LOCAL METEORIC WATER LINE OF MINERAL AND THERMAL WATERS IN SLOVAKIA

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Abstract: In the paper O and D isotopes in mineral and thermal waters of the Central Western Carpathians are treated, Irevaluation of their relation at the same time their radiocarbon age and climatic conditions cluring the Würm 2 and 3 are taken into account. From 32 localities 26 trace the global line of meteoric waters and 6 the local line of meteoric waters.

Key words: Space, time, O, H, ^{14}C dating, Slovakia

INTRODUCTION

In the time of the years 1970-1997 sufficient data on stable isotopes for evaluation of the origin and development of mineral and thermal waters (MTW) of the Central Western Carpathians were gathered. We have available 41 data on $\delta\ ^{18}O$ and δD values from 32 localities and 61 data from 43 localities about the radiocarbon age of waters (^{14}C). When comparing the global meteoric waters line (GMWL) with the local meteoric waters line (LMWL) we use the snow line from the Würm glaciation in the Vysoké Tatry Mts. (the highest mountain range in Slovakia – Gerlach 2655 m a. s. l.).

RADIOCARBON AGE OF MTW

The methods of choice of bereholes, sampling and measuring of samples and discussion about achieving the results are described in the works by Franko (2001) and Franko – Šivo (2002). The age of waters varies within the limits of 32000-9000 years. In fact, not age of waters is (or is?) concerned, but the time of retention of infiltrating water to its present-day outflows. In the former Czechoslovak Federal Republic (ČSFR) radiocarbon dating was studied by J. Šilar (for instance, 1976). Relation of the time of infiltration and/or age of waters and snow line in the Vysoké Tatry Mts. is in Fig. 2. From it one may see that the waters infiltrated not only in interstadials of the Würm 3 (Paudorf, Bölling, Alleröd) but practically throughout the Würm 3. Climatic changes are represented by oscillation of the snow line in the Vysoké Tatry Mts. (Lukniš, 1964). Partial periods of the Würm 3 are correlated with its periods in Central Europe and the course of the snow line with glaciation in the Alps and Northern Europe. From Fig. 2 it is visible that glaciation in the Würm 3 practically descended to the altitude of 1700-1650 m. We cannot take this boundary absolutely, because all localities of MTW (besides Vyšné Ružbachy) have the infiltration areas below this altitude. It is necessary to add to the Last Würm Stadial that not only in the time of it, but throughout the Würm glaciation was in the Tatras and Nízke Tatry Mts. only (Lukniš – Plesník, 1961). According to differences between the considerable glaciation of the N slope of the Nízke Tatry MTs. and insignificant traces at their S slope, the ridge of this mountain range was an important climatic boundary in the time of the Last Glacial. Then outside the area of the Tatras and Nízke Tatry N slope precipitation infiltrated in the remaining territory of Slovakia. This statement is justified as in this period through the territory of Slovakia the January isotherms with values around – 16 °C to – 18 °C and the July isotherms with values 11-12 °C look their course (Klute, 1951).

On principle, however, it is valid that the more waters of meteoric origin are older and infiltrate in higher altitudes, the lighter they are and/or have lighter oxygen. $\delta\ ^{18}O$ values of present-day precipitation on the territory of Slovakia are varying within the limits of – 8,70 ‰ to – 10,44 ‰ on an average (for the years 1988-1997). In lowlands $\delta\ ^{18}O$ varies between – 8,70 ‰ and – 9,45 ‰ on an average and mountains between – 10,10 ‰ and 10,44 ‰ (Michalko, 1999). The altitude of lowlands varies within the limits of 113-345 m a. s. l. and of mountains 692-2008 m a. s. l. When tracing the springs in the Veľká Fatra Mts. from carbonates of the envelope unit and lower nappe (Krížna nappe) it has been established that with higher altitude the value of $\delta\ ^{18}O$ sinks by 0,1 ‰ on 100 m (Michalko and Malík, 1998). With regard to the infiltration areas we may take into account the values from mountains, knowing that their altitude in the Würm was different (lower) than at present. So, for instance, the Tatras were uplifted by about 300-400 m during the Pliocene and Pleistocene (Lukniš, 1959). In spite of that most geothermal waters have $\delta\ ^{18}O$ lighter than recent values of precipitation in the mountains. The oldest waters (32000-23000 years) which infiltrated in the Paudorf (snow and ice melting), have the lightest oxygen ($\delta\ ^{18}O$ from – 10,75 to – 11,83 ‰) and vice versa. This obvious relation is shown in Fig. 3.

ORIGIN OF WATERS AND DISCUSSION

As we have already mentioned, the evaluated waters are of meteoric origin. The data oxygen and hydrogen isotopes are in Tab. 1. From 40 data (Michalko, 1999) 32 are copying regional MWL. The $\delta\ ^{18}O$ values are varying approximately within the limits of -10 to -12 ‰ and δD values within the limits of – 70 to – 90 ‰. From the point of view of present - day values of precipitation in mountains ($\delta\ ^{18}O$ = - 10,10 to - 10,44 ‰) $\delta\ ^{18}O$ values in MTW belong to precipitation in them. With regard to the radiocarbon age MTW are older and therefore also lighter than recent precipitation.

