

IP_Prediction2D

**Machine learning prediction using surface
property or seismic traces waveform**

User Manual

IPLAB LLC

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Table of Contents

1. Introduction	4
2. Start	5
3. Input parameters	6
4. Calculation	13
5. Results	15

1. Introduction

The **IP_Prediction2D** IP_Seismic plug-in (version: 2019.1.0.1, release date: October 2019) can be used for sweet spot analysis based on wells production rate prediction or any wells log property prediction on map using a set of surface attributes or seismic trace waveform using machine learning algorithms (linear regression, ACE regression, nearest neighbor regression, random forest, classic neural network and T-neural networks). The result of this plug-in application is the maps (surface attributes) with average, standard deviation, min, max, P10, P50, P90 predictions according to several cross validations calculations

The **IP_Prediction2D** IP_Seismic plug-in allow to predict effective parameters of the rock in layers using a set of the surface attributes or seismic trace waveforms and a set of points in places of the layer intersection by the boreholes.

There are two main calculation studies to perform this prediction:

1. Training stage – to train machine learning according to the array of training pairs – points with a value of predictive parameters and values of surface attributes around the borehole points.
2. Calculation stage – to calculate values of predictive parameter for each node in the surface based on surface attributes or based on the trace waveform.

2. Start

Procedures -> Surface Attributes-> Machine Learning surface property prediction

3. Input parameters

Plug-in has two input options:

- **Surface attributes**
- **Seismic cubes for defined layer**

The first input option **Surface attributes** allows to define a set of maps like surface attributes to perform predictive analysis.

The second input option **Seismic cubes for defined layer** allows to define seismic trace waveform to perform predictive analysis.

According to the input options, input tab will be different like shown in Figure 1 and Figure2.

3.1. Surface attributes input option

The screenshot shows the 'IP_Prediction2D' dialog box titled 'Machine Learning map property prediction'. The 'Input data option' is set to 'Surface attributes' and the 'Algorithm' is 'NearestNeighbor regression'. The 'Input surface data' tab is active, showing a list of surfaces to be used for training. The list includes 'Top_CPS3' and 'Z'. The 'Z' surface is selected. Below the list, there are checkboxes for 'Extract value: Norm [Realized] 1' through 'Extract value: Norm [Realized] 1; -60'. The 'Calculate results' button is highlighted. Other buttons include 'Correlation analysis' and 'Cancel'.

Surface	Extract value: Norm [Realized] 1	Extract value: Norm [Realized] 1; -4	Extract value: Norm [Realized] 1; -8	Extract value: Norm [Realized] 1; -12	Extract value: Norm [Realized] 1; -16	Extract value: Norm [Realized] 1; -20	Extract value: Norm [Realized] 1; -24	Extract value: Norm [Realized] 1; -28	Extract value: Norm [Realized] 1; -32	Extract value: Norm [Realized] 1; -36	Extract value: Norm [Realized] 1; -40	Extract value: Norm [Realized] 1; -44	Extract value: Norm [Realized] 1; -48	Extract value: Norm [Realized] 1; -52	Extract value: Norm [Realized] 1; -56	Extract value: Norm [Realized] 1; -60
Top_CPS3	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Z	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Figure 1: Input surface attributes data tab dialog view **IP_Prediction2D** for input option **Surface attributes** to define a set of surfaces for predictive analysis.

Input option Surface attributes

Parameters for the input option **Surface attributes** are defined before calculation:

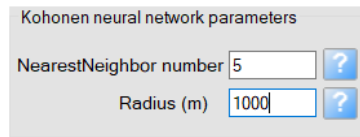
Algorithms: allow to select the following algorithms for predictive analysis:

Kohonen neural network regression

With parameters:

Nearest neighbor number allow to define number of points (wells) to current surface node with maximum similarity of set surface attributes or seismic traces form.

