

The Deployment of an Azimuthal Resistivity Tool for Geosteering - A Case Study from the Foinaven Field (North Sea)*

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Abstract

The use of an Azimuthal Resistivity tool has been evaluated on BP's Foinaven Field with the expectation that its ability to look deeper into the rock formation would provide key information on bedding dip and fluid/structural boundaries to greatly improve geosteering capability. The key drivers were to maximise net sand and reduce the likelihood of unplanned sidetracks. This presentation explains the results of Baker Hughes AziTrak tool in three wells and how this has influenced the future deployment of the tool.

The turbidite sands of the Foinaven Field are generally drilled at low angle to bedding. Wells have been previously geosteered using azimuthal gamma and density. However, with limited depth of investigation there is the possibility of exiting sand before the need for a geosteering decision is realised. The azimuthal resistivity tool, in contrast, has a greater depth of investigation which potentially gives much better predictions of fluids and lithology above and/or below the well bore.

The Azimuthal Resistivity tool was initially evaluated in Foinaven P111 well. The Azimuthal Gamma and Density were run and used for geosteering in real-time with the Azimuthal Resistivity run in memory mode to permit later assessment as a future logging option. The results showed that the Azimuthal Resistivity tool could have been used to inform better geosteering decisions, potentially saving time and cost of additional sidetracks. The Azimuthal Resistivity tool was subsequently run in P16Z, real-time, and resulted in (i) avoiding the premature exit of a thin sand body by identifying an underlying conductive shale bed, (ii) recognising a key channel transitions, and (iii) confirming the presence of a water-wet sand below the bore thereby initiating an earlier than usual decision to steer up.

Finally, the Azimuthal Resistivity tool was run in well P43. The trajectory was planned to cross a series of turbidite channels with limited scope for geosteering. The high resolution of the Azimuthal Resistivity tool did, however, provide information on the dip and thin-bedded nature of the channel sands and influenced the decision to turn the well trajectory downwards at the toe of the well to pick up additional net sand. Based on the above experience it is concluded that Azimuthal Resistivity data can usefully influence trajectory decisions where there is flexibility to geosteer. Where trajectories are more geometric, then Azimuthal Resistivity is less useful.



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Outline



- What successful Geosteering looks like
- Foinaven field – background
- Azimuthal Resistivity Tool – design
- Azimuthal Resistivity Tool – data received
- Pilot study in P111
- Azimuthal Resistivity for Real-Time Geosteering – P16z
- Azimuthal Resistivity for Real-Time Geosteering – P43
- Conclusions



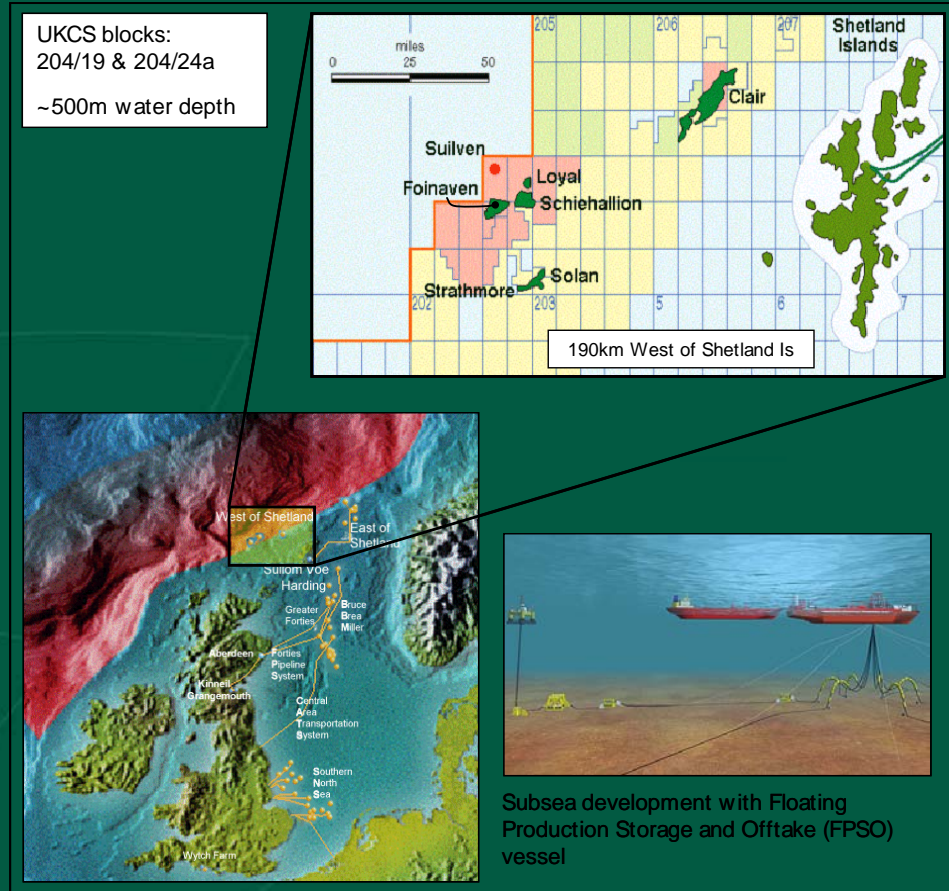
What successful geosteering looks like

- Success criteria
 - Maximising contact with net sand
 - Understanding which are the best sands to geosteer
 - Avoiding water
 - To know which direction to geosteer
 - TD early
- Evolved Foinaven Enabling strategy
 - Cut down through stratigraphy before geosteering – provides a lookahead to which sands to geosteer especially in low n/g sands
 - Use imaging tools (GR and density) to geosteer
- Wishlist
 - An azimuthal tool which looks ahead or deep into the formation to see roof, floor, next sand, water.

Foinaven Field Background



- UKCS blocks 204/19a, 204/24a & 204/25b
- Main field + East Foinaven + T35 + T25
- ~500m water depth
- Good quality Tertiary Turbidites @ ~2200 m tvdss; 26 API crude
- Sanctioned in 1994 @ 200 mmbbls;
 - 1st prod Nov-97 - produced by Jun-04
- STOIP _[01/10] 1.4 bnbbbls
- Produced _[01/10] 304 mmbbls of oil

