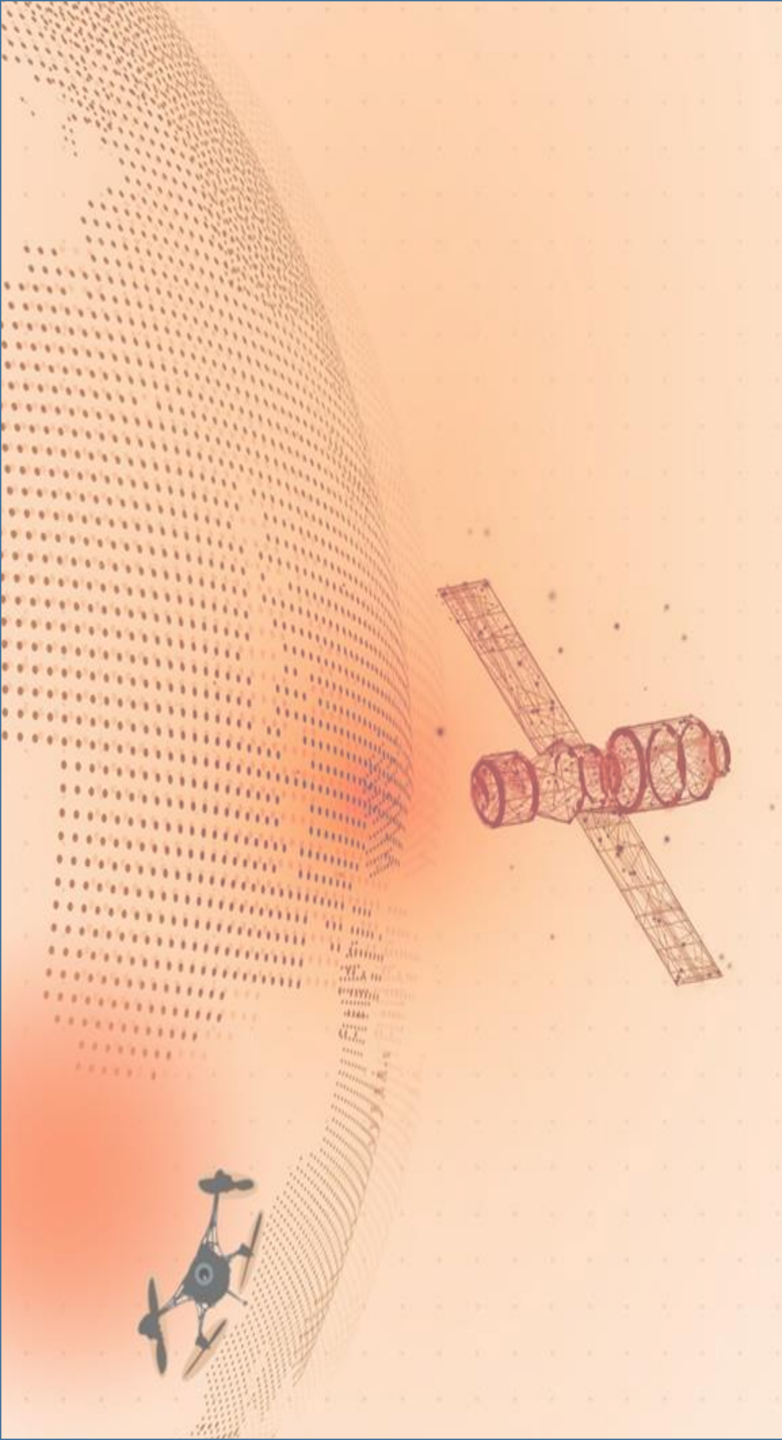


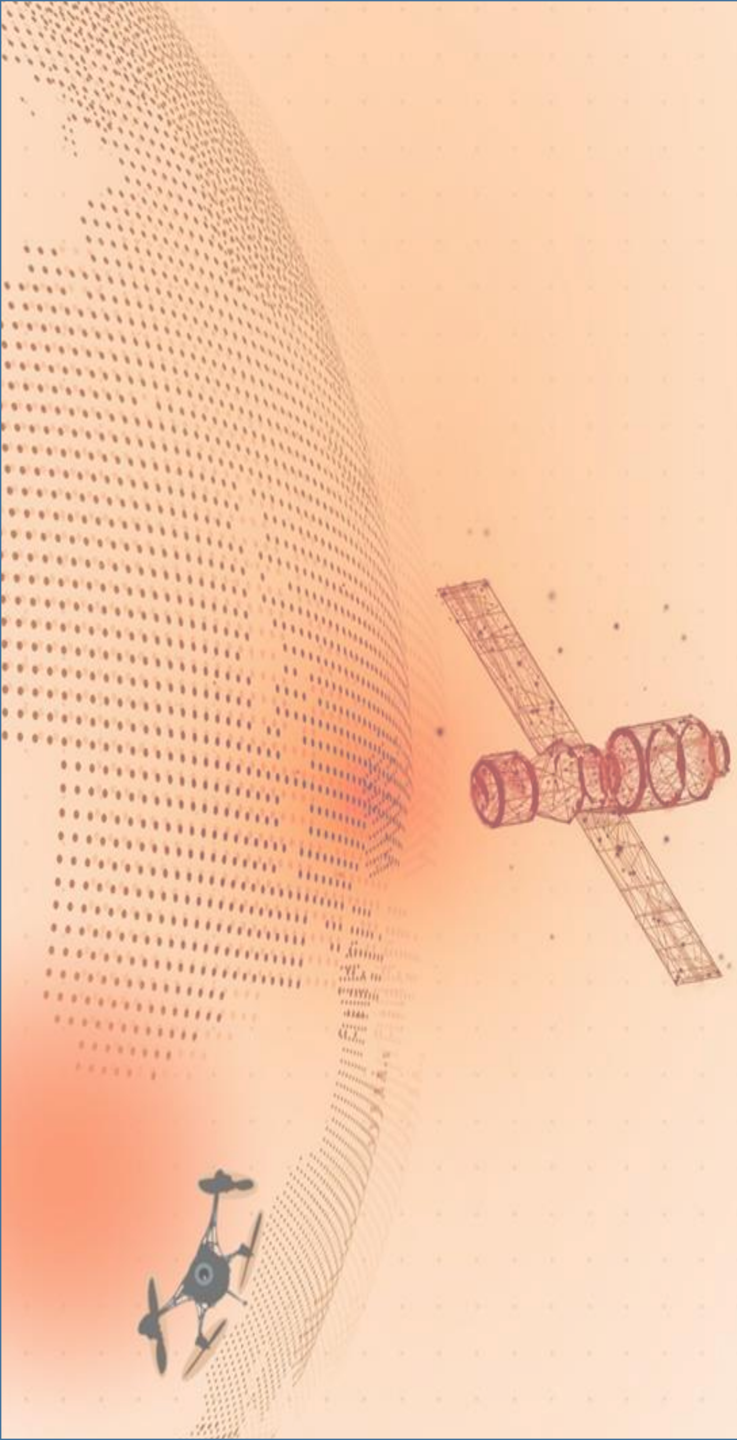
Center of Aerospace Technologies ltd

Radio-Thermal Imaging Technologies for Construction

Center of Aerospace Technologies ltd

The basis for high-quality design and construction of buildings, structures and other infrastructure facilities, as well as the routes of main roads, pipelines and other linear structures, is reliable information about the engineering-geological structure of the base of the construction site and the geodynamic conditions of the construction area. One of the newest methods for studying the construction area at the pre-project stage is Earth remote sensing (ERS). Radio-Thermal Imaging Technology (RTT), which our company owns and is an element of remote sensing, is used to solve a wide range of geological problems around the world.

At Center of Aerospace Technologies ltd. extensive research experience has been accumulated to study the geological and tectonic structure of the territory, map faults in the earth's crust, and predict dangerous geological processes. RTT has established itself as a working tool for studying geological massifs, as well as one of the most efficient methods for obtaining information about the internal structure of geological and tectonic structures, including for built-up areas and areas with limited traffic.



1. RADIO-THERMAL IMAGING TECHNOLOGIES (RTT)

RADIO-THERMAL IMAGING TECHNOLOGIES (RTT)

RTT is considered as a passive remote sensing method based on recording the radiated thermal energy of the Earth, which is represented by a continuous spectrum of electromagnetic waves and is expressed by a physical parameter - radio brightness temperature.

To quickly obtain materials on the geological and tectonic conditions of a construction site (route), the most informative are methods that have the effect of “translucency” of the Earth’s crust, which is characterized by **Radio-Thermal Imaging Technologies (RTT)**.

RADIO-THERMAL IMAGING TECHNOLOGIES (RTT)

The technology is based on remote sensing using multi-temporal satellite images of thermal radiation from the Earth's electromagnetic spectrum.

