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SPE Seismic 2017

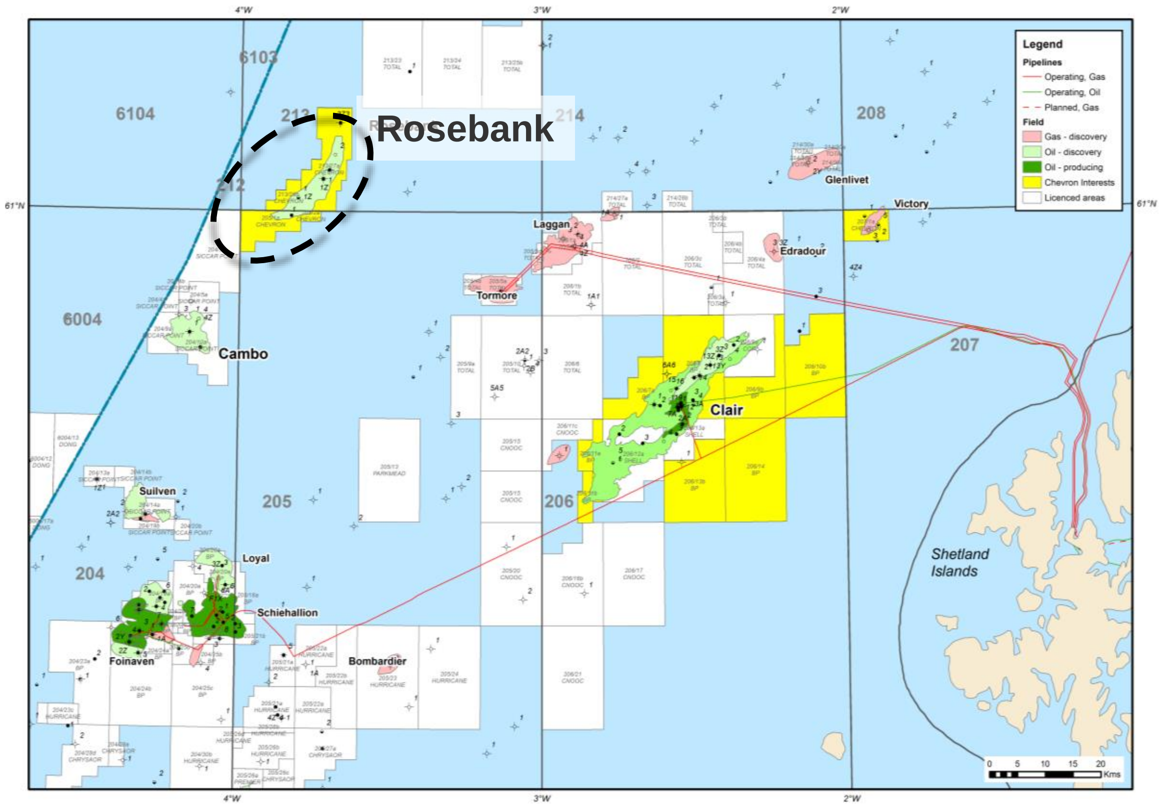
Addressing seismic challenges on Rosebank through targeted use of technology

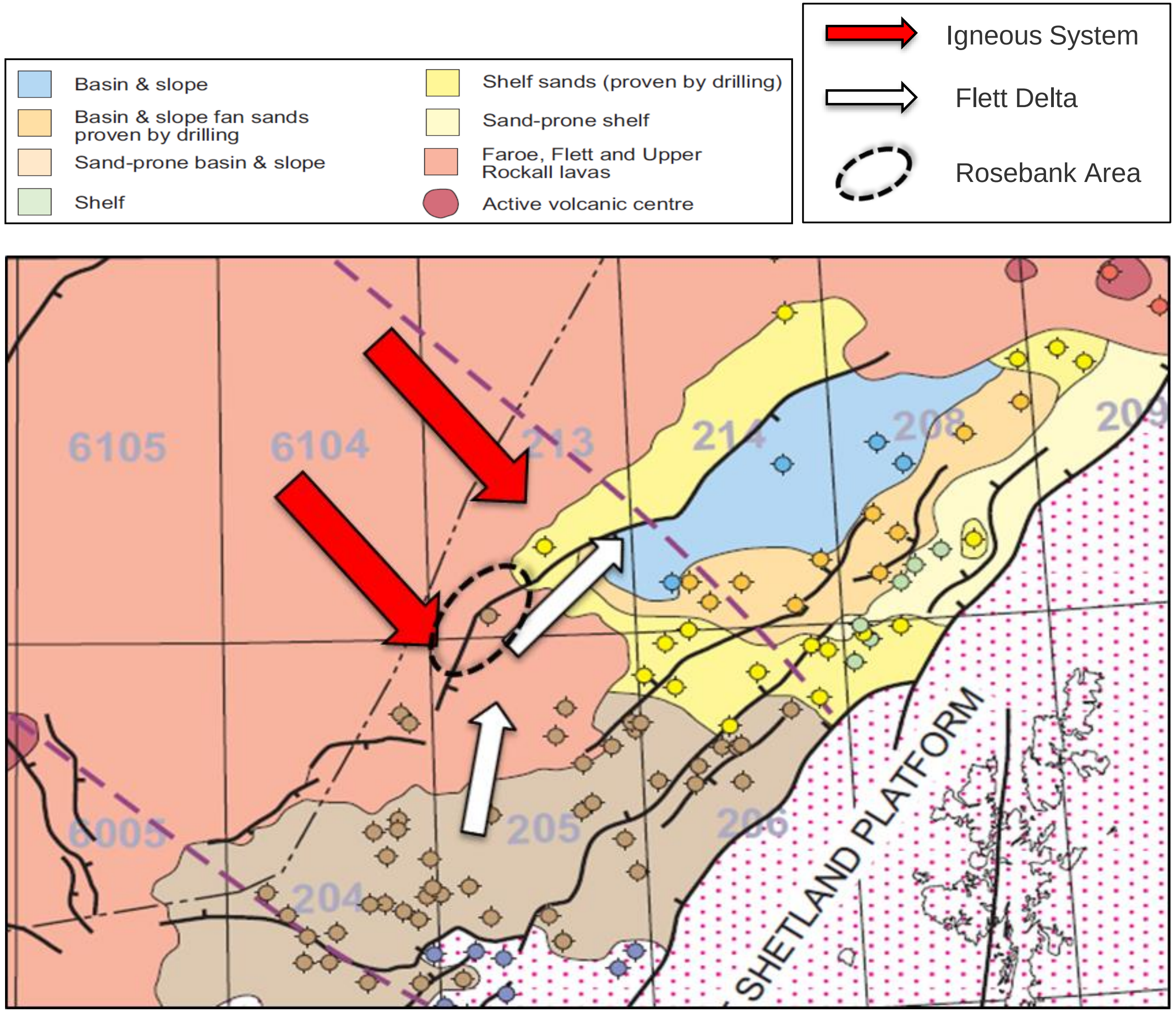
11th May 2017

Outline

- Introduction
- Regional Geology and Play Concept
- Seismic Challenges
- 3D Streamer Data
- Acquisition Modelling
- Ocean Bottom Node Seismic Data
  - Velocity Modelling
  - Spectral Decomposition
  - Spectral Enhancement
  - Inversion
- Conclusions

Rosebank Location - Faroe-Shetland Basin





After Ternan, 2009

- Confluence of volcanic and sedimentary systems:
  - ➢ Easterly advancing volcanic system of extrusive basalts and volcaniclastics
  - ➢ Contemporaneous Flett Delta siliciclastic system to the SSW prograding in a NNE orientation

