Effcient Compaction Modelling on the Valhall Field

by

Øystein Pettersen

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Outline

- ***Why***
- ~~***How***~~
- ***Results, challenges***

Compaction

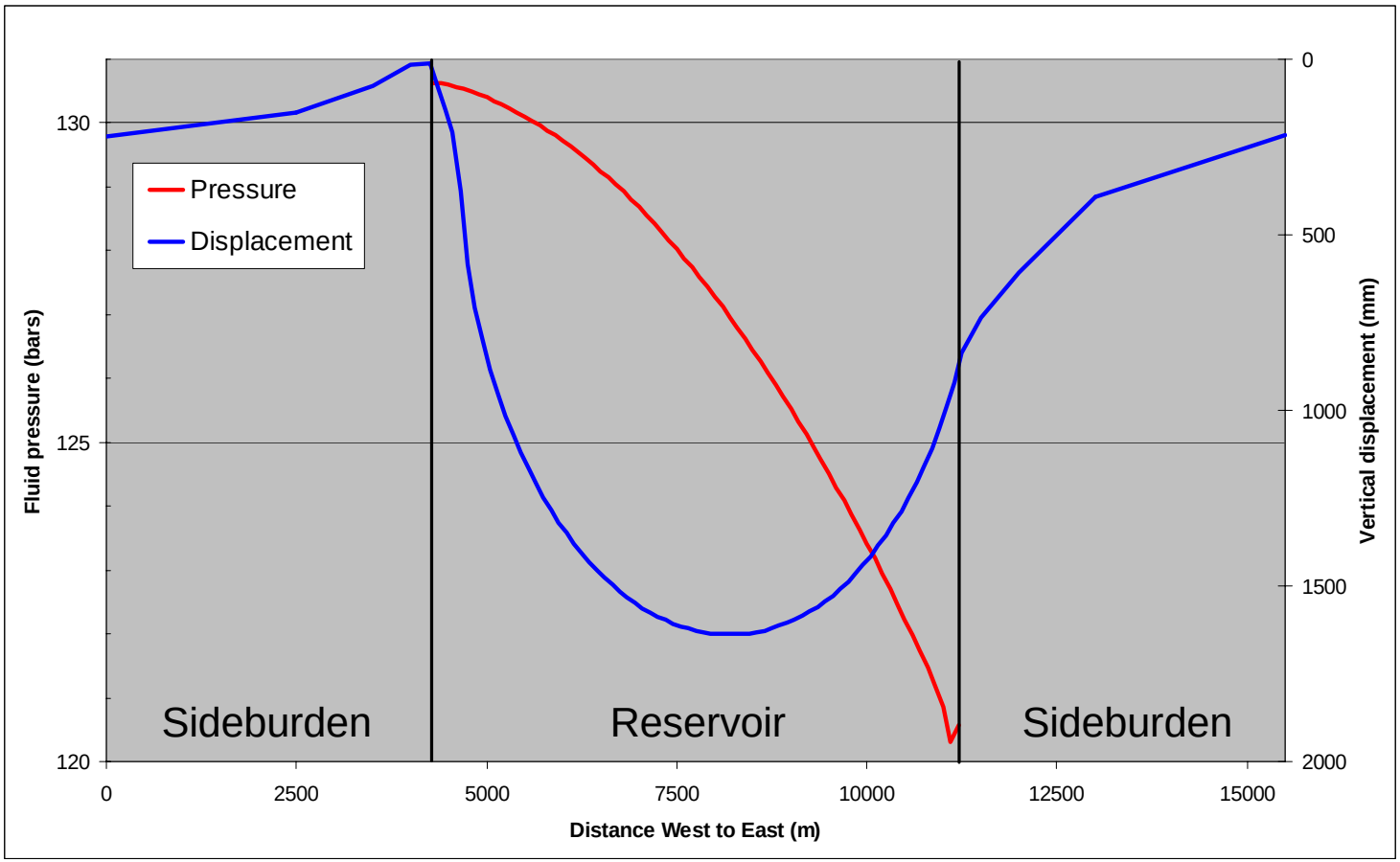
Compression of pore space

Commonly defined by the
Pore Volume Multiplier:

$$PVM = m = \frac{\text{Current Cell Pore Volume}}{\text{Initial Cell Pore Volume}}$$

In Flow Simulators, PVM is a function of pressure,
$m = m(p)$
This is not correct

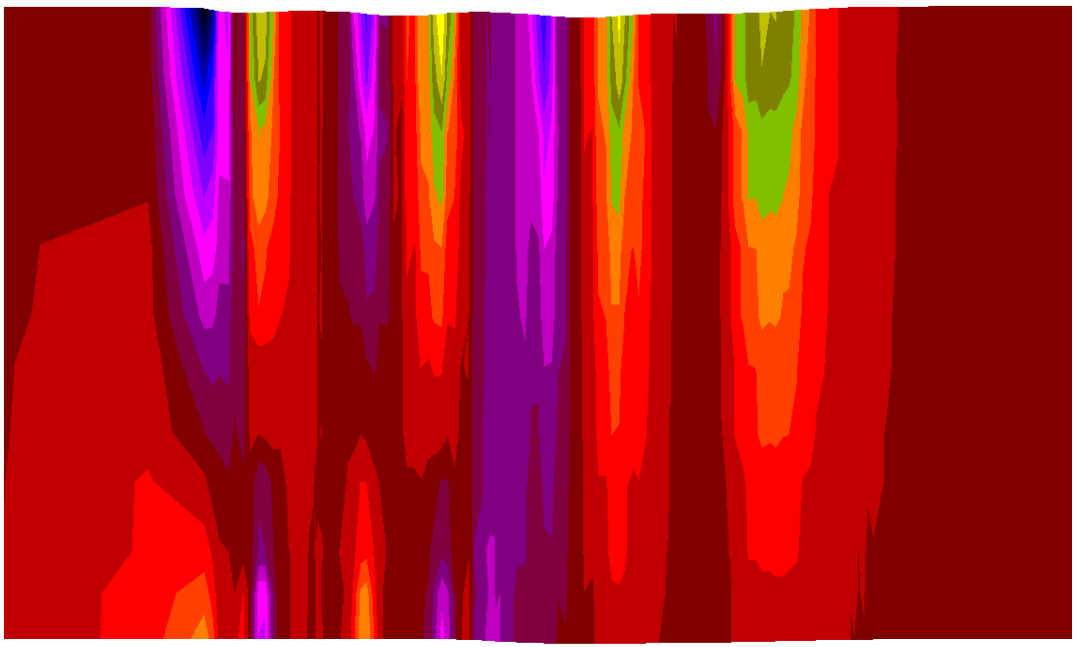
Compaction – Vertical Deformation at top Reservoir



