Understanding Spatial Uncertainty for Drilling Sand Injectites

Nicholas Cooke, Adrian Merry and Claire Sherry

Maersk Oil UK

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Agenda

- Introduction to sand injectites and motivation for the work
- Vertical uncertainty
- Lateral uncertainty
- Discussion

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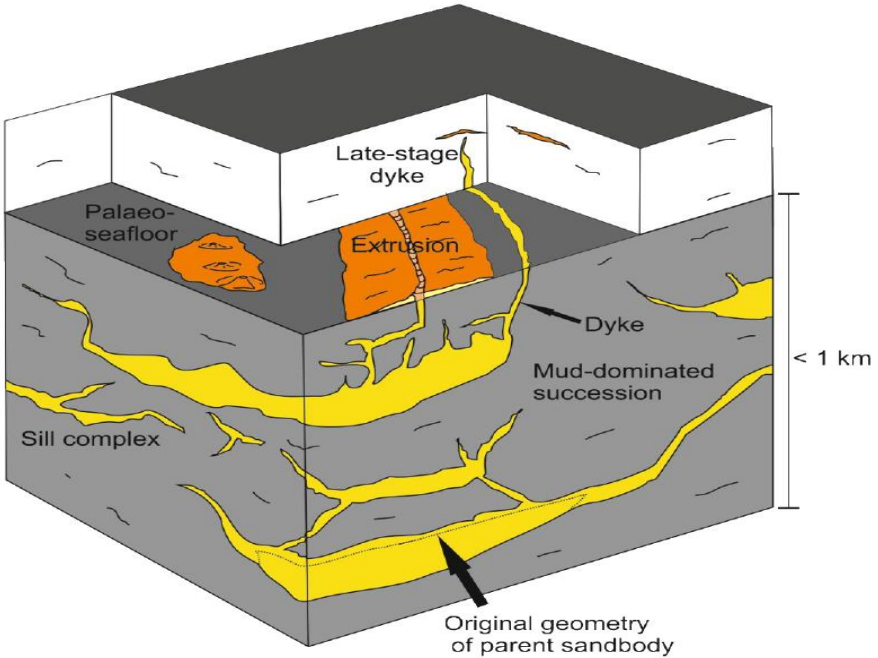
Introduction to Sand Injectites



Most recognised elements of a sand injection complex, modified from Hurst *et al*., 2011

- Extrusions
  - Sand volcanoes and fissures
- Dykes
  - Discordant intrusions
- Sills
  - Concordant, tabular intrusions
- "Parent" or depositional sand

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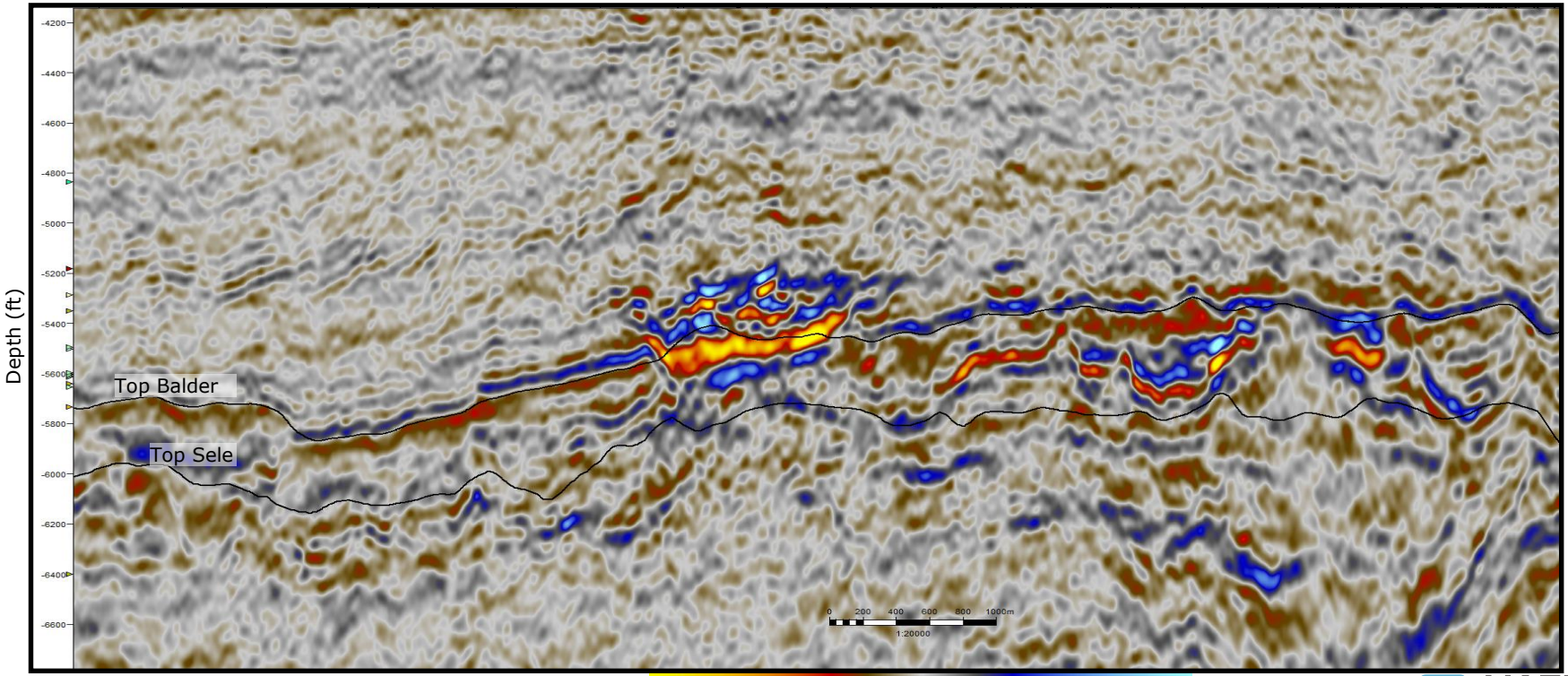
Introduction to the Problem



