Smart Energy and Sustainable Environment

2022, *25*(2): 57-64, https://doi.org/10.46390/j.smensuen.25222.448

GEOLOGICAL STUDY ABOUT THE HYDROMINERAL AND GEOTHERMAL DEPOSIT CĂLIMĂNEŞTI-CĂCIULATA

Natalia-Silvia Asimopolos[1], Violeta Carolina Niculescu[2], Laurentiu Asimopolos[1*], Delia Cristina Papp[1]

[1]Geological Institute of Romania, 1st Caransebeş Street, 012271 – Bucharest, Romania
[2]National Research and Development Institute for Cryogenics and Isotopic Technologies – ICSI Rm. Valcea, 4 Uzinei Street, P.O. Box Râureni 7, 240050, Rm. Valcea, Romania

Abstract:

This paper presents a geological study in the Călimăneşti-Căciulata area regarding mineral and geothermal waters. The detailed geological map at a scale of 1: 50000, made on the basis of detailed geological maps, is the starting material in this study. The types of water sources targeted are mineral springs, boreholes and surface water in the area. The database includes both geological and tectonic elements, as well as 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. In the case of surface water, due to the evaporation produced during the summer months which results in an enrichment in both deuterium and salts, there is a positive correlation between the values δD and Δd. If there are relationships with groundwater, correlation coefficients are low or even negative. For different water sources in the Călimăneşti-Căciulata area (average values), there is a good correlation between the deuterium concentration values and the global salt content. Regarding the seasonal variations, the general behavior of the groundwater in the Călimăneşti-Căciulata area is typical for the waters from the meteoric circuit, both according to the average values of the deuterium concentrations and according to their variations in time. The possibility of defining mixing lines of groundwater sources in this area is a criterion for integration into a single hydrodynamic system, which was formed by mixing, in different proportions, water infiltrated at high altitudes (mountain area) and water. of local infiltration, in accordance with tectonic lines and geological formations.

Article info:

Received 15 December2021
Received in revised form
07 November 2022
Accepted 08 November 2022
Available online 21 November 2022

OBSERVATION: The article is presented to the 23rd International Conference "New Cryogenic and Isotope Technologies for Energy and Environment" ***EnergEn*** **2021,** Băile Govora, Romania, October 26-29, 2021.

Keywords*:*
hydromineral, geothermal, hydrogeological structures, geochemical data

[*]*Corresponding author: Laurentiu Asimopolos, e-mail: asimopolos@gmail.com*

The influence of How to cite: Asimopolos, N. S., Niculescu, V. C., Asimopolos, L., Papp, D. C., (2022). Geological study about the hydromineral and geothermal deposit Călimăneşti-Căciulata. *Smart Energy and Sustainable Environment, 25*(2), 57-64, 2022, https://doi.org/10.46390/j.smensuen.25222.448.

1. INTRODUCTION

The Călimăneşti-Căciulata hydromineral deposit is located in the southern part of the Southern Carpathians, at their contact with the Getic Depression. Within the resort there are two types of relief: a mountainous one with altitudes between 800- 1200 m made up of metamorphic rocks and another of sub-Carpathian hills made up of sedimentary deposits. The Olt crosses both types of relief (Pascu, 1981; Pricajan, 1972). The geological composition of the area includes the crystalline foundation and sedimentary deposits of Cretaceous and Eocene age, arranged transgressively and discordantly over the foundation, based on data from the Geological Map of Romania at a scale of 1:50 000, Călimăneşti sheets (Popescu et al., 1955) and Vânturariţa (Lupu et al., 1978).

The tectonics of the region is dominated by the Intramoesic Fault. This major fault crosses the Făgăraş Massif up to date on the NW-SE Sebeşul de Jos-Nucşoara alignment (Stelea, 2017).

Vertical movements, are recorded on maps in the western half of the Călimăneşti Basin (Lupu et al., 1978), their active character being highlighted by landslides on their route.

Between the crystalline formations of Cozia and the sedimentary of the Getic depression that includes the hydromineral deposits of the resort, there is a major tectonic dislocation (Airinei, 1980) highlighted by the two contrasting relief planes, the mountainous and the hilly, from which downstream the sediment acquires a thickness very big. It is an SSE-oriented monocline with falls of 10^0-35^0 degrees, locally disturbed by small anticlines and a series of faults on which mineral springs usually appear.