If compaction was related to pressure, the red and blue curves should have been proportional. (Piston water displacement)

Reservoir state – significance for compaction

Vertical displacement at top reservoir, including sideburdens



Shear strain ε_{xz} in an XZ cross section

Compaction Determined by

- ***Stress state in reservoir and surroundings***
- ***Reservoir to surrounding rock Boundary Conditions***
- ***Internal material to material interaction***
- ***Fluid pressure***

→ Pressure does play a role, but perhaps not a big one.

The hard facts of (this) life

- *To compute accurate compaction, no alternatives to doing at least some rock mechanics simulations exist*

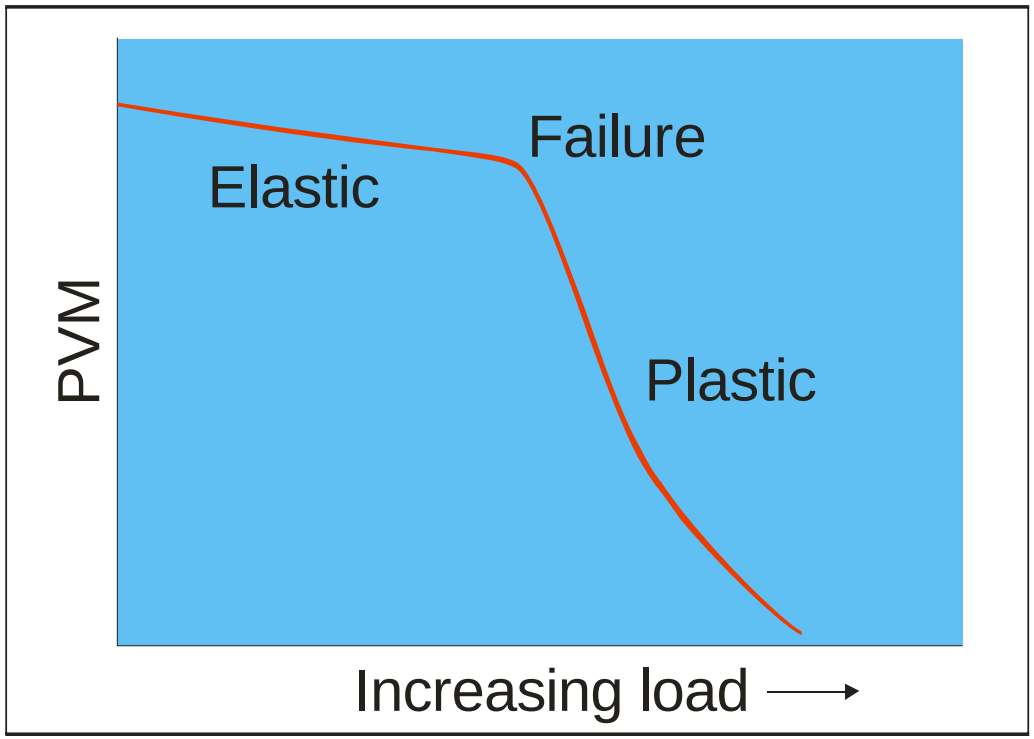
- *Frustrating fact is that this can be very time consuming*

Goal of Valhall Compaction Modelling Project

- ***Much faster simulations****
- ***At least as accurate as traditional coupled simulations, preferably more accurate***
- ***Should be possible to get sensible results from pure flow simulations***

*Current Valhall Full Field Coupled Simulation Model requires one week CPU-time on a 36-processor unix-cluster, even when iterations are not taken to convergence.

Valhall chalk material

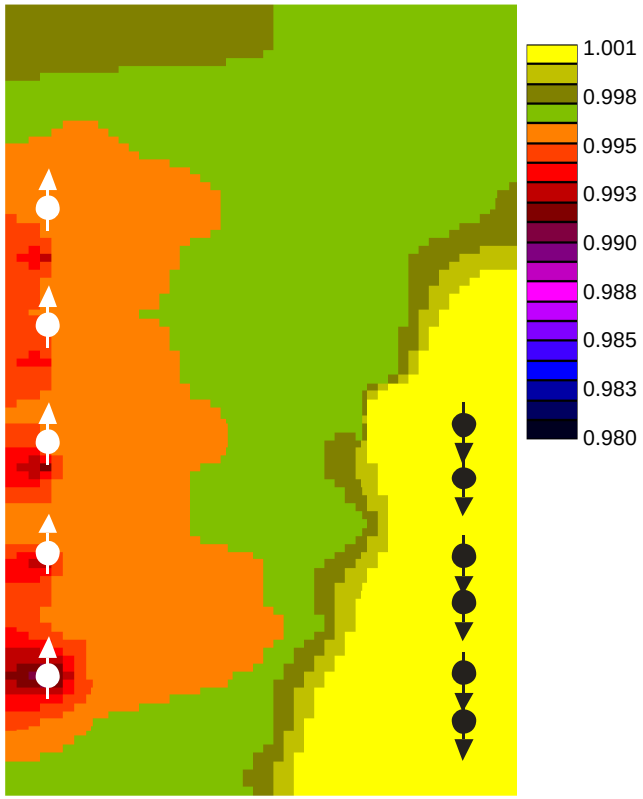


- High porosity
- Low permeability
- Behaviour described by NGI chalk model
- Water weakening
- Anisotropic
- Fractured

