

PHYSICO-CHEMICAL CHARACTERIZATION OF GEOTHERMAL WATER FROM FOUR WELLS IN NORTH-WESTERN ROMANIA WITH TERNARY DIAGRAMS

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Abstract: In this paper presents ternary diagrams for geothermal waters: ternary diagram Na - K - Mg, ternary diagram Cl-SO₄-HCO₃ and calculation model, which allows location of geothermal fluids in these diagrams. Classification of geothermal water with the two diagrams, involving knowledge of their chemical composition. Thus, it was the chemical composition of geothermal water coming from drillings: 4777 Mădăras, 507 Livada, 4699 Cighid situated in Bihor county and the well 4175 Tășnad of Satu Mare. Location of geothermal water on the two diagrams we will establish the type of water, depending to the presence in their content of major anions and cations, what is of great importance for use in various purposes of the geothermal fluids.

Keywords: geothermal water, ternary diagram Na-K-Mg, ternary diagram Cl-SO₄-HCO₃.

1. INTRODUCTION

Using geothermal water in Romania, [1] is based on the quality of drinking water or as needed, directly or indirectly (through heat exchangers) and mixed, water is used for heating, hot water as the greenhouses, swimming pools and technological purposes. Geothermal waters studied in this paper come from four wells in the Western Plain of Romania. Geothermal drilling Cighid 4699 [2], which is arranged inside the home for severely disabled children Cighid. Energy deposit of this type of aquifer is used for heating the hospital complex and the preparation of household hot water consumption. Some water is used for recreation in a swimming pool. Livada perimeter [3] includes a single well, the well 507, located in the west of Oradea, belonging, in terms of its administration. The water is used for geothermal heating of housing and socio-economic objectives and the beach in summer. Geothermal drilling Mădăras 4777 [4], is arranged in the north of the village, near the communal bath. Artesian water extracted from the well is headed in the thermal spa and bath cabinets with the valve communal. The water coming from geothermal drilling Tășnad 4175, is used for recreational in a swimming pool, on heating a restaurant and a motel, the heating of greenhouses and the hot water surrounding the military unit. The future it has in the industrial exploitation of these deposits. For geothermal

waters from the four wells will determine the chemical composition using standard methods of analysis and we construct ternary diagrams, ternary diagram Na - K - Mg and ternary diagram Cl-SO₄-HCO₃, used to characterize these waters.

2. EXPERIMENTAL DATA

Based on physico-chemical analysis is performed ternary diagrams, we allow characterization and use of geothermal water. Chemical analysis was performed in geothermal water wells: 4699 Cighid, 507 Livada, 4175 Tășnad and 4777 Mădăras by sampling water.

- Analysis of sodium, potassium, calcium, magnesium and iron was made by atomic absorption spectroscopy, using a spectrophotometer VARIAN SPECTRA AA 110.
- Analysis of silica [5], was made using UV-VIS spectrophotometric method, using a spectrophotometer CARRY 50.
- Analysis of ammonia from ammonium salts [6] was done by colorimetric determination of NH⁴⁺ ion.
- Determination of carbon dioxide [7], was made by titration with hydrochloric acid solution in the presence of metilorange. CO₂ from the carbonates was determined by volumetric titration. The method is based on neutralization of carbonates with

hydrochloric acid to bicarbonate step, using phenolphthalein as indicator.

- Analysis of chloride [8], was made by titration with silver nitrate in the presence of potassium chromate as indicator (Mohr method).
- Analysis of sulfates and hydrogen sulfide [7] was done by titration with barium perchlorate solution using Thorin as indicator. Determination of hydrogen

sulphide was made by titration with mercuric acetate in the presence of dithizone as an indicator.

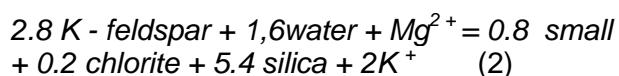
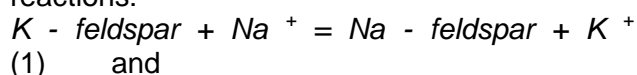
3. RESULTS AND DISCUSSION

Experimental data on the chemical composition of geothermal waters, taken in the survey are given in Table 1.

