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PROSPECTING BY THE GEOTHERMIC METHOD *

BY

B. KRČMÁŘ ** and J. MAŠÍN **

Abstract

A high sensitivity thermometer using a thermistor sensing element was designed for practical measurements in the field.

The most suitable procedures for the elimination of diurnal and seasonal variation of temperature, the influence of vegetation cover and of other effects were investigated.

Positive results of geothermic measurements have been acquired on sulfide deposits. By far the most important results of geothermic measurements have been obtained in hydrogeological problems, e.g. the investigation of circulation of underground water. In the case of prospection for cold mineral waters the combination of geothermic measurements with gasometric analyses is very useful. As the classical domain for geothermic investigation, prospection for hot water is to be mentioned.

Introduction

During the last four years, members of the Institute of Applied Geophysics in Prague have investigated the possibility of applying geothermic observations to some geological problems that are difficult to solve by standard geophysical methods.

In principle, geothermic measurements may be used for the investigation of thermal sources either at great depth or close to the surface. In the first case the heat flow is studied, the value of which may by calculated from the geothermal gradient and the thermal conductivity of the rocks. The research was carried out with the purpose of obtaining further information about the deeper geological structures (Čermák et al. 1968) and also about possible terrestrial energy sources. From a theoretical point of view, the comparison of the values of the heat flow in Czechoslovakia with the results of the geodetically measured vertical movements of the Earth's crust deserves attention. The comparison indicates a definite correlation: the sinking areas show high values of heat flow whereas the rising areas are marked by low values of heat flow.

In the case of the exploration for shallow thermal sources, the measurements

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of temperatures are sufficient. Practical experiments of such measurements using standard thermometers have often been carried out with some success, but the field procedures were tedious.

To meet all requirements of easy and fast field operations and also of a high accuracy and reproducibility of observations, an electrical bridge thermometer with thermistor sensing element was constructed in our Institute (Halousek and Příhoda 1967). With this instrument we are able to measure temperatures from 0°C up to 70°C. For special conditions, the range of the instrument can be extended to 100°C.

Reproducibility of the measurements in the range from 0°C to 30°C is better than 0.06°C; at the temperatures of about 50°C it is 0.1°C. The variation of reproducibility of the measurements over the range of the instrument is due to the compromise between the need for high sensitivity and for simplicity of the instrument and its operation.

The instrument weighs 2,6 kg and thus is easily portable. The sensing element is protected by a small case and may be connected either with a metal rod of a length of 2 to 10 m or with a cable up to 600 m long designed for measurements in boreholes.

Methods of measurements and their corrections have to take into account some disturbing effects (Kappelmeyer 1957), first of all the diurnal variations of the temperatures caused by solar radiation. The variations may be observed in the soil down to the depth of about 1,5 m. In order to eliminate the effect of the temperature changes, measurements are made in shallow boreholes, drilled by a light drilling equipment, or made by means of a steel rod and hammer. During the winter season, satisfactory results may be achieved by measuring beneath the snow cover, as indicated by Krčmář (1968).

Sometimes, the depth of the shallow boreholes is not sufficient to eliminate the diurnal changes of the temperature. Also, if the measurements in a given area are spread over a longer time-period, the mean daily temperature in the boreholes changes with the season, corresponding to the annual temperature variations. For this reason, it is necessary to repeat the observations on some checking point of the measured area in relatively short time-intervals of 2 or 3 hours, during the entire time of the investigations. The changes of the temperature at the checking point have to be introduced in all the measured values, and in this way the temperature measurements in the area are reduced to a common epoch.

Changes of the vegetational cover may also cause differences in temperature of a few degrees Centigrade at a depth of 1,5 m. This effect can be eliminated by introducing a special normal temperature level for each particular type of cover. Under complicated conditions, the investigations of the vertical temperature gradient provide reliable results. From measurements at one observation point carried out at two different depths, for example 1 and 2 m, the gradient may be determined with the accuracy of 0.1°C/m.

The field observations are carried out on a rectangular grid with the distances ranging from 20 × 5 m to 200 × 40 m, depending on the purpose of exploration. The daily coverage of about 50 to 100 points, achieved by a crew of 3 or 4 men, depends principally on the terrain conditions.

