THE ROLE OF RELIEF IN THE PROCESS OF RIVER RUNOFF IN THE CĂLIMAN MOUNTAINS

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Abstract. The role of the relief in the process of water drainage of the rivers in the Căliman Mountains. The analysis of the flow of river water from a certain surface is very important for determining the multi-year flow regime. In the formation of the regime, an important role is played by the features of the relief of the hydrographic basin, which directly influence the direction of flow and the speed of the water, and indirectly, the climatic elements. The Căliman Mountains are less analysed from this point of view, the relief elements being included in only a few specialized works. In the study, the role of the morphometric elements (altitude, geodeclivity, density and depth of fragmentation, orientation of the slopes) and morphological elements of the relief in the flow process from the highest volcanic massif in Romania located in the central part of the Eastern Carpathians was analysed.

Keyword: Căliman Mountains, relief, factor, water runoff

1. INTRODUCTION

The flow of river water is influenced by many factors, among which one of the most important is the relief. It directly influences the flow, the variation of the water flow of the rivers depending a lot on the size of the hydrographic basin, the average elevation of the relief and the other elements of the relief (slope, fragmentation of the relief) determining the direction of orientation and the speed of the flow, but also indirectly, the relief being a main factor in determining the amount of precipitation that falls in a certain region, the variation of runoff being much greater where the response to climatic factors, an important role here having the exposure of the slopes.

On the Căliman Mountains, the highest massif in the central group of the Eastern Carpathians, several works have been carried out over the years that analysed the relief of these mountains, among them those by Posea (2001) and Arsene (2012), these mountains being also included in the work *Geografia României, Vol. I, Geografia fizică,* which analysed the relief of the whole of Romania.

2. DATA AND METHODS

For the analysis of the relief elements, data obtained by processing the data from the Digital Elevation Model over Europe (EU-DEM) were used, which provided us with the starting point for determining the features of the relief in the Căliman Mountains.

Several types of methods were used in this work, the most important of which are: - general methods, specific to other disciplines: the analysis method (cause-effect analysis, statistical and correlation analysis of the data string, quantitative analysis of data strings), the observation method (of important elements in the field), the comparative method (to comparatively analyse the spatial and temporal differences in the manifestation of geographical relief, climatic and water phenomena), the synthesis method (used for the centralization and final analysis of the data obtained from the field and from the processing of data obtained from hydrometric and climatic stations).

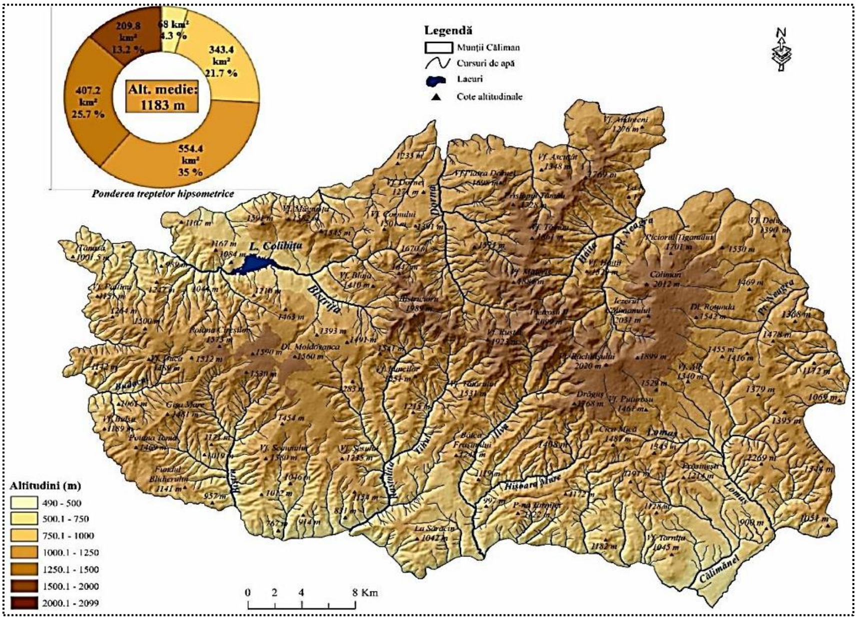

Fig. 1. Hypsometric map of the Căliman Mountains
(processed after Digital Elevation Model over Europe (EU-DEM))

