Machine Learning in Geophysics/Geology: Some Examples

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March 16, 2018

SEG
SOCIETY OF EXPLORATION
GEOPHYSICISTS

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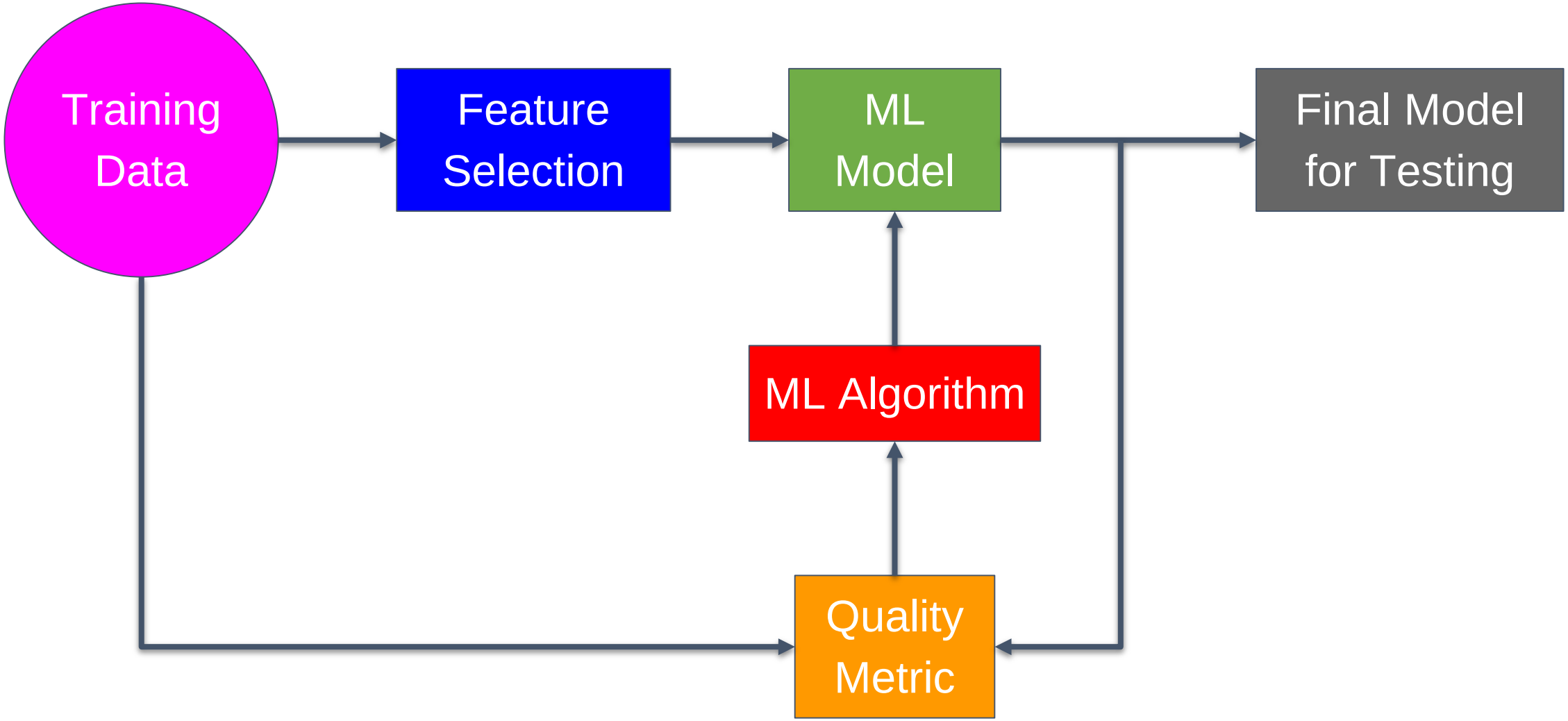
*'**Machine learning** is a field of computer science that gives computer systems the ability to "learn" (i.e. progressively improve performance on a specific task) with data, without being explicitly programmed.'*

Wikipedia

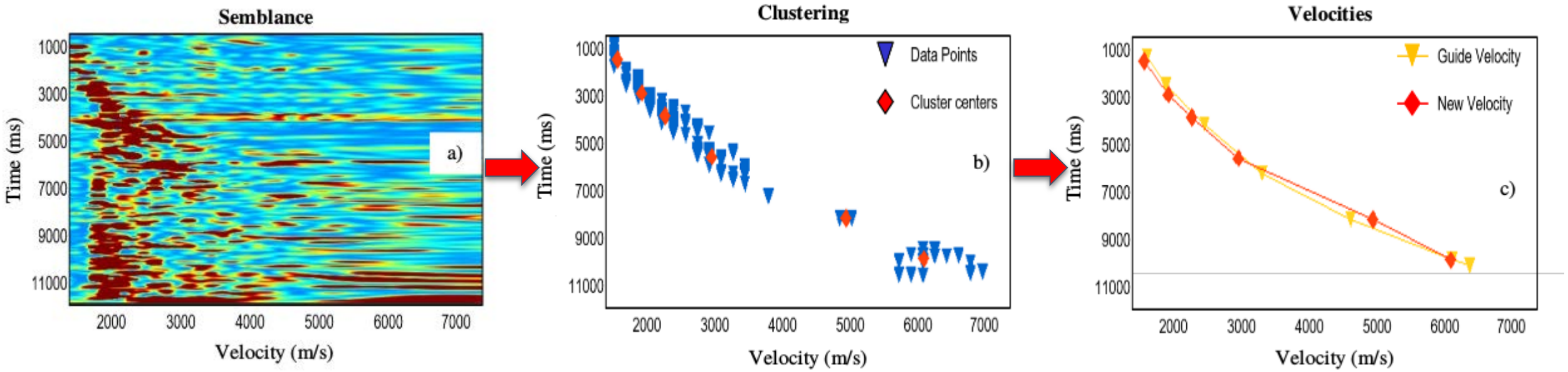
Supervised Learning



Unsupervised Learning

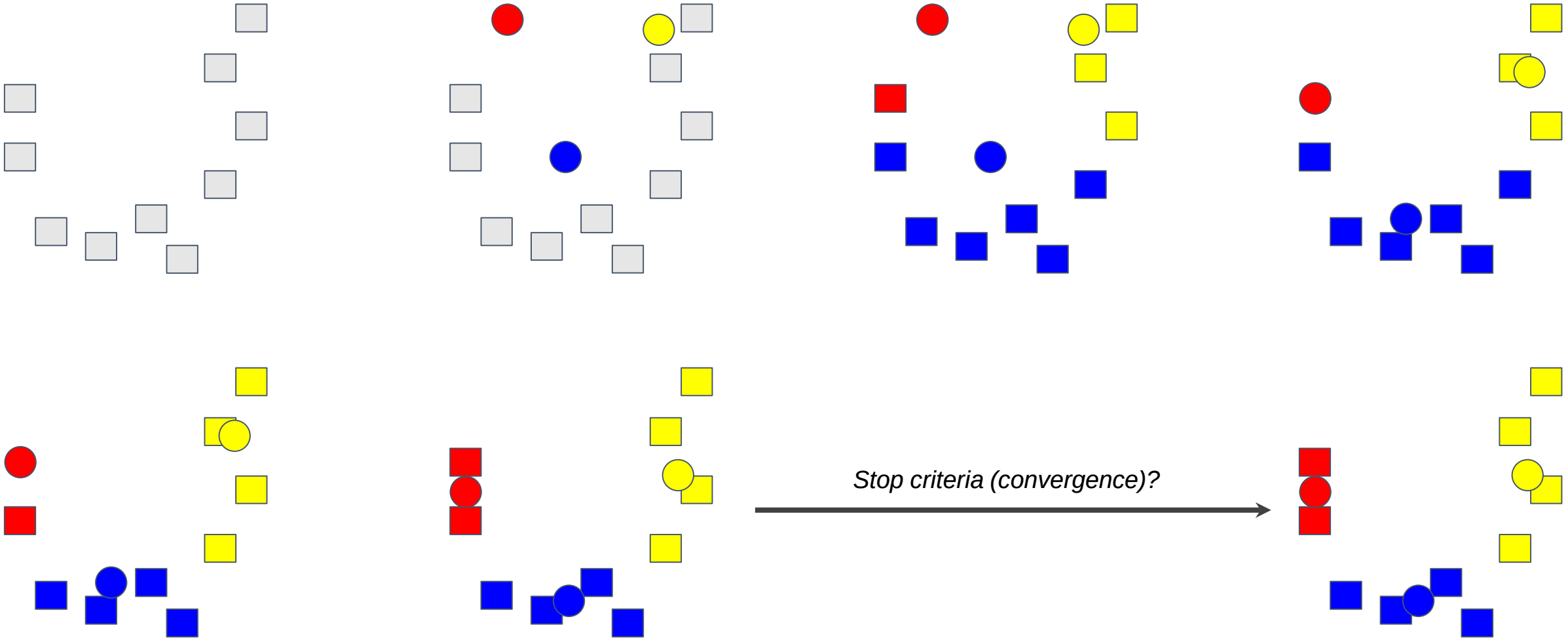
- Unlabeled data
- No evaluation of the accuracy
- Approaches to unsupervised learning include:
  - Clustering
  - Anomaly detection
  - Neural Networks
  - And a few others...

