Visualization and the Use of Real Time Data While Geosteering - Onshore Algeria*

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Abstract

Good communication and understanding between all parties involved with geosteering decisions is seen as one of the key factors to a successful operation. The use of rigsite 3D visualization was used in a recent onshore Algeria well. The geosteered well remained 100% within a thin reservoir and proved up future development.

Generally, during the planning phase of a well to be geosteered, 3D models are built and pseudo log responses along the proposed trajectory are then computed. While drilling if the modelled and actual log responses match everything is going to plan. The challenge comes when these responses start to diverge, the reason for this divergence needs to be understood and, if necessary, an updated forward plan generated. There are three distinct phases in this process; the first is updating the model to account for the divergence, the second generating and communicating a new forward plan and third ensuring that the updated plan is correct. Depending on the ROP, tool response and consequence of diverging from the plan it might not be possible to complete phase one before making a decision.

Phase One: One way to update a 3D model is to generate additional top and base reservoir control points. The additional control points are generated through matching modelled and actual log responses through changing the distance the modelled boundaries seen by the logs. A series of top and base reservoir control points can now be generated and the model updated, for further control additional points can be generated by projecting ahead the modelled dip at the well.

Phase Two: The updated 3D model can now be used to plan a new look ahead trajectory by extending the existing well. The use of 3D rigsite visualization facilitates this process through using an application that accesses the same data that is being used in the office. The rigsite can monitor changes in the model and can comment on the validity of the model. Once the rigsite and office agree a forward plan can be generated.

Phase Three: On implementation, progress is then monitored. If the expected log response starts to differ from the actual response then the cycle is repeated.

Case Study: This process was successfully implemented on a recent well on the Teg field (In Salah Gas, Algeria). This well was the first geosteered.

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Visualization and the Use of Real Time Data While Geosteering- Onshore Algeria

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In Salah Gas (ISG) project

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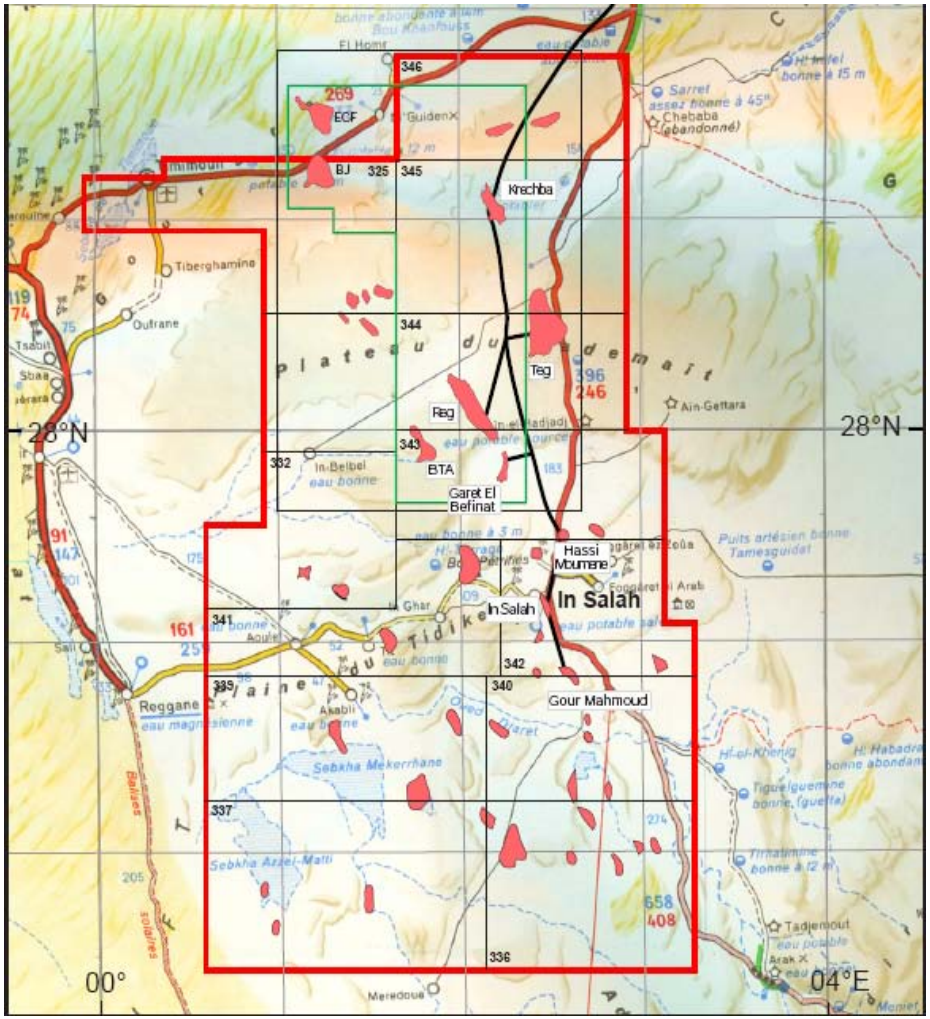

- 3 fields on production since 2004:
  - Krechba
  - Teg
  - Reg
- Southern fields
  - Gour Mahmoud
  - In Salah
  - Hassi Moumene
  - Garet el Befinat

Teguentour (Teg) Field

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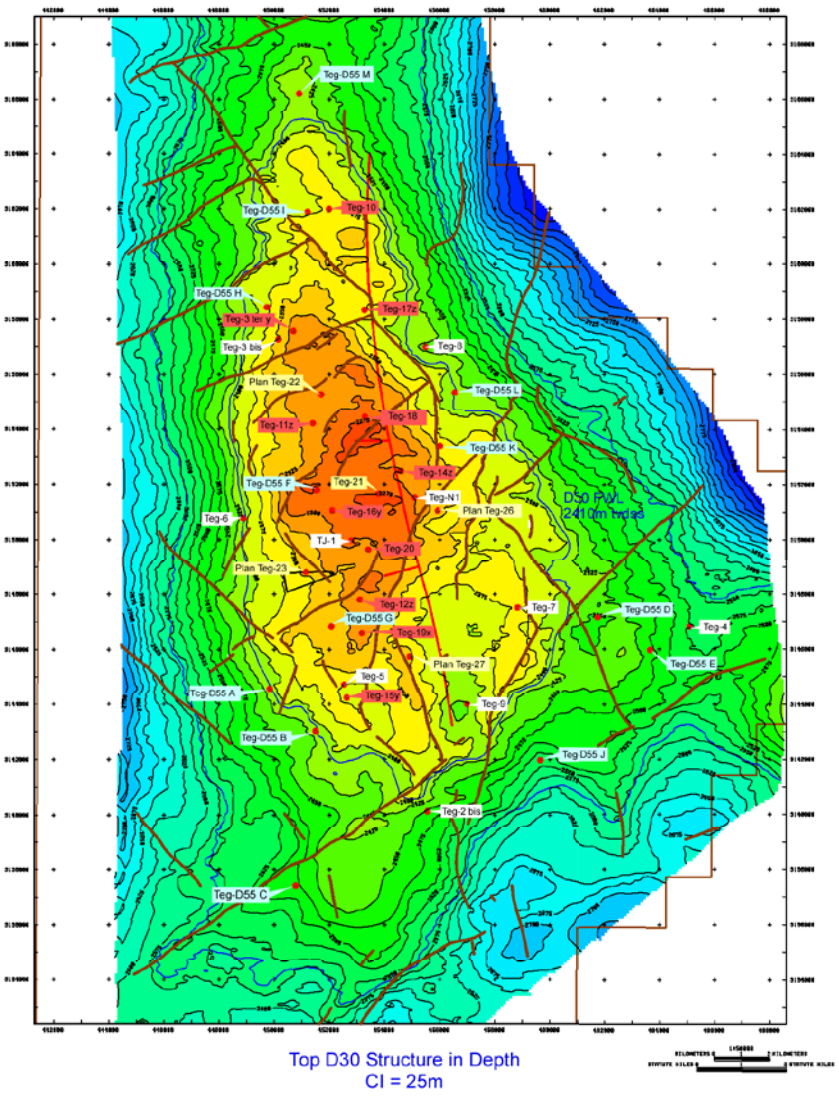

- 4-way dip anticline
- Devonian reservoirs
  - Main reservoir: Lower D40-D30 (Siegenian-Gedinnian)
  - D55 (Emsian)
- Started production in 2004.
- Phase 2 drilling (since 2008)
  - Teg-18
  - Teg-19x
  - Teg-20 (new casing design)
  - Teg-21z (first multilareal)
  - Teg-22 (second multilateral)

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Teg Reservoirs

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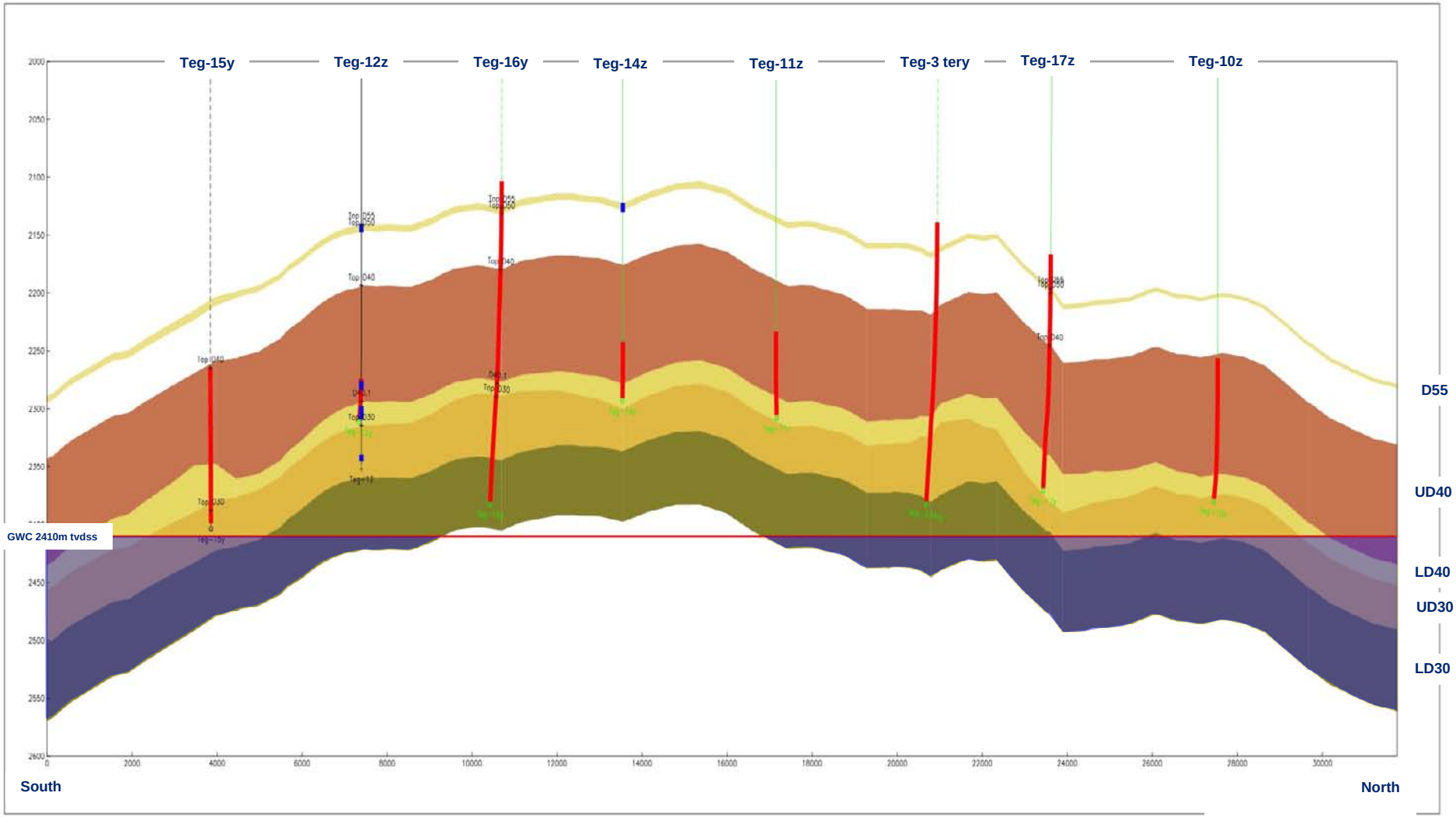

Teg Reservoirs

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- LD40/UD30
  - Approx 2.5 tcf GIIP (development plan)
  - Developed for first gas
- D55
  - Approx 1.1 tcf GIIP (development plan)
  - Post first gas
  - Challenges
    - Horizontal
    - Formation 3-6m thick
    - 1-3m sweet spot
    - Need to build to 55 to 60 deg in unstable shale (previous highest successful inclination 10 deg)
    - Remote location, limited tool availability

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Wellbore Stability

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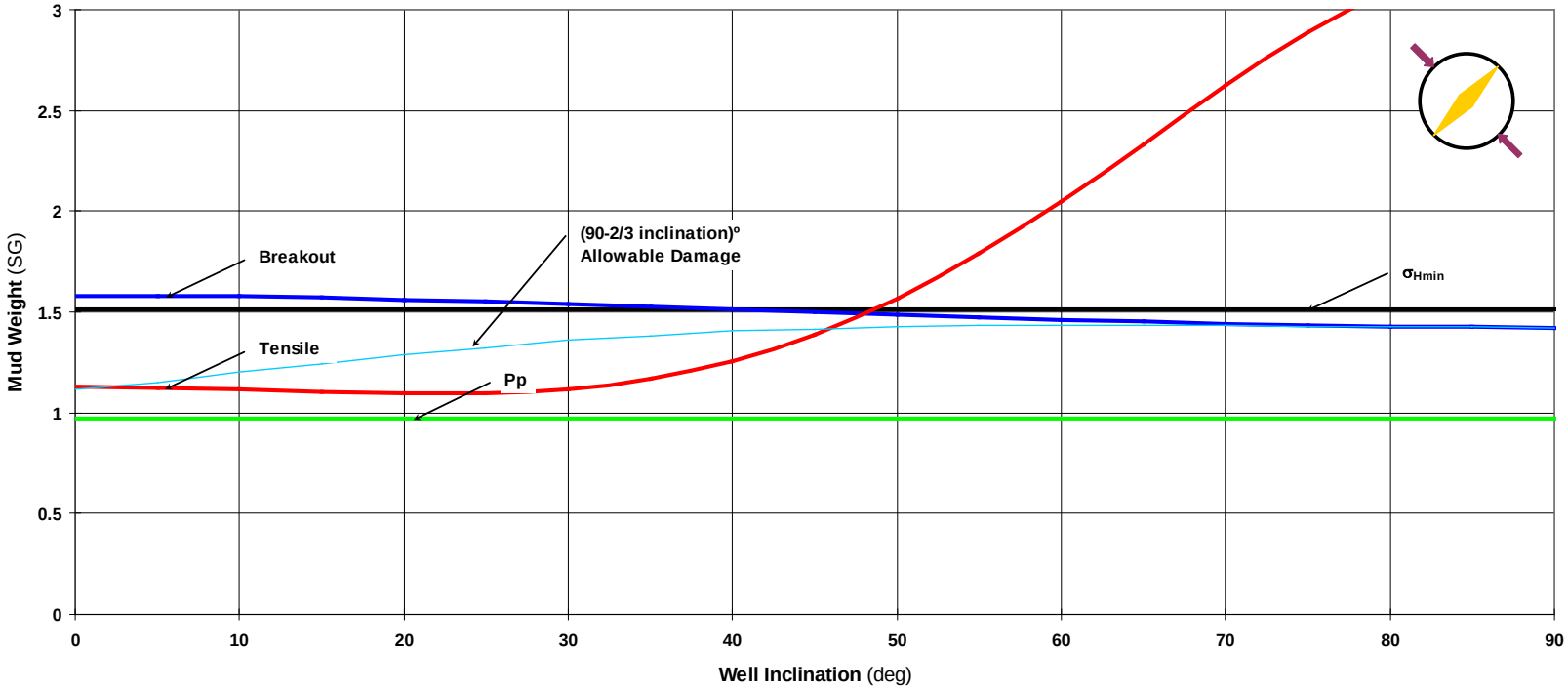
Field = ISG
Well = Teg-18
Poisson's Ratio = .2942751
σ_{Hmax} Azimuth = 135°
Well Azimuth = 282°
Calculation Azimuth = 223° (solid)
Well Inclination = 3°

TVDss = 1748.4 m
RKB Elevation = 343 m
TVDRKB = 2091.4 m
Thermal Calculation = No
Modulus = 0
Thermal Coefficient = 0
Degrees Cooling = 0°

σ_V = 6643.44 psi
σ_{Hmin} = 4498.95 psi
σ_{Hmax} = 7693.2 psi
Pp = 2888.13 psi
Stress Path = 1
DP = 0 psi
Biot = 1

Damage Angle = 0°
Criterion = 2
P1 = 4454.72 psi
P2 = 3.597967
P3 = -445.4722
Formation = Famennian