For the calculation of climatic and hydrological indicators and parameters, the statistical method was used, and for the representation of quantitative data, different types of diagrams made with the help of Microsoft Excel 2013 programs and geospatial analysis in the field of GIS.

3. RESULTS AND DISCUTIONS

Through its geomorphometric characteristics (altitude, fragmentation, orientation of the slopes and inclination), the relief nuances the conditions of reception, accumulation and movement of water from precipitation and snowmelt.

3.1. Morphometric characteristics.

The elevation of the relief has an important role in determining the characteristics of water bodies in the Căliman Mountains, because it causes the vertical zonation of the main climatic elements, vegetation and soils, which have an important role in the formation of water resources and in the development of water courses. Altitude influences the types of river feeding, at higher altitudes in the Căliman Mountains increasing the weighting of snow feeding.

Within the Căliman Mountains, the altitudinal steps vary between 600 and 2100 m (Pietrosul Căliman Peak). The largest part of the studied area is between the altitude of 1000 and 1400 m (52.13%), approximately an area of 810 km^2 (Fig. 1), represented by the volcanic plateaus located at the base of the main peaks.

The highest level, of over 2000 m, has a relatively small area of about 0.07 km^2 and is represented by the floor of peaks found in the upper part of the caldera.

The role of altitude in the distribution of water resources in the three hydrographic basins belonging to the Căliman Mountains (Mureș, Siret and Someș) can be observed by studying the organization of the hydrographic network in this sector. Thus, following the general law, the hydrographic basins of the rivers in the region appear in an incipient form, poorly organized at high altitudes, so that as the altitude decreases, the streams in the region receive tributaries that will fill their hydrographic basin. Due to this aspect, the volume of water transported on the streams in the region increases, as the altitude decreases. The territory related to the Siret hydrographic basin has higher altitudes than the other two hydrographic basins. Thus, 91.46% of the area of this basin is located between 1000 and 1700 m, while in the other two hydrographic basins most of their surface is developed between the altitudes of 700 and 1500 m (Someș – 94.09%, Mureș – 87.21%).

The geodeclivity. Slope is one of the most important factors controlling surface and subsurface runoff, determining the direction and speed of water runoff on slopes. The slopes of the watersheds of the main rivers in this area vary between 0 and 63°, which means a considerable slope of the slopes in this study area. Almost half of the studied area (46.5%) is included in the slope range between 15 and 30°, and 41.2% in the range between 5 and 15° (Fig. 2).

The degree of inclination of the slopes influences the runoff and speed coefficients, the concentration and propagation of riverbed floods. Thus, in the case of the hydrographic basin with steeper slopes, the time of concentration and propagation of floods is shorter, and the negative effects more violent .

Unlike other morphometric indices, geodeclicity represents homogeneity and a similar percentage of slope intervals across the three watersheds (Table 2).

Table 1. Percentage of elevation ranges for the three watersheds (processed according to data from digital Romania)

