Effects to be considered when planning Late Stage Depressurization

Øystein Pettersen and Arne Skauge

CIPR ann. meeting 4-5. May 2004

Main effects of depressurisation influencing oil recovery

Change in fluid properties

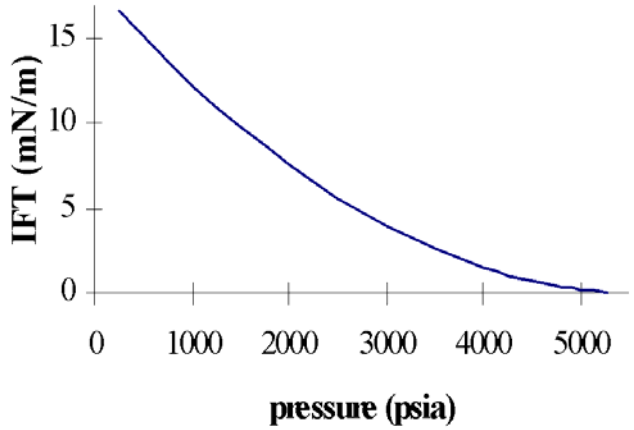
Change in fluid saturation

Change in phase mobilities

Change in rock properties

+ +

Main effects of depressurisation



Change in fluid properties

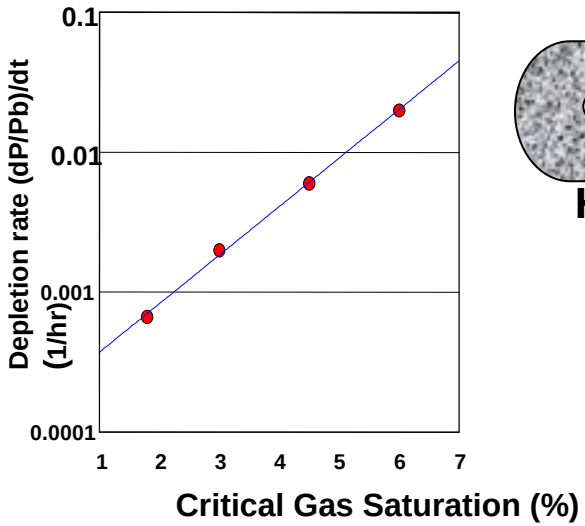
Pressure decline will give:

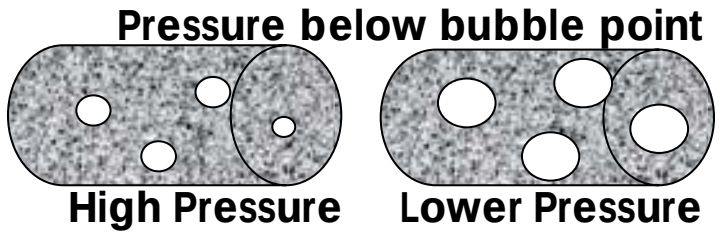
- larger phase viscosities and densities
- G/O capillary pressure will increase
  (because gas-oil IFT is larger at lower pressure)

Change in fluid saturation

Pressure decline will give:

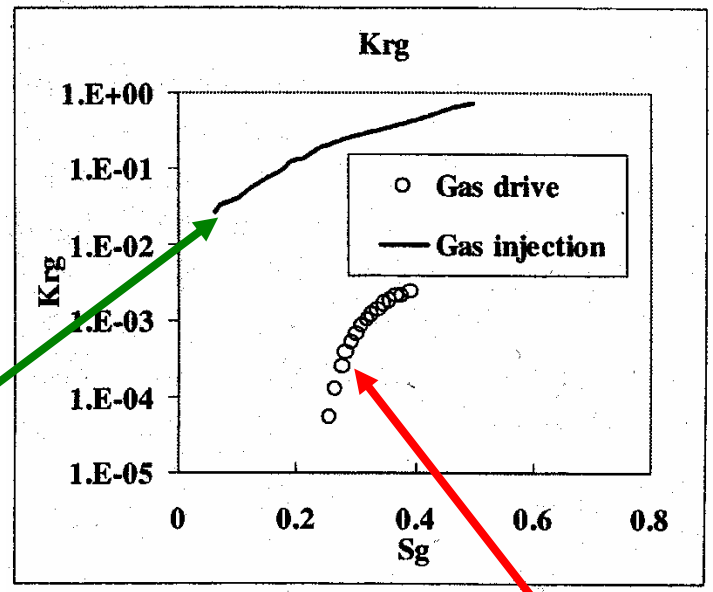
- shrinkage of oil due to mass exchanges
- gas expansion
- immobile gas (Sgc)

