De-risking Drill Decisions - A case study on the benefit of re-processing conventionally acquired seismic data with the latest broadband processing technology.

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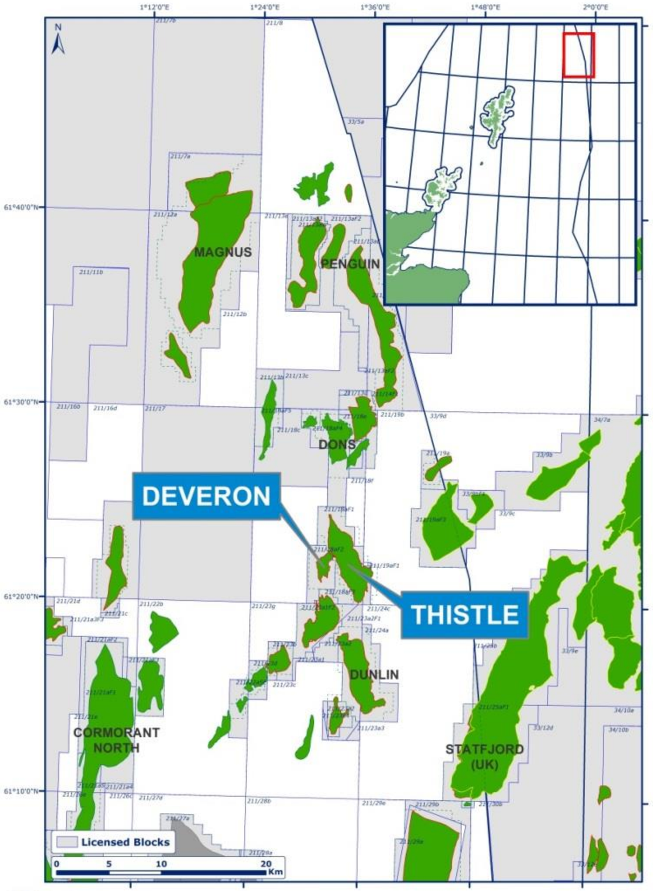
Outline

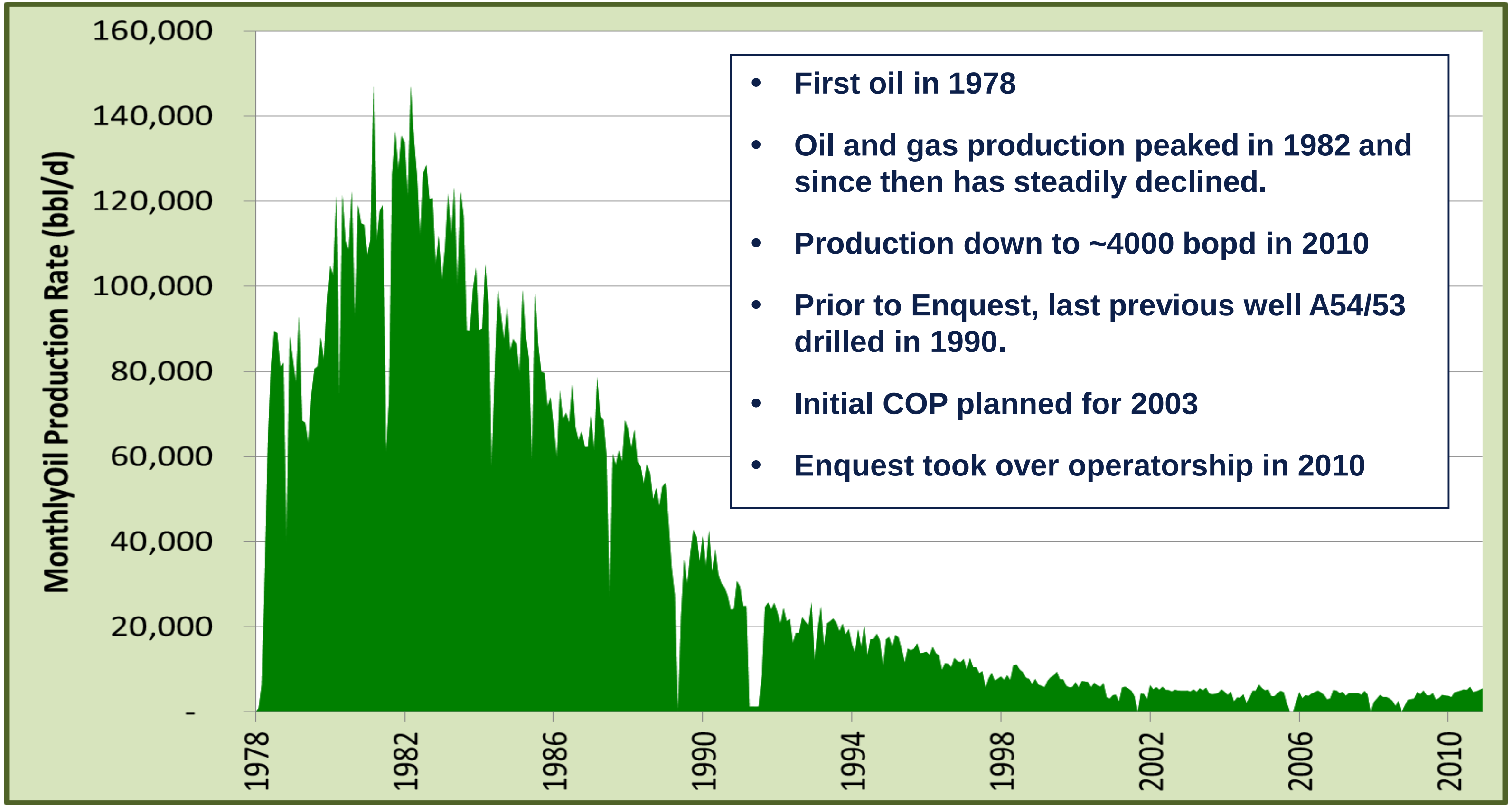
- Thistle Field Location and History
- Re-processing Objectives
- Seismic Processing
- Examples of Results
- Summary / Conclusions

Thistle and Deveron Field Location

- **Location** — UKCS Northern North Sea
  580km NE of Aberdeen
- **Blocks** — 211/18 & 211/19a
- **Water depth** — ~180m
- **Equity partners** — EnQuest 99%
  BP 1%
- **Discovery date** — 1973
- **1st Production** — 1978 (Thistle)
  1984 (Deveron)
- **Cum prod** — 447 MMstb (to end 2015)
- **Wells available** — 60 slots
  - 13 active producers
  - 7 injectors

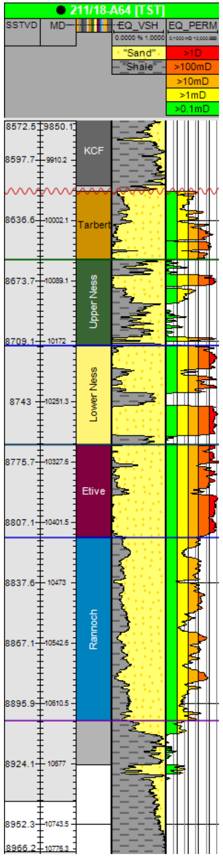


Field Production History (pre 2011)

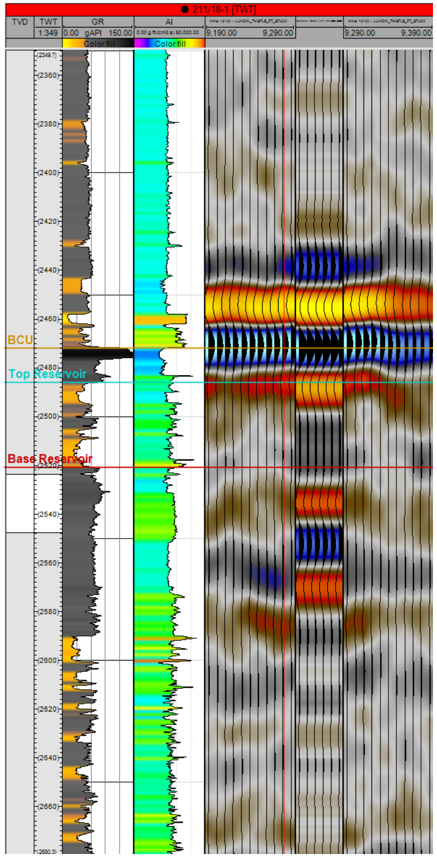


- **First oil in 1978**
- **Oil and gas production peaked in 1982 and since then has steadily declined.**
- **Production down to ~4000 bopd in 2010**
- **Prior to Enquest, last previous well A54/53 drilled in 1990.**
- **Initial COP planned for 2003**
- **Enquest took over operatorship in 2010**

Geology

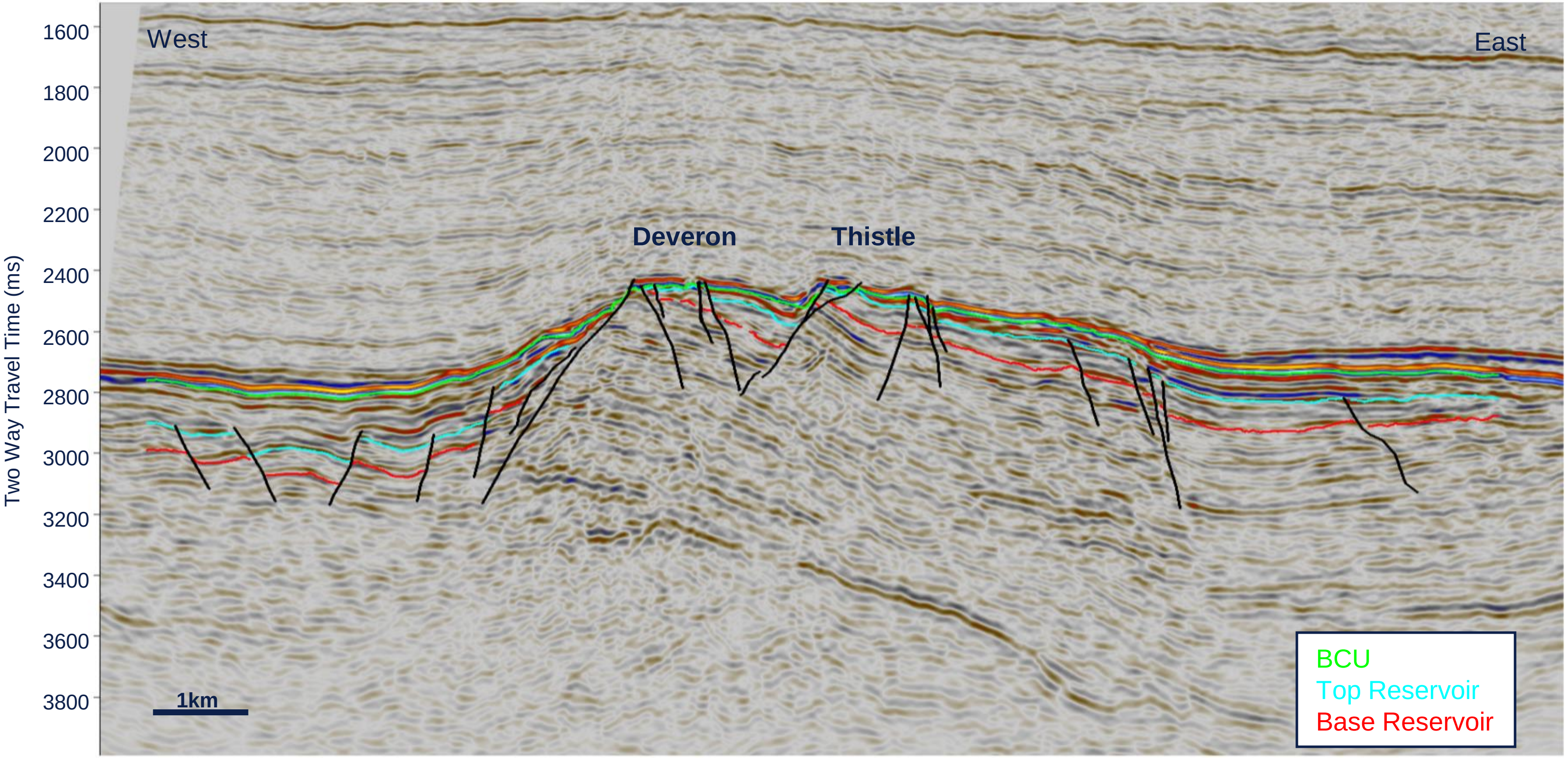


- Typical example of a Brent Province Oilfield
- Middle Jurassic Brent sands (~2650m TVDSS at the crest)
- Deposited in a shallow marine, prograding deltaic system resulting in:
  - Layered reservoir with true stratigraphic thickness up to 140m.
  - Some excellent reservoir quality layers.
  - Some more heterogeneous reservoir quality layers.
  - Field-wide shales within the Ness Formation.
- Structural trapping mechanism from rotated fault blocks formed during period of extension in Late Jurassic.
- Erosion and thinning over the reservoir over the crest.
- Overlain unconformably by mudstones of the Humber Group, Heather and Kimmeridge Clay Formations.