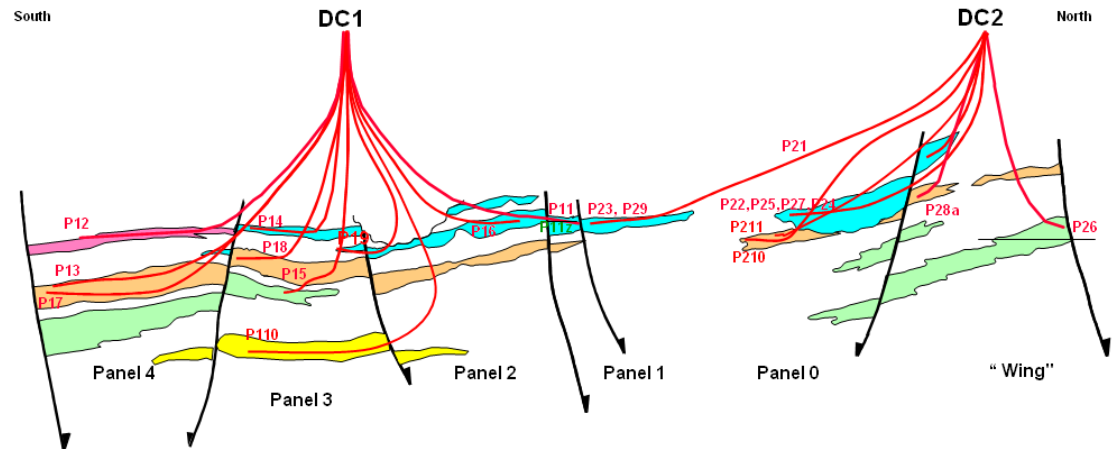


- Drilled to date: 26 producers, 12 water injectors, and gas disposal well (2 water injectors currently being drilled)

Foinaven Field and Reservoir Layering



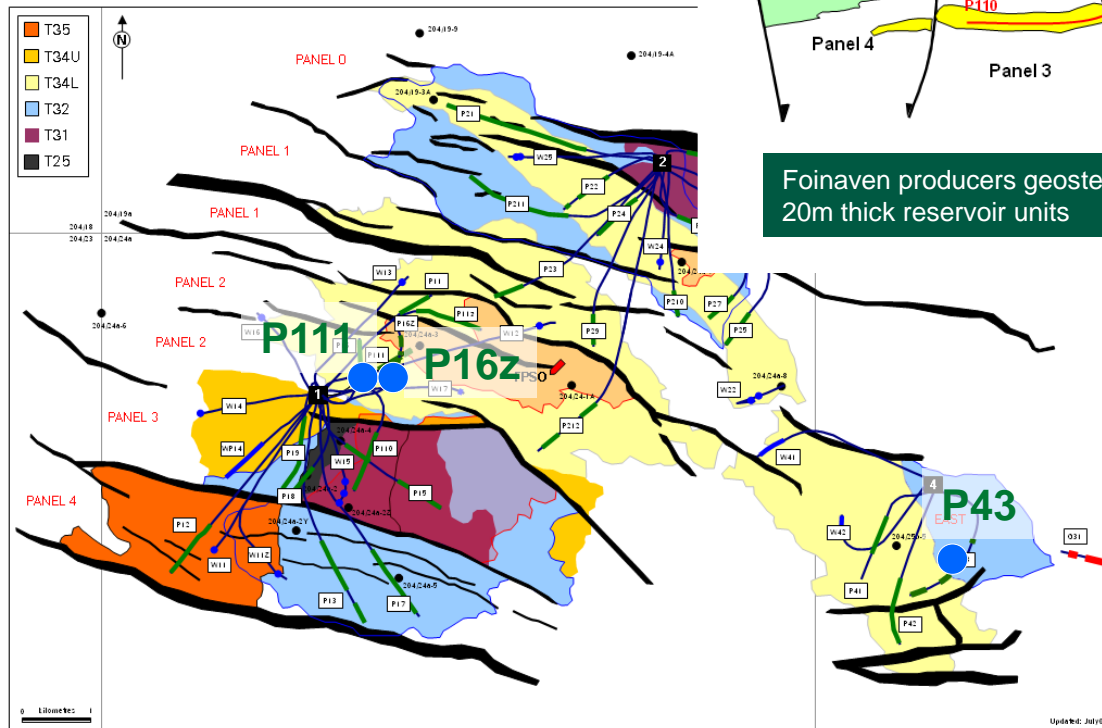
Reservoir Layering Scheme



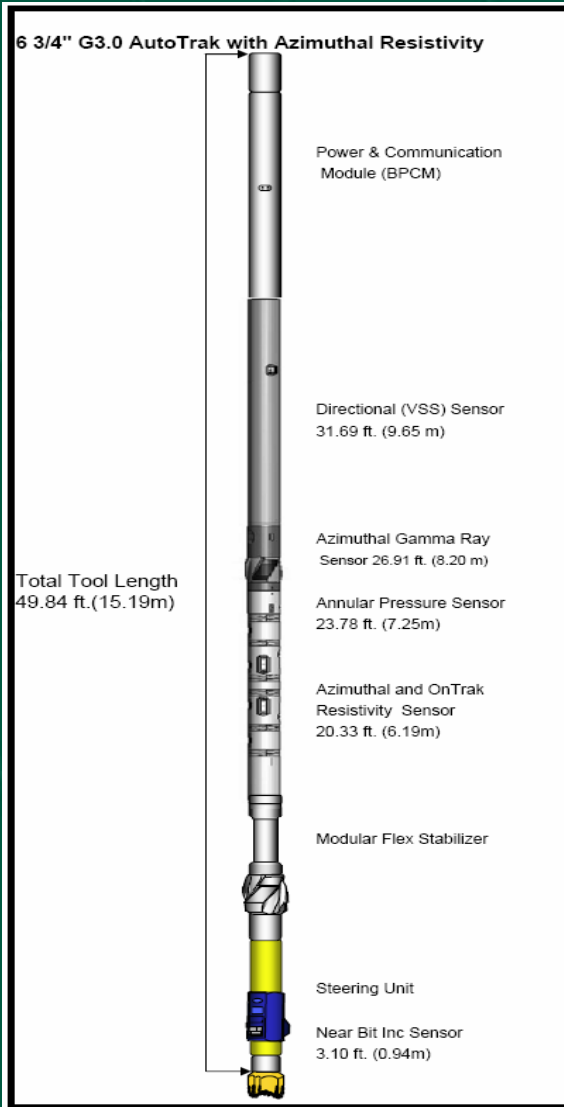
Foinaven producers geosteered in 10-20m thick reservoir units

