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Exploration and Development based on RTH Technology and AI

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Reverse Time Holography (RTH) Technology

- RTH is approach for processing and interpreting seismic data based on the principles of holography and scattered wave reversal in time
- The technology is a further vector-based development of Reverse Time Migration and is an alternative to FWI, AVO, Acoustic Inversion etc.
- Technology fully compatible with Machine Learning geology prediction based on well-logging data
- The principles of two beams interferometry, which underlie RTH, significantly increase the spatial resolution of seismic exploration on scattered waves, which is limited only by the size of the voxels into which the entire volume is divided
- The backscattering model in RTH allows scattering to depend not only on direction (angular anisotropy), but also on frequency

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RTM &RTH processing workflow comparison

Common-shot gathers

RTM

Data decomposition based on second order wave equation with known velocity

p^f -forward pressure

p^b -back pressure

Decomposition

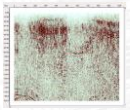
Voxel x

Common Image Gathers $(p^f, p^b) \in R^2$

Appling RTM Imaging Condition (integration by sources and time)

Attributes Syntheses

RTM Imaging



Depth Cube

RTH

Common-shot gathers

Data decomposition based on first order acoustic equation with initial velocity model

p^f -forward pressure

p^b -back pressure

$\vec{f}$ -forward vector particle velocity

$\vec{b}$ -back vector particle velocity

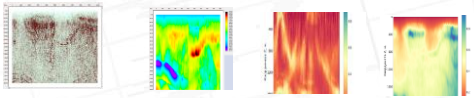
Voxel x

Vector Domain Common Image Gathers $(p^f, p^b, \vec{f}, \vec{b}) \in R^8$

Statistical parameters estimation of multidimensional stochastic distribution

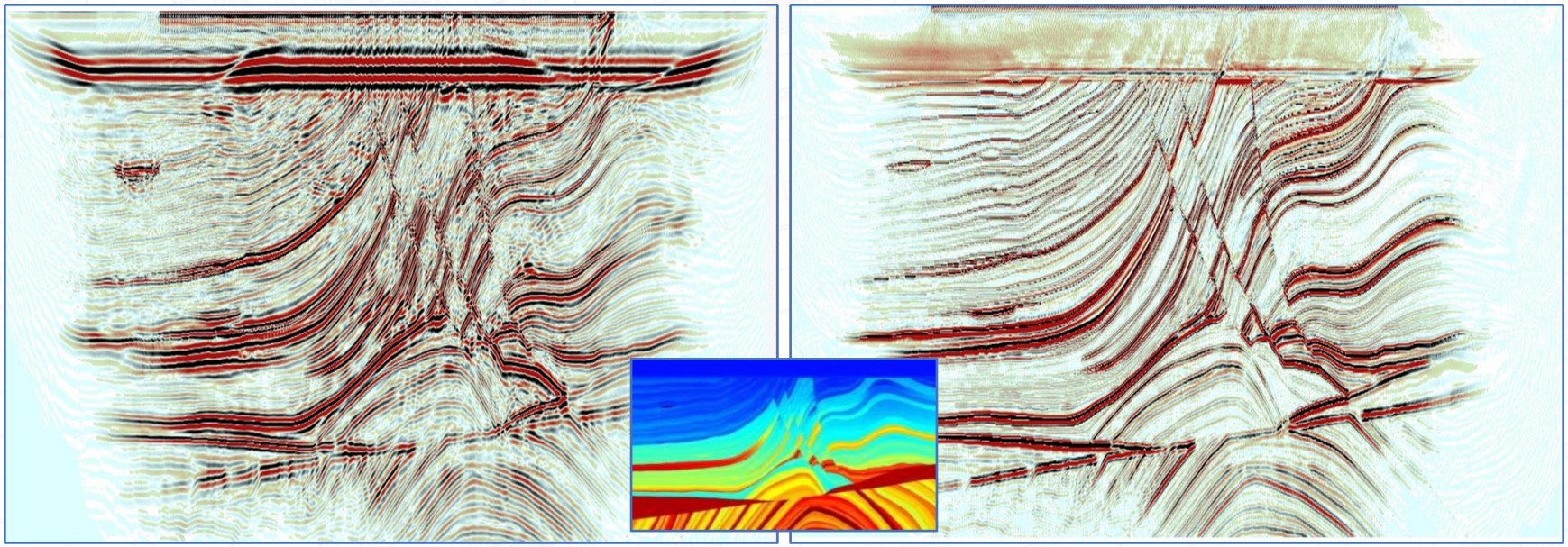
There is no summation by sources and time