Tab.1. Chemical composition of geothermal waters (concentrations of ions, mg / L)

Chemical Characteristics	507 Livada	4699 Cighid	4175 Tăsnad	4777 Madaras
pH	6,5	7,0	7,5	8,2
Na ⁺	103	1042	4210	338
K ⁺	42,7	29,9	38,5	4,5
Ca ²⁺	114	16,22	24,0	3,9
Mg ²⁺	95,5	6,02	30,2	4,9
Cl ⁻	175	232	4875,5	76,5
SO ₄ ²⁻	208	49	6,0	11,0
HCO ₃ ⁻	610	2901	1522	829
SiO ₂	120	43	40,1	66,5
Fe ²⁺	0,02	0,119	0,26	0,79
CO ₂	815	2300	1220,09	30
Mineralization	1801	4287	10045	1504
H ₂ S	-	-	0,9	0,4

Experimenting with some techniques of derivation the geoindicators Na - K - Mg - Ca, it can be Na, K, Mg a triangular diagram, that can be used to distinguish waters balanced or partially balanced by the mixed water and immature, Figure 1. This allows the measurement of balance and combination of deep water can be made on several samples. Making a diagram are based primarily on the dependence of temperatures of the two reactions:



Theoretical temperature that depends on the correlation coefficients of concentration, can be used for preparation of two geotermometre:

$$t_{k_n} = \left(\frac{1390}{1,75 - L_{k_n}} \right) - 273 \quad (3) \quad \text{and} \quad t_{k_m} = \left(\frac{4410}{14,0 - L_{k_m}} \right) - 273 \quad (4)$$

where: $L_{k_n} = \log \left(\frac{C_K}{C_{Na}} \right)$ (5) and $L_{k_m} = \log \left(\frac{C_K^2}{C_{Mg}} \right)$ (6)

Applying individual equations (1) and (2) leads balancing very different temperatures. Coordinates of a point on the diagram are calculated using the equations:

$$S = \frac{C_{Na}}{1000} + \frac{C_K}{100} + \sqrt{Mg} \quad (7), \quad \%Na = \frac{C_{Na}}{10S} \quad \text{and}$$