Reservoir
T35
T34
T32
T31
T25

Horizontal Scale 1Km
Vertical Scale 0 50 100m

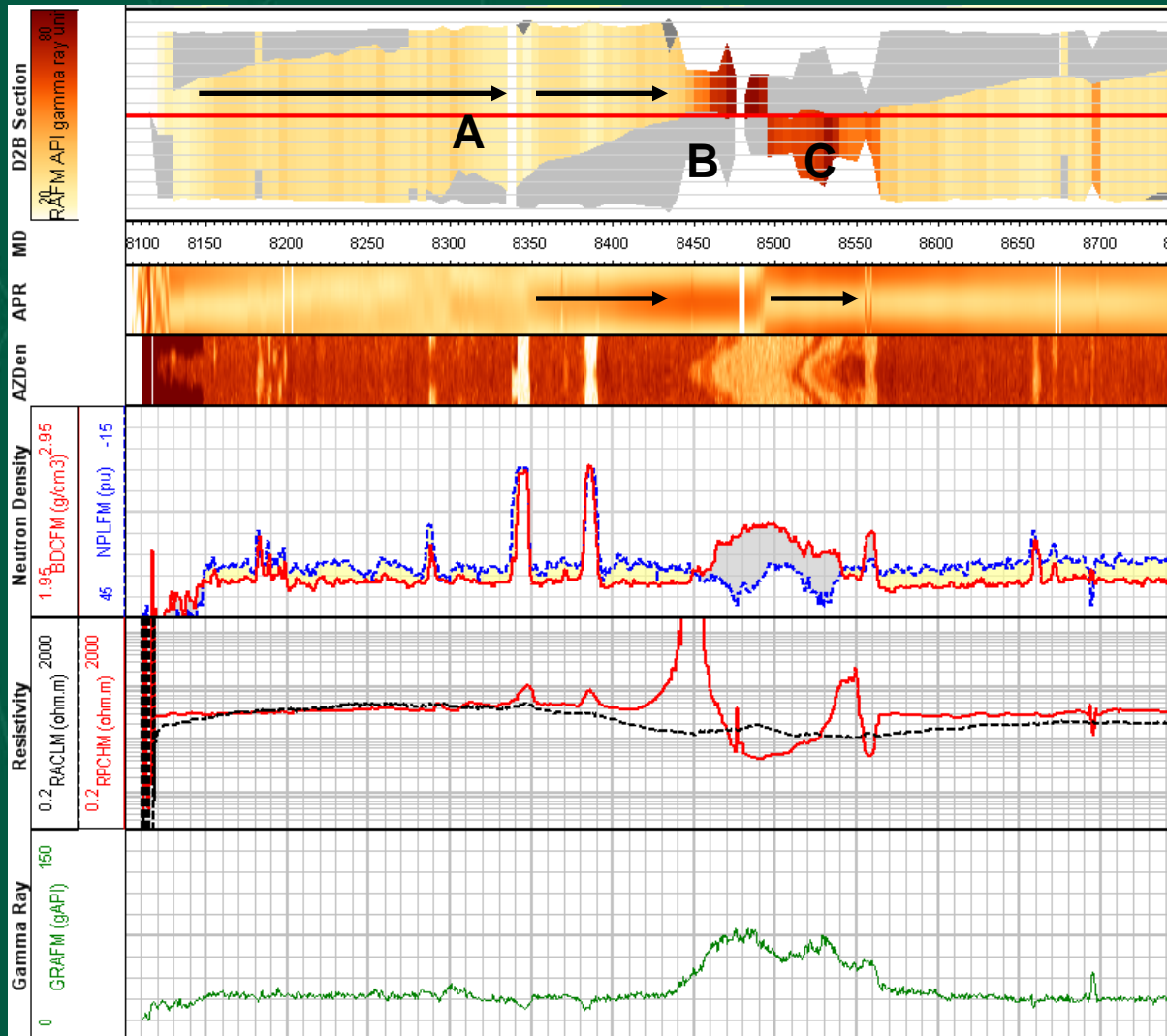


Azimuthal Resistivity tool: AziTrak™



- Provides a deep reading azimuthal resistivity measurement (bed boundary detection).
- Provides the direction and the distance to bed for boundaries up to 17 ft (5 m) away from the borehole
- This means:
 - the ability to optimise bit position within the reservoir with respect to stand-off from a fluid or lithological boundary.

The Azitrak tool – data received



Distance to bed shows depth of detection and distance to boundary

Azimuthal Resistivity

Azimuthal Density

Entered reservoir sand at 8100ft

A. Depth of detection ~4m, shows sand below but encroaching shale seen from 8300ft

B. Shale encountered at 8450ft, DOD limited to ~1.5m

C. Re-entry of sand indicated by Azimuthal Resistivity at 8490ft & moving away from bed boundary (cf Azimuthal image brightening)

Foinaven P111 Objectives and Plan

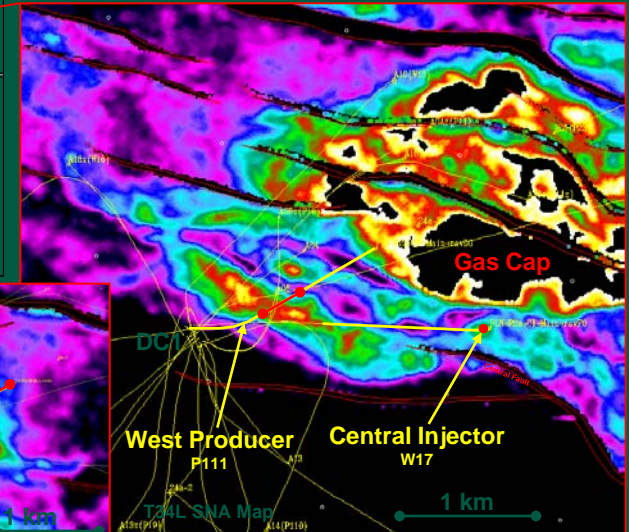
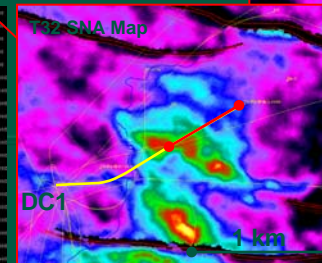
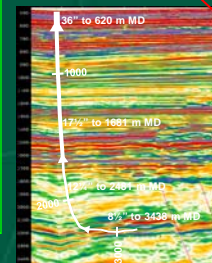
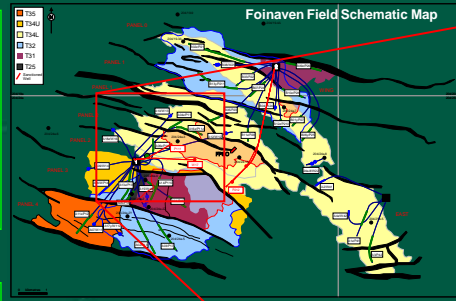


P111 Objectives

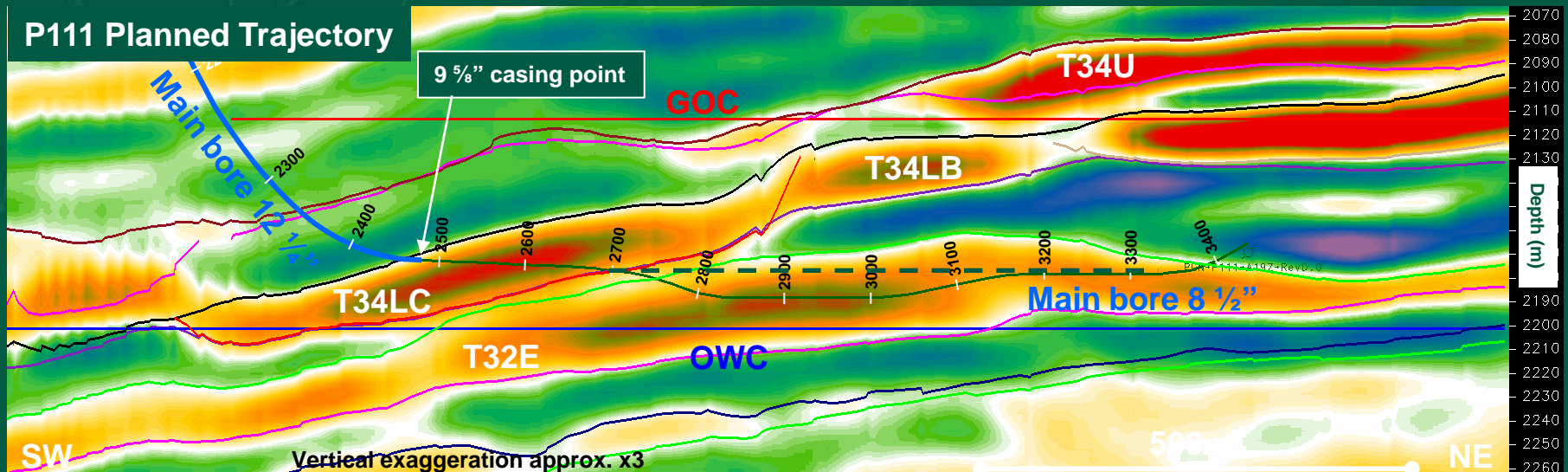
- Access reserves in the T34LC and T32) sands by drilling approximately 960m of 8 ½" hole.
- Dual zone producer on west flank of Panel 2