Radius allow to define Radius of influence of a point (well) for correction of values to the exact values. If radius = 0 then there is no any correction.



Kohonen neural network parameters

NearestNeighbor number: 5

Radius (m): 1000

Linear regression

With parameters:

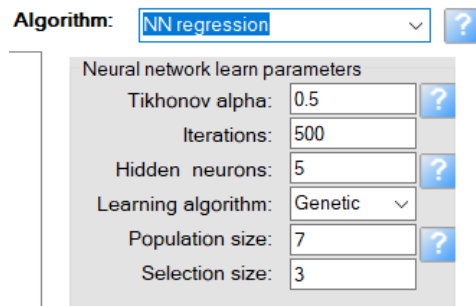
Tikhonov alpha: >0 and <1000 allow to avoid overlearning effect or instability for prediction. If alpha=0, then we can get very high approximation of the training set, but the predictability can be very low and results can be quite different for every realization. If alpha > 0, then training quality (correlation coefficient) will be less if to use alpha=0, but predictability will be much higher (quality control with "blend well" test).

ACE regression

Tikhonov alpha: 0 and <1000 allow to avoid overlearning effect or instability for prediction.

Maximum iterations

Neural network regression



Algorithm: NN regression

Neural network learn parameters

Tikhonov alpha: 0.5

Iterations: 500

Hidden neurons: 5

Learning algorithm: Genetic

Population size: 7

Selection size: 3

Tikhonov alpha: 0 and <1000 allow to avoid overlearning effect or instability for prediction.

Iteration: Maximum iterations in the course of learning

Hidden layers neurons: define structure of neural network. If several hidden layers are required, it is necessary to use comma: 10, 5, 3 mean 10 in first, 5 second and 4 in third hidden layers.

Learning algorithm:

Genetic – use genetic algorithm

Gradient – use gradient algorithm

Hybrid – use genetic + gradient algorithms

Population size – used only for genetic algorithm

Selection size - used only for genetic algorithm

Random Forest regression

Algorithm: Random Forest regression

Random Forest regression parameters

MaxProbability: 0.95

MaxDeep: 500

Max probability – need to stop the iteration for the results.

Max deep – max deep for random forest

TNN regression

Algorithm: TNN regression

TNeural network learn parameters

Tikhonov alpha: 0.5

Iterations: 500

Hidden neurons: 3

Learning algorithm: Genetic

Population size: 10

Selection size: 5

Size TFunction: 10

Tikhonov alpha: 0 and <1000 allow to avoid overlearning effect or instability for prediction.

Iteration: Maximum iterations in the course of learning

Hidden layers neurons: define structure of neural network. If several hidden layers are required, it is necessary to use comma: 10, 5, 3 mean 10 in the first, 5 in the second and 4 in the third hidden layers.

Learning algorithm:

Genetic – use genetic algorithm

Gradient – use gradient algorithm

Hybrid – use genetic + gradient algorithms

Population size – used only for genetic algorithm

Selection size – used only for genetic algorithm

Size TFunction – parameter for TNN ≥ 5 and ≤ 100

Surface: allow to select a surface with a set of surface attributes from the project tree. All marked attributes will be used for calculations.

Moving window radius i, Moving window radius j: allow to define moving window size around the production points in the course of training stage and around node for calculation in the course of calculation stage.

Validation option

No validation

Number realization

Number realization – number of stochastic realizations to calculate separate prediction on each to calc average, standard deviation, P10, P50, P90 predictions

Number points removing– this number of points will be randomly removed from learning for each realization

