Pore Pressure Prediction in Shell

Havtil Well Control Seminar - 18 January 2024

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Agenda

- 5-point PPP: Why and how is it used ?
- PPP Workflow in Shell
- Internal guidelines: Content and implementation
- How do we develop and maintain competence
- Subsurface incident trends in Shell

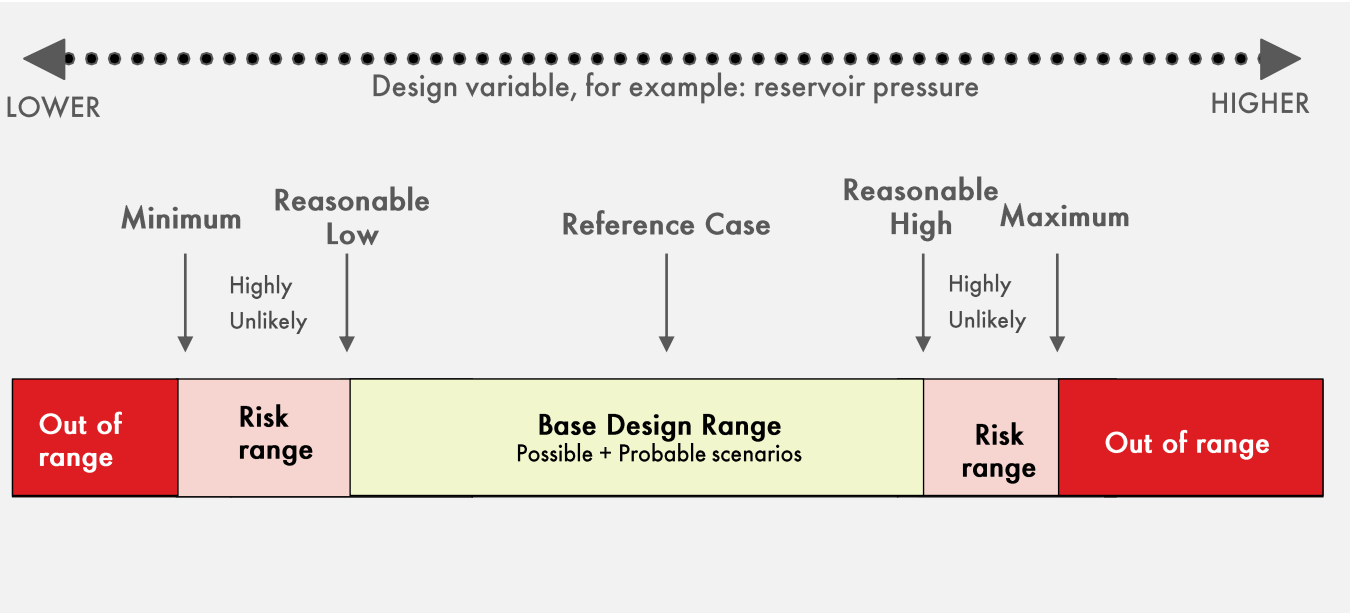
5-point PPP: Why and how is it used?

- Formation pore pressure, fracture gradient (PP/FG) and borehole stability predictions:
  HSSE Critical Activities required for all well types, well entries and abandonments.
- Major impact HSSE incidents can occur if well design, material design and execution planning are not based on the full range in potential PP and FG.

5-point PPP is required:

- Absolute Minimum
- Reasonable Low – Possible low pressure scenario with lower probability of occurrence than expected.
- Expected
- Reasonable High – Possible high pressure scenario with lower probability of occurrence than expected.
- Absolute Maximum

5-point PPP: Why and how is it used?



Base Design Range – Between reasonable low and reasonable high

- Basic Design Range is the range for which well is designed.
- Ideally, this range should cover the whole reasonable range (reasonable low to reasonable high).