Altitude range (m)	Hydrographic basin						Total	
	Someş		Mureş		Siret			
	F (km²)	%	F (km²)	%	F (km²)	%	F (km²)	%
485 -600	0	0	5,44	0,70	0	0	5,44	0,35
601 - 700	2,94	0,89	24,9	3,18	0	0	27,84	1,76
702 - 800	18,5	5,63	64,04	8,19	0	0	82,54	5,21
801 - 900	37,67	11,47	90,16	11,53	0	0	127,83	8,07
901 - 1000	52,24	15,9	111,5	14,25	4,22	0,89	167,96	10,6
1001 - 1100	56,23	17,12	116,9	14,94	45,58	9,63	218,7	13,8
1101 - 1200	49,25	14,99	103,15	13,19	79,28	16,75	231,68	14,63
1201 - 1300	39,75	12,1	80,26	10,26	79,39	16,77	199,4	12,59
1301 - 1400	30,27	9,21	70,76	9,05	75,51	15,95	176,54	11,14
1401 - 1500	25,2	7,67	45,4	5,80	64,72	13,67	135,32	8,54
1501 - 1600	12,65	3,85	30,11	3,85	52,97	11,19	95,72	6,04
1601 - 1700	1,84	0,56	16,15	2,06	35,52	7,5	53,51	3,38
1701 -1800	1,19	0,36	12,8	1,64	20,58	4,35	34,57	2,18
1801 - 1900	0,66	0,2	7,68	0,98	10,2	2,15	18,53	1,17
1901 - 2000	0,16	0,05	2,45	0,31	4,86	1,03	7,46	0,47
2000 - 2100	0	0	0,52	0,07	0,64	0,13	1,16	0,07
Total	**328,55**	**100**	**782,22**	**100**	**473,46**	**100**	**1584,23**	**100**

The strongly inclined slopes, between 30 and 63° belong to the floor of the volcanic cones, characterizing the walls of the volcanic craters, from the central-axial part and from the northern and southern edges, showing a very low weight in the three basins, as well as for the entire mountain group, below 6%. The slopes with slopes between 10 and 30° extend over the largest area, approximately 1086.27 km^2, i.e. 68.57% of the entire area of the territory. At the basin level, this type of slope holds 70.11% of the surface belonging to the Someş basin, respectively 68.69% of the surface belonging to the Mureş basin, and 67.29% of that of the Siret basin.

Slopes between 5 and 10° also have a higher weight, varying between 18.04% (Mureş) and 21.13% (Siret) (Table 2). Territories with a slope of less than 5° occupy a small area, varying between 5.97% in the Someş basin and 8.18% in the Mureş basin.

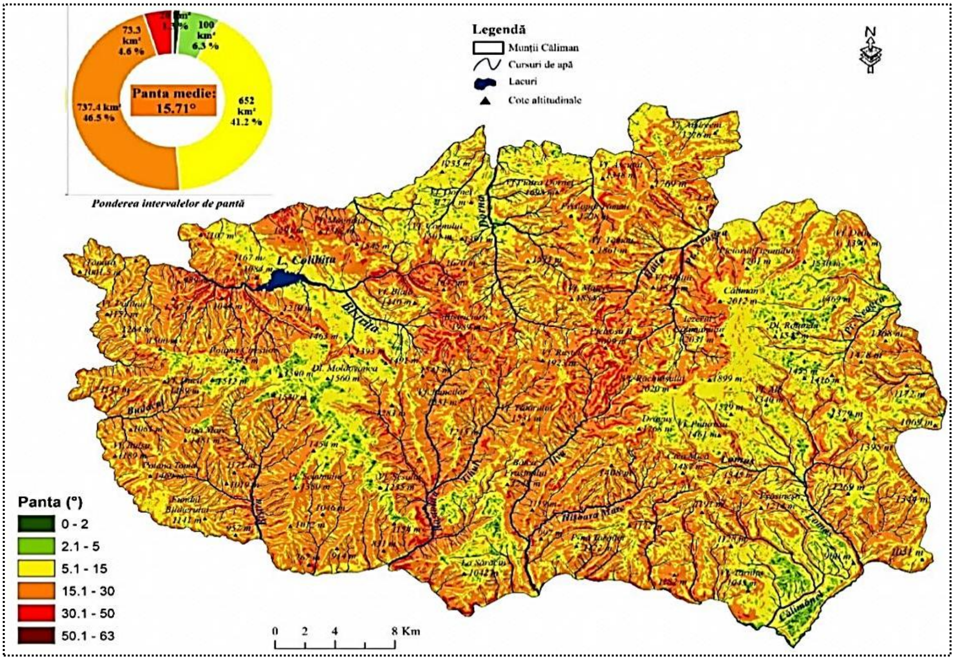

Fig. 2. Map of the geodeclivity of the Căliman Mountains
(processed after Digital Elevation Model over Europe (EU-DEM))