3.2. Surface attributes input option

The screenshot displays the 'Machine Learning map property prediction' dialog box in the IP Prediction2D software. The 'Input data option' tab is active, showing a dropdown menu for 'Input data option' set to 'Seismic cubes in the defined I'. The 'Algorithm' dropdown is open, showing options: 'NearestNeighbor regression', 'Linear regression', 'ACE regression', 'Neural Network regression' (selected), 'Random Forest regression', and 'TNN regression'. The 'Training data points' tab is also visible, showing a list of cubes: 'Cube' and 'Cube2'. The 'Graphics' tab is also present. The 'Validation option' is set to 'Number realization' with a value of 50. The 'Points to remove' is set to 10. The 'Neural network learn parameters' section includes: 'Tikhonov alpha: 0.5', 'Iterations: 500', 'Hidden neurons: 3', 'Learning algorithm: Gradient', 'Population size: 7', and 'Selection size: 3'. The 'Use Surface' section has checkboxes for 'Top' and 'Bottom' surfaces, with 'Top' selected. The 'Use Constant' section has checkboxes for 'Constant' and 'shift+up/-down', with 'Constant' selected. The 'Constant' value is set to 0, and the 'shift+up/-down' value is set to 0. The 'Run' button is highlighted in green, and the 'Cancel' button is highlighted in red.

IP Prediction2D

Machine Learning map property prediction

Input data option: Seismic cubes in the defined I ? Algorithm: Neural Network regression ?

Input seismic waveform data Training data points Graphics

Seismic cubes: [Add] [Remove] Cube Cube2

Radius inlines: 0 ? Radius xlines: 0 ?

Validation option: Number realization ?

Number realization: 50

Points to remove: 10

Neural network learn parameters

Tikhonov alpha: 0.5 ?

Iterations: 500 ?

Hidden neurons: 3 ?

Learning algorithm: Gradient ?

Population size: 7 ?

Selection size: 3 ?

Use Surface: Use Constant shift+up/-down: ?

Top: [Add] Top [] 0 0

Bottom: [Add] Bottom [] -1000000000 0

Run Correlation analysis Cancel

Figure 2: Input data tab dialog view **IP_Prediction2D** for input option **Seismic cube in the define layer** to define a set of seismic trace waveform for predictive analysis.

Parameters are defined before calculation:

Algorithms: - the same line like in previous input tab options.

Seismic cubes: allow to select one or several seismic cubes with similar geometry from the project tree.

Radius inlines, Radius xlines: allow to define moving window size around central trace during training stage and for calculation during calculation stage.

Validation option

No validation

Number realization

Number realization - number of stochastic realizations to calculate separate prediction on each to calc average, standard deviation, P10, P50, P90 predictions

Number points removing- this number of points will be randomly removed from learning for each realization

Seismic waveform length can be defined by

Top surface or **constant**, both with **shifts**

Bottom surface or **constant**, both with shifts

3.3. Train data tab

To select production points attributes, it is necessary to use second tab:

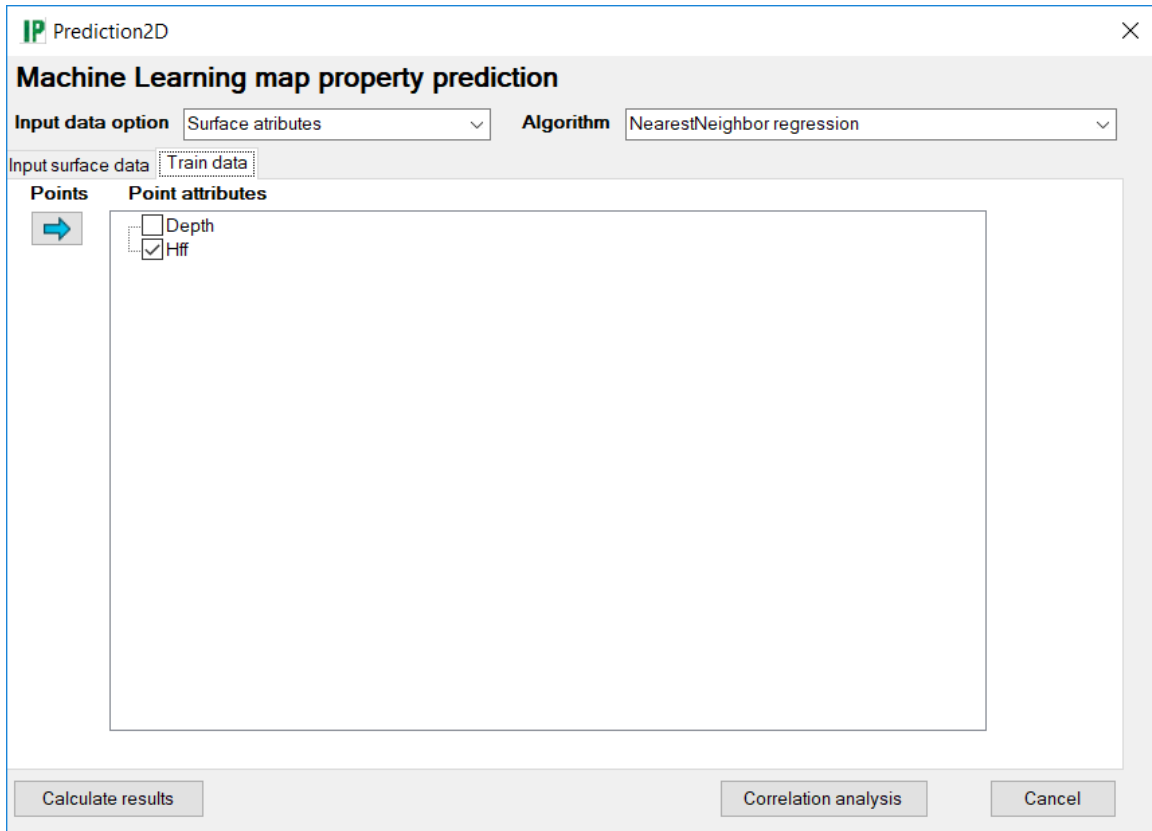


Figure 3: Input production points attributes tab dialog

3.1. Correlation analysis

To perform correlation analysis, it is necessary to push “Correlation Analysis” bottom. After calculation, a correlation table is displayed (see Figure 4) with cross correlation values and with Principal components (shift table to right). Table is sortable for every column (click on column name). Double click – sort from big to small. The “Restore original sorting” button restores the original view.

IP CorrelationAnalysis											
Restore original sorting		Number points used for calculation									
		34									
	Heff	Ar1[0.0]	Ar4[0.0]	Ar7[0.0]	Ar10[0.0]	Ar13[0.0]	Ar16[0.0]	Ar19[0.0]	Factor1 weight= 49.19% sum= 49.19%	Factor2 weight= 31.61% sum= 80.79%	Factor3 weight= 15.42% sum= 96.21%
Heff	1.0000000	0.22415479	-0.20435614	-0.78135648	-0.53630199	0.70526138	0.87873962	0.13623111	0.4404	-0.2396	-0.1134
Ar1[0.0]	0.22415479	1.0000000	0.05518230	-0.69074214	-0.79253106	-0.07465705	0.13356756	-0.04687940	0.2956	0.4885	-0.1442
Ar4[0.0]	-0.20435614	0.05518230	1.0000000	-0.25564216	-0.52466220	-0.45694075	-0.29705896	-0.18913207	0.0759	0.6030	-0.1459
Ar7[0.0]	-0.78135648	-0.69074214	-0.25564216	1.0000000	0.87084567	-0.51273142	-0.74343405	-0.19638600	-0.4897	-0.0845	0.0453
Ar10[0.0]	-0.53630199	-0.79253106	-0.52466220	0.87084567	1.0000000	-0.08278205	-0.55148723	-0.34584529	-0.4245	-0.2904	-0.1802
Ar13[0.0]	0.70526138	-0.07465705	-0.45694075	-0.51273142	-0.08278205	1.0000000	0.73771459	-0.19528455	0.2962	-0.4106	-0.3957
Ar16[0.0]	0.87873962	0.13356756	-0.29705896	-0.74343405	-0.55148723	0.73771459	1.0000000	0.39032402	0.4334	-0.2793	0.1273
Ar19[0.0]	0.13623111	-0.04687940	-0.18913207	-0.19638600	-0.34584529	-0.19528455	0.39032402	1.0000000	0.1314	-0.0536	0.8571