From the figure it is further to be seen that 7 data (6 localities) are concentrated around the local MWL, which is parallel with the regional MWL and takes its course below it. δ ^{18}O are practically varying within the same limits as in 32 data, however, δ D in lighter values from - 80 to - 95 ‰. Another particularity of these 7 data is their division into 2 groups. To the first with the lightest oxygen and hydrogen (-11,28 to -11,59 and -87,1 to -92,3 ‰) the localities Gánovce, Vrbov and Sivá Brada belong. To the second group with heavier oxygen and hydrogen (-10,03 to -10,36 and -79,6 to -83,5 ‰) the localities Baldovce, Šindliar and Lipovce belong. The age of waters of the first group (the age of waters of the second group we do not know) reaches 276000 - 25200 years and falls on the Würm 2-3 and/or Paudorf Interstadial, which is part of the Würm 3. The waters differ from each other. So, for instance, they circulate in Triassic carbonates of varieous tectonic units (waters in Gánovce and Vrbovo in the Choč nappe with the „Melaphyre Series", waters in Baldovce and Sivá Brada in the envelope of the Veporicum, waters in Lipovce and Šindliar in the Choč nappe; Franko, 2000). The difference of the units is reflected in various total mineralization of waters (Sivá Brada and Baldovce around 7 g/l, Gánovce and Vrbov around 4 g/l, Lipovce 4,5 g/l and Šindliar 2,7 g/l). Waters of 5 localities are of Ca-Mg-HCO_3-SO_4 type, waters in Lipovce and Šindliar of Ca-Mg-HCO_3 type. Similarly they differ in temperature - waters in Gánovce and Vrbovo are thermal, other are cold. What mainly separates these 2 groups of waters, are different altitudes of infiltration areas. Lighter waters (the first froup - mainly Gánovce and Vrbov) have infiltration areas (Kozie chrbty, SE slopes of the Tatras) in the altitude above 950 m and heavier waters (second group - mainly Lipovce and Šindliar) in the altitude below 930 m (recent altitudes are concerned). With regard to the mentioned isotopic competence of waters of these localities to one line, taking into account the clifferent altitudes of the infiltration areas and the occurrence of waters approximately in one area, we could give this straight line a geographic name (eg. MWL of mineral and thermal waters of the Popradská kotlina depression). In contradiction to such names are, however, thermal waters in Poprad (no. 30) and Vyšné Ružbachy (no. 7,38). The projection points of ^{18}O and D are copying regional MWL. The difference from waters of the mentioned 7 data is in their age (20900 and 18300 years). Then the only explanation of this difference is the quality of precipitation in the time dating back 27600-25200 years and 20900-18300 years. The first soaked in the Würm 2-3 and the second in the Würm 3. Therefore for the local straight line I recommend to use designation MWL W 2-3. In W 2-3 there was distinct warming up, the snow line in the Vysoké Tatry Mts. rose to an altitude of about 1850 m. In the W_3 (waters in Poprad and V. Ružbachy) distinct cooling took place, the snow line descented to na altitude of about 1650 m.

CONCLUSION

From the relation of the age of MTW and late Pleistocene glaciation (snow line) in the Vysoké Tatry Mts. on the one hand and from the relation of the age of MTW and $\delta\ ^{18}O$ on the other hand it has resulted that **the more the waters of meteoric origin are older and infiltrate in higher altitudes, the lighter they are.** It has been shown from the relation of $\delta\ ^{18}O$ and δ D that MTW from 32 data trace the regional MWL and from 7 data **the local MWL W_{2-3}**. Waters from the local line infiltrated in the time of the W_{2-3} dating back 27600-25200 years when the snow line in the Vysoké Tatry Mts. retreated from altitude of about 1650 m to 1850 m (warming up set in - melting of snow and ice - the Paudorf warm period).

References

Barnes, I. and O´Neil, J. R. 1976: Metamorfic reaction in flysch rocks. Proceedings inter. symp. on water – rocks interaction. ÚÚG Praha. 309-316.

Franko, O. 2000: Pôvod CO_2, H_2S a SO_4 v minerálnych a termálnych vodách Západných Karpát z pohľadu stálych izotopov a horninového prostredia. Podzemná voda. VI. 2. 102-113. (Origin of CO_2, H_2S and SO_4 in mineral and thermal waters of the Western Carpathians from the point of view of stable isotopes and the rock).

Franko, O. 2001: Pôvod a vývoj minerálnych a termálnych vôd Slovenska v priestore a čase z pohľadu veku travertínov a izotopov O, H a ^{14}C. Podzemná voda. VII. 2. 26-45. (Origin and development of mineral and thermal waters of Slovakia in space and time from the view of the age of travertines and ^{18}O, D and ^{14}C isotopes).