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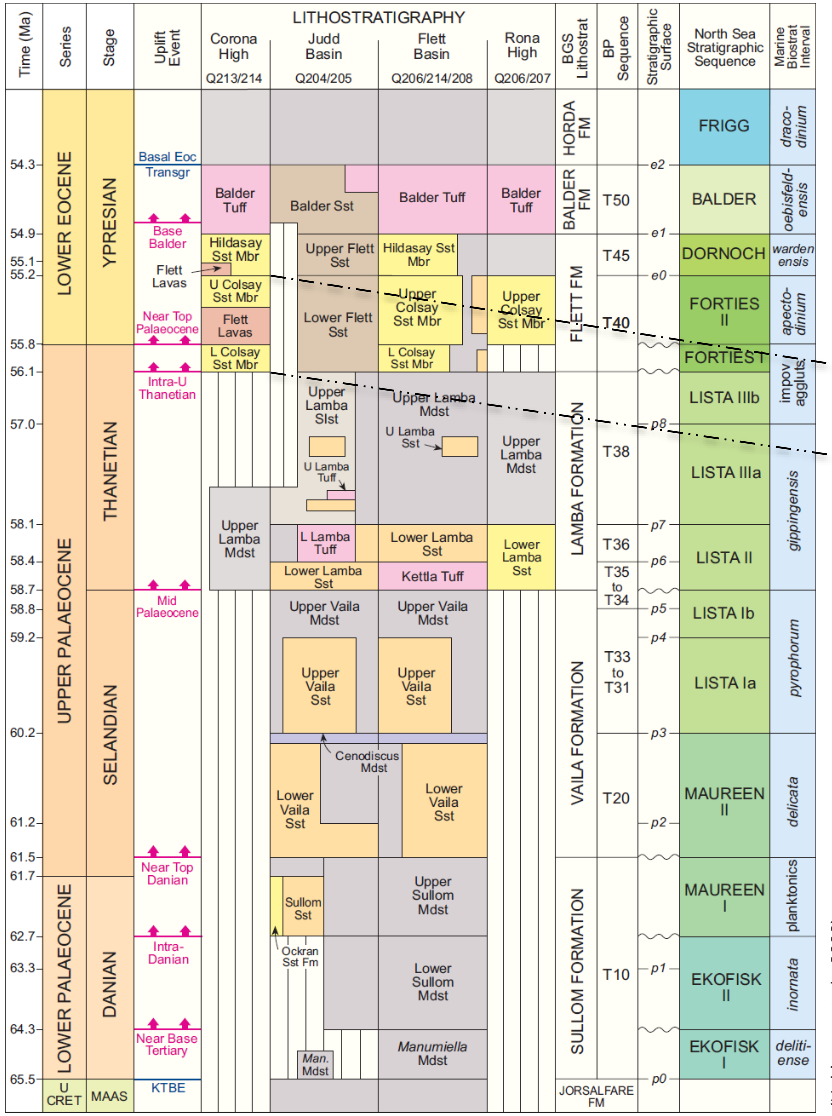
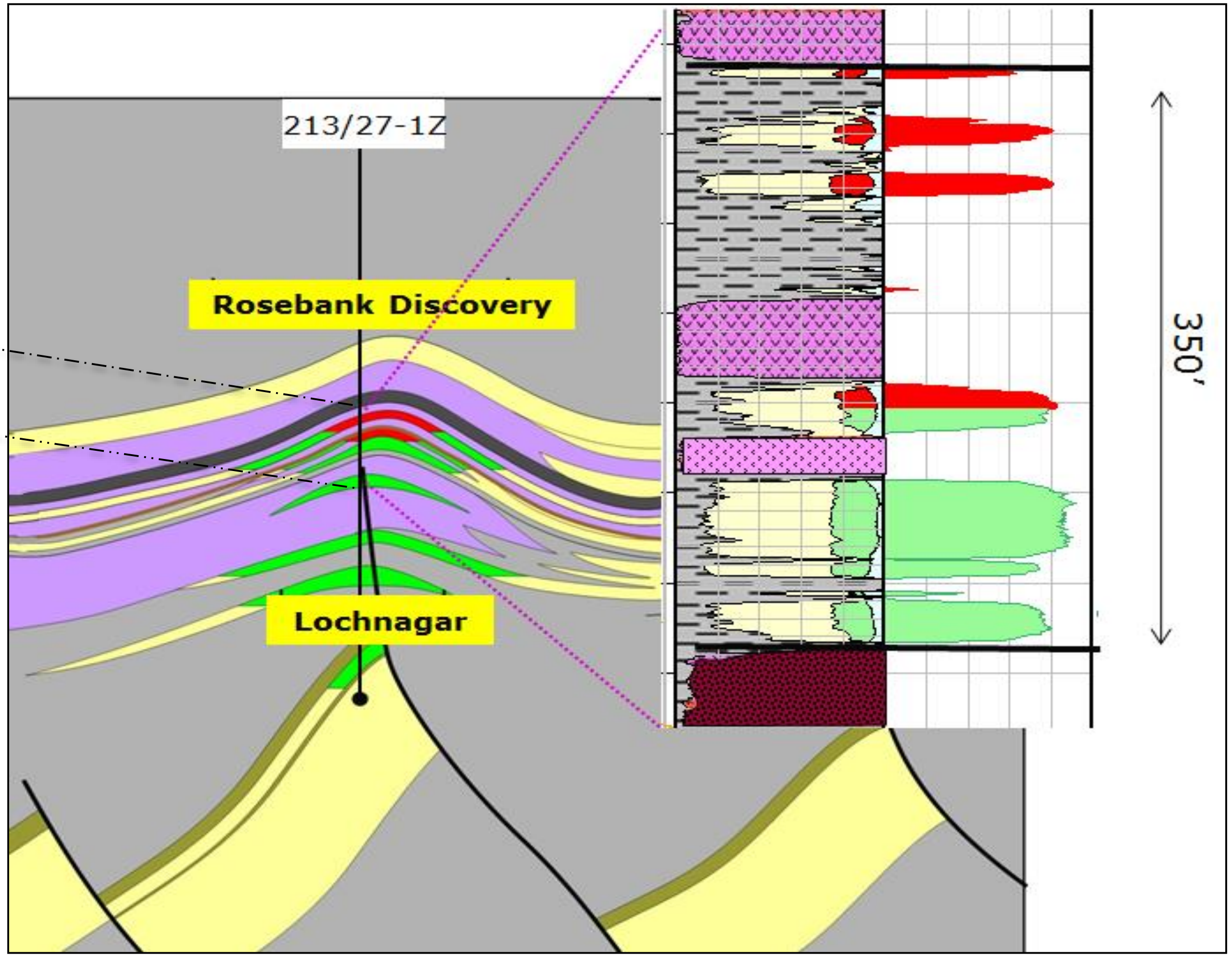
Faroes Shetland Stratigraphy:
Intra- and Sub-Volcanic Reservoirs



(Holdoway et al., 2009)