Depending on their lithological constitution of the formations present in the geological structure of the region have been defined hydrogeological characteristics by various authors (Pricăjan, 1972; Blaga, 1975, 1977, 1979, 1984; Papp, 2014). The physical characteristics and the energetic potential of the geothermal resources from the perimeter of the Calimăneşti-Căciulata spas, as well as the solution for the integration of the geothermal resources available in the perimeter, are presented by N. Burchiu, 1999.

2. GEOLOGICAL AND TECTONICAL SETTINGS

The formations of the sedimentary cover in the Călimăneşti post-tectonic basin, located on the northern flank, with Carpathian foundation, of the Getic depression, cover the time interval Upper Senonian (Campanian + Maastrictian) -Lower Miocene.

The geological considerations are based on data from the Geological Map at a scale of 1:50 000, Călimăneşti (figure 1) and Vânturariţa sheets. In figure 2 is map of digital terrain model, after ETOPO 1.

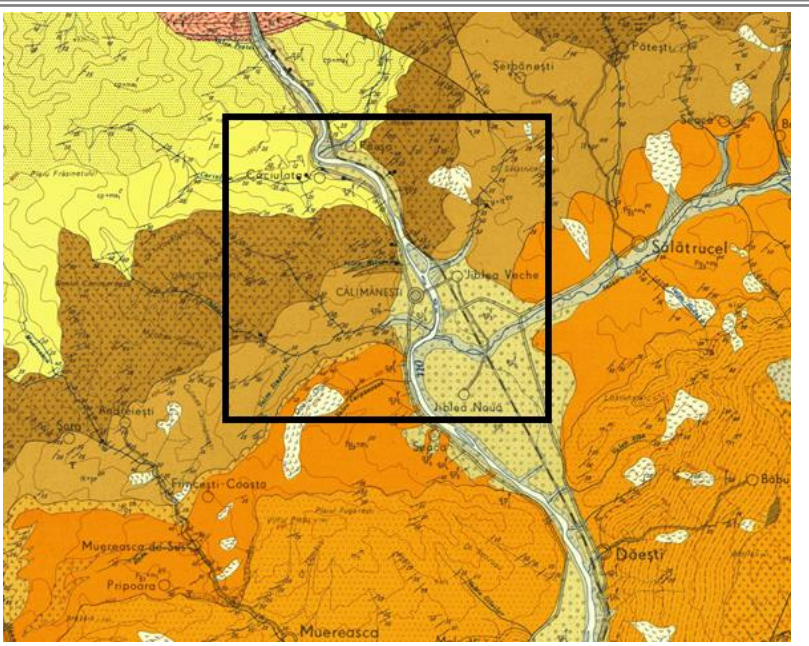

Figure 1. Geological map, Călimăneşti sheets, scale: 1:50000, showing the location of the study areas

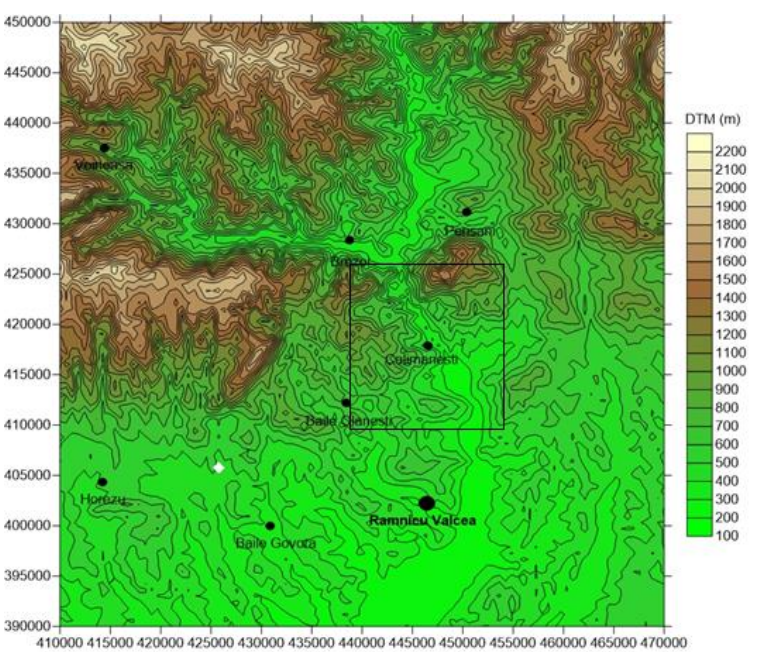

Figure 2. Digital terrain model (DTM) map, after ETOPO 1, showing the location of the study areas

Until the Upper Eocene, the Călimăneşti and Brezoi-Titeşti basins, located north of the Coziei horst, were a unitary sedimentation basin, in which flysch formations accumulated, covering the Upper Senonian-Eocene time interval and representing the post-tectonic blankets of the Mesocretacic (Austrian), Upper Cretaceous (subhercinic and laramic) and Lower Miocene (Old Styrian and New Styrian) orogenic phases.