$$\%Mg = 100 \frac{\sqrt{C_{Mg}}}{S} \quad (8) \quad \text{and} \quad (9)$$

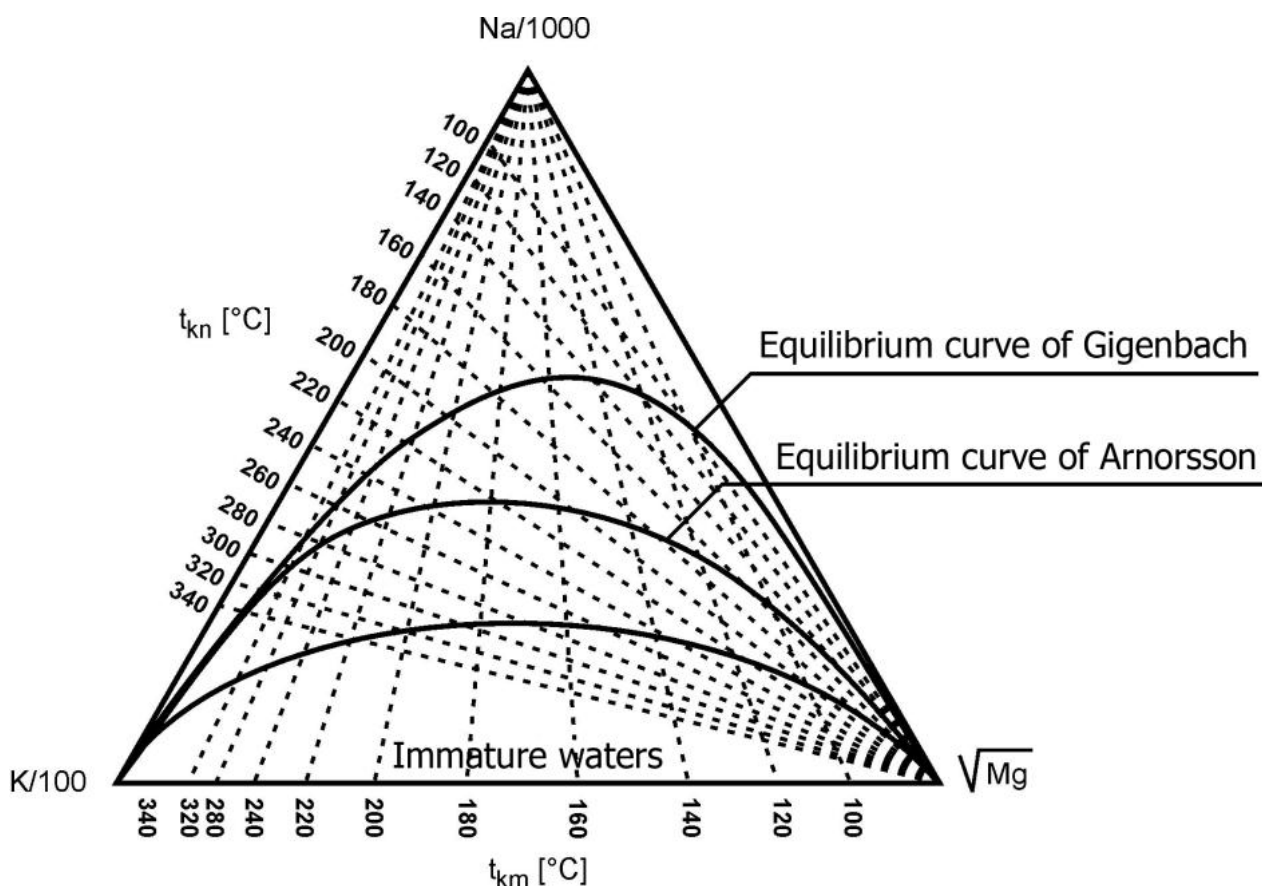


Fig 1. The ternary diagram Na - K - Mg for geothermal waters.

Because of nonlinear variation of the term CK^2 , the starting point is taken on the concentration of magnesium. Concentrations

Na and K are divided by 1000 and a 100 to fit best with geothermal waters. The data obtained are given in Table 2.

Tab. 2. Results for geothermal waters from four wells

Well	Na (mg/L)	K (mg/L)	Mg (mg/L)	$\frac{Na}{1000}$	$\frac{K}{100}$	\sqrt{Mg}	% Na	% K	% Mg
Cighid 4699	1042	29,9	6,02	1,042	0,298	2,453	27,472	7,857	64,671
Livada 507	103	42,7	95,5	0,103	0,427	9,772	0,996	4,144	94,850
Mădăras 4777	338	4,5	4,9	0,338	0,045	2,211	13,030	1,734	85,235
Tășnad 4175	4210	38,5	30,2	4,210	0,385	5,495	41,724	3,815	54,460

On the majority of cations was built ternary diagram Na-K-Mg. The data obtained allowed the positioning of geothermal water, taken in

the study, the ternary diagram N - K - Mg, Figure 2.