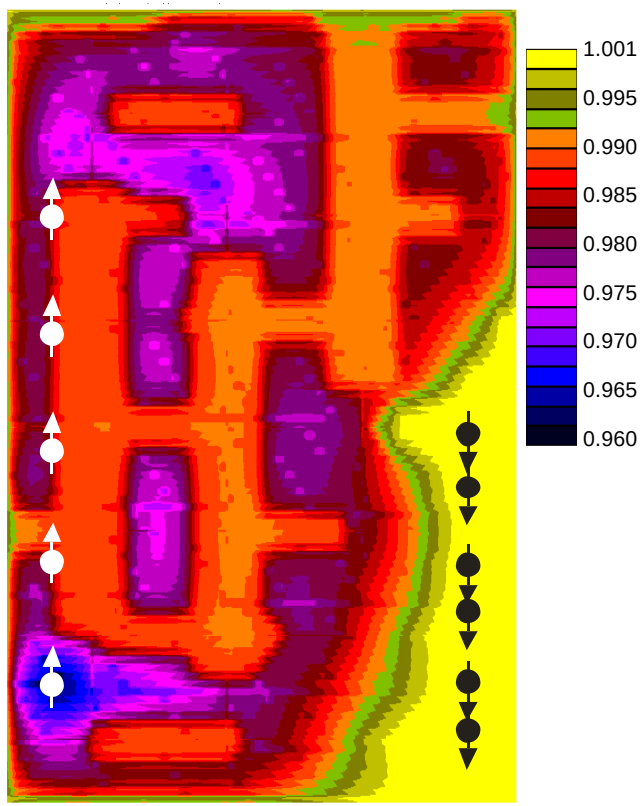
Characteristic: Plastic failure is very steep, and PVM approaches zero at finite, achievable loading.

Accurate compaction modelling is a major factor in prediction of reservoir behaviour and production.

Does it matter anyway?

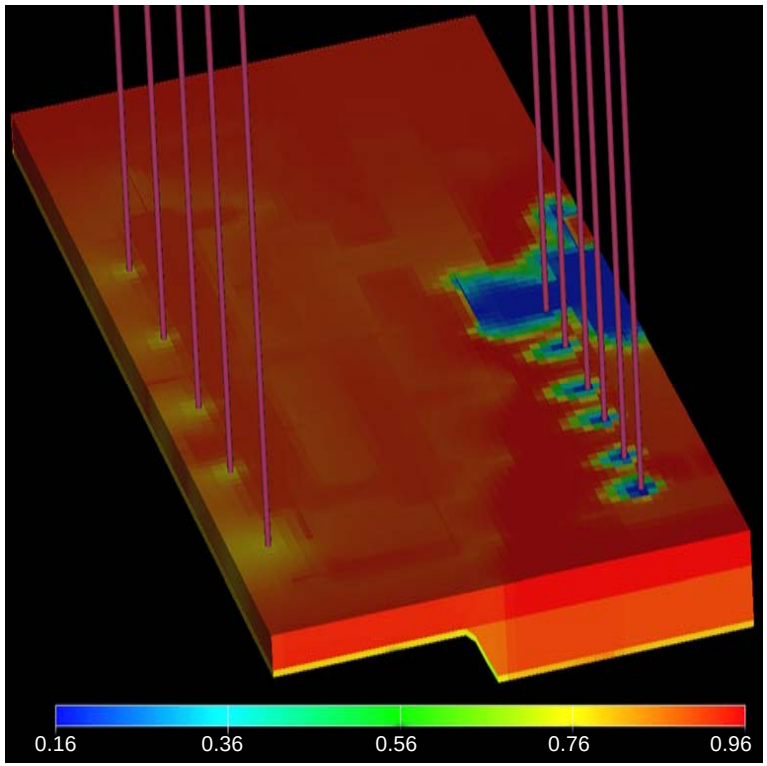


Contours of PVM as computed by ECLIPSE, traditional approach

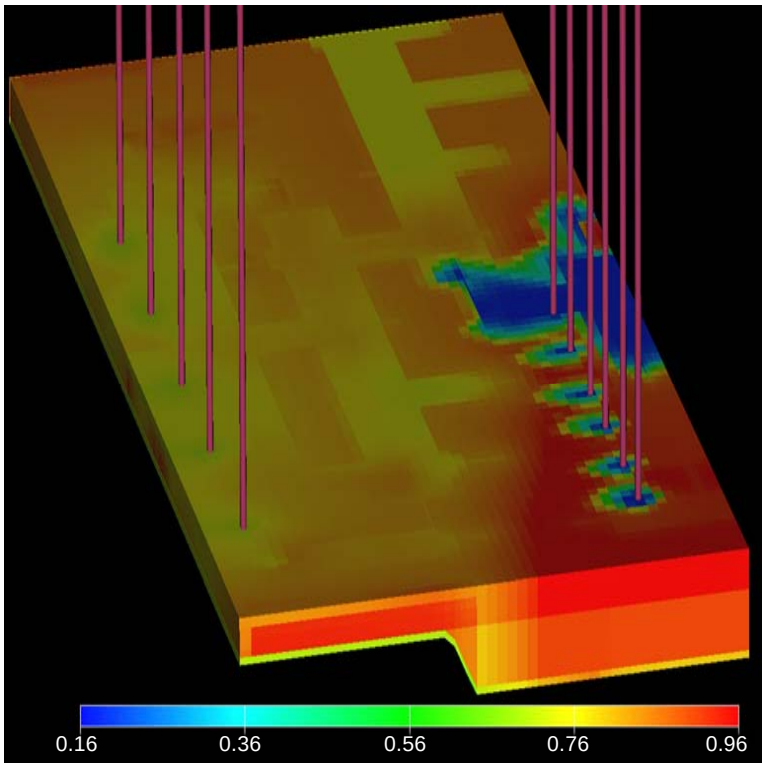


Correct PVM contours

Does it matter anyway?