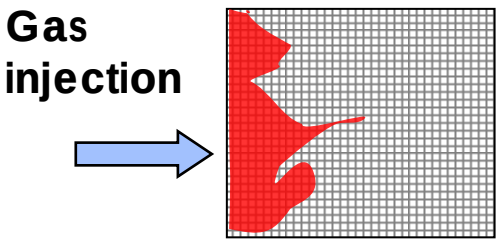


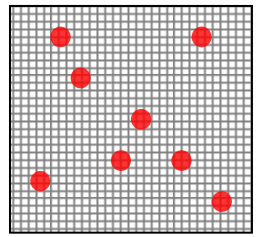


Change in phase mobilities

Source: Egermann et al, SCA 2000







Discontinous gas from pressure decline

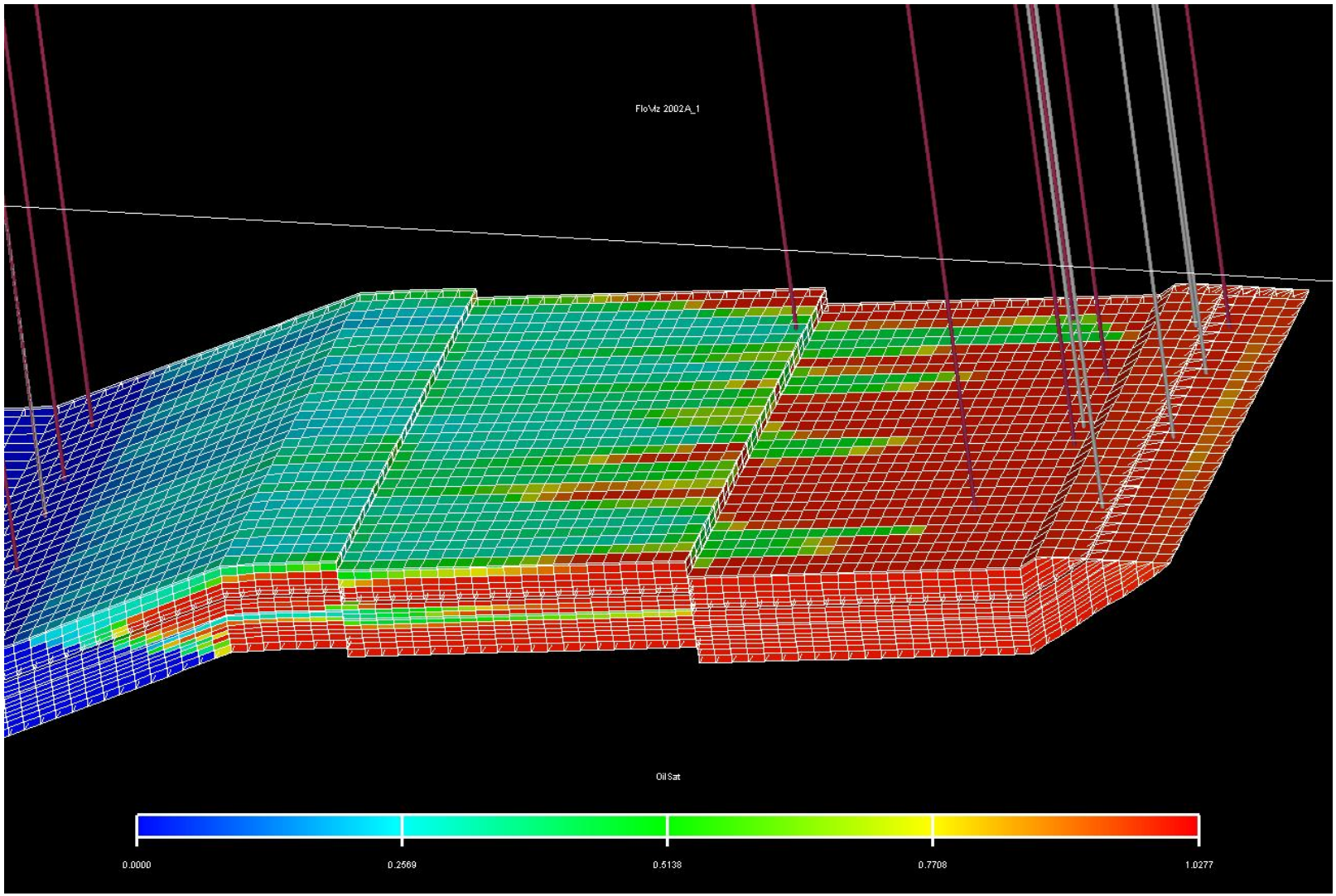
Gas originating from depressurisation has mobility that may be 2 orders of magnitude lower than injection gas

Altered flow pattern caused by change in rock properties

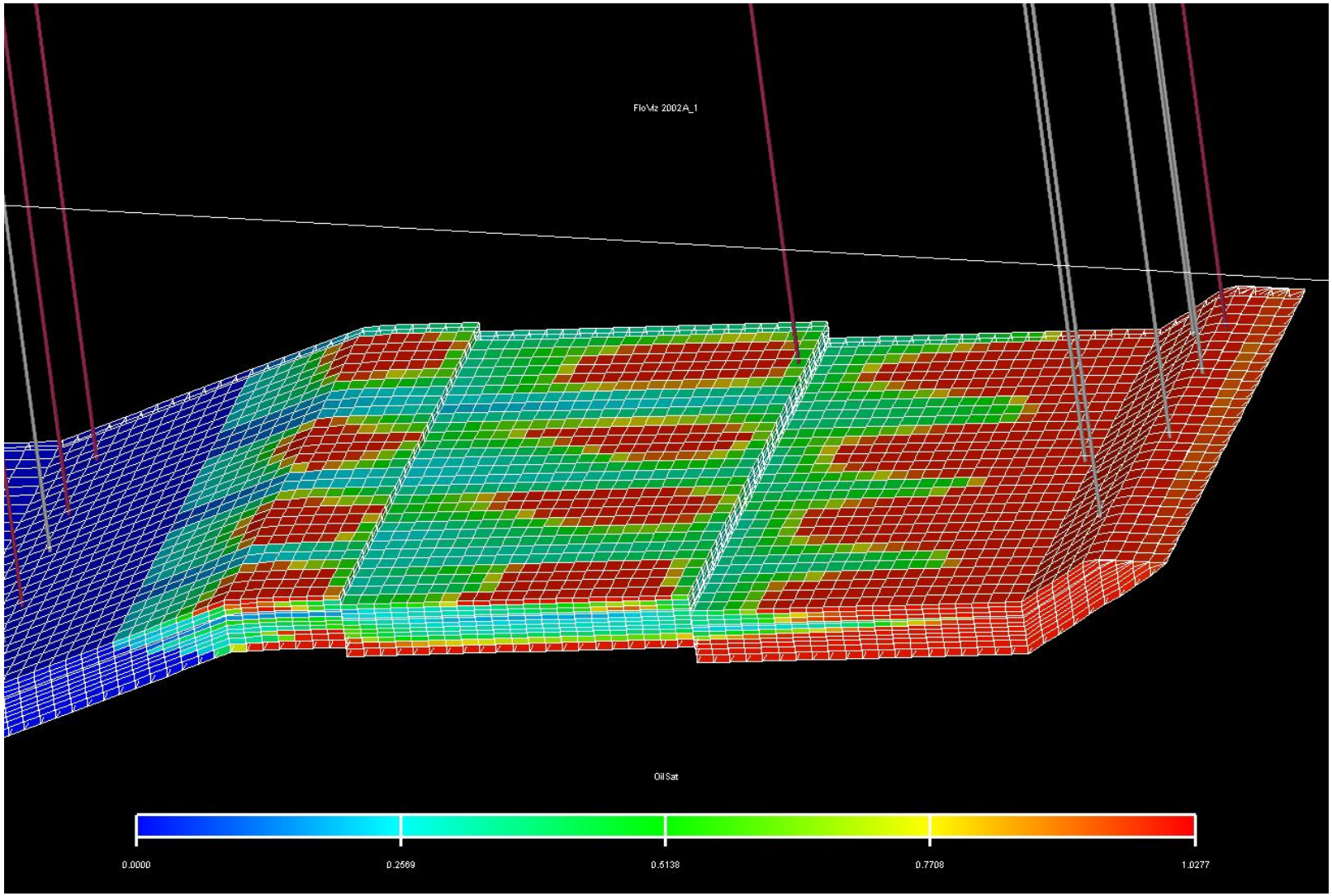
Which conditions are needed to reduce flow preference to high permeable channels?
(homogenization of reservoir sands)

Are necessary conditions present?