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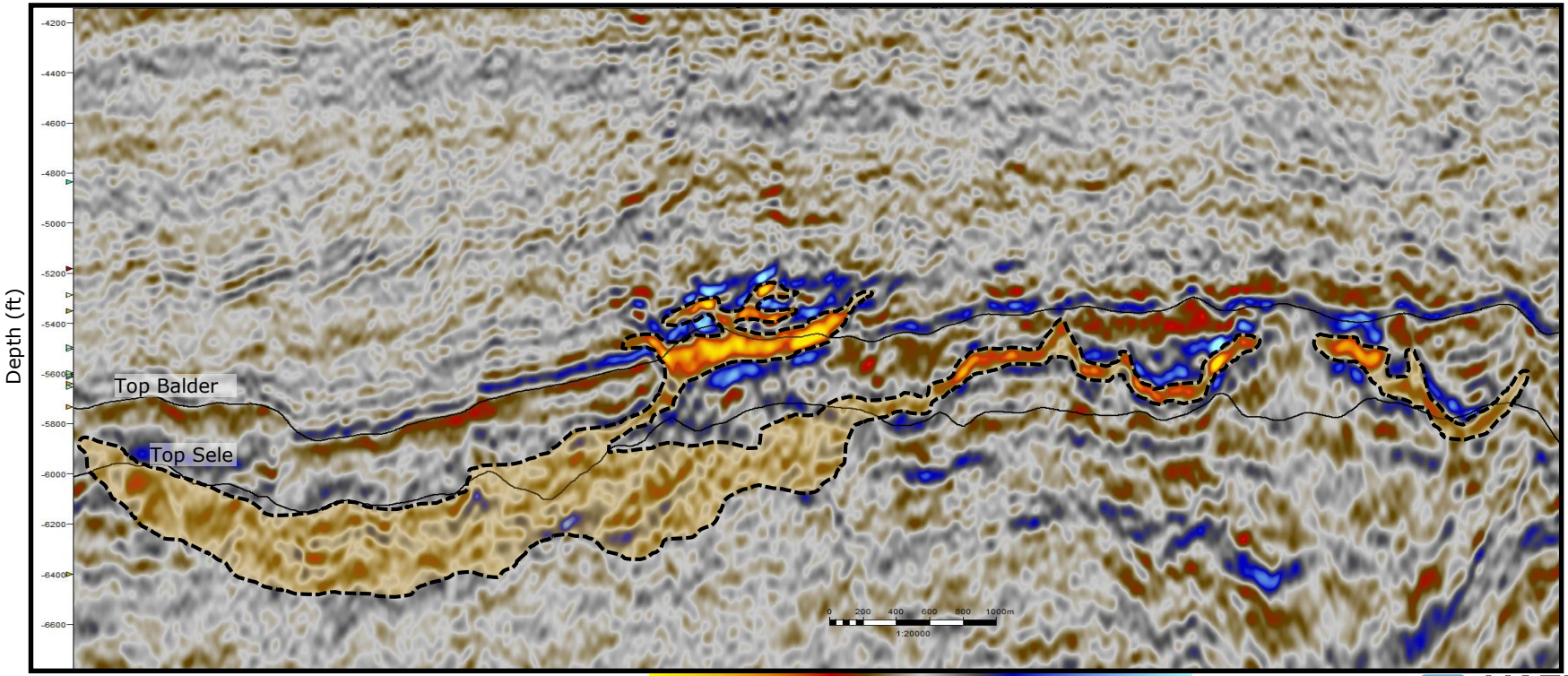
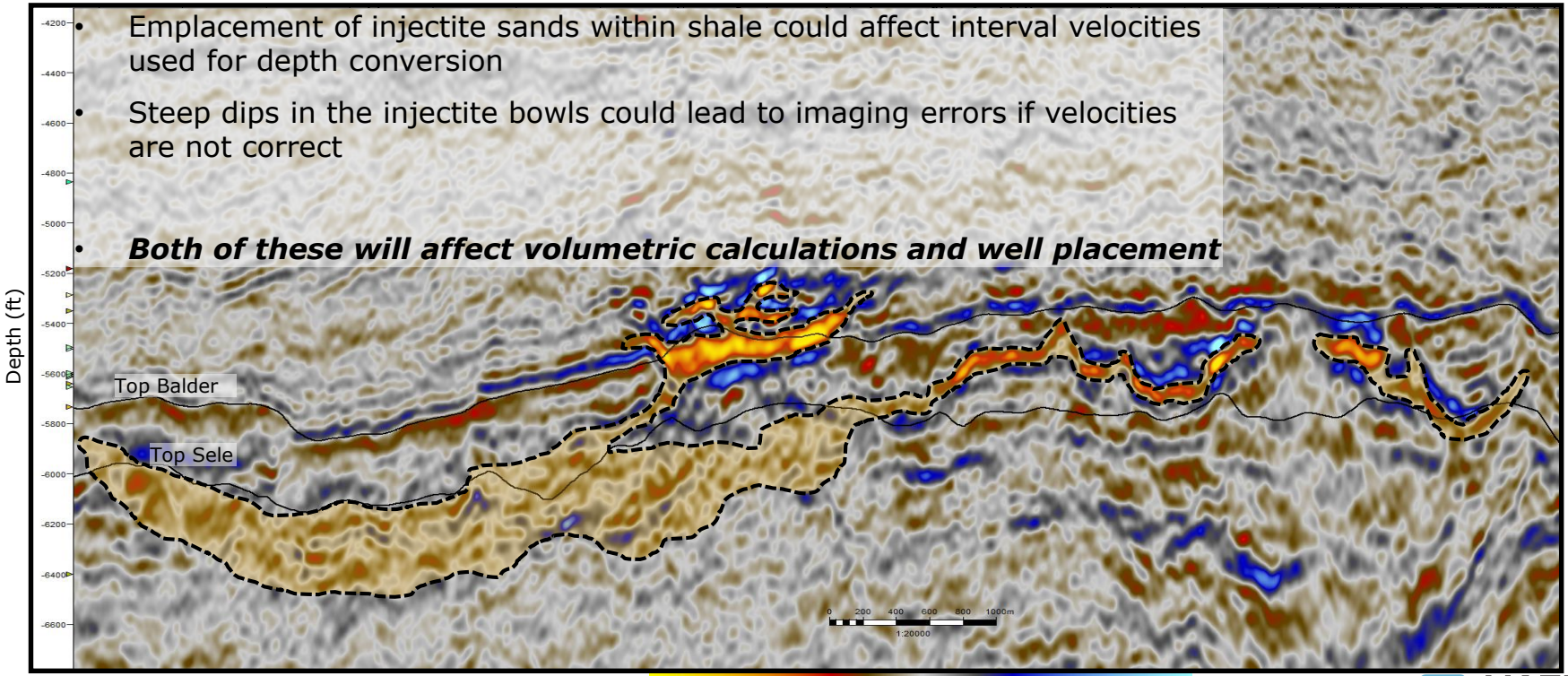
Introduction to the Problem



Introduction to the Problem



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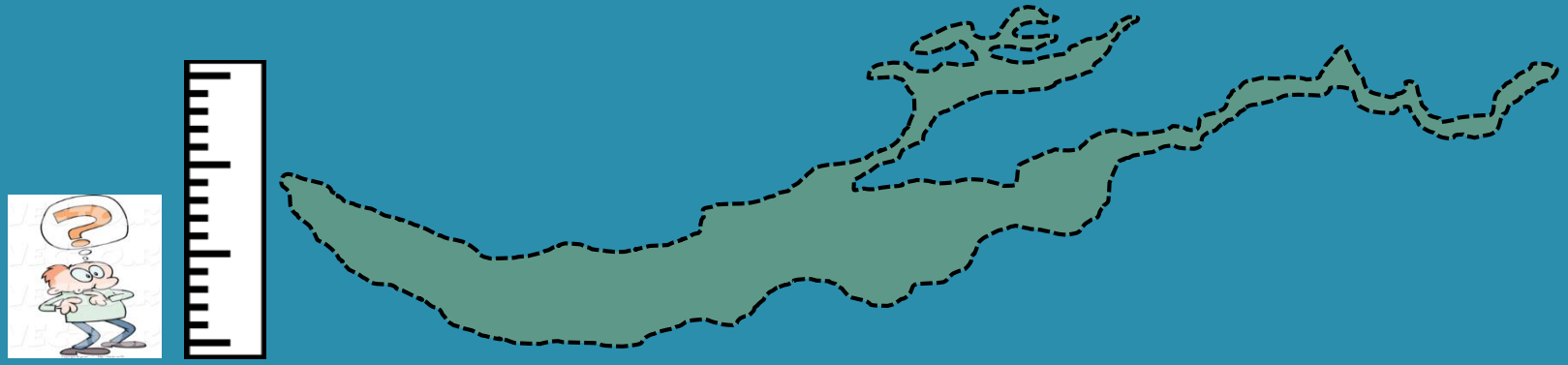

