Perforating Requirements for Fracture Stimulation

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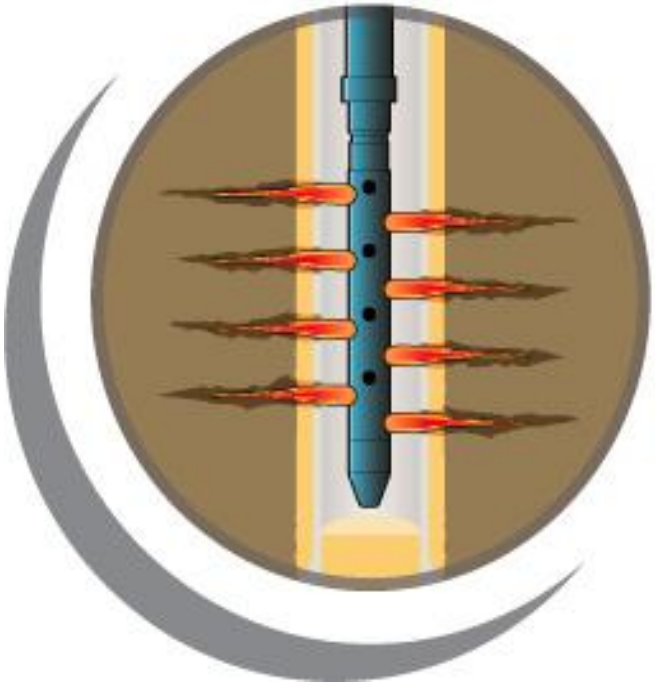

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Agenda

- Perforating objectives for fracture stimulation
- Effect of perforating parameters
- Horizontal wells
- Conclusions

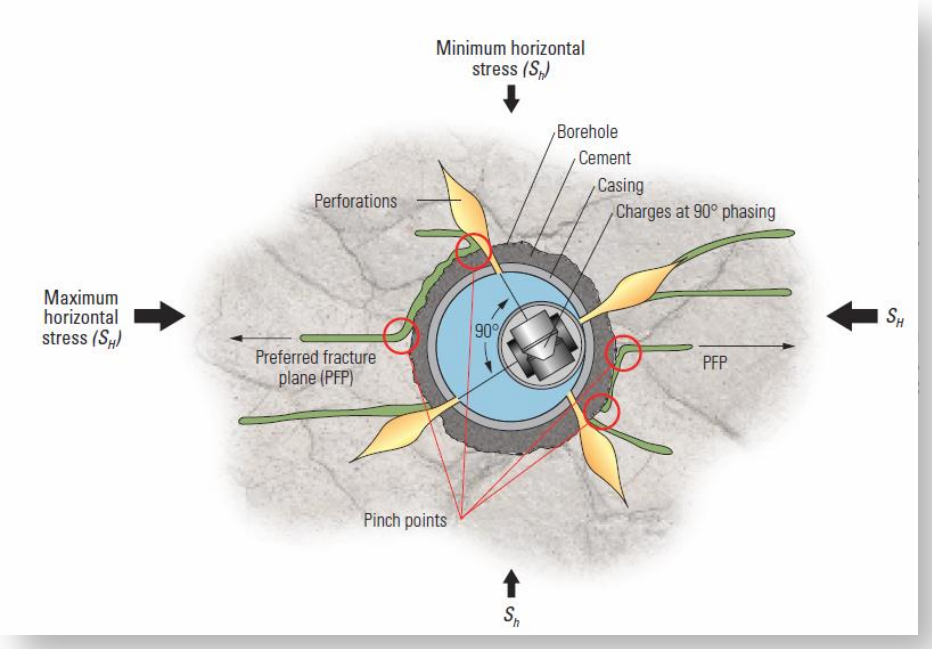
Perforating Objectives for Fracturing

- Make frac jobs more effective
  - Lower breakdown pressures
  - Lower treatment pressures with better treatment rates
  - Controlled frac placement

- All of this leads to better production
- Also helps avoid disasters like aborted jobs

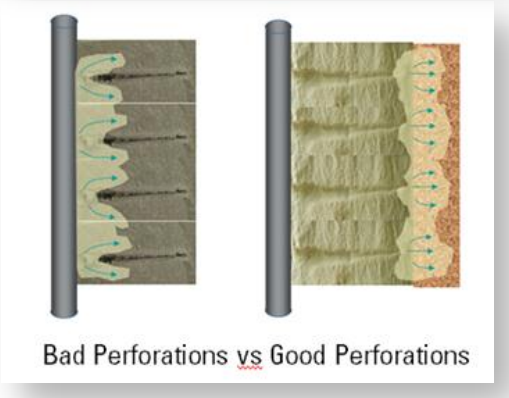
Perforating Objectives

- Perforations should minimize:
  - Near wellbore pressure drop
  - Perforation friction
  - Tortuosity
  - Micro-annulus pinch points
  - Multiple competing fractures



What can we control?

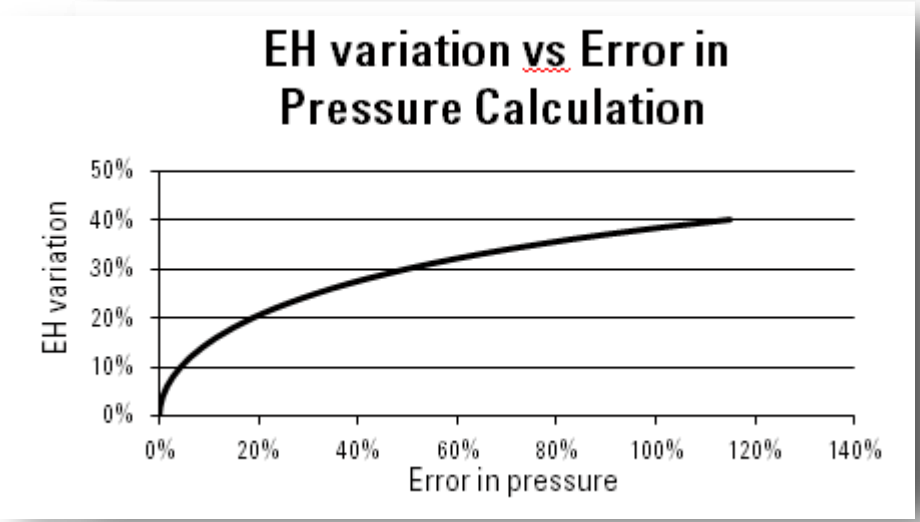
- Size and type of gun
- Penetration (type of charge)
- Casing entrance hole
- Shot density
- Shot phasing
- Interval length
- Gun orientation

