Thermal Recovery of Bitumen

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Thermal Recovery of Bitumen

1. **SAGD as a mechanism (instead of a process)**
2. **How a Steam/Oil Ratio is Determined**
3. **Optimizing Thermal Bitumen Recovery**

SAGD as a Mechanism

- By default, bitumen recoveries > 5-10% must be due to gravity:
  - *water is 100x more mobile @ 200C*
  - *oil:gas is gravity dominant, i.e. one or both phases will be moving vertically*
- physical understanding allows tailored application to reservoir circumstances

Gravity Drainage Requirements	
requirement	*methods*
oil mobility:	•heat •solvent
permeability:	•rock quality •dilation?
gas phase voidage:	•steam •solvent •methane, etc.

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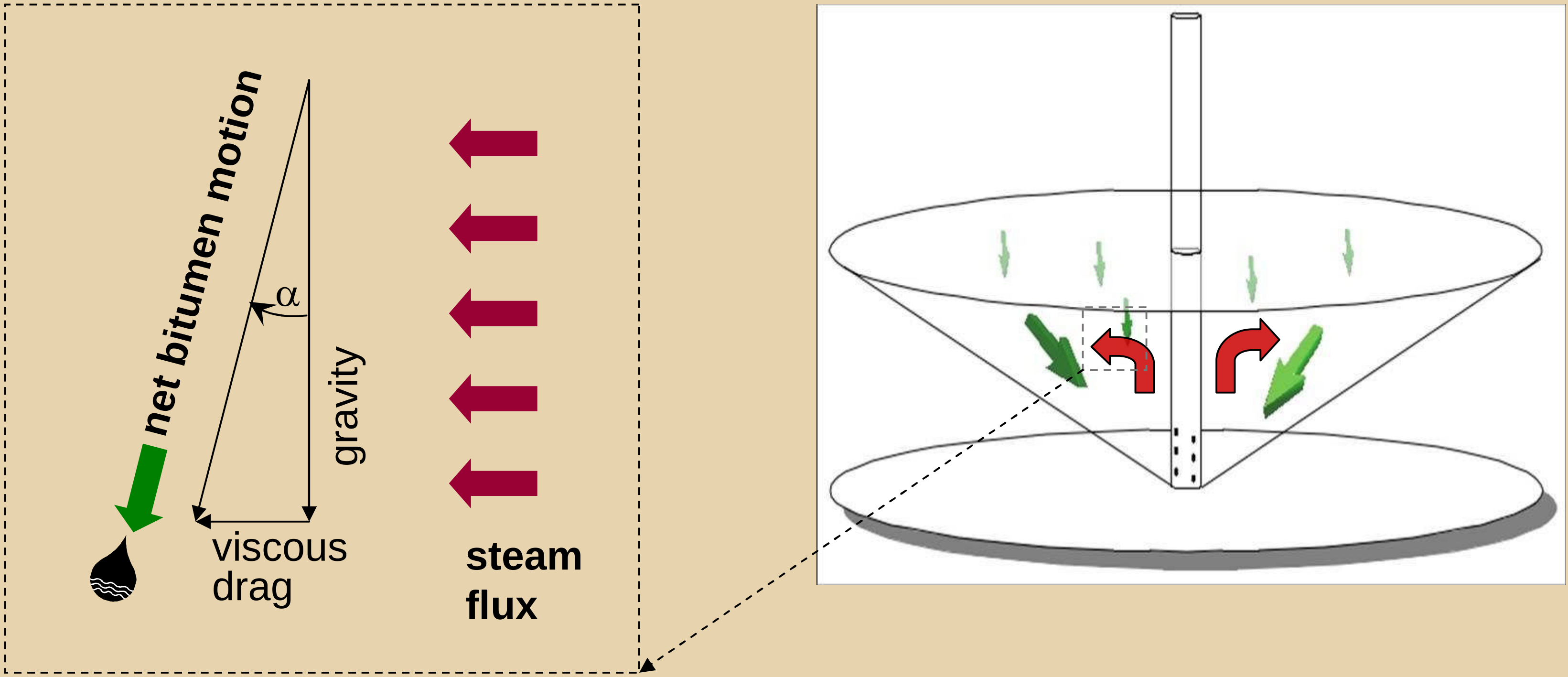
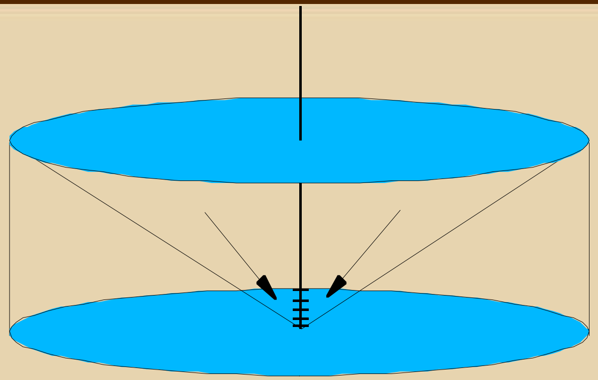
Gravity Dominant Conditions



