THE EVOLUTION OF THE SALT LAKES FROM OCNA ŞUGATAG BETWEEN RISK AND CAPITALIZATION

G. ŞERBAN[1], *M. ALEXE*[1], *R. RUSU*[1], *D. VELE*[1]

ABSTRACT. – The Evolution of the Salt Lakes From Ocna Şugatag Between Risk and Capitalization. The diapir anticline microdepression of Ocna Şugatag underwent an accelerated transformation immediately after the end of salt mining (at the beginning of the 1960s). During this period of over 50 years of evolution, lake basins formed and disappeared, either naturally, in small sinkholes, or mostly due to the collapse of salt mine adits or chambers, which led to the creation of large-sized lake basins. There is an accelerated dynamics of these basins, as indicated by the sliding of part of the banks at a pace of 0.5-1.5 meters/year. The collapse of the mines is far from over, because the largest mines (Mihai and Dragoş) are partly affected and the pillars supporting the ceiling of the adits have a small diameter. Given the present conditions, when the underground brine is used for bathing and treatment purposes, in short time it is possible that new lakes emerge, even larger than the already existing ones. From the point of view of the lake potential, there are important differences, according to the degree of salinity of the water and the more or less accelerated dynamics of the lake basins. The latest two years witnessed an important development of the tourism infrastructure in the analysed area, as well as arrangements of the lakes, which determined a significant increase in the number of tourists searching for outdoor bathing, especially during week-ends.

Key words: diapir, anthropogenic-salt lakes, pseudokarst-salt lakes, evolution, risk phenomena, brine use.

1. INTRODUCTION

In the area of Maramureş, mining is a traditional activity, both regarding the excavation of salt, and especially the mining of complex ores related to the volcanic structures which close Maramureş Basin to the South. As the salt deposit of Ocna Şugatag lies at only few meters from the ground, it is possible that rudimentary excavations existed since the Dacian-Roman period. Certain pieces of information concerning salt mining in an industrial manner have been provided

[1] „Babeş-Bolyai" University, Faculty of Geography, Cluj-Napoca, Romania;
serban@geografie.ubbcluj.ro, malexe@geografie.ubbcluj.ro, rrusu@geografie.ubbcluj.ro, dan.vele@geografie.ubbcluj.ro

since the 15th century. Historical sources attest that salt cutters worked in Maramureş salt mines in 1492. They were paid either in money or in kind (salt, food, cloth). Auxiliary labour was performed by serfs (Pânzaru, 1969).

The capitalization of the salt water from the lakes within the Carpathian arch is attested in documents of the Middle Ages (16th century). Several important people of the age (princes, noblemen, physicians) mentioned the curative effect of these waters in their official or private correspondence.

The studies concerning the quality of the salt water of the lakes started a bit later (19th century). They were performed by physicians, chemists and biologists, at the request of the salt mines administration, aiming at the planning of tourism or treatment units. In this sense, one may mention Pataky at Ocna Sibiului (1820), Hanko at Turda (1844) and Sovata (1879), Lengyel, Telegdi and Roth at Sovata (1898), Entz (1886). They analyzed several physical and chemical parameters (temperature, salinity) or the bioitic composition of the water of the salt lakes.

In the first half of the 20th century, researches intensified: Kalecinszky (1901 – Sovata, the first person who studied and explained the heliothermic phenomenon), Schafarzik (1909 – Sovata), Visky (1911 – Turda), Maxim (1929-1943 – Sovata, Sic, Ocna Sibiului, Turda) etc. Most of these researches concentrated on the study of physical and chemical parameters, but also on the dynamics of lake basins.

In the second half of the 20th century, the first complex limnological and hydrogeological studies are published by Gâştescu (1963 and 1971), and later by Pandi (2004), Sorocovschi (2005), Alexe et al. (2006), Şerban (2007). Other studies, regarding the dynamics of the lake basins and salt massifs, were written by Marosi (1959 – Ocna Mureş), Pişota & Popa (1960 – Sovata), Bobeică (1969 – Ocna Sibiului), Panait et al., (1969 – Sovata), Pânzaru (1960-1970 – numerous locations in Transylvania), Trică Valeria (1983 – Sovata), Baciu (2000), Şerban et al. (2005).