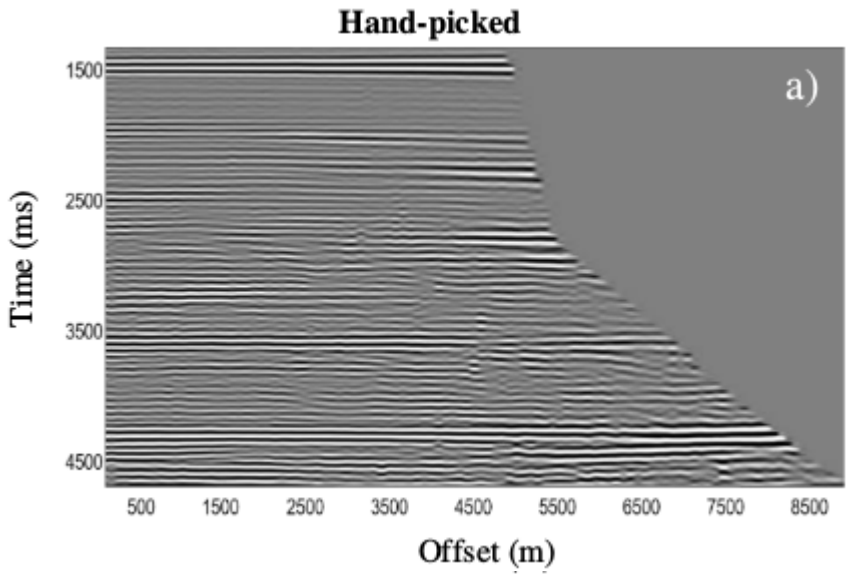
Smith, K. J., 2017, **Machine learning assisted auto-picking**, SEG *International Exposition and 87th Annual Meeting*, 5686-5690

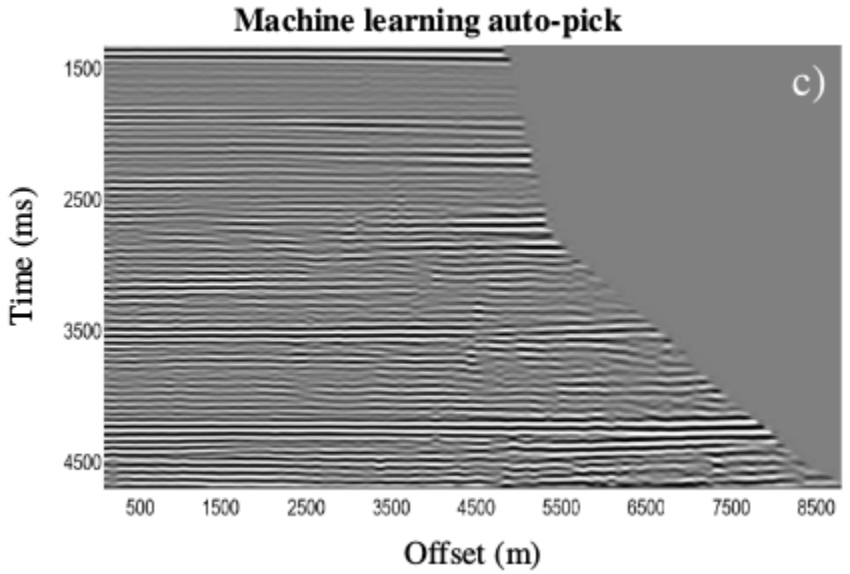


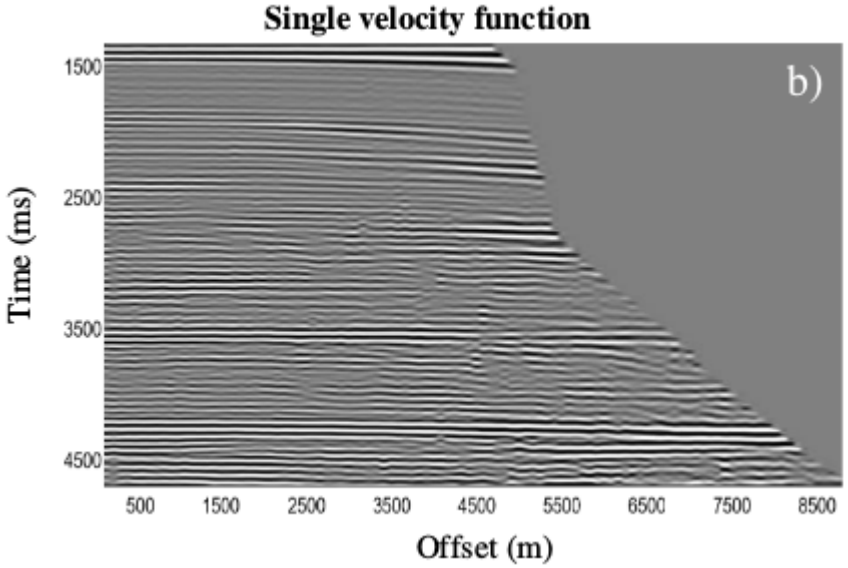
- Guide velocity (one CMP manually picked)
- Semblance
- Threshold (red or blue)
- Filter using others attributes (not clear)
- Group picks into “clusters”
- Determine clusters centers as the picking velocity
- Include new estimation in the guide velocity

Clustering > *k-means* (or k-nearest neighbours)?