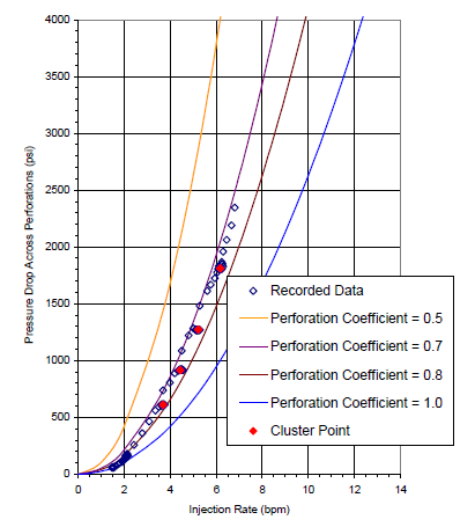


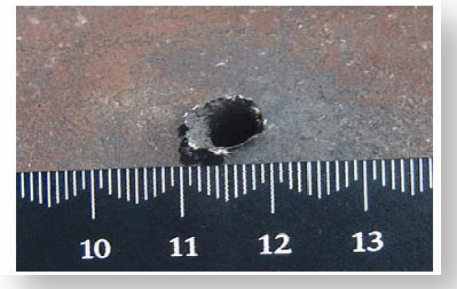
Casing Entrance Hole

$$\Delta p = \frac{0.239\rho}{D_p^{\,4} C^2}\left(\frac{q}{n_p}\right)^2$$

- EH size about 8 to 10 times proppant diameter to prevent bridging
- Consistent EH for accurate limited entry designs
- 40% variation in EH results in 120% increase in pressure drop



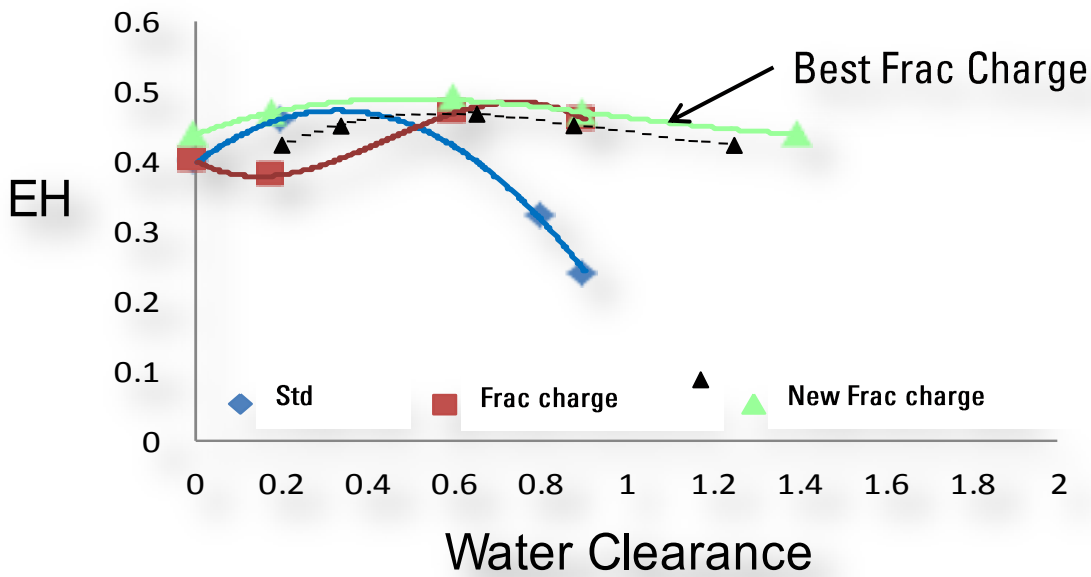




(from SPE 83590)

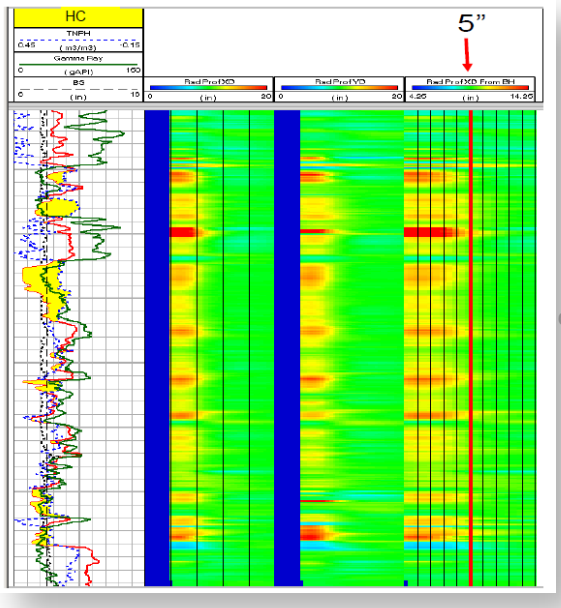
Minimizing Casing Entrance Hole Variation

- Use largest gun possible to reduce water clearance
- Centralize gun
- Design shaped charge for minimum variation even across large water clearances



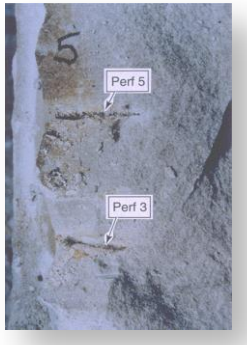
Is Penetration Important ?

- Sometimes ignored (we just need some holes in the casing)
- What about near wellbore conditions?
  - *breakouts*
  - *formation damage?*
  - *near wellbore stress?*
- Frac experts starting to realize that penetration is a benefit (>1 BH)
- Connection to the far field helps avoid near-wellbore tortuosity effects

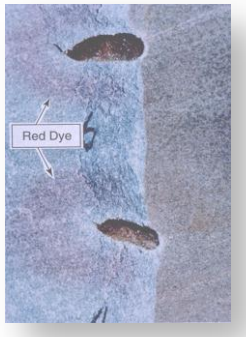


Up to 5-inch damage (SPE 112862)

What about Clean Perforations?



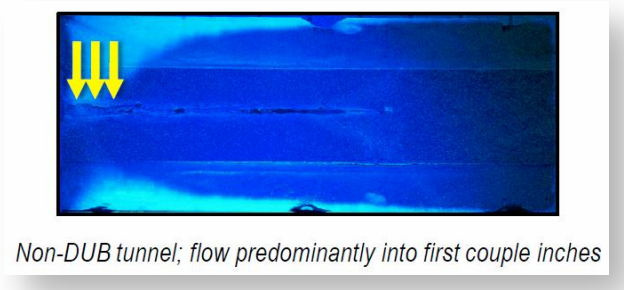
Plugged perforations NO fracture



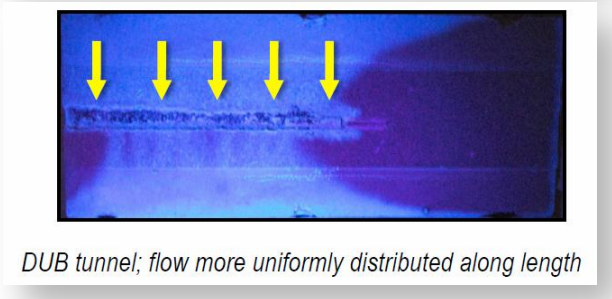
Clean Perforations with fracture passing through perforations

(from SPE 20661)

- Enable injection to start deeper in formation, avoids near wellbore damaged zone
- Fractures may not initiate from plugged perforations (see "big block" tests left)
- Clean perforations allow fluid leak-off, increasing near-wellbore pressure prior to fracture initiation