Examples of Geothermic Prospecting

In the Spiš-Gemer area (Slovakia), sideritic-sulfidic ores occur in crystalline schists of palaeozoic age together with graphitic beds. Mostly, the ores do not contain magnetic minerals, and their conductivity is similar to that of the graphites. For this reason, both magnetic and electrical surveys do not yield

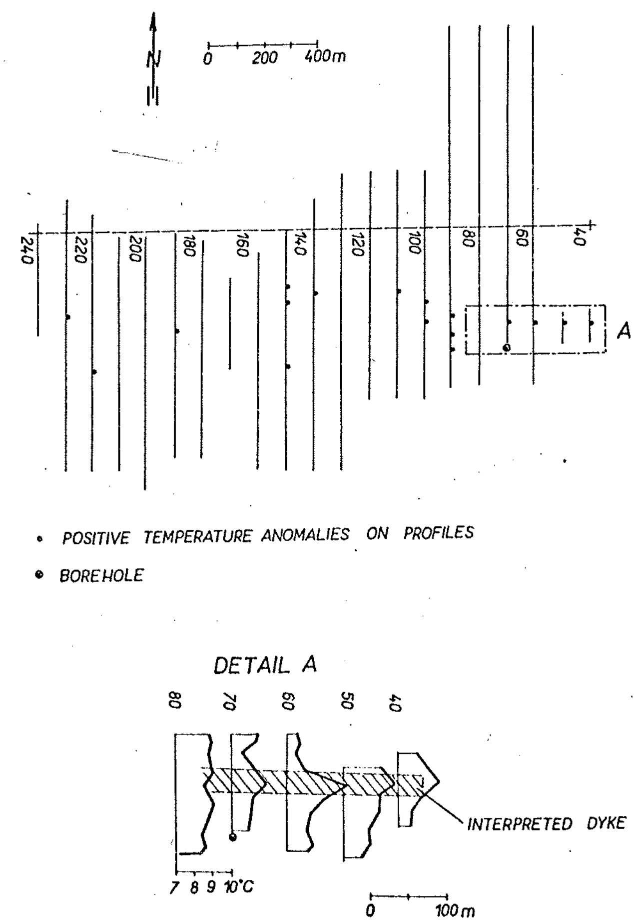

Fig. 1. Temperature anomalies above sulfidic deposits.

satisfactory results. However, the exothermal reaction occuring in the oxydation zone of *the sulfidic deposits* gives a possibility to apply geothermal investigations.

An area of about 2 km² was covered by traverse lines 100 m apart (Fig. 1). Rough topography and changes in the vegetational cover caused differences in the temperature level. For this reason only local anomalies higher than 1 or 2°C were marked. The zone of the positive temperature anomalies in the eastern part of the area was examined in detail and checked by drilling, which intersected a vein with sulfidic mineralization.

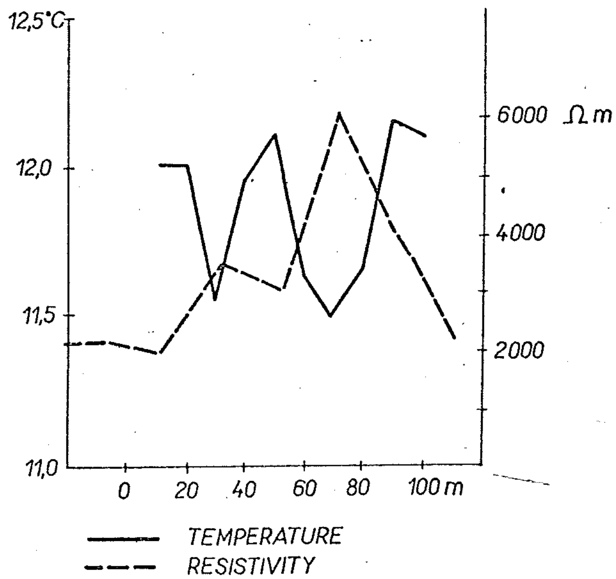

Fig. 2. Temperature and resistivity measurements in Karst area. The temperature lows correspond to cavities.

The geothermic measurements can also be applied to the investigation of *underground cavities* in karst areas. The temperature differences are caused by the flow of air or water, which warms up or cools down the surrounding rocks. An example of geothermic measurements above two cavities at a depth of about 15 m shows negative anomalies of about 0.5°C (Fig. 2). In this case, resistivity measurements gave very similar results.

Very promising are the results of geothermic investigations applied to *hydrogeological problems*. The circulation of ground water along a fault changes the temperature in the near vicinity. In the winter, the faults are connected with positive temperature anomalies, whereas in summer they cause negative ones. Figure 3 is a compilation of temperature measurements over an area of 400 × 500 m done in winter. The isothermal map is based on data measured

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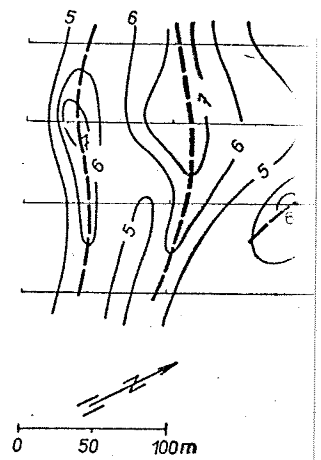

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at a depth of 1,4 m under the soil surface. The faults are clearly indicated by anomalies of about 2°C. Resistivity measurements in the same area met with difficulties due to the swampy surface.