Very high channel perm, high background perm

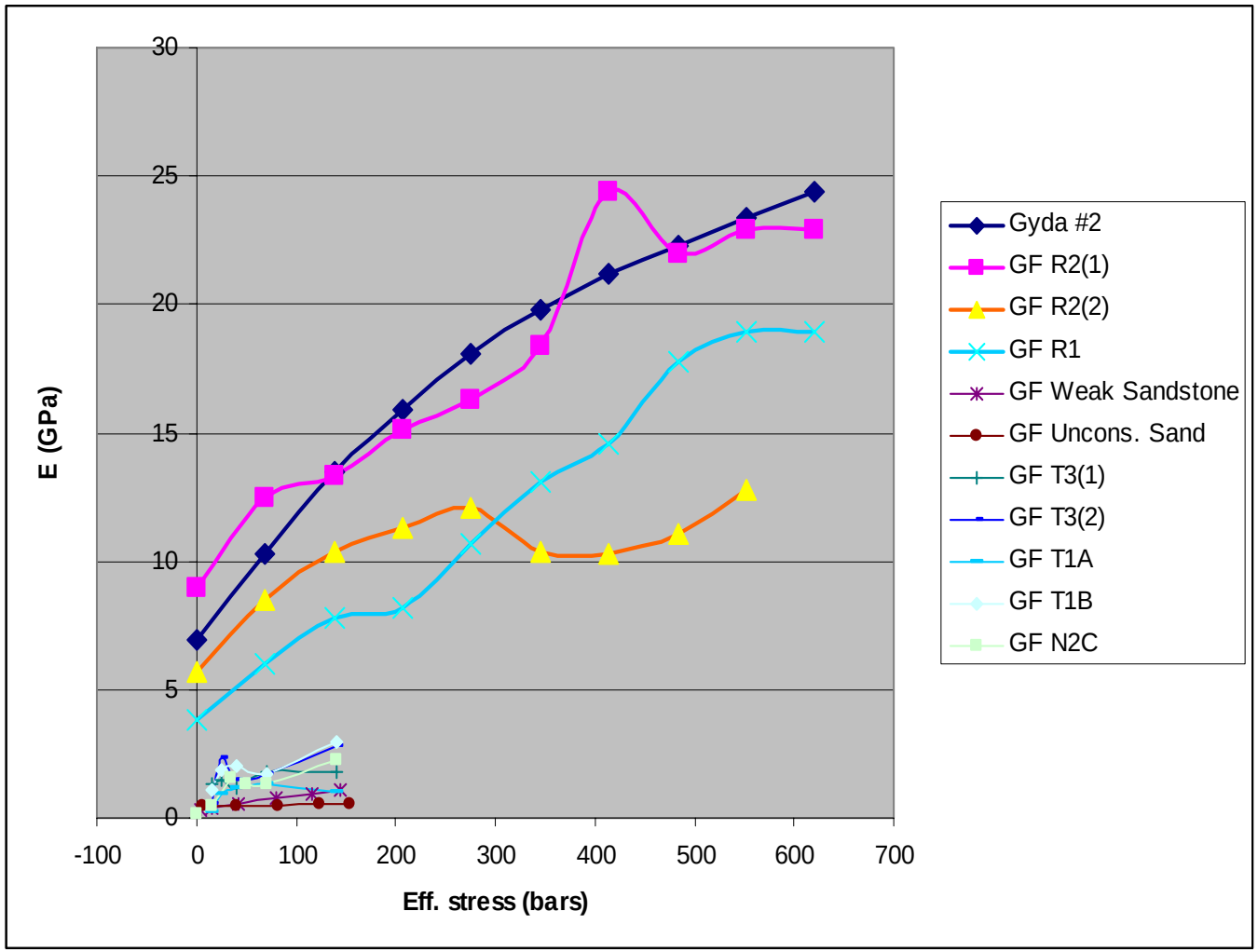


Moderate channel perm, low background perm



Young's Modulus vs. rock strength

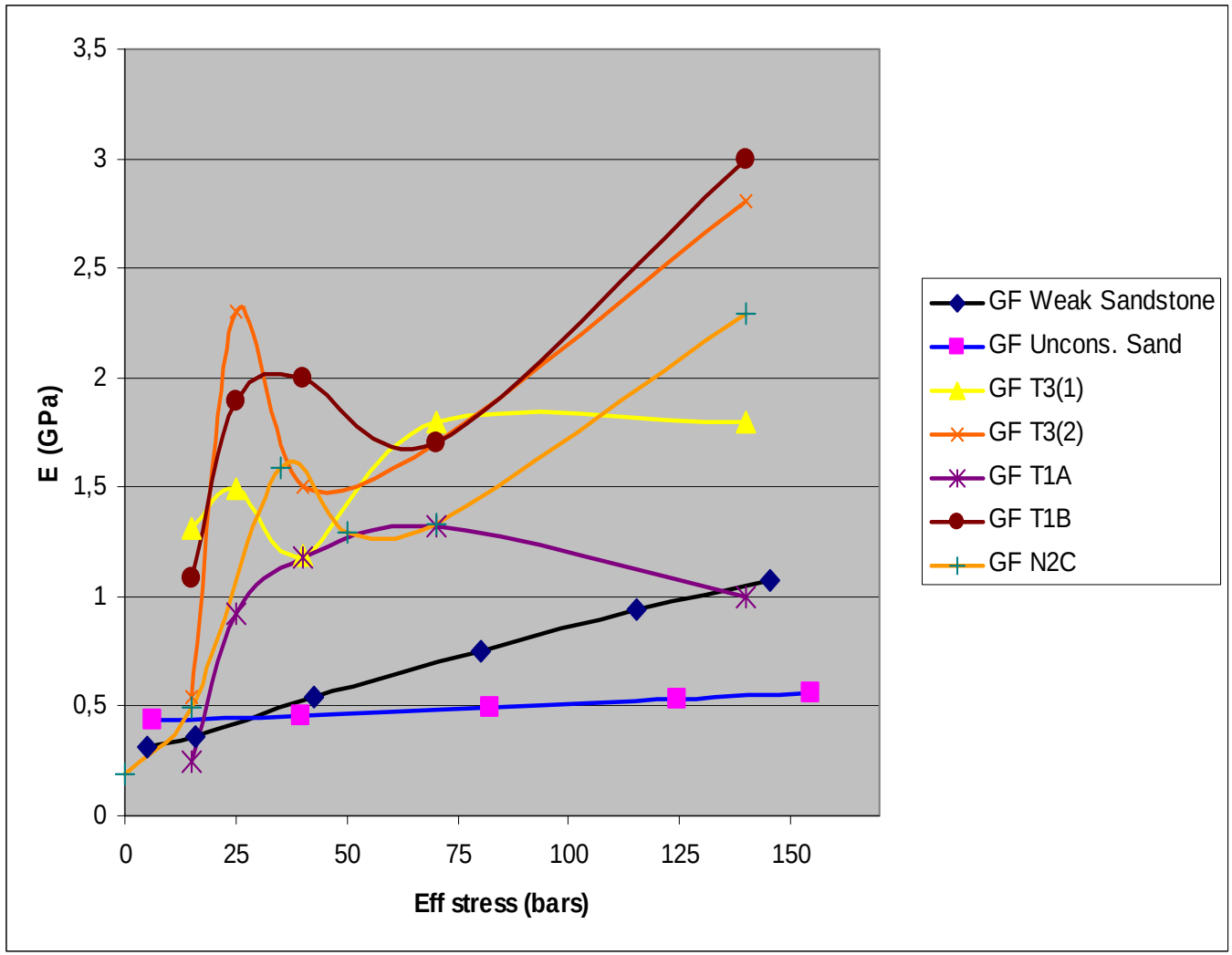
Observed trend:
Curves are steeper when initial E is larger,
i.e.