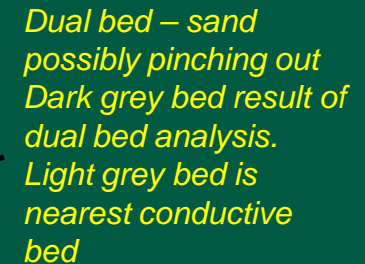
Data Acquisition

8 ½" hole: azimuthal GR, Res (2MHz, 400 KHz), Azimuthal Density, Neutron. Pressures (TesTrak). LWD NMR (MagTrak) Azitrak run in **memory mode**



P111 Planned Trajectory



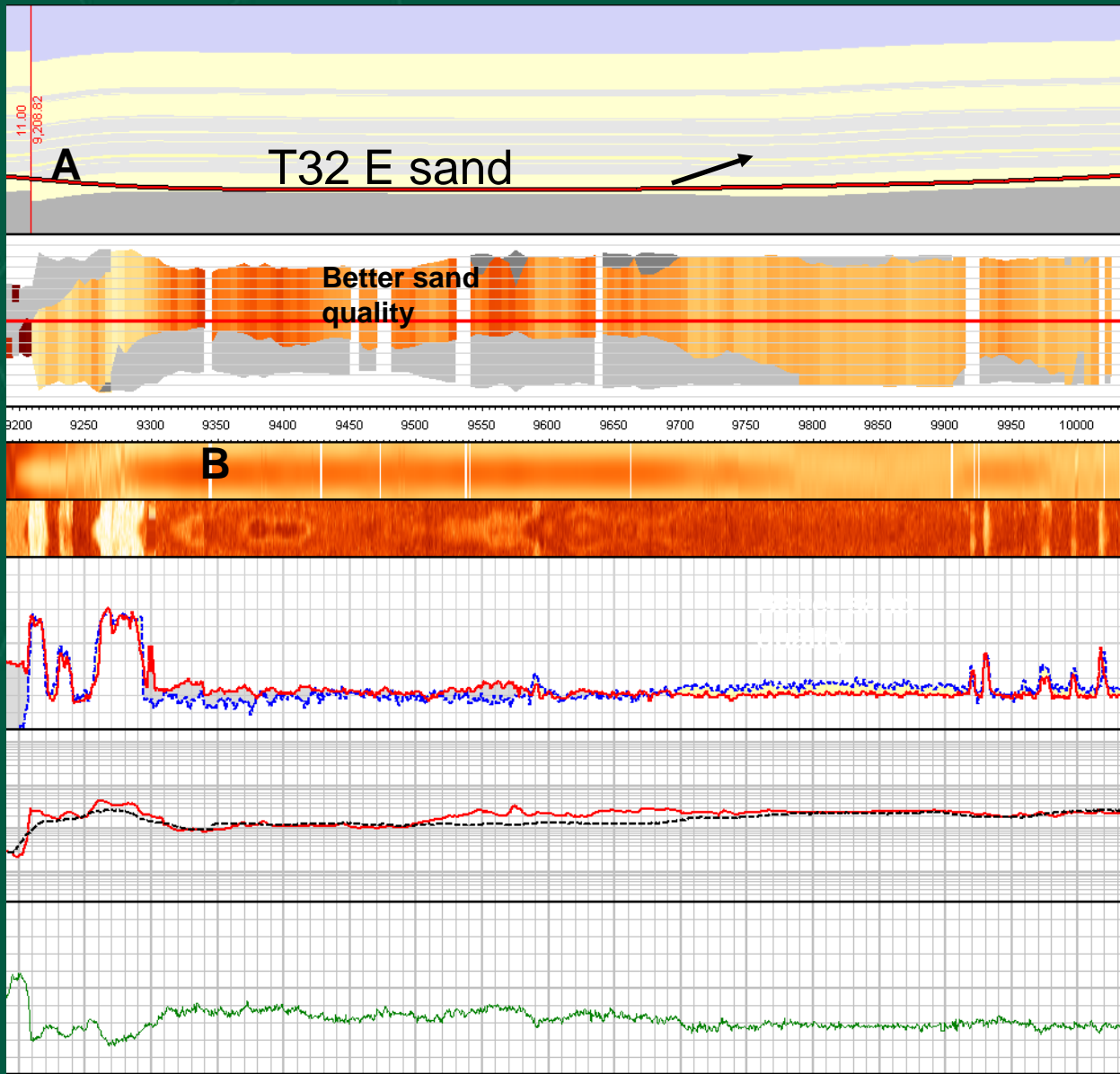


A. Depth of detection ~4m,
shows sand below but
encroaching shale seen from
8300ft

B. Shale encountered at 8450ft, *DOD* limited to ~1.5m

C. Re-entry of sand indicated by Azimuthal Resistivity at 8490ft & moving away from bed boundary (cf Azimuthal image brightening)

