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Groundwater dynamics of Beiuş Basin basement and its surrounding mountain areas *)

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Abstract. The Galbena crustal fracture system, along which the north-east border of Beiuş Basin basement is subsidized, strongly affected the deposits of Codru Nappes System, of Bihor Autochthon and the banatite rocks of Vlădeasa Massif. From a hydrogeological point of view, the system constitutes a major drain that collects surficial and underground waters from the mountain rim(s) while converging them into a rapid regional flow towards north-west. The thermal water reservoir of Felix -1 Mai Spa, a zone which has a reduced extension and is peculiar due to significant flow-rates and temperatures of the thermal waters from the west border of Apuseni Mountains, is structurally located at the crossing of Galbena fault system with the fault system along which the Pannonian Basin had sunk.

Key words: Beiuş basin, Galbena Fracture System, hydrogeology, thermal waters.

Introduction

„Beiuş Depression" (Sawicki, 1912), „Beiuş Basin" (Ficheux, 1933; Paucă, 1935), „Beiuş country", (Berindei, 1967, 1977) or „Crişu Negru Depression" (Pop, 2005) name the same corridor which deeply penetrates the Apuseni Mounatins being towered by Pădurea Craiului, Bihor and Codru Moma mountains and is longitudinally crossed over by Crişu Negru river. The corridor is characterized by a hilly

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relief, and the following geomorphology units are individualized within Beiuş Basin: Beiuş depression and Tinca-Holod depression, defined by Măgura Forăului, and Lăzărenilor hills, developed north of Holod-Topa river until Sânmartin, west of Pădurea Craiului Mountains (Pop, 2005).

Geological and structural data

The chronology of the tectonic events of this area is characterized by the overthrust of the Codru Nappe System over the Bihor Autochthon from Turonian, by the laramic eruptions of Vlădeasa Massif, the Senonian post-tectonic transgression, by the Alpine basement subsidence in Miocene and the formation of Beiuş Basin, by its further filling-up and subsequent exondation.

The basin basement is heterogenous, consisting of Mesozoic, Paleozoic and Proterozoic rocks belonging to the Codru Nappe System of the Northern Apuseni Mountains. The deposits of this system overlap the Bihor Unit formations, the overthrust face forming an alignment which defines the basin's north-east border.

The subsidence of the north–east part of the basin occurred along a NW-SE oriented crust fault, while the subsidence of the opposite part occured on a less extended fault system (Merten et al., 2011; Săndulescu, 1994; Balintoni, 1994; Bleahu et al., 1981).

The crustal fracture where the basin's north–east part subsidence took place is revealed by a fault system that was mapped by geologists from Arieşu Mic valley up to Tăşad and Beftia. The system has the best morphological visibility in the Bihor Mountains, the Galbena fault, which imposed from a tectonic perspective the straight route of the homonymous valley, creating a spectacular discontinuity of the relief. Further on, we shall name this system the Galbena Fracture System, which has been well revealed by contour map images along its entire paths (Figure 1).

The Galbena system fractures develop within the overthrust face area of Codru Nappe System over Bihor Autochthon and they strongly crush the deposits of the two tectonic units and Vlădeasa eruptive rocks of the west side of the massif (Figure 2).

The sinking of the Beiuş basin basement changed the drainage direction of main surficial streams (Topa, Vida, Albioara, Sohodol) from north east – south west to north – south. The inflexion segments are setting in a straight line on the axis of Galbena Fracture System.

The Neogene filling of Beiuş Basin (Preda, 1935; Istocescu et al., 1968; Istocescu & Istocescu, 1974), consists of Badenian deposits made of a torrent complex with gravel, boulders and sands overlain by pelagian and reef deposits.

The Sarmatian base is formed of a tuffaceous diatomite complex following a succession of sedimentary deposits in carbonaceous continental – lacustrian pelagian, conglomerate and reef complex. The Pannonian base is clastic with white tuffaceous marns at the upper part followed by alternating marns and sands and compact sands.

The basement outcrops are rare within the depression area, forming islands that cross over the basin filling deposits at Măgura Forăului (Răbăganilor), near the Dopşii old abandoned church in Coşdeni and north of Calea Mare, consisting of dolomites and/or Triassic quartz sandstones. The well 4008 drilled at Corbeşti, Cotiglet commune, the wells 3001, 3003 and 3004 from Beiuş and the drill hole 3002 from Ştei provided significant data about the basement lithology.

