Application of Unsupervised Machine Learning Techniques in Detailed Recognition of Gas Producing Subtle Submarine Channel System

Mariusz Łukaszewski

GT Technology Workshop

The role of geophysical company in the energy transition

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International Meeting for Applied Geoscience & Energy

Purposes of the presentation

If you think you are too small to make a difference, try sleeping with a mosquito

Dalai Lama XIV

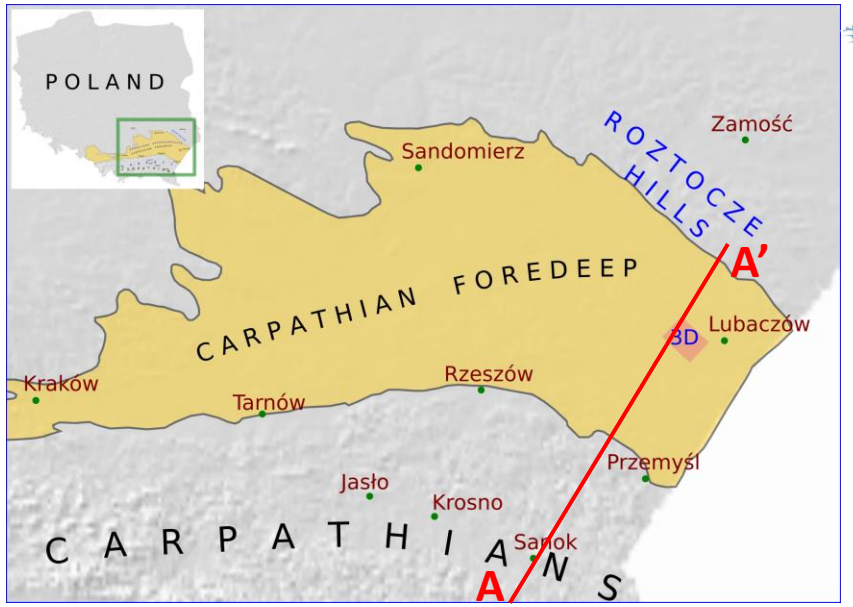
- Introduction to a modern way of interpreting 3D seismic data
- Demonstration of the effectiveness of the application of ML techniques in the interpretation of high-quality 3D seismic data
- Comparison of the results of the classical approach to seismofacial analyzes with the outcomes of the application of self-learning systems

Outlines

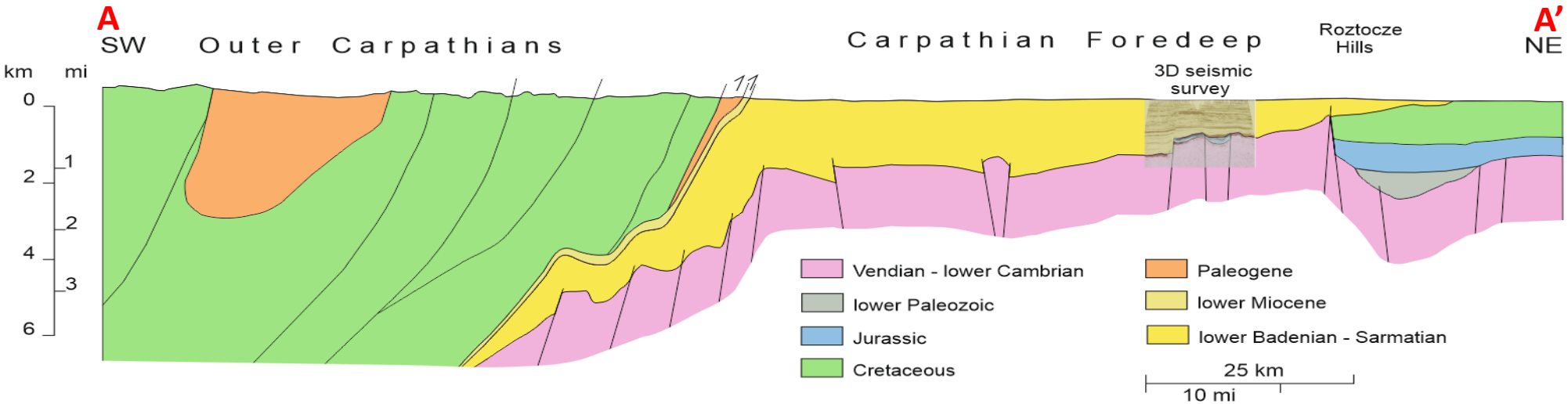
- Introduction:
  - geological settings and exploration challenges
  - conventional interpretation methods: results, limitations and expectations
- Machine Learning application:
  - workflow description
  - unsupervised classification results
  - ML applied to derived frequency data
- Discussion
- Implications for the gas field
- Conclusions

Geological settings and exploration challenges

NE part of the Carpathian Foredeep Basin, which belongs to the foreland basin system that surrounds the Carpathian orogenic belt.

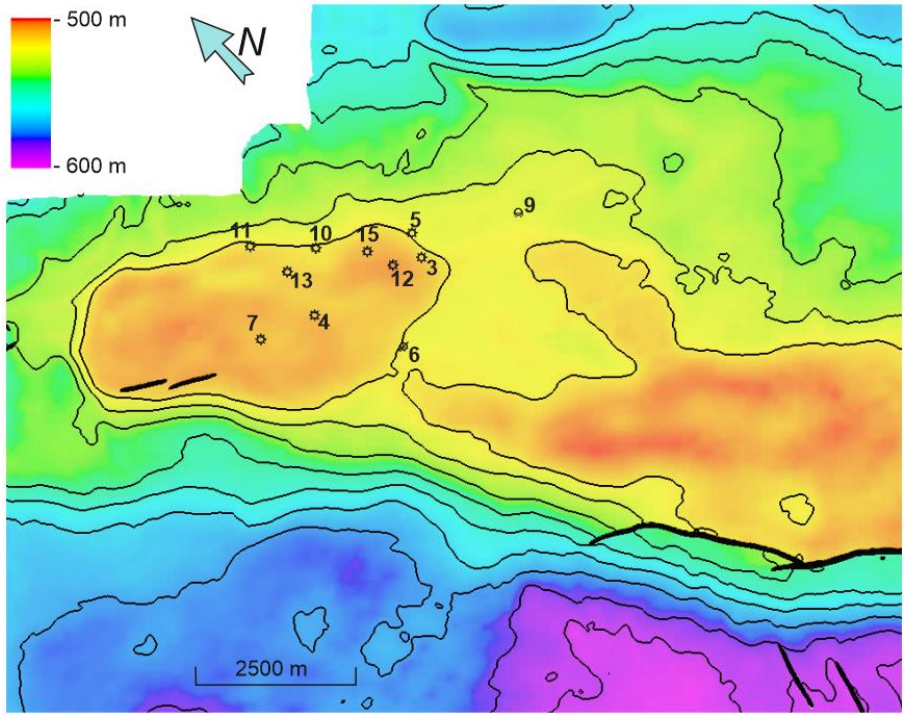


Location map of the study area: NE part of Polish Carpathian Foredeep and the 3D seismic survey



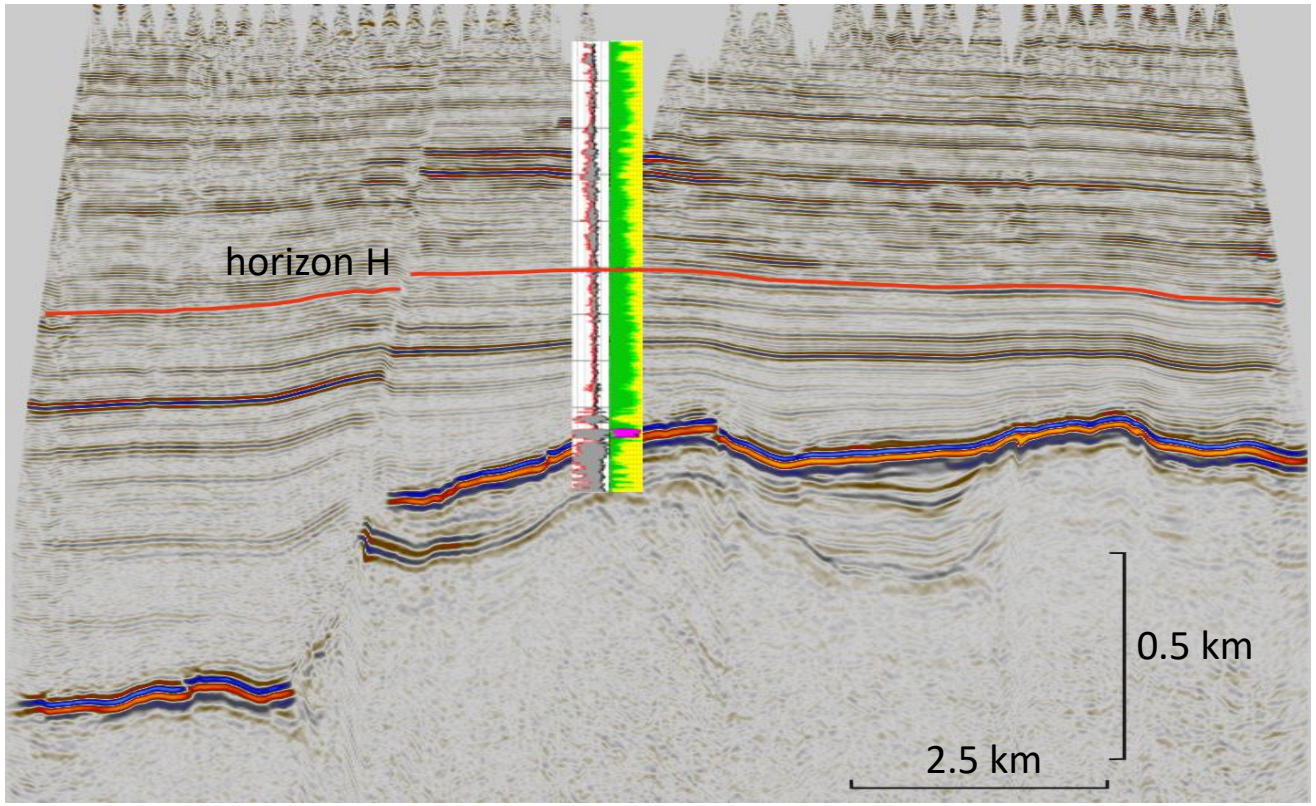
Geological cross section AA' through the eastern part of the Polish Outer Carpathians and their foreland (modified after Oszczypko et al., 2005).