P111 Part 2 Azimuthal Resistivity evaluation



A. Cut down stratigraphy according to plan

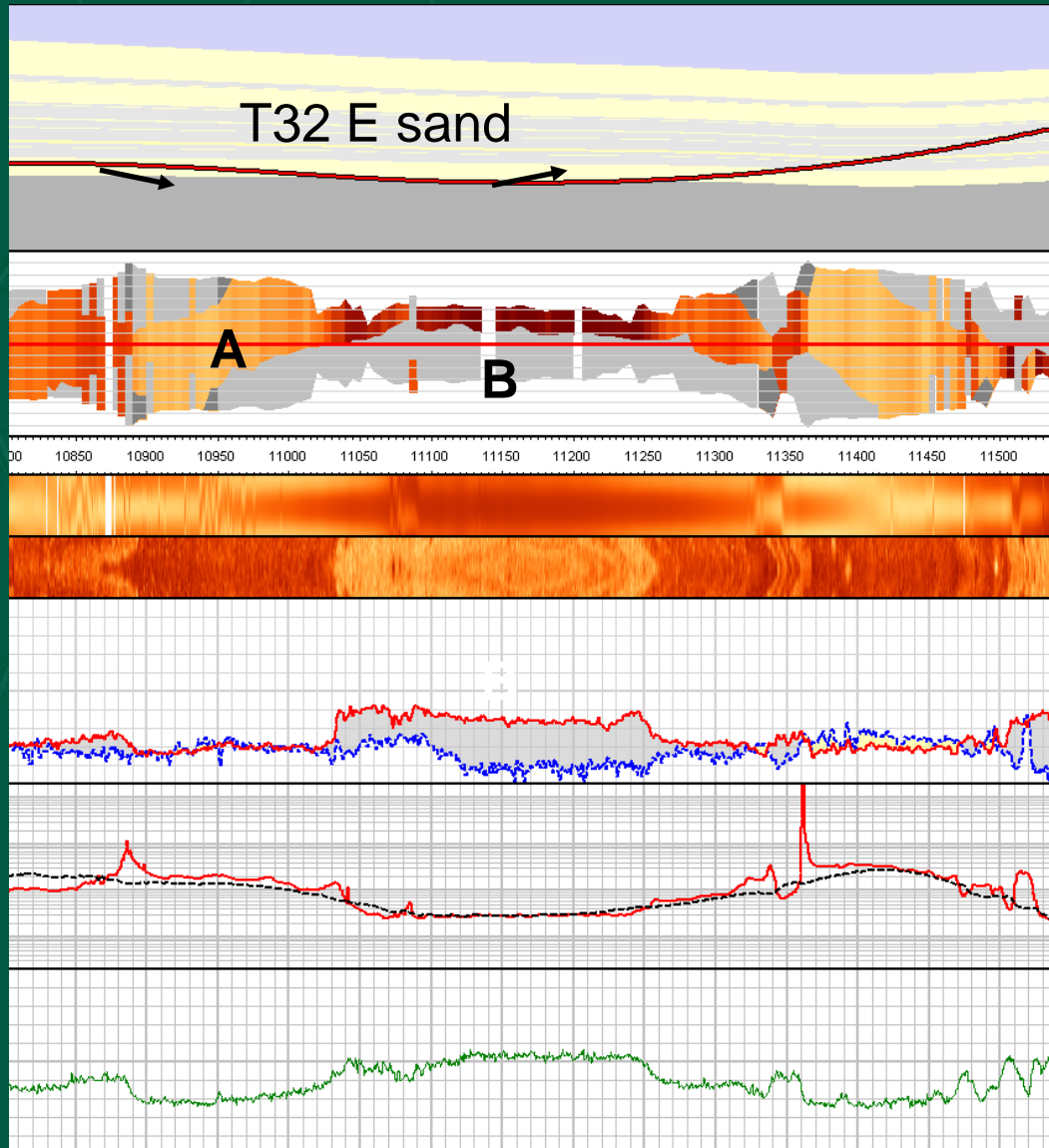
T32 – poor sand quality

B. Drilling bed parallel – AziRes indicates better quality rock above than below

Decided to steer upwards at 9670ft to find better sand

Azimuthal resistivity suggests we could have made this decision >200ft earlier

P111 Part 3



Found poor sand. At 10860ft pushed wellpath down to find sand suggested by seismic.

Encountered floor of T32, trajectory raised from 11115ft

Azimuthal Resistivity & Distance to Bed data would have:

A. Predicted shale below

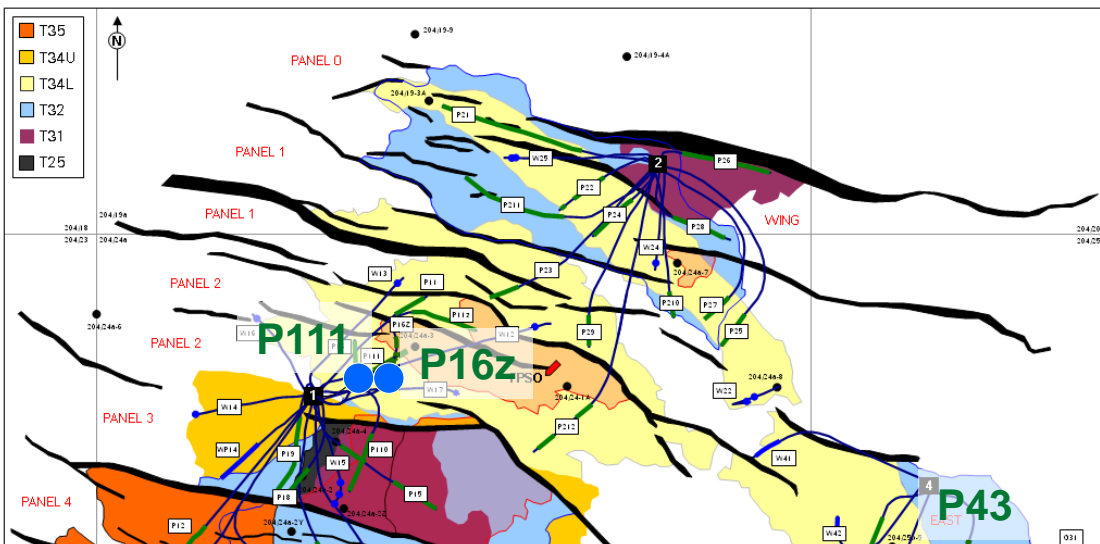
B. prevented ~200ft of shale from being drilled



P111 Conclusions – Pilot in Memory Mode

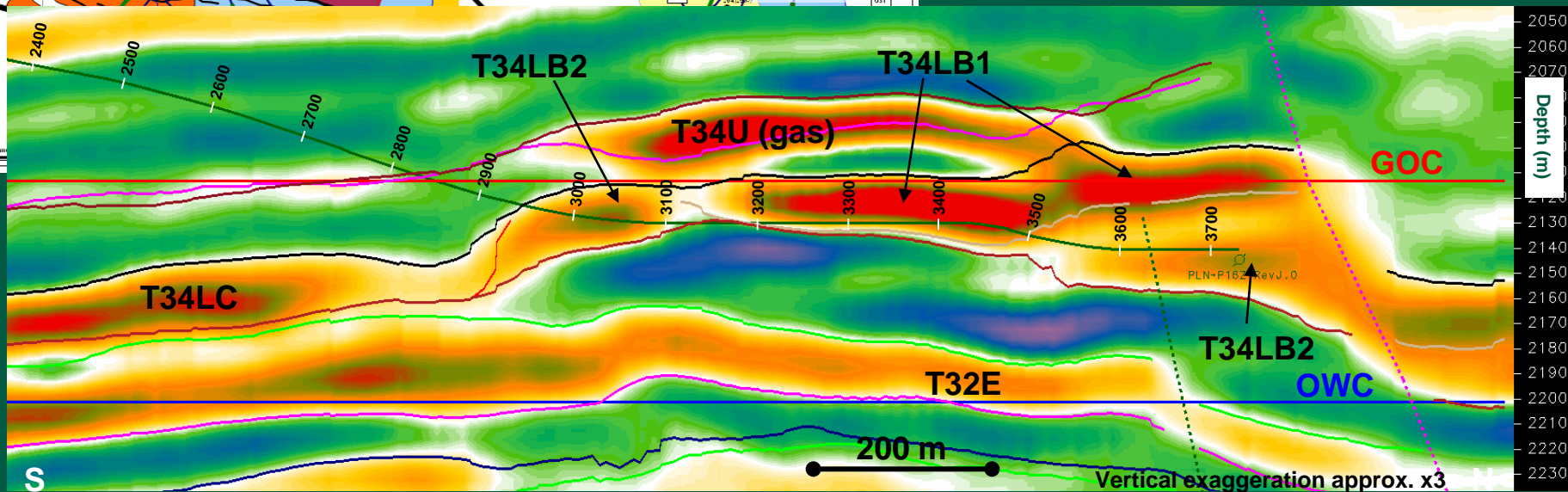
- Strategy of cutting stratigraphy in initial downpass provides a look-ahead to target best sand
- AziRes foresaw thin intermediate shale in T34L C sand. Azimuthal Res confirms shale is thin
- AziRes would have prevented a steer down in the latter part of T32E with resultant drilling of >200m of shale
- Decision to steer upwards into better sand in the T32 E unit would have been made much earlier with the Azimuthal Resistivity data
- **Based on these advantages Azimuthal Resistivity was used in Real-Time in two subsequent wells**