The distribution of water resources in the Căliman Mountains is influenced by the weight of the slope categories, thus more than half of the slopes that make up this mountain area have slopes between 10-30°, a fact that causes a rapid concentration of water on the beds already formed on the slopes and an increased speed of water transport.

The fragmentation density (horizontal fragmentation of the relief) represents the ratio between the length of the hydrographic network and the surface unit (in km/km2), being one of the basic indicators in defining the morphodynamic potential of the relief (Posea G., Cioacă A., 2003).

From the point of view of the depth of fragmentation, the studied area obeys the laws that govern mountain areas, namely the depth of fragmentation is reduced in the area of origin of the valleys, then increases on the slopes, and then decreases towards their edge.

Table 2. Area and slope weight for the three watersheds (Source: Extract from the previously processed Slope Map)
(processed according to data from Digital Romania)

Slope range (°)	Hidrographic basin						Total	
	Someș		Mureș		Siret			
	F (km²)	%	F (km²)	%	F (km²)	%	F (km²)	%
0 - 2°	3.09	0.94	11.32	1.45	5.95	1.26	20.36	1.28
2 - 5°	16.51	5.03	52.66	6.73	31.28	6.61	100.45	6.34
5 - 10°	59.28	18.04	144.48	18.47	100.05	21.13	303.81	19.18
10 - 15°	69.69	21.21	159.60	20.40	119.61	25.26	348.90	22.02
15 - 20°	69.83	21.25	164.00	20.97	98.68	20.84	332.51	20.99
20 - 30°	90.84	27.65	213.71	27.32	100.31	21.19	404.86	25.56
30 - 50°	19.29	5.87	36.41	4.65	17.59	3.71	73.29	4.63
50 - 63°	0.02	0.01	0.03	0.00	0.00	0.00	0.06	0.004
Total	**328.55**	**100**	**782.22**	**100**	**473.46**	**100**	**1584.23**	**100**

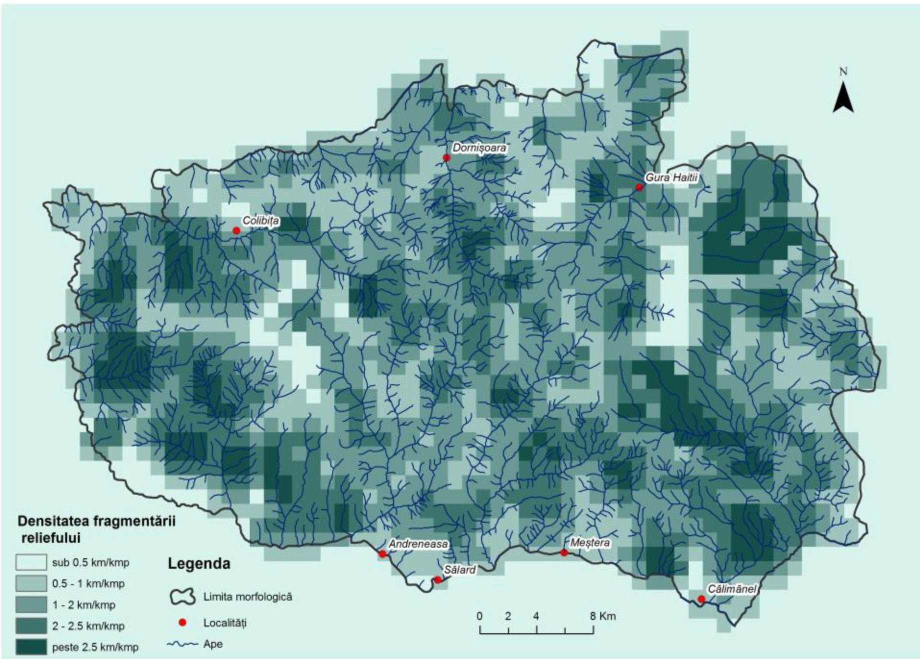

Fig. 3. The density of relief fragmentation in the Căliman Mountains (processed according to the Digital Elevation Model over Europe (EU-DEM))