Teg Multi Lateral Design

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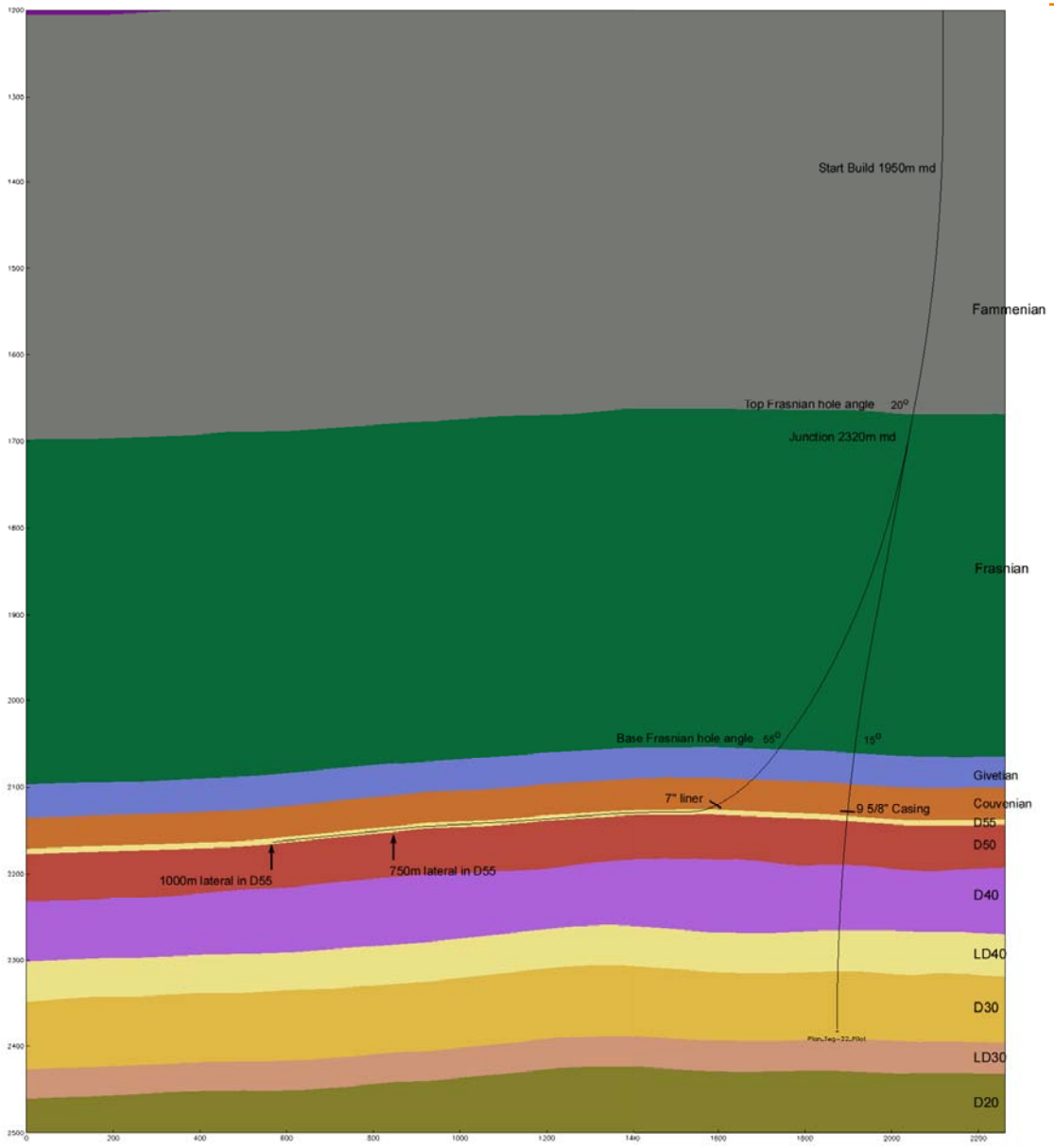
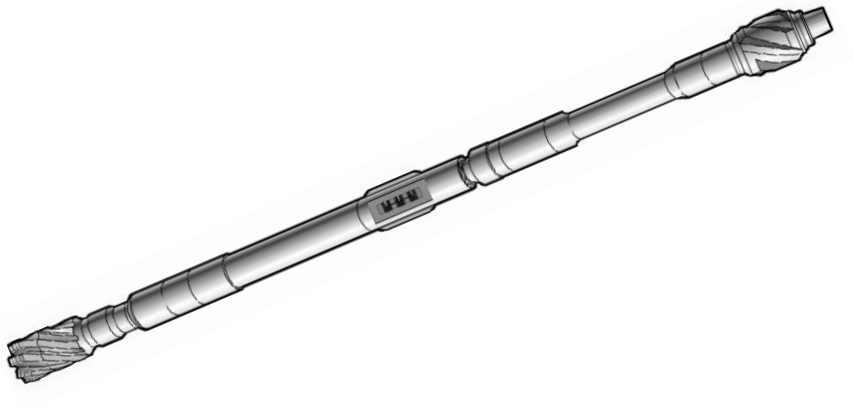
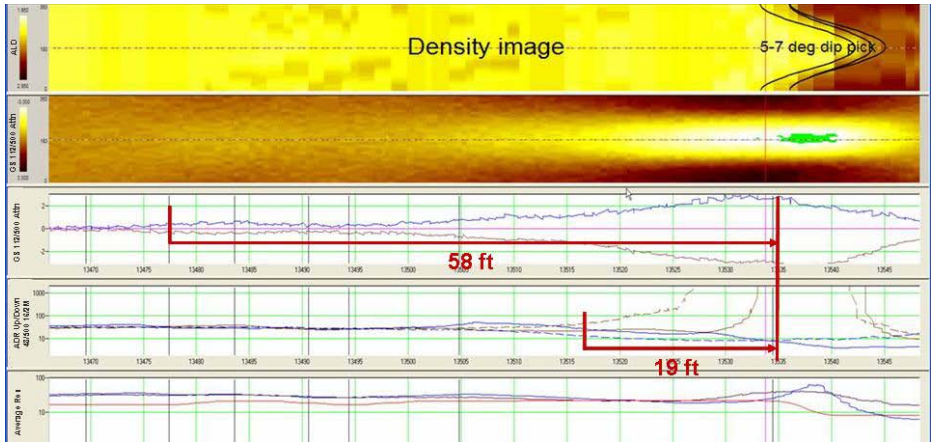


- Motherbore
  - Build to 20 deg in overburden
  - Drop to vertical 100m past junction
- Lateral
  - Build to max 56 deg
  - Hold tangent through unstable lower Frasnian to Top Givetian
  - Build to 75, TD 5m tvd above D55

Geosteering BHA





- Geo-Pilot steerable assembly
  - Smoother hole
- MWD:
  - GR
  - ADR (Azimutal Deep Resistivity)
    - Depth of investigation: up to 16-18ft
  - If get faulted out of D55 and lost, possibility to run ALD (Azimutal Litho Density) but only on wiper trip

Offset wells

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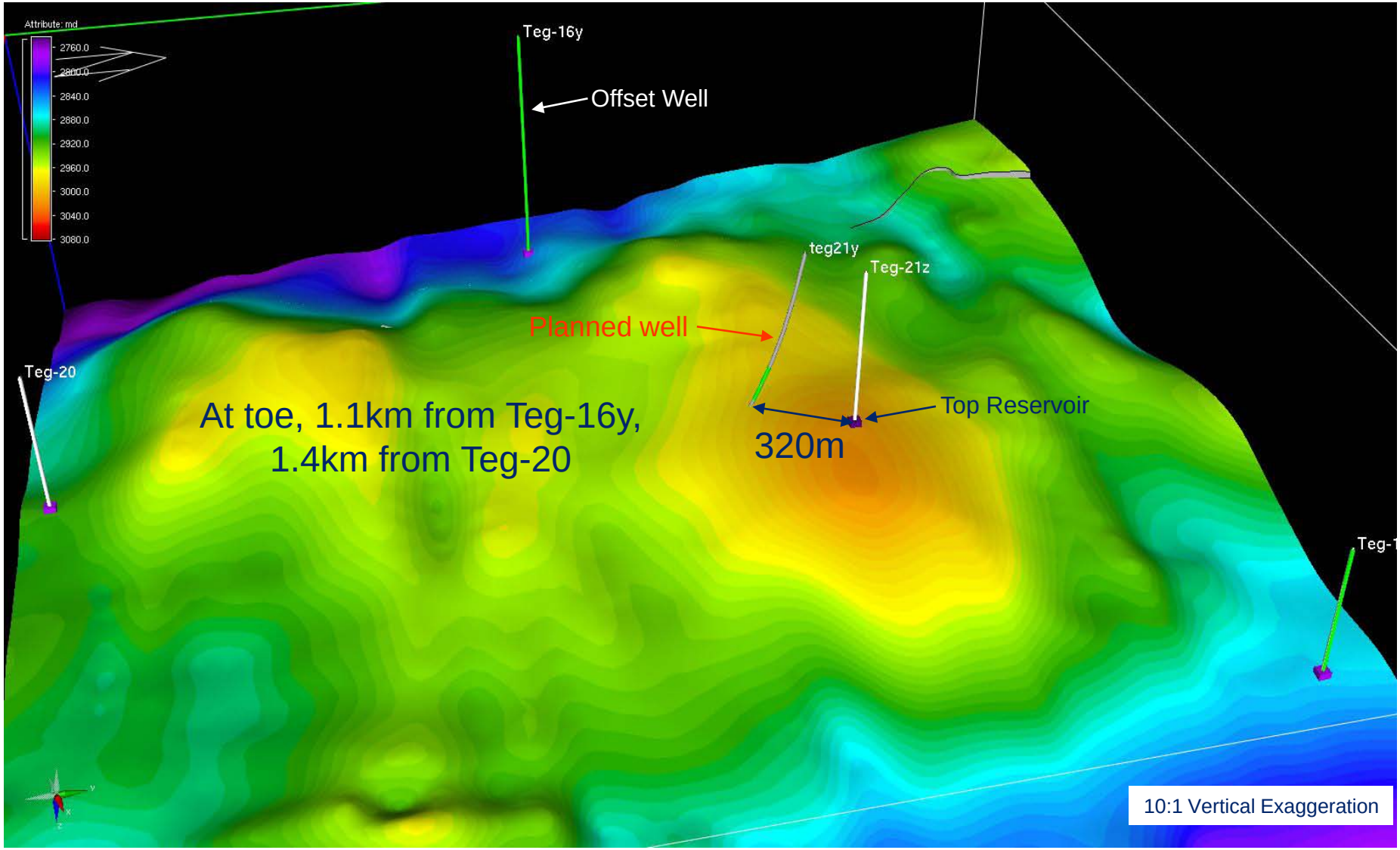

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Closest offset well: motherbore Teg-21z

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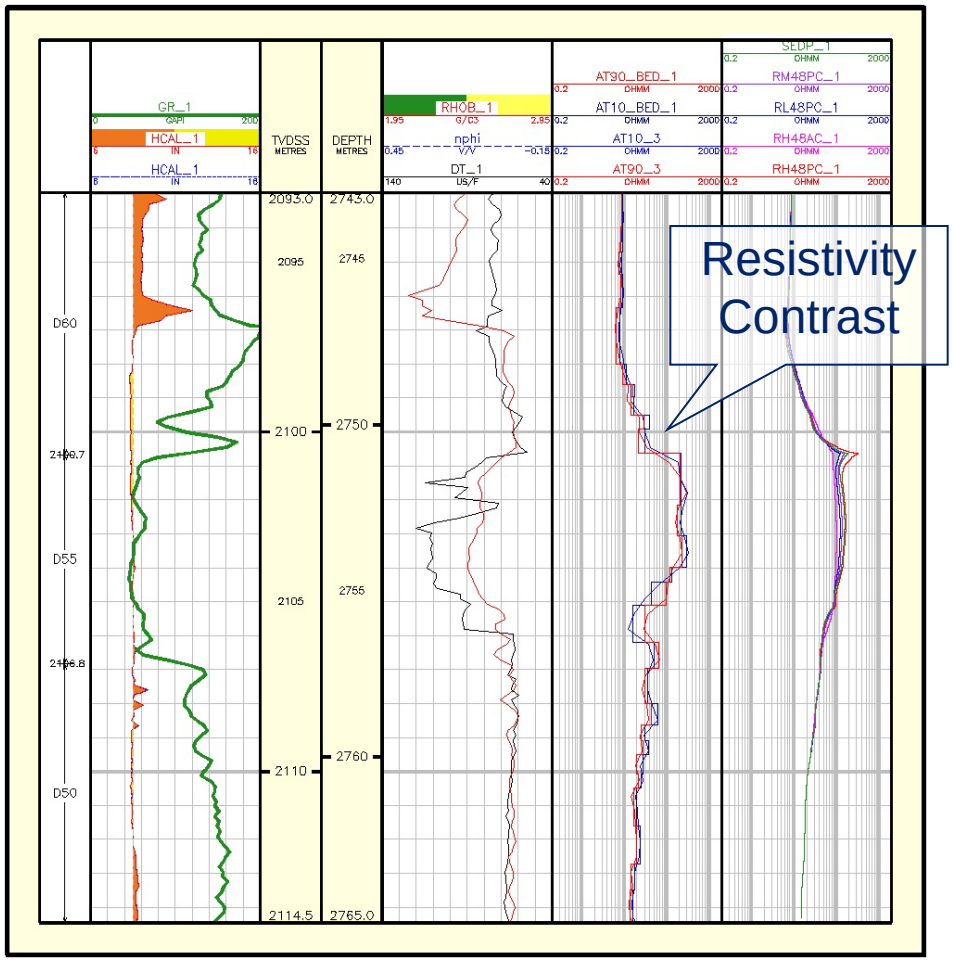
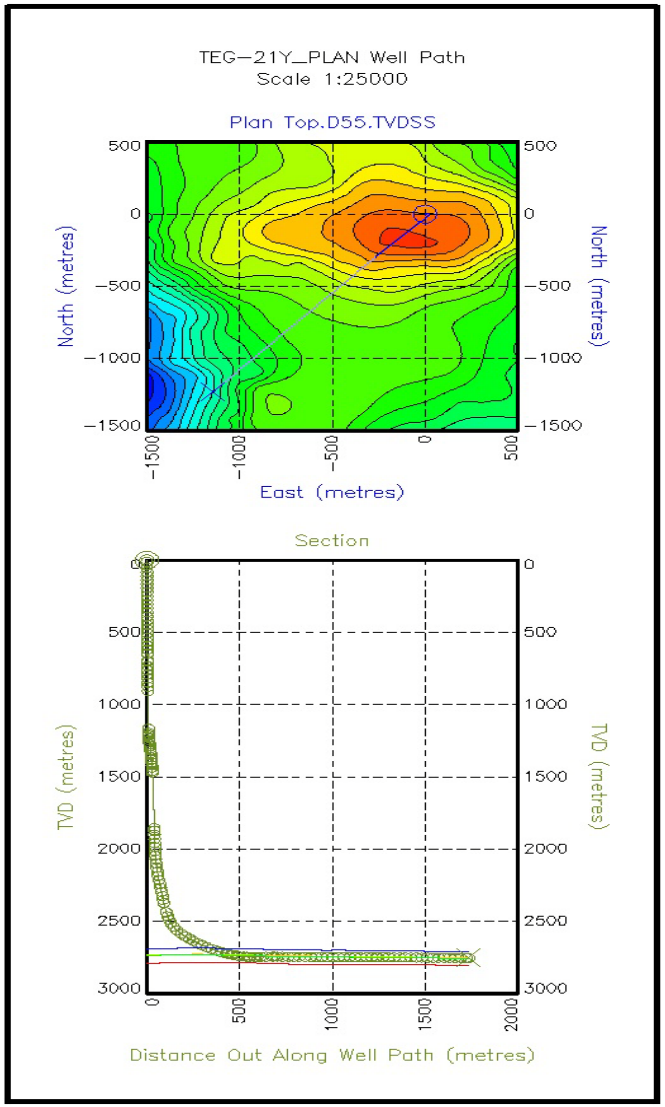
Offset well resistivity modelling





Log modelling

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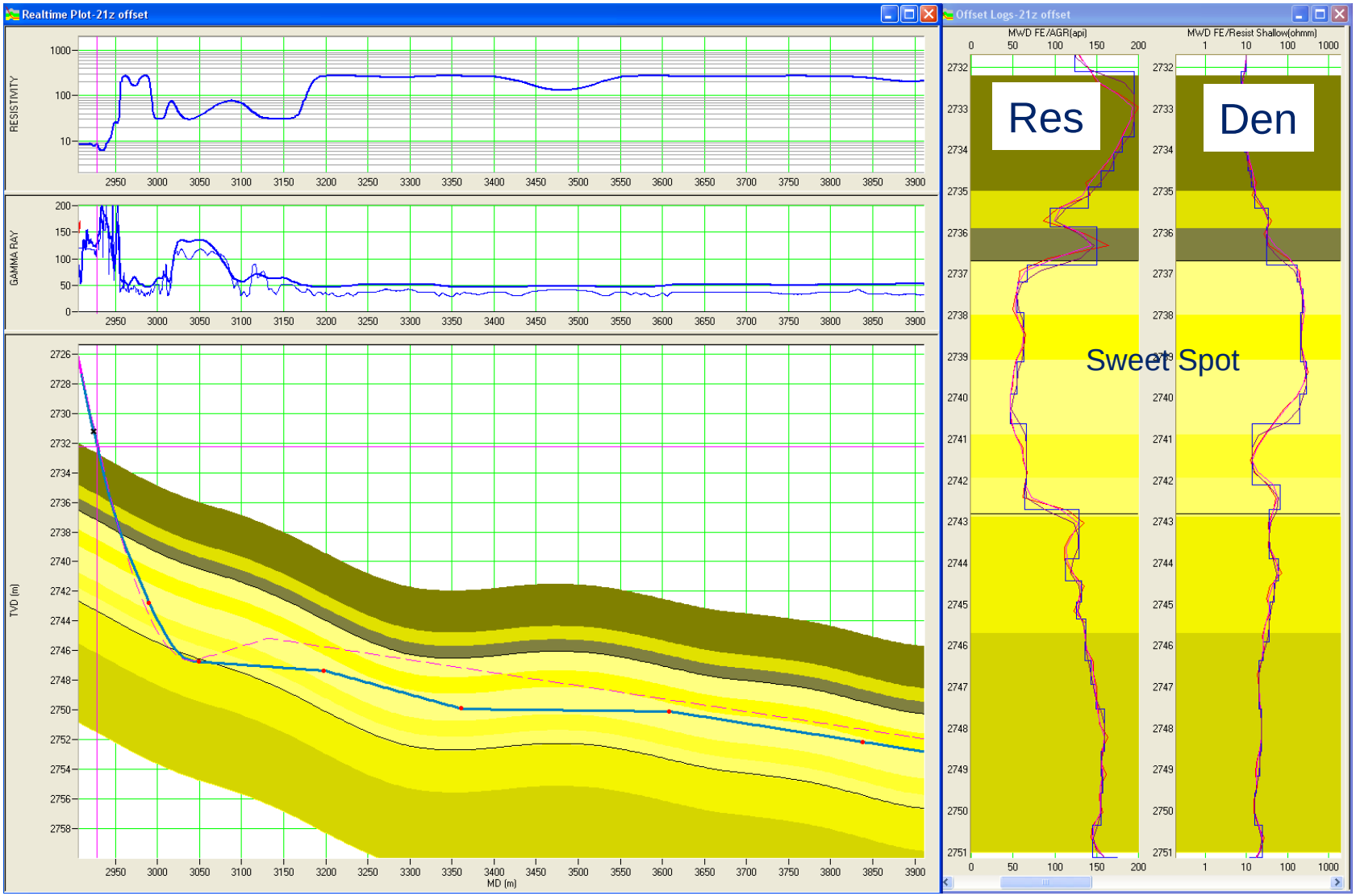

