Geothermal research in the Subcarpathian region

Dr. habil Göőz Lajos

College of Nyíregyháza, Department of Geographic

Hungarian geologists played a crucial role in the research of the Subcarpathia region already before World War I, or, more specifically, in the last century. Research fellows of the Ukrainian Geological Survey still respect their early results and the geological concept based on them. The Subcarpathian Research Centre of the Ukrainian Geological Survey (Lvov) is situated in Beregovo. The research system and management developed during the Soviet era used to work with a very high number of drilling per metre, which was typical of the then socialist countries. This approach in turn resulted in the decrease of quality of the geophysical measurements. Therefore, the information given by the Survey, stating that 13.000 deep drillings were effectuated in the area since 1947, seems quite unrealistic. During this very same socialist period, less drillings were made on the area of the entire Hungary i.e. 93 000 km^2 than on this 13.000 km^2 area. As no detailed data are available concerning the Ukrainian drillings, we assume that the above number contains the ordinary water and metal research drills. Also, due to the lack of data concerning the depth, we are not able to classify neither the deep, nor the shallow drillings according to the Ukrainian terminology, which makes them even more difficult to compare to the Hungarian system. However, it is obvious that intensive research activity has been carried out in the Subcarpathian region. As the Galicia area used to have well known hydrocarbon reserves during the era of the Austro-Hungarian Empire, attempts were made to clarify the situation within the Carpathian basin as well.

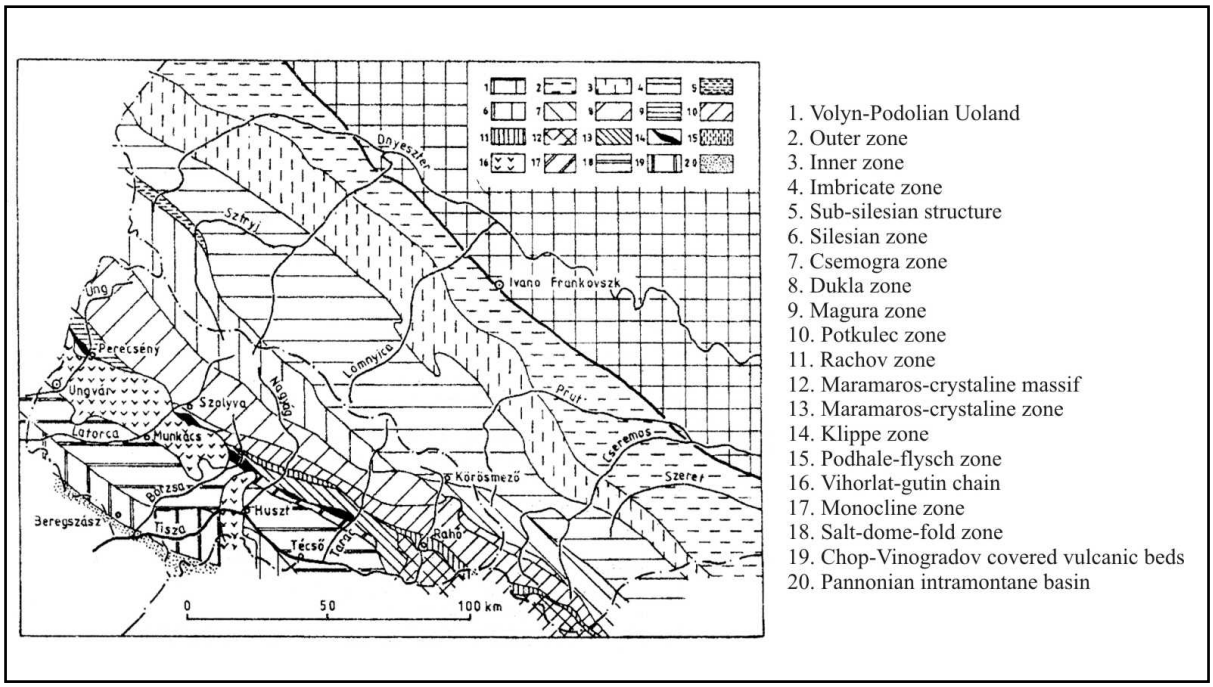
Despite the previously mentioned problems, the layers of deep drillings are especially important for us. The deepest (4230 m) drilling is situated near Alsóremete, close to the Hungarian border. This one provides us useful information concerning the geological development of the region.