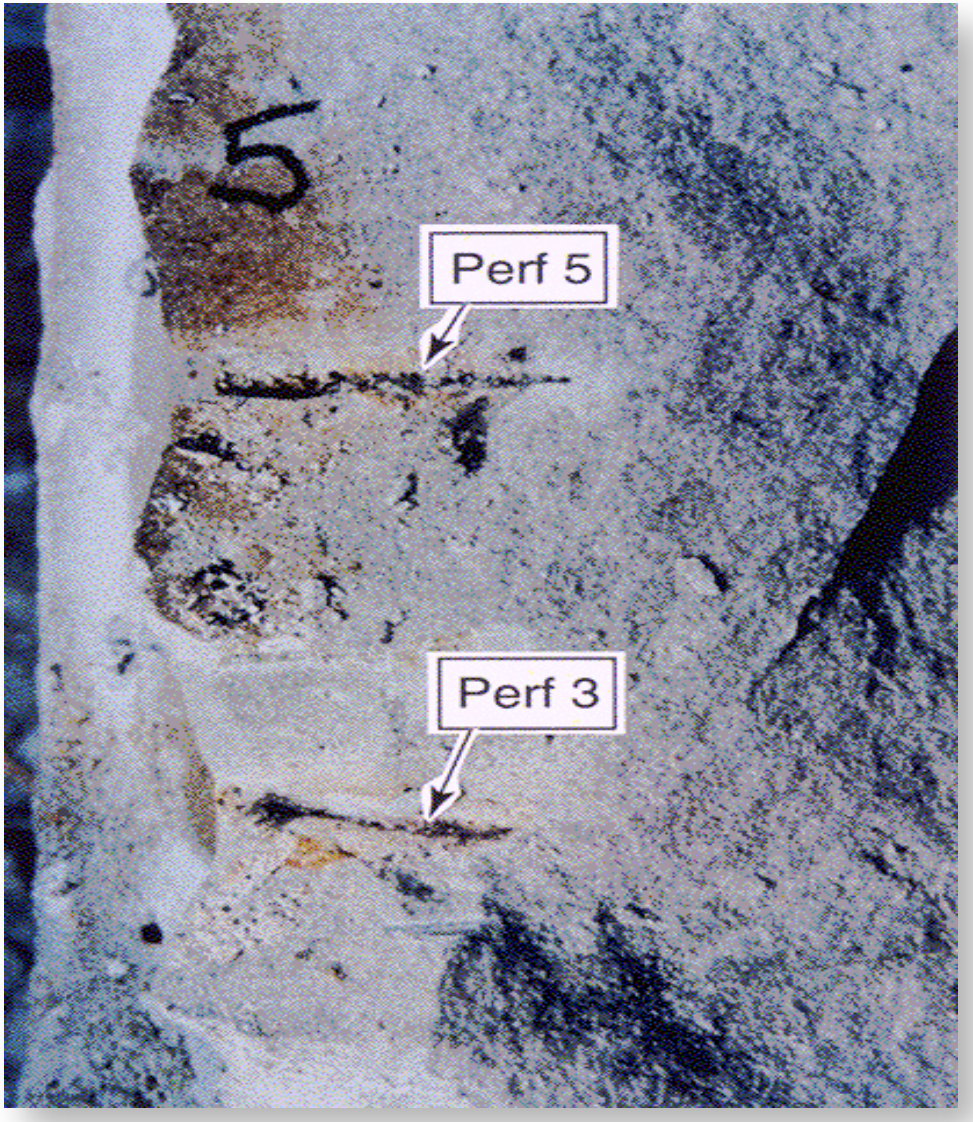
Non-DUB tunnel; flow predominantly into first couple inches



DUB tunnel; flow more uniformly distributed along length

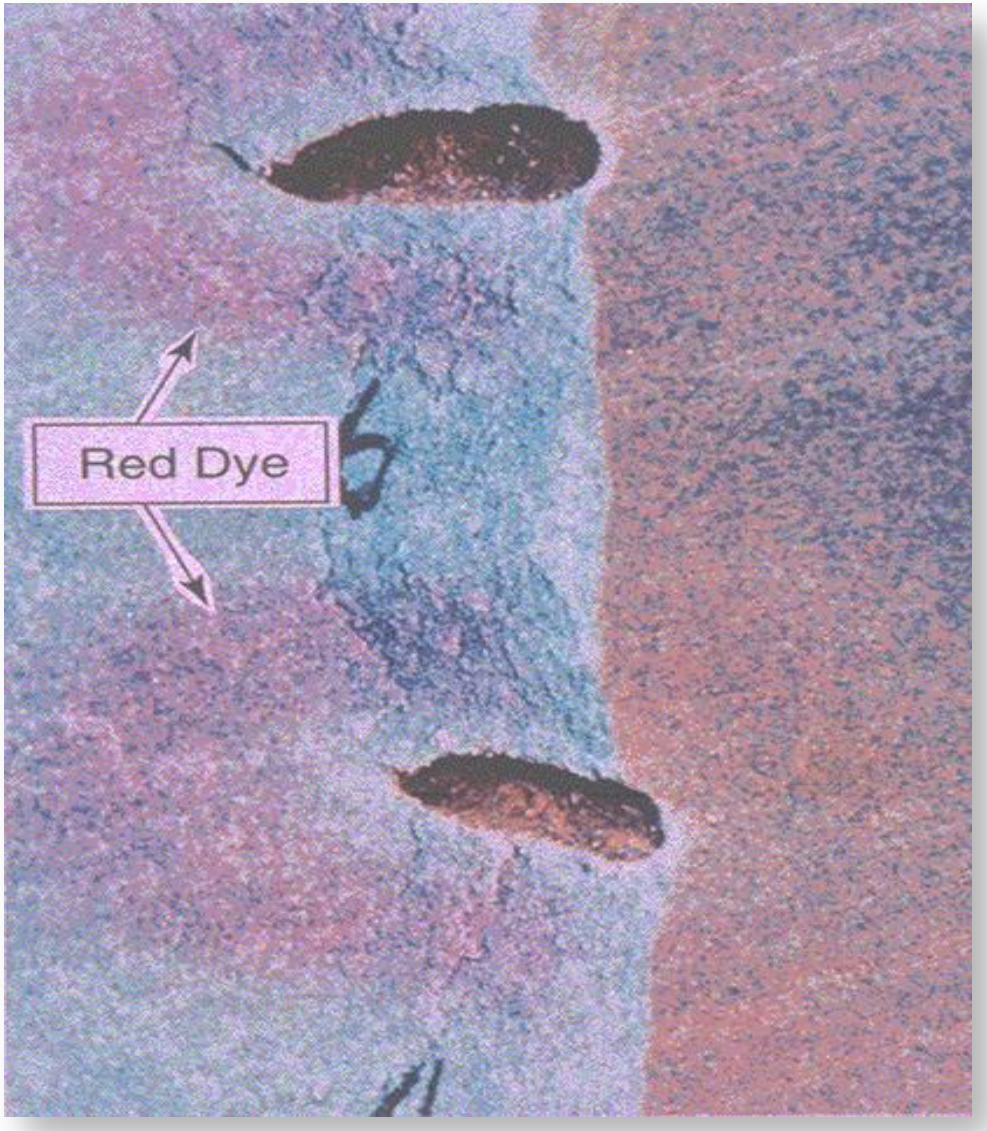
(from SPE 143997)

Plugged perfs → NO fracture



(from SPE 20661)

Clean Perfs → Fracture



(from SPE 20661)