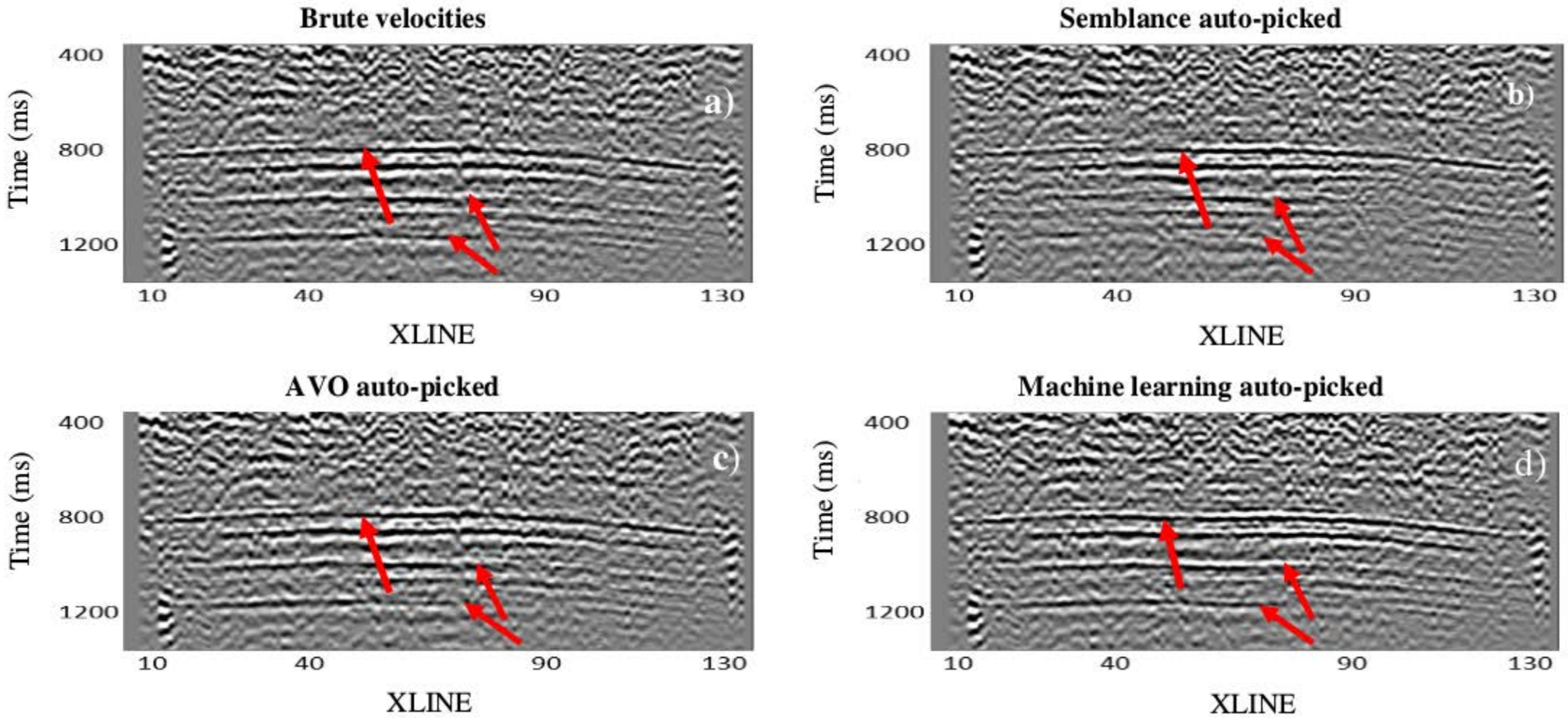


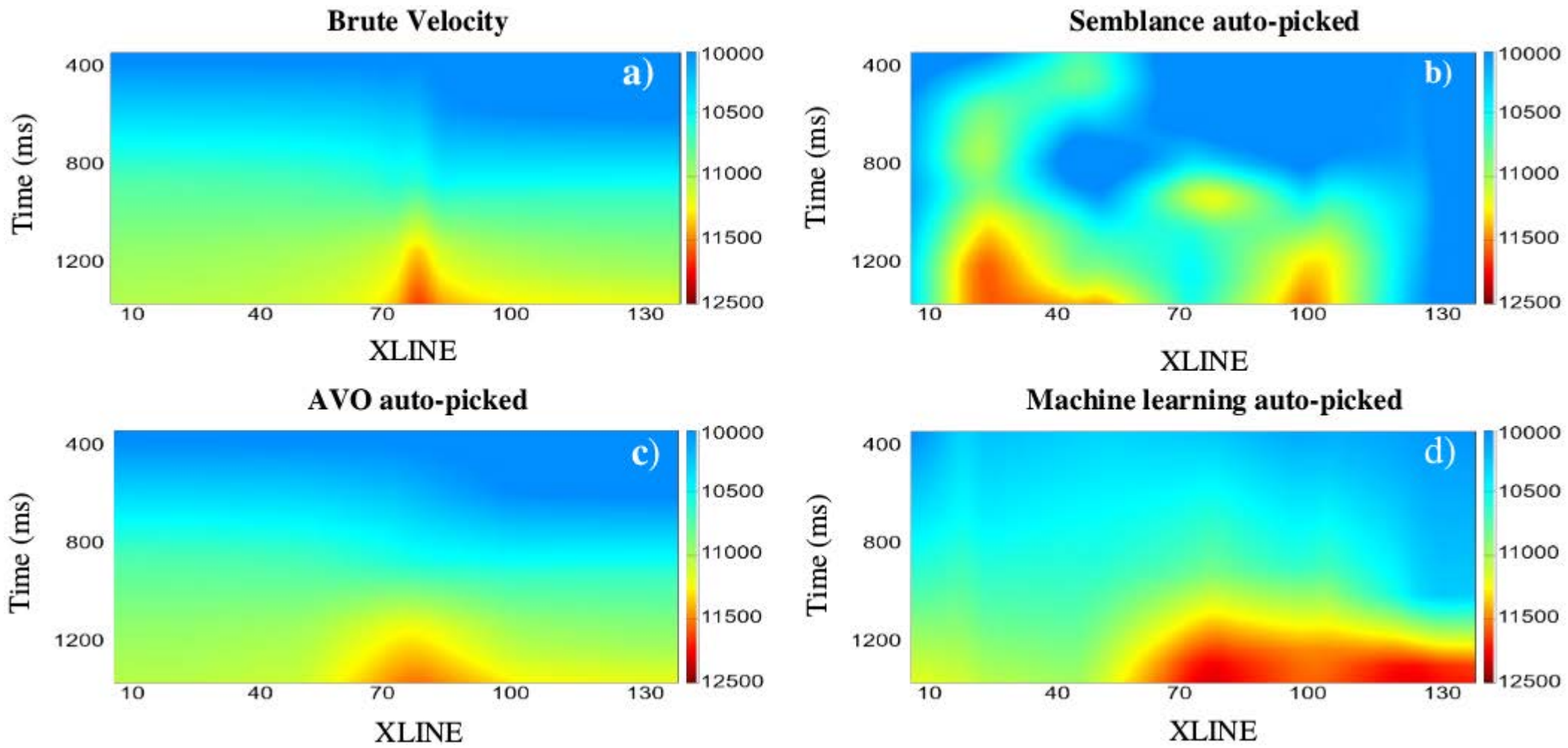






- Marine data
- CMP gather - NMO correction
- *"The gather from the machine-picked velocity is virtually indistinguishable from the gather with the hand-picked velocity"*


Brute velocities
Time (ms)
400
800
1200
a)
10
40
90
130
XLINE
Semblance auto-picked
Time (ms)
400
800
1200
b)
10
40
90
130
XLINE
AVO auto-picked
Time (ms)
400
800
1200
c)
10
40
90
130
XLINE
Machine learning auto-picked
Time (ms)
400
800
1200
d)
10
40
90
130
XLINE


Brute Velocity
a)
Semblance auto-picked
b)
AVO auto-picked
c)
Machine learning auto-picked
d)
Time (ms)
400
800
1200
10
40
70
100
130
XLINE
10000
10500
11000
11500
12500

Paolo, B., Lipari, V., Tubaro, S., 2017, **A machine learning approach to facies classification using well logs**, SEG *International Exposition and 87th Annual Meeting*, 2137-2142

One of the proposed solutions of a Machine Learning Contest in 2016:

https://github.com/seg/2016-ml-contest

It was a contest to classify facies using the given well logs. The author's solution can be downloaded from:

https://bitbucket.org/polimi-ispl/

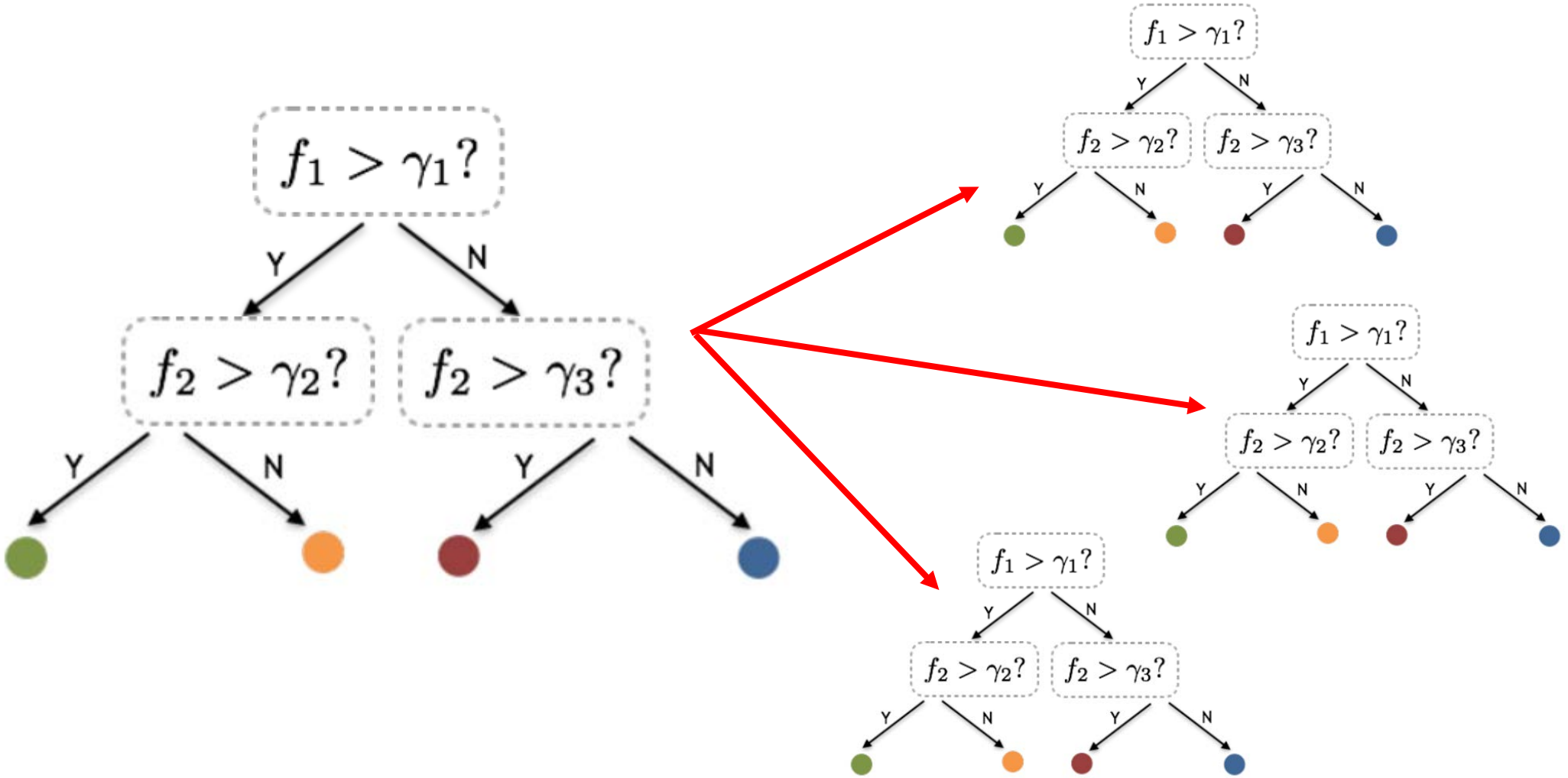
Well Logs ($f_{d,w}$)

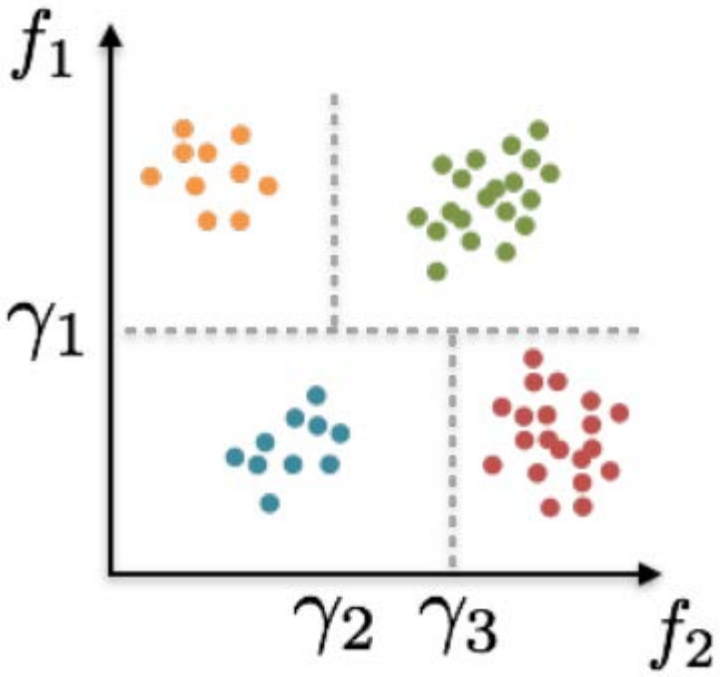
- Gamma ray
- Resistivity
- Photoelectric effect
- Neutron-density porosity difference
- Average neutron-density porosity
- Nonmarine/marine indicator
- Relative position