Vertical Uncertainty

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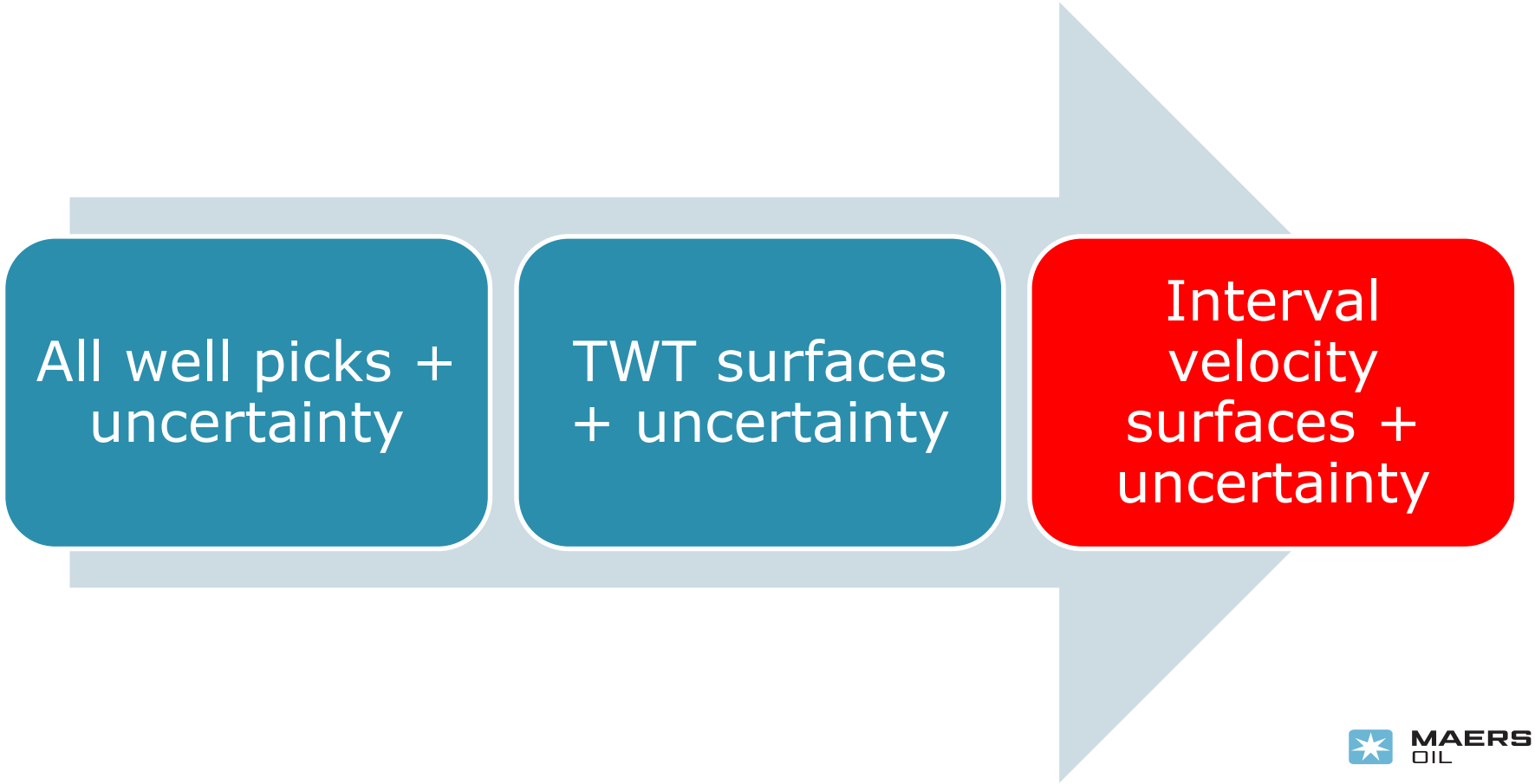
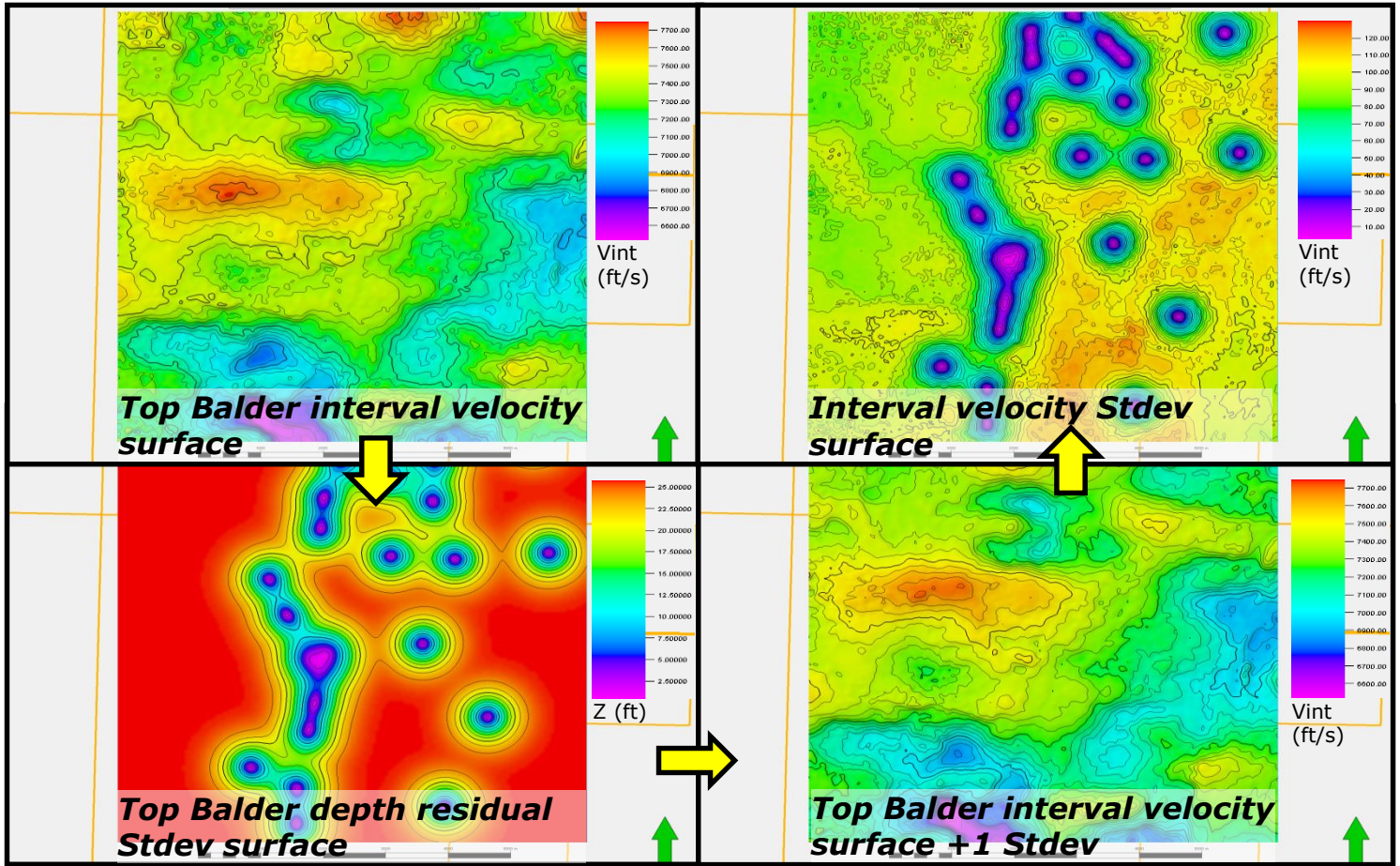
COHIBA Workflow



Velocity Uncertainty



- Depth residuals were used to generate an interval velocity standard deviation surface
- These are used to understand the uncertainty in the interval velocity

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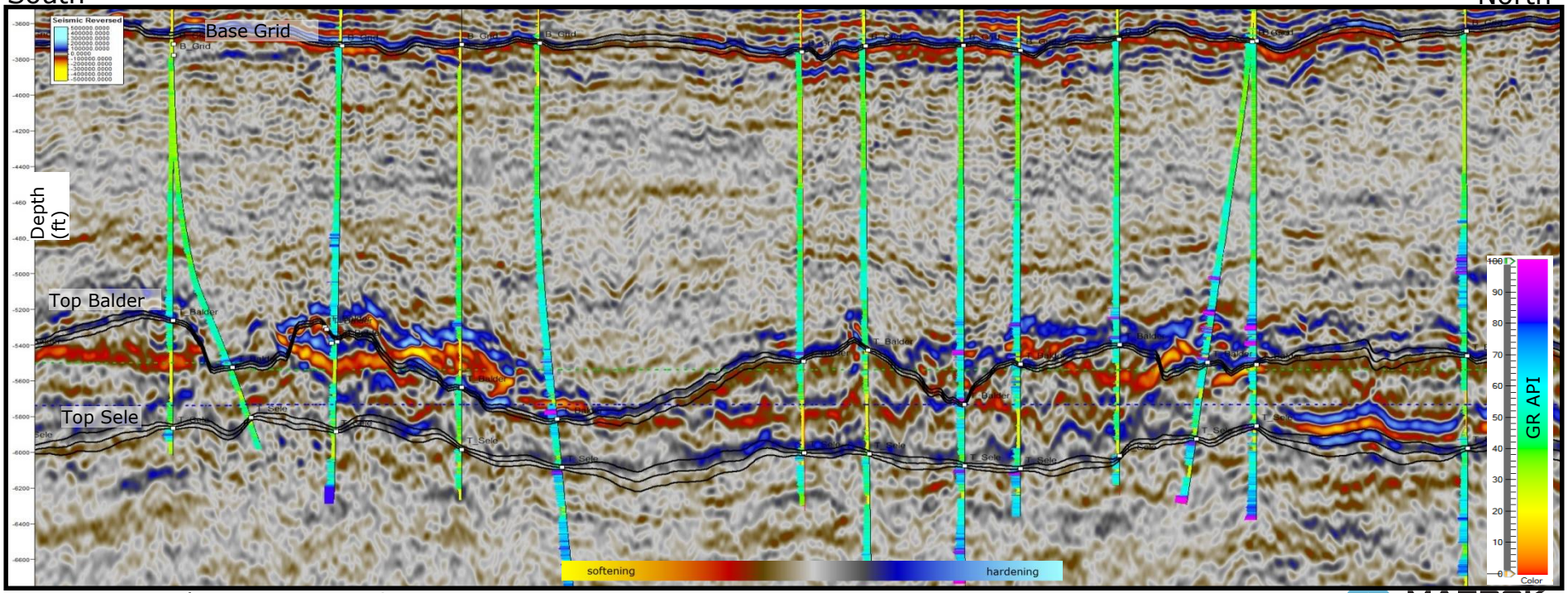
COHIBA Depth Conversion

