18674

Thermal Conditions for Geothermal Energy in Transcarpathian Depression

D. Majcin* (Geophysical Institute of SAS), R.I. Kutas (Institute of Geophysics, NASU), D. Bilčík (Geophysical Institute of SAS) & V. Bezák (Geophysical Institute of SAS)

SUMMARY

The contribution presents the results of our cooperative geothermal works in the Transcarpathian depression - very perspective region for exploitation of geothermal energy both for Slovakia and for Ukraine. The activities were focused on interpretation of temperature and heat flow data, geothermal modelling results and relations of the thermal state of the lithosphere to the tectonics in the region under study and surrounding geological units. These results and additional modelling works afforded us the opportunity to construct the terrestrial heat flow density map and maps of the temperature distribution in various depth levels and consequently to analyse the thermal conditions for the exploitation of geothermal energy in separate basins of the Transcarpathian depression.

Introduction

The Transcarpathian depression represents the most perspective region for exploitation of geothermal energy both for Slovakia and for Ukraine because it is the thermally most active area for both mentioned countries. The separate subareas of the Transcarpathian depression belong also in the most explored ones concerning the density of geothermal measurements as well as structural knowledge because of massive gas/oil prospecting.

The thermal conditions of the Transcarpathian depression were mostly explored separately in individual countries. The direct methods (i.e. mainly the measurements in boreholes) and also modeling approaches were utilized for determination of temperature field distribution in the region under study. The results were summarized in publications Rudinec 1989, Majcin 1993, Franko et al. 1995, Gordienko et al. 2002, Gordienko et al. 2004, Kutas 2011 and others. Some synthetic works have tried to interconnect the selected geothermal data (most of them were the terrestrial heat flow data) over wider regions in Europe (e.g. Čermák and Hurtig 1979, Hurtig et al. 1992, Hurter and Haenel 2002).

The aim of our contribution comprises three main points.
1. The complex interpretation of the measured data, the supplemented data from model calculations of temperature fields and the up-to-date knowledge from tectonics of studied region
2. The construction of maps that portray the thermal state of upper crust parts belonging to Transcarpathian depression together with surrounding geological units
3. The analysis of the thermal conditions for the exploitation of geothermal energy in separate basins of the Transcarpathian depression.

Methods and results

For the maps construction, interpretation and analysis of input data of both heat flow density and temperature distribution in boreholes (authors own data, Franko et al. 1995, data from international databases and others) there were utilized models of temperature fields based on the solution of heat transfer equation in steady and transient state as well. Derived math-physical tasks in bounded areas were solved by means of finite difference methods. In selected simplified structural cases there were used analytical solutions and approaches for solution of boundary-value problems as well. Moreover, we have utilized the both qualitative and quantitative analyses as well as methodical conclusions from refraction effects study carried out on the contrast conductivity structures together with earth's surface topography considered (Majcin 1992, Majcin and Polák, 199, Majcin et al. 2012).

In addition, some of existing temperature history models applied on profiles that cross the Transcarpathian depression (Kutas et al. 1989, Majcin and Tsvyashchenko 1994, Tarasov et al. 2005) as well as results obtained by the integrated geophysical modelling (Dérerová et al. 2006) where both involved in our analysis.

The construction of maps utilized both the data obtained from measurements in boreholes and calculated data from 2D models applied on vertical profiles where structures as well as tectonics of studied area have been taken into account (Kováč et al. 1995, Lashkevitsch et al. 1995, Pecskay et al. 2006 and others). The complete model of the thermal state of upper parts of the lithosphere over Transcarpathian depression as well as neighbouring geological units is portrayed by both the map of the terrestrial heat flow density distribution (Fig. 1) and the distribution of the temperature at the depths of 1000, 2000, 3000 a 5000 m from the surface.