Phases and cycles of the geological development of the Surcarpathia region:

I. During the first cycle: from 1 billion - 550 million years, the area can be characterised as a marine geosynclinal, with a thick layer of sandy deposits on it;
II. The second cycle is the “Caledonian cycle”, from 550-400 million years, when the sandy deposits folded, the area dried up and the orogenesis had started;
III. The third cycle, from 400-230 million years, is the “Hercinan cycle”, during which volcanic rocks accumulated and great folding activity was typical;
IV. Finally the last cycle in the area of Subcarpathia corresponds to the “Alp cycle’, that started during the early Triassic, i.e. 230.000.000 years ago, and the movement and development of which still lasts.

The last, so-called orogenic phase, developed between the Paleogene and Neogene periods, i.e. approximately 23 million years ago and still lasts. According to the theoretical research of tectonic experts and geophysicists, the intensive orogenetic phase was developed due to the movement of the Eurasian and the Pannonian plates. This phase can also be divided into three stages, i.e. the early, the middle and the late orogenic stages. In fact, the Pannonian structural unit, to which the Southern part of the Subcarpathia region belongs, has also developed during

the middle cycle. The Pannonian structure extends as a wide belt towards Southwest and crosses the Hungarian border as well. Its line can be followed in the Čop-Bégány-Beregovo-Újlak direction. The Pannonian deposit is present in the entire area. Its development and layering is primarily due to eolian processes, erosion, surface and subsurface waters. These layers are indeed considered as the best water containing layers, i.e. the best category from the point of view of geothermal energy research, on the Ukrainian as well as on the Hungarian side. A deep fractured belt on the Southwestern side closes the Pannonian basin; or rather it results in the development of two inner depressions, which are the Čop-Munkacevo basin in the Northwest, and the Aknaszlatina basin in the Southeast. The Vihorlát-Gutin volcanic chain separates the two basins.



1. Volyn-Podolian Uoland
2. Outer zone
3. Inner zone
4. Imbricate zone
5. Sub-silesian structure
6. Silesian zone
7. Csemogra zone
8. Dukla zone
9. Magura zone
10. Potkulec zone
11. Rachov zone
12. Maramaros-crystaline massif
13. Maramaros-crystaline zone
14. Klippe zone
15. Podhale-flysch zone
16. Vihorlat-gutin chain
17. Monocline zone
18. Salt-dome-fold zone
19. Chop-Vinogradov covered vulcanic beds
20. Pannonian intramontane basin

Fig. 1. Geological map of Subcarpatian region

On this very area, depressed parts of the once several metres high volcanic mountain chain can be either explored, or indicated. They later moved, broke up and submerged. It is known that volcanic layer thicker than 4000 m can be found in several places in Szabolcs-Szatmár-Bereg County. They indicate that the breaking up and submerging happened exactly in the same way, and also in several phases, in the North-eastern part of the Great Plain. This volcanic range of layers here is not as thick (700-1000 m in Beregovo, 1800 m in Nagydobrony and 700-1500 m in Uzgorod, 1400 m in Cop) as in the previously mentioned, Nagyecsed depression area (Szabolcs-Szatmár-Bereg County). The Pannonian Basin, which is in fact a Neogene basin, is represented here by the Pliocene deposits among the characteristic ones and can be found in the Csapmunkács basin. This is a Neogene depression of a heterogene base. Neogene sedimentary rocks (Molasses) can be localised until the depth of 2-3 km. The folded structure of the pre-Neogene base consists of sedimentary, volcanic and metamorphic, Paleogene, Cretaceous, Triassic and Paleozoic formations. Drillings cross them in several places. From the point of view of geological test drillings, the most important are the MK-1, the 3Tp and the 4Yzs drillings.