Surface	Average (ft)	SD (ft)
B_Grid	7	33
T_Balder	0	21
T_Sele	-2	27

South North



Vertical Exaggeration x2

CI Far Stack 30-36°

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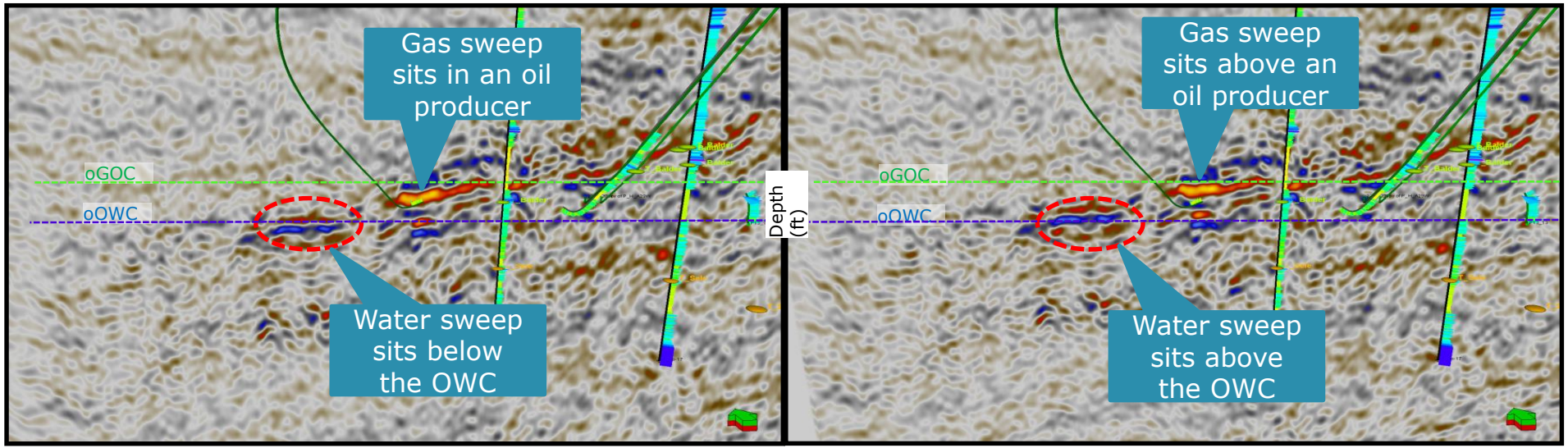
4D QC of the Velocity Model



CI 4D 2011-1990

Old Velocity Model

Vertical Exaggeration x2

CI 4D 2011-1990

New Velocity Model

Gas replacing oil softening

Water replacing oil hardening

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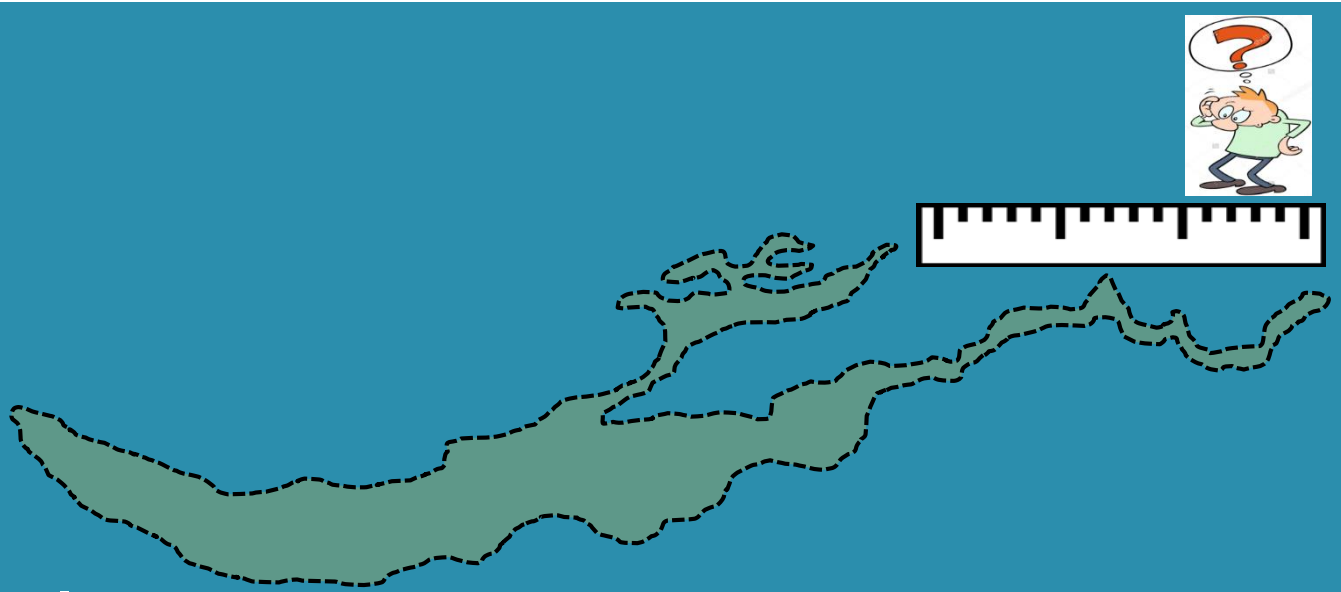

Lateral Uncertainty

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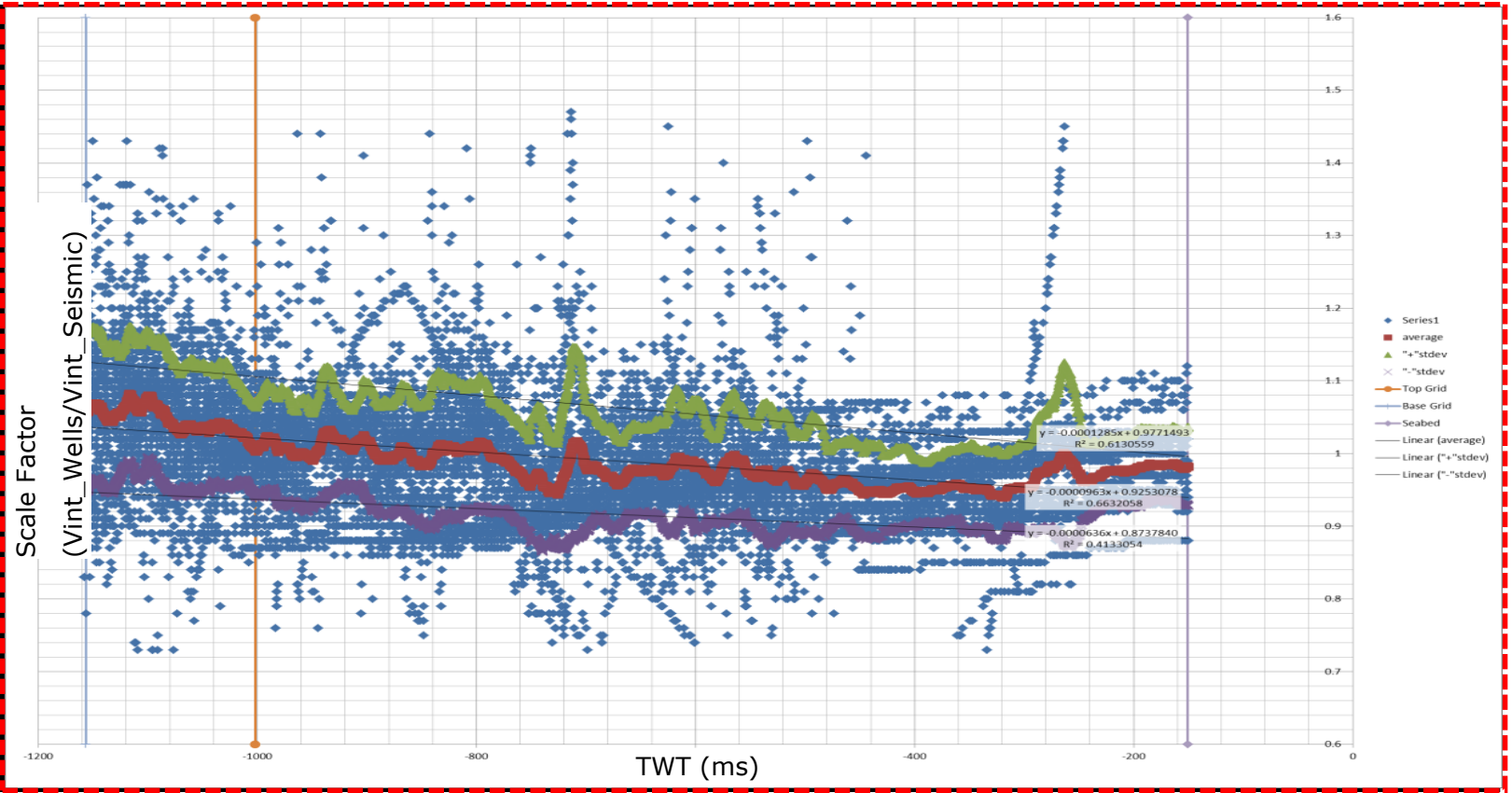
Scale Factor Curves