Geological settings and exploration challenges



Depth structure map of horizon H.

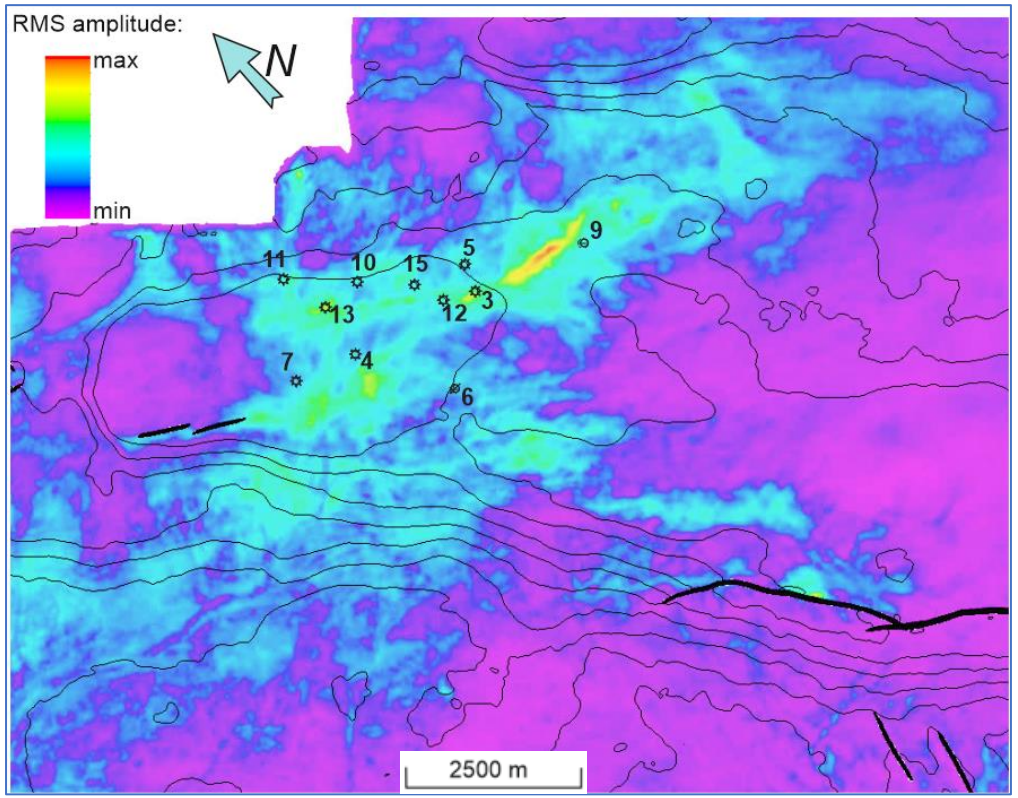
Most commercial gas accumulations were discovered in structural traps.



Depth converted seismic section, 3D seismic survey.

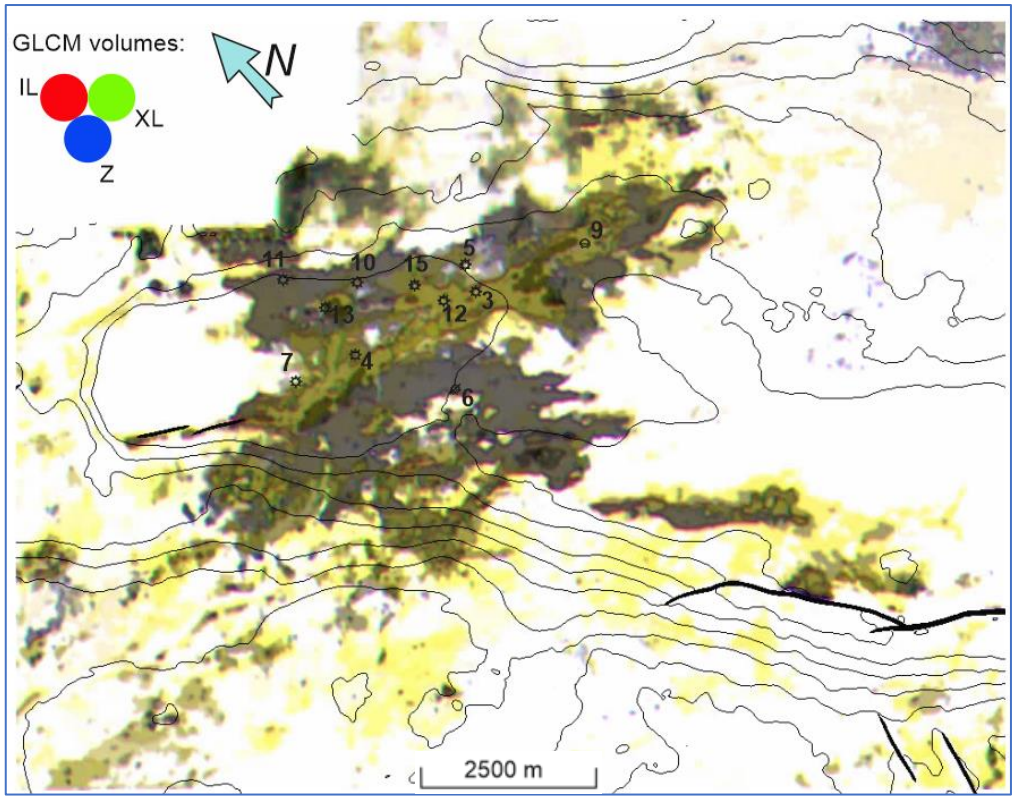
Thick pelagic and turbidite formations of Miocene age form the bulk of basin fill.

Conventional interpretation methods: results, limitations and expectations



RMS seismic amplitude values distribution map within the chosen interval.

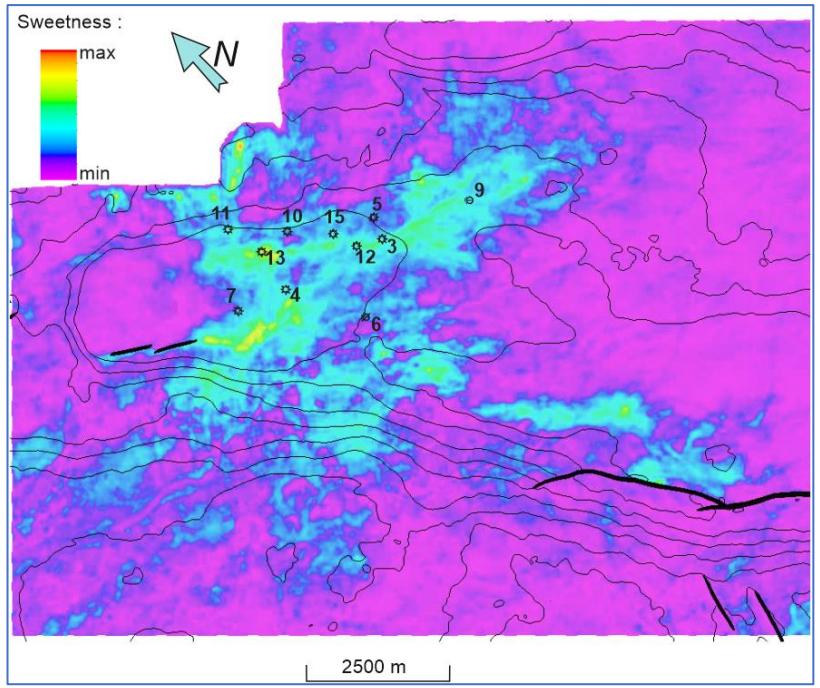
Amplitude attributes allow you to focus on the right seismic interval and capture potential objects.



GLCM Energy. Interesting texture elements - geobodies.