The Geophysical Institute of the Ukrainian Academy of Science carried out intensive geothermal research work in the area during the past decades, and also represented its results on maps. They studied data of thermal water production of the wells, as well as their hydrogeologic and geothermal conditions. The latter indicators are outstandingly important from the point of view of the Ukraine, as despite of the Krím area, only Subcarpathia has been defined within the entire Ukraine as the place where geothermal research can be of positive result. We have to mention amongst the researchers Sz. G. Dumanszkij and D. É. Kulcsickij, who mapped the anomalies in the 1960s. At the present, there are 27 thermal drills in Subcarpathia with a depth of 800-1500 m. As a result of the detailed chemical analysis and data processing, several artesian basins were found. According to the geothermal anomalies, the most perspective area is the Zaluzs one, where the temperature of rock is 170°C in the depth of 3.5 km, on an area of 30 km^2. Most intensive thermal water research have been carried out in the plain area of Beregovo and Uzgorod, where very favourable geothermal gradients have also been identified. The 50°C isotherms are situated in the depth of 520-600 m. As we have already mentioned; the highest temperature gradient is near Zaluzs, in Munkacevo County. If we move towards Southwest from here towards Beregovo, temperature values decrease until 48°C, while towards the West (Uzgorod) they are only of 30°C. Nevertheless, this does not mean that higher temperature cannot be detected in the depth of 1000 m. Research records showed temperatures of even 70°C, and 90°C in the depth of 500 m. Gradient values were much more favourable in the mountainous areas than in the plains. A temperature of 5°C/100 m was detected at some places on the plains, while maximal values were above 6-6.8°C/100 m.

The Earth heat flux is 67-110 mW/m^2, the average value of which is 50 mW/m^2 in the planet. This value is 90 mW/m^2 in Hungary. Therefore, as we can see, the heat flux values in this area are twice of the world average.

Table 1. Test thermal drillings in Subcarpathia

	No. of well	**Location**	**Foot depth of well**	**Interval of the depth of water income**	**Series of layers of the well**	**Geological signs of layers**	**Output of the well M3/day**	**Temperature of water on the surface**	**Mineral content g/l**
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1.	1-T	Rozivka District of Uzgorod	2058	1733-2042	limestone, crystal schist	PZ	200-500*	58	48.3
2.	5-T	Uzgorod (centre)	1181,2	1048-1150.5	Marble, limestone	PZ	164	28.5	44.3
3.	32-T	N. Solotino	640	381,7-632,5	andesite	N2ht	717	41-42	12,1
4.	11-T	Erdőoatak (Lisarnya), Munkacevo district)	1289,5	480-600, 870-960	Andesite tuffs	N2ht	78	35	0,8
5.	1-M	Munkacevo (Tourists' area)	1350	480-618	sandstone	NIS	389	34	20,4
6.	6-T	Beregvar, Carpathian Sanatorium	1480	710-920	Conglomeratzes and sandstone	NIS	173	42	110
7.	113-A	N. Rostoka, D. of Ilosva	622	481-622	sandstone, argilite	NIS	380	37,5	11,5
8.	2	Greblja D. of Ilosva	3209	472-582	sandstone	Ntb-S	44	39,5	19,4
9.	8-J	V. Rostoka, D. of Ilosva	446	440-446	sandstone	NIS	1434	39	12
10.	1164	N. Bégány D. of	695	594-683	rhiolite	Ntb-S	135	36,6	7,5

		Beregovo			tuff, xenotuff				
11.	2-T	Beregovo sport centre	930	877-926	tuff, argilite	Ntb-S	345	58-60	23-25
12.	8-T	Beregovo	1050	876-993	tuff, sandstone	Ntb-S	185	54-56	25
13.	12-T	Beregovo Geological Expedition	1083,4	813-902	rhiolite-tuff	Ntb-S	259	48,2	8,1
14.	16-T	Kasony Sanatorium, D. of Beregovo	1190	800-862	rhiolite-tuff	NIS	363	51	8,5-10
15.	16-P	Mezőkaszony, D. of Beregovo	901	600-901	rhiolite-tuff, xenotuff	NIS	1063	50-51	9,5-10
16.	27-T	Mezőkaszony, D. of Beregovo	1348	651-1348	tuff, sandstone, argilite	Ntb-S	864	50	9,1
17.	3-T	Makkosjánosi, D. of Beregovo	1211	470-668	andesite, andesite tuff	NIS	2021	27,5	6,6
18.	50-C	Gút, D. of Beregovo	1325	600-680	andesite	NIS	125	45.7	7,5
19.	21-T	Bakta, Test station	1150	781-1070	tuff, tectonised fractured rock	Nlnv	250	58-60	19,1
20.	22-T	Bakta, D. of Beregovo	1154	902-1129	rhiolite tuff, sandstone	Ntb-K2	749	35-.36	10,9-11,2
21.	4-T	Borzova, D. of Beregovo	1530	994-1060	rhiolite tuff	Ntb	345	38	1,8
22.	23-T	N. Palád, D. of Szőlős	1481	1005-1226	sandstone	N1-2pa-NIS	432	52	9,5
23.	18-T	Teplica, Black Mountain, D. of Szőlős	961	595-755	andesite, tuff, argilite	NIS	374	40	46
24.	9-T	Saján sanatorium, D. of Huszt	1251	771,8-826,9	rhiolite-tuff	Ntb	90	31	11,2
25.	10-T	Saján, D. of Huszt	1271	1120-1190	rhiolite tuff, limestone	Nlnv-2-3	86	40	125
26.	14-T	Nárcisz (Veljatino) D. of Huszt	1002	943,8-1000	rhiolite tzuff, argilite	Ntb-Nlnv	1088	56	88
27.	6-Tp	Tereblja, D. of Técső	2497	2009-2354	rhiolite tuff	Nlnv	500	80-89	142