Figure 4: Correlation table results according to Correlation Analysis bottom

4. Calculation

To start the prediction, it is necessary to push “Calculate result” bottom (in the course of the training stage, error and correlation curves will be calculated in Graphics window, only for Neural network or for TNN algorithms options, see Figure 5)

If **Cross validation** =0, only two curves will be calculated and **Cross validation** >0 four curves additionally with error and correlation according to cross validation set of points (see Figure 6). Dispersion of quality controls curves around main curves allow to estimate predictability of the DNN operator.

If to use **Number realization** >3 prediction results will be calculated several times according to this number.

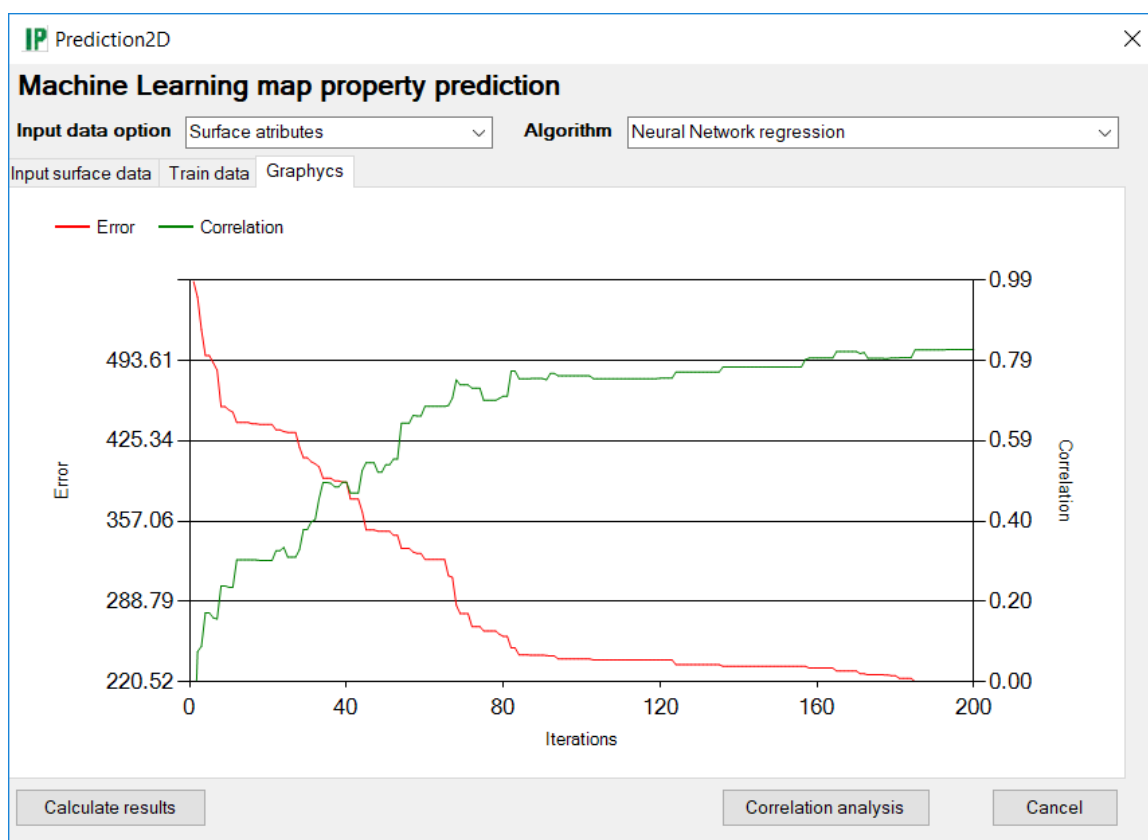


Figure 5: Output graphics window with error and correlation values during learning iterations