The effect of "translucency" of the earth's crust is explained by the tectonically caused fracturing of its upper floors, which is reflected in the thermal field of the Earth both on the day surface in relief and in the subsurface.

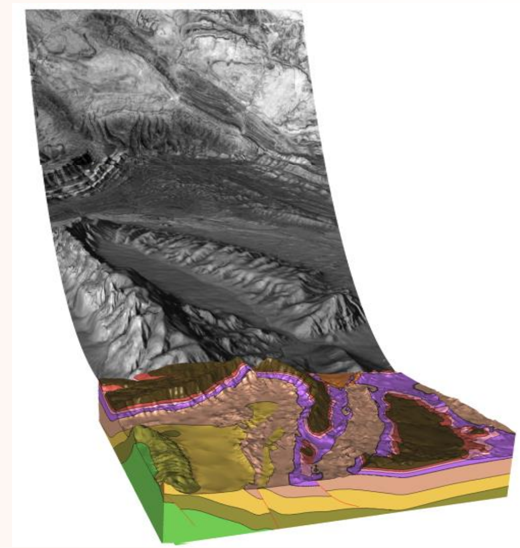
Information received from Earth satellites in the radio-thermal range of electromagnetic waves (Landsat 8 (OLI/TIRS), GCOM-W1 (AMSR-2), ASTERGDEM, Sentinel, etc.) is used as initial data.

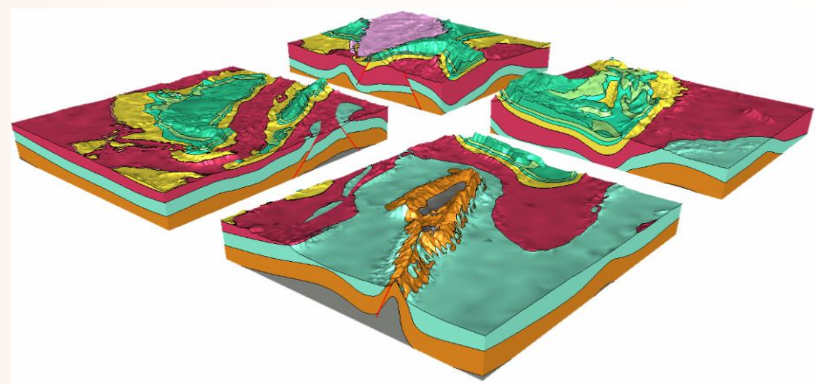
Satellite images in the radio-thermal range are the initial information basis for geophysical introscopy in the presence of an appropriate processing tool (in our case, this is our own software), decoding and target interpretation.

Processing of space images is carried out in the Software (through a training sample) with the construction of a 3D cube model.

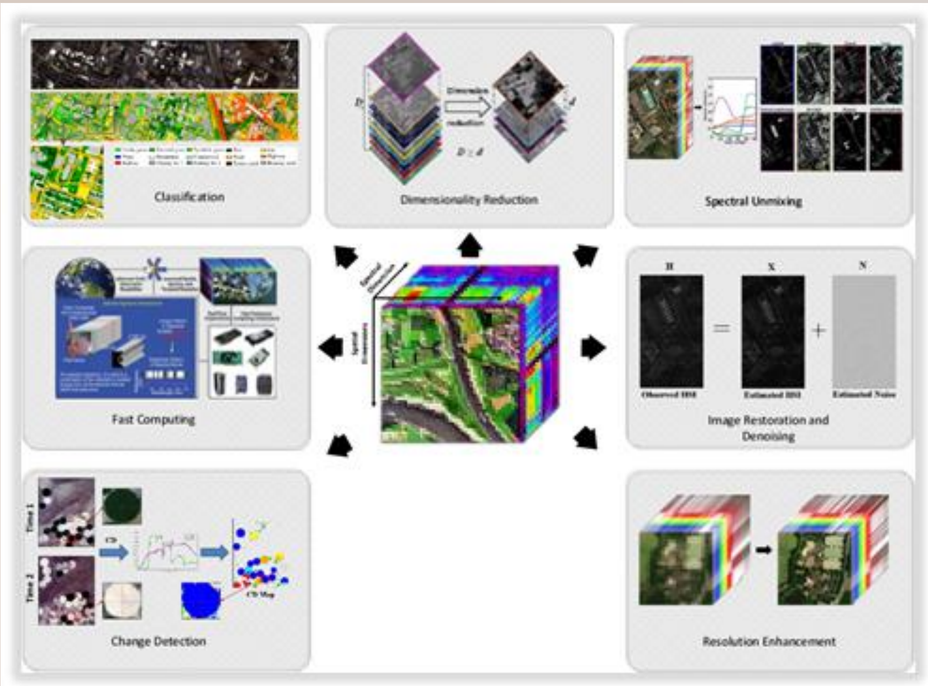
RADIO-THERMAL IMAGING TECHNOLOGIES (RTT)

A significant difference between RTT lies in the algorithm for processing aerospace images: the contrast value of radio brightness temperatures [ΔT] and heat flux density are used to calculate and visualize all inhomogeneities of the Earth’s crust, including faults of various ranks. In addition, the processing program allows you to enter an infinite number of points carrying initial a priori information about the geological section, increase the temperature sensitivity and resolution of the survey, and, as a result, obtain a more reliable and more accurate picture of the structure of the Earth in the process of interpretation.





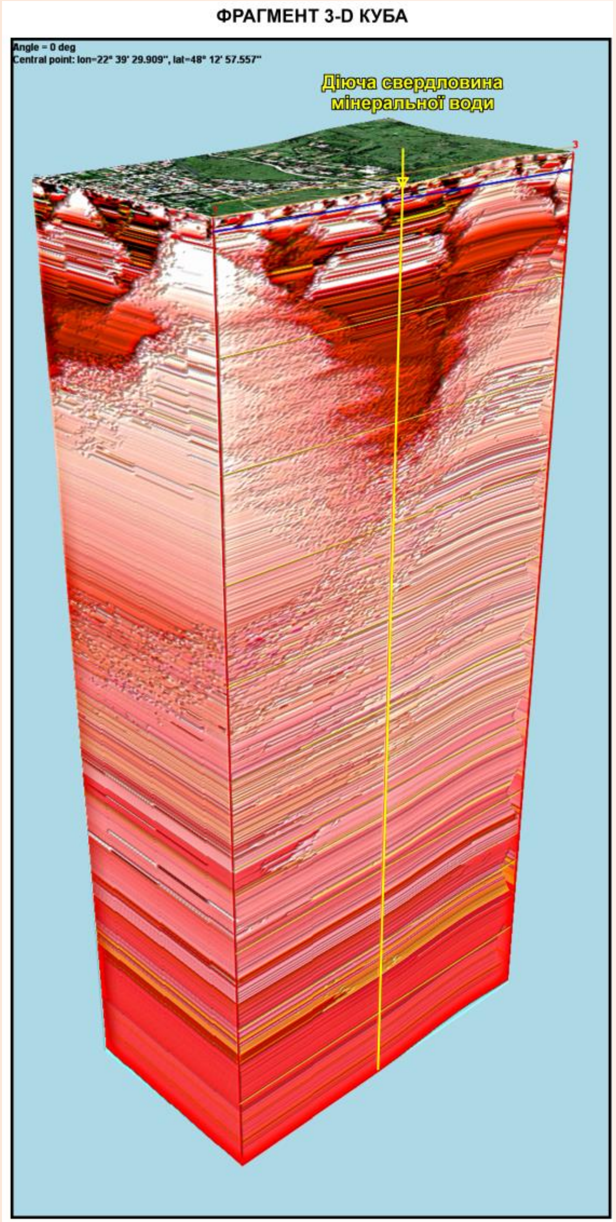
Building a geothermal model of a 3D cube



The construction of a geothermal model of a 3D cube is carried out through a combination of several microwave channels, then the information of the resulting vertical profiles of radio brightness temperature can be calculated. One of the elements of constructing a geothermal 3D cube is the use of technologies to increase temperature sensitivity at each point of the cube (pixel). For example, the generalization method.

By applying decoding elements to a digitally processed integral thermal satellite image of the surface, we obtain layer-by-layer geothermal scenes that make up a volumetric geothermal 3D cube.

