Distinguished Lecturer Program

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Distinguished Lecturer Program

SPE International

Formation Damage – Any Time, Any Place, Any Where

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Senergy

Society of Petroleum Engineers
Distinguished Lecturer Program
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Lecture Outline

- Definition of damage and cost
- When does damage occur?
- At what stage of field development does damage occur?
- Where does damage occur?
- Damage Mechanisms –
  Some Examples
- Conclusions – Any time, any place, any where, any how……

Definition of Damage

- **Formation Damage can be defined as any reduction in near wellbore permeability which is the result of “any stuff we do”**

- **…….such as drilling, completion, production, injection, attempted stimulation or any other well intervention**

What is the impact of damage?

- Shell has estimated that at oil price of less than $20 / barrel the cost of damage on Shell operated assets was $1 billion / year.
- Shell, at that time, was producing roughly 3.3 % of total world production.

- $70 / barrel and global perspective means current best estimate for cost of damage due to deferred production and dealing with damage is $100,000,000,000 / year

Cost versus Value

- How much does our industry currently spend on understanding and avoiding formation damage?

- Maybe $100 million?
- Or 0.1 % of the cost!!

When does damage occur?

- Drilling
- Completion
- Attempted Stimulation
- Production
- Well Intervention
- Injection

Damage Risk Assessment

Operation	% of total damage	Impact / removable?(1-5)	Importance
Drilling	25	2	50
Completion	25	3	75
Attempted Stimulation	15	4	60
Production	15	3	45
Well Intervention	10	4	40
Injection	10	2	20

Drilling Formation Damage

- **Mud cake**
  - Thickness / Permeability
- **Solids Invasion**
  - Shallow (surface pores only?)
  - Solids size and concentration – pore throat size distribution (not pore size distribution)
- **Filtrate Invasion**
  - Clay Swelling
  - Fluid Retention – water block
  - Emulsion and sub micron emulsion
  - Scale
  - Fines Migration

Mud Cake

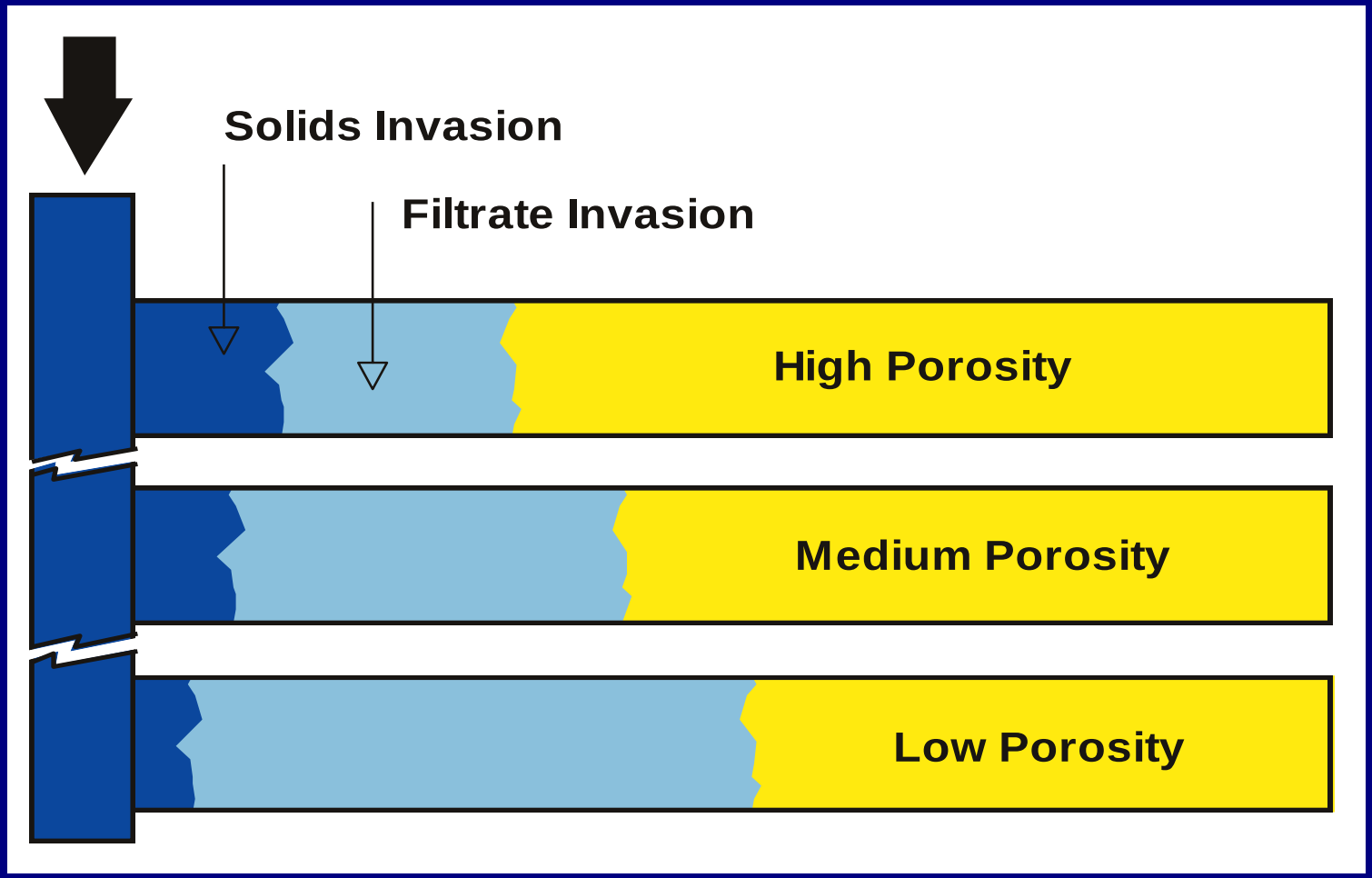
- Ideal would be thin, impermeable, removable
- Pin holing and permeable mud cakes are acceptable
- Beware of valves or bi-directional permeability contrast in mud cake for water injectors or gas storage
- Thickness and quality can vary – even in the same well
- Impact of drilled solids
- Impact of well geometry
  - Erosion
  - Sagging

Solids Invasion

- Can be controlled by sizing mud particles if pore throat diameters are understood
- Less invasion than modelled
- Fine particles will invade deeper than large particles
- Higher overbalance = deeper invasion
- Bridging with soft materials

- Solids impact on chemistry
  - Eg Calcium carbonate - raises pH – may induce naphthenate soaps with some crude oil