Execution

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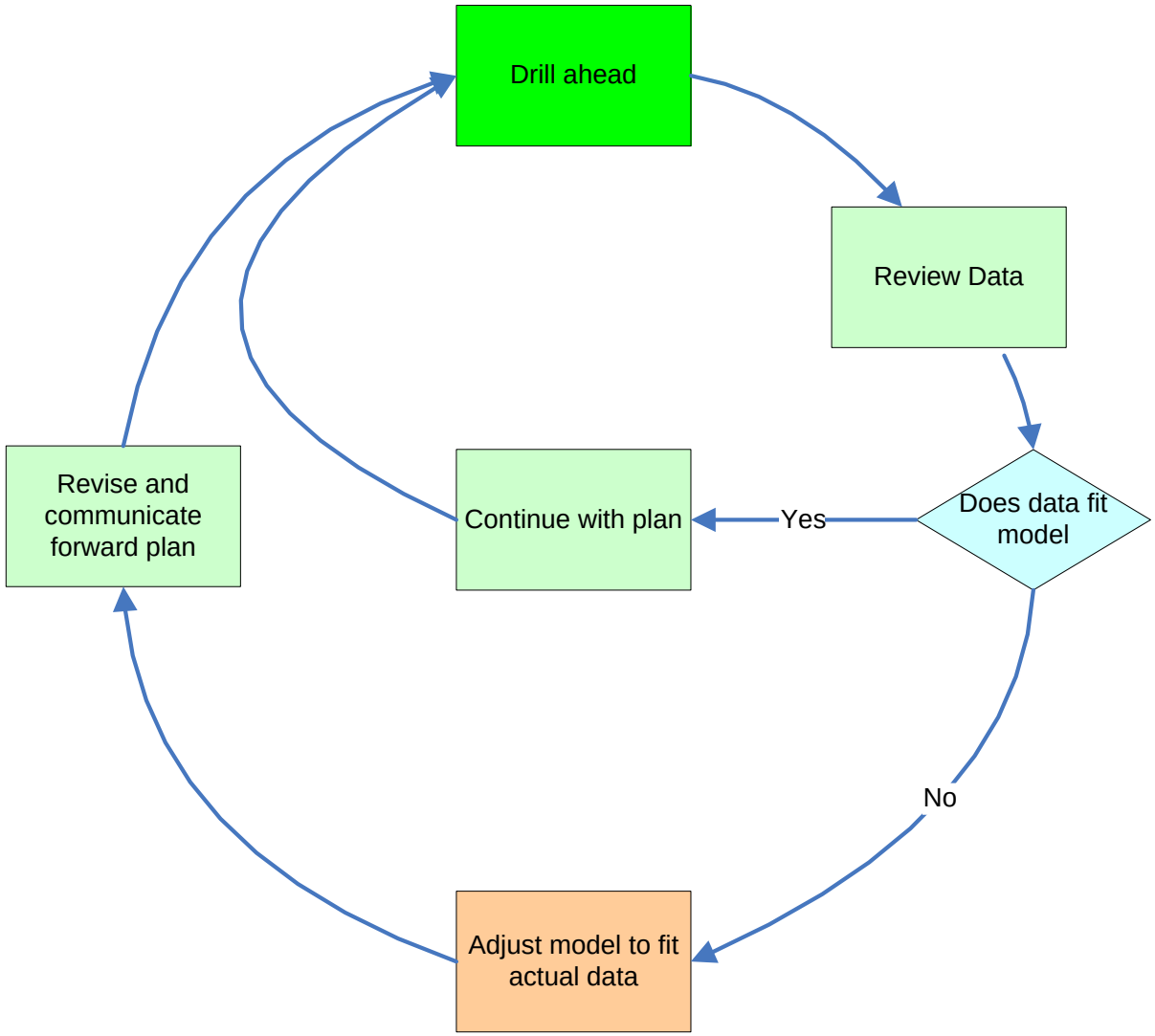

- Regular rig calls
  - am and pm with both crews
- RACI Chart
- Applications
  - Office
    - Stratasteer
    - EarthVision
    - CoViz
    - Geolog
    - OpenWorks
  - Rig
    - CoViz

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Setup

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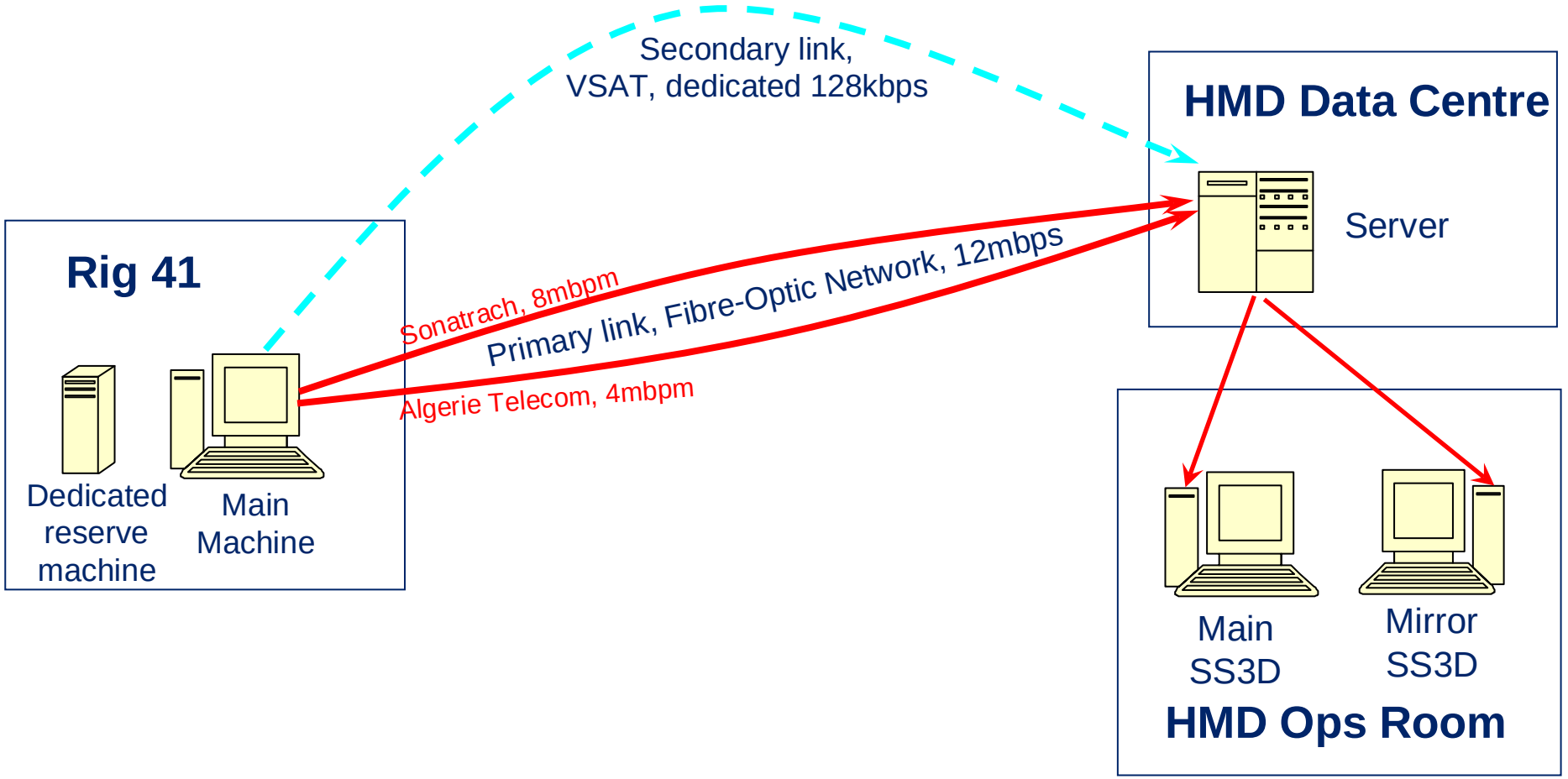
TEG

HMD



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Example Report

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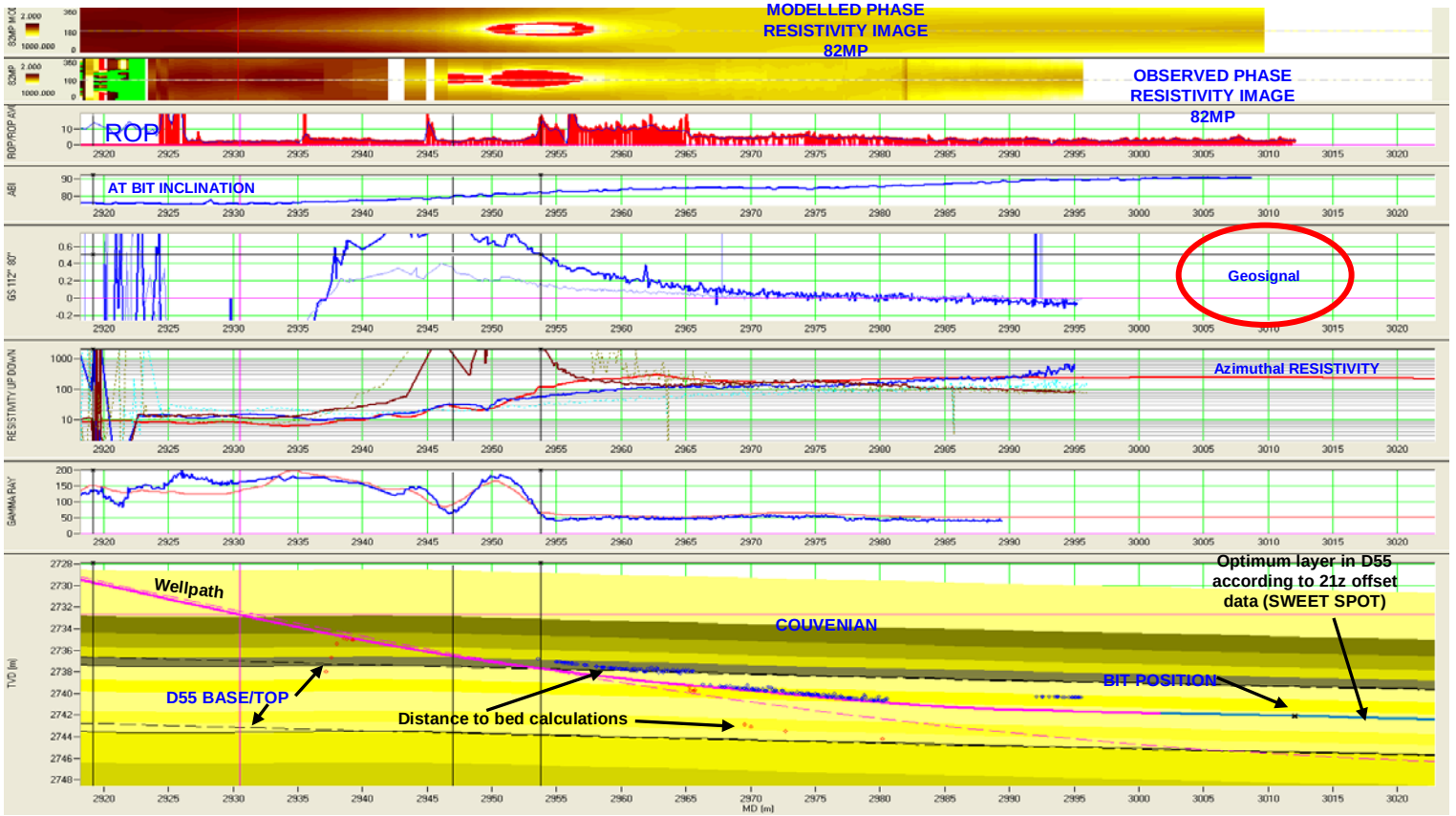
StrataSteer® 3D Report

14th June 2009 @ 06:00

Customer: JV Gas
Well: Teg-21y
SS3D Engineers: Jim Johnston / Kristian Petersen

HALLIBURTON
Sperry Drilling Services

Current Status: Pulling out
Current Depth: Hole depth 3012m MD / 2741.75 TVD inc: 89 degs.
Formation: D55 in middle clean zone – i.e. the sweetspot. **Offset well:** Teg 21z
Summary: Very good stratigraphic control through the D55. The ADR distance to bed calculations provide excellent QC on the stratigraphic position. The ADR distance to bed calculations are identical with the interpreted position of the intra D55 bed boundaries.
The ADR 82" senses poorer resistivity below.
Recommendations: Hold current angle 89 degs and if required geosteer to stay within sweetspot. Use ADR and DDTB calculations to keep track of top and base of sweetspot.