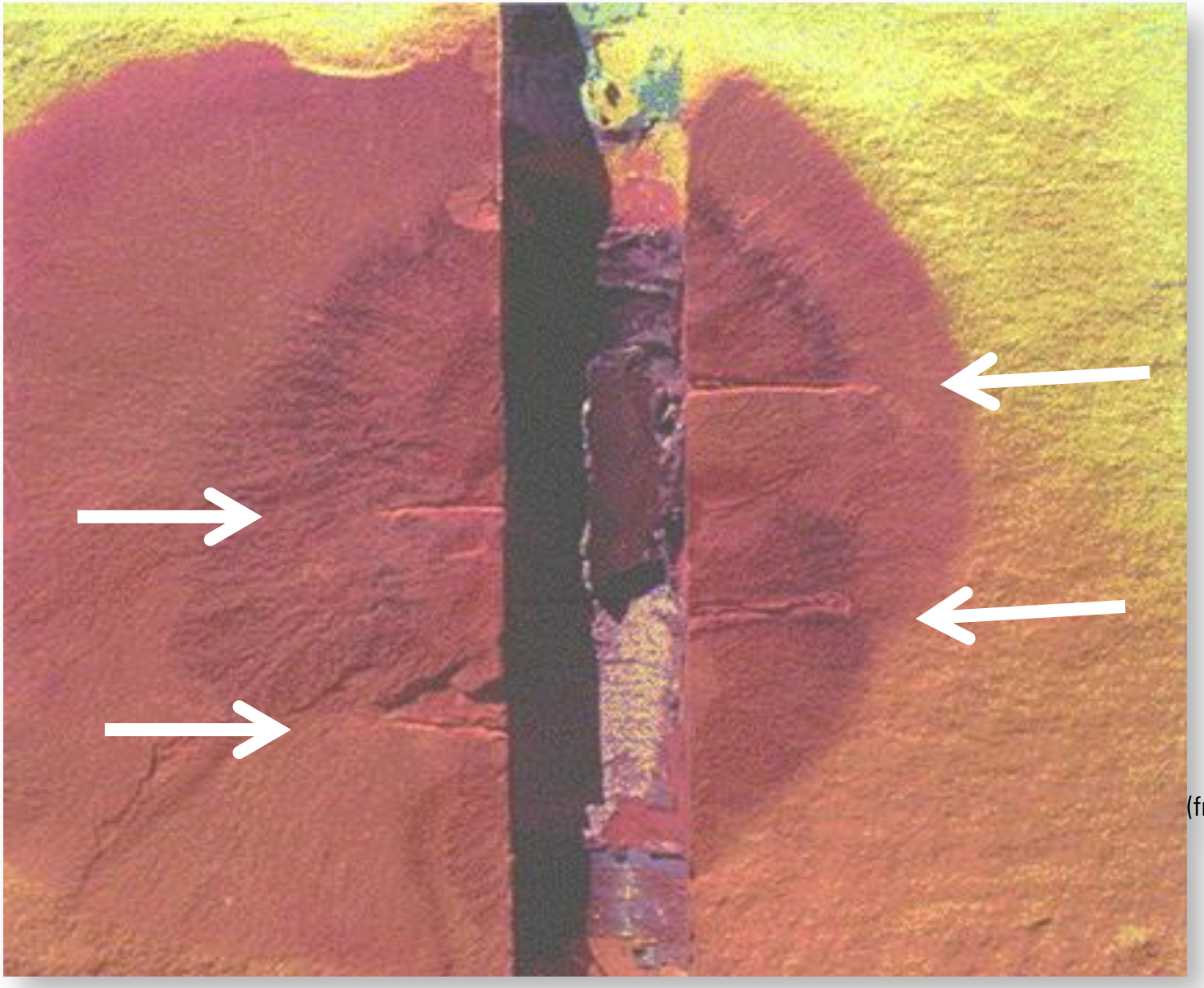
Gun Phasing and Direction
Near-vertical wells

- Fractures initiate from perforations aligned with maximum stress direction
- Best gun phasing is 0° – 180° in max stress direction

Perforations aligned with maximum horizontal stress

(from SPE 20661)

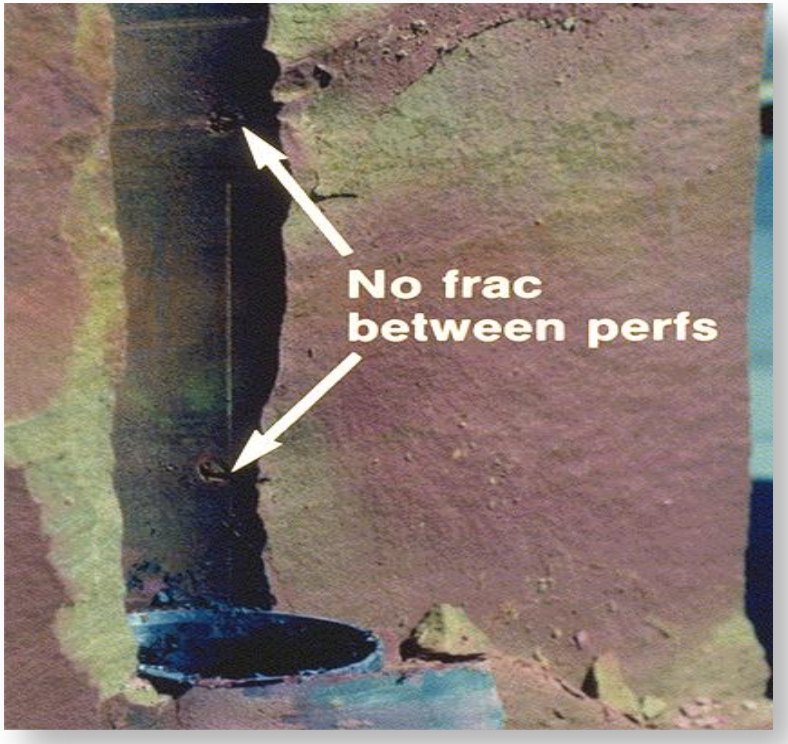
Perforations aligned with maximum horizontal stress



(from SPE 20661)