Risk Range

- Risks and consequences are acceptable
- Range over which well operations can be safely conducted (for example, within pressure rating of equipment), but where well objectives may not be met.
- Absolute max is typically not used for well design but triggers conversations on well design and associated risks and is used to ensure we can safely walk away if encountered. It is used for well control and tool lift assessments, abandonment design and BOP rating.

Out of Range

- It is no longer safe to operate

PPP workflow in Shell – 5-point PPP developed in an 8-step process

8 Monitor operation's outcomes

7 Document & communicate results

6 Compute pressures

5 Include uncertainties impact

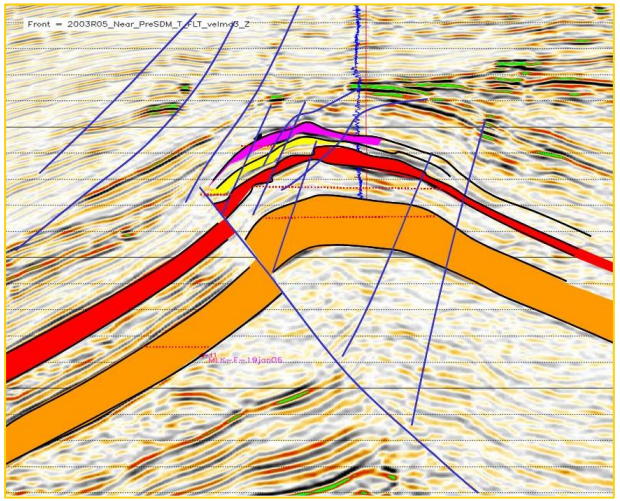
4 Develop pressure scenarios

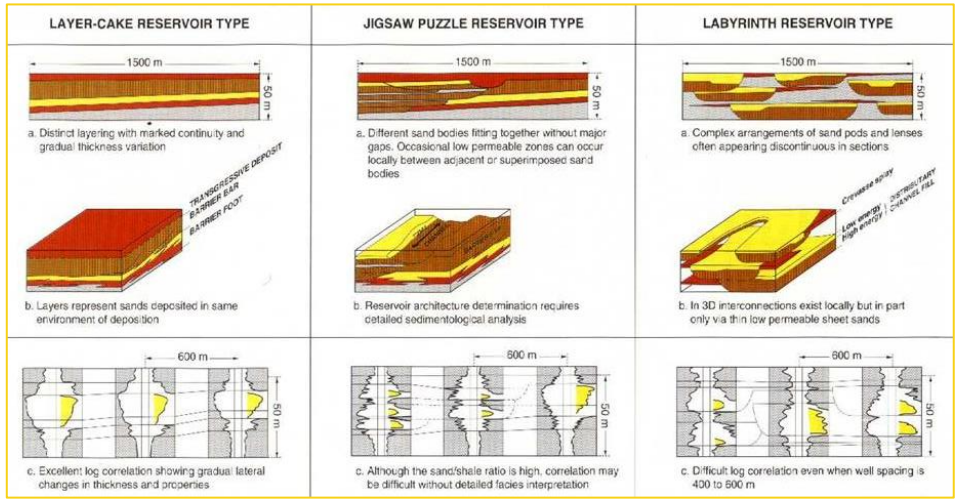
3 Which abnormal pressure source applies