Model update

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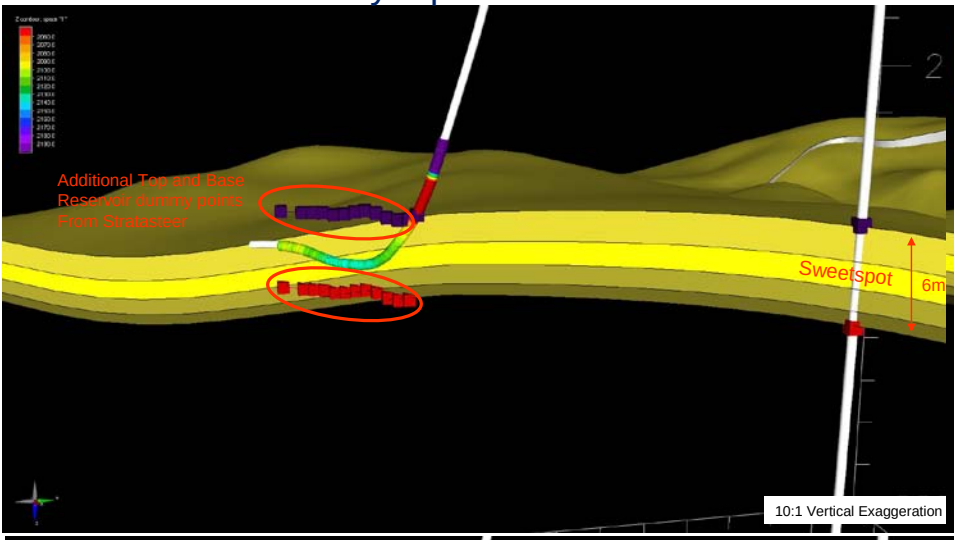
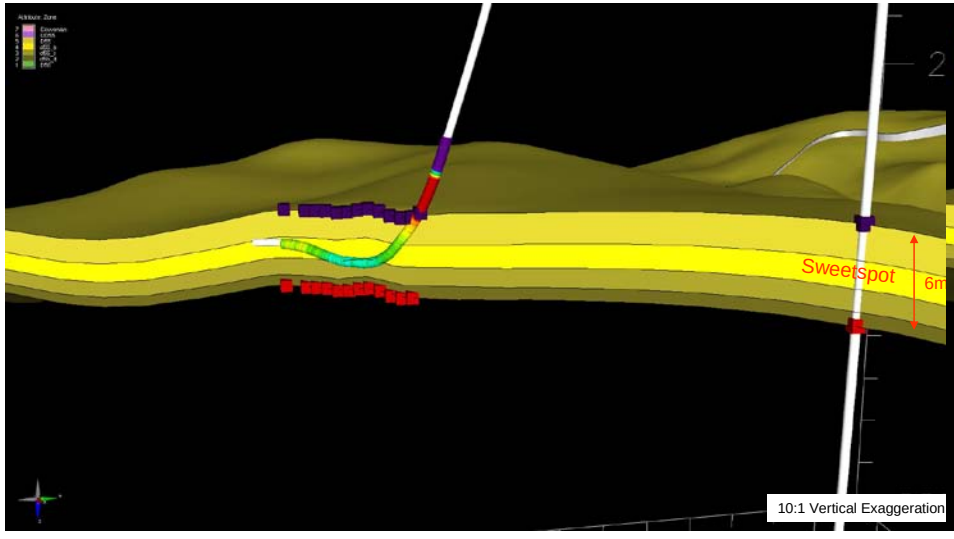
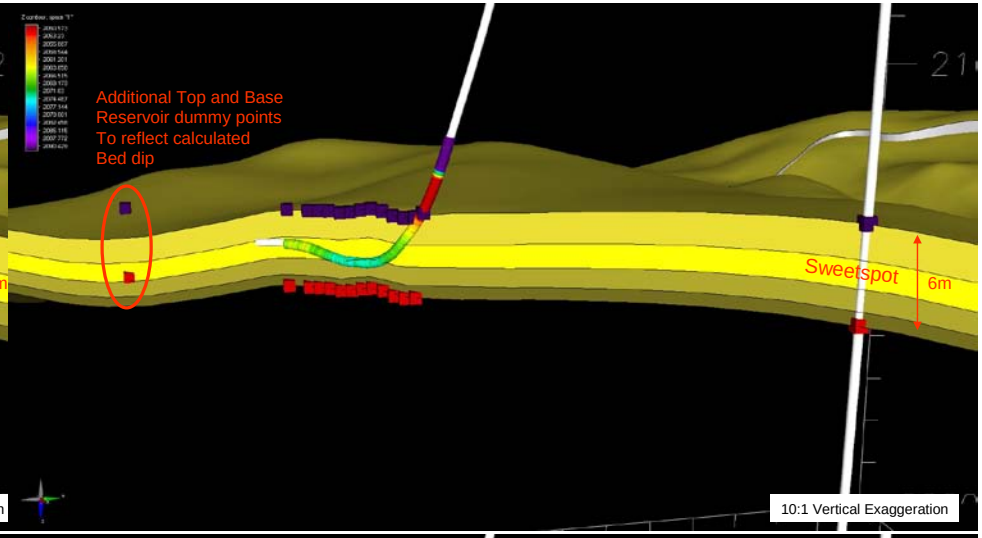
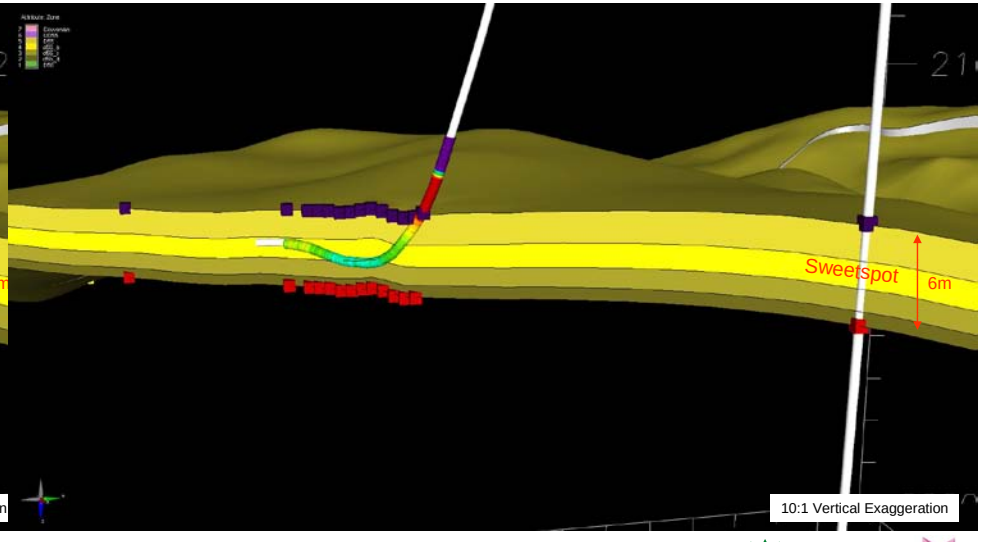
1. Integrate computed distance to top/bottom from Stratasteer as dummy tops





2. Integrate lookahead dip





Trajectory update

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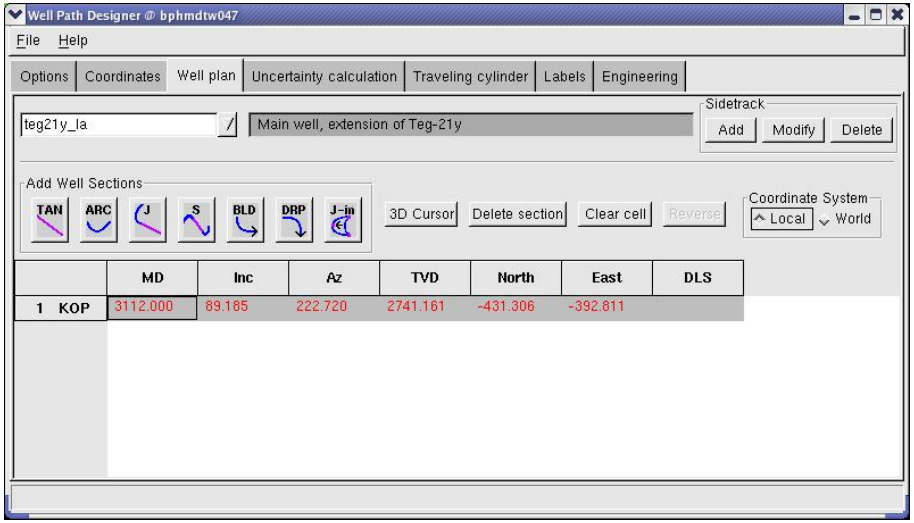

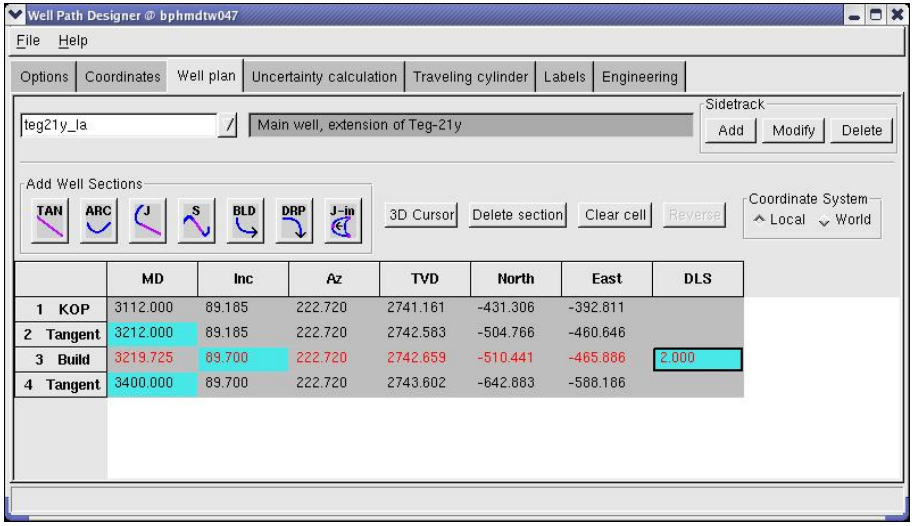

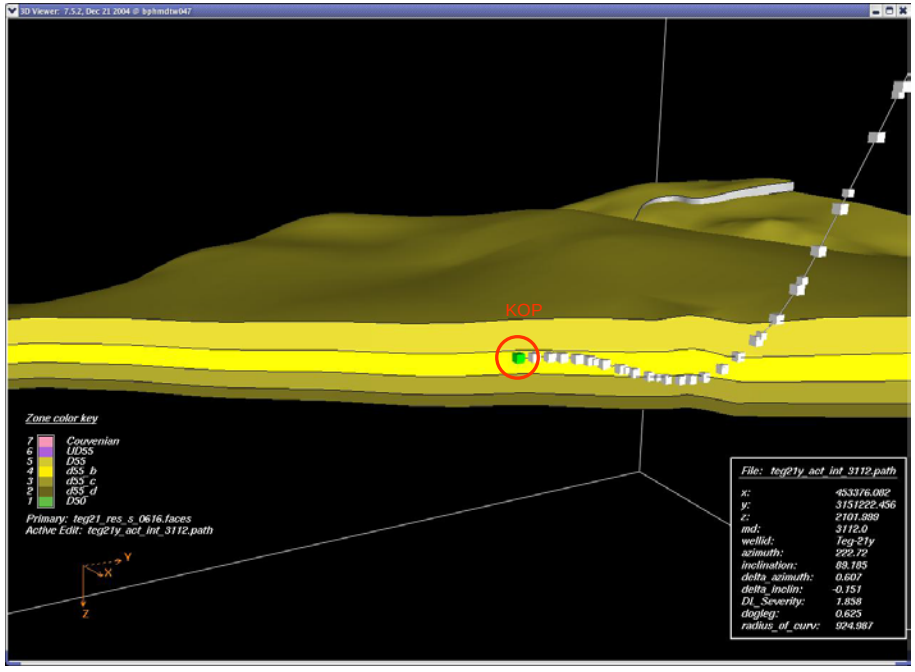

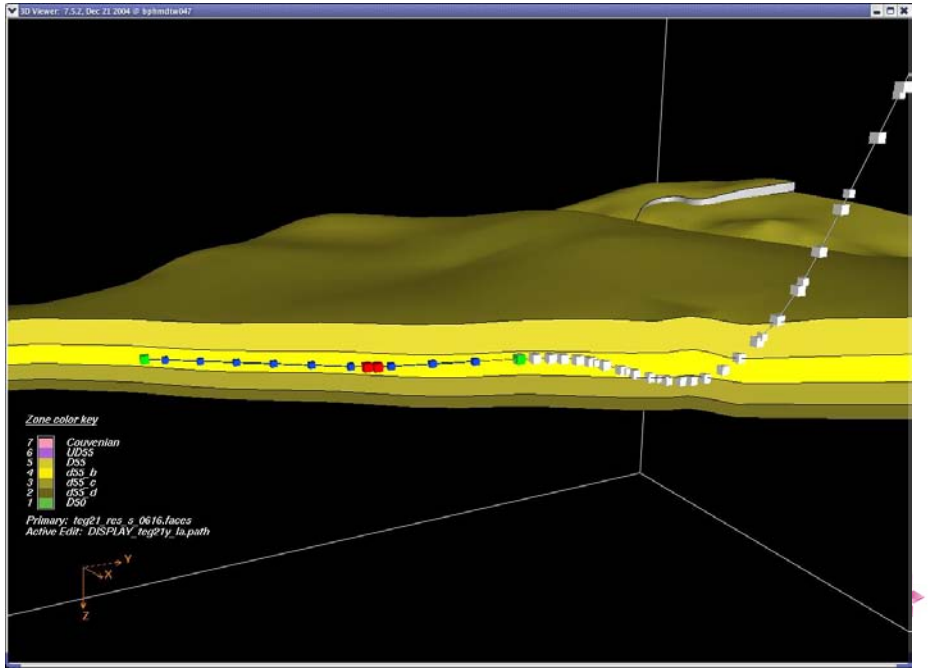

Co-Vizualization – Rigsite and Office

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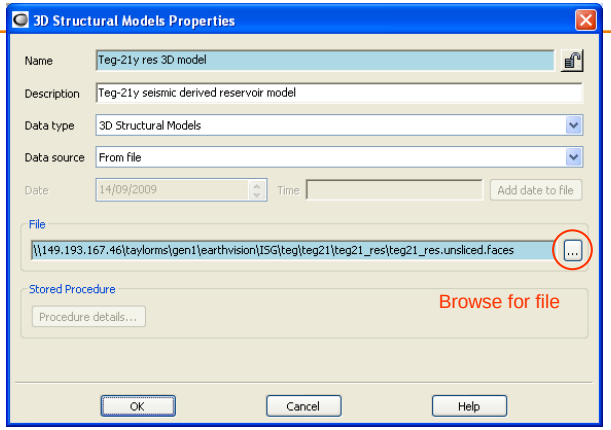
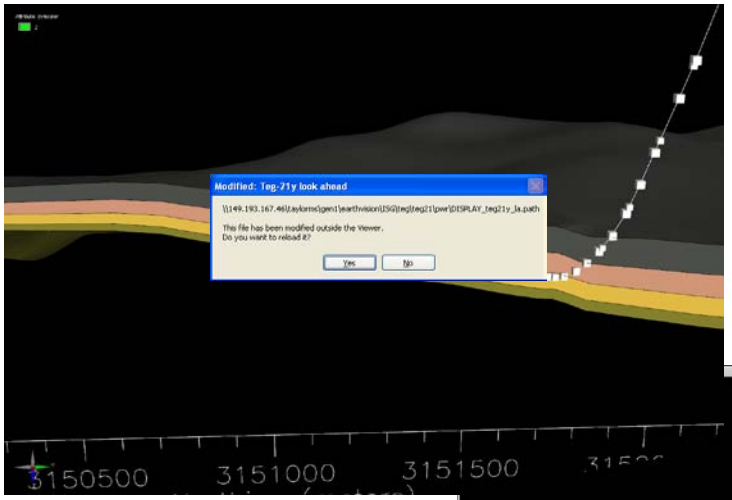
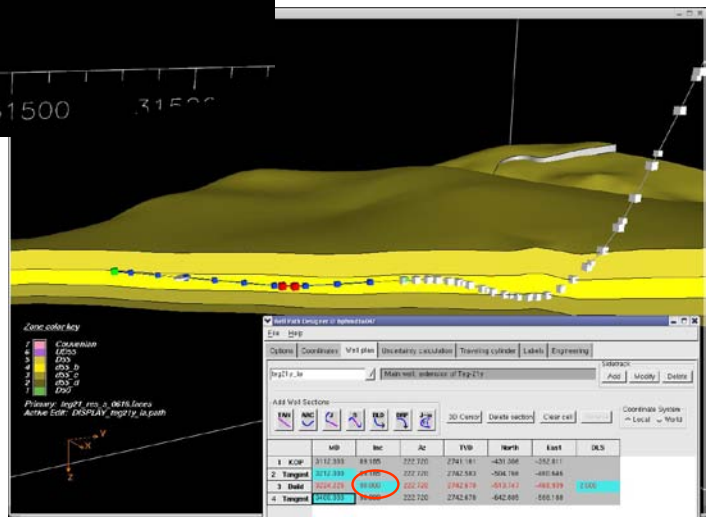
- Co-Vizualization application open on Rig
- Access identical dataset as office
- Automatic update
- Allows wellsite geologist to communicate with rig personnel





Rig View



Office View

10th June, 2924m md
0m daily progress, 0m reservoir

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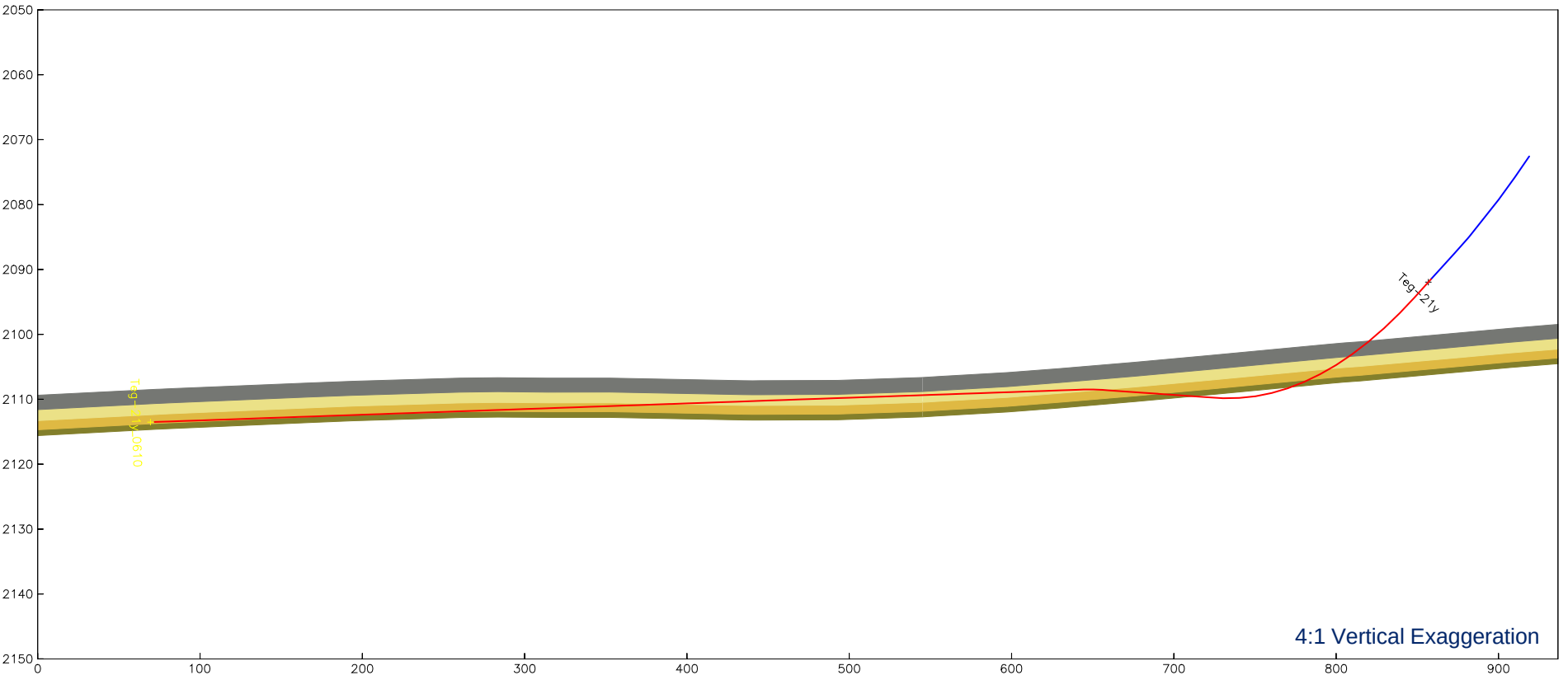

