

**ReLoc software**  
*version 1.1*

**User manual**



2023

## Disclaimer

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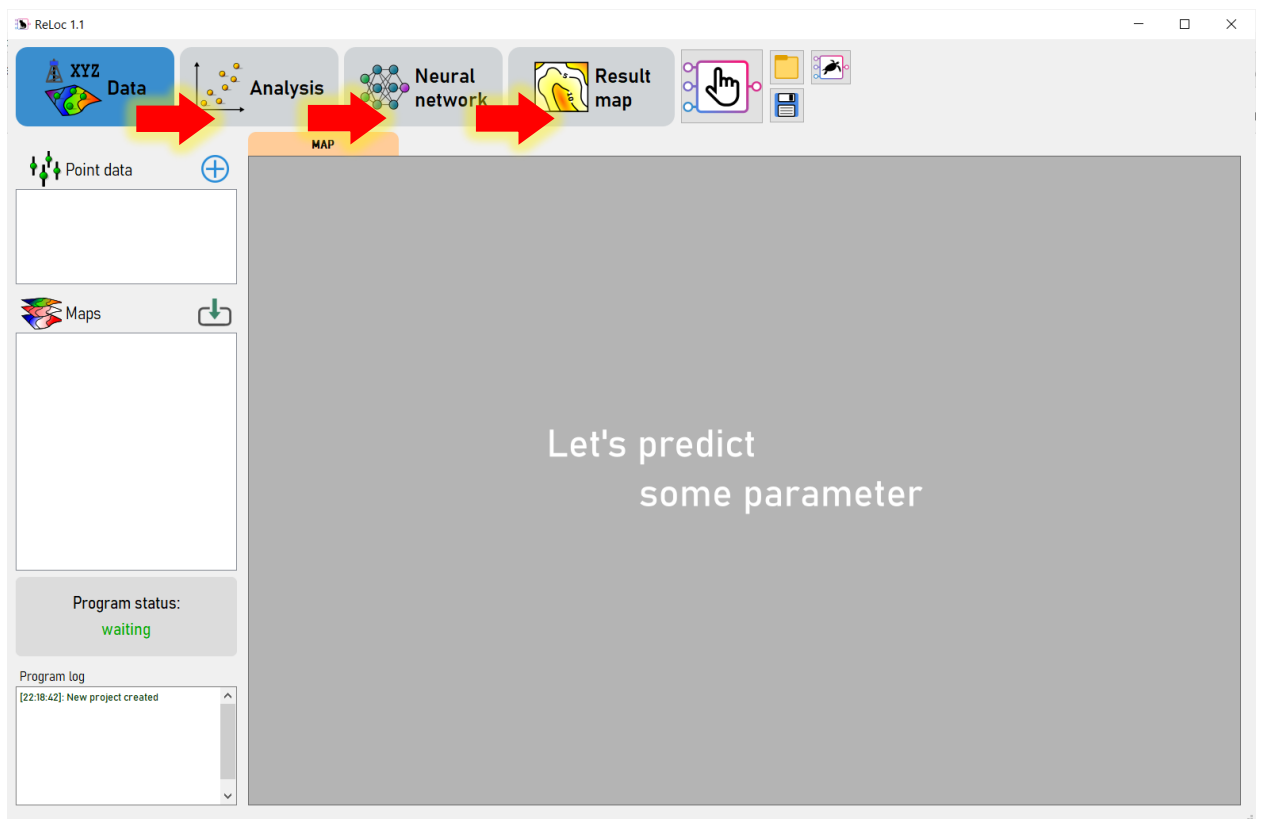
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## Introduction

The ReLoc software allows you to calculate predictive maps of oil and gas reservoir parameters, for example, effective reservoir thicknesses or location of remaining oil (LTRO), using neural networks.

In the ReLoc software, the predictive map of the target parameter is calculated from a non-linear dependence – through a neural network from several input maps that are loaded by the user. In this case, to train the neural network, well point data is used in which the target parameter is known. The user needs to choose such neural network parameters that provide the maximum accuracy of the target parameter prediction.

Working in the ReLoc software is structured in such a way that you go through the path in the main menu from left to right, performing actions in each section of the menu in turn.

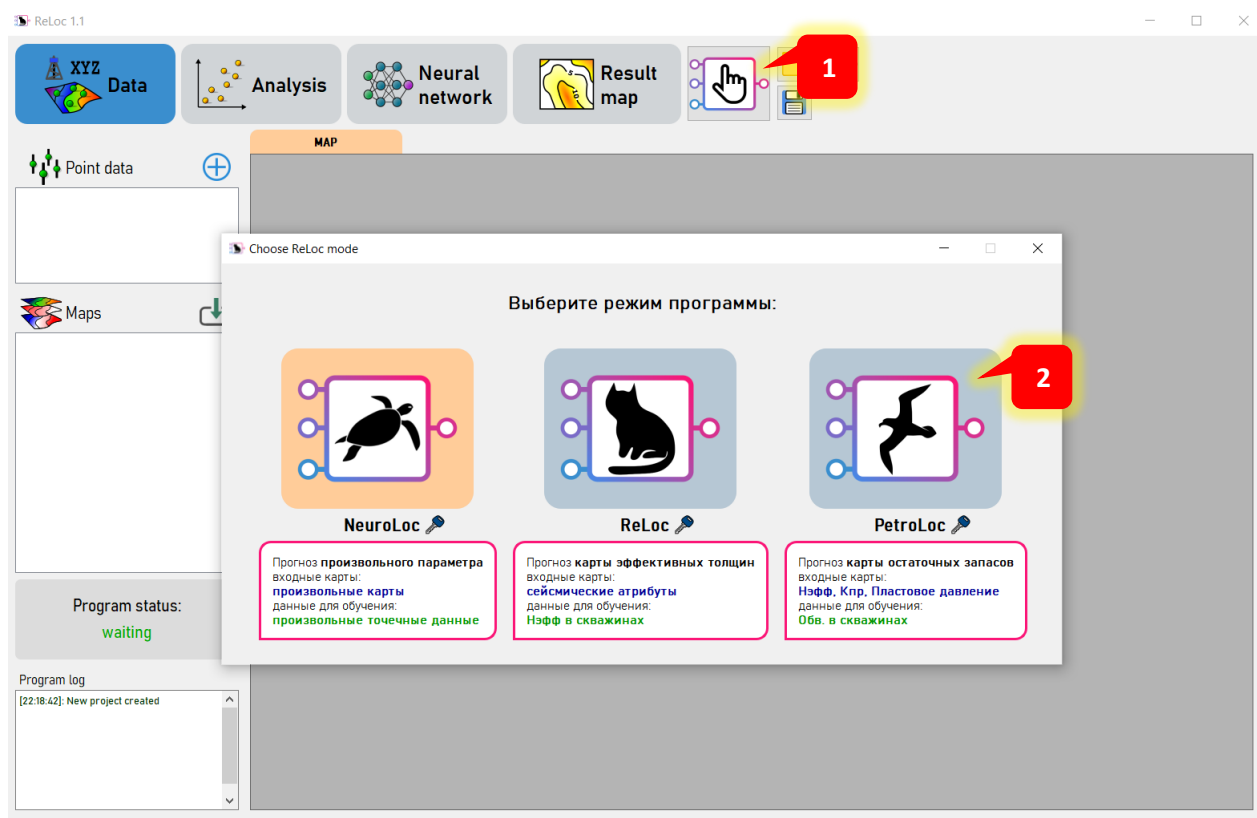


## Program operating modes

In ReLoc version 1.1, three modes are available, depending on which parameter you want to predict:

1. **NeuroLoc** – used to predict a map of an arbitrary parameter using an arbitrary set of maps and point (well) data
2. **ReLoc** – used to predict a map of effective reservoir thicknesses using a set of seismic maps (seismic attributes) and point (well) data
3. **PetroLoc** – used to predict reservoir water cut map and remaining reserves (LTRO map) map using a set of input maps (net pay, average permeability, reservoir pressure) and point (well) data

To switch between modes, you must click on the button with the image of a hand in the upper part of the program, then select the required mode in the window that appears.




