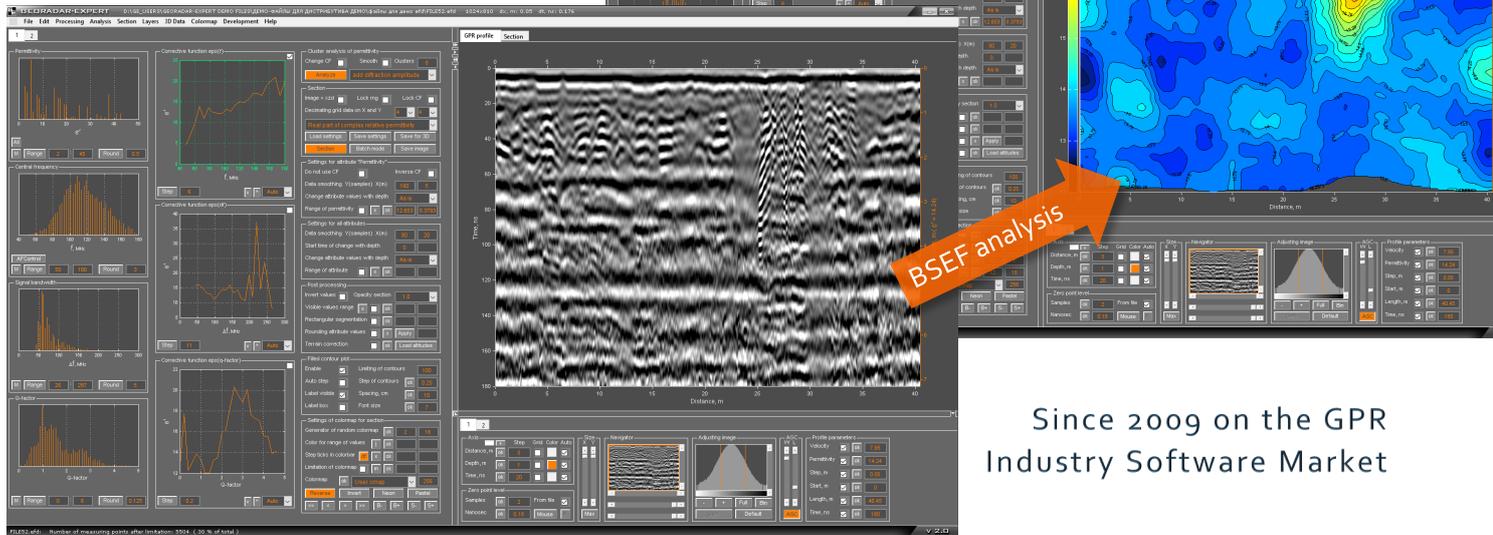


GEORADAR-EXPERT

Software System for Automated
Processing of GPR Data



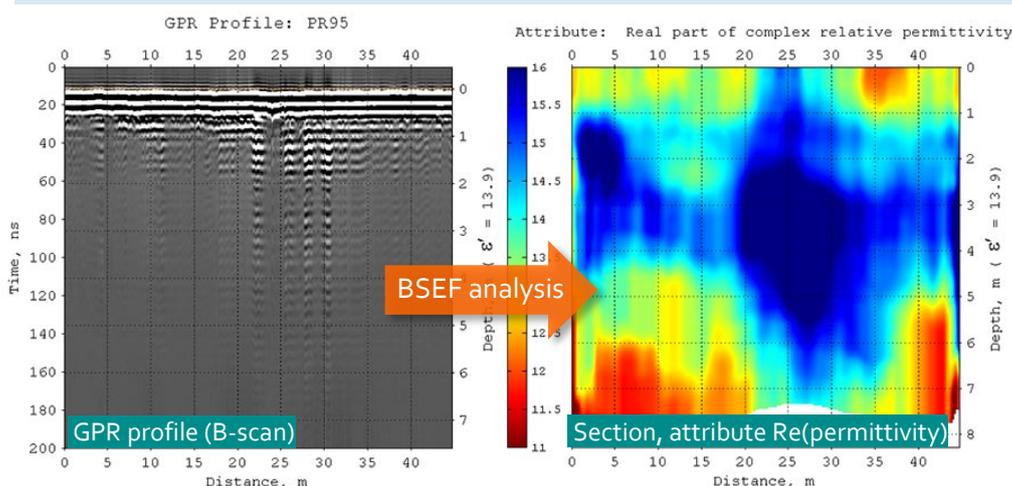
Since 2009 on the GPR
Industry Software Market

GEORADAR-EXPERT software system is designed for the automated processing of GPR profiling data. GEORADAR-EXPERT includes both standard options implemented in many software products for processing GPR data, and algorithms developed specifically for GEORADAR-EXPERT that serve to provide a greater level of informative of GPR research. GEORADAR-EXPERT can work with 2D and 3D GPR data. GEORADAR-EXPERT demonstrates its capabilities most conspicuously when processing difficult GPR profiles. Automation of GPR data processing in GEORADAR-EXPERT allows minimizing the influence of the human factor on the result and saving the time spent on processing.

