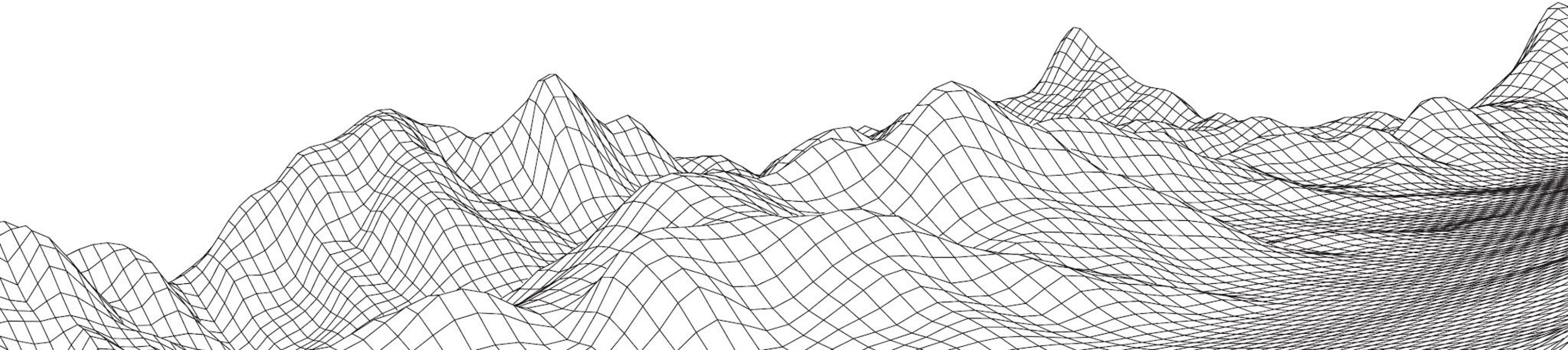
EARTH SCIENCE ANALYTICS

Machine learning assisted seismic interpretation

An integrated workflow for structural/stratigraphic interpretation, combined with reservoir characterisation

Behzad Alaei, Steve Purves, Eirik Larsen, and Dimitrios Oikonomou



Artificial Intelligence / Machine Learning

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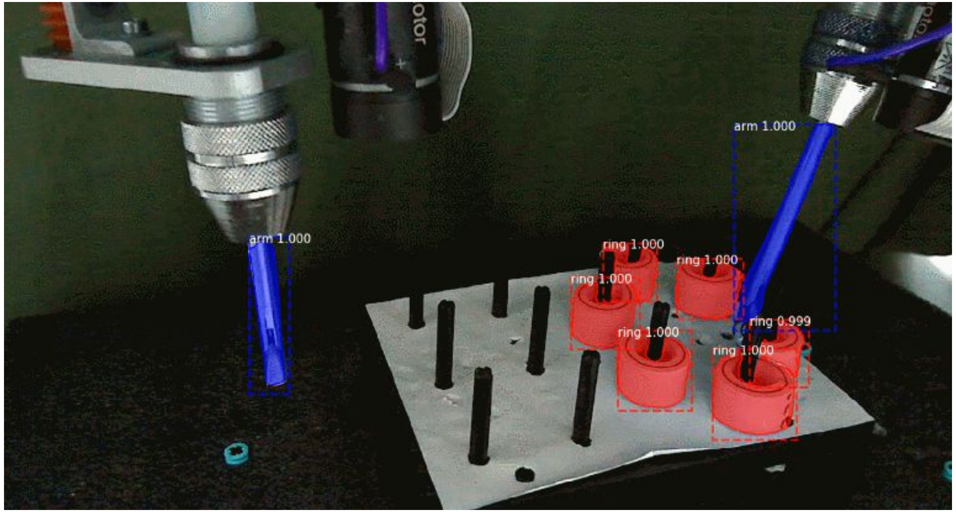

Computer Vision

Mask R-CNN for object detection and instance segmentation on Keras and TensorFlow
https://github.com/matterport/Mask_RCNN

AI is Changing Geoscience Work

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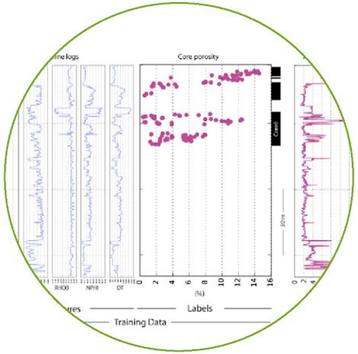
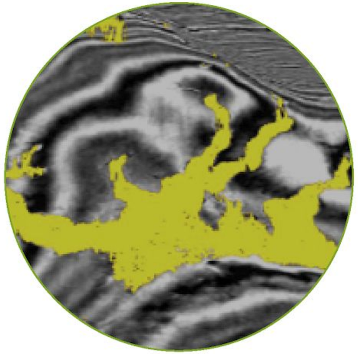
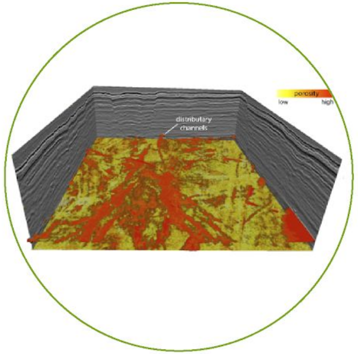
AI-assisted
well-data analysis



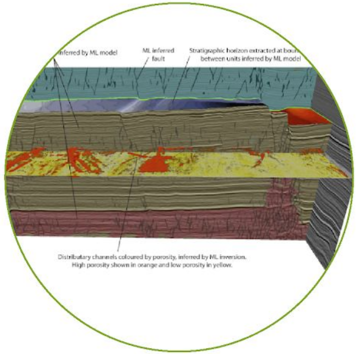
AI-assisted
seismic interpretation



AI-assisted
seismic inversion



AI-assisted
geomodelling



Enablers

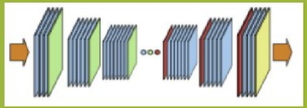
DISKOS
NORWEGIAN PETROLEUM DATA

Democratization of Sub-Surface Data

TensorFlow
python™

Open Source Libraries

GPU Enabled High Performance Computing



Algorithmic Development

amazon web services

Data Analytics Platforms

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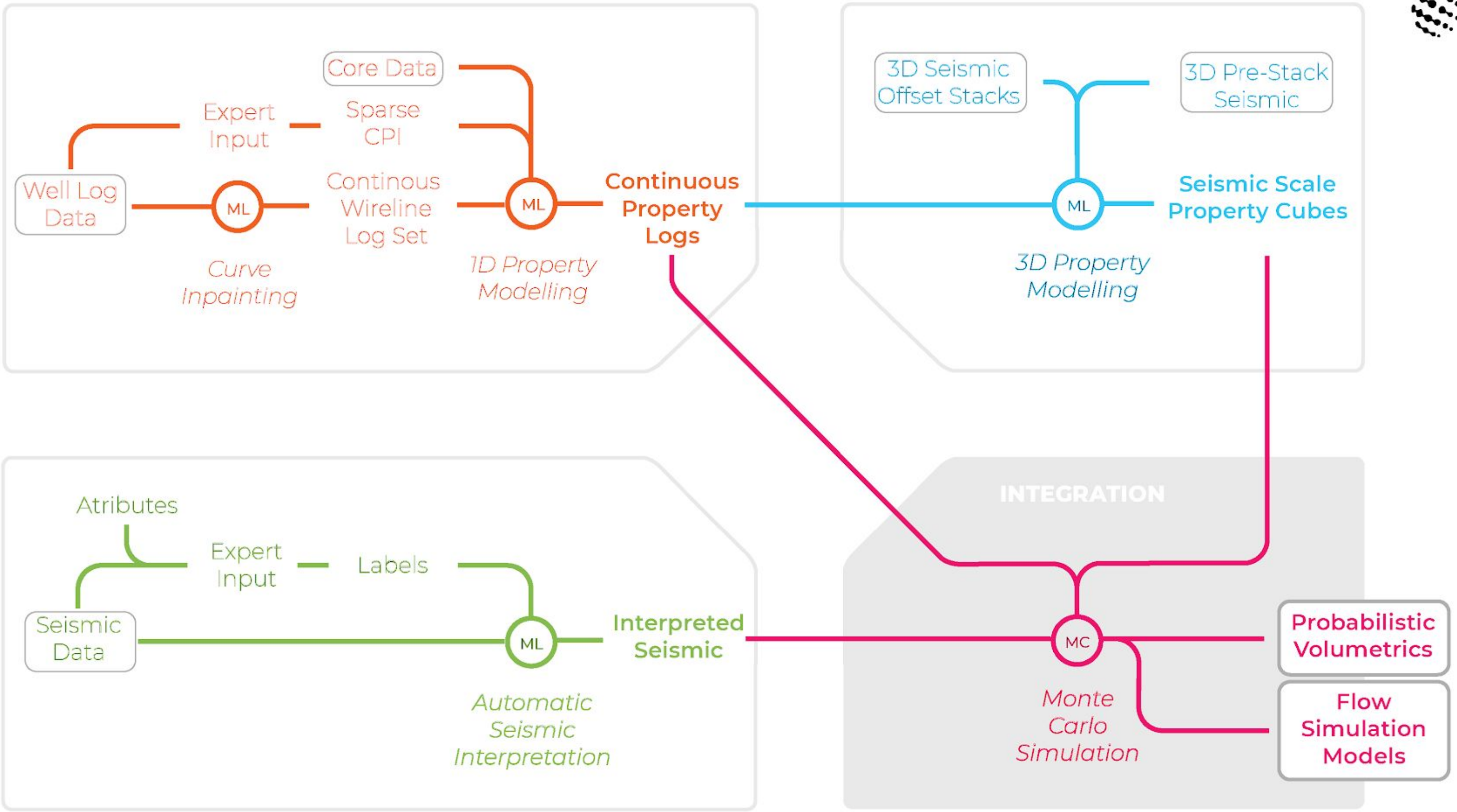
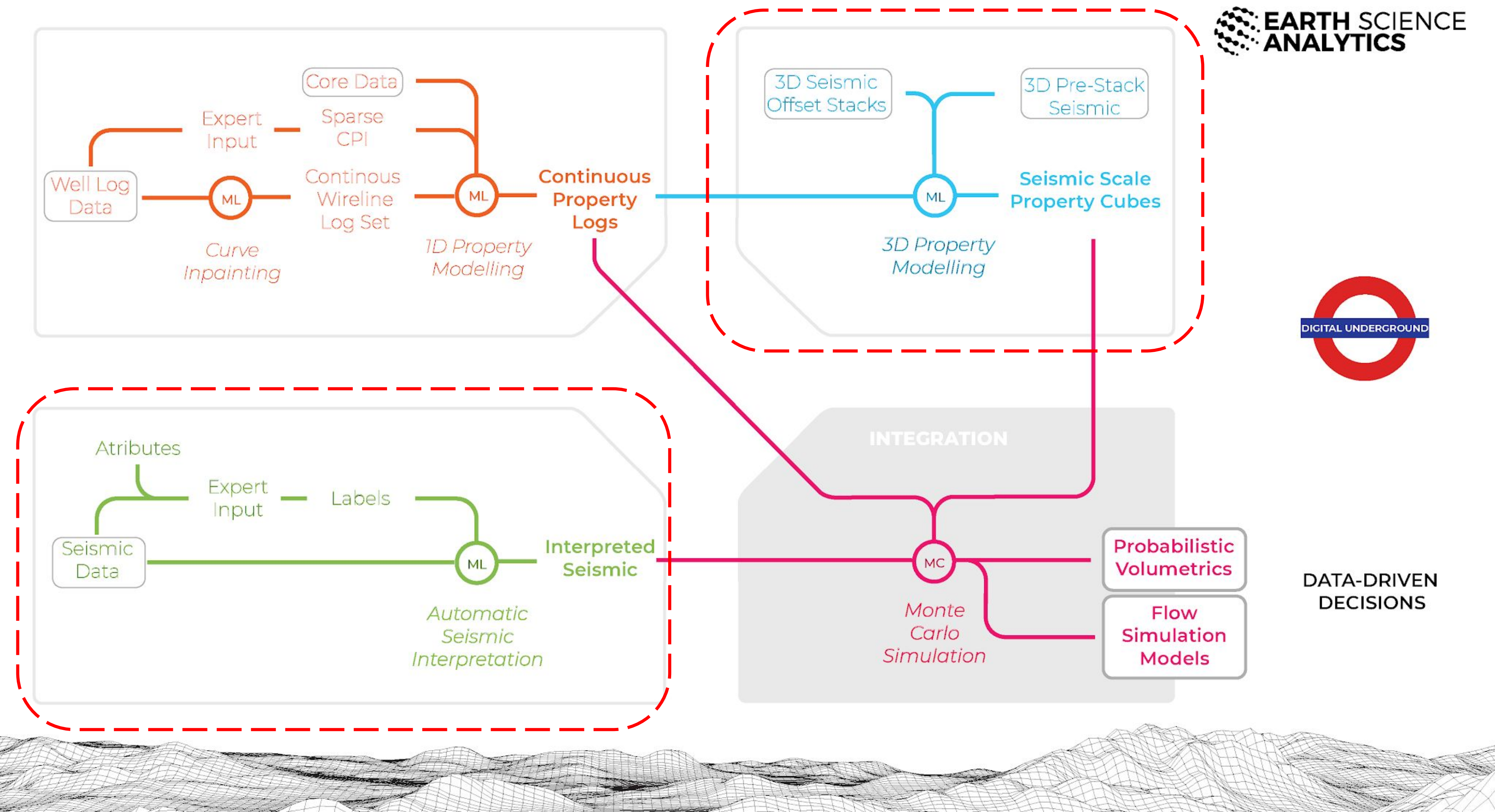


