,048**

O&G Journal, 2014

Thermal Methods

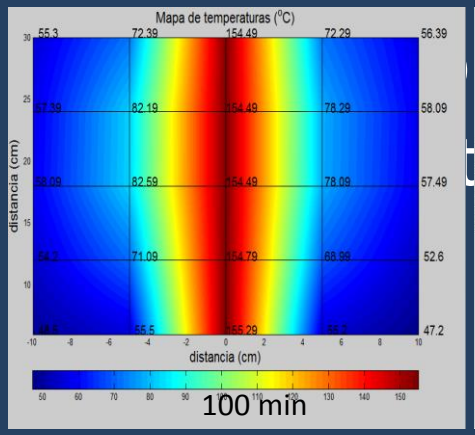
Steam Injection

Lab tests

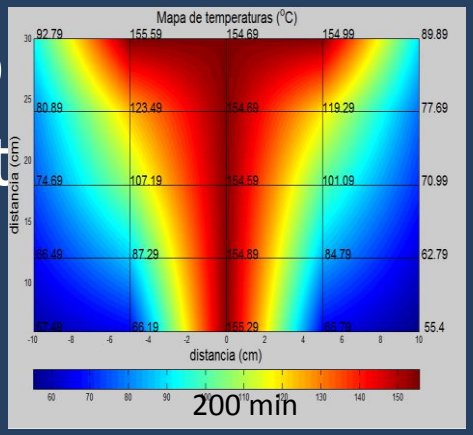
Thermal Methods

Steam Injection

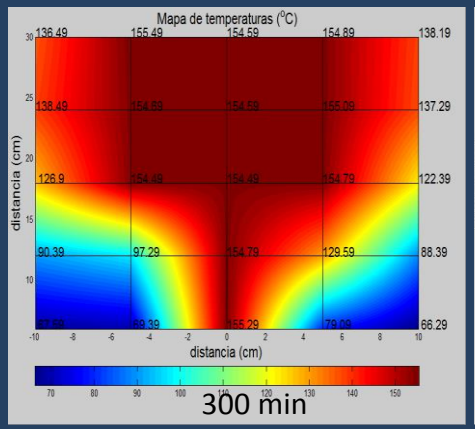
Lab tests



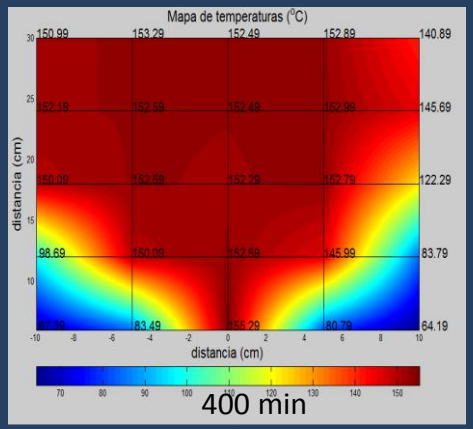
100 min



200 min



300 min



400 min

Steam Injection parameters

- varying steam quality
- with nitrogen
- with solvent
- with flue-gas
- SAGD

5 Master thesis

Thermal Methods