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Automated Analysis of the Backscattering Electromagnetic Field (BSEF)

- Allows to obtain the result of GPR processing in the form of sections of attributes of electrophysical characteristics of the investigated medium or wave field ($\text{Re}(\text{permittivity})$, Frequency, Signal bandwidth, Q-factor, Loss tangent, Resistivity, Damping rate, Weight water content and much more). Such a representation of the result is the most informative than the amplitude mapping of the GPR profile (B-Scan);
- Effective even in the case of a smooth change in the electrophysical properties of the subsurface medium - i.e. when there are no reflections from the boundaries of the layers on the GPR profile (see the picture below);
- Increases the depth of GPR survey, since the BSEF algorithm has good noise immunity;



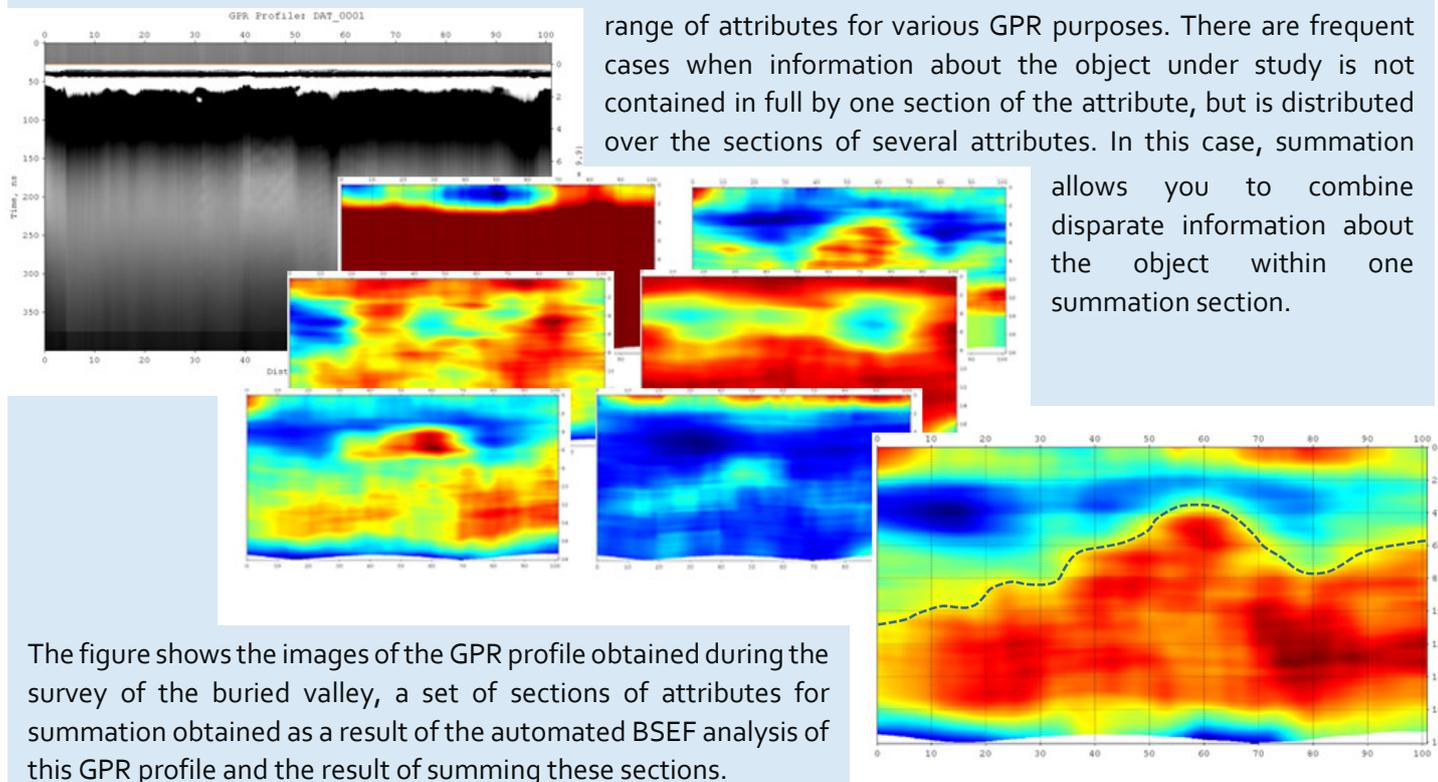
- Increases the speed of processing of GPR data, which is important for the constantly increasing volumes of georadar work;
- Opens new opportunities for exploring complex subsurface media.