Notes
geological signs:

1. N2ht Paleocene, Huta area
2. NIS Miocene, Sarmata layer
3. Ntb- Miocene, baden
4. N1-2pn- Pliocene-Miocene unrelieved Pannon
5. K2- Upper-Cretaceous
6. J2-3- Upper-Middle Jurassic
7. N1nv Miocene, novoszelickaja belt

* well is closed, due to high mineral content

When summarizing the study of the thermal anomalies, we can assume that the highest values were detected where the faultline of the tectonic zones is situated. Also, exo- and endothermic processes, typical of the upper layers, influence anomalies. The heat flux dispersion is strongly linked to the heat conductivity of different rock types, the thickness of their layers and the downward circulation of water.

According to the Ukrainian geothermal classification, hot water must of a temperature higher than 37°C. As we can see, water of a temperature suitable for energetic use is unlikely to be found in Subcarpathia.

When analysing waters of the region, we can see that medium, or low mineral content waters (2,2-3,2 gram/litre) are dominant. Water output of wells is an average of 430-1500 m^3/day. Salty, carbonic, subthermal waters can be found in the area of Visk. The chemical composition of the water of some wells is very interesting. Thermal waters of Munkacevo District belonging to the group of salty thermal waters (e.g. water of the Carpathian Sanatorium from the depth of 690-920 m and that of Huszt District in the area of the Saján Sanatorium) are worth to be analysed. Thermal water in the Ilosvai District is hydrocarbonate, containing sodium chloride. Although temperatures above 50°C are not common, they still occur in the Uzgorod, Beregovo, Huszt and Técső area. E.g. the well of the Sport Swimming pool in Beregovo, provides sulphuric, carbonic, sodium chloride containing (20-254 g/l mineral content) water of 62°C, from a layer between 930-1100 m, and has an output of 180-400 m^3/day. Some anomalies have to be mentioned in the Huszt District as well, near the settlement of Nárcisz, where 60°C water of high mineral content (sodium chloride) was found in the depth of 1000 m. The output of this well is 780 m^3/day. Following an oil drill, at Terebes, in the Técső District, 90°C temperature water of a mineral content of 131 g/l was found. Soon a well of 500 m^3 daily output had been drilled in the depth of 2354-2360 m. Concluding the above facts, thermal waters in the Subcarpathia area are usually very salty, which is most probably due to the fossil salt layers present in the area both beneath and under the surface e.

Finally, we have to mention, the total lack of crude oil production in Subcarpathia. Despite the high intensity drilling research there is not much natural gas exploration.

REFERENCES

f. Horváth, S. Cloething: Geodinamic of the Pannonian Basin. Tectonophysics 266. (1966) 287-300.

Göőz L.: A Nyírség földtani, geofizikai kutatásának néhány sajátos problémája. BGYTKF Tud. Közleményei Tom. 6/F. 1974.

Göőz L.: Szabolcs-Szatmár megye természeti erőforrásai. Földrajzi Közlemények 1985. 3. sz.

Kulcsár L.: A mezőkaszonyi szigetvulkánok. Közl. Debreceni Tisza I. Tud. Egyetem Ásv.-Földtani Intézetéből (6. kötet 1943)

Székyné Fux V. – Pécskay Z. – Balogh K.: Észak és Közép-Tiszántúl fedett miocén vulkanitjai és K/Ar radimetrikus kronológiájuk. Földtani Közlöny 1987. 117.

Tyitov E. M.: Ignimbritü Zakarpatja = i. nauesnaja szesszija Zakarp. Otgyel. Lvov. Geol. Obses. Beregovo, 1966 pp. 49-50.