Because of the specific mining activity (salt or complex ores), many studies of the area were undertaken by geologists, like Dessila Marcela, 1951, Popescu-Voiteşti, 1953, Năstăseanu, 1956, Maxim, 1962, Kacso (2006), Simon (2006), Damian et al., 2007 etc.

The limnological research of the lake system was performed only between September 1966 and December 1968 by Theodor Pânzaru, who made a complete assessment of all the lake units and executed thorough measurements of their morphological and morphometric elements.

1.1. Geological and morphological aspects

Before the present configuration, Maramureş Basin witnessed several genetic stages (Pop, 2000):

- A Paleogene bay located between Maramureş Mountains and the crystalline ranges of Rodna, Preluca, Dealu Mare, Dealu Codrului. It was a continuation of the Transylvanian inner-Carpathian basin, a bay where thick strata of Eocene and Oligocene sandstones deposited (fig. 1);

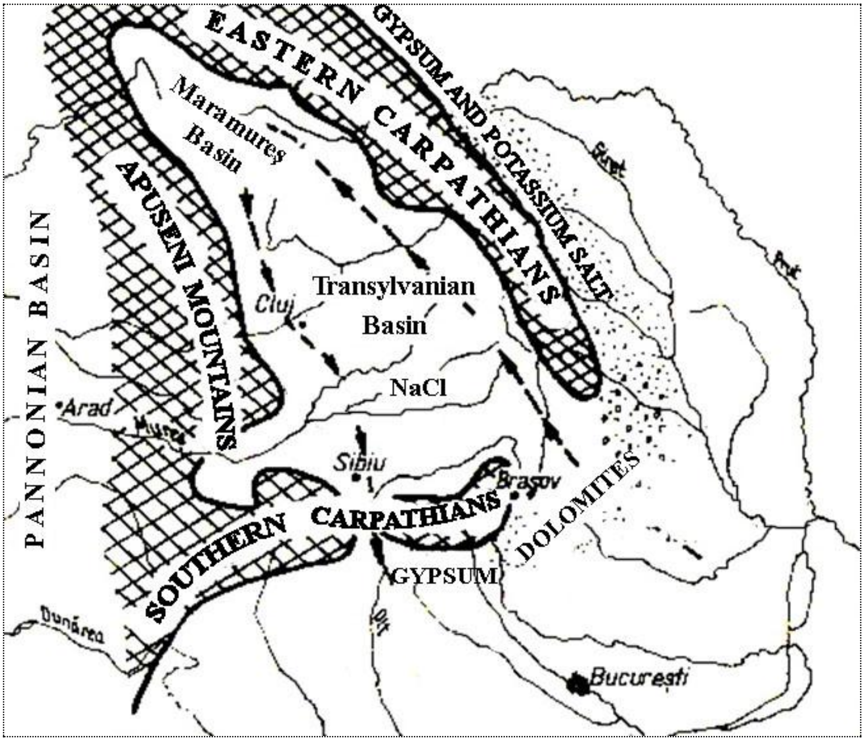

Figure 1. The lagoonal stage of the inner-Carpathian basin during the pre-volcanic period (according to Ciupagea et al., 1970).

- Starting with the Badenian, the volcanic range Oaş-Gutâi-Ţibleş was formed as a result of tectonic fragmentation. The former bay was divided into two longitudinal compartments: the eastern one comprised Maramureş Basin, while the western one included the basins of Baia Mare, Copalnic and Lăpuş. In Maramureş Basin, the Miocene-Pliocene bay continued only in the middle and lower part of Iza basin, where a number of sedimentary rocks deposited: marls, clays, sands and salt (Coştiui, Ocna Şugatag);

- The Upper Pliocene marks the third stage, when the subaerial modeling of the glacis on the northern side of Gutâi Mountains started as a consequence of the retreat of the sea waters.

The salt massif of Ocna Şugatag represents an apophysis of the unitary massif of Maramureş Basin. Reaching the surface of the ground, it was cut by the

Pliocene erosion, then covered by the piedmont deluvial and colluvial deposits of the Quaternary (Pânzaru, 1969). This hypothesis was also supported by other authors, like Popescu-Voiteşti, 1953; Năstăseanu, 1956; Iorgulescu et al., 1962.