Building a geothermal model of a 3D cube



Fragment of a 3-D cube. An example of constructing volumetric vertical sections based on geothermal 3-D cube data

Building a geothermal model of a 3D cube

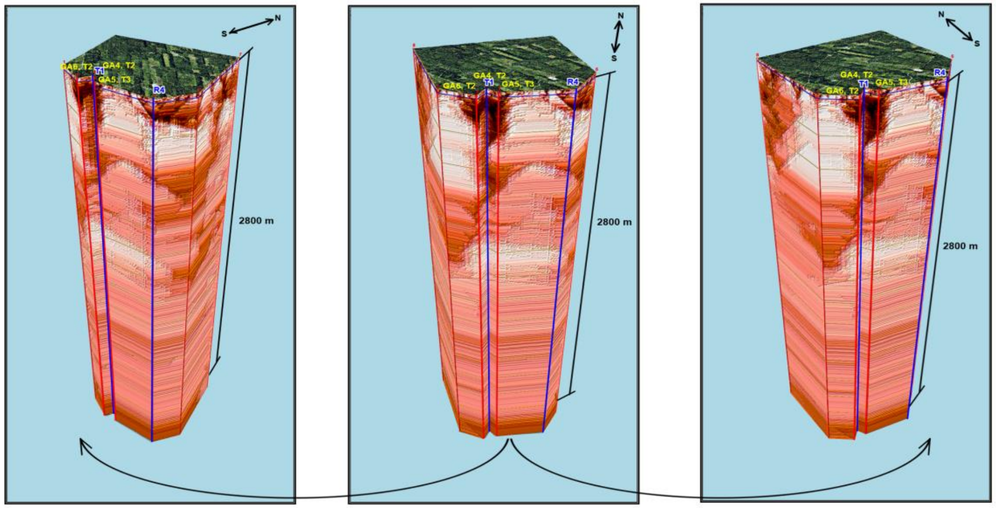


Fig 5.38 Объемный вертикальный разрез 3DV2. Построен по данным геотермического 3D куба масштаба 1:25 000.

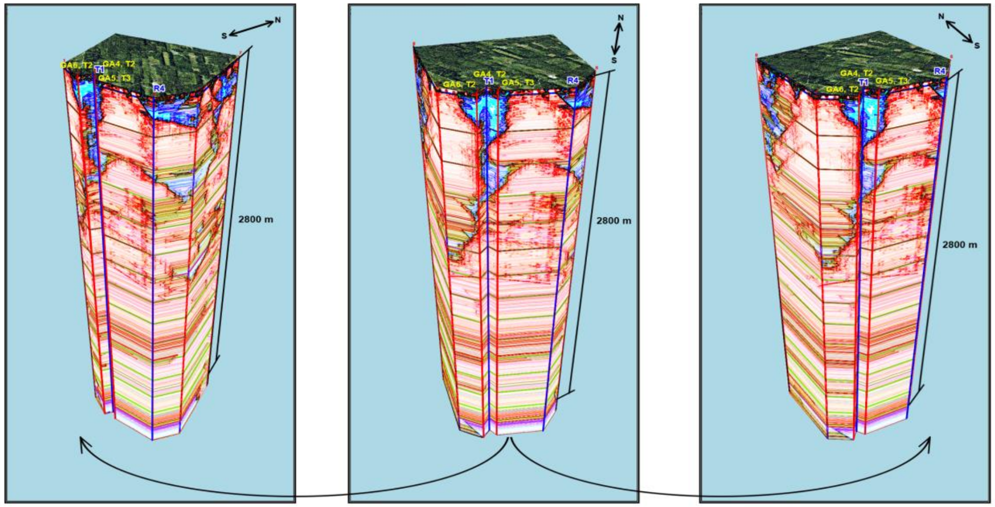


Fig 5.39 Объемный вертикальный разрез 3DV2. Выполнено тематическое контрастирование.

Легенда

- Проекция линии вырезки фрагмента 3D куба, используется для построения объемных вертикальных разрезов.
- Расположение лицензионной площади Välikorpi
- R1 — Расположение буровых скважин GTK
- T1 — Точка, соответствующая группе скважин GTK R358-R372
- GA6, T2 — Расположение рекомендуемых скважин для первоочередного бурения на лицензионной площади Välikorpi. По данным вертикальных геотермических разрезов GA5, GA6.
- GA6, T2 — Рекомендуемые скважины для первоочередного бурения на лицензионной площади Välikorpi. По данным вертикальных геотермических разрезов GA5, GA6.
- R4 — Буровые скважины GTK
- Угловая стрелка, показывающая разворот разреза

Примечания:

1) Описание горных пород геологического разреза приведено на рисунках 5.25, 5.26 (Лист №12 "Приложения 5" Книги 2)

2) Координаты и глубины скважин, рекомендуемых для первоочередного бурения на Лицензионной площади Välikorpi приведены на Рис. 5.27-5.33 (Лист №13 "Приложения 5" Книги 2)

An example of constructing and interpreting volumetric vertical sections based on geothermal 3-D cube data

Optimal scales for constructing 3D models. Possibility of retrieving information from a 3D cube model

Using the RTT method and the capabilities of satellite radio-thermal imaging data, you can create 3D models of the Earth or other planets on scales from M1:50,000,000 to M1:10,000. Depends on the globalization or detailing of geological problems. To solve design and construction problems, the most applicable scales are 1:25,000 – 1:5,000. In the near future, we can expect to receive materials using low-flying aircraft for constructing 3D models at scales M1:5,000 to M1:500.

Retrieving information at any point of a 3D cube is possible by constructing horizontal sections of any shape and size along the envelope of the terrain or by cutting (like a knife) with a given discrete distance between layers.

Receiving information at any point of a 3D cube is also possible by constructing vertical sections of any length with a horizontal pixel increment. Or by constructing 3D volumetric sections (perspective) of any shape in any direction with pixel increments horizontally and vertically. With any top background that is included in the database (topographic map, photograph, relief, thematic map, etc.).

Discretion, accuracy, detail in area and depth

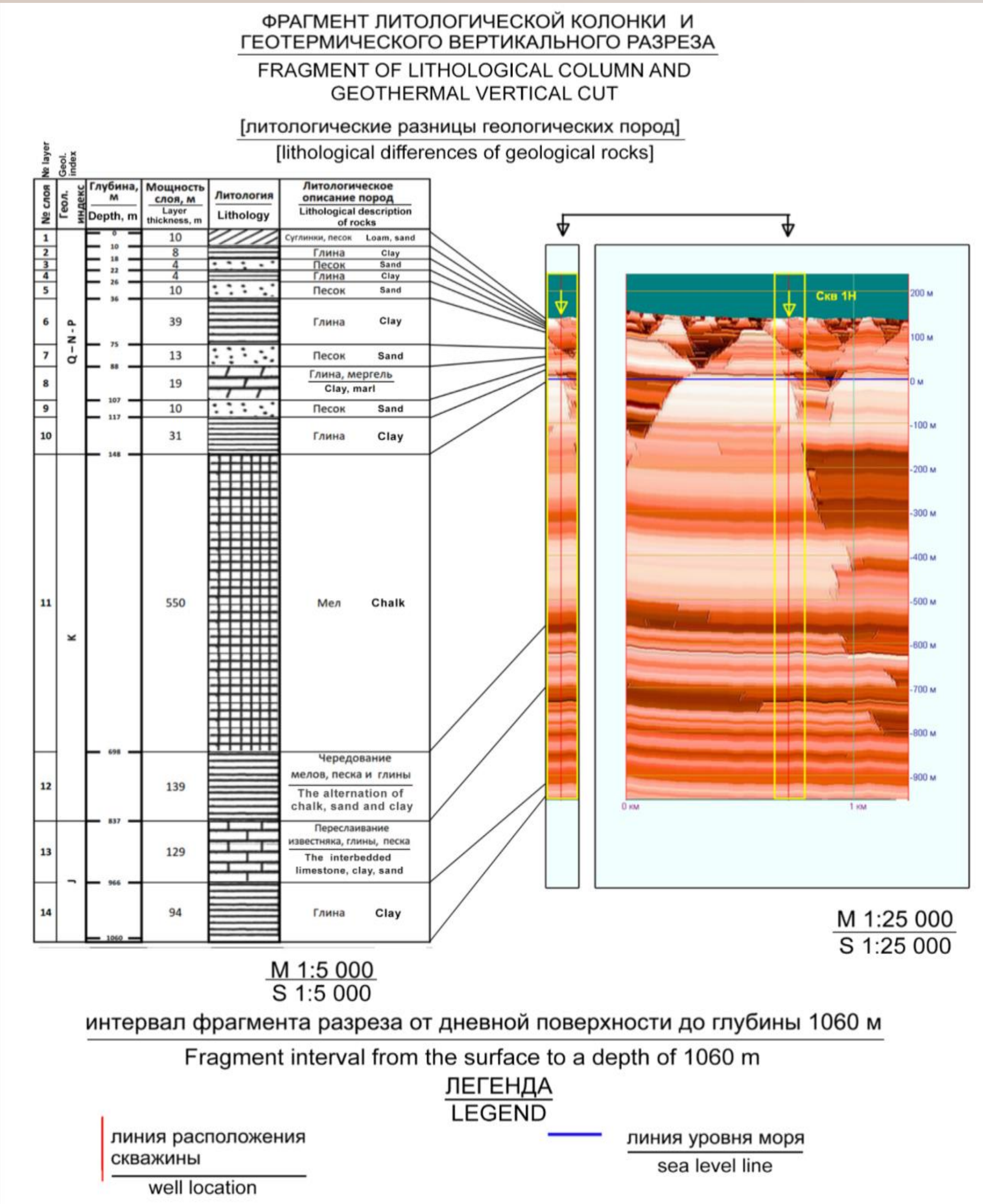
The detail of near-surface skin layers depends on the detail of thermal infrared (IR) images. For example, IR images of the Landsat-8 thematic cartographer are considered correct for work scales no larger than M 1:25,000 horizontally and no larger than M 1:10,000 vertically. IR images of the Aster thematic cartograph can be considered correct for work scales no larger than M 1:10,000 - M 1:5,000.