- Model based on Seismic adjusted to Teg-21z results
- D55 subdivided into 4 layers from Teg-21z GR and Density
- GeoPilot max dls assumed to be 4 deg / 30m

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11th June, 2928m md

4m daily progress, 0m reservoir

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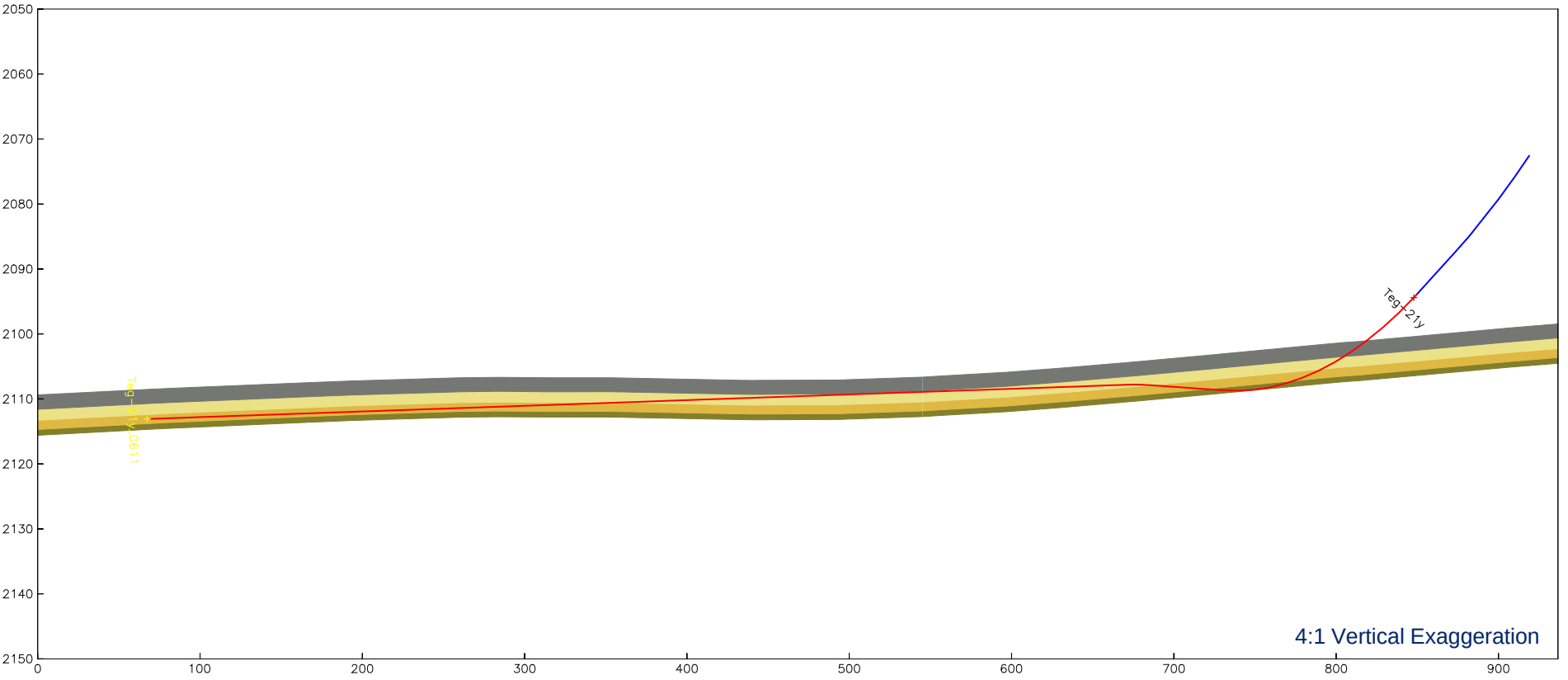

- Drilled 4m new formation, POOH to PU GeoPilot
- BOP Test

Statoil

12th June 2943m md

15m daily progress, 0m reservoir

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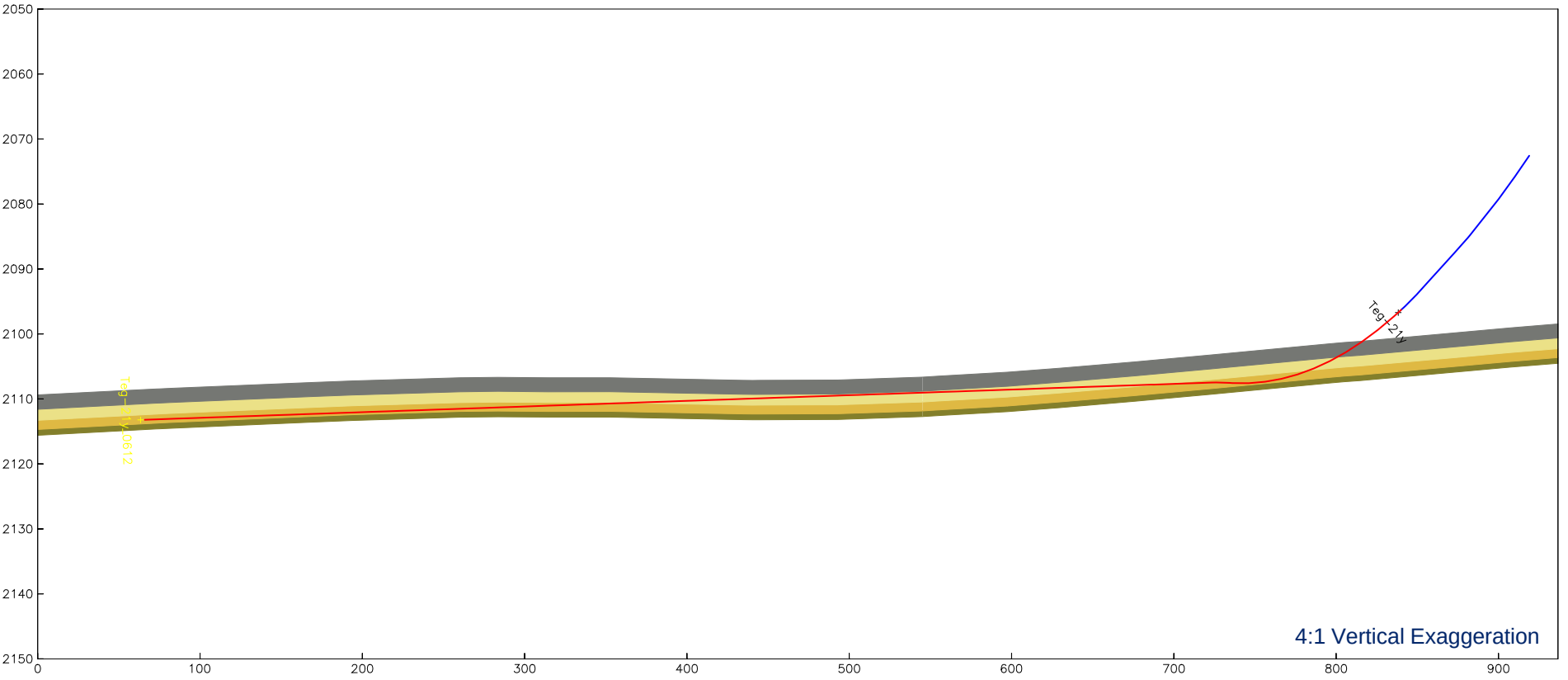

- Started drilling ahead to Landing point
- DLS higher than modelled
- 3hrs NPT – possible stuck pipe but pipe rams were not re-opened following BOP test

13th June 3012m md

69m daily progress, 60m reservoir

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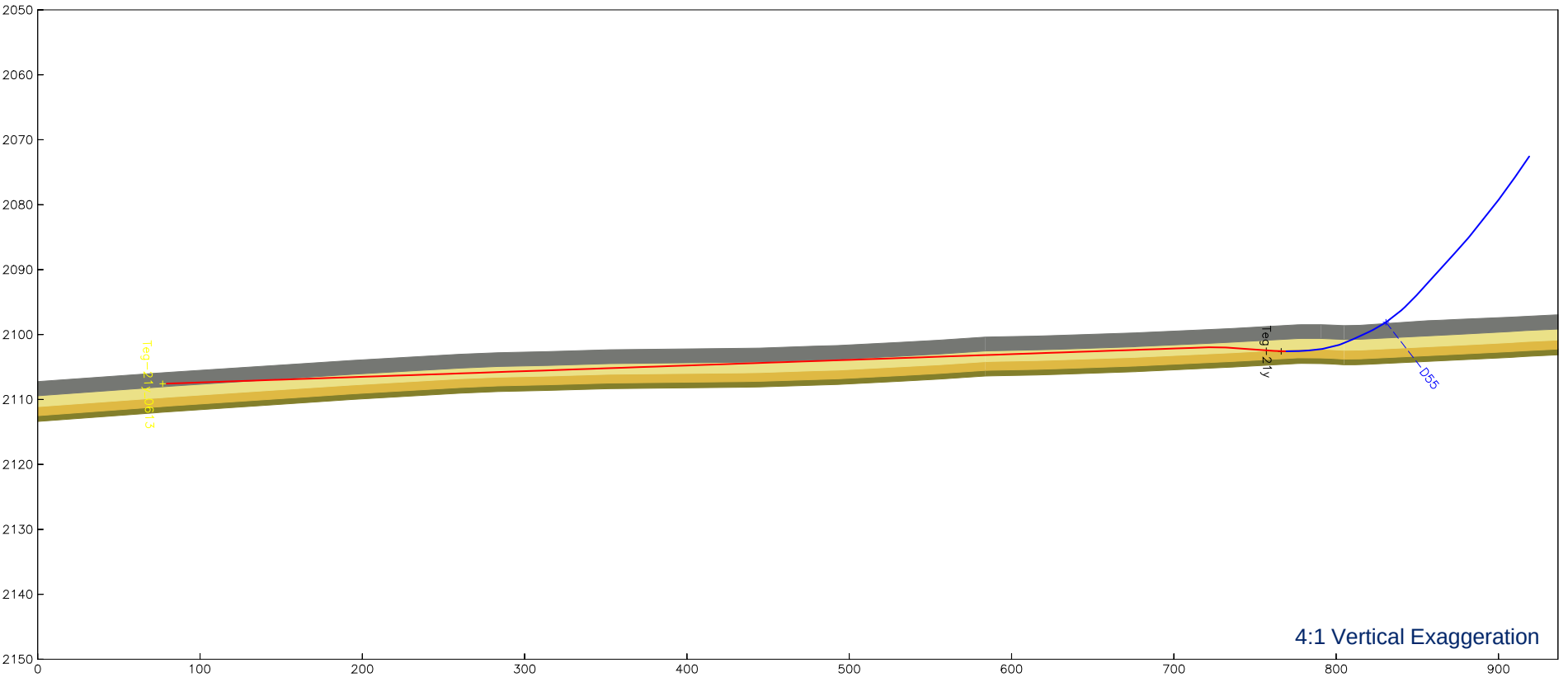

- Drill ahead to landing point, DLS up to ~9 deg/30m
- POOH to PU PDC bit

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14th June 3012m md

0m daily progress, 60m reservoir

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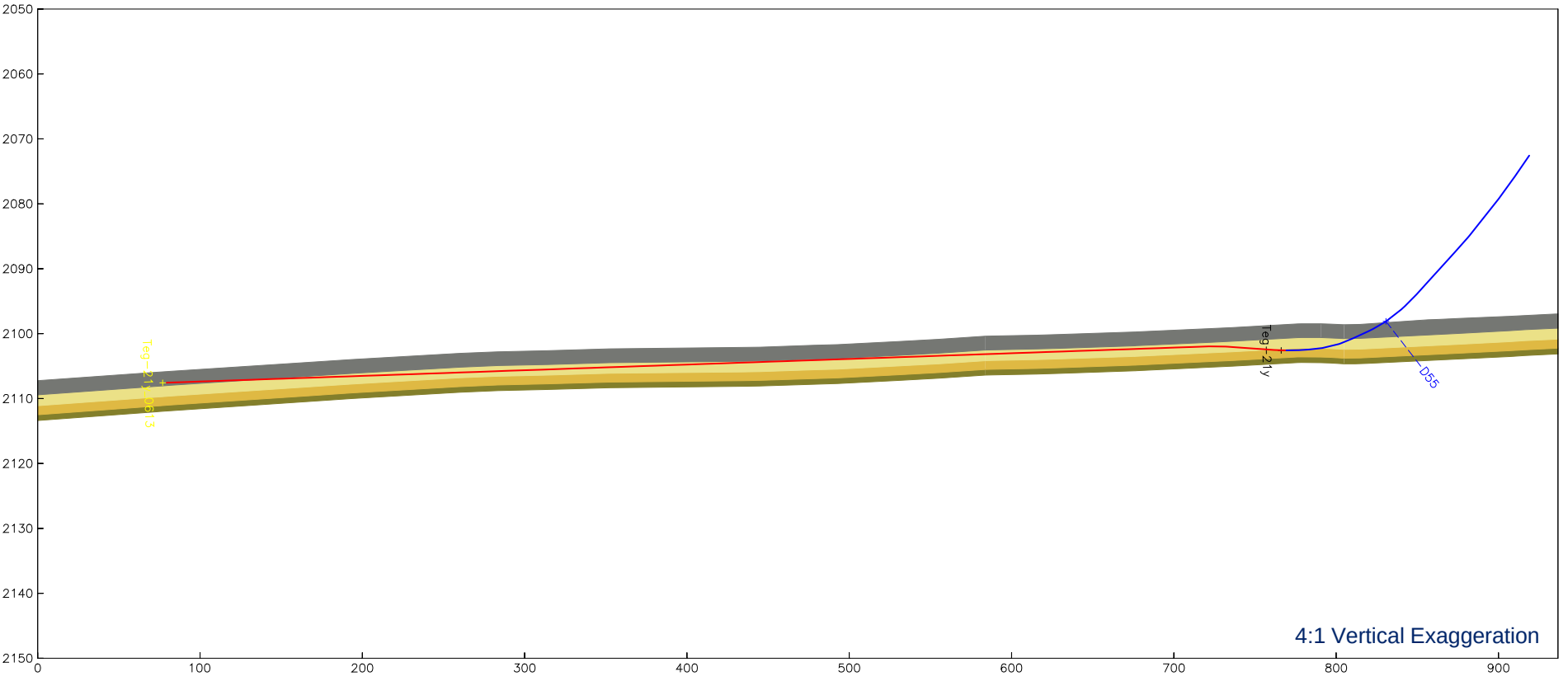

- RIH with GeoPilot and PDC bit
- 2 hrs NPT – MWD tool not pulsing

15th June 3012m md

0m daily progress, 60m reservoir

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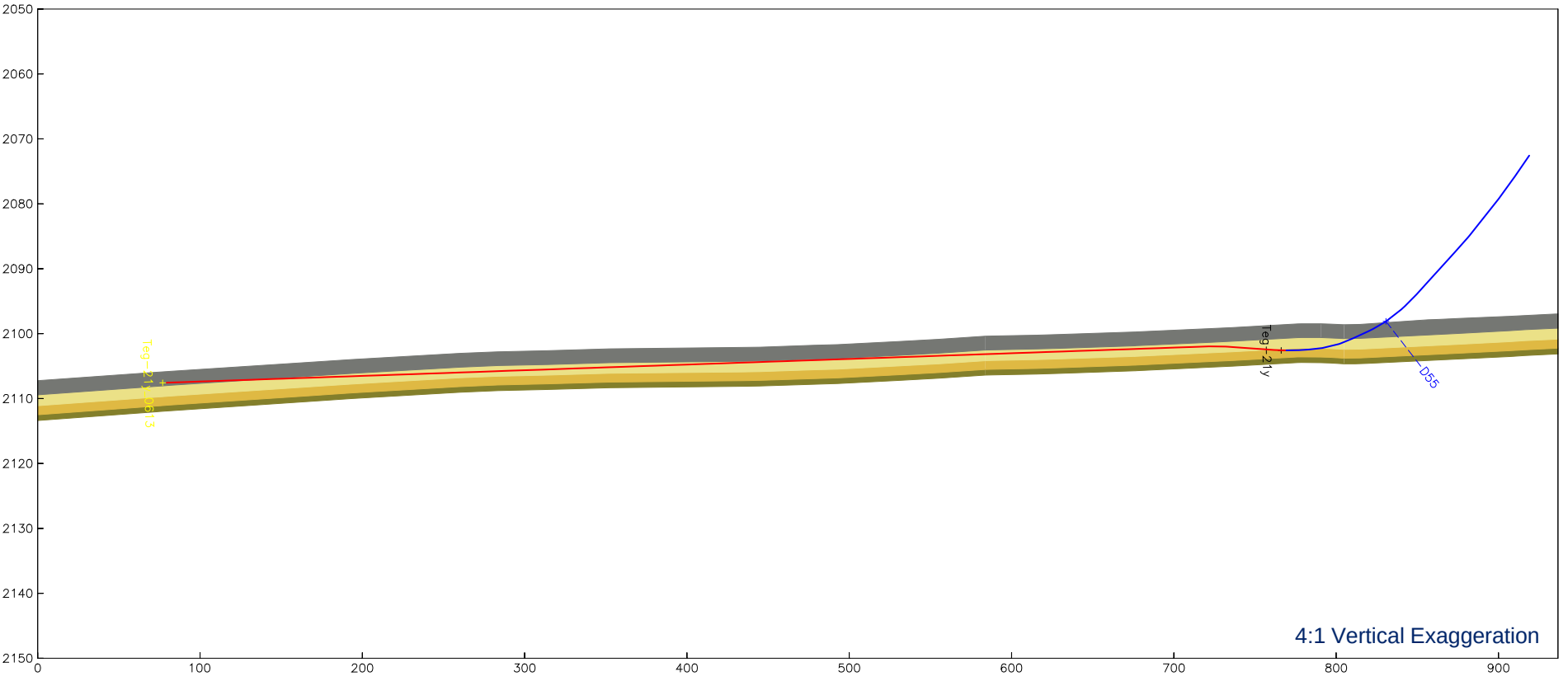