The piedmont cover in the North of Gutâi Mountains, which extends all over the watershed between Mara and Cosău rivers, was removed by the erosion of Pârâul Sărat (Salty Brook). The result was an egg-shaped microdepression, with the long axis oriented from North to South, which corresponds to the upper basin of Pârâul Sărat.

1.2. The closing of the salt mines

The slopes of the basin are steep on the eastern and western sides and gentle towards South, where torrential erosion penetrated regressively in the piedmont structure. The microdepression bed presents a chaotic morphology, as a consequence of the joined action of subaerial agents, Pârâul Sărat and the anthropogenic factor. Apart from the disordered storage of the waste resulted from salt mining, people created the conditions for an accelerated dissolution of the mineral, both at the surface and especially underground. The result was the appearance of several lakes, on the location of the former mines or in small sinkholes, which emerged due to the dissolution of salt and the settling of the covering sedimentary material.

The system of drains organized on the surface and the guidance of the underground waters to the collecting pits allowed the development of salt mining activities until the date of June 24, 1948, when water started to infiltrate through the ceiling of Dragoş mine (the last functional mine). The outcome was the execution of a complex geological study concerning the mines and the adjoining territory, in 1949. The conclusions of the study were not in favour of the continuation of mining, because they revealed a network of secondary fault lines crossing the area, including the salt massif. These fault lines facilitate a good underground drainage of water and significant infiltrations in the salt mine chambers and adits.

Taking into consideration these conclusions, the state institutions ordered the termination of salt mining on May 11, 1950, and the official closing of the salt mine took place in May 31, 1950. Water was no longer extracted from the main mines (Bogdan, Mihai and Dragoş) and the underground equipments were dismantled on September 1, 1950. The flooding of all the underground empty spaces and the accelerated dissolution of salt started after this moment.

2. METHODS

Compared to the previous measurements, performed with levels and theodolites for the operation of topometry, and with a simple manual sounding line for bathymetry, the recent technical devices facilitated the development of campaigns with precise measurements.

In this purpose, GPS Trimble and Magellan terminals were used for the execution of topometry, together with total stations in the sectors with consistent tree tops. For bathymetry, simple sounders or sounding winches were used in the case of small and less accessible lakes. On Gavrilă Lake, we managed to draw profiles using the ultrasonic sounder. In the shallow areas, the profiles were doubled by classic measurements.

For other measurements (for instance, physical and chemical parameters), we used portable cases for water quality, comprising sensors capable of measuring the values of 12 parameters (such as transparence, temperature, pH, conductivity, dissolved oxygen, salinity, resistivity, oxygen saturation).

The information was centralized and processed with the help of the computer, using the following systems and programmes: GPS Utility, Microsoft Office; The Scientific Software Group's "Groundwater Modelling System-GMS"; ESRI ArcView 3.x; ESRI ArcGIS/ArcINFO 10.x.

3. RESULTS AND DISCUSSIONS

Before the closing and abandonment of the mines, the state institutions had applied measures of protection for the mining perimeter (draining of the water pockets on the surface of the salt, draining of the infiltrated underground waters, the deviation of Pârâu Sărat etc). After this moment, the anthropogenic factor drastically limited the interventions upon the formerly mined salt structure. The effect of the dissolution of salt in the underground and on the surface of the diapir was immediate, resulting in the formation of 8 anthropogenic salt lakes and 35 pseudokarst salt lakes (Pânzaru, 1969). Many of the latter ones were in fact only small-sized holes.

One of the results of the recent researches made by the authors is a new inventory of all the lake units of the system. For now, there are 8 anthropogenic salt lakes (some of the older ones disappeared and some new ones appeared later on) and only 4 pseudokarst salt lakes, while the others silted up and were invaded by hygrophilous and halophilic vegetation (fig. 2).

The anthropogenic salt lakes were created generally due to the collapse of the ceiling of the salt mines as a result of the dissolution of the supporting pillars within the mining chambers and adits. The process took place because of the infiltration of phreatic waters in the salt mines and their flooding after the evacuation of the mining equipments. Several huge holes were formed on those locations. They were gradually filled up with water, coming either from rainfall and slope streams, or from underground sources. In many cases, the haline solution formed within the salt mines reached saturation, therefore the dissolution stopped and the unaffected support elements (pillars) witnessed a relative stability.