The lowest horizontal density (below 0.5 km/km^2) is found where there are no watercourses or their density is very low (Fig. 3). This density is found at altitudes above 1800 m, where no watercourses are found.

As the density of watercourses increases, so does the density of horizontal fragmentation. The greatest horizontal fragmentation (over 2.5 km/km^2) is found in the middle courses of the rivers, where the convergence of several water courses takes place. High values of the density of relief fragmentation are found on the middle courses of the rivers Lomaş, Călimănel and Neagră (in the east), and Bistra, Budacul and Bistrita (in the west).

The depth of the fragmentation of the relief highlights the degree of deepening of the valley network, from which the stage and mode of its evolution can be deduced (generations of valleys, intensity of erosion, behaviour of rocks in fluvial erosion, etc.) (Ursu, 2010) The areas with the least erosion vertical are found on the periphery of the mountain group and in the territories with a lower density of the river network (below 100 m/km2) (Fig. 4). The highest values of the depth of vertical fragmentation (more than 400 m/km) are found at the main volcanic peaks, where the radiation leakage is very evident. The mountain peaks, where this erosion is most obvious, are Căliman and Iezerul (Căliman in the east of the mountain group, Pietrosul Căliman, Rustei and Bistricior in the central part, and Măgurita in the northwest part).

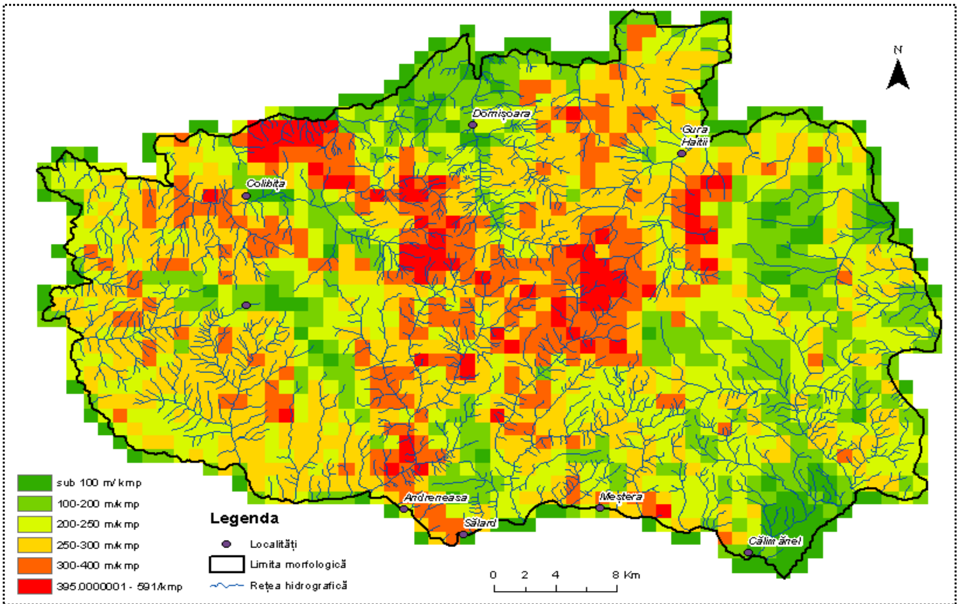

Fig. 4. The depth of relief fragmentation in the Căliman Mountains. (processed after Digital Elevation Model over Europe (EU-DEM))

The exposure of the slopes in the Căliman Mountains is very varied and has a direct role in the formation and distribution of water resources, primarily influencing the climatic conditions, especially the temperature, which in turn influences the quantity and quality of the existing water resources in this area.