Gun Phasing and Direction
Near-vertical wells

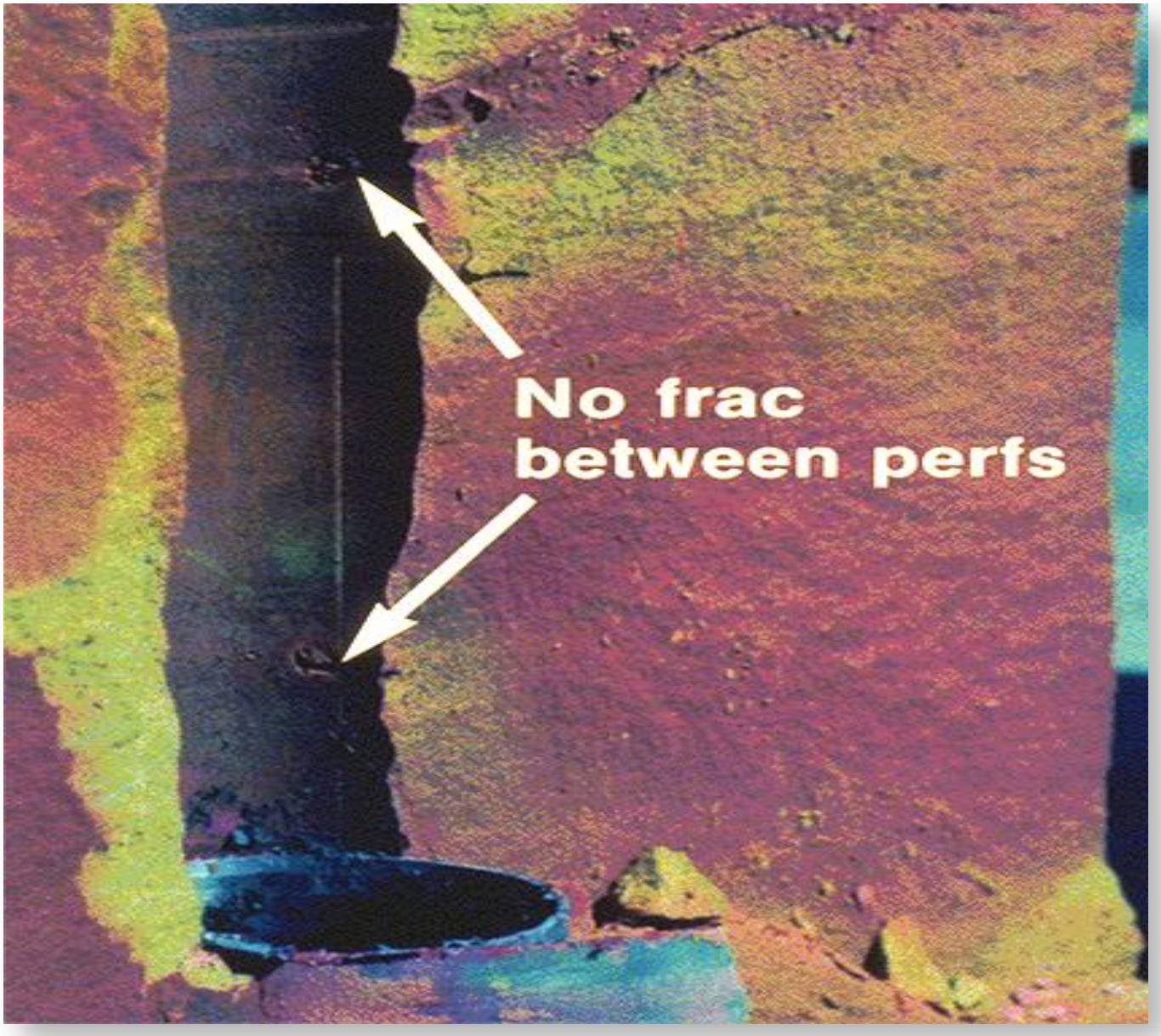
- Fractures initiate from sand-face when perforations are misaligned
- Other gun phasings: 120° (at 1 ½ times spf); 60° (at 3 times spf)



Perforations misaligned with maximum horizontal stress

(from SPE 20661)

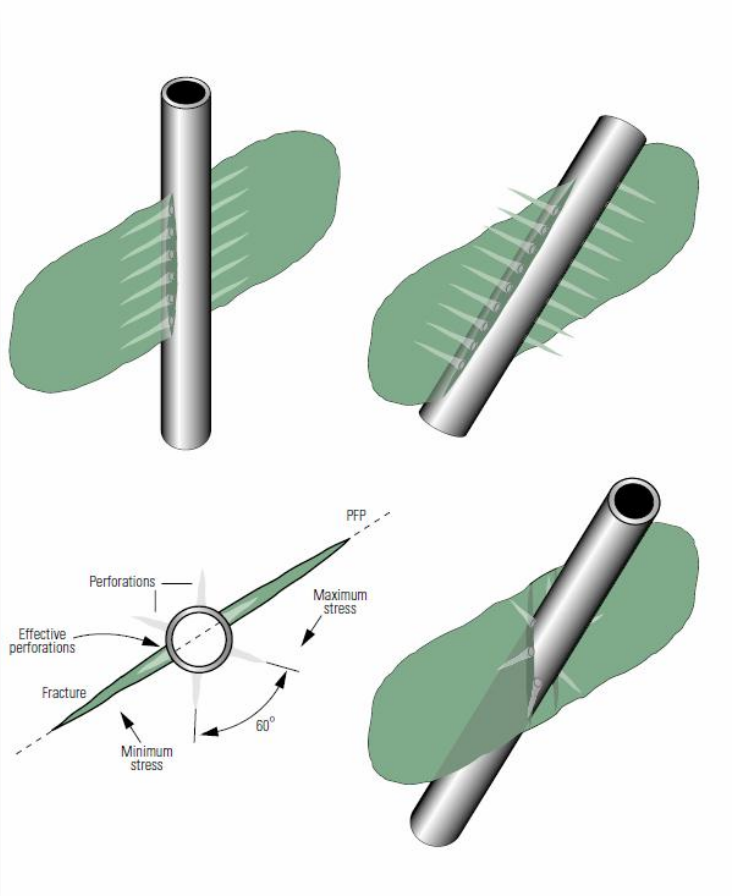
Perforations not aligned with maximum horizontal stress



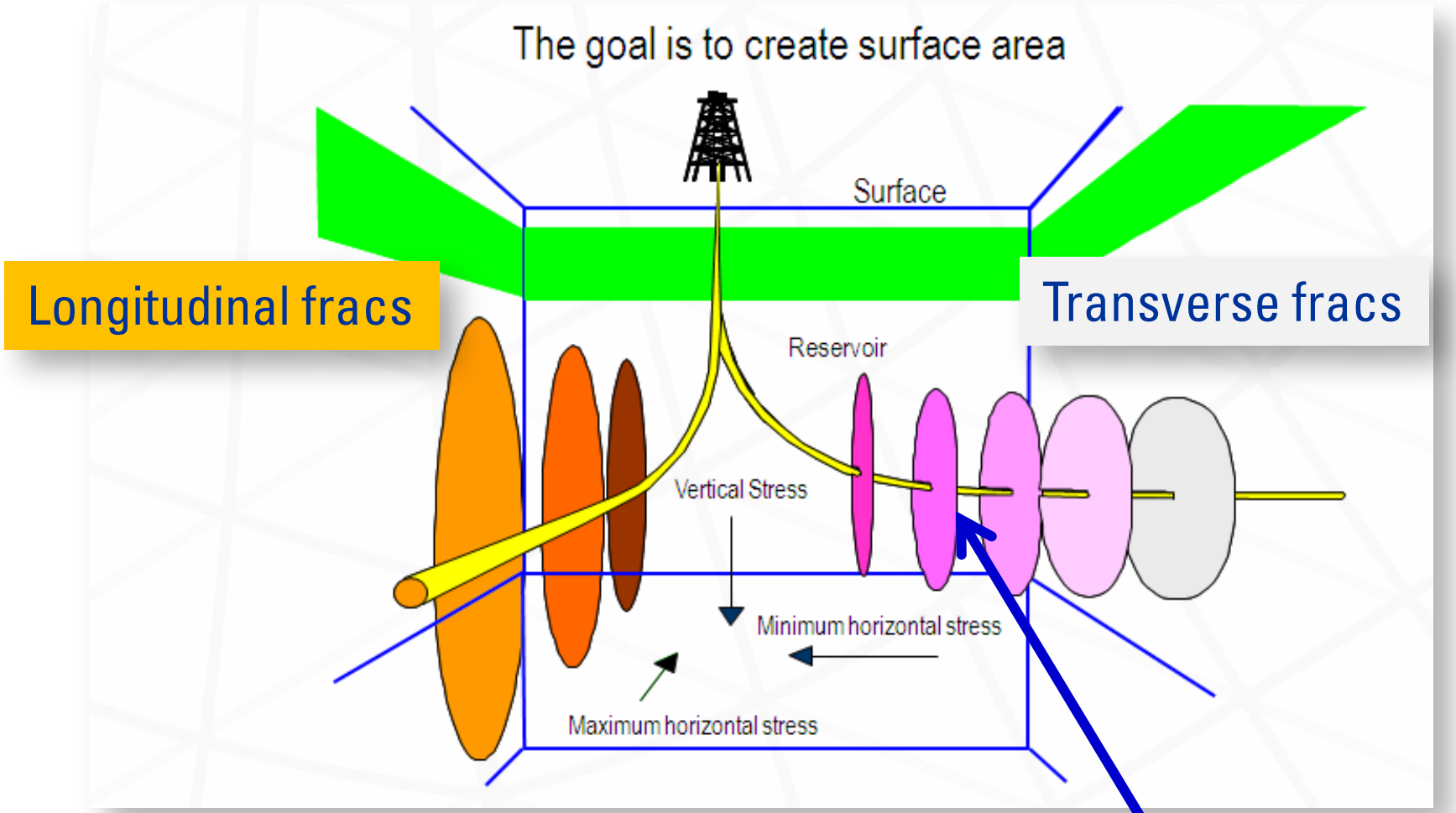
(from SPE 20661)

