Short Course – Ground Modelling

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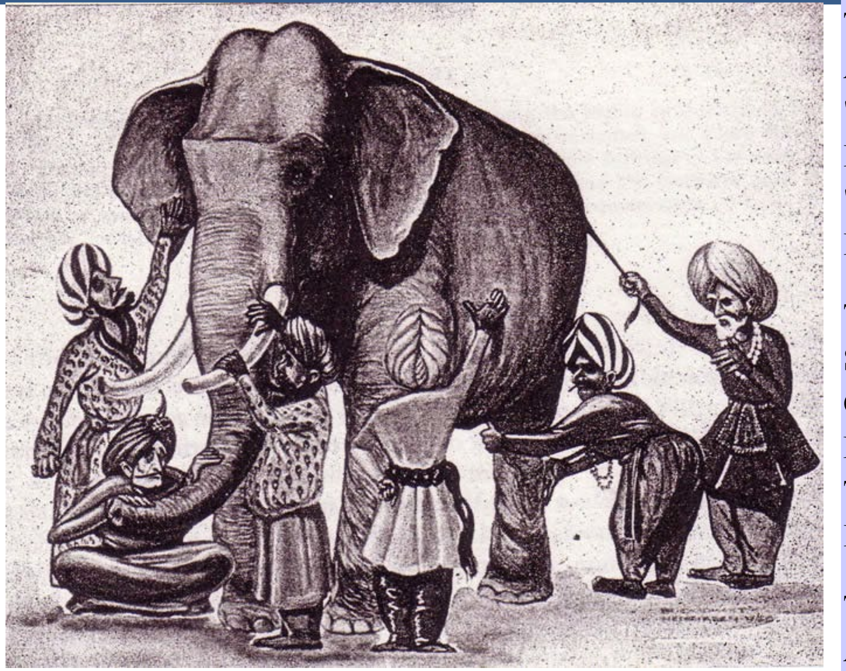
What do we Know?

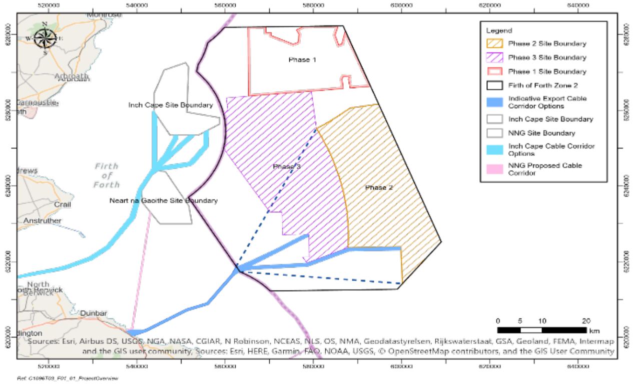
It was six men of Indostan
To learning much inclined,
Who went to see the Elephant
(Though all of them were blind),
That each by observation
Might satisfy his mind.

The ***First*** approached the Elephant,
And happening to fall
Against his broad and sturdy side,
At once began to bawl:
"God bless me! but the Elephant
Is very like a **WALL**!“

The ***Second***, feeling of the tusk,
Cried, "Ho, what have we here,
So very round and smooth and sharp?
To me 'tis mighty clear
This wonder of an Elephant
Is very like a **SPEAR**!“

The ***Third*** approached the animal,
And happening to take
The squirming trunk within his hands,
Thus boldly up and spake:
"I see," quoth he, "the Elephant
Is very like a **SNAKE**!





Consider this for a moment !

The ***Fourth*** reached out an eager hand,
And felt about the knee
"What most this wondrous beast is like
Is mighty plain," quoth he:
"'Tis clear enough the Elephant
Is very like a **TREE**!“

The ***Fifth*, **who chanced to touch the ear,
Said: "E'en the blindest man
Can tell what this resembles most;
Deny the fact who can,
This marvel of an Elephant
Is very like a **FAN**!“

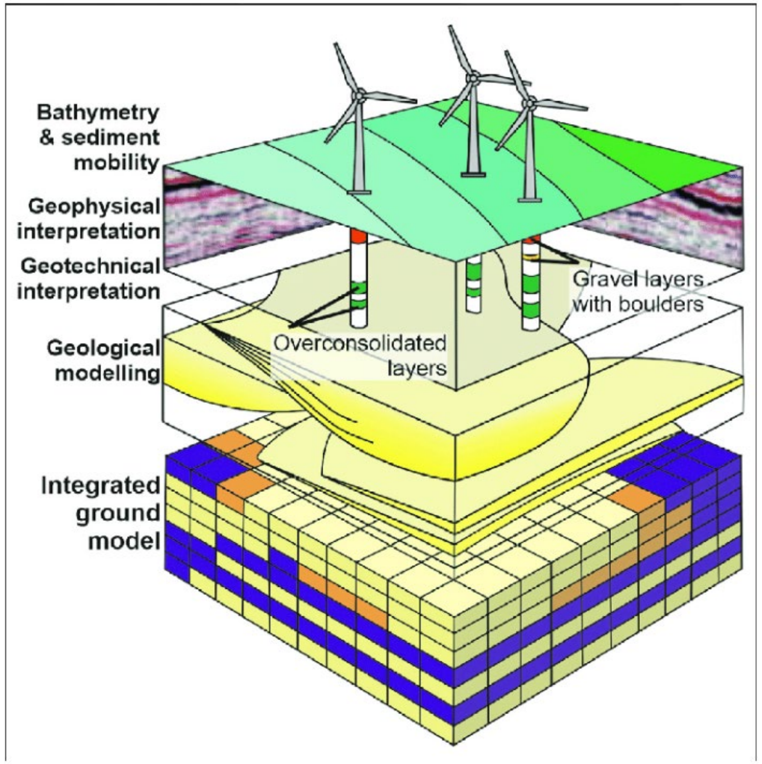
The ***Sixth*** no sooner had begun
About the beast to grope,
Than seizing on the swinging tail
That fell within his scope,
"I see," quoth he, "the Elephant
Is very like a **ROPE**!“

And so these men of Indostan
Disputed loud and long,
Each in his own opinion
Exceeding stiff and strong,
Though each was partly in the right,
And all were in the **WRONG**!

