18356

Application of geophysical methods in the study of karst

S. Vyzhva, ***V. Onyshchuk**, **I. Onyshchuk**, **M. Reva**, **O. Shabatura** *(Taras Shevchenko National University of Kyiv)*

SUMMARY

The paper discusses the results of the study of karst processes by geophysical methods. In examining of karst processes it is important to find out the features of their structure but it should always be remembered that karst-prone rocks, as a rule, have the various combination of contrasted boundaries sometimes with a high gradient of physical properties. Analysis of karst zones suggests that it is not always possible to obtain reliable and sufficient information using just one geophysical parameter. Therefore, mapping of rocks that were impacted by karst should be performed by a wide range of geophysical methods. To study karst processes, electrometry, magnetometry, thermometry, gamma surveying and some other geophysical methods are used. High resolution and efficiency of geophysical methods in the study of karst processes has been proved in many examples in different regions of the country, including areas that are under man-made impact. We have intention to present an example of geophysical studies performed at the Lubenske deposit of native sulfur in the Lviv region.

Introduction

Taking into account the increasing urbanization of the environment and building development, the study of karst processes with geophysical methods has become really important. Particularly, the study of karst is essential for hydrotechnical construction, since the various cavities and sinkholes in the body of the rock mass are potential ways of increased filtration of water from reservoirs, channels and tunnels. In the construction and operation of mines, karst displacements determine the technological features of the mine workings and complicate the extraction of mineral deposits. In the presence of karst cracks and voids, conditions for intensive groundwater inflow are created, which can lead to major accidents and catastrophes.

When the geology condition under research, the attention is drawn to the allocation of zones, which are the most karst dangerous in their geotechnical indicators. These are mainly readily soluble rocks (limestones, dolomites, marls, gypsum, anhydrites, chalk, sodium chloride and potassium salts and the like).

The development of karst processes is significantly influenced by the features of groundwater occurrence and flow. The presence and position of regional waterproof layers is one of the most important factors that controls the inflow of water into rocks prone to karst. It should be emphasized that the development of karst is a dynamic process, which at each stage of its development is determined by a lot of various natural factors. In examining of karst zones, it is important to find out the features of their structure.

Method and/or Theory

For the occurrence of karst, it is necessary: 1) the presence of soluble and/or permeability rocks (permeability, which is mainly the result of tectonic fracture); 2) active movement of groundwater (groundwater dissolves rocks and carries away dissolution products).

Analysis of the conditions of karst makes it possible to outline the following main groups of tasks in the study of this phenomenon: allocation and lithological characteristics of mass composed of soluble rocks; identifying the shielding role of hydrophobic formations that are covered with soluble rocks; determining the position of local and regional watersheds; mapping of ancient buried erosion down-cuttings, which are local or regional bases of karst origin; the study of tectonic dislocations and the accompanying to them fractures that contribute to the development of karst.

An important task is the organization of geophysical monitoring of karst processes, studying their dynamics, forecasting of the development of negative changes and issuing recommendations for the adoption of protective engineering and technical decisions, as well as monitoring of the efficiency of anti-karst engineering and technical measures – assessment of the quality of drainage systems, artificial strengthening of rocks etc ((*Vyzhva et al., 2018*), (*Vyzhva et al., 2017*), (*Ogilvi, 1990*), (*Vyzhva et al., 2019*), (*Vyzhva et al., 2019*)).

As a rule, karst-affected rocks significantly differ from rocks that are resistant to karst. In the karst development zone, the rocks become deteriorated, their structure are changed, the content and mineralization of the pore moisture are increased. These changes are reflected in a number of geophysical parameters. It follows that mapping of rocks that were impacted by karst can be performed by a wide range of geophysical methods. The set of the geophysical methods is determined by the size of the studied area and geological bodies that make it up, the thickness of the overlying sediment rocks, the nature of the surface relief and other natural and man-made factors ((*Vyzhva et al., 2018*), (*Vyzhva et al., 2017*), (*Ogilvi, 1990*), (*Vyzhva et al., 2019*), (*Vyzhva et al., 2019*)).

Underground air-filled cavities have high electrical resistivity, abnormally low density and velocity of elastic waves; on the contrary, if they are filled with water or clay material, they are characterized by reduced electrical resistivity (by 2-3 orders of magnitude). Fault-disturbed, disintegrated carbonate and sulphate formations, cracks and cavities (with or without filler) are characterized by reduced values of the density and velocity of elastic waves. In some cases, the filling material may contain magnetic inclusions, and this is indicated in local magnetic field anomalies.

A rational geophysical set of methods is determined by the stage of work (regional, prospecting, exploration or monitoring), the geological region (platform or folded area) and the project area background data.

The regional stage includes the usual set of methods for geological survey for specifying the features of the geological structure (remote studies (airborne method), magnetic exploration, gravimetry, electrical exploration in various modifications, seismic exploration).

At the search stage of karst effects, the method of geophysical studies is determined by the degree of karstification and depth of occurrence of karst-prone rocks. In areas of poor karst development and shallow karst-prone rocks, medium-scale (scale 1:25 000 – 1:50 000) surveys are performed using electric profiling (EP) methods: symmetric (SEP), dipole (DEP), combined (CEP) and self-potential (SP) method. In areas with deep occurrence of karst-prone rocks, microelectric sounding (MES) is predominant. For individual profiles, surveys are supplemented by seismic and in some cases gravimetry. When a high degree of karstification, the detail of the research increases to a scale of 1:10000 – 1:5000.

At the stage of exploration of deposits of carbonate rocks and in evaluative studies of karst for civil and industrial construction, detailed geophysical studies of scale 1:5000 – 1:1000 are performed. The works include circular and cross MES to study the anisotropy of rocks. The materials obtained at this stage provide the solution of tasks for mapping the top of karst, the allocation of zones of disturbances and monoliths, the detection of karst on the top and inside the solid mass, determining the size and depth of karst occurrence, clarifying the hydrogeological situation. These materials are the starting point for the calculation of the reserves of productive deposits, volumes of karstified rocks or are the basis for the selection of construction sites.

In the study of karst phenomena, the main role belongs to the electrical surface methods. Microelectric soundings (MES) are used to study the karst relief of the top of soluble rocks, their subdivision by lithological properties, the separation of tectonic, fractured and karst zones, determination of the depth of groundwater and base level of erosion, the study of karst zonal sequence, and also solving other tasks associated with the vertical subdivision of geological profile.

The main method of direct isolation of surface and underground karst disturbances is electrical profiling. Observations should characterize the geological situation at two depths. On small electrode spacing, information about the thickness of rocks within the aeration zone is obtained. On large electrode spacing of the current circuit, basic information about the rocks in the zone of full water saturation is obtained.

For studying systems of elongated karst disturbances and rock-fracture zones, circular electrical sounding and circular electrical profiling are used. The asymmetry of the obtained polar diagrams indicates the elongation of karst voids and cracks.

It should be noted the efficiency of the charged-body potential method in the study of karst areas. The charged-body method is included in the recommended set of geophysical researches at a detailed survey of intensively karst territories in order to assess the stability of foundations of engineering structures ((*Vyzhva et al., 2018*), (*Ogilvi, 1990*)). At present, seismic methods are widely used in the study of karst.

For underground construction and operation of mineral deposits, it should be obtained information on the distribution of karst disturbances to the depth of the massif, the nature and geotechnical properties of the filler and surrounding rocks. These problems can be solved by geophysical exploration in wells, cross-borehole exploration, geophysical survey of mines and some other observations.

Geophysical explorations in wells make it possible to: allocate karst and fractured intervals with refinement of the position of individual cavities in section; evaluate the relative and absolute voidness of rocks; characterize the composition, properties and condition of the cavity filler; study the zonation of fractured-karst groundwater, determine its mineralization; find out the structure of the physical fields in the karst areas.

Geophysical information of well research allows to determine the exact geometric parameters of the geological section, physical properties of rocks and groundwater. Based on these data, correlations between geophysical and engineering-geological parameters are established.

At the monitoring stage, geophysical observations of changes in geophysical fields with time, which are associated with the dynamics of karst processes, are carried out. In addition, the effectiveness of anti-karst engineering measures is monitored. The researches are carried out by a set of geophysical methods on pre-selected key profiles. The frequency of cycles of geophysical measurements is determined by the rate of development of karst processes and the specific geological and geophysical situation of the study area. Integrated analysis of monitoring observation materials allows to predict the development of karst processes, make adjustments during the implementation of protective engineering and technical measures and monitor their effectiveness.

Example

As an example, some of the results of geophysical studies of karst at the Lubenske deposit of native sulfur in the Lviv region will be presented (Fig. 1).

The main object of study is the sulphate-carbonate deposits of the Tyras strata of the Upper Torton – productive sulfuric formations. These are well-soluble, karst-prone rocks. They are geoelectric marker horizon. Below them are the limestones and sandstones of the Lower Torton, which in physical parameters are indistinguishable from the rocks of the Tyras strata.

Together, sedimentary rocks make up a three-layer geoelectric section with contrasting transitions of resistivity (90-130; 5-25; 250-500 Ω·m), which allowed for a reliable mapping of two boundaries - the above Kosiv strata surface and the bottom of the Quaternary deposits. The karstification and fracture of the rocks transform the geoelectric section, reducing the resistivity of the layers, which is a criterion for the diagnosis of zones of filtration and karst development (filled with fragmental and clay material).

The main factors of karst development are the water saturation of the above-gypsum aquifer of the limestones and the filtration rate between the aquifers. To solve geological tasks, the method of MES over a network of 250x100 m (AB = 300 - 1000 m), as well as the self-potential (SP) method over a network of 100 x 25 m was applied.

As a result of processing the obtained data, a set of maps was compiled, accompanied by geological and geophysical sections on the supporting profiles, among them: the isoresistivity map ρ_a, AB = 9 m (reflects the lithological composition and filtration properties of Quaternary deposits); the isoresistivity map $\rho_{a,min}$ (characterizes the degree of fissility or permeability of Kosiv clays); the asymptote angle map α – (reflects the degree of karstification of the productive gypsum-carbonate horizon); isopach maps of overlapping deposits: Q i Q+N t_{2ks}; the structural and tectonic map and the map of karstification of the deposit area. A fragment of the integrated interpretation map is shown in Figure 1.

According to the results of the researches, the contours of distribution of the gypsum-carbonate horizon of the Tyras strata were determined. Karst formation is associated with the presence of "hydrogeological windows" with increased water permeability of the above-Tyras terrigenous sediments. The impenetrable water aquaclude of the Kosiv formation corresponds to monolithic non-karstified rocks. It should be noted that infiltration processes play an important role in karst formation. According to self-potential (SP) method, the direction of the watercourse was established in the areas of high filtration in terrigenous formations.

The obtained geophysical data were used for the reasonable ways of geological prospecting and have long-term practical meaning in the following stages during the exploitation of the deposit, industrial and civil construction on the area.

Conclusions

1. Study of karst processes with geophysical set of methods includes remote (airborne methods), electrometric, seismic, emanation, gravimetric, magnetometric, thermal investigation and logging. There are four stages of researches: regional, prospecting, detailed and monitoring.

2. High resolution and efficiency of geophysical methods in the study of karst processes has been proved in many examples in different regions of the country, including areas that are under man-made influence. The main advantages of geophysical methods are efficiency, ecological safety and low cost.

In the conditions of the considerable depth of karst-prone rocks, geophysical researches allow to decrease the scope of drilling. The latter is important because the mechanical dissection of these formations by a well or the connection of aquifers enhances the karst process.

3. To avoid environmental accidents and disasters the application of a rational geophysical complex and the organization of the geophysical monitoring of karst hazardous areas is urgently needed. The complex has to be economically viable for the effective planning and development of protective engineering and technical measures.

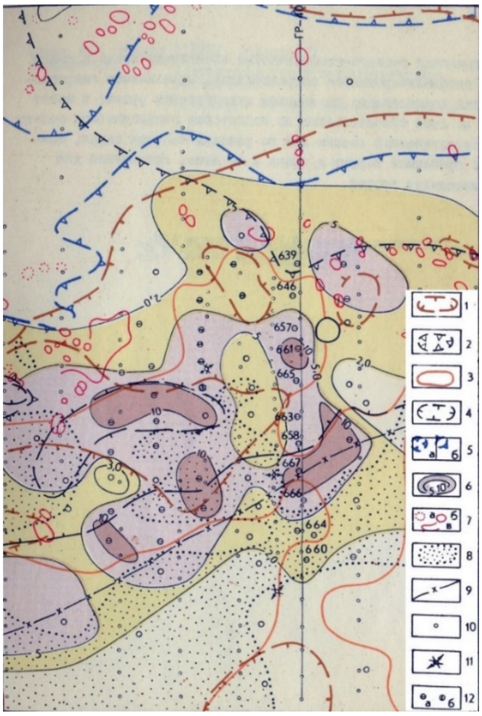

Figure 1. *Map of karstification of the Lubenska region. Lineaments of karst occurrence according to drilling data:*

1 – gypsum anhydrite; 2 – metasomatic limestones; 3 – sulfur limestones. Lineaments of geological formations according to geophysical data: 4 – water permeable rocks of the overlying rock cover; 5 – gypsum carbonate rocks of the Tyras strata: a) karstified, b) non-karsted; 6 – isopaches of karst rocks (according to drilling); 7 – karst: a) depression, b) conical depression, c) valleys; 8 – zones of infiltration of surface waters (increased values of apparent resistivity AB = 9 m); 9 – tectonic disturbances; 10 – MES points; 11 – the direction of fracture according to circular MES; 12 – wells, including those that revealed karst: a) filled, b) cavities.

References

Vyzhva, S.A., Onyshchuk, V.I., Onyshchuk, I.I., & Reva, M.V. (2018). *Engineering geophysics*. Kyiv: Kyiv University Publishing. [in Ukrainian].

S. Vyzhva, V. Onyshchuk, K. Ivanchenko, I. Onyshchuk, M. Reva, & S. Deineko (2017). Research of geologic structure of territories of hydrotechnical systems allocation by means of geophysical methods (using "Senzhe" HPP as an example, Equatorial Guinea). *Visnyk of Taras Shevchenko National University of Kyiv: Geology*, 77, 36-42. [In Ukrainian].

Ogilvi, A.A. (1990). Fundamentals of engineering geophysics ods. Moscow: Nedra. [in Russian].

S. Vyzhva, V. Onyshchuk, I. Onyshchuk, M. Reva, O. Shabatura (2019). Application of geophysical methods in the study of landslides. *18th International Conference; Geoinformatics: Theoretical and Applied Aspects*, May 13-16, Kyiv, Ukraine. https://doi.org/10.3997/2214-4609.201902066

S. Vyzhva, V. Onyshchuk, I. Onyshchuk M. Reva, O. Shabatura (2019). The mapping of submerged (flooding) lands by geophysical methods. *XIII International Scientific Conference: Monitoring of Geological Processes and Ecological Condition of the Environment*, November 12-15, Kyiv, Ukraine. https://doi.org/10.3997/2214-4609.201903225