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PRIMARY ROCK TEMPERATURE FIELDS IN CZECH AND POLISH PART OF THE UPPER OF THE UPPER SILESIAN COAL BASIN

POLE TEMPERATURY PIERWOTNEJ SKAŁ W CZESKIEJ I POLSKIEJ CZĘŚCI GÓRNOŚLĄSKIEGO OKRĘGU WĘGLOWEGO

Knowledge of the temperature of rock mass is no doubt of substantial meaning, both for the solution of economicaly demanding protection of mine workers in difficult microclimatic environment and for perspective usage of geothermal energy from the depth of the earth. International cooperation of our and Polish specialists is in this sense more than welcome, also because the exploitation of coal seams takes place in the same Upper Silesia rock coal basin.

This profesional article is concentrated on complex analysis of temperature fields of the Ostrava-Karviná district, mainly from results of *thermologging measurements in geological survey boreholes both on surface and underground, and also from the actual temperature measurements in the coal mines*. One chapter of this article describes the original approach to the survey of *temperature field and its prognosis in the Polish part of the Upper Silesia coal basin by a researcher from GIG Katowice.*

The most suitable method of analysis of primary temperature field seemed the preparation of isocurves of temperature(isothermal lines) for the existing mine working areas, even if the method of obtaining them was different. The Czech method is based on determination of the quantitative dependence of temperature on the rock mass depth from the abovementioned measurement results, calculation of geothermal gradients and the following recalculation of real temperature values for various depth levels. Then isothermal lines for these depth levels are created together with colour distinguishing of their value limits. The Polish method is sufficiently described in a dedicated chapter. The conclusion of the article underlines the decisive role of the structuraly tectonic composition of the rock mass on the temperature field in the long term thermic evolution of the Earth.

Keywords: primary temperature field, temperature measurement in geological survey boreholes, geothermal gradient, maps of isothermal curves

Znajomość rozkładu temperatury górotworu ma bez wątpienia istotne znaczenie, zarówno dla rozwiązania poważnych problemów, również ekonomicznych, wiążących się z pracą górników w trudnych

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warunkach mikroklimatycznych jak i perspektywicznego wykorzystania energii geotermalnej. Współpraca czeskich i polskich specjalistów jest w tym aspekcie jest konieczna dlatego, że eksploatacja pokładów węgla odbywa się w tym samym Górnośląskim Zagłębiu Węglowym.

W niniejszym artykule przedstawiono analizę rozkładu pola temperatury pierwotnej górotworu w rejonie Ostrava-Karviná, opartą głównie na wynikach pomiarów geologicznych z odwiertów, wykonanych zarówno z powierzchni jak i pod ziemią, ale również na podstawie bezpośrednich pomiarów temperatury w kopalniach węgla kamiennego. Jeden z rozdziałów tego artykułu opisuje oryginalne podejście do badania rozkładu pola temperatury i jego prognozowania w odniesieniu do polskiej części Górnośląskiego Zagłębia Węglowego, opracowane przez specjalistów GIG w Katowicach.

Najbardziej odpowiednią formą obrazowania rozkładu pola temperatury pierwotnej wydaje się opracowanie izolinii temperatury pierwotnej (linii izoterm) dla istniejących kopalni i miejsc pracy, niezależnie od metody uzyskiwania danych. Metoda czeska jest oparta na ustaleniu ilościowych zależności temperatury od głębokości górotworu na podstawie pomiarów, obliczenie gradientów geotermicznych i następnie obliczenie rzeczywistych wartości temperatury dla różnych poziomów głębokości. Następnie opracowywane są linie izoterm dla danych poziomów głębokości z wykorzystaniem kolorów dla odróżniania granic wartości. Polska metoda jest wyczerpująco opisana w osobnym rozdziale. W konkluzji artykułu podkreślono decydującą rolę struktury tektonicznej górotworu dla zmian rozkładu pola temperatury pierwotnej w długim okresie ewolucji termicznej Ziemi.

Słowa kluczowe: pole temperatury pierwotnej, pomiar temperatury w odwiertach geologicznych, gradient geotermiczny, mapy izoterm

Introduction

Mining of black coal in general, not only in the Upper Silesia coal basin, advances into increasingly bigger depths. With increasing depth of mining, the microclimatic conditions get remarkably worse and come into conflict with safety and hygiene standards, the implementation of which gets technically and economically more difficult and costly, above all when considering the costs of ventilation and air conditioning, cost of the workforce.

Measurement and analysis of the rock mass primary temperature is therefore of substantial meaning considering the branch, societal and economical impacts, the area of health protection of mine workers, design of ventilation networks and air conditioning systems. The knowledge of temperature fields in the rock mass stands in the forefront of interest of the mining world, especially because of the effort to get new sources of energy and make use of geothermal energy from deep coal mines.

International cooperation of our and Polish specialists increases the meaning of carrying out temperature analysis with effective impact on their practical exploitation during mining coal deposits in both parts of the basin.

Only the knowledge of primary rock temperature will enable correct design of ventilation and air conditioning in deep coal mines thus preventing national economic losses that could result from using not suitable way of air conditioning, eg. artificial cooling of the airflow in case when climatic difficulties can be handled by natural measures, i.e. by more intense ventilation(increasing the airflow velocity, increasing the cross section of mine workings) at lower economiác expenditure.

This profesional article concentrates on complex analysis of temperature fields in the Ostrava-Karviná District from the results of *thermal logging measurements in geological survey boreholes both on surface and underground as well as from the results of actual mine temperature measurements*. One chapter of this article describes the original approach to the *temperature field research and its prognosis in the Polish part of the Upper Silesia basin*.

1. Primary temperature field

Primary temperature field of the rock mass is a spatial variable, the value of which depends on the depth, structure and build-up of the rock mass, on temperature characteristics of the rock, on distance from the magma chamber. The notion *primary means original temperature field* in the rock mass depth, uninfluenced by external antropogenous interference, boring or mining activity. In this sense it practically cannot be exactly determined by any measurement.

Temperature field of the rock mass or the extracted rock samples exhibits a number of characteristics, physical and thermal properties such as heat flow, heat capacity, temperature gradient(negative temperature gradient), thermal conductivity. These properties are not the subject of this article.

The most commonly used and measured variables characterizing the primary temperature field are the *geothermal degree* G_S ($\text{m} \cdot 1°\text{C}^{-1}$), eventually *geothermal degree gradient* G_{100} ($°\text{C} \cdot 100 \text{ m}^{-1}$),

The value of geothermal degree gives

– depth in meters, corresponding to the increase in temperature by 1°C, calculated from the relationship

$$G_S = \frac{H_K - H_O}{t_K - t_O}$$

the value of the geothermal degree gradient gives

– the increase of °C for 100 m of depth, calculated from the relationship

$$G_{100} = 100 \cdot \frac{t_N - t_{N-1}}{H_N - H_{N-1}}$$

where

$H_K - H_O$ is the difference between the final and initial depth of temperature measurements,

$t_K - t_O$ is the difference between the temperatures in the finbal and original depths.