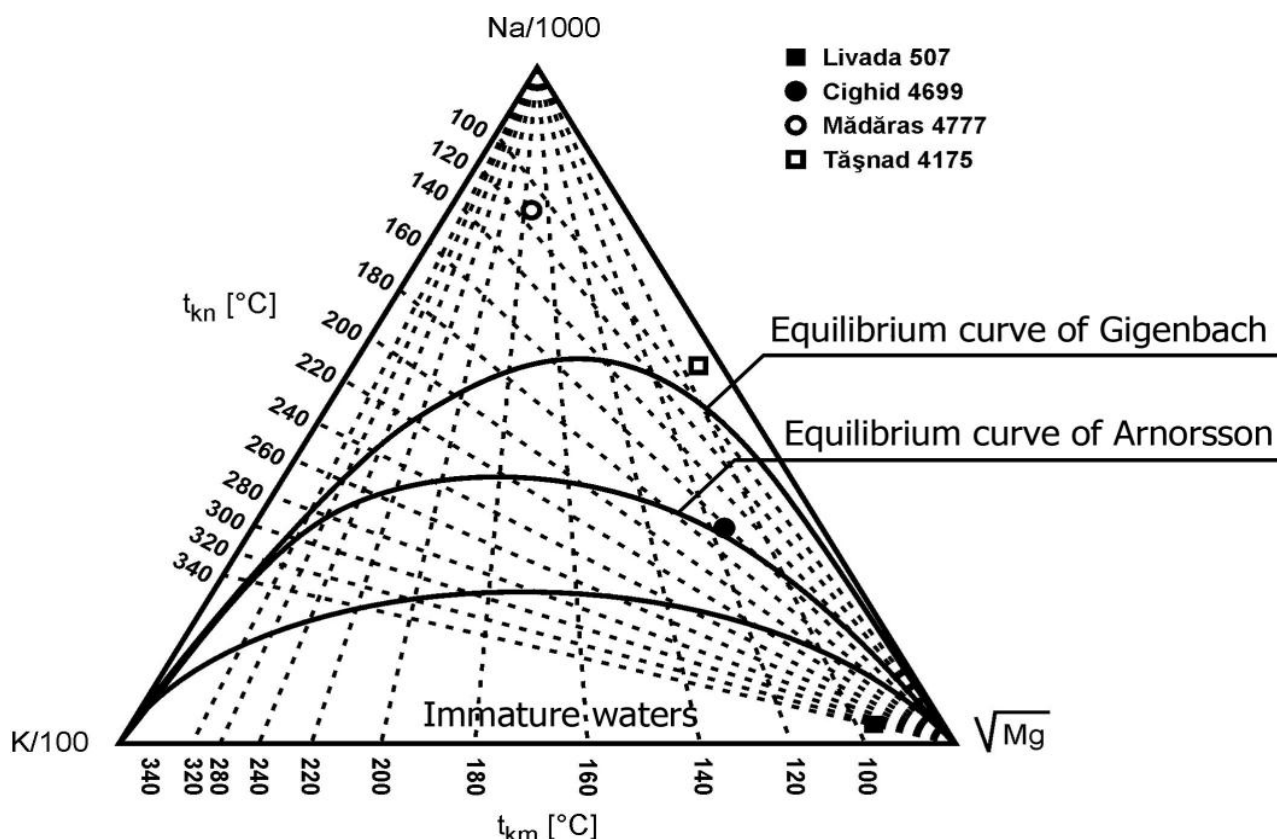


Fig 2. Ternary diagram Na - K - Mg for geothermal waters from wells: Cighid 4699, 4175 Tasnad, 507 Livada and Madaras 4777.

From Figure 2 it is noted that water from wells 4175 Tasnad and 4777 Madaras are above the equilibrium curve of Gigenbach, water is considered balanced. The temperature: 85 -95°C are balanced Tasnad waters, and 170 to 180°C are balanced geothermal waters from Madaras. Water from Livada is located in immature waters, is balanced at a temperature of 70-80°C, so the 100°C. The waters from well 4699 Cighid are almost to equilibrium curve's Arnorsson, being partially balanced. Partial equilibrium may be the consequence geothermal fluid reactions with the rocks they penetrate, or could be the result of mixing waters from different areas of food temperature. When the points of ternary diagram Na-K-Mg are found in the corresponding region metastable equilibrium, is a good indication that the chemical composition of these waters can be successfully used for calculations geotermometre.