strong rocks grow stronger more rapidly under load than weaker rocks



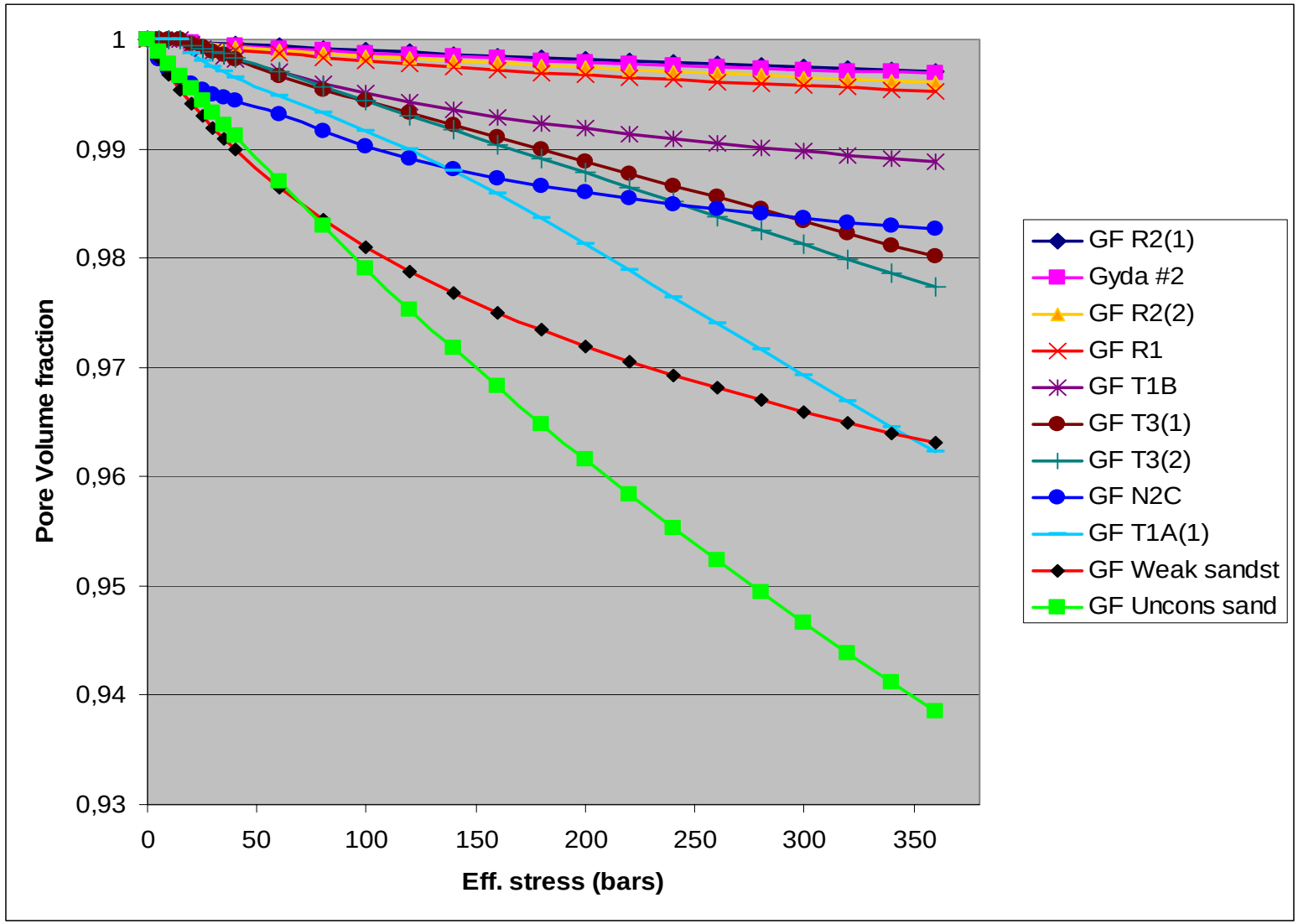
Young's Modulus, weak sands / sandstones

(Zoomed in on lower part of prev. slide)

Weak sands appear to fail under rel. small load, then fall back on "general trend"