The most favorable application of the geothermic method is the investigation of warm mineral waters due to the pronounced differences in temperatures. A great number of succesful investigations were made on several localities in Czechoslovakia. Our experts also solved similar problems in southern Serbia and in Macedonia.

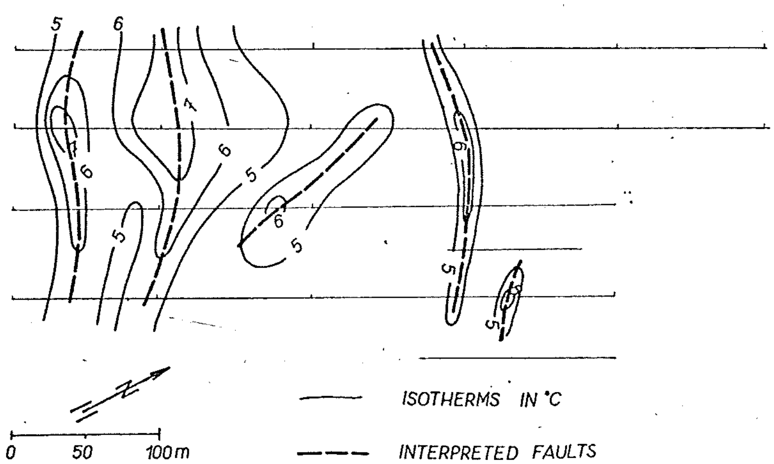

Fig. 3. Temperature anomalies indicating faults with circulating ground water.

In certain cases, however, unfavorable terrain and weather conditions, the inhomogenity of the surface layer and other obstacles can make the solution of such problems rather difficult. In a Spa in Slovakia the mineral waters with a temperature of 23 to 33°C were drained from alluvium. The search for the main mineral water channel by drilling did not have the expected result. The first thermal measurements showed that the temperature is strongly influenced by varying surface conditions. The observations were therefore made at two depths of 90 and 140 cm, and a map of contour lines of the vertical gradient was compiled (Fig. 4). The maximal values of 2°C/m indicate the position of faults with ascending mineral water. The results of thermal measurements were verified by gasometric analyses for CO_2 of probes of soil air taken along the same traverse lines. The anomalous values of CO_2 content are rather dispersed, but the highest values are close to the maximum of the temperature gradient.

In this paper the application of the geothermic methods only has been discussed. It should be kept in mind, however, that best results are achieved if the geothermic survey is carried out and evaluated in connection with some other geophysical methods.

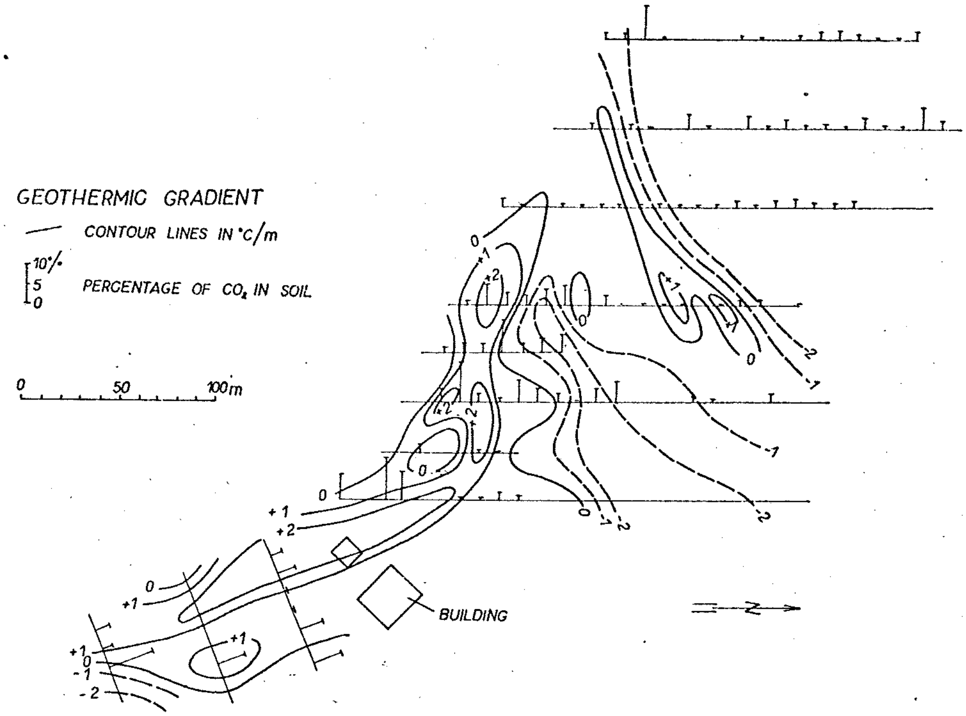

Fig. 4. Contour lines of the geothermic gradient in an area with warm mineral water.

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