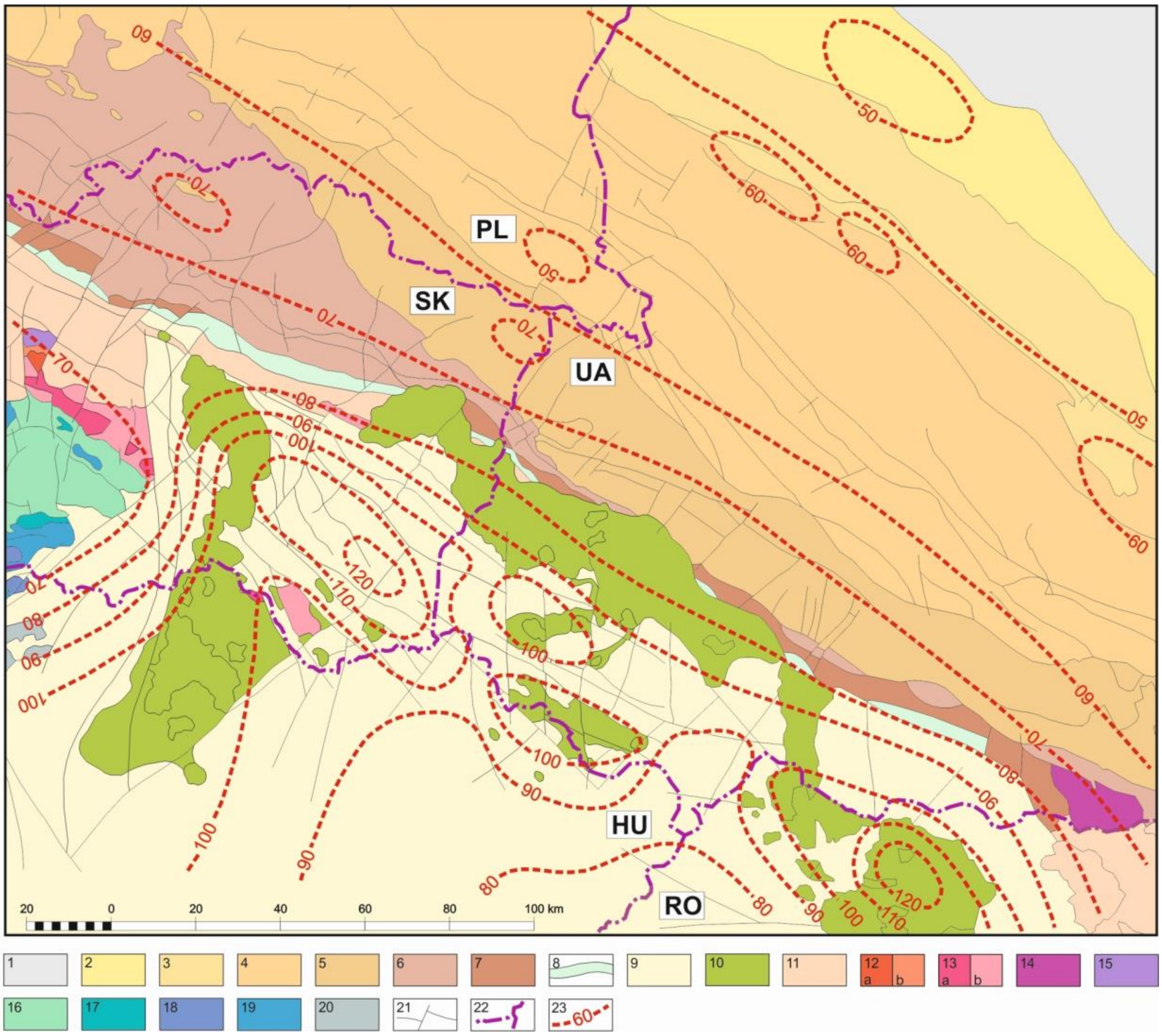

Figure 1 *Terrestrial heat flow density distribution in Transcarpathian depression and surrounding units. 1 - East European platform, 2 - Carpathian Foredeep, 3 - Outher Carpathian Flysch, folded molasse units, 4 - Krosno Nappes group of the Flysh Belt, 5 - Foremagurian units of the Flysch Belt, 6 - Outher Magura Nappes of the Flysch Belt, 7 - Inner Magura nappes of the Flysch Belt, 8 - Pieniny Klippen Belt, 9 - Neogene and Quaternary sediments of the Inner Carpathians, 10 - Neogene volcanic rocks (andesites, rhyolites), 11 - Paleogene sediments of the Inner Carpathians, 12 - Tatricum: a. basement, b. sedimentary cover, 13 - Veporicum, Zemplinicum: a. basement, b. sedimentary cover and Krížna Nappe, 14 - Marmarosh Massif, 15 - Hronicum, 16 - Gemericum, 17 - Meliaticum, 18 - Turnaicum, 19 - Silicicum, 20 - Paleozoic of the Uppony-Szendrő, 21 - Faults, Alpine overthrust lines and geological boundaries, 22 - State borders, 23 - Isolines of heat flow density distribution in mW/m².*