After, Duncan, Helland-Hansen & Dennehy, 2009

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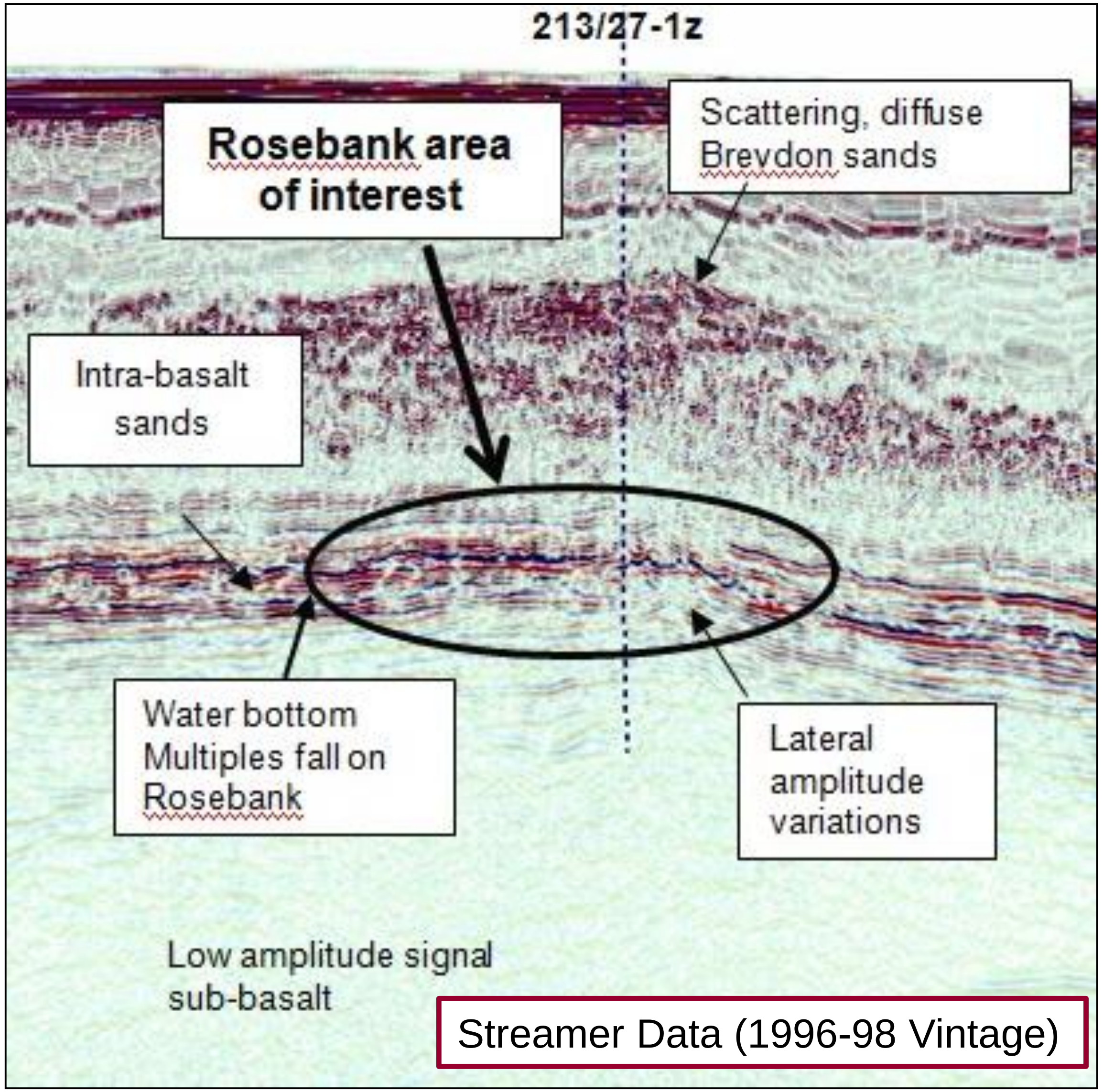
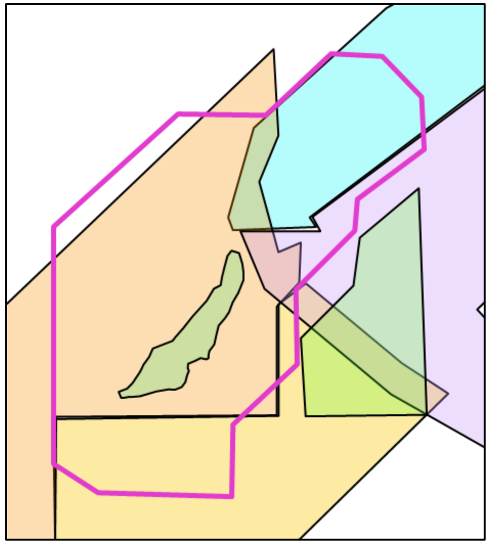
Rosebank Seismic Challenges

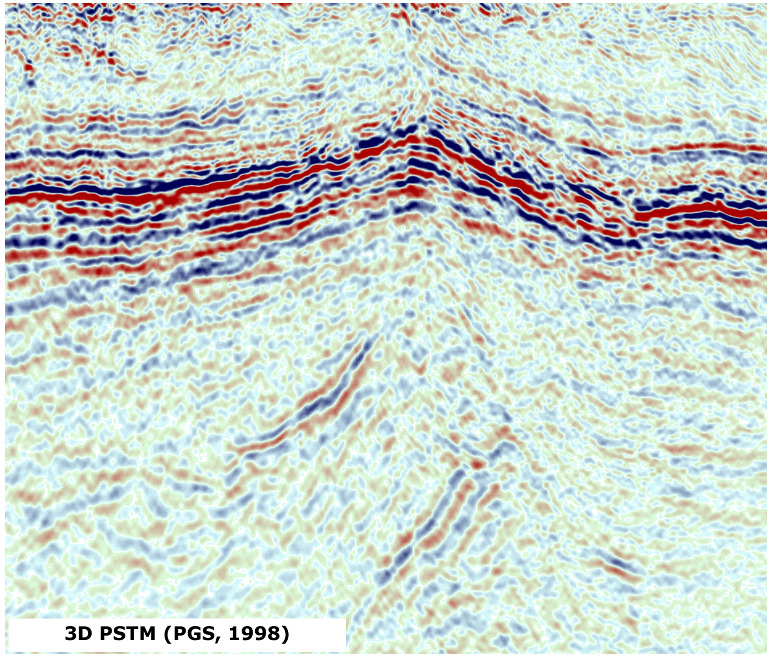


- Complex overburden
  - WB and near WB multiple noise train over target
  - Scattering due to sand injectites
- Sub and Intra basalt imaging
  - Heterogeneous volcanics interval (scattering and intrinsic attenuation)
  - Poor seismic penetration sub-basalt
- Reservoir thickness at edge of detectability
- Difficult to separate seismic response of sands/shales/volcaniclastics

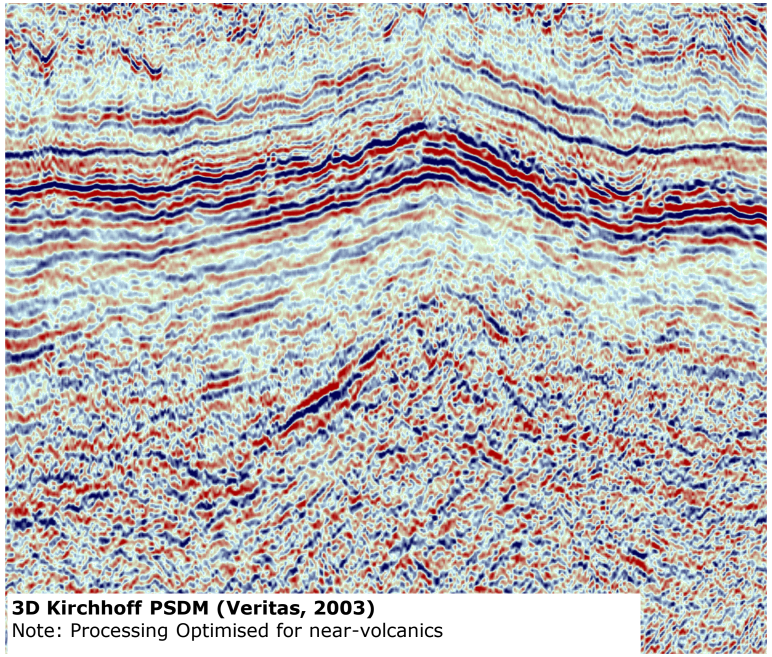
1996-2008 - 3D Streamer Data



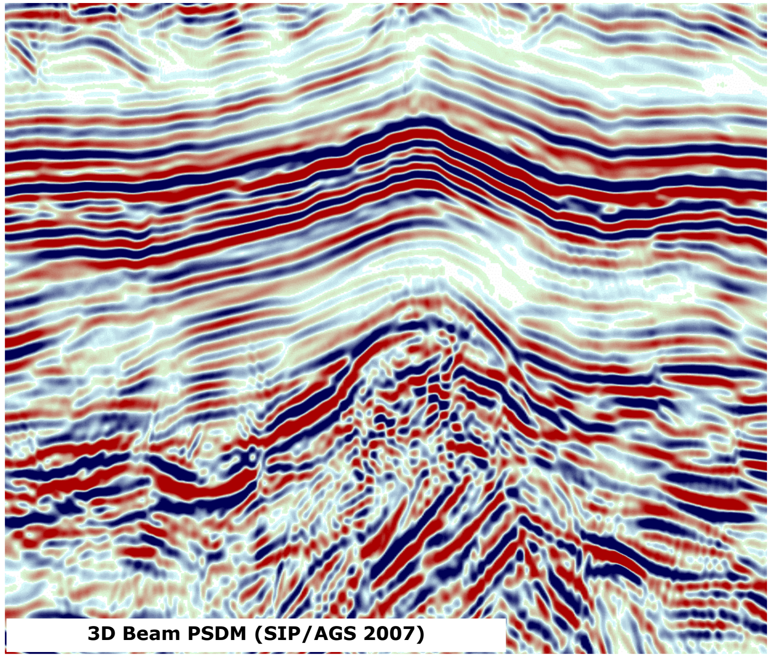
- Numerous efforts to reprocess the data were undertaken prior to and after the discovery well
- Lead to an improved image but were limited by the difficulties of merging several surveys and sub-optimal acquisition parameters for intra and sub-basalt imaging



3D PSTM (PGS, 1998)