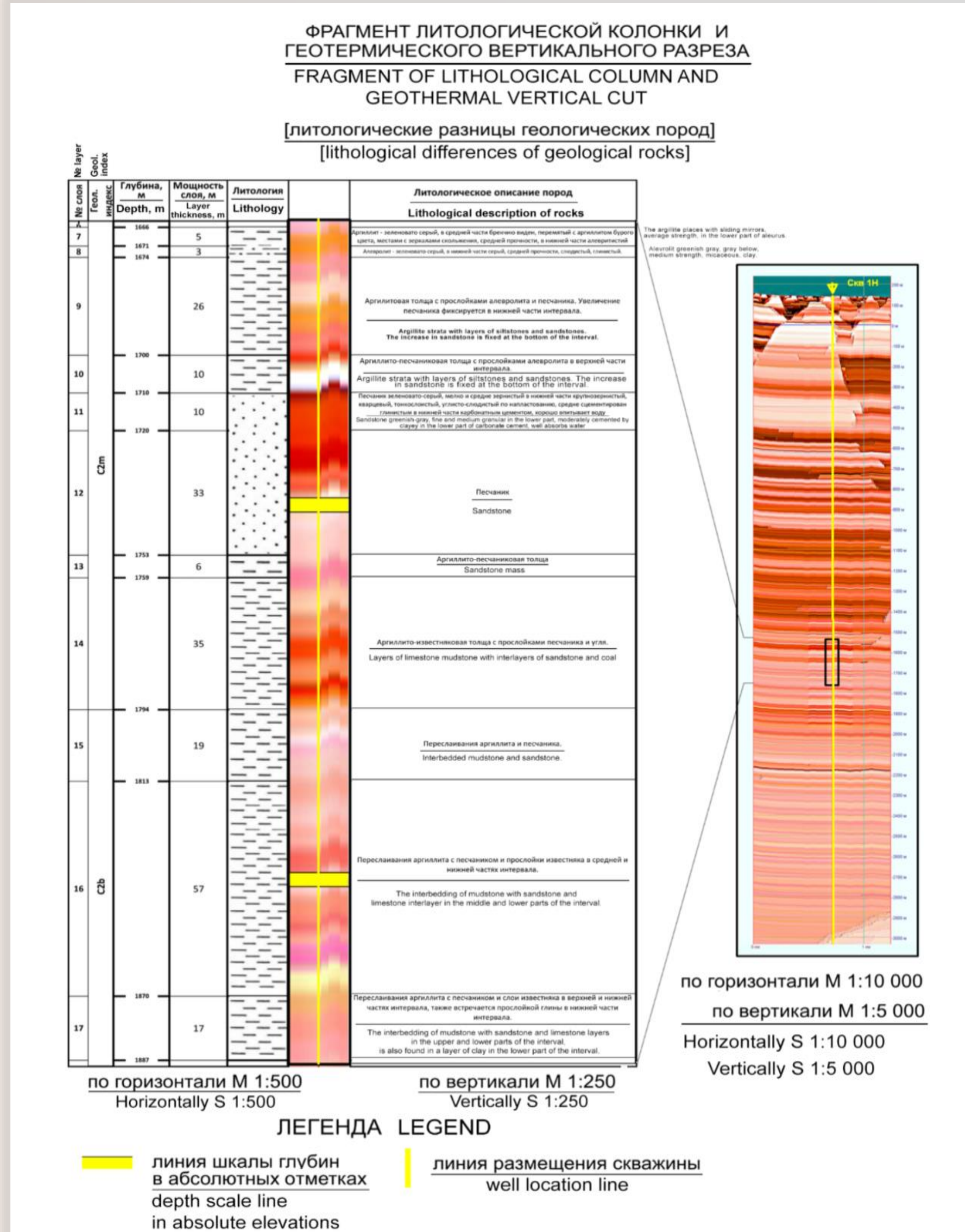
For these and larger scales, satellite radiometers can also be used: AVHRR, MODIS, AMSR, SSMI, WINDSAT, VIIRS, ATMS and others.

There are technologies for restoring image resolution: IR images can be realized on a scale of work 2-5 times more detailed (using technologies for restoring resolution and image detail). It is practically possible to refine images using Landsat and Aster materials down to 2.5 m and 1.25 m, respectively.

Examples of detailing the geological section on a vertical geothermal section are shown on **slides 12, 13**, where the lithological differences in rocks identified from drilling data are clearly highlighted in color and tone.

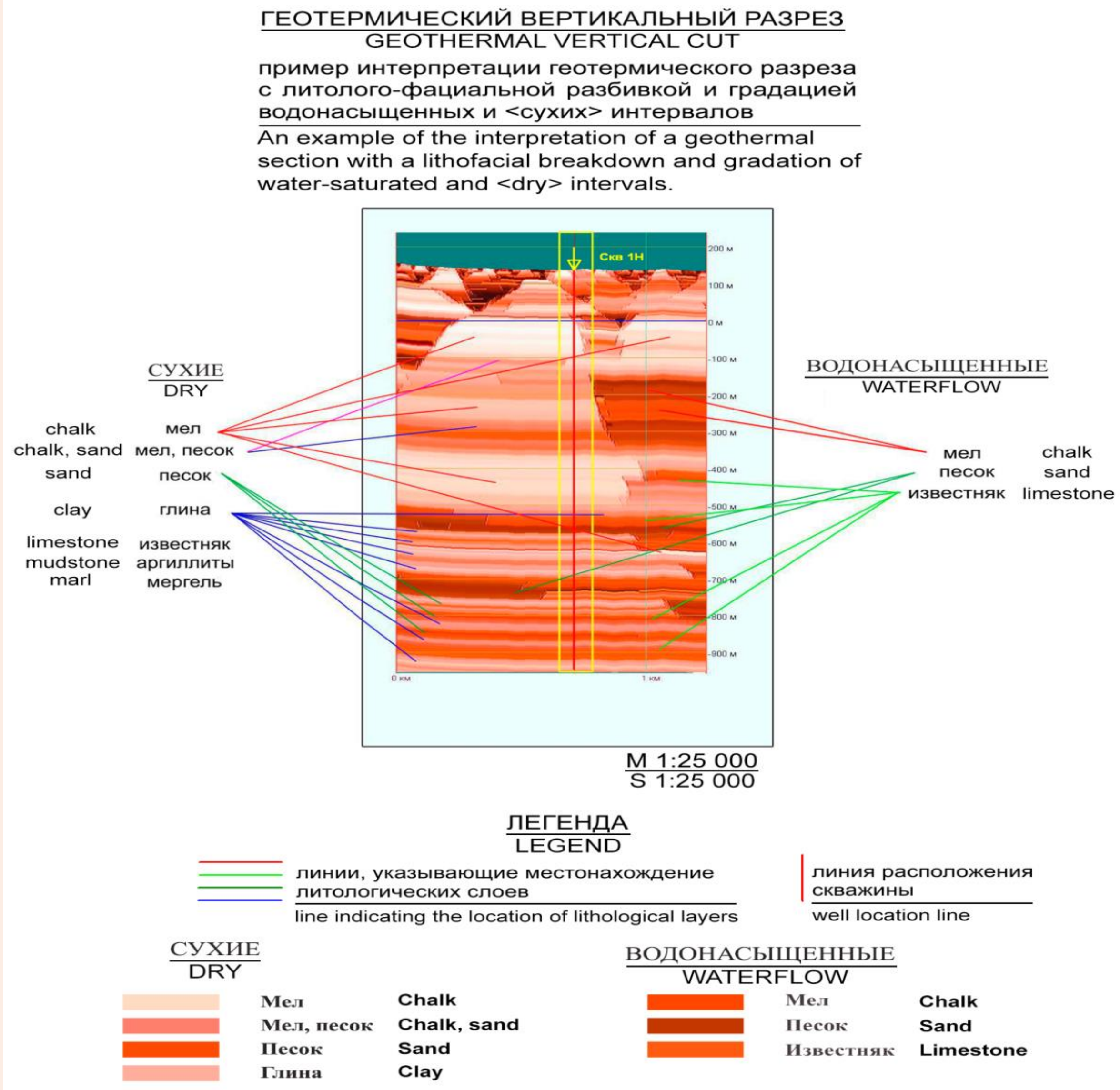
Identification of lithological intervals of a well section using RTT data





Identification of lithological intervals of a well section using RTT data

An example of identifying low-moisture and water-saturated lithological intervals of a well section using RTT data



Model calibration

Calibration of the 3D cube model is carried out to clarify the position and depth of structural heterogeneities of the geological section, by comparison with a reference object, for example, an exploration well.