In many cases, the haline solution formed within the salt mines reached saturation, therefore the dissolution stopped and the unaffected support elements (pillars) witnessed a relative stability.

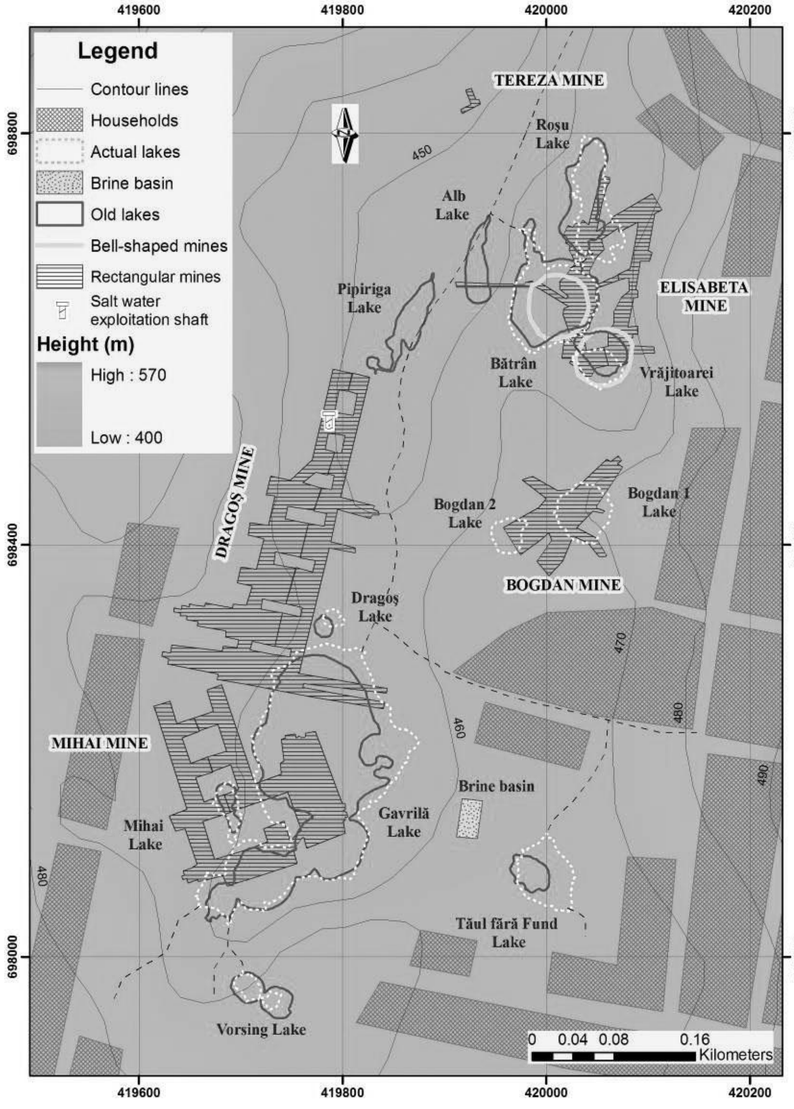

Figure 2. Old and new lakes in the diapir anticline microdepression of Ocna Şugatag.

The pseudokarst salt lakes were formed in sinkholes, which were created, in their turn, in two ways: the small-sized collapse of the ground covering underground empty spaces, determined by the infiltration of underground waters on the surface of the salt massif and the slow settling of the ground, as a result of chemical suffusion and of the dissolution of saline outcrops or even of the mineral from the surface of the salt massif, succeeded by mechanical suffusion because of the infiltration waters or underground waters.

In previous studies, professor Pânzaru identified three areas of distribution of the lake units across the microdepression (1969, Lacurile antropice p. 253). The southern area includes several anthropogenic salt lakes, like Gavrilă, Tăul Fără Fund, the basin of the ancient spa, and a few pseudokarst salt lakes – e.g. Vorsing, Mihai, etc. The North-East area comprises the anthropogenic salt lakes of Vrăjitoarei, Bătrân and Roşu, as well as some pseudokarst salt lakes (Lacul Alb), among others. The Pipiriga area consists exclusively of pseudokarst salt lakes, such as Pipiriga de Sus, Pipiriga de Mijloc and Pipiriga de Jos (Upper, Middle and Lower Pipiriga), Fântâna de la Slatină, and other very small water bodies, named by the author with Arab numbers (lakes 4 … 25) (fig. 2).