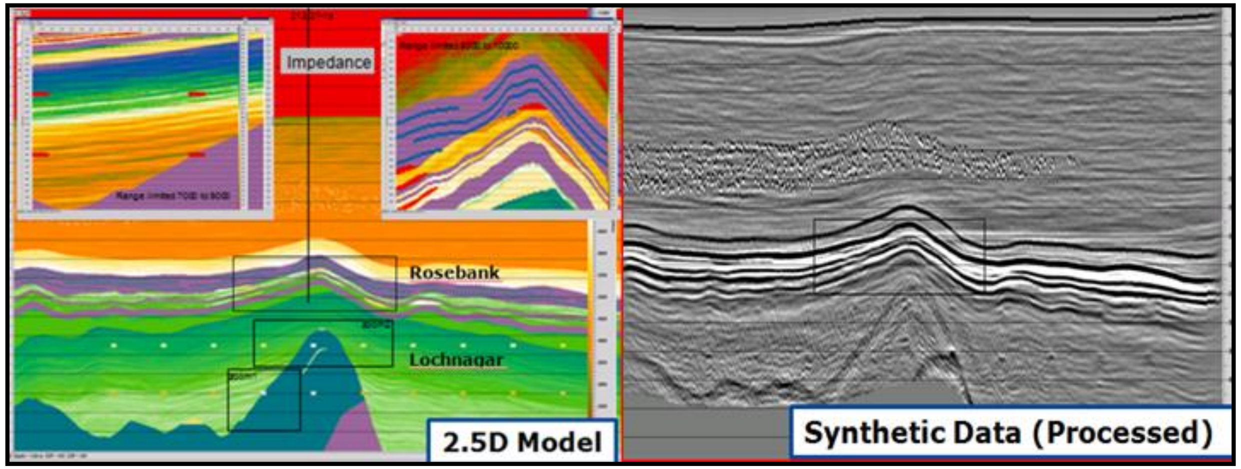


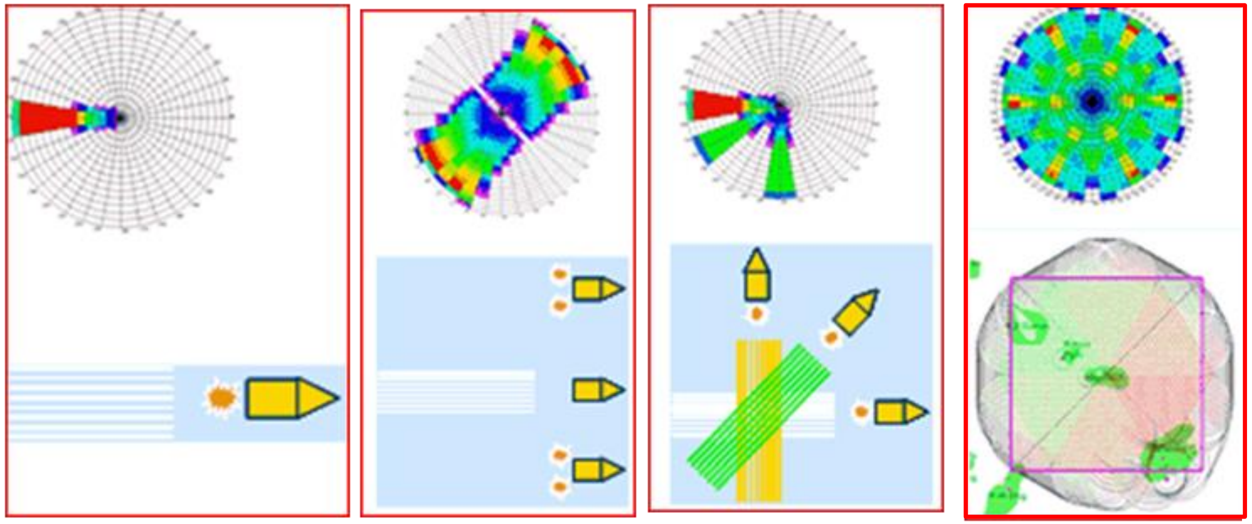
3D Kirchhoff PSDM (Veritas, 2003)
Note: Processing Optimised for near-volcanics



3D Beam PSDM (SIP/AGS 2007)

2008-9 Seismic Modelling & Feasibility Studies

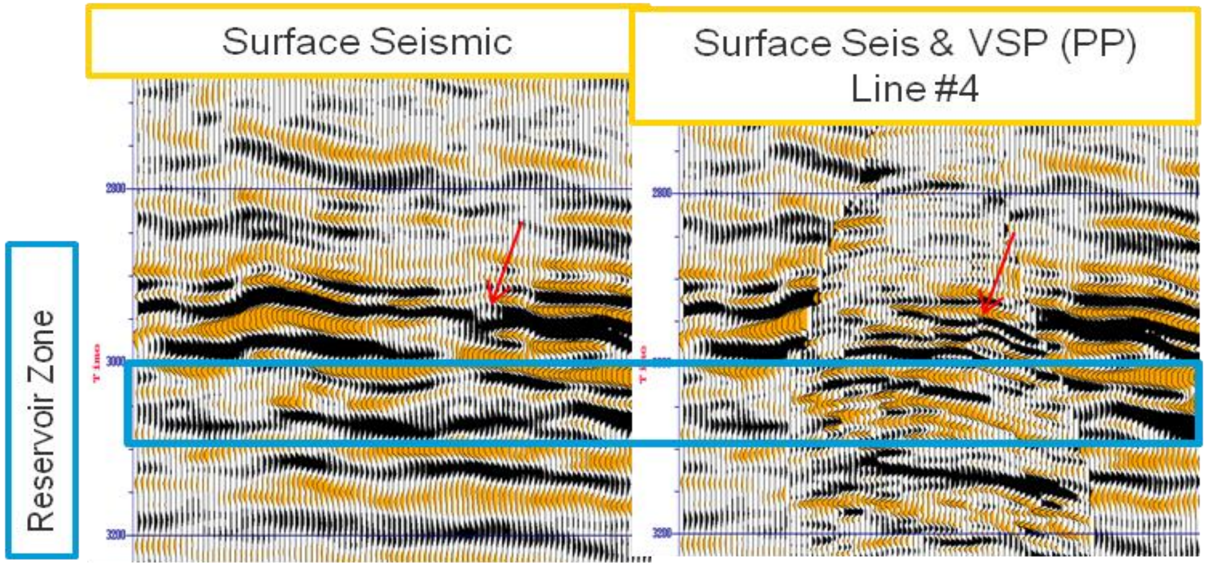


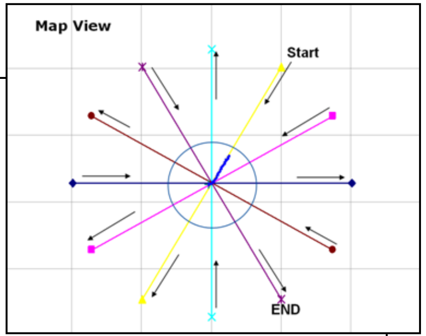


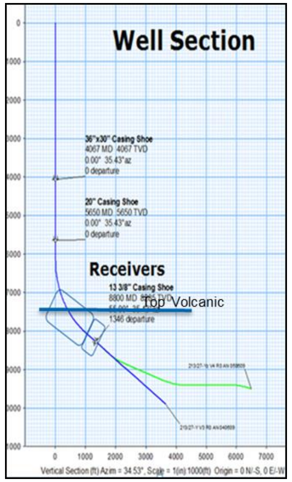
Example survey types: Single, Multi-, Wide and Rich Azimuth

- Conducted feasibility studies to enable technology selection
  - 2.5D Finite Difference Modelling and Processing (CGGVeritas) used to assess different acquisition methods
  - Extensive 4D Study; Rock Physics; Core Analysis, etc.
- OBN technology showed best results and was chosen as the preferred method.
  - Best Structural Image
  - Highest Bandwidth
  - Optimal Multiple Attenuation
  - Rich Azimuths & Best Illumination
  - Converted waves for Reservoir Characterisation
  - Best 4D Baseline (best repeatability)

