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GEOLOGICAL AND GEOPHYSICAL CONSIDERATIONS REGARDING THE MINERAL AND GEOTHERMAL WATERS FROM THE RAMNICU VALCEA - GOVORA AREA

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Abstract:
For understanding of complex geological and geophysical phenomena, regarding the mineral and geothermal waters, we must base on the whole of knowledge and available data for the study area. The input data include: digital terrain models, geological and geophysical maps, sections, drill-holes and geological interpretation, for assemble together into the same space data from various sources, in order to ensure geometrical coherence. Also, the database includes measurements of deuterium (δD (‰)) and overall salt content (Δd (mg / l)) expressed as the difference in density between a distilled water taken as a standard and water sample. Are important to take into account the geology 'boundary' data (geology contacts, interfaces and limits), the deep geology and processing/filtering of geophysical data with properly algorithms. The type of filtering of gravimetric and magnetic data must be chosen based on the depth of the model we want to get. This is necessary because the values of the geophysical parameters recorded at the surface of the terrain contain weighted average information from both the surface and from different depths, even to the base of the Lithosphere. In this paper we made some geological and geophysical considerations regarding the mineral and geothermal waters from the Ramnicu Valcea - Govora area. The types of water sources targeted are mineral springs, boreholes and surface water in the area.

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1. INTRODUCTION

The hydromineral deposits genetically belong to the Eocene and Miocene age formations and mineral waters mainly have a sulfurous and chlorosodic character (Pricăjan, 1972). These mineral waters have allowed the development of several spas, the most important of which are those in the Olt Valley, respectively Căciulata, Călimănești, Olănești and Govora (Roanghes-Mureanu, 2012). The main features that define the hydrogeological conditions of the Getic Depression are described in Roanghes-Mureanu, 2012.

Important from the point of view of mineral waters is the fact that this major structure is fragmented into hydrodynamic units through the Blidari longitudinal fault, which affects its southern flank, and through a series of NE-SW oriented fault faults (Blaga et al., 1977; 1979; Blaga et al., 1977-1979; Blaga et al., 1977; 1975; Blaga & Florian, 1984; Papp, 2014; Pricajan, 1972). In addition to the mineral waters of the resort, in the spa cure is also used the therapeutic mud accumulated in the collapsed spaces of the old salt mines from Ocnele Mari (Roanghes-Mureanu, 2012, Roanghes-Mureanu, 2013).

Regarding geophysical data, filtration of gravimetric and magnetic data is a very important step in achieving a more realistic model. Gravimetric and magnetic anomalies include cumulative surface effects up to very large depths. The filtering procedures for analytical continuation in the upper half-space (using the Laplace equation) and the analytical continuation in the lower half-space (using the Poisson equation) were presented by many authors (Cruz & Laskowski, 1984; Kem, 2003; Huang, et al., 2003).

Also, filters using the direct Fourier transform and the inverse Fourier transform.

Principles of trend surface analysis are also applicable for filtering data. Trend analysis is part of the field of regression analysis that satisfies the smallest squares criterion. The difference between the calculated value of the trend surface at a certain point and the value observed at that point is the residual value.

The removal of the regional trend has the effect of highlighting the local components represented by residual values.

A surface occupying a three-dimensional space is a mathematical function with a dependent variable and two independent variables.

Viewing spatial relationships in a three-dimensional space is very difficult. The best method is to assign a constant value to an independent parameter and to represent the parameter that depends only on two independent parameters, as in the case of trending surfaces. This type of representation is the general trend of the parameter dependent on two independent parameters (Asimopolos & Asimopolos, 2018; Asimopolos & Asimopolos, 2017(a), Asimopolos & Asimopolos, 2017(b)).

Typically, the dependent parameter is a geophysical parameter and the two independent parameters are latitude and longitude.

Depending on the degrees of the calculated trend, we can get the effect of the filters on anomalies. The high pass filters are obtained by the difference between the initial values (measured) and the values calculated for the trending surface in the same nodes of the network.

The band pass filters, are obtained by the difference between the calculated values for two levels of degrees for trend surfaces in the same nodes of the network.

Low pass filters are represented by the values calculated from the surface analytical expressions of the network nodes used.

2. GEOLOGICAL AND TECTONICAL SETTINGS

The main features that define the hydrogeological conditions of the Getic Depression are (Blaga et al., 1977-1979):

- a great development of coarse detrital rocks in the stratigraphic interval Badenian - Villafranchian;
- the existence of frame sectors, in which the hydrocarbon sectors discharge into the coarse deposits of the depression;
- a more moderate relief energy;
- absence of eruptive formations;
- absence of post-volcanic manifestations;
- a quiet tectonic framework, with anticlines and synclines in the northern central area, and in the rest of the depression a monoclinal style;
- the existence of areas of neotectonic subsidence, which have led to hydrographic convergences:
- at the exit from the mountain area, the more important rivers formed developed manure cones;
- in some areas where the rivers flow on Pliocene sands or Cândești gravels, they lose part of their flows, sometimes completely drying up;
- locally, the routes of these rivers are of hydrogeological interest due to the presence of springs;
- Pliocene deposits contain important reserves of groundwater under pressure, manifesting artesian in favorable morphological conditions;
- locally, the presence of evaporites conditions the high mineralization of groundwater;
- related to the presence of hydrocarbon deposits, associated waters are known, with very high mineralizations, in some structures being known thermal waters;
- for groundwater in pre-Quaternary formations, it is important to supply them from the hydrographic network;
- the springs from the aquifers of the pebbles of Cândești on the terraces and on the interfluves have rain-snow supply;
- up-to-date hydrotechnical arrangements and coal mining have led to local changes in hydrogeological regimes;
- the area less favorable for the existence of groundwater is between the Olt Valley and the Argeș Valley (Cotmeana Platform area). The main types of hydrogeological structures in the Getic Depression are:
- alluvial structures in meadows, including terraces and manure cones, locally groundwater being under slight pressure in meadows and manure cones;

- frame hydrostructures, fed by the discharge of hydrocarbon structures and from the hydrographic network at the contact with the frame;

- deep hydrostructures, in granular formations of Miocene - Pliocene age, the waters being under pressure and manifesting artesian on the valleys.

The Govora hydrothermal deposit is located in the area of the Oltenia Subcarpathians, in the basement of the Hința valley basin, and partially in that of the Gătejești brook. The sub-Carpathian relief is characterized locally by a hilly relief, with altitudes between 200 and 500 m. From a geological point of view, the area of Govora resort is part of the Getic Depression and is located in the western part of the Ocnele Mari - Govora Anticlinal, with E-W orientation.

The boreholes indicated the existence of Miocene formations, alternating Sarmatian sands and marls, marls, sands, Badenian salt levels and Swiss conglomerate, sandy and marly horizons.

The major structural character of the area is given by the presence of the Govora anticline, having a general E-V development, with a slight inflection to the SE near the resort.

The axis of the anticline consists of deposits belonging to the Helvetian, and the flanks are formed by Badenian and Sarmatian deposits.

Mineral waters differ hydrodynamically in two categories related to structural tectonic conditions, namely: sulfurous, related to the fissure systems of Sarmatian, and chloride-sodium-bromide-iodide, stored in aquifers and cracks in Swiss deposits.

The first have total mineralizations between 1435 and 44398 mg/l, and those in the second category between 31024 and 87337 mg/l. It should be mentioned that in sulfurous waters the H_2S content reaches a value of 26 mg/ l, and in chlorosodium waters, iodine has maximum values of 58 mg/l (Pricajan, 1972).

From a genetic point of view, sulphurous waters are considered to come from the mixture of surface waters with reservoir waters, in a long process of formation, which gives them a mixed chlorurosodium, bicarbonate and sodium character in which crude oil impregnations, deposits are observable of sulphur and the release of gaseous hydrocarbons.

The sources belonging to this genetic type are grouped on the right slope of the Hința brook located on the southern flank of the Govora Anticlinal. The second genetic type, that of high concentration waters, which accompany the hydrocarbon deposits are chlorinated-sodium-calcium-magnesium-iodinated-brominated and have been identified in wells especially in the northern flank of the Govora Anticlinal.

Sulphur mineral waters were identified in catchment wells no. 1-7, and chlorosodium mineral waters, through the group of wells no. 606 and 606bis, respectively no. 617 and 618.

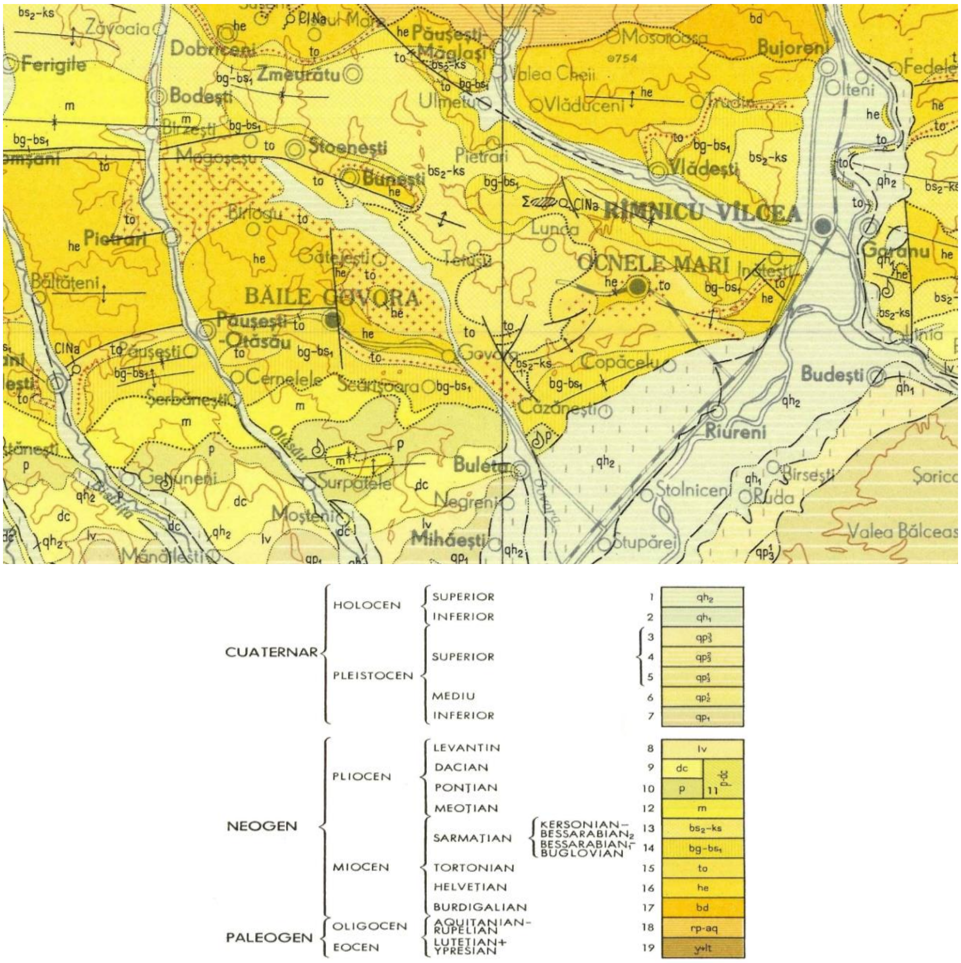

Figure 1. Part of geological map 1:200000, L-35-XXV with legend of age

In figure 1 is a part of geological map 1:200000, L-35-XXV with legend of age (from archive of Geological Institute of Romania, https://www.igr.ro). Provide a brief overview of the state of the art, the working hypotheses and the theoretical and/or experimental results.

2. GEOLPHYSICAL SETTINGS

The sources of geophysical data, which formed the basis of the maps presented in figures 2, 3, and 4 are the following:

- Vertical component of the magnetic field; Source: Airinei St., Stoenescu S., Velcescu G., Romanescu D., Visarion M., Radan S., Roth M., Besutiu L., Besutiu G. (1983), Magnetic map of R.S. Romania, scale 1: 1,000,000;

- Vertical component (ΔZ), printed Institute of Geology and Geophysics, 1983. [Gamma] isolation values transposed into ArcGIS/ArcInfo Grid with cell side of 200 m;

- Anomaly of the vertical component of the magnetic field; Source: Airinei St., Stoenescu S., Velcescu G., Romanescu D., Visarion M., Radan S., Roth M., Besutiu L., Besutiu G. (1983), Magnetic map of R.S. Romania, scale 1: 1,000,000;

- Anomaly of the vertical component (ΔZa), printed by the Institute of Geology and Geophysics, 1983. [Gamma] isolation values transposed into ArcGIS / ArcInfo Grid with cell side of 200 m;

- Anomaly Bouguer; Sources: Nicolescu A., Rosca Vl. (1991), Gravimetric map of Romania scale 1: 1,000,000. Bouguer anomaly for δ = 2.67 g/cm^3, printed by the Institute of Geology and Geophysics, 1991 (WGM 2012);

- Regional gravimetric anomaly; Source: ArcGIS Spatial Analyst processing of Bouguer anomaly using a 25 km mediation window. [Mgal] values in 200 m grid cells rendered as RGB (tiff format);

- Local gravimetric anomaly; Source: ArcGIS Spatial Analyst processing using Bouguer anomaly and regional gravimetric anomaly. [Mgal] values in 200 m grid cells rendered as RGB (tiff format);

- Geoisotherm at 3000 m deep; Source: Veliciu S., Negut A., Vamvu V. (1985), Geothermal map of R.S. Romania, scale 1: 1,000,000, printed Institute of Geology and Geophysics, 1985. Isolation values [degrees Celsius] transposed in ArcGIS / ArcInfo Grid with cell side of 200 m;

- Geothermal flow; Source: Veliciu S., Negut A., Vamvu V. (1985), Geothermal map of R.S. Romania, scale 1: 1,000,000, printed Institute of Geology and Geophysics, 1985. Isolation values [mW/m^2] transposed in ArcGIS/ArcInfo Grid with cell side of 200 m.

In addition to the data, presented above, from the geophysics portal in the institute's archive (https://www.igr.ro), we also used the data of the International Gravimetric Bureau (https://bgi.obs-mip.fr).

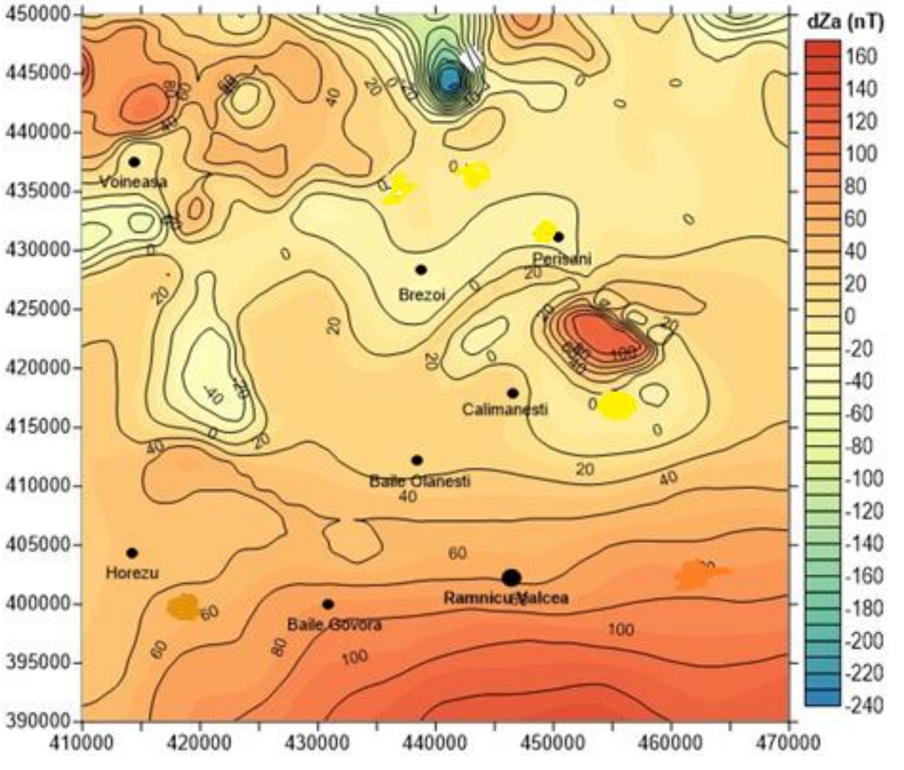

Figure 2. Map of the vertical magnetic anomaly (ΔZ, with isolates nT and ΔZa, in color shades represented in the adjacent legend nT)

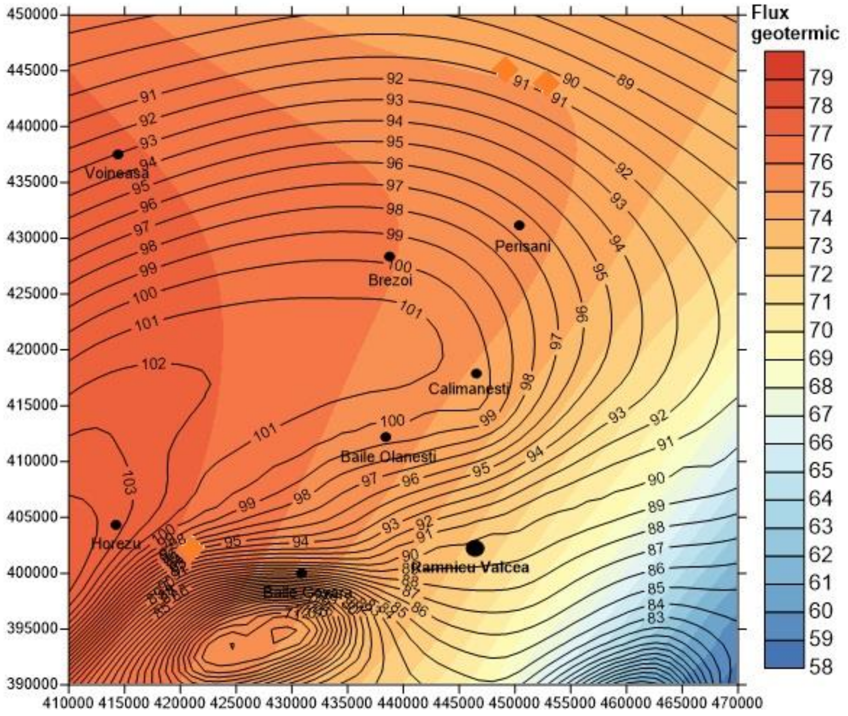

Figure 3. Map with temperature isolines at a depth of 3000m, expressed in degrees Celsius superimposed over the geothermal flux map in mW/m^2, expressed in color shades in legend.

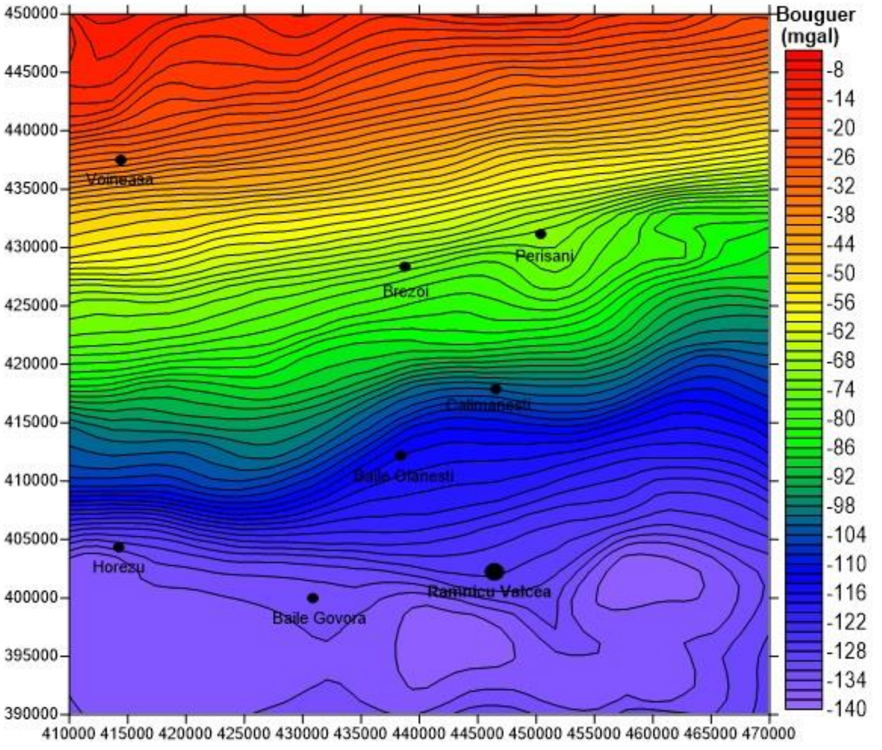

Figure 4. Bouguer anomaly map (mgal)

The construction of the maps of the vertical component of the geomagnetic field was performed based on the data contained in the existing measurement summaries at Geological Institute. These registers contain the geographical coordinates of the measuring points, the values ΔZ of the vertical component recorded at the base stations of the network where the measurements were made, the values ΔZ of the vertical component recorded at each point of the network and the corrected values ΔZ of the reduced vertical component for 1967,5.

The calculated values ΔZ of the ΔZ anomaly are also found in these registers. The values ΔZ used in the variation maps of the vertical component of the magnetic field are those reduced at that time and those of the variation of the Z component uncorrected for the secular variation (transmitted Z). The value of the ΔZ anomaly is calculated by applying a normal field correction to the value of the vertical component of the geomagnetic field.

The normal field correction represents the subtraction from the reduced value at a certain epoch at a certain point, of the normal value of the field at that epoch. The value of this correction corresponds to the variation with the latitude of the vertical component and represents the difference between the values ΔZ recorded at a given time between the component recorded at Surlari and the one recorded at that station at that time, after both values ΔZ were applied secular.

It should be noted that the data contained in these summaries are not evenly distributed and the number of values ΔZ is variable (between 600 and 1800 measurements on a 1: 200000 map sheet). There are areas with a high density of measurement points (in areas of interest at the time of prospecting, in valleys and in areas with accessible relief) but also areas with very poor coverage (in areas of low interest and in areas with heavy relief accessible.

Such an inhomogeneous distribution can create problems in choosing the most suitable form of interpolation network. The resulting data were interpolated by the krigging method using the Surfer program using a quadratic interpolation network (figure 2 - ΔZ and ΔZa).

The maps of the magnetic anomalies (ΔZ and ΔZa) in figure 2 show that the bodies with high magnetic sensitivity that generate the anomalies are in the superficial geological environment, extending in depth. Positive anomalies coincide with fault zones. The map with temperature isolines at a depth of 3000m, expressed in degrees Celsius superimposed over the geothermal flow map in mW/m^2, (figure 3) gradually indicates the areas with geothermal potential, by correlating the two parameters.

The Bouguer gravitational anomaly map (figure 4) reflects the gravitational effects of large-scale structures. These suggest thick geological bodies that extend from the depths to the surface. The strong negative anomaly to the east corresponds to the folded and thickened crust of the Carpathian orogen, which reflects the low density of sedimentary deposits.

5. HYDROMINERAL AND GEOTHERMAL DEPOSIT FROM GOVORA AREA

For the analyzes performed for the Govora hydromineral deposit, were taken into account wells, springs and running waters from the perimeter of Govora resort.

Two main groups of sources were distinguished. The first group was characterized both by high values in deuterium (between -5.2‰ and -30.2‰) and in salts (between 70771 mg/l and

27270 mg/l). The other group included the other sources with lower values for both deuterium (between -51.4‰ and -72.6‰) and for the salt content (between 307 mg/l and 29478 mg/l).

In the first group, wells from deep depths entered exclusively. Due to their high deuterium content, as well as salts, they were considered as fossil (deposit) waters. This type of water does not participate in the current meteoric circuit. In the second group entered waters, which, in one form or another, participate in the current meteoric circuit.

The distribution of δD values and overall salt content (Δd) can be followed in the table below (Table 1). All values in the table represent average values for one year of observation (Papp, 2014).

Table 1. The distribution of δD values and overall salt content (Δd)

	Source	**δD (‰)**	**Δd (mg/)**
1	Drilling 100ISPG	-22.86	46608.00
2	Drilling 601	-10.68	38256.21
3	Drilling 606	-8.67	29950.80
4	Drilling 600bis	-14.58	58992.92
5	Drilling 608	-12.68	29044.69
6	Drilling 2PG	-10.89	30838.29
7	Wells no. 1	-64.69	5940.33
8	Wells no 2	-63.72	11567.00
9	Wells no. 3	-65.89	9634.07
10	Wells no 4	-61.70	2792.08
11	Wells no 5	-59.98	2324.71
12	Wells no 6	-61.75	2360.00
13	Wells no 7	-63.50	13672.79
14	Spring no. 23_AUG.	-62.94	1560.50
15	Spring no. 30 DEC.	-63.03	1384.71
16	Spring no. SLF1	-63.75	5683.00
17	Spring no. SLF2	-58.49	4332.00
18	The well	-65.23	510.17
19	The well	-60.09	952.33
20	The well	-64.27	395.75
21	Stream	-58.81	1387.36
22	Stream Viorel	-62.08	479.60
23	Stream Hința	-60.46	759.29
24	Stream Vila 9	-64.75	559.43
25	Stream	-61.38	407.73
26	Stream	-56.80	1146.75

Most of the water sources tested within the Govora deposit show seasonal variations typical of meteoric water. Waters characterized by high values of deuterium concentration and overall salt content from great depths have a major component of reservoir water and therefore seasonal variations are very small.

For the waters in the meteoric circuit the seasonal variations of the δD values are between the same limits for all the studied sources, but the minimum and maximum sequences differ from one source to another. ΔD values are at their maximum in the warm months due to intense evaporation in the warm periods. The values decrease with the melting of the snow.

The highest Δd values appear in the autumn-winter months when the contribution of precipitation and infiltration water is low. During the spring months, the infiltration of water from melting snow produces a dilution of groundwater. As already mentioned, within the Govora resort, two main groups of sources were distinguished: (1) waters characterized by high values of deuterium and salts and (2) waters characterized by lower values both for the content in deuterium as for the salt content.

However, for all mineral water sources in this resort a positive correlation was obtained between the δD values and the overall salt content, with statistical significance ($r = 0.89$) suggesting the existence of a unique underground mixing system of these two groups of mineral waters.

In Govora resort there are two genetic types of water, completely different from each other: - deuterium and salt salts (fossils), - waters from the meteoric circuit. The waters of the meteoric circuit can in turn be divided into two subgroups: - waters from local infiltrations with relatively low salt concentrations (wells 4, 5 and 6); - waters mainly from winter infiltrations or from high altitudes which are strongly loaded in salts and have the lowest values in deuterium. The influence of reservoir waters on the waters of the meteoric circuit is proved by the definition on the correlation diagrams between the average values of δD and Δd of some mixing lines that include both genetic types.

5. CONCLUSIONS AND DISCUSSION

All the knowledge about geophysical data must be filtered according to the depth of the model we want to achieve. For a small depth model, we need to enter the residual data. As the depth of the model increases, the filtered data with different windows must be entered, going to the regional models and very deep to the trending surfaces. Trending surfaces with higher degree reflect a lower depth and trending surfaces with lower degree reflect a higher depth. The limit case for the largest depth is given by the regional trend plan.

In the geological/geophysical models we need to use geophysical data appropriate to the depth we are reporting.

In the area of the Govora hydromineral deposit, mineral waters are hydrodynamically differentiated into two categories related to structural tectonic conditions, namely: sulfurous, related to the fissured systems of Sarmatian, and chloride-sodium-bromide-iodide, stored in aquifers and in cracks in Swiss warehouses. The first have total mineralizations between 1435 and 44398 mg/l, and those in the second category between 31024 and 87337 mg/l. It should be mentioned that in sulfurous waters the H_2S content reaches a value of 26 mg/l, and in chlorosodic ones, iodine has maximum values of 58 mg/l.

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