More than 100 RTH attributes



Depth Cubes

Comparison of RTM and RTH

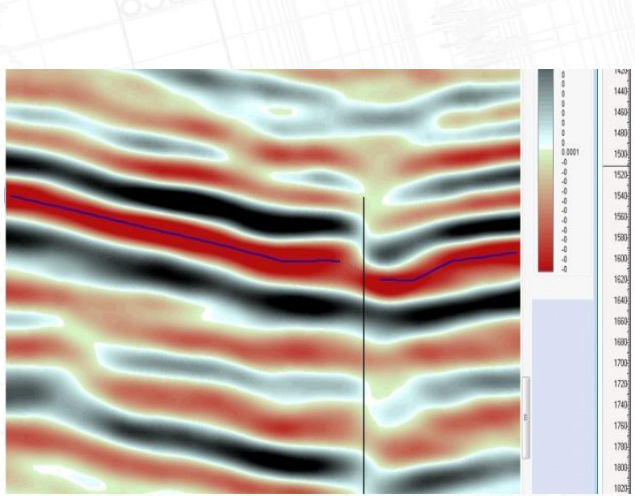


RTM

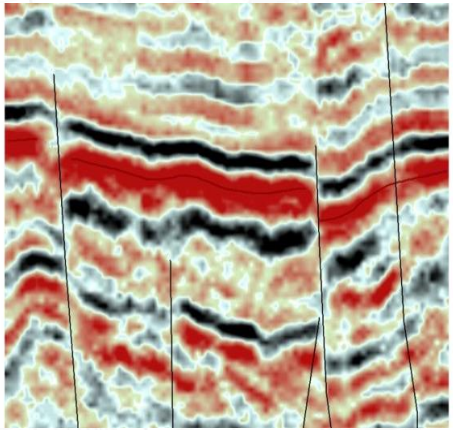
RTH

4

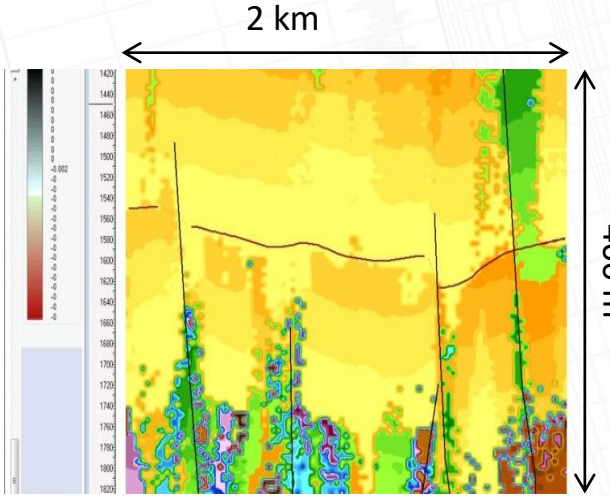
Comparison of RTM and RTH for fractured foundation



RTM



RTH Phase



RTH velocity

Voxel size is 12.5x12.5x2.5 m

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Seismic methods and RTH

Time-dependent scattering

Dip Angle

$$\theta = (\alpha + \beta)/2$$

Conventional Scattering Indicatrix: $J(\theta)$

At present, it is generally accepted to divide the wave field into:

- ❑ **Reflected component** (in-phase scattering at sharp boundaries)
- ❑ **Diffraction component** (weak scattering by small inhomogeneity)

$J(\theta, t)$

- RTH- full wave time-dependent scattering inversion
- RTH is the tool for time-dependent scattering analysis at each point in space.

Methods:

Reflection
PSTM
PSDM
RTM
AVO

Diffraction
CSPD
ES360

Migration Velocity Analysis

Inversion
AI
FWI

RTH

RTH – tool for time-dependent scattering seismic exploration

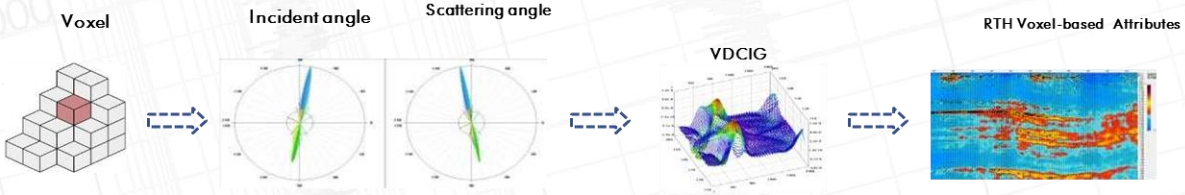
RTH Time-dependent Scattering Indicatrix:

WWW.SCATTERINGSEISMIC.COM

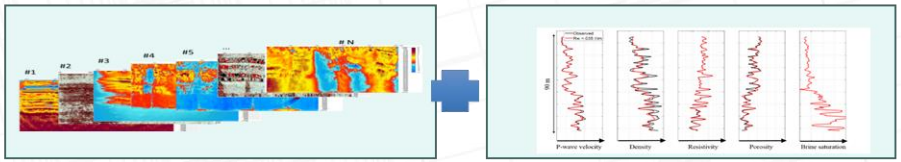
RTH & Artificial Intelligence

The uniqueness of RTH technology for geological prediction using artificial intelligence (AI) methods is based on two RTH properties:

1. **RTH is the voxel-based approach**: RTH attribute information is known in geocoded cells (voxels) of arbitrary size (up to 2 meters) fixed in space which simplifies integration with drilling data



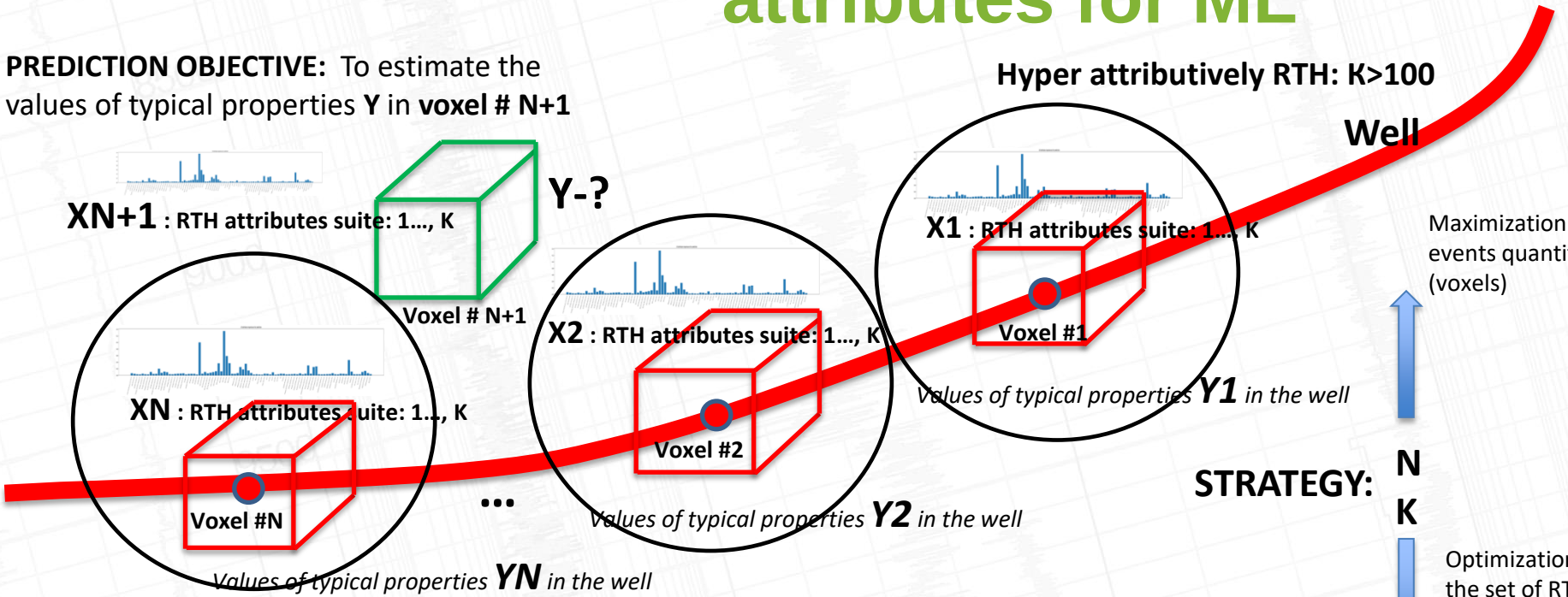
2. **RTH is the hyper attributes approach:** Each voxel contains the values of a large number (more than 100) of RTH attributes



AI TECHNOLOGY!

Well-log Data and RTH attributes for ML

PREDICTION OBJECTIVE: To estimate the values of typical properties **Y** in **voxel # N+1**



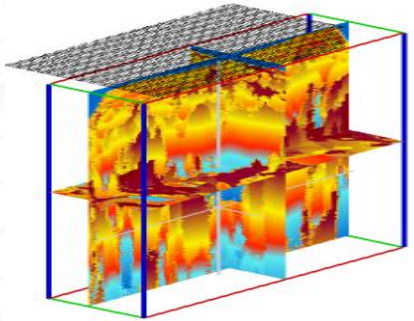
The training set of properties **Y** consists of **N** events (voxels) **Y**=(Y1,…, YN) using the attributes vector **X**=(X1,…,Xk)