Another classification, depending the majority anions present in geothermal water is made using a triangular diagram Cl-SO₄-HCO₃, Figure 3, [9].

Position points inside the triangle is obtained by making the sum of concentrations three components, in mg/L, followed by calculating the percentage: % Cl, % SO₄ and % HCO₃. In this case is calculated:

- the sum of:

$$S = C_{Cl^-} + C_{SO_4^{2-}} + C_{HCO_3^-} \quad (10)$$

- percentage composition Cl⁻ and HCO₃⁻:

$$\%Cl = \frac{100C_{Cl^-}}{S} \quad (11) \quad \text{and}$$

$$\%HCO_3^- = \frac{100C_{HCO_3^-}}{S} \quad (12)$$

- percentage of sulfate is obtained as follows:

$$\%SO_4^{2-} = S - (\%Cl^- + \%HCO_3^{2-}) \quad (13).$$

The data obtained are given in Table 3.

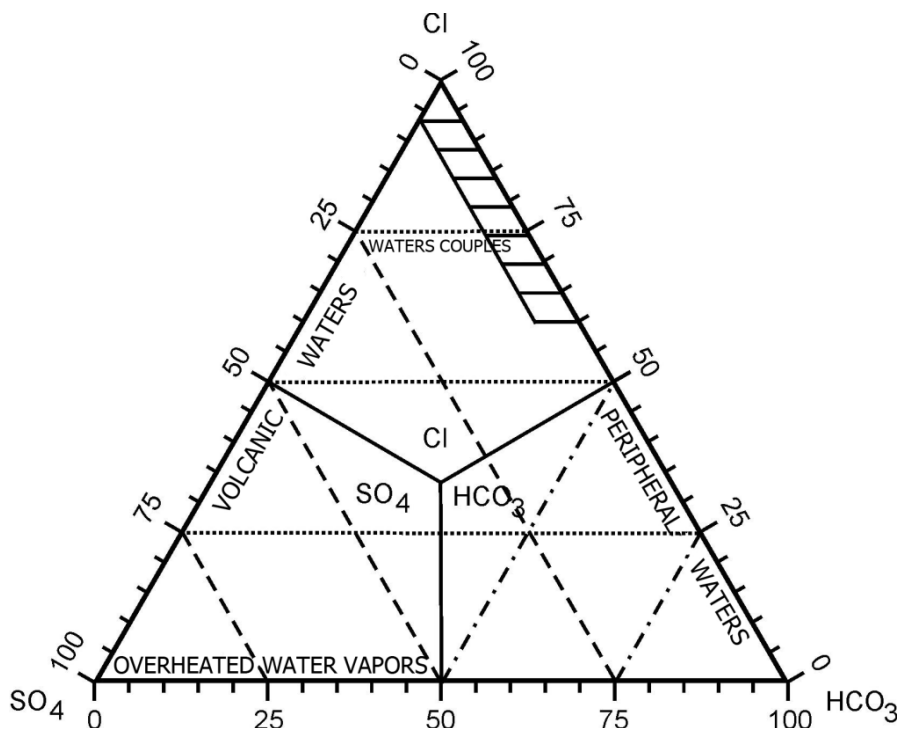


Fig 3. Ternary diagram Cl-SO₄-HCO₃ for geothermal waters.

Tab.3. Results for geothermal waters studied

Well	Cl ⁻ [mg/l]	SO ₄ ²⁻ [mg/l]	HCO ₃ ⁻ [mg/l]	% Cl ⁻	% SO ₄ ²⁻	% HCO ₃ ⁻
Livada 507	175	208	610	17,63	20,940	61,42
Cighid 4699	232	49	2901	7,28	1,540	91,18
Madaras 4777	76,5	11	829	8,35	1,197	90,45
Tasnad 4175	4875	6	1522	76,14	0,001	23,76