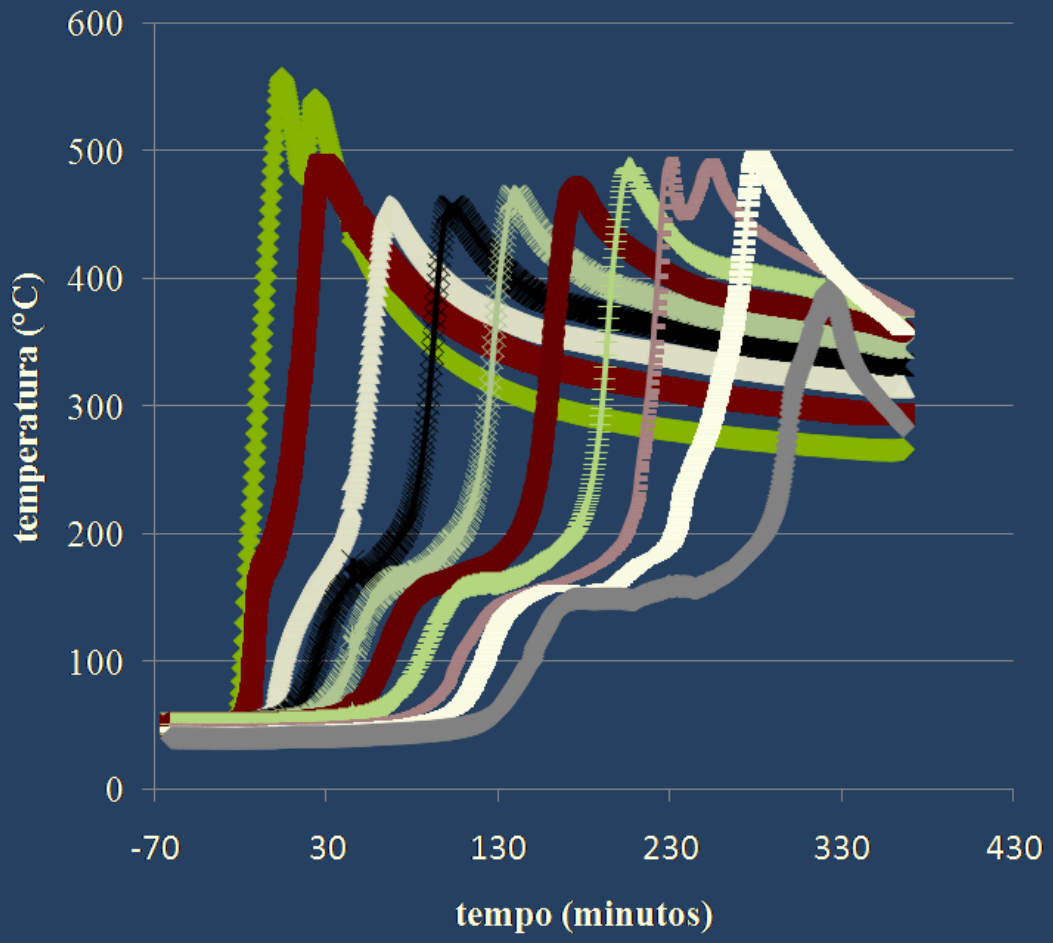
In-situ Combustion

Lab tests

Thermal Methods

In-situ Combustion

Lab tests



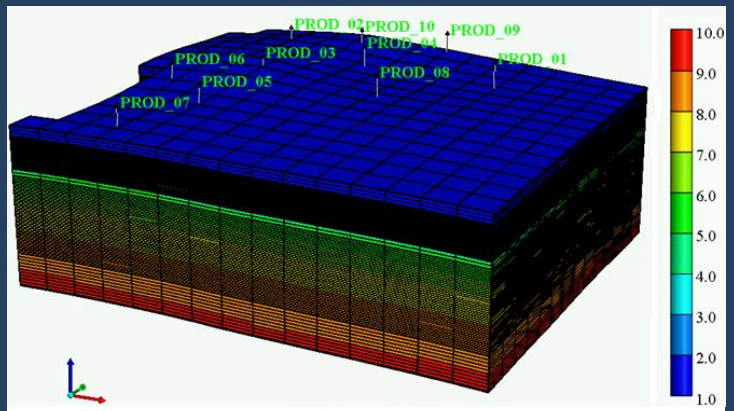
Tube combustion parameters
- dry
- wet
- with additives

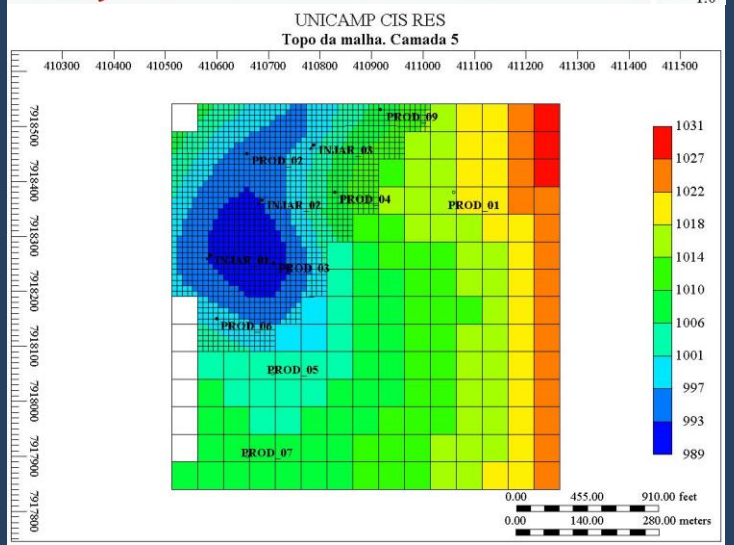
Kinetics of oxidation
- oil
- oil/sand/clay
- oxygen/air
- SARA components

7 Master thesis

Thermal Methods

Simulation





In-situ combustion
- reaction modeling
- scale effects
- matching at lab scale
- field scale modeling