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Module for summing heterogeneous data

The **Summation** module is designed to summarize sections of heterogeneous attributes or cross-sections of a 3D assembly. As a result of the summation, artifacts caused by the accumulation of errors in the process of collecting and processing GPR information are eliminated, and the model of the subsurface environment is reconstructed from the summation elements (attribute sections or cross-sections of the 3D assembly), each of which contains only some of the useful information. The GEORADAR-EXPERT software contains a fairly wide

range of attributes for various GPR purposes. There are frequent cases when information about the object under study is not contained in full by one section of the attribute, but is distributed over the sections of several attributes. In this case, summation allows you to combine disparate information about the object within one summation section.



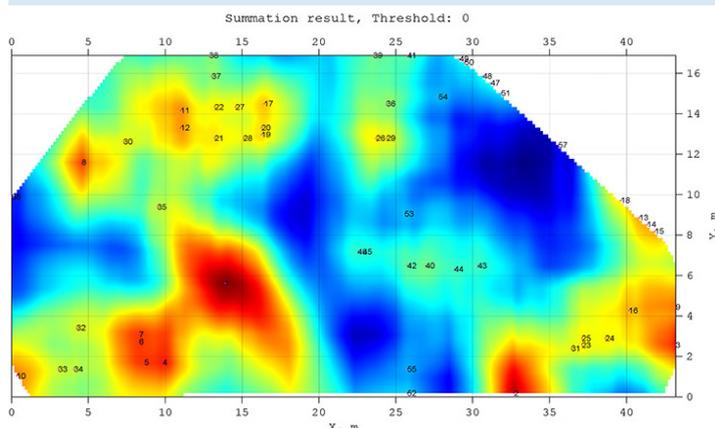
The figure shows the images of the GPR profile obtained during the survey of the buried valley, a set of sections of attributes for summation obtained as a result of the automated BSEF analysis of this GPR profile and the result of summing these sections.

The GPR profile is not very informative at depths of more than two meters, but the depth of the buried valley, according to a priori information, exceeds this value. On the sections of the attributes, some details of the buried relief are visible, however, each of the sections separately does not provide complete information about the structure of the studied subsurface. The summation operation made it possible to bring these disparate fragments of useful information into one whole. The relief of the buried valley on the summation section is well traced everywhere. In the figure, the relief of the valley is marked with a dotted line. This example shows how the use of the summation module made it possible to effectively solve the problem of insufficient information content of the ground penetrating radar profile and individual sections of the attributes created from the results of the automated BSEF analysis of this profile.

In addition to summation, the Summation module implements the function of automatic detection of local maxima on the summation elements and on the summation result and saving these data to the MS Excel format table.

	A	B	C	D
1	Summation result peaks table			
2	The result of summing the sections:			
3	Frequency, Basement floor, Section X-Y, 0.2 m on Z-axis, Invert data: Yes			
4	Re (permittivity), Basement floor, Section X-Y, 0.2 m on Z-axis, Invert data: No			
5	Threshold: 0			
6	Number	Value	X, m	Y, m
7	1	13.892	5.633	
8	2	0.938	32.696	0.171
9	3	0.852	43.2	2.561
10	4	0.846	9.826	1.707
11	5	0.822	8.64	1.707
12	6	0.817	8.301	2.731
13	7	0.817	8.301	3.073
14	8	0.807	4.574	11.608
15	9	0.759	43.2	4.438
16	10	0.751	0.339	1.024

Typically, local maxima are indicators of the presence of a defect, the presence of an anomaly or a local object in the studied subsurface medium. With the help of this function, the user quickly receives the marks of the position of local maxima using markers on the image of the summation element or the summation result, as well as a list of coordinates of these markers with the values of local maxima.