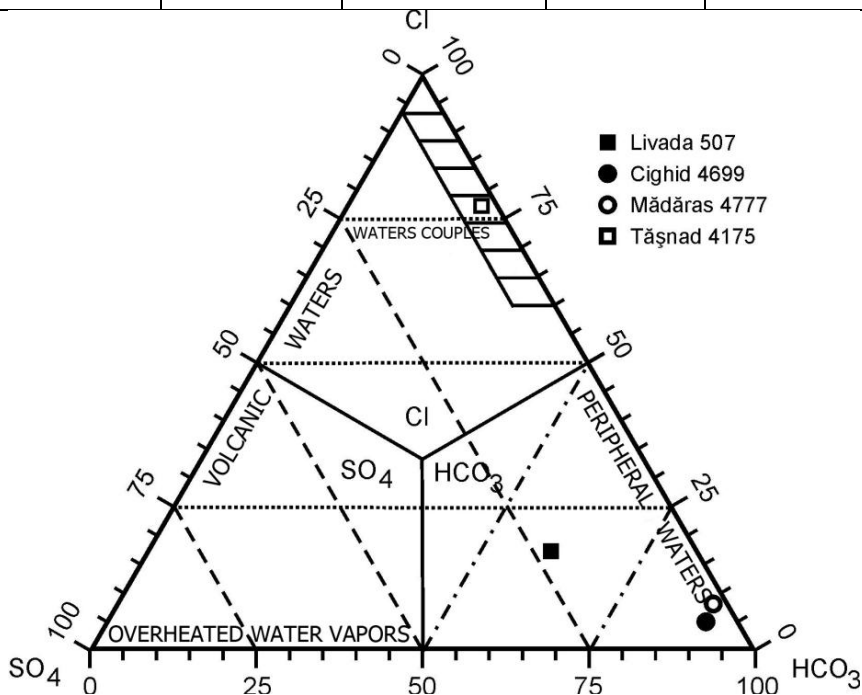


Fig 4. Ternary diagram Cl-SO₄-HCO₃ for waters from the four geothermal wells.

The data obtained were used to position geothermal water studied within the ternary diagram $\text{Cl}-\text{SO}_4-\text{HCO}_3$, Figure 4.

Ternary diagram $\text{Cl}-\text{SO}_4-\text{HCO}_3$ for geothermal waters studied gives us the following information: for waters from Mădăras and Cighid, points are close the corner of HCO_3^- and are in remote waters. These waters are heavily bicarbonate. The similarity between the two waters may be due and that from the same area, or could be due movement of groundwater.

Geothermal waters from the Livada are located throughout the area water periperale (peripheral), and are bicarbonate, but HCO_3^- ion concentration in the water is lower. For waters from Tasnad points are located near the corner Cl^- , and water are in couples, these waters are so strong chlorine.

4. CONCLUSIONS

The optimum conditions for use a geothermal water is necessary to know their chemical composition. Based on chemical analysis were characterized geothermal waters from four wells. Using ternary diagrams, ternary diagram $\text{Na}-\text{K}-\text{Mg}$ and ternary diagram $\text{Cl}-\text{SO}_4-\text{HCO}_3$ was determined that: water from 4175 Tasnad and 4777 Madaras wells are balanced water. The temperature: 85 -95°C are balanced Tasnad waters, and 170 to 180°C are balanced geothermal waters from Madaras. Water from well 507 Livada is located in waters immature, being balanced at a temperature of 70-80°C, so the 100°C. The waters from well 4699 Cighid are almost to equilibrium curve's Arnorsson, being partially balanced. According to the ternary diagram $\text{Cl}-\text{SO}_4-\text{HCO}_3$ was determined that geothermal waters from Tasnad are couples water, strong chlorine and chloro-

bicarbonato-sodium type. The waters from Mădăras and Cighid are peripherals water, power bicarbonate and type bicarbonato-sodo-chlorine. Geothermal water from well Livada is periperal (peripheral) water, bicarbonate, bicarbonato-chloro-sodium type. Chemical characterization of geothermal waters analyzed, assessment of geothermal potential in a given area, is possible by using triangular diagrams [10].

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