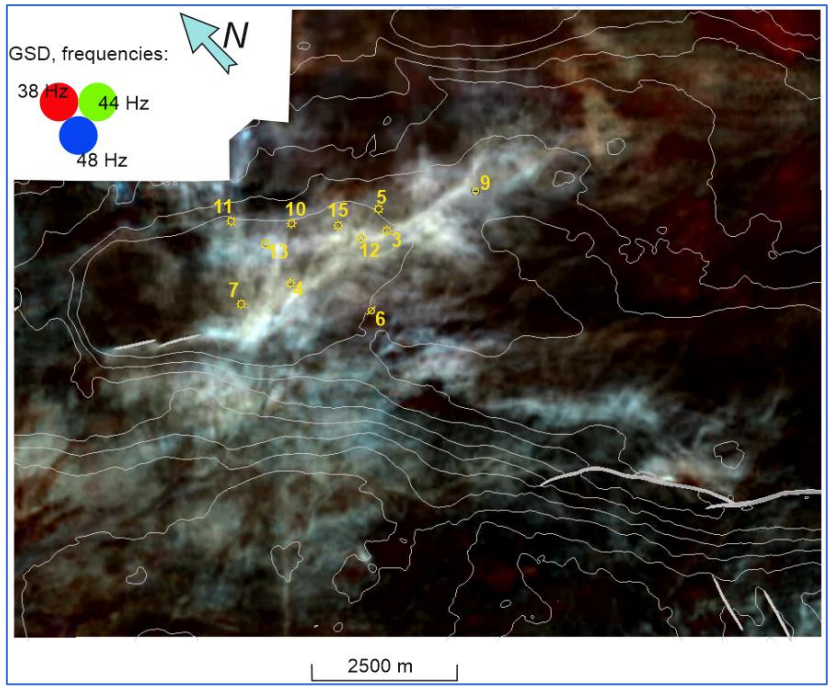
Texture attributes help to discover the subtle geological features, hidden between the seismic traces.

Conventional interpretation methods: results, limitations and expectations



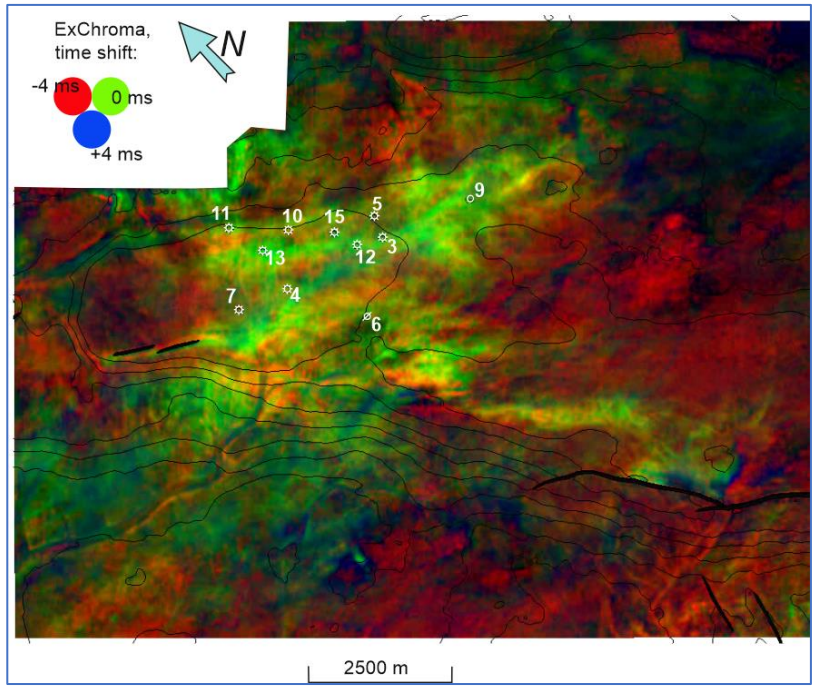
Sweetness values distribution map within the chosen interval.

The combination of amplitude and frequency is used to highlight the HC filled reservoir.



Composite of iso-frequencies 38, 44 and 48 Hz within the chosen interval.

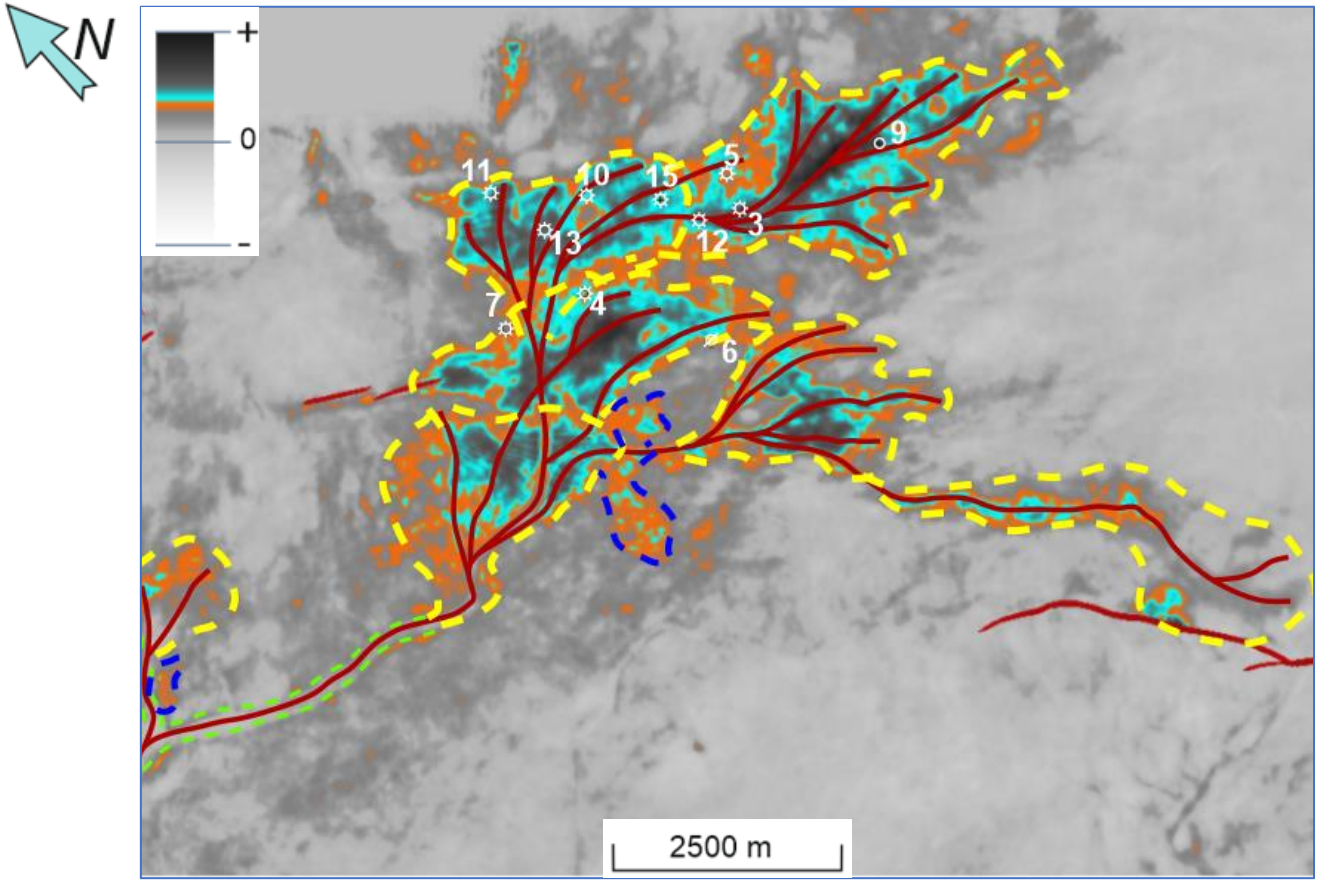
Spectral decomposition RGB blending for subtle stratigraphic feature detection.



ExChroma, seismic amplitude volume.

Alternative stratigraphic imaging techniques – no seismic attribute involved.