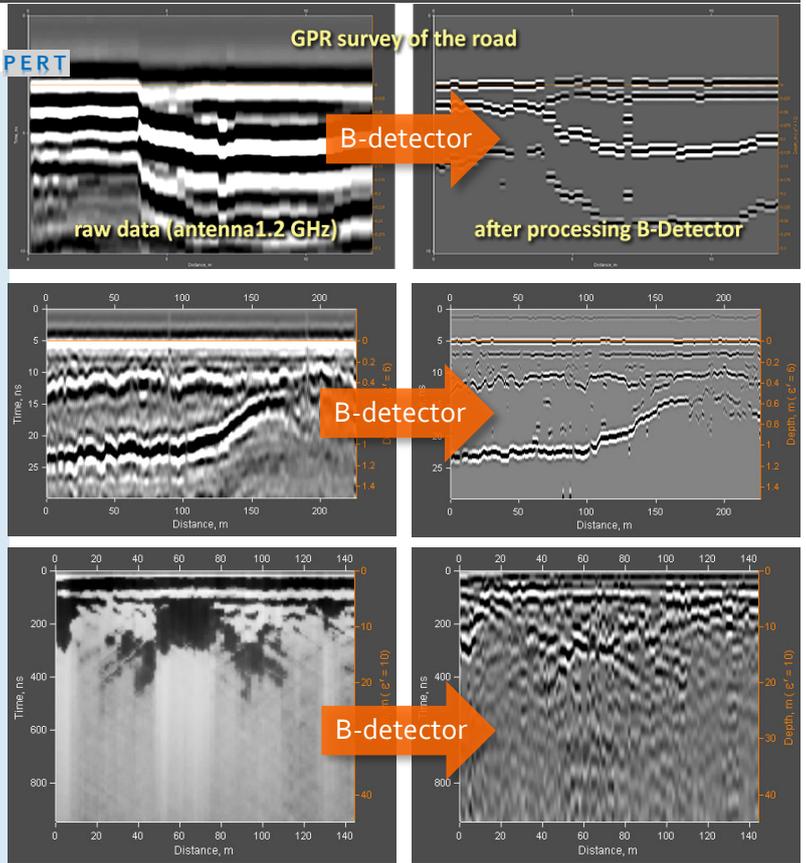
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B-detector

Method B-Detector (Boundaries Detector) is designed to detect boundaries of layers and increase the vertical resolution of signals of the GPR data.

The main advantages of the B-Detector method:

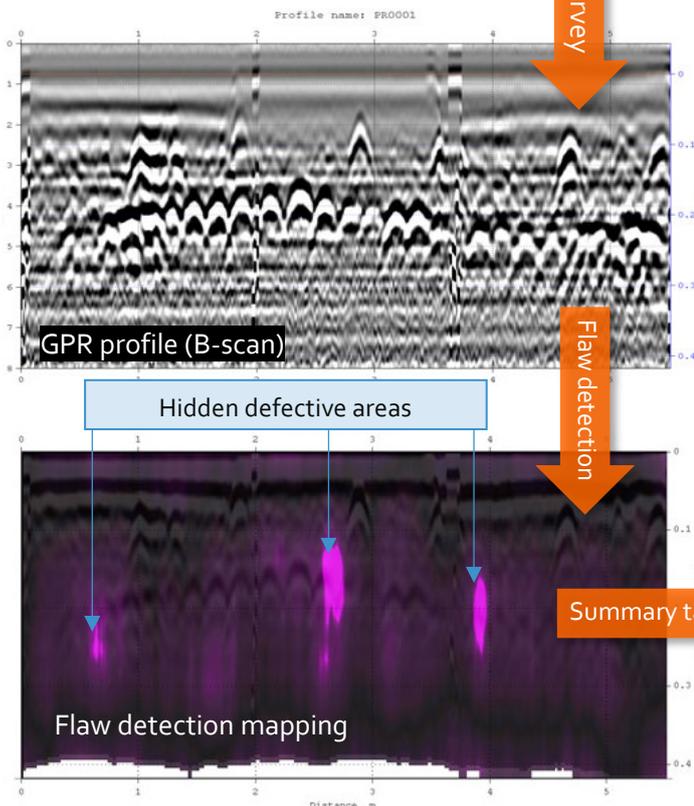
- Effectively improves the vertical resolution of GPR signals;
- Improves positioning accuracy of layer boundaries;
- Extends the application of low-frequency GPR: after processing low-frequency GPR data using the B-Detector method, the GPR signals look as if they were obtained by a high-frequency GPR, but with a penetration depth similar to a low-frequency GPR.



Using the B-Detector method, it is possible to solve a wide range of research tasks requiring, at the proper depth of the survey, to provide high data resolution, positioning accuracy of boundaries and processing speed of GPR data. Especially effective is the use of the B-Detector method in the road and rail industry, where traditionally a large volume of GPR profiling.

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GPR survey of the support beam