$H_N - H_{N-1}$ is the difference between the specified depth levels,

$t_N - t_{N-1}$ is the difference between temperatures measured at the respective depths H_N, H_{N-1}.

Changes of temperature field with temperature are roughly proportional so that it is possible to express them by a linear equation, where the value of thermal degree gradient is the slope of the line of temperature T dependance on depth H in the linear regression $T_H = G_{100} \cdot H + c$ .Since the geological profile of the rock mass contains geologically different horizons with different thermal conductivities, it is essential to consider the *calculated values of geothermal degrees and their respective gradients only as average values.*

1.1. Literature survey knowledge

The first temperature measurements of the rock mass in OKR mines were carried out by the VVUÚ Ostrava-Radvanice staff as early as 1956 (Brudnik), however, their contribution to the knowledge of the temperature field of the hardcoal OKR district is not very significant. The systematic *mine research measurements* of rock temperatures begun only in 1967 with the aim to *determine temperature isolines in the critical depths of 800-1200 m under surface* (Suchan, 1967). Some temperature measurements were carried out in cooperation with VŠB-Technical University Ostrava. The results of Dr. Suchan´s work are comprehensively treated in research reports of VVUÚ Ostrava-Radvanice.

The issues of temperature field measurements begun to be adressed by the staff of the Institute of Geonics ČSAV in the eighties, namely by (Taufer & Fiala, 1982), and their followers, especially (Trojanová, 1987-91) and (Špirko, 1991).

The situation in the research of the temperature field in the Upper Silesia basin on the Polish side is significantly different. The Polish standard PN-G-04038 „Mine security at rock temperature threats. Measurement of primary temperature“ was issued as soon as 1998, apparently provoking the systematic research from 2003. More detailed description of the Polish analysis of temperature field and of its results is given in Chap. 3.

1.2. The analyzed region

The analyzed region is above all the Czech part of the Upper Silesia coal basin and the adjacent border area of the Polish part. The situation is best represented in the map on Fig. 1.

This map shows the individual OKR mines prior to their restructuring and prior to the closure of many of them(mines Odra, Šverma, Heřmanice, Ostrava, Fučík – in the so called Ostrava part of OKR) and some others in the Karviná part(mines Dukla, František, Barbora). In their present form the mines are cioncentrated into larger units, namely into

- Karviná mine, including the former mines(nowadays plants) ČSA, Doubrava, Lazy,
- Darkov mine, including the former mines(nowadays plants) Darkov, Gabriela and 9. květen,
- ČSM Mine centralizing the former plants ČSM north and ČSM south.

As far as the remaining mines Paskov and Staříč, belonging into the so called southern part of OKR are concerned, the mine Paskov was closed down and only the Staříč mine goes on in mining the Ostrava seams formation.The quoted southern part of OKR is relatively isolated, not connected to the Ostrava-Karviná part. The separation of the Paskov mine results from the so called *Bludovice pothole*, tectonically predisposed erosion paleo valley. The same is true of the *Oprechtice pothole* separating the Paskov mine from the Staříč mine. The height gradient oif the axis of the Bludovice pothole from the Ostrava-Karviná ridge is over 1000 m.

The divide between the Ostrava and Karviná part of OKR is created by the most important fold structure oriented NNE-SSW, the so called *Orlová fold*, going through the mining area of the Fučík mine. The Orlová fold is a typical fault-propagation fold structure, with the lift amplitude of cca 600-700 m.*

* By fault propagation we understand a very flat overthrust. In the Czech part of the Upper Silesia basin the rearrangement is in the order of hundreds of meters, then in the Polish part (Jejkovice and Rybnik brachystructure) is up to 5 km, ie. on overlay limit.

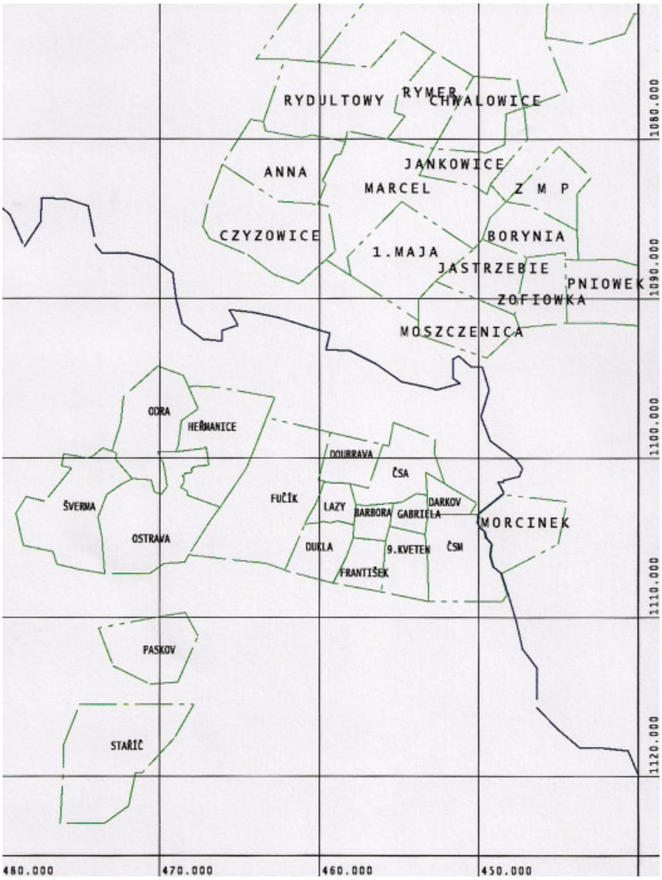

Fig. 1. The map of mining areas of OKR and the adjacent Polish part of Upper Silesia basin

The Orlová fold separates stratigraphically completely different carboniferous strata, formed of
- Petřkovice, Hrušov, Jaklovec and Poruba layers in the West,
- Suchá, Doubrava and saddleback seams in the East.

These facts we give to document that in difference to the linked mining areas in the Polish part of much simpler tectonic structure it is appropriate to study the individual parts of OKR separately, without the *real possibility to continuously connect the temperature fields of the Ostrava, Karviná and southern parts.*

2. Methods for determining the primary temperature field

The real possibility how the determine the „primary" temperature field is repreesented by such methods that enable to measure temperature in the rock mass uninfluenced by any human interference, which is in reality impossible.

Therefore it is used in practice

a) continuous temperature measurement in survey boreholes from surface (conventional *thermologging*),
b) *temperature measurement in freshly driven mine workings*, in short boreholes in the side of the opening drift,
c) *physico-geological models*,
d) *mathematical models for temperature forecasting* at great depths.

In our contribution we deal only with methods ad a), b), the Polish part adds the method ad c).