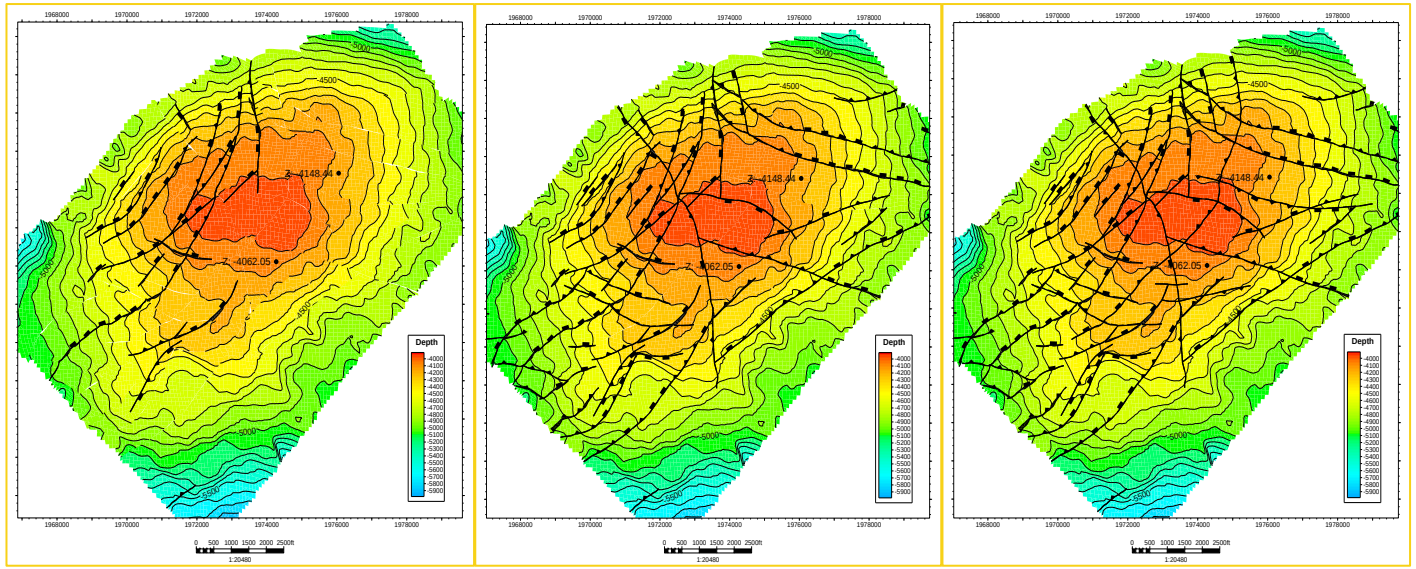
2 Brainstorm for abnormal pressure sources

1 Understand reservoir characteristics

PPP workflow: Understanding reservoir characteristics







- To what extent does the faulting process occur? Will the faults prevent pressure communication?
- Are the reservoir sands correlatable? Are they likely to communicate?
- Is the depositional model and the structural picture clear?
- How much do we <u>really</u> know?

PPP workflow: Brainstorm sources of abnormal pressure - Multidisciplinary Session

Depletion through production:

- Differential depletion (pressure gradients or areas unaffected by depletion)

Injection:

- Including cuttings or liquids disposal
- Injection conformance (out of zone injection ?)

Faults (or other barriers) preventing lateral communication

Vertical communication

- Permeability variation (differential depletion in the vertical sense)

Faults as communication pathways for fluids/pressure

Induced fractures

Other potential communication pathways:

- Well-bores (including abandoned wells or side-tracks)
- Cross-flow
- Poor cement bonds

Unexpected permeable zones (not encountered in previous wells)

Others…

PPP workflow: Develop a number of pressure scenarios consistent with the available data

- Integrated subsurface understanding needs to be developed to evaluate all possibilities.
- Every case is different – carefully think through; there is no 'standard' way.
- Absence of evidence is not evidence of absence.
- Bear in mind what the data does not tell us. For example, if we encountered a high pressure sand previously, we may never have known anything about it (except that it was below mud pressure), because the sand may not have been tested or perforated.

	Example of Scenario table (asset specific aspects need to be evaluated)									
	Lateral connectivity			Input data			Vertical connectivity		Other	
	Stratigraphic barriers	Fault	High perm streaks	Uncertainty in measurement	Fluid fill/contacts/ PVT gradients	Depth uncertainty	Discontinuous/ thin shale	poor cement behind casing	Aquifer/ pressure support	Integrity/ major event
Minimum										
Reasonable Low										
Reference Case										
Reasonable High										
Maximum										

PPP workflow: Include impact of uncertainties

Pressure scenarios must be complemented with input uncertainties, especially in Min and Max scenarios
Some examples:

Depth uncertainty of predicted tops

- Discuss with Geophysics and Geologist members of the team.
- When formation comes in shallower in gas/oil reservoirs, the overpressure increases.
- Either make an allowance on predicted pressures or make a separate pressure prediction for shallower top.