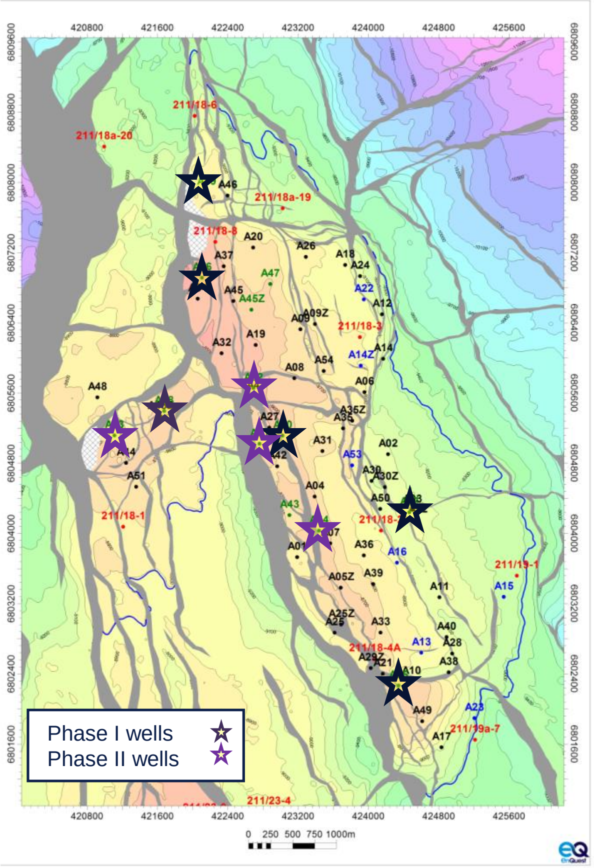


Seismic Section through Thistle/Deveron

2007 acquisition legacy seismic section.



Thistle Late Life Extension



- **The Thistle Late Life Extension program (LLX) is a major program of work to extend the life of the field including:**
  - **drill rig reactivation.**
  - **major power upgrading**
  - **a new process control and safety system**
  - **multi-faceted topsides integrity work.**
  - **structural integrity**
- **LLX has enabled two drilling campaigns to be undertaken:**
  - **Phase I drilling campaign (2010-2013)**
    - 6 new wells drilled (3 natural flow, 2 dual ESP and 1 single ESP producer)
    - 2007 PreSTM seismic used for well planning
    - Each targeting independent fault blocks
  - **Phase II drilling campaign (2015)**
    - 4 new wells drilled
    - Reprocessed 2015 PreSDM used for well planning.
    - Short duration operations to accelerate first production
    - Crestal targets in the main fault block prioritised

Rationale for Reprocessing

- Thistle and Deveron field wide recovery factors approaching 60%
- Water cut rates in excess of 90% for many of the existing producing wells.
- Future wells likely to be smaller and riskier targets than those drilled to date.
- Remaining oil volumes will be small and uncertain.
- Accurate placement of additional wells is key to extending the future life of the field.
- In the current low price environment, maximising the value of existing seismic data is crucial.

Therefore, prior to commencement of the 2015 drilling campaign Enquest decided to reprocess the 2007 acquired seismic data.

Reprocessing Objectives

- **Minimise multiple contamination with recent de-multiple techniques.**
- **Recover broader frequency spectrum through latest deghosting processing solutions for improved resolution and clarity.**
- **Iterative velocity model building and PreSDM for accurate fault positioning over the crest of the field.**

Processing Highlights

- **Input data**
  - Modern acquisition (2007).
  - Conventional bandwidth survey.
- **Noise attenuation**
  - Frequency domain median threshold filter, radial filter and Tau-P muting.
- **Multiple removal**
  - Shallow water (short period) multiple attenuation (SPMA).
  - Long period multiples (3D SRME and Radon).
- **Deghosting**
  - Application of a data derived iterative inverse operator to suppress side lobes and increase bandwidth.
- **Imaging**
  - 6 iterations of hybrid tomographic and layer based velocity model building.
  - 3D regularisation to an interpolated bin spacing of 12.5 x 12.5m.
  - Anisotropic TTI Kirchhoff depth migration.

Key Acquisition Parameters and Vintage Processing

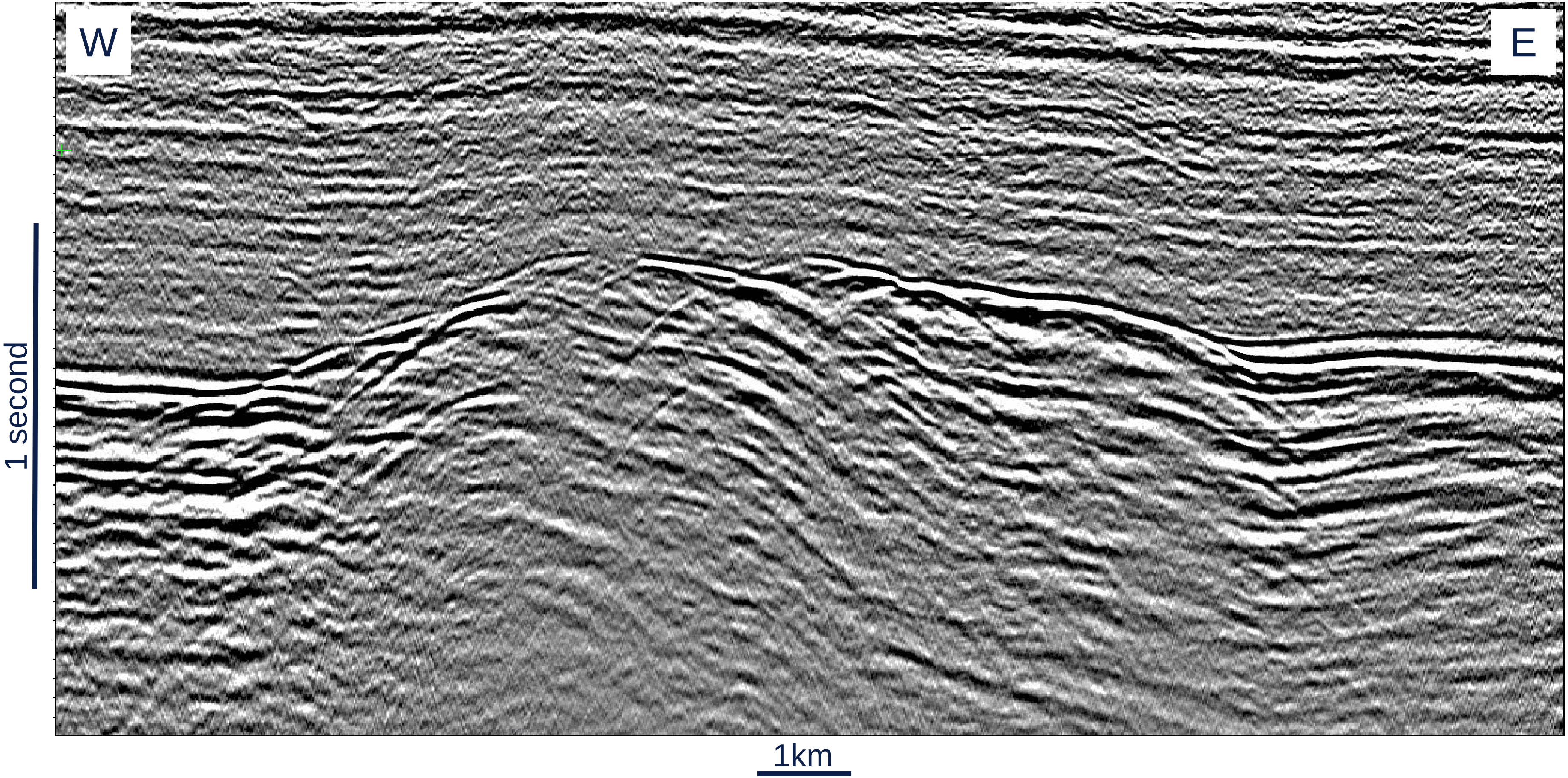
Number of Cables	8 x 408 channels (5100m offset)
Source Depth	7m
Cable Depth	8m
Shot Point Interval	12.5m (Fold 102)
Acquisition Bin Size (XL x IL)	6.25m x 25m

Vintage Processing

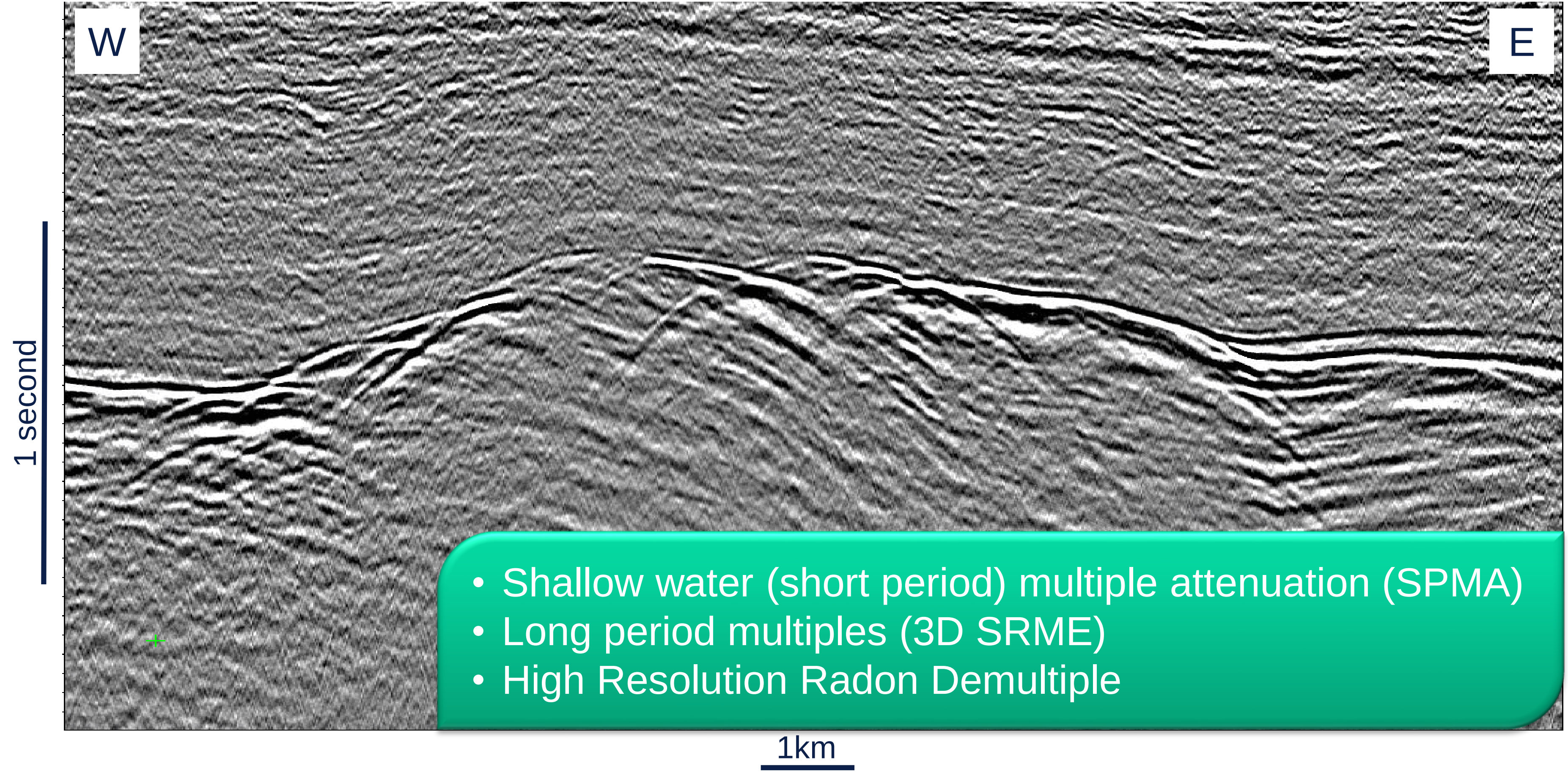
- Demultiple
  - Tau-P Predictive Deconvolution (Shot Domain)
  - Tau-P Predictive Deconvolution (Receiver Domain)