Water – oil saturation as computed by ECLIPSE, traditional approach

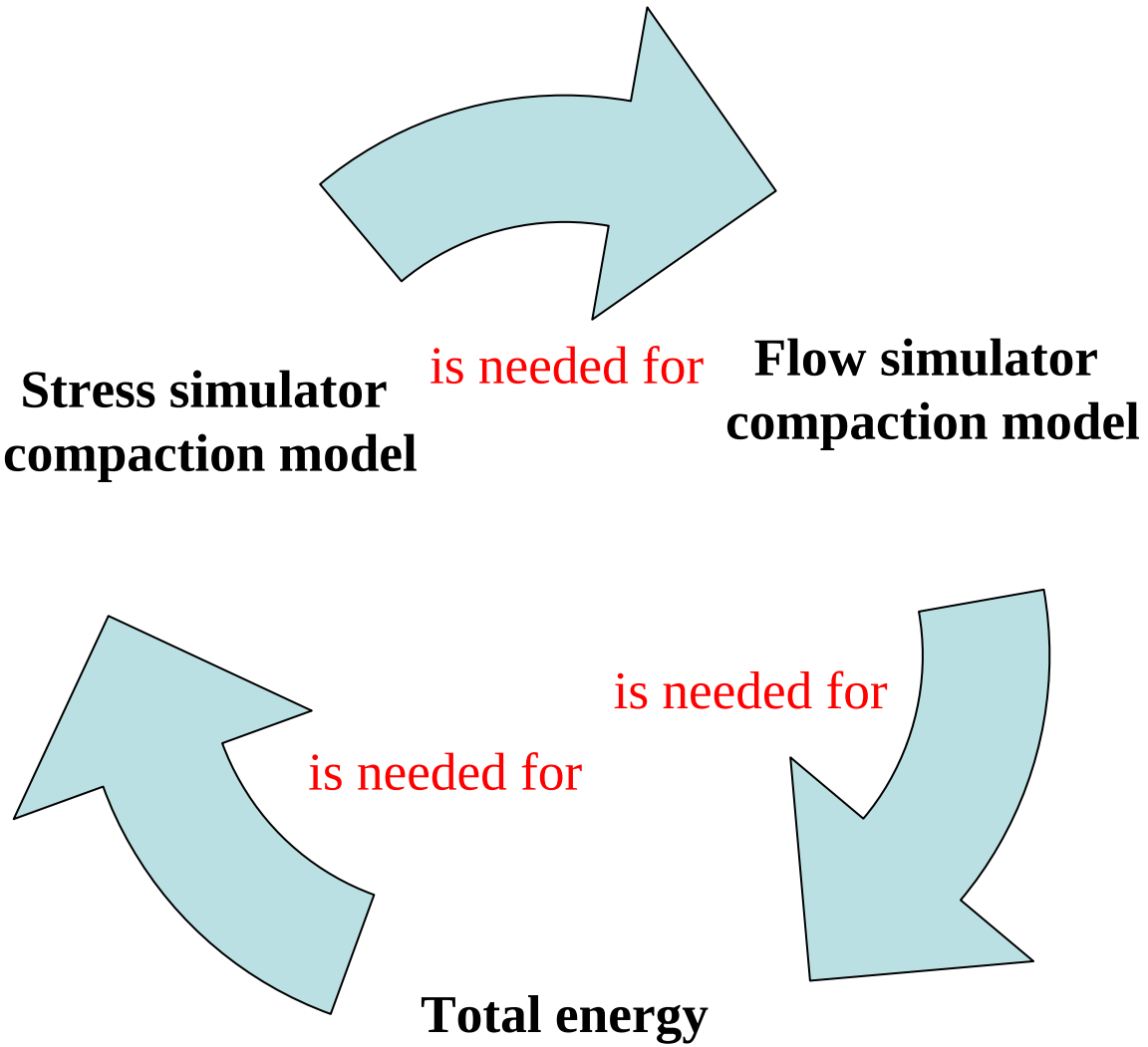


Computed using “correct” compaction model

Coupled Simulations

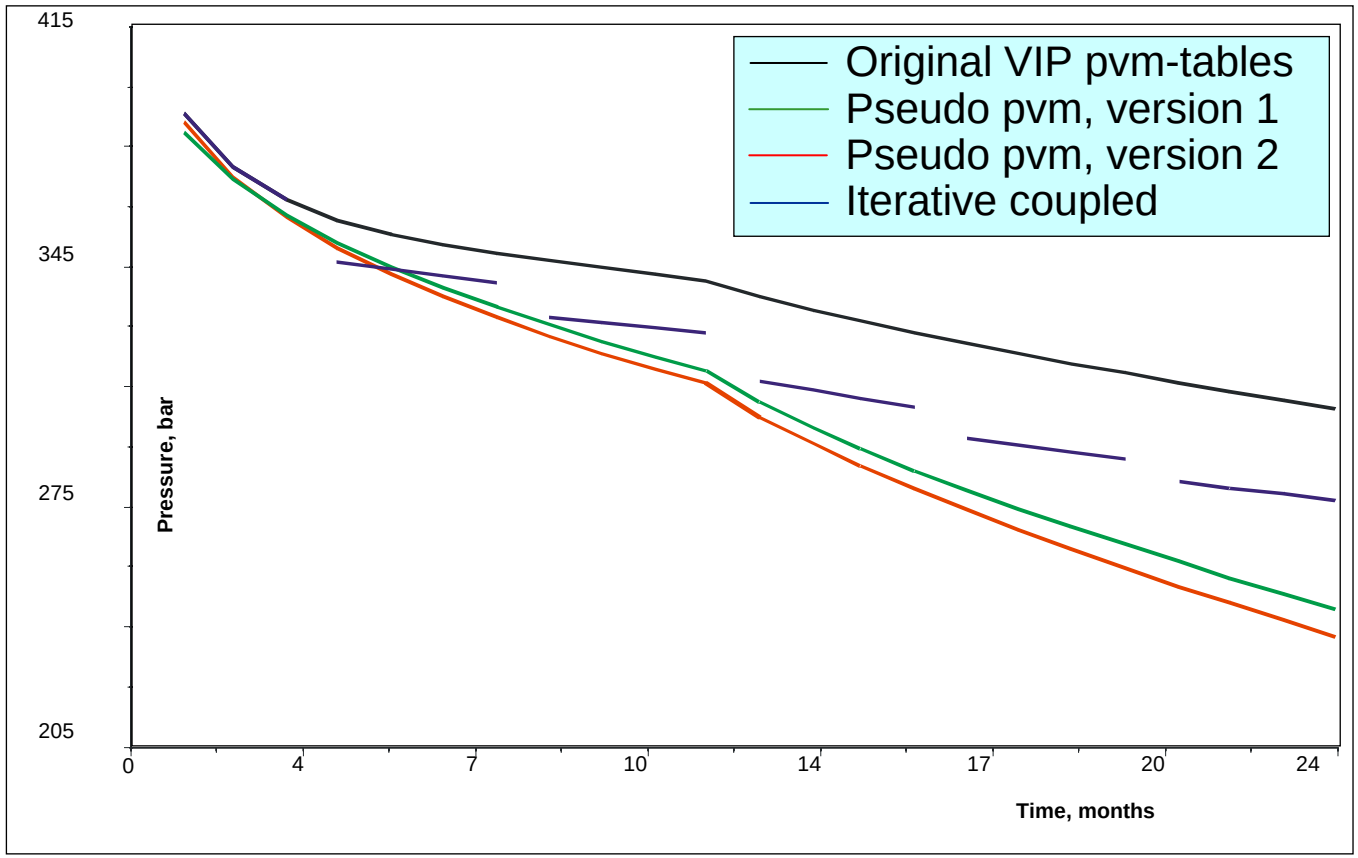
- *Valhall compaction modelling has been done by Coupled Simulations (Flow Simulator ↔ Stress Simulator)*
- *Stress simulator is initialised by pressure / compaction state as computed by flow simulator (static)*
- *In the stress simulation phase, energy is conserved*
  - *I.e. The total energy in the rock mechanics system is determined by the flow simulator reservoir state.*