Flaw detection

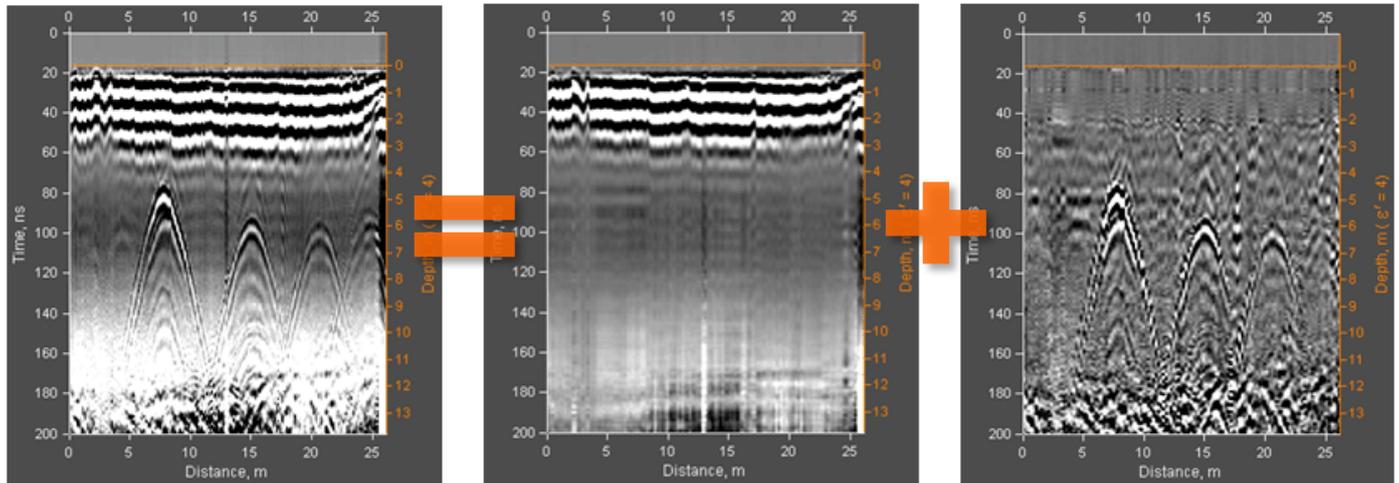
Detection of hidden defects in concrete building structures or in layers of road pavement. Local areas of low-density ground can also be detected. Flaw detection is performed by analyzing the Q-factor attribute, which is the result of an automated BSEF analysis. Based on the results of the flaw detection, GEORADAR-EXPERT generates a summary table in MS Excel format, where the color indication is used as additional information about the condition of the objects. Red, yellow and green colors are used to display poor, satisfactory and good condition of objects.

	A	B	C
1	Flaw detection		
	Profile	Length,m	Percentage of defect
2	PR0001	5.504	5 (bad condition)
3	PR0005	5.712	5.1 (bad condition)