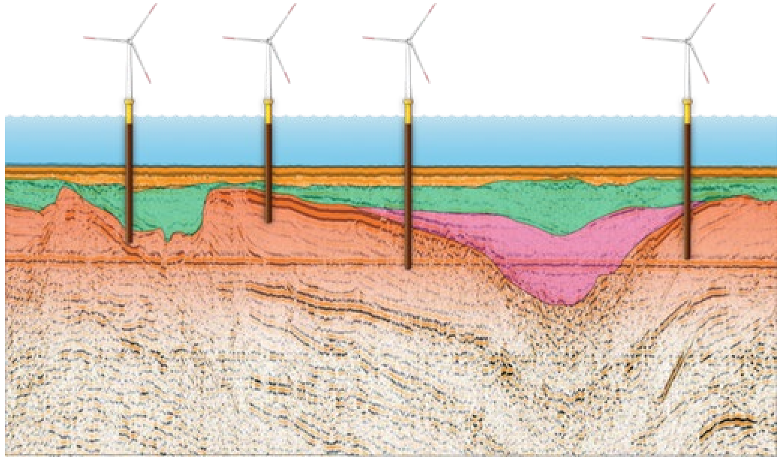
John Godfrey Saxe (1816-1887)

Introduction

- Objectives of Ground Modelling
- Timeline and Process
- Particular issues identified in BB Ground Model
- Adding value to our data and taking the Ground Model forward

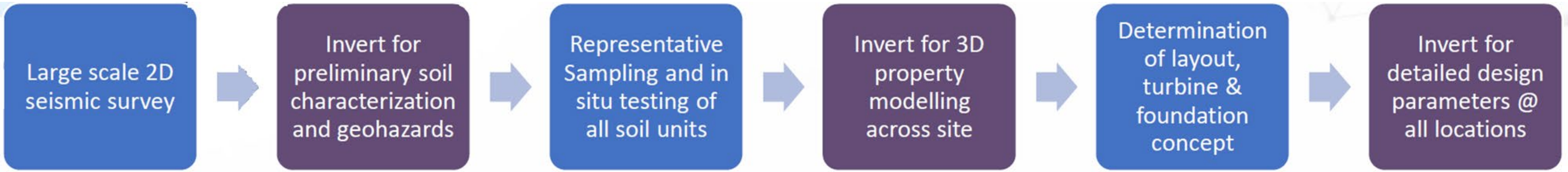


| Recommended integrated three-dimensional ground models that capture sediment mobility, and integrate geophysical, geological (including geomorphological) and geotechnical information. Adapted from Bentley and Smith (2008) and Cobain et al. (2021).



Objectives

- Ground modelling is used to better understand the process and mechanisms that create the particular ground conditions on our sites by using integrating techniques for greater understanding.
  - Better understand the variation in ground conditions,
  - Better assess the engineering risks at our sites, to help us place Foundations and Cables and avoid difficult areas
  - Embedding geoscience understanding and unlocking collaborations between engineers and geoscientists,
  - Accelerate economic benefits to support decision-making and commercial adoption of that knowledge,
  - Identify any knowledge gaps in ground conditions.
  - Helps us identify uknowns and hazards
  - Select the right type and installation methods for our foundations, cables and other infrastructure
  - Design of foundations
- Effective integrated Geoscience (geophysics, geotechnics, GIS) is integral to the development of offshore windfarms, from initial site evaluation, foundation, and layout design, through installation, and operations and maintenance, to lifetime extension, repowering and decommissioning strategies.
- Ultimately, increased confidence in the understanding of the ground conditions translates to reduced engineering costs, and uncertainties in ground conditions, when engineering parameters and variation of the soils and seabed are better understood.

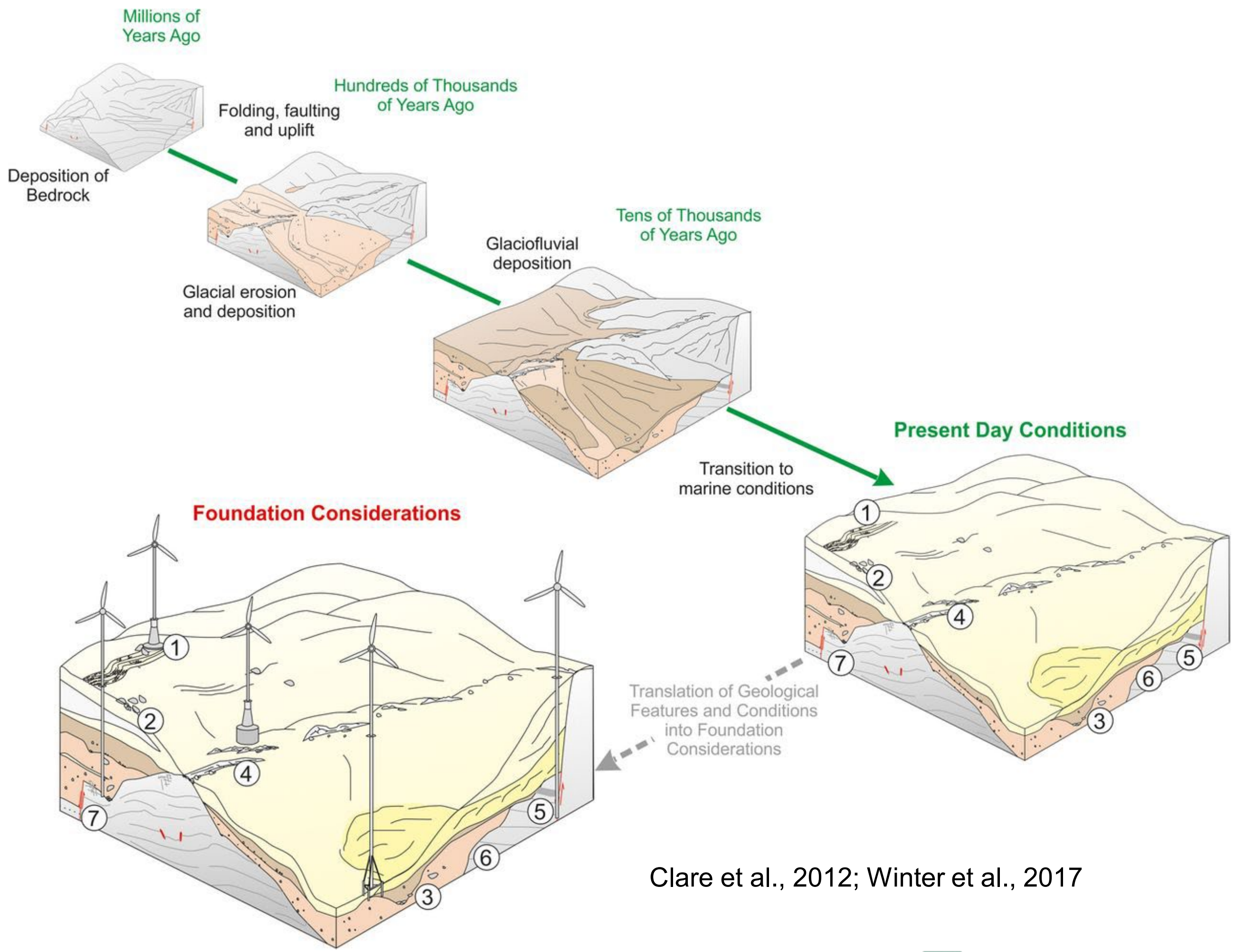


Offshore Windfarm Ground Models and Site Characterisation

- Hydrographic/UXO survey
  - Multibeam sonar bathymetry
  - Sidescan Sonar
  - Magnetics

- **Geophysical site characterization**
  - Sub-bottom profiler
  - Single-/Multi-channel Seismics
  - Geological model
  - Geological hazard identification (boulders, faults)

- **Geotechnical site characterization**
  - Cone Penetration Tests (CPT)
  - Bore holes
  - Soil model



Clare et al., 2012; Winter et al., 2017

Integrated Ground Model → Foundation and Cable Design and Installation

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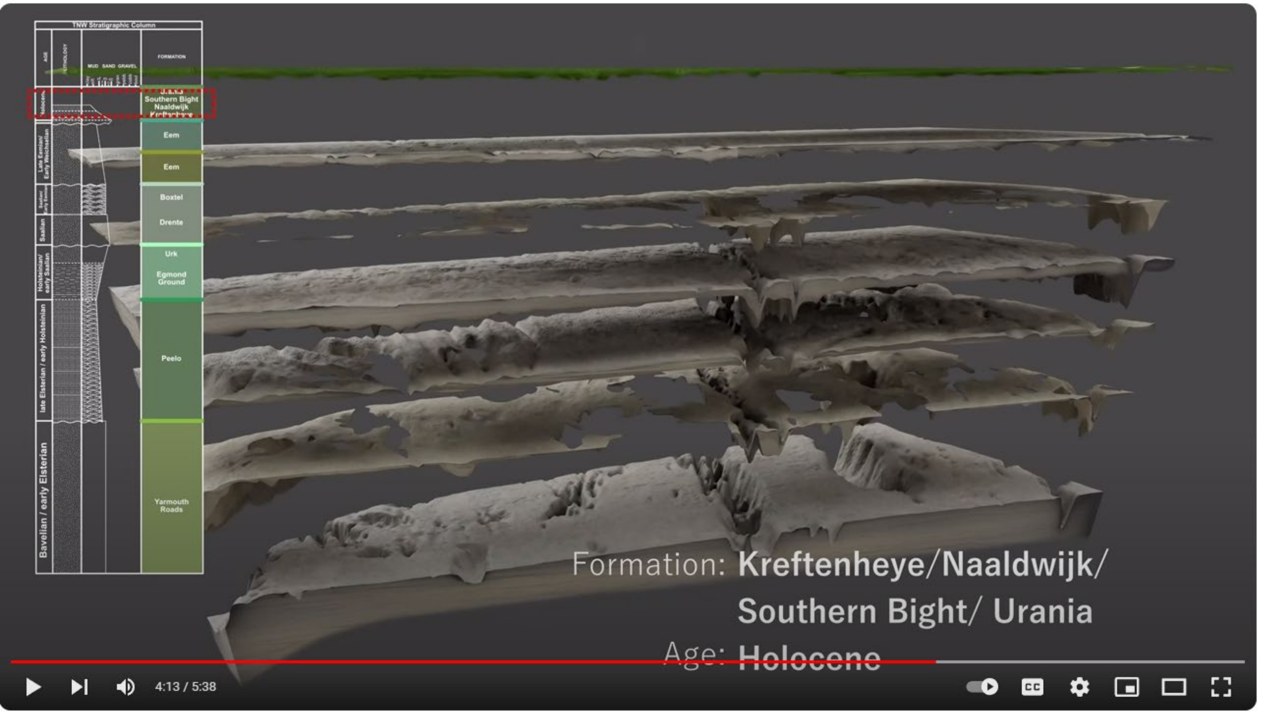
Offshore Windfarm Ground Models and Site Characterisation



Ten noorden van de Waddeneilanden Wind Farm Zone animation

[Ten noorden van de Waddeneilanden Wind Farm Zone animation - YouTube]

Ten noorden van de Waddeneilanden Wind Farm Zone animation

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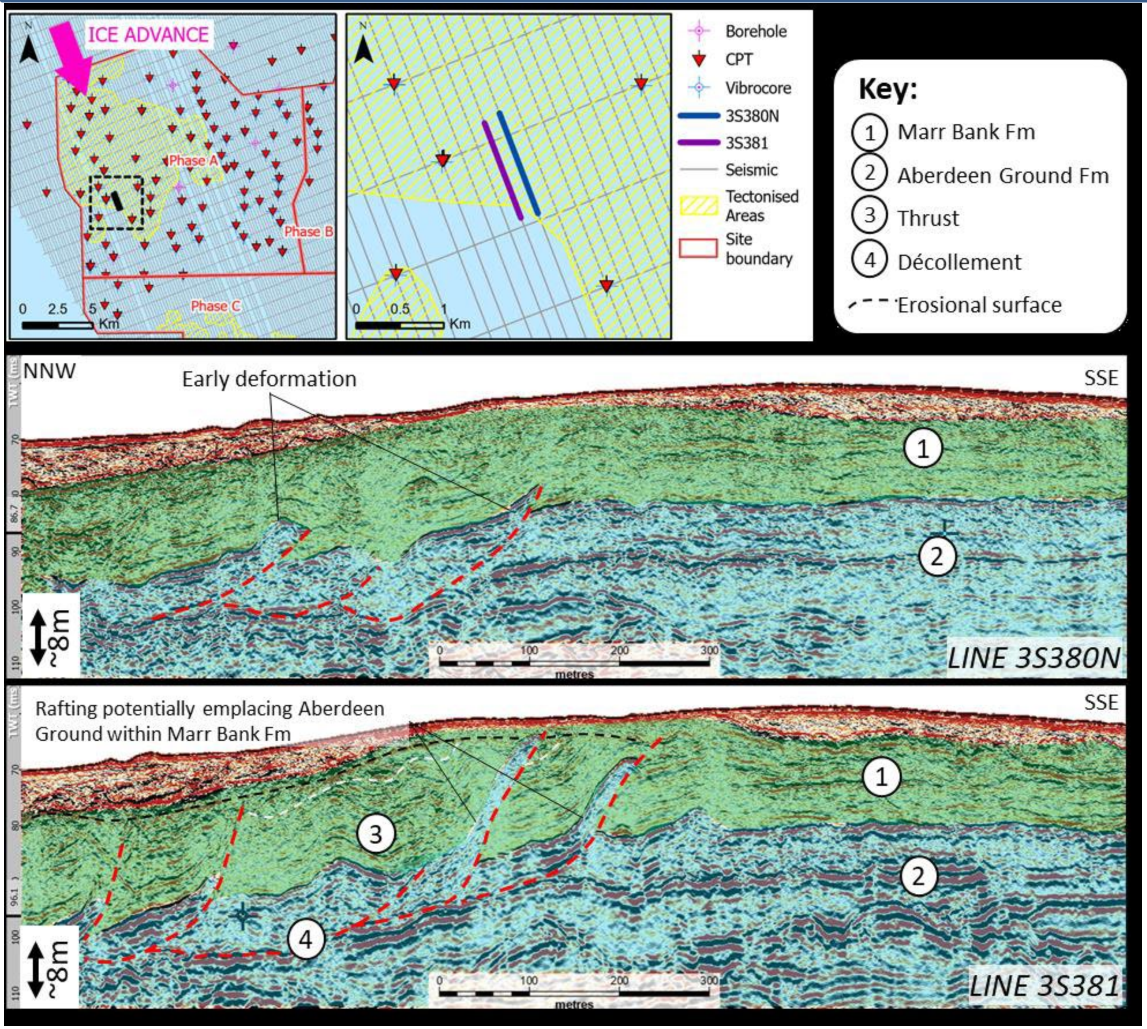
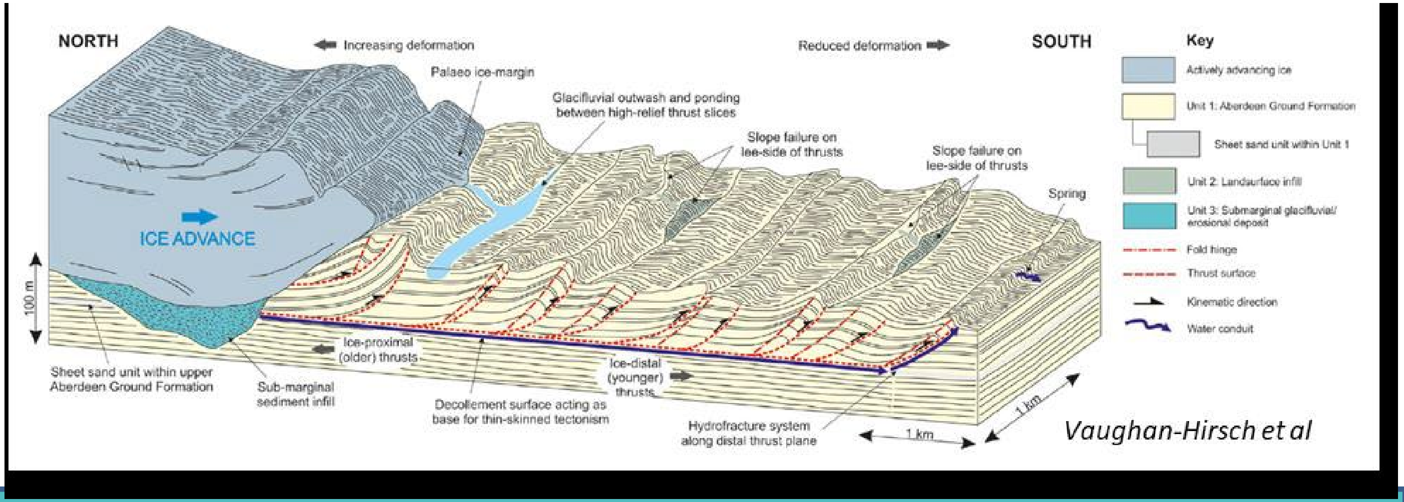
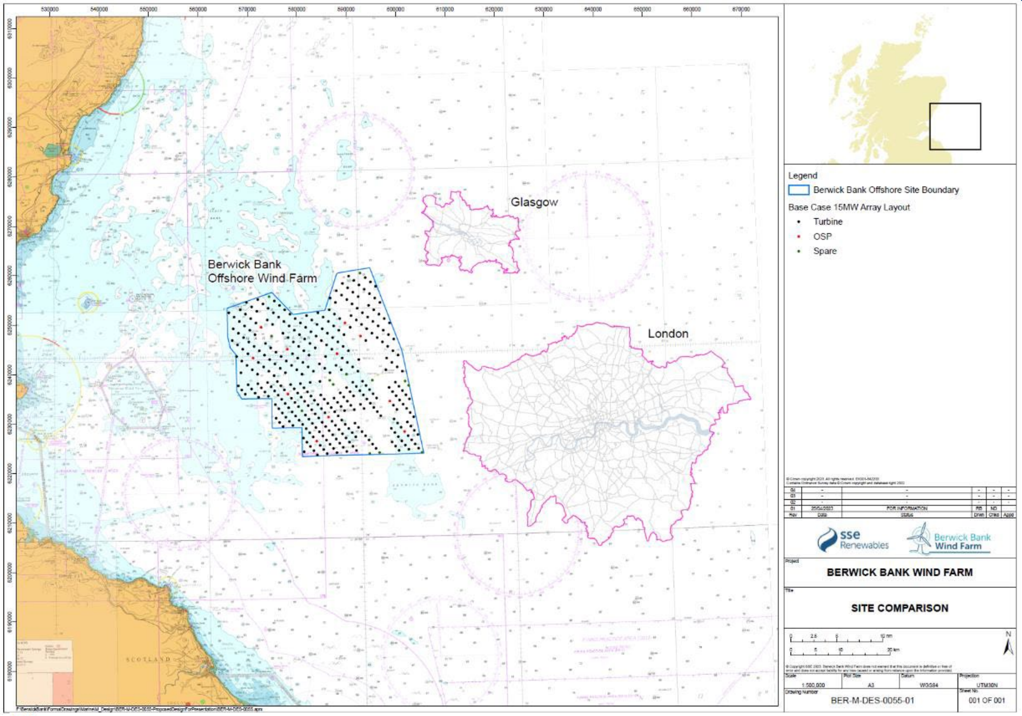
Issues Identified in the Developing Ground Model

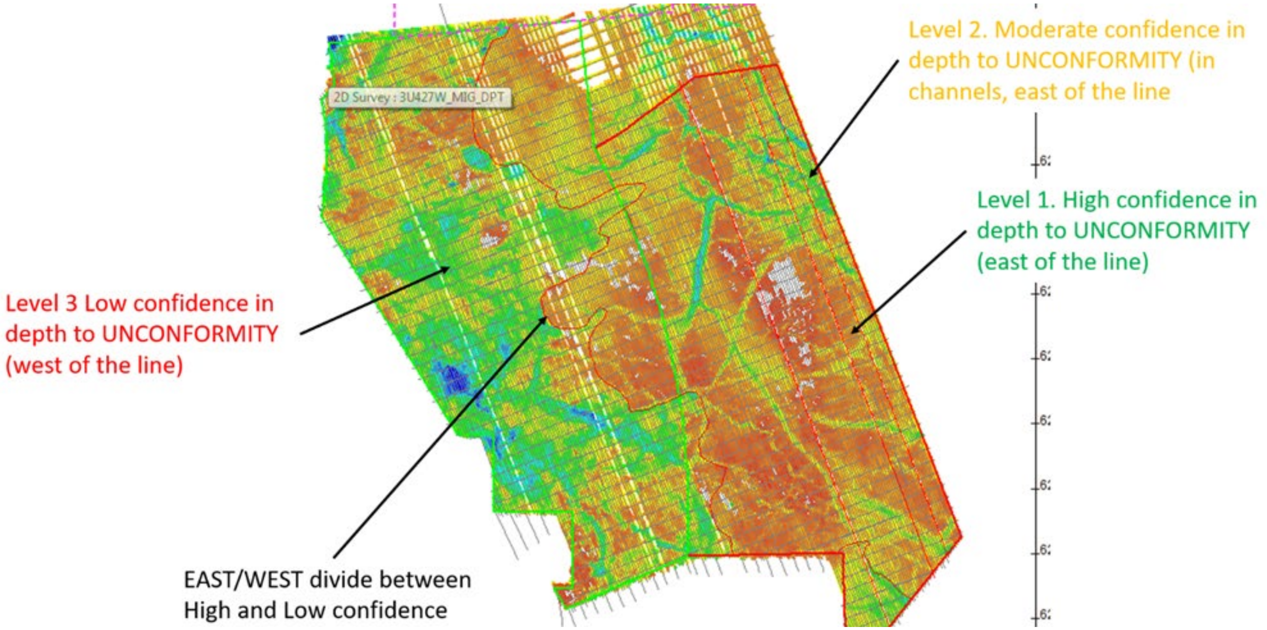


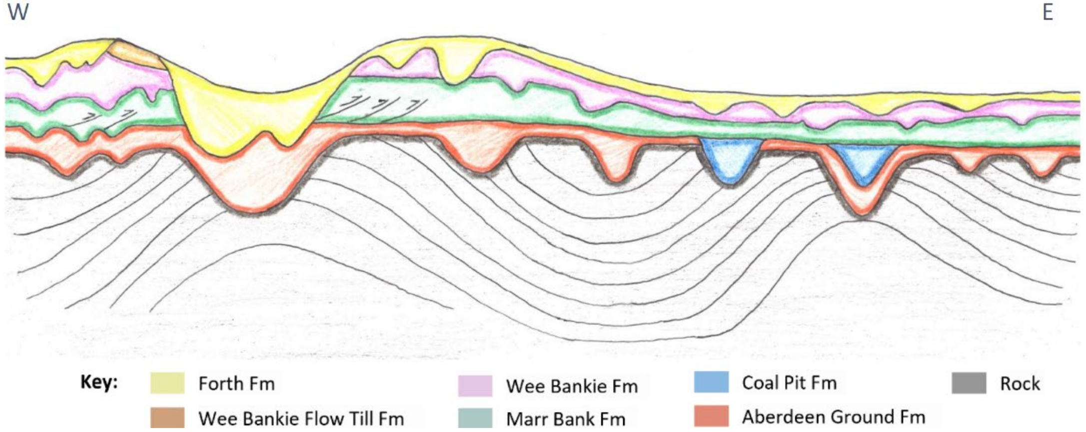
- Existing preliminary ground model substantially updated with new geotechnical data
- New geotechnical data required a comprehensive re-evaluation of some geological units; notably Wee Bankie Formation
- Over 9000km of seismic data was re-evaluated and integrated with over 500 individual geotechnical investigation locations
- Integrated approach across geophysics, engineering geology, geotechnical engineering and GIS
- Aberdeen Ground formation inclusions into Quaternary sediments due to glacial action was identified

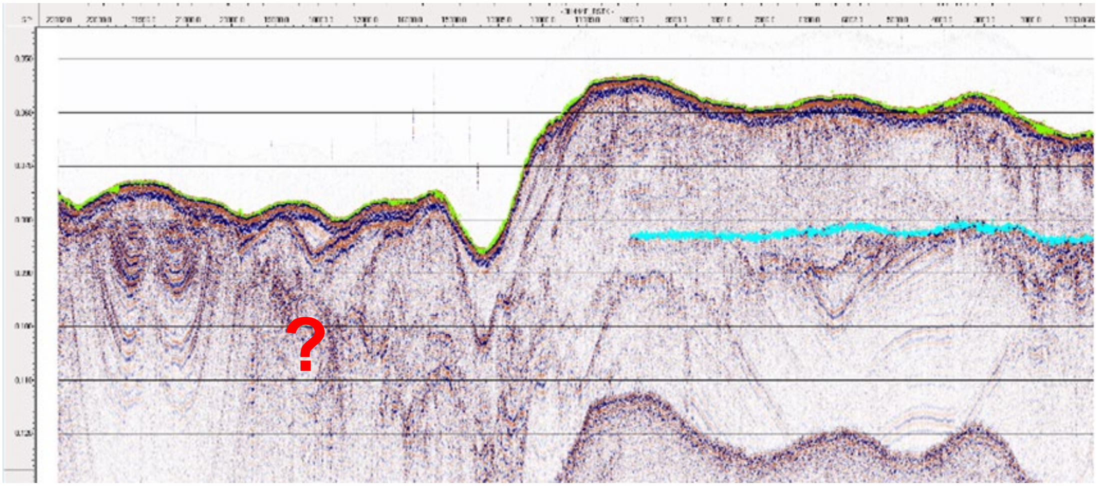


Mapping the Bedrock



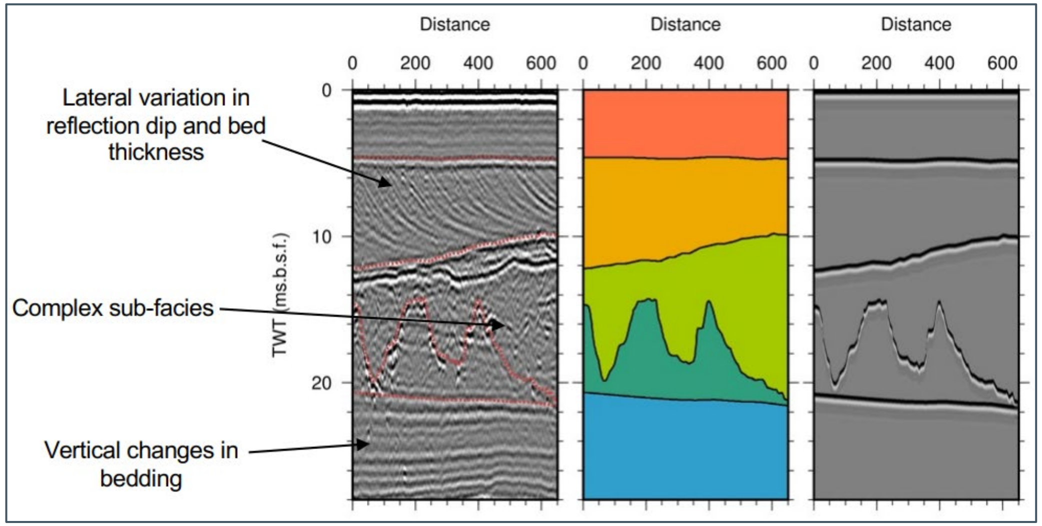




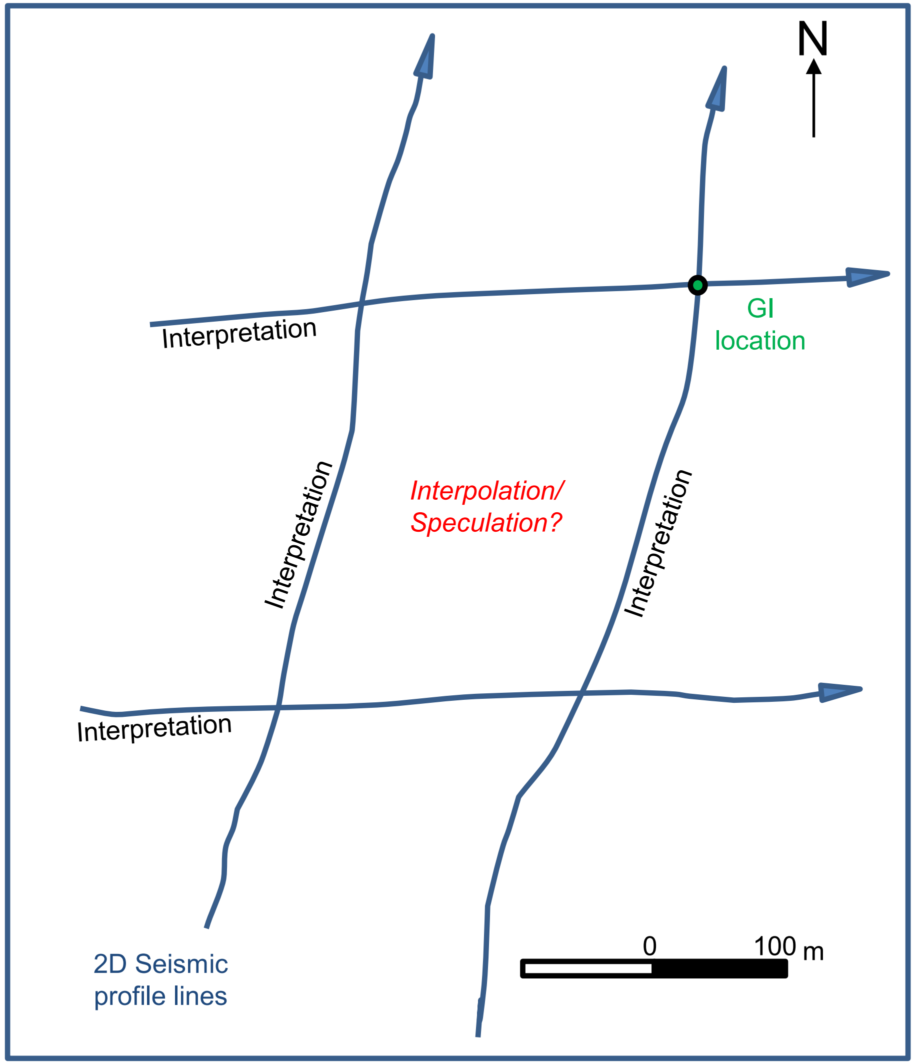


Are we Maximising Geophysical Ground Models?

- Geophysical site characterisation typically performed using 2D profiles.
- 2D Ultra-High Resolution Seismic (UHRS) is very common in offshore windfarm surveys. and achieve vast site coverage easily.
- Geophysical observations and Geotechnical ties are interpolated between 2D lines to create continuous 3D surfaces to cover the AOI.
- Geophysics data commonly regarded as a ‘qualitative’ dataset, whereas the Geotech provides the quantitative measurements.



c/o SAND Geophysics



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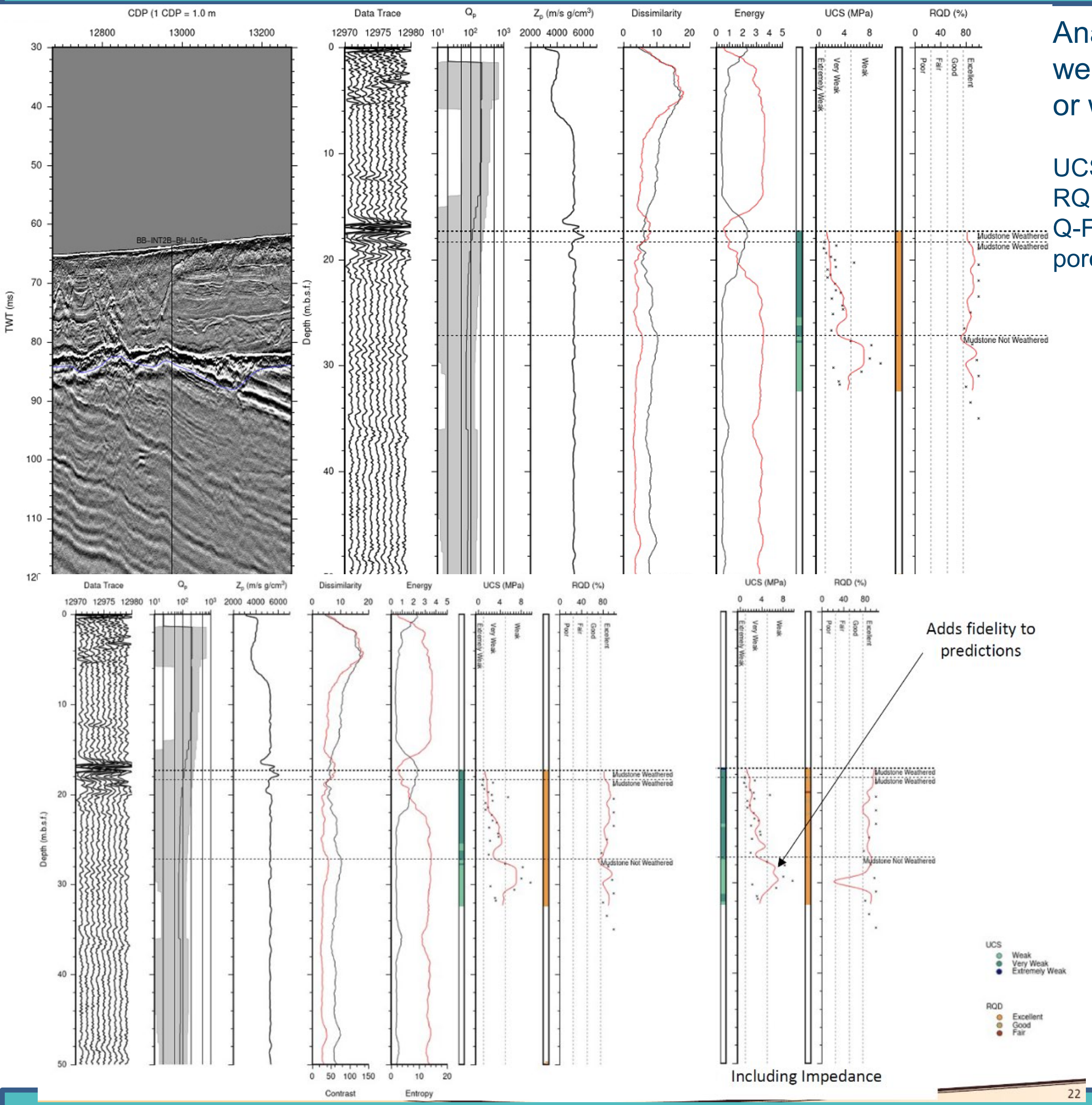
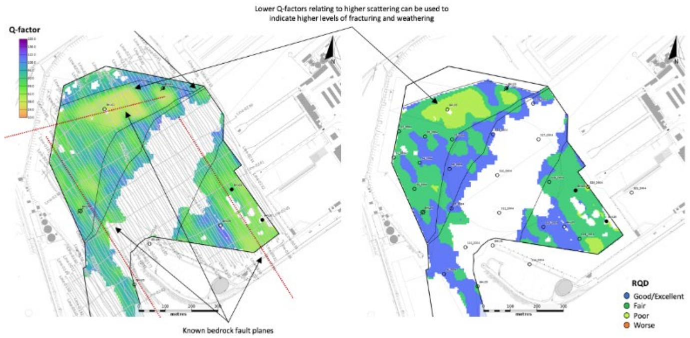
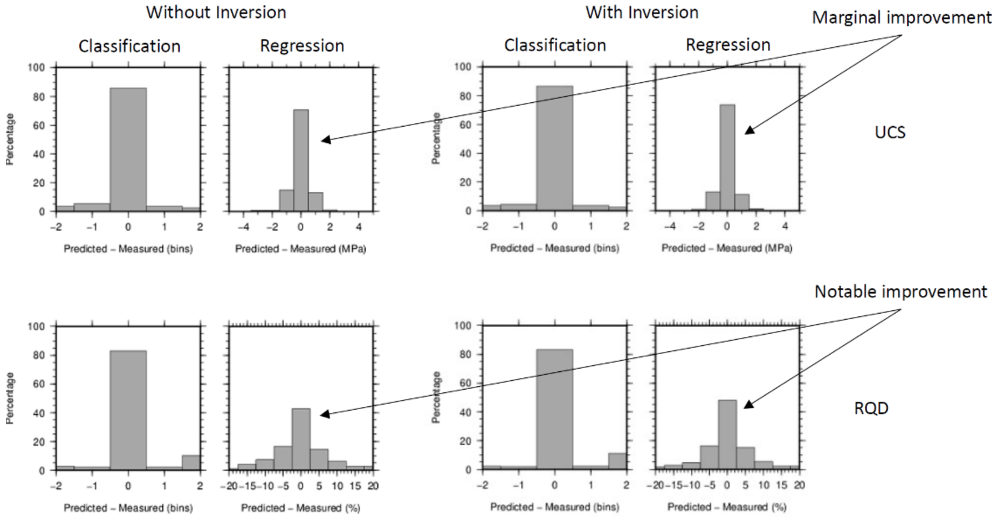
Getting Added Value From Existing Survey Data- Weathered Bedrock??



Analysis required to understand the relationship and certainty of interpreted weathered bedrock v un-weathered bedrock to support an understanding of the driveability of piles where bedrock is close to or within intended depth

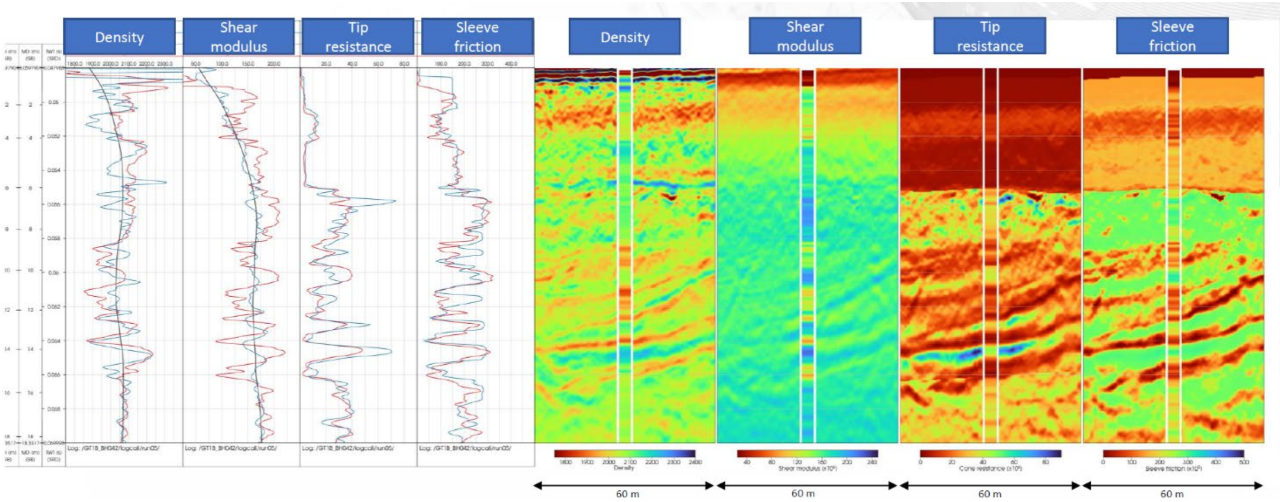
UCS=Unconfined Compressive Strength
RQD= Rock Quality designations
Q-Factor= is a physical parameter that is very sensitive to the saturation of rocks with fluids and partial melts, essentially porosity of rocks

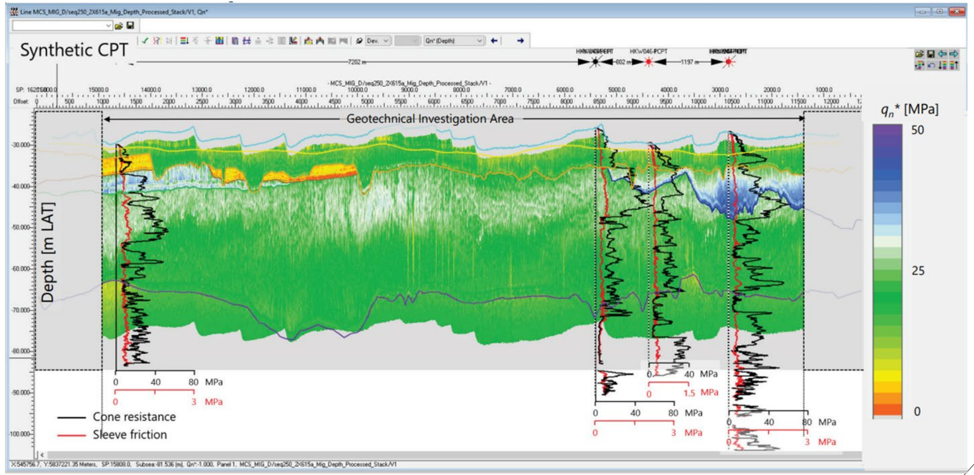


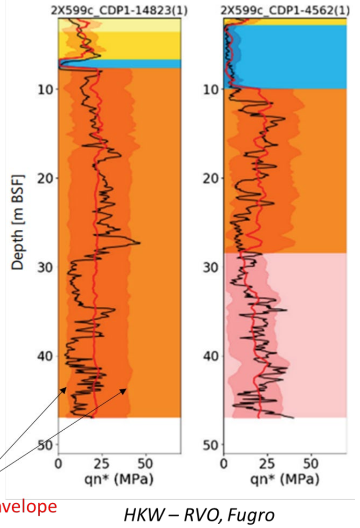


Seismic Inversion to Extend our Knowledge of Soil Properties

- The information is not lost – there *is* quantitative information that can be extracted from seismic reflection data which can be used to create a ‘synthetic’ CPT trace at thousands of points along a seismic survey line to fill geotechnical data gaps.
- Uses machine learning to take the amplitude, phase, and frequency content of seismic reflection data to derive quantitative information regarding the nature of the sediments.
- In theory, allows a more direct link into engineering parameters of interest, such as elastic properties (Poisson’s Ratio) and compaction properties (cone resistance).
- Allowing for a probabilistic assessment of parameter envelopes at an arbitrary ‘CPT’ position.
- Derived geotechnical properties, such as relative density and undrained shear strength, can be mapped continuously across study areas.
- High density of available synthetic CPTs – one ‘CPT’ every ~1m along a single seismic line!
- The synthetic CPT profiles can be used as background information to subdivide the study area into regions in which different foundation designs may be preferable.







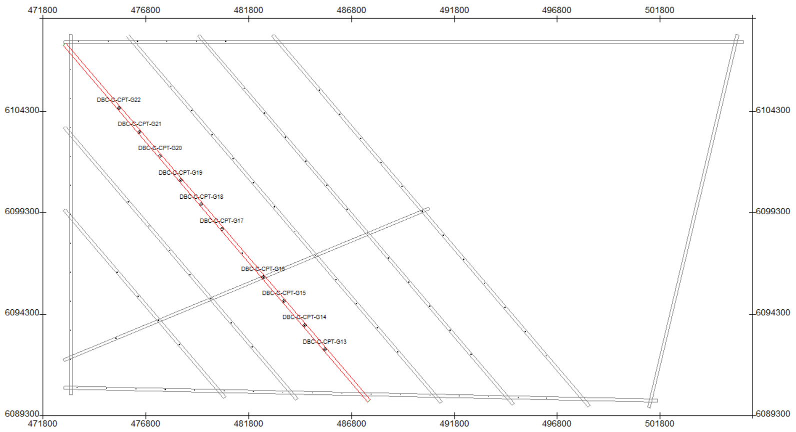
HKW – RVO, Fugro

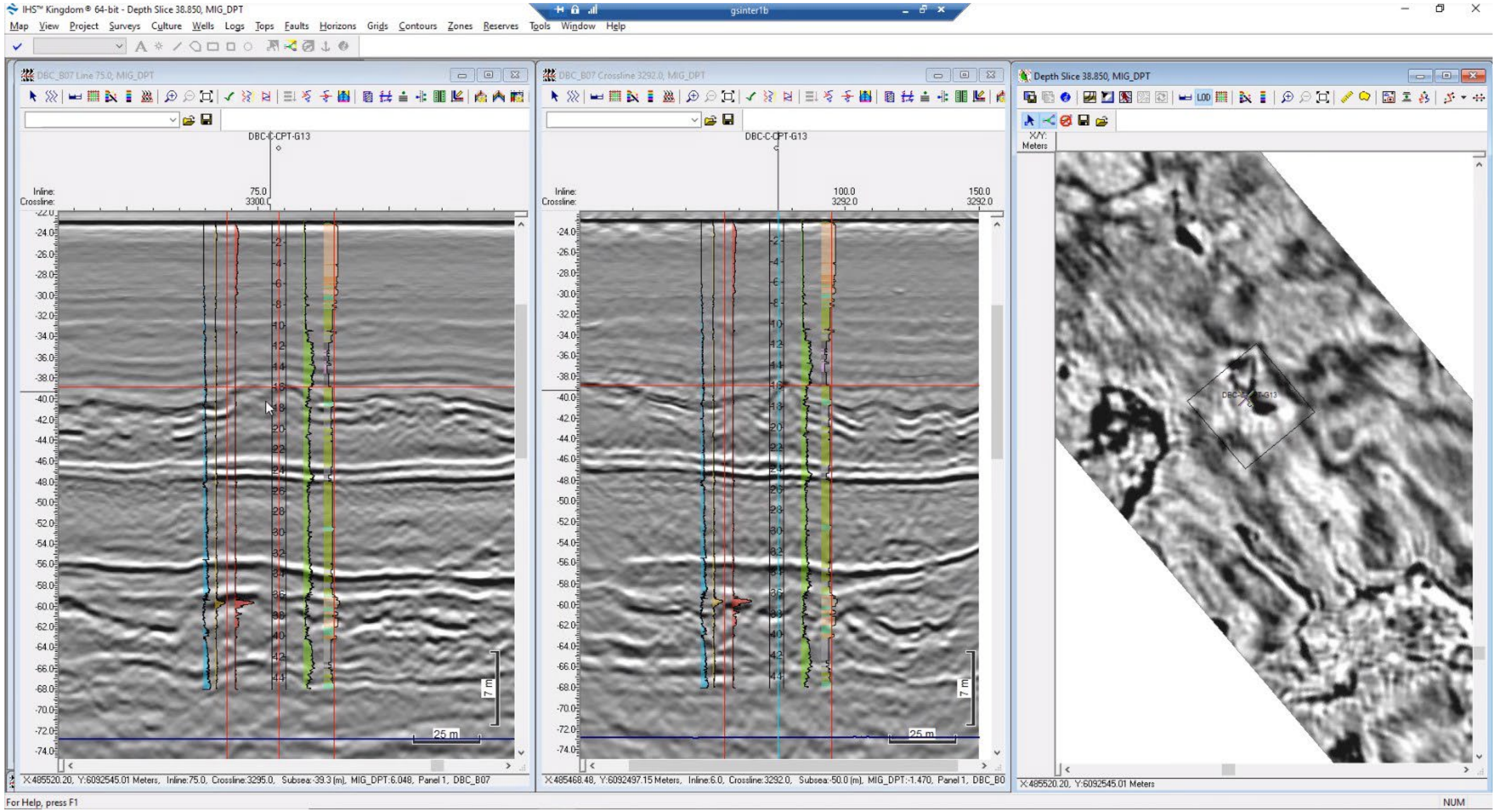
3D to Extend our Knowledge of Soil Properties

2D and 3DUHRS are proven technology using existing tools

3DUHR multi-channel seismic has refined and fine tuned these traditional offerings and the data offers:

- Improved vertical and horizontal resolution
- Increased along track sampling
- Higher fold of data
- Improved signal to noise ratio
- Improved positioning
- Fewer grey areas in interpretation
- Improved confidence
- Greatly reduced impact of out of plane effects
- Greatly reduced impact of feather angle
- Improved positioning
- Aids stratigraphic/structural interpretation
- Aids shallow hazard assessment





And now consider this !

Are there any engineering or consenting problems out there that geophysics may be able to assist with.

Consider what you know about other's area of expertise.

Consider where do you go for answers to a question or issue if you don't know the answer.

Consider what do you need to know, do you need to know it, how do you find out about it?

How can our knowledge be improved and expanded?

THANK YOU AND ANY QUESTIONS?