Conventional interpretation methods: results, limitations and expectations



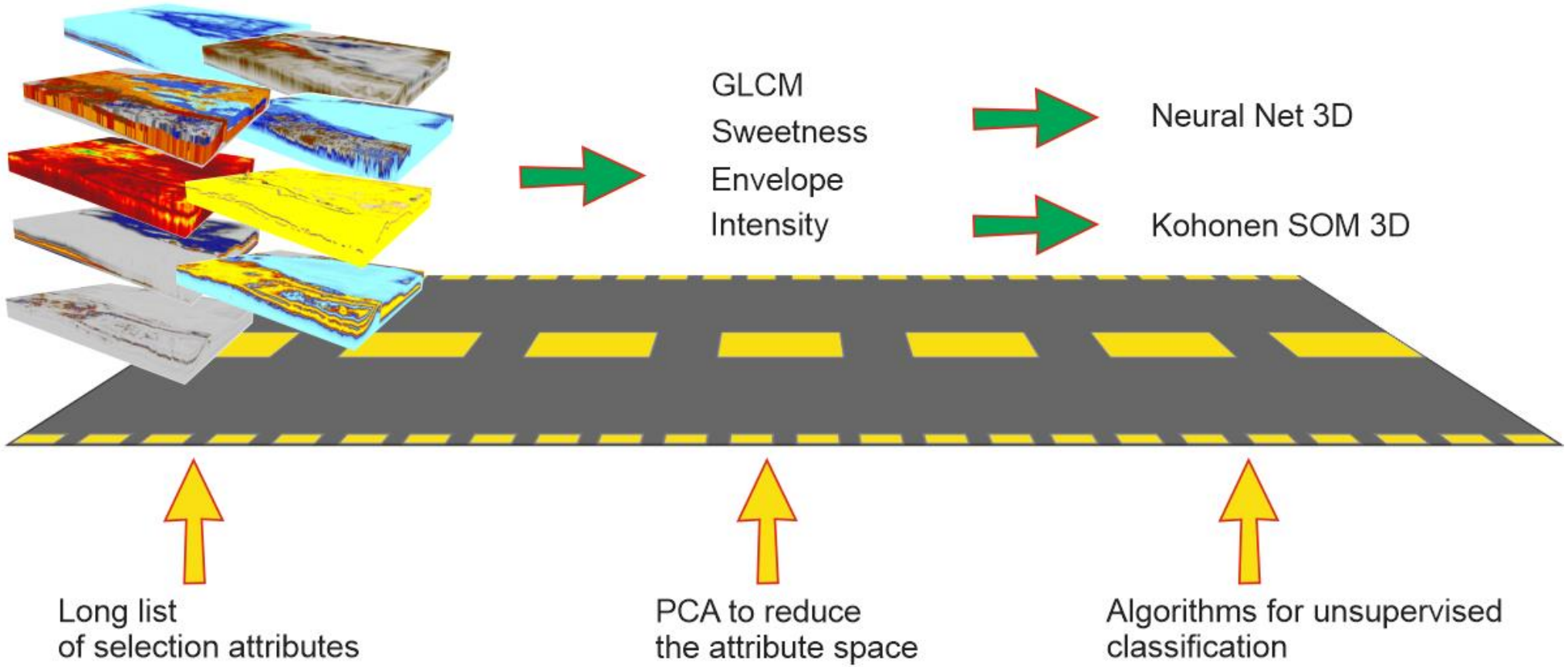
Horizon slice, amplitude seismic volume, dedicated color bar.
Interpreted distributary channels along with levees, probable crevasse splays and fans.

The result of 3D seismic data interpretation based on conventional approach using seismic attributes.

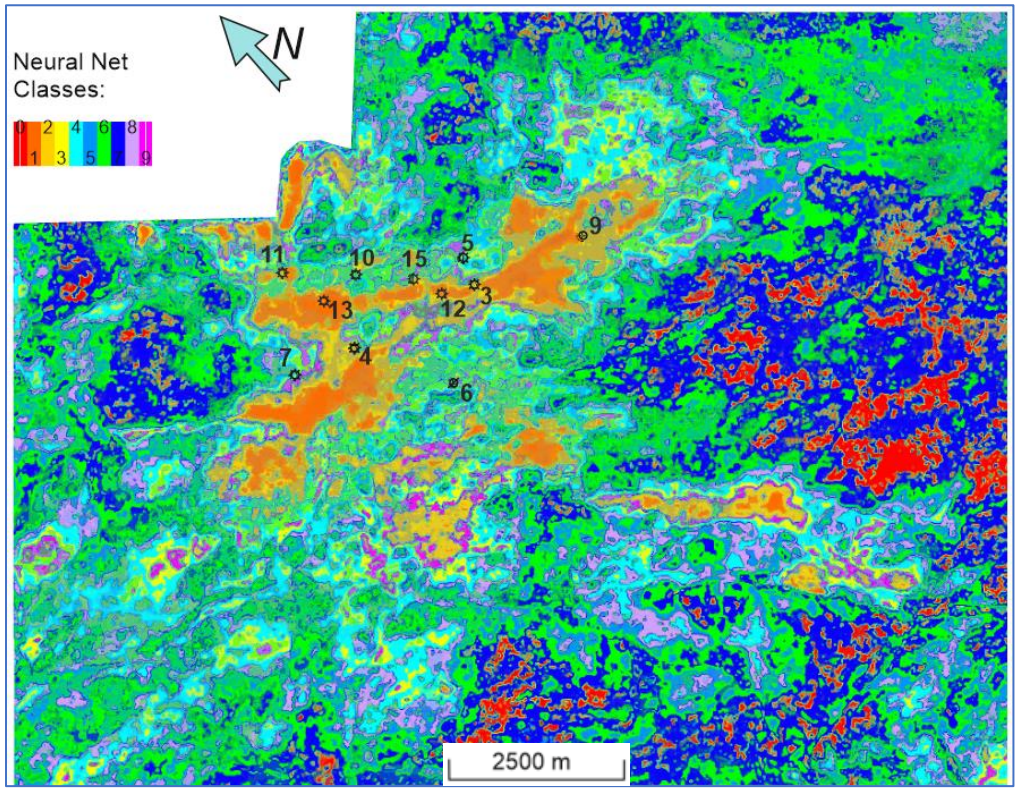
Imaged complex of channels with frontal splays and leveed channel.

This is an example of the presence of a lithofacial gas object in the Miocene formations, the geometry of which is not determined by the structural arrangement of the layers.

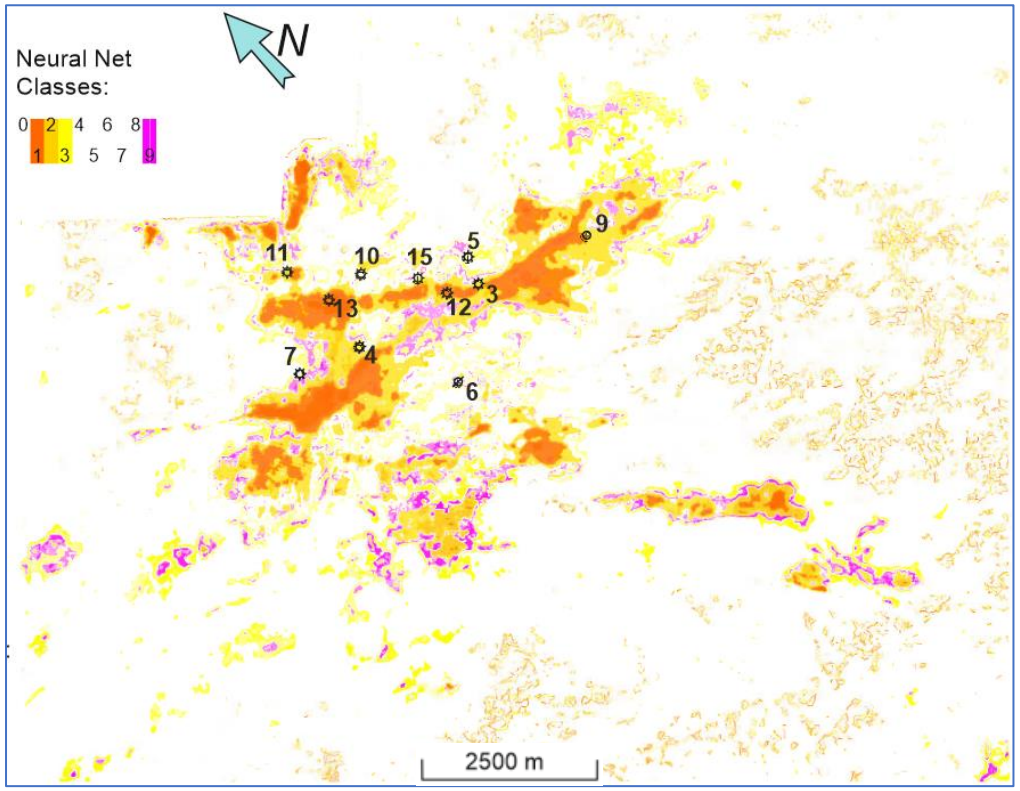
Machine Learning application



Machine Learning application

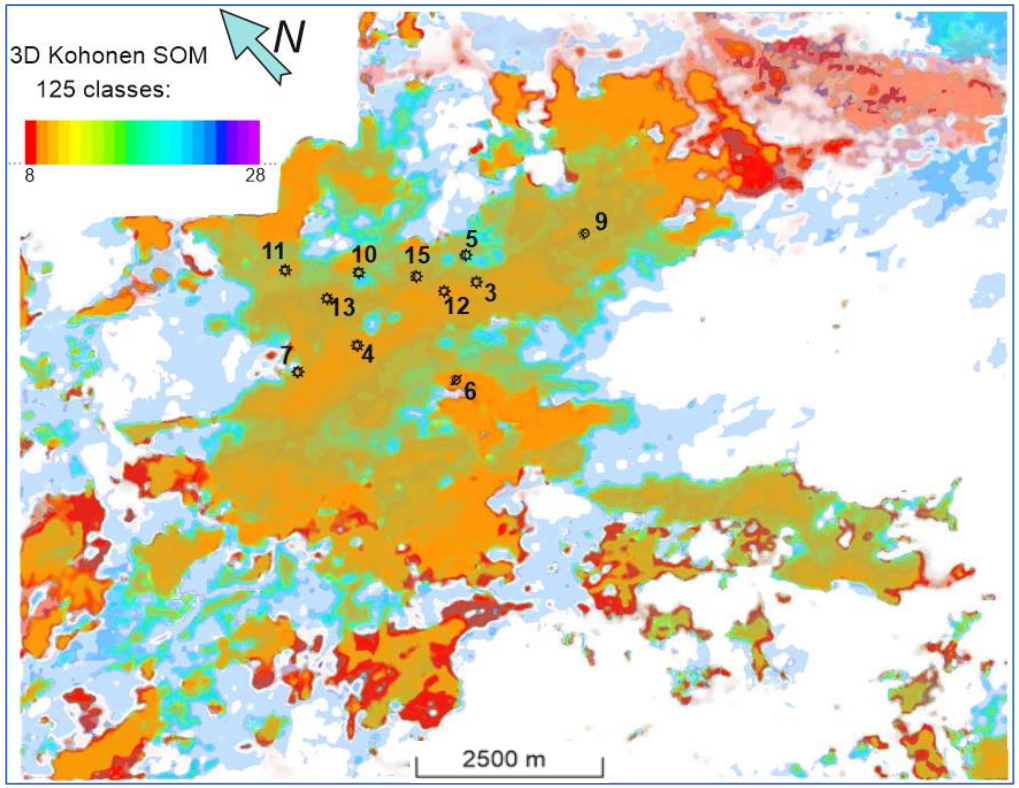


Resulting 10-class volume after applying **Neural Net 3D** algorithm.
Box probe with manipulated transparency.

