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THE APPLICATION OF GEOPHYSICAL REGIONAL SURVEY METHODS FOR PREDICTION OF THE THERMAL WATERS DICSCHARGE PATHS IN REGION AFFECTED BY SURFACE COAL MINING (CZECH REPUBLIC - SOKOLOV COAL BASIN)

Summary. The aim of the regional geophysical survey has been to complete the results of geological and hydro geological research works for mapping zones potentially dangerous from the point of view of perspective continuation of the coal exploitation and its hydraulic influence to possible groundwater circulation along deeply based structures in Sokolov Coal Basin which is close to discharge paths and springs of natural curative thermal waters of world famous Karlsbad Spa Region. On the basis of a complex of regional geophysical methods (airborne Cs-magnetometry and airborne gama-spectrometry with high resolution and using also results of regional gravity measurements in the area of interest) the hydrogeological regime in the wider area and relation of hydrogeological units and structures of the both Karlsbad and Sokolov regions has been solved. The most up-to-date computer-processing software has been successfully utilized during data processing and interpretation and a reinterpretation of present and former regional results and measurements. The final result of the regional research is a location of risk zones for their springs and discharge paths.

ZASTOSOWANIE METOD REGIONALNYCH BADAŃ GEOFIZYCZNYCH PRZY OKREŚLANIU DRÓG MIGRACJI WÓD TERMALNYCH W REJONIE DOTKNIĘTYM WPŁYWAMI ODKRYWKOWEGO GÓRNICTWA WĘGLA BRUNATNEGO (ZAGŁĘBIE SOKOŁOWSKIE – REPUBLIKA CZESKA)

Streszczenie. Celem regionalnego rozpoznania geofizycznego było uzupełnienie i aktualizacja wyników geologicznych i hydrogeologicznych prac badawczych, mających za zadanie sporządzenie mapy stref potencjalnie niebezpiecznych z punktu widzenia wpływu eksploatacji wegla brunatnego na obieg wód podziemnych w głębszych strukturach geologicznych niecki sokołowskiej. W obrębie tych struktur znajdują się drogi migracji wód

podziemnych, eksploatowanych w światowej sławy uzdrowisku Karlowe Wary. Na podstawie kompleksowych geofizycznych aerodetekcyjnych badań regionalnych: Cs magnetometrii, spektrometrii gamma wysokiej rozdzielczości oraz pomiarów grawimetrycznych w rejonie między Karlowymi Warami (KV) a Zagłębiem Sokołowskim (SB), zaktualizowano stan wiedzy na temat warunków hydrogeologicznych oraz budowy geologicznej i wzajemnych relacji między obszarem KV i SB. Do przetwarzania, interpretacji oraz reinterpretacji danych współczesnych i archiwalnych wykorzystano najnowocześniejsze oprogramowanie. W rezultacie prac udało się zlokalizować strefy zagrożenia dla źródeł wód leczniczych oraz dróg ich zasilania.

1. Introduction

Situated in close vicinity of the world-renowned mineral and thermal spa town of Karlovy Vary in West Bohemia is the tertiary Sokolov Coal Basin, where coal is mined in the Družba and Jiří deep open-pit mines. Prospective mining might have an unfavourable impact on the hydrogeological regime and circulation of underground waters along the deep-based failures, to which the Karlovy Vary curative thermal and mineral springs are bonded. The objective of the Regional Studio was to assess the relationship of groundwater units and structures of the Karlovy Vary hot-spring area and the surroundings of the Sokolov brown coal basin from the viewpoint of selecting zones potentially dangerous in case of continued mining in the Sokolov Coal Basin.

As regards financial costs and time required for conducting the survey, as well as the benefits of information on the structure of the region and its tectonic affection to relevant depths of several km, aero geophysical (AGf) survey has proved highly effective. **Aero geophysical Survey** included high-resolution aeromagnetomy (Amg) and aerogamaspectrometry (AGS). AGf surveying with high sensitivity of advanced survey instruments applied and the use of up-to-date software for data processing and presentation form the basis of a new type of geophysical surveys with detailed resolution capabilities.

Also processed within the framework of complete interpretation of regional data have been the results of previous **regional gravimetric survey** with density of gravity points 4-6 points/sq km [3]. Figure 1 shows the extent of area of interest between the Sokolov Coal Basin and the Karlovy Vary hot-spring area.