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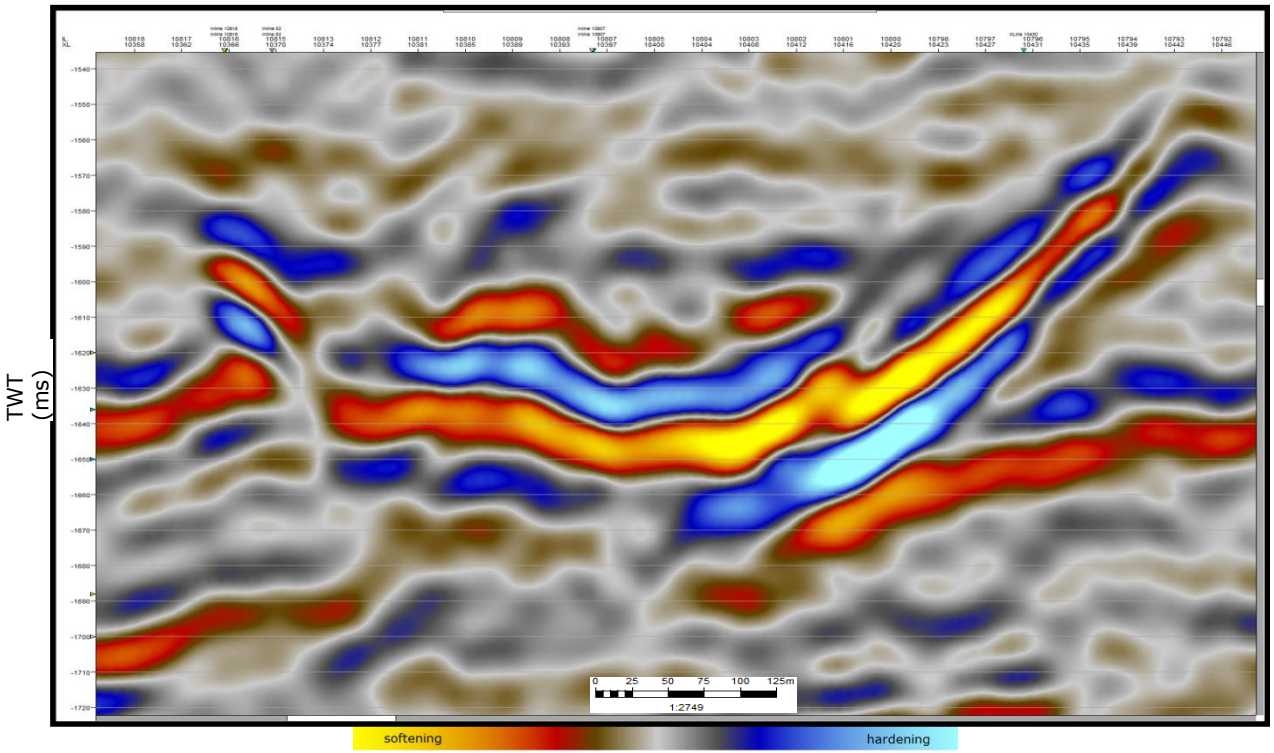
Original



Vertical Exaggeration x5

Full Stack Reflectivity

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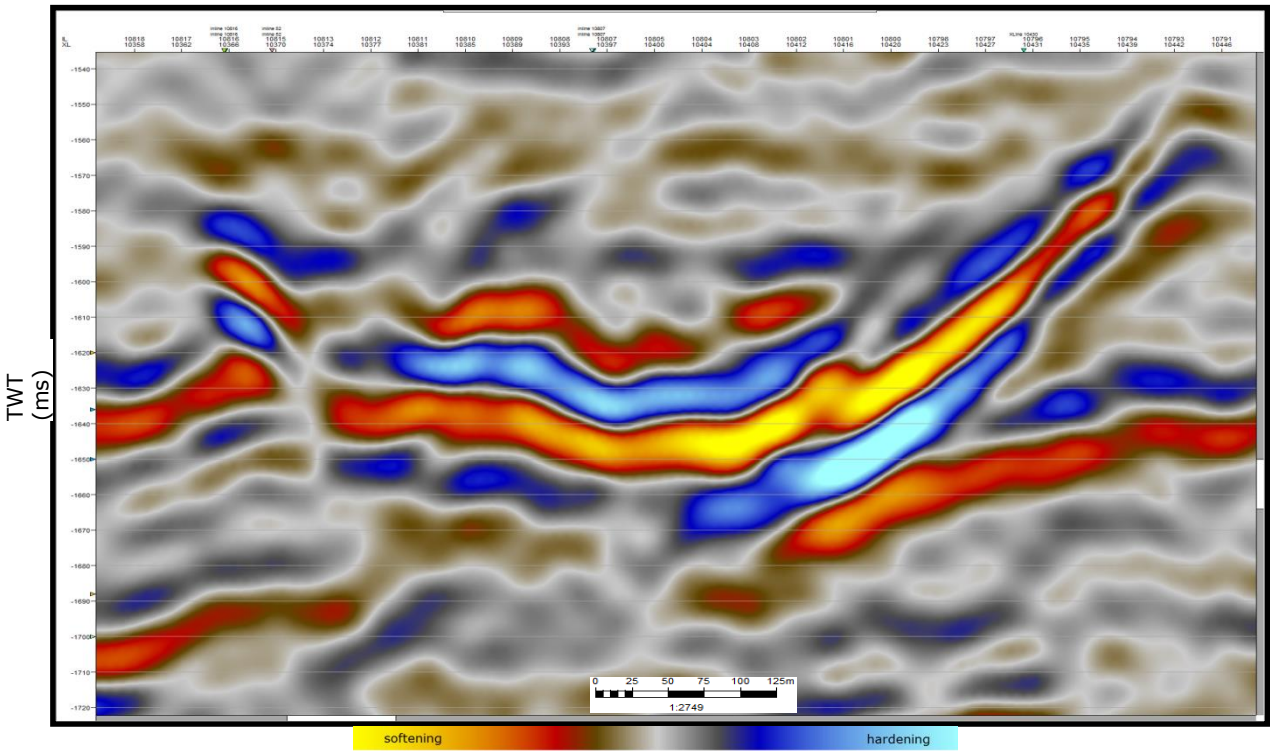
Average Migration Velocity Model



- Not much different to the original full stack seismic

Vertical Exaggeration x5

Full Stack Reflectivity

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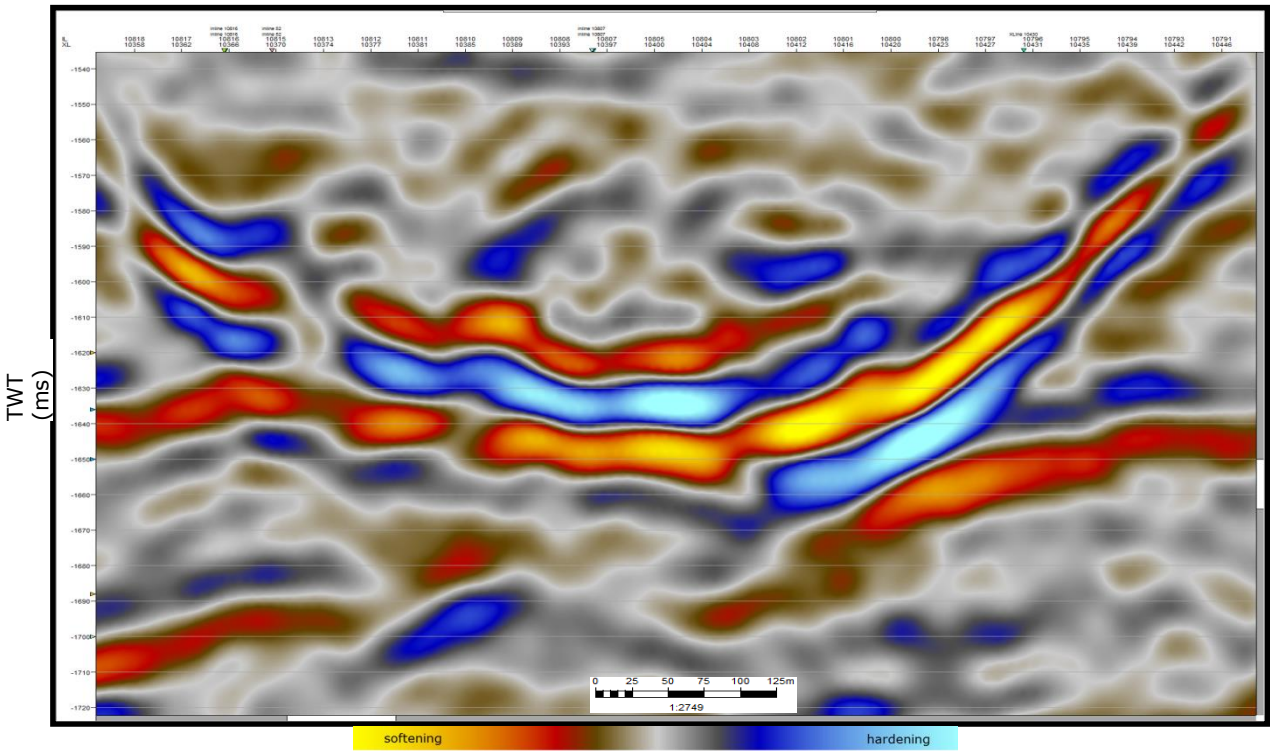
+1 Standard Deviation Migration Velocity Model