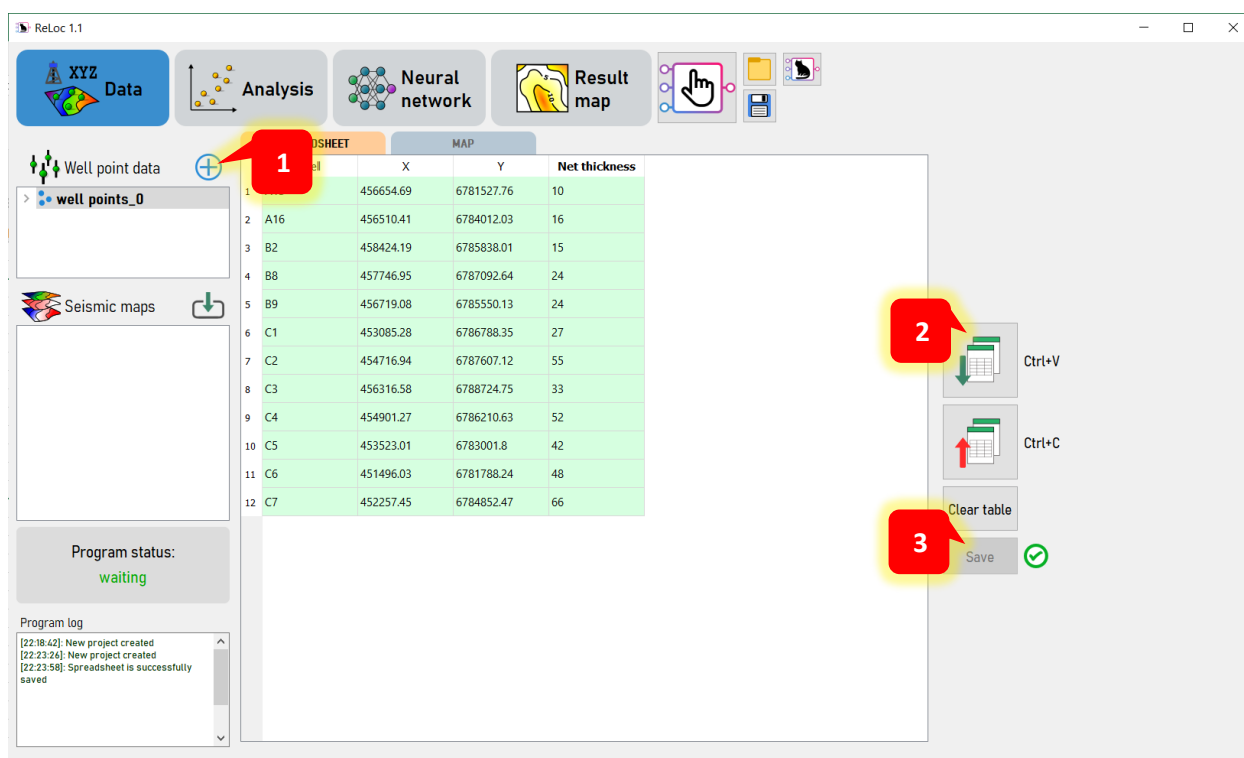
## Loading data

So, let's get down to the first section of the menu: Data. In this section you can upload your input data.

To download data on effective well thicknesses, create an Excel spreadsheet with the following columns:

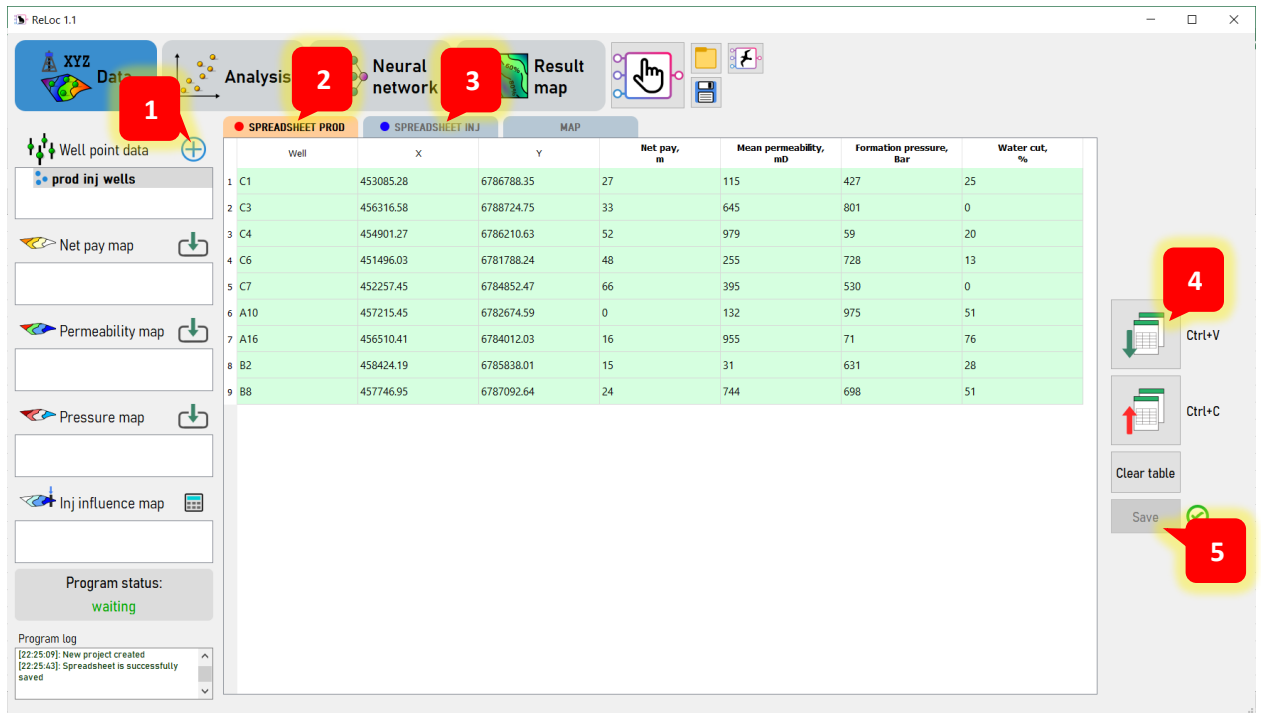
Well name	x – coordinate of formation penetration	y – coordinate of formation penetration	net pay thickness
...	...	...	...


Next, click on the button  in the well tree in the left area of the window, while in the window SPREADSHEET a table will appear where you can insert your prepared data. Paste the data by clicking on the *Paste button*, or by pressing ctrl+v. Then, to save the data, be sure to click on the *save button*.

