

## UP-TO-DATE GAS-GEOCHEMICAL TECHNOLOGIES FOR CONTROL OF TECHNOGENESIS PROCESSES DURING EXPLORATION OF RESOURCES AT VERKHNEKAMSKY REGION\*



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*It is given results of gas-geochemical study of the territory of Verkhnekamsk deposit of potassium salt. It has been studied influence of the techno-genesis processes, stipulated by underground mining of potassium ore and by exploiting of the under-salt hydrocarbon deposits, on the gaseous medium near the surface. It has been substantiated usage of the gas-analyzer Ecoprobe-5 for control of the techno-genesis processes in geological medium.*

**Key words:** Verkhnekamsk potassium salt deposit, halogen formation, deformation of the rock-salt massif, under-salt hydrocarbon deposit, absorbed and dispersed gas, gas survey, gas-analyzer Ecoprobe-5, monitoring

Combined bedding of the different raw minerals on the same territory is well known and wide spread natural phenomenon. In full measure it concerns combined territorial bedding of the salt and oil and gas-bearing seams that is typical for many oil and gas-bearing provinces in the world. But common mining of the territorial combined salt and oil deposits is little known fact. In this respect Verkhnekamsk region is unique object. Joint development of resources of potassium ore and under-salt hydrocarbon deposit is carried out here over a long period of time. It has been realized earlier only on the conjugate territories. But recently it is worked up the projects for joint simultaneous mining of potassium ore and oil at the some areas of the Verkhnekamsk deposit of potassium salt (VKDPS). It has to be noted some additional feature of the region. Territory of mining production is conjugated with Beresnikovsko-Solikamsk town-industrial agglomeration. Extraction at the some mine fields is carried out directly under the buildings and some oil-

producing objects are located near underground water-intakes intended for industrial-drinking water supply. It determines necessity to carry out efficient monitoring of the techno-genesis processes in geological medium for prevention their negative influence on the vital functions of population.

Different modifications of the gas survey are the methods of control of state of geological medium. They have shown their efficiency in solution of wide range of geological and mining-technological tasks (mapping of the ruptures, control of strained-deformed state of rock massif, forecast of geo-dynamical processes, monitoring of underground gas-depot and abolished coal mines and so on). Fulfilled investigations show that gas is the most mobile component of the lithosphere, it gives the important information about state of the bowels of the earth and about natural and natural-technogeneus processes in the rock massif.

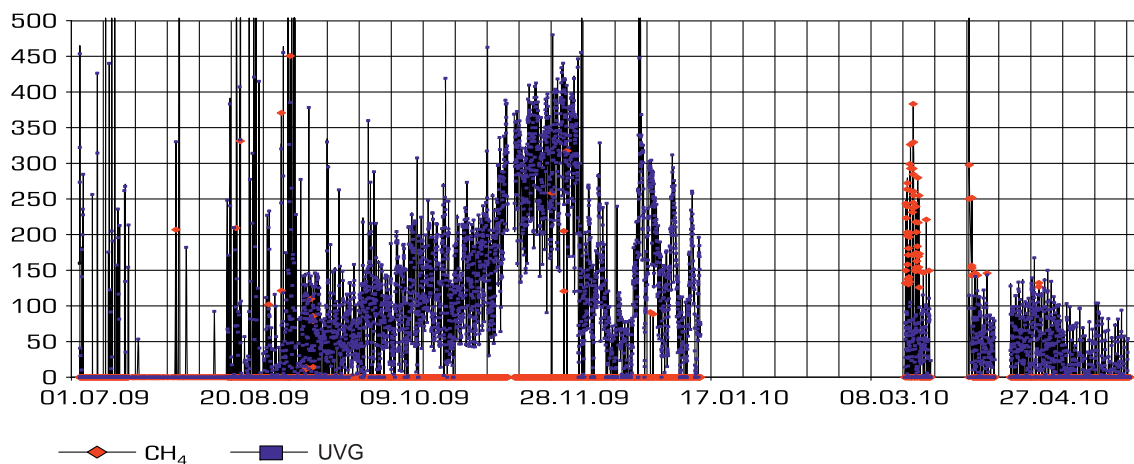
Today following gas-surveys are used in practice in the Perm region:

- atmo-gas-geochemical (emission) — study of composition of the under-soil air and free gas;
- litho-gas-geochemical — study of absorbed gas in the soil and rock;
- hydro-gas-geochemical — study of gas solution in the hydrosphere near the surface [1].