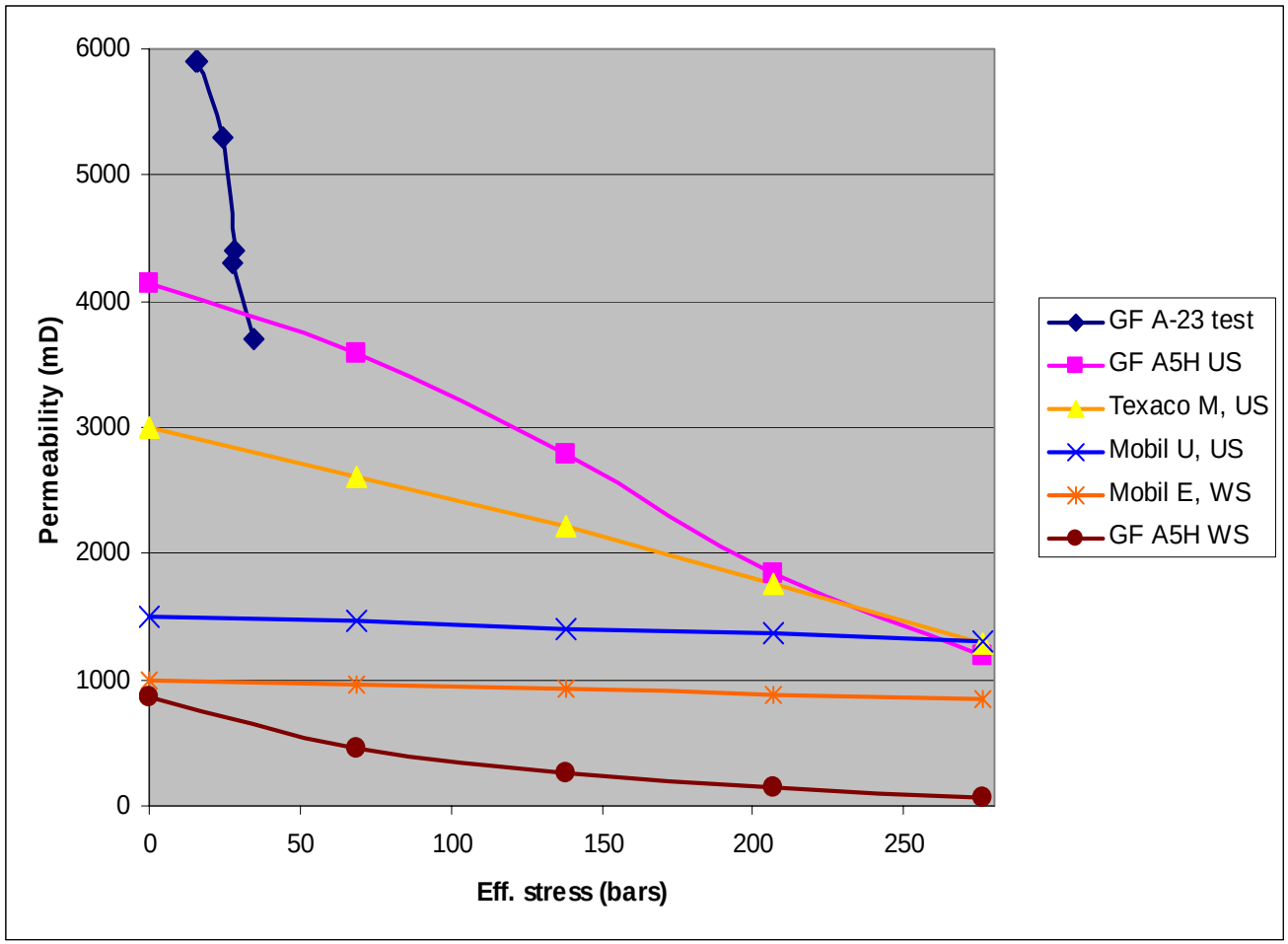
Specific Volumes vs. sand strength



Permeability vs. load – measured data

Weak sands appear to have greater loss of conductivity than strong sands

Proposition: Permeability reduction is "proportional to" initial value, i.e. Medium is homogenized by loading