Y is a set of facts

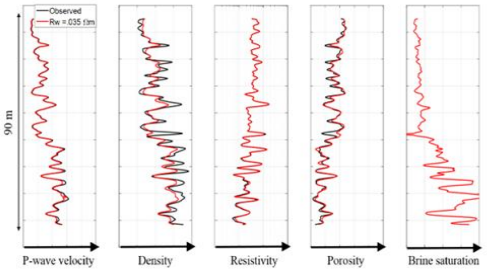
{ presence/absence of brine, gas, water, fluid; porosity value; permeability value; GK value; value DT, …}

RTH Prediction Scheme

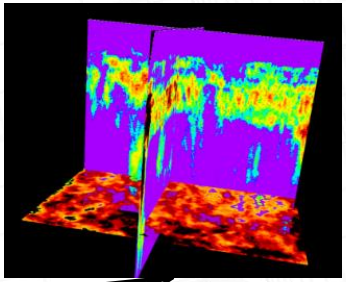
RTH attributes



Well-log data



Prediction cube



Prediction of fluid zones and reservoir properties

Flow prediction

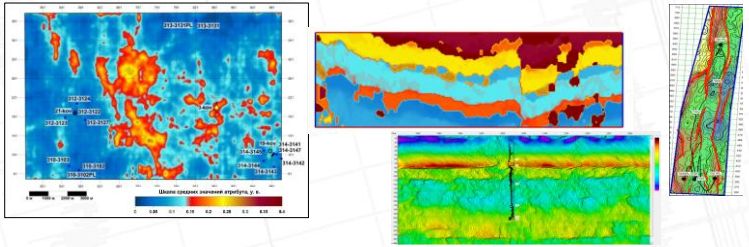
Prediction of possible accidents during the drilling process

Inclusion of the results of RTH-prediction in the process of supporting the development of hydrocarbon fields in order to clarify existing hydrodynamic models

RTH Prediction Scheme

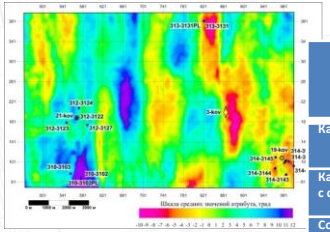
Step 1. RTH processing and interpretation

Result: RTH cubes, stratigraphic boundaries, fracture zones, fault zones, angular anisotropy, frequency

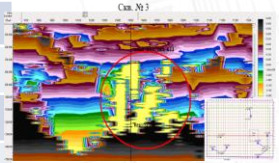


Step 2. Selecting a prediction object, preparation geological data and RTH attributes

Result: generation of sufficient data sets for training using AI algorithms

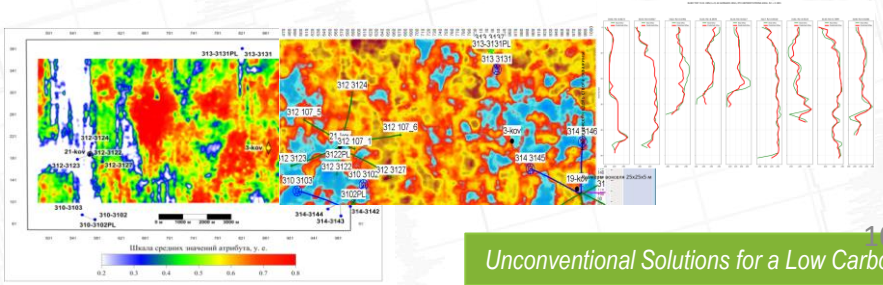


	Радиус окружности, м	Число отсчётов в обучающей выборке	Число отсчётов в тестовой выборке	Скважины тестовой выборки
Карбонаты	200	63334	24010	3, 3127,
	300	146688	55370	3145,
	400	251932	96580	3147
Карбонаты с солью	200	30966	10682	19, 3127,
	300	72390	24634	3145,
	400	125974	42946	3147
Соль с карбонатами	200	65568	26410	19, 3127,
	300	151870	59630	3145,
	400	262338	102950	3147
Терригенные отложения	700	94028	17700	19, 3122, 3142, 3147