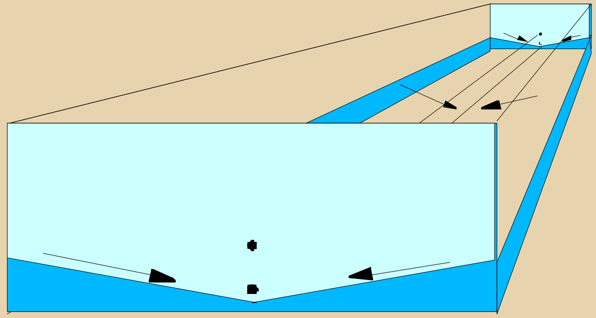
- the gravity vector (velocity of fall) is proportional to permeability
- the drag due to steam injection is inversely proportional to permeability
- above about 1 Darcy, gravity tends to dominate, & bitumen falls close to vertical

Gravity Depletion Geometries

- vertical wells tend to drain inverted cones
- horizontal wells drain trough-like shapes
- at the economic limit, horizontals recover ~2.5x more oil from same heated area



Vertical CSS (i.e. radial, cyclic SAGD):
- 1/3 sweep @ 10 years (typ.)
- 1/3 * (.85-.15) = **23%** recovery



(Horizontal) SAGD:
- 85% sweep @ 10 years (typ.)
- .85 * (.85-.15) = **60%** recovery

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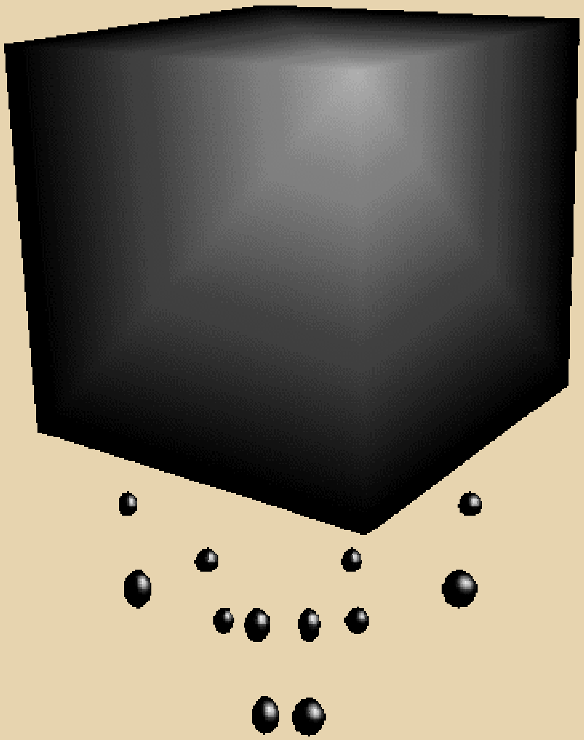
SAGD: “Reservoir” Steam/Oil Ratio

1 m^3, 5 Darcy, 30% porosity:



Steam at 2250 kPa:

Temperature	10	→	225˚C
Viscosity	10^6	→	5 cp.
Oil Sat.	85%	→	15%

Heat Required:	0.46 GJ
G/O fall velocity:	3.3 m/day
Oil Recovered:	1.3 bbl
Equivalent SOR:	1.2

