

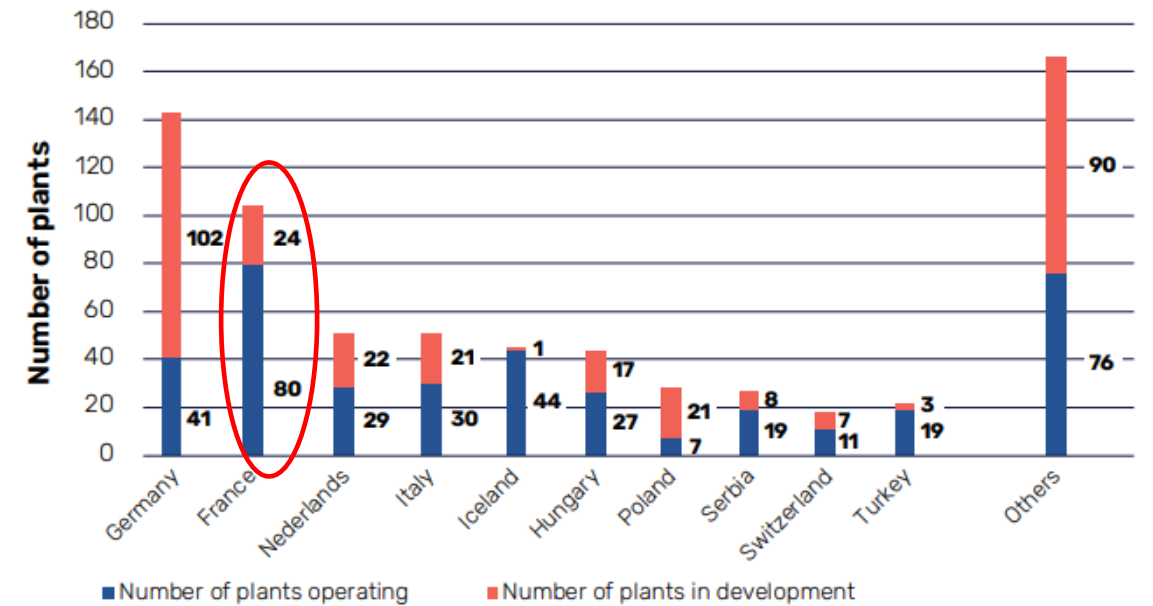
A world's First Geosteering Application in Geothermal

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GeoThermal Heating Districts – France, Paris Basin

- The Paris basin services over 250000 homes with 50 heating network from the Dogger aquifer.
- Over time, doublets aged, and their capacities declined.
- With surface location restrictions in urban regions, subhorizontal wells were found to be a viable solutions to replace old wells and increasing demand.

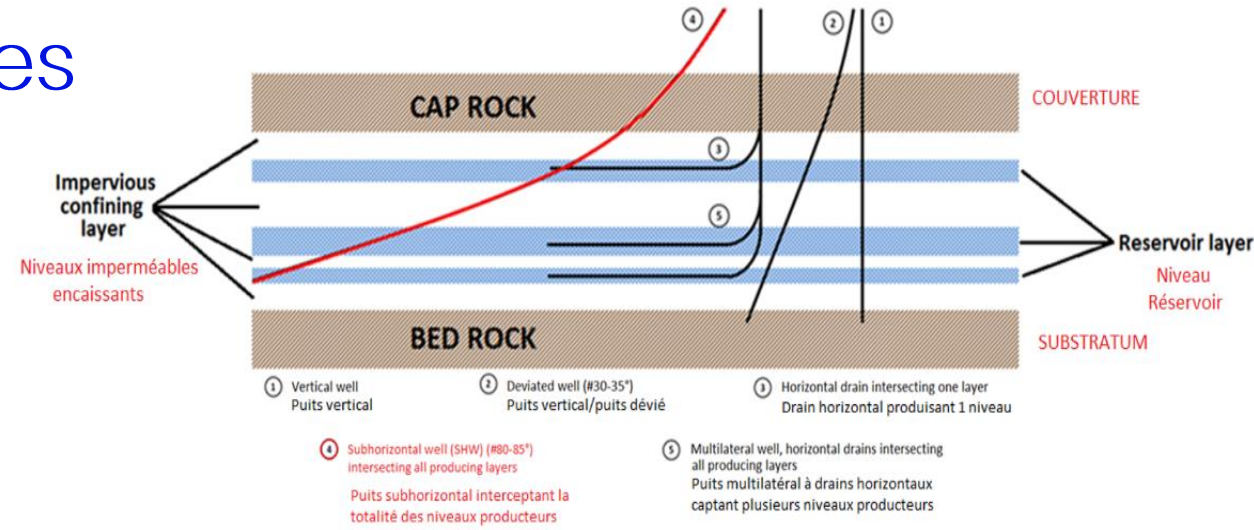
Largest European Geothermal district heating and cooling markets in 2022: number of systems operating and in development