It has been offered to use hydrocarbon gases and radiogenic inert gases

(helium, radon, argon) as indicators for control of techno-genesis processes. They give the best information in case of presence powerful sources of hydrocarbon (oil and gas, methane-bearing coal and potassium seams) in the rock massif.

Efficiency of usage of different modifications of the gas-surveys is determined in many cases by geological-tectonic conditions of the studied objects that determine contrast range of development of the gas-generating sources in the zone near the surface of the section. In spite of evident rise in efficiency of gas-geochemical sounding with increase of depth of testing, it is quite explainable aspiration for application of more express and cheap surface methods in practice. Investigations have shown that usage of the



**Fig. 1. Change of hydrocarbon content in under-soil air on the territory of the mine field of BKPRU-1 (in accordance with data of the station of gas-geochemical monitoring)**

soil cover as bearing horizon in gas-geochemical testing is the most effective one. Soil cover is the sorption geochemical barrier that intercepts migrating components from the lower part of the section [1].

Recently, it has been designed new generation of the gas-analyzers. They permit to analyze gas composition with high precision directly in the field conditions. Besides, they increase possibility of application of the methods of gas-geochemical sounding near the surface. Gas-analyzer Ecoprobe-5 (produced by the firm RS DINAMICS Ltd., Czech Republic) belongs to above-mentioned generation. It permits to carry out express-analysis of composition of the under-soil gas [2]. Combination of the photo-ionization (FID) and infra-red (IR) detectors allows determine concentration of methane, carbon dioxide, content of hydrocarbon  $C_1 - C_5$  (sensitiveness 20 ppm) and total content of the volatile organic compounds (LOS — sensitiveness 0.0001 ppm). VOC involves more than 150 substances (alcanes  $C_4 - C_{11}$ , alkenes  $C_2 - C_6$ , benzol, toluol, ethylbenzol, xylols, organic acids, alcohols, ethers, chlorinated hydrocarbons, nitric- and sulfur-organic structures). It significantly widens spectrum of recorded gas-geochemical parameters.

Brief description of results of testing of the device on the territory of Verkhnekamsk region is given below.

Usage of gas-geochemical methods for control of processes of potassium salt mining is based on presence of considerable concentration of dispersed and combined gases ( $0.024 - 0.216 \text{ m}^3/\text{m}^3$ ) in the rock of halogen formation of VKDPS. Principal feature of composition of the gas is high degree of saturation with hydrocarbons (total content of methane and its homologous forms reach 5–20 %), presence of hydrogen and radiogenic argon. Deformation and breakage of the rock will lead to disengage of some volume of combined gases into three phases and to subsequent re-distribution of the gases in the over-productive part of section. It permits to use the gases as indicator of intensity of above-mentioned processes. They will reach maximum intensity in case of leaching of the rock-salt