Coupled Simulations



Catch 22?
–
or iterations

Iterative Coupling Drawback

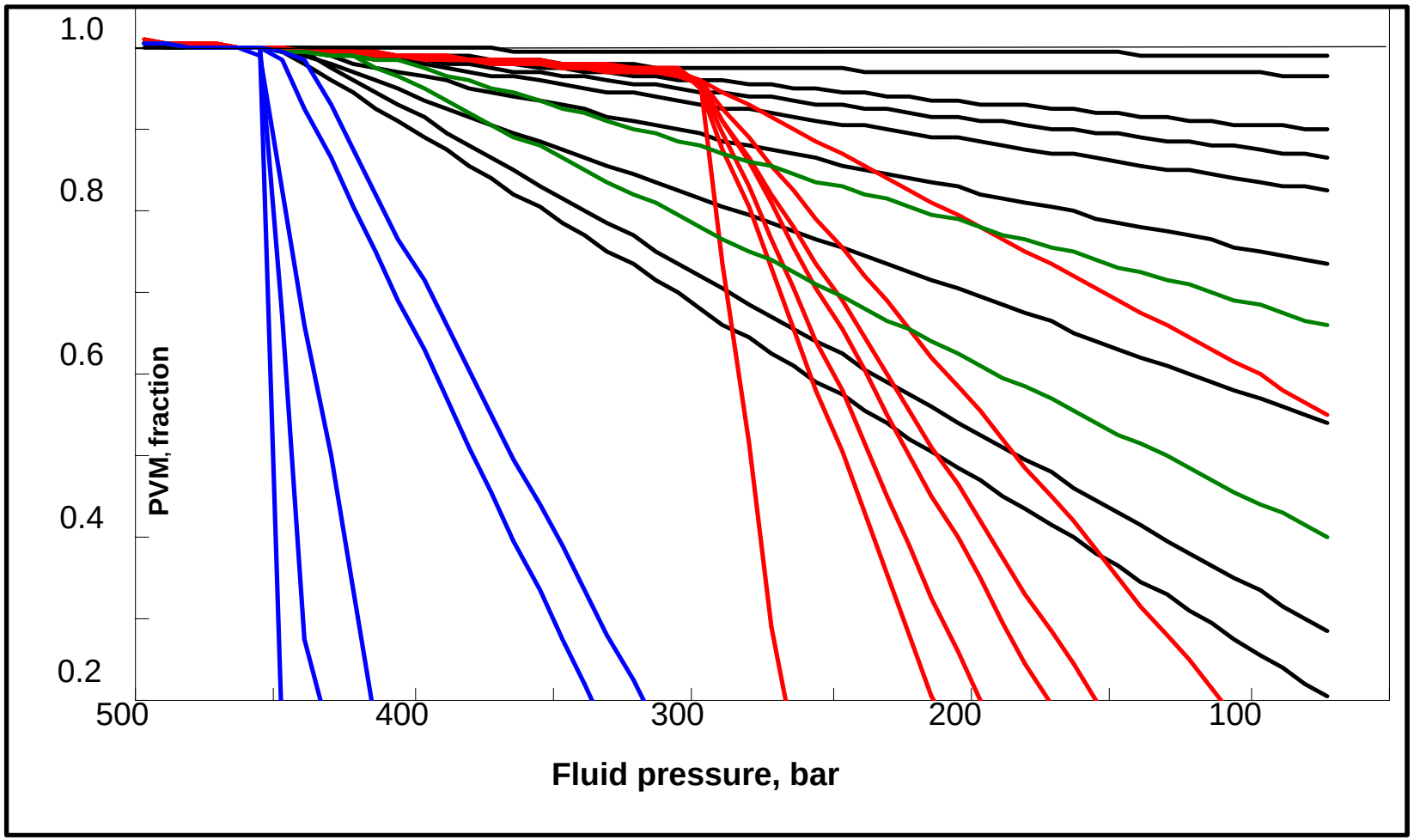


Pressure solution is valid at (and only at) the stress steps

Solution? (mech2sim)