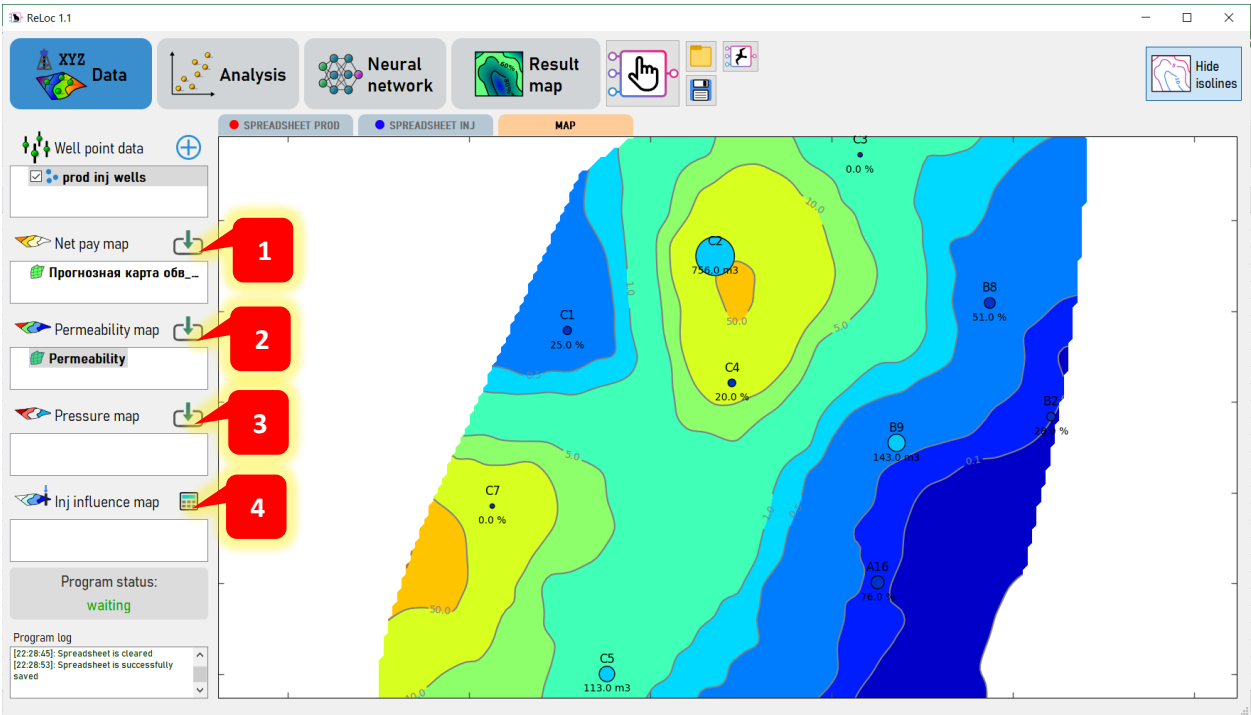
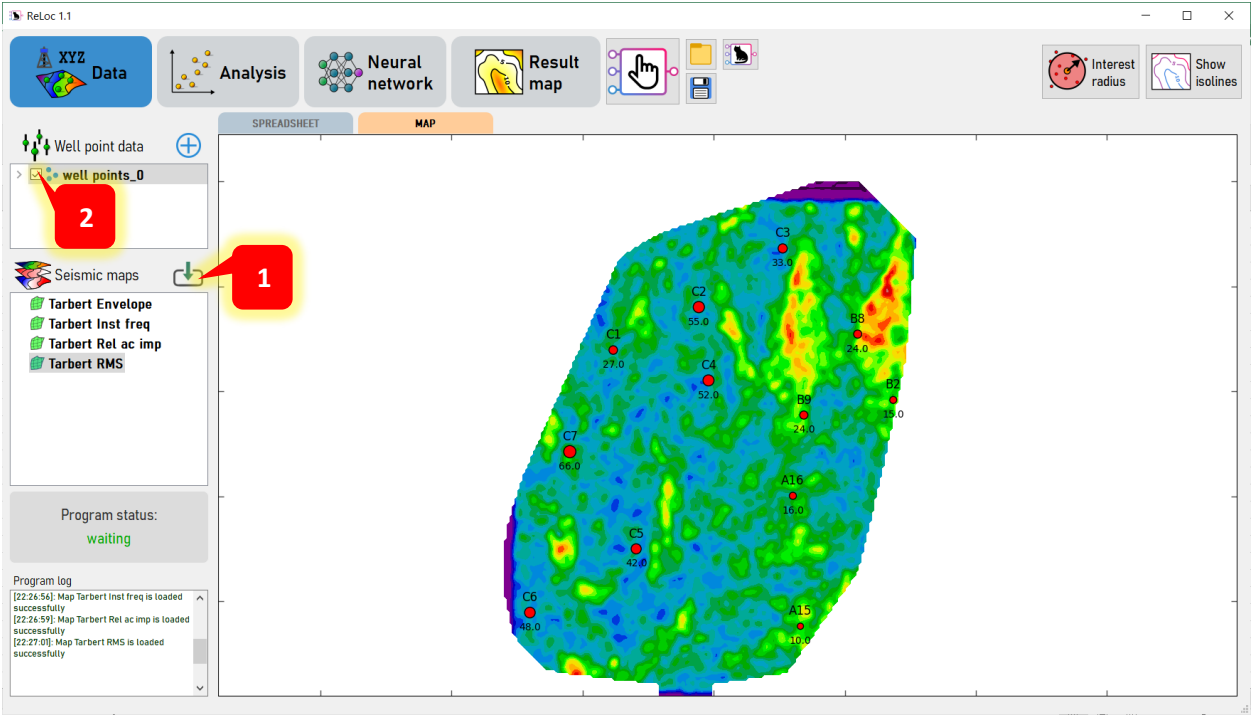


In the case of the PetroLoc mode, it is also necessary to fill in the columns with data with average permeability, reservoir pressure, water cut and cumulated volume of injected water for injection wells. These data must

be downloaded separately for production and injection wells in the respective tabs.



To download input maps, click on the button  , select one or more maps, select one of the IRAP or CPS formats. Wait for all maps to load. You can display maps in a window MAP by clicking on them, as well as wells with effective thicknesses (for ReLoc mode) or water cut (for PetroLoc mode).