Well Direction and Gun Phasing

Gun phasing and interval perforated should be based on well direction compared to the preferred fracture plane



Hydraulic Fractures in Horizontal Wells



What we want

What We Get

with 60° Phasing

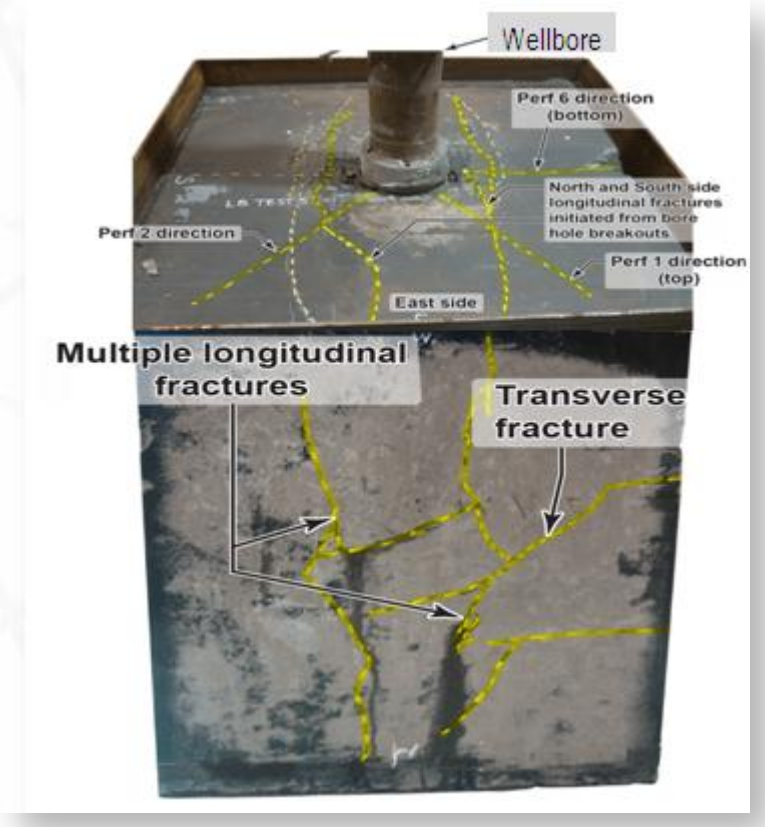
Longitudinal fractures initiate first

Terminate about 2 wellbore diameters in vertical direction

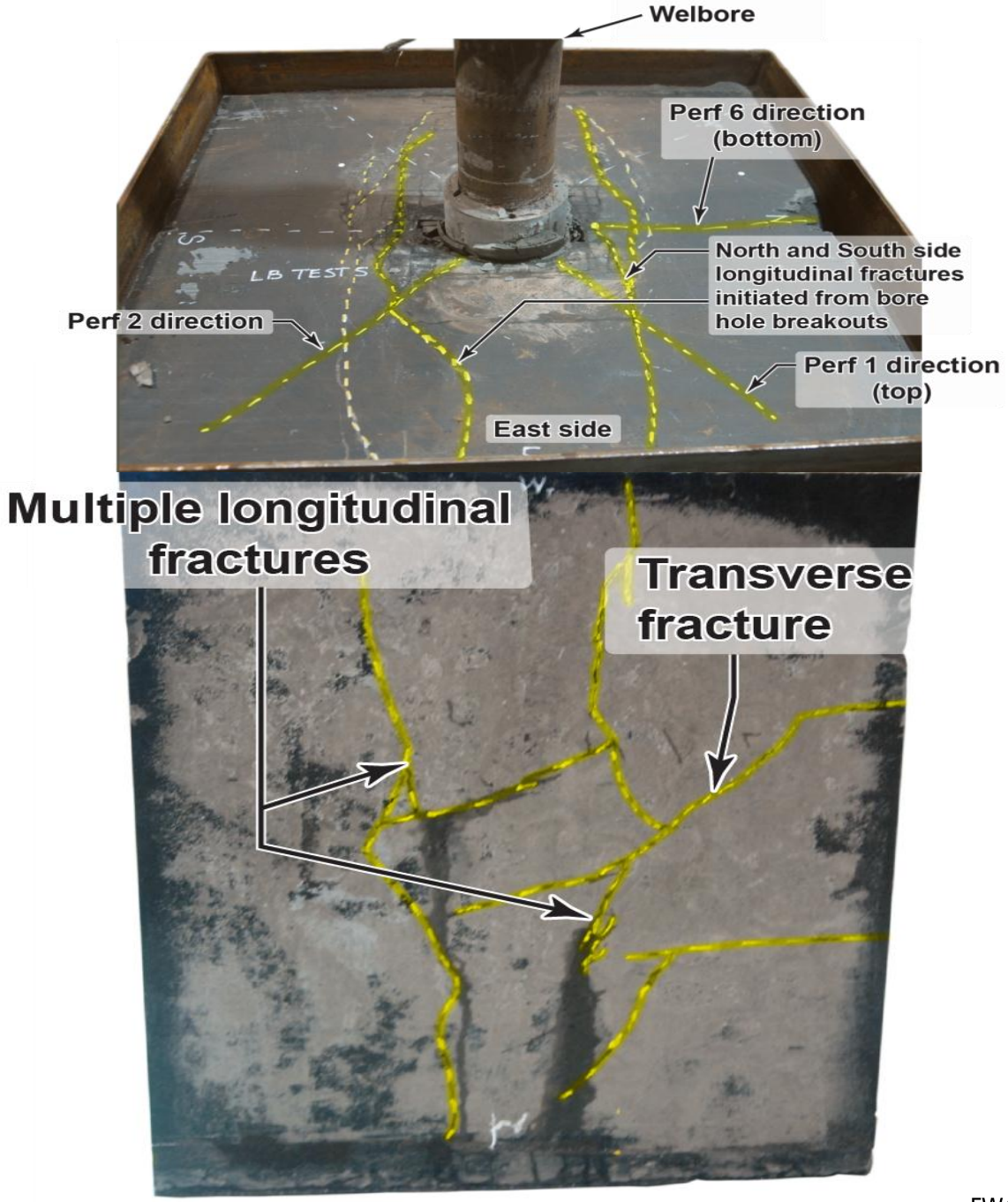
- Extend along wellbore
- Initial pumped volumes dominated by longitudinal fracs