- Vertical extension of the injectite is apparent (migration "smiles")

Vertical Exaggeration x5

Full Stack Reflectivity

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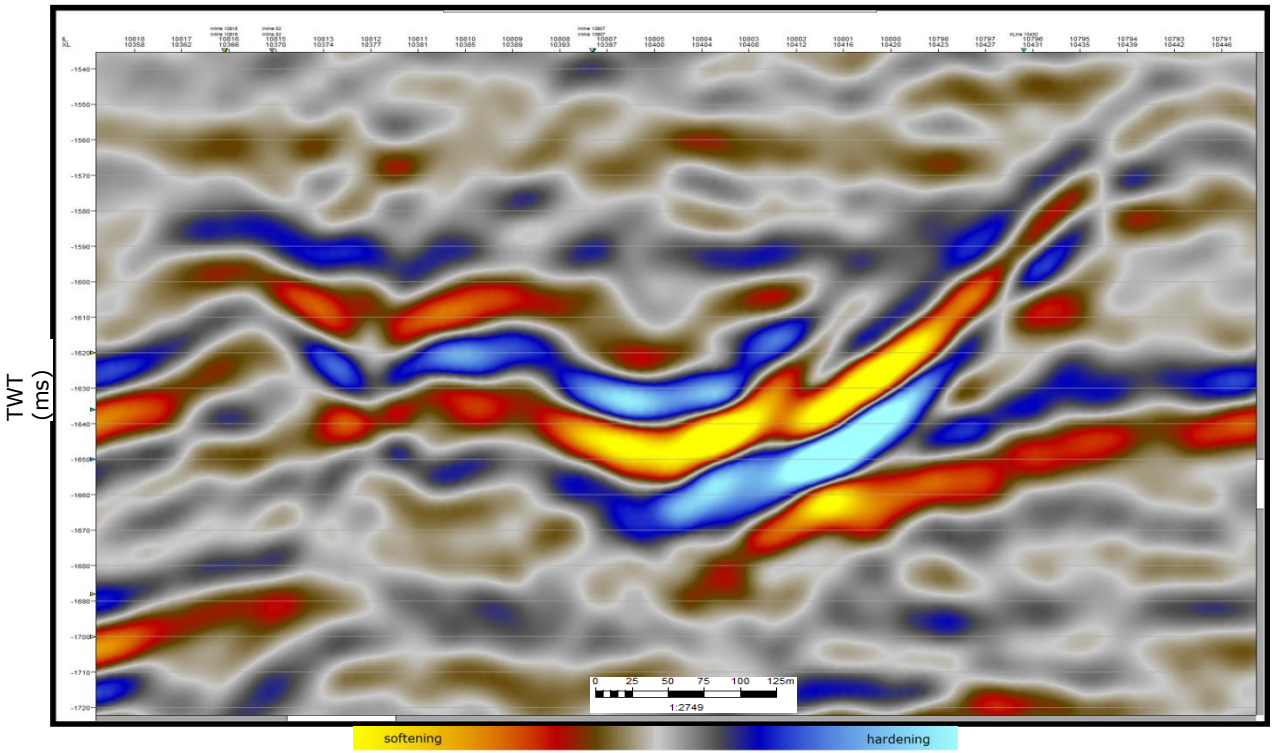
-1 Standard Deviation Migration Velocity Model



- The injectite is not vertically extensive (migration "frowns")

Vertical Exaggeration x5

Full Stack Reflectivity

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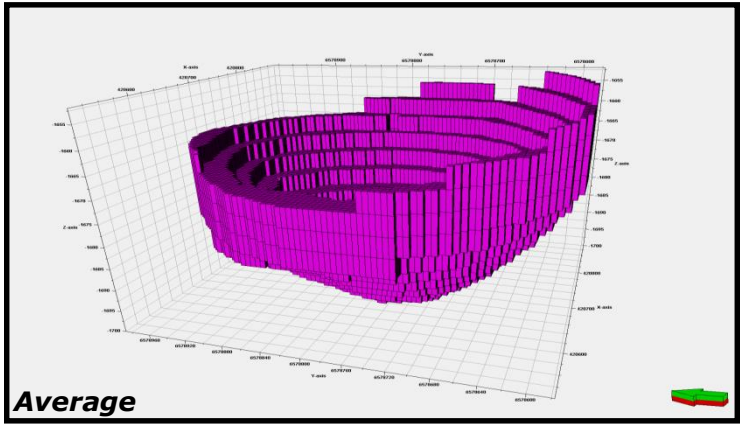
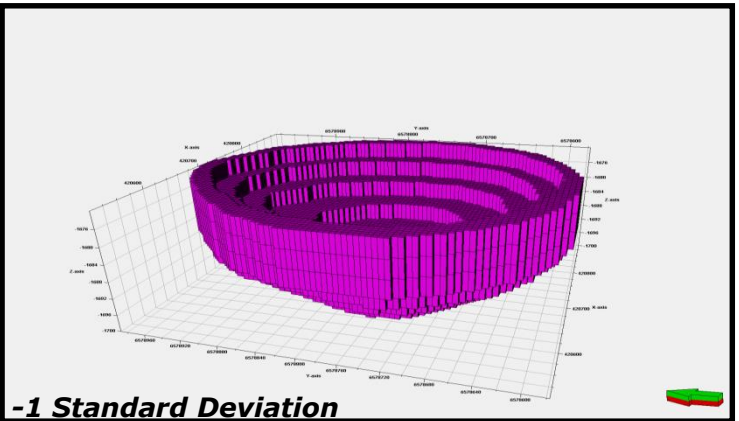
Injectite Geobodies for Lateral Uncertainty Workflow

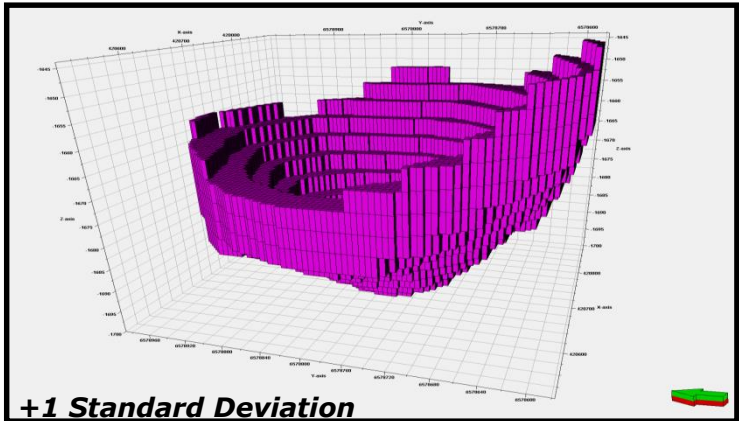
- All bodies were mapped directly from their associated seismic data