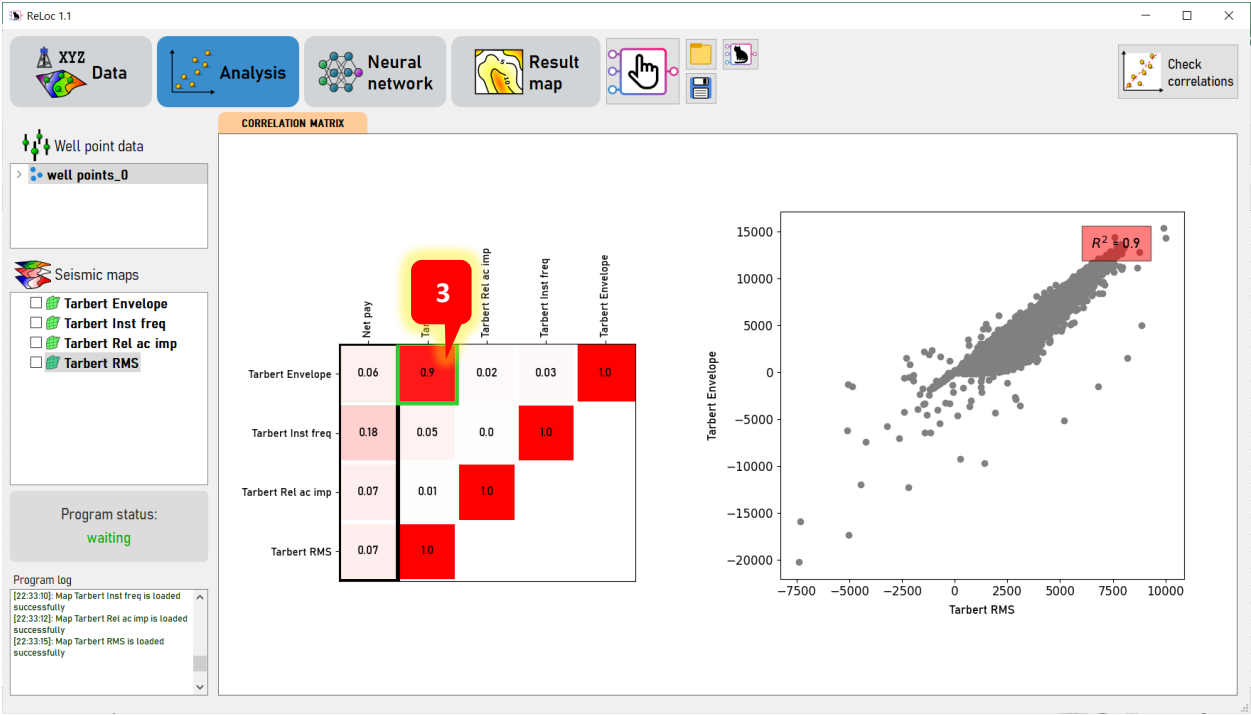
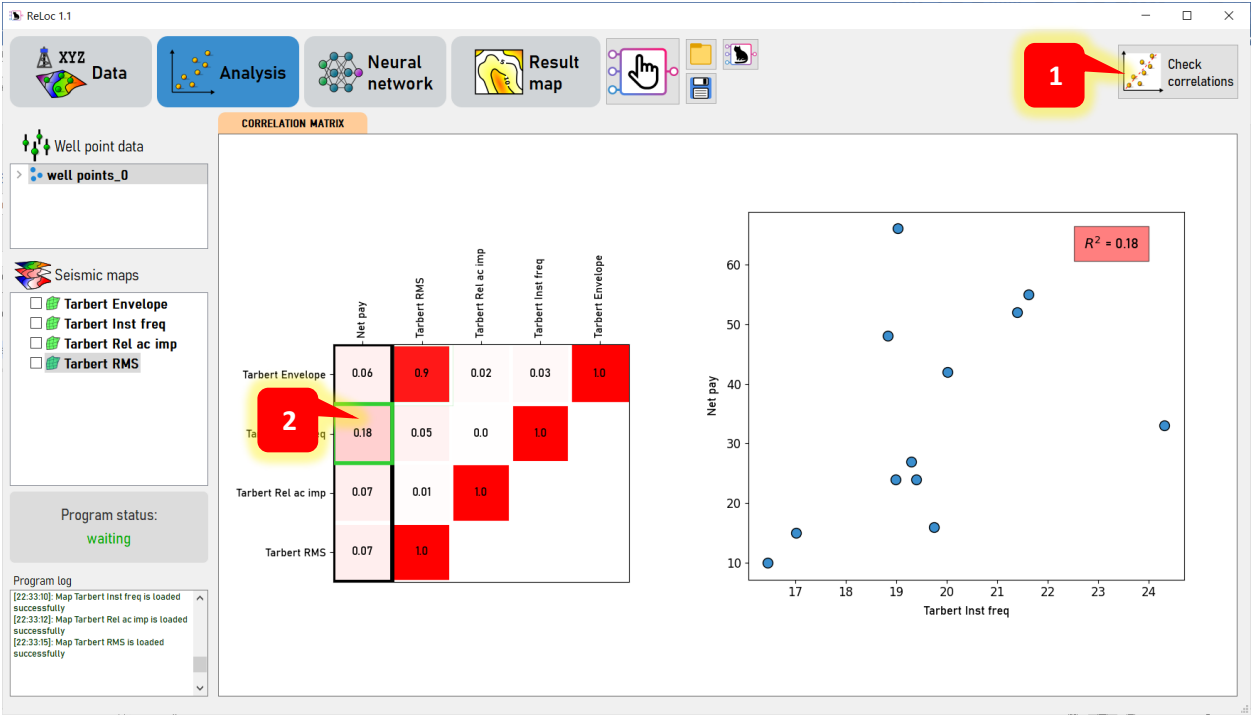


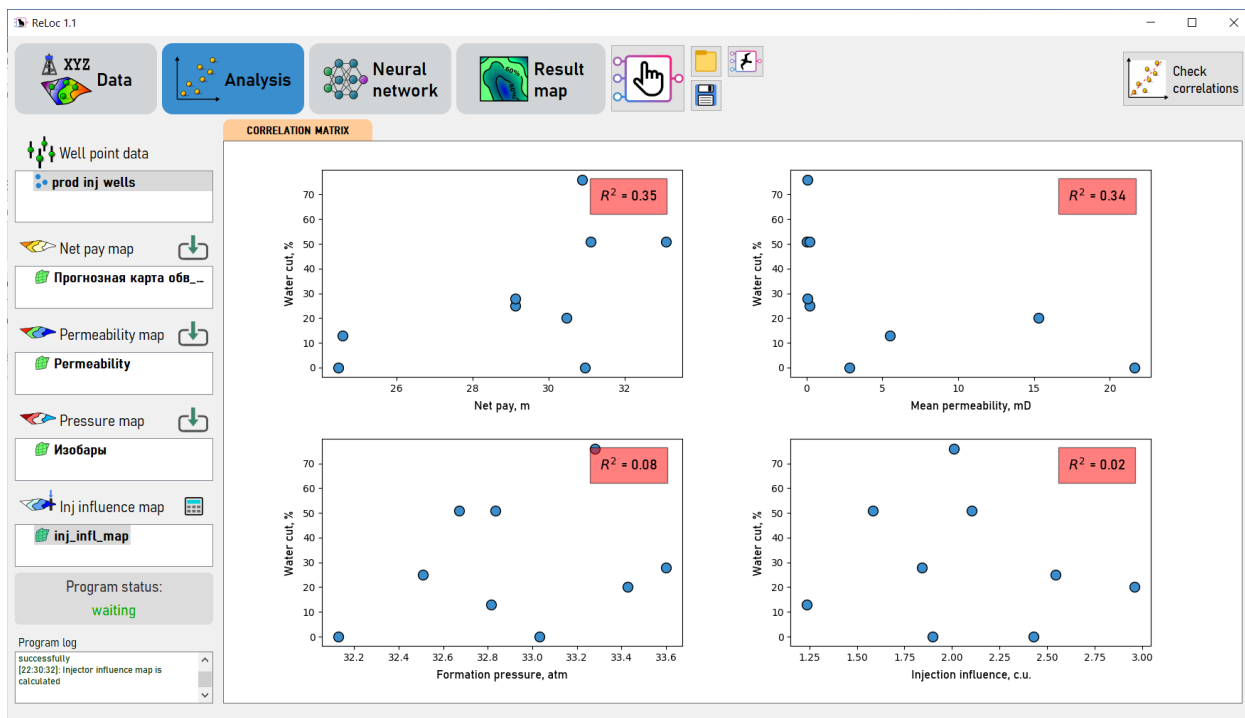


## Data analysis

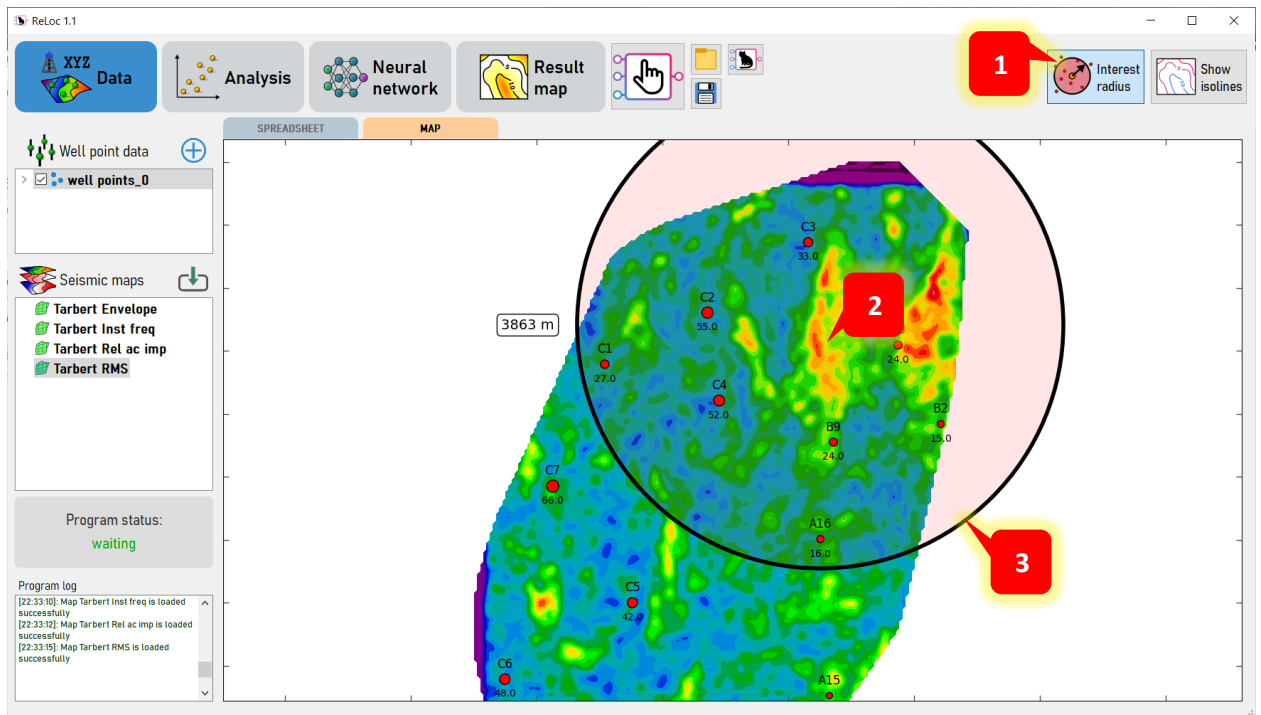
In the second menu section, Analysis, you can analyze the downloaded data. In the upper right corner, click the *Find Correlations button*. After that, a correlation matrix will be displayed on the left, and a cross plot of two parameters (for ReLoc and NeuroLoc mode) or a cross plot between water cut in wells and input maps (for PetroLoc mode) will be displayed on the right.