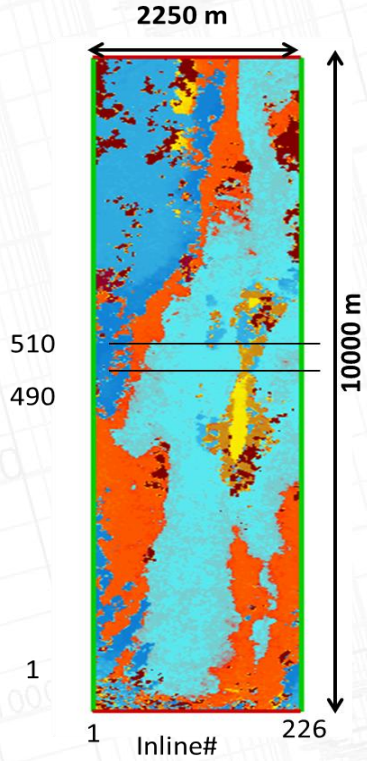
Step 3. AI Prediction

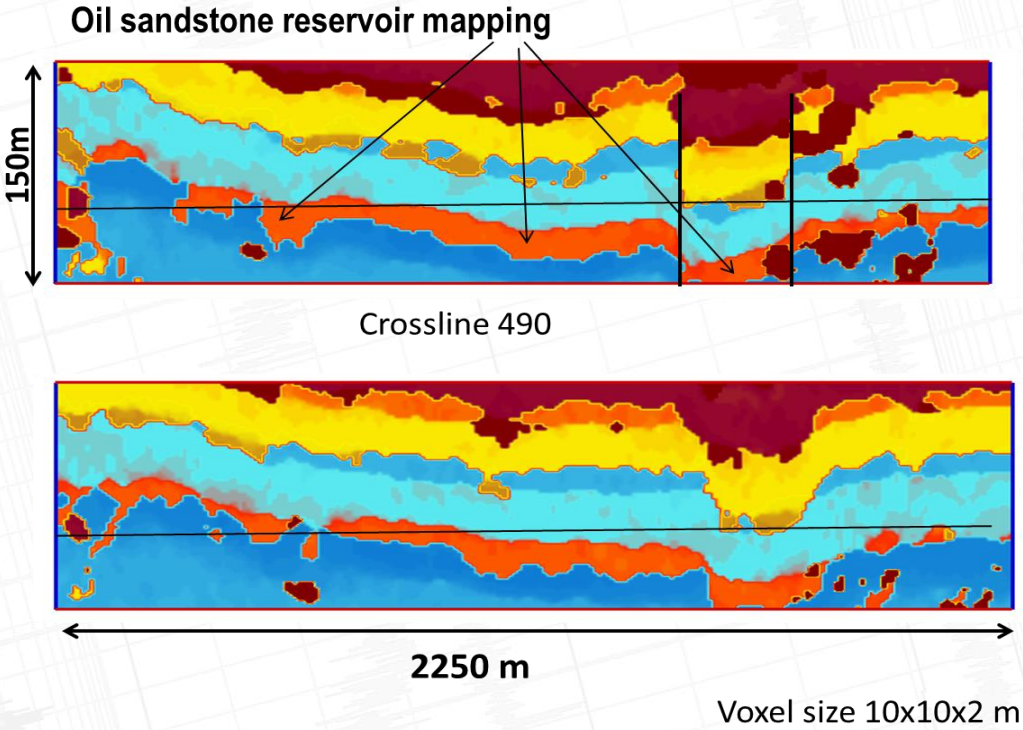
Result: predicted cubes of porosity, gas, oil, permeability, fluid show, flow rates, possible drilling accidents