4	PR0006	5.52	3.5 (bad condition)
5	PR0013	4.768	0 (good condition)
6	PR0014	4.984	0.2 (good condition)
7	PR0015	5.064	0 (good condition)
8	PR0017	2.848	0.1 (good condition)
9	PR0018	2.912	1.6 (satisfactory condition)
10	PR0019	2.928	0.8 (good condition)

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Wave Decomposition

Decomposition of GPR signals into components in order to isolate or suppress single-type waves. If decompose the GPR signal and then restore it, excluding some decomposition levels, for example, containing information about interference, then this interference will not be present on the restored GPR signal.



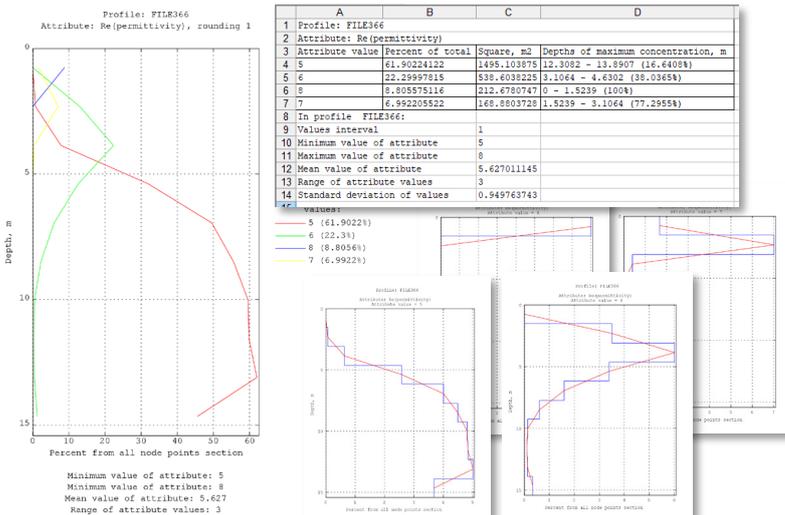
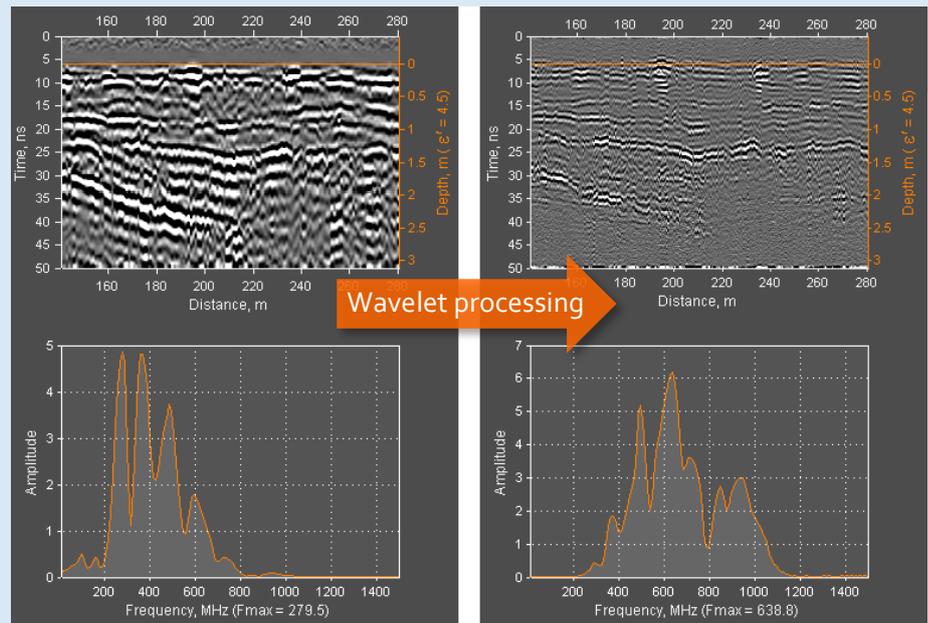
Raw GPR data