DIGITAL UNDERGROUND

DATA-DRIVEN DECISIONS



EARTH SCIENCE ANALYTICS
Core Data
Expert Input
Sparse CPI
Well Log Data
ML
Continous Wireline Log Set
ML
Continuous Property Logs
Curve Inpainting
1D Property Modelling
3D Seismic Offset Stacks
3D Pre-Stack Seismic
ML
Seismic Scale Property Cubes
3D Property Modelling
DIGITAL UNDERGROUND
INTEGRATION
Atributes
Expert Input
Labels
Seismic Data
ML
Interpreted Seismic
Automatic Seismic Interpretation
MC
Probabilistic Volumetrics
Flow Simulation Models
Monte Carlo Simulation
DATA-DRIVEN DECISIONS

Outline

Seismic to well tie

Automatic seismic interpretation: Horizon picking

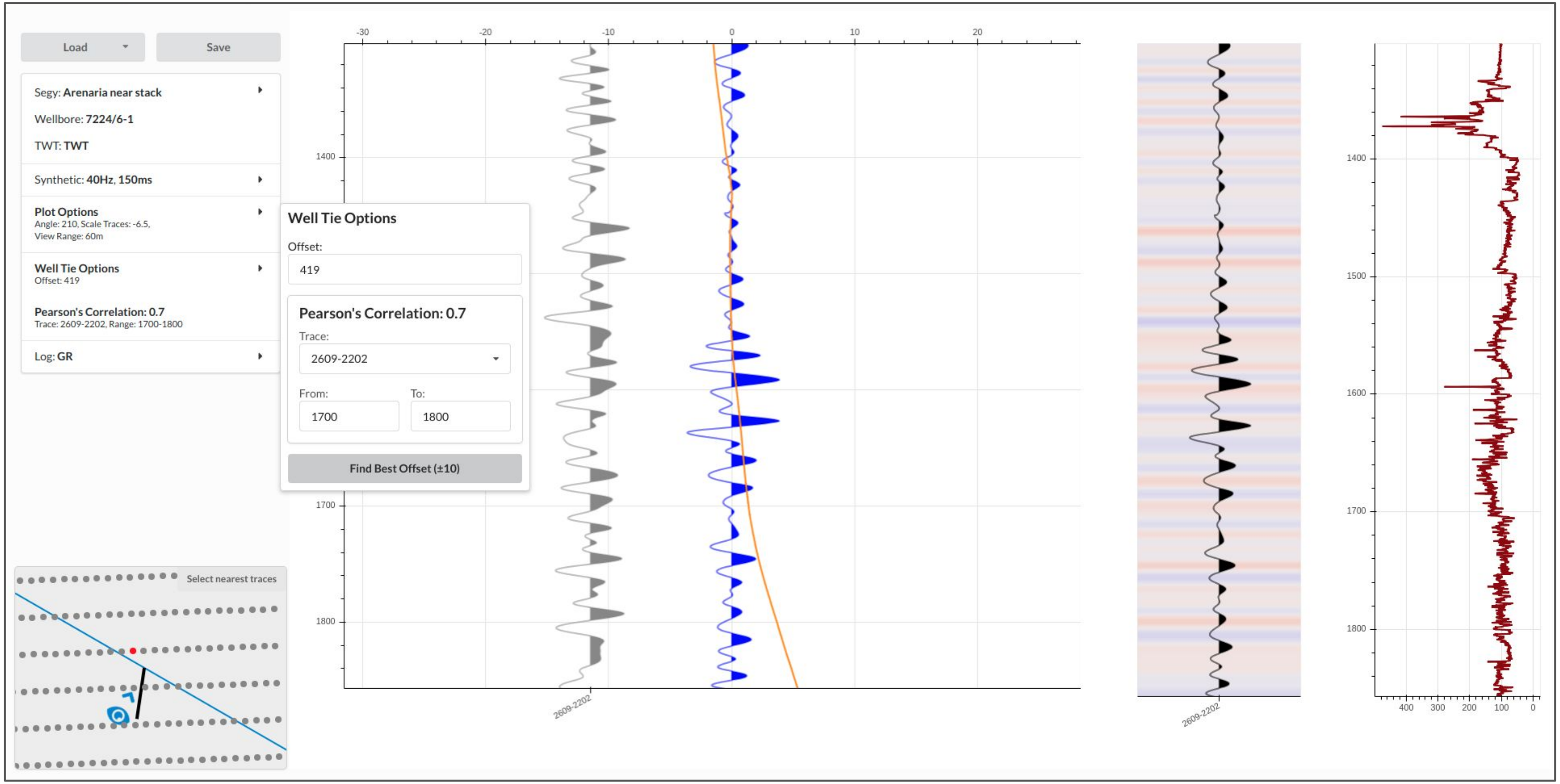
Fault identification and extraction

Geobody extraction

Property predictions

Uncertainty

Seismic to well tie



Automated Seismic Interpretation
Horizon picking

Workflow for lithostratigraphic picking:

Labels: Geological intervals and

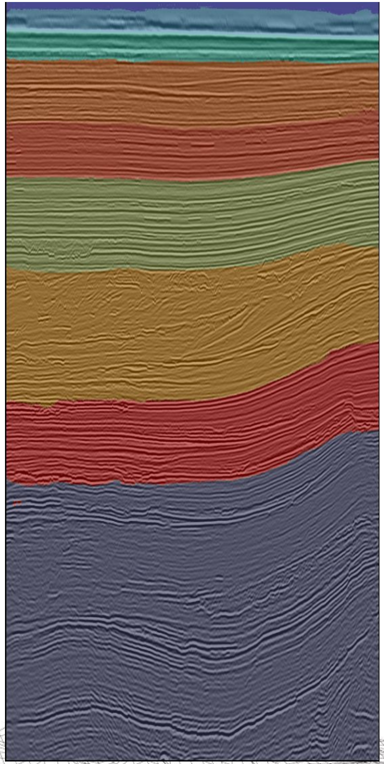
ML Algorithm: Volumetric classification of stratigraphic units units using deep neural networks

Output:

- Stratigraphic containers
- Extract surfaces as interfaces between units

Example labels

Inline Prediction



Automated Seismic Interpretation Norwegian Barents Sea

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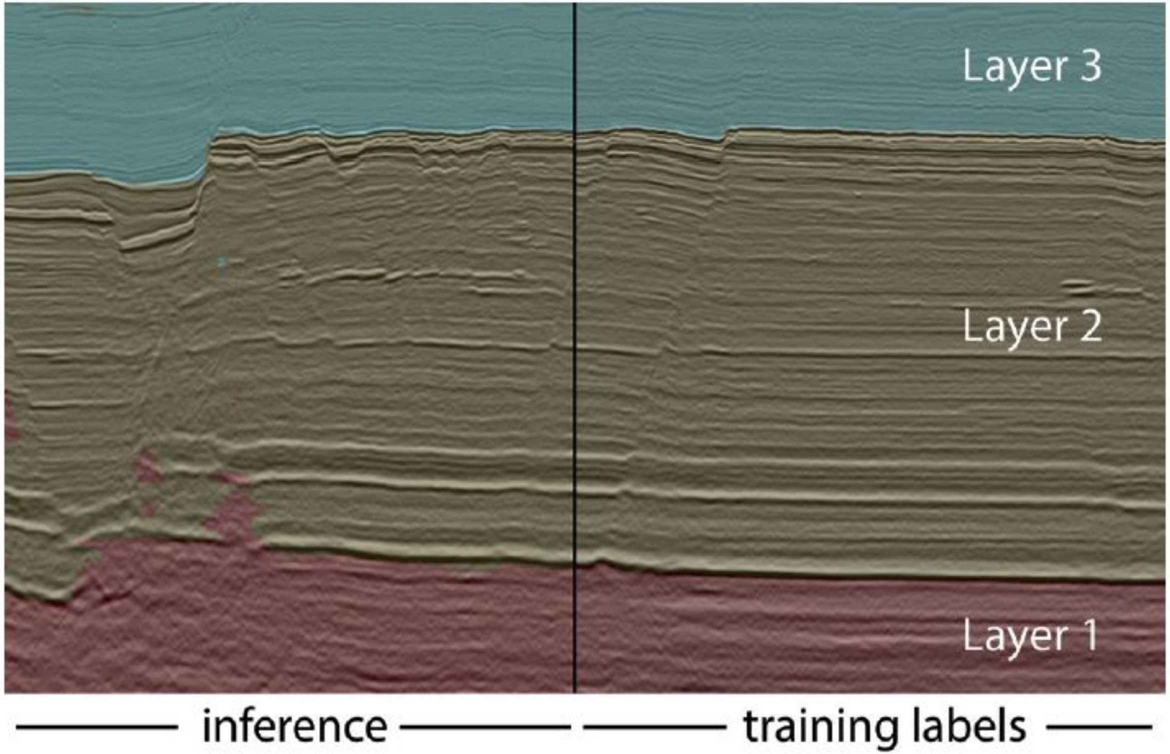
stratigraphic interpretation



Automated Seismic Interpretation Norwegian Barents Sea

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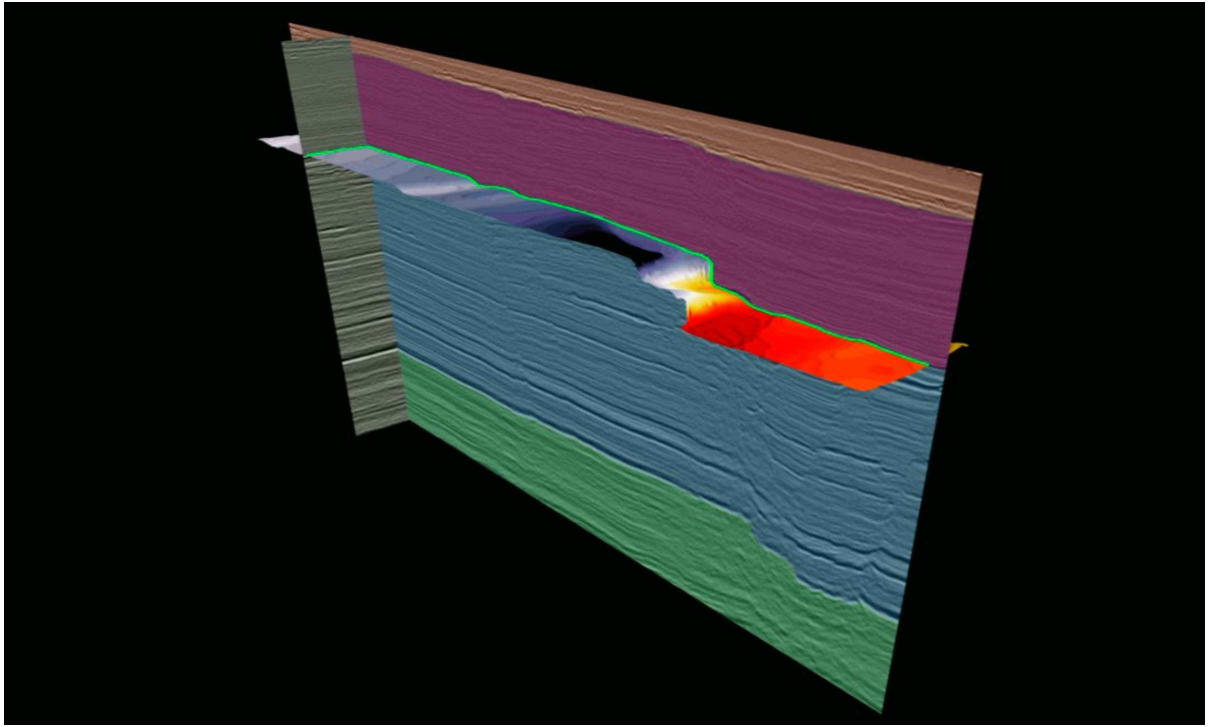
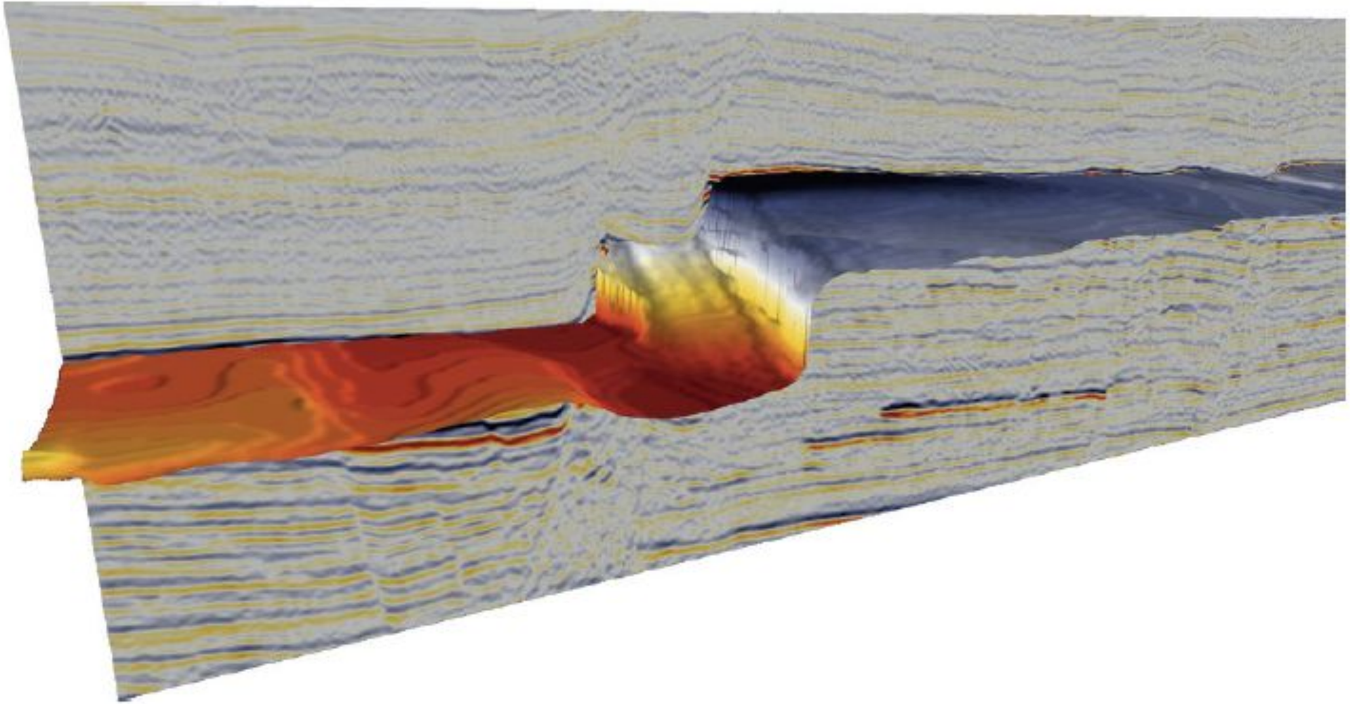