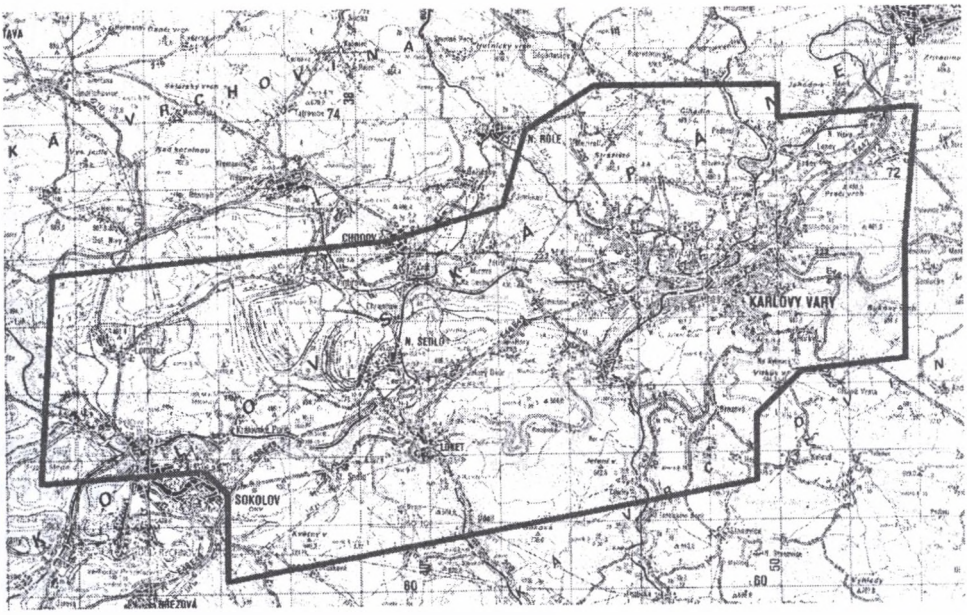

Fig. 1. Specification of the area of aerial magnetometric and gamaspectronic survey between the Karlovy Vary thermal zone and the Sokolov Brown Coal Basin
Rys. 1. Obszar badań: aerodetekcji magnetometrycznej i spektrometrii gamma wysokiej rozdzielczości pomiędzy Karlowymi Warami a Zagłębiem Sokołowskim

2. Survey methods and processing of regional geophysical data

Considering that the area in question is a densely populated and industrially highly active area with significant morphological changes of anthropogenic origin and a dense network of overhead and underground lines, high interference of measured data was to be expected. As actually proved, these unfavourable effects, the so called noises, sometimes significantly exceed the useful signal carrying information on the region's geologic structure. Thanks to up-do-date computer technology, the impact of these artificial anomalous sources could be eliminated and - with the exception of extraordinary powerful artificial sources (such as the surroundings of Karlovy Vary radio transmitter) - useful information on geologic structures obtained.

Aero geophysical Survey with flight lines distance of 100 m (Karlovy Vary hot-spring area and the Družba and Jiří open-pit mines) or 200 m (remaining areas) with profiles azimuths 0°/180° was used to survey the area of interest Mi-8 helicopters flew at a height of 80 m. The surveyed area of approximately 180 sq km corresponds to approximately 1,000 flight profile km. ENMOS GPS system with additional introduction of differential corrections (tolerance ± 5 m) was

used to control the helicopter's navigation. Magnetometer (AMg) Picodas with caesium sensor Scintrex CS 2 and gamaspectrometer (AGS) ENMOS 2001 with 1024 channels operating within the range of 0.4 - 6 MeV with crystal volume detector NaITl 20 l. were used for AGf method survey.

Aeromagnetometric caesium sensor was placed in a "bird" suspended approximately 35 m from the helicopter. Data were corrected to magnetic field variations, monitored ground basis and further adjusted by means of World Geoscience Corporation company programs. When processing magnetometry, high-frequency and directional filters for removing larger part of anthropogenic anomalies (electric, railway lines, etc.)

Thorium and caesium samples have been used to set the **aerogamaspectrometric** apparatus, exposure rate has been calculated on the basis of calibrated transmission functions [1]. PICODA and GEONIKA Company – own programs as well as WGC, GEOSOFT and ER-MAPPER commercial programs have been used to process aero geophysical data. The resulting aeromagnetic and aerogamaspectrometric maps have been used for geological interpretation (will be presented at the conference). With regard to the low depth rate of aero radiometric anomalies, the resulting maps have been used as background material for detecting shallow depositional boundaries as well as for mapping tectonic furrow rifts.

Detailed **gravimetric surveys** had been used in the past to survey the area of interest, from which complete Bouguer anomalies have been calculated [4]. Newly, a map of residual anomalies corresponding to the manifestations of local geological phenomena of the region has been derived from complete Bouguer anomalies for reduction density of 2,67 g/cu.m. by means of controlled fast frequency (Fourier) filtration method. Further calculated have been **Linsser indications** for the depth levels of 250, 400 and 800 m, indicating density (depositional and tectonic) in the specified depths. These indications, together with significant gradients of aeromagnetometric anomalies have been used as background material for designing a 3-D tectonic image of the studied area in larger depths. (see Fig. 2).