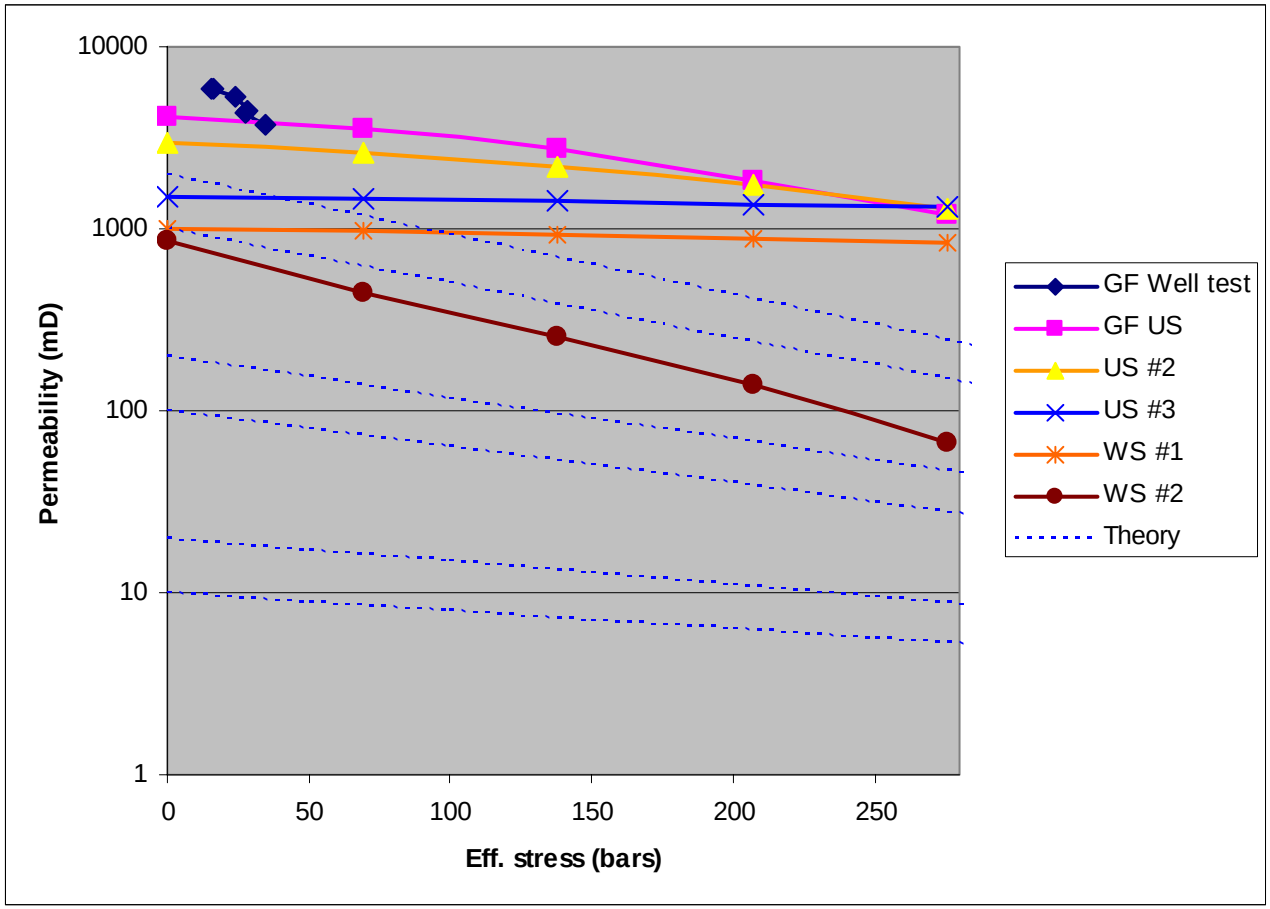
Permeability vs. load – assumption

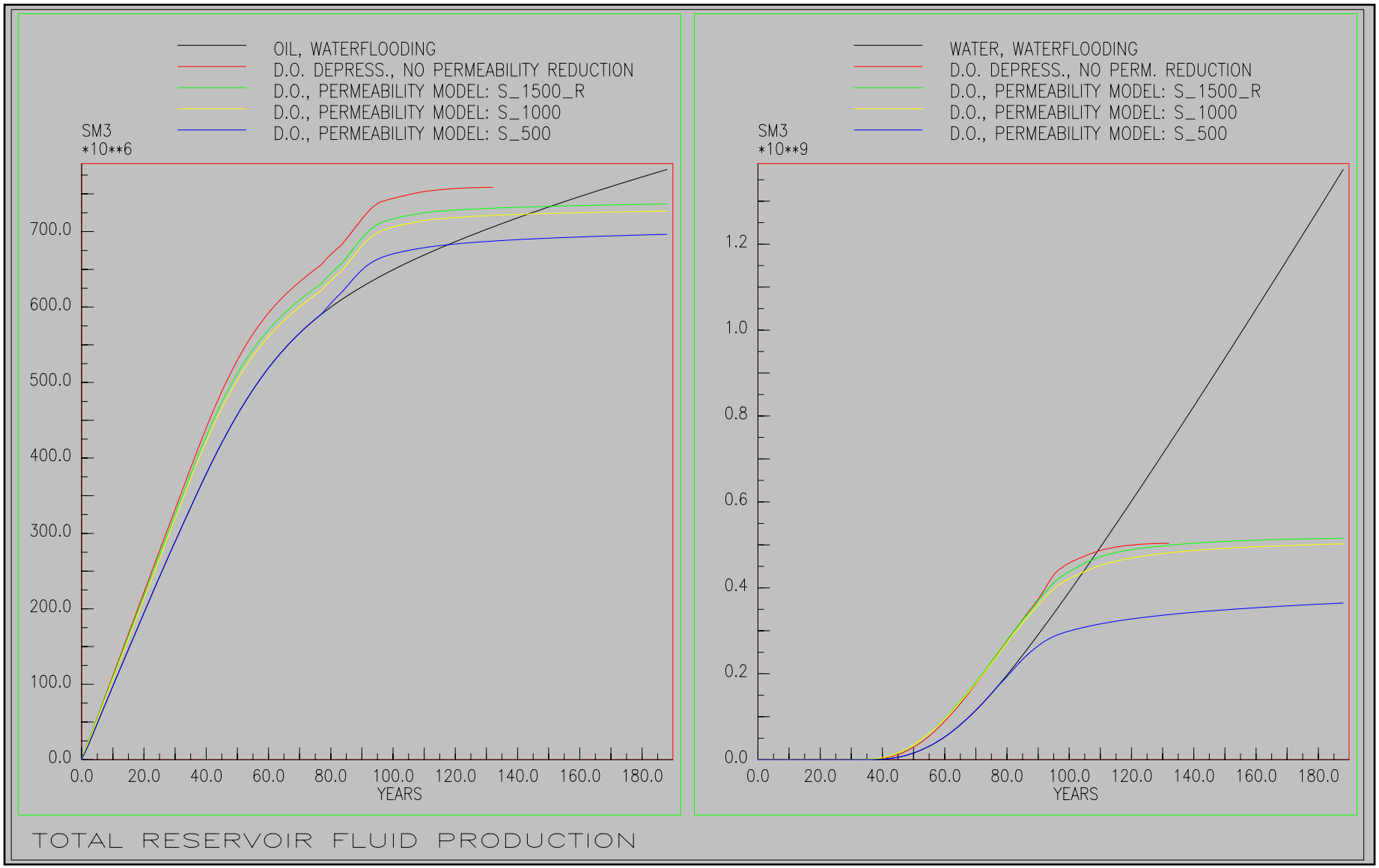
log(K) linear w. σ,
K(σ*) = 1 mD

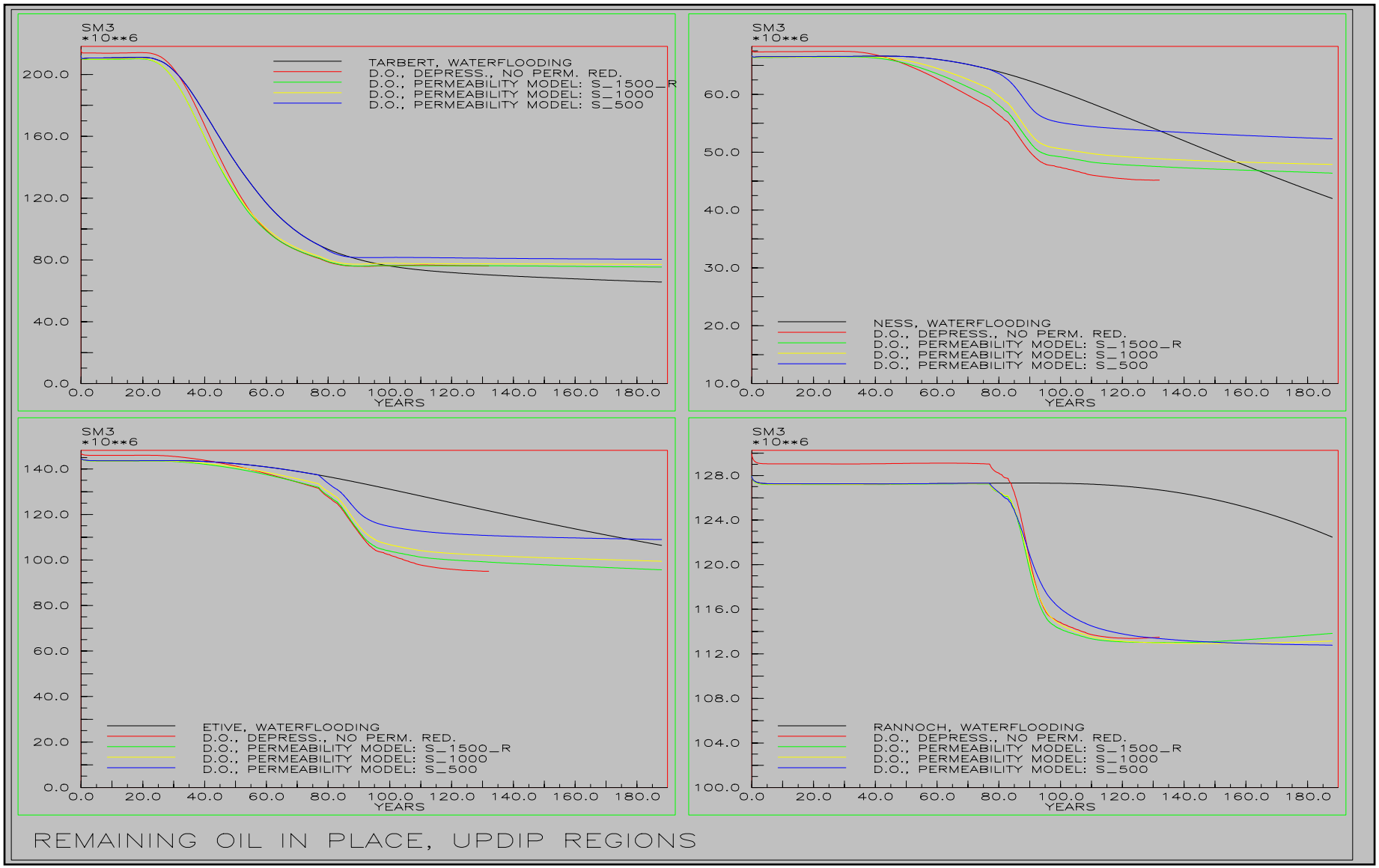
σ* = 1000 bars

fits GF WS

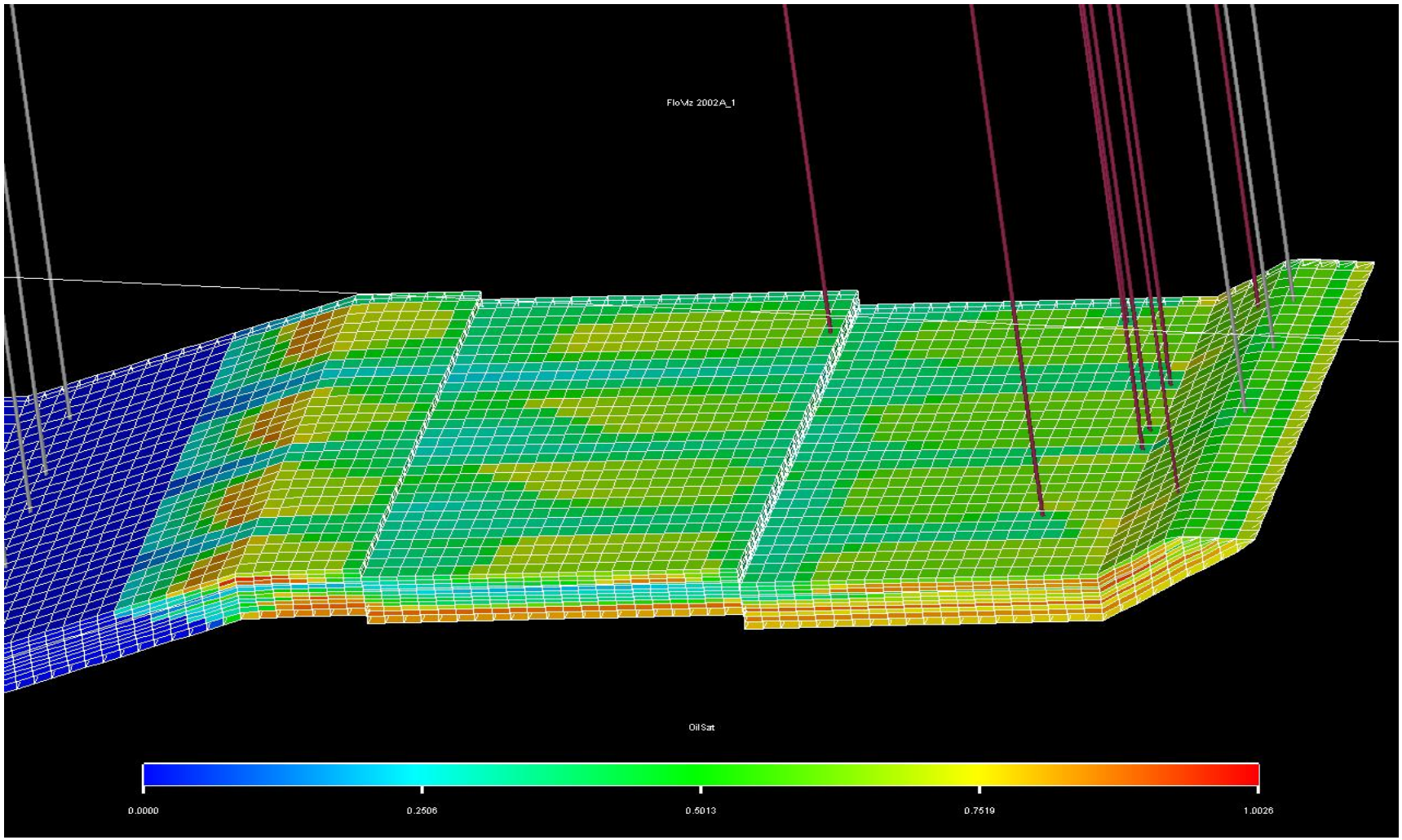
WS: weak sandst.
US: uncons. sand



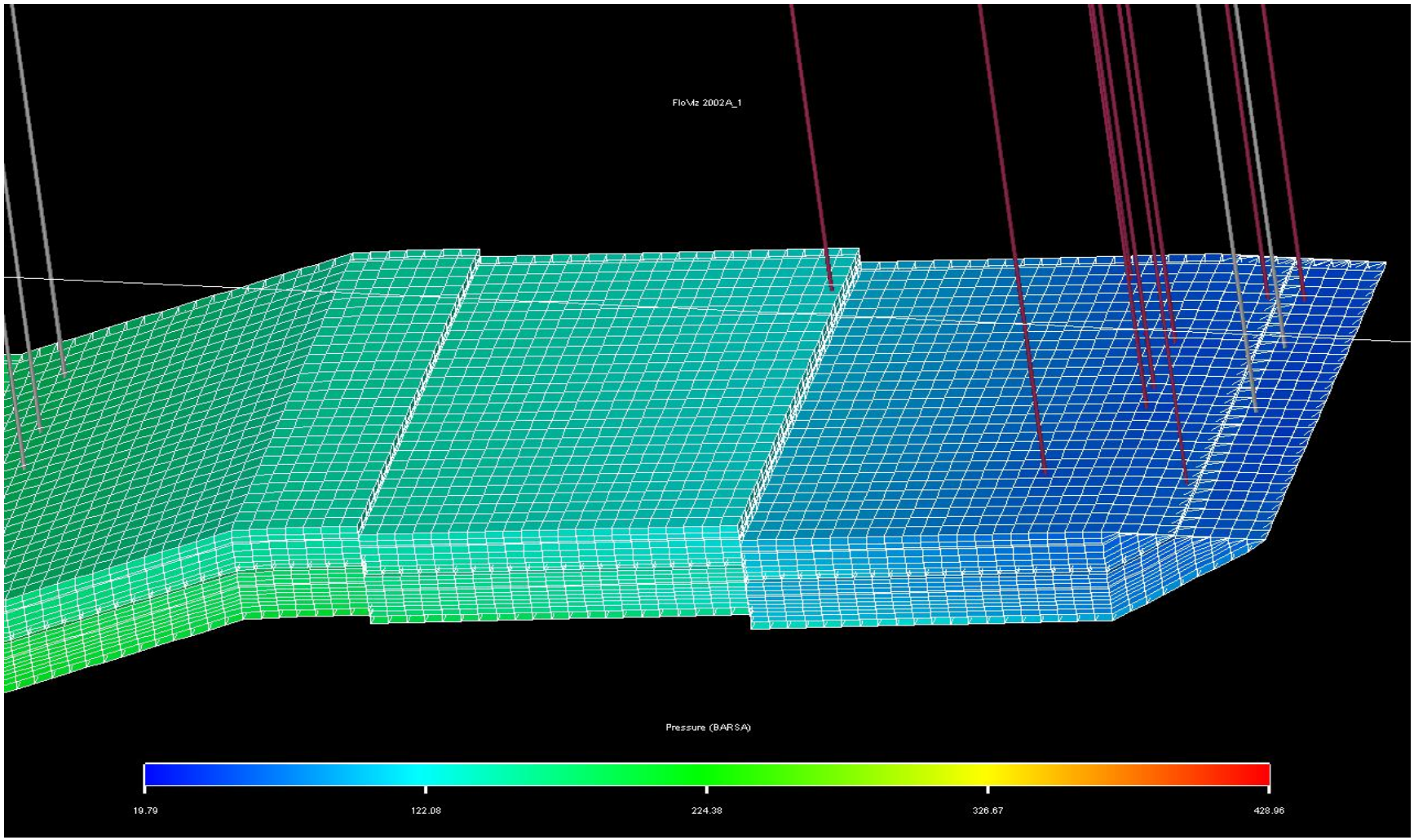

OIL, WATERFLOODING
D.O. DEPRESS., NO PERMEABILITY REDUCTION
D.O., PERMEABILITY MODEL: S_1500_R
D.O., PERMEABILITY MODEL: S_1000
D.O., PERMEABILITY MODEL: S_500
SM3
*10**6
700.0
600.0
500.0
400.0
300.0
200.0
100.0
0.0
0.0 20.0 40.0 60.0 80.0 100.0 120.0 140.0 160.0 180.0