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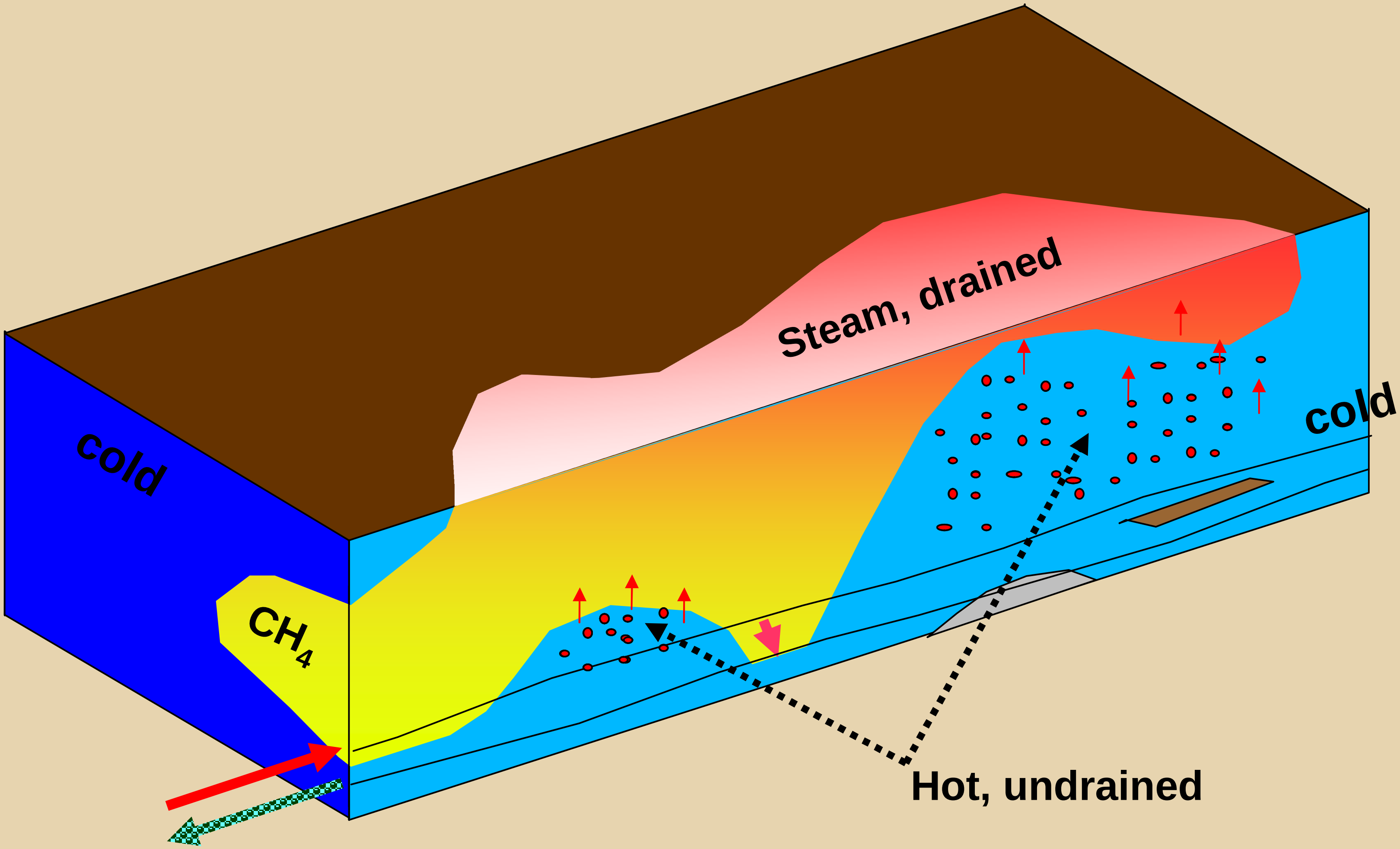
Real World SOR's & Heat Loss