Invasion Profile due to overbalance



Filtrate Invasion

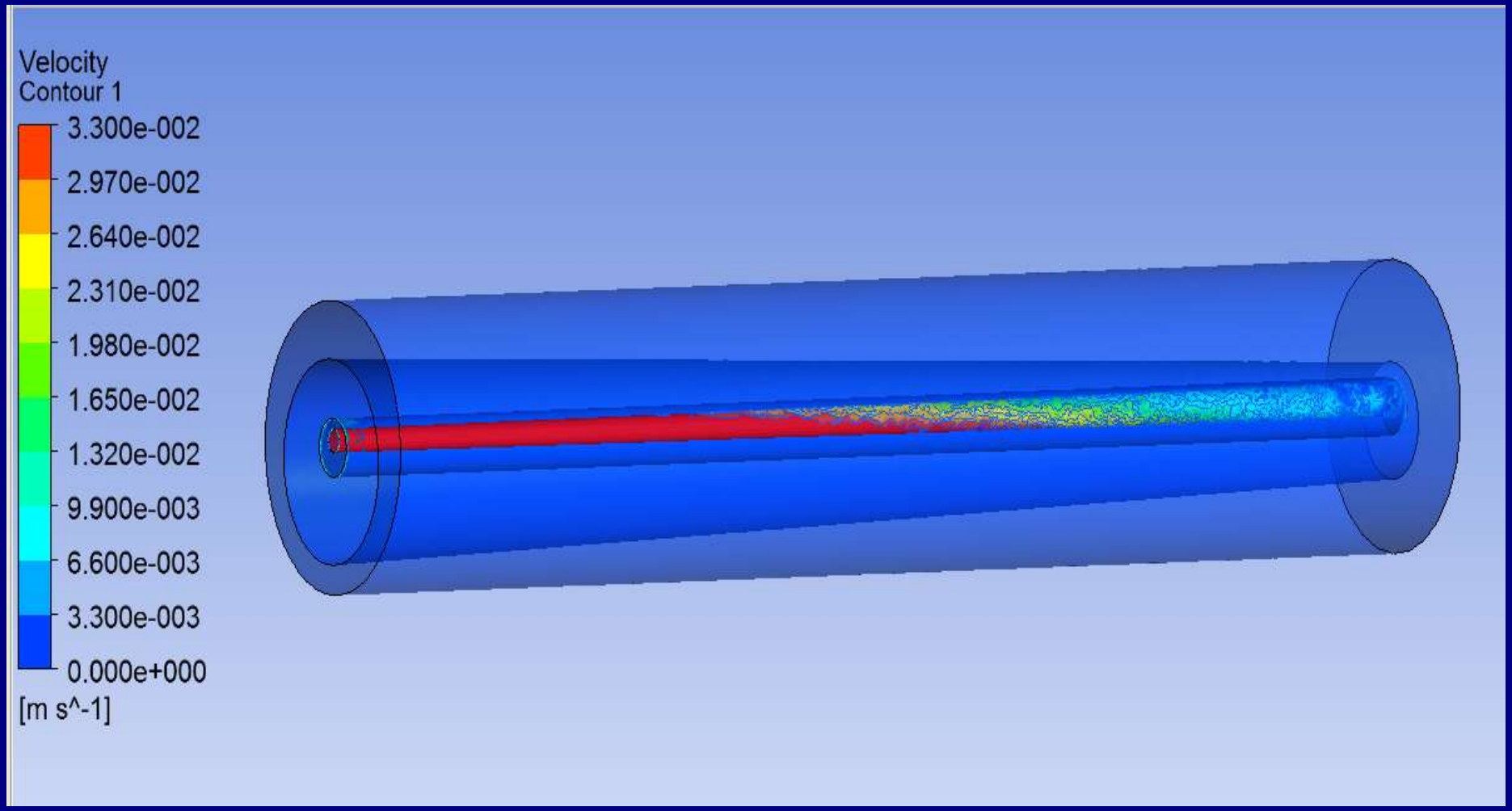
- Deeper Damage
- More difficult to access damage
- Many different mechanisms
- Can be several meters

- May not be damaging!

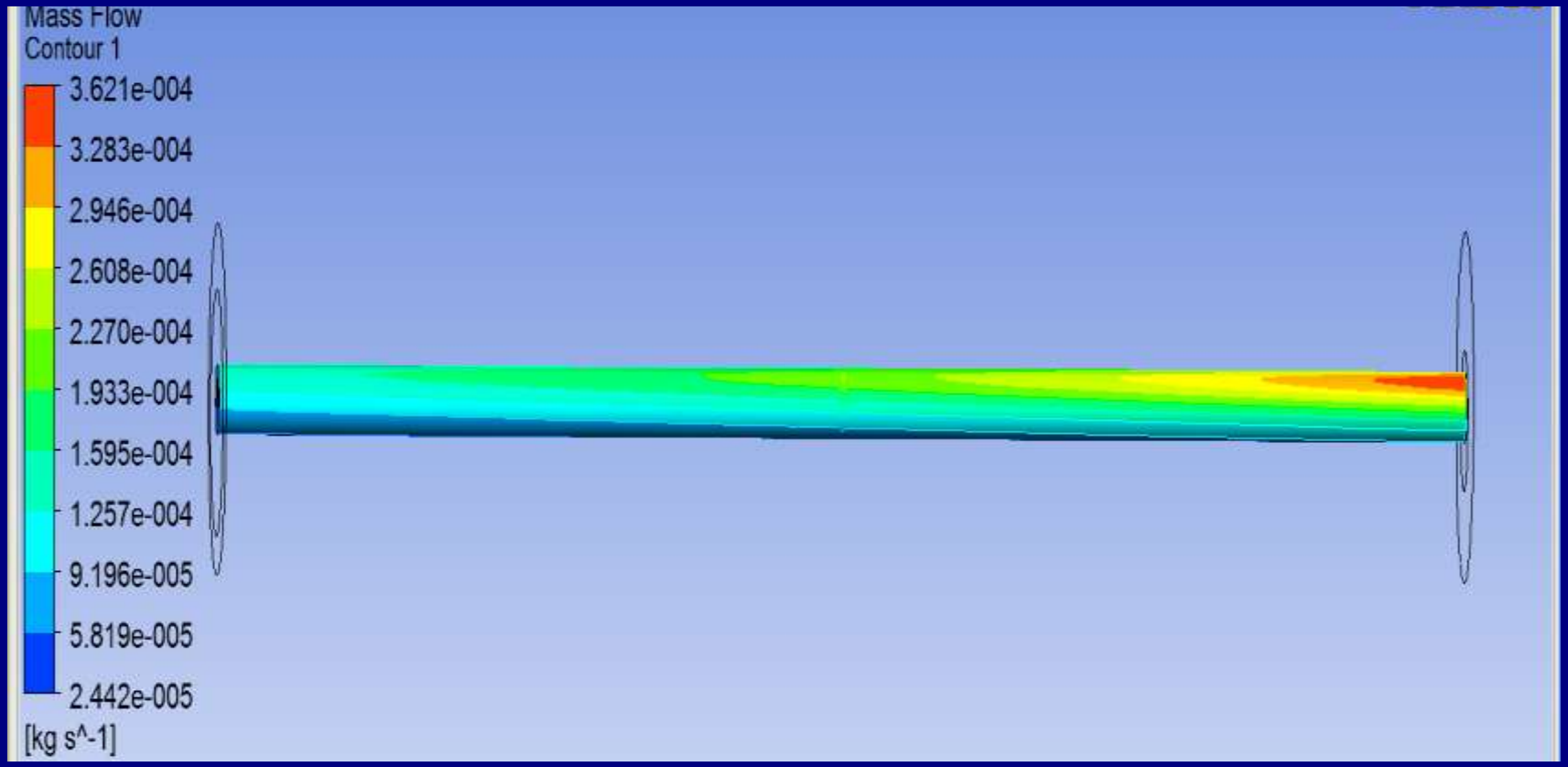
SPE 128082

- Asymmetric Formation Damage in a horizontal well
  - Along the well: heel and toe
    - Heel – higher overbalance, longer exposure time
  - Around the well: high side and low side
    - Low side – thicker cake, more erosion
  - Drawdown: heel and toe
    - Heel – higher drawdown (differential)