- POOH to replace MWD
- 24 hrs NPT

16th June 3110m md

98m daily progress, 158m reservoir

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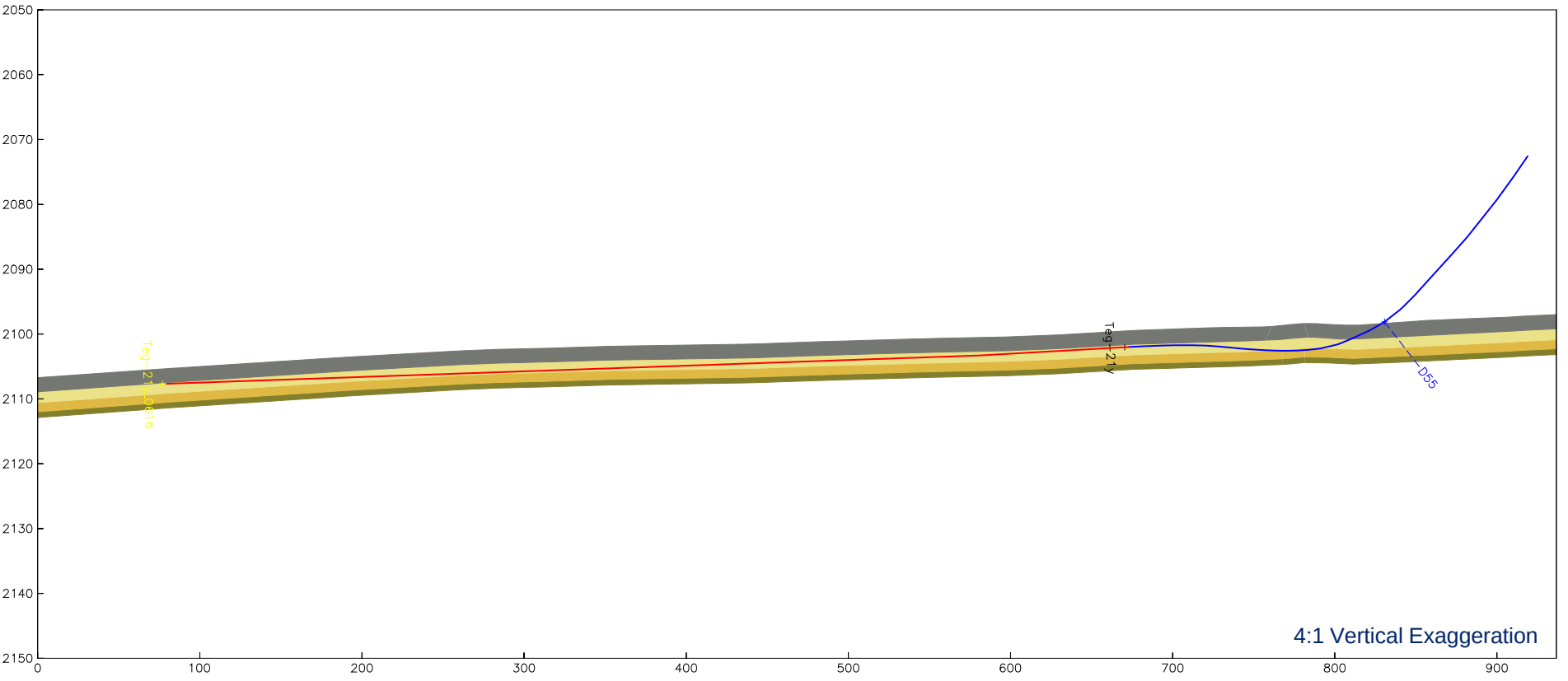

- Drilling ahead
- 6 hrs NPT, 1.5 hrs recovery from MWD failure, 4.5 hrs troubleshooting suspect deep resistivity values

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17th June 3167m md

57m daily progress, 215m reservoir

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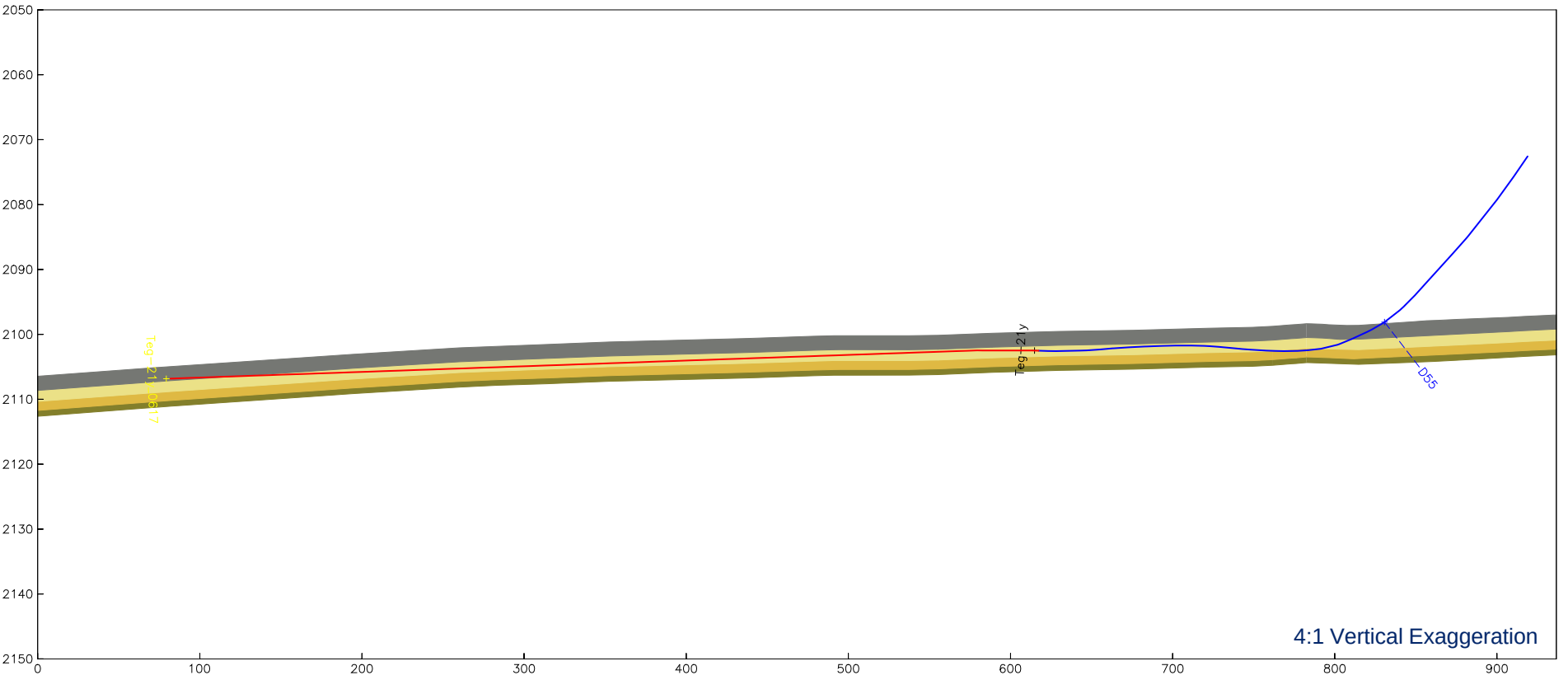

- Drilling ahead, controlled drilling from 3110m md to aid deep resistivity detection
- 9 hrs NPT troubleshooting ADR and relogging

18th June 3167m md

0m daily progress, 215m reservoir

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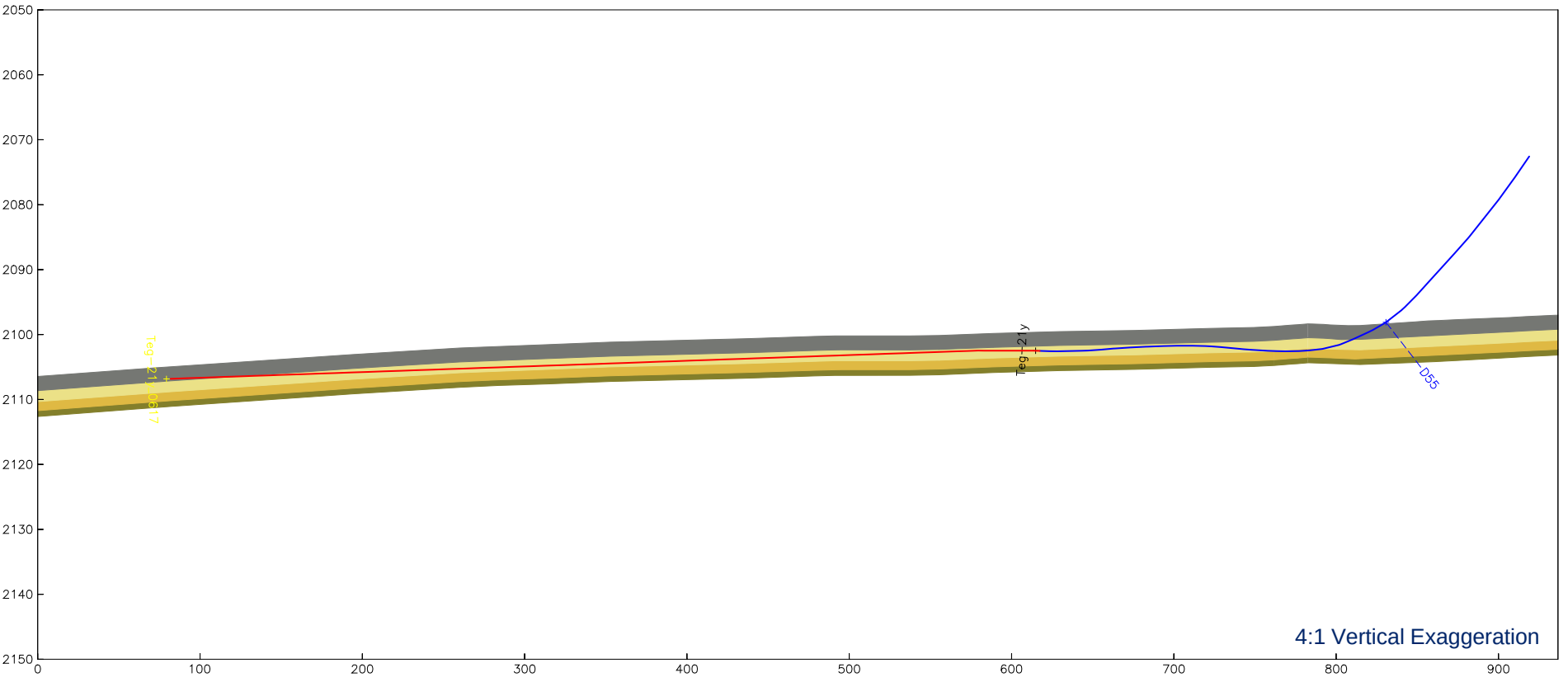

- Pull back to 7” liner shoe
- 24 hrs NPT to replace leaking TDS washpipe

19th June 3254m md

87m daily progress, 302m reservoir

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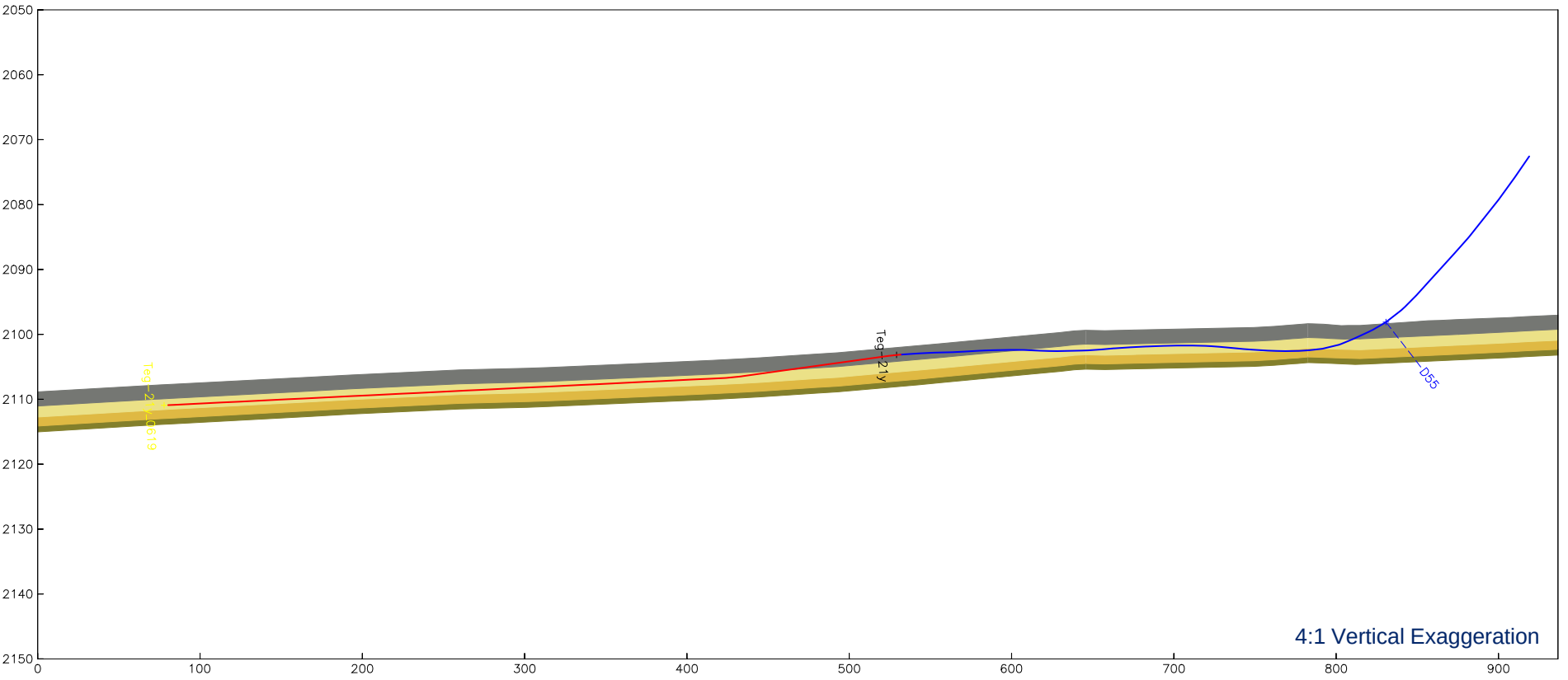

- Drilling ahead, GeoPilot ‘forced’ up at ~3165m md
- Gradually dropping down to Sweet Spot
- 1.5 hrs NPT recovery from TDS failure

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20th June 3318m md

64m daily progress, 366m reservoir

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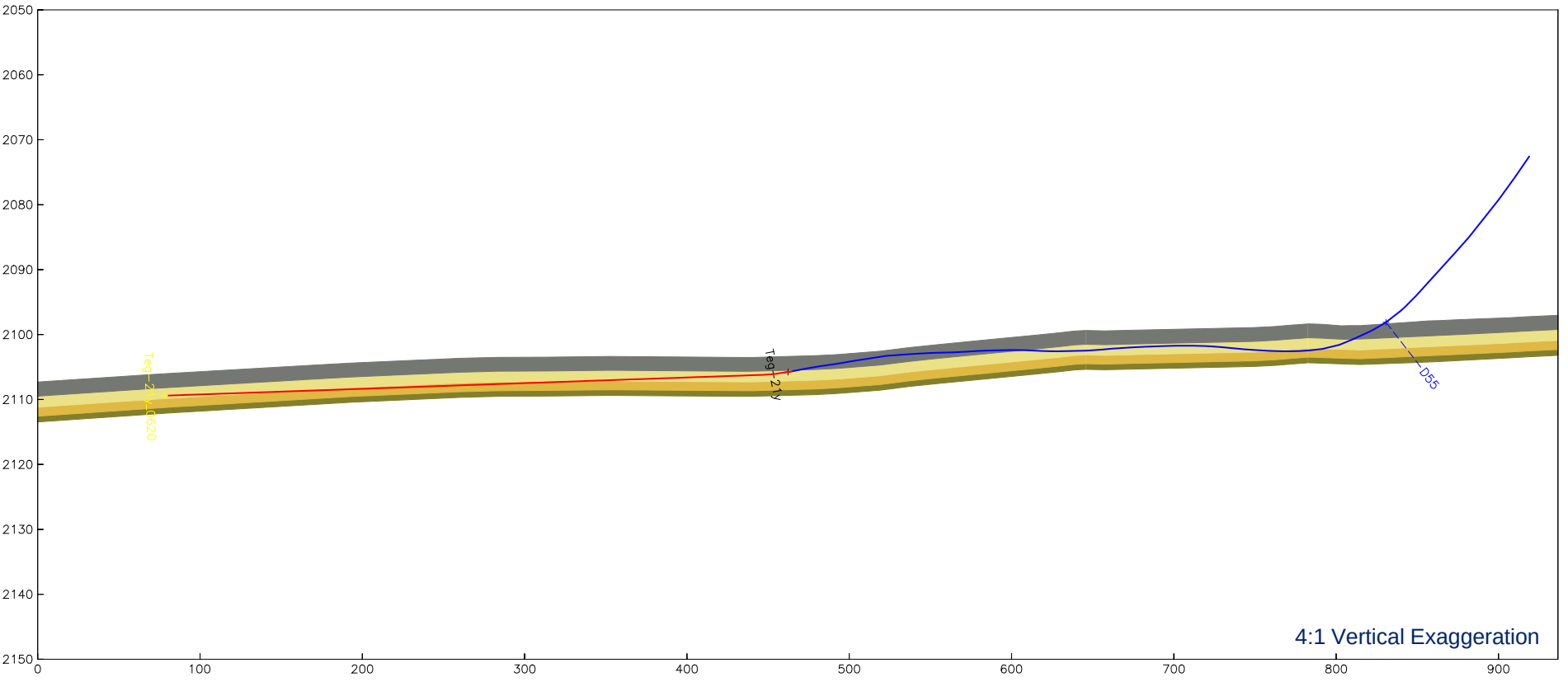