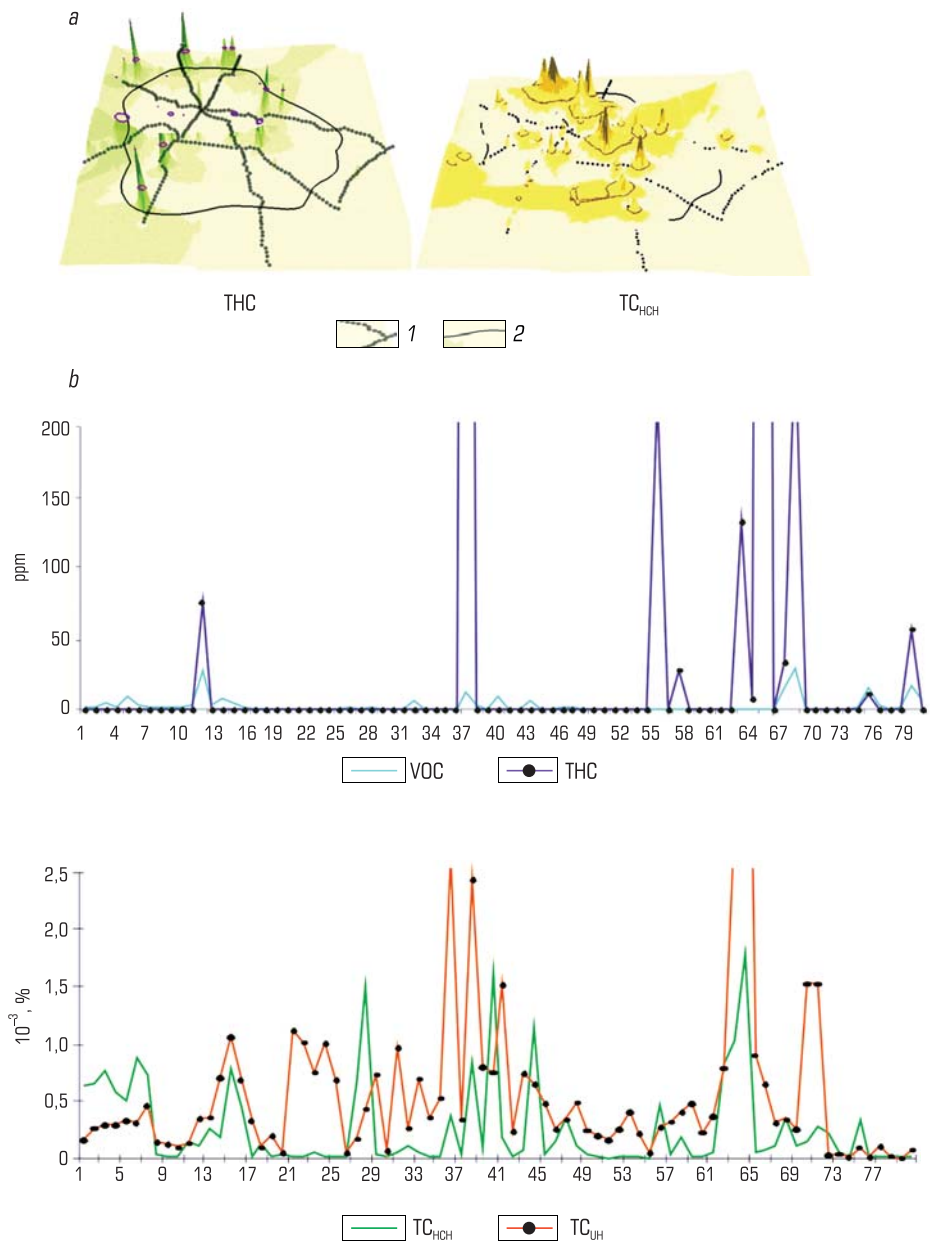
massif, since solution of the rock will lead to disengaging of the gases contented in the rock into the free phase.

First attempts to introduce gas-geochemical methods in complex of geological-geophysical investigations at VKDPS have been carried out in 1988–1989. They were connected with flood of the mine BKPRU-3. Experimental-methodical works, carried out in this period, have shown that gas background near the surface enough sensitively reflects presence of the zones with increased permeability of above-salt part of section of activation of the processes of vertical mass-transfer of the gas components formed in course of leaching of the rock-salt massif [3]. But introducing of gas-hydrochemical (helium-argon) survey in the complex of industrial geological-geophysical investigations at VKDPS has not been realized in that period. In many respects it has been stipulated by high laborious and expenses for its realization (drilling of the special holes up to opening of consistent water-bearing horizons, usage of hermetic sample-cutters for taking of the samples of the gas dissolved in water, mass-spectrometric determination of isotope composition of argon).

Next splash of interest in possible usage of gas-geochemical methods at VKDPS has taken place in 2006. It has been connected with flood of the mine BKPRU-1, since it has appeared necessity of further perfecting of the methods of control of conditions in geological medium for revealing of initial signs of destruction of the water-proof layer (WPL). Positive results of testing of the gas-analyzer Ecoprobe-5 on the territory of the Perm Prikam'e favor interest to the gas-geochemical methods. Efficiency of the method has been confirmed by control of development of emergency situation, connected with flood of the mine. Gas-geochemical investigations have shown that salt leaching, accompanied by forming of the downfall crater over destruction of WPL, has led to letting out of considerable volume of the gases. As a result methane content in the under-soil air in the region has increased to 2–6 %, and in the gases absorbed by the soils — to 7.5–20.6 % [4]. Forming of the high contrasting gas anomaly in the soil cover during relatively short period (4–5 months) indicates that jet mass-carry-over is the most real mechanism of ascending migration of the gases

let out in course of salt solution. Mass-carry-over is realized in form of the micro-bubbles moving along the system of the interconnected pores and cracks. It restricts scale of gas solution in underground water.