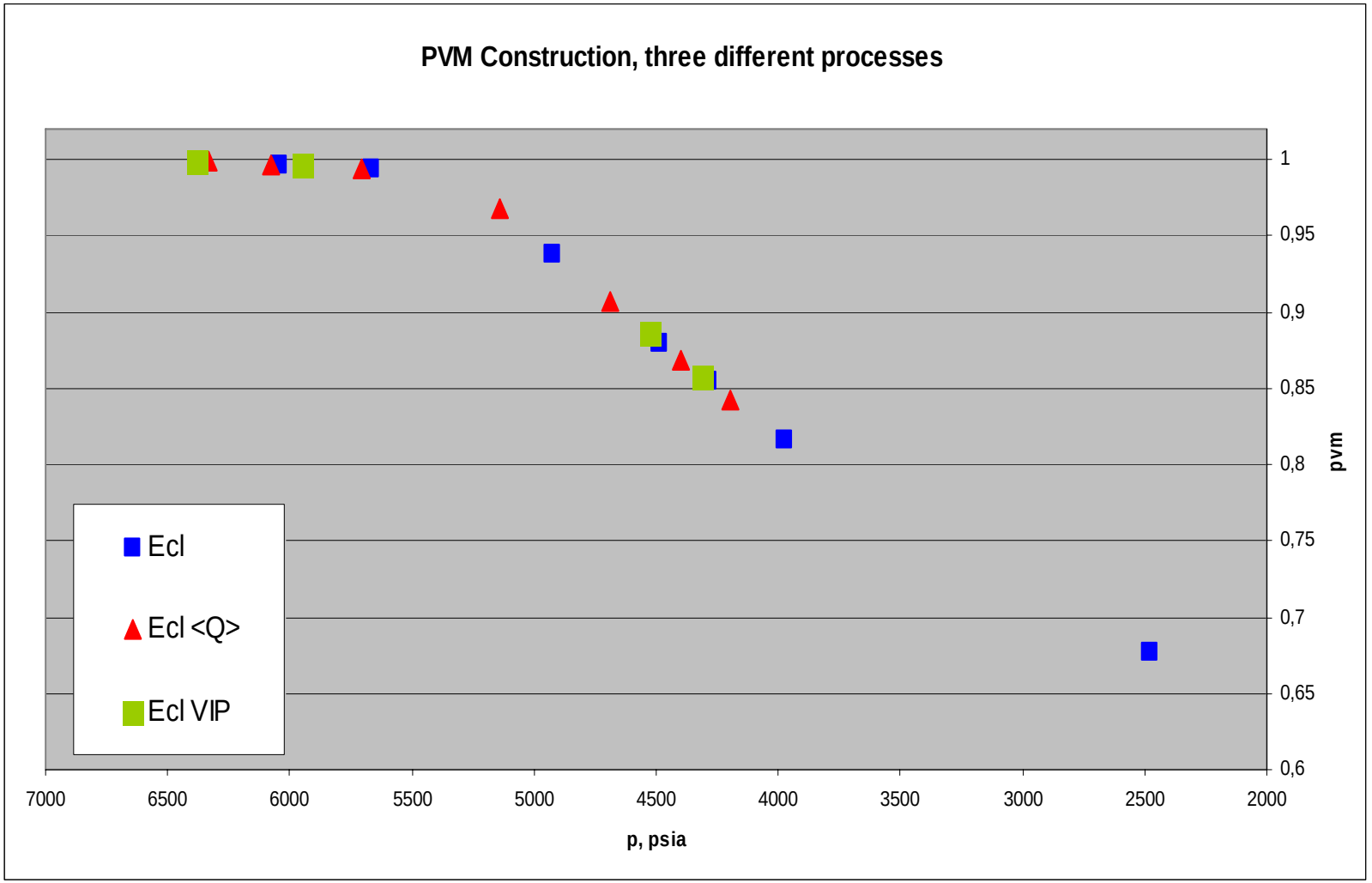
- *Use local (cell) m(p) relations in flow simulator*
- *Flow simulator computes correct PVM and pressure*
  - *At all times, not only at stress steps*
- *Energy and stress state correct in second stress simulation*
- *Compaction model can be chosen by user*
  - *(Strain, Valhall, Settari)*
  - *Else can cause convergence to ”wrong” solution*

Example local PVM vs. pressure curves

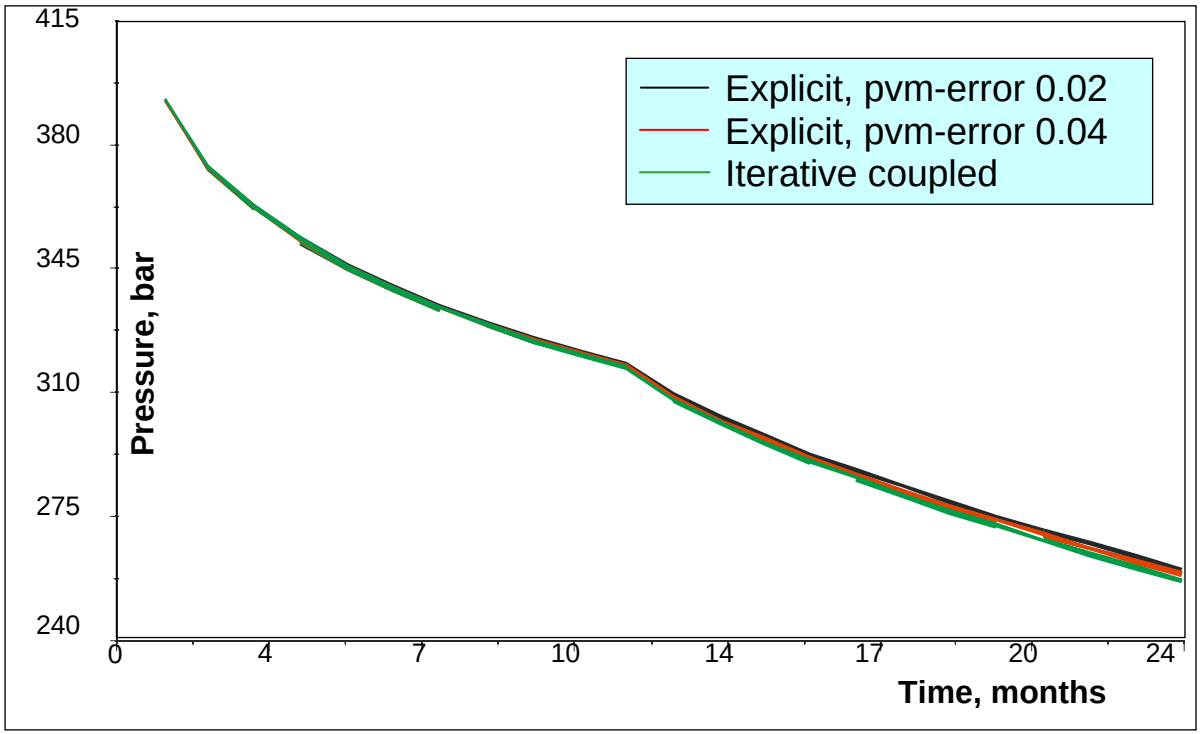


All curves from same material, and for cells not too far apart
(Also shows it's futile to try this with a single curve...)