- **Depth Uncertainty in fluid contacts**

Repeat Formation Tester (RFT)/MDT data uncertainties and errors

- Check RFT/MDT logs (valid points, fully built up and over pressured in the correct formation).
- Uncertainties/errors in depth measurements (Below Drill Floor [BDF] versus Sub Sea [SS])
- It is a good practice to add an allowance to maximum pressures to account for uncertainties.

Do the fluid gradients agree with PVT or salinity data?

- For example, when extrapolating upwards, use light gas and so on.

If uncertain about fluid fill, always use water gradients to extrapolate downwards and gas gradients upwards to arrive at the (abs.) maximum pressure.

Are the measured and predicted pressures in the same pressure cell? (Possible pressure difference across faults)

PPP workflow: Document and communicate results

Internal Shell Global Guidelines require amongst others:

- Certain elements to be included in PPP and FGP tables and plots.
- A communications session with customer (typically Well Engineering) and other relevant parties (Operations etc) is mandatory.

Scope communications session:

- The main uncertainties and the resulting range of uncertainty in the prediction.
- An explanation of how the range was derived.
- The full range of potential pressure conditions.
- Identification of potential hazards and associated mitigation/recovery measures.
- How the predictions impact the well design and design of the execution (borehole stability, mud weight envelope, close-in of wells) => Integration between all relevant disciplines.

PPP workflow: Best practise to ensure communication between disciplines

- Operational readiness review ahead of start operation
- Communication protocol
- Pre-section meetings with dedicated time to PPFG monitoring and communication protocol
- Additional communication events when approaching drilling window limits
- Management of change process
- Emergency response protocol
- Active duty team
- Morning meetings

** For all reviews/meetings the following applies: All relevant disciplines/specialists need to be present.

PPP workflow: Monitor outcome from operations

Maintain updated database for future predictive work.

Perform After Action Reviews – learnings shared and incorporated in Guidelines.

Global Learning from Incidents Panel – learnings shared and incorporated in Guidelines.

After the well is drilled or intervention completed:

- Compare actual pressures with predictions.
- Check if the pressures are within the predicted range:
  - If not, why not?
  - What can we learn?
  - How best to distribute the learning? (Internal networks, discipline communities, presentations, update guidelines, and so on)

Internal Guidelines/Requirements: Content + Implementation

- Internal PPP Guidelines contains mandatory requirements to mitigate process safety risks.
- When Guidelines are applied, a Management of Change (MOC) process shall be implemented after DG3.
- **PPP/FGP quality and guideline compliance is assured by dedicated Technical Assurers of all relevant disciplines and in challenging environments (like HPHT gas fields) additional technical assists take place by a global network of Shell subject matter experts (SME's).**

How do we develop and maintain competence ?

- Dedicated courses for graduates on PPP + coaching of graduates
- PPP course for all subsurface staff. Mandatory for all RE's
- TA's: Mandatory course on PPP guidelines + requirements –and mandatory refreshers
- Global sharing of learning from operations and incidents
- Internal PPP network
- Part of external networks: Geopressure Management Network (GMN), active members of IOGP PPFG group*
- University research projects
- Well engineering: Round 1 and 2 programme, 2-3 years each. Well control certifications etc.

* *Issued IOGP Report 608 (Recommended practice for pore pressure and fracture gradient analysis for well design – construction, intervention, and abandonment) last year, and currently working on another one (Communicating PPFG Interpretation and its Uncertainty).*

Subsurface Incident Trends in Shell

The number of subsurface incidents has significantly reduced in the last 10 years, due to:

- The introduction of the subsurface guidelines
- The PPP guidelines
- The mandatory PPP training
- The subsurface incident panel reviewing all incidents and sharing of learnings with community