Well Model – final



Results



Mass flow higher at toe – damage more critical than drawdown in this case

Completion Formation Damage

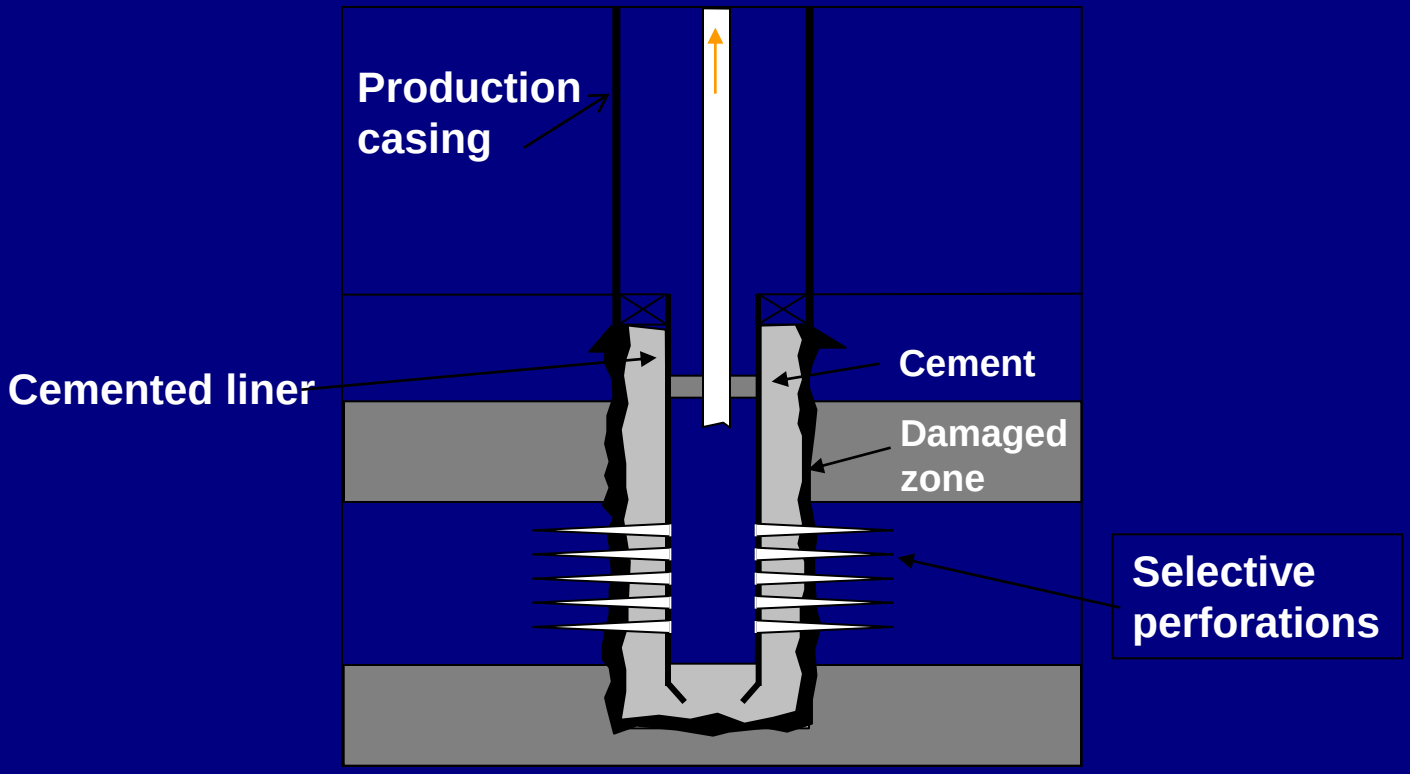
- **Cased and Perforation Specific**
  - Mechanical Damage
  - Charge Debris
  - Cement and Spacers
- **Solids Invasion**
  - Mud or other solids
  - Completion fluid filtration
  - LCM and Kill Fluids
- **Filtrate Invasion**
  - Is it bypassed by perforation
  - Compatibility with other fluids
  - Cement filtrate
  - Mechanisms
    - Clay Swelling
    - Fluid Retention – water block
    - Emulsion and sub micron emulsion
    - Scale
    - Fines Migration

Cased and Perforation Specific

- Mechanical Damage
  - Crushed Zone
  - Plugged Perforation
  - Underbalance?
- Charge Debris
  - Physical block
  - Chemical reactions (eg with completion fluid)
  - Solids tolerance of pumps?
- Cement and Spacers
  - Spacer compatibility
  - Cement filtrate

Perforations

- Perforations usually designed to bypass damage but do they?



Damage During Attempted Stimulation

- Iron dissolution and precipitation
- Fines Migration
- Asphaltene deposition
- Fracture fluid damage
- Formation Failure
- Sludge

Acid Stimulation

- “There will be dissolution!”
- “There will be precipitation!”
- “Know your reservoir”
  - Dr Hisham Nasr El Din (Texas A&M)

- “Simulate before you stimulate”
  - Computer and laboratory

When is Formation Damage Important?