2.1. Continuous thermologging in survey NP bores from surface

This is done on completed geologic survey bores led from surface in OKR up to depths of 1500 m – these were realized during the fifties to nineties of the last century by Geologický průzkum Hrabová. This method in spite of being often unjustly criticized comes closest to the primary temperature state of the rock mass when rtespecting the strict conditions of stabilized temperature regime in the completed borehole. The geologic survey bores were drilled in dense network of cca 2 × 2 to 5 × 5 km preferrably in the border parts of OKR out of the range of mining activity.

The results of continuous thermologging measurements showed the possibility of detecting very detailed temperature changes in the bore profile. Nevertheless, in the following analyses only the results of *average values of geothermal degrees and their gradients* are given.

It is essential to point out that this method of primary temperature field analysis from the results of thermologging measurements is subject to errors associated with the process of drilling that represents not very significant intervention when compared to mining activity, but there is still partial deformation of the temperature field in the bore vicinity by errors caused by circulation of the drilling fluid with its cooling effect, by heating of the rock by the drilling tool, by water inflow into the borehole, by gas leakage and expansion from the surrounding rocks, by its possible chemical interaction with the drilling fluid, by bore rinsing after completion of drilling, by cementing the bore casings(considerable amount of heat during cement setting).

For these reasons, to prevent these influencing factors, the thermologging measurements are taken only on completed bores, when the disturbed temperature field slowly recovers, and that after a period of rest lasting not less then 104 days.

To analyze the temperature field by this method, 37 bores were selected with the effort to cover and represent the Karviná area of interest ikn its primary diversity. Average values of geothermal gradients were calculated for these boreholes and isothermal line maps were prepared for the specific depths from –450 to –1 050 m with 100 m increment using the SURFER program.

An example of a map of thus produced isothermal lines for the currentmining depth of –650 m is given in Fig. 2.

2.1.1. Ressults of thermologging measurements

The completed analyses of thermologgs from geologic survey NP bores together with isothermal line maps for various depth levels give the basic regional picture of the size and distribution

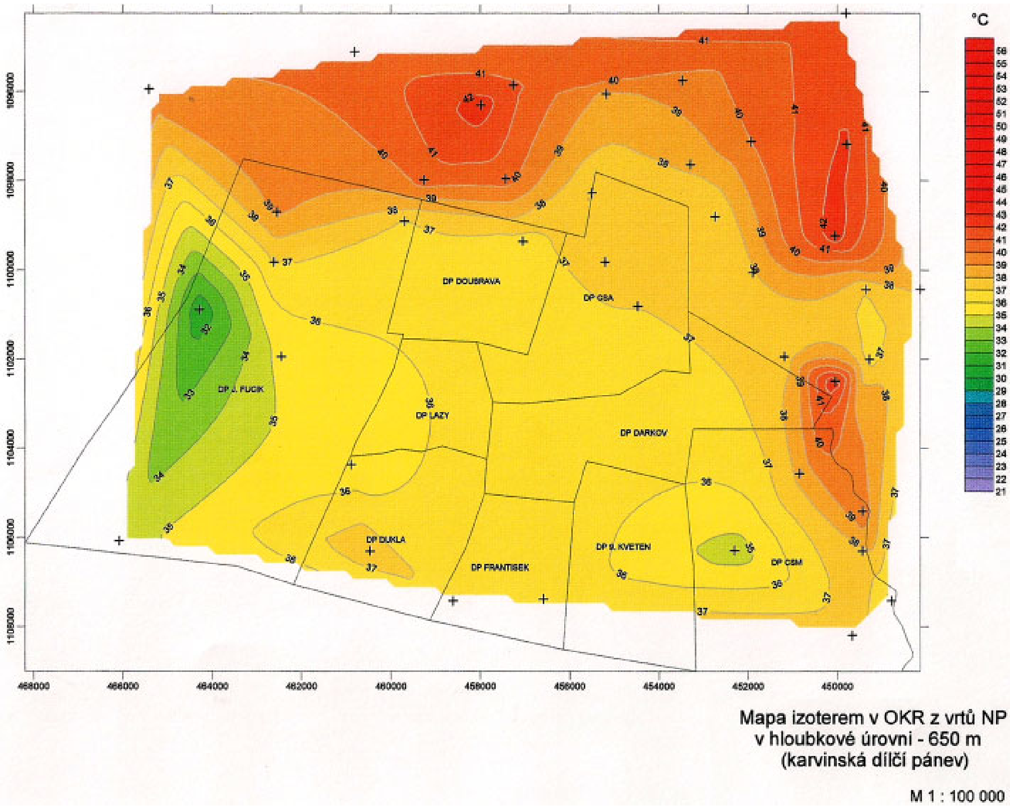

Fig. 2. Example of a map of isothermal lines in the Karviná subbasin of OKR from NP bores in the depth of –650 m. Crosses indicate the location of boreholes

of the primary temperature field in the Karviná part of OKR. From these results, it is posible to draw the following conclusions:

a) though the geologic survey bores were drilled at different times, namely during 1957-94 and measured by different thermologging devices, thanks to the calibration of the thermologging sensors (thermometers) on known etalons and thanks to strict respectation of the sufficientř recovery period after the completion of drilling, i.e. at stabilized temperature regime, it is possible to consider the completed analyses of thermologiing results *as reliable*, even if they are *just of regional significance*.
b) temperature field found in this way for the area *outside the former and present mining activities* for the same depth is highly variable. The values of the geothermal degree vary between 27 to 41 m/1°C, those of the gradient between 2,6 to 3,7°C/100 m. Temperatures eg. at this depth of –650 m also vary widely from 32 to 42°C. This difference cannot be caused at the relatively identical geological profile only by changes in thermal conductivity of rocks and by different hydrogeological conditions and is probably associated with the very complicated structural.tectonic arrangement of the Czech part of Upper Silesia basin.

c) The middle area of the Karviná part, represented by the Lazy, Dukla, František, 9. květen mines, further by the eastern part of the Fučík mine, western part of Darkov and ČSM mines can be characterized by relatively smooth and steady temperature field. The western part of the Fučík mine appears as the coldest, exhibiting temperatures from 32 to 34°C in the area of the Orlová fold overlay. Lower temperature is probably characteristic also for the Ostrava subbasin as well as for the southern part of OKR, mining the coal seams of the Ostrava strata. On the other hand, the northern and eastern Karviná parts represented by the ČSA and Doubrava (north) mines plus Fučík (north) and ČSM (east) appear as the warmest. To the north and outside of the exploited Karviná area we find extremely high temperatures for this depth, namely up to 42°C.

d) *Results of regional significance cannot cover all details of temperature distribution in the exploited part of the district*. They will be therefore completed and confronted with other methods of primary temperature field analysisi in further chapters.