- Migration
  - Isotropic Kirchhoff PreSTM

Demultiple - Stack Before Demultiple

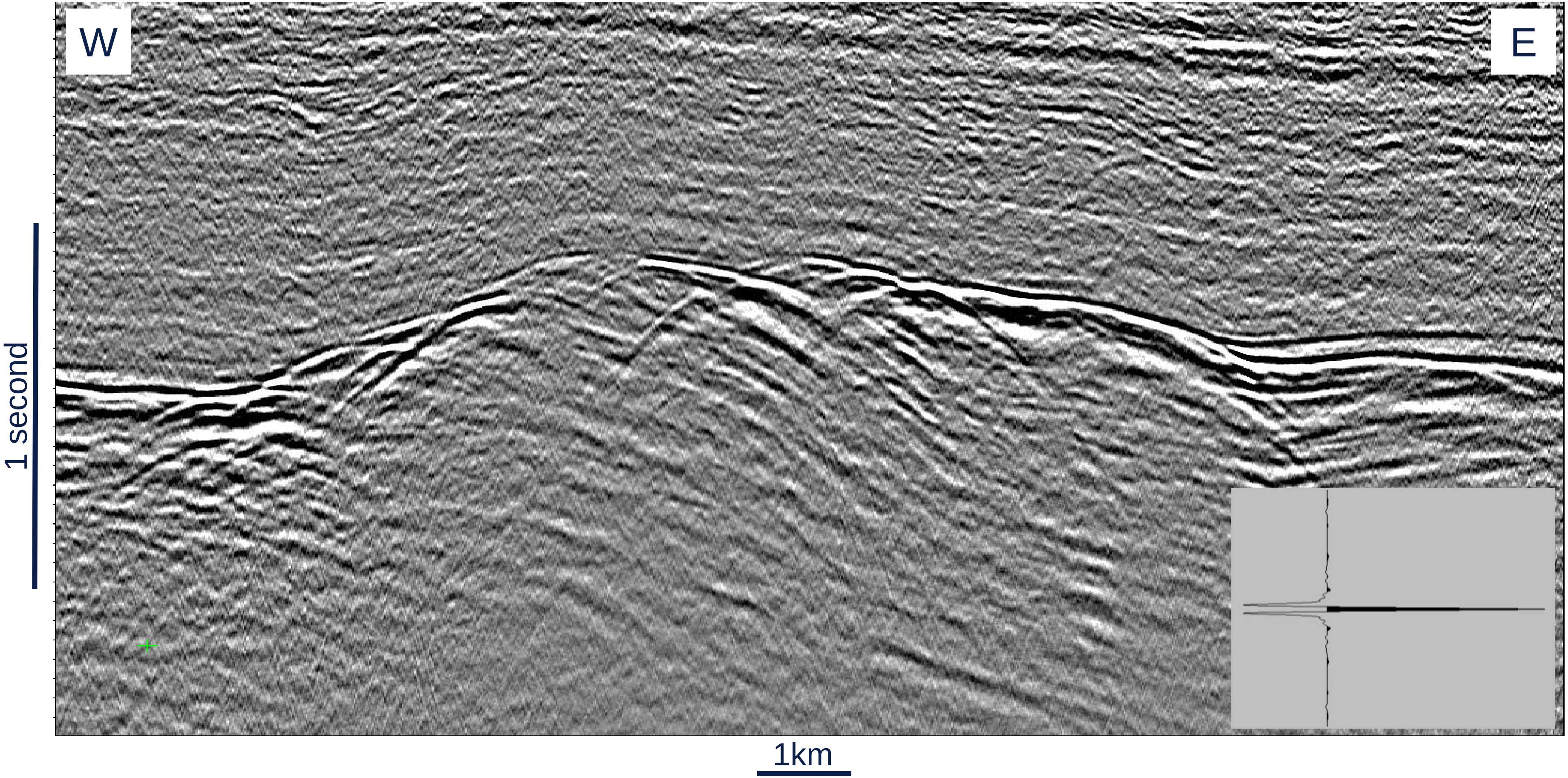


Demultiple - Stack After Demultiple

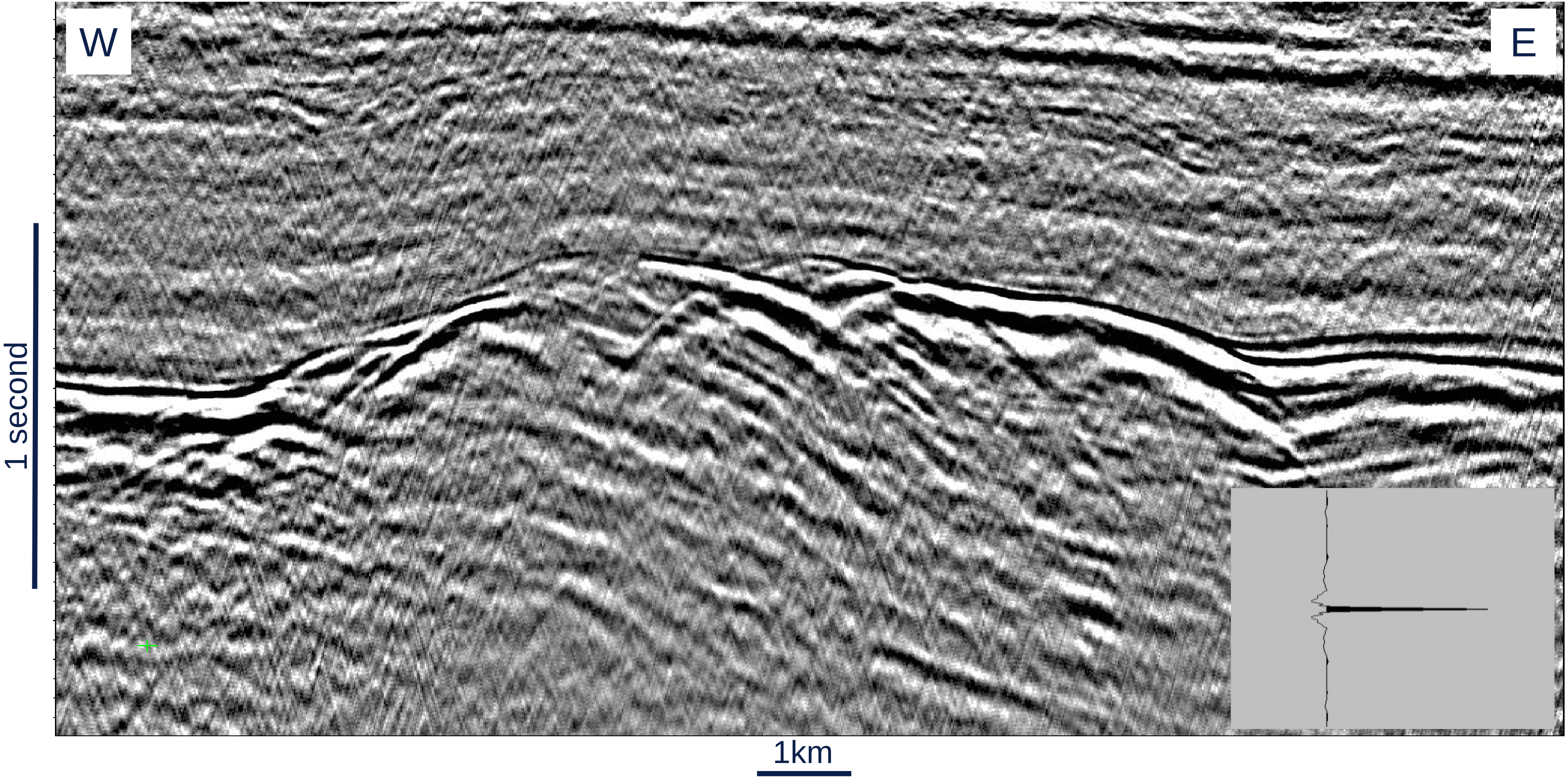


- Shallow water (short period) multiple attenuation (SPMA)
- Long period multiples (3D SRME)
- High Resolution Radon Demultiple

Deghosting - Stack Before Deghosting

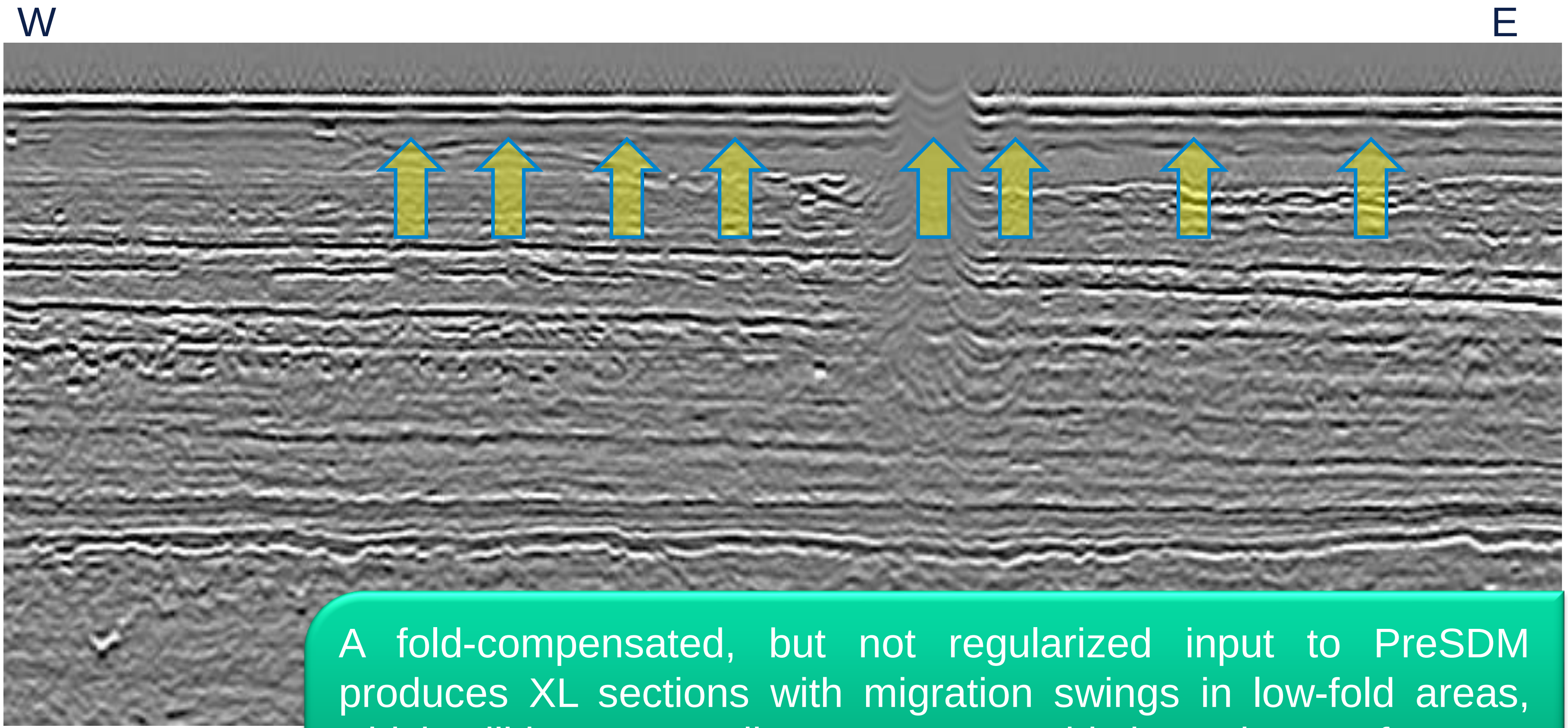


Deghosting - Stack After Deghosting



Impact of data input on Velocity Model Building

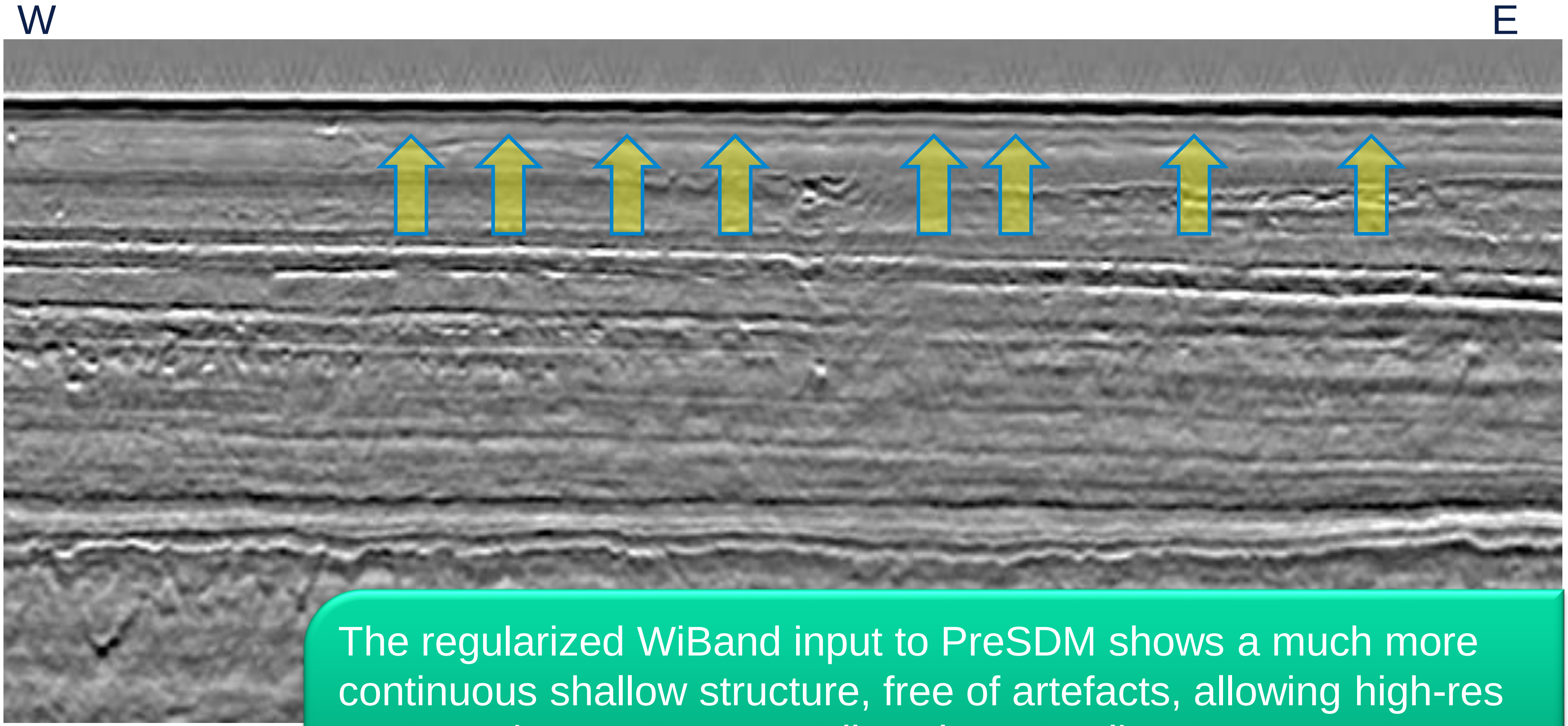
PreSDM stack from conventional, non-regularised input