Steam injection
- lab scale modeling
- SAGD variations
- mechanisms in NFR

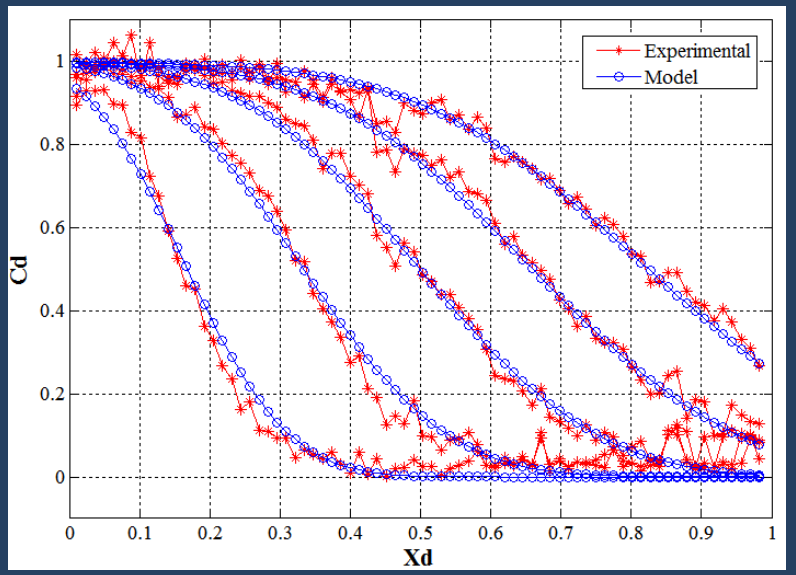
5 Master thesis , 1 PhD

Miscible Methods

(Gas Injection)

Rock-fluid Properties

- Dispersion in heterogeneous media
- Hysteresis in relative permeability
- Effects of dissolution on the rock properties
- Wettability at high pressure



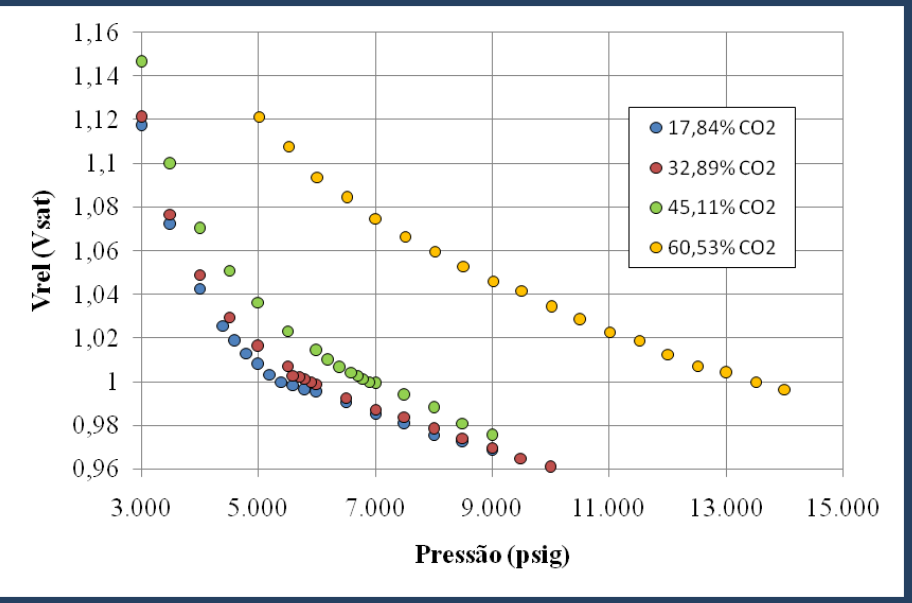
5 Master thesis , 2 PhD

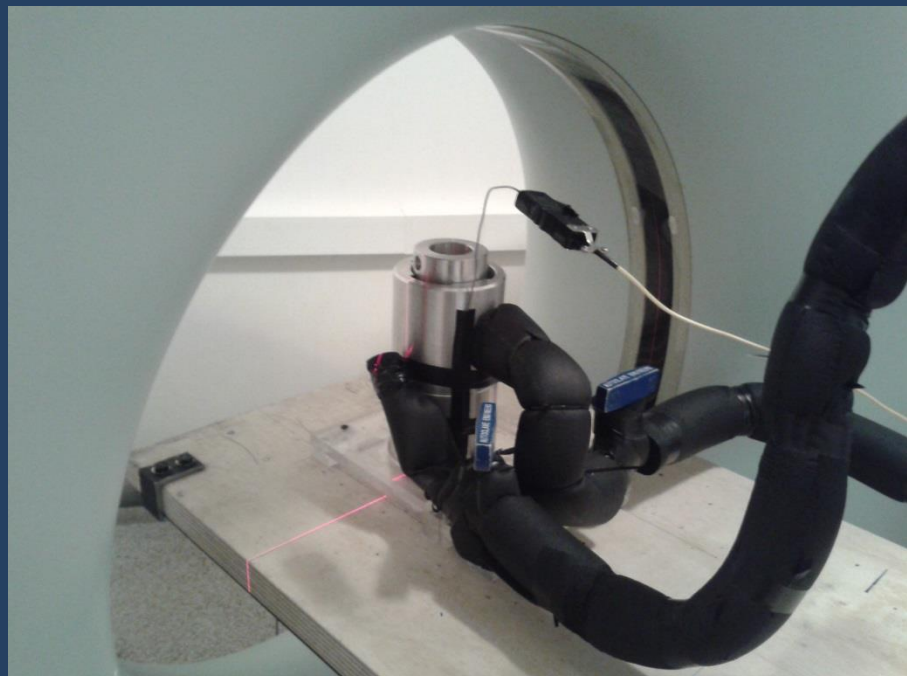
Miscible Methods

(Gas Injection)