Franko, O. and Šivo, A. 2002: Relative, geological and radiocarbon age of mineral and thermal waters in Slovakia. Hydrogeology journal. In the press.

Klute, F. 1951: Das Klima Europas wärend des Maximum der Weichseleiszeit und die Änderung zur Jetztzeit. Erdkunde 5. 273-283.

Lukniš, M. 1959: Reliéf a rozčlenenie kvartérnych útvarov vo Vysokých Tatrách a na ich predpolí. Geol. Zbor. 10. 1. SAV Bratislava. 233-268. (Relief und Gliederung der quärtaren gebilde in der Hohen Tatra und deren Vorlande).

Lukniš, M. 1964: The course of the Last Glaciation of the Western Carpathians in relation to the Alps, to the glaciation of Northern Europe and to the division of the Central-Europian Würm into periods. Geografický časopis (SAV) XVI 2. 127-142.

Lukniš, M. and Plesník, P. 1961: Nížiny, kotliny a pohoria Slovenska. Osveta Bratislava. 135 s. (Lowlands, depressions und mountains of Slovakia).

Michalko, J. and Malík, P. 1998: Príklady aplikácie izotopovej geochémie v procese poznávania genézy prírodných vôd Slovenska. Podzemná voda. IV. 1. 42-51. (Isotope geochemistry applications in the process of study of Slovak natural waters genesis).

Šilar, J. 1976: Radiocarbon ground – water dating in Czechoslovakia – first results. Vestník ÚÚG 51. 209-220.

No	Locality	Source	Sam-pling	$\delta^{18}O$ H_2O (‰)	δD H_2O (‰)	Quotation Remark
1	Piešťany	-	1970	-11,30	-78,3	I. Barnes – J. R. O´Neil (1976) Sampled by I. Barnes accompanied by O. Franko (1970) $\delta^{18}O$ values are from δO completely calculated, not measured
2	Trenčianske Teplice	-	1970	-10,40	-71,0	
3	Nosice	-	1970	-10,30	-69,7	
4	Martin	-	1970	-11,00	-76,2	
5	Korytnica	-	1970	-10,30	-68,3	
6	Liptovský Ján	-	1970	-10,90	-73,9	
7	Vyšné Ružbachy	-	1970	-10,70	-73,5	
8	Sivá Brada	-	1970	-11,50	-82,9	
9	Kováčová	-	1970	-11,30	-78,3	
10	Sliač	-	1970	-11,80	-80,4	
11	Dudince	-	1970	-11,40	-80,5	
12	Patince	-	1970	-10,80	-75,5	
13	Komárno	M-1	1970	-12,00	-88,0	
14	Turčianske T.	pitná váza	1991	-10,97	-78,3	The data are from manuscript reports (J. Michalko, 1998)
15	Záturčie – Fatra	BJ-2	1996	-10,60	-73,8	
16	Záturčie – Fatra	BJ-4	1996	-11,14	-76,1	
17	Ludrová	HNT-7	1994	-10,49	-75,2	
18	Matejková	Pod pňom	1997	-10,75	-77,0	
19	Korytnica	HK-41	1994	-10,52	-74,5	
20	Donovaly	Medokýš	1994	-10,74	-74,9	
21	Lipt. Štiavnica	LŠH-1	1998	-10,47	-69,8	
22	Pavčina Lehota	FGL-1	1989	-10,96	-71,0	
23	Liptovský Ján	B-2	1997	-10,65	-76,5	
24	Bešeňová	ZGL-1	1994	-10,63	-71,2	
25	Lúčky	BJ-101	1994	-10,75	-75,3	
26	Kaľameny	Medokýš	1994	-10,64	-75,6	
27	Lipt. Trnovec	ZGL-2/A	1991	-10,41	-70,1	
28	Lipt. Kokava	ZGL-3	1990	-11,79	-74,4	
29	Oravice	Oz-2	1997	-11,20	-78,2	
30	Poprad	PP-1	1994	-11,01	-78,1	J. Michalko et al. in J. Franko et al. (1995)
31	Gánovce	Kúpeľný	1994	-11,28	-87,1	
32	Vrbov	VR-1	1994	-11,59	-92,3	
33	Vrbov	VR-2	1994	-11,43	-91,0	
34	Baldovce	BL-1	1994	-10,36	-83,5	
35	Sivá Brada	Sv. Kríž	1994	-11,59	-91,5	
36	Šindliar	Sultán	1994	-10,04	-79,6	
37	Lipovce	S-II	1994	-10,03	-80,8	
38	Vyšné Ružbachy	Izabela	1994	-10,83	-80,0	
39	Arnutovce	HKJ-3	1994	-11,20	-82,1	
40	Sivá Brada	pr. č. 34	1993	-11,40	-73,2	J. Michalko in M. Haluška – P. Petrivaldský (1994)
41	Lúčka	BŠ-1	1993	-14,30	-86,9	

Tab. 1: Central – Carpathian zone - $\delta^{18}O$ and δD data (Franko, 2001)