For these purposes, materials from engineering and geological surveys of previous years are used as a reference object.

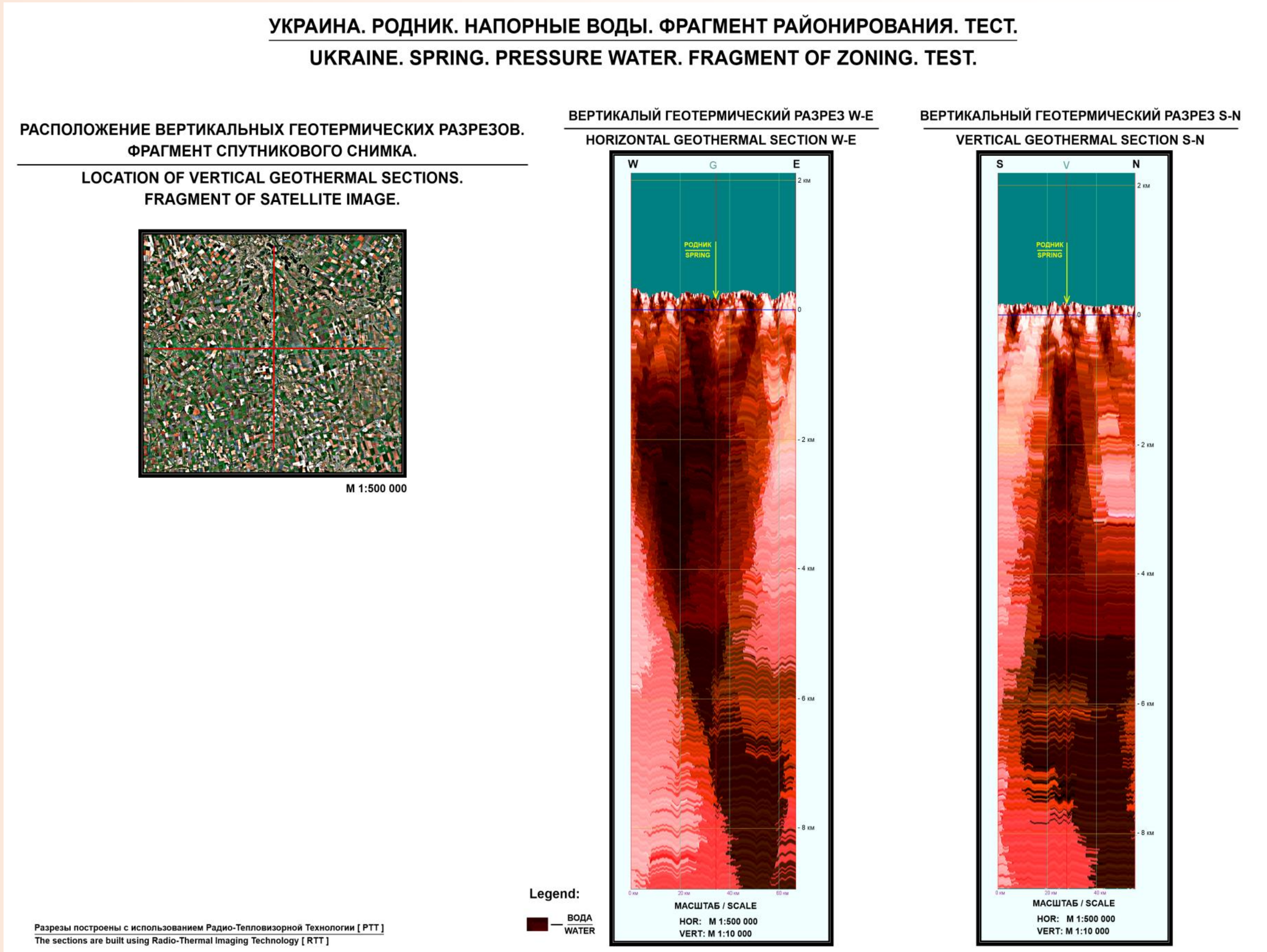
For correlation, a graph of the dependence of the nomenclature of a layer (multiple layers) on depth is used. Data obtained empirically during calibration. The supporting layers (aquifer, crystalline basement, subsidence rocks, etc.) are identified based on unambiguous engineering-geological materials.

It should be noted: the more reliable engineering-geological material is used for the study area (sampling), the more accurate the calibration is, and as a result, the geothermal cube maximally reflects the geological structure of the study area (route).

Examples of a test site in the Dnepropetrovsk region (Ukraine) are shown on **slide 15**

Test area

Vertical geothermal section through a permanent spring in the Dnepropetrovsk region, Ukraine. Flooded fault zone. Pressure waters. The release of groundwater to the surface of the relief.



Faults identified by the RTT method

One of the main advantages of the method is the ability to map and determine the spatial position of zones of tectonic faults and faults, which create the block nature of the structure of the Earth’s crust, influence the formation of water-flooded crack zones in rocks, appear as weakened zones in the sedimentary strata of rocks, in the relief - in the form of ravines, beams.

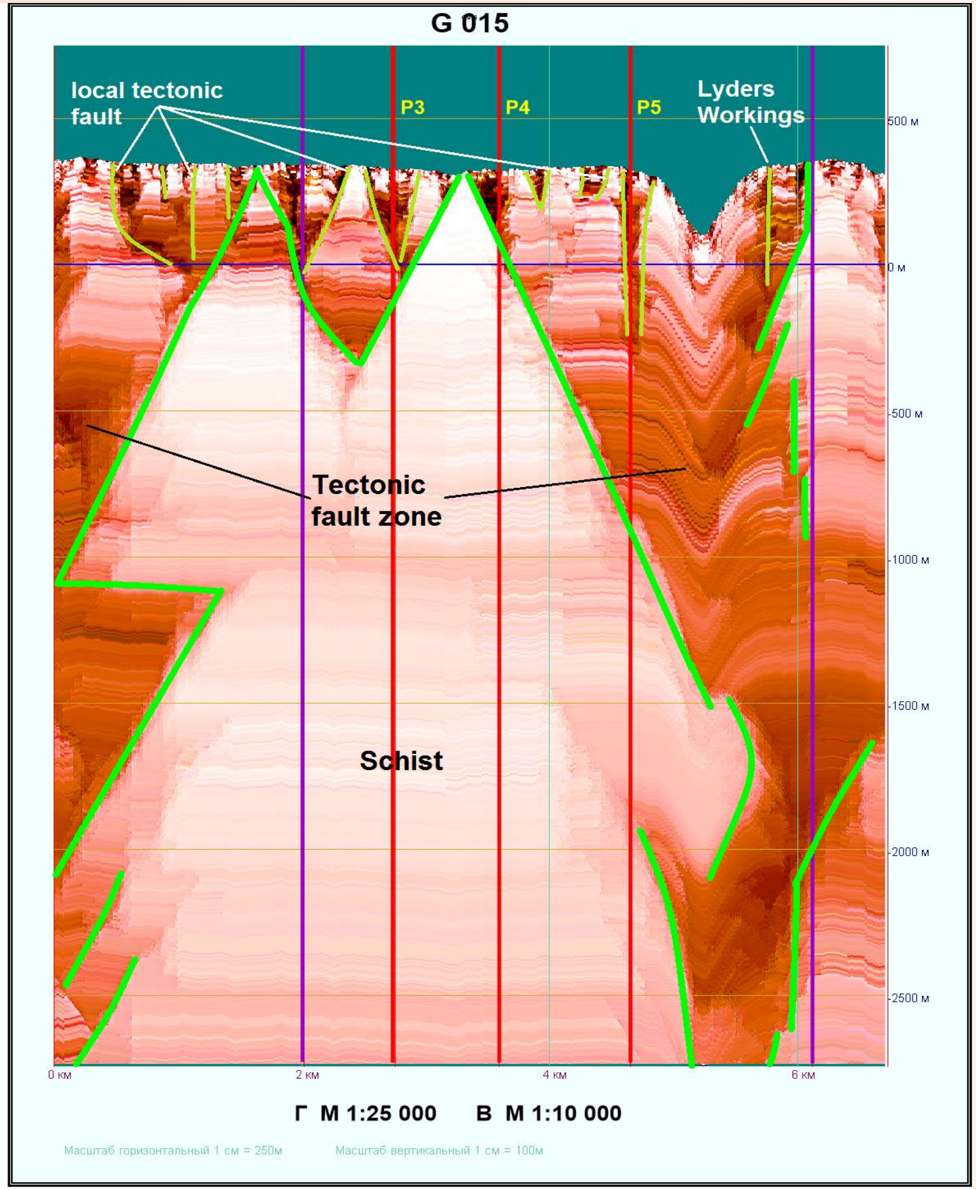
Using RTT materials, we obtain a three-dimensional spatial picture of fault zones and faults with the ability to trace the strike of the destructive fault zone in any direction, both vertically and horizontally, to identify the roots of deep faults and blocks, connections with the crust and mantle.