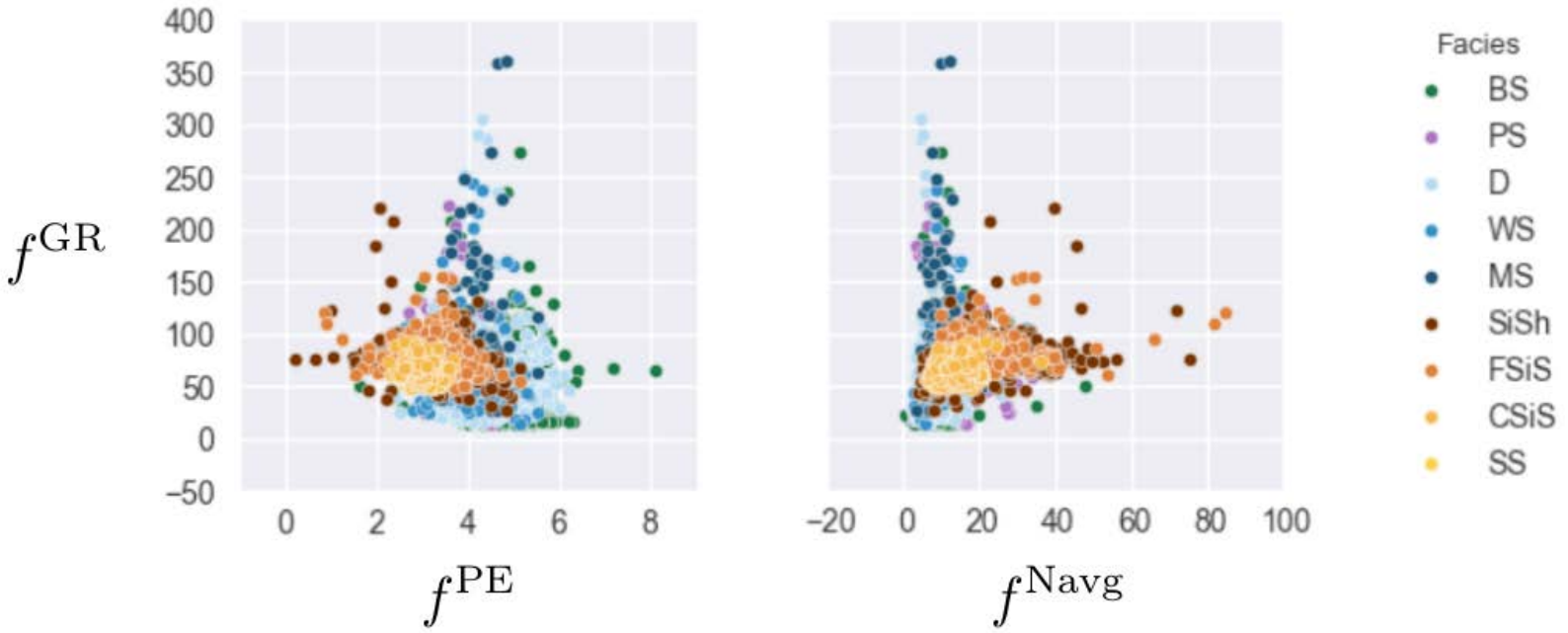
Facies ($c_{d,w}$)

- Nonmarice sandstone (SS)
- Nonmarine coarse siltstone (CSiS)
- Nonmarine fine siltstone (FSiS)
- Marine siltstone and shale (SiSh)
- Mudstone (MS)
- Wackestone (WS)
- Dolomite (D)
- Packstone-grainstone (PS)
- Phylloid-algal bafflestone (BS)

Classification > *Gradient boosting classifier* (an ensemble of *decision trees*)

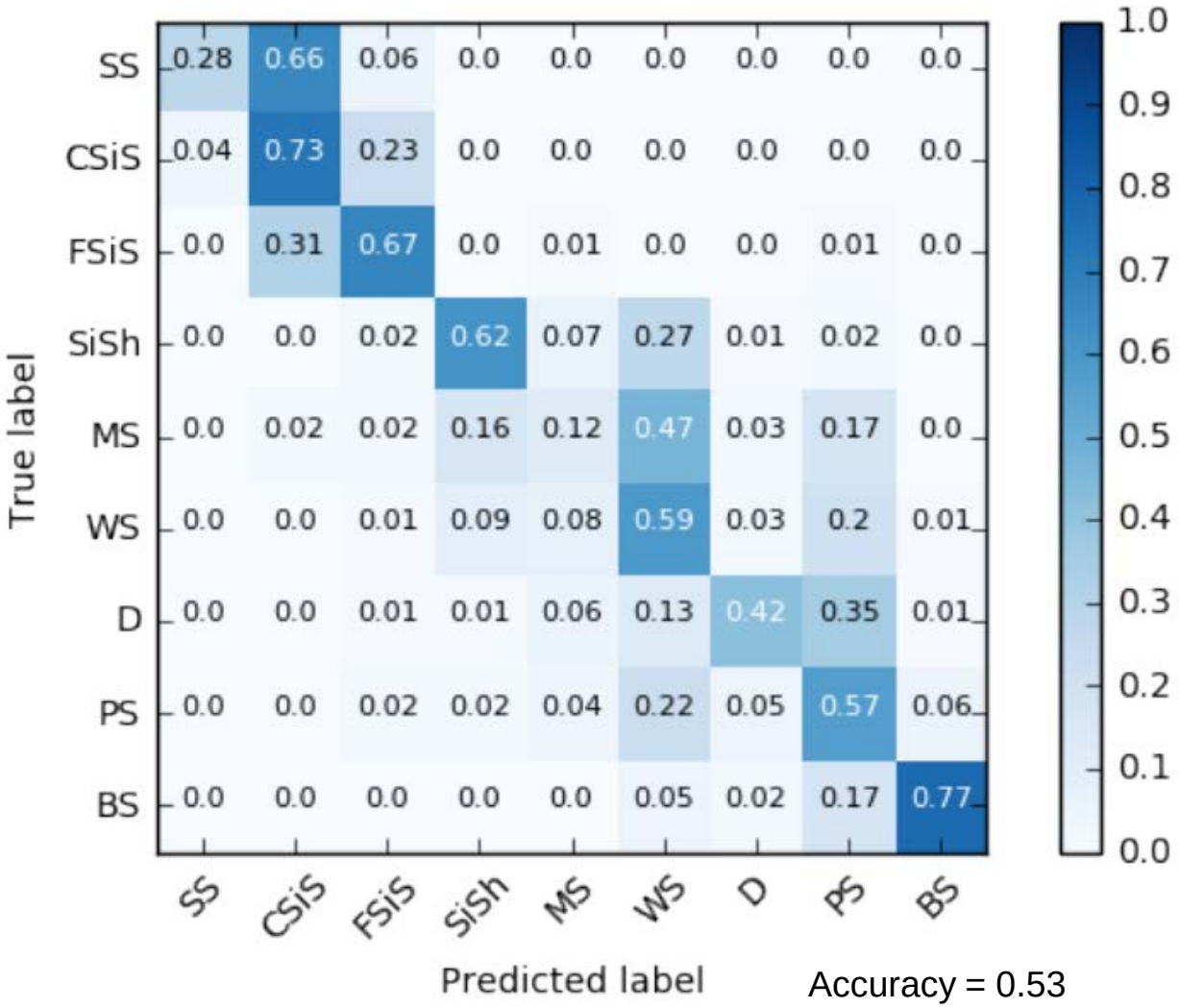






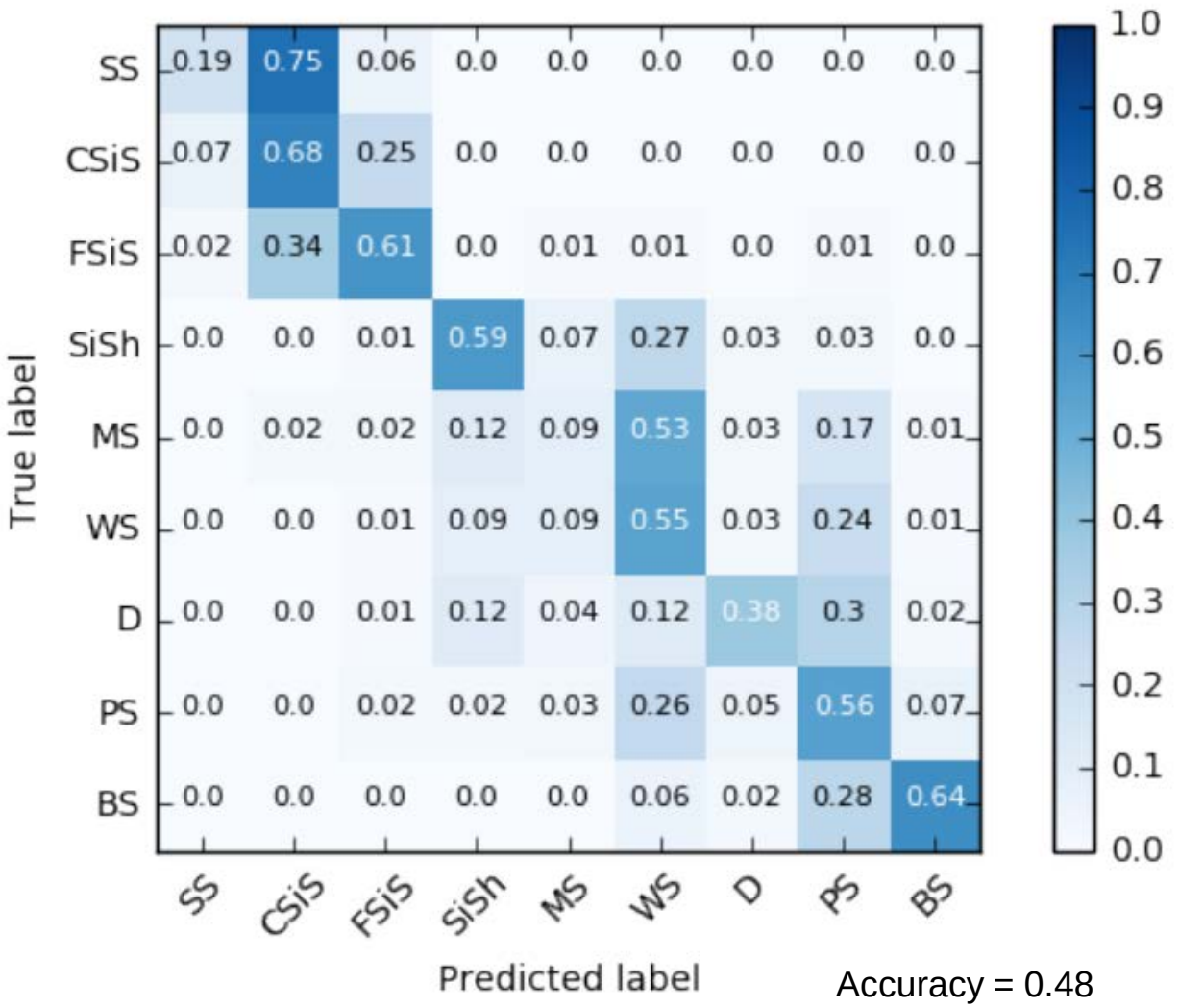
Proposed solution > *Feature augmentation* (generate new features from the available ones)

Confusion Matrix



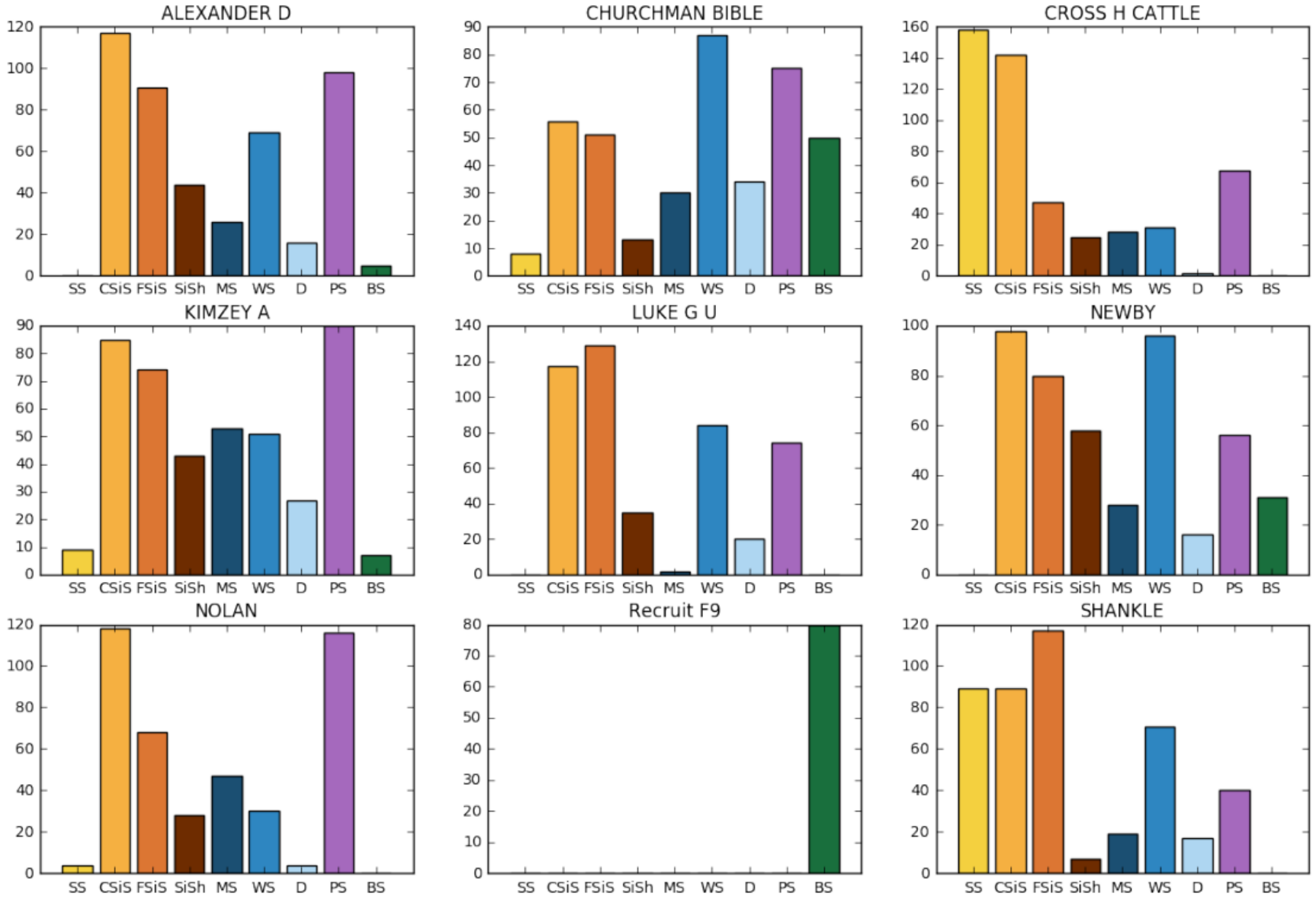
Accuracy = 0.53

(a) With feature augmentation



Accuracy = 0.48

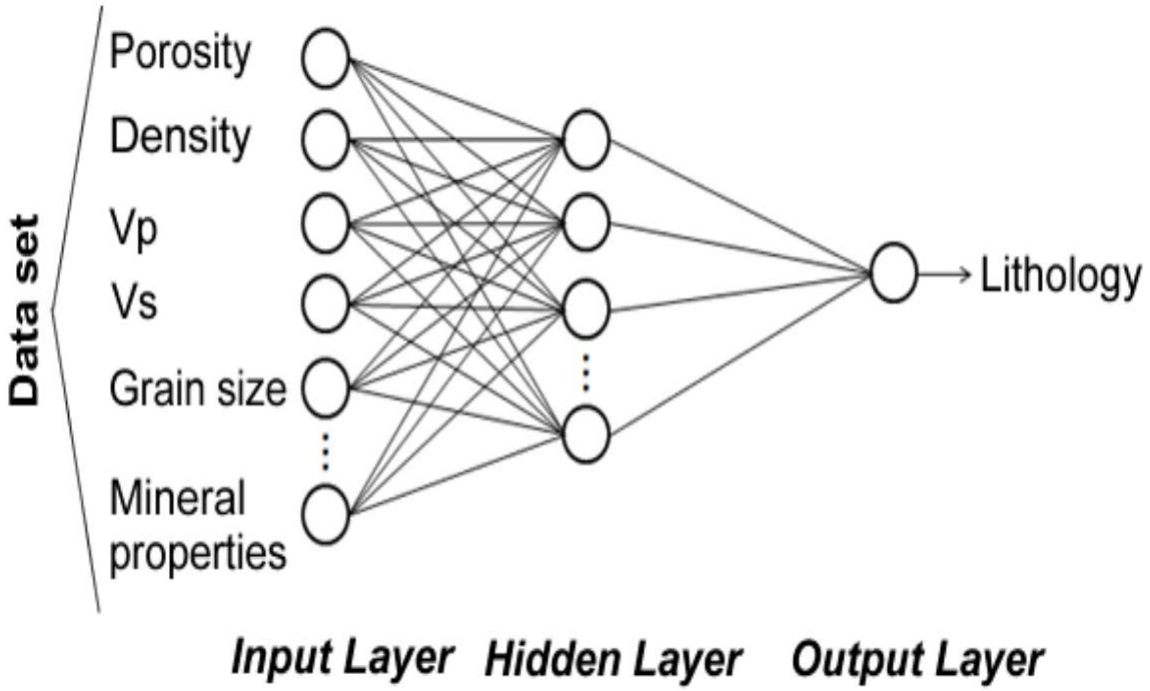
(b) Without feature augmentation

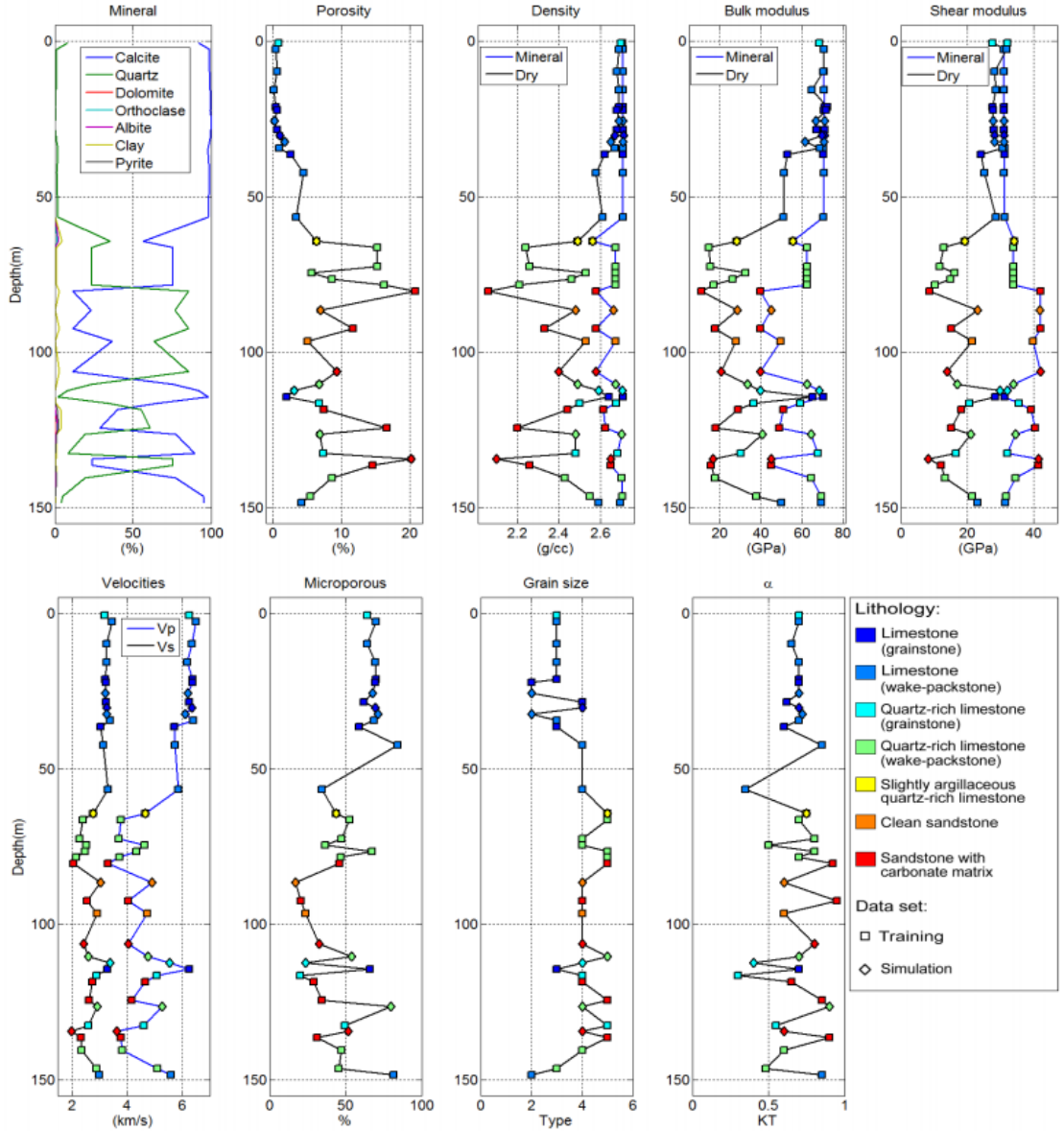


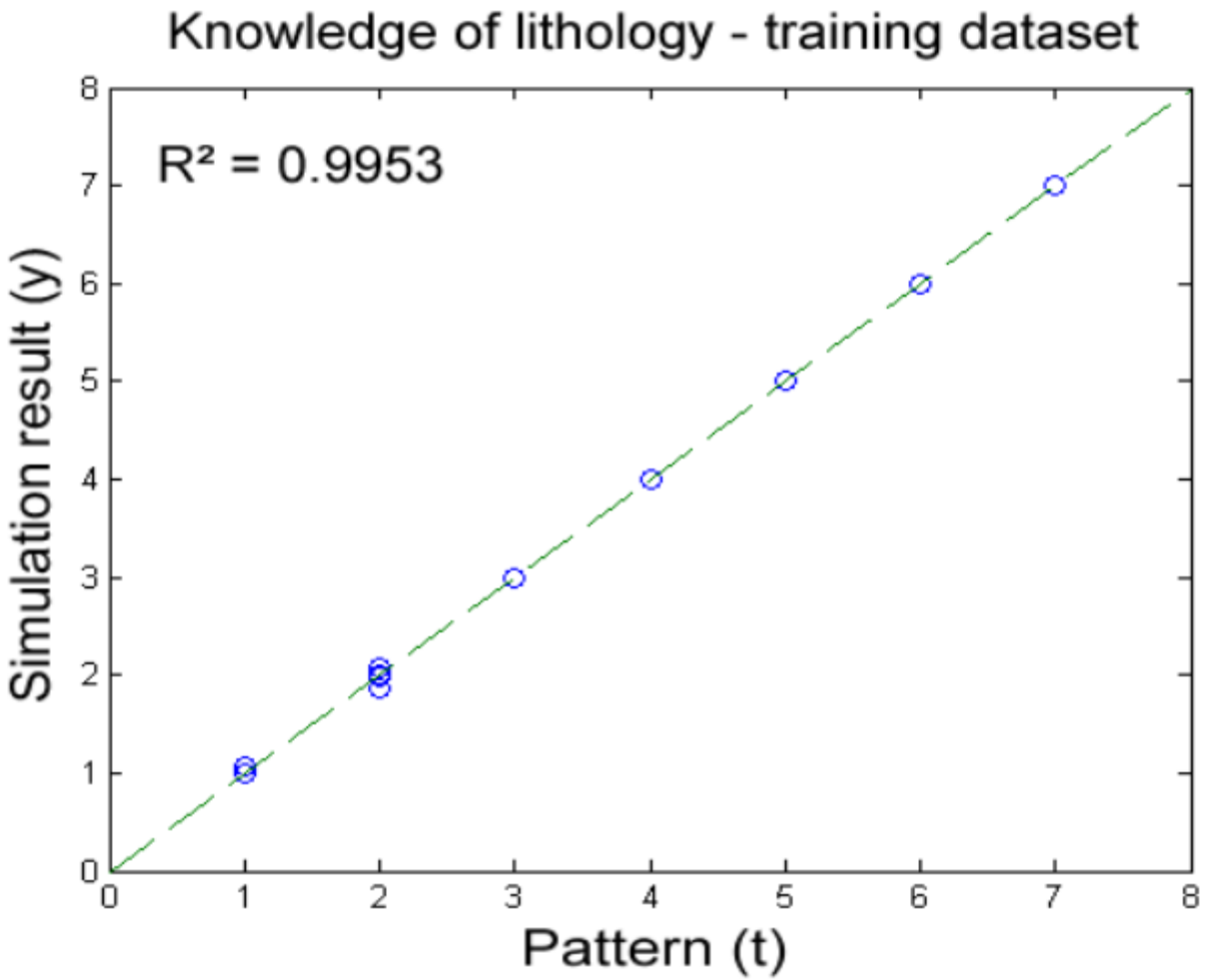
Unbalanced classification

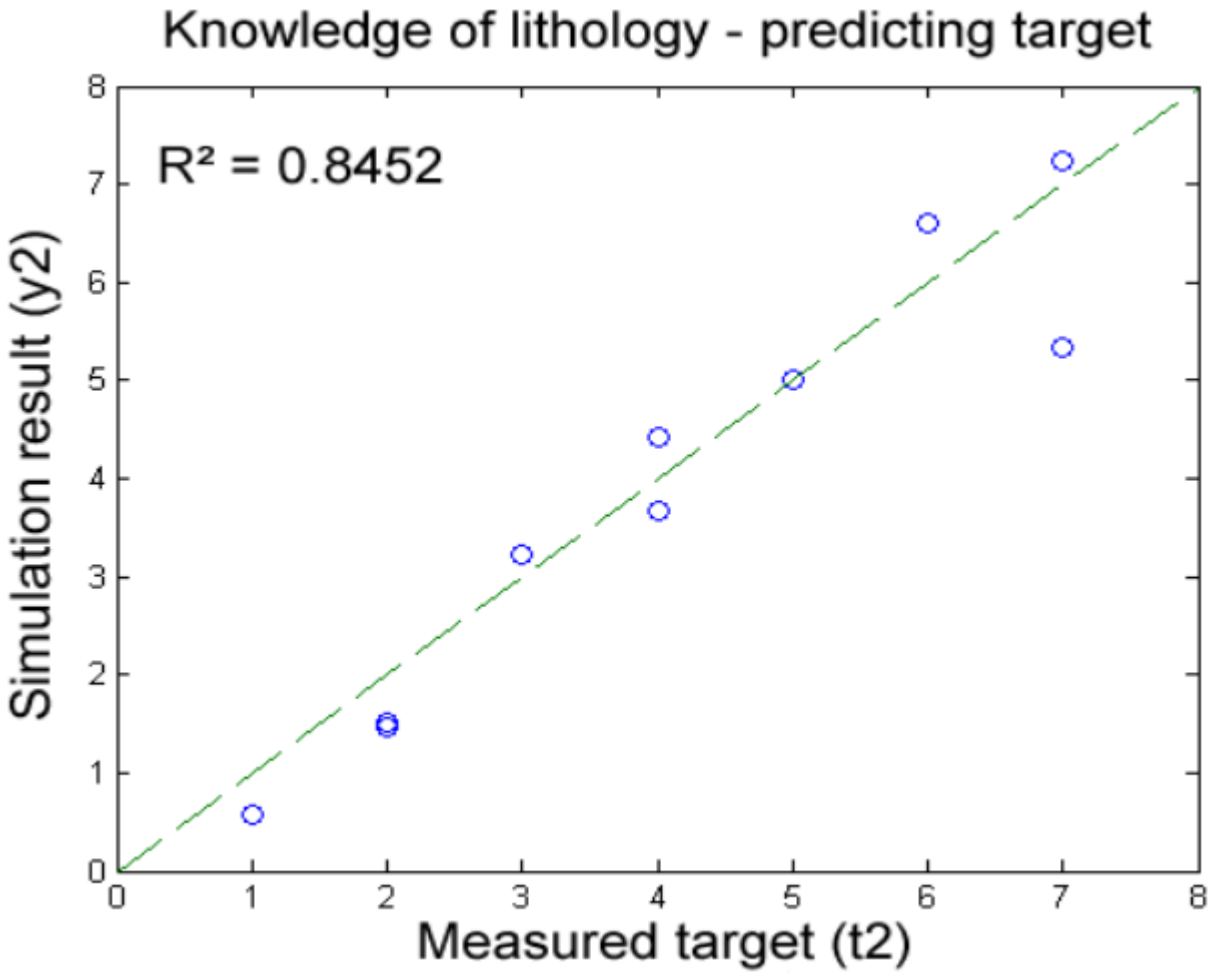
Silva, A., Neto, I. L., Carrasquilha, A., Missagia, R., Ceia, M., Archilha, N., 2013, **Neural network computing for lithology prediction of carbonate- siliciclastic rocks using elastic, mineralogical and petrographic properties**, *Thirteenth International Congress of the Brazilian Geophysical Society*, 1055-1058

1	Limestone (grainstone)
2	Quartz-rich limestone (grainstone)
3	Quartz-rich limestone (wacke-packstone)
4	Limestone (wacke-packstone)
5	Slightly argillaceous quartz-rich limestone
6	Clean sandstone
7	Sandstone with carbonate matrix





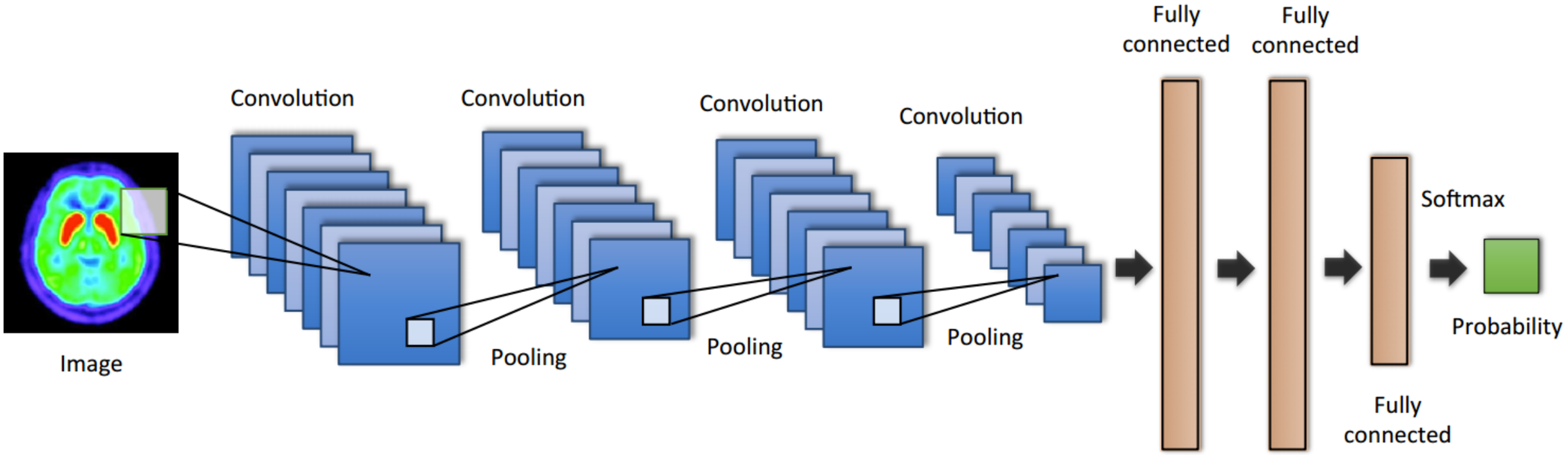




Accuracy = 84.52%

Lewis, W., Vigh, D., 2017, **Deep learning prior models from seismic images for full-waveform inversion**, SEG *International Exposition and 87th Annual Meeting*, 1512-1517

- FWI > issues inverting salt bodies
- Regularization using Tikhonov method
- Uses information from others surveys
- Train a *“Convolutional Neural Networks”* model for salt bodies
- Incorporates in the FWI routine


Fully connected
Fully connected
Convolution
Convolution
Convolution
Convolution
Softmax
Image
Pooling
Pooling
Pooling
Probability
Fully connected

Training dataset (known models)

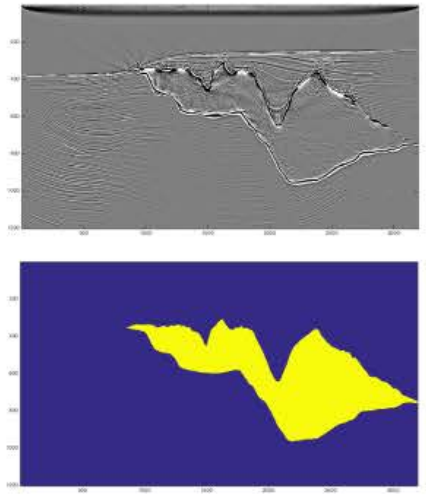


Image patches with structure

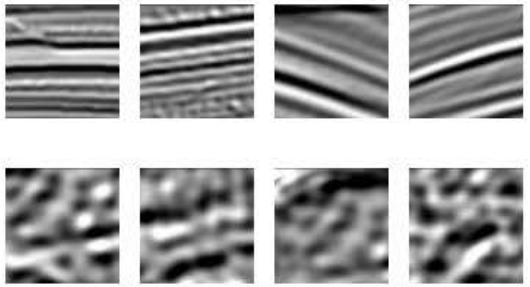
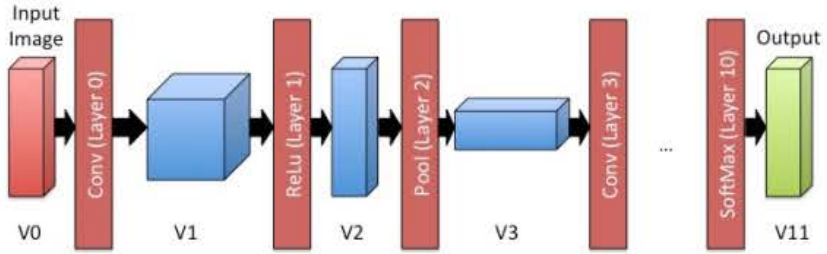
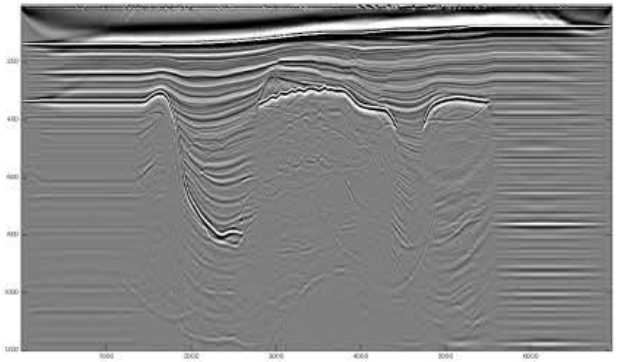


Image patches without structure

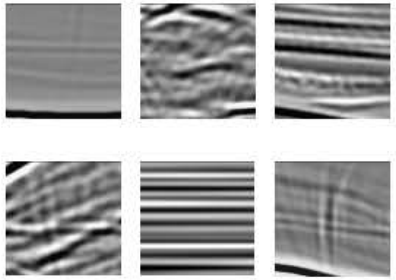
Train deep learning model



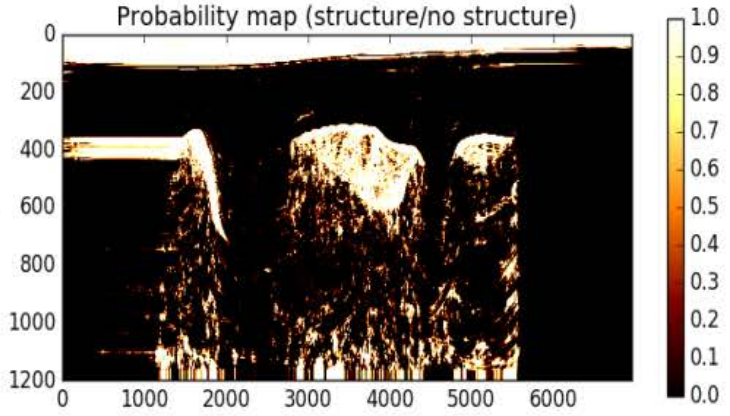
Run prediction

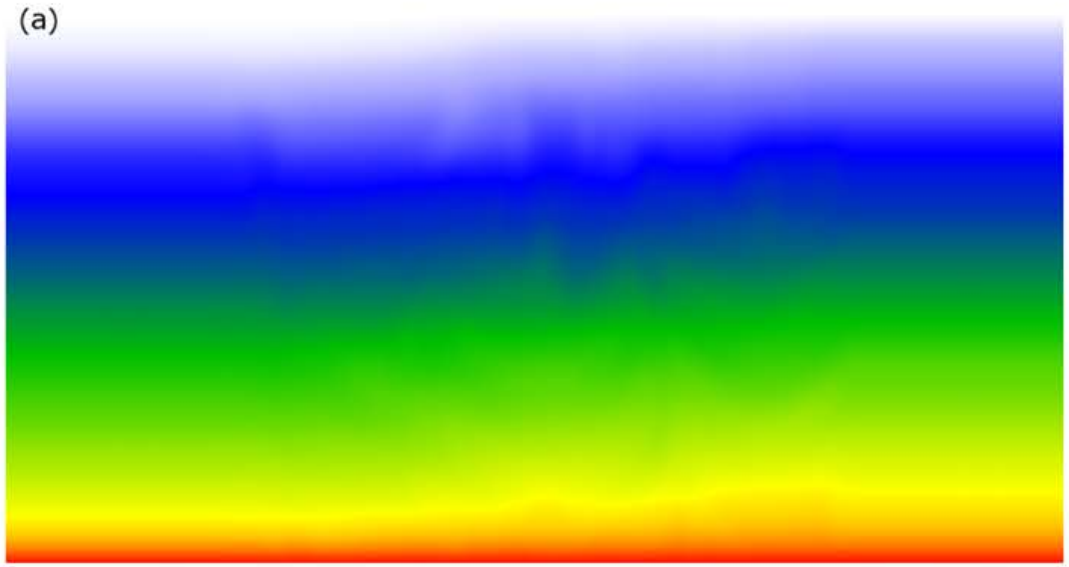


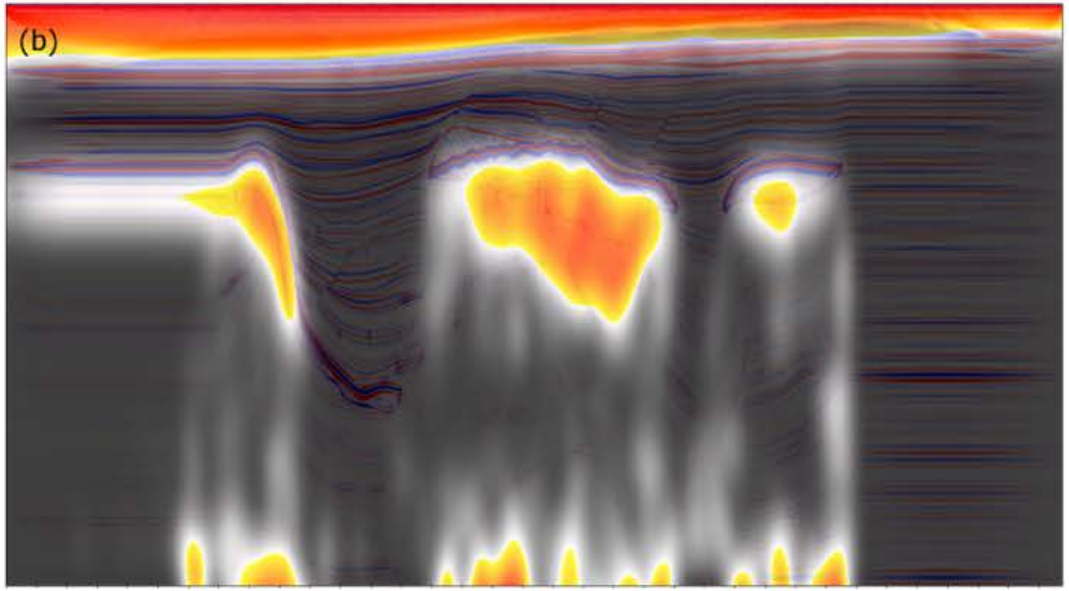
Test dataset (unknown models)

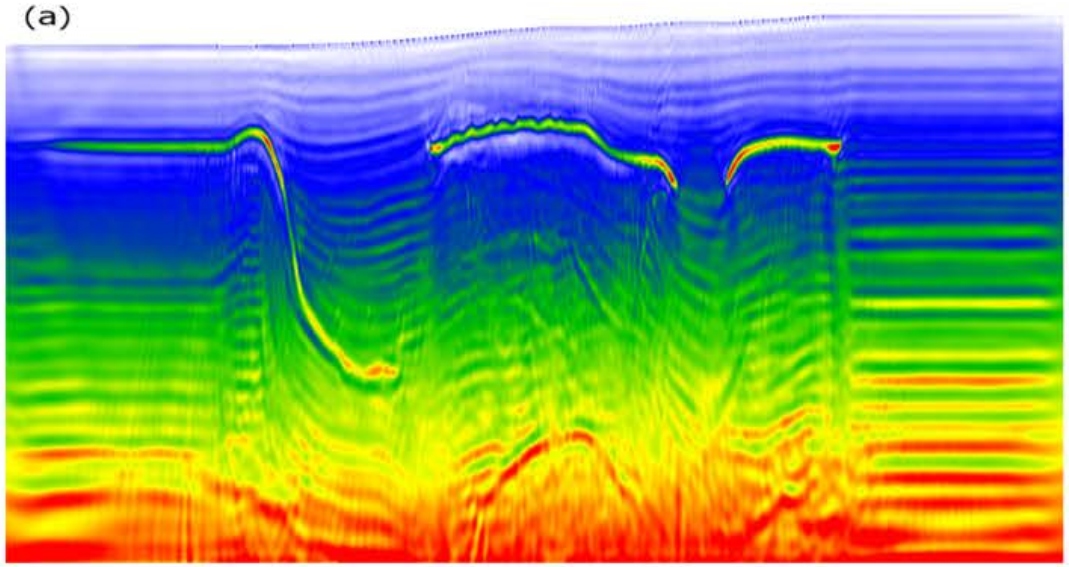


Extract image patches




(a)


(b)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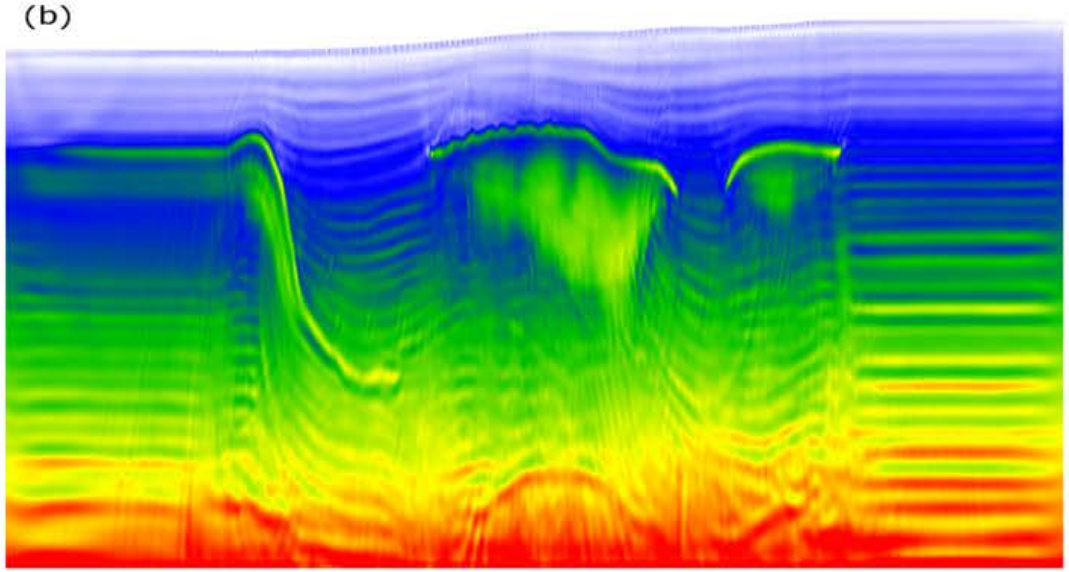
(b)

Comments

- Machine learning is an area in full expansion and applicable on many different sciences.
- Increased computer power, such as use of GPUs.
- Need to handle “big data”.
- Promising applicability in geophysics/geology
- **We should be part of this!**