The post-Austrian cover does not emerge in the Călimăneşti Basin, but the post-subhercine cover appears on large areas and is composed of terrigenous deposits of Campanian-Lower Maastrichtian age, represented by massive sandstones (Turnu sandstone) and sandstones alternating with marls (layers of Hat).

The first term of the post-laramic cover consists of Lower Paleocene-Eocene age formations, made up of conglomerates, breccias and sands (Călimăneşti conglomerates). The second term of the post-laramic cover, in continuous sedimentation, is represented by a monotonous alternation of marls and sandstones (Olăneşti marls), of middle-upper Eocene age.

At the end of the Eocene, the subsidence of the Brezoi-Titeşti basin begins and the rise of the Cozia horst, an event marked by the discordant deposition of the Oligocene Cheia conglomerates. The intense tectonic activity determined eugenic sedimentation conditions both in the Brezoi-Titeşti basin and in the Călimăneşti basin. Under these conditions, Oligocene deposits composed of bituminous clay shales associated with sands and tuffs (Upper horizon of disodilic shales), silty black clays, marl limestone, spherosiderites and marls (Pucioasa type marls) accumulated.

The general uplift of the crystalline foundation of the Făgăraş Massif, as an effect of the old Styrian (Aquitanian / Burdigalian) and New Styrian (intraburdigalian) orogenic phases, led to the rapid clogging of the Oligocene basin with lower Miocene deposits, of less and less deep water, predominantly terigene. These consist of coarse sandstones with marl intercalations (Muiereasca sandstones), followed by an alternation of marls, sands and sandstones (Gura Văii strata) with intercalations of tuffs and gypsum over which the Mătău conglomerates stand. The tuffs emerge on large areas in the Govora-Ocnele Mari area.

Starting from the Quaternary, there are subsidence of the crystalline foundation in the south of the Făgăraş Massif on NW-SE oriented tectonic alignments that cross the eastern half of the Călimăneşti Basin.

The tectonics of the region is dominated by the Intramoesic Fault. This major fault crosses the Făgăraş Massif up to date on the NW-SE Sebeşul de Jos-Nucşoara alignment. It is a seismically active fault, with hypocenters located over a large depth range (2-70 km). Most of the earthquakes in the Făgăraş Massif area occur in the Câmpulung-Muscel, Vidraru and Căineni areas, on V. Oltului. It is a transcurrent fault, with a dextral displacement of 1.2-4.5 km in the orogenic area. The width of the tectonic alignment is 1-2 km on the southern slope and 6-7 km in the western extremity of the northern slope, where the fault branches.

The secondary tailings, also in NW-SE direction, from the south-western compartment of the Intramoesic Fault represent the surface expression of a deep tree structure (flower structure), asymmetrically branched (half-flower structure). On these fractures there are numerous landslides in the sedimentary formations from the Brezoi-Titeşti Basin and the eastern half of the Călimăneşti Basin. NW-SW oriented fractures, but with vertical movement, are recorded on maps in the western half of the Călimăneşti Basin.

3. HYDROMINERAL AND GEOTHERMAL DEPOSIT CĂLIMĂNEŞTI-CĂCIULATA

The Cretaceous appears up to date on the course of the Olt in the form of the Turnu Layers formed predominantly of conglomerates and the Căciulata Layers, with a predominantly marly-sandy character. The Eocene, found in boreholes, is represented by conglomerates and sandstones (Fig. 3). Over these formations, on both banks of the Olt, there are deposits of the two terraces that can reach thicknesses of several tens of meters (Jiblea area).

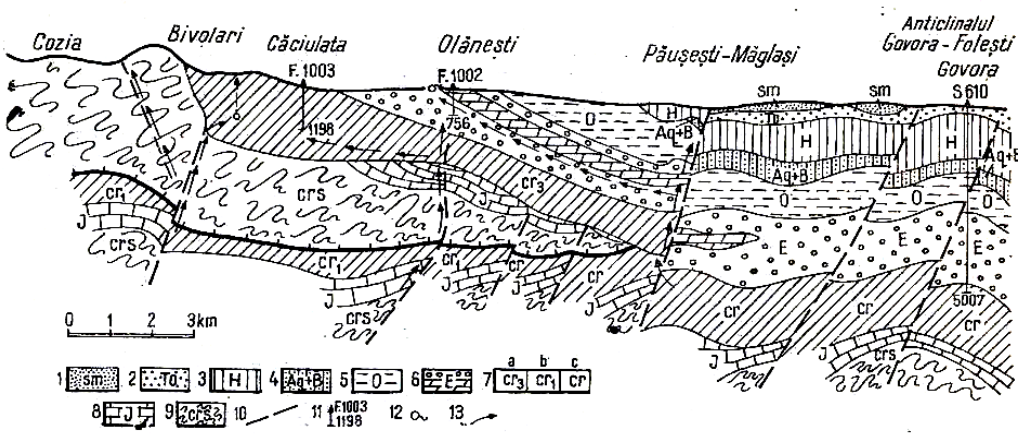

Figure 3. Geological profile between Cozia and Govora (after Feru, in Pricăjan, 1985); 1 - Sarmatian; 2 - Badenian; 3 - Helvetian; 4 - Acvitanian-Burdigalian; 5 - Oligocene; 6 - Eocene (conglomeratic horizon, marly horizon); 7 - Cretaceous (a-upper, b-lower, c-undifferentiated); 8 - Jurassic; 9 - crystalline; 10 - faults; 11 - deep drilling; 12 - mineral springs; 13 - probable directions of rise of reservoir water and gaseous hydrocarbons.

Depending on their lithological constitution, the formations present in the geological structure of the region have the following hydrogeological characteristics:

- the lens, due to the strong tectonization, has a network of faults and cracks, and on the surface has a blanket of alteration, favoring the circulation of groundwater;
- Cretaceous deposits (Senonian) consist predominantly of sandstones and conglomerates with an accentuated fissure, favored by the presence of numerous tectonic micro-accidents; in the cracks of Senonian detrital deposits it is possible to accumulate significant amounts of groundwater;
- pelitic intercalations do not always constitute screen surfaces, the waters having favorable circulation conditions;
- Eocene deposits allow the accumulation of groundwater in the fissures of the two conglomerate horizons, basal and upper. The medium marly, impermeable horizon has a role of screen in the way of the expansion of the underground waters from the basal horizon;
- Oligocene deposits, predominantly marly, represent an impermeable package;
- the mineralized springs, which appear from the Eocene conglomerates at Călimăneşti, are arranged near the contact with the medium marly horizon, being ascending springs.

Mineral water sources are represented by springs or boreholes. The mineral waters from Călimăneşti-Căciulata are cold or thermal waters, chlorosodic or bicarbonate, alkaline, calcium, magnesium, sulfurous, sometimes bromoiodinated.

In the Călimăneşti area there are two groups of springs, some located on the right bank of the Olt River inside the resort, and others on the Glodu brook. In the resort, the best known are: Spring no. 7 (sulfurous water, bicarbonate, calcium, oligomineral), Spring no. 14 (weakly sulfurous water, sodium bicarbonate, calcium, magnesium, oligomineral), Source no. 6 (sulfurous, brominated, iodinated, chlorinated, sodium water), Source no. 4 (sulfurous, brominated, iodinated, chlorinated, sodium water) and Spring no. 3 (sulphurous, brominated, iodinated, chlorinated, sodium water). A number of 14 mineral springs appear in the Glodul Valley area.

In the Căciulata area can be mentioned the sources: Spring no. 1 (sulphurous, brominated, iodinated, chlorinated, sodium, oligomineral water), Drilling 1004 (sulphurous, brominated, iodinated, chlorinated, sodium thermomineral water, having a temperature of approximately 45°C) and Drilling 1003 (sulphurous, brominated, iodinated thermomineral water, chlorinated, sodium, having a temperature of about 50°C).

In the Cozia area there are several drillings: Drilling no. 1 (sulfurous, brominated, iodinated, chlorinated, sodium water), Drilling no. 2 (sulfurous, brominated, iodinated, chlorinated, sodium, tonic thermomineral water), Drilling no. 3 (sulfurous water, weakly brominated, sodium chloride with low concentration), Drilling no. 4 (water similar to Drilling no. 3) and Drilling no. 5 (sulfurous, brominated, iodinated, chlorinated, sodium thermomineral water, having a temperature of about 43°C).

In the Păuşa area the most important sources are Spring no. 1 and Spring Nr. 2, both flowing sulfurous mineral waters, weakly brominated, iodinated, chlorinated, bicarbonate, sodium.

For the Călimăneşti-Căciulata deposit, the analyzed samples come from mineral water springs, wells and boreholes, as well as from surface waters in the area. The distribution of δD values and the 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.

Table 1. Distribution of δD values and the overall salt content (Δd)

Source	**δD** (‰)	Δd (mg/)
Stream Păuşa	-64.20	329.80
Spring no.1 Păuşa	-71.62	1181.65
Spring no.2 Păuşa	-64.42	921.70
Spring no. 6 Călimăneşti	-53.44	12395.95
Spring no. 4 Călimăneşti	-65.55	1733.00
Spring no. 5 Călimăneşti	-63.30	5557.00
Spring no. 7 Călimăneşti	-62.85	388.85
Spring no. 8 Călimăneşti	-61.87	5821.48
Spring no. 9 Călimăneşti	-61.64	7161.50
Spring no. 10 Călimăneşti	-60.35	7448.40
Spring no. 11 Călimăneşti	-58.27	10618.00
Spring no. 12 Călimăneşti	-54.47	14528.17
Spring no. 12bis Călimăneşi	-56.72	13440.00
Spring no. 13 Călimăneşti	-61.83	4908.20
Spring no. 14 Călimăneşti	-62.51	357.63
Stream Caciul	-62.60	310.00
Spring no. 1 Caciu	-61.49	2931.90
Spring no. 2 Caciu	-75.58	1452.78
Drilling 1003	-68.76	4832.77
Drilling 1004	-73.10	2736.37
Drilling 1005	-54.40	13497.52
Drilling H1	-71.68	2999.50
Drilling H2	-70.73	3700.43
Drilling H3	-69.77	3750.86
Drilling H4	-75.10	1765.25
Drilling H5	-75.50	1087.00
Drilling H6	-74.86	1729.33
Spring no. Bolnt	-64.95	429.57
Drilling 1 Cozia	-70.56	3646.23
Drilling 2 Cozia	-65.68	794.60
Drilling 3 Cozia	-73.44	3318.82
Drilling 4 Cozia	-73.28	3856.68
Drilling 5 Cozia	-70.06	4411.81
Drilling 1 Arutel	-70.63	3423.35
Drilling 2 Arutel	-73.12	2504.12
Spring no. 1 GLOD	-58.74	7941.40
Spring no. 2 GLOD	-58.49	8751.00
Spring no. 3 GLOD	-62.71	4172.33

Spring no. 4 GLOD	-59.05	8178.25
Spring no. 1 MUERS	-64.11	5211.00
Spring no. 3 MUERS	-78.31	979.50
Spring no. Cabana Cozia	-63.75	67.56
Spring Stana	-61.25	57.33
Stream Olt Călimănești	-73.57	293.86
Lotru	-72.29	67.50
Lotrișor	-58.74	73.75
Lotrița	-69.40	149.00
Stream MACIE	-66.80	84.00
Stream MANAI	-73.60	94.00

The range of variation of δD values for groundwater sources is between -54.4‰ and -75.5‰, and overlaps the range of surface water variation in the studied area (-53‰ ÷ -76‰), suggesting that the waters underground belong to the meteoric cycle. In the case of surface water, due to the evaporation produced during the summer months which causes an enrichment in both deuterium and salts, there is a positive correlation between the values δD and Δd. If there are relationships with groundwater, correlation coefficients are low or even negative.

4. CONCLUSIONS

For different water sources in the Călimănești-Căciulata area (average values), there is a good correlation between the values of deuterium concentration and global salt content. Regarding the seasonal variations, the general behavior of the groundwater in the Călimănești-Căciulata area is typical for the waters from the meteoric circuit, both according to the average values of the deuterium concentrations and according to their variations in time.

The possibility of defining mixing lines on the "*δD ‰ - d mg/l*" correlation graphs that include all sources in the area is a criterion for integrating all types of groundwater into a single hydrodynamic system, which was formed by the mixture, in different proportions, of infiltrated waters at high altitudes (mountain area) and local infiltration waters.

For most water sources, the lowest δD values were recorded in July, while the highest values appear in September - November. Some mineral springs have high values in the spring months.

The lowest salinity values appear in April - June. In general, seasonal variations in groundwater suggest as supply areas water infiltrations from rainfall at higher altitudes (mountain area) mixed with local infiltrations. For Probe 1005, the presence of a minor component of reservoir water can be admitted, which is less affected by temperature variations. Extrapolation of mixing lines to include Probe no. 1005 suggests a minor participation of groundwater (fossils) in the area. The general behavior of the underground waters in the Călimănești-Căciulata area is typical for the waters of the meteoric circuit, both according to the average values of the deuterium concentrations, and according to their variations over time.

Acknowledgments: We thank for support by the Ministry of Research for financing of the project "The realization of 3D geological / geophysical models for the characterization of some areas of economic and scientific interest in Romania", with Contract no. 28N / 2019.

Author Contributions: NSA: conceptualization (lead), analyses, review and editing; VCN: conceptualization (support), review and editing (support); LA: conceptualization (support), review and editing (support); DCP: conceptualization (support), review and editing (support).

Conflict of Interest Statement: There is no conflict of interest on this article.

REFERENCES

Airinei, I., 1980. *Radiografia geofizică a subsolului României*, Ed. ştiinţifică şi enciclopedică, Bucureşti.

Blaga, L., Blaga, M.L., Ciobotaru, T., Feurdean, V., *Studiu bazat pe măsurători de concentraţie a deuteriului din apele mineral din zona Călimăneşti-Căciulata*, raport la contractul de cercetare ITIM Cluj-Napoca nr. 780/1977 si nr. 366/1979.

Blaga, L., Blaga, M.L., Ciobotaru, T., Feurdean, V., *Studiu bazat pe măsurători de concentraţie a deuteriului din apele termominerale din zona staţiunilor balneo-climaterice ale judeţului Vâlcea*, raport la contractul de cercetare ITIM Cluj-Napoca nr.593/1975.

Blaga, L.M., Florian, M. 1984. Contribuţii la studiul hidrogeologic al zăcământului hidromineral Olăneşti cu ajutorul izotopilor stabili, *St. tehn. econ. Inst. Geol. Geof.*, Seria E, 14, p. 63-84, Inst. Geol. Geof., Bucureşti.

Burchiu, N., *Geothermal Energy Industrial Development in Romania*, raport de sinteză la workshop-ul: „Promoting renewable energy industrial development in Bulgaria and Romania", Bucureşti, martie 1999 (THERMIE B proiect no1694-98-GB)

Lupu M., Popescu B., Szasz L., Hann H., Gheucă I., Dumitrică P., Popescu G., 1978. *Harta geologică a României la scara 1:50 000, foaia Vânturariţa (Călimăneşti).* Arh. Inst. Geol. Rom.

Papp, D.C. 2014. *Caracteristici izotopice ale apelor minerale din zona subcarpatica (Călimăneşti-Căciulata, Olăneşti, Govora)*, Raport de cercetare la proiectul: PN 09 21 03 06: Interpretarea datelor izotopice pentru stabilirea originii şi dinamicii subterane a apelor minerale din zona Harghita-Covasna. Comparatii cu alte zone carpatice (Faza 14), arhiva I.G.R.

Pascu, M. 1981. *Apele subterane din Romania*. Ed. Tehnica, Bucuresti.

Popescu B., Szasz L., Hann H., Schuster A., 1977. *Harta geologică a României la scara 1:50.000, foaia Vânturariţa (Călimăneşti).* Arh. Inst. Geol. Rom.

Pricajan A., 1972. *Apele minerale şi termale din România*, Editura Tehnică, Bucureşti.

Roanghes-Mureanu, A-M., 2012. The Environmental Impact of Tourist Activities Performed in the Spa Resorts of Vâlcea Subcarpathians, *Analele Univ. Buc., Geografie*, LXI, 147-157.

Roanghes-Mureanu, A-M., 2013. The impact of tourism on the environment in the drainage Basin of the Olăneşti river, *Riscuri şi catastrofe*, nr. XII,vol.13, nr.2/2013.

Stelea I., Intramoesian Fault in the Făgăraş Mountains area. Oltenia, *Journal for Studies in Natural Sciences*, vol. 33, nr. 2, p. 7-12. Muzeul Olteniei Craiova