- Drilling ahead
- Learning how GeoPilot responds

21th June 3318m md

0m daily progress, 366m reservoir

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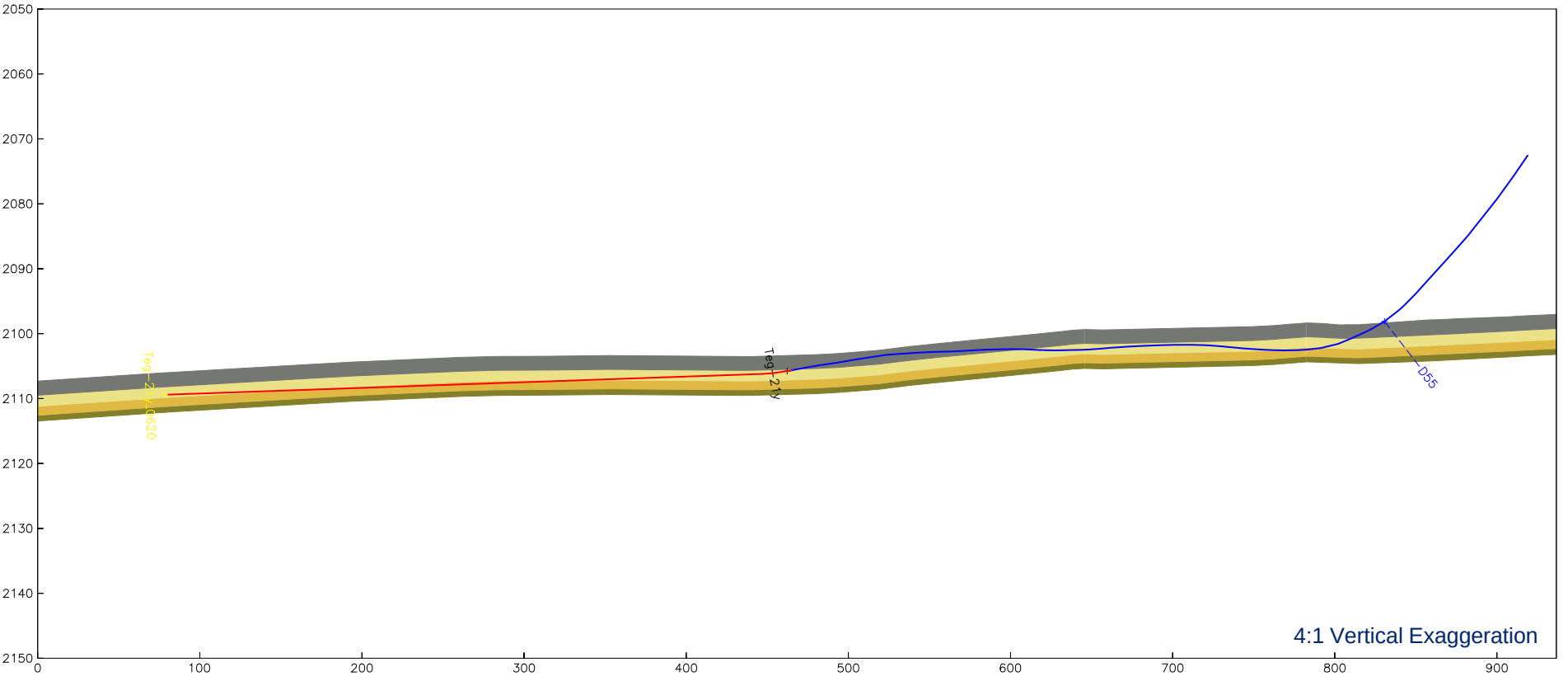

- POOH for GeoPilot failure (sleeve stuck)
- 20.25 hrs NPT

22th June 3328m md

10m daily progress, 376m reservoir

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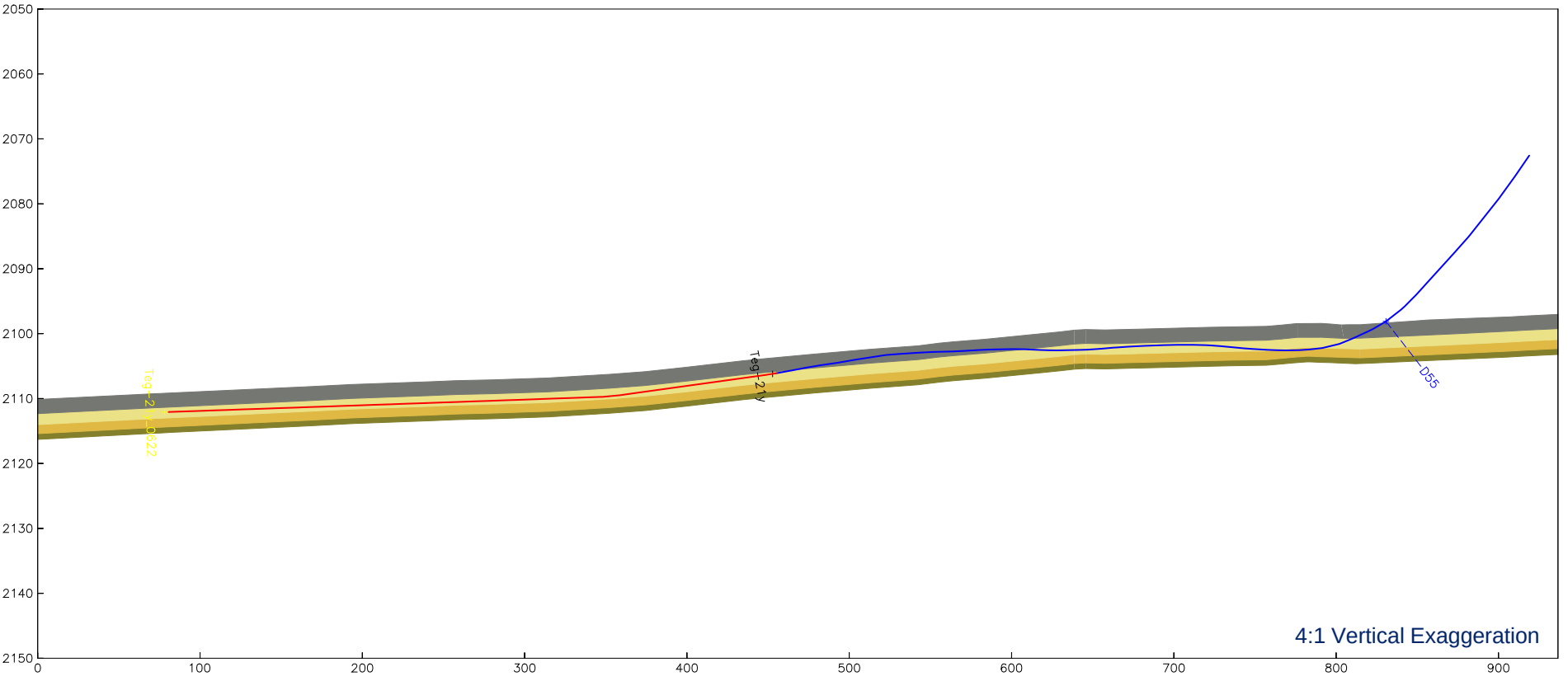

- RIH with new GeoPilot
- 18.5 hrs NPT, recovery from GeoPilot failure

23th June 2409m md

81m daily progress, 457m reservoir

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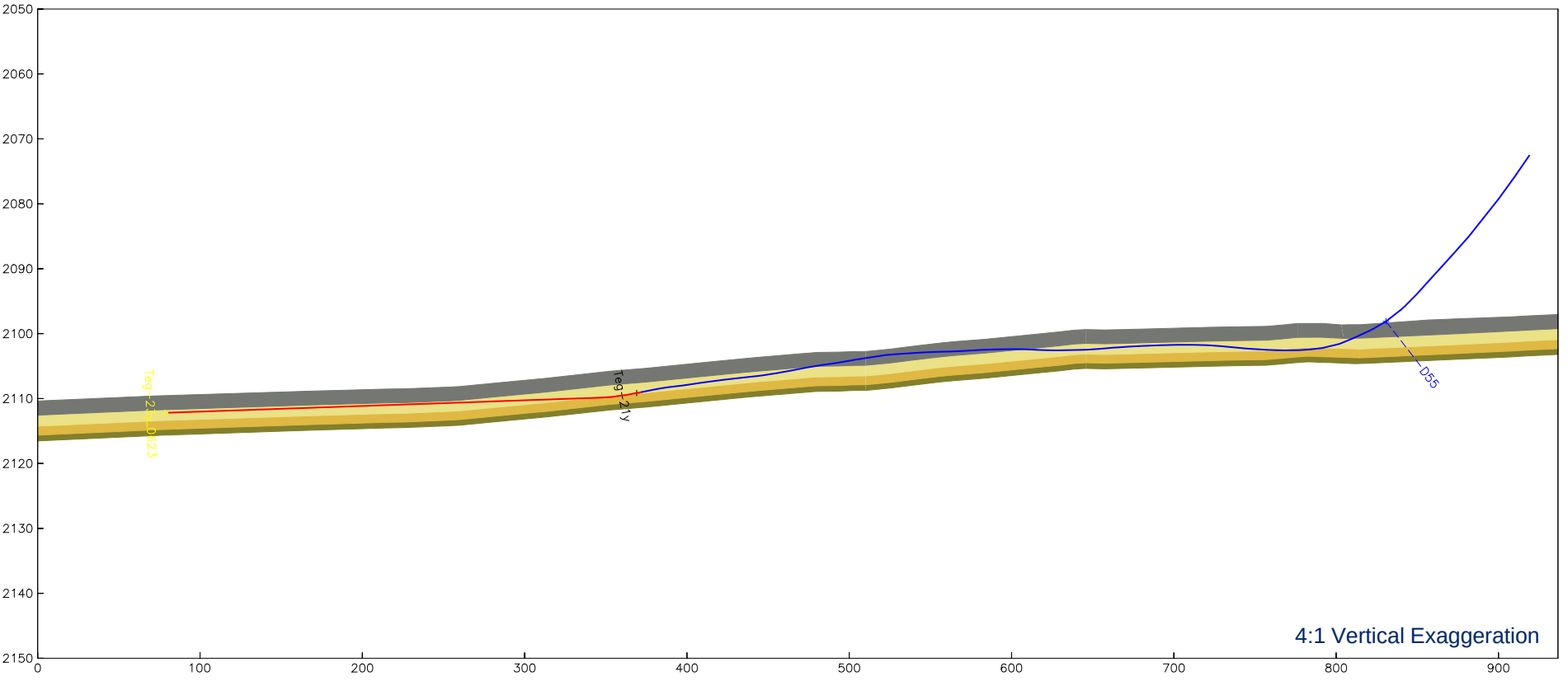

- Drilling ahead
- Attempting to build back up to Sweet Spot

24th June 3437m md

28m daily progress, 485m reservoir

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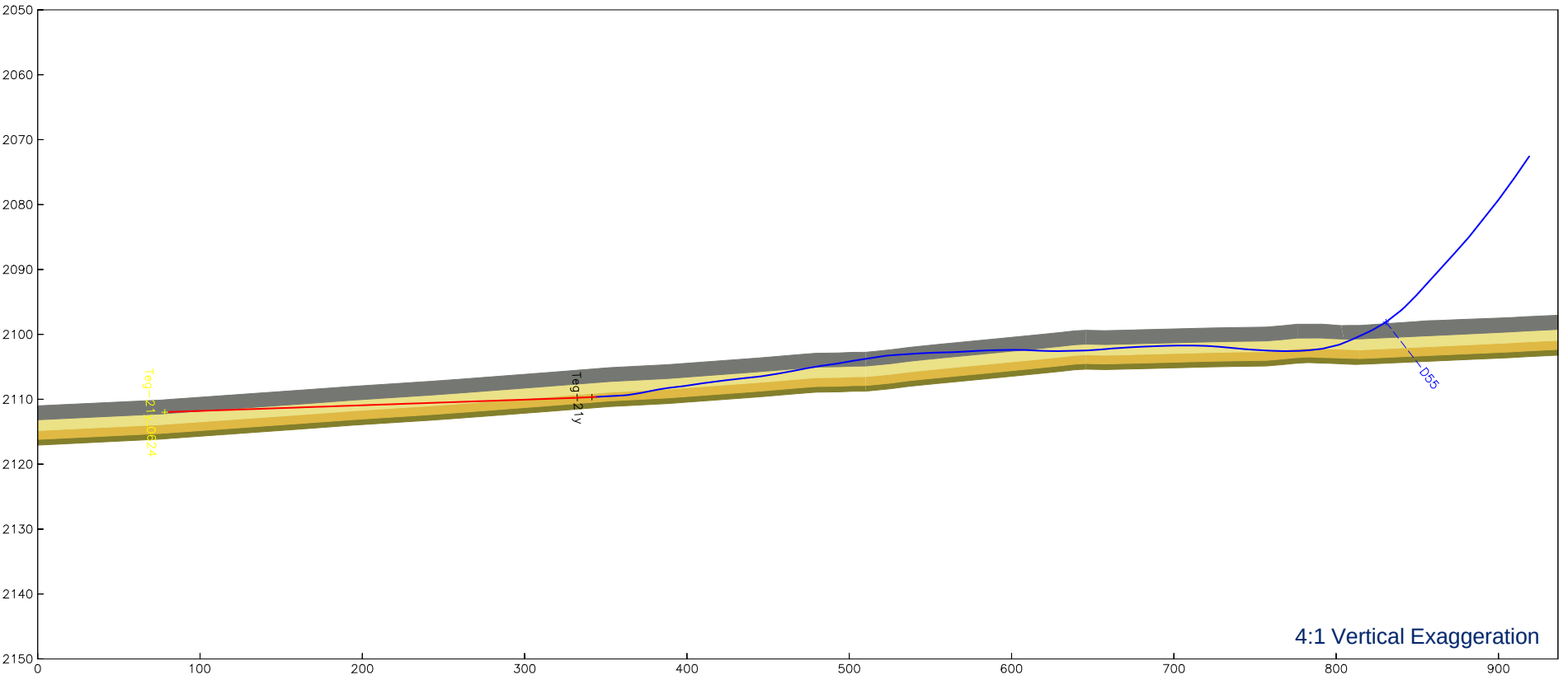

- Drilling ahead, attempting to build up to sweet spot
- 7.75 hrs NPT TDS and surface line repairs

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25th June 3452m md

15m daily progress, 500m reservoir

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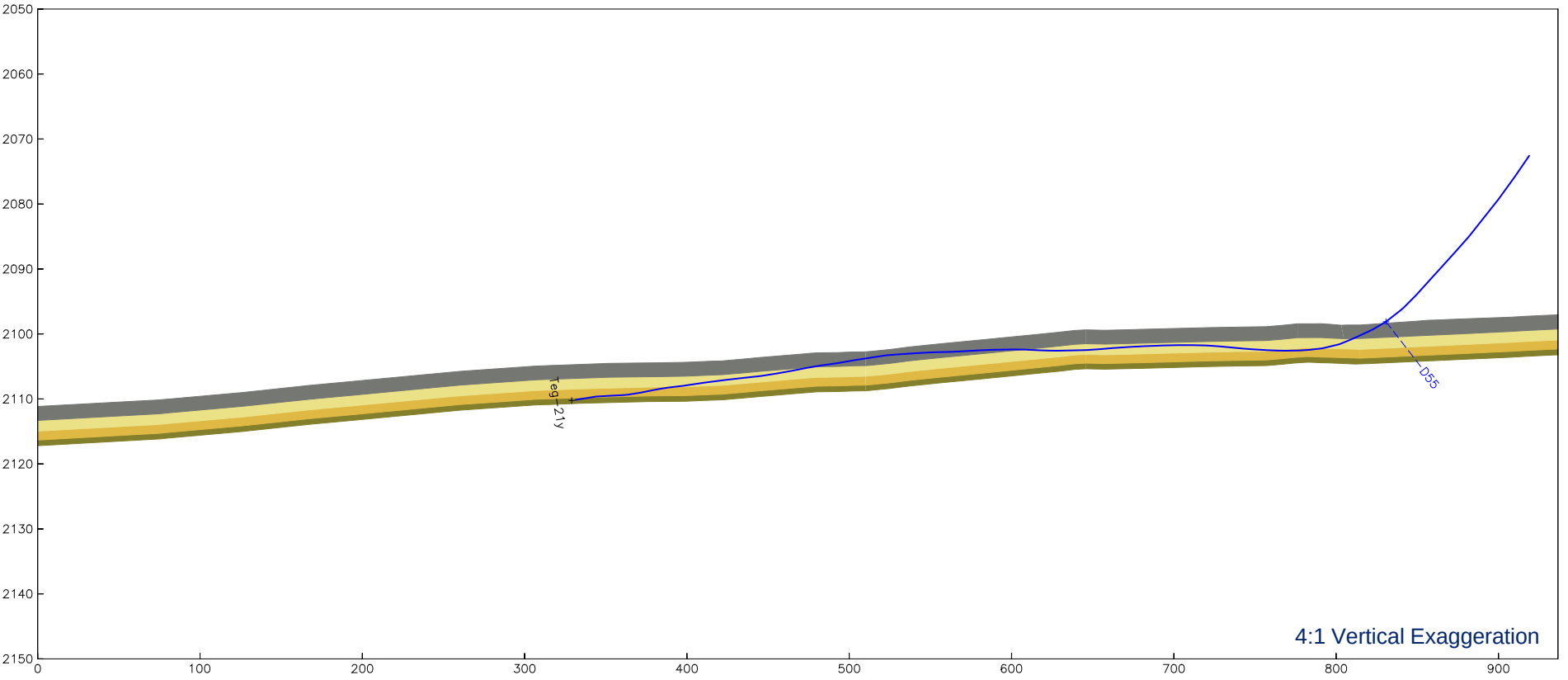