By now, the configuration of the lake system of Ocna Şugatag has changed, which renders evident a very active dynamics of the microdepression and of the lower slopes. Therefore, the lakes of the southern area generally increased significantly their area due to the collapse or abrasion of the banks, while their number remained about the same. In the northern area, the spatial distribution of the lakes has changed much. Some water bodies disappeared completely and were replaced by small barren plateaus (with high salinity – e.g. Pipiriga system – Şerban, 2008).

As a consequence of the continuous process of salt dissolution in the underground, new lake units appeared, like Bogdan 1 and Bogdan 2, creating a new sector in the central area of the microdepression. These lakes were formed and evolved in the 1970s and 1980s due to the collapse of Bogdan mine and its raising shaft to the South-West. Bogdan 1 and Bogdan 2 are very spectacular lakes, due to their shape, and the height difference between the watershed cornice and the water level. Unfortunately, they are not well preserved and became waste deposits for the locals in the latest years.

After the processing of topometry and bathymetry data, one notices significant changes of the main morphometric elements of the lake units (table 1).

Apart from the appearance or disappearance of lakes, one remarks significant increases of the areas or volumes as an effect of the dissolution of salt, the collapse of slopes or the withdrawal of banks (as in the case of Gavrilă Lake – the largest one of its type in Romania, together with the salt lake in Ocna Mureş –, Tăul fără Fund, Mihai and Dragoş lakes). In other situations, one notices a decrease of these elements, due to landslides, alluvial slope flows and silting (Vorsing, Vrăjitoarei and Bătrân lakes).

Table 1. The dynamics of the main morphometric elements of the salt lakes of Ocna Şugatag (after Şerban, 2008).

N°	Element / Lake	Year of survey	Area (S-m²)	Length (L-m)	Average width (B_m-m)	Maximum width (B_{max}-m)	Average depth (h_m-m)	Maximum depth (h_{max}-m)	Volume (V-m³)	Perimeter (m)	Sinuosity index
1	Vorsing *	1968	1514	69.50	21.78	30.00	2.82	6.90	4277	204.0	1.48
		2006	673	54.65	12.31	22.20	1.14	4.10	764	155.1	1.69
2	Gavrilă **	1968	23542	341.50	68.94	134.00	10.58	29.95	249102	1048.0	1.93
		2006	28312	338.78	83.57	162.26	9.70	25.70	274667	953.9	1.60
3	Mihai *	1968	672	47.50	14.15	20.00	0.87	3.80	587	131.5	1.43
		2006	764	62.09	12.30	24.89	0.90	3.10	687	154.8	1.58
4	Tăul Fără Fund **	1968	1625	48.50	33.51	31.00	1.39	32.90	2259	132.0	1.05
		2006	2858	85.93	33.26	54.75	1.41	31.50	4042	228.5	1.21
5	Dragoş **	1968	70	10.30	6.80	9.90	1.28	17.00	89	30.0	1.01
		2006	246	22.17	11.11	18.17	1.20	15.20	295	63.4	1.14
6	Bogdan 1 **	1968	-	-	-	-	-	-	-	-	-
		2006	2324	61.08	38.05	56.58	3.07	7.30	7146	192.2	1.12
7	Bogdan 2 **	1968	-	-	-	-	-	-	-	-	-
		2006	871	42.92	20.30	34.12	1.10	2.70	962	116.5	1.11
8	Vrăjitoarei **	1968	1758	56.80	30.95	43.00	3.49	6.80	6133	160.5	1.08
		2006	1171	52.59	22.27	35.30	2.98	6.00	3485	143.6	1.18
9	Bătrân **	1968	6226	130.00	47.89	85.50	6.13	15.70	38175	369.0	1.32
		2006	6012	129.90	46.28	93.72	5.51	12.70	33149	374.5	1.36
10	Roşu **	1968	3337	125.00	26.70	45.00	1.00	2.25	3337	342.0	1.67
		2006	3590	129.07	27.81	46.50	0.76	2.10	2743	389.3	1.83
11	Pipiriga de Jos *	1968	1708	105	16.27	26.5	2.04	2.65	3485	248.0	1.69
		2006	-	-	-	-	-	-	-	-	-
12	Alb *	1968	1348	84.5	15.95	23.5	0.31	0.74	420	190.0	1.46
		2006	-	-	-	-	-	-	-	-	-

* pseudokarst salt lake
** anthropogenic salt lake

Also, the phenomena and processes that are specific for this class of lakes left their mark upon the evolution of banks, as proved by the changes of the perimeter and of the sinuosity index.