Faults are a striking example of geothermal field inhomogeneities.

The algorithm of the Space Image Processing Software provides for the block structure of the earth's crust.

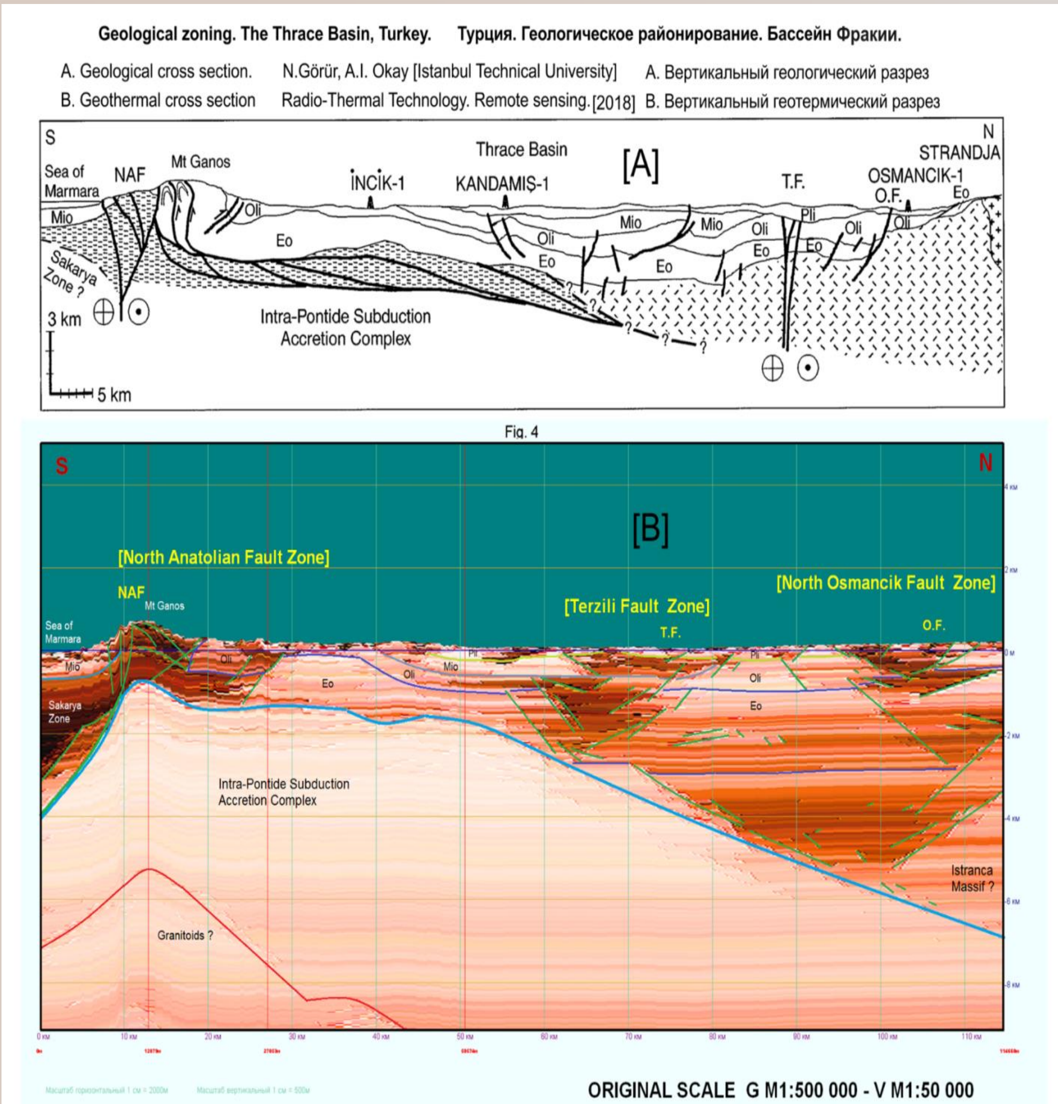
Blocks of any order are separated from each other by discontinuities.

Faults identified by the RTT method



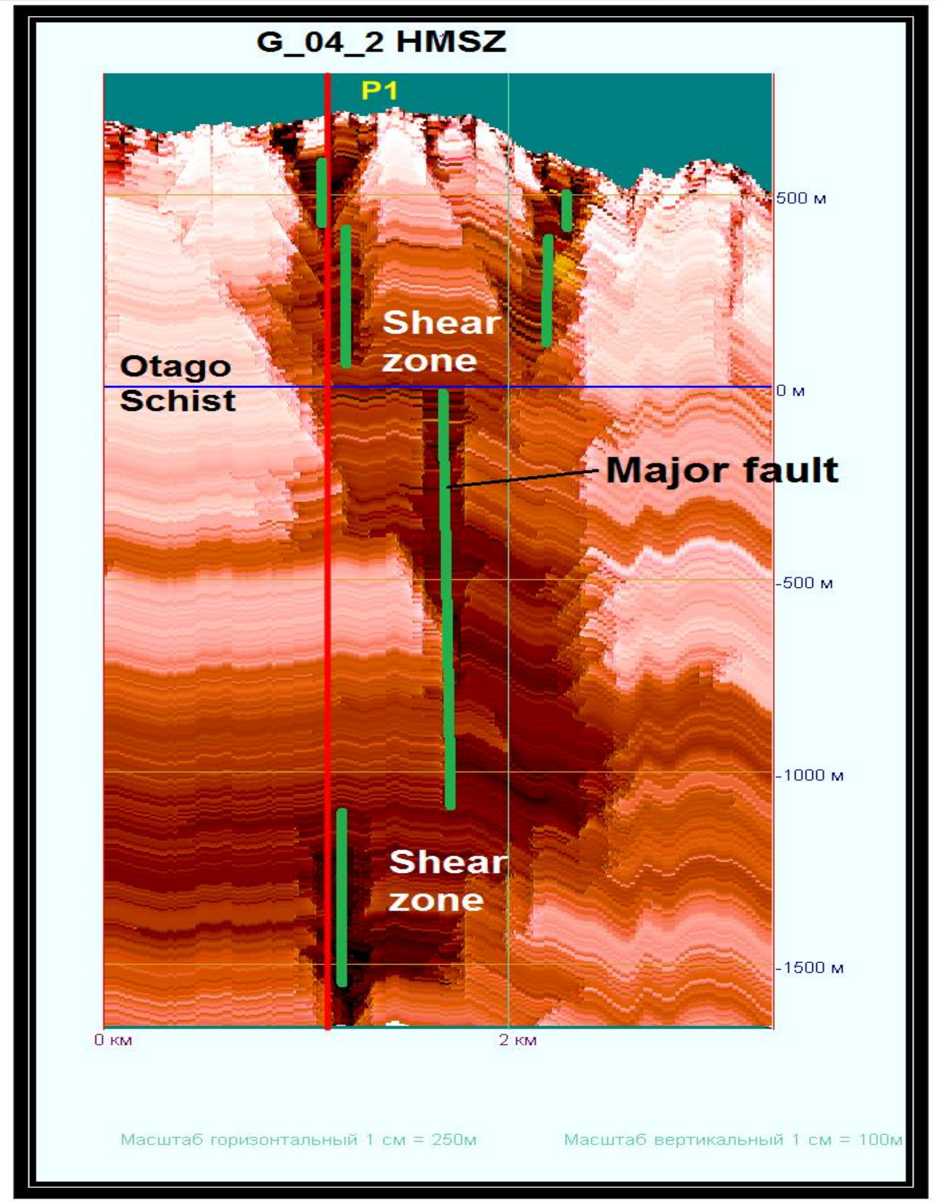
An example of constructing and interpreting vertical sections based on geothermal 3-D cube data highlighting tectonic fault zones

Faults identified by the RTT method



Comparative geological [**A**] and geothermal [**B**] sections showing structural connections between the Thrace basin and surrounding tectonic provinces

Faults identified by the RTT method



An example of constructing and interpreting vertical sections based on geothermal 3-D cube data highlighting tectonic fault zones

2. ZONING OF THE CONSTRUCTION TERRITORY (ROUTE) FOR ASSESSMENT OF HAZARDOUS GEOLOGICAL PROCESSES

The main tasks to be solved for assessing the geodynamic situation

At the pre-design stage of designing buildings and structures, desk tracing of linear objects to assess the geodynamic situation of the construction site (route), mapping is carried out using the RTT method with the construction of a volumetric geothermal model on a scale of 1:25,000 with detailing of potentially dangerous or specified areas in M 1: 10,000- 1:5,000 :

- zones of subsurface faults, faults and fracturing;
- permeability zones, watered and flooded zones;
- zones of landslides, landslides;
- zones of karst-suffusion manifestations, etc.