- **Exploration wells**
- **Appraisal wells**
- **Development wells**

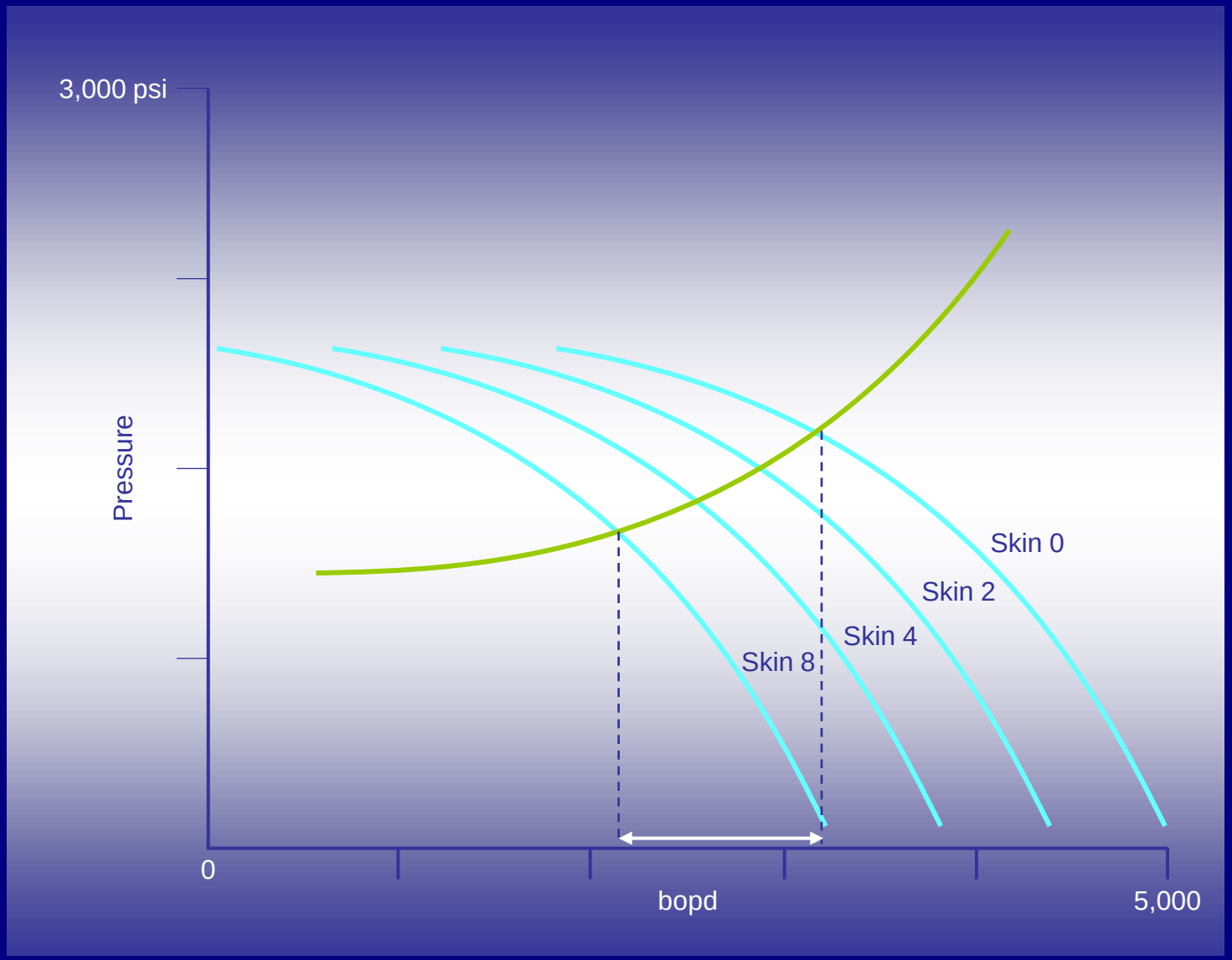
Exploration and appraisal wells

- Undeveloped Discoveries – What if all exploration well test data is tainted by damage?
- Greater Damage in Exploration and Appraisal wells
  - Well objectives
  - Design of fluids
- Prospect Evaluation often ignores damage
- Damage / Productivity potential is the critical factor in many reservoir types from tight gas to friable heavy oil
- Reference SPE 107557, 115690 (Breagh Field)

Damage Mechanisms – Some Examples

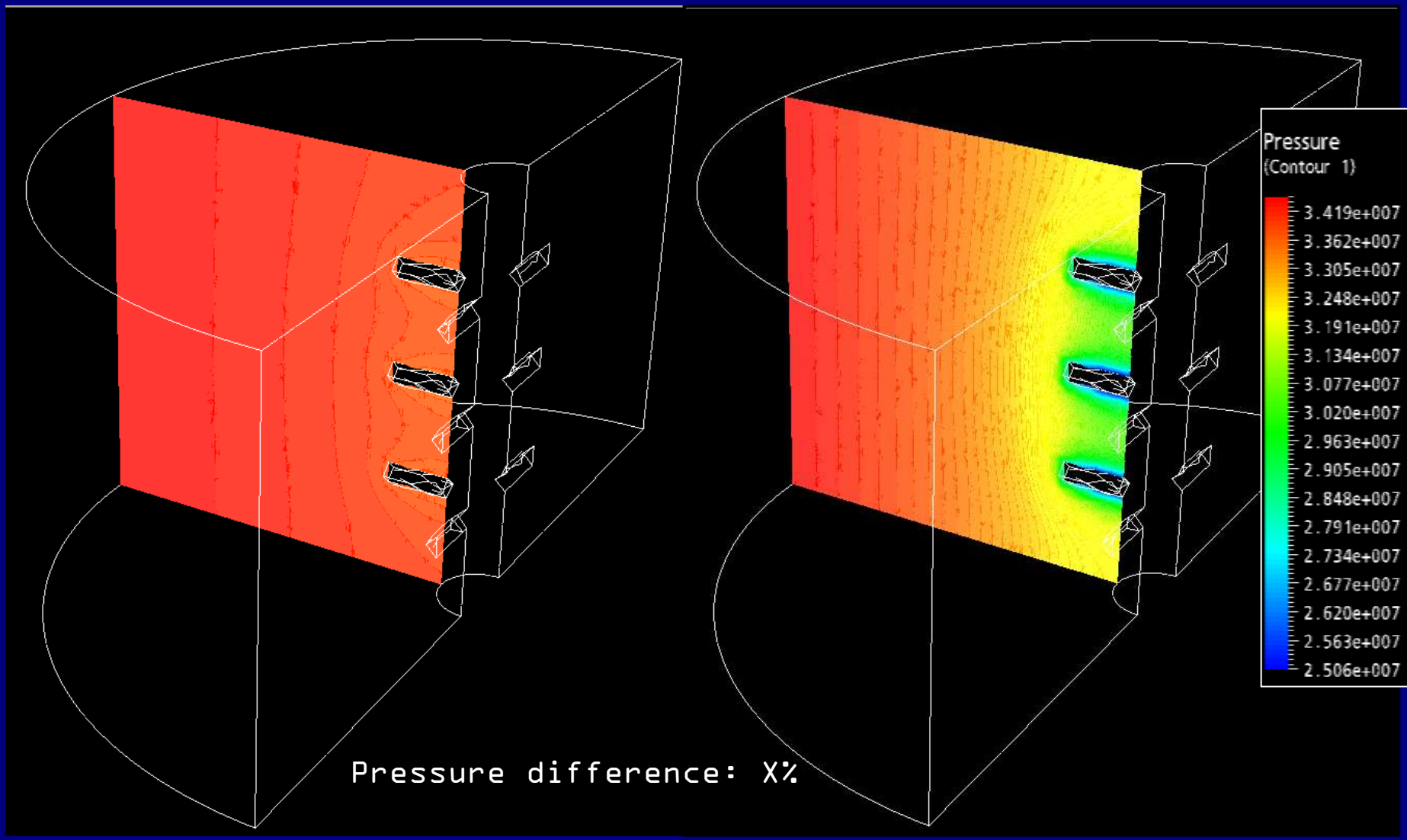
- Example of the impact on well productivity
- Examples from laboratory simulation studies