Conclusions

The results of this contribution represent one of the data sources for the comprehensive evaluation of the Transcarpathian depression conditions concerning the determination of parameters of geothermal energy sources. The temperature distribution maps provide useful information about accessibility of required temperatures in Transcarpathian depression localities. For example, the map of temperature distribution at the depth 3000 m (Fig. 2) shows that the deposit temperature values of 160 °C, considered as the effective ones for the electric energy production by binary cycles, are accessible in northeastern and southern parts of the East Slovakian basin. In Mukachevo basin the maximum temperature values are slightly below this limit (160 °C) over some regions, while in Solotvino basin these values are close to the lower limit of applicability of these technologies for their energetic exploitation.

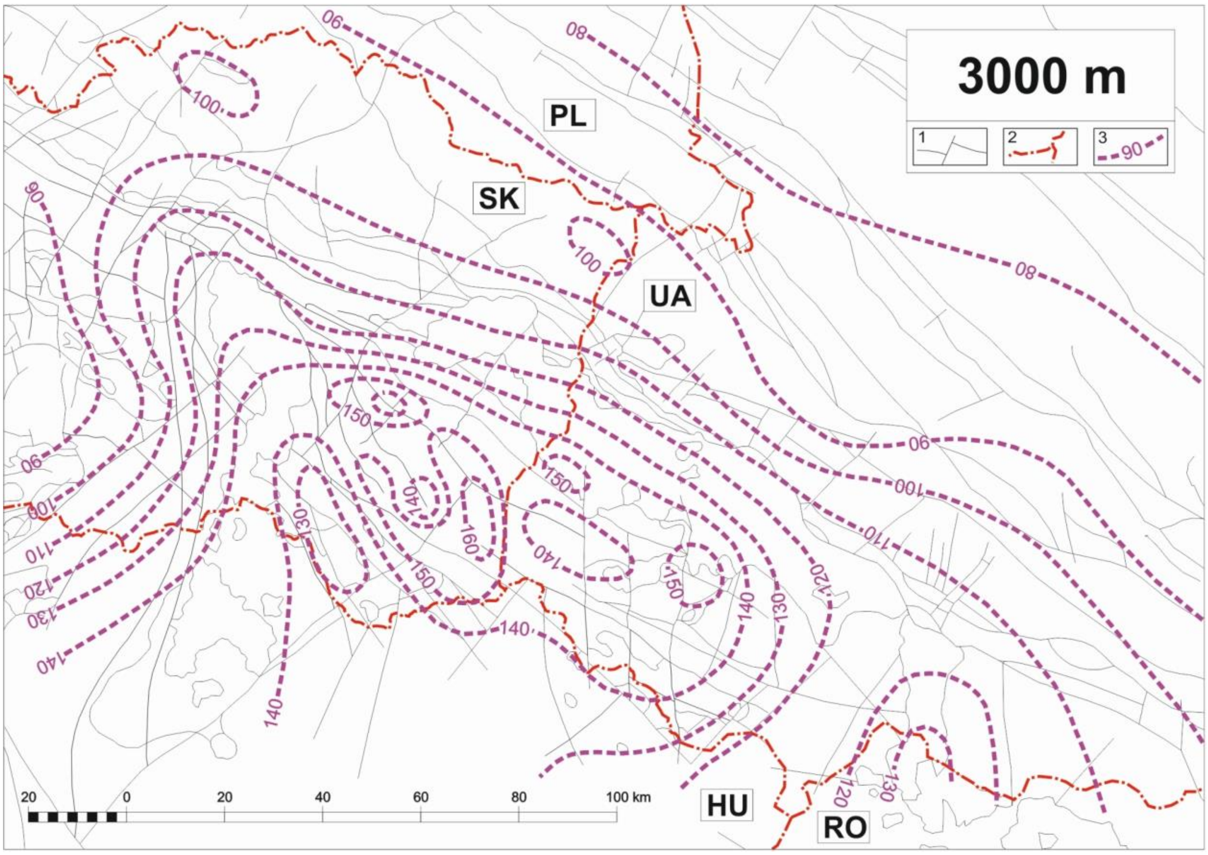

Figure 2 *Temperature distribution map in the depth of 3000 m from the surface. 1 - - Faults, Alpine overthrust lines and geological boundaries, 2 - State borders, 3 - Isolines of temperature distribution in °C.*