Fluid Properties

- PVT of light oil – CO_2
- CO_2 partition between oil and water
- Diffusion and swelling of light oil with CO_2
- IFT at high pressure



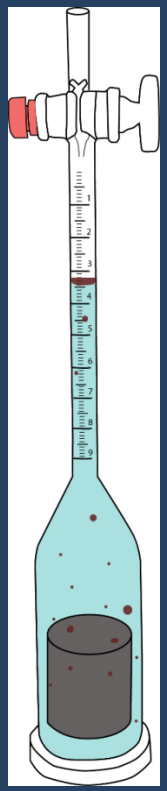


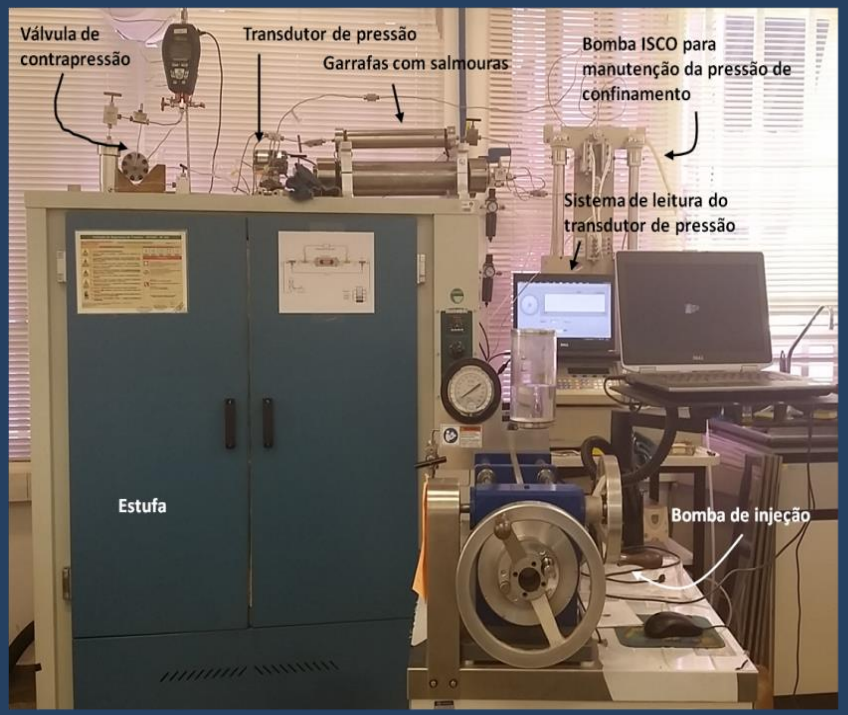
2 Master thesis, 1 PhD

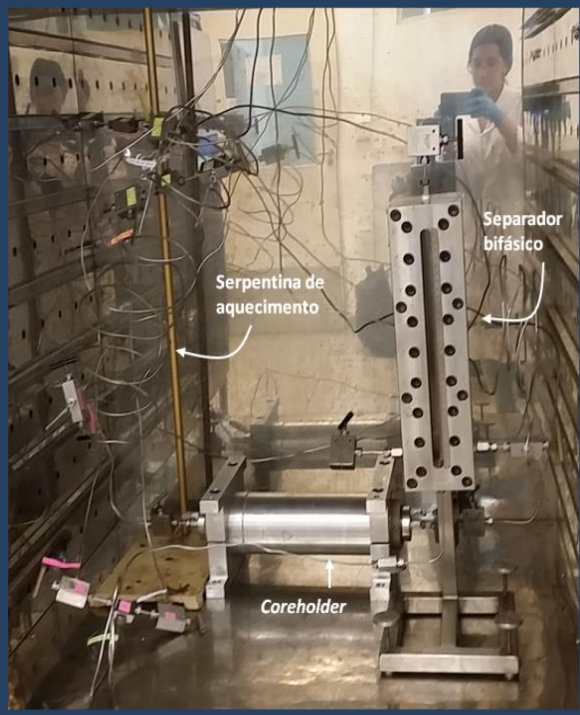
Designed Water

Oil recovery

- Spontaneous imbibition
- Displacement tests
- Effects of dissolution on the rock properties