Roşu Lake represents a different class, intermediate between the two types of evolution. Although its area increased a little, as a result of the basin relocation, the maximum volume and depth decreased significantly because of the slope alluvia and the landslide waves which affect the lake on three quarters of its circumference.

Apart from the measurements concerning morphometric elements of the lakes, we performed measurements regarding several physical and chemical parameters, in order to establish the capitalization potential of the water in the lakes (table 2).

Gavrilă and Bătrân lakes are the most important ones from the point of view of development opportunities (fig. 2). In order to provide an example, we selected the most representative values from the set of data we obtained during our numerous measurement campaigns. These values present the variations of parameters at their highest recorded amplitude.

Table 2. Physical and chemical characteristics of the lakes of interest for bathing facilities on the date of July 5, 2006 (2 p.m.)

Lake	Depth (m)	Temperature (^{0}C)	pH	Salinity (mg/l)
Bătrân	Surface	29.9	7.66	35.8
	-1	25.2	7.80	36.1
	-2	**34.7**	6.56	64.0
	-3	28.3	6.69	65.0
	-4	26.3	6.80	68.0
	-11.5 (bottom)	22.5	6.62	70.0
Gavrilă	Surface	28.8	7.50	0.0
	-1	21.6	7.09	0.0
	-2	14.8	7.17	0.0
	-3	11.1	7.32	0.0
	-4	10.0	7.35	0.0
	-20.5 (bottom)	7.5	6.80	0.8

In this regard, the values of water temperature are high during summer, and they are optimal for bathing. The vertical distribution of the water temperature of Bătrân Lake proves the existence of heliothermy. The presence of this phenomenon at Ocna Şugatag is somehow surprising, taking into account certain local geographical characteristics, such as the latitude and the higher nebulosity, which determine moderate temperatures and relatively high amounts of rainfall during summer.

The salinity of the water in the two lakes is utterly different. For Bătrân Lake, the values of salinity are those characteristic for anthropogenic salt lakes, which keep the contact between the water and the salt at their bottom, ranging between 35 g/l on the surface and 70 g/l at the bottom. In Gavrilă Lake, this contact is interrupted, as the salt was isolated by the clay resulted from the collapse of the ceiling of the former Mihai mine (fig. 2). As a consequence, the salinity of the water in this lake tends to 0 g/l, as proved by the vegetation which extended in the southern part and the well represented fish fauna (including Cyprinidae).

Regarding the values of pH, one notices a specific feature of the lakes developed on salt, that is a transition of the water pH from basic at the surface towards acidic in depth. The nature of the water is reversed within the haline salt layer (between 1.5 and 3 meters) and is due to the increase of the degree of mineralization, of the oxidoreductive processes and of the amounts of carbon dioxide. Also, deeper, the acidification of water is determined by the presence of acidifying proteobacterias and the processes of decomposition.

Some lake units registered visible transformations of their basins, even regarding location. They may represent risks, under the effect of the massive landslides on the eastern and western slope of the microdepression (Roşu, Vrăjitoarei and Bătrân lakes – Şerban, 2008). Practically, these lake basins are permanently unstable.

As a result of the 2008 granting of land, the human intervention (with bulldozers and excavators) on Roşu Lake and some other lakes had negative repercussions on their natural evolution. The intervention was made in order to render the lakes useful for capitalization, and not to preserve or protect them. The perimeters of all the lakes were surrounded by fences in view of their bathing and nautical use, while Roşu Lake was designed for fishing, by excavator dragging. By doing this, the idea of capitalizing the therapeutic muds was given up, and the result will be an aggressive exploitation of the only remaining salt lake of the system, Bătrân Lake.