Formation Damage – Real Impact

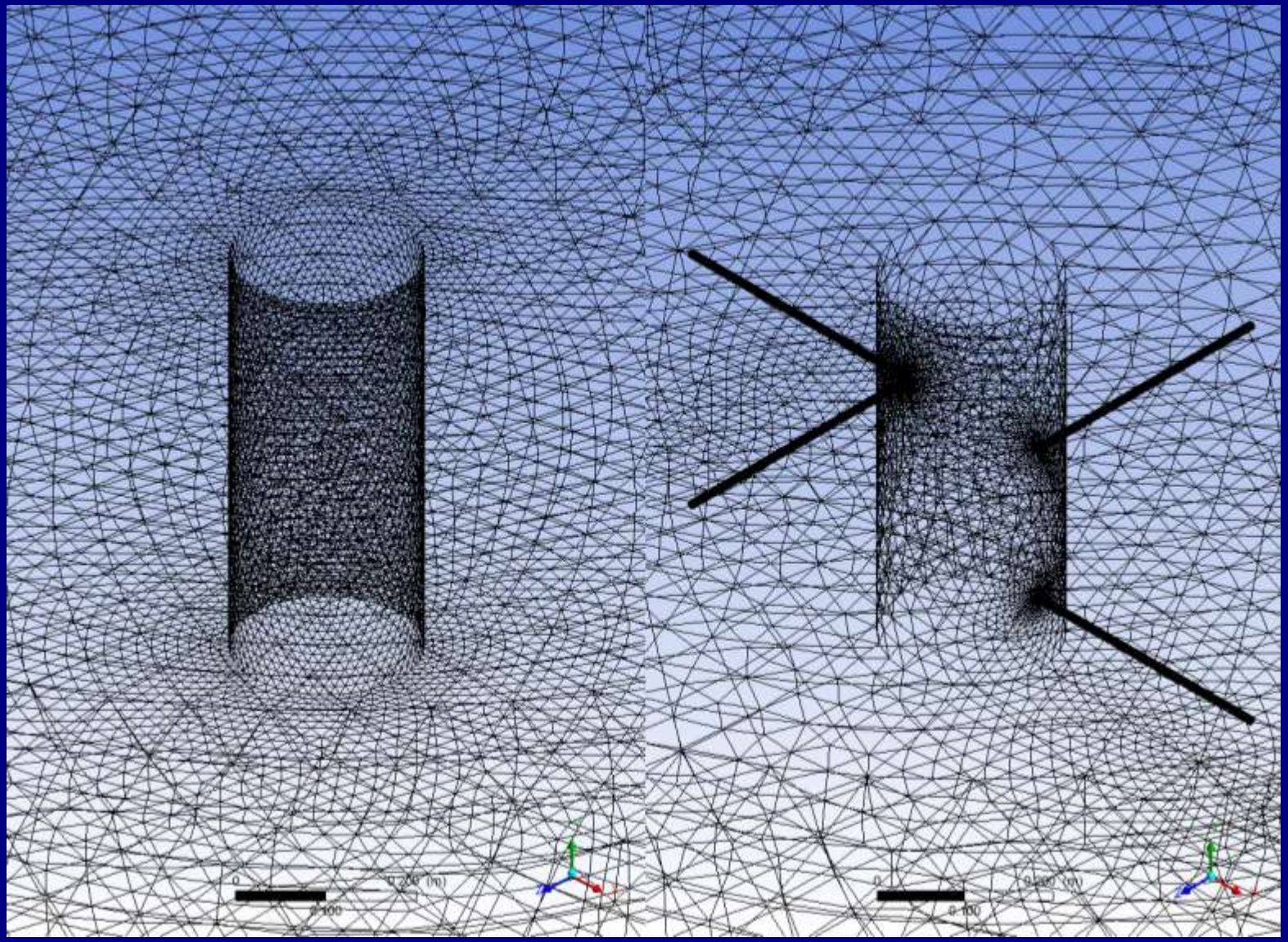


Near wellbore inflow modelling

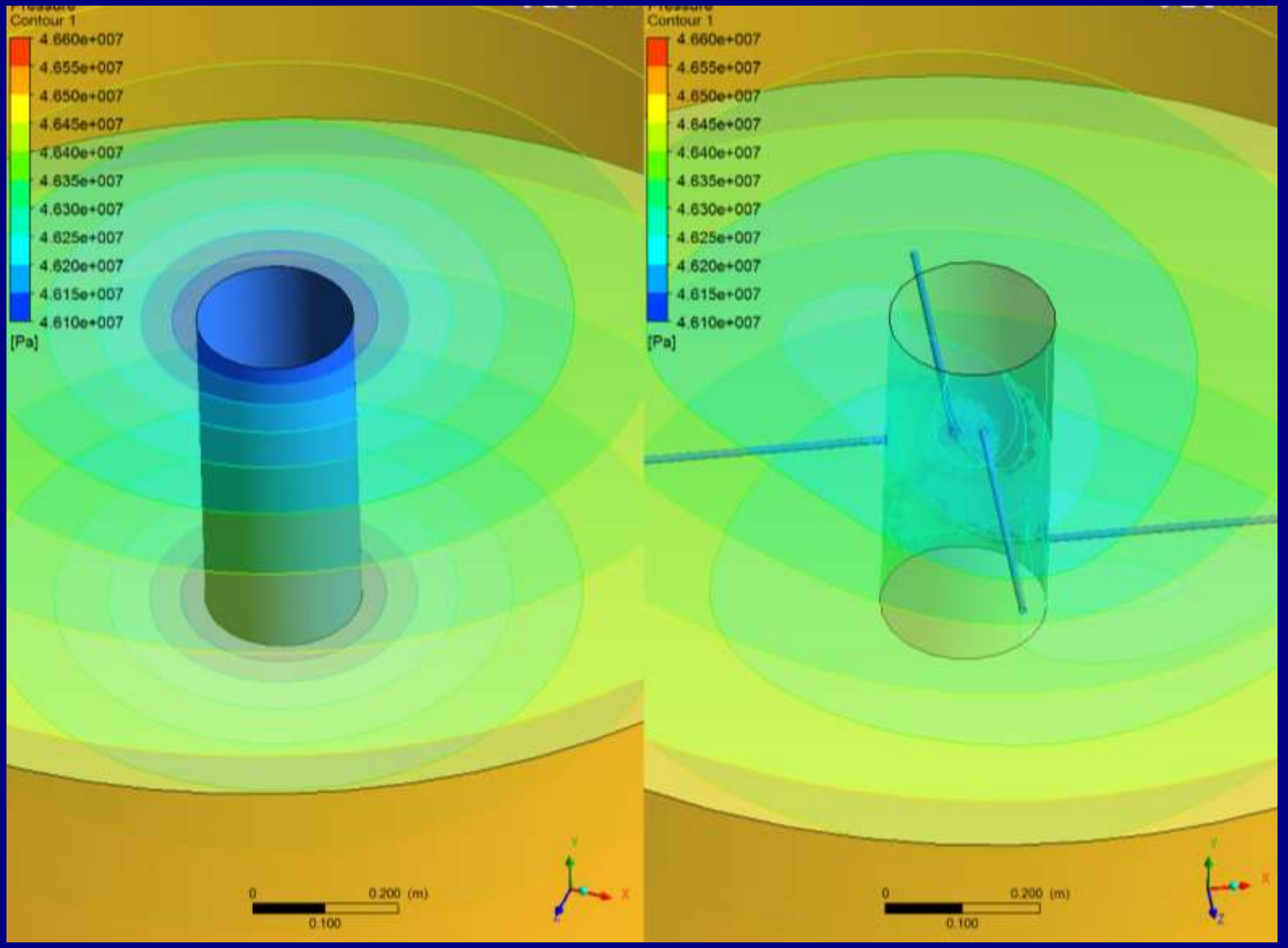
Advances…..