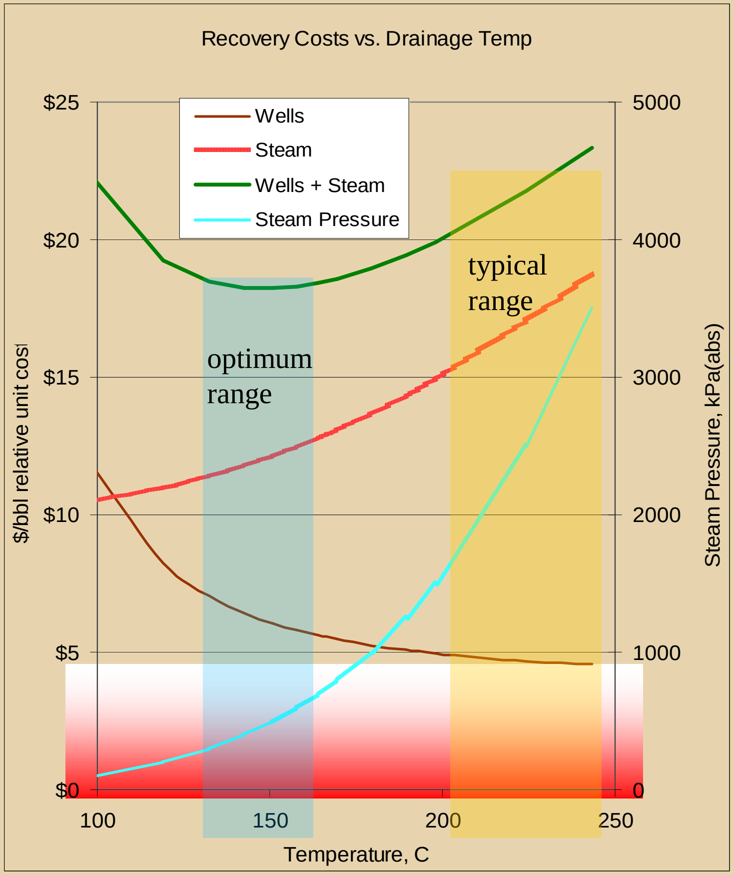
- **Current commercial SOR's are actually 2.5-3.5**
- **Excess steam consumption is due to heat loss to confining strata**
- **Heat losses are proportional to:**
  - ***Steam temperature, i.e. pressure***
  - ***Square root of the pattern operating lifetime***

Real World SAGD



Optimum SAGD

- under steady or cyclic operation, the rate of oil recovery is a function of the (time averaged) reservoir temperature
- in conventional SAGD, supply cost components of steam vs. wells is typically 3:1 or more
- lower temperature → lower SOR but less productive wells (same recovery, just slower)
- “save a lot on steam by spending a little more on wells”



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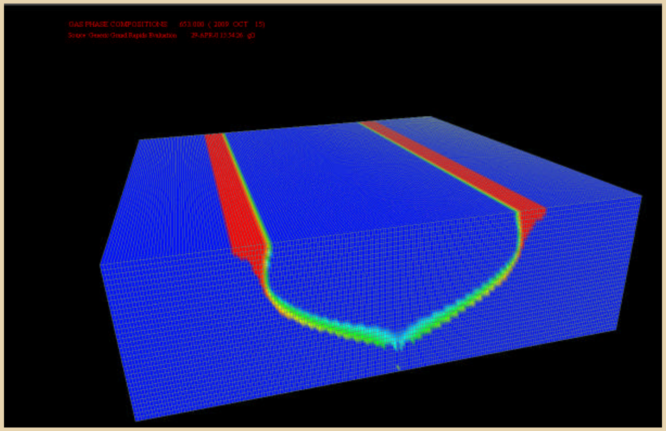
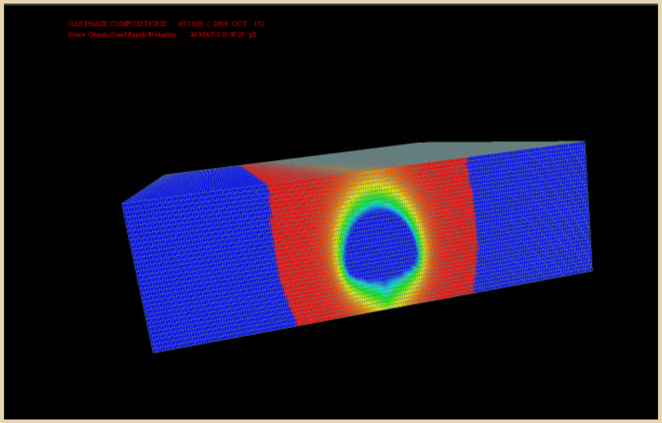
Cyclic SAGD

- ‘ideal’ optimum drainage temperature range is 100 - 150C (i.e. steam pressures 0 - 400 kPag)
- conventional SAGD needs >>500 kPag for well inflow & solution gas management
- cyclic steaming alternates:
  - short periods where steam fills the voidage and the sand is reheated; followed by
  - long production periods while oil drains due to stored heat; gas helps support the pressure.