PVM curve Construction is Independent of Process

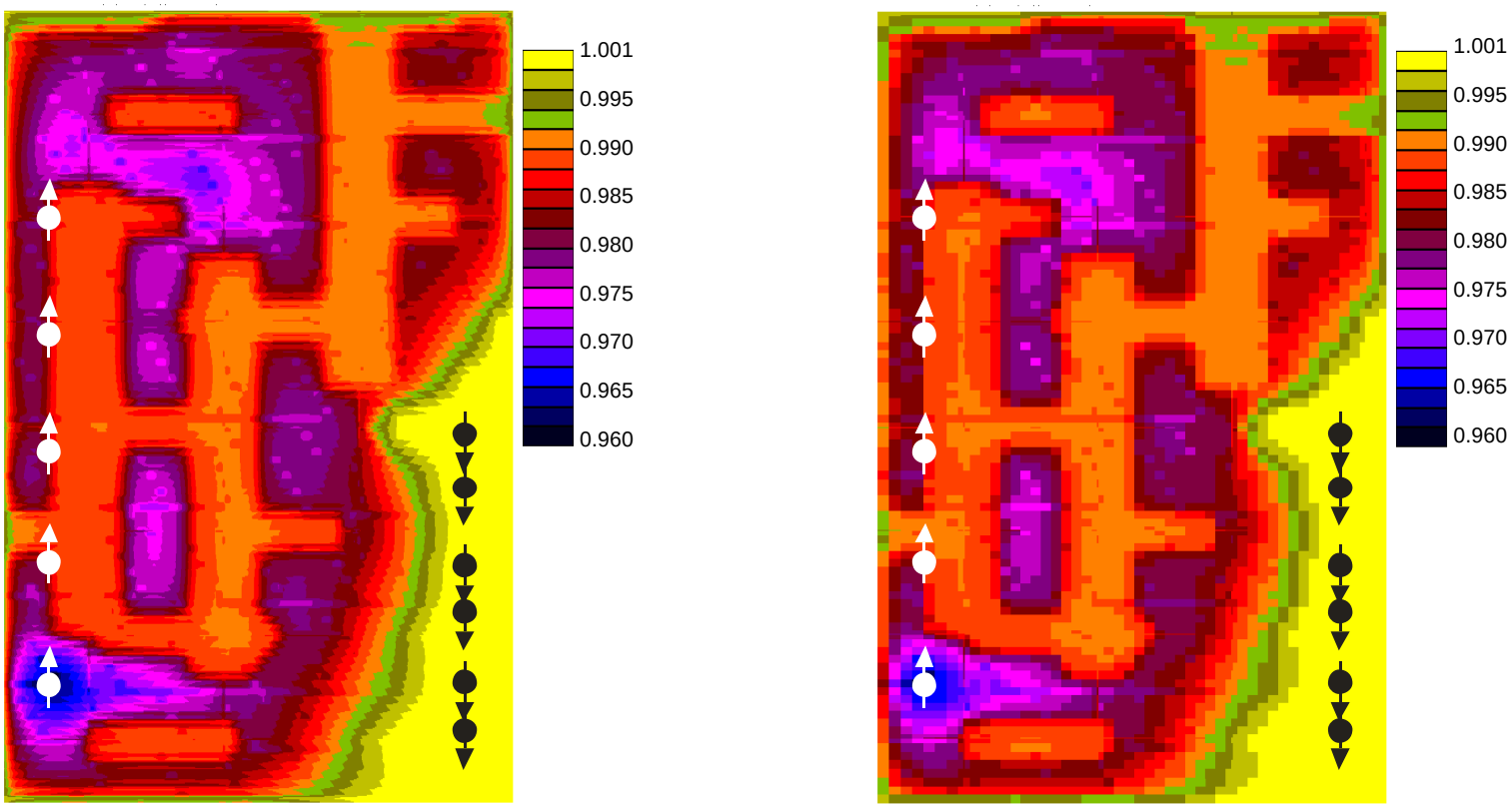


Using Local (Cell-based) PVM-curves



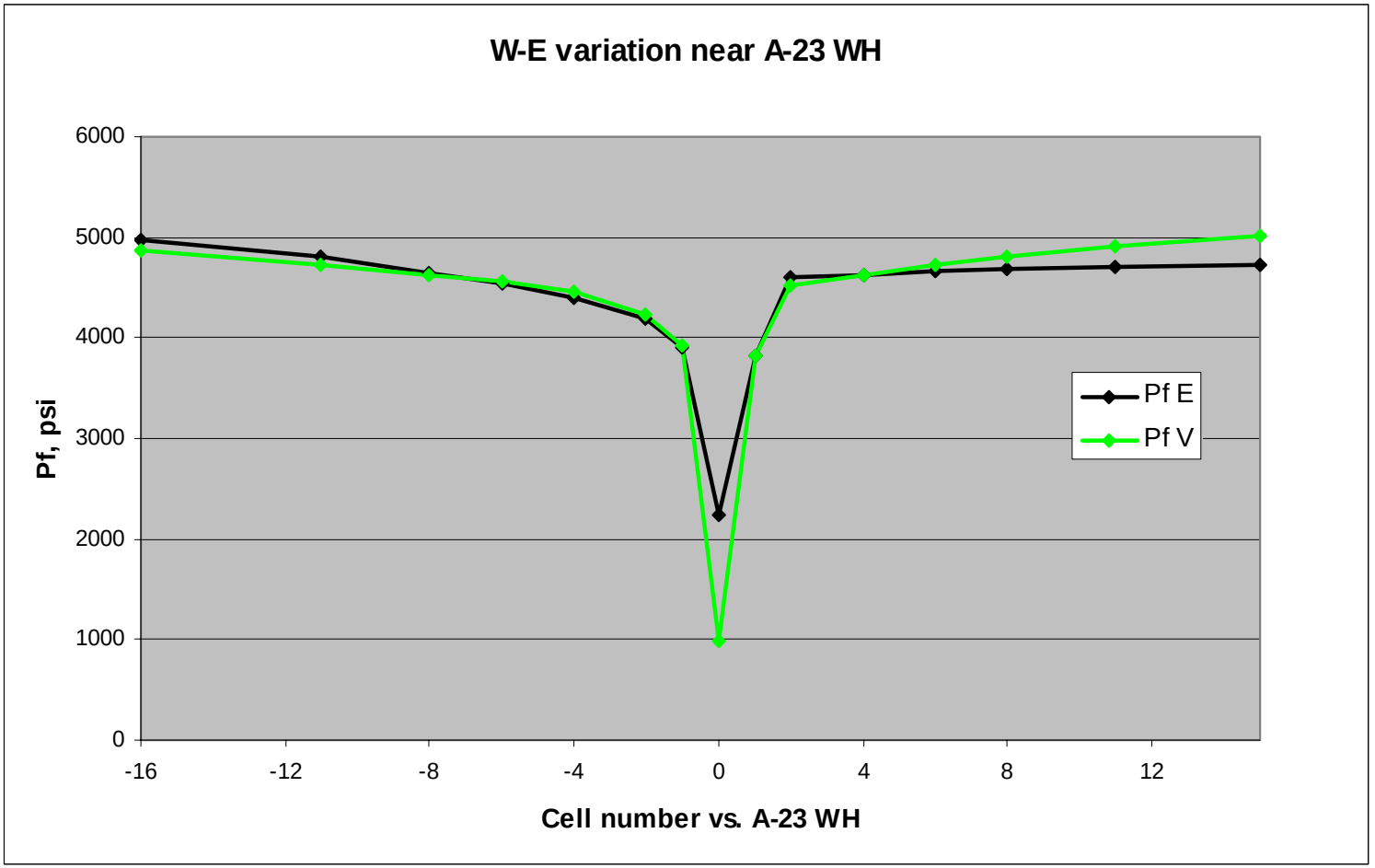
Pressure solution:
valid at all times
≈ identical for flow sim and iterative coupled