Stratigraphy:

- **Stratigraphic intervals as volumetric containers**
- **Interface surface gridding to produce horizons**

Automated Seismic Interpretation Norwegian Barents Sea



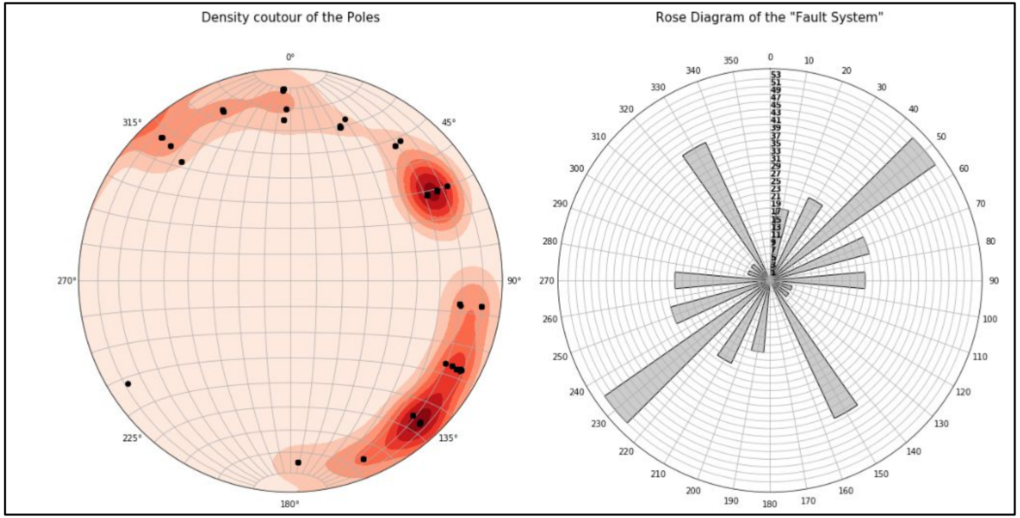
Structural interpretation-Fault imaging

Workflow for Fault Interpretation:

Labels:
- Fault sticks
- Line drawings & images

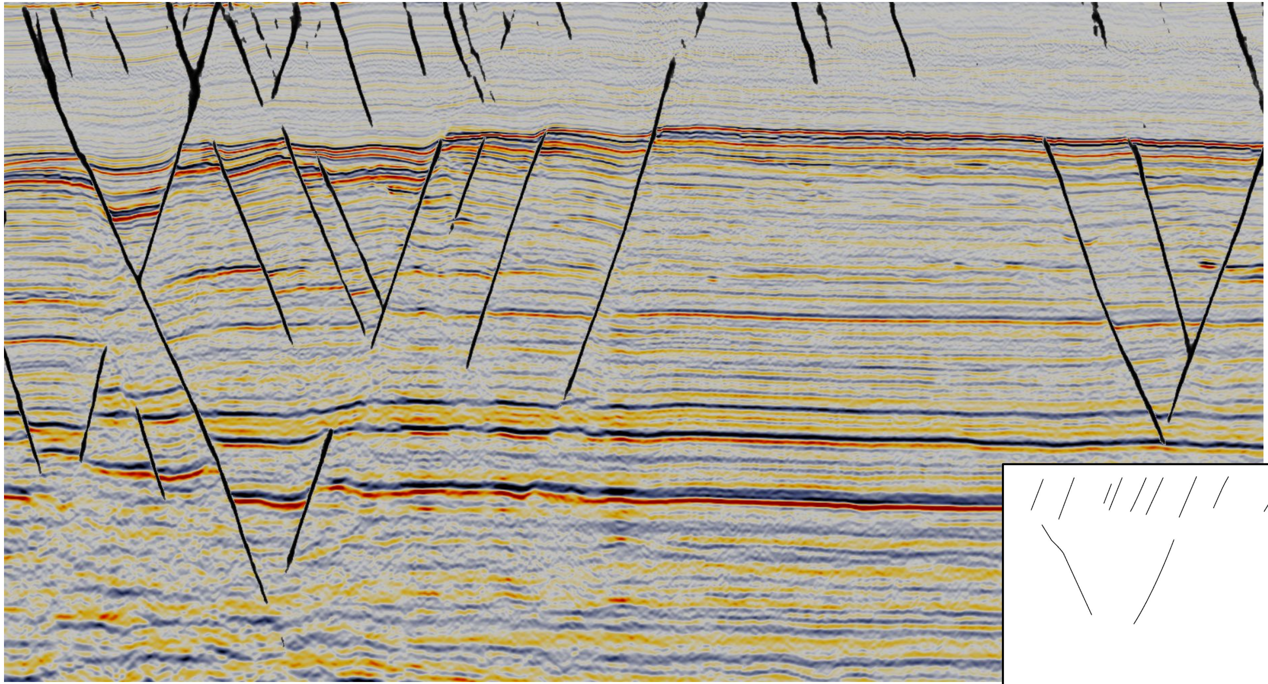
ML Algorithm:
- Deep Fully Convolutional Networks