A fold-compensated, but not regularized input to PreSDM produces XL sections with migration swings in low-fold areas, which will in turn contribute to tomographic inversion artefacts

Impact of data input on Velocity Model Building

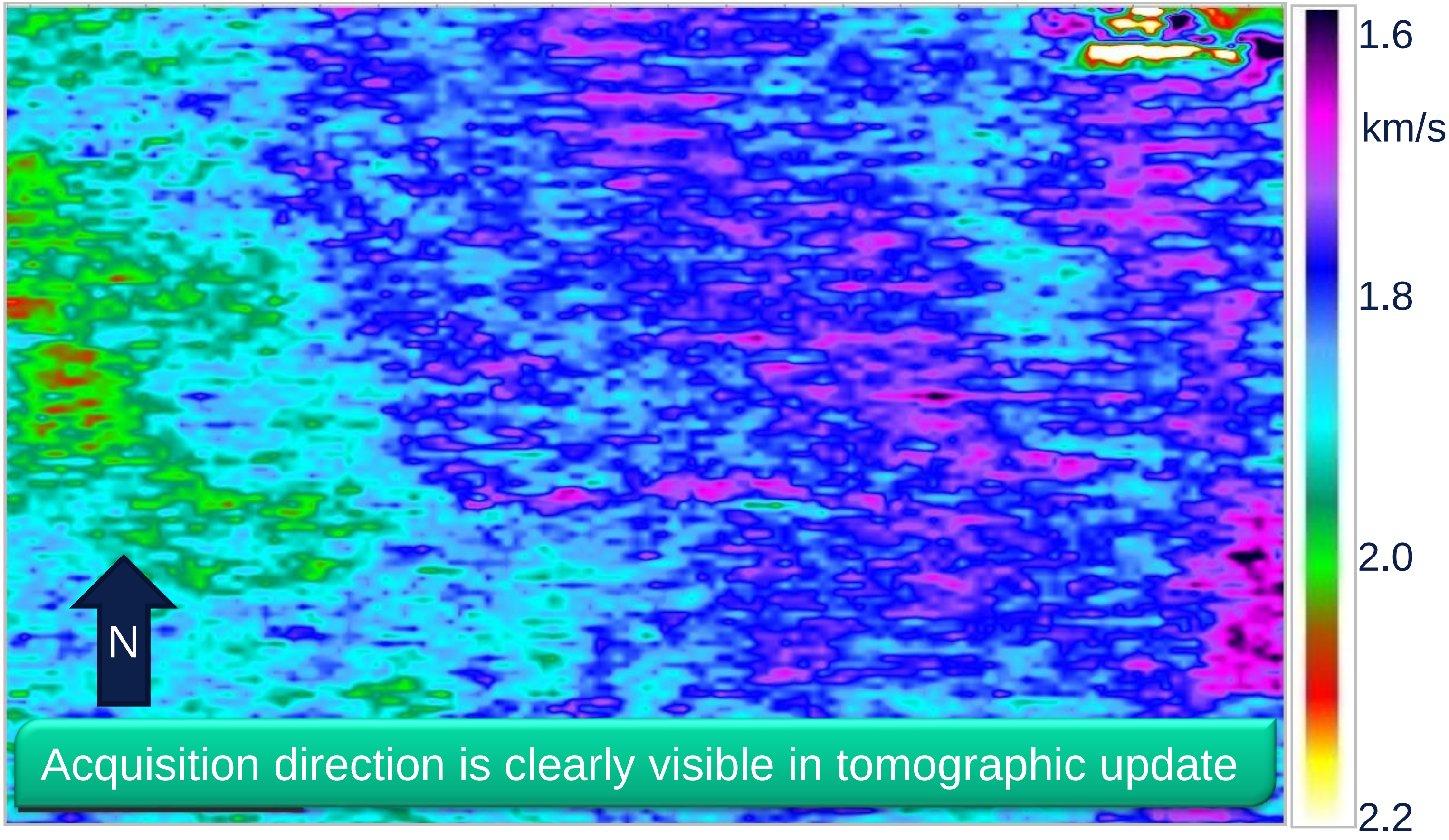
PreSDM stack from regularised WiBand input



The regularized WiBand input to PreSDM shows a much more continuous shallow structure, free of artefacts, allowing high-res tomography to capture small-scale anomalies

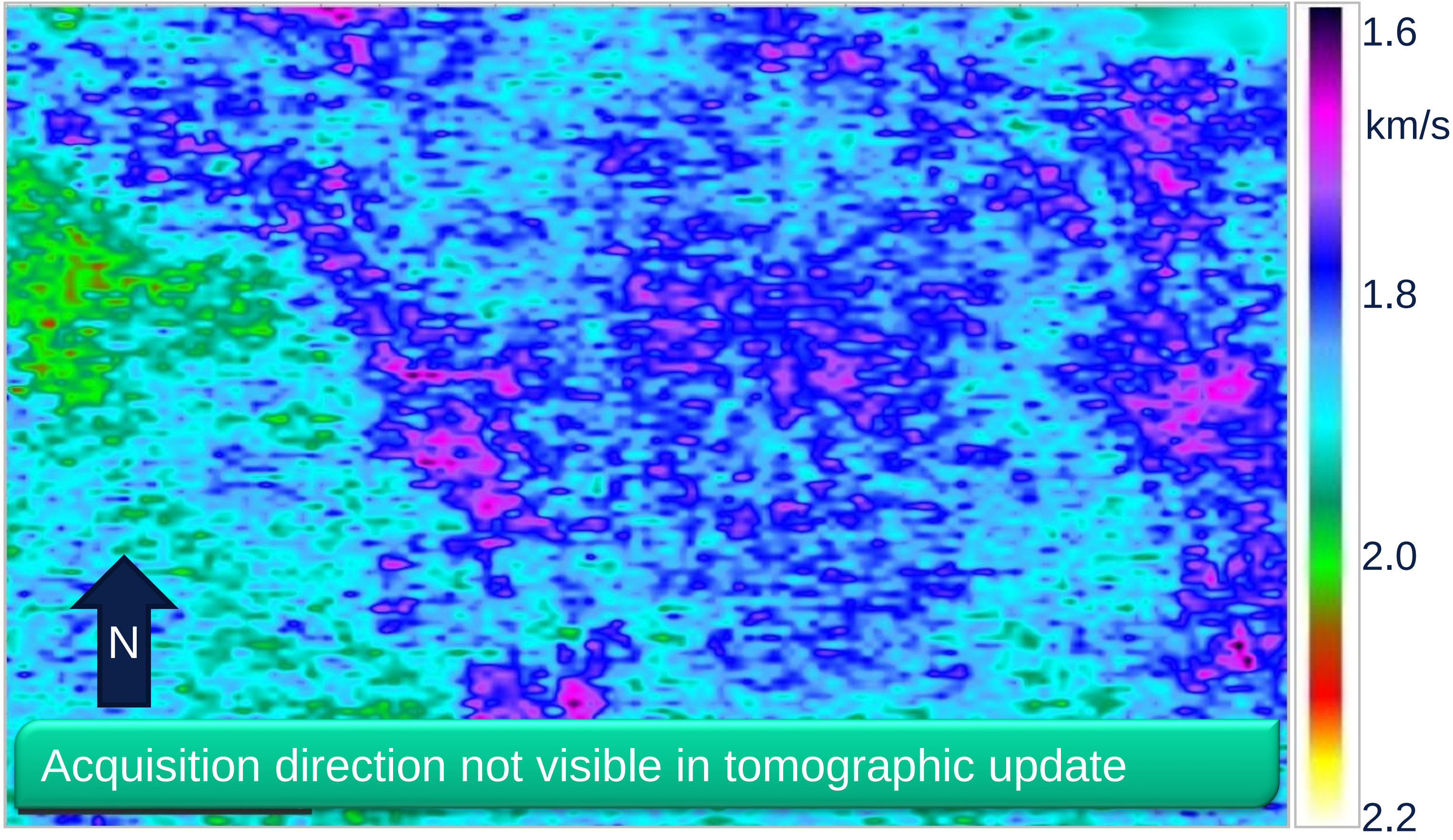
Impact of data input on Velocity Model Building