Identification of target horizon and faults

Step 1. RTH processing and interpretation

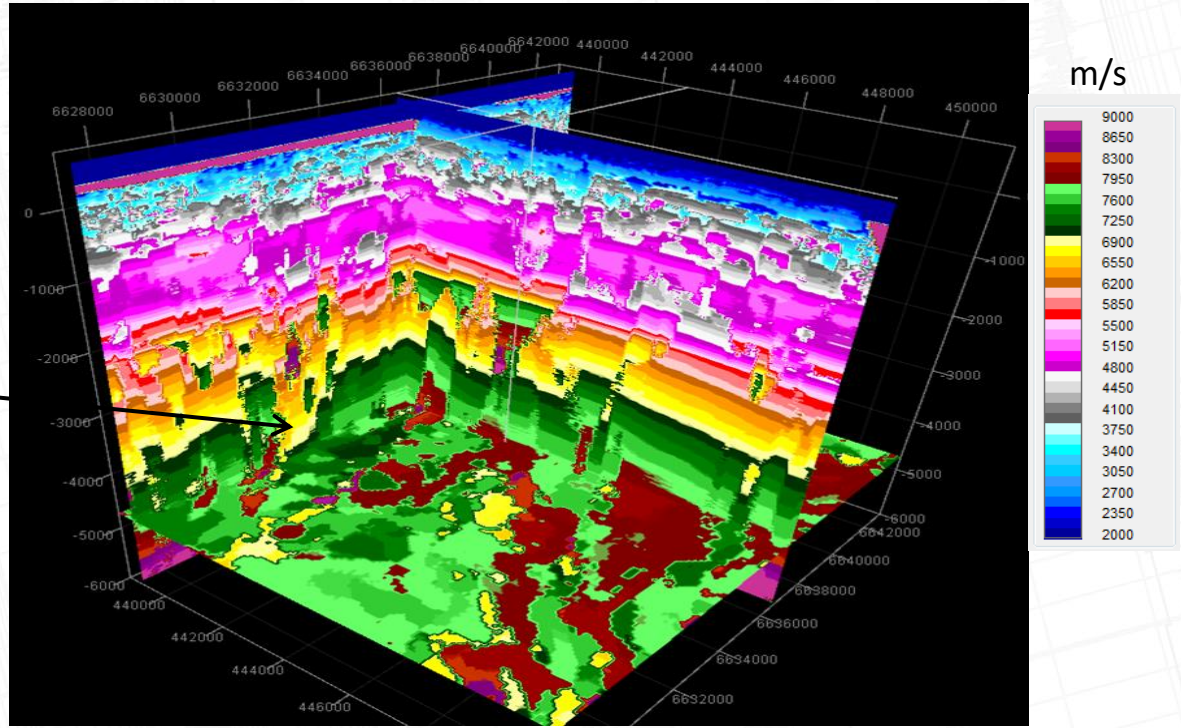




Cube of RTH-velocity

Step 1. RTH processing and interpretation

Low velocity Rufey



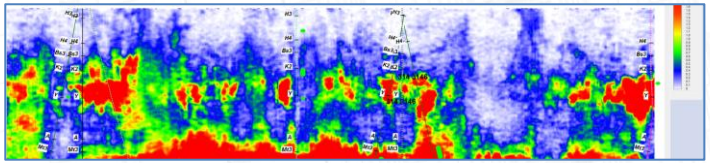
Depth 6 km

300 sq. km

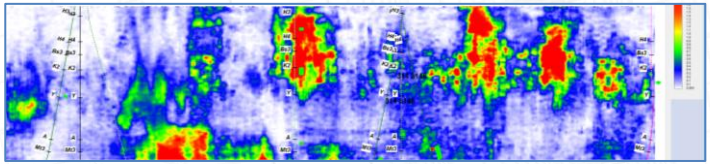
Voxel size is 25x25x5 m

Prediction of Gas, Brine and Fluid based on RTH attributes and well-log data

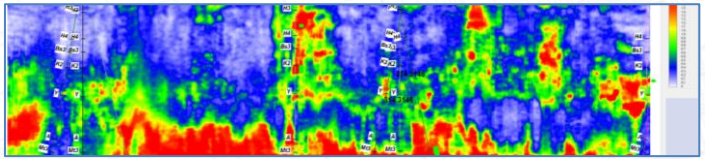
Step 3. AI Prediction



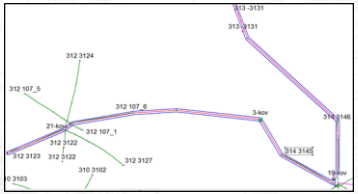
Gas manifestation prediction. Mean 0.018, deviation 0.23