The amount of precipitation received by the watershed also depends on the orientation of the slopes with respect to the general direction of the air masses. The orientation of the slopes produces differences in the duration of solar radiation, together with the slope generates different caloric regimes, a fact that influenced the water resources from a quantitative point of view.

For the entire Căliman Mountains, each orientation has a similar weight, on average, around 12%. If the analysis is done on the three basins, the shaded and semi-shaded slopes are found the most in the Siret basin (62.02 %). These slopes have an important role in the formation of runoff and water resources, the melting of the snow being much later here than on the slopes with western or southern orientation (dominant in the Someş and Mureş basins), where the snow melting is much earlier (Table 3).

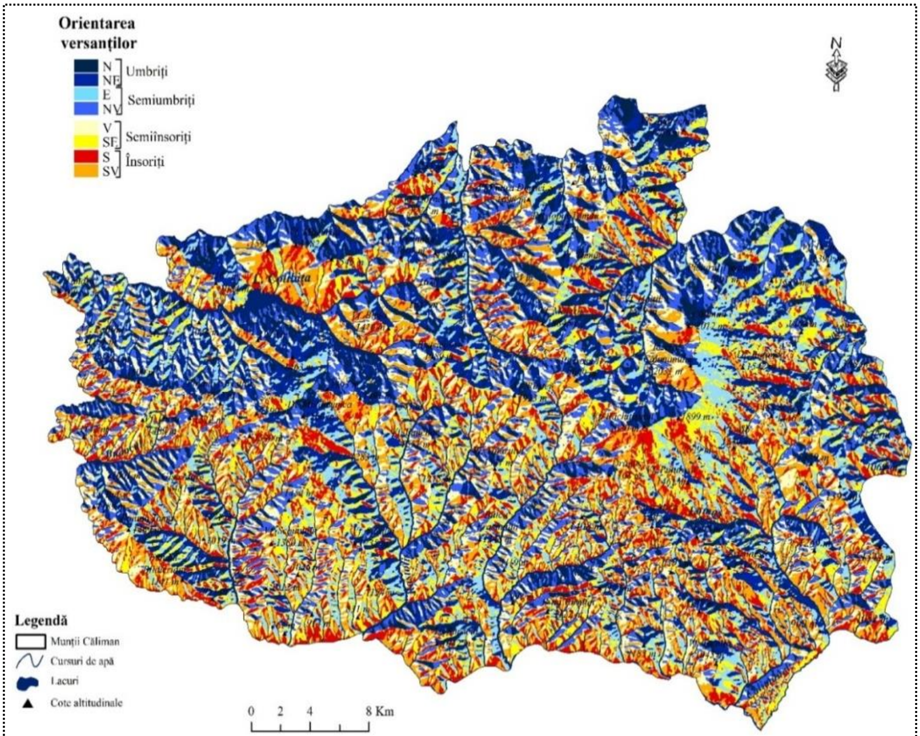

Fig. 5. The exposure of the slopes of the Căliman Mountains (processed from the Digital Elevation Model over Europe (EU-DEM)

In the Mureş basin, the predominant orientation of the slopes (76.97%) is in the E, W, and especially SE, S and SW directions (49.97%) (Table 3), i.e. the sunniest slopes of the entire mountain group, with a richer and faster flow.

The Someş basin presents the highest weights in the N, NE, NW and W directions, more shaded than those in the Mureş basin, but sunnier than those in the Siret basin, also having a lower altitude.