2009 VSP Program Multi-Azimuth Walk-Away VSP

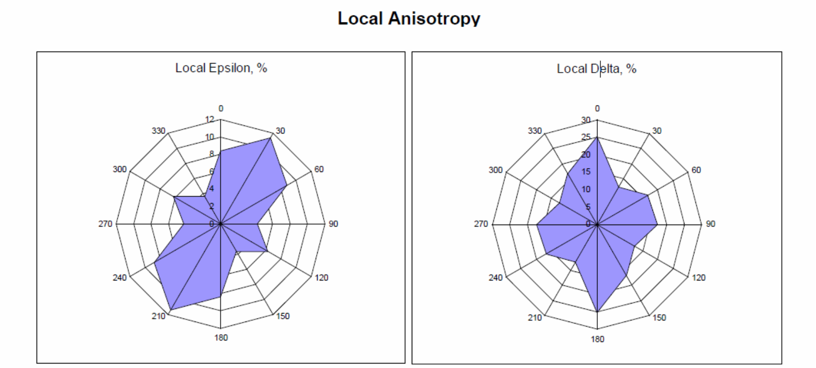




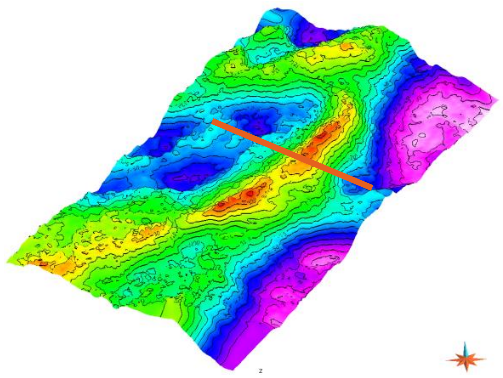


Clockwise: Pattern of VSP lines, Source boat seen from Stena Carron, Well section showing receivers

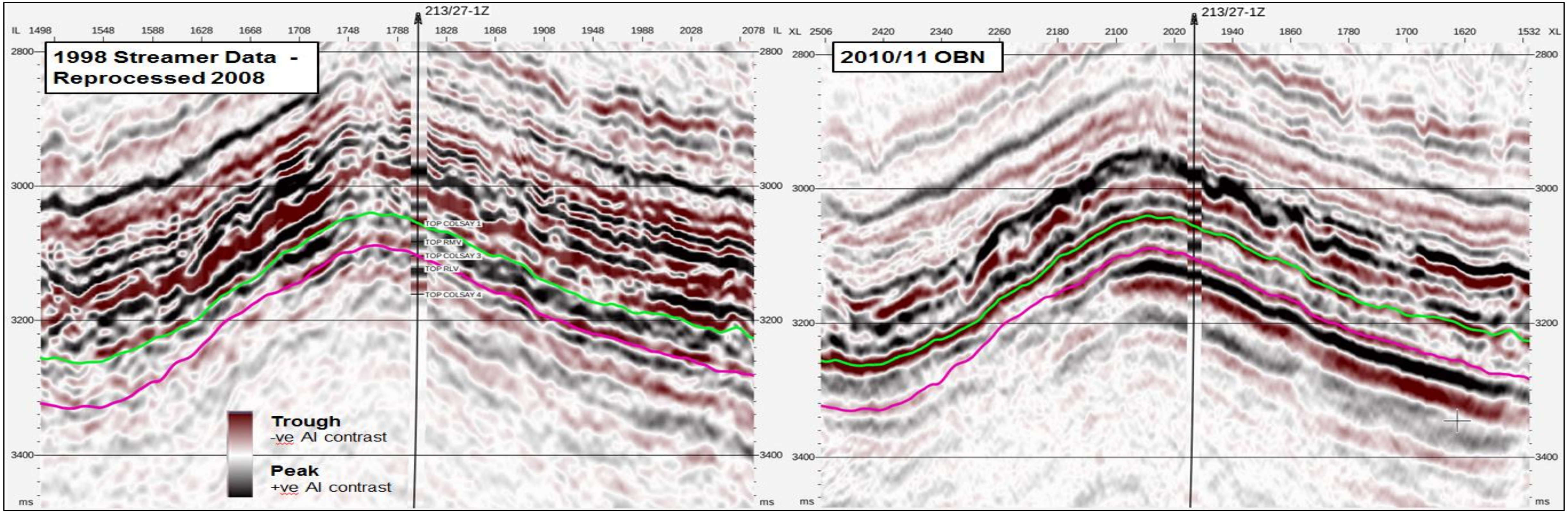
- Objectives:
  - Determine anisotropy for future processing
  - Investigate azimuthal variation
  - Increase resolution in target interval
  - Include learning's for survey planning
- Key Results:
  - Acquired 6x10km Walk-away VSP lines, Vertical Incidence VSP and Walk-around VSP
  - Higher frequencies & azimuthal dependence
  - Anisotropy available for processing of new OBN
  - Results supported OBN decision



2010 and 2011:
Stage 1 and 2 OBN Surveys



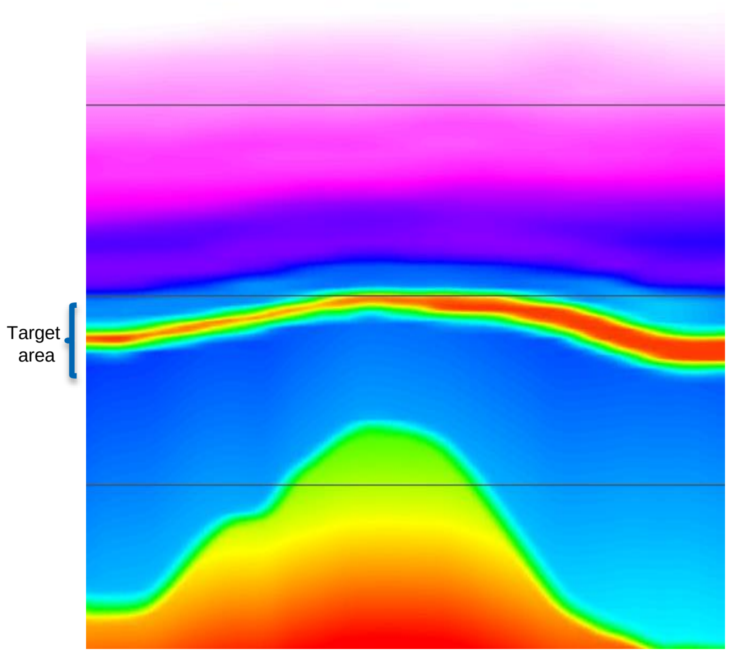
- Two stage acquisition approach to confirm benefits of OBN technology
  - Stage 1 – May-Aug 2010 - 65 km2 node 260 km2 shot area
  - Stage 2 – Apr-Aug 2011 - 109 km2 node 335 km2 shot area
  - The improved demultiple, full azimuth illumination, and increased low frequency content have all helped to increase the S/N level at the target with a much improved tie to the well synthetics



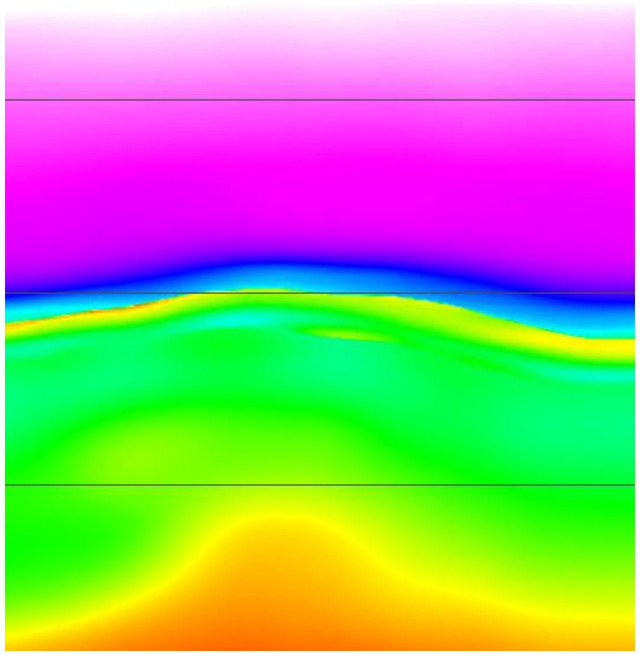
Proprietary to the Rosebank Joint Venture

OBN Seismic Imaging:
Velocity Modelling - Volcanic velocities

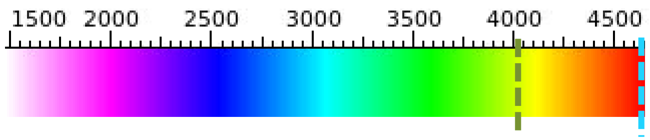
Best Technical Imaging Velocities Pre-OBN