Output:
- Segmented Fault Volumes
- Fault Orientation Volumes



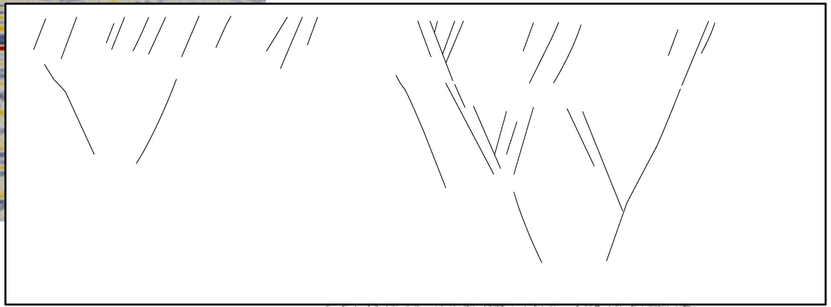
Automated Seismic Interpretation

Fault interpretation

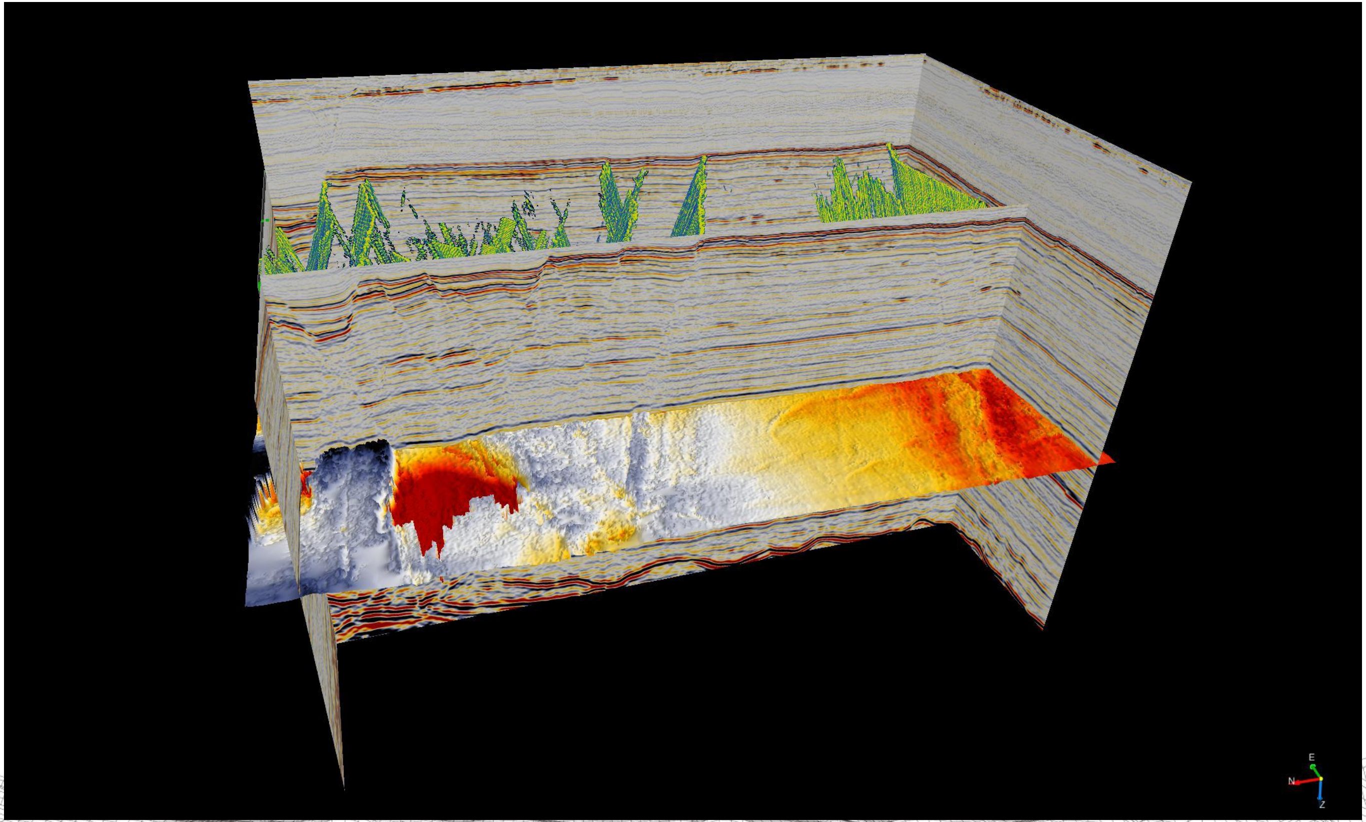


Deep Learning Model
trained on manual fault picks on 15 inlines

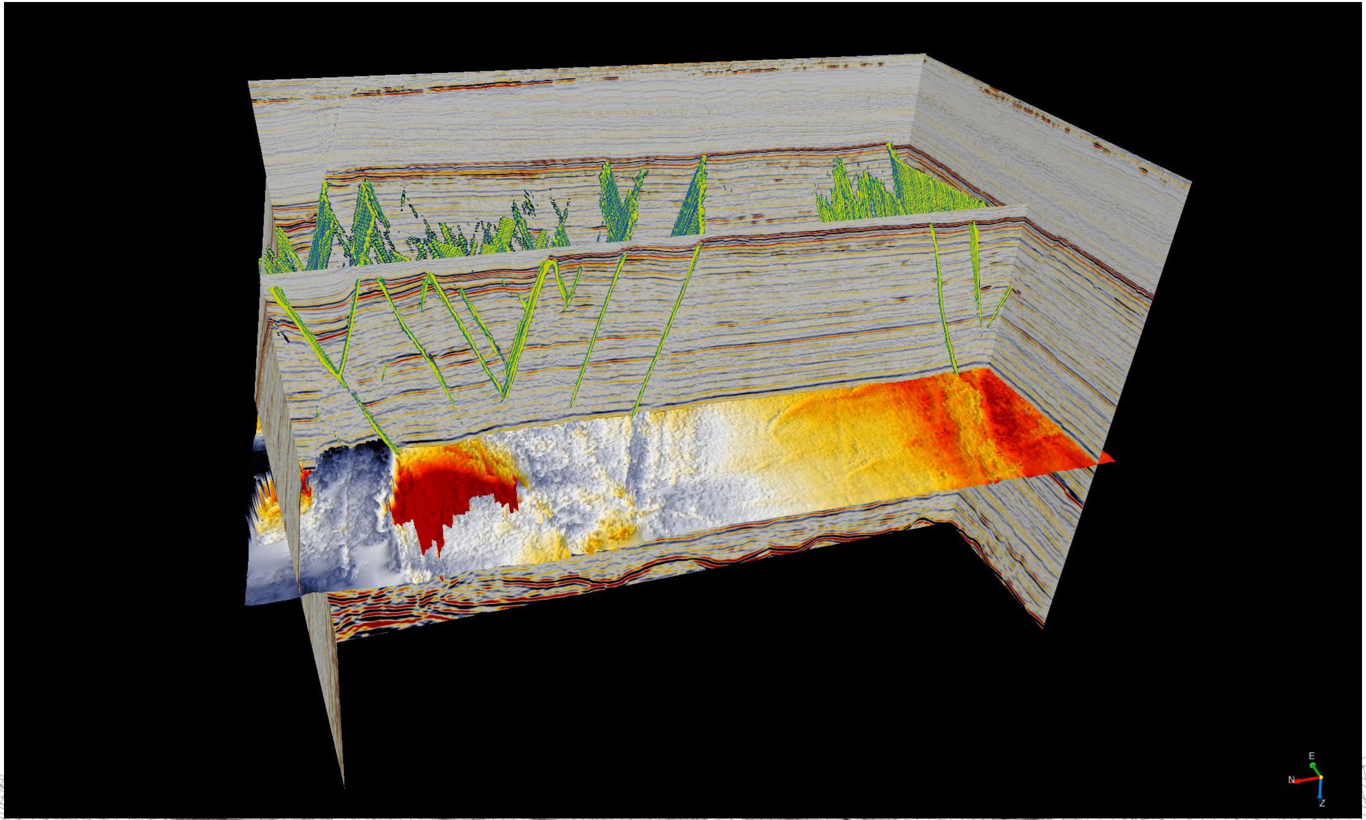
(below) representative labels from a different line



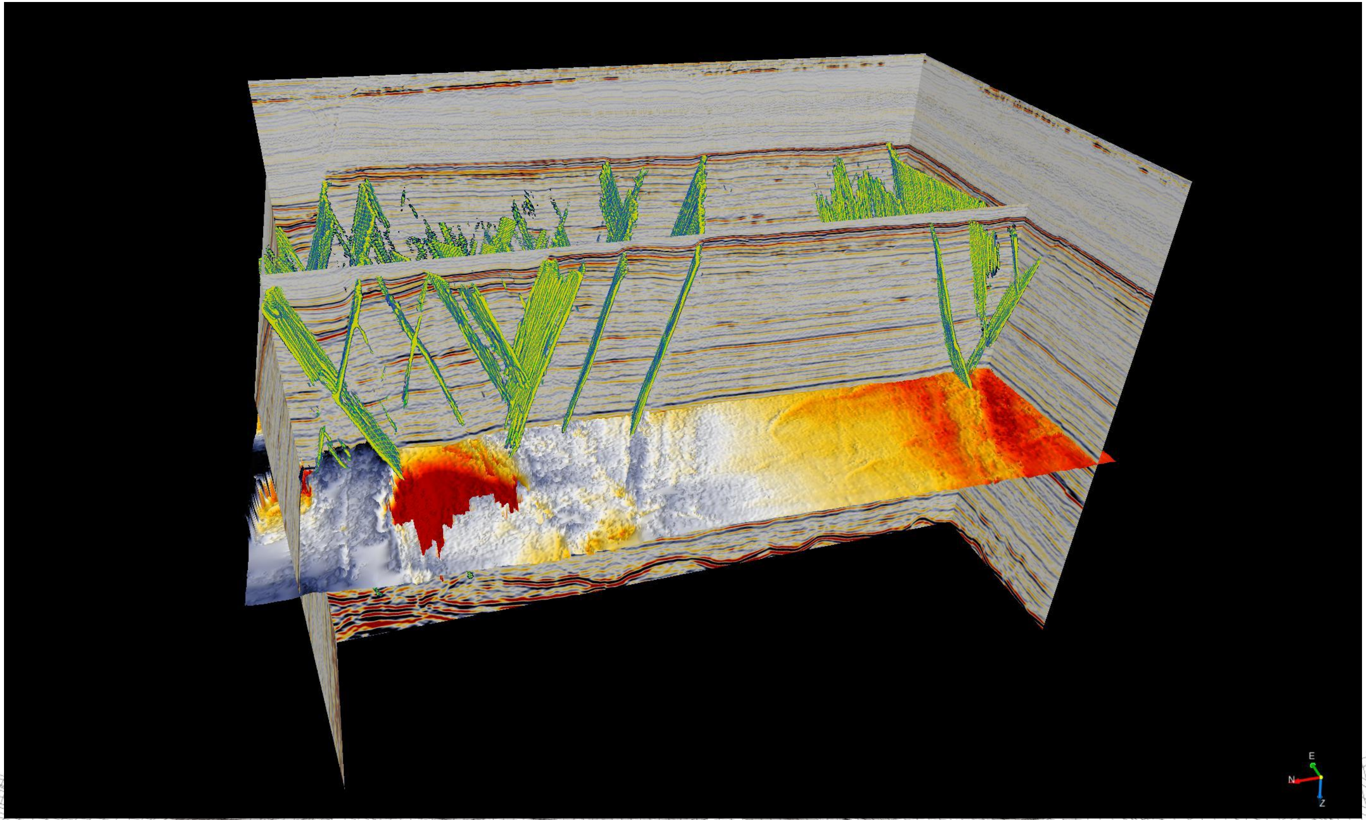
Fault interpretation Arenaria Barents Sea