In the case of the ReLoc (NeuroLoc) mode, the first column of the correlation matrix shows the correlation coefficients between net reservoir thicknesses (target parameter in wells) and seismic attribute maps (input maps). The remaining columns will show the correlation coefficients of seismic maps (input maps) among themselves. By clicking on a certain cell of the correlation matrix, you can see the crossplot of the corresponding parameters. Your task at this stage is, based on the presented correlation coefficients, to select seismic attribute maps (input maps) that will be used to train the neural network. For example, you can exclude maps that have a low degree of correlation with net reservoir thicknesses (target parameter), or maps that have a high degree of correlation between themselves, since they will duplicate information. The choice of maps is carried out by selecting the checkboxes opposite the maps. The first time you press the *Find Correlations button*, the program will select seismic maps (input maps) automatically, then, if necessary, you can change this selection as you wish.





Also, you can take not all wells for analysis and further training of neural networks, but, for example, within a certain radius. To filter wells within a radius, in the section **Data** click on the *Radius of interest button*, then with the first click on the map set the center of the radius, then move the mouse cursor to the desired distance and complete the drawing of the radius with the second click. Please note that after each drawing of the circle, before starting to train the neural network, you must re-check the correlations in the correlation section. After that, in the section **Neural networks** you will see the data already for the filtered radius of the wells.



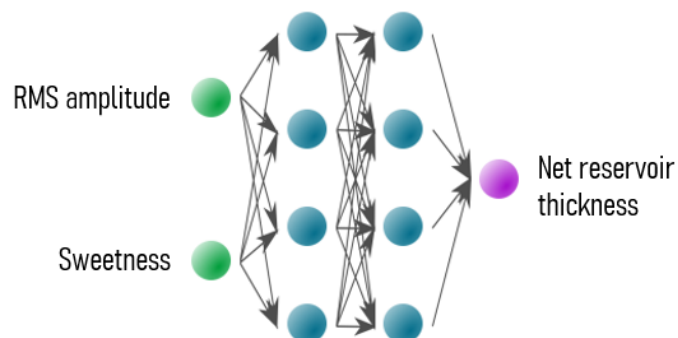
## Creation and training of neural networks, building a predictive map

Next, in the third section of the Neural Networks menu, you can create and train neural networks. But before that, let's say a few words about artificial neural networks.

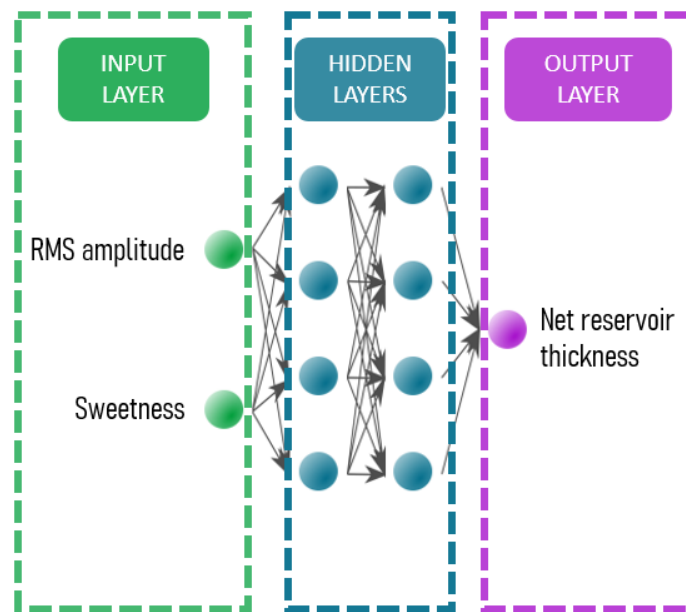
Artificial intelligence and neural networks have entered many areas of our lives, for example, the text that is used in the video version of the manual was also voiced using a neural network. The main application of neural networks in data processing is clustering and regression.

The use of neural networks allows you to find complex non-linear relationships between different data. For example, the cost of renting an apartment can depend not only on its area, but also on the distance to the metro, the year of construction of the house, floor and other parameters. Or, for example, the net reservoir thickness may depend not only on the RMS amplitude attribute, but also on Sweetness and Envelope. So, ReLoc software uses regression - the prediction of the net reservoir thickness value based on the values of two or more independent variables - seismic attributes.

Let's take a closer look at what neural networks are. **Artificial neural network** – it is a system of interconnected and interacting artificial neurons. The figure below shows a multilayer perceptron – one of the simplest feedforward neural networks.



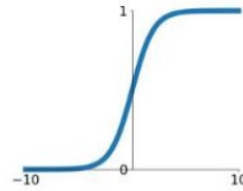
**Neuron** – it is a computational unit that receives information, performs simple calculations on it and transmits it to other neurons. Neurons are combined into layers, in the simplest case, this is the **input layer** (they receive data from the input data), **hidden layers** and the **output layer**. The calculation result of each neuron is transmitted to each neuron of the next layer.



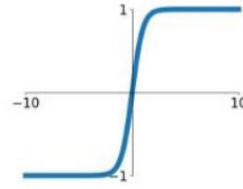
Each neuron has weights, by which the results of calculations of neurons of the previous layer are multiplied. Then the multiplication data in each neuron is added up and, using an activation function, is transferred to the next layer or to the output. An **activation function** – is a function whose argument is the weighted sum of the inputs of the artificial neuron, and whose value is the output of the neuron. The most famous activation functions are sigmoid, hyperbolic tangent, ReLu.