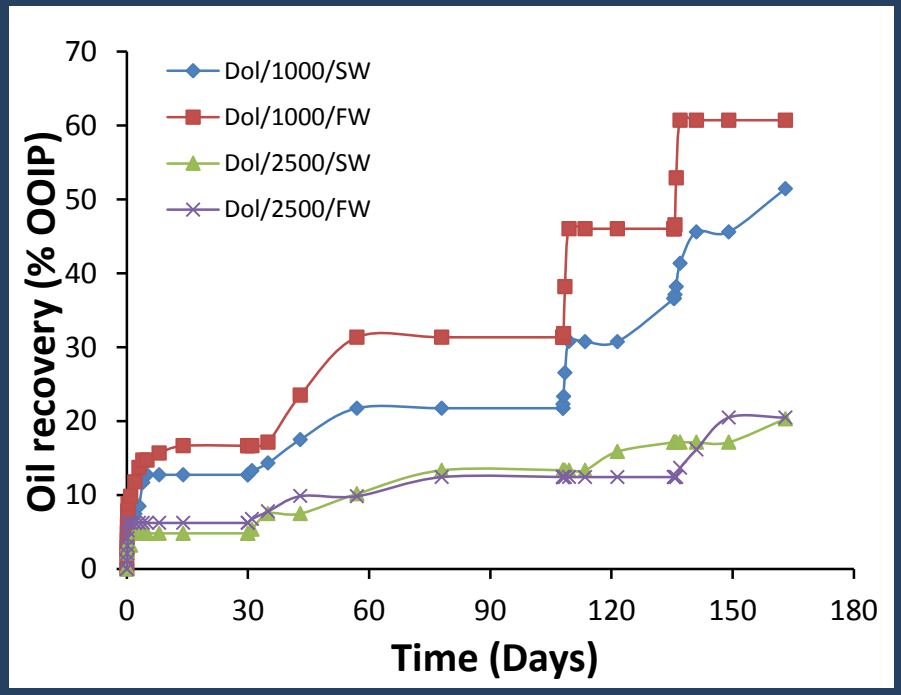




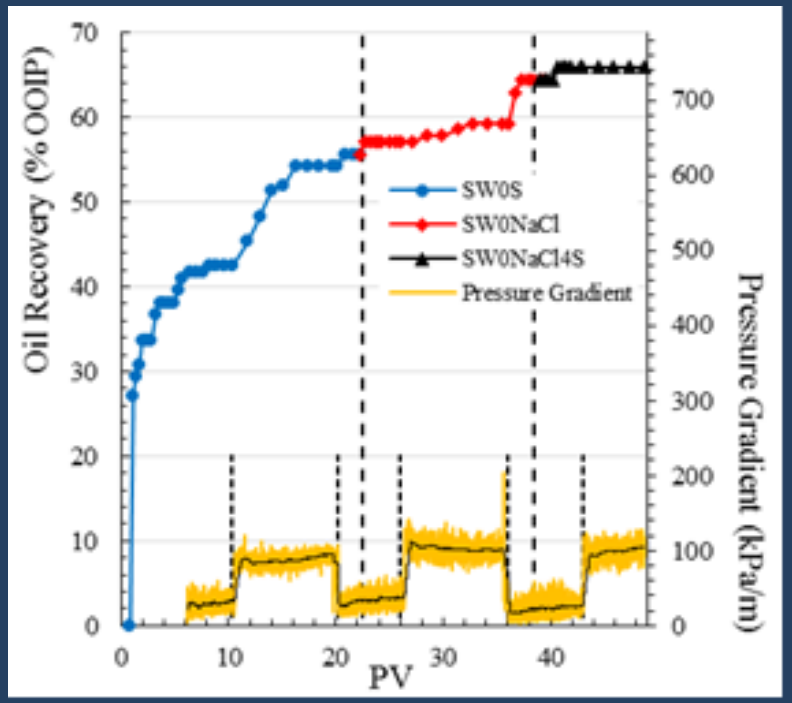


Designed Water

Spontaneous imbibition



Displacement tests



2 Master thesis , 1 PhD

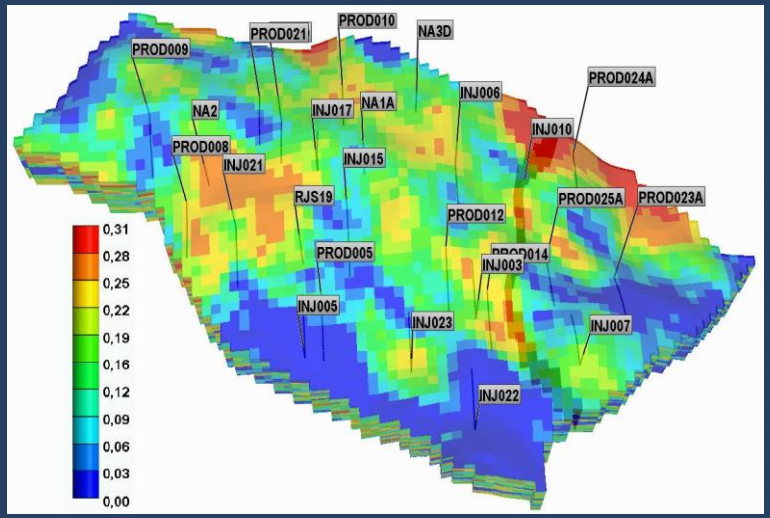
UNICAMP

ANO 50

UNISIM

CEPETRO
CENTRO DE ESTUDOS DE PETRÓLEO

- Mission: improve decision making process related to reservoir development and management
- 20 years of experience
- Team of 60 people (professors, researchers, students and support)
- Projects with industry: 46
- Articles: +430
- Academic : +150
- Prizes: 26
- Students (Concluded): +150
- Support software development
- Creation of benchmark cases used worldwide



