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The Fracts of Life

bp

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Society of Petroleum Engineers
Distinguished Lecturer Program
www.spe.org/dl
THE “FRACTS” OF LIFE
Key Aspects

- GEOMECHANICS
- FORMATION PERMEABILITY
- FRACTURING QA/QC
- VERTICALS TO HORIZONTALS
THE “FRACTS” OF LIFE
Geo-Mechanics “Issue”

Non-Operated JV in South-East Asia

• Multi-layered sands (1,000 – 14,000 ft)
• Produced 13.1 Tcf and 0.4 Bbls liquids
• Deep tight-sand opportunity 0.75 Tcf
• Application of hydraulic Frac technique
• Some 30 years of attempted fracturing
• **Spectacularly** unsuccessful campaign

28 Failures where Post Frac production <= Pre-Frac Production

7 Successes
Multiple Fracturing Service Providers, Expert Fracturing Consultancies … etc reviewed and provided their expert opinion on the causes/solutions.

It’s definitely the proppant, no hang on it’s the frac fluid, yes it’s definitely the fluid, oh that didn’t work, then it must be the well integrity then.
THE “FRACTS” OF LIFE
Geo-Mechanics “Issue”

Independent Frac Reviews Indicated:

- Poor fracturing fluid QA/QC (55 lb/Tg)
- Poor proppant quality/excessive crush
- Poor well design and casing integrity

However, each subsequent Campaign would deliver an equivalent cycle of Review, Absolute Certainty of the Root-Cause, Execution, Failure, Pause and then “rinse and repeat”.
Hall, R. 2002. Cenozoic geological and plate tectonic evolution of SE Asia and the SW Pacific
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THE “FRACTS” OF LIFE
Geo-Mechanics “Issue”

- Poor fracturing fluid QA/QC (55 lb/Tg)
- Poor proppant quality/excessive crush
- Poor well design and casing integrity
- Horizontal or T-Shaped Fractures
  - In-Situ Stress Ordering ($\sigma_v < \sigma_h < \sigma_H$)
  - Horizontal and T-Shaped Fractures
  - Heavily Gel-Damaged Vertical Well
  - Frac Parallel Boundaries and $k_v/k_h$
THE “FRACTS” OF LIFE
Geo-Mechanics “Issue”

Pre-Review

- Fracturing close to or above the overburden for 30 years
- Horizontal Fracs with poor or non-existent delivery/uplift
- Also clearly a complex form of relationship for PPFG

Post-Review

- Fracturing below the value of overburden consistently
- Pore-Pressure depletion has reduced horizontal stresses
- Stress reduction not quite as consistent as we would expect
THE "FRACTS" OF LIFE
Geo-Mechanics “Issue”

Bottom Hole Treating Pressures this side of the line will result in the creation of Horizontal or T-shaped fractures and will have a resulting poor productivity.

Bottom Hole Treating Pressures this side of the line will result in the creation of classical vertical fractures and will have a resulting productivity as expected.

Calculated BHTP (Psi)

Radial Growth
Confined Growth
TSO Growth

Elapsed Time (Minutes)

Standard Design 'Ignoring' BHTP Limitation
Adjusted Design 'Assuming' BHTP Limitation
Maximum allowable BHTP Overburden Limit
THE “FRACTS” OF LIFE
Geo-Mechanics “Issue”
THE “FRACTS” OF LIFE
GeoMechanics Summary

- A deep understanding of the actual in-situ stress-state is essential.

- There are very few valid ‘rules-of-thumb’ that are safe to use.

- When BHTP crosses the 2\textsuperscript{nd} or even 3\textsuperscript{rd} stress then expect issues.

- Micro-Frac (WFT) is an excellent surveillance method in new areas.
THE “FRACKS” OF LIFE
Five Key Aspects

• **GEOMECHANICS**  
  Geometry is the basis of delivery

• **PERMEABILITY**  
  Need accurate order of magnitude of $k_{\text{eff}}h$
THE “FRACTS” OF LIFE
Permeability “Issue”

- We must use all available techniques to estimate.

Linear Flow
\[ \Delta P = (P(t) - P_i) = M_L F_L(t) \]

Radial Flow
\[ \Delta P = (P(t) - P_i) = M_R F_R(t) \]

Two distinct Flow Regimes
so we MUST know \( P_R \) with reasonable accuracy.
• Highly accurate early estimation of $kh$ for design and planning.

First 7 Appraisal wells comparison of ACA with PBU

Understanding $kh$ created 7 Tcf opportunity
As the rock quality reduces, the petro-physics becomes “challenging”.

Log derived $k$ in tight rock often inaccurate (1 or 2 orders of magnitude).

ACA (DFIT) is quick, accurate & ideally suited to E&A environments.

$k_{\text{eff}}h$ is key, importance of early/accurate assessment is fundamental.
THE “FRACTS” OF LIFE
Five Key Aspects

• **GEOMECHANICS**  
  Geometry is the basis of delivery

• **PERMEABILITY**  
  Need accurate order of magnitude of $k_{eff}h$

• **FRAC QA/QC**  
  Defines the Success or the Failure
THE “FRACTS” OF LIFE
QA/QC “Issue”

Photos of debris, valve-seat remover from Manifold and Pumps.
Operator: Right pump it past the surface lines and clear of the tree-saver but not as far as the perforations; then RU CT and clean this mess out.
THE “FRACKS” OF LIFE
QA/QC Summary

• QA/QC must be established quickly in new areas to deliver basics.

• Fundamental system cleanliness often an issue (especially start-up).

• Complex fluid system skills and knowledge, are being forgotten.

• Evidence that automation is surpassing/even exceeding capability.
THE “FRACTS” OF LIFE
Five Key Aspects

• GEOMECHANICS  
  Geometry is the basis of delivery

• PERMEABILITY  
  Need accurate order of magnitude of $k_{eff}h$

• FRAC QA/QC  
  Defines the success or the Failure

• HORIZONTALS  
  Understand Vertical frac/well behaviour
THE “FRACTS” OF LIFE
Horizontals “Issue”

- **Fully perforated interval gives extensive fracture height.**
- **Stress variation can create ‘corrugated’ fractures.**
- **Land Horizontal in one lens and Frac can be confined.**
- **Confinement can push the BHHP above \( \sigma_H \) and even \( \sigma_V \)**
THE “FRACTS” OF LIFE
Horizontals “Issue”

• There are “Trade-Offs” when moving from Vertical to Horizontal wells, which the user must appreciate.

  ➢ Knowledge of the Vertical fracture growth behaviour is absent.

  ➢ Logs not representative of what the frac actually encounters.

  ➢ Almost all staging techniques result in some amount of over-flush.

  ➢ Partial mono-layer/infinite conductivity is a strategic compromise.
THE “FRACTS” OF LIFE
Horizontals Summary

• Why does the Vertical dimension no longer concern us?

• Frac Height/Landing point requires early knowledge/data gathering.

• As Horizontals ‘move’ into good k/kh, we must do Engineering.

• ‘Staging’ developed for ultra-low perm., needs careful application.

• Popular ‘pillar fracs’, insist on extensive proppant near wellbore.
THE “FRACTS” OF LIFE
Five Key Aspects

• GEOMECHANICS  Geometry is the basis of delivery

• PERMEABILITY  Minimum accurate order of magnitude

• FRAC QA/QC  Defines the success or the failure

• JOURNEY from V to H  Understand Vertical frac behaviour

• There is always more to learn so expect the unexpected.
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