**Sigmoid**

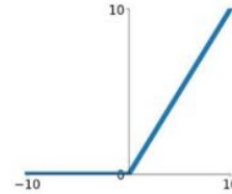
$$\sigma(x) = \frac{1}{1+e^{-x}}$$

**tanh**

$$\tanh(x)$$

**ReLU**

$$\max(0, x)$$

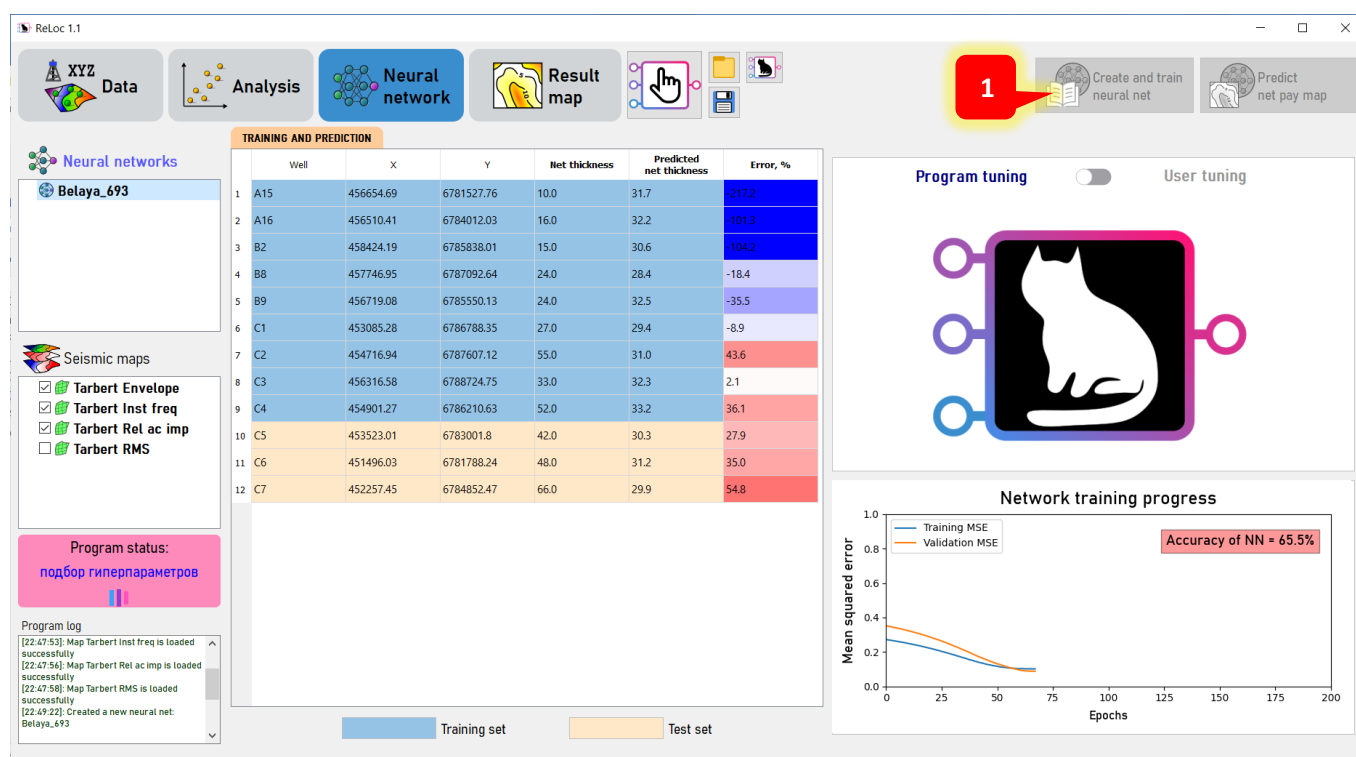


The main advantage of neural networks is the ability to improve their predictive ability through self-learning. During the training of the network, iterative selection of neuron weights takes place in order to achieve the maximum accuracy of the prediction of the target parameter. The number of iterations of weight selection is called **epochs**. The selection of weights for each new epoch is done using **optimizer**. One of the most famous optimizers is the Stochastic Gradient Descent (SGD) algorithm. Thus, with each new epoch, the neural network learns better and better, and **mean squared error (MSE)** decreases. The neural network has other parameters that can be tuned to get the maximum predictive property, these are **number of neurons in hidden layer**, **number of hidden layers**.

So, let's get down to the direct creation of neural networks. In ReLoc, there are two modes for creating and training a neural network: automatically or manually.

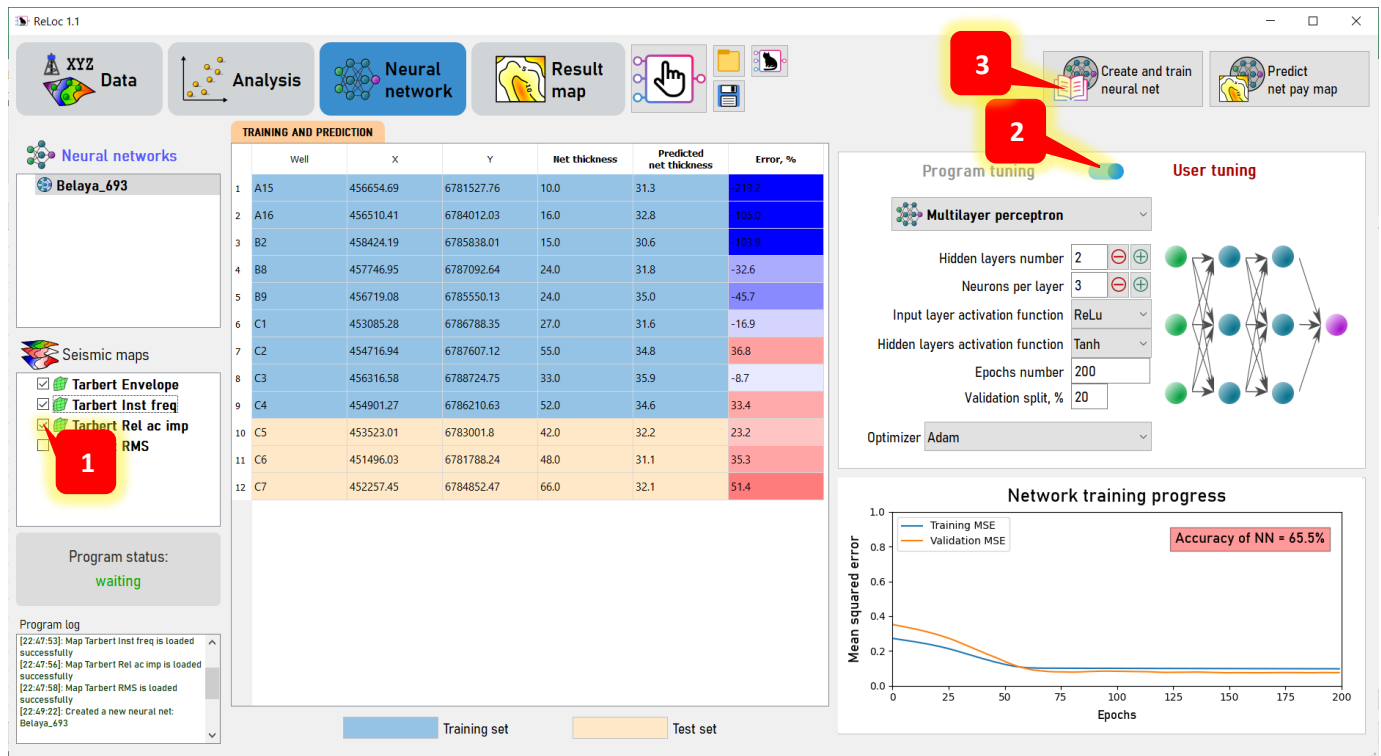
In automatic mode, the program goes through 9 combinations of 2 neural network parameters (number of hidden layers and optimizer), and then selects the neural network that showed the smallest relative error on the test data. To calculate in automatic mode, make sure that the switch is set to the “automatic” position (i.e. the cat sitting in the box is displayed) and click on the *Create and train neural network button* in the upper right corner. As training progresses, the left part of the window will display a table of net

reservoir thicknesses for wells, actual and predicted for the current training epoch, as well as the forecast error in relative percentages (Error, %). The entire sample of wells is divided into trainable (blue cells), which are directly used in training the neural network, and test (beige cells), wells that do not take part in training and which can be used to understand how good the neural network is. The colors of the cells of the last column correspond to the error values, the better the model is trained, the lighter these cells should be. The lower right corner shows the training graph, the change in the standard error of the forecast from the epoch. Wait for the calculations to finish, after which your created neural network will appear in the neural network tree.