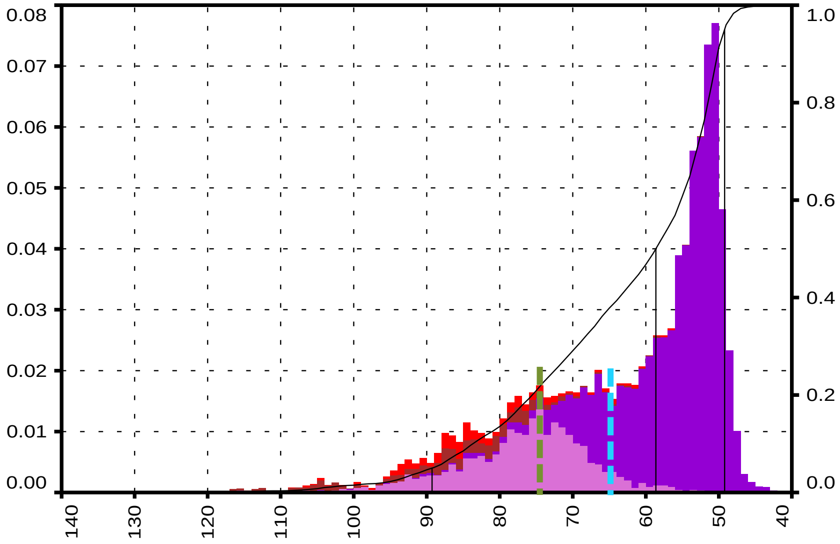
OBN Imaging Velocities



Vp interval m/s



Well Velocities From Sonic Logs



LOG FACIES	DESCRIPTION
	Coarse-grained Volcaniclastic Sandstones
	Fine-grained Volcaniclastic Siltstones
	Vesicular Basalts
	Basalts

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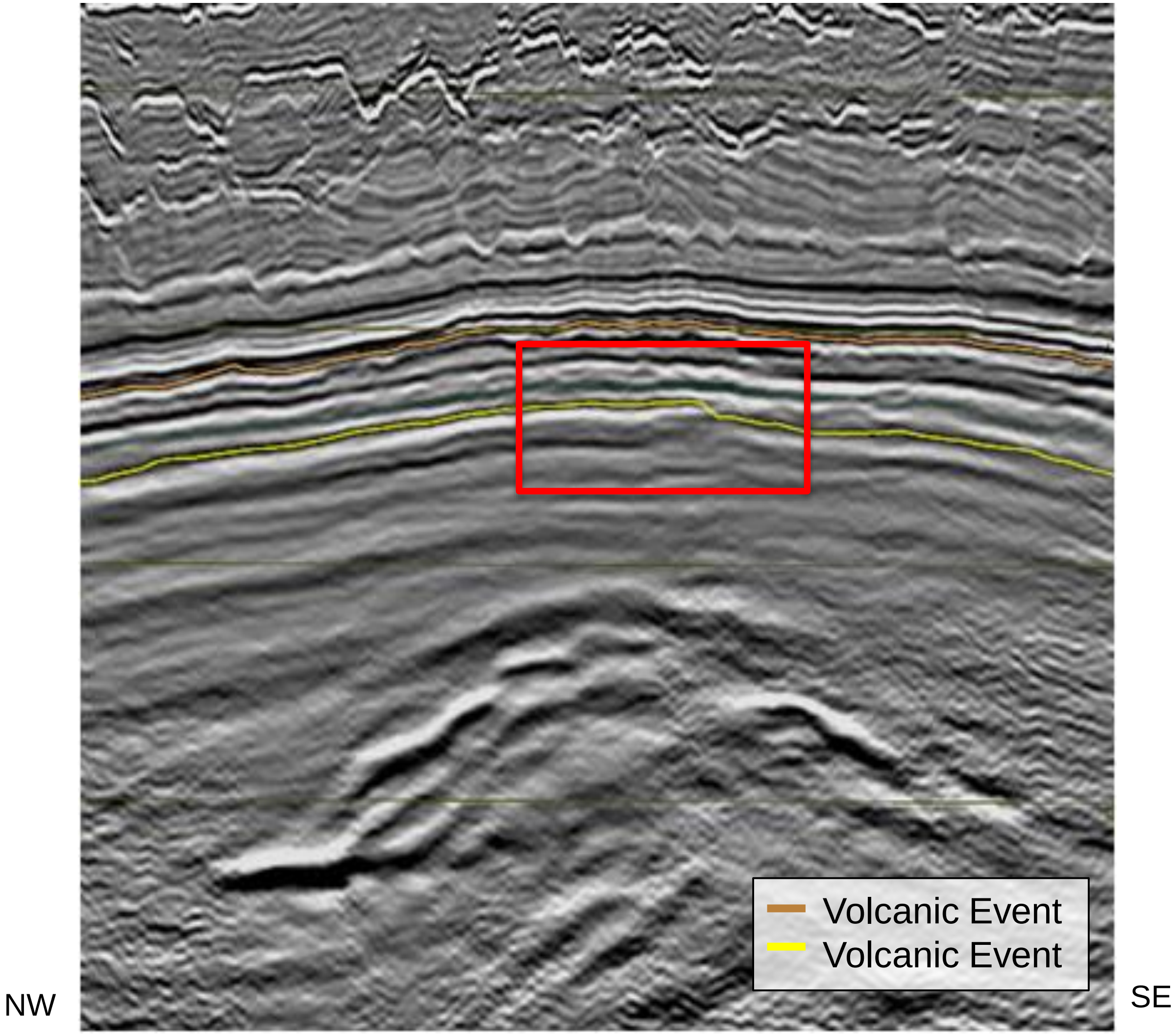
OBN Seismic Imaging
Velocity Modelling – Enhanced structural definition

OBN Inline



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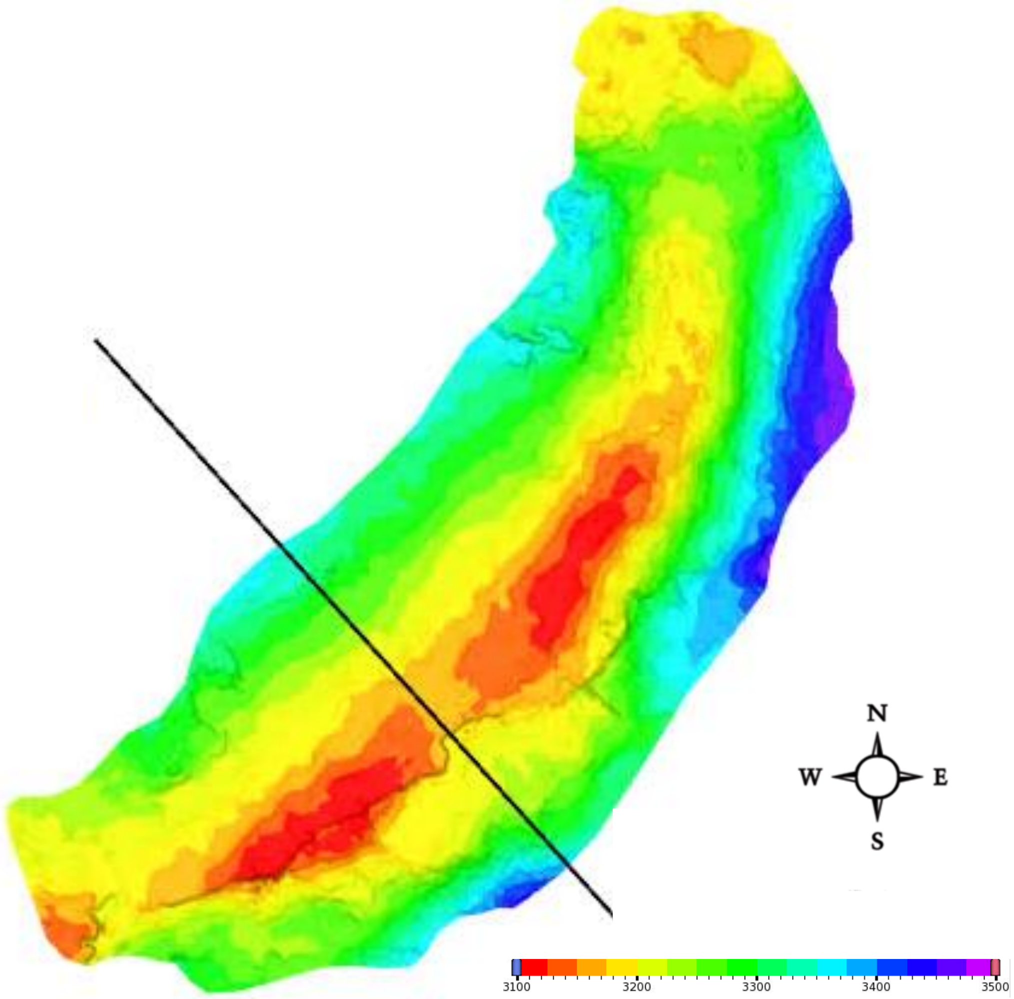
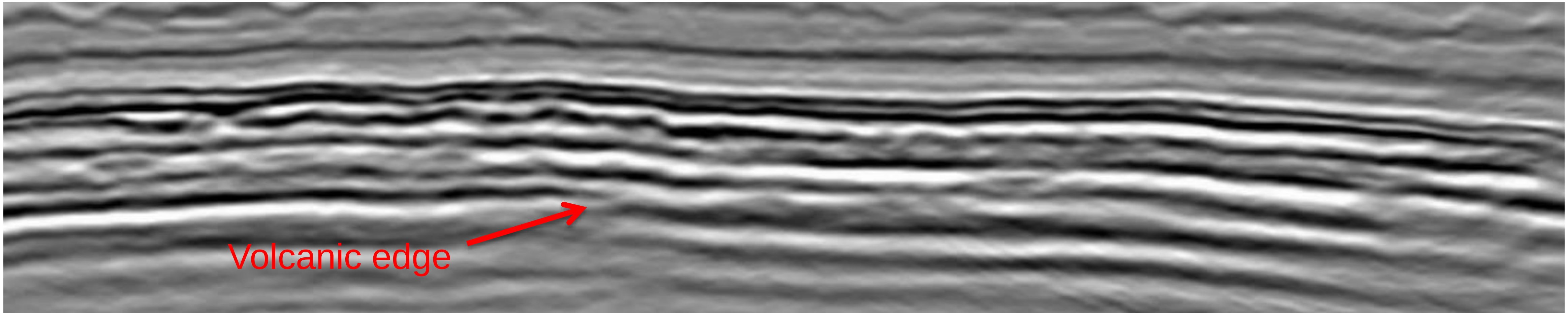
Peak, Black
+ve AI contrast