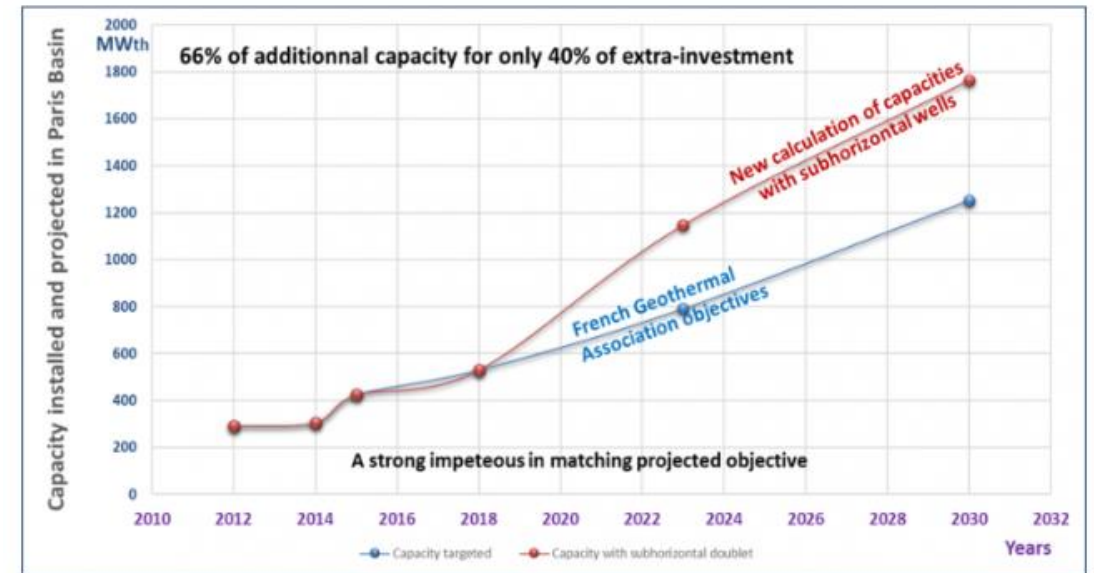
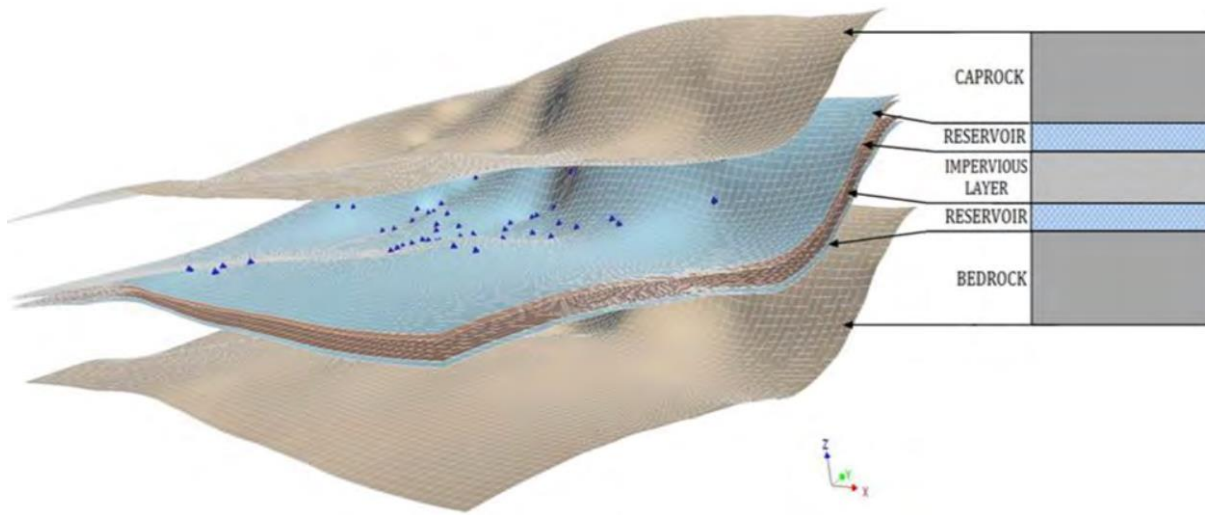
EGEC Geothermal Market report 2022

Reservoir geology and well profiles

Conventional vertical and low deviation wells are being replaced by subhorizontal and horizontal wells to ensure higher exposure to thin reservoir layers.