The construction area (route) is being zoned with the identification and delineation of areas for the development of hazardous geological processes (including potentially dangerous ones). The materials are used to carry out engineering-geological surveys, design preparation of construction, including measures for the engineering protection of the designed facility and environmental protection.

Spatial determination of zones of deep and subsurface faults of different orders will make it possible to select the most stable areas for the construction of high-rise buildings, critical structures and planning of territory infrastructure, the most effective engineering solutions for the construction of bridge crossings, tunnels along the route of linear structures.

Basic approaches to RTT research for construction

Considering the fact that RTT technology refers to remote sensing methods, when assessing geodynamic hazards, space data is used most effectively in combination with available geological and geophysical materials, fundamental structural and tectonic studies, and the results of engineering-geological, geophysical and geodetic work carried out on the construction site.

A feature of the geotechnical surveys necessary for the design and construction of linear structures is that such surveys are carried out over long areas.

The use of a map of the fault block structure and a map of dangerous geological processes of the territory as a “substrate”, supplemented by reference longitudinal and transverse geothermal sections along the route, will improve the quality of engineering geological surveys and reduce the cost of field work through the most optimal placement of exploration wells and test work points.

Main stages of RTT research for construction

Research is carried out in three stages :

At the first stage, the collection of source material is carried out, the analysis of all available materials on the geological structure, stratigraphy, seismic regime, neotectonics, history of relief development, deep structure, stress state and modern movements of the earth's crust. In other words, a regional geological-tectonic database is created and analyzed.

The second stage involves the actual remote sensing :

- Obtaining and spectrometric analysis of satellite images in order to select the optimal sub-range.
- Interpretation of space images in the visible and infrared ranges. Retrospective analysis of known areas and their display on thermal images.
- Construction of a multilayer database of faults and tectonic blocks in order to study the features of the geological structure of the territory, as well as to study the patterns of distribution of anomalies.
- Construction of a multilayer geothermal 3D model of the geological environment.

Main stages of RTT research for construction

The resulting geothermal 3D cube serves as basic information for further geological and geophysical interpretation. Interpretation of radio-thermal imaging data is carried out interactively using appropriate computer equipment and original software and includes the following sub steps:

- Creation of a project in an interpretive system, for which digital topographic maps of appropriate scales are used.
- Loading a multilayer database of faults.
- Loading of all available geological data.
- Correction of a geothermal 3D cube (filtering, selection of dynamic range depending on the geological problems being solved) and its depth reference.

The third stage includes the synthesis of all collected materials, drawing up a map of faults, maps of hazardous geological processes and reference geothermal sections in the formats specified in the terms of reference, and development of a technical report.

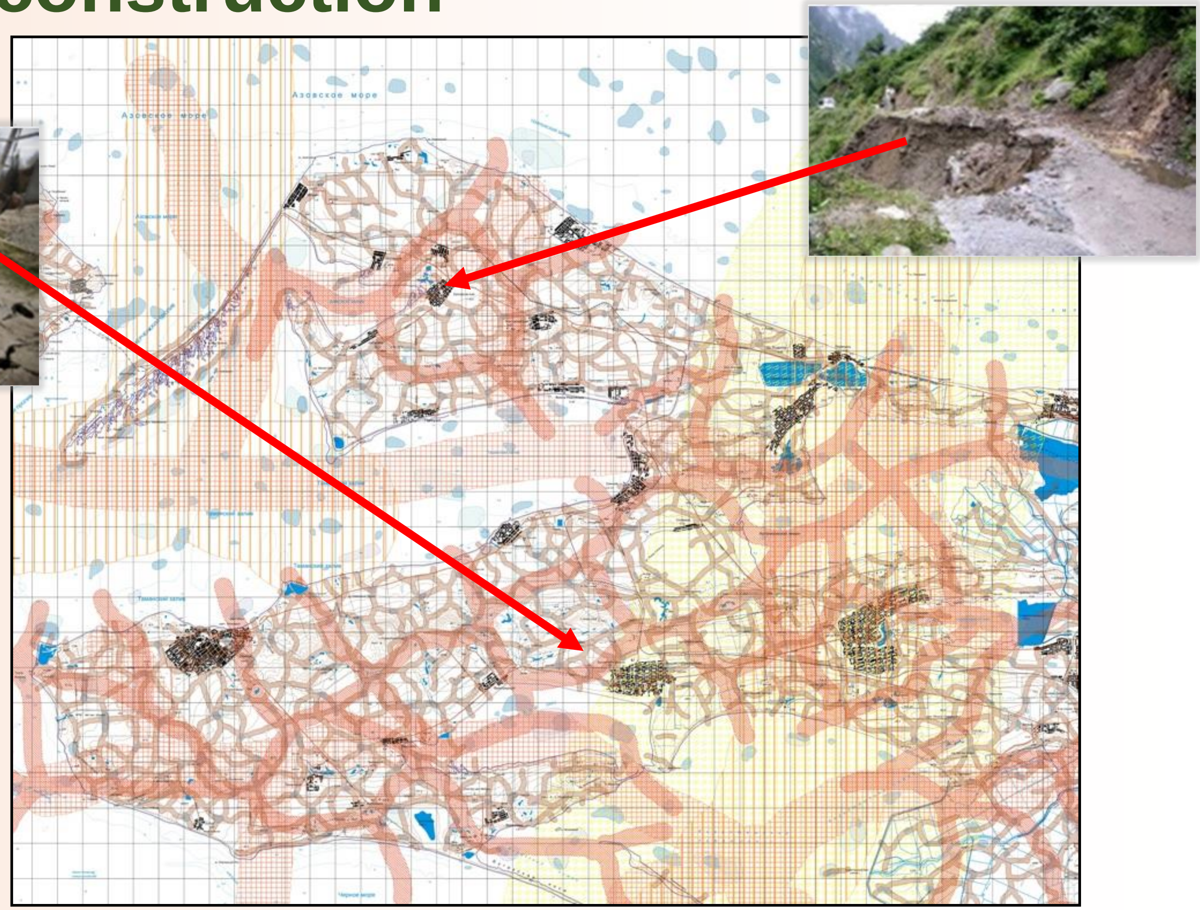
Examples of using the PTT method for construction