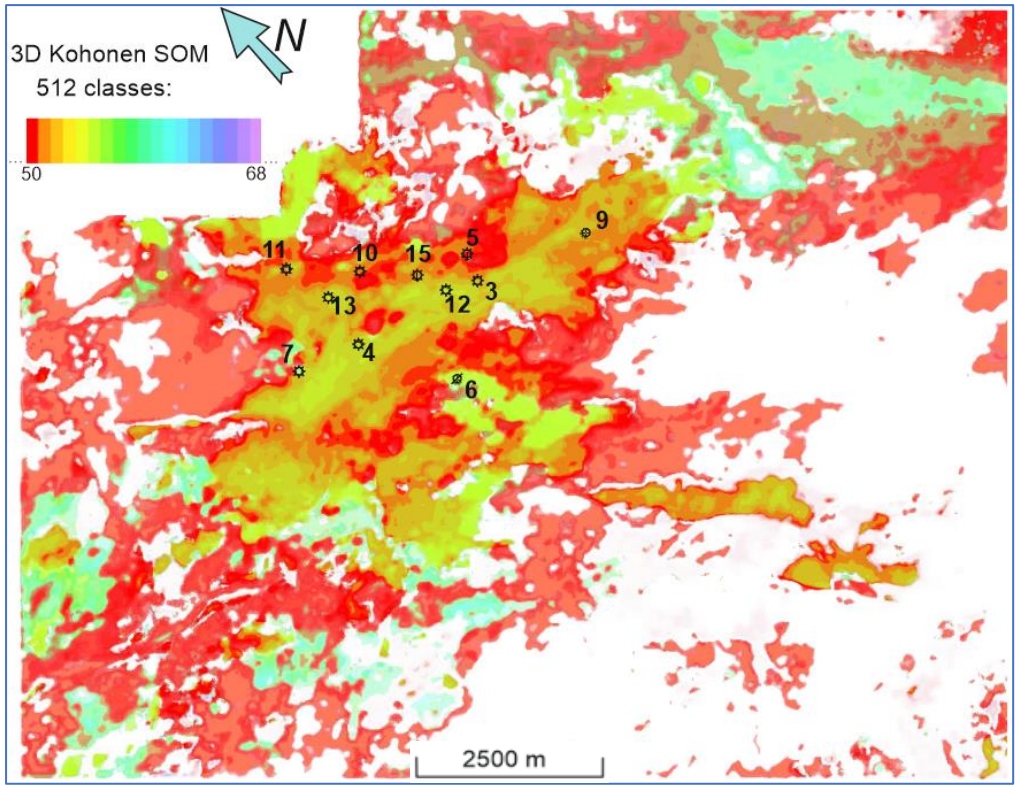


The selected classes well define the main channels of the studied complex.

Machine Learning application



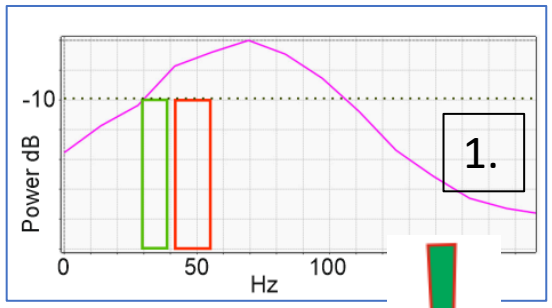
Kohonen SOM 3D classification to **125 classes**.
Classes 8 to 28 displayed.
Box probe with manipulated transparency.

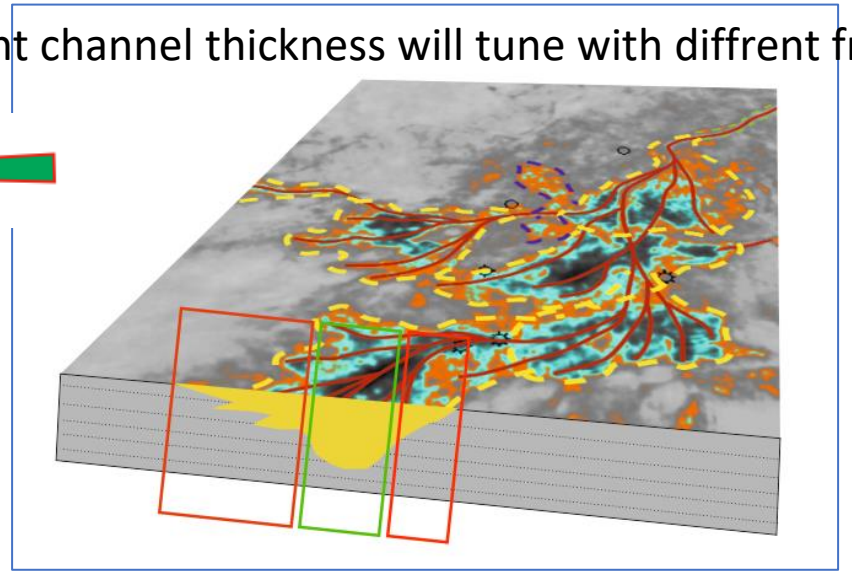


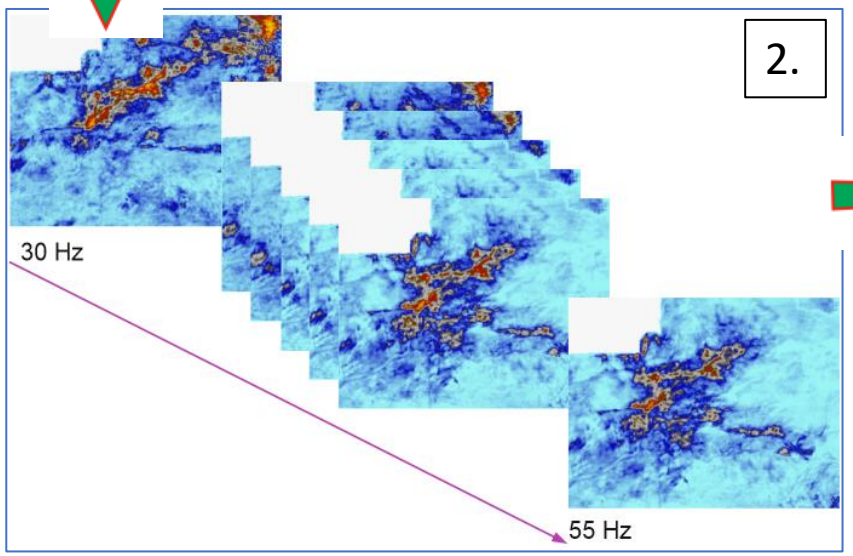
Kohonen SOM 3D classification to **512 classes**.
Classes 50 to 68 displayed.
Box probe with manipulated transparency.

Machine Learning application

Different channel thickness will tune with diffrent frequencies.