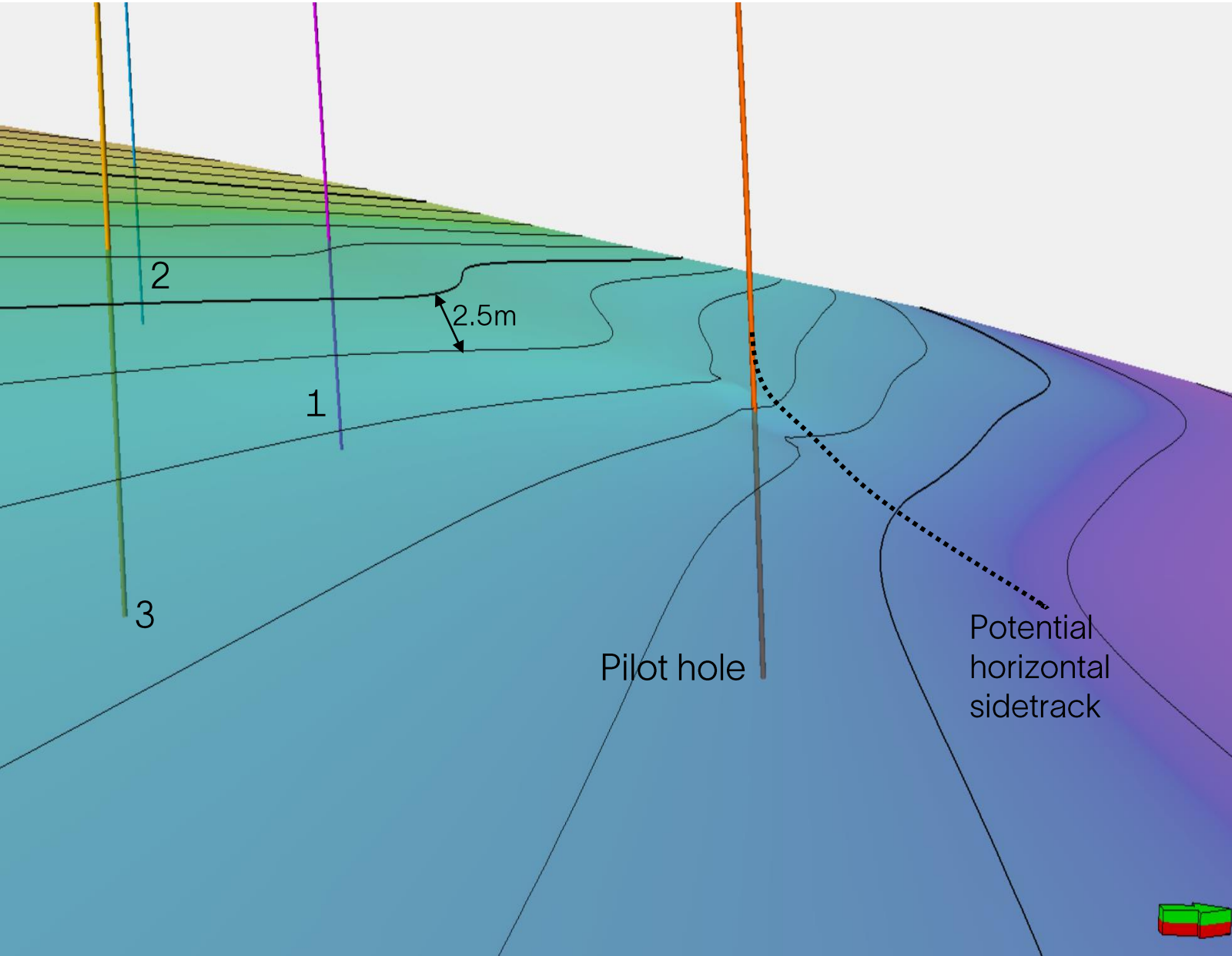


<https://www.geofluid.fr/project/doublet-subhorizontal>



SPE-204012-ms

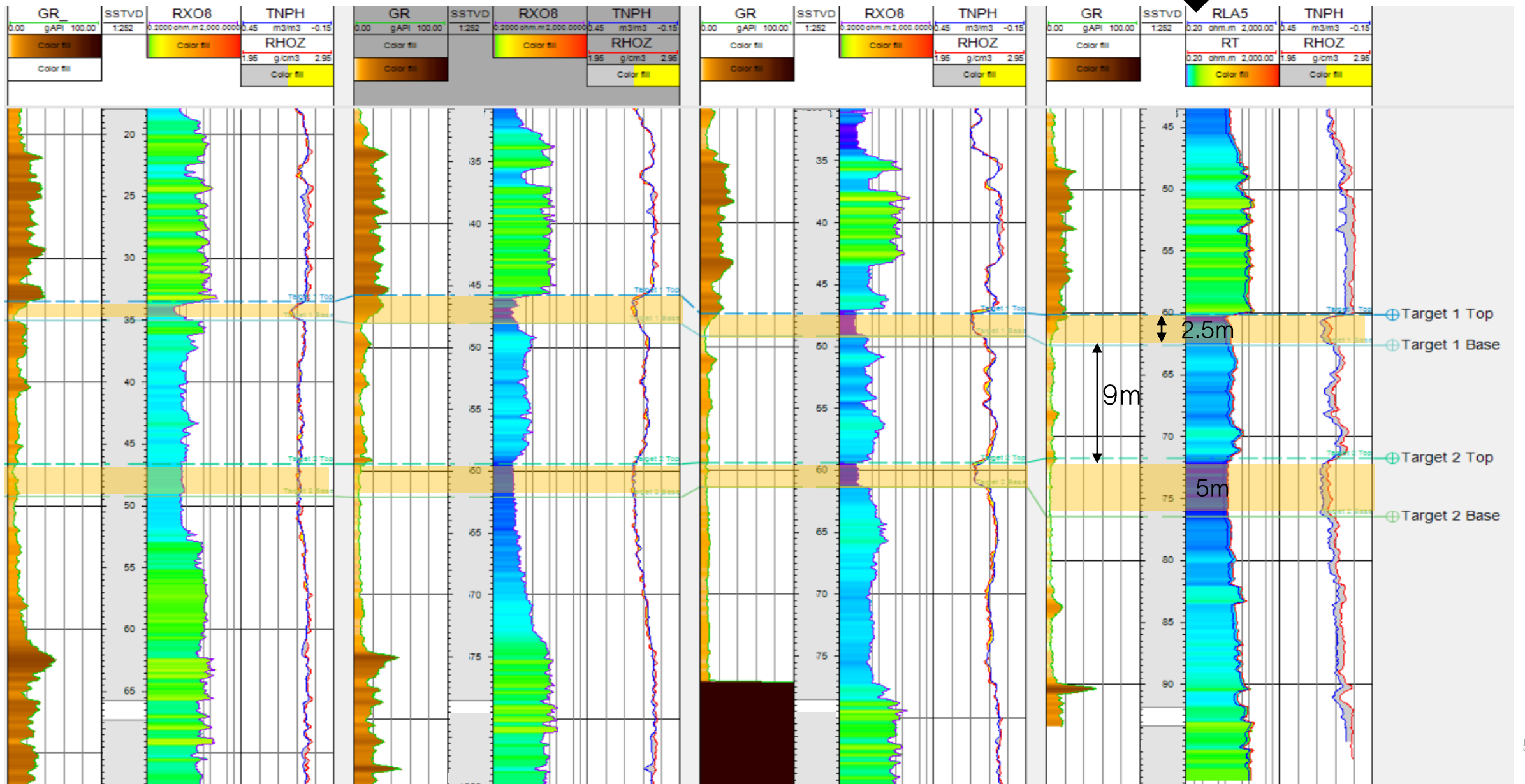
The Grigny doublet



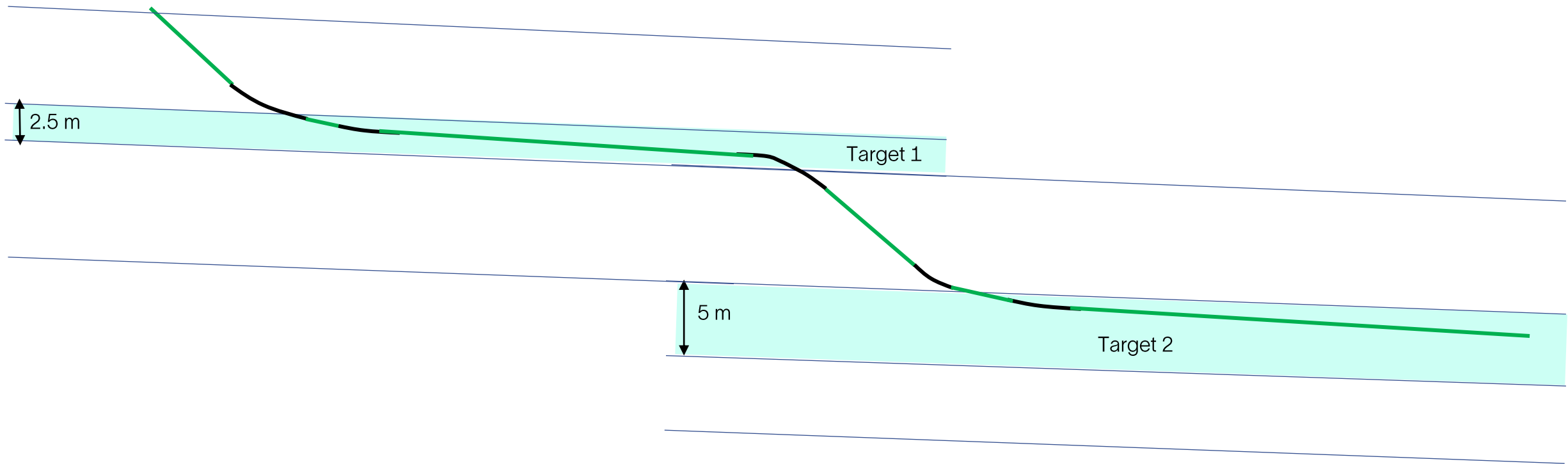
- Initial 3 vertical wells showed large lateral variations in reservoir properties.
- The pilot hole was drilled with the objective to acquire enough data to plan the horizontal sidetrack in the most permeable sub-layers