2.2. Mine measurements of temperature in freshly driven mine workings

The origins of mine rock temperature measurements in short prebores in the vicinity of advancing headings of underground corridors date back to the sixties of last century. About 188 measurements at various depths on various pits both in Ostrava and Karviná subbasins were carried out by the method developed by VVUÚ Ostrava-Radvanice. At the newly opened pits Paskov and Staříč it was not possible to carry out sufficient number of measurements necessary for the construction of isothermal lines(Suchan, 1969, 1970). Isothermal lines were prepared for various levels of depth up to –900 meters, from which it was obvious that

– the warmest part of the district is located in the East and North,
– there is relatively considerablde difference of the temperatures measured in horizontal direction (at the same depth).

The temperature values (of the original temperature field) varied within the following limits

– 500 m 28 – 32°C
– 600 m 30 – 35°C
– 700 m 32 – 37°C
– 800 m 35 – 40°C
– 900 m 39 – 43°C

Note: it is possible to compare these temperature values determined in the seventies with maps of isothermal lines constructed from the thermal logging of surface NP bores in 2010 – Chapter 2.1.1 bringing the following data:

– 450 m 28 – 34°C
– 550 m 30 – 38°C
– 650 m 32 – 40°C
– 750 m 34 – 43°C
– 850 m 37 – 46°C

Upper limits of temperatures are here influenced by the interpolation of high temperatures in peripheral areas (out of region of active working). Real temperature values will be determined by measurement in mine workings together with results commented in the following text.

Results of 372 mine temperature measurements (Taufer, 1985) were collected and completed by 82 mine measurements carried out by technical staff of Darkov, ČSM and ČSA mines for the purpose of new analysis of the temperature field within the grant project solution.

It makes no sense to describe here in detail our own method of temperature measurement in mine workings, since our and Polish methodology are in principle identical.

The measurement is always carried out only in freshly driven mine workings, in the closest vicinity of the heading, namely in short 2 m bores into the coal (event. rock mass). The thermometer sensor is placed into the end of the 2 m borehole in close contact to the coal seam (event. rock mass), the head of the borehole being sealed to prevent the influence of the mine air flow. Temperature readings are taken till the temperature regime settles, practically in 10 minute intervals (for about 1 hour or more).

With all results of mine temperature measurements the coordinates X, Y are documented in Excel (using the Czech systém Křovák) along with the absolute depth value and final temperature after stabilization of the temperature field. In further processing the linear regression graphs are constructed(quantitative dependence of temperature on depth for the individual mines) – see example in Fig. 3.

From thus found values of geothermal gradients the recalculation of temperatures for individual conventional depths –450 to 1050 m takes place followed by construction of isothermal maps for the area in question with the aid of the SURFER program. Altogether 454 points were measured and documented in this way. An example of their location in the mining area of the Karviná subbasin of OKR is given in Fig. 4.

When describing the OKR map as well as the adjacent Polish part of the Upper Silesia coal basin – see Fig. 1 the complicated structural and tectonic arrangement of the Czech part of USB was pointed out. This arrangement *complicates the sequence and continuity of the individual parts of OKR in isothermal maps* constructed by separate analysis of primary temperature field. The same is true regarding the unreality of linking the Czech and Polish parts. Considering certain inaccuracy given by the existence of the Orlová fold, we dare link the Karviná and Ostrava subsets. However, it is not possible to link them to the southern part of OKR(mines Paskov and Staříč), therefore the isothermal maps for the southern part of OKR are constructed separately and not connected.

The limited number of pages in the publication being prepared does not allow to document all maps of isothermal lines in all conventional depths from –450 m to –1050 m.

Following the agreement with our co-author J. Knechtel we give here only the maps of isothermal curves on horizons of active mining, i.e. –650 m(cca 900 m from surface) – Fig. 5 (Karviná and Ostrava subbasin) and Fig. 6(southern part of OKR), thus in the depth where the temperature field reaches in some mining areas anomal values requiring to solve difficult microclimatic environment by technological means of ventilation and air conditioning.

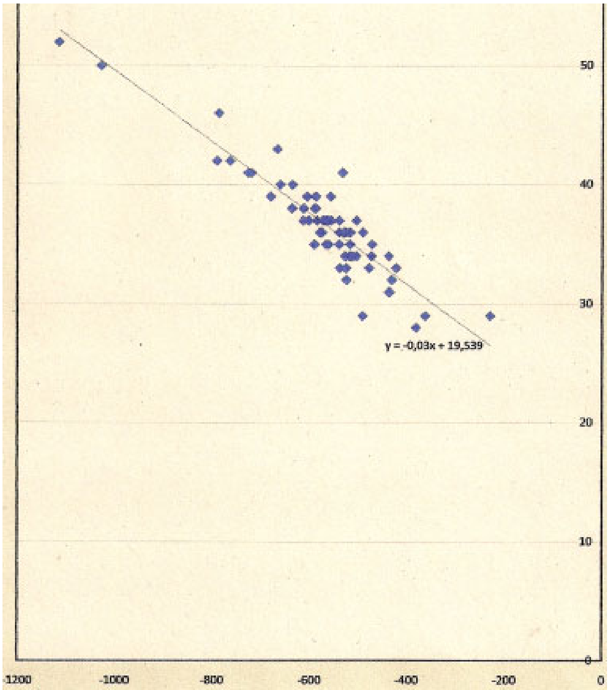

Fig. 3. Dependece of temperature on depth from the measurements of maximum temperature in mine forbores. Calculated values: Temperature gradient $\mathbf{G}_{100}$ = 3,0°/100 m. Correlation coef. –0,905

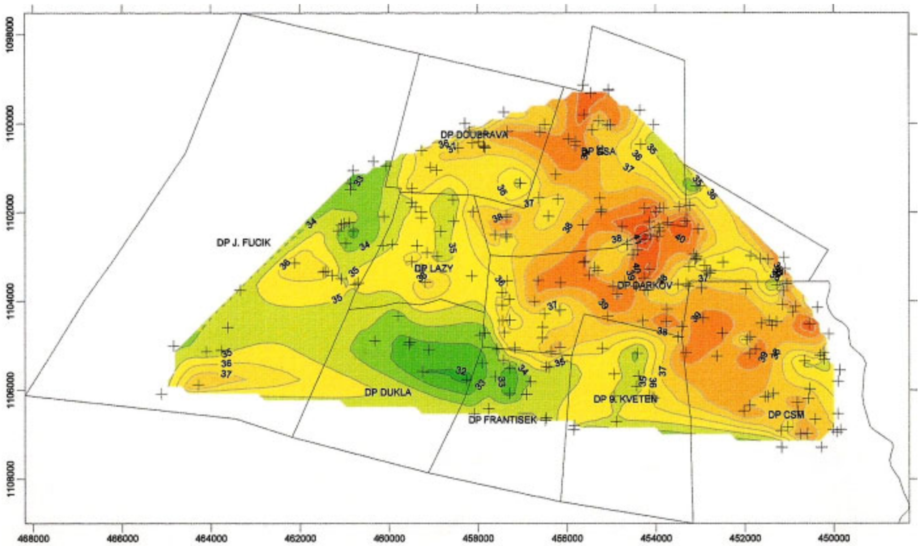

Fig. 4. Placement and position of 231 points of temperature measurements in the Karviná part of OKR along with the map of constructed isothermal curves