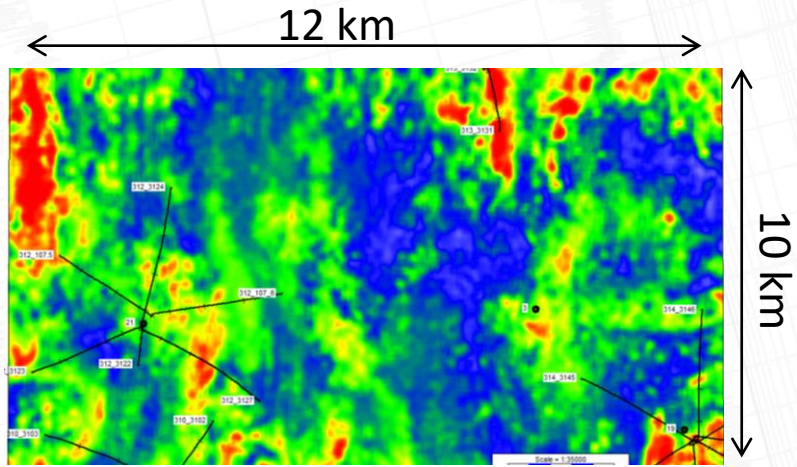


Brine manifestation prediction. Mean 0.015, deviation 0.03



Fluid manifestation prediction. Mean 0.059, deviation 0.064



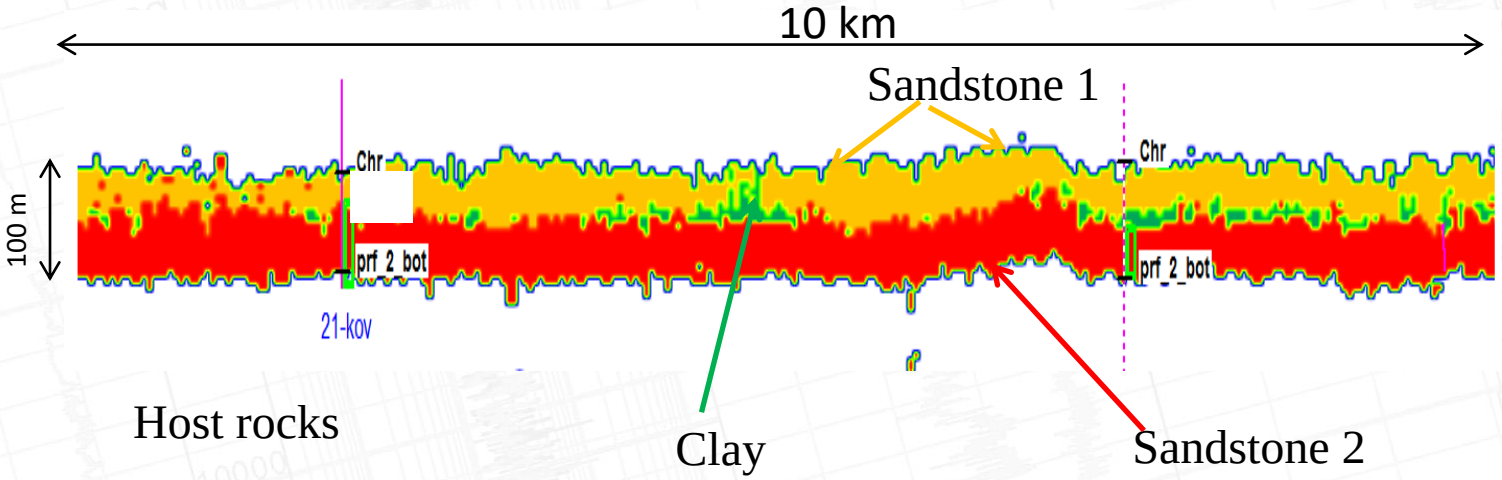


Fluid manifestation prediction in target horizon.
Mean 0.059, deviation 0.064

Voxel size is 25x25x5 m

Lithotypes Prediction of Lower Vendian based on RTH attributes and well-log data

Step 3. AI Prediction



Voxel size is 25x25x5 m

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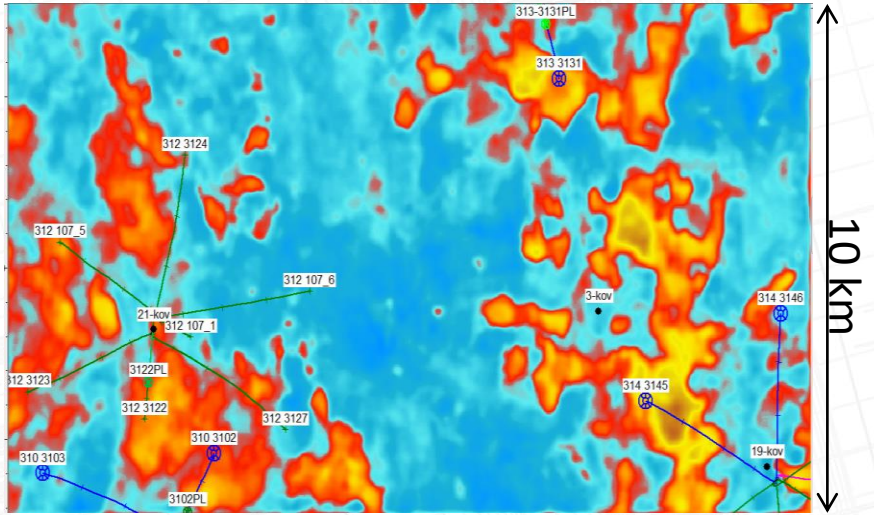
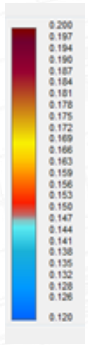
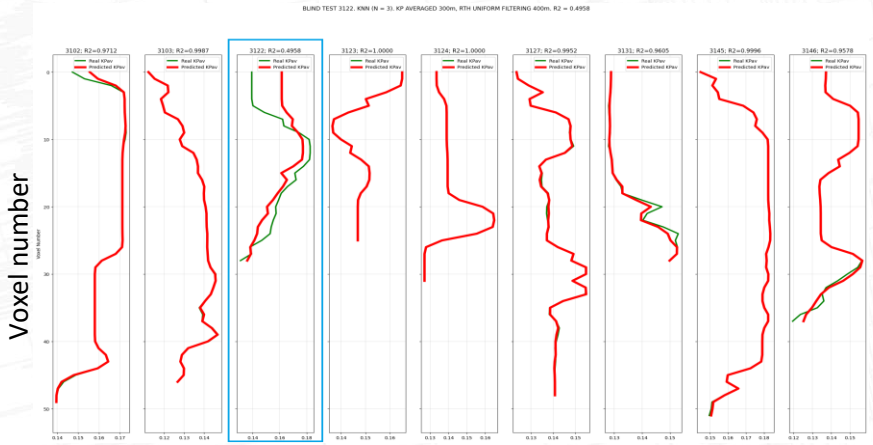
Porosity prediction in Sandstone 2 based on RTH attributes and well-log data