Reservoir properties across the four wells

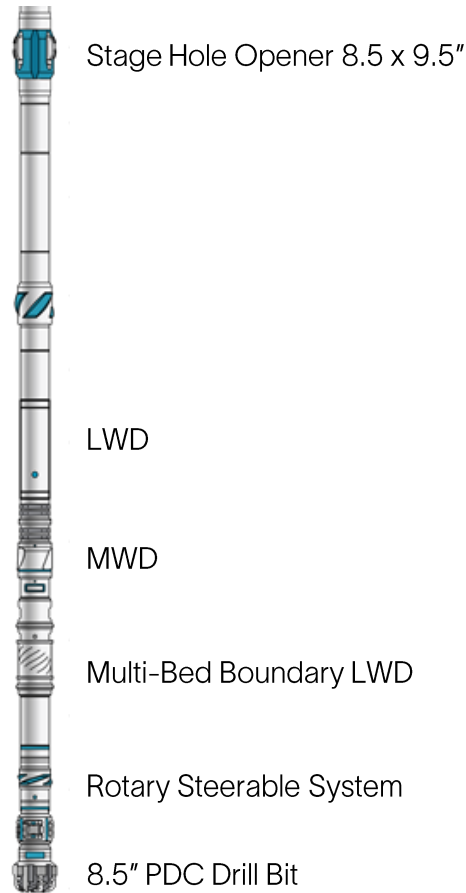
Pilot hole



Final well profile based on PLT results



Drilling Assembly

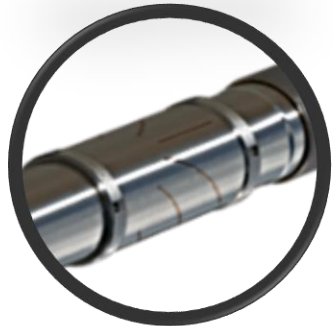


- Advanced Bit cutter selection for durability and performance in the Dogger Limestone
- Push-the-Bit Rotary Steerable System (RSS) for accurate steering control
- Multi-bed Boundary LWD to navigate the reservoir
- Reservoir properties evaluation with LWD to qualify the sweet spot
- Hole Opening While Drilling to enhance flow production