Tomographic velocity update from non-REG input; depth slice at 400m

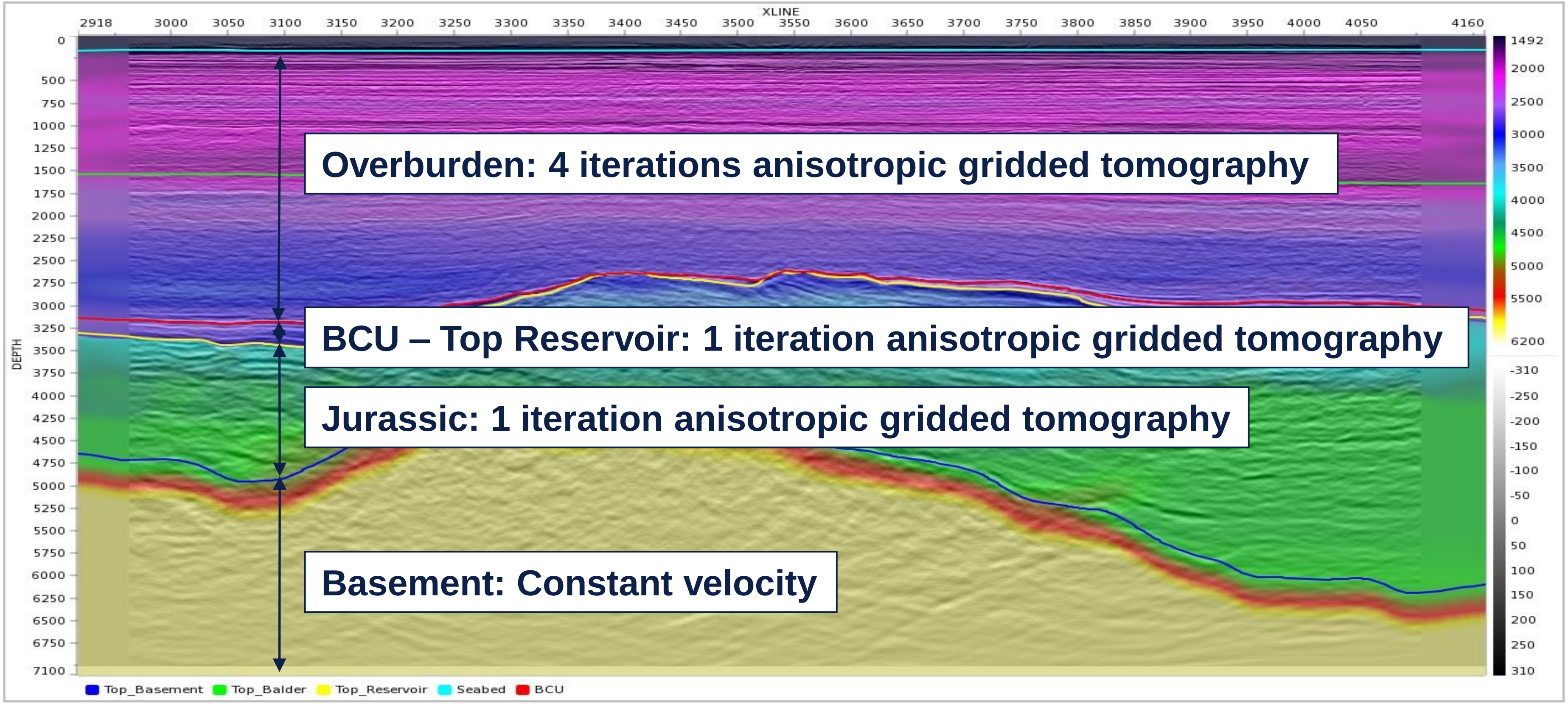


Impact of data input on Velocity Model Building

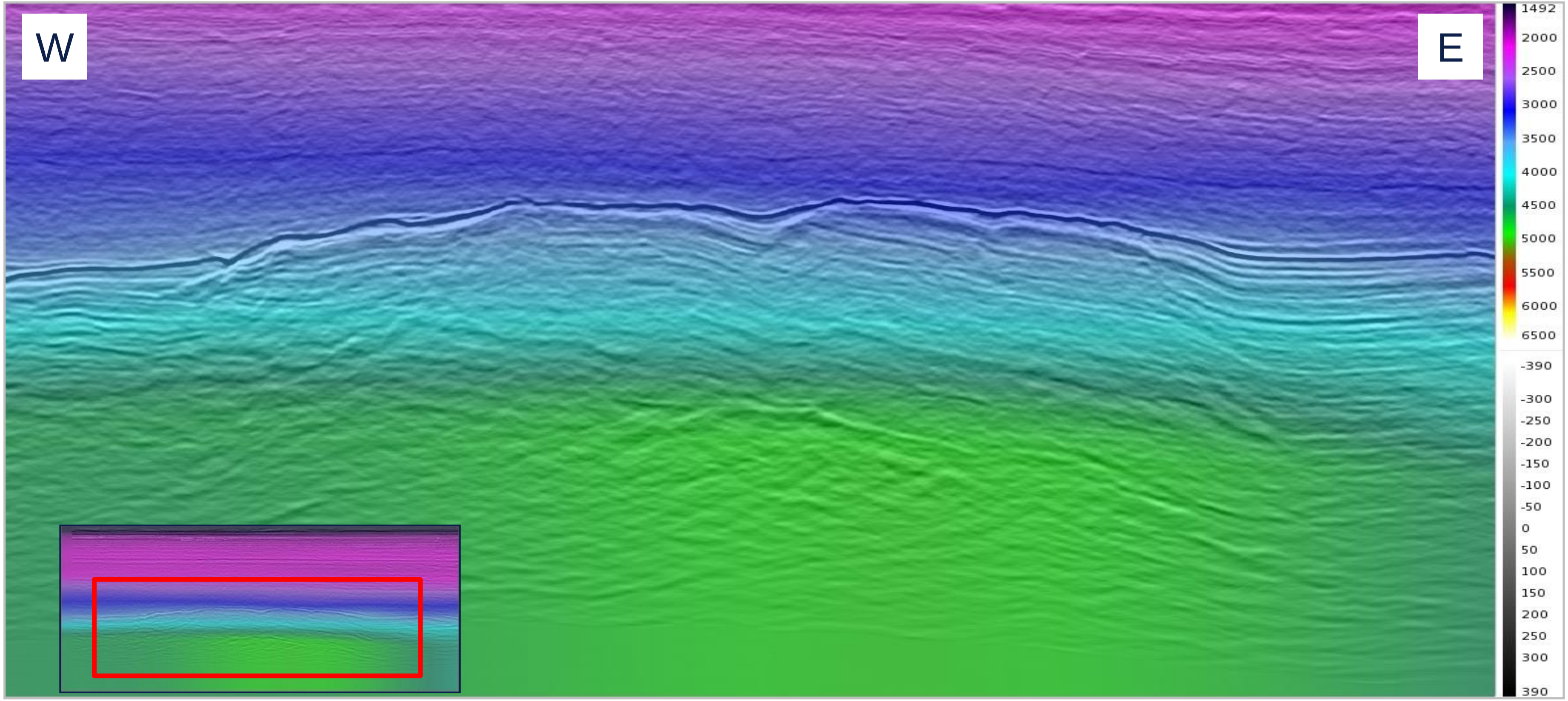
Tomographic velocity update from REG WiBand input; depth slice at 400m



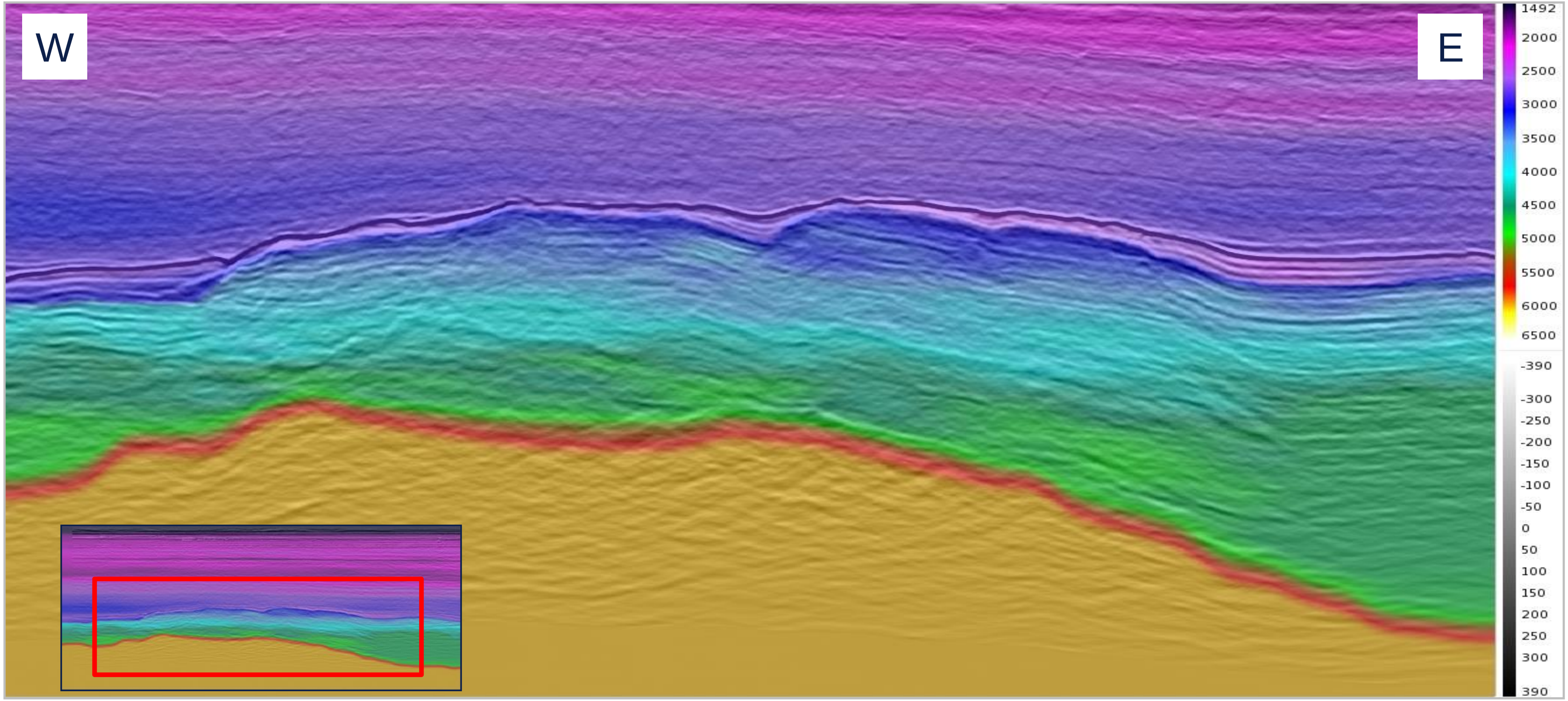
Velocity Model Building: Model Evolution



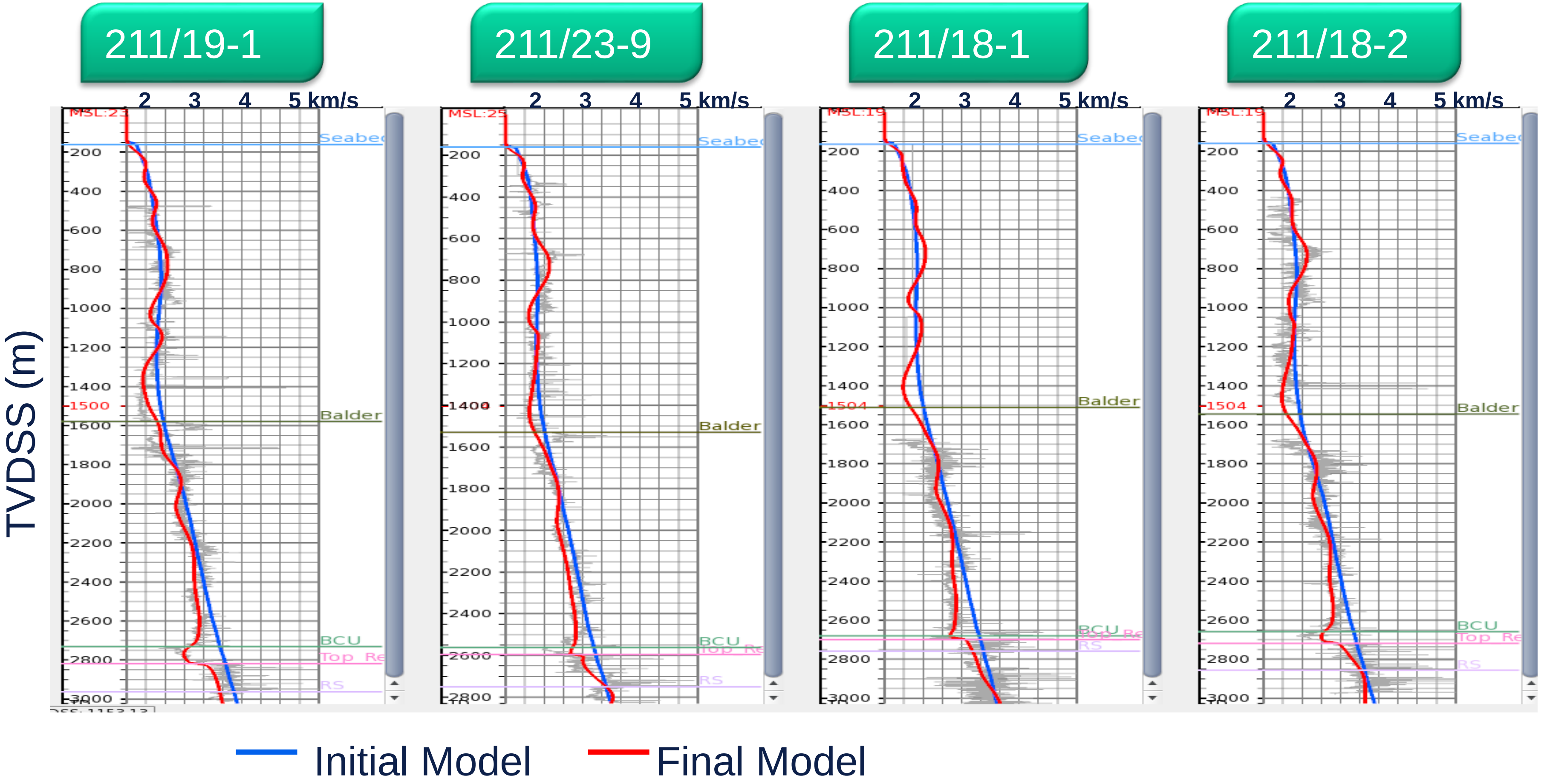
Velocity Model Building: Initial Velocity