Fault interpretation Arenaria Barents Sea

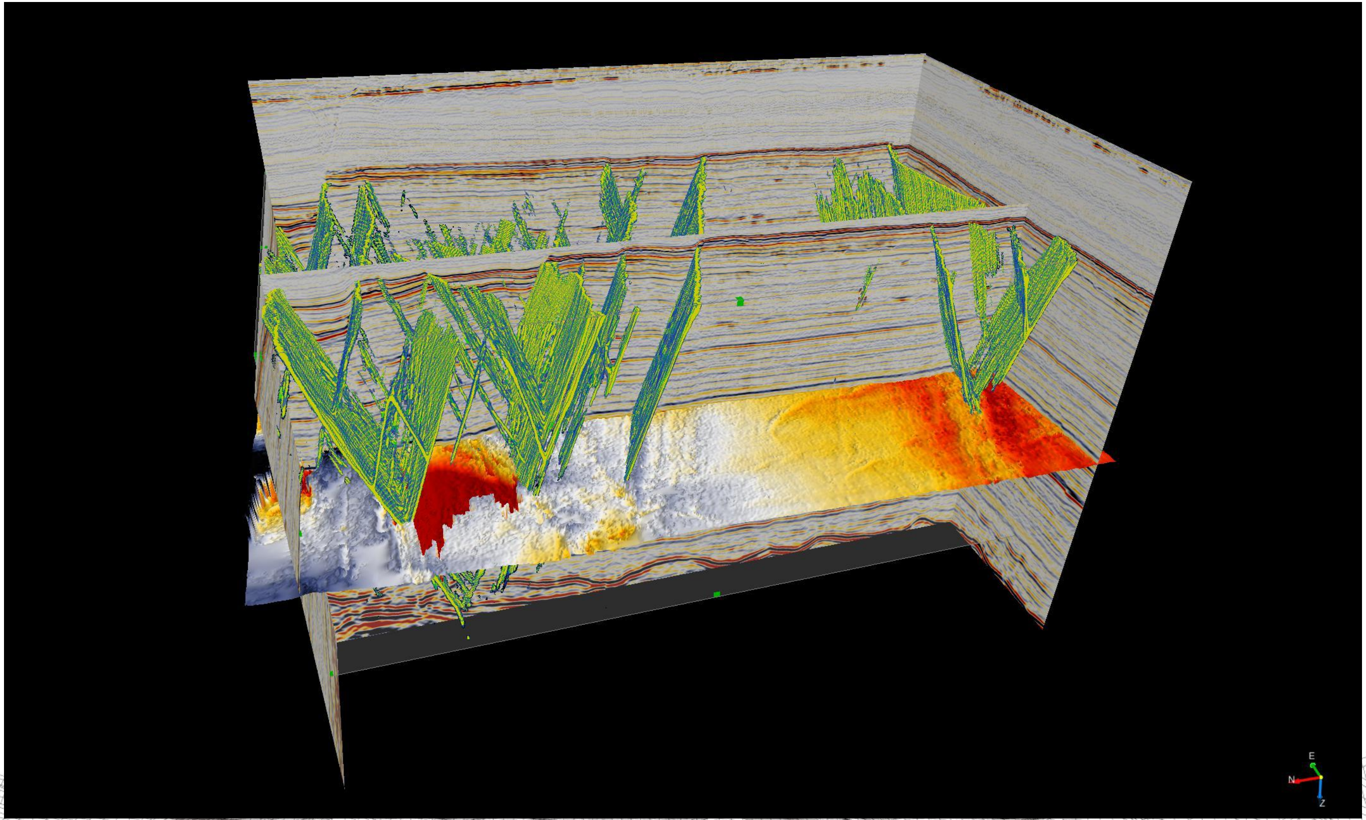


Fault interpretation Arenaria Barents Sea

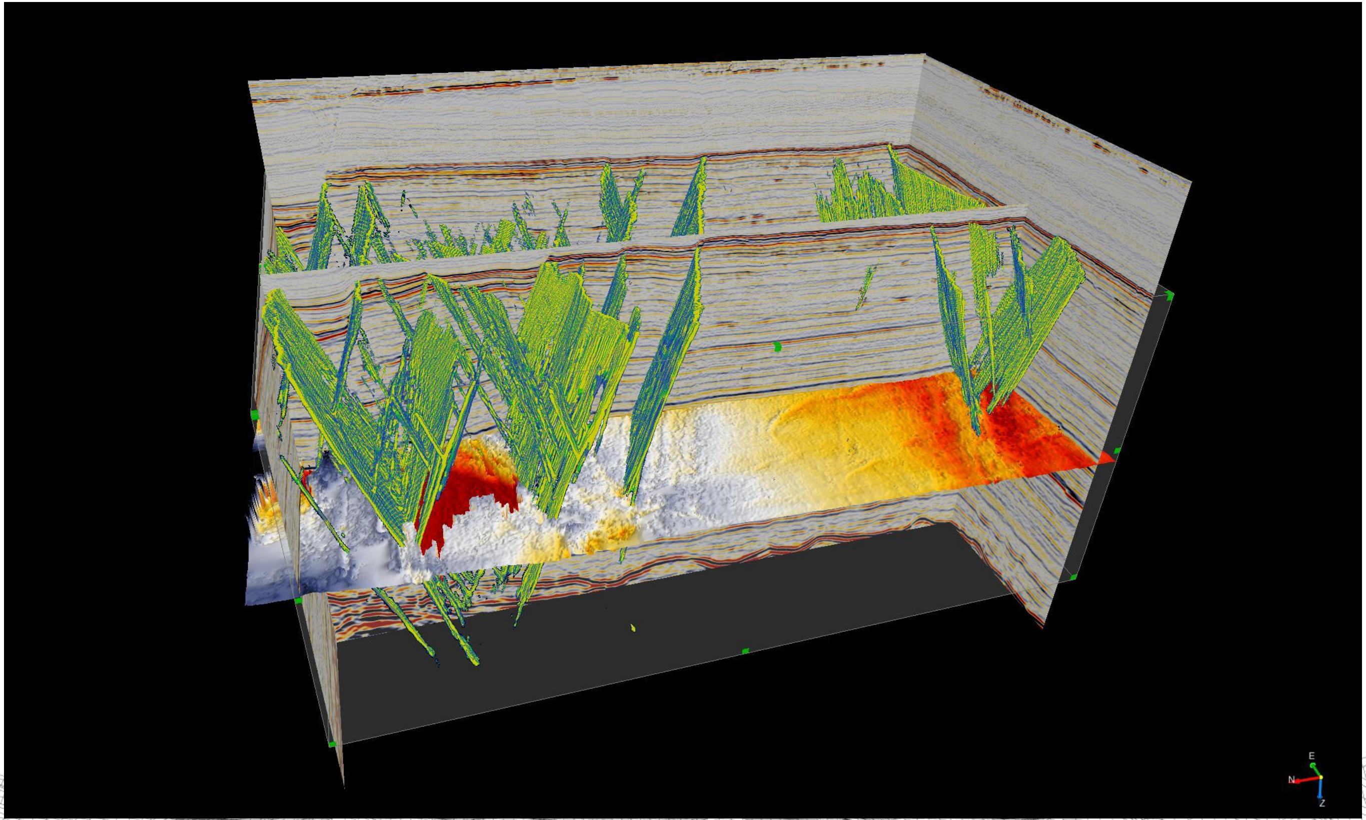


Fault interpretation Arenaria Barents Sea

EARTH SCIENCE ANALYTICS

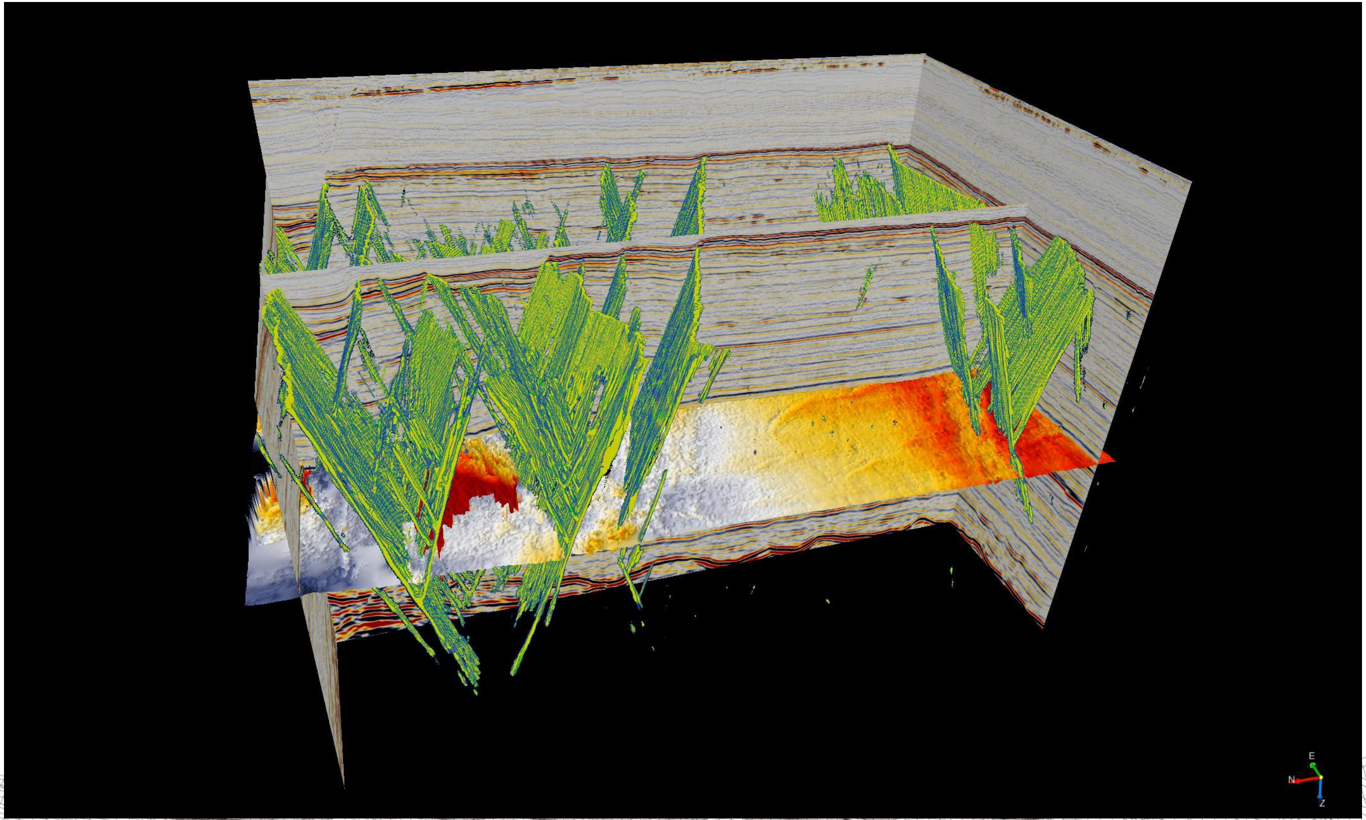


Fault interpretation Arenaria Barents Sea



Fault interpretation Arenaria Barents Sea

EARTH SCIENCE ANALYTICS



ASI and geobody extraction

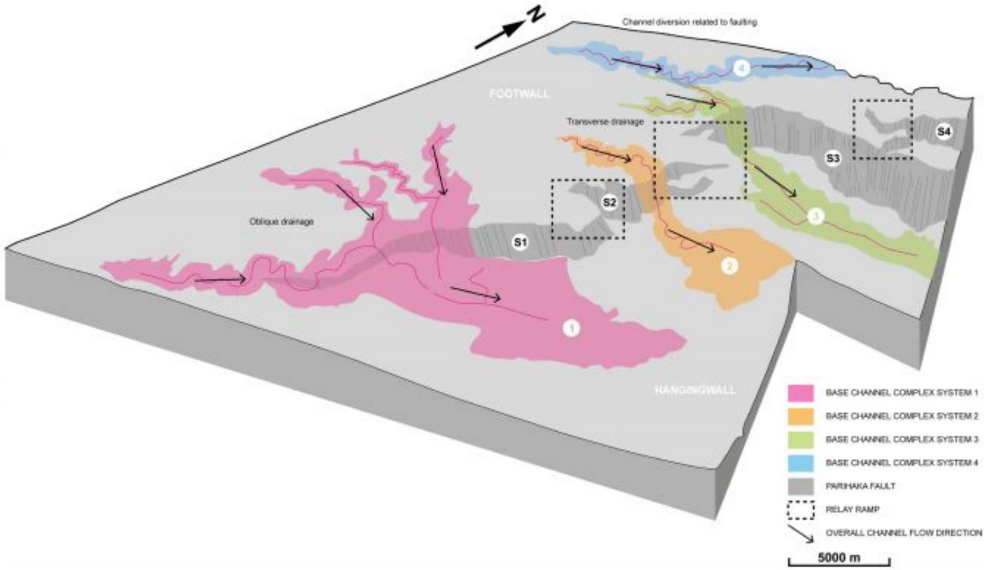
Gully Systems

Potential stratigraphic traps

Complex geomorphology

Varying infill response

Extensive and very difficult to pick



Reproduced with permission from [Mattos, Alves & Scully 2018]

ASI and geobody extraction

Approach

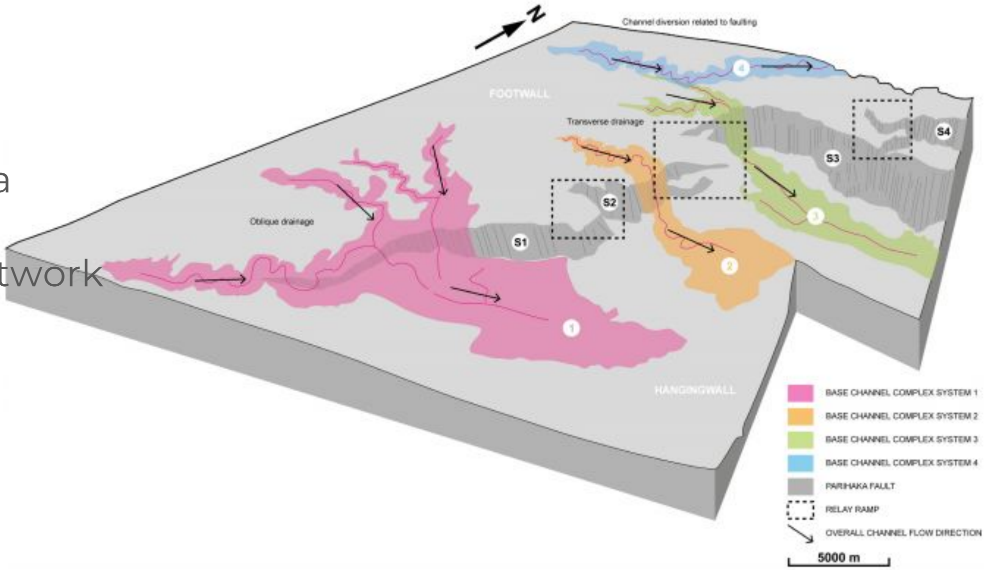
Labels:

- Polygons drawn on inline sections
- Order of 25 inlines over a cropped area

ML Algorithm: Deep Fully Convolutional Network with MonteCarlo Dropout

Output:

- Volumetric Geobodies
- Probabilistic Volumes Mean/Variance



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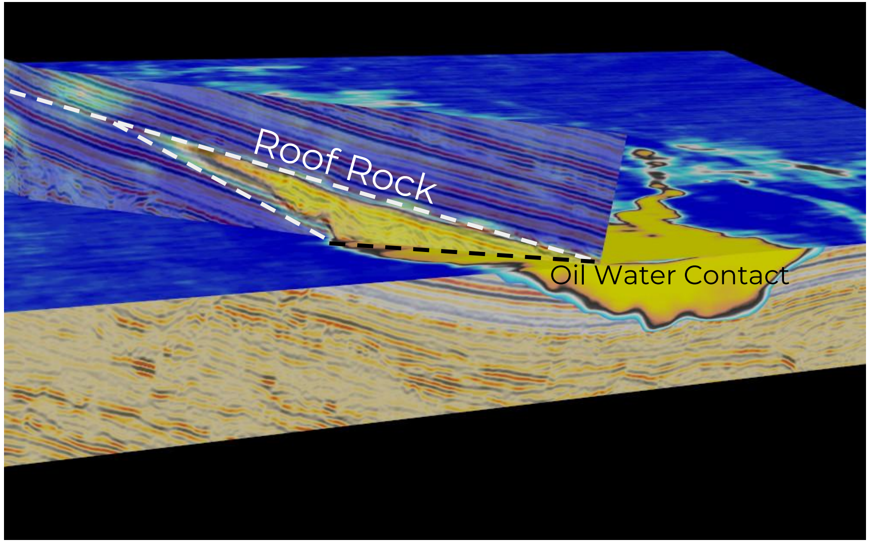
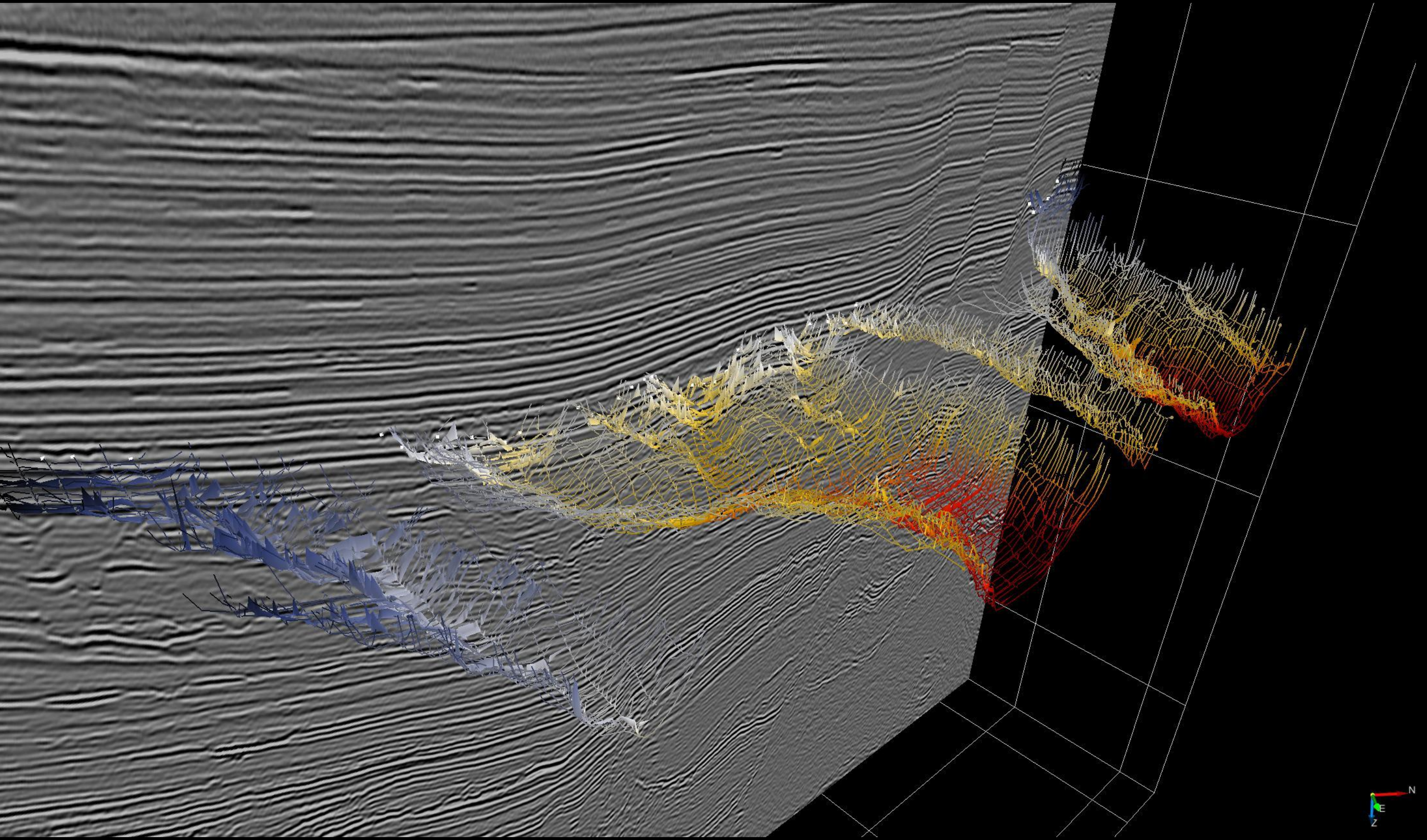
The Objective