Display of tectonic structures of various orders formed by lineament zones

Examples of using the PTT method for construction

Landslide zones

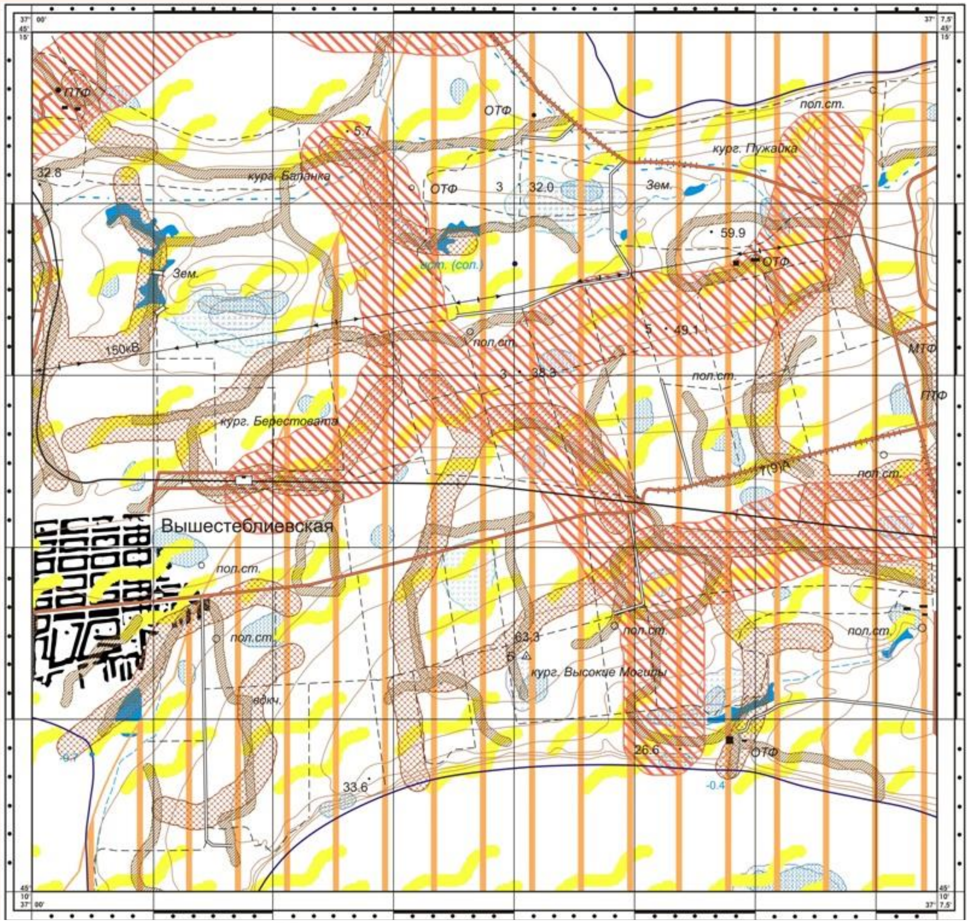
Landslide zones

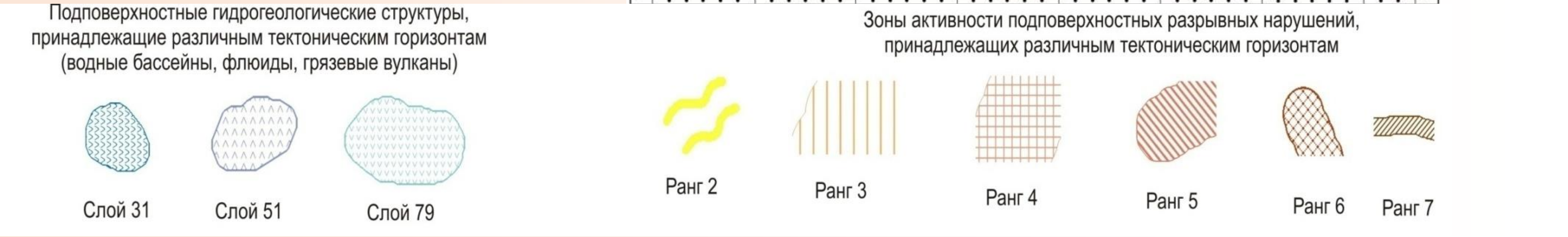


Integrated schematic map of hazardous geological processes

Examples of using the PTT method for construction

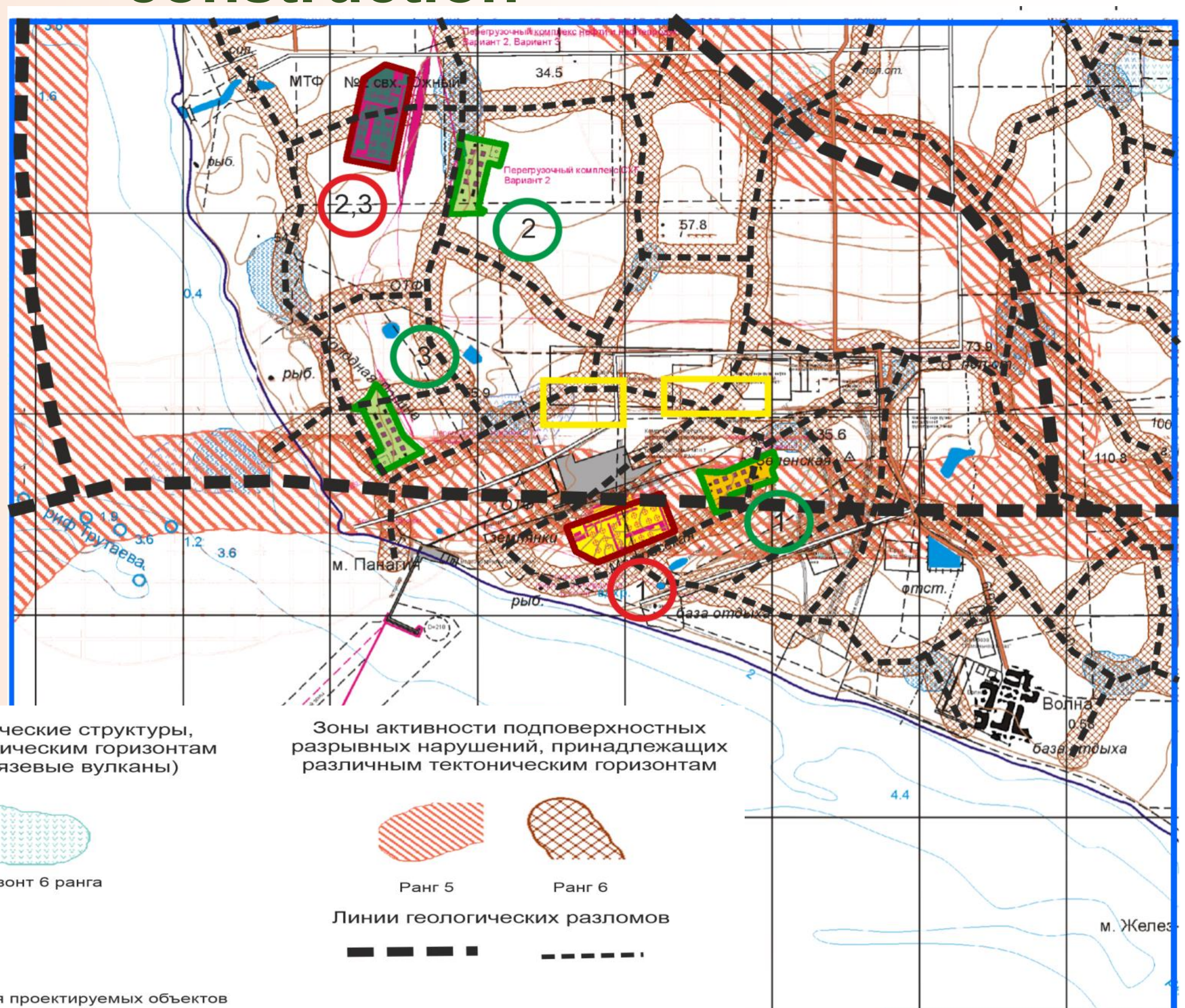
Nomenclature sheet as a fragment of a combined schematic map of hazardous geological processes.Open and hidden water flows and basins, faults and tectonic support structures of the upper structure of the Earth.

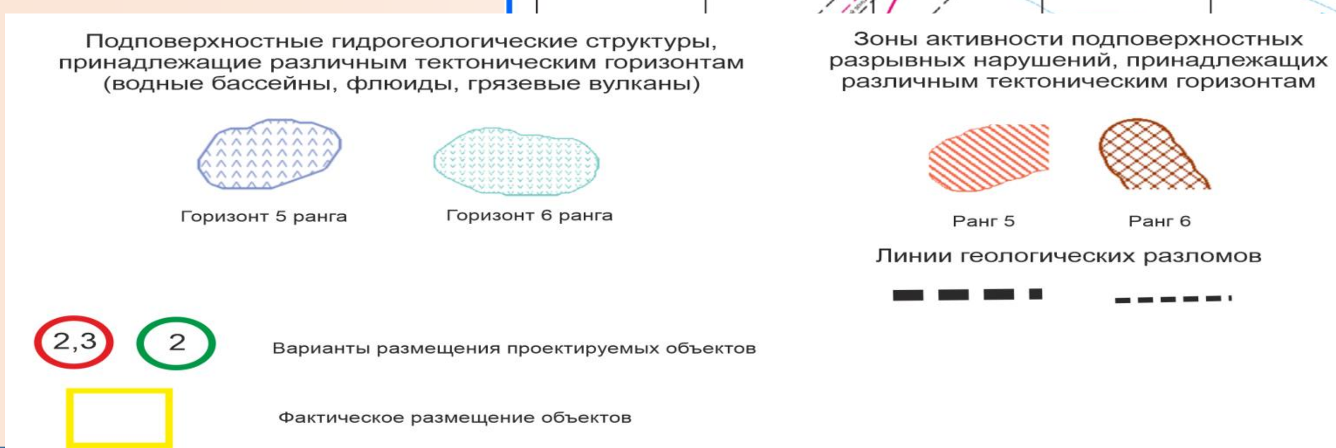




Examples of using the PTT method for construction

A fragment of a map of hazardous geological processes, combined with the contours of the designed objects of an oil terminal and a liquefied petroleum gas (LPG) transshipment complex.





Recommendations for construction

RTT is recommended as a mandatory component in a comprehensive study of the territory, including for construction purposes.

In general, to solve construction problems, we propose to carry out a radio thermal imaging study of the territory with the construction of a 3D geothermal cube model of the area where the buildings, structures, site and construction area, route are located, which will ensure that the databases are replenished with the latest information about the fault block structure. Recommended scales are 1:25,000 - 1:10,000 with detailing of specified areas up to M 1:5000.

The RTT remote sensing method is environmentally friendly. Allows you to optimize economic and environmental risks in the design and operation of buildings and structures.

We are confident that research using RTT will help improve the level of environmental safety of construction, prevent the destruction of buildings and structures, provide a map base with the exact location of stable blocks, faults in the earth's crust and weakened zones for planning the construction of new buildings and structures, roads and railways, bridges, tunnels and etc.

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