Acknowledgements

The authors are grateful for partial support of the work to the APVV agency by means of project APVV-0724-11 and to Slovak Grant Agency VEGA by means of projects No. 2/0067/12 and No. 2/0095/12.

References

Čermák, V. and Hurtig, E. [1979] Heat Flow Map of Europe. In: Čermák, V. and Rybach, L. (Eds.) *Terrestrial Heat Flow in Europe.* Springer-Verlag, Berlin Heidelberg (Enclosure map).

Dérerová, J., Zeyen, H., Bielik, M. and Salman K. [2006] Application of integrated geophysical modelling for determination of the continental lithospheric thermal structure in the Eastern carpathians. *Tectonics*, **25** (3), TC3009.

Franko, O., Fusán, O., Král, M., Remšík, A., Fendek, M., Bodiš, D., Drozd, V. and Vika, K. [1995] *Atlas of Geothermal Energy of Slovakia*. Dionyz Stur Institute of Geology, Bratislava.

Gordienko, V.V., Gordienko, I.V., Zavgorodnyaya, O.V., Logvinov, I.M., Tarasov, V.N. and Usenko O.V. [2004] *Geothermal atlas of Ukraine.* Korvin Press, Kiev.

Gordienko, V.V., Gordienko, I.V., Zavgorodnyaya, O.V. and Usenko O.V. [2002] A thermal field of territory of Ukraine. Znannya. Kiev.

Hurter S. and Haenel R. (Eds.) [2002] *Atlas of Geothermal Resources in Europe*, Office for Official Publications of the European Communities, Luxemburg

Hurtig E., Cermak V. and Zui V. [1992] *Geothermal Atlas of Europe.* Hermann Haack Geographisch-Kartographische Anstalt, Gotha.

Kováč M., Kováč P., Marko F., Karoli S. and Janočko J. [1995] The East Slovakian Basin – A complex back-arc basin. *Tectonophysics*. **252**, 453–466

Kutas, R.I. [2011] Reflection of the Eastern Carpathians tectonic in thermal field. *Geodinamica*, **11**(2), 147-149 (in Ukrainian).

Kutas, R.I., Tsvyashchenko, V.A. and Korchagin, I.N. [1989] *Modelling thermal field of the continental lithosphere.* Naukova Dumka, Kiev (in Russian).

Lashkevitsch Z. M., Medvedev A. P., Krupskiy Y. Z., Varitchev A. S., Timoschuk W. R. and Stupka O. O. [1995]. *Tectonomagmatic evolution of Carpathians*. Naukova Dumka, Kiev. (in Russian)

Majcin, D. [1993] Refraction of heat flow on the near-surface structures with thermal conductivity contrast. *Contrib. Geophys. Instit. Slov. Acad. Sci.,* **22**, 67-80.

Majcin, D. [1993] Thermal state of the West Carpathian lithosphere. *Studia geoph. geodaet.,* **37**, 345-364.

Majcin, D. and Polák, Sz. [1995] Refraction of heat flow near the border of the sedimentary basins with topography. . *Contrib. Geophys. Instit. Slov. Acad. Sci.,* **25**, 99 - 112.

Majcin D. and Tsvyashchenko V.A. [1994] Effect of magmatism on temperature field in the northern part of the Transcarpathian depression. *Contrib. Geophys. Instit. Slov. Acad. Sci.,* **24** (2), 72-86.

Rudinec R. [1989] *Crude Oil, Natural Gas and Geothermal Energy Resources in Eastern Slovakia*. Alfa. Bratislava (in Slovak with English abstract)

Tarasov V., Gordienko V., Gordienko I., Zavgorodnyaya O., Logvinov I., Usenko O. [2005] Heat Field, Deep Processes and Geoelectrical Model of East Carpathians. In: *Proceedings of World Geothermal Congress 2005 Antalya*, Turkey.