HCIIP = GRV x N/G x POR X S_{hc} / FVF

HCIIP	= hydrocarbons in place*
GRV	= gross rock volume
N/G	= net / gross ratio
POR	= porosity
S_{hc}	= hydrocarbon saturation
FVF	= formation volume factor

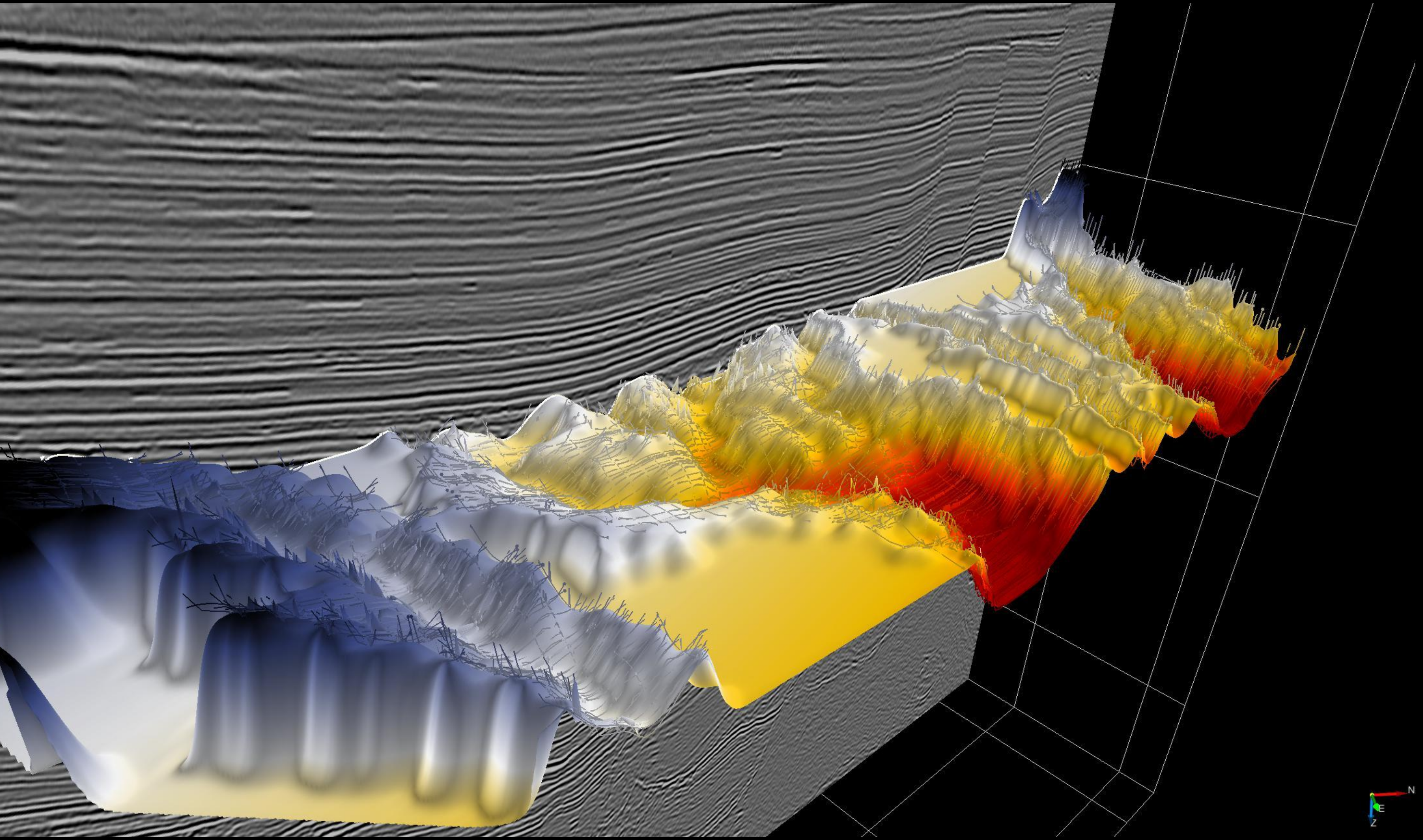
*of oil, solution gs, free gas, condensate and normal surface conditions



Interpretation of complex geobodies

hard-to-track basal surfaces

Manual (point) interpretation in traditional software takes time and is prone to errors



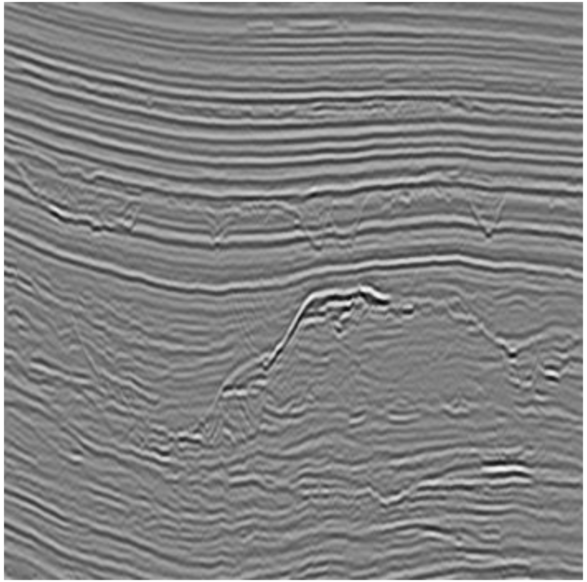
Interpretation of complex geobodies

hard-to-track basal surfaces

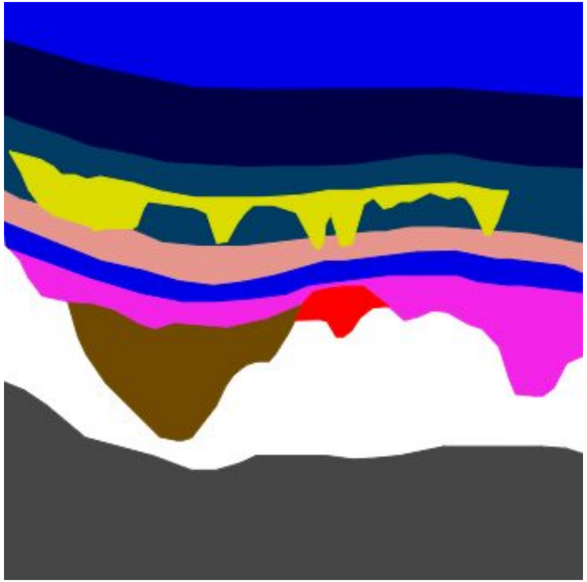
Manual (point) interpretation in traditional software takes time and is prone to errors

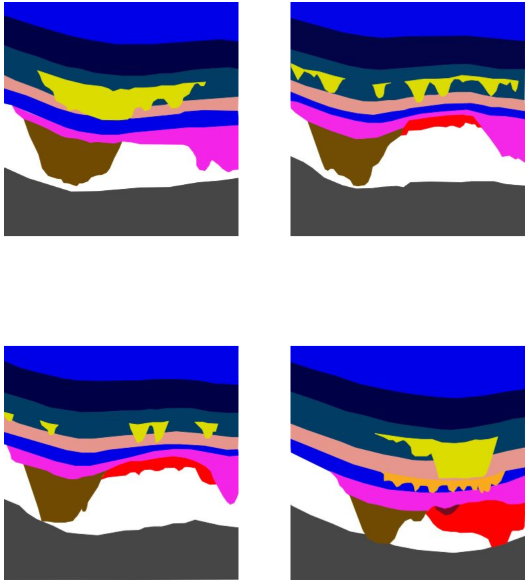
Gridding of manual (point) interpretation suffers from picking inconsistency

Gullies Labels



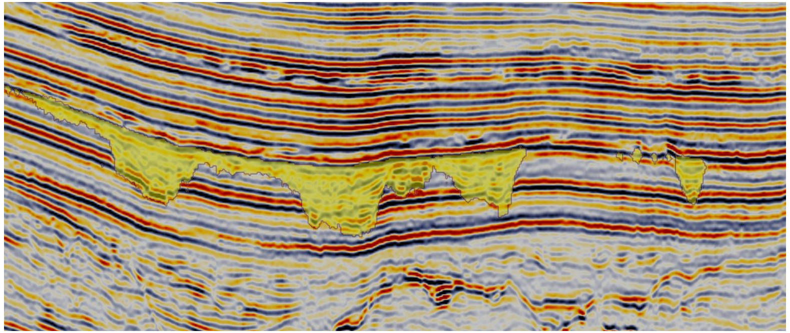
XI4910 - crop



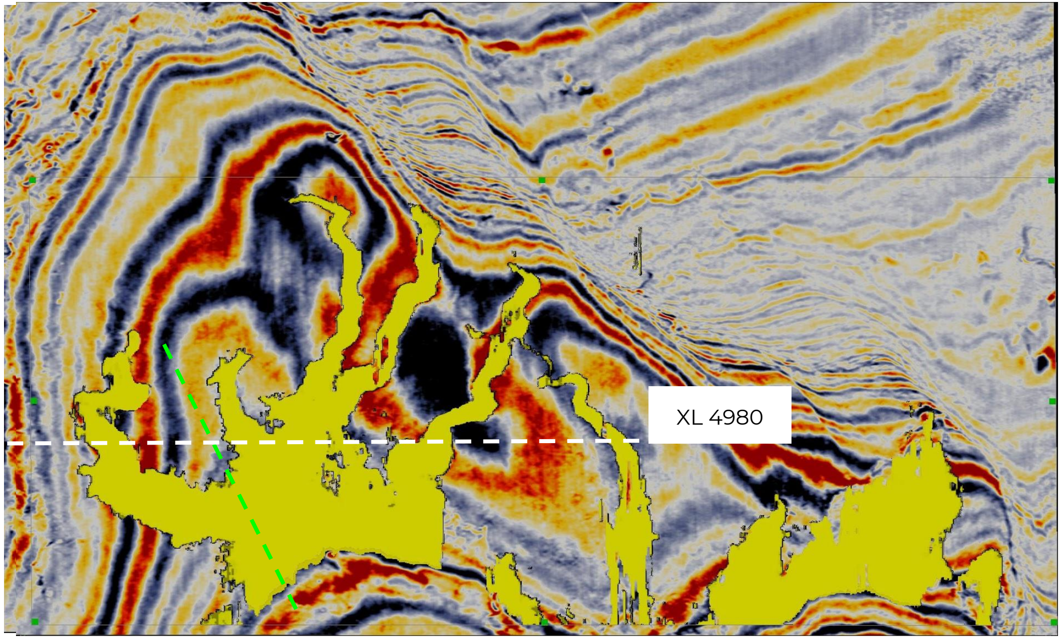


Gullies Labels & Predictions

Gullies Prediction



XL 4980



Property predictions

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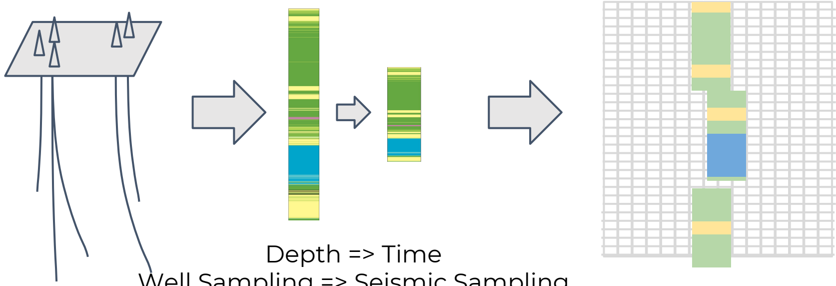
Quantitative interpretation

- Labels:
    - Continuous property logs (e.g. porosity, water saturation, and lithology) at wells
- Features:
    - Full and partial stacks
    - Interval velocity volumes
    - Attributes
- ML Algorithm
    - Deep fully convolutional neural network
- Output
    - 3D volumes of properties
    - 3D litho_fluid volumes