Subsequent gas-geochemical examination of the territory of mine fields of VKDPS has shown that the principal factor (in case of conservation of WPL), that leads to penetration of hydrocarbon gases in the near-surface part of the section, is deformation of extracted rock massif. Hydrocarbon background, formed in the near-surface layer over the zone of extraction, has mosaic character. It reflects different degree of permeability of the zones of technogeneus fissuring in deformed over-salt rock massif since they control intensity of mass-carry-over of the let out gases. It has been noted that most active ascending migration of the gases takes place in the zones belonging to the edge areas of the moulds of settling above the mined (extracted) space. It stipulates forming in the areas in the soil cover of relatively stable local centers with increased concentration of the hydrocarbon gases [5]. At the same time results of gas-geochemical monitoring confirm pulse character of the gas "breathing" in the rock. It stipulates considerable temporal changeableness of the gas background near the surface (Fig.1). To all appearance, intensity of gas inflow in the near-surface area of the section is controlled by character of deformation processes taking place in the rock massif. Deformation processes determine both scale of letting out of combined gases and degree of opening and liquid-permeability of the zones of natural-technogeneus fissuring [5]. It allows consider gas-geochemical sounding of the near-surface area of the section as the method permitting to carry out grading of the marked by geophysical methods anomalies in structure of the over-salt part of the section, estimate their possible fluid-permeability and discover initial signs of destruction of the water-proofing layer. Positive results of testing of the methods of gas survey with



**Fig. 2. Distribution of hydrocarbon (UV) in dissipated and absorbed gases in the soils on territory of the oil deposit named by Arkhangelsky:**

*a* — changeableness of contrast of anomalies of UV on area of the deposit (1 — tested profiles; 2 — contour of the oil deposit); *b* — distribution of UV by profile through the deposit (UVG — total content of hydrocarbons; VOC — content of volatile organic components and components of absorbed gases;  $TU_{utm}$  — total content of heavy utmost UV (methane homologues);  $TU_{non-utm}$  — total content of non-utmost UV (olefins)

application of express-gas-analyzer Ecoprobe-5 were the basis for working out of the program of gas-geochemical monitoring directed for prevention of negative consequences of technogeneus accident, stipulated by flood of the mine BKPRU-1, including control of possible unloading of the gas-air accumulations formed in the flooded mined space [5]. System of monitoring involves periodic gas-geochemical examination of the profiles, cutting regions of supposed



forming of the gas-air capacities ("hats") and shallow holes, intended for control of the scale of let out of hydrocarbon gases from the soils into the free phase. Some holes are equipped with the stations of automated control, worked up by the firm RS Dynamics Ltd. on the base of the gas-analyzers Ecoprobe-5. Stations permit to carry out (with the set periodicity) automated analysis of the gas for content of hydrocarbon components and to carry out in regimen of real time remote transference of obtained information to the station for data processing. Adopted system of gas-geochemical monitoring allows control intensity of gas "breathing" of the rock and realizes additional measures for estimation of danger for vital functions of the people in case of revealing of let out of the gases from productive part of the section.

Control of development of the under-salt hydrocarbon deposits is the more complicate task. Theoretical basis for application of gas-geochemical methods of control of techno-genesis processes of the oil-extracting profile is information about presence over the deposits of specific vertical halo of dispersion formed as a result of diffusion-filtration mass-carry-over of the gases and vaporous hydrocarbons into the covering sediments. As a result, anomalies of the naphtenic type are formed in the near-surface gas background. Specific feature of the anomalies is increased content of methane homologues, especially butane and pentane, in the under-soil gases [1]. Taking into account high migration capacity of the gases we may suppose that activization of the vertical flows of the fluids will be reflected, first of all, in transformation of the gas background near the surface, especially within the bounds of the marked anomalies, reflecting presence of the zones of natural fissuring in the section.