Transverse fractures initiate after

- Perpendicular to longitudinal
- Do not rotate from longitudinal

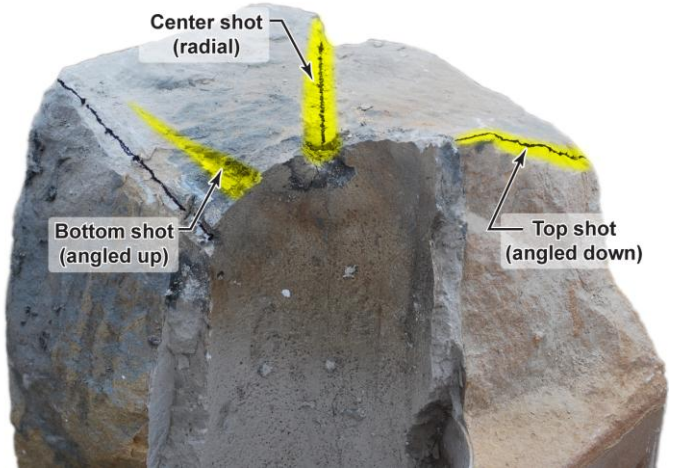


What we get with 60° Phasing

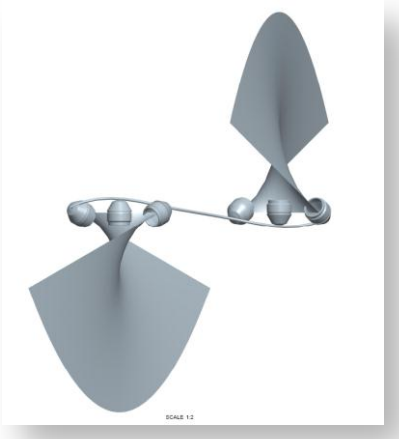


Can We Do Better?

- Several experiments done in large blocks in a tri-axial stress frame to simulate horizontal well
- Both DP and BH charges used
- Directional perforations aimed at the same transverse plane