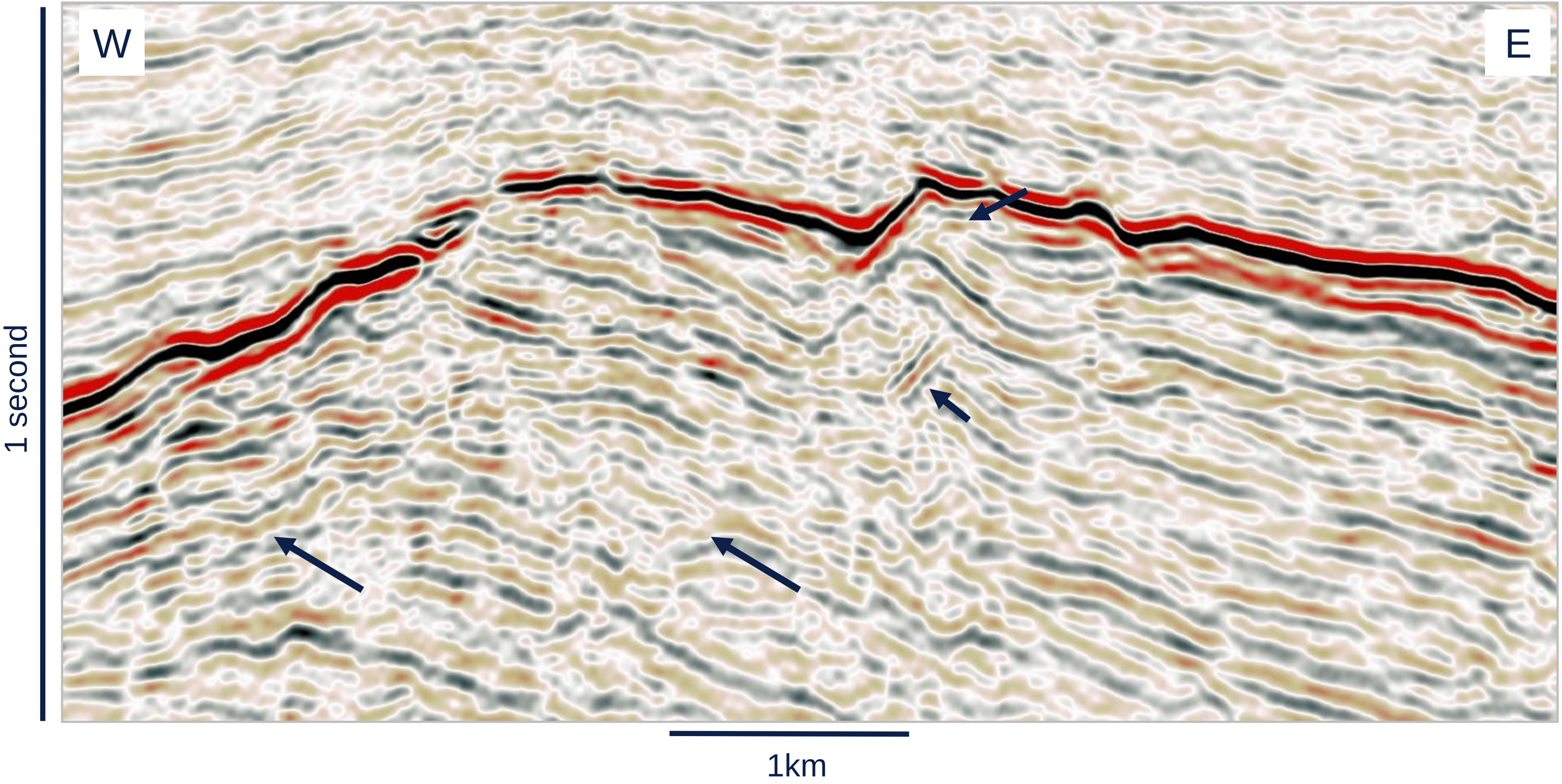
Velocity Model Building: Final Velocity



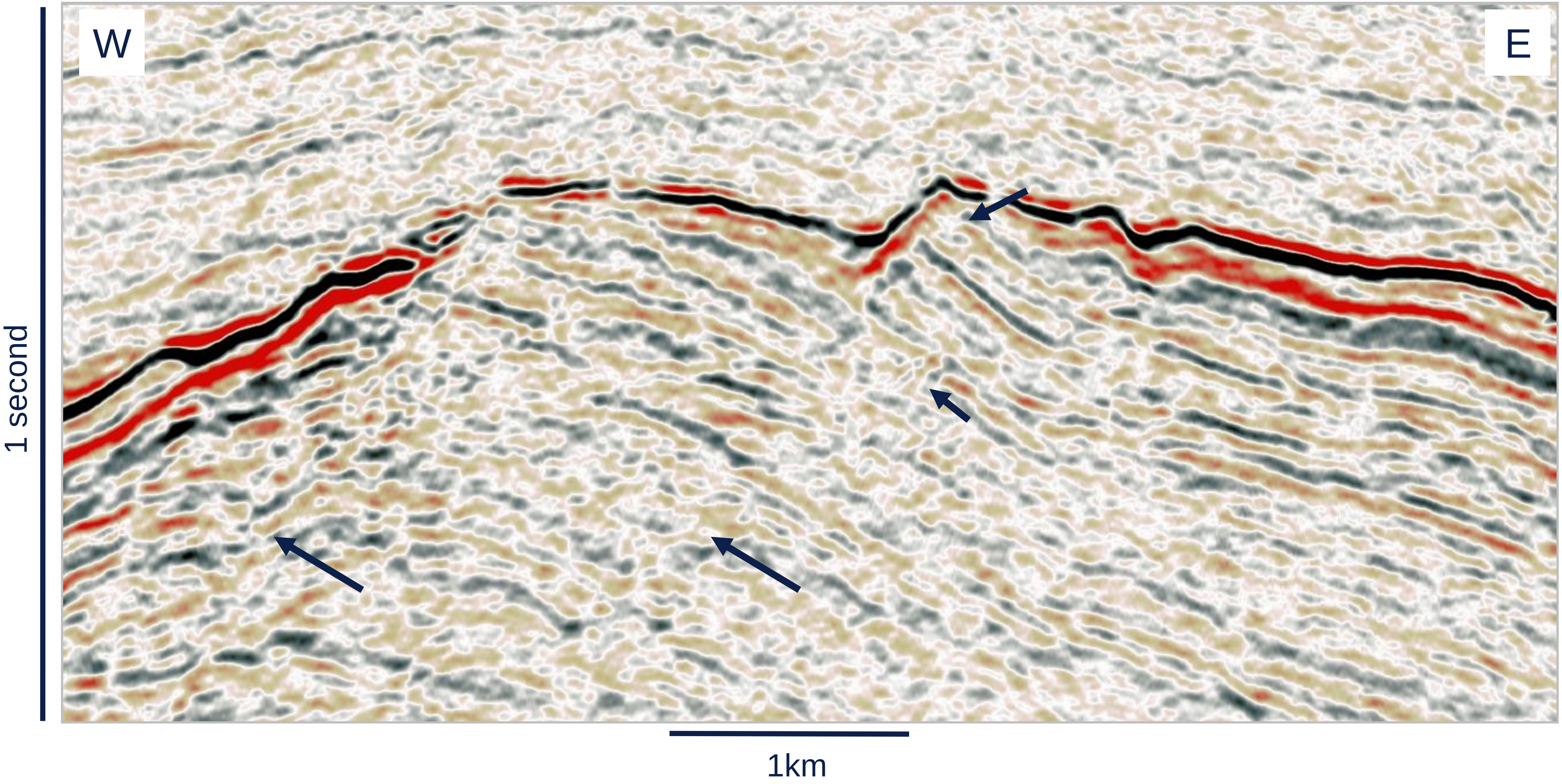
Velocity Model Building: Sample Well Comparisons



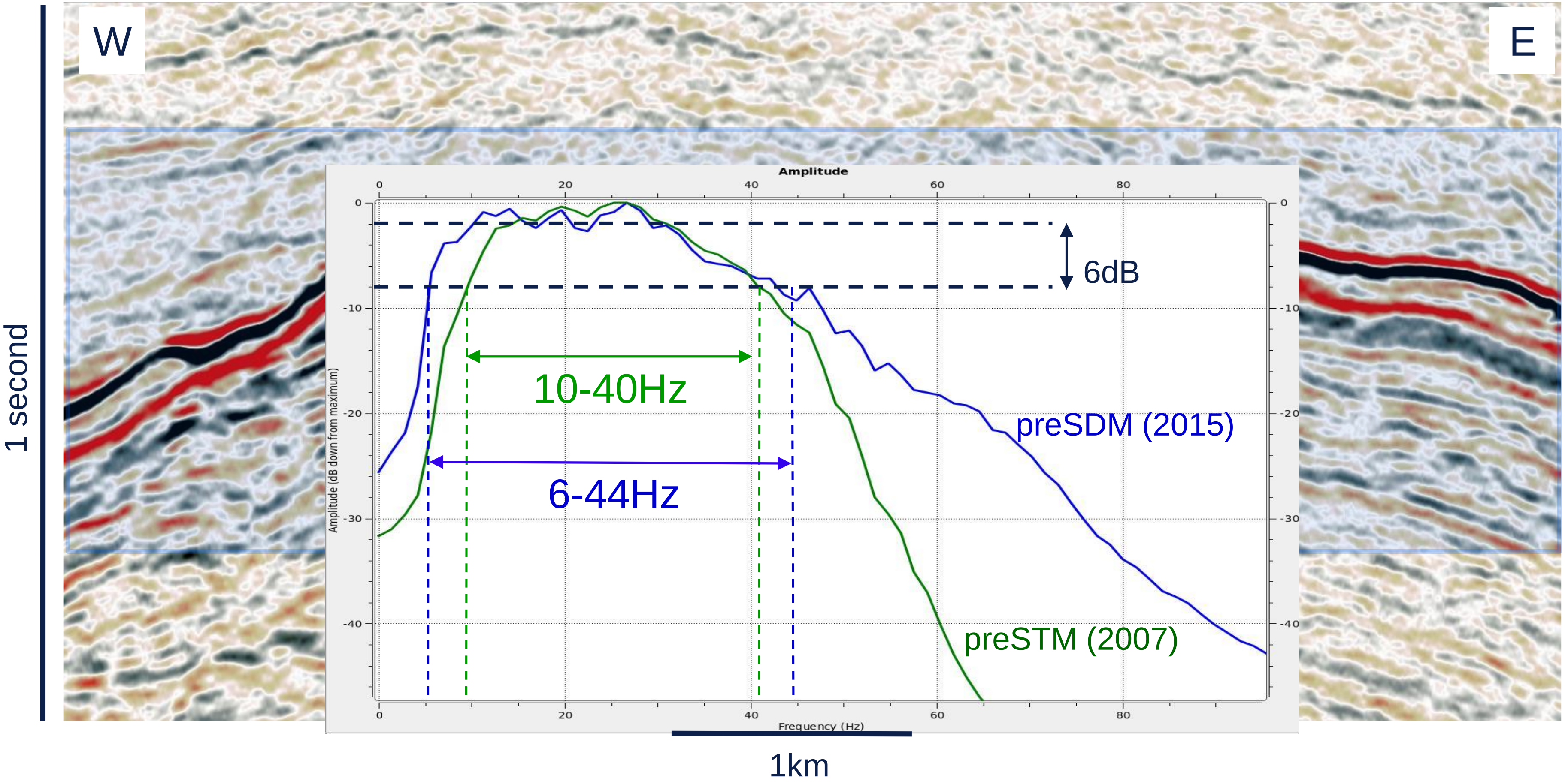
2007 Vintage PreSTM Stack



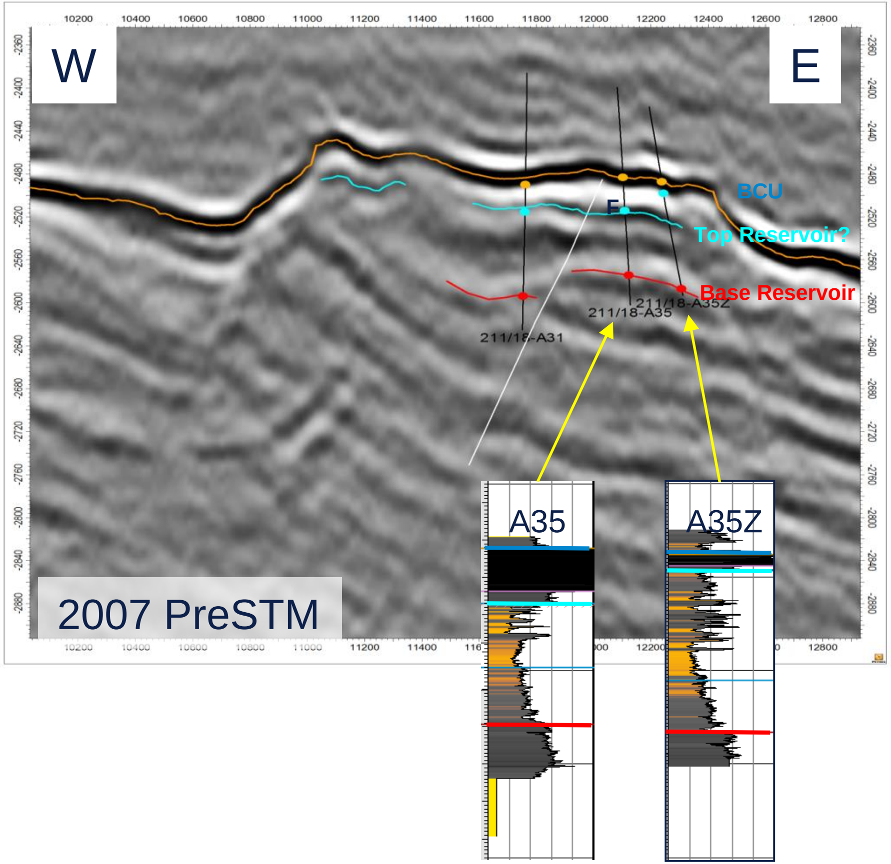
2015 Final Re-processed PreSDM Stack



Spectral Analysis

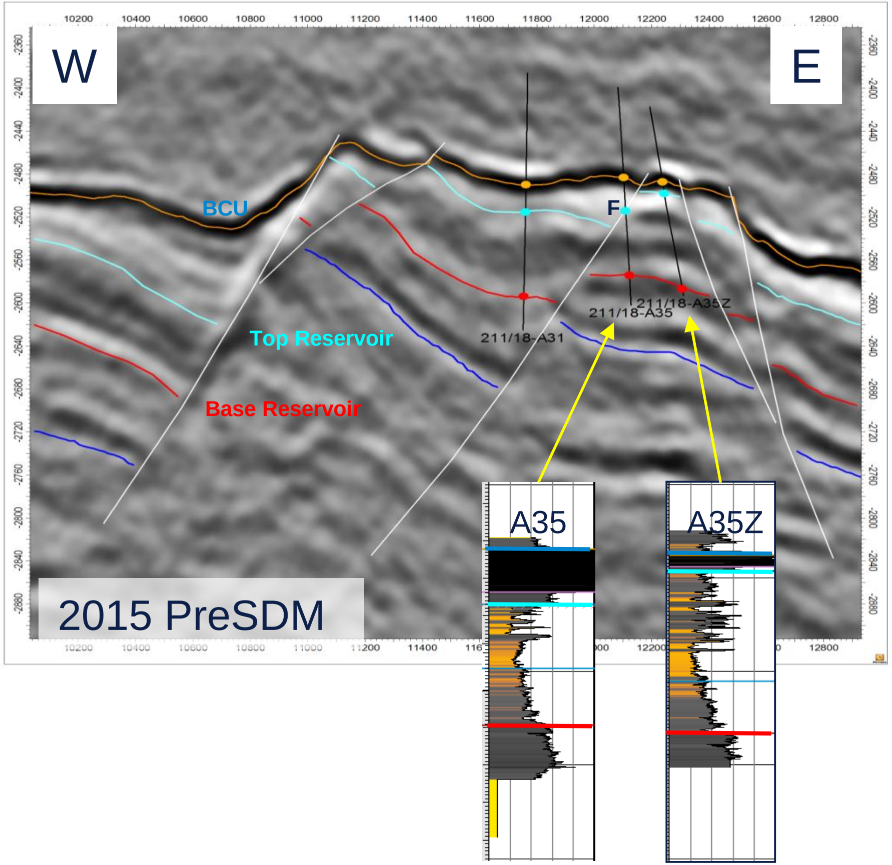


PreSTM vs PreSDM Comparisons: 2007 preSTM



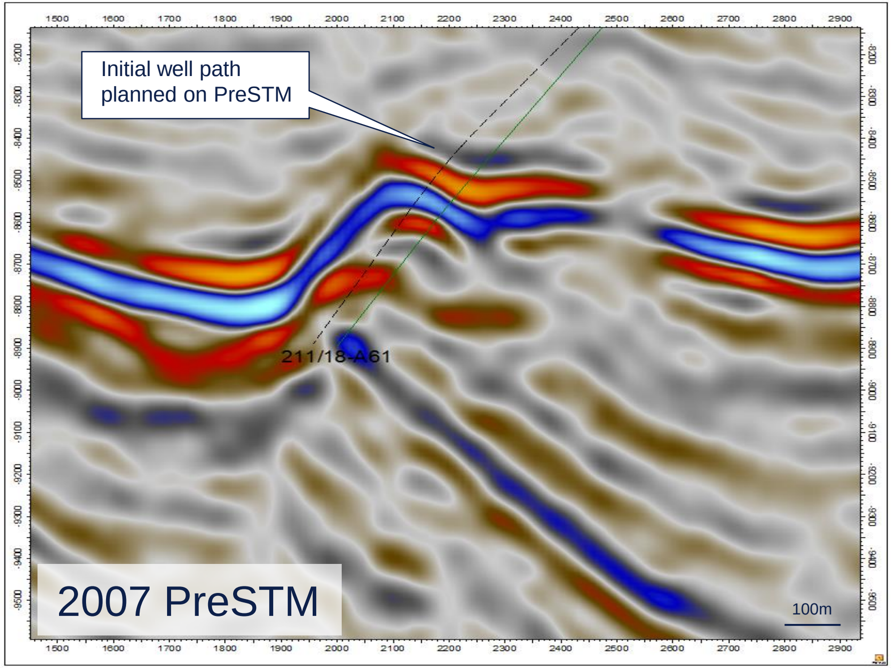
- Very thin KCF encountered in A35Z proved difficult to tie with seismic reflectors.
- A35 enters top reservoir through a fault but only significant seismic fault 100m to the West.
- Some syn-sedimentary thickening into growth fault expected but PreSTM interpretation looks to be excessive.
- Most likely explanation for mistie is that the top reservoir pick is tracking a sidelobe of the BCU.
- Also note the residual multiple diffractions generated from the main Thistle fault boundary which are particularly problematic to remove.