- Communication with GeoPilot lost, drilled ahead blind to gather data on lower D55
- Well TD'ed at 500m md 100% in D55 reservoir

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10th June, 2924m md
0m daily progress, 0m reservoir

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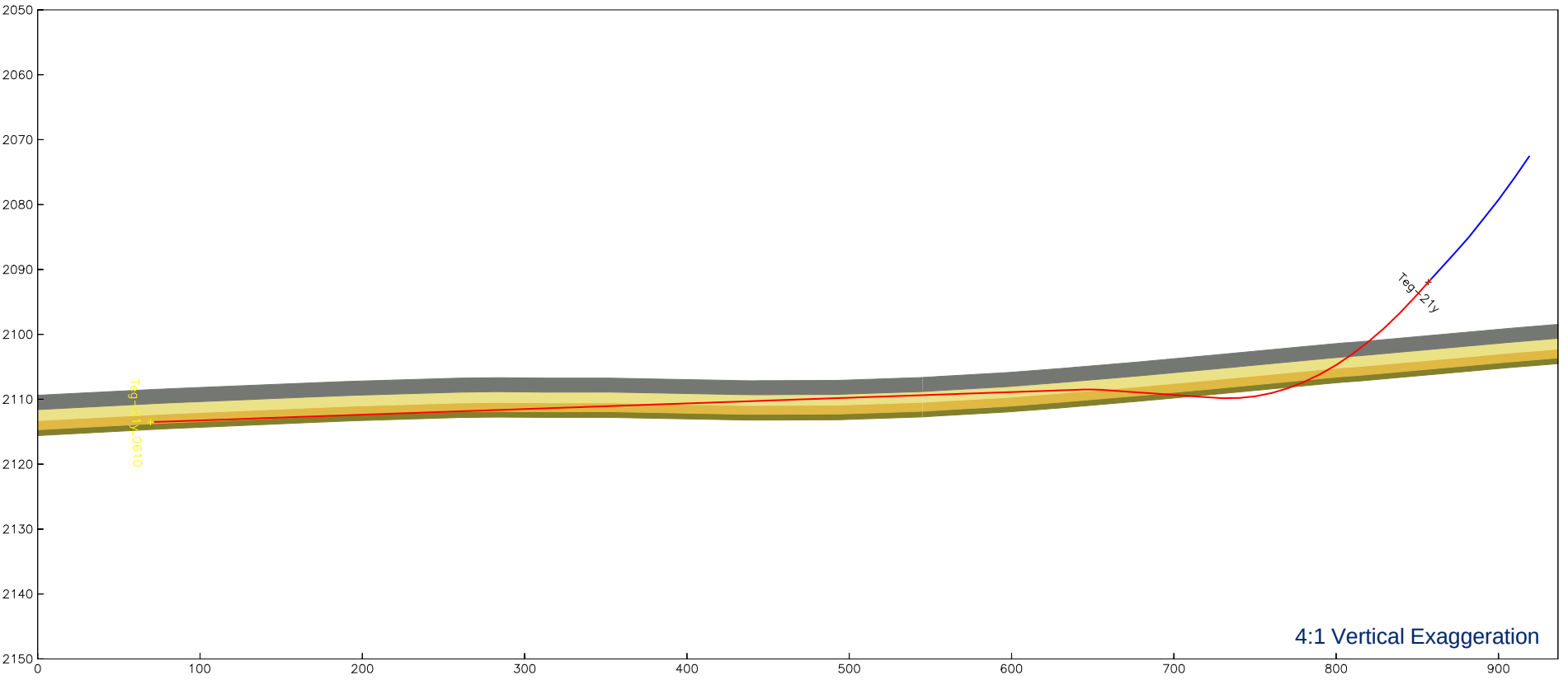

- Model based on Seismic adjusted to Teg-21z results
- D55 subdivided into 4 layers from Teg-21z GR and Density
- GeoPilot max dls assumed to be 4 deg / 30m

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Lateral petrophysical evaluation

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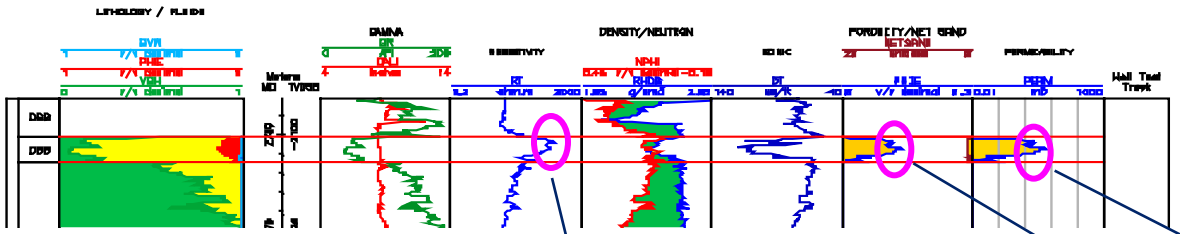
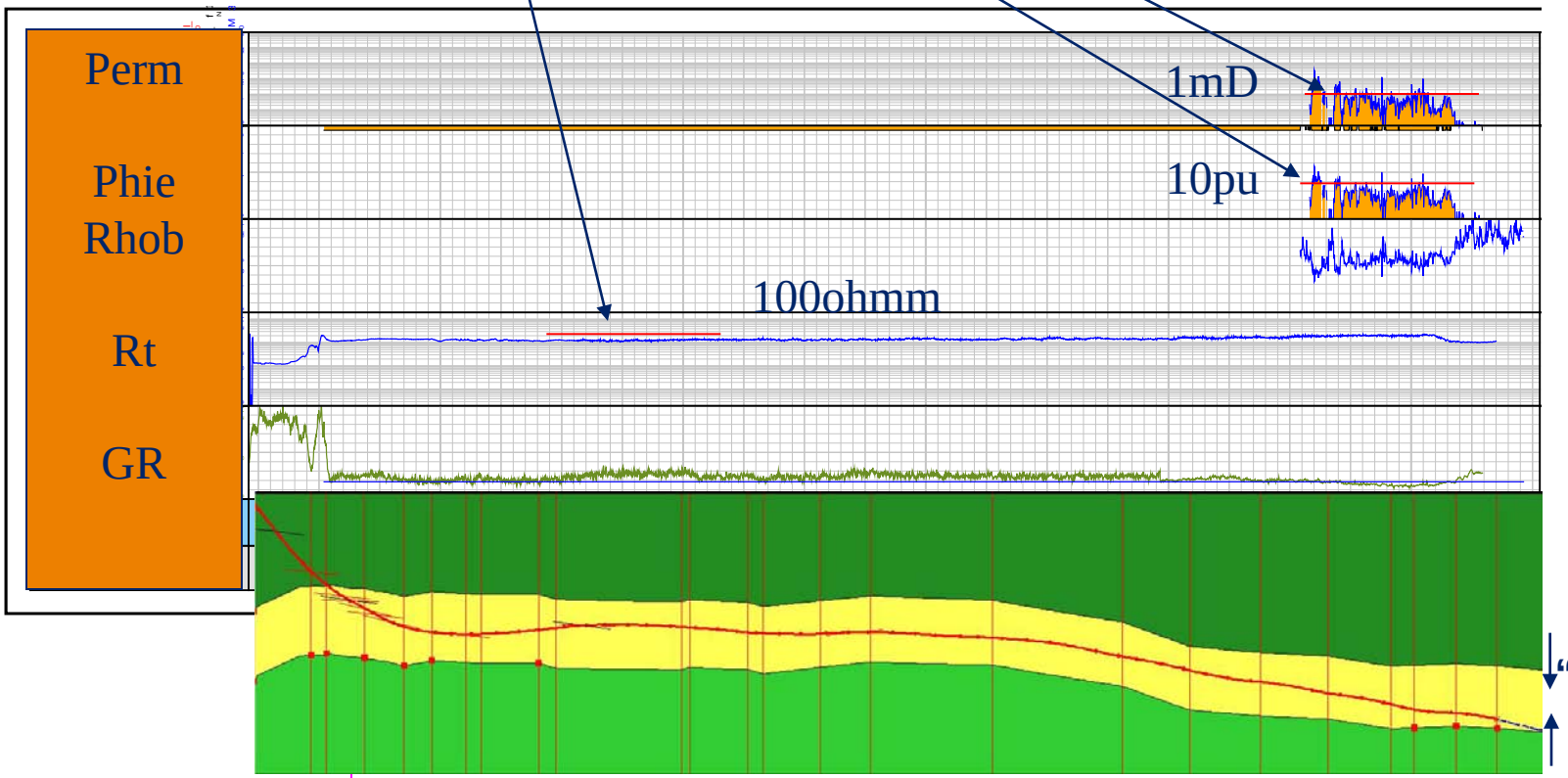
Teg-21z Petrophysical Evaluation



3 m tvd



"Sweet Spot"
3 m TVD

Lateral PDC ROP

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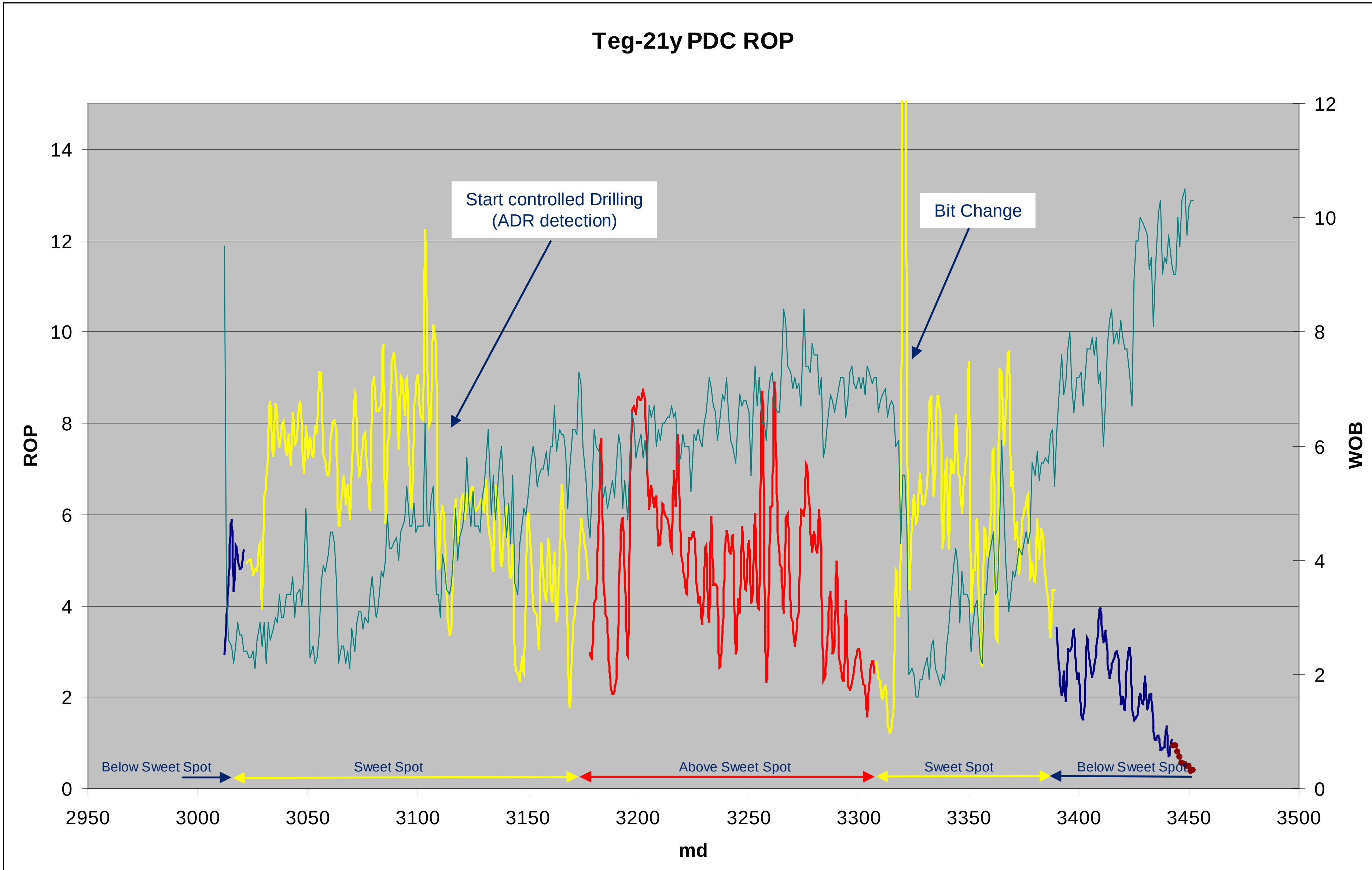

bp
Statoil

TEG-21y (lateral) PLT

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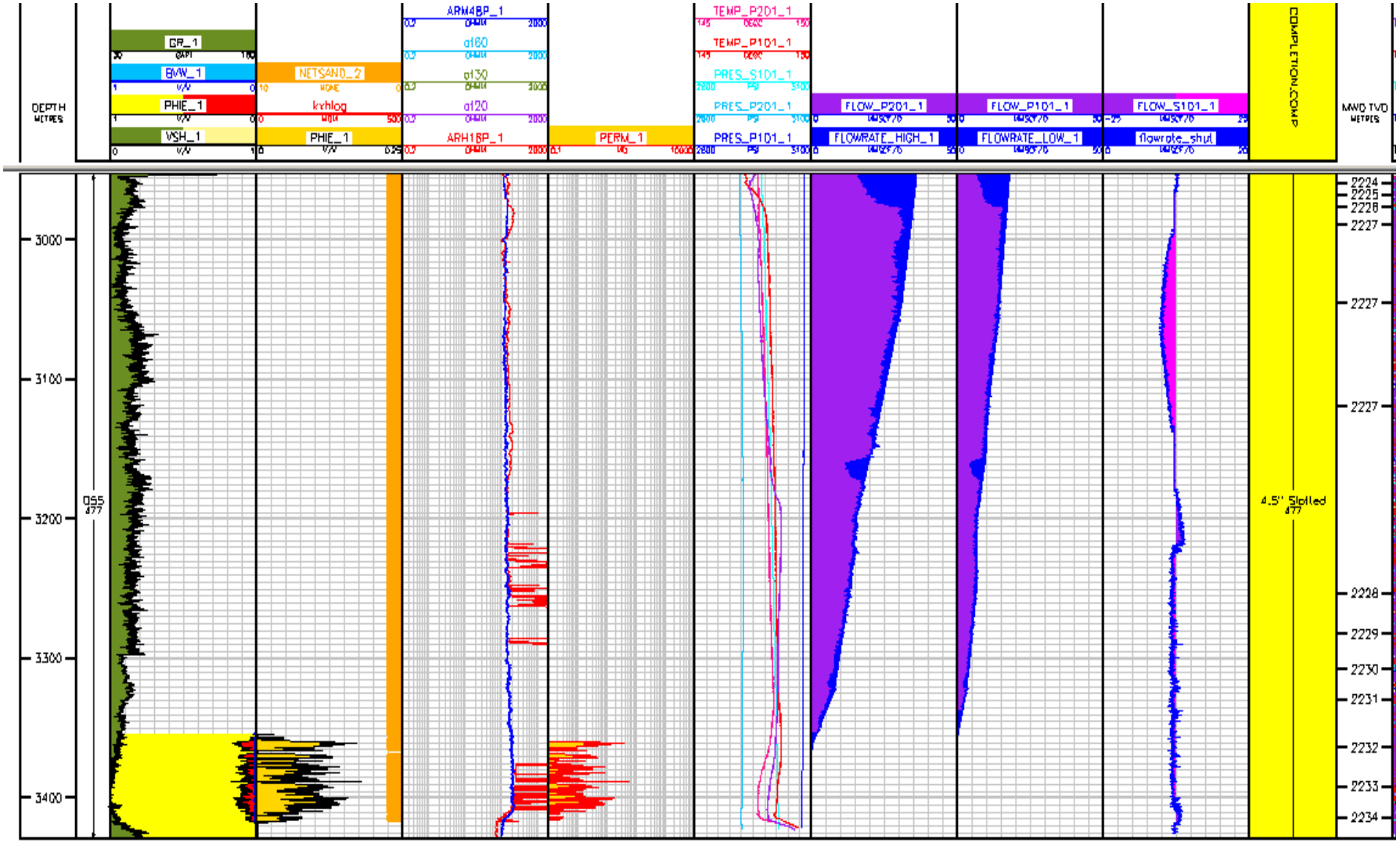

Conclusions

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- Key behaviours for successful geosteering

1. Preparation
2. Good communication
3. Clear instructions
4. Clear understanding of roles and responsibilities
5. Co-Vizualization at office and rigsite

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Thanks

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In Salah Gas Joint Venture

Bp

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Questions?