UNISIM-I Benchmark (UNISIM, 2013)

UNICAMP

ANO 50

UNISIM

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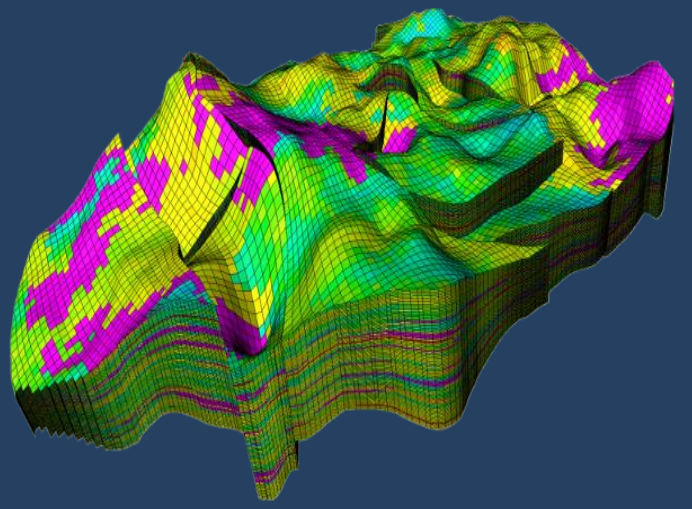
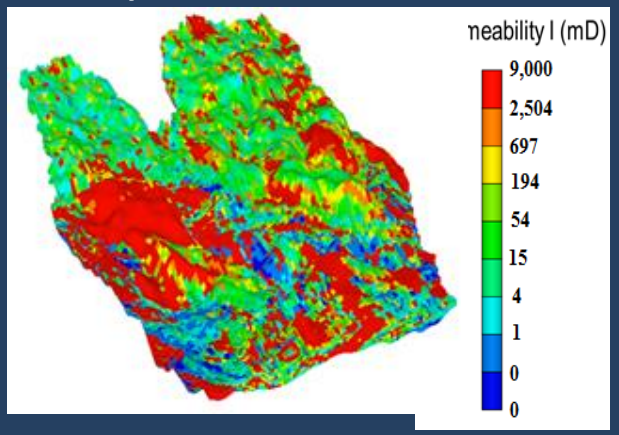
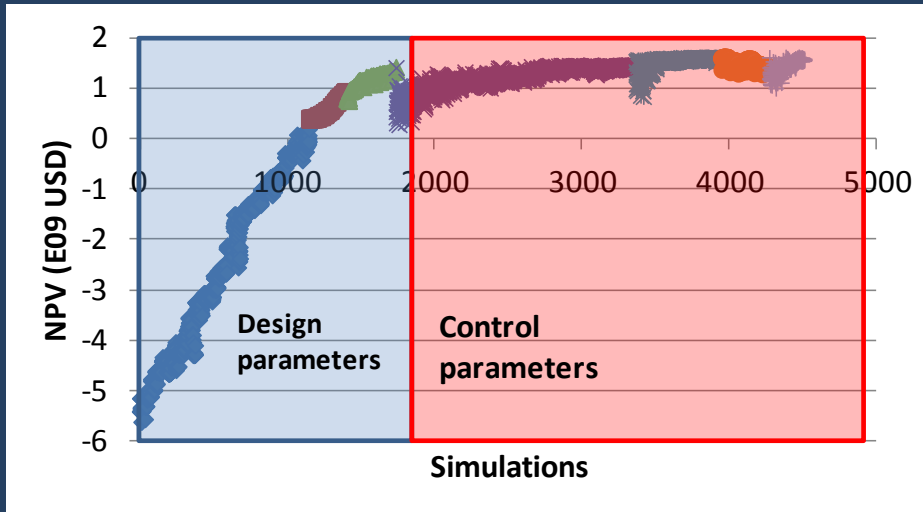
- **Carbonate Reservoirs***
- **Fractured Reservoirs Simulation***
- **WAG, CO_2, Treatment Fluid***
- **Polymer Flooding***
- Model Based Decision Analysis
- Intelligent fields
- Value of Information
- Reservoir Modeling and Optimization of Integrated Systems Surfaces
- Uncertainty reduction with dynamic data assimilation and integration with 4D Seismic
- Applications in Large and Complex Models