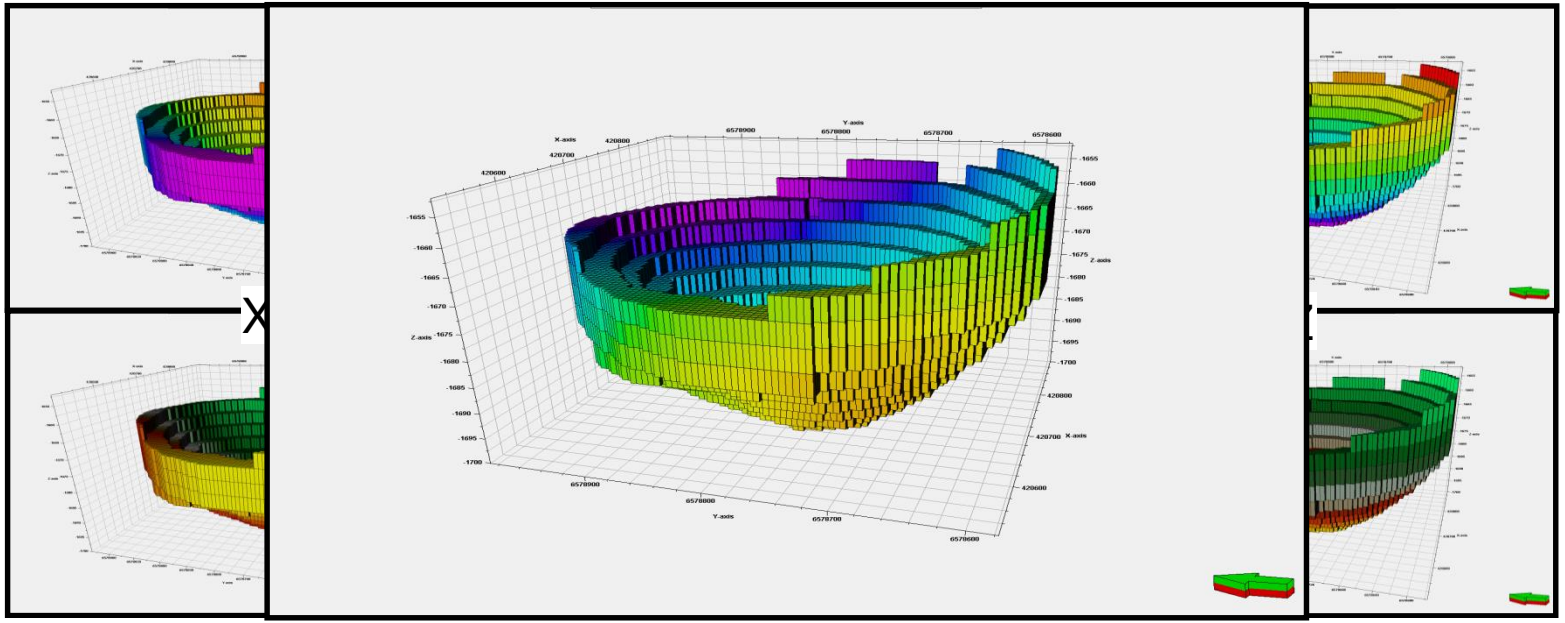
- Key assumption for future work is that the same sand body is being mapped across all the volumes



- How do we track and quantify the movement of the injectite body across all the volumes?



Injectite Geobodies for Lateral Uncertainty Workflow



- The normalised midpoint properties were summed to create a single property where the attribute value acts as a reference system (index attribute)

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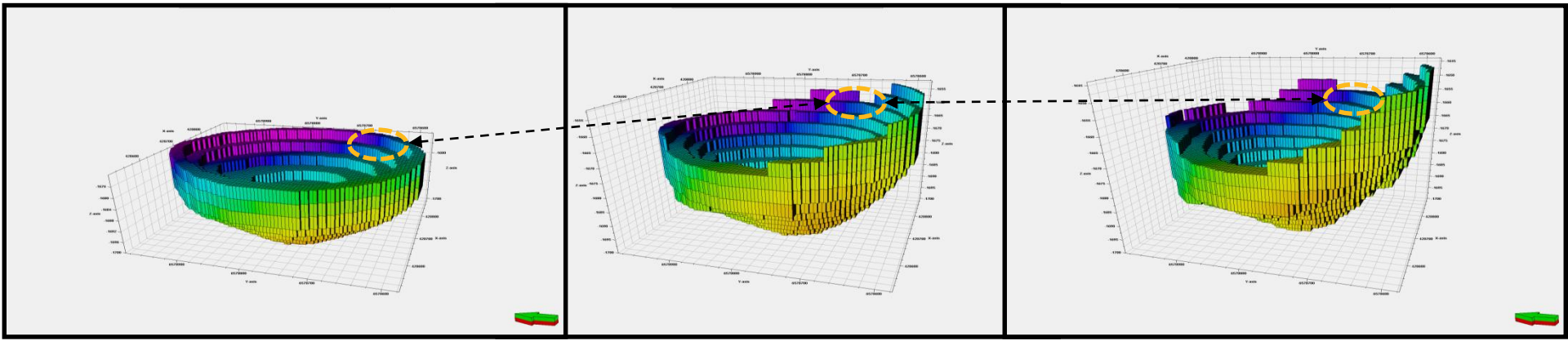
Index Attribute



-1 Standard Deviation Migration velocity

Average Migration velocity

+1 Standard Deviation Migration velocity

- Index attribute was created for the same sand body on each migrated volume (same process as shown in the previous slide)
- Index attribute allows the tracking of points/clusters between the various volumes so that the lateral movement can be calculated

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Lateral Movement Calculation

- The various injectite geobodies with their attribute reference system were converted to point sets and values were imported into Excel

Original and migrated bodies sorted by their attribute

Match function used to match attribute values

Index function used to get X and Y values

Lateral movement was calculated

Orig																				
X (m)	Y (m)	attribute			Orig	remig_min		remig_min				remig_min with same attribute value								
420074.7	6579265	2.9000001		min	-2.7	-2.8		X (m)	Y (m)	attribute	match row	X (m)	Y (m)	dx (m)	dy (m)	vector abs	vector (m)	dx average (m)	-7.7
420074.7	6579265	2.73333335		max	2.9	2.9		420074.7	6579265	2.9000001	1	420074.72	6579265	0	0	0	0	dx stdev (m)	64.0
420099.7	6579265	2.63333321						420074.7	6579290	2.79473686	2	420074.72	6579290	0	25	25	25		
420074.7	6579290	2.62807012						420074.7	6579265	2.71818185	3	420074.72	6579265	-25	0	25	-25	dy average (m)	7.2
420049.7	6579315	2.62280703						420099.7	6579265	2.61818171	3	420074.72	6579265	0	-25	25	-25	dy stdev (m)	96.6
420074.7	6579265	2.5666666						420074.7	6579290	2.61291862	3	420074.72	6579265	25	-50	55.90169944	-55.90169944		
420124.7	6579265	2.5333333						420049.7	6579315	2.60765553	6	420049.72	6579315	-25	50	55.90169944	55.90169944	vector average (m)	10.6
420099.7	6579290	2.52807021						420074.7	6579265	2.5363636	7	420074.72	6579265	-50	0	50	-50	vector stdev (m)	115.9
420074.7	6579315	2.52280712						420124.7	6579265	2.5181818	7	420074.72	6579265	-25	-25	35.35533906	-35.35533906		
420049.7	6579340	2.51754379						420099.7	6579290	2.51291871	7	420074.72	6579265	0	-50	50	-50		
420099.7	6579265	2.4666667						420074.7	6579315	2.50765562	8	420124.72	6579265	75	-75	106.0660172	106.0660172		
420074.7	6579290	2.46140337						420049.7	6579340	2.50239229	11	420049.72	6579340	-50	75	90.13878189	90.13878189		
420049.7	6579315	2.45614052						420099.7	6579265	2.4363637	11	420049.72	6579340	-25	50	55.90169944	55.90169944		
420124.7	6579290	2.42807007						420074.7	6579290	2.43110037	11	420049.72	6579340	0	25	25	25		
								420049.7	6579315	2.42583728	13	420074.72	6579290	-50	0	50	-50		