Another element of risk is the continuous extraction of the brine present in the underground empty spaces of yet uncollapsed mines (especially Dragoş mine). Brine is used for bathing purposes in the new and old spas, and by private entrepreneurs in numerous basins set up recently. The extracted supersaturated salty water is quickly replaced by the fresh water of the phreatic level, which reactivates the dissolution of salt and therefore the destruction of the pillars which support the ceiling of the mines. This fact may generate large-sized collapses which may result in the creation of new lakes, even larger than the existing ones (fig. 2).

The downfall of the yet unaffected parts of mines (Mihai) and of Dragoş mine would determine significant changes in the landscape and would affect the stability of the households located in the western sector of Pârâul Sărat Valley. Practically, the entire floodplain would be covered by a huge lake resulted from the junction of Mihai and Dragoş lakes. It would probably become one of the largest lakes generated by the collapse of a salt mine.

The anthropogenic salt lakes of Ocna Şugatag have quite a high potential of capitalization during summer. The most important parameters for outdoor bathing are water temperature and salinity in the superficial layers. From the point of view of temperature, both lakes are favourable for bathing during summer, because the water temperature in the layer of 0-3 meters was higher than 210C in every year when measurements were performed (2005-2009). At the surface, water temperatures were frequently higher than 25 0C, while the highest values reached almost 300C in the heliothermic layer of Bătrân Lake (fig. 3).

As a matter of fact, this phenomenon represents one of the main attractions of Bătrân Lake, together with the high salinity, which allows people to float almost effortlessly. This lake is visited during the entire warm season, when air and water temperatures are favourable for bathing (fig. 4).

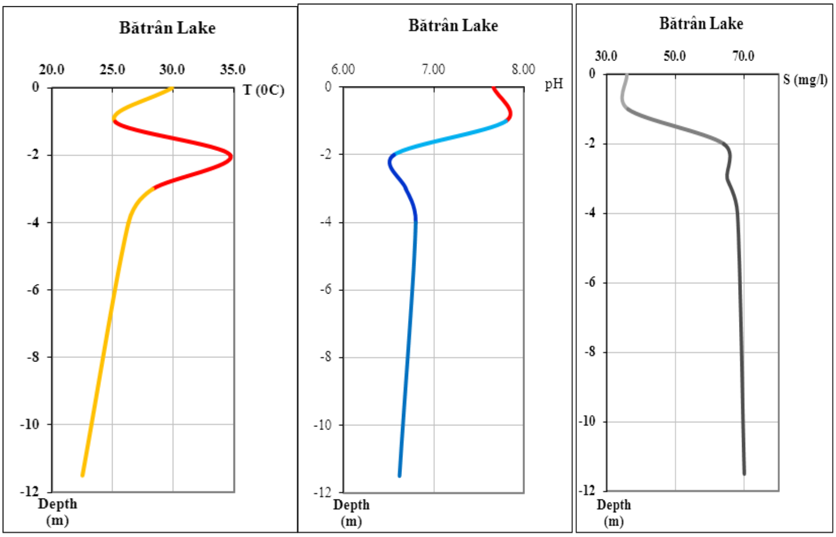

Figure 3. Vertical variation of the temperature, pH and salinity of the water of Bătrân Lake on July 5, 2006 (2 p.m.).

Figure 4. Bătrân Lake – panoramic view.

Figure 5. Gavrilă Lake – panoramic view.

Because of its large size (28312 m^2), Gavrilă Lake is mainly used for the practice of nautical sports and fishing, and less for bathing. The latter activity has been restricted because of the numerous cases of drowning of the latest years. Accidents occur because of a number of cold currents that are present at the surface of the water, as a result of the convective exchange of water between the superficial and deep layers (fig. 5).

Other aspects may be added to those presented above, such as: the favourable location, in the neighbourhood of highly ranked tourist attraction (Bârsana Monastery, Sighet Memorial Museum of the Victims of Communism, the Merry Cemetery of Săpânţa, the traditional hydraulic installations of Hărniceşti, etc); the beautiful landscape, comprising the ancient forest of the northern part of the microdepression, and the surrounding mountain ranges, with numerous landforms generated by the former volcanic activity (Gutâi Peak, Creasta Cocoşului, Igniş Plateau, etc); the recent accelerated development of the tourism infrastructure.