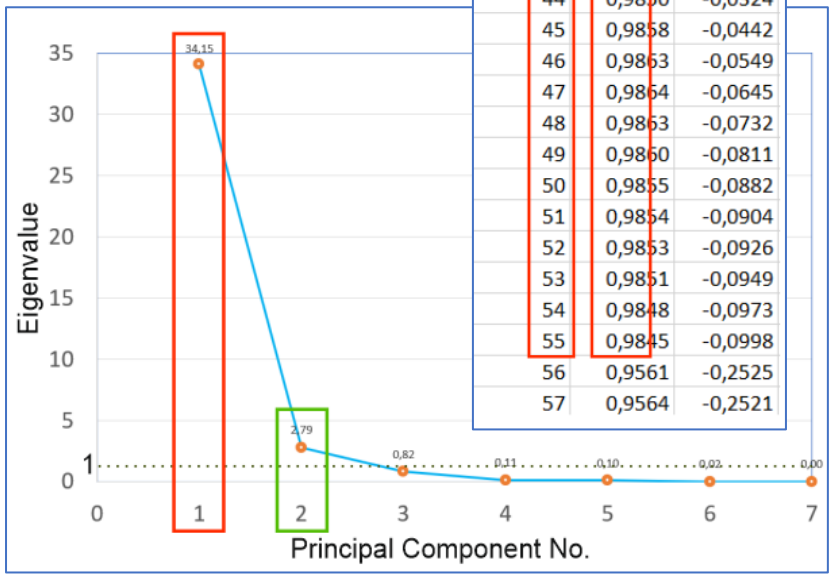




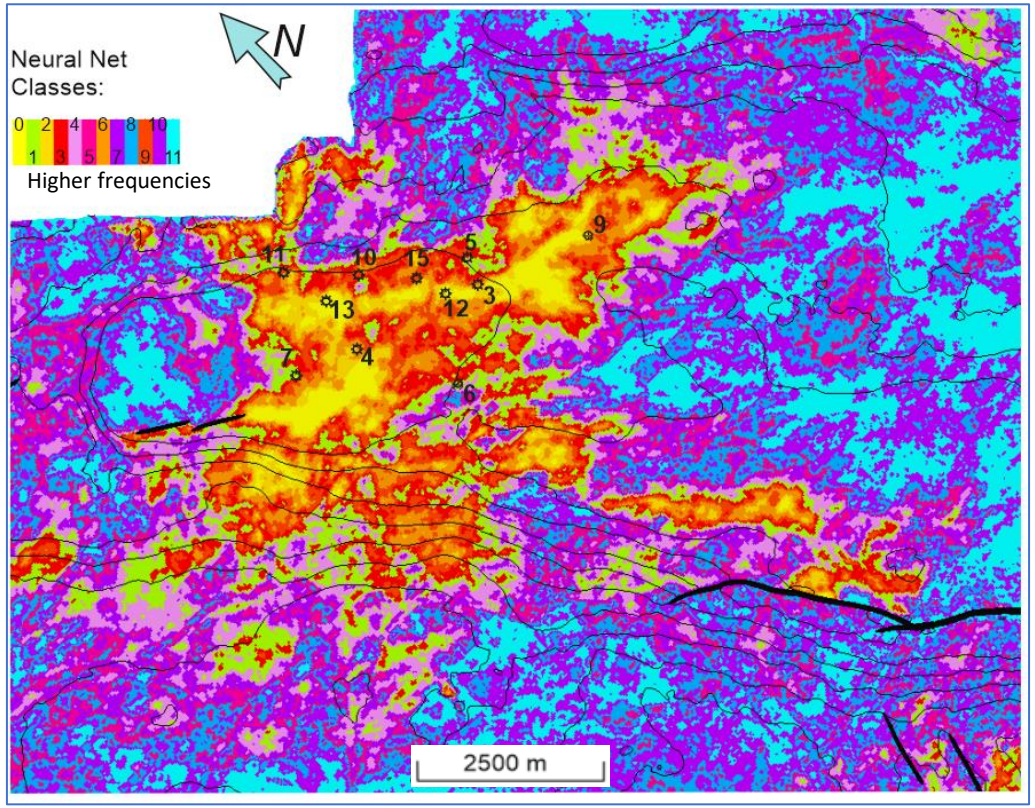
3.

Correlation Coefficients

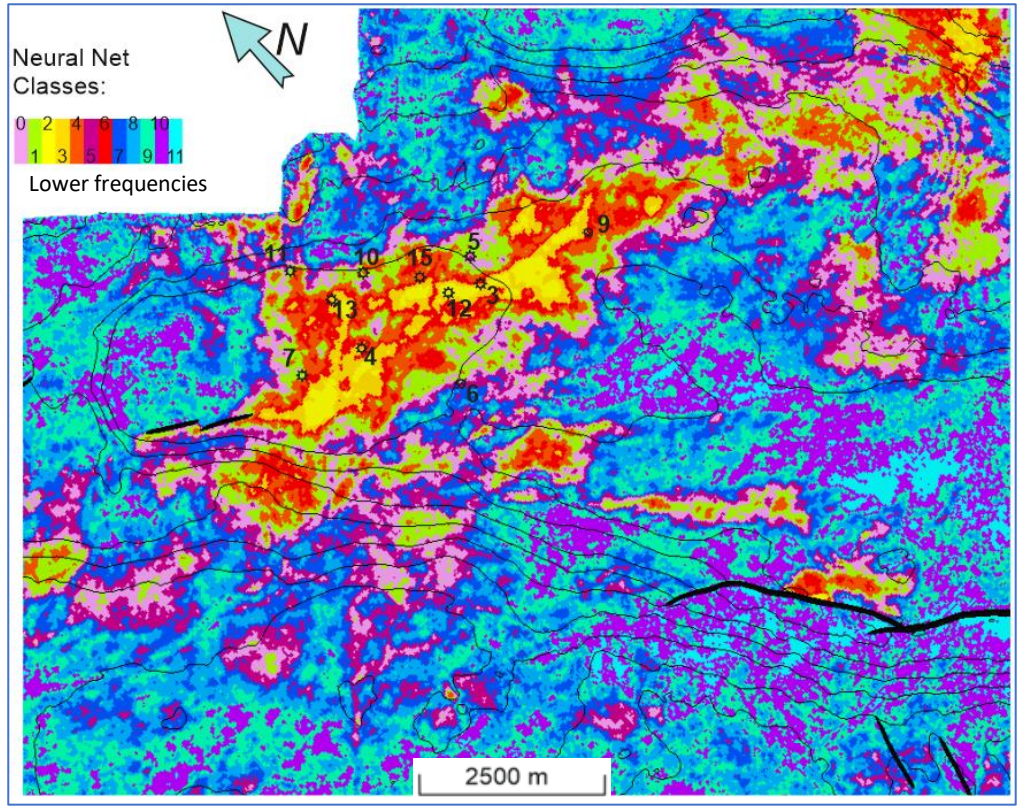
Hz	PC 1	PC 2
30	0,7450	0,6084
31	0,7959	0,5670
32	0,8331	0,5314
33	0,8624	0,4946
34	0,8861	0,4562
35	0,9047	0,4177
36	0,9176	0,3847
37	0,9250	0,3628
38	0,9315	0,3402
39	0,9701	0,0918
40	0,9762	0,0521
41	0,9801	0,0187
42	0,9824	-0,0054
43	0,9839	-0,0195
44	0,9850	-0,0324
45	0,9858	-0,0442
46	0,9863	-0,0549
47	0,9864	-0,0645
48	0,9863	-0,0732
49	0,9860	-0,0811
50	0,9855	-0,0882
51	0,9854	-0,0904
52	0,9853	-0,0926
53	0,9851	-0,0949
54	0,9848	-0,0973
55	0,9845	-0,0998
56	0,9561	-0,2525
57	0,9564	-0,2521