Multi-Bed Boundary Mapping Technology



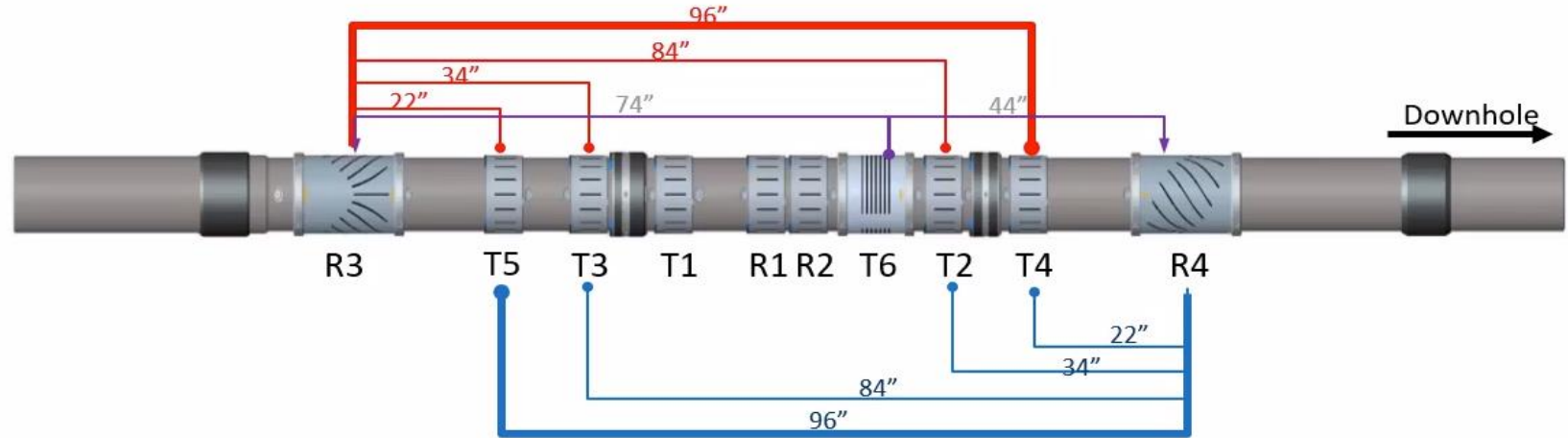
Axial



Tilted



Transverse



NEW DEEP MEASUREMENTS ••••• See >25 ft

BEST IN CLASS INVERSION ••••• Superior continuity, definition & certainty

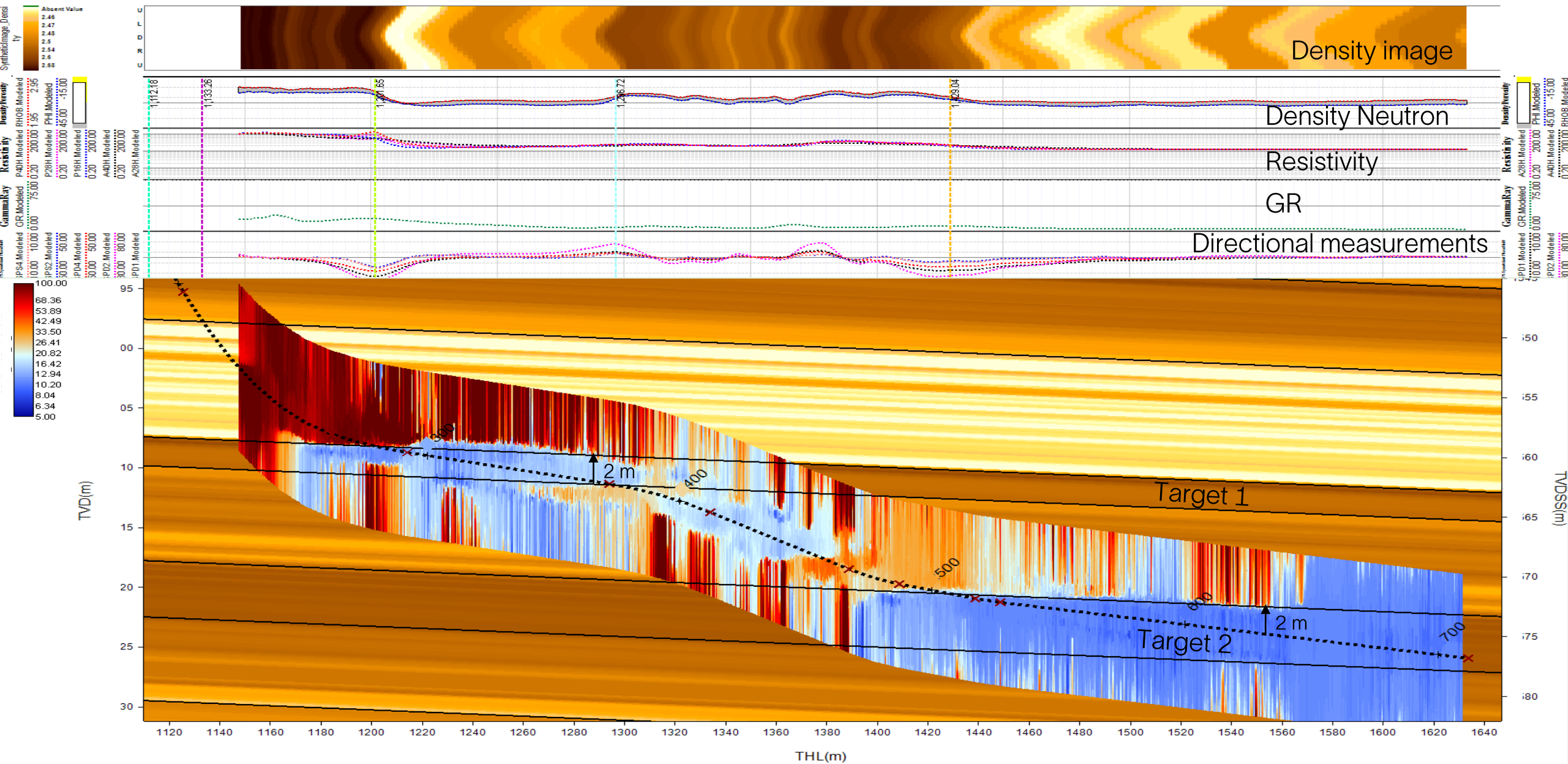
DIGITAL SOLUTION ••••• Faster decision making in collaborative environment

IMPROVED ACCURACY ••••• Multi frequency calibrated EM measurements
New deep EM image