Predicting rock- and fluid-properties from 3D seismic

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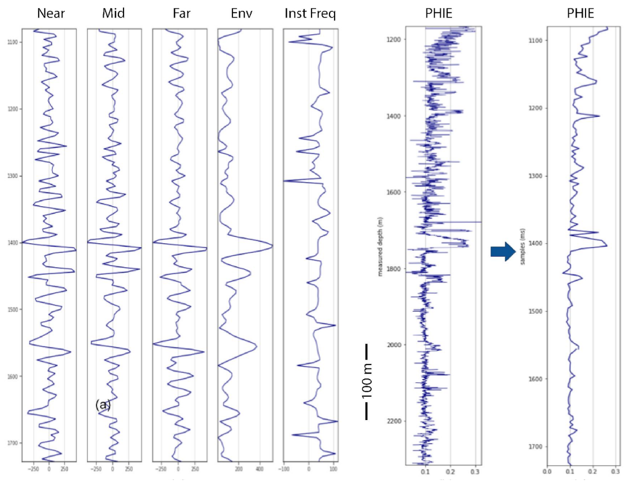
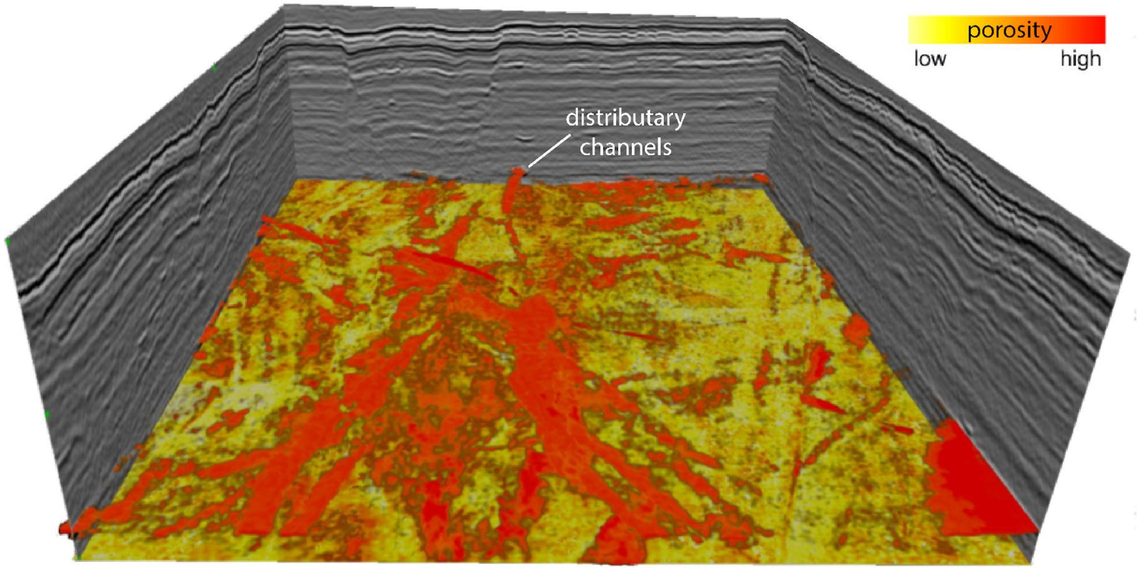
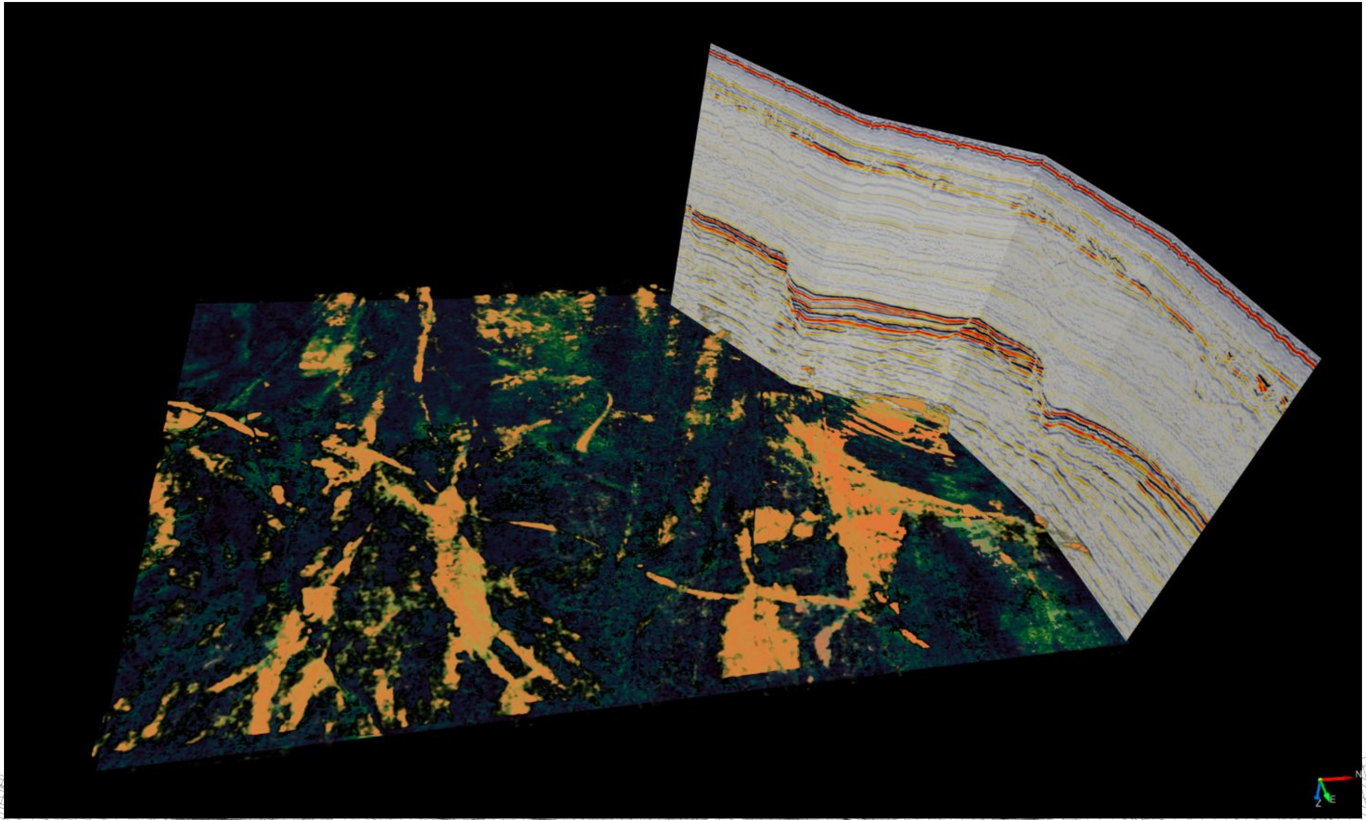


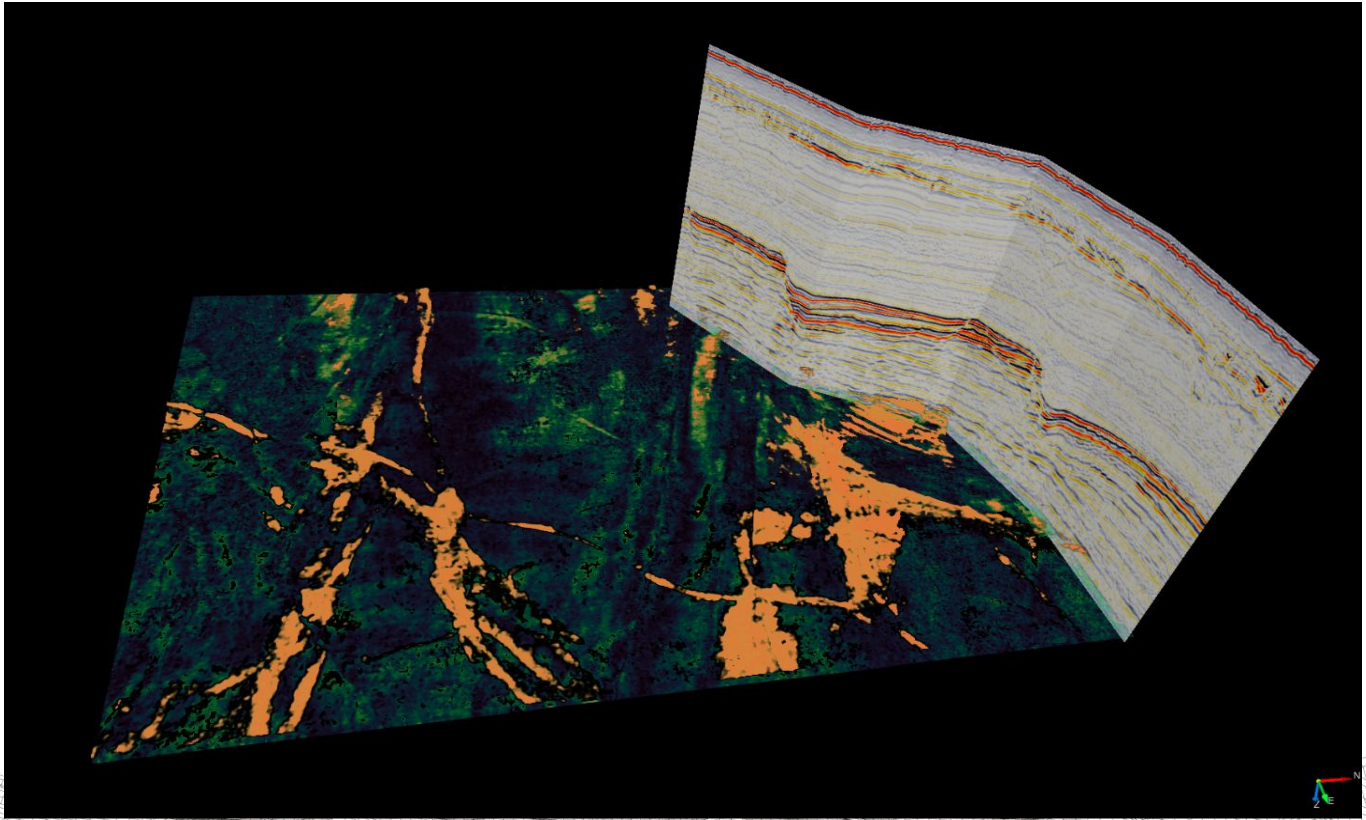
ML-derived 3D porosity model
inferred from seismic traces;
near, mid, far and seismic attributes