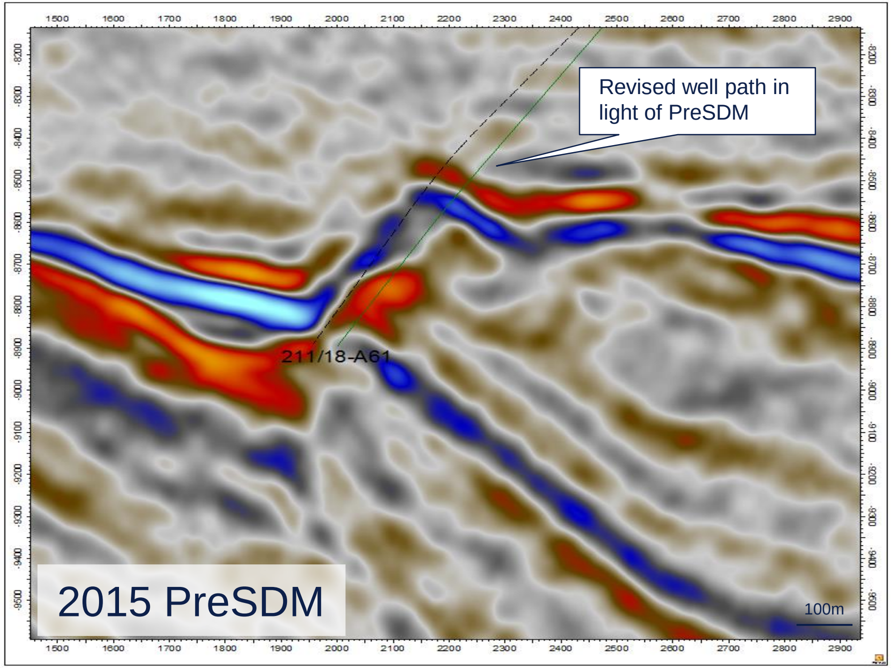
PreSTM vs PreSDM Comparisons: 2015 preSDM



- **PreSDM repositions the low angle fault which now ties the fault penetration at the well.**
- **Broader bandwidth through deghosting removes BCU side-lobes and aids top reservoir interpretation.**
- **Hints of dipping beds evident in the terraces, matching steep dips in the main Thistle field.**
- **Improved multiple removal, particularly the seabed multiple off the BCU.**
- **Also note the improved clarity of the main Thistle bounding fault and terrace fault to the West.**

A61 Well Planning



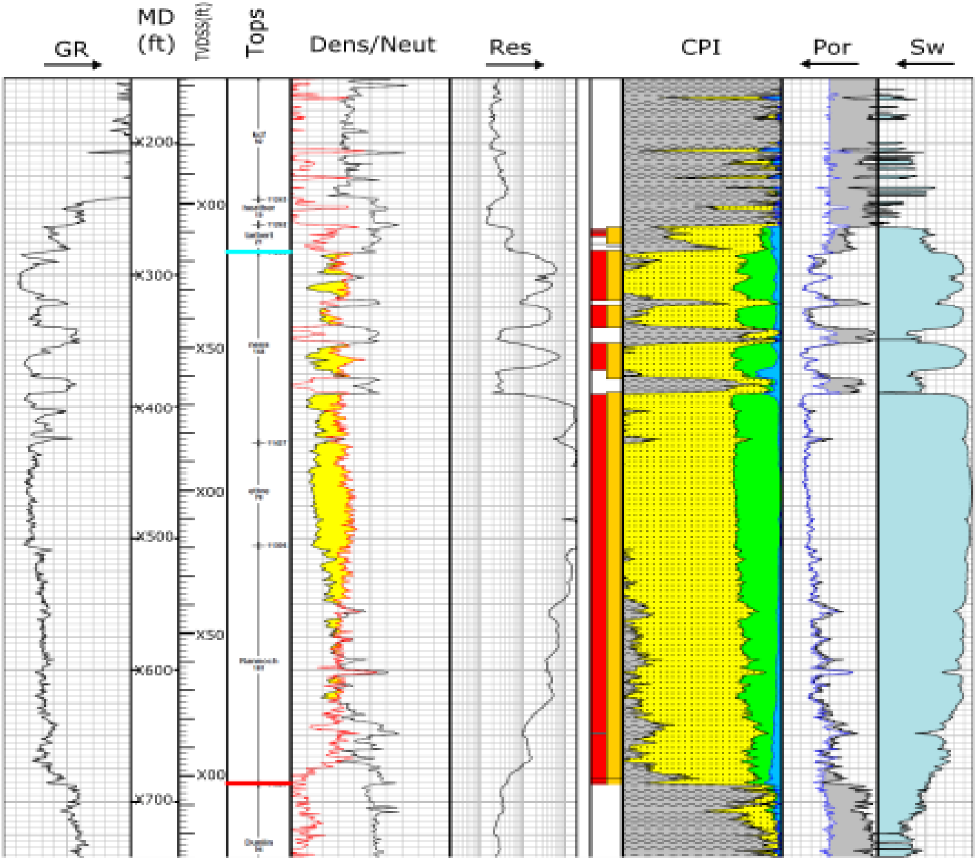


- **Initial well path planned using the PreSTM**
- **Well targeting a narrow, downthrown terrace against main Thistle bounding fault.**

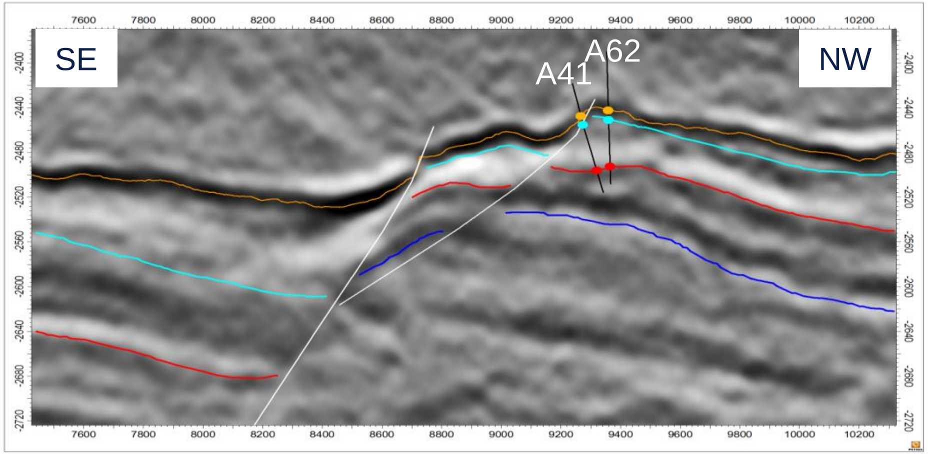
- **PreSDM showed a lateral shift of main Thistle bounding fault.**
- **Well path shifted eastwards by 50m after re-interpretation of PreSDM volume.**

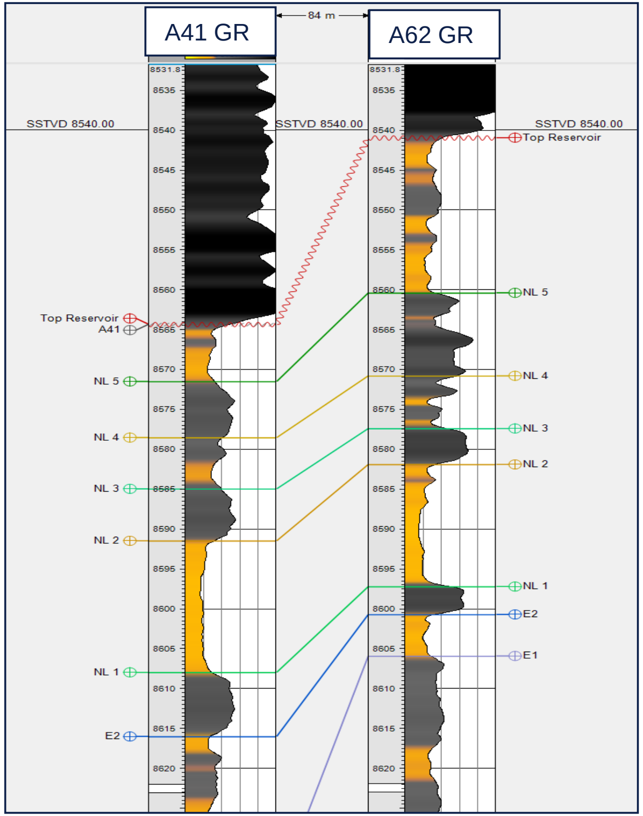
A61 Post Well Summary

- ✓ Successfully drilled terrace target without the need for pilot hole or sidetrack.
- ✓ Avoided drilling through the main Thistle Field bounding fault.
- ✓ Encountered top reservoir 32m updip from A42.
- ✓ Top Brent depth 3m shallow to prognosis.
- ✓ Gross Brent sequence thickness 60m AVT (60m predicted).
- ✓ Excellent reservoir quality throughout.
- ✓ Excellent oil saturations, almost a full oil column.