Yellow Event - TWT Structure Map



OBN Seismic Imaging
Velocity Modelling – Enhanced structural definition



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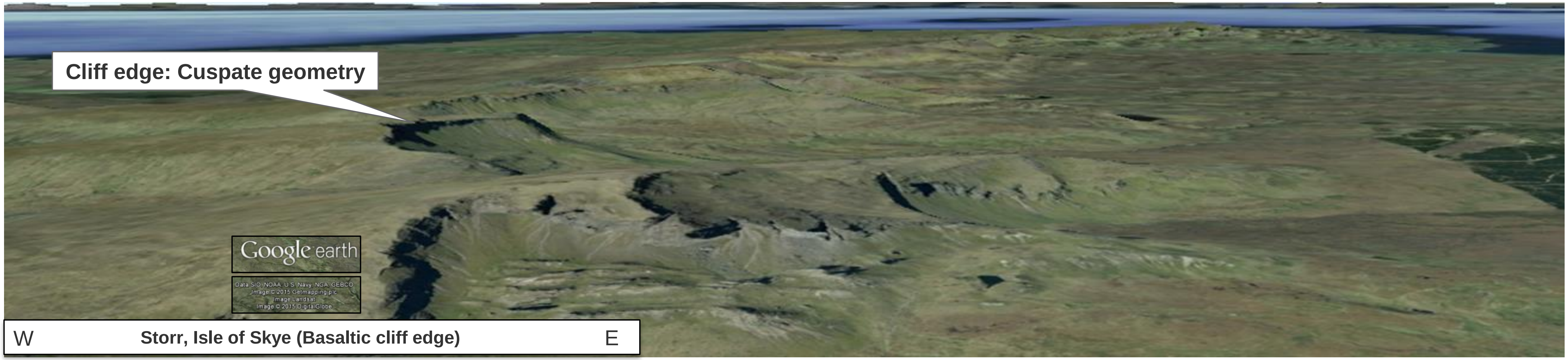
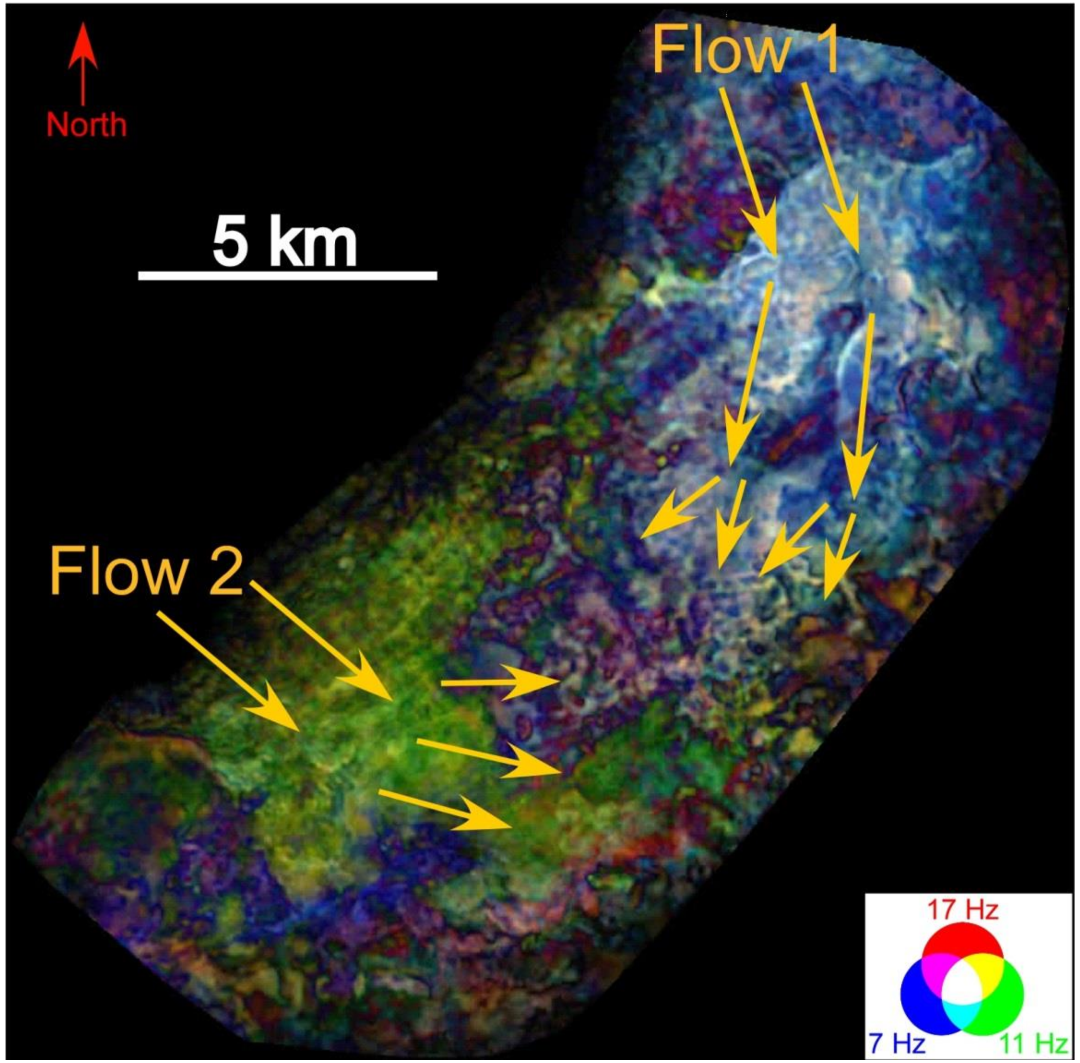