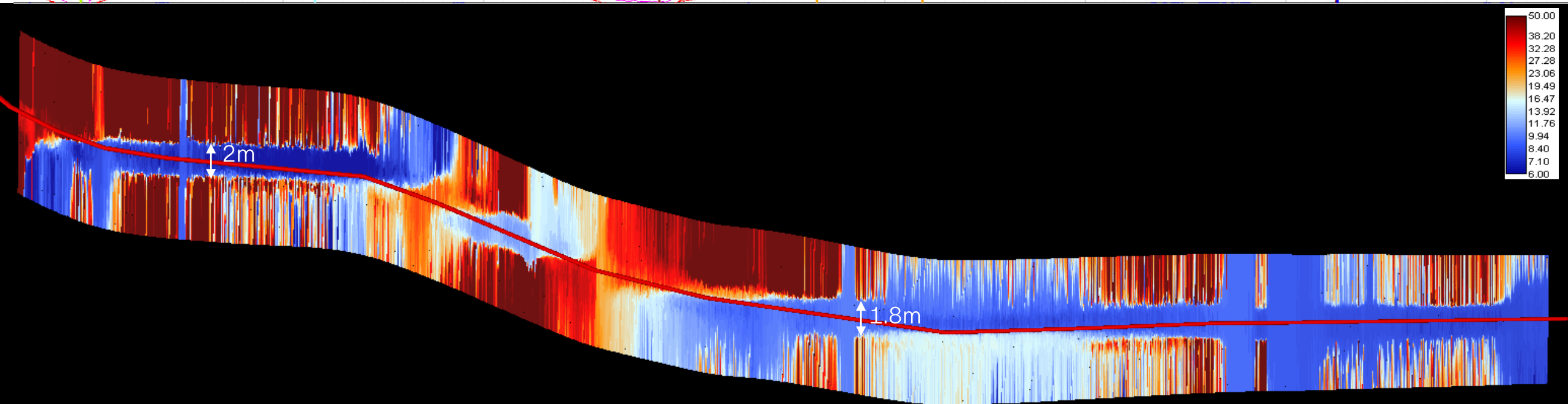
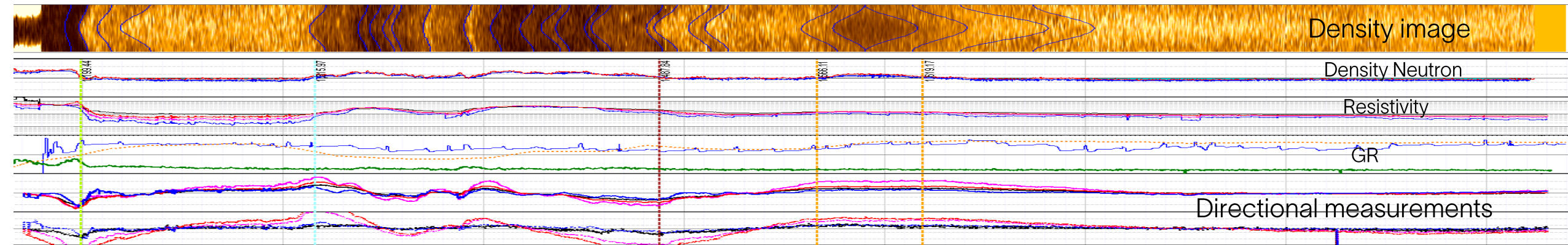
Three Frequencies