Machine Learning application

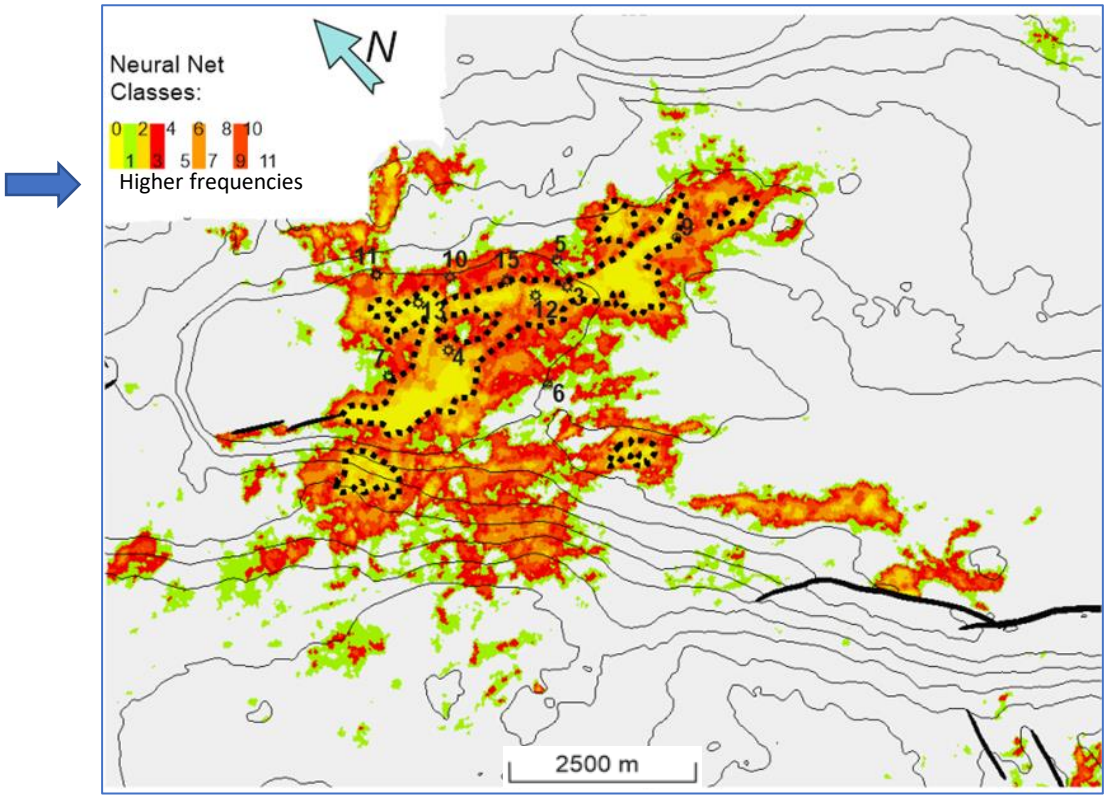


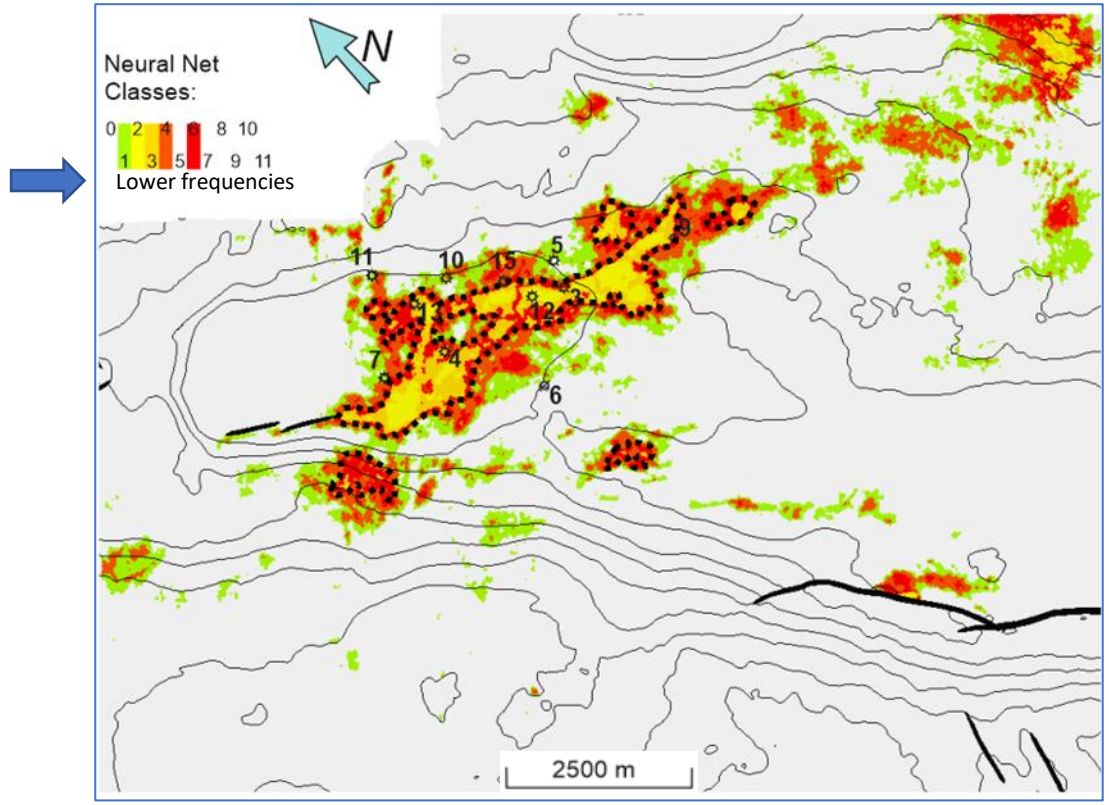
Resulting 12-class map after applying **Neural Net 2D** algorithm. First Principal Component.



Resulting 12-class map after applying **Neural Net 2D** algorithm. Second Principal Component.

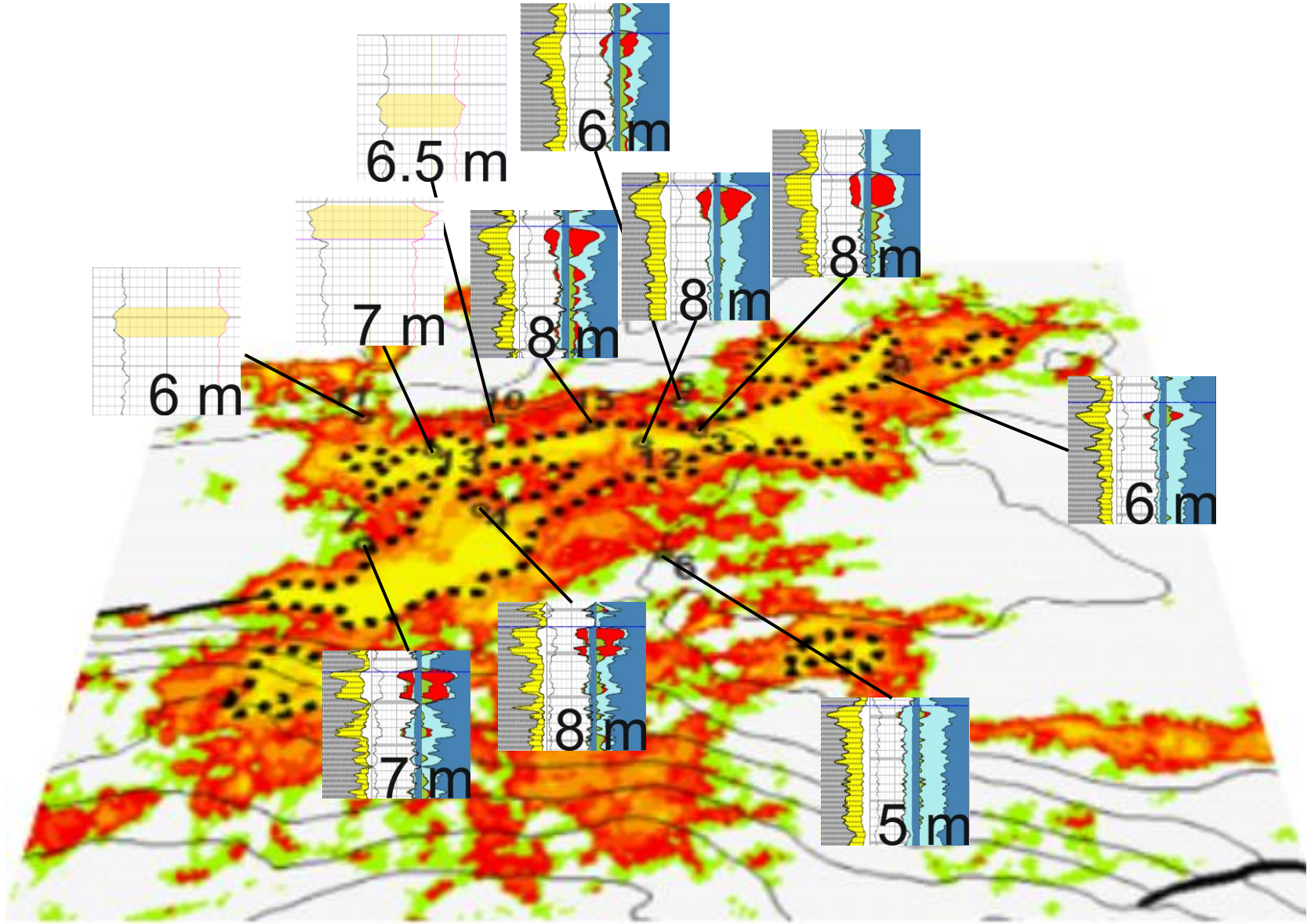
Machine Learning application





The selected classes (for both cases) show the relative thickness differences within the studied complex.

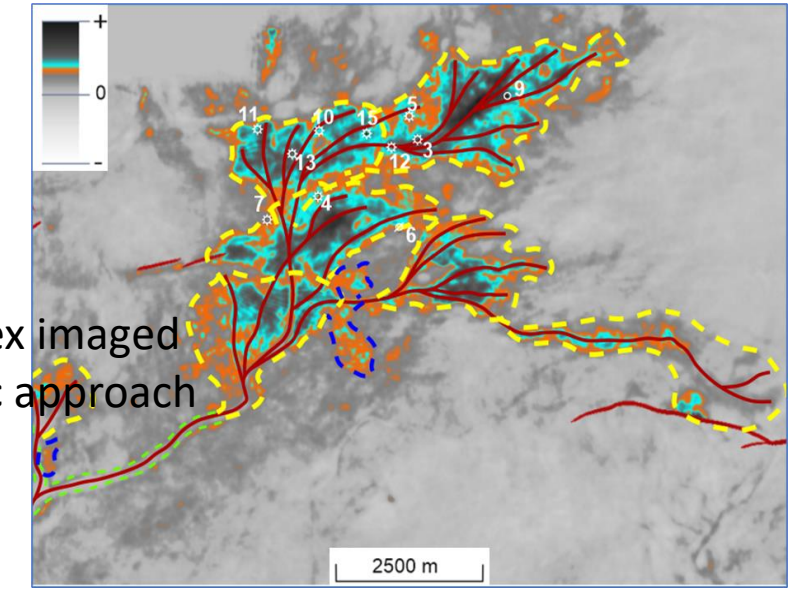
Discussion

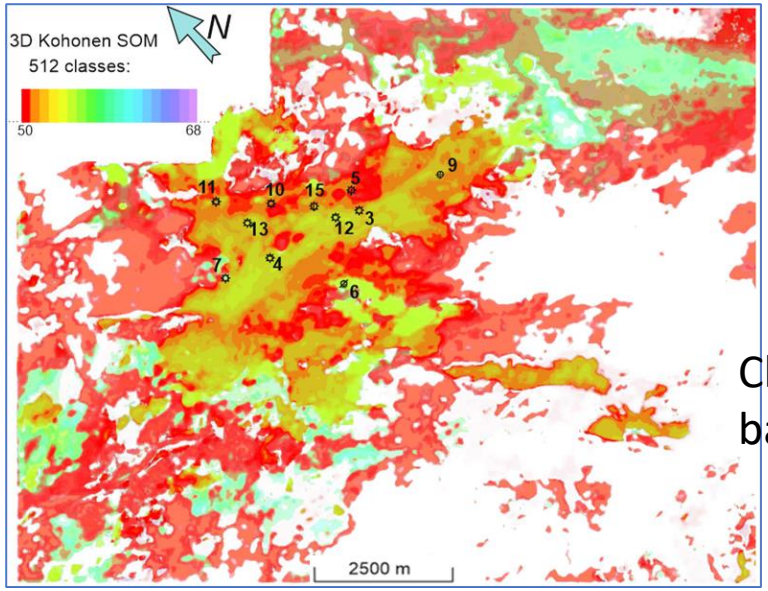


The obtained classification image is consistent with the reservoir thickness found in the boreholes.