P16z Objectives

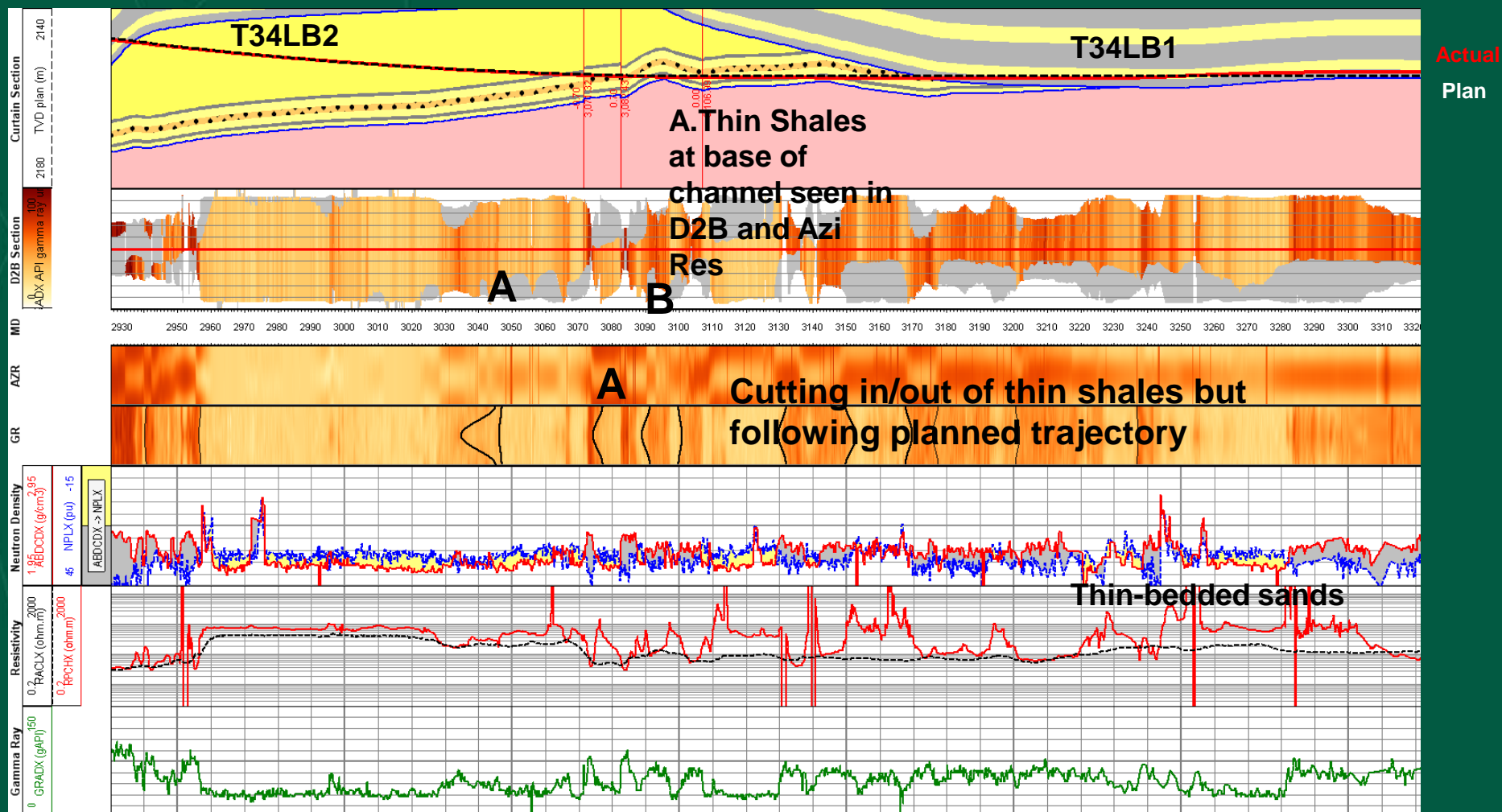


P16Z Objectives

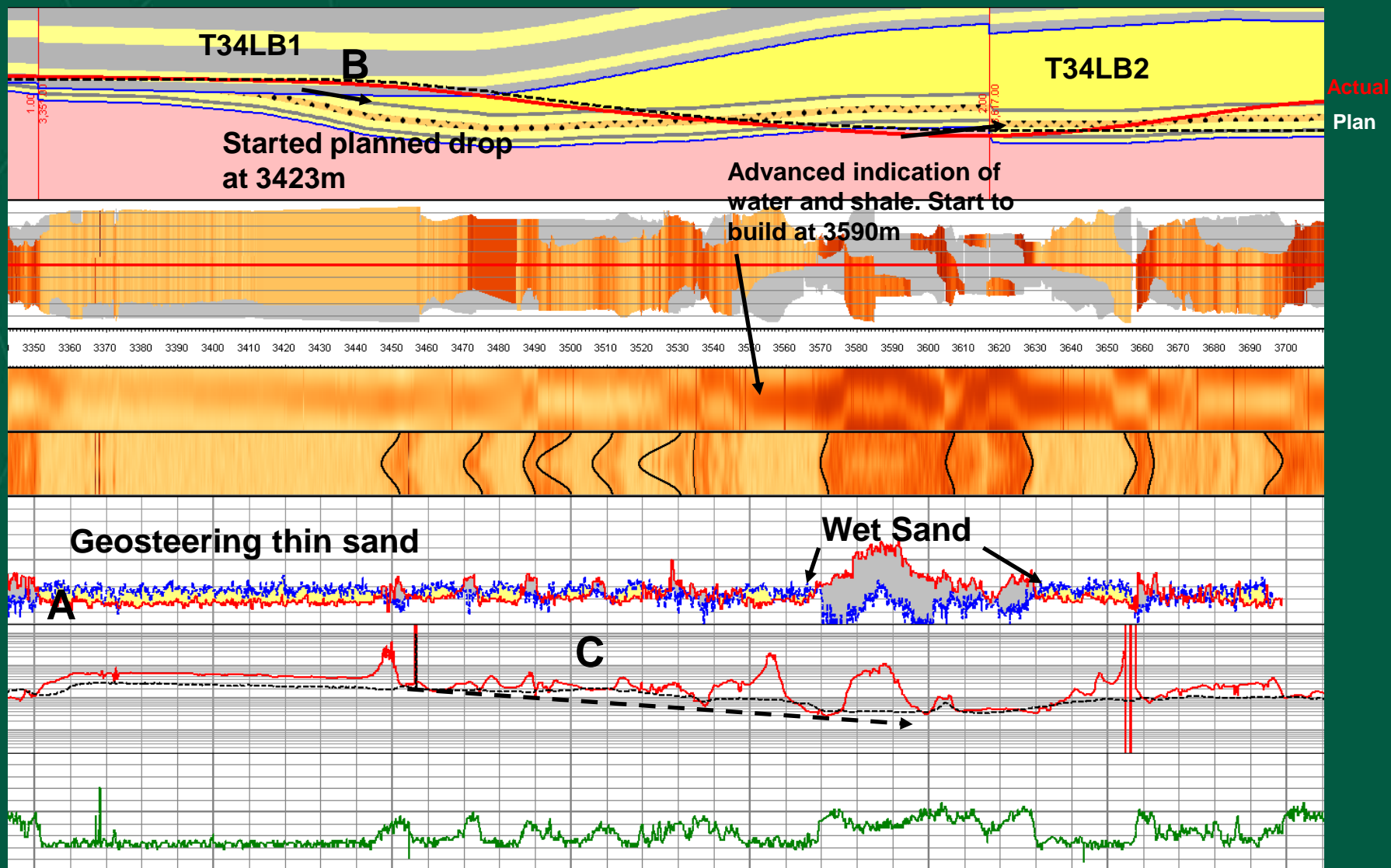
- Sidetrack P16 to an up-dip location east of the current location and extend into Panel 2 North.
- Mill a 9 5/8" window at ~2010 m MD in P16. Drill approx. 1720 m of 8 1/2" hole to TD, including 785 m of reservoir section (T34LB1 and T34LB2 Sands).
- Avoid drilling gas-cap



P16z RT Azimuthal Resistivity - 1



P16z RT Azimuthal Resistivity - 2



P16z Conclusion



- Limited room for Geosteering in P16z due to stand-off from gas-cap but
 - Azimuthal resistivity helped to identify basal shales in B2 sand.
 - Successfully geosteered sands in B1 channel.
 - AziTrak was able to confirm the presence of the water-wet sand and prove it was below the bore, initiating the decision to steer up.