Table 3. The share of slope orientation (in %) from the three watersheds (processed according to data from Digital Romania)

Slope orientation	Hidrographic basin						Total	
	Someş		Mureş		Siret			
	F	%	F	%	F	%	F	%
N	52,61	16,01	43,57	5,57	76,46	16,15	172,63	10,9
NE	45,75	13,93	64,1	8,19	80,73	17,05	190,58	12,03
E	26,25	7,99	111,23	14,22	71,77	15,16	209,25	13,21
NV	55,98	17,04	72,51	9,27	64,65	13,66	193,15	12,19
V	50,18	15,27	99,96	12,78	47,58	10,05	197,72	12,48
SE	25,42	7,74	135,44	17,32	52,28	11,04	213,15	13,45
S	30,31	9,22	131,85	16,86	40,86	8,63	203,02	12,81
SV	42,05	12,8	123,55	15,79	39,13	8,27	204,74	12,92
Total	328,5	100	782,22	100	473,46	100	1584,2	100

3.2. Morphologic characteristics

Naum and Butnaru (1989) claim that in the Căliman Mountains three areas with distinct aspects can be distinguished: an intensely ridged interfluvial relief, modeled in volcanic agglomerates, a plateau area, in the form of a stack of agglomerates and lava flows, and the central caldera surrounded by steep slopes and the dome that dominates the plateau.

The central-axial part represents the unit of the volcanic apparatus or the skeleton of Caliman, which is the result of volcanic eruptions or elements resulting from the collapse of the crater due to violent eruptions.

The most characteristic glacial caldera are grouped on the northern slope of Re8tiş, suspended at a height of 1900 m, in the torrential basins of the most important tributaries of the upper course of the Neagra Şarului river. The lower, peripheral or volcano-sedimentary part has the form of an articulated plateau. Volcanic relief creates radiar-convergent and radiar-divergent outflow. The water courses inside the caldera are placed radially-convergently, and the outer ones are placed radially divergently. Such flow is typical of a volcanic relief (Pop, Gr., 2000).

On the northern slope of the Reţitiş Peak (2021 m), there are the most typical glacial cirques (Fig. 6), two in number, separated by a narrow ridge starting from the summit to the north and drained by the tributaries of the Neagra River. The wall from the summit of the caldera has a steep slope, and their width in a straight line reaches 750-900 m (Someşan, 1948).

The Căliman Mountains are the only volcanic mountains in Romania that bear the imprint of the Quaternary glaciation, whose traces have been preserved in the sectors with high mass and especially in the areas less exposed to solar radiation (Bojan, 1998). The most obvious tectonic-volcanic relief in the geomorphological landscape of the Căliman Mountains is the collapse caldera in its central part.

Fig. 6. Glacier circus in the Căliman Mountains (photo: Costin Hîrlav)

North of Negoiului Unguresc Peak, at an altitude of 1850-1900 m, two smaller calderas appear, below Pietrosul Peak, three calderas located at a height of 1870 m, and on the western flank of Bistricior Peak, two less representative caldera.

The relief surface located between 1700 and 1750 m has a gentle slope and is about 500 m long, ending to the north through a small glacial threshold. On this threshold, from the western cirque, one can distinguish the traces of an arched moraine, which was deposited by the glacier during the last period of evolution (Nagy et al. 2004). Both cirques present the remains of glacial lakes, which were subsequently filled up. Someşan, L. (1948) believes that the two cirque glaciers fed an ice tongue in the valleys that carved a glacial valley of about 3 km in length. The author relies on the "U" shape of the transverse profile of the valley, in the bed of which a postglacial river valley deepened by several meters, but a frontal moraine that would clearly certify this was not detected. The glacial valley here is also confirmed by Naum, Tr. (1970), without providing additional evidence. Also in this region, three cirques entered in the glacio-nival category were identified, two of them being on the northern slope of the Reţiţiş - Bradu Ciont Mountain (Someşan, 1948) and one on the northern side of the Pietricel Mountain (Naum, 1970).

The western side of the caldera represents the appearance of a convex peak, interrupted by vertical walls, there are rocks or rock pillars with special shapes (Twelve Apostles, Santa, Marshal, Martyr) or certain grottoes or caves (Luanei Grottoes).