UNISIM-II Benchmark (UNISIM, 2016)



- Pre-Salt Carbonate Reservoirs
  - Representation of Critical Heterogeneities in reservoir simulation models
  - Fluid Treatment
  - Optimization of WAG and CO_2 injection
  - Importance of models in the decision of: design – G1 (well spacing, prod system, ..); control – G2 (cycles, rates, …)
  - Consequences on the performance of the filed under uncertainties (risk analysis)



- Pre-Salt Carbonate Reservoirs
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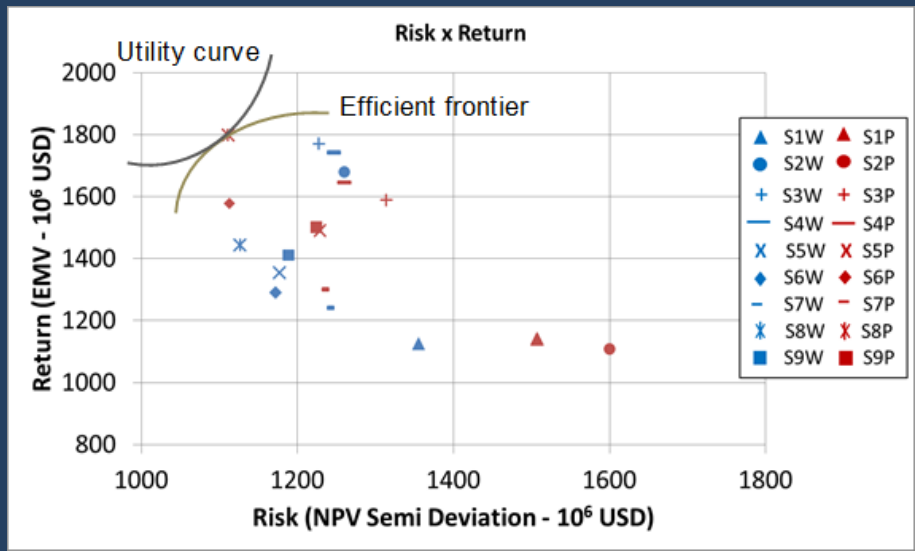
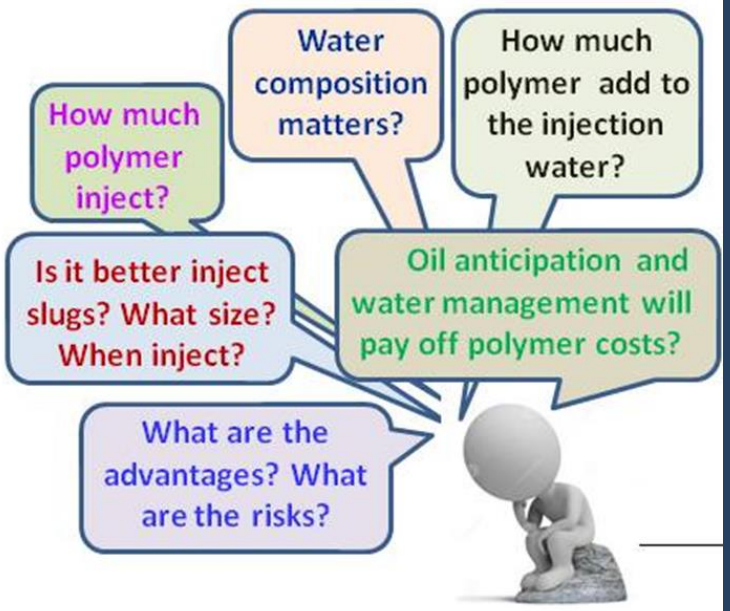
  - Consequences on the performance of the filed under uncertainties (risk analysis)
- Polymer Flooding
  - Complete risk analysis integration geologic/economic uncertainties with polymer properties that affect the efficiency of the recovery process
    - degradation, retention, inaccessible pore volume, dependence of viscosity with concentration, salinity, injectivity)
  - Complete economic analysis for 2 complex cases.