Overburden:
Spectral Decomposition



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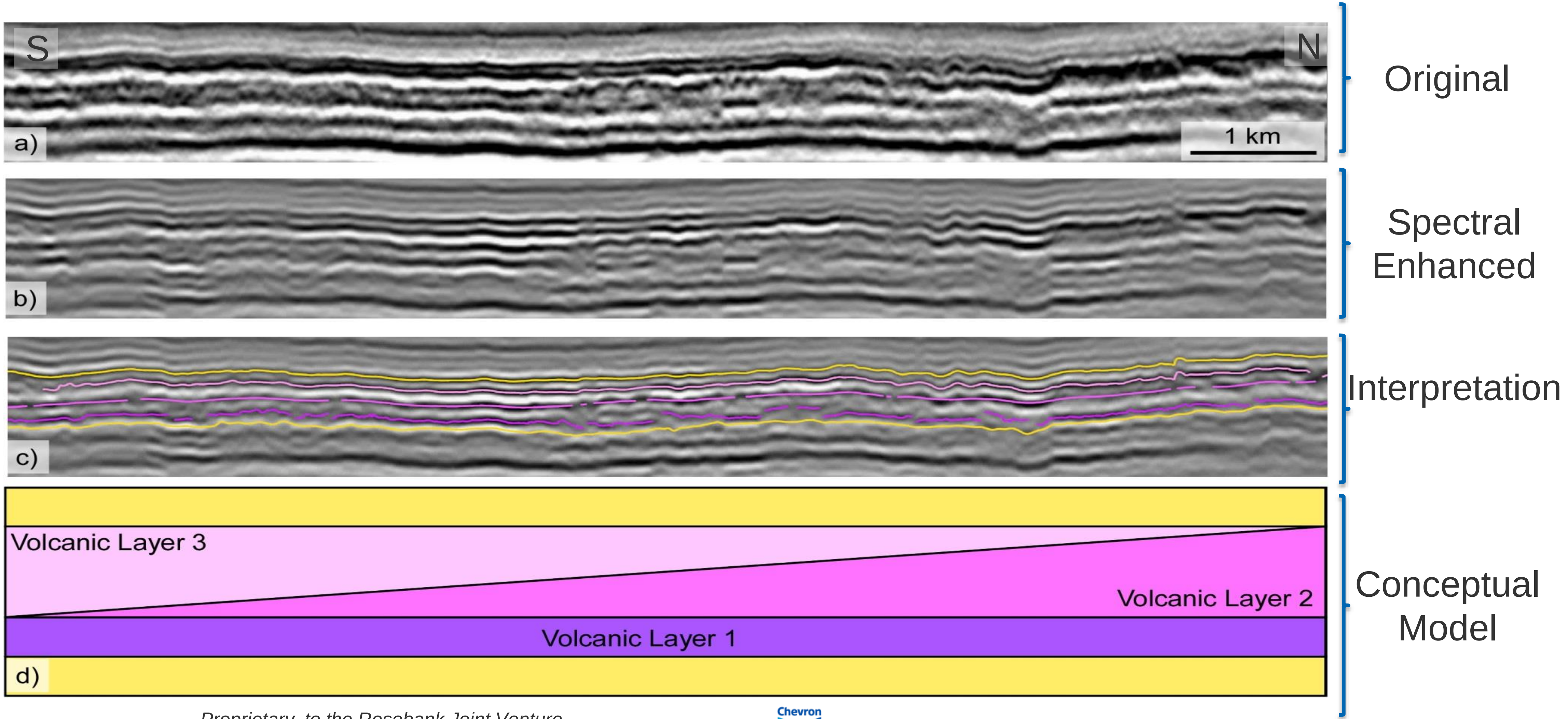
- RGB (Red-Green-Blue) blend of 3 magnitude volumes (17Hz/11Hz/7Hz)
- Northern area characterized by strong 7 Hz signal (Blue)
- South-western area dominated by 11 Hz signal (Green)
- Central area shows a mixed seismic signal
- Spatial geometry of seismic response point towards individual gross flow packages
- Flow 1 = 75% basaltic, Flow 2 = 75% volcaniclastic

Overburden:
Spectral Enhancement



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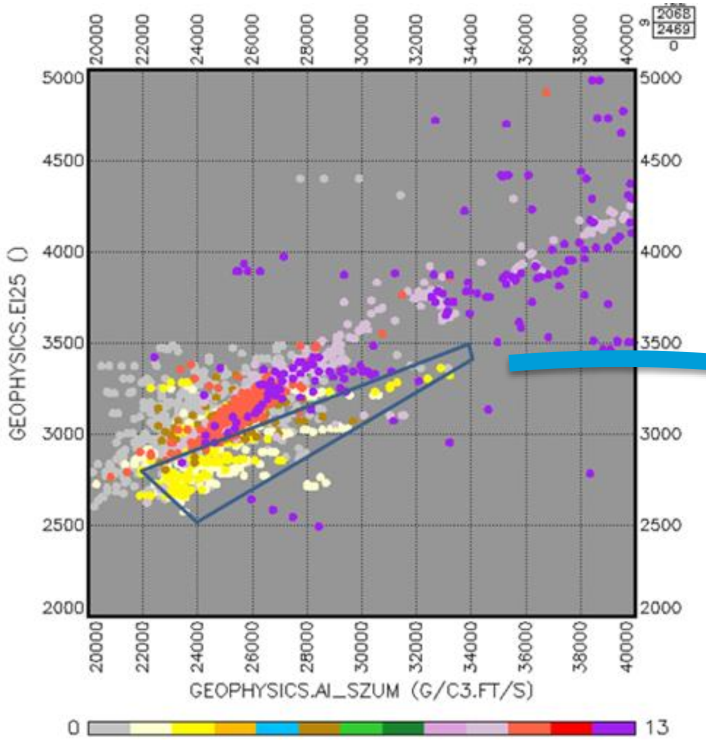
Reservoir Characterisation:
Inversion - interpreting sand vs non-reservoir facies

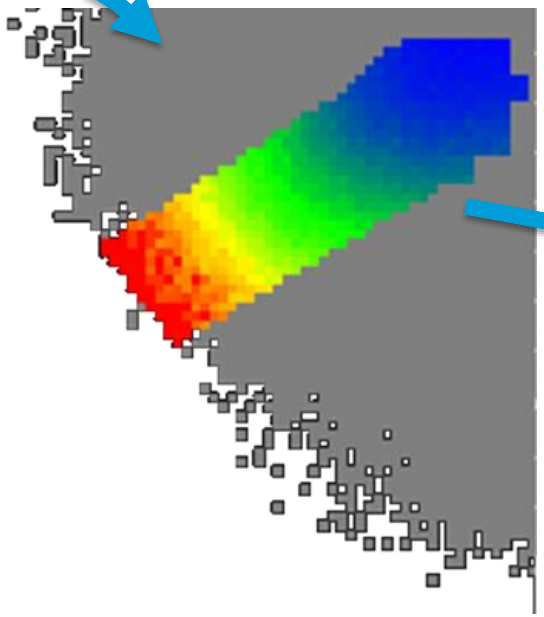


Acoustic vs Elastic Impedance

Well Data *Coloured by Facies*

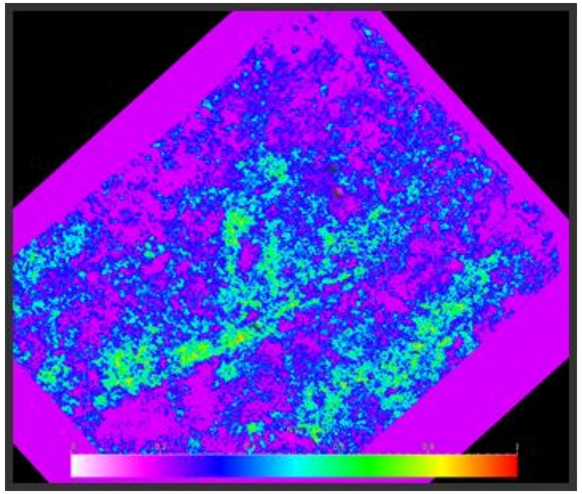
Acoustic vs Elastic Impedance

Seismic Data *Coloured by Sample Density*



Facies	
Background shale	
Braided sand bars	
Inter-bar sands	
Mouth Bars	
Overbank	
Proximal Pro-delta	
Distal Pro-delta Silts	
Coarse Volcaniclastic	
Fine Volcaniclastic	
Coarse Volcanic	
Basalt	

Sand Probability Map



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Conclusions

- Rosebank reservoir unique in subsurface context
  - Significant technical challenges
- Technologies have been screened and selected based on their ability to address these challenges
- Significant image uplift from high quality OBN data acquisition
  - OBN has provided a legacy dataset for the asset
  - Improved structural definition across the Rosebank prospect
  - Quantification of volcanic velocities and improved imaging leading to refined velocity models.
  - Identification of individual basaltic flow units using spectral decomposition techniques.
  - Increased confidence in sand distribution in inter-well space for development planning
- Improve subsurface decision making
  - Better definition of in-place and resource distributions
  - Potential to reduce costs through optimal placement of wells

Acknowledgements

Rosebank Co-Venturers:

- Chevron North Sea Limited
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- Siccar Point Energy Limited
- DONG E&P (UK) Limited