However, there are also less favourable factors for the capitalization of the natural potential of Ocna Şugatag area during summer, such as: lower values of insolation; the rather high frequency of rainy days; the relatively high residual pollution of certain lakes; the improper behaviour of some tourists and some local investors.

CONCLUSIONS

The egg-shaped diapir anticline microdepression of Ocna Şugatag is one of the most active in Romania. It has a much accelerated dynamics, as proved by the appearance and disappearance of numerous water bodies and a fast transformation of the existing lakes in a relatively short period of time.

The new techniques used to perform observations and measurements and to process the resulting data determined higher levels of performance as regards the analysis of processes and phenomena that take place in diapir areas.

Numerous elements of risk are identified as a result of the ancient and recent chaotic intervention of the anthropogenic factor upon the natural balance between the landscape elements of the area.

We consider that there are high chances for Ocna Şugatag to develop further as a tourist attraction and to overcome the level of a local interest SPA resort.

REFERENCES

1. Alexe, M., Şerban, Gh., Fülöp-Nagy, J., 2006. *Lacurile sărate de la Sovata*. Editura Casa Cărţii de Ştiinţă, Cluj-Napoca, 107 p.
2. Baciu, C., 2000. *Evoluţia rezervoarelor de apă sărată de la Ocna Sibiului din perspectiva geologiei ambientale*, Studii şi cercetări, Geologie-Geografie, seria Geologie, nr.5, Bistriţa.
3. Bulgăreanu, V.A., 1982. *Studii limnologice şi hidrogeologice complexe în zona lacurilor sărate carstosaline şi antroposaline de la Ocna Şugatag şi Coştiui, jud. Maramureş*, Arhiva A.N.R.M.
4. Ciupagea, D., Paucă, M., Ichim, Tr., 1970. *Geologia Depresiunii Transilvaniei*, Editura Academiei R. S. România, Bucureşti.
5. Damian, Gh., Damian Floarea, Macovei, Gh., Constantina, C. & Iepure, Gh., 2007. Zeolitic tuffs from Costiui zone - Maramures Basin, Carpthian Journal of Earth and Environmental Sciences, vol. 2, no. 1, pp. 59 – 74.
6. Dessila, Marcela, 1951. *Raport geologic preliminar asupra regiunii Ocna-Şugatag-Breb*, Comitetul Geologic, nr. 902, Bucureşti.
7. Gâştescu, P., 1963. *Lacurile din R.P.R.–Geneză şi regim hidrologic,* Editura Academiei R.P.R., Bucureşti.
8. Gâştescu P., 1971. *Lacurile din România-Limnologie regională.* Editura Academiei R.S.R., Bucureşti.
9. Gâştescu, P., Driga, B., Anghel, Cornelia, 1985. *Noi posibilităţi în valorificarea lacurilor helioterme din România,* Studii şi cercetări de Geologie, Geofizică şi Geografie, seria Geografie, tom XXXII, Bucureşti.
10. Kacso, C., 2006. *Date cu privire la exploatările timpurii de sare din Maramureş.* În volumul "Sarea, Timpul şi Omul", Editori Cavruc, V., Chiricescu, Andrea, Editura Angustia, Sf. Gheorghe (CV), 250 p.
11. Iorgulescu, T., Niculescu, N., Peneş, Maria, 1962. *Vârsta unor masive de sare din România,* Editura Academiei Române, Bucureşti.
12. Maxim, I. Al., 1962. *Câteva observaţii asupra aspectelor morfologice ale locurilor de apariţie a masivelor de sare din Transilvania (II)*, Studia Universitatis „Babeş-Bolyai", Seria Geologie-Geografie, Fasc. 1, Cluj-Napoca, pp. 17-39.
13. Morariu, T., Gâştescu, P., Savu, Al., Pişota, I., 1960. *Les types génétiques de lacs et leur délimitation sur le territoire de la Roumanie.* Reccueil d'études géographiques concernant le territoire de la Roumanie, Bucureşti, pp. 83-89.
14. Năstăseanu, S., 1956. *Contribuţii la cunoaşterea miocenului din regiunea Sighet-Ocna Şugatag,* Dări de seamă ale Comitetului Geologic, vol. XL, Bucureşti.
15. