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POSSIBILITIES OF GEOPHYSICAL METHODS FOR MAPPING ZONES WITH AN INCREASED RISK OF SLOPE DEFORMATIONS

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ABSTRACT. The presented paper analyses some possibilities of geophysical methods for mapping zones with an increased risk of slope deformations probably caused after coal deposits near the base of mountains slope would be mined. This situation is demonstrated on the Northern Bohemian brown coal district, where owing to the coal mining activity along south–eastern (SE) slopes of the Krušné hory Mts, the problem of slope stability became critical. One of the main factors of a lower stability of the steep slopes in the metamorphites of the Krušné hory Mts and a predisposition to greater slope deformations is predetermined by tectonic phenomena in the area. Therefore, mapping the tectonic phenomena by the geophysical methods, in cooperation with other geological investigations, may increase quality of the investigation and substantially decrease investigation expenses.

In this paper, I refer to a possibility to trase areas or zones in which disturbances of equilibrate conditions of rock slopes may be a very probable cause of the slope deformations.

On the break of the 70th and 80th the exploitation of brown coal in the Northern Bohemia Brown Coal Basin continued towards the bases of slopes of Krušné hory Mts. The exploited seam along the NW margin of the basin ascends up to the surface along the Krušné hory fault under the angle 60 – 70 degrees while the natural angle of the SE slopes of the Krušné hory Mts is about 15 – 45 degrees. In the case of extracted seam which originally was at depths from several tens to several hundreds meters underneath the surface, the extremely steep and high slopes raised with the slant markedly greater than the natural slope at the SE base of the Krušné hory Mts. Under this circumstances the problem of slope stability became highly critical.

One of the main factors influencing the stability of extremely steep slopes in the metamorphites or the soils of the Krušné hory Mts is their tectonic disturbance. And just geophysical methods besides geological (engineering–geological) are the key methods in investigating and predicting the tectonic disturbances and/or weakened zones of the rock massif.

The aim of the geophysical measurements in this case was to determine depths of rock basement under colluvial deposits and investigate its physical character,

to find and trace fault lines or, eventually, fault zones and zones of tectonically highly disturbed (weakened) rock both in the horizontal and vertical direction, and, finally, to investigate lithological differentiation of the rock medium according to its different physical parameters.

The geophysical measurements were realized in the area of SE slopes of Krušné hory Mts in the section between the valley of Vesnický potok (brook) and Albrechtice (village) in the Most district. This area is located near the SE border of the Krušné hory anticlinorium in the E part of the Kateřinská hora arch and just its SE margin reaches the area of the Most part of the Northern Bohemia brown coal basin. The boundary between the two geological units was tectonically predisposed by the Krušné hory fault zone.

Predominating rock materials of the Kateřinská hora arch are formed by various kinds of orthogneisses of migmatite character. Crystalline rocks of the Krušné hory Mts steeply dip along the "Krušné hory fault" beneath the sediments of the Northern Bohemia brown coal basin formed by series of strata represented by clays, claystones with intercalations of sands and sandstones, and mined brown coal beds. The Quaternary cover on the SE slopes of Krušné hory Mts are essentially formed by relicts of accumulations, which are, as a rule, represented by loamy, sandy and gravel sediments. A significant tectonic element of the metamorphites of the Krušné hory Mts is foliation of rocks which penetrates the rocks of this area regardless of their lithology and thus it wipes off their pre–metamorphic structure. Therefore, the post–metamorphic fault tectonics is characteristic for the Krušné hory Mts; majority of faults belong to two tectonic systems: WSW–ENE and to its approximately perpendicular direction NW–SE to NNW–SSE. The most outstanding fault structure of the WSW–ENE system is the so–called "Krušné hory fault", which is formed by a system of more or less parallel dislocations of the NE–SW to ENE–WSW direction. These faults delimit the SE slopes of the mountains and a total vertical shift of the range of 700 to 1000 meters took place along the faults.

The increased attention of geological and then also of geophysical surveys in the investigated area was concentrated on the surroundings of the prospect galleries Jezeří (under the Jezeří vrch – hill) driven in the direction of approximately NW–SE.

By the surface and subsurface (in galleries) geophysical prospecting practically all commonly known geophysical methods were applied. Geoelectrical methods – combined, dipole and symmetrical resistivity profiling, vertical electrical sounding and very–low–frequency electromagnetic method were used in the greatest extent. Also seismic measurements, both in the modification of the shallow refraction method, and in the modification of transmitting waves surface to gallery were realized in a relatively great extent. Geomagnetic and gravity measurements and gamma spectrometry were applied as complementary methods. Laboratory measurements of physical parameters (density and electrical parameters) and total gamma activity and U, Th, and K concentrations on rock samples were determined as well.

The results of geophysical measurements yield information on the course of tectonic dislocations, dislocation zones and resistivity boundaries, as well as on the physical character of rock media both in the horizontal and vertical directions. In

individual survey stages the partial results were demonstrated together with their interpretations by profile graphs or isoohmic or eventually velocity sections and in maps of apparent resistivities ρ_a and ρ_{VLF}. The main results of comprehensive elaboration of all measurements are demonstrated in the map of ρ_a isolines for the electrode arrays A30M20N30B, and eventually A30M10N30B derived from the combined resistivity profiling and in the correlation map of geophysical indications and in the structural–tectonic scheme, which yield an areal image of the physical–geological conditions of the measured area.

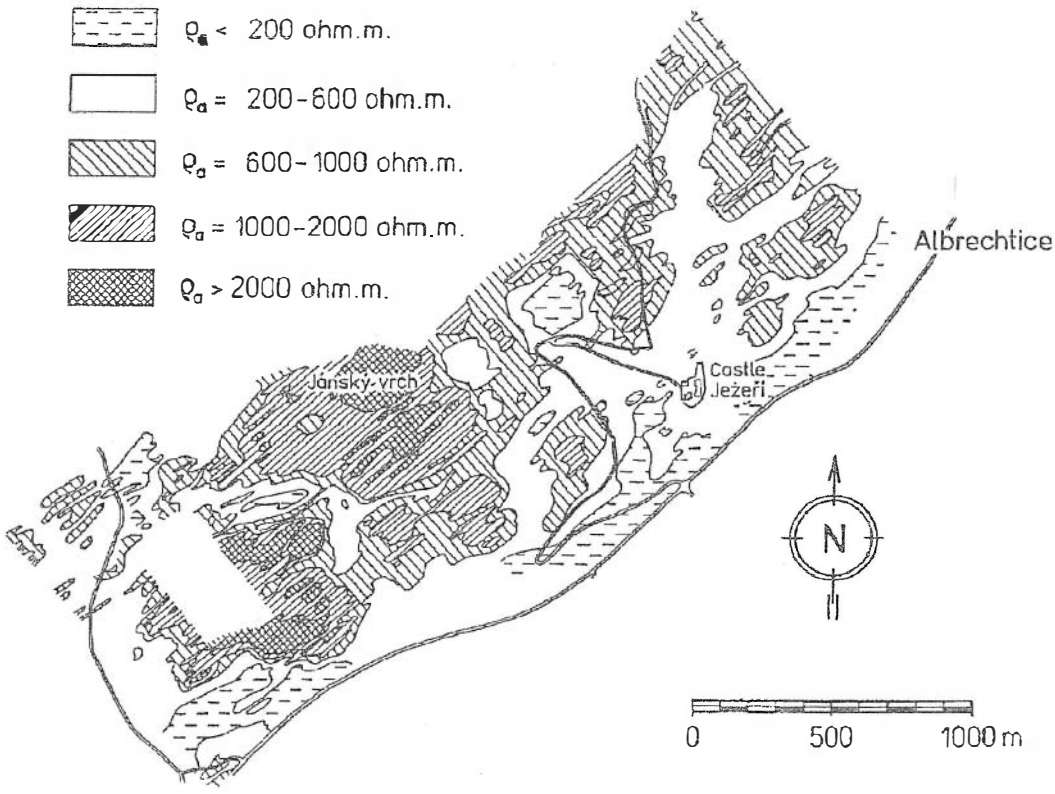

FIG. 1. The map of ρ_a isolines

The map of ρ_a isolines (Fig. 1) represents the resistivity field corresponding to the rock medium as deep as approximately 17 to 20 m below the surface. Both the resistivities and apparent resistivities of major part of rocks, including metamorphic ones, are dependent, to a limited degree, on their mineral composition, but mainly on degree of their saturation by natural solutions, and on mineralization of these solutions. However, the degree of the rock saturation depends mainly on the rock porosity, in the case of metamorphites on their jointing, and particularly on the degree of the rock weathering, or, eventually, alteration. Since most rock–forming minerals behaves as isolants, a slight increase of the rock moisture provokes a rapid decrease of resistivity values. Consequently, the map of ρ_a isolines represents, to a certain extent, the character and degree of tectonic disturbances of the rock medium in particular parts of the investigated area.

Minimum values of apparent resistivities in the investigated area usually vary about $\rho_{a(\min)} < 100$ to 200 ohm.m, maximum values in particular parts of the area fluctuate, however, in a rather wide interval $\rho_{a(\max)} = 1677$ to 7950 ohm.m with increasing values from NE to SW. In order to delimit areas of relatively compact, or eventually intensively disturbed rocks we chose the "limit value" $\rho_a = 600$ ohm.m and supposed that the metamorphites of the Krušné hory Mts characterized by apparent resistivities $\rho_a < 600$ ohm.m are rather intensively disturbed.

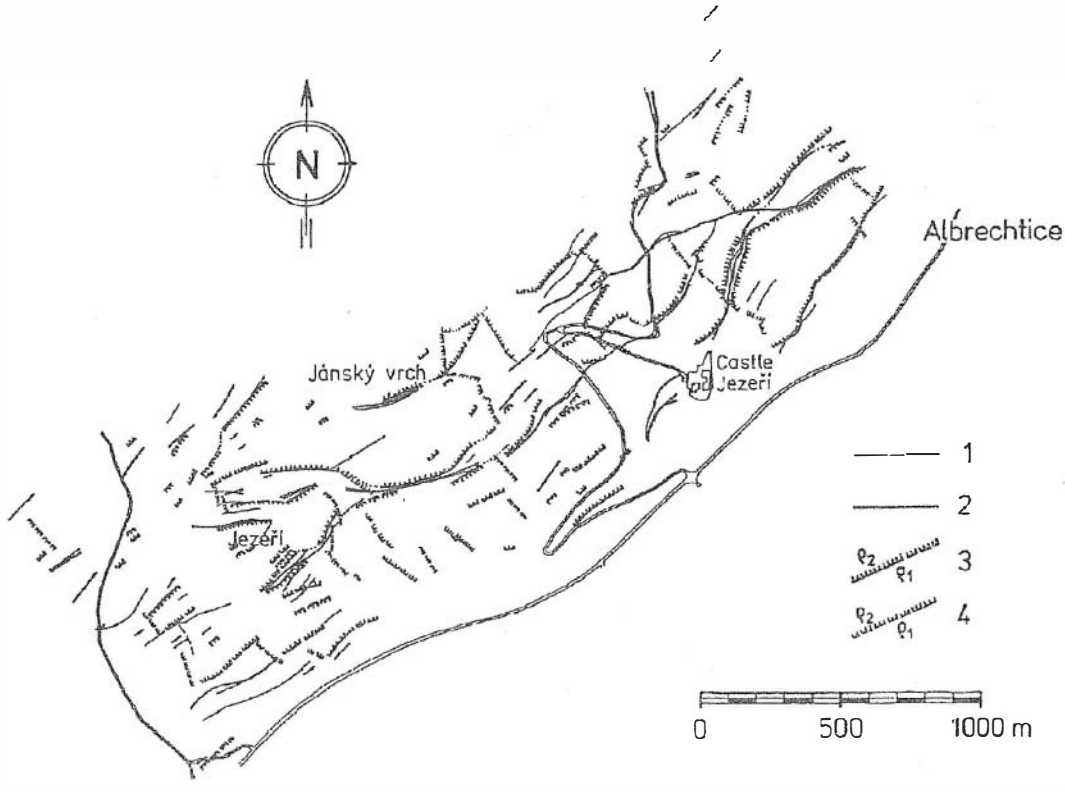

FIG. 2. The correlation map of geophysical indications 1 – conductivity line (VLF), 2 – conductivity line (symmetric, combine, dipole resistivity profiling), 3 – resistivity boundary indicated on geophysical profile, 4 – resistivity boundary derived from the map of ρ_a isolines

The most important zone of reduced apparent resistivities ρ_a is the zone running along the base of the SE slopes of Krušné hory Mts. Its general direction in the SE part is ENE–WSW, in the NE part NE–SW. It is obvious that the zone follows the Krušné hory fault zone, formed by a system of more or less parallel faults. These can be followed even in considerable distances from the main fault where they disrupt even a rather compact rock medium. Beside this fault system (NE–SW), the map of ρ_a indicates also an existence fault zones running transversely to this direction. They are rather wide, directionally variable while keeping the

general NW–SE direction, and they can be followed, though not continuously, to a considerable depth in the mountain massif; they usually follow the transverse valleys. Besides this disturbances of NW–SE direction, the disturbance zones of E–W direction may occur in the area.

The correlation map presents locations of geophysical indications (Fig. 2) on the profiles and, in most cases, their interpreted mutual correlation, e.g. conductive lines and resistivity boundaries. The tectonic predisposition of the conductive lines is almost hundred–per–centual. On the other hand, resistivity boundaries may, but need not, be conditioned tectonically.

In tectonic arrangement of the investigated area, a line running discontinuously, but essentially along the whole length of its SE border, has evidently the greatest significance. This line represents very likely the boundary between the sedimentary filling of the basin in the SE and the proper crystalline rock complex of the Krušné hory Mts in the NW. The line is tectonically conditioned and belongs likely to the Krušné hory fault system. Northwest of this line, already in the proper Krušné hory massif, a row of other tectonic disturbances occur. They are largely parallel with this line, just exceptionally turning nearly to the E–W direction. Existence of these disturbances, together with the zones of reduced resistivities running more or less "perpendicular" to the Krušné hory direction in this area, indicates a comparatively considerable tectonic disturbance of the Krušné hory crystalline rocks. Comparatively large areas of reduced resistivities corresponding to the zones of tectonically disturbed rocks, and numerous tectonic disturbances indicated as far as to 1 km distance from the border of the coal basin together with the information on slope deformations in the SW part of the Krušné hory Mts have been a demonstrable evidence on possible risk of the slope deformations (landslides) in the area of the SE slopes of the Krušné hory Mts.

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