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Discussion

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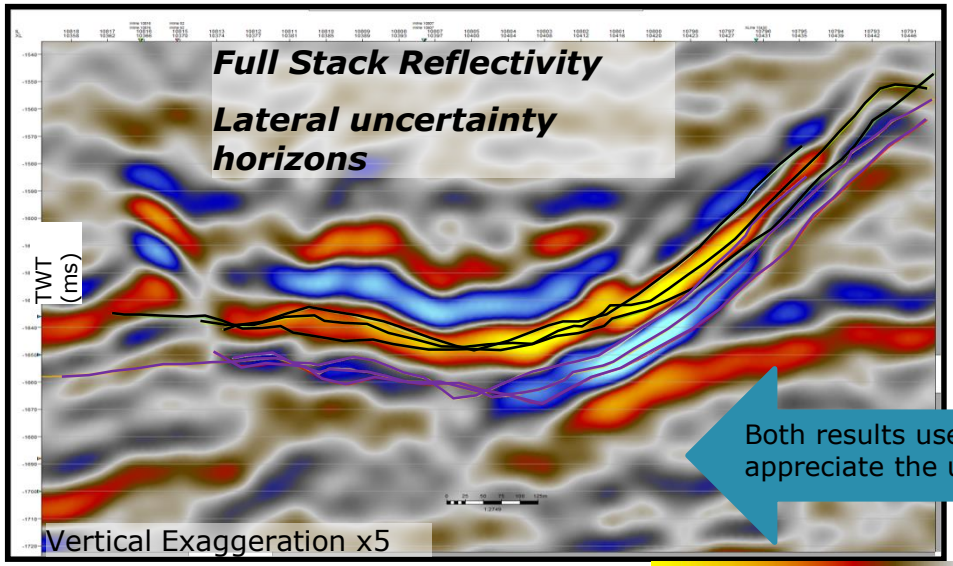
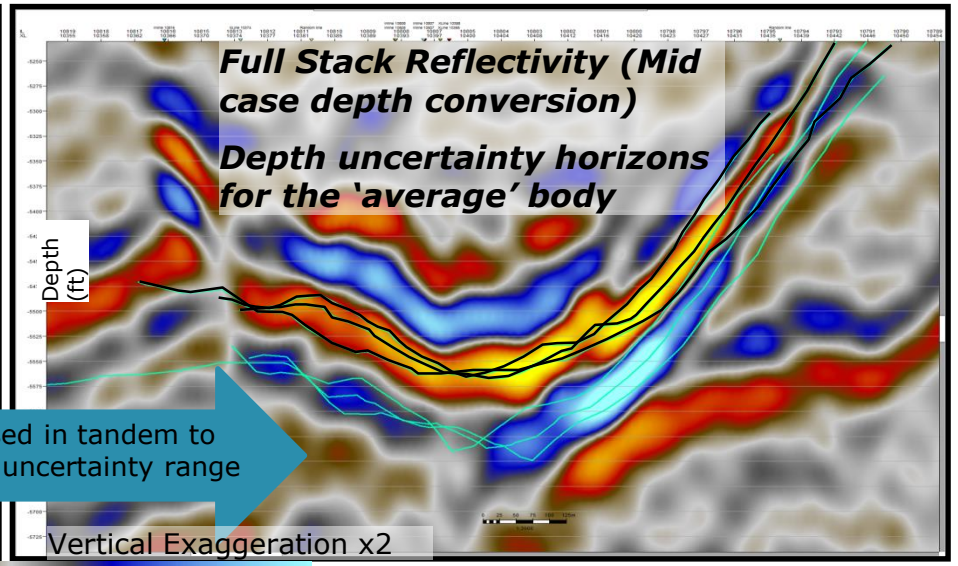
Spatial Uncertainty Model





Both results used in tandem to appreciate the uncertainty range

softening — hardening

- Spatial uncertainty modelling has to be a combination of vertical and lateral uncertainty
- This information can be used in a range of scenarios:
  - Probabilistic volumetric calculations
  - Well placement
  - Geological target uncertainty
  - Decision making (e.g. the usefulness of a downhole tool with a certain depth of investigation)

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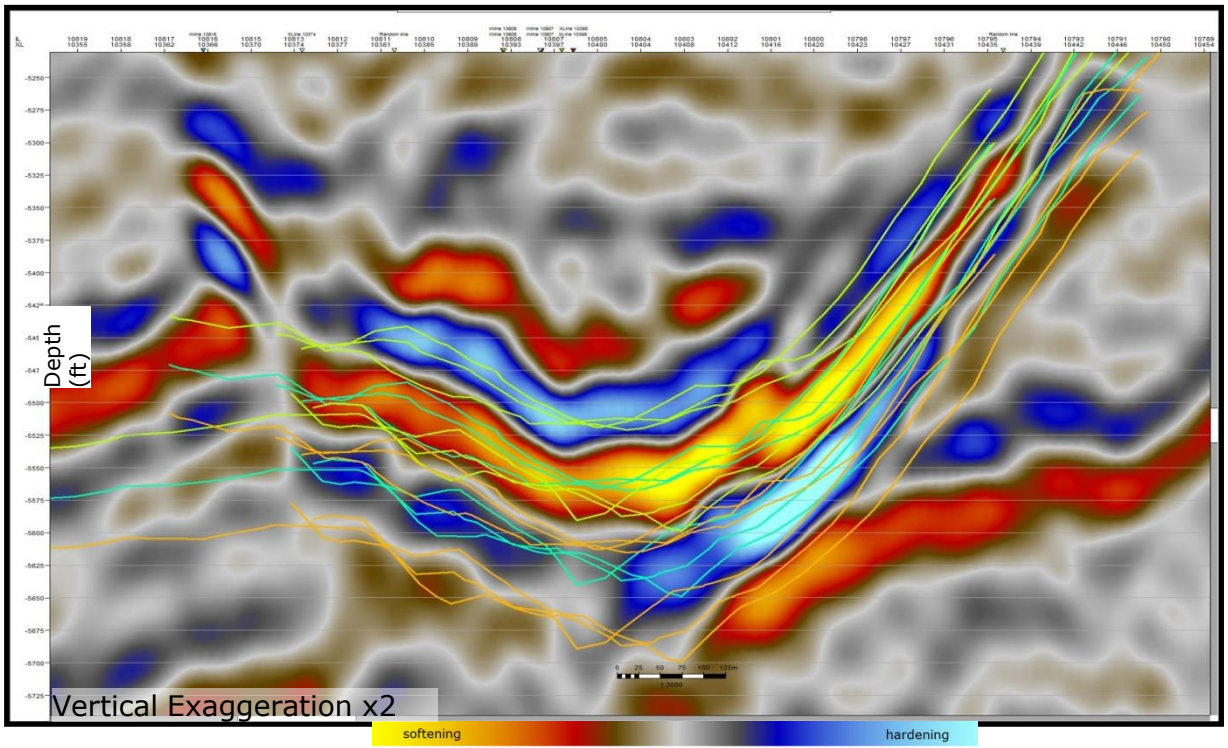
Future Work

If all the results were combined it would look like this…



Full Stack Reflectivity (Mid case depth conversion)

Depth uncertainty horizons for the all bodies with all depth conversions

- Untidy results
- Difficult to interpret

However…

- Potential to represent all this information in a sand probability model based on spatial uncertainty?

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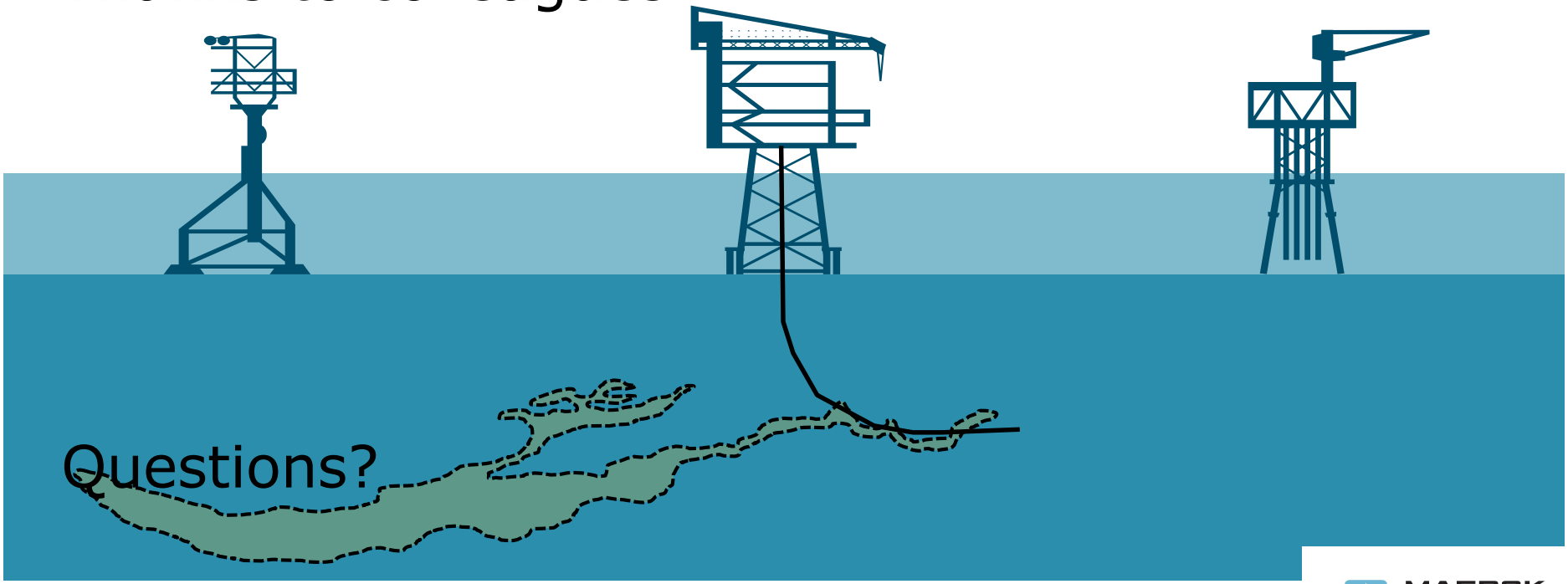
Conclusions

- Vertical uncertainty understood through velocity modelling and COHIBA
- Lateral uncertainty understood through migration
- Results combined to understand the overall spatial uncertainty
- Cost effective solution
- Potential for future work

Thanks to Maersk Oil and TAQA

Thanks to colleagues



Questions?