Results of gas-geochemical testing of Palashersky plot of VKDPS, involving oil deposit named by Arkhangelsky, have shown that anomalies of the naphtenic type, marked in the near-surface gas background within the bounds of its contour, have local (point) character and relatively small size (Fig. 2). Comparison of results of gas-geochemical investigations with materials of geophysical works confirms territorial coincidence (or conjunction) of majority of the anomalies of the naphtenic type with the marked zones of structural-lithological heterogeneity and un-consolidation of the salt and over-salt rock massif. So, it is not excluded that above mentioned anomalies reflect of the though vertical haloes of dispersion, formed in period of activization of tectonic regimen, rather than current "breathing" of the deposits. Reality of stated assumption is confirmed by examination of the core materials. It has demonstrated "oil type" of composition of dispersed gases and organic materials within the bounds of revealed anomalies along the all section of the rock salt [5].

Repeated gas-geochemical testing of territory of the deposit named by Arkhangelsky after putting in exploiting of the laid up (in the past) oil holes has shown that increase of contrast of the marked earlier anomalies of the naphtenic type has been noted near some holes in one year. Probably it has been stipulated by activization of the fissured zones in the rock massif near the holes.

Besides, results of gas-geochemical examination of the oil deposits for long time have shown that in case of damage of hermetic properties of the casing strings it takes place appearance of liquid flow behind of the holes walls. Liquid moves in form of filtration (jet-bubble) mass-carry-out along the system of the pores and cracks. Sum concentration of hydrocarbon in composition of under-soil gases near the holes mouths reaches "hurricane" means (more than 100000 ppm) during short period (1–3 months) [5]. It allows usage of the gas-analyzer Ecoprobe-5 as efficient tool for operative control of hermetic properties of the holes. In case of necessity it may be used for mapping of the zones of the fluid inflow into the near-surface part of the section.

Thus, given results of gas-geochemical examination demonstrate that study of features of gas "breathing" of the rock by the modern analytical apparatus gives unique information for solution of wide range of geological, mining-industrial and geo-ecological tasks.

#### References

1. Bachurin B. A., Borisov A. A., Baboshko A. Yu. *Nauchno-metodicheskie podkhody k provedeniyu gazogeokhimicheskikh issledovaniy pri reshenii neftepoiskovykh i geoekologicheskikh zadach* (Scientific and methodical approaches to behavior of gas and geochemical researches in the process of solving of oil-exploring and geoecological tasks). *Izmenyayushchayasya geologicheskaya sreda: prostranstvenno-vremennye vzaimodeystviya endogennykh i ekzogennykh protsessov* : materialy Mezhdunarodnoy konferentsii (Changeable geological environment: spatio-temporal interactions of endogenous and exogenous processes : materials of International conference). Kazan : Publishing House of Kazan State University, 2007, Vol. 1, pp. 315–319.
2. Blaha G., Retief E. *New method and instrumentation for the soil contamination survey* (basic introduction). Available at: <http://www.rsdynamics.com>.
3. Bachurin B. A., Novoselitskiy V. M., Tarkashev V. V. et al. *Informativnost gazogeokhimicheskikh issledovaniy pri otsenke sostoyaniya vodozashchitnoy tolshchi na Verkhnekamskom mestorozhdenii* (Informativeness of gaseous and geochemical researches during the estimation of state of waterproof layer at Verkhnekama deposit). *Geologiya i razvedka neftyanykh i gazovykh mestorozhdeniy: mezhvuzovyy sbornik nauchnykh trudov* (Geology and exploration of oil and gas deposits: inter-university collection of scientific papers). Perm : Perm Polytechnic University, 1990, pp. 95–102.
4. Bachurin B. A., Borisov A. A. *Gornyy Informatsionno-analiticheskiy Byulleten – Mining Informational and Analytical Bulletin*, 2009, No. 4, pp. 371–378.
5. Bachurin B. A., Borisov A. A., Glebov S. V. *Gornyy Informatsionno-analiticheskiy Byulleten – Mining Informational and Analytical Bulletin*, 2011, No. 6, pp. 126–132. **ТЖ**

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