The geological structure of the mountainous zone continues in Beiuş Ba-

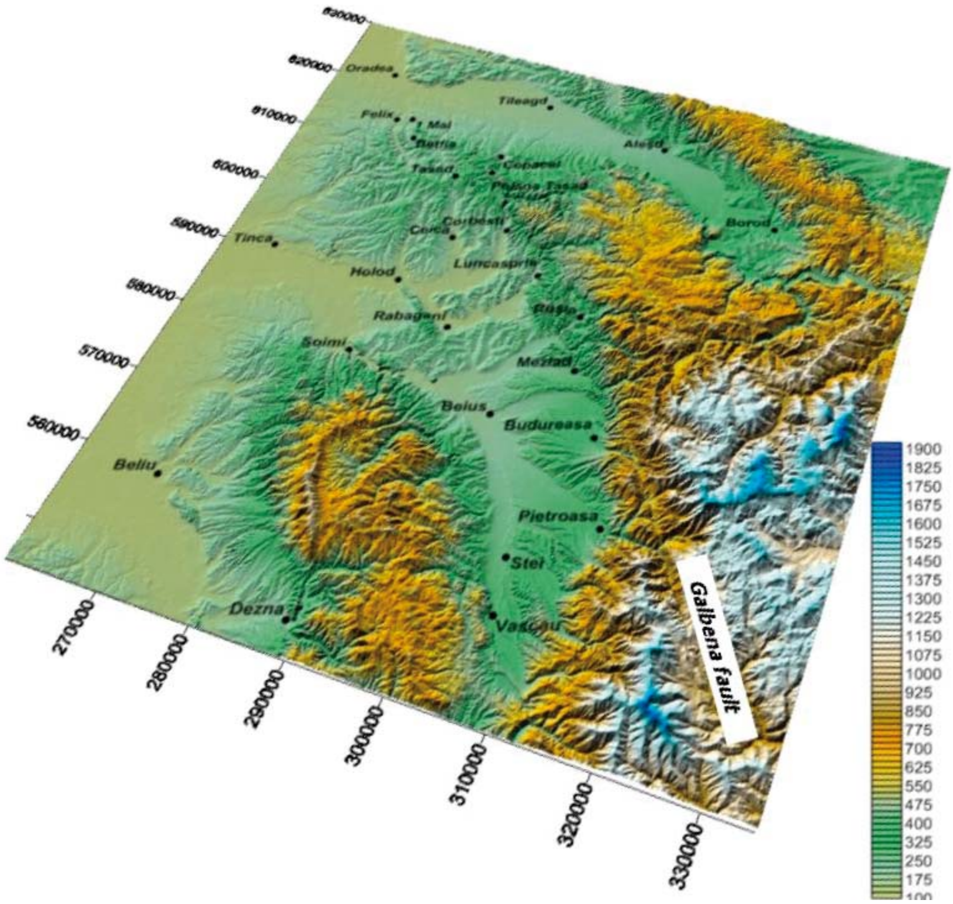

Figure 1. Contour map of the Beiuş Basin and adjacent areas

sin basement where it is expected to be identically complicated in the nappes structure, similar to the bordering zones. The picture of the northern part of the basin basement is presented by Dinu et al., 1991, by the interpretation of the geological, drilling and geophysical data, the authors published maps showing the thickness of the basin filling deposits, the structural elements and geological cross sections. These data are presented below and the structural map of the basement is integrated in the regional geological ensemble of Figure 2.

The basin basement is divided by fracture systems in blocks with different altimetry positions. The fracture systems are predominantly east –west oriented in the north sector and north west–south east in the south–east sector. The two systems are connected in the uplift Dobreşti-Răbăgani sector which has a highly faulty tectonic structure because of the Neogene intrusive magmatic bodies at depth.

The basin basement shows an important axial uplift sector along Josani-Coşdeni-Rotăreşti-Miheleu direction, revealed by the Triassic rock outcrops from Fântâna Dopşii and shallow drill holes exploiting the thermal water of Triassic dolomites. Their rise is limited laterally by two downgoing sectors, namely Beiuş-Lupoaia to the south–west and Sitani-Ceica-Lăzăreni to the north–east, near the Corbeşti filling deposits having a maximum thickness of 1300 m (Fig. 3).

Hydrogeological data

The carbonate deposits occupy important intervals in the stratigraphic columns of Bihor Autochthon and Codru Nappe System. They develop over large surface areas of Pădurea Craiului, Bihor and Codru Moma mountains and of the alpine basin basement and are in direct lithologic contact with the filling deposits of the Neogene bordering basins.

The underground waters from the karstic areas of the previously mentioned mountainous massifs are involved in local karst systems which discharge through the springs, most of them located at their periphery, at the contact with Beiuş and Vad depressions (Orăşeanu, 2010). They also feed the deep aquiferous accumulations of depression basement, being enclosed in the regional groundwater system drained to the west. In Beiuş Basin the Triassic dolomites form the main karst reservoir for underground water, partially thermalised. There exists a permanent recharge – drainage relation between the groundwater of Beiuş Basin basement and covering neogene filling deposits.

The supply of the aquiferous from the depression basement by the aquiferous located within the bordering mountainous zones is shown by the hydrogeological and hydrochemical data, among which we mention:

- Indium-EDTA labellings performed in 1983 by the present author toge-

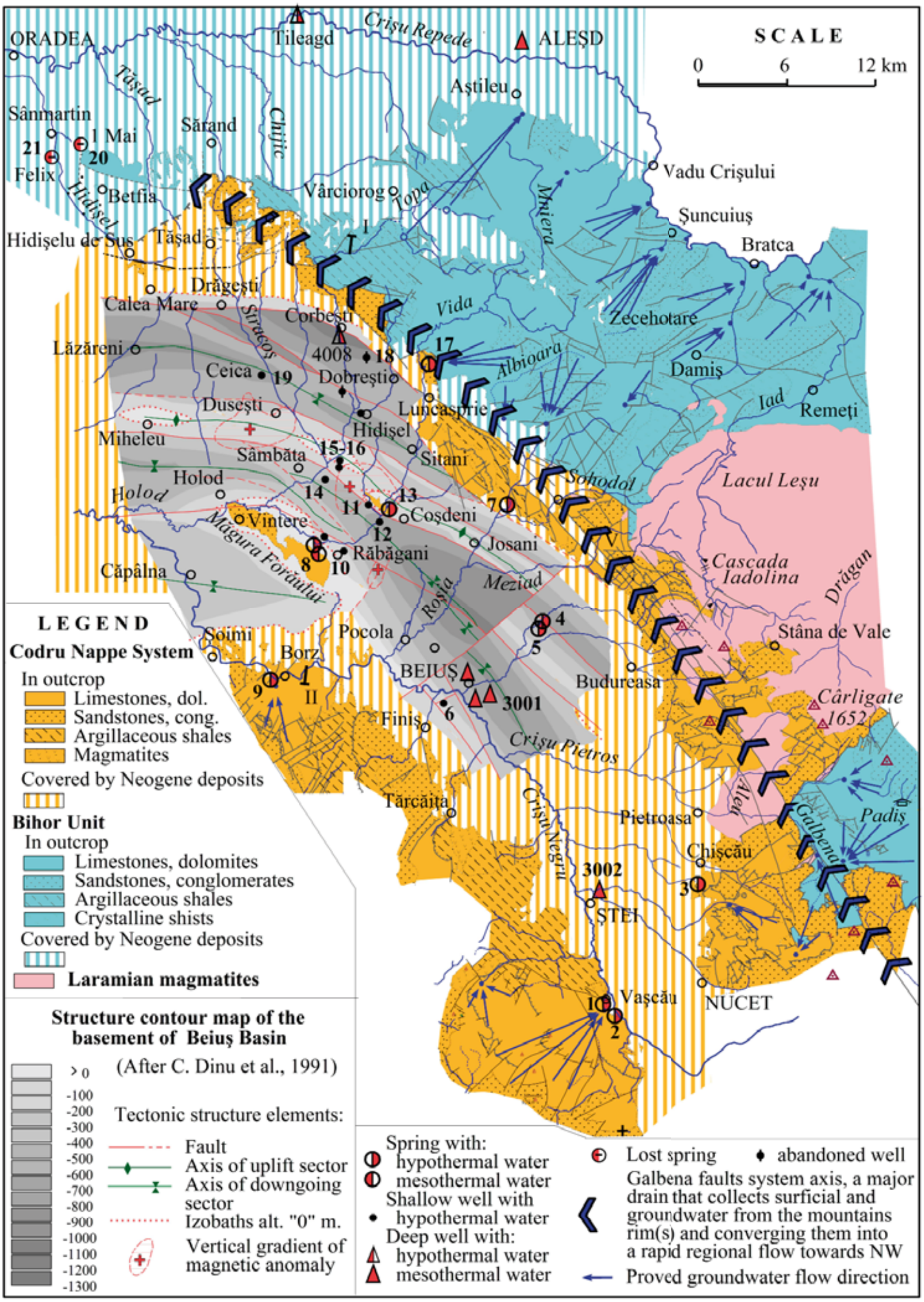

Figure 2. Hydrogeological map of Beiuş Basin. Geological data are after maps published by Geological Institute of Romania, scale1:50.000. The structure contour map of the basin is after Dinu et al.,1991.

ther with Gaşpar indicated that the sinking waters of the upper tributary brooks of Topa stream in Pădurea Craiului Mountains are only partly found in Aştileu spring, a significant part being engaged in an underground flow oriented to the west through the carbonate deposits of Vad Basin basement. The hydrogeology balance drawn up for the period 1983-1985 confirmed these results (Gaşpar & Orăşeanu, 1987; Orăşeanu, 1991).

- The tracers launched in the sink holes from the Vaşcău Plateau west end occurred both in Boiu spring and in the thermal springs from its neighborhood whose geochemical footprint is strongly connected to the basin deposits (Orăşeanu, 1985; Orăşeanu & Mather, 2000).

- The chemical composition of the thermal waters hosted in neogene deposits of Beiuş basin indicate a significant contribution of the karst waters at their formation.

When crossing the Galbena Fracture System**,** the discharge through surficial courses gradually reduces, while the valleys are large and filled with alluvial sediments. The infiltration is mostly diffuse, occurring preferentially through the carbonate beds of the valleys but also through quartz slates, conglomerates and even banatites. We mention some of them:

- Galbena stream indicates the existence of permanent diffuse infiltration in the river floor along the entire course standing out the segment developed between Păuleasa spring and the confluence with Luncşoara stream;

- Boga stream indicates the presence of infiltrations within the perimeter of the homonymous holiday village situated at the intersection of Bulz fault with a fault associated to Galbena system. Between 1984-1985, when the trench for the pipeline supplying water from Valea Rea to the water power plant was excavated, at about 100m upstream from the bridge from the forestry hut, significant infiltrations of water occurred from the stream in the underground. The flow measurements and the tracer labelling indicated that the mentioned losses are not returned in the surface flows of Bulz stream up to the confluence with Galbena (Orăşeanu, 1996);

- The upper courses tributaries of Nimăeşti, Binşele, Meziad and Sohodol streams indicate the existence of long periods of dryness;

- Iad river, on its Voivodeasa brook – bridge downstream the Iadolina waterfall sector is losing through infiltration in the rhyolite fractures more than 20% of the discharge occurring during the low water season. The survey of the infiltration areas is concluded through river gauge measurements (on relevant sectors) for the surficial drainage and through water budget calculations for the specific catchments.

The Galbena Fracture System constitutes from a hydrogeological point of view, the major drainage collecting the surface and underground waters from the

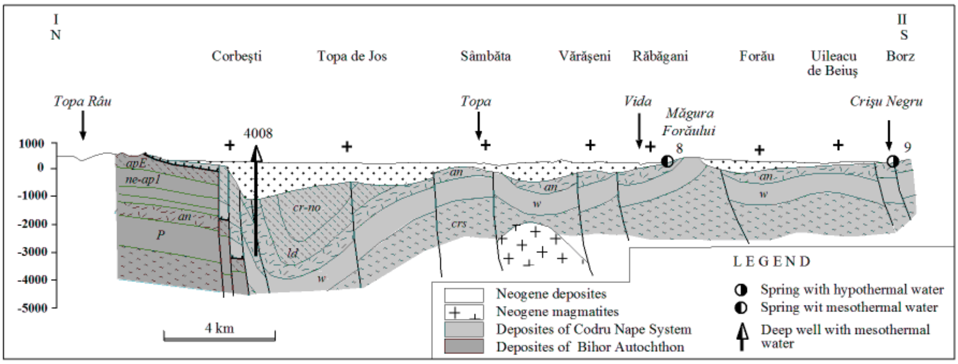

Figure 3. Cross section between Corbeşti – Borz. Line of section in Figure 2.

north-east mountainous border of the Beiuş basin and involves them in a rapid regional flow toward nord-west. The hydrogeological characteristics of the drain is influenced both by the evolution of the supply action of the mountain zones adjoining the system and by the volume of discharges to Beiuş basin.

Thermal water occurrences. The thermal waters of Beiuş Basin are mostly found in the Triassic dolomites. These basement rocks outcrop in many places on the south–west and north–east borders of the basin and within the basin at Răbăgani, Coşdeni and Calea Mare near Hidişelu de Sus (Figure 2). In some places from the Anisian dolomites several springs with warm water with temperature up to 24 ^{0}C emerge.

The thermal reservoir of the Triassic dolomites has been intercepted by deep wells drilled at Corbeşti, Beiuş and Ştei and by shallow holes from the uplift sector of basement in Coşdeni-Hidiş (Fig. 2, no. 11) - Rotăreşti (Fig. 2, no. 14) - Ogeşti (Fig. 2, no. 15, 16) area. It is to be noted that most of the drilled wells located in the filling deposits of the basin intercepted low temperature thermal waters.

The main thermal water sources are (Fig. 2 and Table 1):

-To the west of Vaşcău town, at the base of the neotriassic limestones and from Crişu Negru river and Boiu stream alluvium four hypothermal springs occur: Sfărăşele (Fig. 2, no. 1), Rengle, Racova (Fig. 2, no. 2) and Ţucreşti, with temperatures ranging between 14.5 and 17.2 ^{0}C and a cumulated flow-rate of about 15 l/s;

- Warm spring „Şapte Izvoare"(„Seven Springs") situated along Izbucului stream upstream Valea Neagră, close to the cold spring caught to supply water for the inhabitants downstream (fig. 2, no. 3). Its temperature is 17,2 ^{0}C and flow-rate of 1.5 l/s (Orăşeanu, 1996);

Table 1. Chemical composition of groundwater in the Beiuş Basin

No.	Source	Sampling date	Elev. m	t °C	Q l/s	F^-	Cl^-	I^-	$SO4^{--}$	$HCO3^-$	Na^+	K^+	Mg^{++}	Ca^{++}	Fe^{++}	TDS	MT
						mg/l											
1	Sfărăşele spring, Vaşcău *)	12.12.86	295	17,2		sld	14,2	sld	105,6	317,2	69,8	1,0	u	95,4	0,1	454,6	613,2
2	Racova spring, Vaşcău *)	12.12.86	305	17,0		sld	14,2	0,1	19,2	524,7	65,8	1,6	25,3	88,9	0,1	488,1	763,6
3	Seven springs, Valea Neagră *)	12.08.85	375	17,2	1,5	sld	10,6	sld	3,7	274,5	2,2	0,7	12,1	74,1	0,2	247,0	395,5
4	Beciului (Morii) spring , Curăţele	27.07.95	240	16,4	10,0	0,10	3,5	sld	21,1	24,4	4,6	2,6	sld	14,8	sld	64,9	94,0
5	Florii spring, Curăţele	27.07.95		16,0	1,0	sld	21,3	sld	28,8	61,0	15,4	8,8	sld	27,3	sld	201,8	201,8
6	Fântâna Popii well, Finiş	16.03.96		13,2	O,1		7,1			231,8	28,1	4,4		52,1	0,6	214,9	345,1
7	Tăul Fierbintea spring, Căbeşti *)	29.10.82	220	18,0	4,0	0,2	7,1	0,1	11,5	317,2	43,0	2,5	2,0	60,9	0,2	313,8	516,4
8	Swiming pool spring, Răbăgani	14.03.96	150	24,0	15,0	0,10	7,1	sld	48,0	366,1	62,8	2,2	12,1	68,5	sld	390,8	597,8
9	Căuaci spring, Borz	13.12.86	156	13	0,5		21,3		13,4	488,0	18,4	1,6	55,4	69,7	0,2	436,0	693,2
10	CAP well, Răbăgani	14.03.96		16,6		1,00	28,4	0,20	245,8	549,1	305,5	5,6	sld	24,0	0,2	901,1	1181,7
11	Well Hidiş	1974		15,0	0,5		10,4		7,7	231,8	92,4	0,4	u	5,2	0,1	255,5	380,2
12	Well CAP, Coşdeni	14.03.96		12,6	0,25	sld	7,1	sld	sld	268,4	81,4	0,9	sld	16,0	0,4	232,3	374,2
13	Fântâna Dopşii spring, Coşdeni	14.03.96	150	15,2	1,5	0,30	7,1	sld	53,8	378,3	102,8	2,5	7,3	48,1	0,6	416,0	620,1
14	Well Rotăreşti	14.03.96		15,2	0,5	0,10	35,5	sld	sld	439,3	144,7	1,2	sld	32,1	sld	454,2	685,3
15	Well Ogeşti, downstream	14.03.96		17,0	0.25	0,10	7,1	sld	5,8	463,7	145,6	0,9	sld	26,1	sld	434,4	666,3
16	Well Ogeşti, centrum	14.03.96		13,2	0,1	sld	7,1	0,13	34,6	451,5	165,8	1,0	sld	16,0	0,2	457,9	690,5
17	Warm spring Topliţa de Vida *)	30.11.97	230	20,8	2	0	7,1	0,1	9,6	292,8	2,3	0,4	8,5	88		268,6	442,7
18	Well Topa de Sus**)	1974					3,5		11,5	305,0	1,4	0,6	14,6	72,9	0,1	285,0	456,2
19	Well Ceica centrum	1974		19,6			42,5	0,50	u	2208,6	775,1	50,0	9,7	16,8	0,2	2108,0	3317,9
20	Peţea lake spring, 1 Mai spa***)	10.09.98	155	27,4		0,19	10,6	sld	22,6	353,2	4,4	1,6	17,5	98,2	0,4	334,0	528,1
21	Balint spring, Felix spa***)	1974					21,3		164,1	421,0	0,4	4,6	40,1	149,9	0,1	624,0	875
	Well 3001, Beiuş	01.08.99	170,9			0,10	8,5		58,6	231,8	11,1	7,2	48,1	26,8	0,1	303,6	468,5
	Well 4008, Corbeşti	1974	175				7,1		604,8	219,6	87,6	13,3	56,9	151,5		1054,4	1182,3

MT- total mineralisation; *) - degassing water (gas containing O_2 and N_2); **) - abandoned well; ***) - lost spring.

- On the left bank of Roşia stream, upstream the locality of Căbeşti, a subthermal spring known as Fierbintea pool or Ţiganilor spring (fig. 2, no. 7) occurs from alluvium.The flow rate of the spring is about 4 l/s and the temperature is 18 ^{0}C (Orăşeanu, 1991);

- To the west of Răbăgani locality, from the Anisian dolomites of Măgura Forăului a mesothermal spring occurs with a temperature of 24 ^{0}C and a flow-rate of about 12 l/s (Fig. 2, no. 8). The spring supplies Băi stream, which is tributary to Holod river. Until 1990 the spring was used for supplying water to a swimming pool which has been abandonned and is highly damaged (Paucă, 1958; Slăvoacă, 1974; Goina, 1978).

- At about 400m north-west of the above mentioned mesothermal spring, at the place called by the locals „Tina cea Rea”, from the clays beneath the national road backfill, a line of springs occur at 140 m elevation, with temperatures ranging between 14 -17 ^{0}C and a cumulated flow-rate of 3-5 l/s, drained towards Holod river and Ciorgău brook.

- Crişu Negru river form Borz gullet which mostly consists of Triassic dolomites. It fits the spur of Piatra Pietranilor hill and the river deepens a route containing karst forms between Uileacu de Beiuş and Borz. On the left bank of Morilor stream, near the confluence with Crişu Negru, occurred two springs in 1986, La Covaci (Fig. 2, no. 9) and the other beneath CFR bridge, their temperatures ranging between 13.2 and 13 ^{0}C and with flow-rates of about 1 l/s each.

- On the left hillside of Vida water course, at the confluence with Cornetu stream, at the northern end of Coşdeni village at an elevation of about 145 m, close to an abandoned church, the spring Fântâna Dopşii penetrates through the Anisian dolomites. In 1974 the spring flow-rate was 3 l/s and its temeprature was 17 ^{0}C, in 1996 the flow-rate was 1.5 l/s and the temperature 15.2 ^{0}C, în 2015 springtime, 0.2 l/s and 13.3 ^{0}C, while in 2015 summertime the spring dried out. The diminuation of the spring flow-rate is caused by the dragging of the Vida stream valley planning works in its vicinity and by the increase of the drill holes for the exploitation of the thermal waters in the area.

- The well 4008 was drilled by IFLGS in 1965 downstream Corbeşti village, Cotiglet commune, on the right side of Topa river. It crossed through Pliocene (0-382 m), Sarmatian (382-1045 m), Tortonian (1045-1190 m), Triassic (1190-3040 m) and Permian deposits (3040-3303.5 m). The casing was perforated over the interval 1200-1250 m the water discharging artesian at a temerature of 34 ^{0}C and a flow-rate of 1.5 l/s. The hydrostatic level of the aquiferous was at +50m. In 1974 the water discharged at a flow rate of 3 l/s at a temperature of 37 ^{0}C and during the 2015 spring the flow rate was 0.2 l/s at 22.8 ^{0}C. The water sample collected in 1974 looked like sulphated calcium low concentration water (Table 1).

- The well 3001, drilled between 1995-1996 at Beiuş by S.C. TRANSGEX S.A., intercepted the basin basement at a depth of 988 m. It crossed Jurassic and Rhaetian deposits and after that in the interval 1580-2280 it crossed through Triassic aquiferous dolomites, the drilling operation being stopped at 2576 m when it reached the Werfenian quarzite sandstones. The level of the thermal aquiferous was situated at -18,48m (172.4 m elevation), and the temperature of the water at the drill rig bottom was 88 ^{0}C. The water from the drill hole is used to supply heating to the dwellings and in such periods the temperature of the pumped water is 84 ^{0}C (Antal et al., 2009).

- The well 3002 was drilled in 2001 at Ştei up to 2400 m depth. The drill hole penetrated the basement at 850 m, and then got directly in the triassic deposits which it crossed over up to 1600 m depth. The water is artesian (+22m) and the temperature is 63 ^{0}C.

The map of piezometric contours of the Triassic thermal aquiferous of Beiuş Basin basement elaborated on the basis of the thermal emergence elevations from the basin border and central part and of the water level elevations measured in the wells from Corbeşti, Beiuş and Ştei after drilling operations is shown in Figure 4. The flowing directions from the central part of the basin gravitate towards Coşdeni-Răbăgani-Borz zone, towards the springs occurring in the two errosion windows and on the banks of Crişul Negru river at Borz.

Piezometric contours are parallel with the north–east border of the basins, by passing the hills of the north–west end of Pădurea Craiului Mountains, continuing in Vad basin. Their value gradually decreases from the mountainous promontory towards Felix -1 Mai zone, the average elevation of the aquiferous from Cretaceous limestones being at 155 m (Ţenu, 1981; Cohut, 2013; Paal, 2013; Orăşeanu et al., 2015).

Because of the insufficient data for the west pat of the basin between Răbăgani and Hidişelu de Sus (Lăzărenilor hills), the piezometric contours are only orientative.

The Felix-1 Mai area, a reduced extension zone, peculiar for the behavior of the thermal waters with significant flow-rates and temperatures from the west side of Apuseni Mountains, is situated at the intersection of Galbena fault system with the fault system along which the Pannonian Basin subsidence occurred. The crushed zone of Galbena fracture system represents a drainage for the recharge of the thermal reservoir with cold waters.

The chemical composition of the underground waters of Beiuş basin and from the mountainous border is much varying representing the large geochemical diversity of the deposits from the basin basement and his filling (Table 1 and Fig. 5).

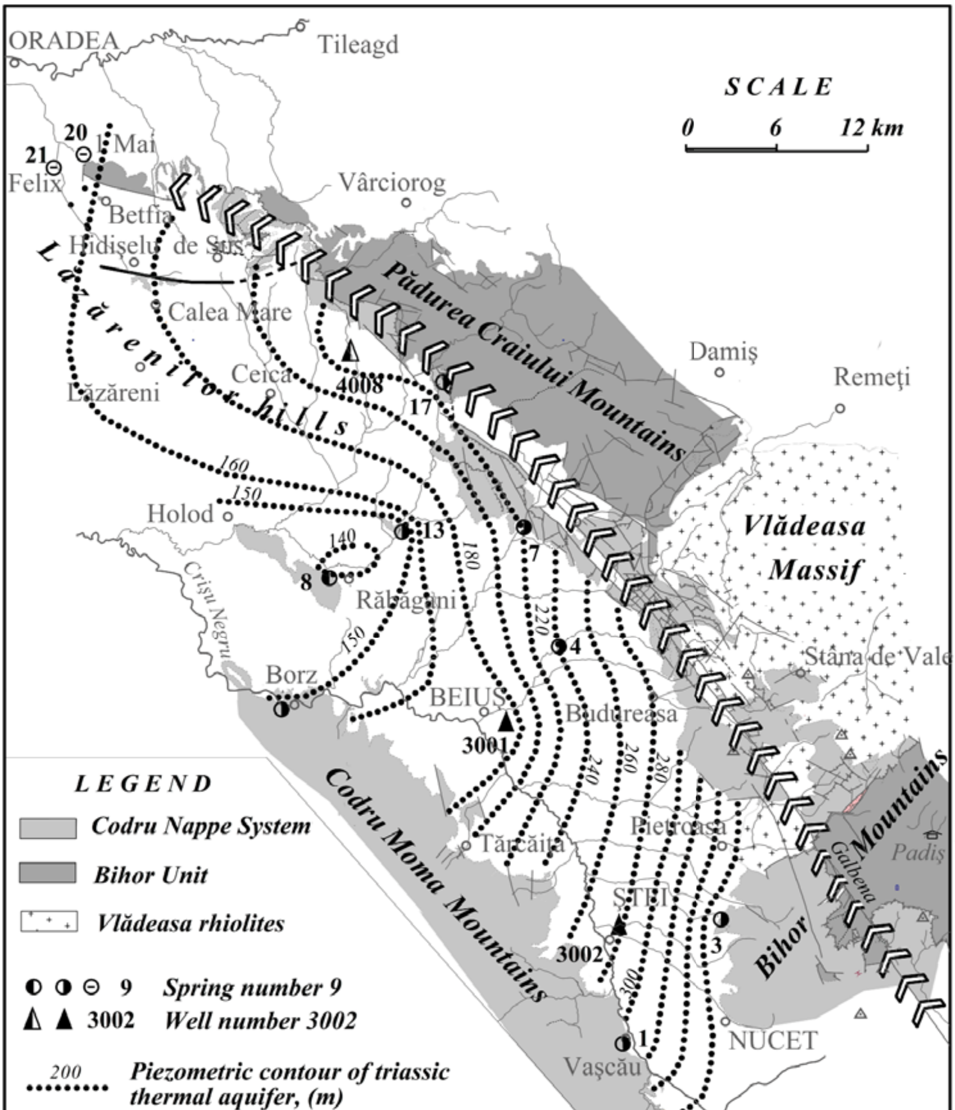

Figure 4. Piezometric contour of the Triassic aquifer in the Beiuş Basin basement.

The springh water of the Mesozoic carbonate deposits is of the Ca(Mg)-HCO3 type, and the water of springs and wells drilled in the Neogene deposits is Na-HCO3 type. Most of the waters from thermal sources of the basin range betwe-en these two types, indicating a mixed genesis.

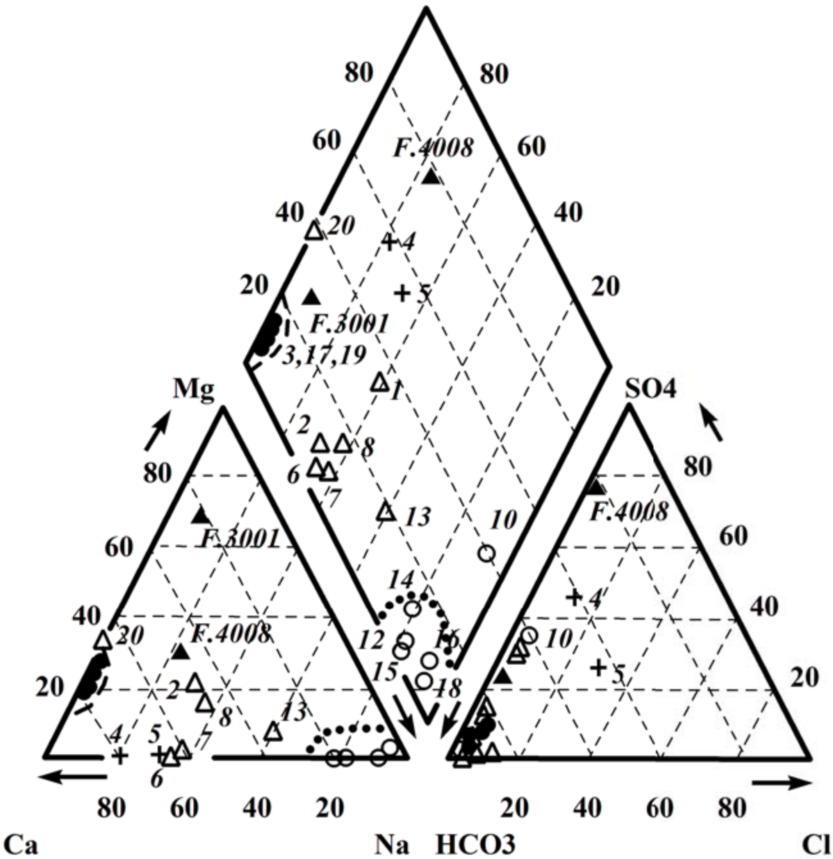

Figure 5. Chemical composition of the groundwater ploted on the Piper diagram.

The water of some of the springs and wells contains iodine (Table 1) or bromine (3 mg/l in well CAP Răbăgani) and has a high content of free H_2S (0.5 mg/l, Hidiş, Topa de Sus and 4008 Corbeşti wells, 0.3 mg/l, wells Ogeşti downstream and Ceica center and Fântâna Dopşii spring, resulted from the sedimentary deposit levigation. The water discharged from the shalow well of the central part of Ceica commune has a low CO_2 content (105.6 mg/l), result of the late mofette stage of deep Neogene eruptive bodies.

For comparison purposes, Table 1 includes the analysis performed in 1974 on the samples from Balint and Ochiul Mare springs in Felix-1 Mai Spa.

Conclusions

The subsidence of the North–East side of the Beiuş Basin basement occurred along the crustal Galbena fracture impacting the deposits situated within the overthrust area of the Codru Nappe System overlapping Bihor Unit.

Galbena crustal fracture system plays a major part in the configuration of the regional hydrogeological model. It consists of basin dipping faults while the width of the zone associated to the rock breakage is more than 1 km. The system acts as a surface and underground water drain of the impacted zones and these waters flow to the North –Vest suppling Felix -1Mai – Oradea geothermal system.

The seasonal variations of the precipitations cause fluctuations of the flow-rates / pressures of the water flowing through the drain and such fluctuations are found in the seasonal variations of the thermal aquiferous level of Felix -1 Mai zone.

Based on the lithology sequence of the basin basement, one can identify, from hydrogeology point of view, the aquiferous hosted by Anisian dolomites, partly thermally altered and fed from the mountainous contour and pointed out by several springs and drill holes. The aquiferous naturally discharges through the thermal springs from Răbăgani-Coşdeni alignment.

References

Antal, C., Setel, A., & Gavrilescu, O. 2009. - *Exploitability of geothermal resources in Pannonian Depression*, Secţiunea nr. 2, Oradea, vol. 15: 1224-1261

Balintoni, I. 1994. - Structure of the Apuseni Mountains. , vol. 75, Supplement no. 2, ALCAPA II, Field Guidebook: 51-58.

Berindei, I.O. 1977. - Ţara Beiuşului. In Berindei I.O., Măhara Gh., Pop Gr. P., Posea Aurora. 1977. Câmpia Crişurilor. Crişul Repede. Ţara Beiuşului. Ed.ştiinţifică şi enciclopedică, Bucureşti, 371 p.

Bleahu, M., Lupu, M., Patrulius, D., Bordea, S., Stefan, A., & Stefana. P. 1981. - The structure of the Apuseni Mountains. Guide to excursion B3. XII Congres of Carpato-Balkan geological association. Ed. IGG, Bucharest. 107 p.

Cohut, I. 2013. - Dinamica sistemului hidrogeotermal Oradea – Felix – 1Mai, *Nymphaea* **40**:109-125.

Dinu, C., Calotă, C., Mocanu, V., & Ciulavu, D. 1991. - Geotectonic setting and the particular structural features of the Beiuş Basin, on the basis of geological and geophysical data synthesis. *Revue Roumaine Geophysique, Bucharest,* **35**: 77-87.

Gaşpar, E. & Orăşeanu, I. 1987. - Natural and artificial tracers in the study of the hydrodynamics of karst. *Theoretical and Applied Karstology* **3**: 31-107.

Istocescu, D., Mihai, A., Diaconu, M., & Istocescu, F. 1968. - Studiul geologic al regiunii cuprinse între Crişul Repede şi Crişul Negru. *Dări de seamă ale şedinţelor*, *Tectonică şi geologie regională, IGG Bucureşti* **55**(5): 89-106.
Istocescu, D. & Istocescu, F. 1974. - Contribuţii geologice asupra depozitelor neogene ale bazinului Crişurilor. *St. cer. geol., geofiz., geogr., Seria geologie*, 19: 115-127.
Merten, S., Matenco, L., Focken, J.P.T., & Andriessen, P.A.M. 2011. - Toward understuding the post-collisional evolution of an orogen influenced by convergence at ajacent plate margins: Late Cretaceous-Tertiary thermotectonic history of the Apuseni Mountains. *Tectonics* **30**: 1-28.
Orăşeanu, I. 1985. - Considerations on the hydrogeology of Vaşcău Plateau (Codru Moma Mountains). *Theoretical and Applied Karstology* **2**: 199-209.
Orăşeanu, I. 1991. - Hydrogeological map of the Pădurea Craiului Mountains, scale1:50.000. (Romania). *Theoretical and Applied Karstology* **4**: 97-127.
Orășeanu, I. 1996. - Contributions to the hydrogeology of the karst areas of the Bihor-Vlădeasa Mountains. (Hydrogeological map, 1:50.000 scale). *Theoretical and Applied Karstology* **9**: 185-214.
Orășeanu, I. 2010. - Karst hydrogeology of the Apuseni Mountains. *Karst Hydrogeology of Romania.* Ed. Belvedere, Oradea, p. 181-324.
Orăşeanu, I. & Mather, J. 2000. - Karst hydrogeology and origin of thermal waters in the Codru Moma Mountains, Romania. *Hydrogeology Journal* **8**: 379-389.
Orăşeanu, I., & Iurkiewicz A., Malancu F. 2015. - Preliminary data concerning the dinamics of the geothermal aquifer of Felix-1 Mai Spa, Bihor Country, Romania. Proceedings of the IAH Central European Groundwater Conference-2015, *Groundwater risk assessment in urban areas*, October 14-16, 2015, Constanţa, Romania: 25-27.
Paal, G. 2013. - Sinteza particularităţilor hidrogeologice ale acviferului termal de la Băile Felix-1 Mai. *Nymphaea* **40**: 83-107.
Paucă, M. 1935. - Le bassin neogene de Beiuş. *Ann. Inst. Geol. Roum.*, 17, București.
Paucă, M. 1958. - Izvoare termale de la vest de Munţii Apuseni. *Natura* **10**(2): 5-16.
Pop, G. 2005. - Dealurile de vest şi Câmpia de vest. Ed. Univ. din Oradea, 176 p.
Răbăgia, A. 2009. - Studii de stratigrafie secvenţială a părţii de nord a Bazinului Panonic pentru stabilirea evoluţiei tectono-stratigrafice. Rezumat teză de doctorat, Univ. Bucureşti, Fac. de Geologie şi Geofizică, 20 p.
Săndulescu, M. 1994. - Overview on Romanian geology. *Romanian Journal of Tectonics and Regional Geology*, 75, Supplement no. 2, ALCAPA II Field Guidebook: 3-15.
Slăvoacă, D., Feru, M., Geamănu, V., Simion G., Goliţă, N., & Lungu, P. 1978. - Consideraţii hidrogeologice asupra ivirilor naturale de ape termale din Romania. *Studii tehnice şi economice*, *Seria E* – Studii de hidrogeologie, **13**: 5-15.
Ţenu, A.1981. - Zăcămintele de ape hipertermale din nord-vestul României. Ed. Academiei RSR, 208 p.