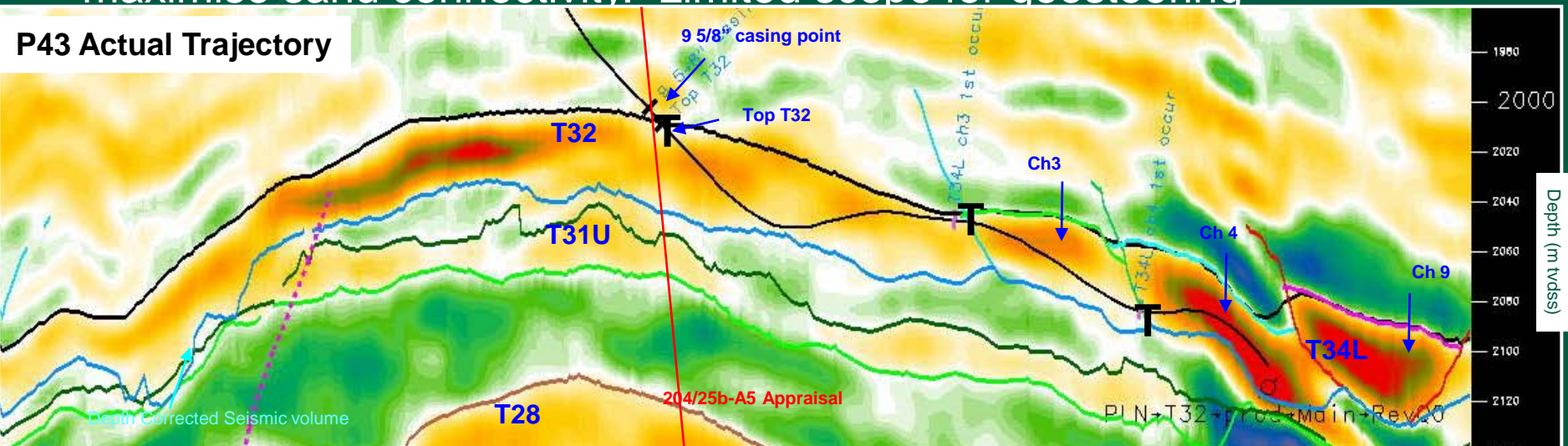
P43 – post-pilot plan



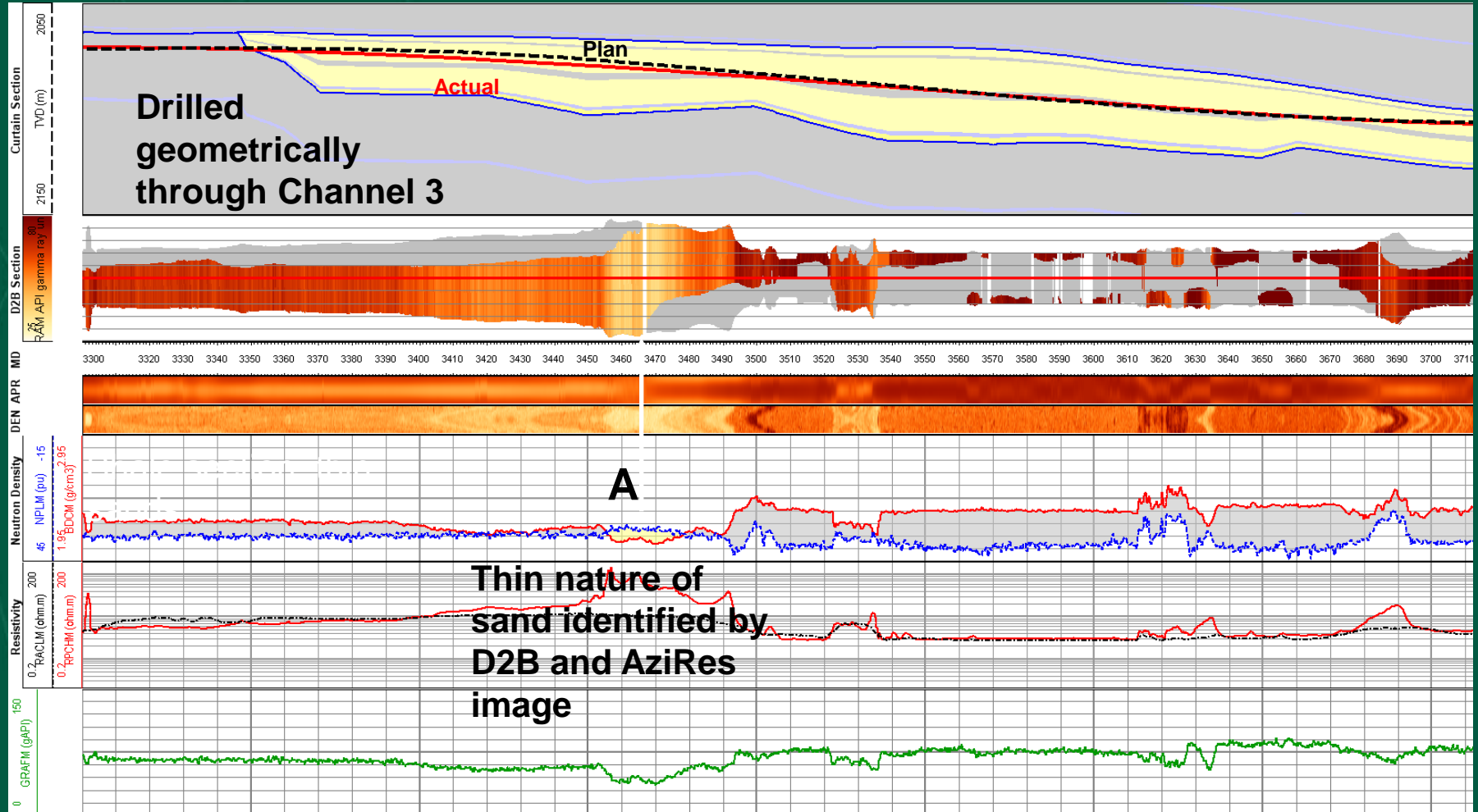
Challenges

- Navigate across a sequence of incised channels to drain T32 & T34L sands.
- Identify the presence of sand during the landing phase within the T32 channel sequence and optimise the well-path to attain maximum reservoir contact.

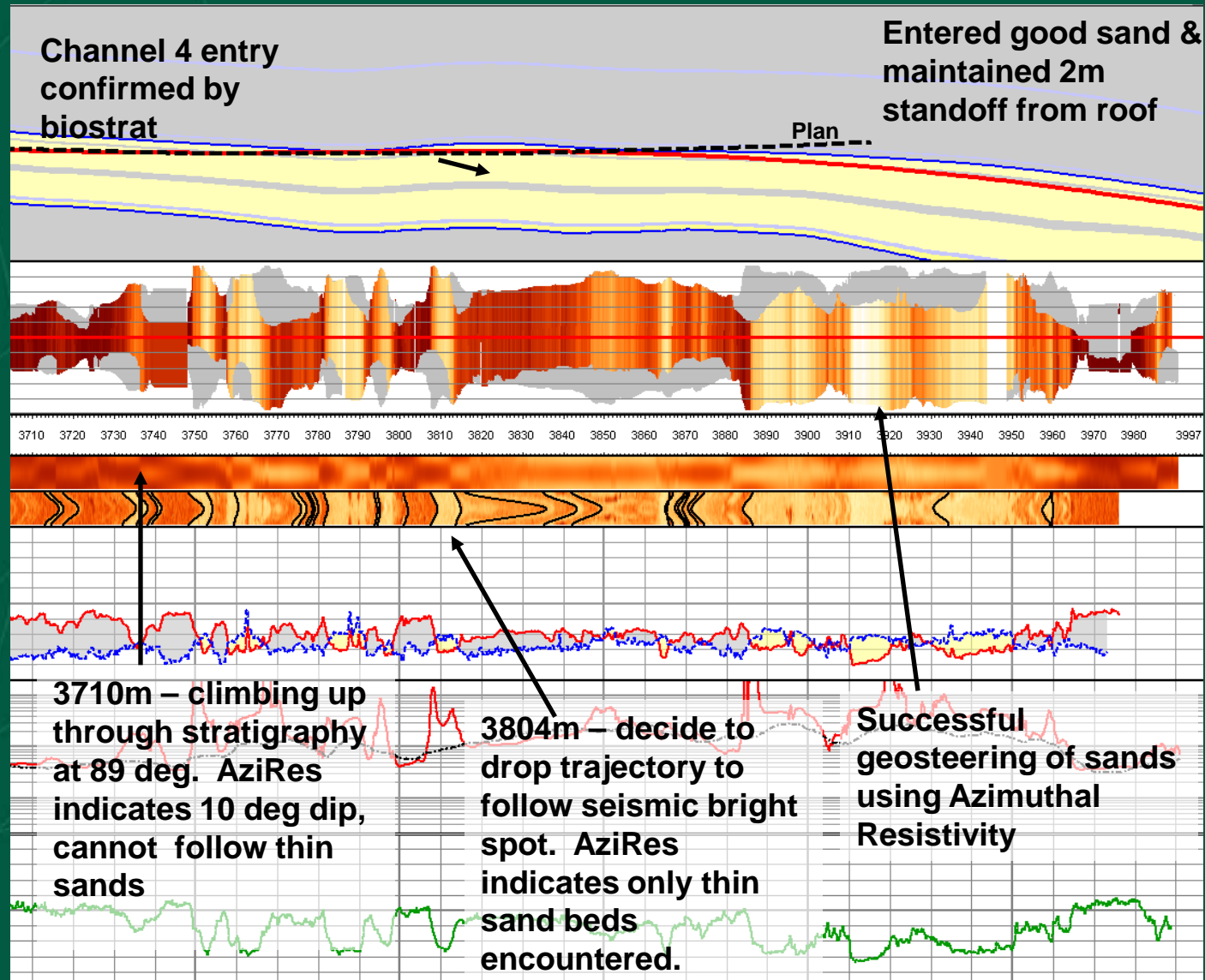
Based on low n/g pilot well decision made to cut across stratigraphy to maximise sand connectivity. Limited scope for geosteering



Channel 3 interpretation



Channel 4 Interpretation



P43 Conclusion



- Limited room for Geosteering due to poor result in T32 pilot and decision to cut stratigraphy geometrically
 - Azimuthal resistivity confirmed the thin-bedded nature of the sand and structural dip
 - Azimuthal Resistivity aided geosteering of sand in Channel 4.

Final Conclusions



- Success criteria
 - Maximising contact with net sand
 - Understanding which are the best sands to geosteer
 - Avoiding water
 - To know which direction to geosteer
 - TD early
- Traditional Foinaven Enabling strategy
 - Cut down through stratigraphy before geosteering – provides a lookahead to which sands to geosteer especially in low n/g sands
- Wishlist
 - An azimuthal tool which looks ahead or deep into the formation to see roof, floor, next sand, water.



Acknowledgements



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