Discussion

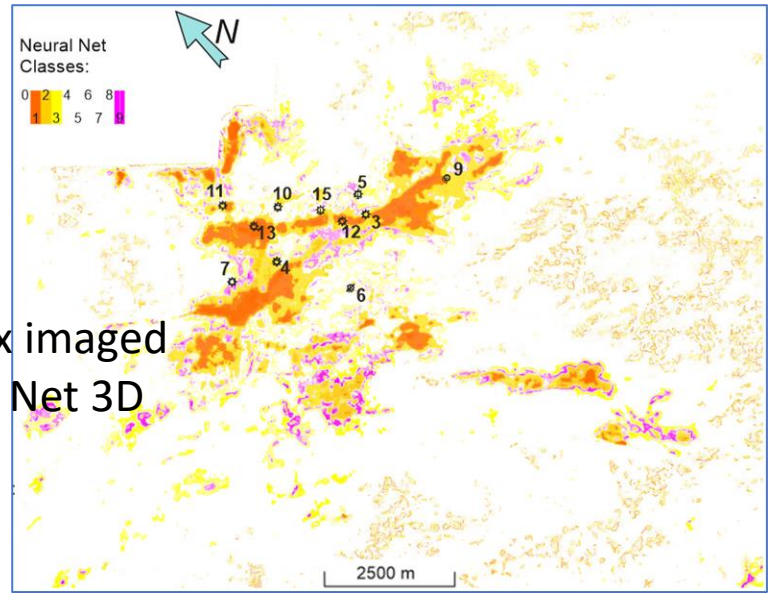
Channel complex imaged based on classic approach

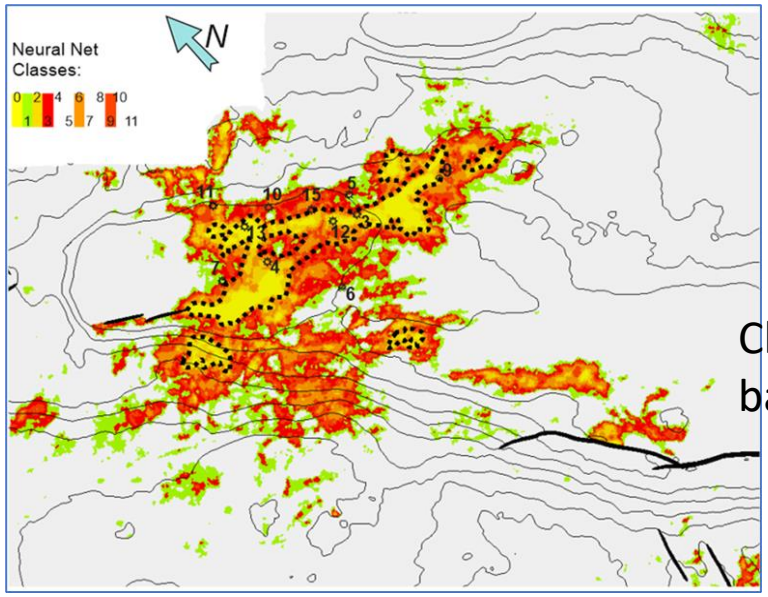




Channel complex imaged based on Kohonen SOM 3D

Channel complex imaged based on Neural Net 3D

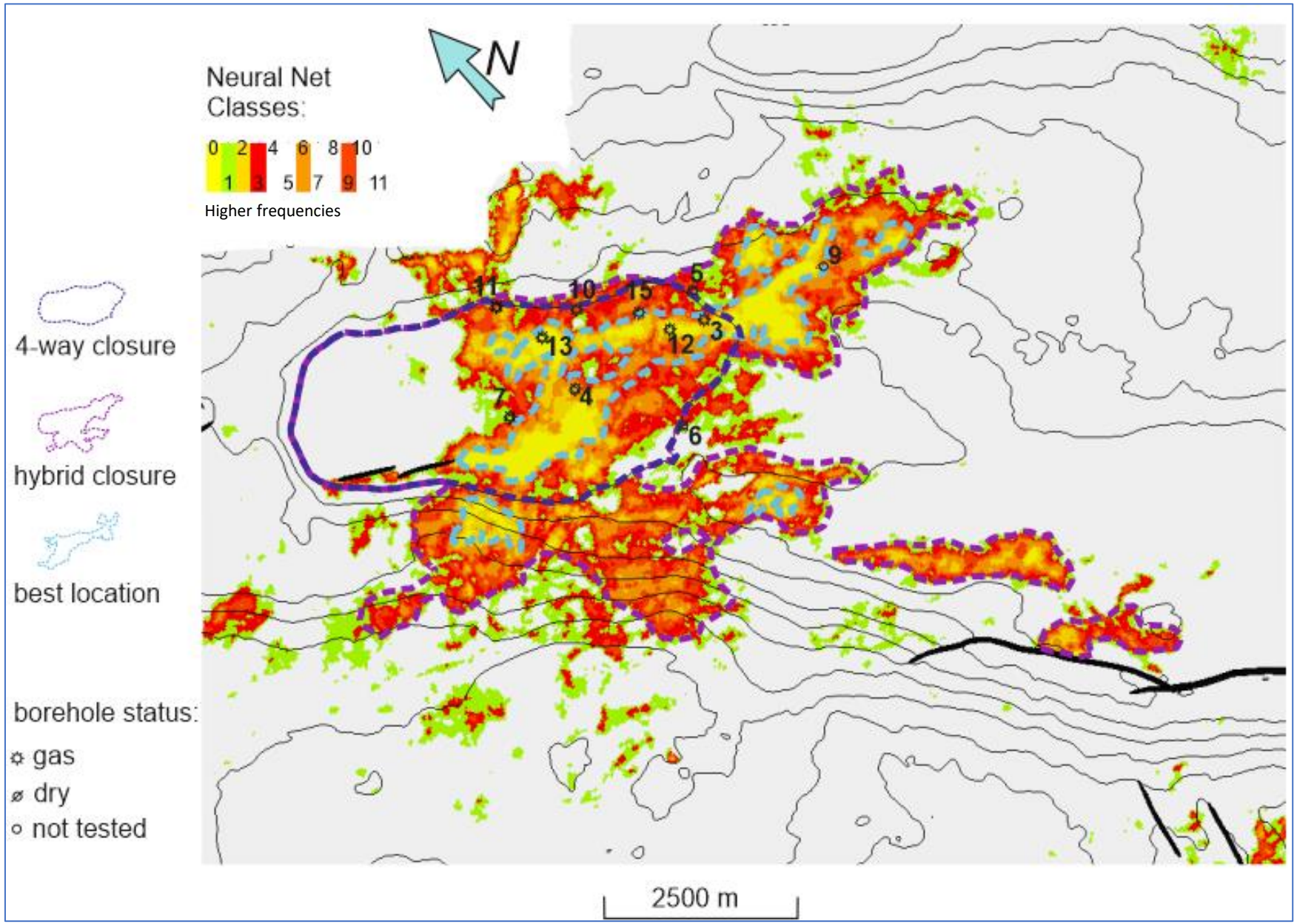




Channel complex imaged based on Neural Net 2D

The use of self-learning systems makes it possible to generate models classifying seismic facies with a high degree of accuracy.

Important implication for the gas field



Conclusions

- ML techniques require very good quality seismic data, with real amplitude relations preserved, often after appropriate data preconditioning.
- The use of self-learning systems makes it possible to generate models classifying seismic facies with a high degree of accuracy.
- Application of unsupervised Machine Learning techniques as a complementary method to the classic interpreter approach, resulted in tangible benefits.
- The obtained results allowed for a geological interpretation consistent with the borehole data, revealing previously unnoticeable elements of the examined structural object.
- The Miocene age sediments filling the Carpathian Foredeep Basin are characterized by the lithological and facies diversity. This in turn provides an excellent opportunity for implementing Machine Learning techniques in search of hydrocarbon traps.
- GT performs advanced analyzes using ML techniques. Further works are also carried out on the application of self-learning systems for the identification of various geological objects.

Thank you for your attention

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