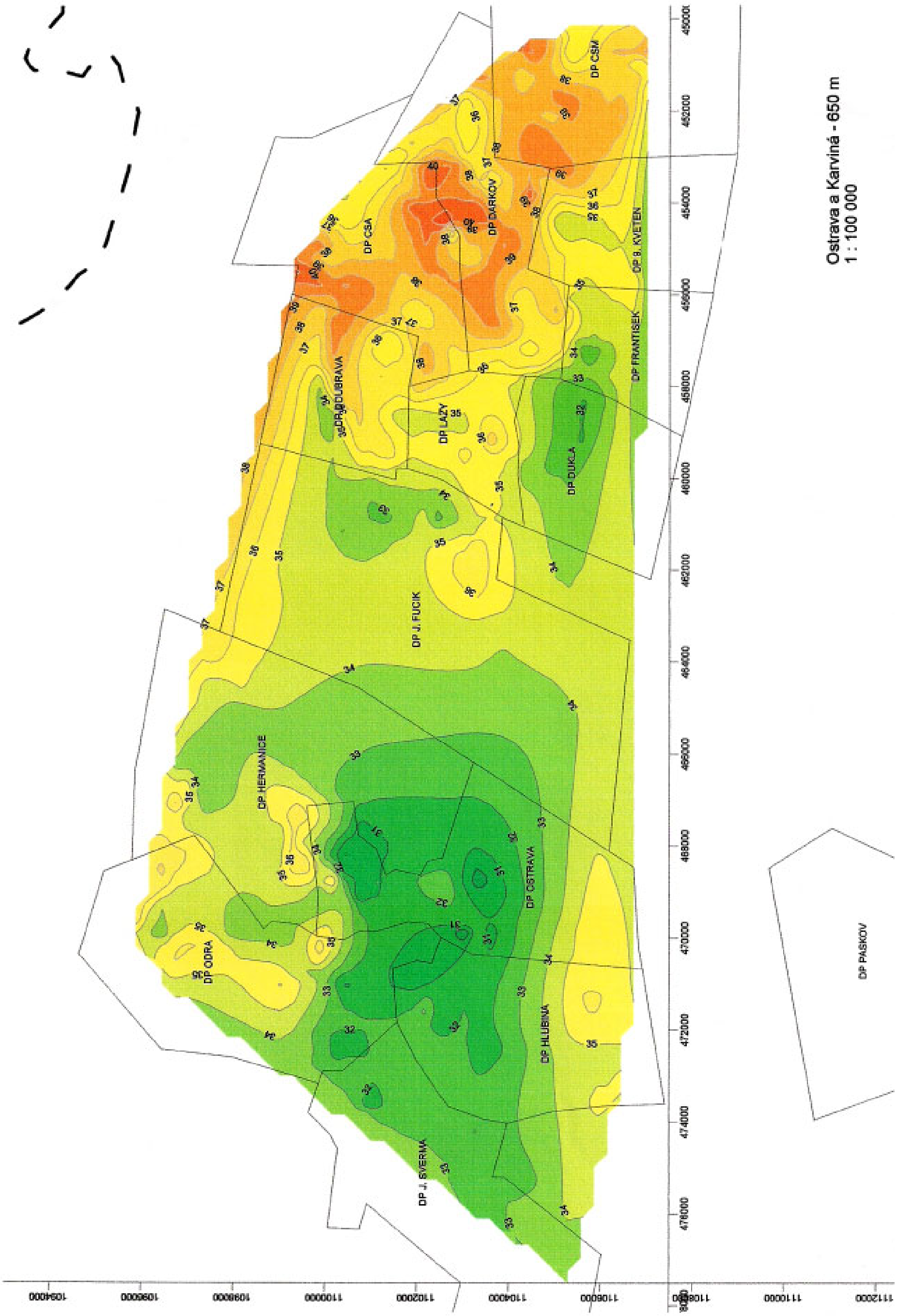

Fig. 5. Map of isothermal curves of the Karviná and Ostrava subbasin in the depth of –650 m

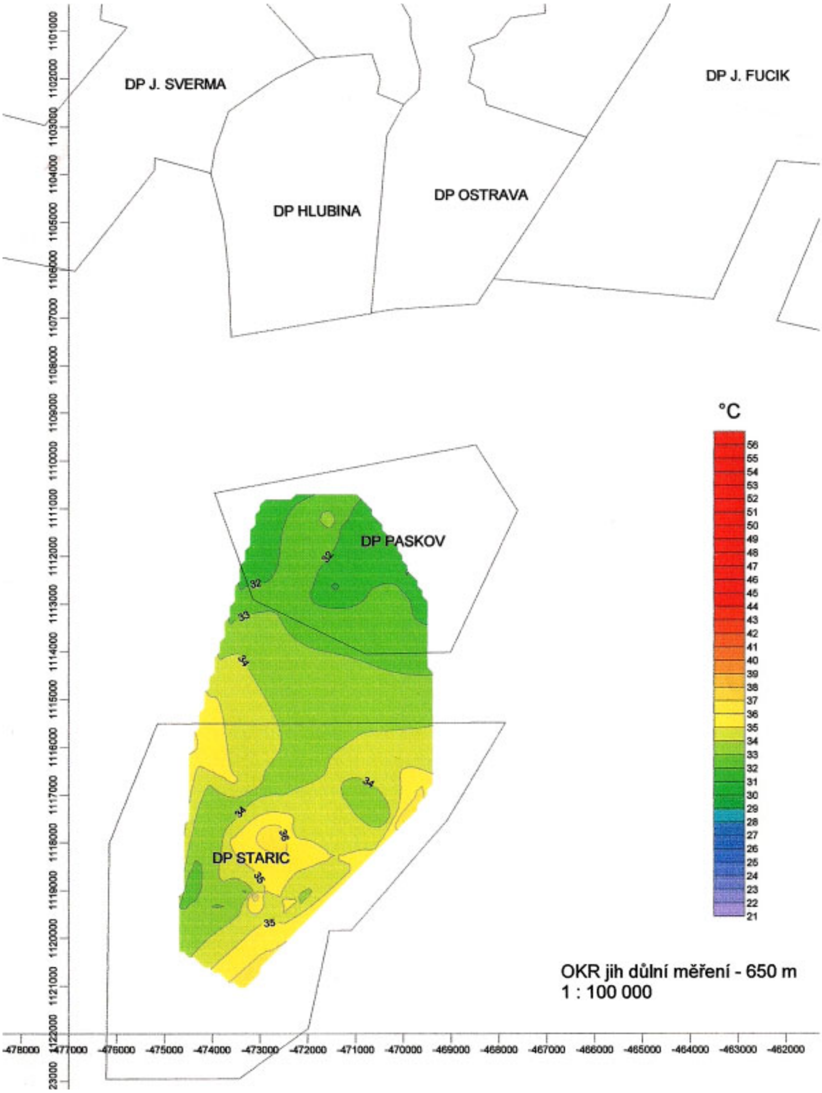

Fig. 6. Map of isothermal curves of the southern subbasin in the depth of –650 m

2.2.1. Description of isothermal curves of primary temperature fields of OKR subparts

Results of the completed analysis of temperature fields in Karviná, Ostrava and southern parts of OKR confirm what was found previously – see eg. / Suchan 1969 /, namely that the temperature values at the same depth level vary considerably. The existing explanation of these differences emphasized above all stratigraphical, litological differences and their representation in geological profile, further differences in thermal conductivity of the rock, changes og hydrological conditions etc. However, their sources are to be found in the so far exactly not analyzed influence of structurally-tectonical pecularities. This problem is currently also being solved within the framework of the grant project.