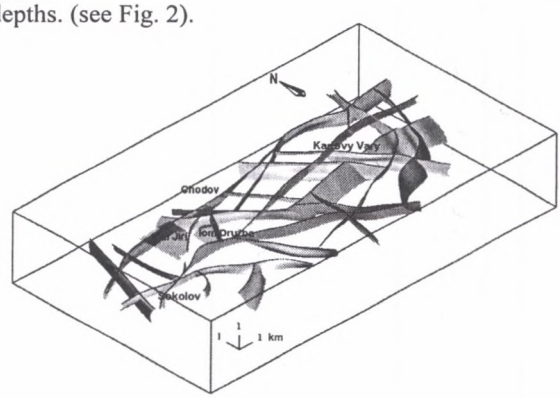

Fig. 2. 3-D model of interpreted tectonic faults according to regional geophysical survey
Rys. 2. Trójwymiarowy model interpretacji uskoków tektonicznych na podstawie badań geofizycznych

The methods indicating the composition and structure of pre-tertiary (deeper) bottom thus include a) set of derived gravity maps, b) Linsser indications in diverse depths and c) significant anomalies from AMg outputs. The methods registering earth surface situation form a complex of AGS outputs: a) ternary map, b) activity map ^{232}Th, c) activity map ^{238}U, d) activity map ^{40}K a e) AMg map. Elongated linear anomalies have been used for the interpretation of regional tectonic lines. Used for the interpretation of geophysical surface and aerial anomalies have been extensive studies of physical properties of rocks in the region [2, 6].

3. Geological Structure of the Region according to Regional Geophysical Surveys

Typical for the northern part of the locality are exposures of plutonic rock of the Krušné Hory (Ore Mountains) pluton. Also to be found in the north-east part of the locality are exposures of Cornish stone and exposures of Loket granite in the south-western part. Tertiary period is represented by a broad spectrum of rocks, ranging from the Staré Sedlo basal sedimentary complex, clay, rock clay, tuff and pyroclassics- tuffites to brown coal measures [5]. From the viewpoint of physical properties, it is the pyroclassics and tuffs that are able to trigger significant magnetometric anomalies Clay rocks, too, have their share in some radiometric anomalies.

The structural-tectonic chart, shown in Figure 2, has been based on regional maps of geophysical fields. Major structures are manifested in magnetic and gravitational field (above all in Linsser indications map). This basic picture is well supplemented also by aero radiometric data. At the same time, all data sets and derived maps have been processed for the final interpretation. Diverse static and dynamic graphic presentations, in combination with various pre-exposure and other software enabled outputs have been used. The summary result of the geophysical survey is a **3-D tectonic image of the surveyed area.** Figure 2 shows one of the possible views. This is a qualitatively new view of the geologic structure making it possible to better understand some of the relations that have so far been virtually impossible to imagine when using horizontal maps.

So for example the course of discontinuities as well as their depth range could be verified. From the viewpoint of threat to mining as well as possibilities of ground water body communications, marked fault zones appear as highly significant zones; out of these zones, the

"Sokolov Fault Zone" appears as the most significant one, mainly impacting the stability of the south-south-western foreground of the Družba open-pit mine. The "Chodov Fault Zone ", newly defined on the basis of this project, is that much significant also with regard to the field of gravity that it may well be considered significant even from the hydro geologic point of view. Quite remarkable is the cross-course of the Nové Sedlo fault which manifests itself less markedly in geophysical fields, with deeper "gravimetric" structure of the Jiří and Družba open-pit mines. Further confirmed have been known structures, defined as Thermal Fault Zone, Svatava Fault Zone as well as the structures of the Oharecký Chain manifesting themselves all over the zone of interest, called Alber Fault and Lipnice Fault in its north-western part. The zones correlating with significant Linsser indications (in all three depth levels) and concurrently with increased magnetic field gradient may be defined as risk zones for further mining in the Jiří and Družba open-pit mines.

In conclusion it may well be said that completed up-to-date processing of aerial and gravitational data significantly helped to further specify the hydro geologic situation and its regime in the given area with regard to the impact of possible successive mining in the Sokolov Basin on the Karlovy Vary thermal system. When comparing the costs incurred to acquire these data with the value of information outputs it becomes evident that regional aerial survey is convenient even in conditions with relatively high level of geological exploration and that new effective methods of aerial and ground survey and new forms of processing by means of powerful computes help to provide new essential information.

Acnowledgement

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