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BRIEF DESCRIPTION OF RADIO-THERMAL IMAGING TECHNOLOGIES IN GEOLOGY ON THE EXAMPLE OF OIL AND GAS CONDENSATE FIELDS

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Annotation: *The brief physical foundations of Radio-Thermal Imaging Technologies are considered, the geophysical aspects of deciphering and interpreting aerospace data, the relationship of satellite images with the deep structure of the Earth are shown with an illustration of the results of research. As examples of works, horizontal and vertical geothermal cross-sections of the Earth's crust are presented. The receipt of fundamentally new, more informative data on the structures of the Earth's crust is noted.*

Keywords: *Radio-Thermal Imaging Technologies, Remote sensing of the Earth, electromagnetic radiation, radio brightness temperature, aerospace images, Earth's crust, thermal exploration, rocks, geothermal anomalies, geothermal cross-sections, geological structures, minerals, hydrocarbon deposits, oil and gas condensates, hydrocarbon traps.*

Introduction

All over the world, one of the latest methods for studying the geological and tectonic structure, forecasting and searching for mineral deposits is remote sensing of the Earth (ERS). All remote sensing methods are based on the registration of electromagnetic radiation: reflected or emitted by natural sources (passive) or reflected from objects exposed to radiation from artificial energy sources (active). For solving geological problems, the most informative methods are those that have the effect of "transmission" of the Earth's crust and mantle – Radio-Thermal Imaging Technologies (RTT).

Brief Description of Radio-Thermal Imaging Technologies

RTT is considered as an element of remote sensing of the Earth, a passive method based on the registration of the radiated thermal energy of the Earth (in the form of an endogenous heat flux), which is represented by a continuous spectrum of electromagnetic waves and is expressed by a physical parameter called radio brightness temperature, the radiation can be received at the input of the antenna system (detector, optical or electronic). The name "Radio-Thermal Imaging Technologies" itself reveals the ranges of the Earth's electromagnetic radiation used: radio, infrared and optical.

In fact, these are technical vision technologies that form images with long wavelengths (radio waves). The longer the operating wavelength of radiometric receivers, the higher the efficiency of receiving radio brightness temperature from the subsurface of the Earth's thickness.

The radio brightness temperature of each resulting pixel is characterized by the effective temperature and the emissivity of specific elements of geological structures.

RTT technologies do not provide for the use of true values of temperature gradients, but their differentiable contrasts and heat flux density, allow calculating and visualizing all the inhomogeneities of the Earth's crust.

The contrast scale has a higher resolution of the relative value: hot and cold. Relative, due to the fact that, in some cases, for a more visual presentation of information, an inversion is performed, as a result, the scale changes its value to the opposite.

Hot and cold also have a relative value and depend on the emissivity of each physical object (geological structural inhomogeneities) through which electromagnetic waves generated by the Earth's core pass (wide continuous spectrum, with noise temperatures around 6400 K). A sharp drop in radio brightness temperatures suggests the presence of a boundary of geological structural heterogeneity.

One of the factors of penetration (depth) is the possibility of increasing the sensitivity of radio-thermal space scenes, which make it possible to form images of the Earth's subsurface.

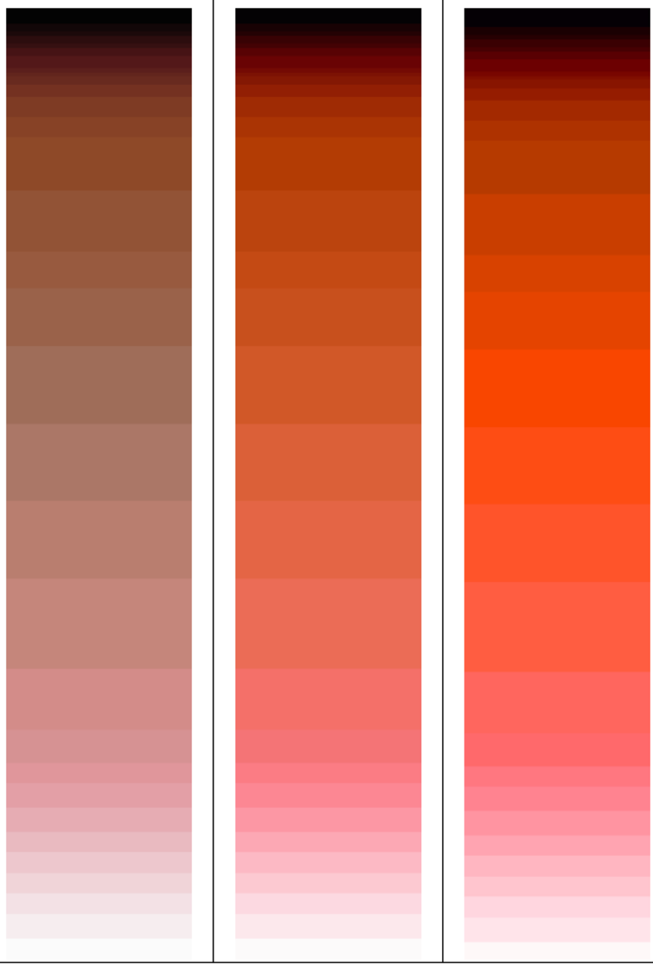
The use of algorithms for correcting source materials makes it possible to exclude the influence of the landscape surface (vegetation, road network, hydro network, etc.) - the skin layer - on the results of the work. The use of algorithms for increasing the sensitivity of the initial radiometric scenes (images), algorithms for constructing a three-dimensional model (3D-cube) of the geological environment, make it possible to form block layers of radiometric images at a given depth, and make it possible to obtain a deep “transmission” effect. Consistent horizontal "transmission" of the Earth's thickness, this is a kind of "X-ray" only in the microwave radio range.

Horizontal "transmission" allows you to see all geological structural heterogeneities, where some elements are recognized as: water, gas, oil, ore formations and their host rocks. The places of their greatest concentration are visible. Recognition of minerals is carried out by calibration classifiers. Geothermal horizontal cuts and geothermal vertical slices are built.

Technologies use block-mosaic representation of information (formation of cubic pixel images) with the construction of a geothermal 3D-cube of a given scale, a given fragment of the Earth's subsurface.

Constant improvement of the RTT method, both in the direction of increasing the depth of research, and in the direction of increasing the resolution and accuracy of the results obtained, opens up new prospects for forecasting and searching for mineral deposits, assessing the seismicity of the territory, fundamental and applied research of the Earth's crust. It opens up prospects for building geodynamic models in time, with the possibility of using operational data for the last decade, on the territory of any fragment of the globe.

Table 1: Qualitative Color-synthesized calibration scale for fluid recognition*

Scale	Qualitative Color-synthesized calibration scale			Denotation	Material / Element	Emissivity (direct scale) (λ = 8...14 µм)	
	Saturation						
	Weak	Medium	Strong			Min	Max
0,99					Water (Fresh, mineral, thermal, …)	0,7	0,99
0,97							
0,95					Oil	0,95	
0,9					Gas	0,93	
0,7					Basalt, Graphite	0,7	
0,6							
0,5							
0,4					Granite, Sand	0,4	
0,2					Iron	0,05	0,2
0,1							
0,05					Copper	0,05	0,1
0,03							
0,01					Gold	0,01	0,1

*** Note:** *conditional classification of components is performed using cluster analysis by numerical values of color, brightness, saturation, which are part of color-synthesized sections, in comparison with the average self-emission coefficients of gas, oil, water and other corrective values for the increase in radio-brightness temperature (*$\Delta T_b = k \cdot T_e$ *where* ΔT_b *- is the increment of radio-brightness temperature (temperature contrast),* k *- is the self-radiation coefficient of the component,* T_e *- is the effective temperature of the component). An example of a color-synthesized scale for the conditional classification of components is shown in* ***Table 1.***

Examples of using RTT technology

APPLICATION OF THE METHOD OF RADIO THERMAL IMAGING TECHNOLOGY USING SMALL-SCALE SPACE IMAGES FOR SEARCH AND ADDITIONAL EXPLORATION OF HYDROCARBON DEPOSITS ON THE EXAMPLE OF THE GAS-CONDENSATE FIELD "STEPOVOE" (KHARKOV REGION, UKRAINE)

Fig. 1. Gas condensate field "Stepovoe", well № 120.
Location of the vertical geothermal section [G C 120].
A fragment of a topographic map [A] and a satellite image [B].

Legend:

- contours of the deposit

G C 120 - projection of a vertical geothermal section [G C 120]

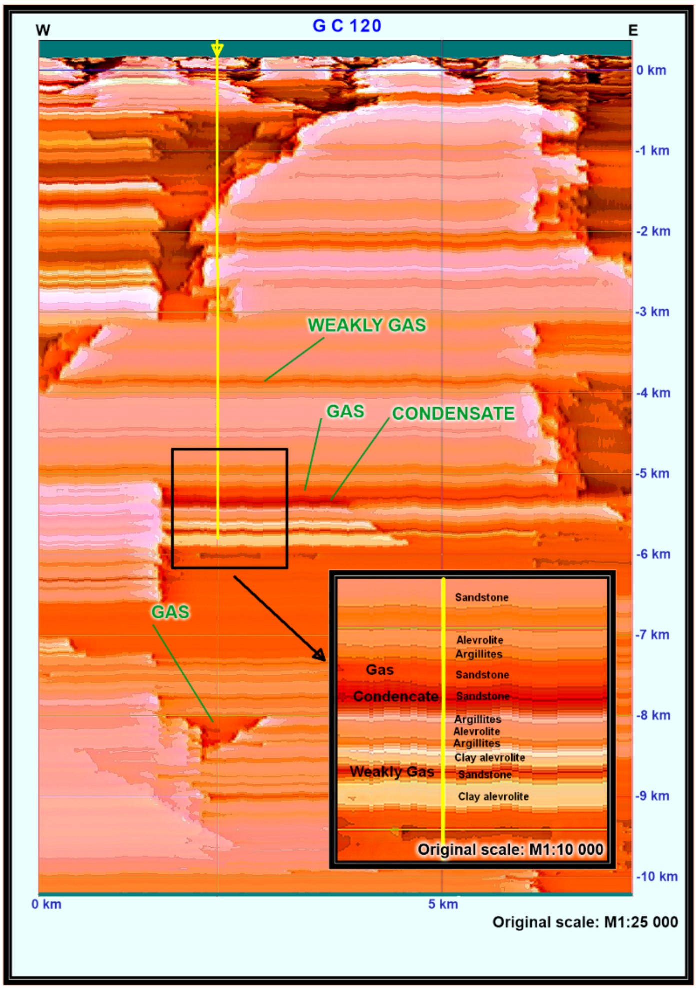


Fig. 2. Vertical geothermal section [G C 120]

Legend:

- Location of the well №120

Impenetrable rocks:
- argellites
- clay alevrollite

Saturated rocks:
- sandstone, sand
- sandstone, sand

At the heart of the Radio Thermal Imaging Technology (RTT) is the construction of a geothermal 3D cube of a fragment of the Earth's subsurface. To build a 3D cube, technologies have been developed for restoring the detail of images of small-scale radiometric satellite images.

The results are used for searching for and recognizing geological structures, in this case, hydrocarbon deposits. Scale 1:50,000 - 1:25,000.

To recognize deposits, cluster analysis technologies of a color-synthesized calibration scale are used, taking into account the emissivity coefficients of materials (water, oil, gas, sandstone, mudstone, etc.).

The use of small-scale images makes it possible to perform "rapid mapping" over a large area (400 x 400 km) and depth of subsurface strata.

It is worth noting that the use of medium-scale satellite images allows obtaining results on a more detailed scale, up to a scale of 1: 5,000, but this reduces the depth of research and increases the time for completion of work.

Remote sensing data of the Earth were obtained using the AMSR-2 microwave radiometer (GCOM-W1 satellite).

The radiometer channels record the radio brightness temperature in the ranges:

6,925 GHz	- wavelength: 4.560 ... 4.121 cm (45 600 ... 41 210 microns);
7,30 GHz	- wavelength: 4.314 ... 3.919 cm (43 140 ... 39 190 microns);
10,65 GHz	- wavelength: 2.842 ... 2.789 cm (28 420 ... 27 890 microns);
18,7 GHz	- wavelength: 1.620 ... 1.586 cm (16 200 ... 15 860 microns);
23,8 GHz	- wavelength: 1.281 ... 1.239 cm (12 810 ... 12 390 microns);
36,5 GHz	- wavelength: 0.844 ... 0.799 cm (8 440 ... 7 990 microns);
89,0 GHz	- wavelength: 0.349 ... 0.326 cm (3 490 ... 3 260 microns).

Materials prepared:
"Center of Aerospace Tehnologies" Ltd. (Burgas, Bulgaria);
"Special Centre Of Aerospace Technologies «TSENTAVR»" (Dnipro, Ukraine).

Date of preparation of materials: 06/06/2022

APPLICATION OF THE METHOD OF RADIO THERMAL IMAGING TECHNOLOGY USING SMALL-SCALE SPACE IMAGES FOR SEARCH AND ADDITIONAL EXPLORATION OF HYDROCARBON DEPOSITS ON THE EXAMPLE OF THE GAS-CONDENSATE FIELD "SHEBELINSKOE" (KHARKOV REGION, UKRAINE)

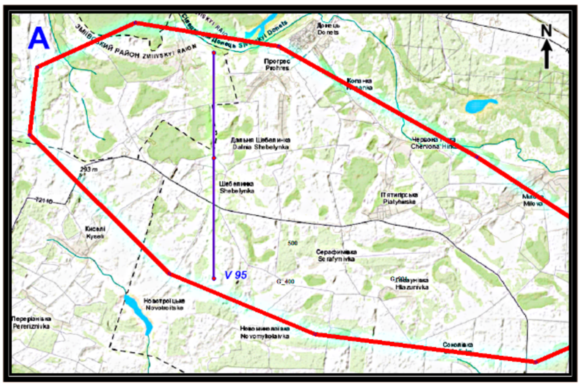


Fig. 3. Gas condensate field "Shebelinskoe", well № 95. Location of the vertical geothermal section [V 95]. A fragment of a topographic map [A] and a satellite image [B].

Legend:

- contours of the deposit

V 95 - projection of a vertical geothermal section [V 95]

At the heart of the Radio Thermal Imaging Technology (RTT) is the construction of a geothermal 3D cube of a fragment of the Earth's subsurface. To build a 3D cube, technologies have been developed for restoring the detail of images of small-scale radiometric satellite images.

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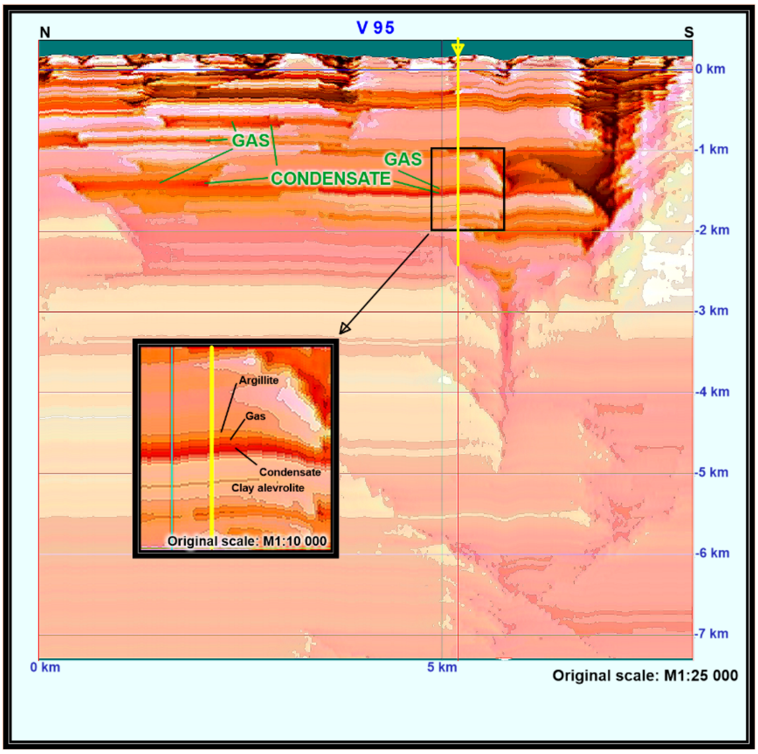

Fig. 4. Vertical geothermal section [V 95]

Legend:

Impenetrable rocks:	Saturated rocks:
- mudstones	- sandstone, sand
- clay siltstones	sandstone, sand

Characteristics of well No. 95:

- productive horizon: 1565 - 1690 m;
- initial flow rate: 15,000 cubic meters. m / d
- current flow rate: 9,000 cubic meters. m
- the current volume of withdrawal: 634,670 thousand cubic meters. m

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Date of preparation of materials: 06/06/2022

Conclusion and Summarize

The results of the presented work allow us to state that the remote sensing of the Earth RTT method can be widely used in geological exploration for the purpose of forecasting and identifying new and additional exploration of old deposits containing hydrocarbon or ore deposits. Structural heterogeneities are confidently recognized on vertical geothermal sections, which make it possible to distinguish between linear horizons, which, by the nature of saturation, can be interpreted as structures saturated with hydrocarbons. The structures are usually limited by a "cover" and have an impermeable "substrate" at the base. These results are confirmed by the data of operating wells and are given in the description.

On geothermal sections, the contours of traps and deposits are distinguished, which makes it possible to recommend this method for work on oil and gas condensate and other mineral deposits of endogenous genesis.

Geological studies allow to calibrate and interpret the model, to clarify the content of useful elements in deposits.

The remote sensing of the Earth RTT method is environmentally friendly. Technologies allow express mapping of significant territories anywhere in the world. Allows you to optimize economic and environmental risks in the design and development of fields, including those in hard-to-reach places on land and sea.

Bibliography:

1. *Vinnichenko N.K., Vinnichenko O.N., Glushchenko I.V., Stepchenko V.N., Bagryantsev V.A.* Theory and practice of thermal exploration technologies based on multispectral satellite imagery data. - Geoinformatics. 2015, №1(53) pp.27-38

2. *Gubin V.N., Kovalev A.A.* Space geology of Belarus. - Minsk: Lazurak, 2008. pp. 7-14, 42-44, 90-104

3. *Onegov V.L.* Mathematical modeling of geological environments based on thermal imaging. Dissertation abstract. Ulyanovsk. 2011

4. *Seminsky K.Zh.* Faulting in the Earth's crust and related processes: an applied aspect. Irkutsk Scientific Center SB RAS. pp.534-542

5. *Timurziev A.I.* Mantle sources of hydrocarbon generation: geological and geophysical features and predictive and search criteria for mapping; patterns of oil and gas content of the interior as a reflection of the unloading of mantle hydrocarbon systems in the Earth's crust. Tectonics and stratigraphy, 2015, issue 42. pp. 121

6. *Tronin A.A.* Space thermal imaging in the study of seismic activity. Doctoral dissertation. St. Petersburg - 2010

7. *Tumanov V.R.* The method of video thermal imaging generalization in geological exploration. / Tumanov V.R., Mukhamedyarov R.D. - In the book. "The thermal field of the Earth and methods of its study". - Moscow: RIO RGGRU. - 2008. - pp.250-256

8. *Tumanov V.R. Cheban V.D.* Application of the method of thermal imaging generalization for assessing the minds accumulated in carbohydrates in Western Egypt. Oil & Gas Industry of Ukraine. 2013. №3. pp. 10-16

9. *Tyapkin K.F.* A new look at geotectogenesis due to a change in the position of the Earth's tectonosphere relative to its axis of rotation // Geology and Minerals of the

World Ocean. 2014. No. 1. pp. 5-19.

10. *Sharkov E.A.* Radiothermal remote sensing of the Earth: physical foundations. Volume 1. IKI. Moscow. 2014. pp.20-26

11. *Shutko A.M.* Microwave radiometry of the water surface and soils. Moscow. THE SCIENCE. 1986. pp. 10-11

Аннотация: *Рассмотрены краткие физические основы Радио-Тепловизорных Технологий, показаны геофизические аспекты дешифрирования и интерпретации космической информации с иллюстрацией результатов исследований, связь спутниковых снимков с глубинным строением Земли. В качестве примеров работ представлены горизонтальные и вертикальные геотермические разрезы Земной коры. Отмечено получение принципиально новых, более информативных данных о структурах Земной коры.*

Ключевые слова: *Радио-Тепловизорные Технологи, Дистанционное зондирование Земли, электромагнитное излучение, радиояркостная температура, аэрокосмические снимки, Земная кора, термоpазведка, горные породы, геотермические аномалии, геотермические разрезы, геологические структуры, полезные ископаемые, залежи углеводородов, нефтегазовые конденсаты, ловушки углеводородов.*