<u>Methane accumulation in SAGD</u>



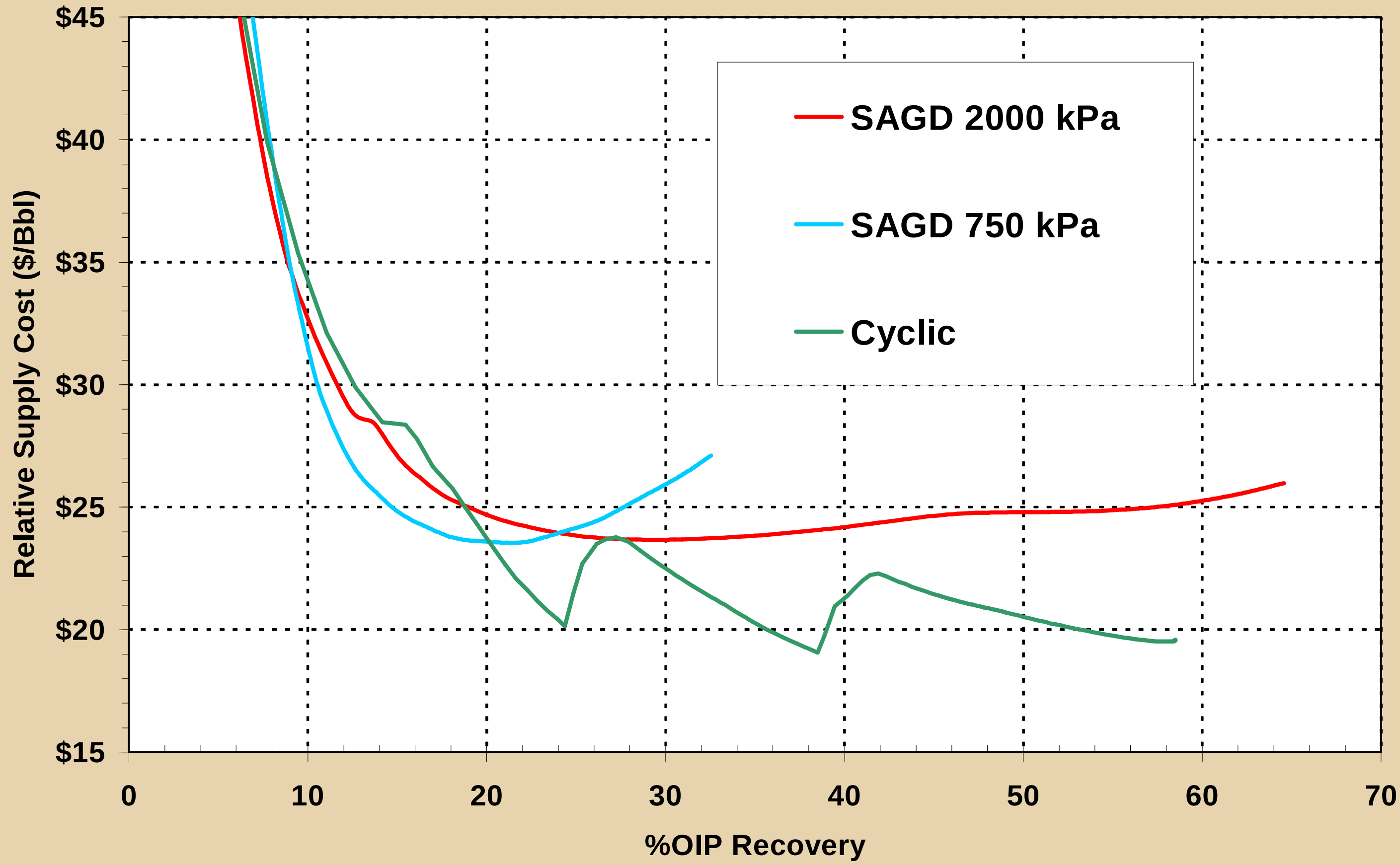
a) 2000 kPa



b) 750 kPa

Example Uplift - Cyclic Operation

- Thin Reservoir example:



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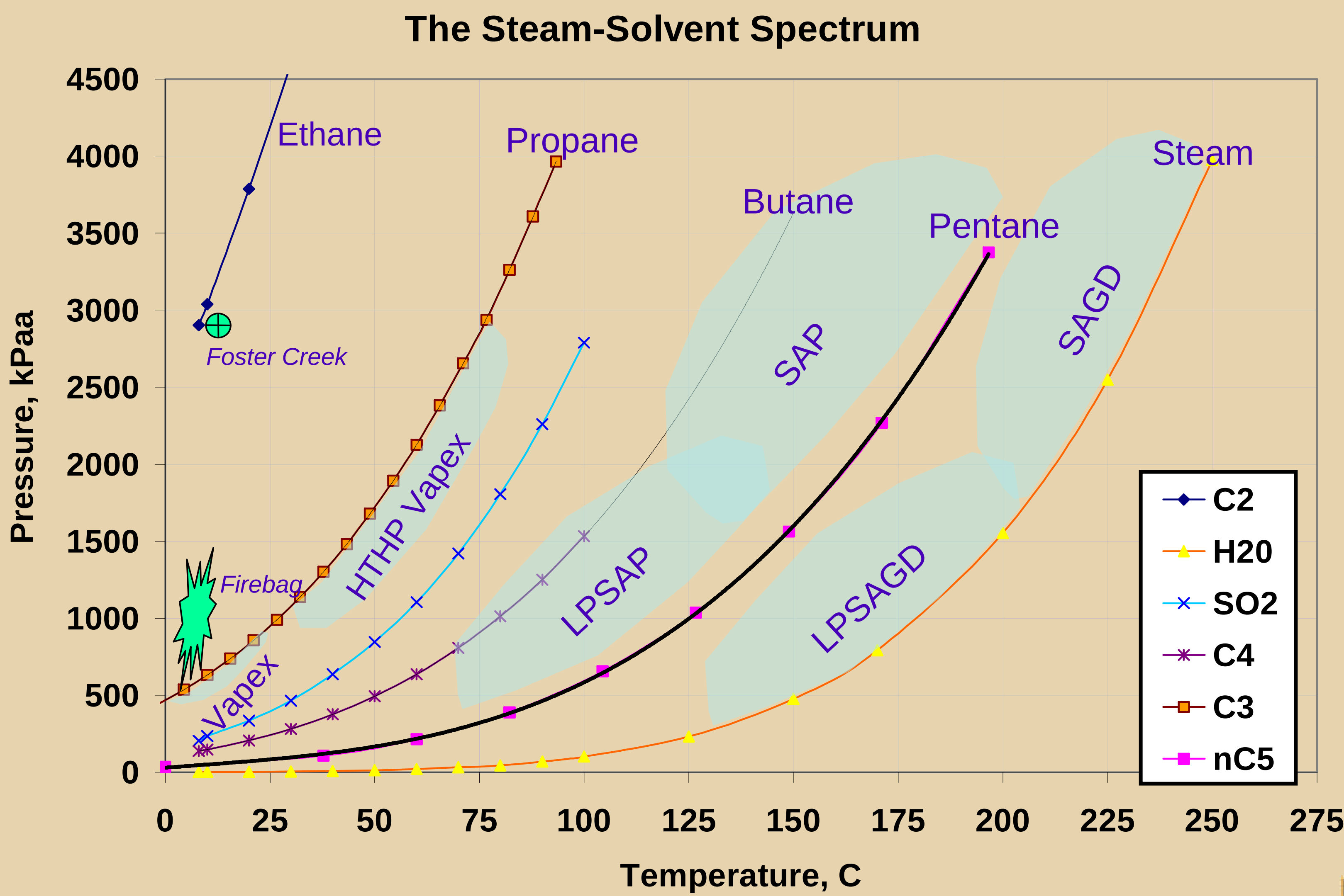
The Steam-Solvent Spectrum



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The Laricina Technology Suite

- NC gas transport modelling
  - large impact on carbonates & LP, cyclic processes
- Cyclic steaming
  - lower (optimal) average res. temperature
  - temperature cycles, not necessarily pressure
  - twin or single
- Single wells
  - thin pay
  - startup by reservoir failure (geomechanics)
- Solvent additives
  - cyclic operation -> lower avg. inventory

Technologies for Reservoirs

Reservoir Type	Challenges	Approach(es)
thin (<20m)	• high SOR's • low OIP/pattern	• single (horizontal) well cyclic • solvent additives • gas cycling
shallow (<100m)	• startup @/enforced low pressure • producer inflow	• fracture, solvent, and/or electrical startup • colloid science,
complex (top gas, usually depressured, usually wet)	• enforced low pressure operation • losses to & encroachments from the cap	• production inflow enhancements • repressurization w/air • dewatering

Conclusion

- A first-principles approach to SAGD yields locally tailored and optimized recovery schemes
- There is a large opportunity in reducing the thermal intensity (average temperature) of conventional SAGD
- Cyclic steaming is key; solvent enhancements are a further opportunity to reduce temperature
- Laricina is advancing two pilot/prototypes and will solicit participants in June/July 2007

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