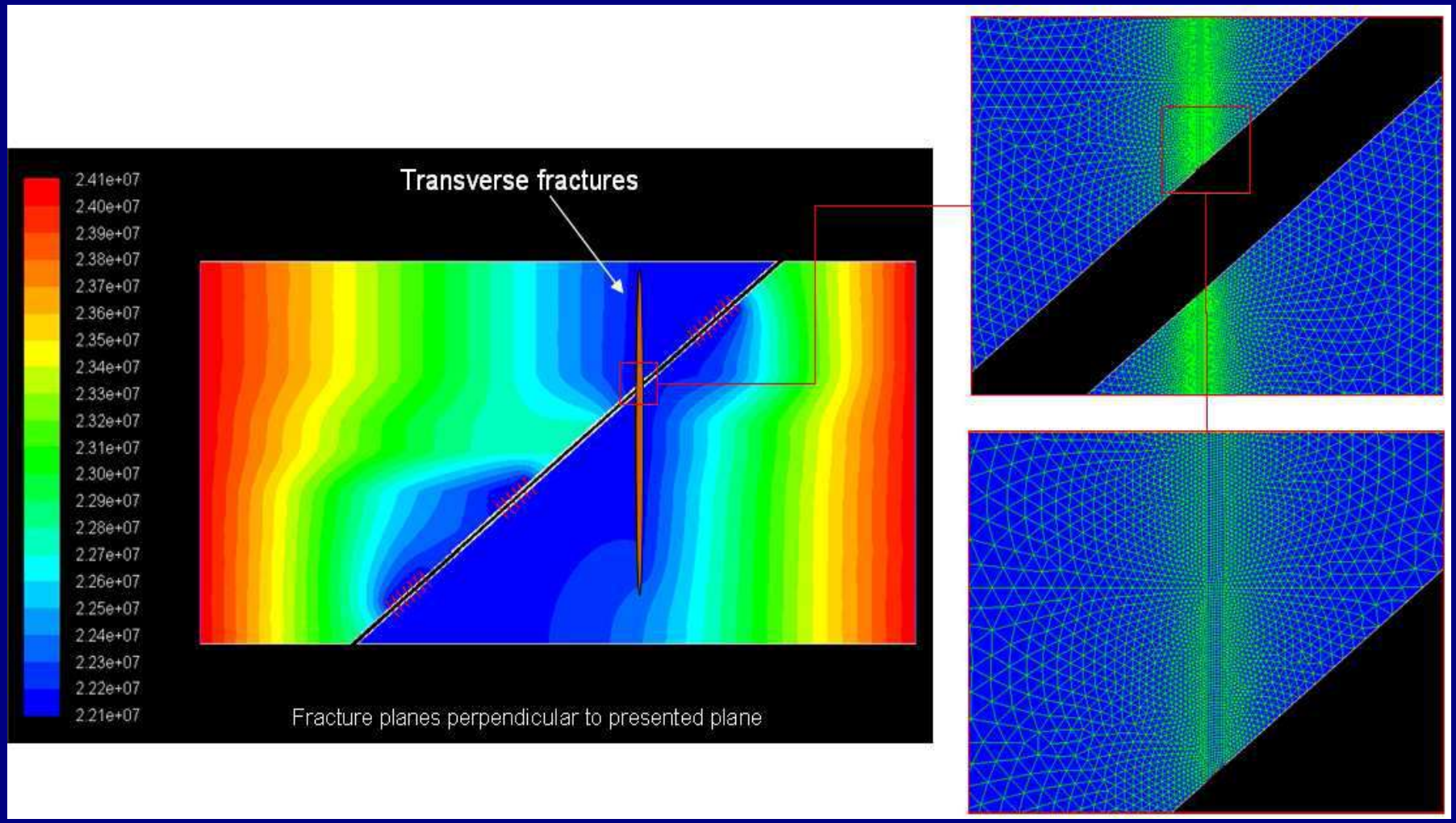
Vertical Open Hole Versus C&P



Vertical Well Pressure Profiles



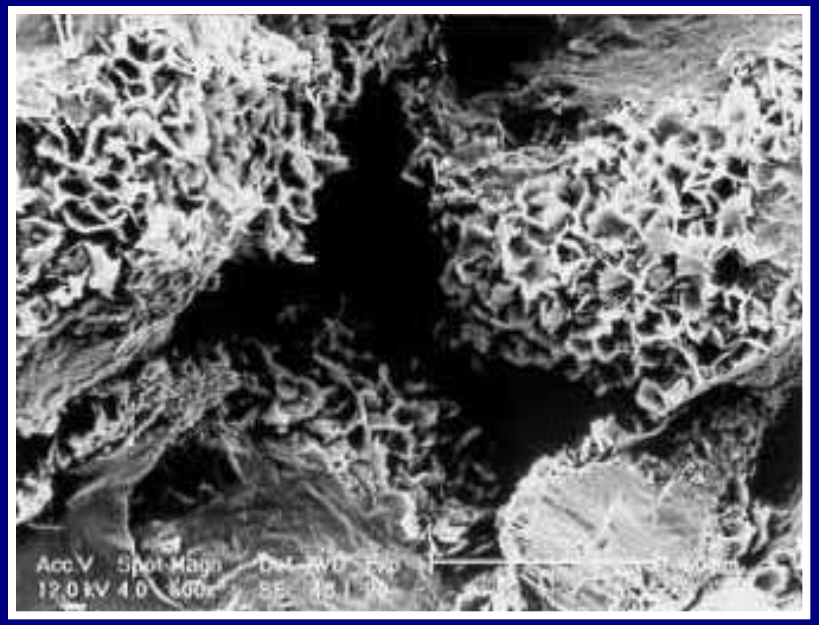
Case Study – Deviated Well



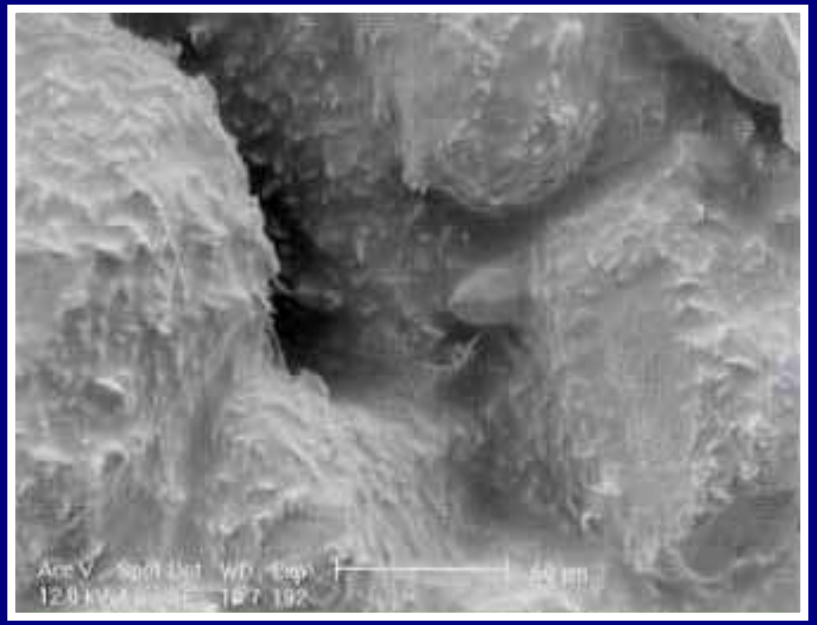
Pressure Profile (Pa)

Filtrate Retention – Gas Reservoir

RETAINED MUD FILTRATE LOSSES



BEFORE TEST



AFTER TEST

Fluid has been retained in the micropores between the chlorite platelets

90% reduction in permeability

Solution was to treat with solvent, reduce interfacial tension and release most of the retained fluid – very successful in a laboratory and in the well

(Photographs courtesy of Corex UK Ltd)

Fines Migration
Myth or Reality?