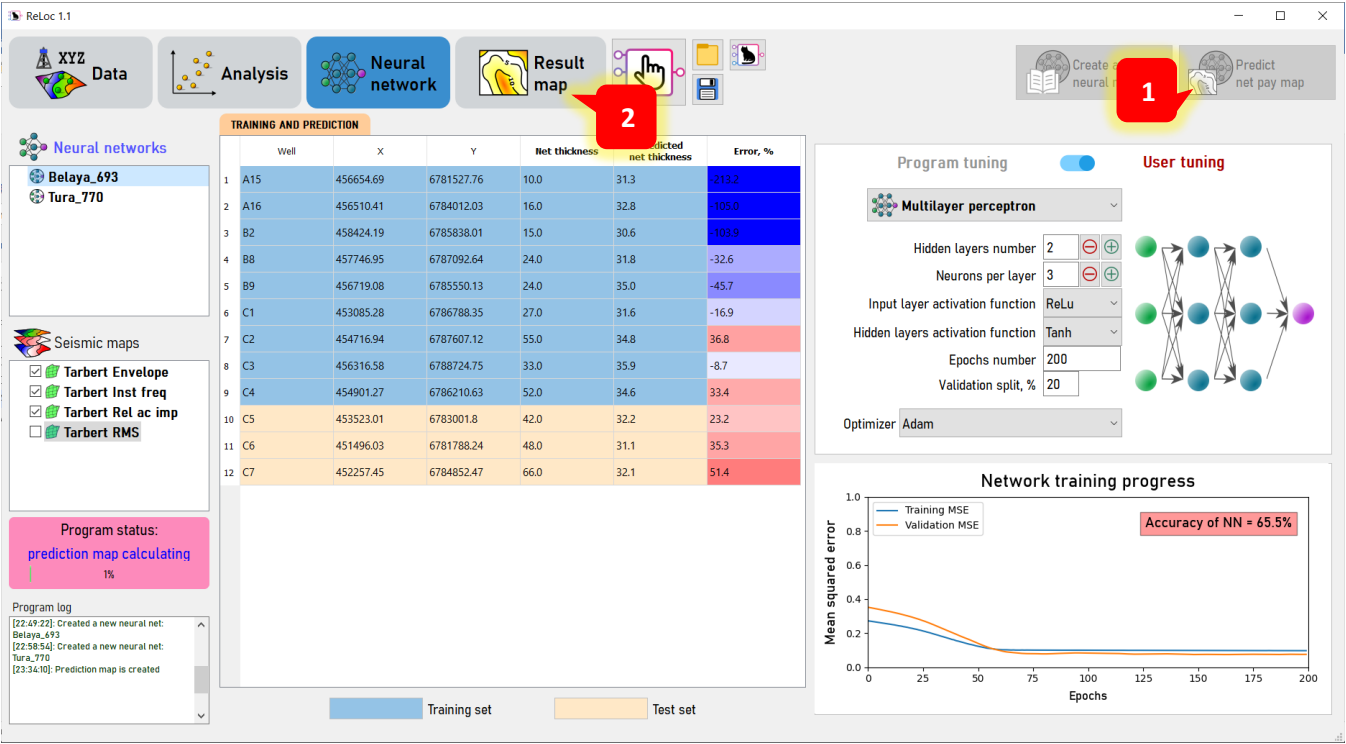
In manual mode, you yourself can adjust the parameters of the neural network, such as: the number of neurons in hidden layers, the number of hidden layers, optimizer, **validation split** – the percentage of data not participating in training, the number of training epochs. After setting the parameters, click on the *Create and train a neural network button* in the upper right corner, after which training will begin. Wait until the end of the calculations, then in the tree neural networks your created neural network will appear.






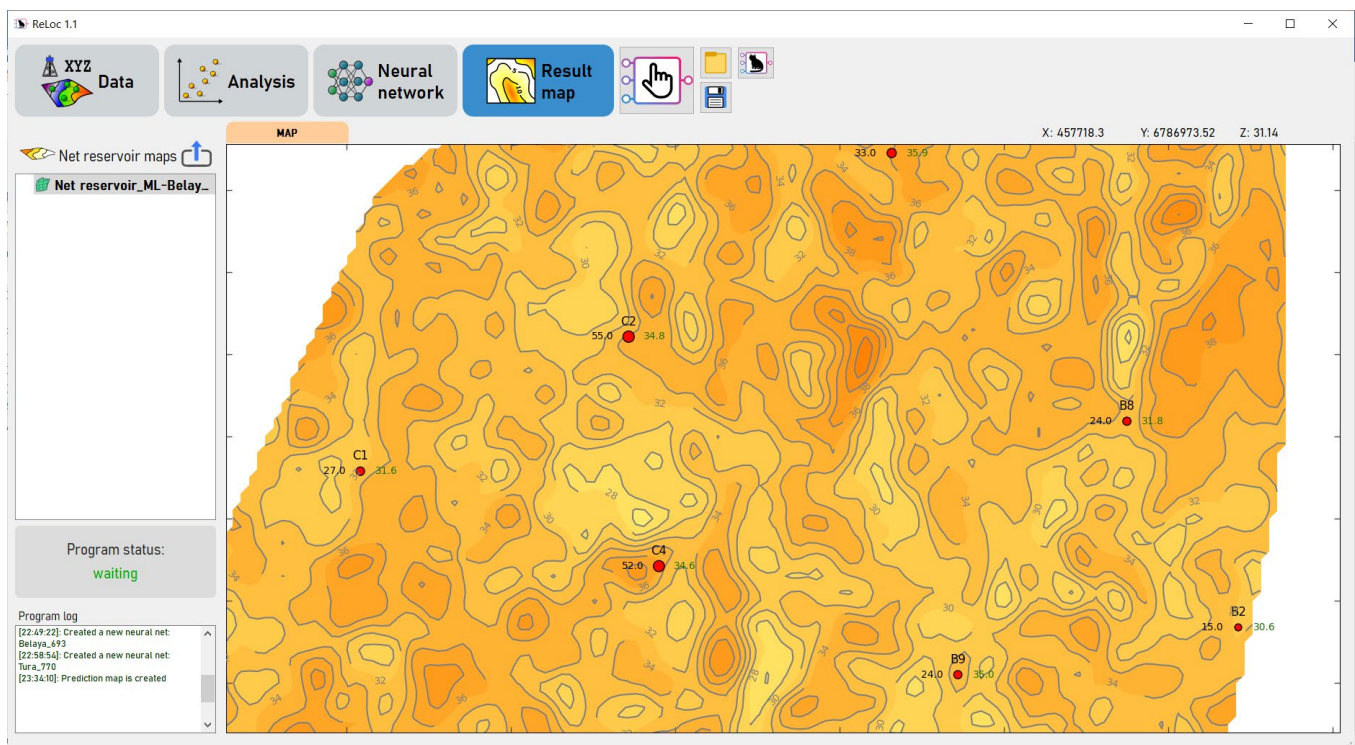
When a certain neural network is selected in this tree, the screen will display the settings that were used during training, as well as a table with calculated predicted well net reservoir thicknesses (for ReLoc mode).