Horizontally oriented GPR signals

GPR diffracted waves

Wavelet processing

Increasing the resolution of GPR data by using wavelet processing of GPR signals. The figure shows a fragment of the GPR profile before the wavelet processing (left) and after (right). Under each image the corresponding spectrum of signals is shown. As a result of the wavelet processing, the central frequency of the GPR signals (Fmax) has increased by more than two times - from 279.5 MHz to 638.8 MHz, and the localization of reflections from the layers boundaries has improved.



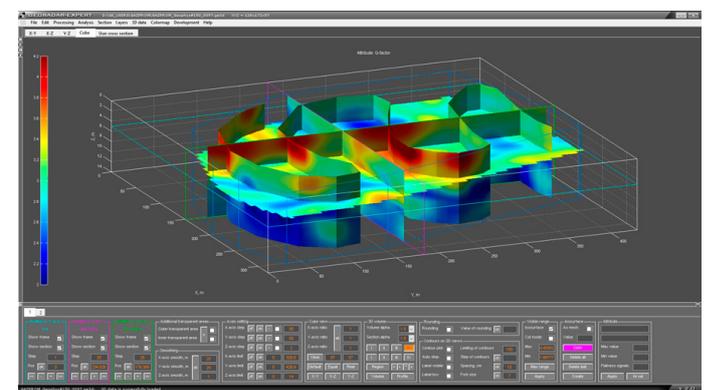
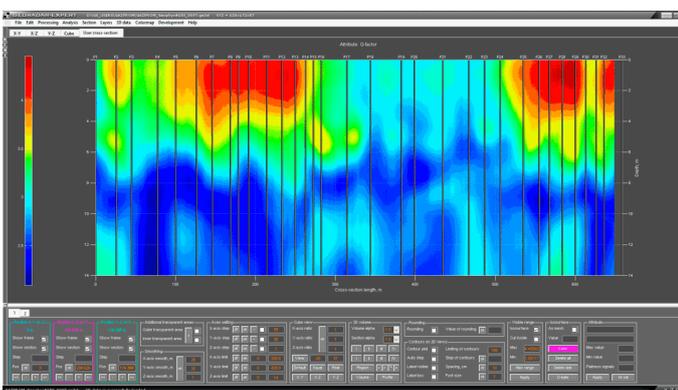
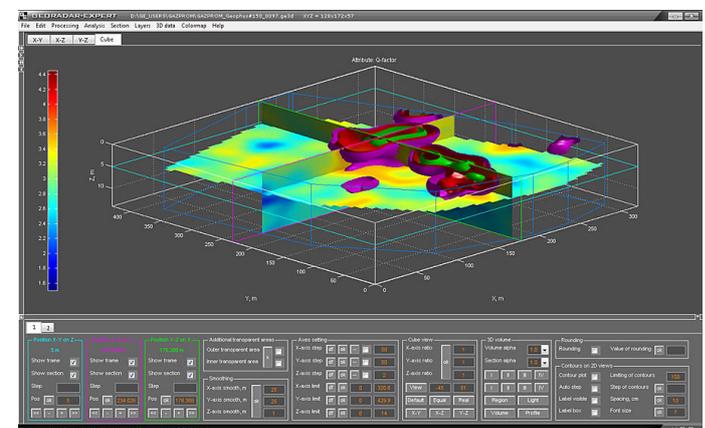
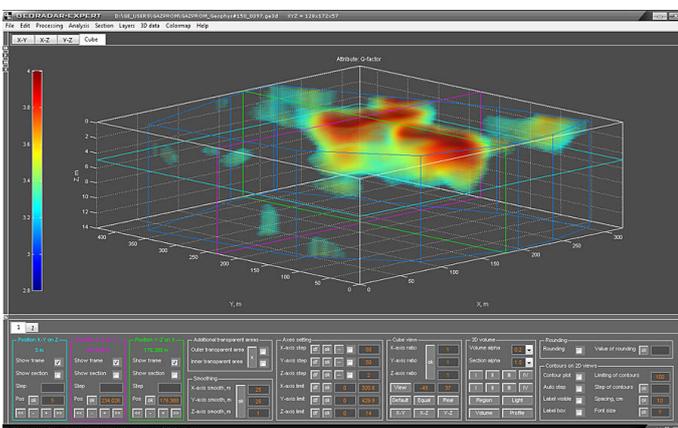
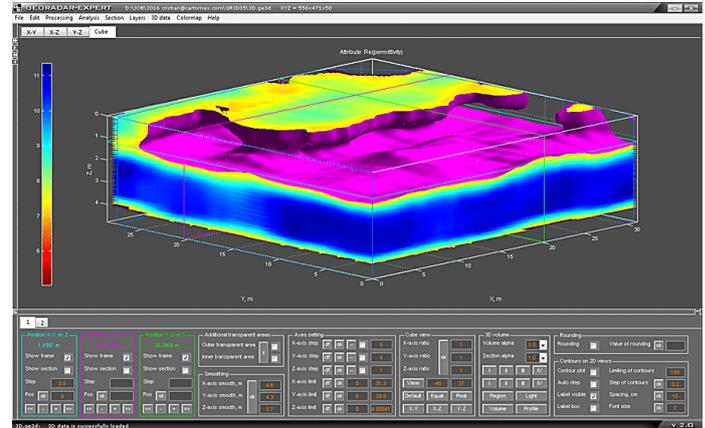
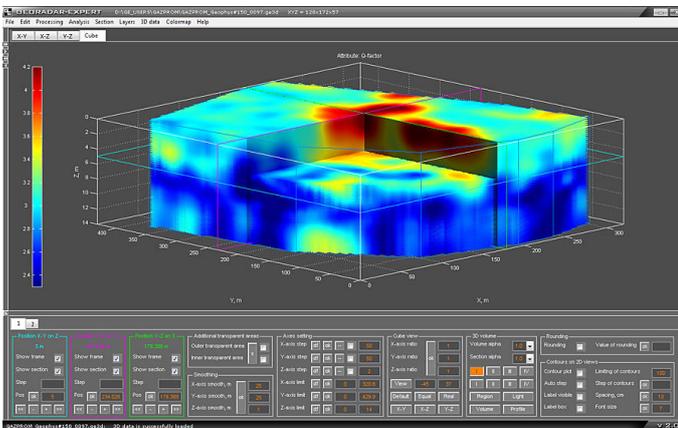
Spatial Analysis Attributes (SAA)