Polymer Design

Rheology and Degradation

- ***Focus:*** Tailoring of chemical flooding according to the target reservoir

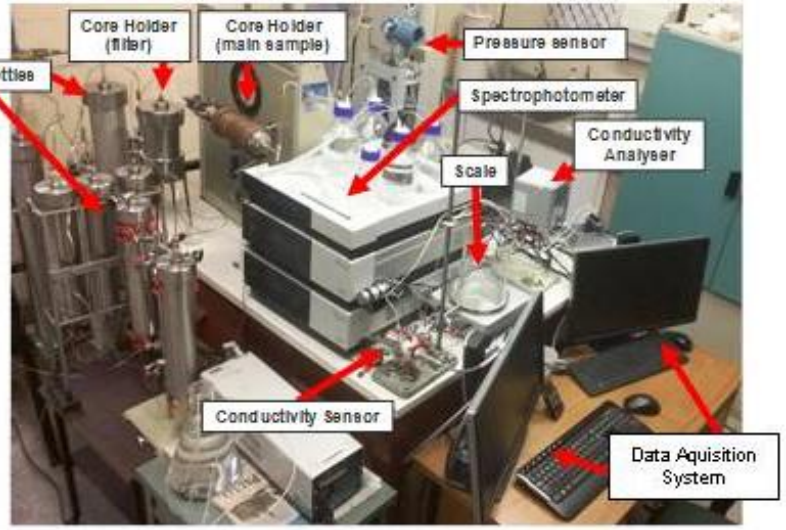


Fluid Design: viscous and elastic properties, critical concentration, influencing factors

Polymer Sweep Eficiency in Heavy-oil Reservoirs

- *Experimental Setup 1*:
  Injection strategies, injectivity and displacement efficiency

- *Experimental Setup 2*:
  Retention, Adsorption, RF, RRF, IPV and in-situ viscosity



Chemistry Institute

NMR Investigation on Rock Wettability

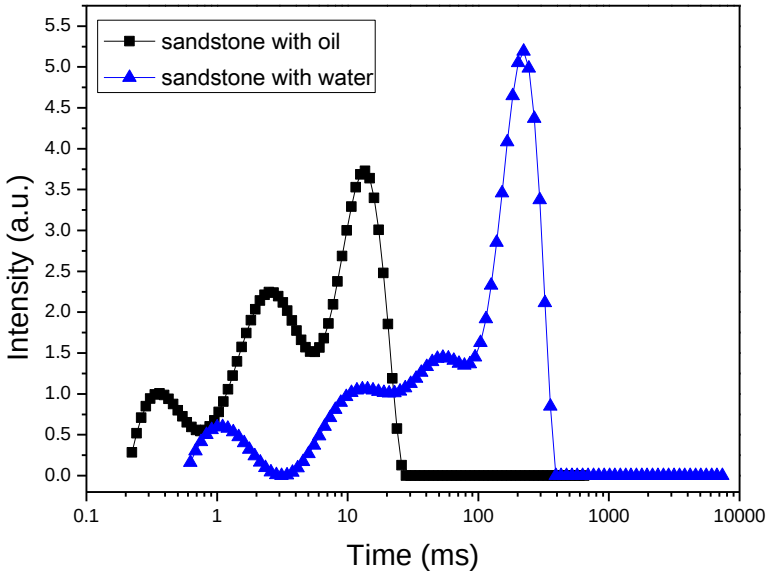
EOR by combination of zwitterionic and non-ionic surfactants

SB 3-16

ImS 3-16

ImS 3-14

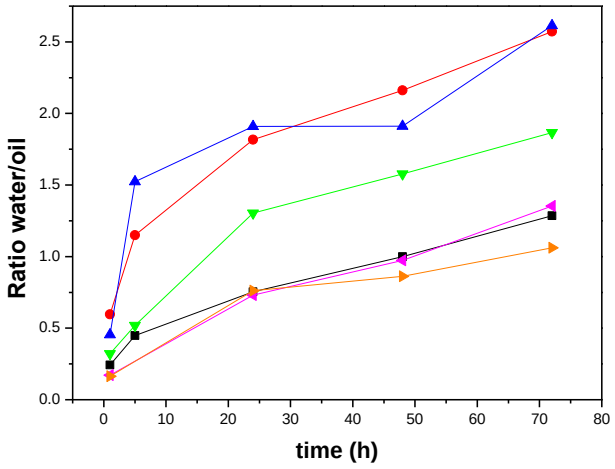
ImS 3-5,7



Chemistry Institute

NMR Investigation on Rock Wettability

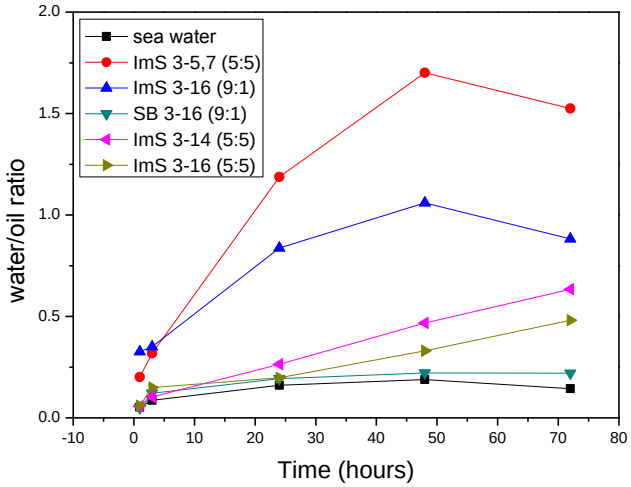
Sandstone



ImS 3-5,7 (5:5)

ImS 3-16 (9:1)

Limestone



Thank You!

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