What is the reality in the found differences of OKR temperature fields? It confirms again, in the necessary detail, that the „warmest“ is the Karviná part, the „coldest“ are both Ostrava and southern parts of OKR (mines Paskov, Staříč). Here the temperature values *at –650 m depth range within*

- 32 to 40°C in the Karviná subbasin with anomal maxima of temperatures in the north-eastern part(works Doubrava, Darkov, Gabriela, ČSA and ČSM). On average thermally stable region is represented by the works Fučík, Dukla, František and 9. květen.
- 31 to 36°C in the Ostrava subbasin with average temperatures on the works Odra and Hlubina
- 32 to 36°C in the southern part of OKR with average temperatures in the central area of the Staříč mine.

Bigger differences in temperature values up to 8°C and maximum temperatures are exhibited in the Karviná subbasin. The Ostrava and southern parts are „colder“ and do not exhibit such temperature extremes.

3. Polish analysis of the temperature field

Systematic research of temperature fields in the Polish part of the Upper Silesia Basin(USB) started after 1998, when the Polish standard PN-G-0438 „Mine security at rock temperature threats. Measurement of primary temperature“ was issued. To give an example, 132 mine measurements of primary rock temperature in short bores during driving of new mine workings were made according to this standard in the Rybnik district ROP – within its 10 KWK's (Rydultowy, Anna, Chwalowice, Jankowice, Marcel, Jas-Mos, Borynia, Pniówek, Zofiówka, Morcinek) under the supervision of GIG Katowice. The results were published during 2003 to 2009, namely (Knechtel, Gapinski).

The Polish analysis of temperature field differs from the Czech analysis in principle, it can be for the purpose of this work characterized as one of the „physico-geological“ methods. It is knoen from the existing literature(Knechtel, Markefka, Zgryza 1980) that the rock temperature at specified depth depends on the yearly average air temperature on surface t_0, on thermal flow density q_1, q_2 ... q_i, penetrating from the Earth nucleus through (1st, 2nd, … i-th) layer into higher layers, on thickness of the individual rock layers Δz_1, Δz_2, … Δz_i, on thermal coductivity coefficient of these layers λ_{g1}, λ_{g2}, ... λ_{gi}. There is according to (Chmura 76) the following relationship of these varikables:

$$t_{pg} = t_0 + (q_1 \,.\, \Delta z_1)/\lambda_{g1} + (q_2 \,.\, \Delta z_2)/\lambda_{g2} + \ldots\ldots + (q_i \,.\, \Delta z_i)/\lambda_{gi}$$

The variable t_0 takes the value of 8°C. Thickness of the individual layers can be found using geological profiles. However we do not know the values of coefficints q and λ_g, where the values vary widely depending on the type of the rock. But thermal flow values q_1, q_2 … q_i for the whole GZW basin are not known. It is possible to determine the values of thermal conductivity λ_{gi} of these layers above the spot on which we study the primary rock temperature using the geological profiles, even if faultless determination of these values from the charts is difficult. Using direct mine temperature measurements however enables to determine statistic values of thermal flow related to thermal conductivity $a_i = q_i/\lambda_{gi}$.

When considering the individual stratigraphic layers, ie. Overburden (a_n), carbon (a_k) and coal seams (a_w), GIG Katovice studies (Knechtel, Gapinski 2004) determined these values using the method of least squares:

$$a_n = 0{,}019853, \quad a_k = 0{,}029494, \quad a_w = 0{,}075137$$

Maps of temperature isolines in 43 spots in the mining area of the Rybnik district were then prepared using the SURFER 8 program for horizons of –450 m, –650 m, –750 m –850 m. These maps are, especially for greater depths, of prognostic value.

The method of determination of the primary rock temperature from the results of temperature measurements in boreholes led from surface was also tried out in Polish coalmining, namely in the Lubelský coal district. Regarding the effect of factors influencing the measured temperature values(see the Czech analysis in Chapter 2.1.) and the impossibility of drilling the survey bores from surface in the area of mining activity, this method is not used in the Polish analyses of the temperature field.

Another method, widely used in research, is the individual temperature measurement in short 2 m pre-bores in the vicinity of mine workings under the following conditions:

– regular progress of the mine working heading,
– the heading is not located in preferred exploitation area or in the vicinity of mine fire field,
– there is no waterflow from the rock mass on the heading.

This method and methodology is sufficiently well know and the same as in the Czech part of the Upper Silesia basin so that it is not necessary to describe it in detail.

3.1. Map of isothermal lines in the Polish part adjacent to the border

This map of isothermal lines covers a part of the reserve field of the former Rybnik district, southern part of the Marcel mine (plant 1. maja), and the Jas-Mos mine. It was prepared using the principles of isothermal lines construction described in the report Knechtel, Gaoinski 2004. 12 mine temperature measurements were conducted in the investigated area (1. Maja mine, future parts of the Marcel mine) and only 6 measurements were conducted on the Moszczenica mine (future part of the Jas-Mos mine). When analyzing the geological profiles and determination of thickness of the stratigraphic layers above the measurement spots and with the use of the least squares method, the following heat transfer parameters were calculated

$$a_n = 0{,}03732 \text{ K/m}, \quad a_k = 0{,}03188 \text{ K/m}, \quad a_w = 0{,}09849 \text{ K/m},$$

differing quite significantly from the values given in the report Knechtel, Markefka, Zgryza 1980 covering the whole of the Rybnik district(ROP).This difference was up to 2°C.