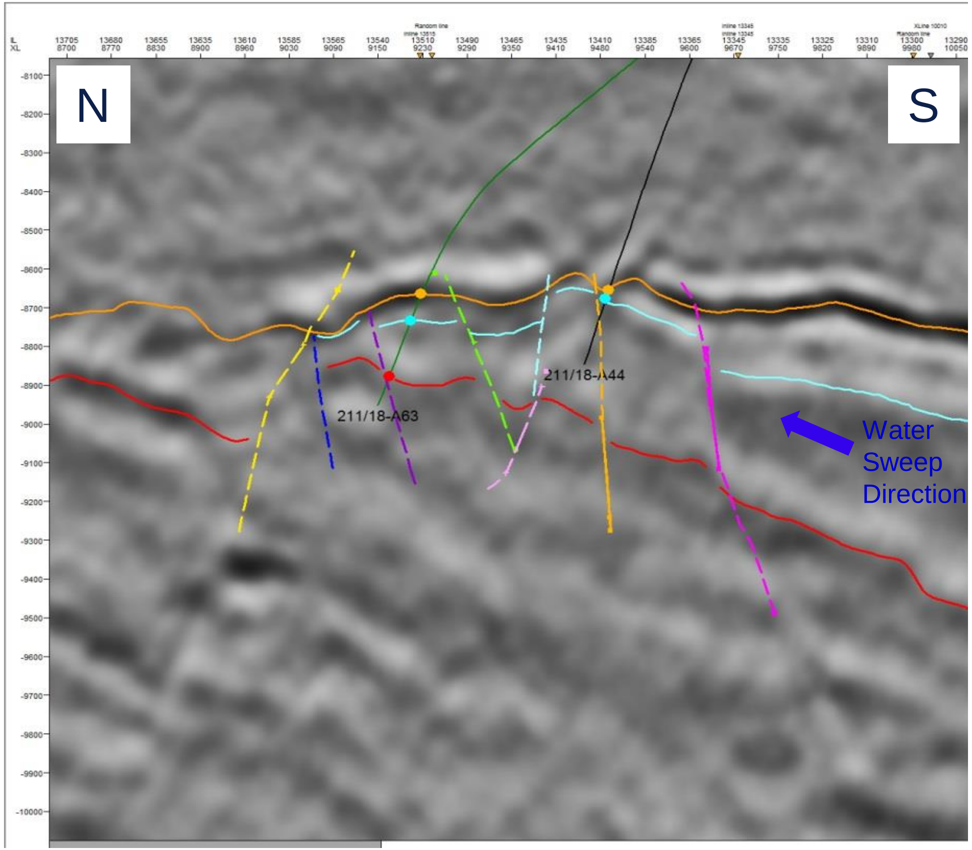
A62 Results





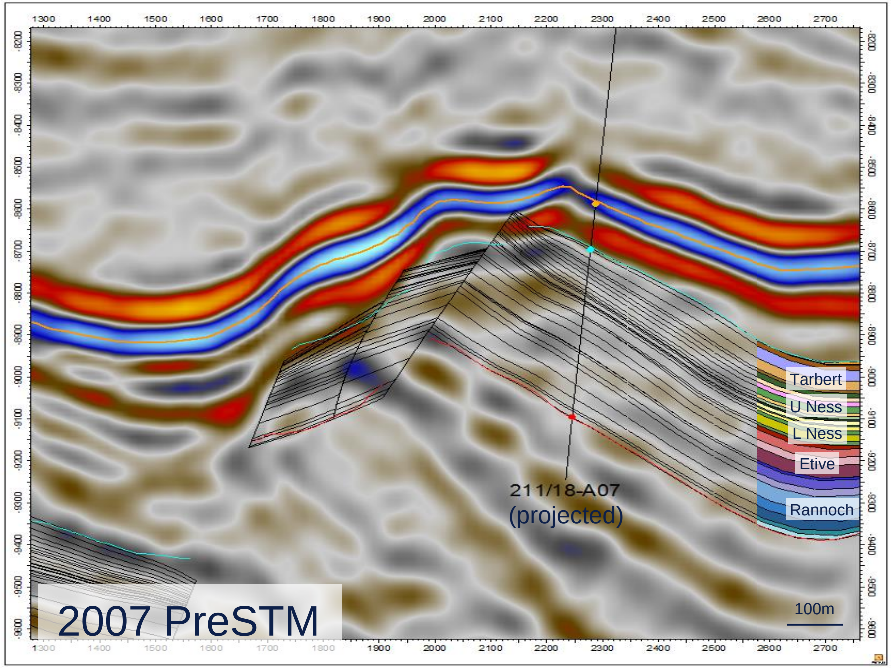
- A62 drilled as a replacement well for A41 which had to be shut-in due to integrity issues.
- A62 designed to avoid faults and target structural crest observed on seismic.
- NL5 mid Ness Shale ~3m structurally higher
- Additional 3m of uppermost NL sand encountered which had been faulted out in A41.

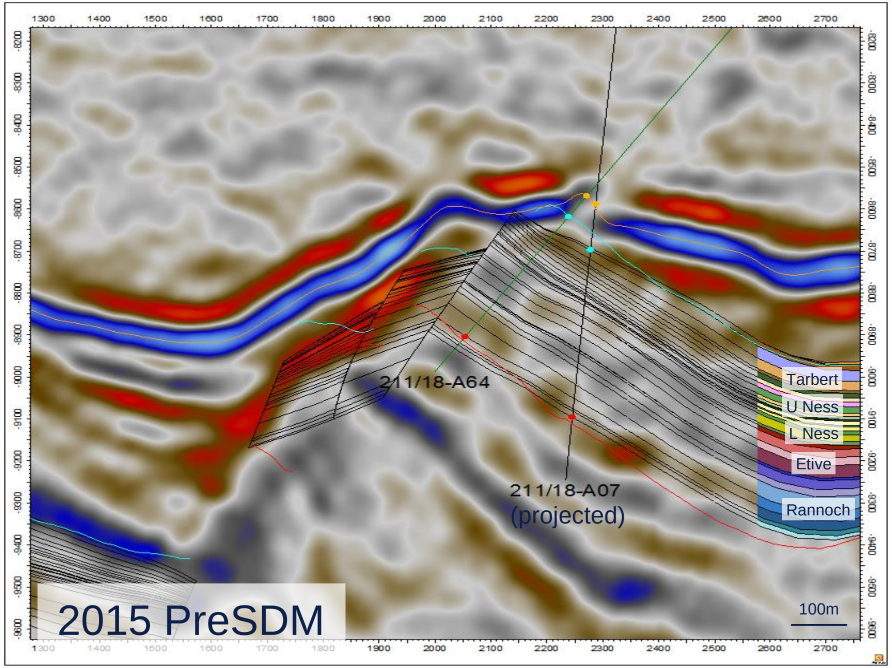
A63 Results



- A44 shut-in and used as the donor well for drilling A63 in NW corner of Deveron.
- Moved away from aquifer water sweep path to access additional reserves and improved water cuts.
- BCU and base reservoir depths were within 3m although top reservoir was 17m deep to prognosis.
- Gross Brent sequence thickness 44m AVT (62m predicted).
- Despite thinner reservoir good oil saturations encountered in Ness and Upper Etive.
- Well appears to be performing in the upside of the predicted range.

A64 Well Planning

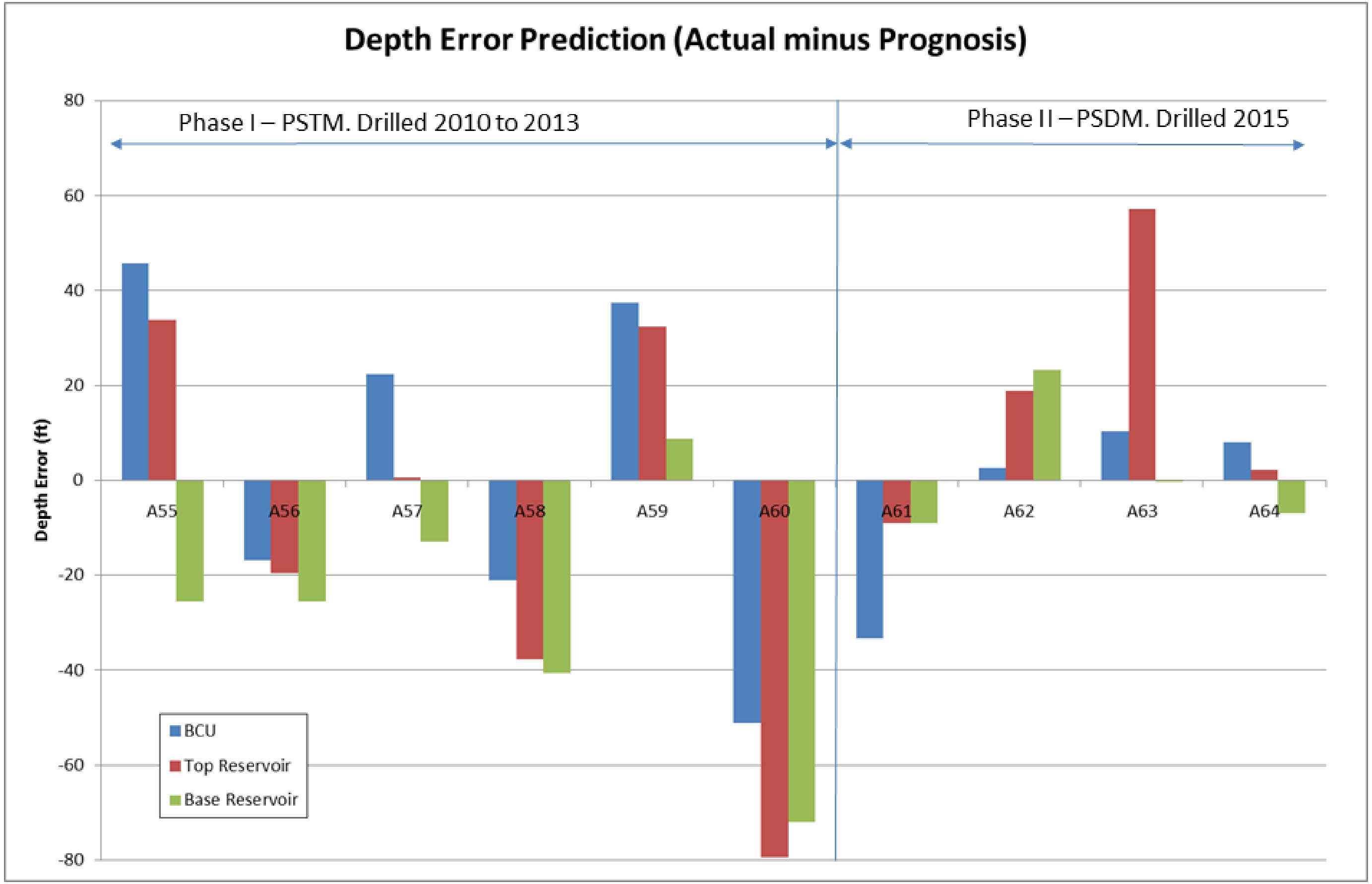




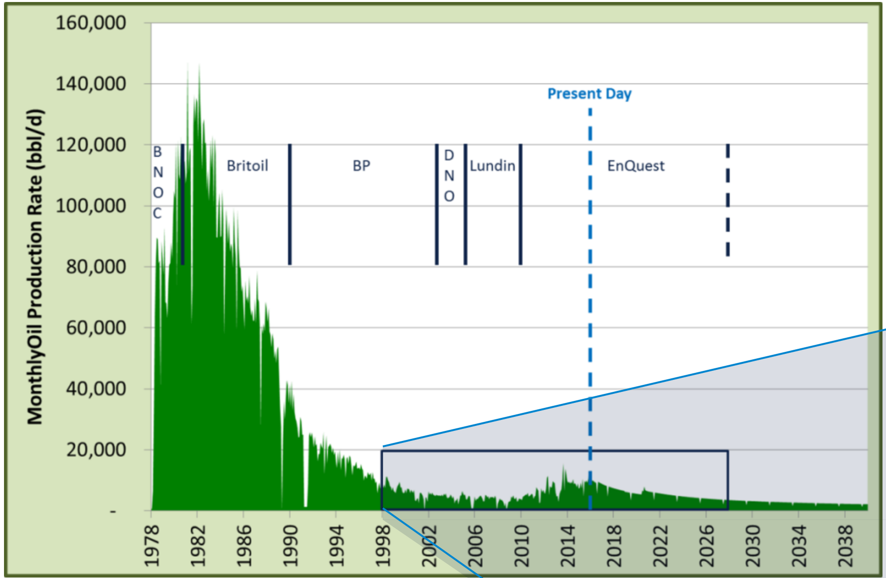
- **Strong BCU ghost interferes with top reservoir reflection.**
- **Very little intra-reservoir seismic character.**
- **High degree of uncertainty over top reservoir pick**

- **Intra-reservoir reflectors rising steeply up towards the crest**
- **This pre-drill interpretation, used to plan the well, predicts a substantially elevated top reservoir.**
- **A64 top reservoir came in 0.3m deep to prognosis and 24m shallower than A07.**

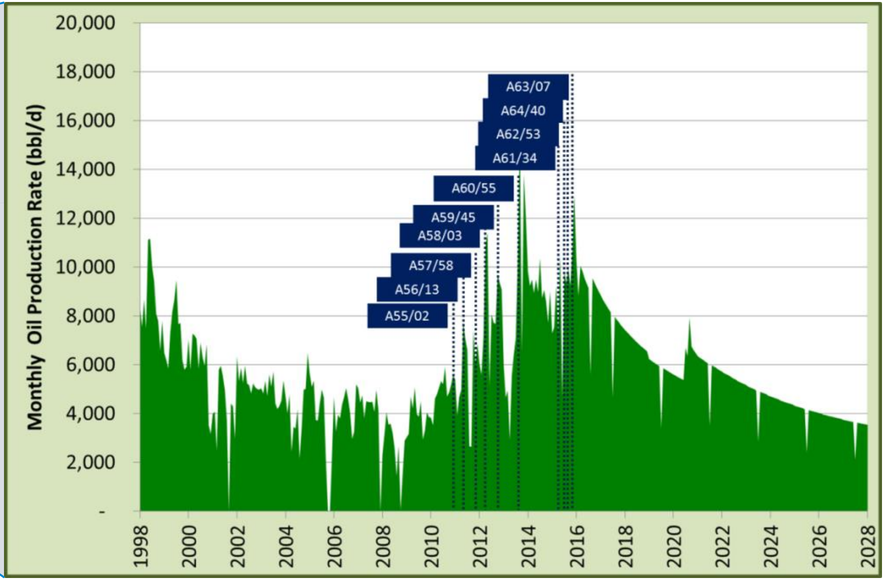
Thistle Phase I&II depth prediction errors



Field Production History



- **Over the past 6 years the Thistle installation has successfully completed 10 new wells.**
- **A61, the most successful well of the recent campaign, paid back within 3 months.**
- **Field production averaged 9,000 bopd through 2015**



- **Thistle's 2015 oil production of 3.3 MMbbls was the highest since 1997.**
- **Current COP extended to 2028**

Field Production History

- It is well known that the value of existing seismic surveys can be improved through reprocessing.
- Modern processing technologies and model building techniques can help:
  - improve accuracy of imaging
  - reduce uncertainty in positioning of faults
  - improve overall geological understanding of the results obtained from previous well campaigns
- This case study has demonstrated the benefit of this sort of re-processing.
- The new seismic image resulted in the crucial repositioning of well locations, ultimately de-risking the drilling campaign and extending the life of the Thistle field.

Acknowledgements

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- ION Geophysical for processing the data and permission to present their processing technology.
- Peter Brown[1], Clare Goodall[1] and Juergen Fruehn[1] for their contributions to the success for the project.
- Ian Jones[1] for his input to the preparation of this talk.

[1] ION Geophysical