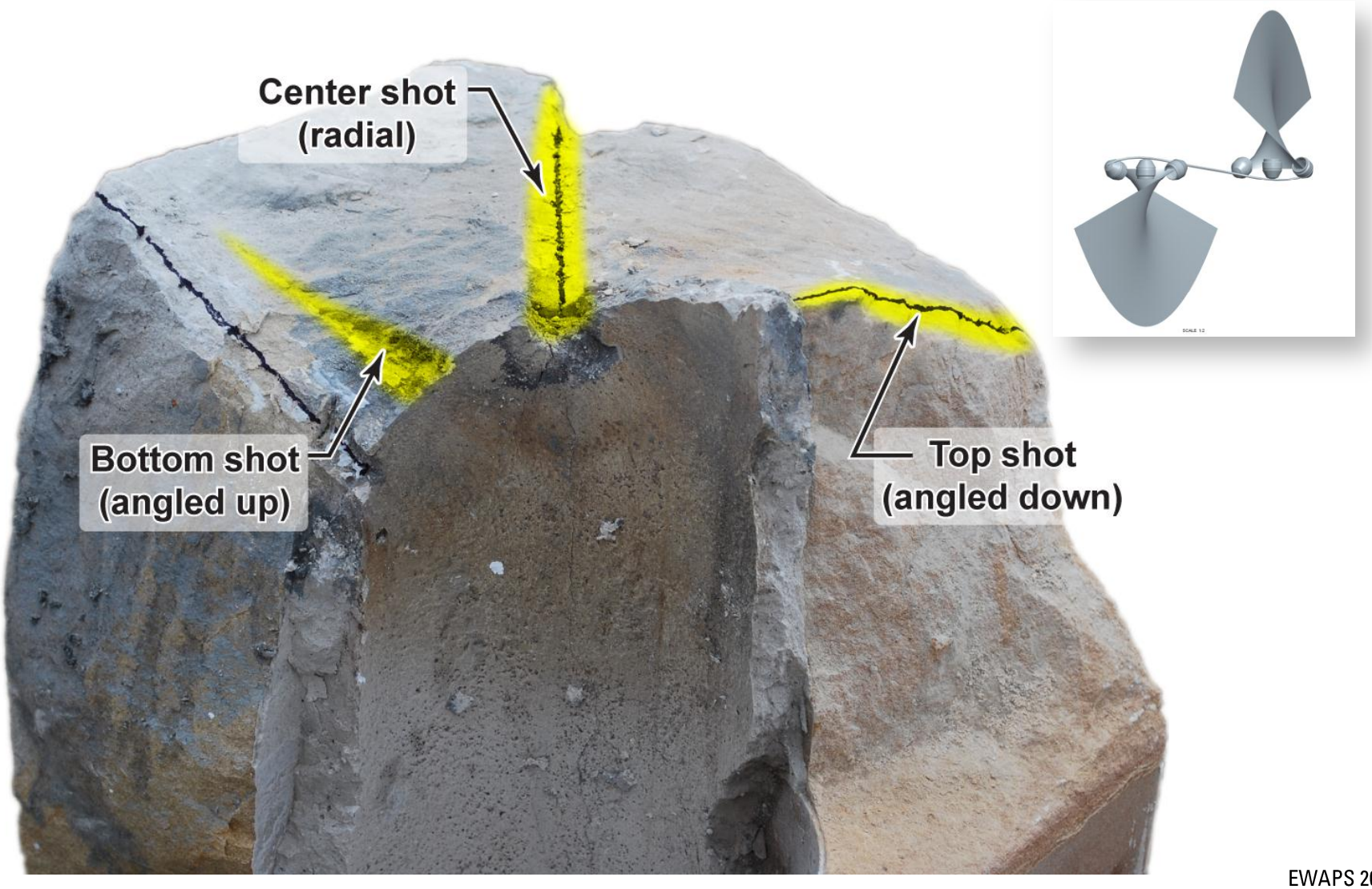


Transverse fracture from directed perforations



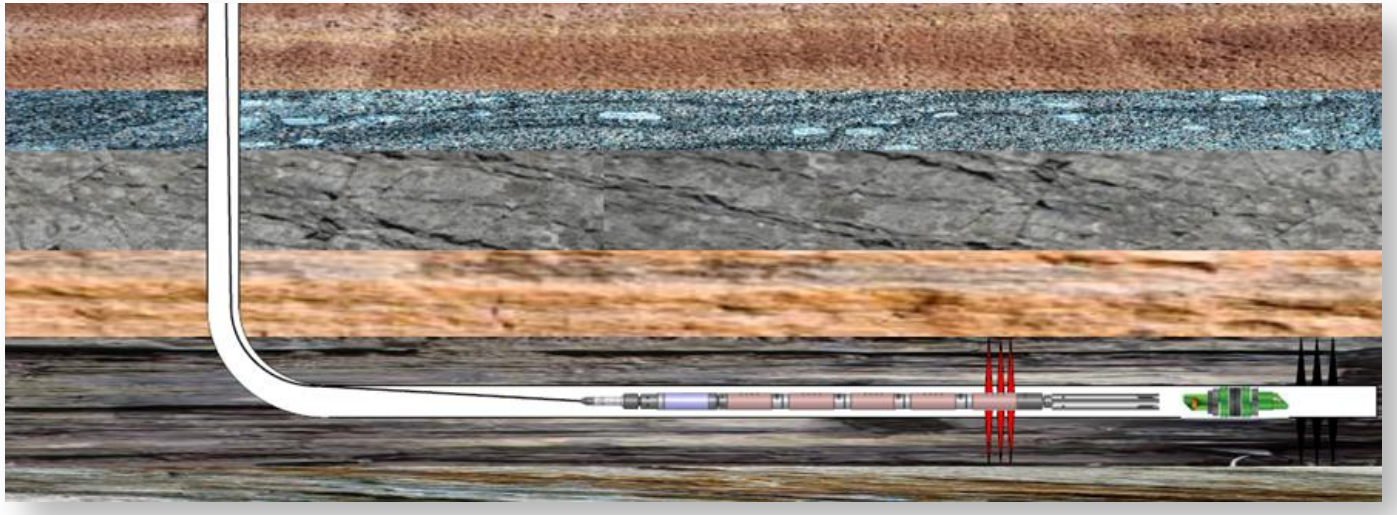
Result: Transverse fractures created

Directional perforations in the same transverse plane →transverse fractures are created



Perforation Gun Length-Horizontal Wells

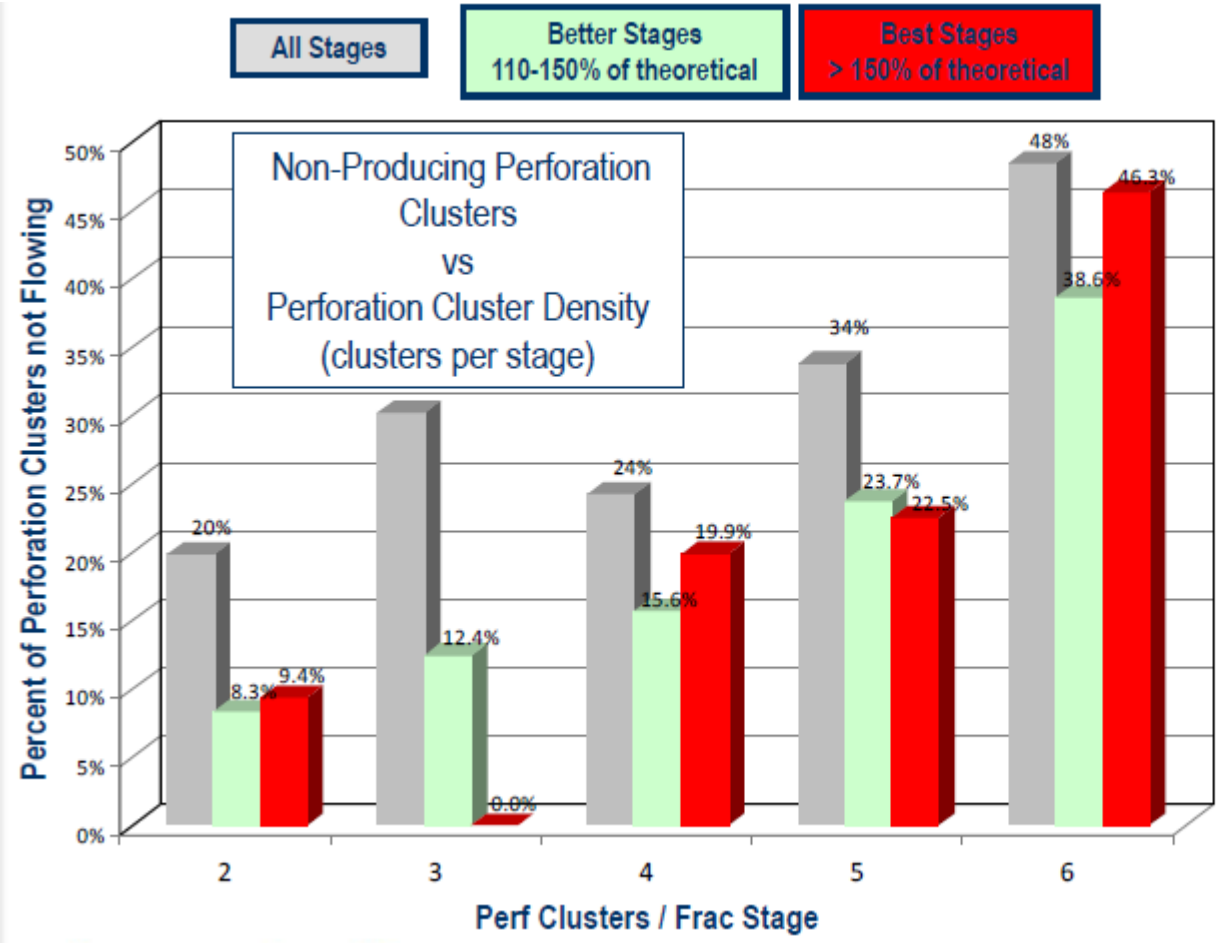
- In horizontal wells perforation length should be limited to about 2 to 4 times the wellbore diameter (ref SPE 19720)
  - Minimizes multiple competing fractures
- Typical gun contains 6 to 10 shots (60° phased)
- 2 to 4 guns are shot for each frac stage
- Guns run with addressable switches in pumpdown plug-n-perf mode



How Many Clusters per Stage?

- Closely spaced clusters increases flow rate in gas shales
  - Trade off is cost (number of fractures vs production)
  - SPE 144326 shows study on production vs clusters for major shale plays
- Reducing the number of clusters increases odds of all clusters being stimulated
  - 48% of perf clusters aren't contributing in wells having 6 or more perf clusters / frac stage
- Cluster placement should be matched to reservoir quality
  - Requires detailed modeling
  - SPE 146872 and SPE 146876 detail modeling work flow

Horizontal shale well production log analysis

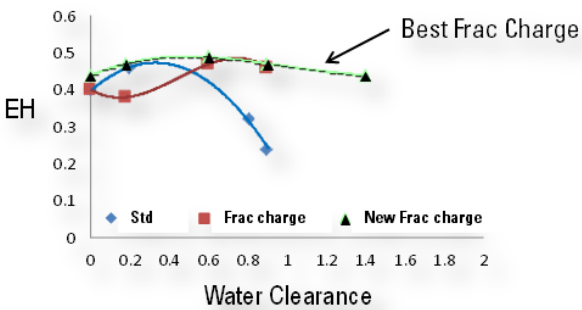


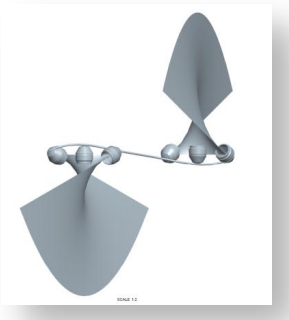
Increasing clusters per stage improves operational efficiency, but compromises well productivity

SPE144326

Conclusion

Well planned perforating will make frac jobs more effective





- Careful choice of shaped charges, gun phasing and orientation will help initiate fractures and minimize tortuosity

- In horizontal wells selection of number of shots, position of clusters impacts well productivity

Questions?