When describing the changes of the primary rock temperature at the level of =650 m in the whole Rybnik district – Fig. 7 it is possible to state that the temperature varies in very wide range

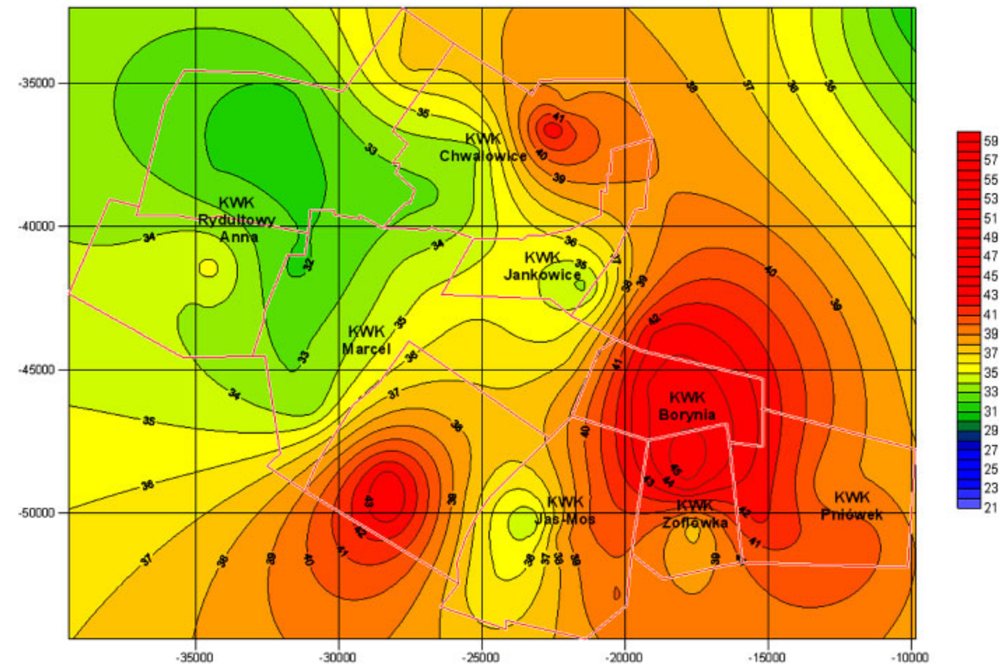

Fig. 7. Map of isothermal lines of the primary rock temperature at the level of –650 m in the whole Rybnik district

from 32°C in the Rydultowy-Anna mine (plant Rydultowy) up to 45°C in the Borynia-Zofiówka mine (plant Zofiówka), where the centers of increased temperature occur in the northern part of the Zofiówka mine and in the southern part of the 1. maja plant.

The general tendency of growth in temperature is from northwest to southwest. This increase is substantial because of the inhomogenous rock mass(numerous tectonics), varying thickness of coal seams as well as of overbuden. AS already given above, average values of heat transfer coefficients a_i were adopted for the whole Rynik district area. These adopted values of coefficients differ significantly from the analogous values for the border area.

When describing the changes of the primary rock temperature in the border area – Fig. 8 it is possible to state that the temperature changes for this case are slightly lower, ie. from 33,5°C in the ROP reserve area up to 41°C in the southern part of the Marcel mine-plant 1. Maja. Two centers of increased temperatures rise in the southern part of the Marcel mine and there is 1 center of relatively lower temperature in the west central part of the Jas-Mos mine with temperature t_{pg} = 34,5°C.

The border area exhibits lower temperature values in Fig. 8 than in Fig. 7.

Fig. 8 gives the maximum temperature in the border area cca 2°C lower from the analogous value in Fig. 7. The average rock temperatures in Fig. 8 are by 1°C to 2°C lower than temperatures for the same area in Fig. 7.

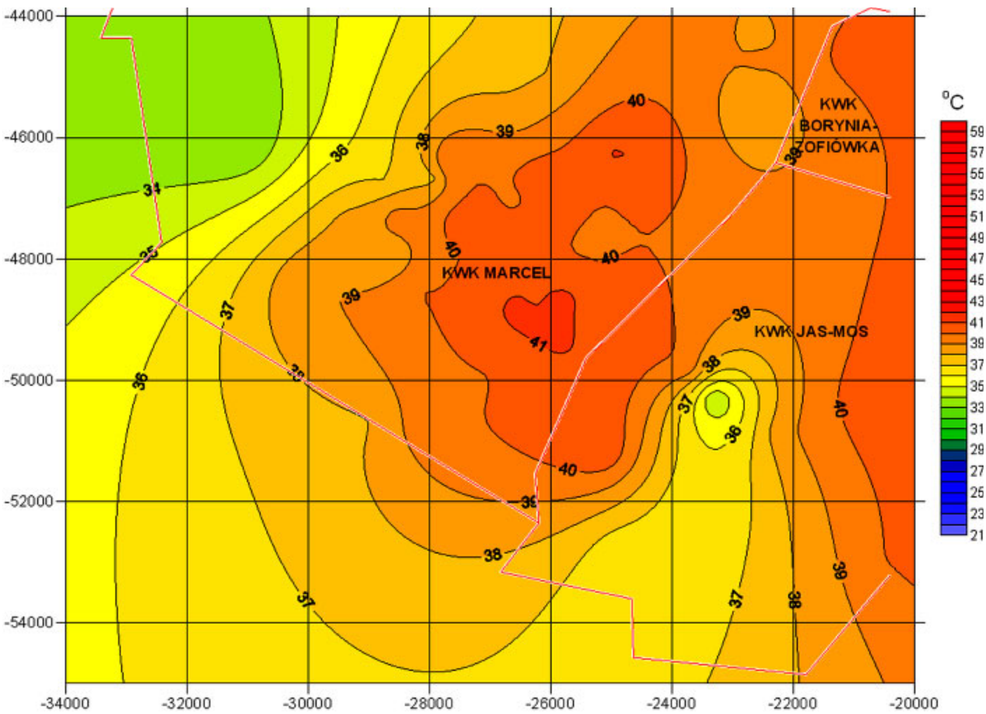

Fig. 8. Map of isothermal lines of the primary rock temperature at the level of –650 m in the border area

3.2. Comparison of isothermal lines for rock mass in OKR and the Polish border area

In Ostrava-Karviná district (OKR), namely in the Karviná subbasin, the temperature of the rock mass at the ´650 m level ranges from 32 to 40°C. The Polish part of the Upper Silesia coal district in the area adjacent to the Czech border exhibits this tenperature in the range of 33,5 to 41C, which is slightly higher. This may be caused by the increasing trend in temperature in the northeast part of OKR in direction to the Polish border. The temperature isolines in the Polish part unlike thes in OKR have a smooth, less rugged course suggesting the „regional" character of the temperature field changes, possibly caused by lower density of underground measurement spots.

As far as the shut-down Morcinek mine located in direct contact with the Czech-Polish border is concerned, due to the short time of exploitation it was not possible to get more mine temperature measurements to construct the same temperature lines. Only 4 temperature t_{pg} measurement values were obtained for this mine, these were for depths

z = –535,5 m t_{pg} = 37,0°C

z = –521,8 m t_{pg} = 36,2°C

z = –716,7 m t_{pg} = 42,0°C

z = –750,0 m t_{pg} = 42,6°C,

which is in good accordance with the results gained by mine measurements in the closest Darkov mine (plant Darkov) with temperatures 36 to 40°C at the depth of –650 m (the trend of higher temperatures in the Polish part is preserved here).