Using the SAA module, the distribution of the various attribute values in depth is analyzed. The spatial analysis can be performed for sections created by the results of the automated analysis of BSEF, and for 3D assembly of these sections.

SAA results are saved as images of spatial distribution curves of attribute values and MS Excel tables that contain statistical information.

3D visualization

To obtain the most complete information about the subsurface environment, the grid GPR survey method is used. The GEORADAR-EXPERT provides visualization of the results of the grid GPR survey in the form of 3D assembling of sections, obtained based on BSEF analysis of GPR profiles of unequal length and arbitrary orientation.

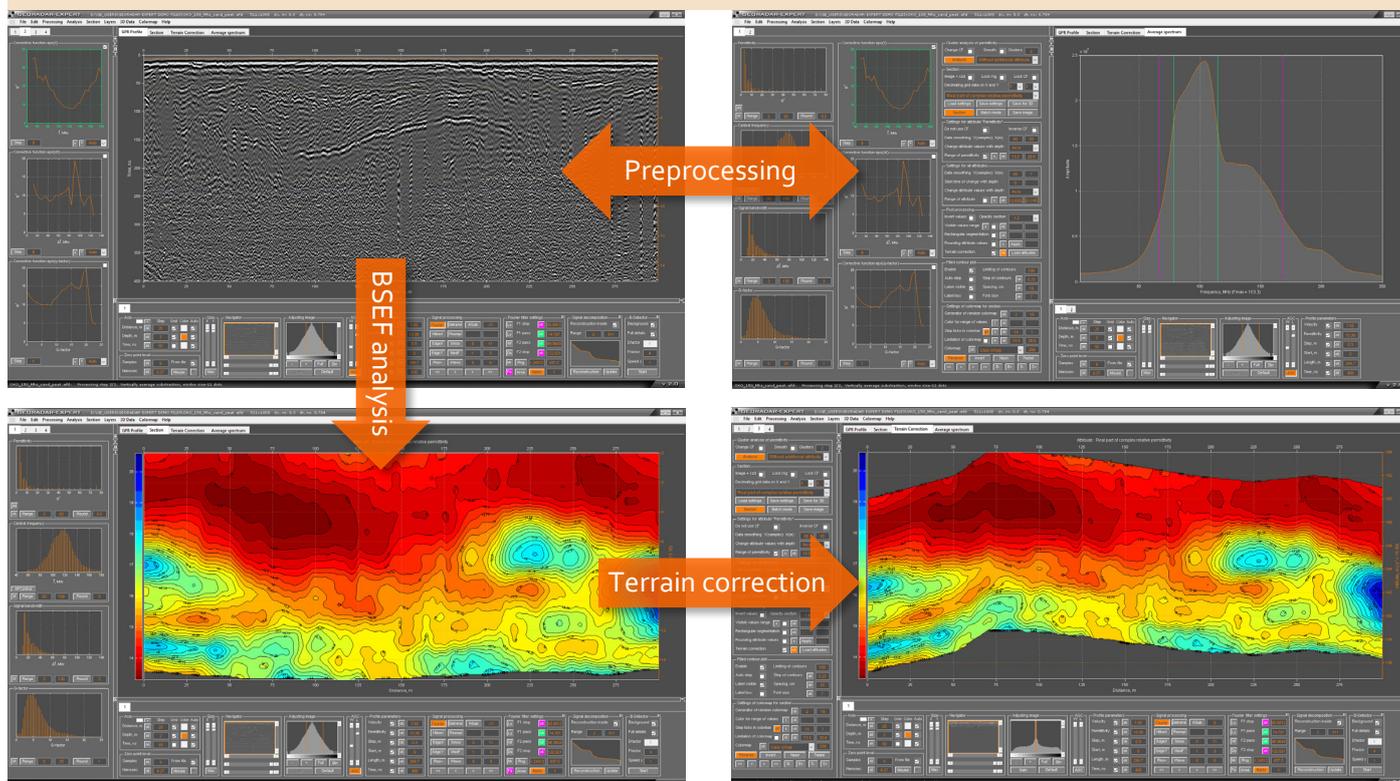


In the 3D visualization mode, the user can:

- Create arbitrary curvilinear sections of 3D assembly and save them to a file for later use;
- Cut out arbitrary areas of the 3D assembly;
- Track the change of the 3D assembly attribute with the change of depth at a given point (Logging trace). Save Logging trace data to an image file and a text file;
- Picking the boundaries of layers, save to a file and load them from a file;
- Perform all the necessary manipulations with the 3D assembly - rotate in all planes, change the positions of the orthogonal sections, control the light source, turn on and off the display of the 3D assembly elements, control the parameters of the axes, change the rounding and smoothing of the attribute values, adjust transparency and much more;
- Create isosurfaces. An isosurface is a three-dimensional analog of an isoline. It is a surface that represents points of a constant value within a volume of space of 3D assembly;
- Save the 3D assembly image and its slices. It is possible to save to scale.

In addition to the above features, GEORADAR-EXPERT contains all the necessary options for processing and visualization of GPR data. Here are some of them:

- Methods of GPR signal processing: various frequency filters, muting, average subtraction, detrend, dewow and much more;
- Editing GPR profiles - resampling, reversing, trimming and combining, time-zero and geometry correction, velocity analysis, terrain correction etc.;
- Manual and automatic modes of picking the boundaries of layers on the GPR profile, the attribute section or slice of the 3D assembly. Saving these boundaries to a file for further work with them, as well as export data about the position of boundaries to the MS Excel format table;
- Exporting the GPR profile data, the attribute section or slice of the 3D assembly into a text file or in the grid format GRD of the Golden Software Surfer. The presence of export from GEORADAR-EXPERT to GRD format opens the possibility to export the results of processing of the GPR data via Surfer to the format DXF (AutoCAD Drawing), KML and KMZ (Google Earth), MIF (MapInfo Interchange Format) and many other formats;
- Saving GPR signal processing flow in a file for later use. The presence of the batch processing mode of the GPR profile allows you to apply a processing flow for several files. This is convenient when you want to process many profiles at once - GEORADAR-EXPERT automatically downloads the profile file, processes it and saves the processed data on the HDD of the computer;
- GEORADAR EXPERT contains all the necessary controls for visualization of GPR data and processing results, as well as tools for editing the color map of the attribute section or 3D assembly. User-created color maps can be saved to a file for later use. In addition, GEORADAR-EXPERT already contains several dozens of ready-made color maps for different tasks.



COMPATIBLE WITH WINDOWS XP, VISTA, 7, 8, 10, 11

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