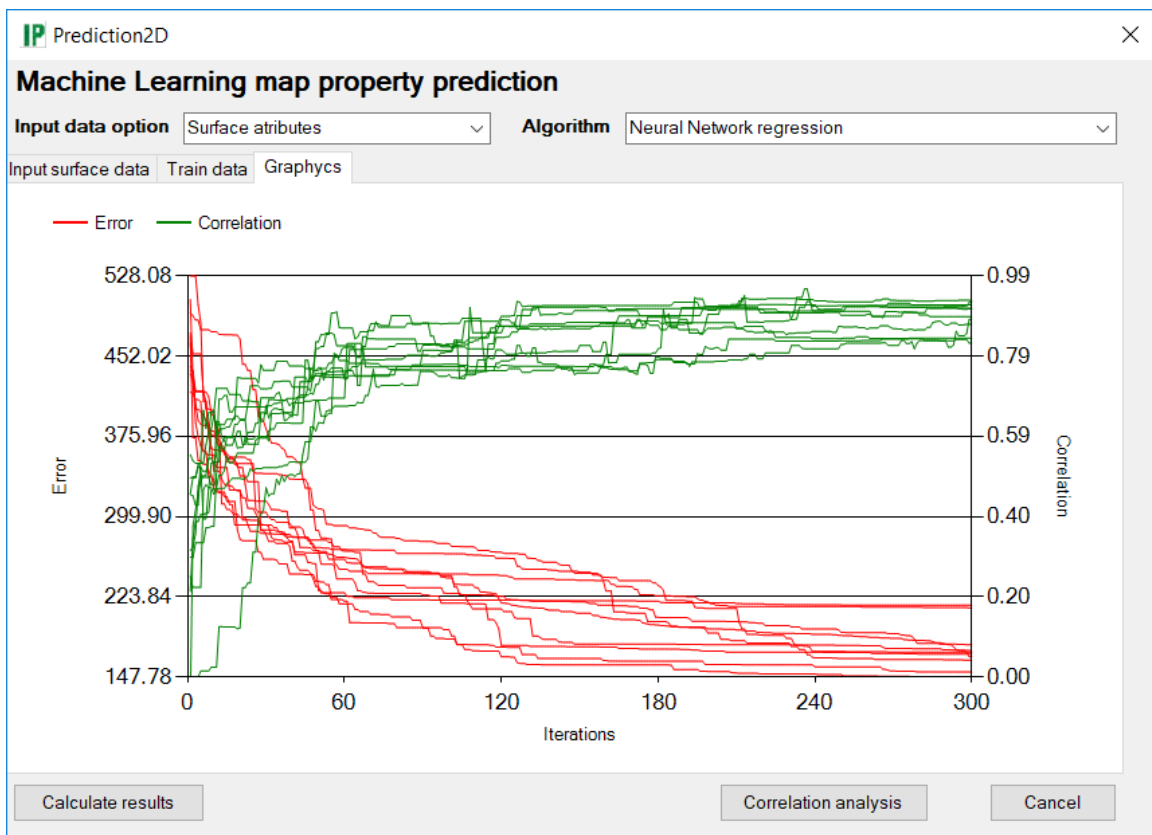


Figure 6: Output graphics window with error and correlation in the course of learning iterations for number realization =10 and number points to remove =5.

5. Results

Predicted surfaces will be added like surface with attributes in folder IP_Prediction2D.

The result surface will be named like **P_<algorithm>**

Number of results attributes will be according **Validation option**

If the option = **No validation**, only one attribute will be added to the results surface with name **default(propertyName)**.

If the option = **Use validation calculation**, several resulting attributes will be added – Mean, Standard, Minimum, Maximum, P10, P50, P90.

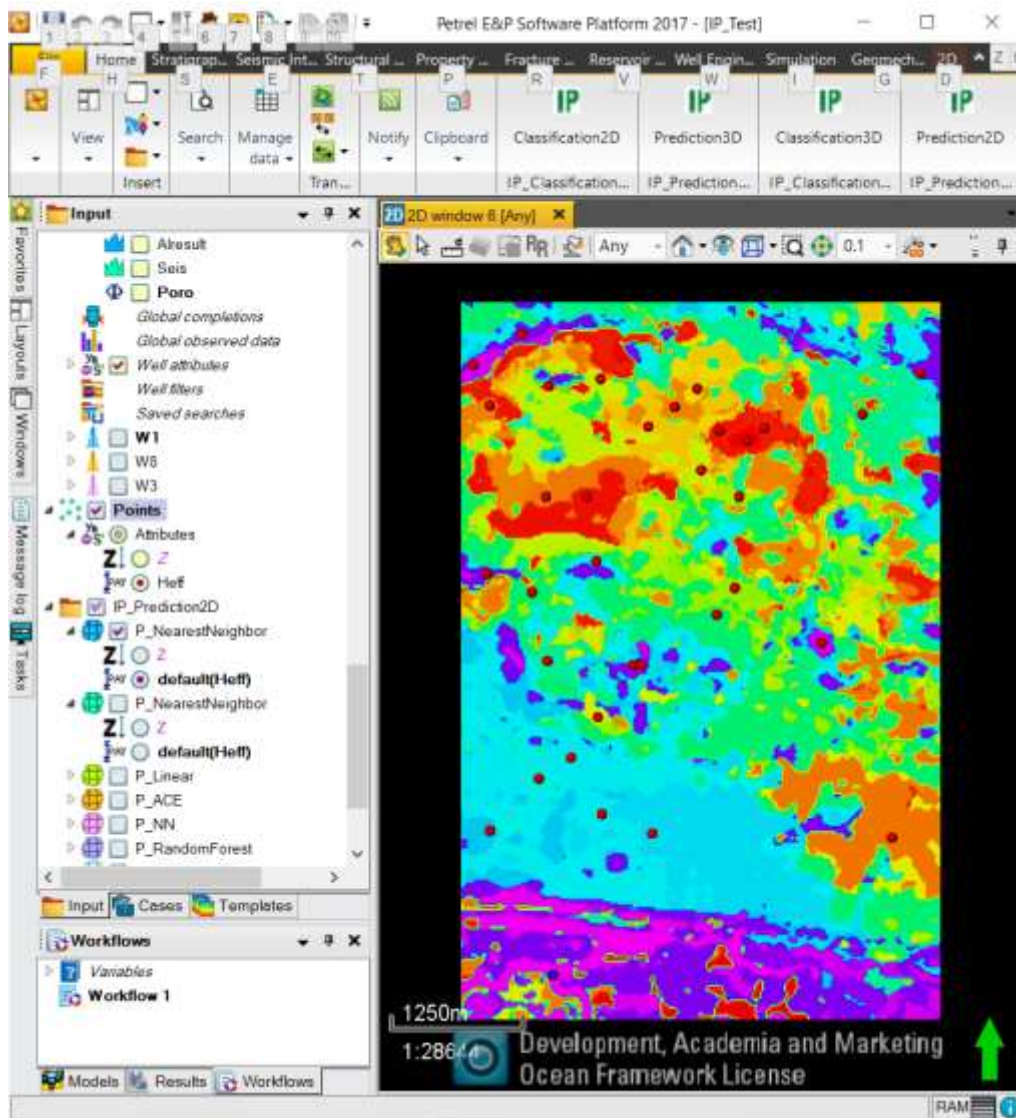


Figure 7: Result predictive map.