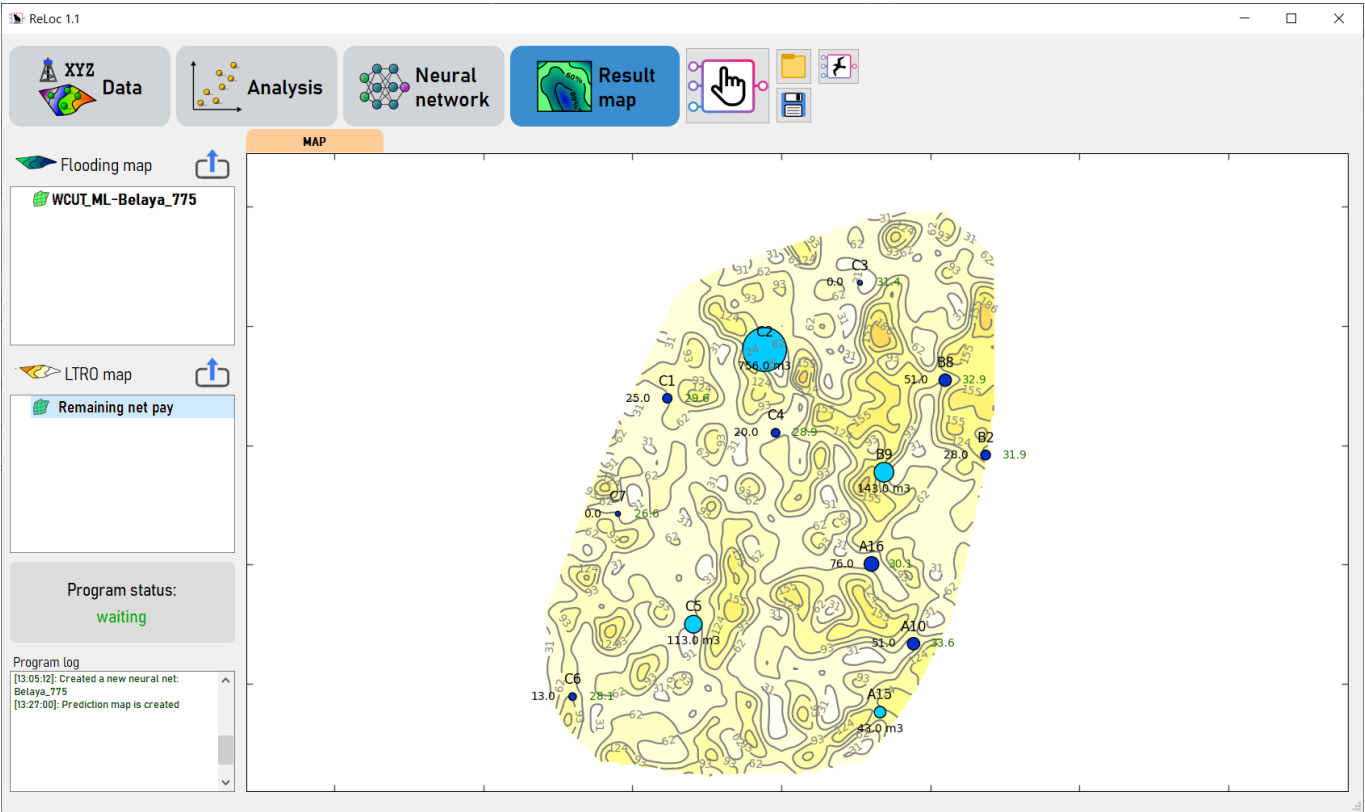
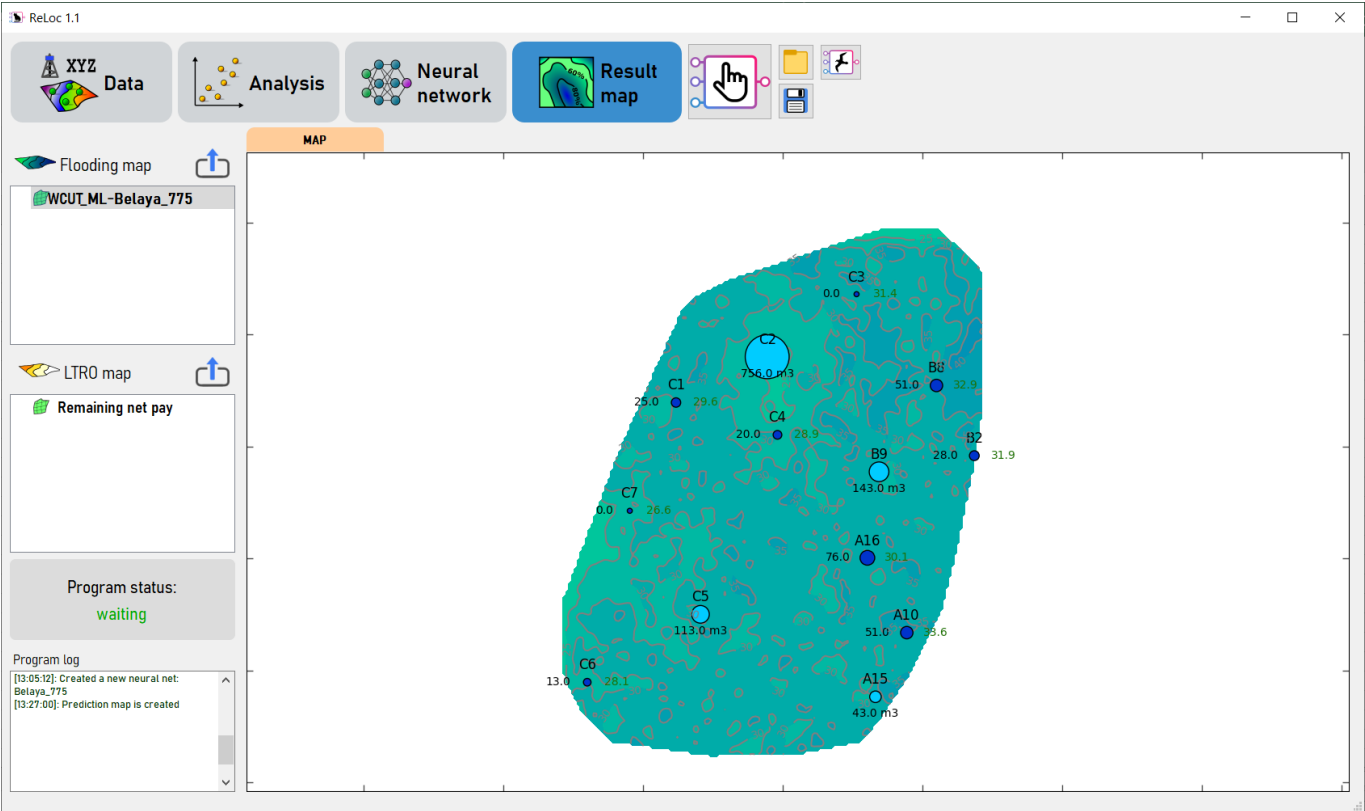
Once you have created a neural network with good predictive ability (for example, the **accuracy** parameter on the training plot is above 85%), you can calculate the net reservoir thickness predictive map (for ReLoc mode) using this neural network. To do this, select your neural network in the tree neural networks and click on the *Build forecast map button* in the upper right corner. Wait for the end of the map calculation, as a rule, this time is somewhat longer than training.



## Analysis and upload of a forecast map

In the fourth section of the menu, **Result map**, you can view your net reservoir thickness prediction map (for ReLoc mode) calculated through the neural network. The map shows the actual (left) and predicted (right) net reservoir thicknesses for the wells. From this data, you can estimate how accurately your neural network predicts effective thicknesses. By clicking on the  button you can export this map in irap classic grid format. For PetroLoc mode you will get current water cut prediction, and remaining net pay thickness maps.





## Working with the ReLoc project

All your work and data in ReLoc can be saved to a project and reopened later if needed.

To save the project, click on the button with the blue floppy disk icon. Next, select the directory and name of your project, click on the "save" button. The project file will be saved as .rlp (reloc project). If your project contains neural networks, then a folder like "*project\_name\_models*" will also be saved with this file. Please note that in this case, when copying the project to another folder, you must remember to copy this folder with neural networks as well.

To open a previously saved project, click the folder button. Select the .rlp file and click on the "*open*" button.

You can also create a new project by right-clicking on this folder icon and selecting the appropriate context menu. By right-clicking on the save button, you can select the menu to save the current project under a different name.