- What are fines?
- Clay?
- <44 micron?
- <45 micron?

Fines Migration - Reality

- Fines are…….
- “Any part of a rock that can move through or within the pores of the rock”

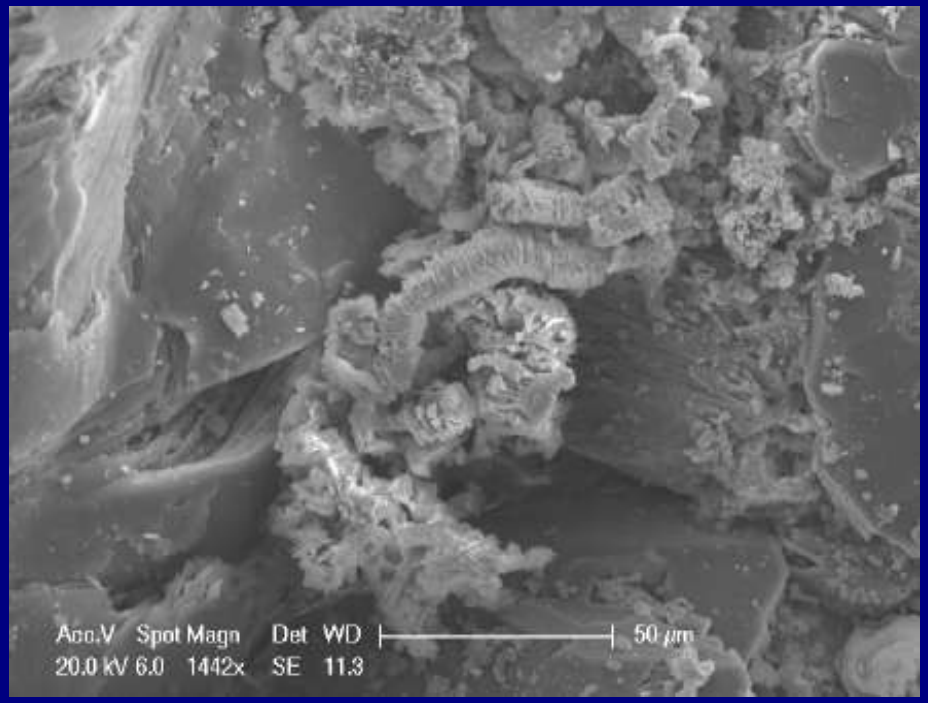
- Fines migration is very common, very complex and deserves our care, understanding and attention!

- Solutions to this problem can include reducing near wellbore flow rates, using less damaging fluids or even stabilising fines – see SPE112455

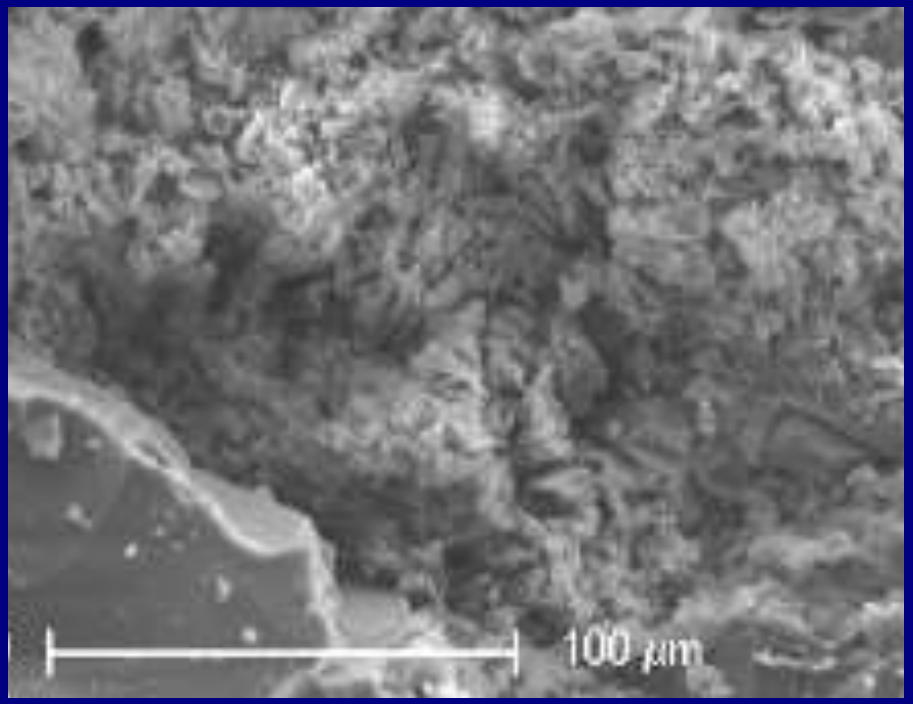
Example of Fines Migration

From SPE 107758 (courtesy of StatoilHydro)

