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AN OUTLOOK ON THE INTERPRETATION OF THE HYDROCHEMICAL DATA OF THE GEOTHERMAL SYSTEM ORADEA-FELIX, ROMANIA

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ABSTRACT

This study outlines once more the importance of hydrochemistry in the general context of geothermal research. The monitorization of each well all over its life is useful, supplying data that can shows the variations, the changes of downhole conditions. Once more being one of the geo-scientific discipline, hydrochemistry can contribute .as a part to the development of the conceptual model.

The users of geothermal energy can gain many benefits fiom this energy, on the condition to have arid to use correctly and carefully reliable data.

We have done the monitorization of the geothermal system Oradea-Felix that contains two different types of' water. This is the first assessment with an interpretation of data obtained in 15 years of monitorization, such a long time interval indicating some changes of geothermal water chemistry.

Introduction

'The research on hydrocheinical situation of geothermal system it must be consider a very important activity from economic point of view. One economic aspect which must be take into consideration is the fact that this resource it is riot renewable, and wrong actions, wrong interventions, or a wrong exploitation can lead to its premature depletion.

In this region from the multitude of data on the chemical composition of geothermal waters, we can distinguish from the beginning different types of aquifers in different reservoirs.

'She hidrochemid indicators for establishing the main chemical features of the aquifer were: pH, conductivity, TDS (total dissolved solids), organic substances, hardness, Silica, phenolic compounds, boric acid; anionic components: chloride, nitrite, nitrate, bicarbonate.. carbonate, sulfate. phosphate; cationic components: ammonium, natrium, potassium, calcium, magnesium. iron.

'She aquifer embedded in the *Triassic* ***reservoir*** has the total mineralization around 1g/L and the water is calcium-magnesium-sulfate-bicarbonate type. 'The aquifer embedded in the *Cretaceous reservoir* has the total mineralization around 0.5-0.9g/L, the water character being calcium-magnesium-bicarbonate-sulfate type.

These varieties of characteristics of geothermal water need a detailed study related not only to the physical-chemical characteristics but also to their interrelations and even the water-rocks interaction's.

Provided that we *can* find some significant distinction or similitude among different geothermal sources (wells). it must be interpreted as a unitary system, dynamic and equilibrated, each with the own specific conditions.

Hydrochemistry of Triassic aquifer

This aquifer is located in a Triassic limestone-dolomite reservoir, with favorable conditions for water accumulation, at 2000-3000m depth (average 2500m). The geothennal waters of this reservoir reach a temperature of 67 -105° C All wells are producing artesian. The main flow of circulation is from the East to West, following a preferential path along the fractures in basement. The fractured deep structure and the carstic structure of the zone binds the reservoirs (Triassic and Cretaceous aquifers) leading to a geothermal system. It is a convergent flow towards Felix Spa This is also providing hidrochemical data

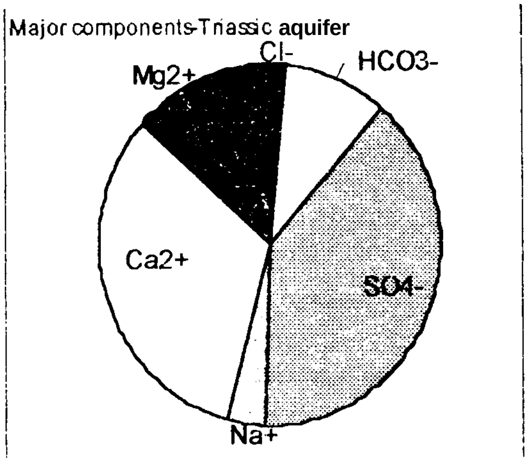
In fact there are more, but the Triassic geothermal aquifer was constantly investigated in 6 wells. The time interval taken into consideration by this paper is 1971-1990

By processing the elementary data fiom chemical analyses, we obtained the following results (average values).

Table 1: The percentage composition of the equivalent of the main elements in Triassic geothermal aquifer

Well no.	Cl^- meq %	HCO_3^- meq %	SO_4 meq %	Na^+ meq %	Ca^{2+} meq %	Mg^{2+} meq %
4004	3,95	24,28	71,76	8,29	61,7	27,23
4005	3,14	16,42	80,44	5,83	66,9	24,92
4006	3,18	18,67	78,15	6,96	65,4	25,51
4081	1,42	13,22	85,34	4,54	63,0	30,21
4767	4,54	27,77	67,69	11,8	62,9	21,23
4797	2,36	16,77	80,86	4,62	64,5	29,45

Figure 1 was obtained by plotting grand average values of majour components.



The water type results as main feature. Particularizing each well by the ionic composition a detailed individualization *can* be notice **as** following:

- 4004: its water belongs to the class of **strong** sulfate –weak bicarbonate –strong calcium – moderate magnesium;
- 4005: its water belongs to the class of strong sulfate –strong calcium – weak magnesium;
- 4006: its water belongs to the class of strong sulfate –weak bicarbonate –strong calcium- moderate magnesium;
- 4081: its water belongs to the class of very strong sulfate –strong calcium –moderate magnesium;
- 4767: its **water** belongs to the class of strong sulfate **-weak** bicarbonate –strong calcium – moderate magnesium;
- 4797: its water belongs to the class of strong sulfate – weak bicarbonate – strong calcium – weak magnesium.

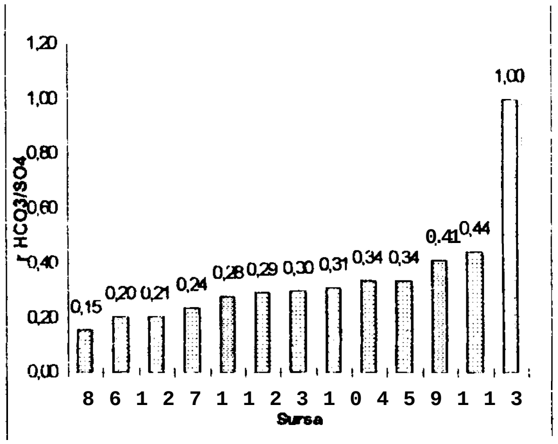
Legend 1:

1 Oradea 1709
2 Oradea 1715
3 Oradea 1716
4 Oradea 1717
5 Oradea 4004
6 Oradea 4005
7 **Oradea** 4006
8 **Oradea** 4081
9 Oradea 4767
10 Oradea 4795
11 Oradea 4796
12 Oradea 4797
13 Livada 507

According to diagrams and tables data, we notice a repeated chemistry till now. This proves a relative high stability ***of*** the chemistry of the aquifer in discussion.

From the survey of the characteristic ratio $HCO3/SO_4$ it can be remarked that the values are smaller than the unit. The source 13-livada507 does not belong to this aquifer.

Figure 2 The characteristic ratio $HCO3/SO_4$ some sources of Triassic aquifer

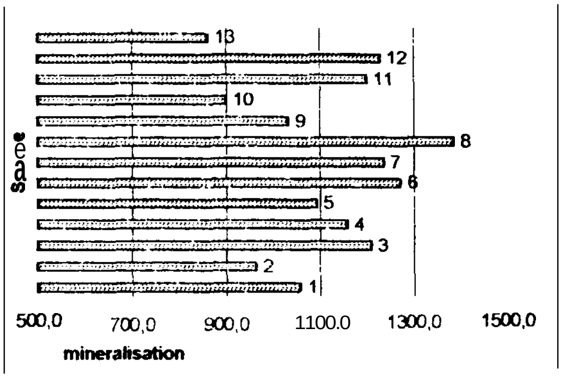


Distinguishing between the hydrochemistry of these wells, we remark that the water from 4801 located in the South of Oradea has the highest content of sulfate (around 18,5%meq/L), followed by 4005; 4006, 4797; 4004; and finally 4767(11 %meq/L)

The decrease of sulfate ion at well 4081 comparated to well 4767 occurs with an increase of bicarbonate content.

A correlation *can* be done (see Table 1). Figure 3, shows clearly a typical interdependence of ionic concentration, couch **as** mg/L function by total mineralization. The sulfate ion concentration increases at the same time with the increase of total mineralization, while the bicarbonate ion concentration decreases **equally** (the Same proportion). The increase of total mineralization, of sulfate ion concentration and the decrease of bicarbonate ion concentration converge toward well 4081.

Figure 3 the mineralization of the source that belong to 'Triassic aquifer(see Legend 1)



A perspective of geothermal waters by comparison with Cherebotaev's segments leads to the next conclusion. On their path of flow, the water which dissolved limestone and dolomite till saturation. in a congruent system, contacts a geologic material containing gypsum or anhydrite; **a** material which is more soluble than limestone or dolomite (in close system) and which under the common ion effect, has began to deposit carbonate simultaneous with the increasing the sulfate ions concentration, till it is reach an equilibrium. Maybe due to this equilibrium, in spite of the hardness of geothermal waters, in this area there was not recorded deposition of scale or incrustation phenomena during completition

Commenting on the microelement composition of this aquifer their abundance surprises. These data were obtained by Spectroscopy of Emission.

The microelements composition **of** Triassic

Well No.	V (mg/L)	Co (mg /L)	Ni (mg/L)	Mn (mg/L)
4004	2.1×10^{-3}	-	4.5×10^{-3}	5.2×10^{-3}
4005	3.5×10^{-3}	-	1.8×10^{-3}	6.9×10^{-3}
4006	5.4×10^{3}	-	1.1×10^{-4}	3.3×10^{-3}
	4.8×10^{-3}	-	-	1.3×10^{-3}
	4.2×10^{-3}	8.9×10^{-4}	3.8×10^{-2}	2.6×10^{-3}
	8.8×10^{-3}	-	8.5×10^{-3}	4.6×10^{-3}

result :al

data. It is **not** a perfect identity:, each well in its **own** conditions reflects a dynamic equilibrium integrating the specific characteristics of the entire: hydrothermal structure.

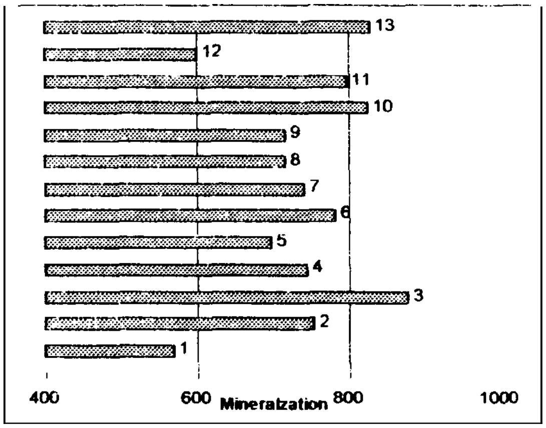
Hydrochemistry of Cretaceous

This geothermal area was the subject of various researches, or applied works. The first data were recorded in **1833(A.Baue)** Many teams worked along years in this area, enriching the scientific and tehnical knowledge regarding it.

The description of hydrologeologie must be correlated io the extremely favourable structural conditions of reservoir (A.Ţenu, 1975). This aquifer Lies down in a carstic structure as well as a very well developed fissured structure. The depth is extremely fracture, very tectonized. These conditions ensure the ascension path of thermal water from depth. The upper layer constitute from limestone is an ideal preservation of the energetic potential and in the same time an ideal storage area

The perimeter is located at 10km Southwest from the town of Oradea, in the zone of Felix Spa. This reservoir is from a physical point of view, the continuation of the regional Mesozoic hydrostructure of Pădurea Craiului, as its terminal part. The average depth of accumulation is at 1800-2000m The geothermal waters of this reservoir reach a temperature **of 45** -80" C.

Figure 4. The mineralization of the source that belong to Cretaceous aquifer(see legend 2)



'The Cretaceous geothermal aquifer **was** constantly investigated in 9 wells, in fact there are more, and there also are 4 natural springs. The time interval taken in consideration paper is 1971-1990. The hidrochemical indicators for establishing the main chemical **features** of the aquifer were the same with those investigate in the Triassic aquifer

The thermal water hydrochemistry the whole is calcium-magnesium-bicarbonate-sulfate type, very low mineralized. It is like the Triassic aquifer but the dominant ion is reversed, sulfate instead of bicarbonate. The prevalent feature is given here by bicarbonic ion.

By processing the elementary data from chemical analyses, we obtained the following results.

Table 3: The percentage composition of the equivalent of main the elements in Cretaceous geothermal aquifer

Well no. /Source	Cl^- meq %	HCO_3 meq %	SO_4^- meq %	Na^+ meq %	Ca^{2+} meq %	Mg^{2+} meq %
1Mai Izbuc	4,03	61,99	33,97	9,17	65,22	24,64
Felix 4003	4,07	63,4	32.4	9,2	69,1	20,6
Felix 4011	4,06	55.01	40,94	9,01	66,10	23,96
Felix 4012	3,43	80,19	16,34	6,74	59,27	32,84
Felix Balint	4,60	57,26	38,14	10,1	58,57	30,19
Felix4087	4,67	71,86	23,49	8,85	68,55	21,27
FelixVila-4	4,20	65,02	30,71	9,19	64.47	25,38
Cordau402	4,24	71,59	24,17	8.9	69,19	20,97
Rontau F2	4,34	57,97	37,69	8,93	63,79	26,22
Frederich	4,85	65,50	29,63	10,5	63,40	25,47
OchiuMare	4.73	74,88	20,37	5,74	65,19	27,61
OchPompei	4,76	69,21	26,01	9,00	63,17	27,14
OchTiganul	3,18	56,92	39,45	13,3	65,12	21,35

Figure 5 is obtained by plotting grand average value of major components

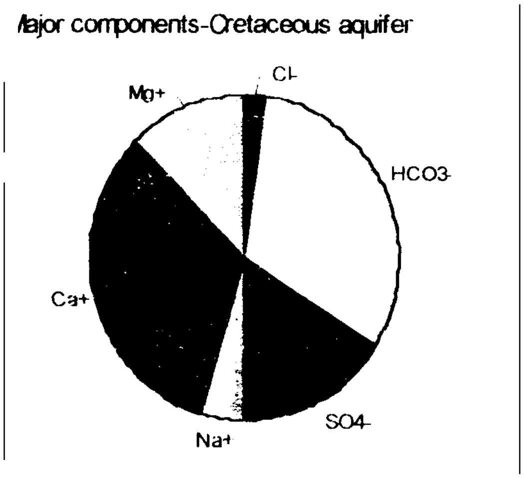


Figure 5

Particularizing each source the by its ionic composition, a detailed individualization can be notice as following:

- Izbuc: its water belongs to the class of strong bicarbonateweak sulfate --strong calcium - weak magnesium;
- 4003: its water belongs to the class of strong bicarbonate--weak sulfate –strong calcium weak magnesium; .
- 4011: its water belongs to the class of strong bicarbonate– moderate sulfate - strong calcium –weak magnesium;
- 4012: its water belongs to the class of very strong bicarbonate –moderate sulfate –strong calcium - weak magnesium;
- Ralint: its water belongs to the class of strong bicarbonate – moderate sulfate - strong calcium –weak magnesium;
- 4087: its water belongs to the class of strong bicarbonate– weak sulfate –strong calcium - weak magnesium;
- Vila 4: its water belongs to the class of moderate bicarbonate –moderate sulfate · strong calcium –weak magnesium;
- 402: its water belongs to the class of strong bicarbonate – weak sulfate --strong calcium - weak magnesium;
- F-2: its water belongs to the class of strong bicarbonate -moderate sulfate strong calcium --weak magnesium;
- Frederic- it is a thermal spring the water its belong to the class of strong bicarbonate - moderate sulfate - strong calcium --weak magnesium;
- The next sources (OchiuMare, OchPompei, and OchTiganu) are natural emergencies; in fact there are lakes. Their compositions are not relevant for the downhole aquifer being mixed with meteoric water. The prelevation directly from spring being not possible

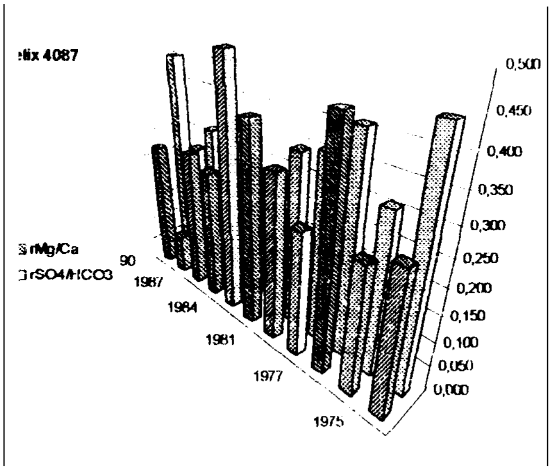
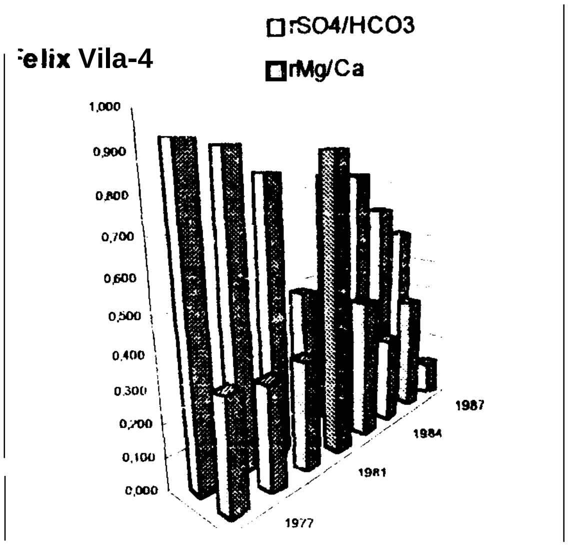


Figure 6. The evolution rSO4/HCO3 and rMg/Ca of Felix Vila-4

According to diagrams and tables data, there was not a repeated chemistry along the time. This indicates some changes of the chemistry of the aquifer in discussion. **Figure 6** -7 shows the chronological evolution of characteristic rapport of two sources that belong to this aquifer.

Figure 7. The evolution **rSO4/HCO3** and **rMg/Ca** of Balint

The cationic general characteristic belongs to strong calcium, weak magnesium class. By observing the anionic distribution, it can be remarked a certain difference among the sources Distinguishing between these sources. we can notice the higher concentration of bicarbonate at 4012(80,19%), located in the North of Felix Spa; well 4011 has the highest content of sulphate (around 40,94%meq/L), followed by Balint,



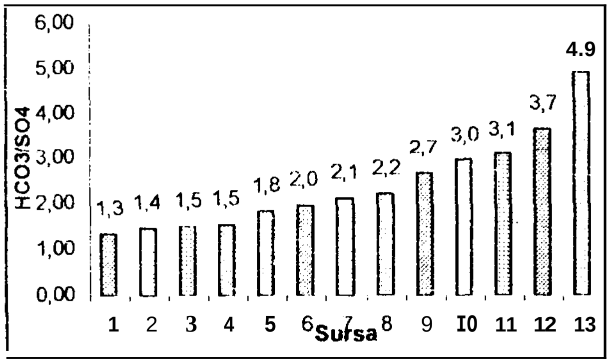


Figure 8 the diagram of r HCO3/SO4 (average value) of different sources of Cretaceous aquifer

Legend **2:**

1 Felix **4011**
2 **Ochiul Tiganului**
3 **Felix Balint**
4 Rontau **F2**
5 1 Mai **Izbuc**
6 Felix 4003
7 Felix Vila-4
8 1Mai Frederich
9 Ochiul **Pompei**
10 **Cordau 402**

Legend 2:

11 **Felix 4087**
12 Ochiul Mare
13 Felix **4012**

Examining the hydrochemistry variation of characteristic rapport an interesting change **can** be **F2,** Izbuc, **4003,** Vila 4, Frederich, **402. 4087;** and finally 4012**(**16.34%meq/L).

The decrease of bicarbonate ion at well **4012** compared to well **401**1 is occurs with an increase of sulfate content.

It *can* be remarked by surveying characteristic ratio HCO_3 /SO_4that the values are greater than the unit. noticed in 1975 at **Balint.(see** Table **4).**

Table 4: The variation of characteristic rapport of **Balint** geothermal source

Year	rSO4/HCO3	rMg/Ca
1887	1,600	0,270
1926	1,900	0,250
1951	1,000	0,270
1960	1,050	0,460
1966	1,170	0,250
1969	0,980	0,290
1975	0,411	0,270
1976	0,431	0,577
1977	0,877	0,365
1981	0,834	0,398
1983	0,646	0,298
1984	0,514	0,150
1986	0,856	1,554
1987	0,500	0,470
1990	0,670	0,330

As regarding the relation between HCO3 and the mineralization on the Cretaceous reservoir, a systematic increase of HC03 *can* be remarked, but the curve breaks on the Triassic reservoir (see Figure **4)** An exception to this are the wells **4087,** 402 and 4003, where there probably is a maximum mixture. On the contrary, in the Triassic reservoir HCO3 decreases at the same rate with the mineralization, as a result of the common ion effect.

Following the frequency of the presence of certain ions in traces along the time, we inferred that the waters of the Cretaceous reservoir could sporadically contain NO_2^- and PO_4^- 'This sporadic appearance of NO_2^- and PO_4 is very interesting and we consider it to be a contamination resulted fiom the spreading of agricultural fertilizers The issue may have two aspects

First, there may be a possible pollution of the reservoir with NO_2^- and PO_4 ions, although in their sporadic appearances these ions are much below the limit of danger.

Second, such an investigation is very **important** for us; following the chemistry of geothermal waters in the area in question during the period of artificial fertilization, we could find the area where they mix and the contribution of infiltration waters to its general chemistry. In this case the ions NO_2^- and PO_4^- could act as tracers.

The composition in microelements, determined by emissions spectrums on TDS, and by gammaspectroscopy by means of neutronic activation, indicates a resemblance with the waters of the Triassic reservoir. The frequency of elements such as Vanadium, Cobalt, Nickel and Manganese (see Table 5) is the same as in the Triassic reservoir (see Table 2). Approxiniately the same frequency was also found in the case of isotope analyses.

Table 5: The concentration in microelements of the waters belonging to wells from Felix – 1 Mai area.

Well No.	V (mg/L)	Co (mg/L)	Ni (mg/L)	Mn (mg/L)
Izbuc	2.1 x 10^{-3}	-	2.2x10^{-3}	2.5x10^{-3}
4003	2 9 x 10'	4.3 x 10^{-3}	1.9x 10^{-2}	1.4 x10^{-2}
4011	1 3 x 10^{-3}	-	.5 x 10^{-3}	4.1x 10^{-3}
4012	1 1 x 10^{-4}	-	-	-
Baht	9 9 x 10^{-4}	5.2 x 10^{-4}	-	5.6x 10^{-3}
4087	5 x 10^{-4}	-	-	3.0 x 10^{-3}
Vila-4	8.0 x 10^{4}	8.9 x 10^{-4}	-	6.0 x 10
402	5 0 x 10^{-4}	-	-	3.3 x 10^{-3}

Table 6: The frequency of appearance of certain isotopes in the geothermal waters and rocks of the Cretaceous reservoir (qualitative)

Isotope	4003	Lime stone*
^{40}Sc	+	+
^{47}Sc	+	+
^{51}Cr	+	+
^{56}Mn	+	+
^{58}Mn	-	-
^{59}Fe	+	+
^{58}Co	-	+
^{63}Zn	-	-
^{71}Zn	-	-
^{82}Br	+	-
^{84}Sr	-	-
^{85}Sr	+	+
^{87}Sr	-	-
^{100}Ag	+	+
^{124}Sb	-	-
^{128}I	-	-
^{132}Cs	-	+
^{134}Cs	+	-
^{131}Ba	+	-
^{137}Ba	-	+
^{140}La	+	-
^{142}La	-	-
^{148}Pm	-	+
^{152}Eu	+	-
^{156}Eu	-	+
^{181}Hf	+	+
^{188}Hf	-	-
^{190}Ir	+	+
^{191}Pt	-	-
^{199}Pt	-	-
^{196}Au	-	-
^{198}Au	-	-
^{206}Bi	+	+
^{238}Np	-	-

* Limestone **from** Zece Hotare

The microelements that are present in geothermal water were identified on TDS by Gamma-spectroscopy Technique and Neutronic Activation Techniques and are indicating a resemblance between the Triassic aquifer and **Cretaceous** aquifer

Conclusions

We consider that this study of the distribution of microelement isotopes in geothermal waters is very important and it should be enlarged on.

As a matter of fact, this investigation was aimed not only to improve the study on the chemistry of the geothermal waters, but also to have in view the ratio **of** Strontium isotopes as a possible tracer for the path ***of*** underground waters in the area. Still, the small number of determinations didn't allow us an approach from this point **of** view. We succeeded **to** establish the methodology of research and also to elaborate the first data regarding the isotopic composition of some geothermal waters and rocks from cores extracted from well 4768 **as** well **as** for rocks collected **from** Padurea Craiului Mountains. Chemical and isotopic analyses might be done both in waters and in rocks in order to get a clear idea on the forming mechanism of the chemistry of geothermal waters.

The Triassic, and Cretaceous aquifers, although separated, are hydrochemically related, constituting a unitary hydrothermal system.

The modifications of their chemistry support the geophysical research in this direction.

We consider this study as an incipient phase, unfortunately the lack of financial and technical means stopped the research and many aspects are not explored yet.

We would also like to draw the attention on the differences in the hydrochemistry, which we consider a signal for those using these waters, as these waters could be profitably exploited for a long time provided a careful analysis is done in due time

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