YEARS
WATER, WATERFLOODING
D.O. DEPRESS., NO PERM. REDUCTION
D.O., PERMEABILITY MODEL: S_1500_R
D.O., PERMEABILITY MODEL: S_1000
D.O., PERMEABILITY MODEL: S_500
SM3
*10**9
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0 20.0 40.0 60.0 80.0 100.0 120.0 140.0 160.0 180.0
YEARS
TOTAL RESERVOIR FLUID PRODUCTION


SM3
*10**6
TARBERT, WATERFLOODING
D.O., DEPRESS., NO PERM. RED.
D.O., PERMEABILITY MODEL: S_1500_R
D.O., PERMEABILITY MODEL: S_1000
D.O., PERMEABILITY MODEL: S_500
YEARS
NESS, WATERFLOODING
ETIVE, WATERFLOODING
RANNOCH, WATERFLOODING
REMAINING OIL IN PLACE, UPDIP REGIONS

Moderate channel perm, low background perm, Permeability reduction model $\sigma^* = 1000$



Pressure distribution “some time” into depressurisation, consequence for wells’ PI



Inferences – effects of compaction during depressurisation

+ Reduces pressure reduction rate – energy supply
+ Reduces permeability contrasts – stops water cycling through high permeability channels

- Reduces well productivity
- Reduces general conductivity
- May induce pore collapse / sand production

? Production scheme may be critical
? Late stage injection may be advantegous
? Stimulation, fracturing, gas lift may be necessary