Conclusion

The research of temperature fields is no doubt of great importance for the solution of microclimatic conditions at great depths while respecting safety and hygiene regulations. These more complicated conditions have negative impact both on the workforce and on the ventilation and air conditioning means. This importance of research is further enhanced at present times by the effort to gain new sources of energy and utilize the geothermal energy from deep mines.

The analysis of the temperature field in Ostrava-Karviná district conducted within our present study is a part of the solution of the grant project titled „Research of temperature fields of active mines in the Czech Republic and their impact on mining economics“, reg. No. 105/09/1792., filling in full the first part of the project title.. An integral part of the project solution became the renewed cooperation with a specialist and management of GIG Katovice.

Results *from thermologging temperature measurements in NP geologivcal survey bores led from surface* and *results from mine technical temperature measurements in short boreholes near the headings of freshly driven mine workings* were used in this analysis of temperature field.

The results can be summarized into the following conclusions:

- *continuous thermologging measurements* of geological NP bores give reliable, usable results for the primary temperature field analysis. They enable to obtain graphs of linear dependence and determine the geothermal gradient with relatively high degree of correlation(above 0,9). However, they are only of regional importance since they do not capture temperature details in the active mining area, where they have not been and cannot be realized.
- *Mine temperature measurement in freshly driven mine workings*, if performed by a trained personnel, is no doubt the most accurate method of mapping the primary temperature field. The need for a large number of measurements is however opposed by certain operational demands as well as the research character of these measurements. The conducted analysis showed surprisingly good agreement with the results of continuous thermologging, above all in the found limits of temperature difference in individual depths, eg. at the –650 m depth the limits of measured temperatures 32 to 41°C are totally identical. And it is similar for higher depth levels.
- *Preparation of isothermal line maps in the commonly used coordinate system for each mining plant up to great depths of future exploitation* appears as the most suitable way of temperature field analysis presentation.

We suppose that also in Czech specific conditions and after the Polish standard PN-G-04038 example, the grant solution conclusions will contain Guidelines or Methodological guidelines specifying the procedures nand measures under difficult microclimatic conditions and document the temperature field analyses on particular mine plants up to depths of 1 500 m under surface.

Reference

Chmura K., Chudek M., 2001. *Geotermo-mechanika górnicza.*Mikolów, wyd. Suplement-Ksiegarnia Nakladowa.

Chmura K., 1975. *Analiza ziemskiego strumienia ciepla na przykladzie kopalni Borynia*. Przeglad Górniczy nr 12/1975, p. 480-489.

Doležal L., Taufer A., Trávníček L., 2010. *K problematice zjišťování teplotního pole karbonského masivu v Ostravsko-karvinském revíru*. 3. mezinárodní geomechanické a geofyzikální kolokvium. Sborník Documenta Geonica, ÚGN AV ČR, Ostravice 2010.

Grygar R., Waclawik P., 2004. *Analýza strukturně-tektonických poměrů karvinské dílčí pánve (hornoslezská pánev) ve vztahu k vytěžitelnosti slojí s postupem těžby do větších hloubek. Závěrečná zpráva grantu GAČR 105/04/0884*. VŠB Technická univerzita Ostrava, Hornicko-geologická fakulta, Institut geologického inženýrství.

Karwasiecka M., Siwek Z., 1996. *Atlas geotermiczny Górnośląskiego Zagłębia Węglowego 1:300 000*. Wyd. Kartograficzne PAE.

Knechtel J., Markefka P., Zgryza S., 1980. *Mapy pierwotnej temperatury skał Górnośląskiego Okręgu Przemysłowego dla horyzontów -450, -550, -650 i -750 m*. Prace Naukowe Głównego Instytutu Górnictwa. Komunikat nr 719.

Knechtel J., Gapinski D., 2003. *Mapy izolinii temperatury pierwotnej skalkopaln Rybnickiego okregu przemyslowego*. Zeszyty Naukowe Politechniki Slaskiej, Seria Gornictwo, z. 258, Gliwice, p. 435-445.

Knechtel J., Gapinski D., 2004. *Zasady sporzadzania map izolinii temperatury pierwotnej skal projektowanych do eksploatacji poziomow i pokladow weglowych*. Wydawnictwo GIG, seria: Instrukcje Nr 16, Katovice.

Knechtel J., Gapinski D., 2005. *Zaktualizowane mapy izolinii temperatur pierwotnej skal kopaln GZW.* Wydawnictwo GIG, Katovice.

Knechtel J., 2009. *Wytyczne efektywnej i ekonomicznej klimatyzacji wyrobisk slepých i odzialow wydobywczych*. GIG. Seria: Instrukcje Nr 21, Katovice.

Knejzlík J. a kol., 1982. *Výzkum a vývoj přístrojové techniky pro laboratorní a důlní měření*. Dílčí úkol II-6-1/02.04. HoÚ ČSAV Ostrava.

Polska norma: PN-G-04038, 1998. *Zabiezpieczenie kopalń przed zagrozeniem temperaturowym skal. Pomiar temperatury pierwotnej*.

Szlązak N., Obracaj D., Borowski M., 2008. *Methods for Controlling Temperature Hazard in Polish Coal Mines*. Archives of Mining Sciences, Vol. 53, No. 4, p. 497-510.

Suchan L., 1969. *Průběh izoterm v dobývacím prostoru OKR*. Zpráva č.70, VVUÚ Ostrava-Radvanice.

Suchan L., 1970. *Rozložení teplotního pole karbonského masivu v OKR*. Závěrečná zpráva úkolu III-1-5- 2.1/11, VVUÚ Ostrava-Radvanice.

Špirko K a kol., 1991. *Změny teploty a vlhkosti ovzduší v podzemních prostorách za nestacionárních podmínek.* Zpráva k projektu č. 3009, HoÚ ČSAV Ostrava.

Taufer A.,Trojanová J. a kol., 1987. *Zjištění rozložení teplotních polí v OKR do hloubky -1200 m*. Závěrečná zpráva úkolu II-6-1, etapa E 01. HoÚ ČSAV.

Taufer A., Fiala J., 1982. *Stanovení teplotních polí OKR*. Acta Montana č. 59, ÚGG ČSAV, Praha.

Taufer A., 1985. *Rozložení teplotního pole karbonského masivu OKR*. Kandidátská disertační práce, ÚGG ČSAV Praha.

Taufer A., Doležal L., Gálik D., 2010. *Zmiany temperatury skal w Ostravsko-Karwiňskym Zaglebiu Weglowym (Variations of RockTemperature in Ostrava -Karvina Coalfield*. Archives of Mining Sciencies, Vol. 55, No. 1. p. 151-162.

Trávníček L., Kalus D., 2008. *Teplo jako geoenergetický zdroj*. Interní výzkumná zpráva VŠB-TUO Ostrava.

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