Using Local (Cell-based) PVM-curves



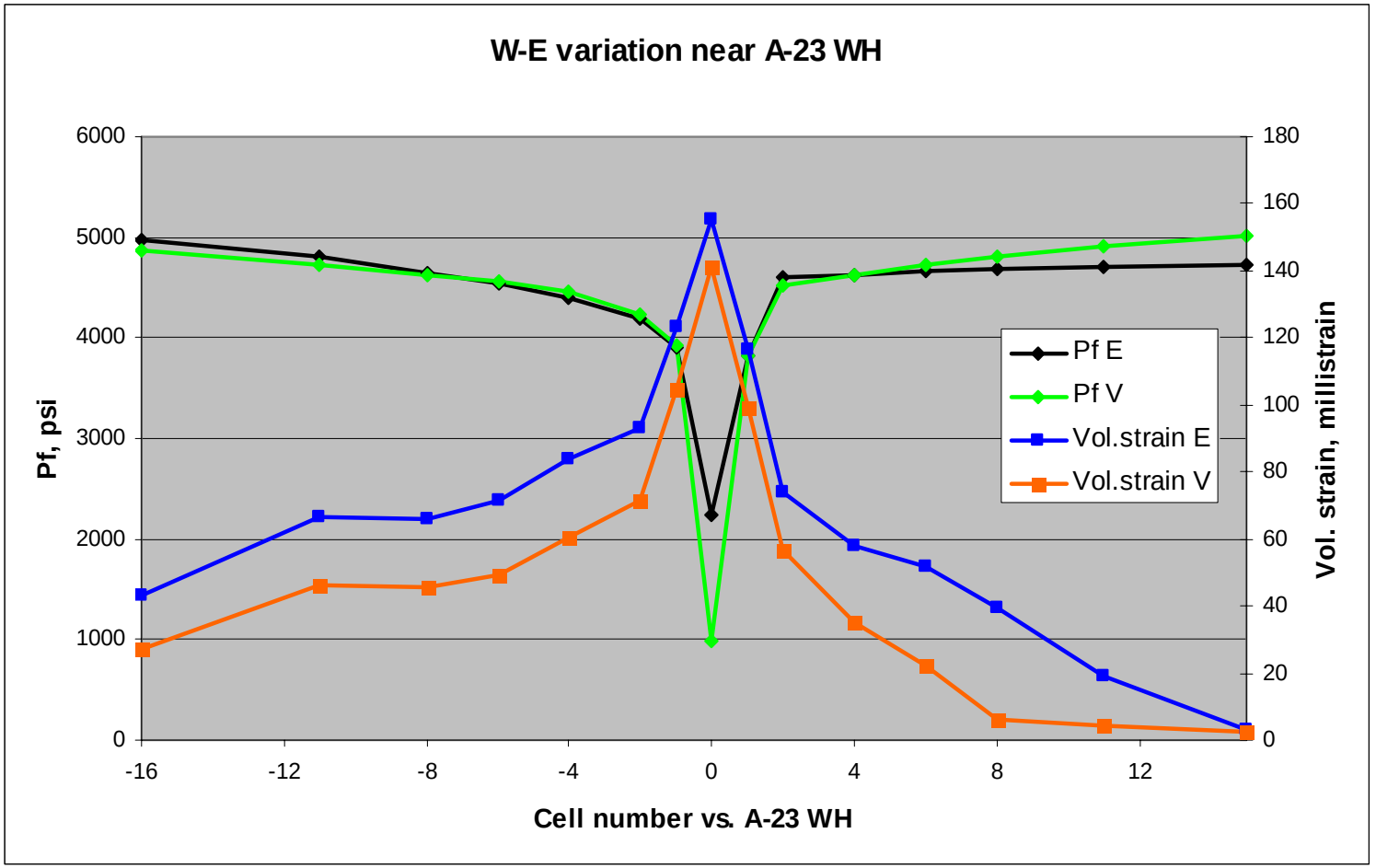
Contours of compaction as good as identical from stress simulator (left) --- flow simulator (right)

Work in progress: History Matching



History data indicated well productivity should be increased (Skin, Kh) → Local pressure change

Work in progress: History Matching



Corresponding change in strain state is global (??)

→ History data signifies the near-well material is untypical, and must be assigned prop's to honour data.