Pre-test



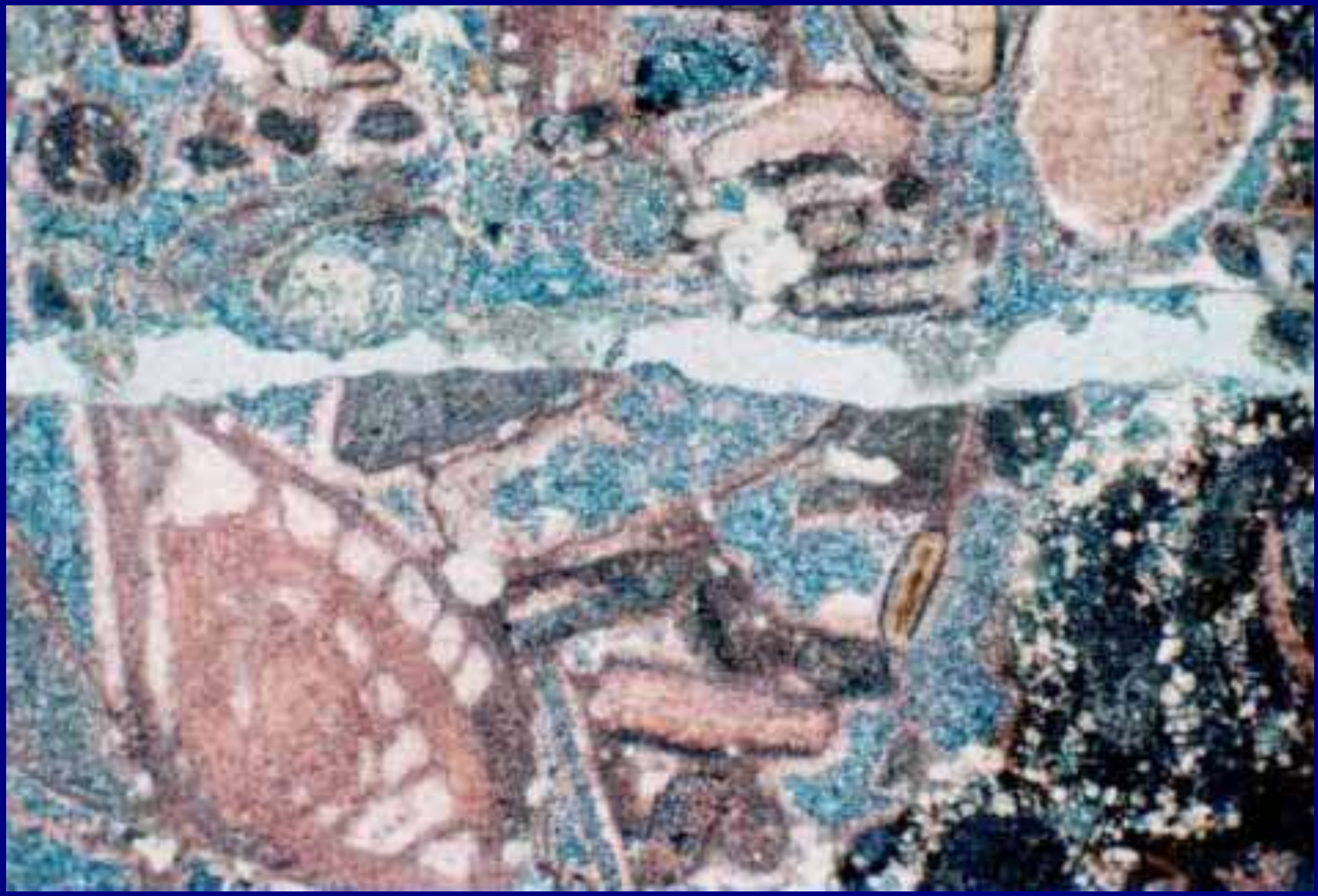
Post-test



Carbonate Reservoirs

- 60% of current proven conventional reserves are located in carbonate reservoirs
- Formation Damage exists in carbonate reservoirs but is different from that in clastic reservoirs
- Consideration needs to be given to design of the wellbore / reservoir conduits interface. This is where damage and stimulation matter most and for carbonates can be difficult to model accurately

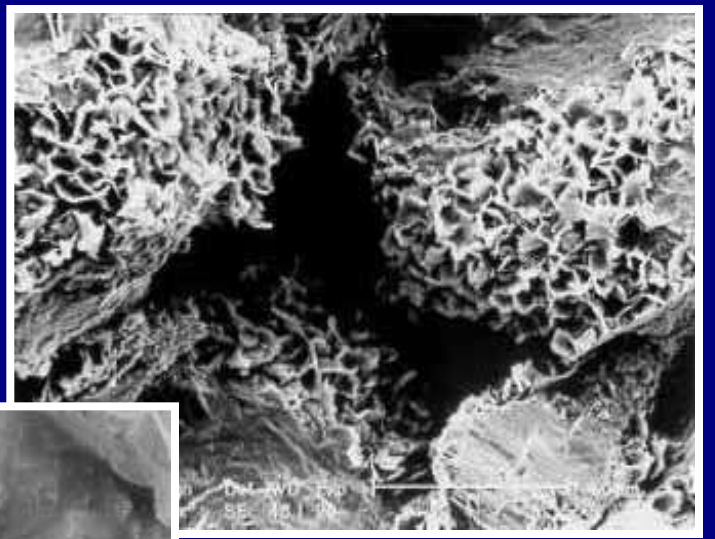
Example of whole mud losses to a fracture system (2mm apertures)



Formation Damage Any Time

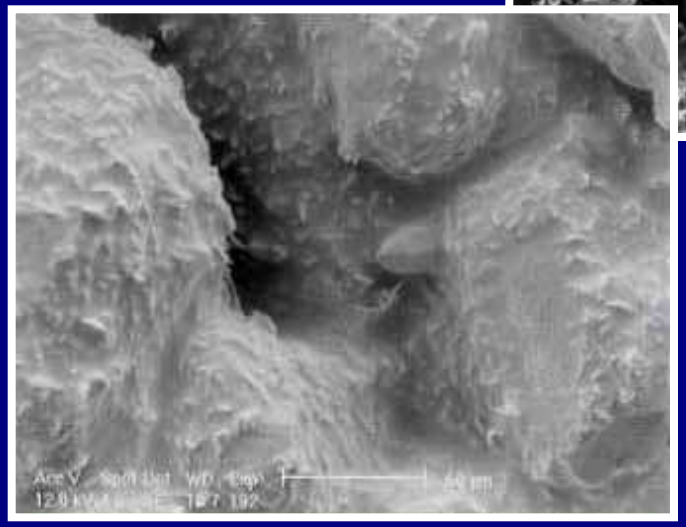
- Drilling
- Completion
- Production
- Injection
- Well Intervention
- Stimulation

RETAINED MUD FILTRATE LOSSES



BEFORE TEST

AFTER TEST



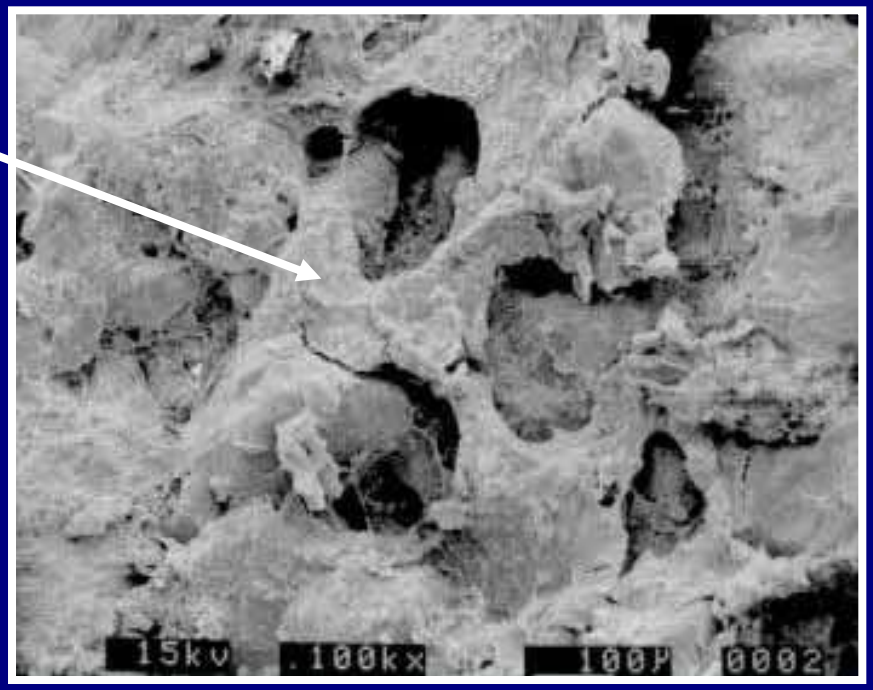
(Photographs courtesy of Corex UK Ltd)

Any Place

- Exploration Wells
- Appraisal Wells
- Production Wells
- Injection Wells
- Well Re-entry, Re-completion

Any Where

- Damage at completion
- Mud cake
- Near Wellbore
- A bit deeper!
- Deep damage



SPE 68969 (Photograph courtesy of Corex UK Ltd)

Any How

- Pore Blocking
  - External – mud cake, particles etc.
  - Internal – introduced solids, fines, fluid retention, etc.
- Chemical
  - Dissolution and precipitation
  - Swelling, wettability etc.

Conclusions

- Formation damage is everywhere
- Understanding impact and mechanisms are the key
- We can minimise most formation damage through understanding

Thank You!

- Formation Damage – Any Time, Any Place, Any where
- Any……
- Questions??