An unusual volcanic relief is that modelled in volcanic agglomerates, which cover large areas. Where erosion has been activated and managed to shape meteorites resulting from eruptions. This erosion witness relief is found only on peaks and interfluves, where the slope contributed to the intensification of erosion, being absent in the river basins, where the conglomerate cover, being thicker, was better preserved.

4. CONCLUSIONS

The relief of the Căliman Mountains is an important element of the geographic framework within these mountains, with an important influence on runoff. Through the vertical zonation of the main climatic elements, vegetation and soils, which have an important role in the formation of water resources and in the development of water courses. Altitude influences the types of river feeding, at higher altitudes in the Căliman Mountains increasing the weighting of feeding from snow, but also the volume of water transported on the streams in the region, which increases with the decrease in altitude. The slope of the relief is one of the most important factors controlling surface and underground runoff, determining the direction and speed of water runoff on the slopes. The degree of inclination of the slopes influences the coefficients of runoff and speed, concentration and propagation of bed floods – homogeneity,

The differences in orientation, altitude and positioning of the relief between the 3 hydrographic basins determine the amount of precipitation and, consequently, the level of runoff from these basins. The runoff is the richest in the Mures river basin, followed by the Siret basin and the Someș basin, the positioning of the Mures and Someș basins in the path of western air masses influencing the increase in precipitation amounts, the Căliman Mountains acting as a dam in the path of these air masses, on the slope east of these mountains, falling less amounts of precipitation.

REFERENCES

1. Arsene, G. (2012), *Relieful Munţilor Călimani,* [s.n.], Vaslui
2. Bojan, Gh. (1998), *Carpaţii Orientali – 1*, Edit. Cantemir, Bucureşti
3. Mihăilescu V. (1963), *Carpaţii sud-estici de pe teritoriul R. P. Romîne : studiu de geografie fizică cu privire specială la relief*, Edit. Științifică, București
4. Nagy şi colab. (2004) 2004), *Investigation of postglacial surface-evolution in the alpine region of the Calimani Mountains - with an outlook to the cirque region of the Rodnei Mountains*, Analele Universităţii de Vest din Timişoara, GEOGRAFIE, XIV, 101-118
5. Naum, Tr. (1970), *Complexul de modelare nivo-glaciar din Masivul Căliman*, [s.n.], București, Extras din: Analele Universităţii Bucureşti, Geografie, anul XIX, 1970
6. Naum, Tr., Butnaru, E. (1989), *Munții Căliman*, Edit. Sport Turism, București
7. Pop, Gr. (2000), *Carpaţii şi Subcarpaţii României*, Edit. Presa Universitară Clujeană, Cluj-Napoca.
8. Posea, Gr. (2001), *Vulcanismul și relieful vulcanic*, Edit. Fundației "România de Mâine", București
9. Posea Gr., Cioacă A. (2003), *Cartografierea geomorfologică*, Edit. Fundația Zilei de Mâine, București
10. Someşan, L. (1948), *Consideraţiuni geomorfologice asupra Munţilor Călimani,* [s.n.], Cluj-Napoca, Extras: Lucrările Institutului de Geografie, vol. 8, 1947
11. Sorocovschi, V. (2009), *Hidrologia uscatului*, Edit. Casa Cărţii de Ştiinţă, Cluj-Napoca.
12. Sorocovschi, V., Mocrei, I. (1996) – *Diferențieri regionale ale scurgerii râurilor din lanțul neoeruptiv sudic,* în "Studii și Cercetări de Geol., Geof. Și Geogr.", Seria Geografie, T XLIII
13. Ursu, A. (2010), *The contribution of geographic information systems and remote sensing in determining priority areas for hydrogeology*, în Hydrogeology Journal, Vol. 18, pp. 1157-1171
14. *** (1983), *Geografia României, vol. I, Geografia fizică*, Edit. Academiei Republicii Socialiste România, Bucureşt