100 KHz
400 KHz
2 Mhz

Sensitivity Analysis

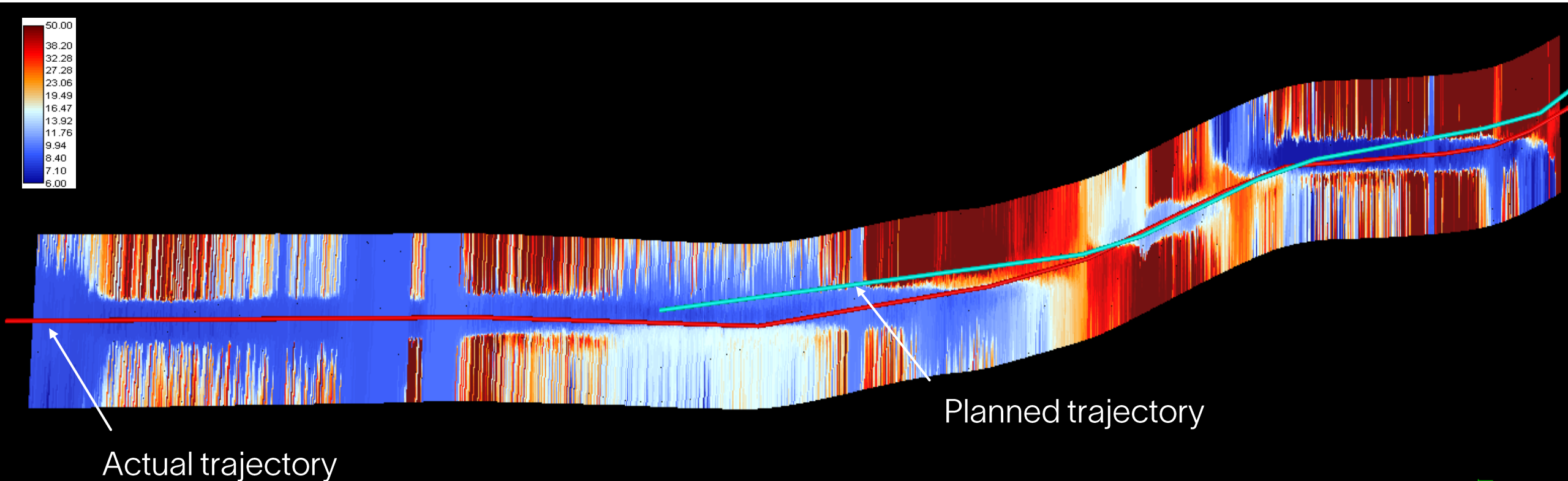


Results - Producer

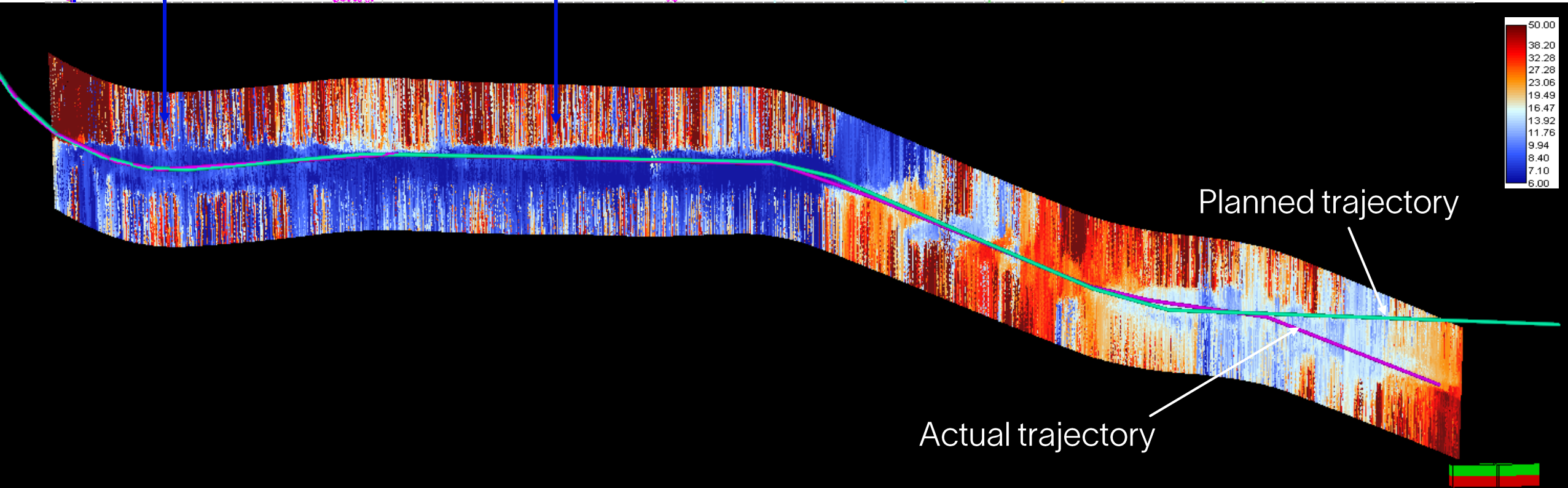
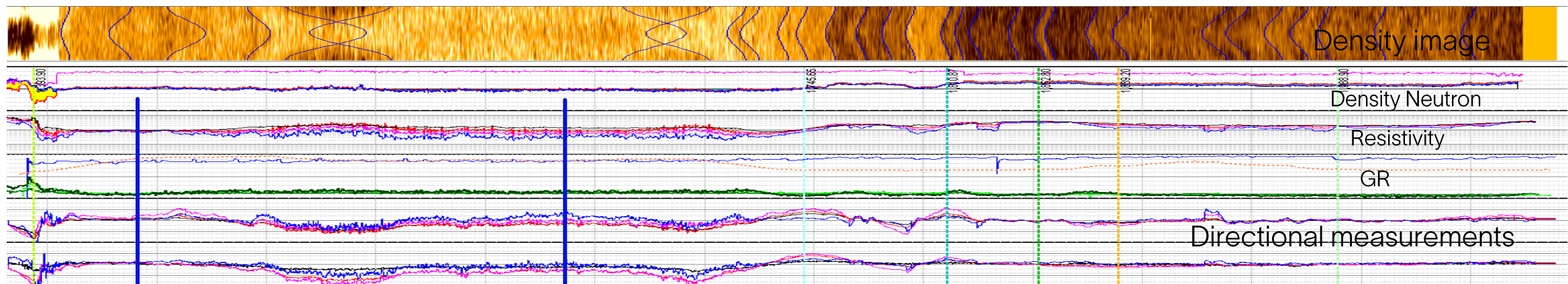


Results – Producer, actual trajectory vs plan

- The original plan was to drill the second target with 88.5 degrees for 200m MD.
- The second reservoir thickness was found to be half of what was logged in the pilot hole.
- Reservoir mapping allowed to extend the horizontal by resolving for the top and base and ensure enough footage is drilled in the most permeable zone to secure the needed production



Results – Injector, actual trajectory vs plan



Conclusion

- The Confidence brought by the Multi-Boundary Mapping technology enabled to optimize the well's production potential with real time decision making. It also led to budget and energy savings by eliminating the second pilot hole.
- The Grigny doublet will provide hot water and heat to residents of about 8,000 homes with renewable energy. This project alone will avoid the emission of 15,000 metric tons of CO2 equivalent per year.
- The planned expansion of the Grigny project to neighboring cities will create a 60km heating network by 2028, providing heat to over 47,000 houses and 100 public buildings. This would contribute to avoiding over 80,000 metric tons of CO2 equivalent per year.



Annual Production	(MWh)
GGR1 / GGR3	63 317
GGR2	14 000
GGR4 / GGR5 (Nouveau doublet)	71 231