3D porosity volume Arenaria Barents Sea



3D porosity volume Arenaria Barents Sea



3D porosity volume Arenaria Barents Sea

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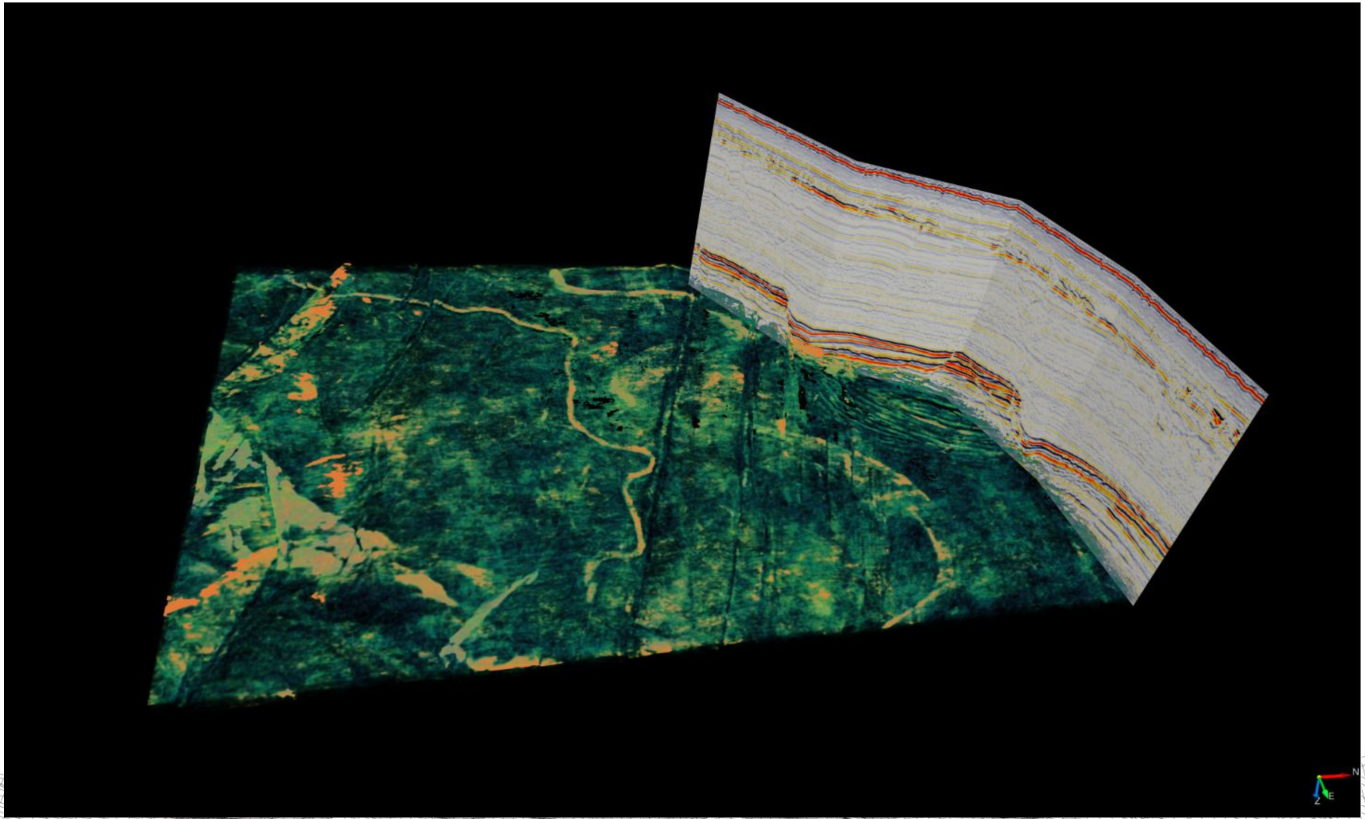
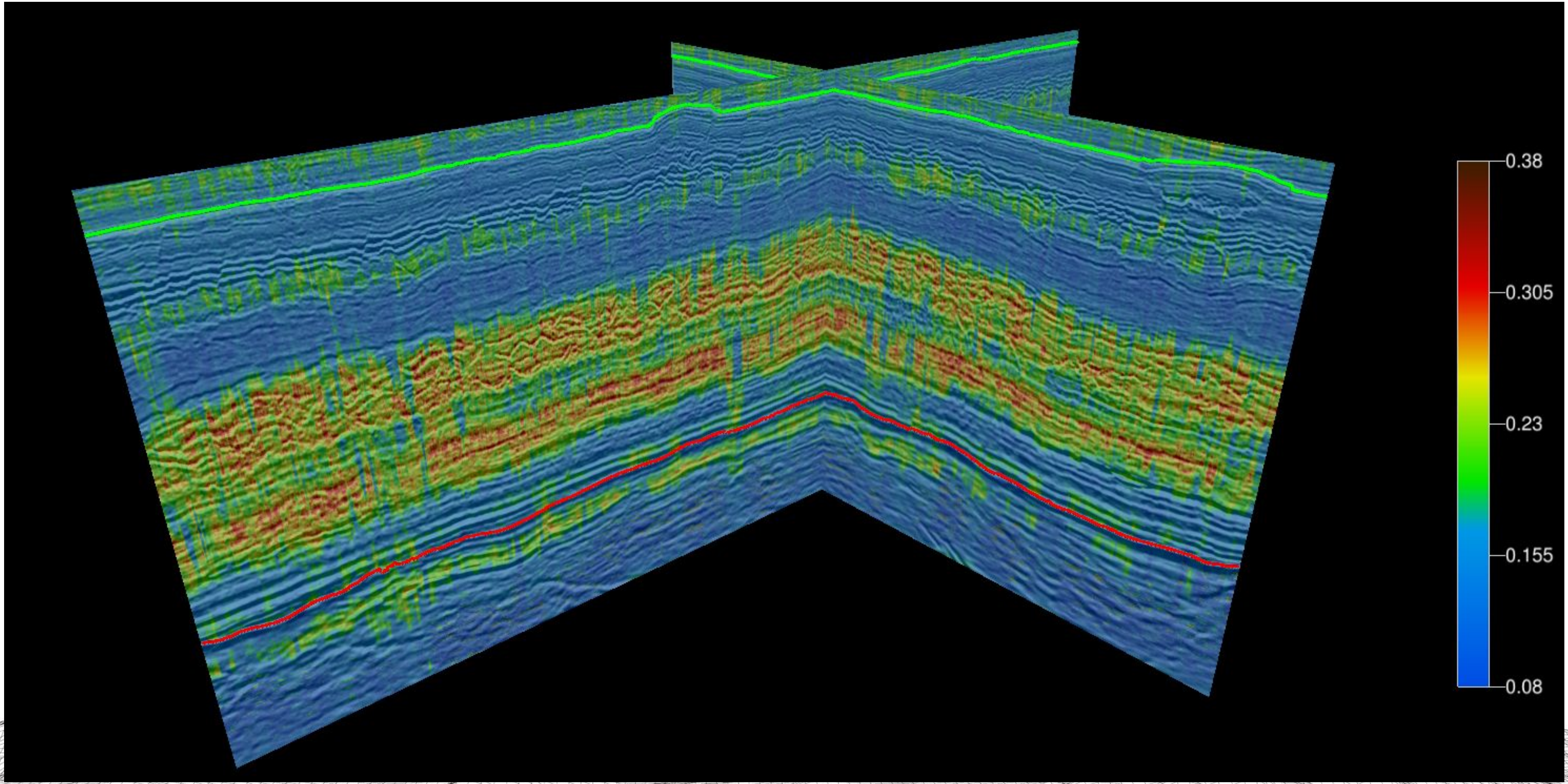
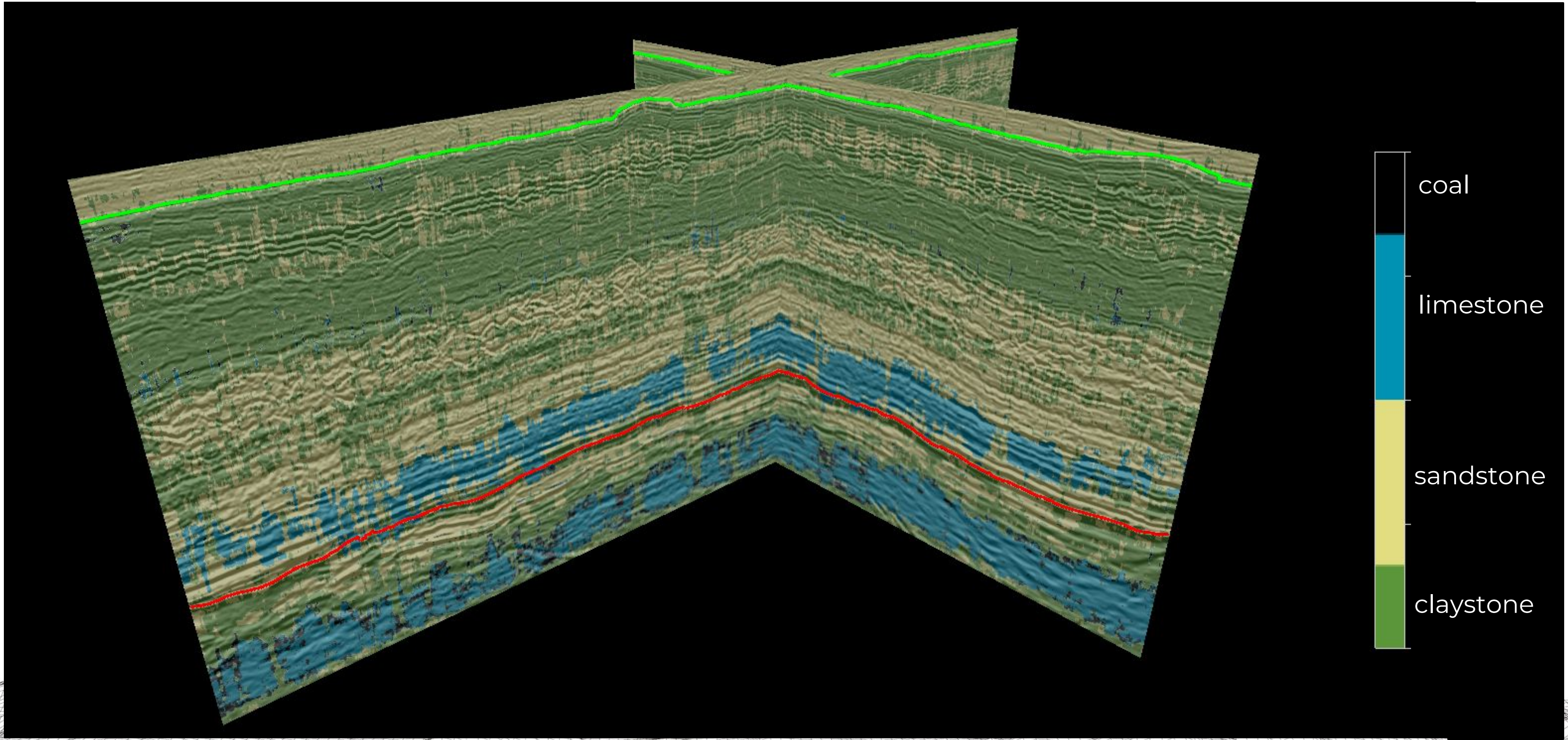


3D porosity volume Sleipner Vest North Sea

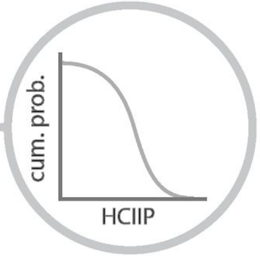


3D multiclass lithology volume Sleipner Vest North Sea

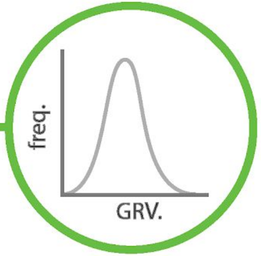


Uncertainty

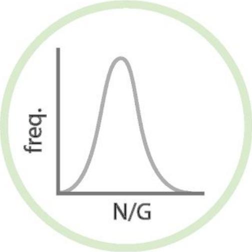
$$HCIIP = GRV * N/G * POR * SHC / FVF$$



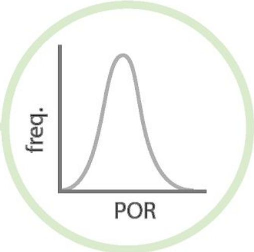
Monte Carlo simulation based on below distributions



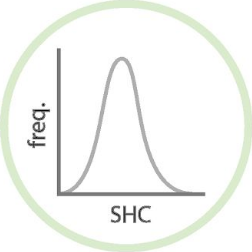
Deep Learning ASI with Uncertainty



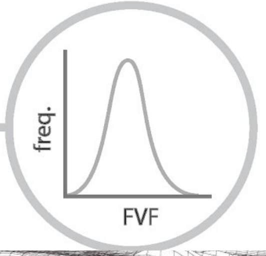
ML inversion and/or contextual queries on ML derived N/G logs



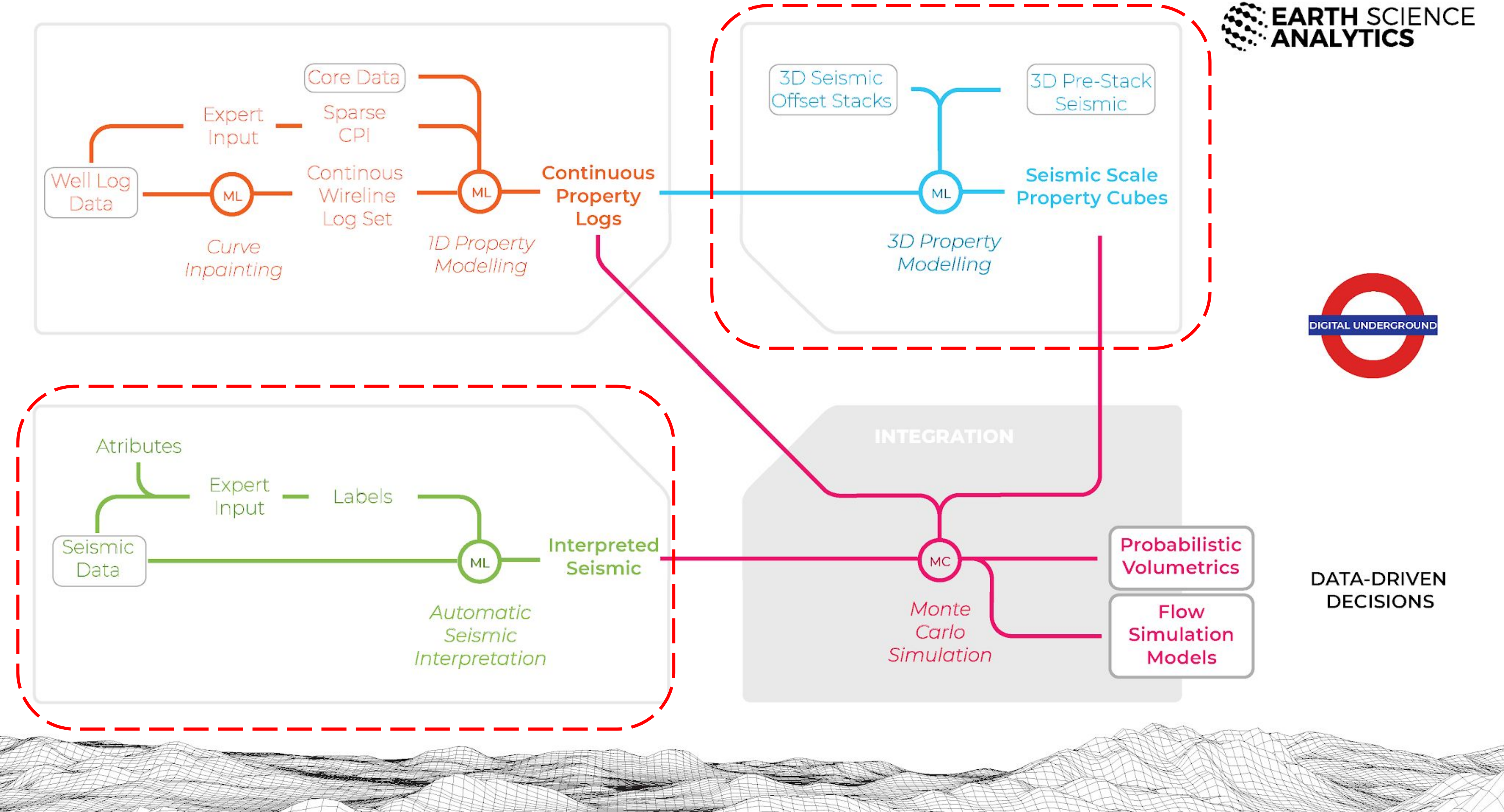
ML inversion and/or contextual queries on ML derived POR logs



ML inversion and/or contextual queries on ML derived SHC logs



Contextual queries on analogous field data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