Step 3. AI Prediction



Predicted porosity coefficient





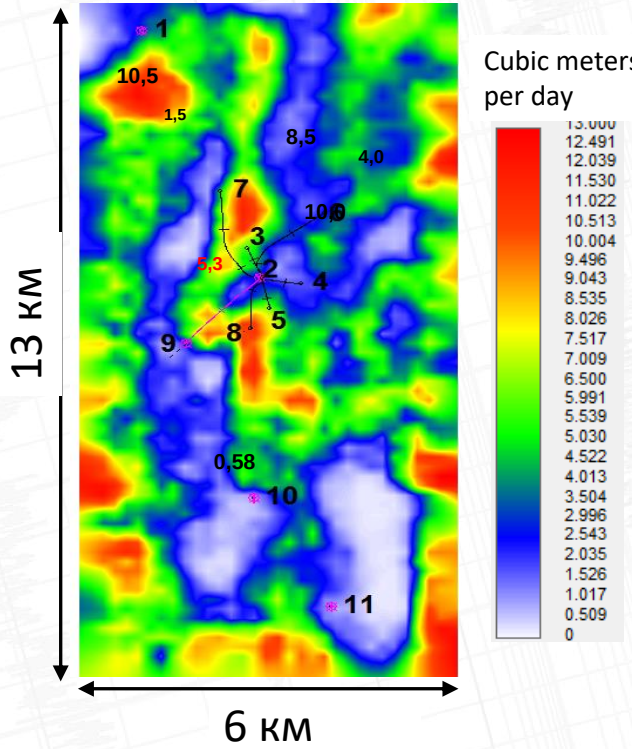
Comparison of predicted porosity in Sandstone 2 (red) and well-log data (green)

- the blind test well

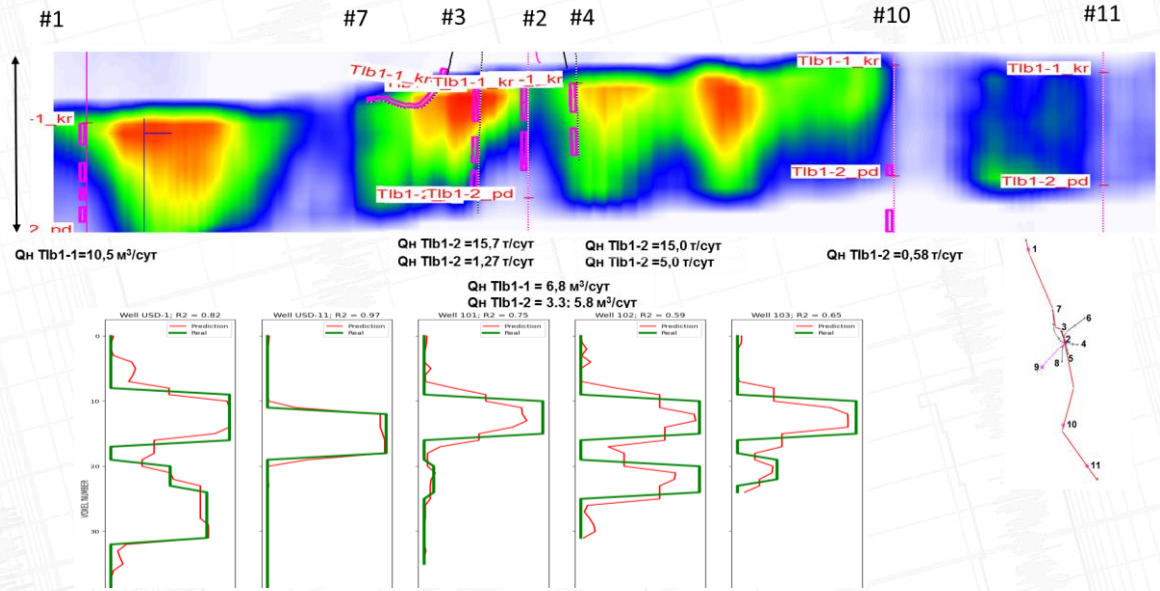
Voxel size is 25x25x5 m

Prediction of Oil Production in Target Horizon

Step 3. AI Prediction



Cubic meters per day



Comparison of predicted Oil Production (red) and well-log data (green)

Voxel size is 25x25x5 m

ACKNOWLEDGEMENTS

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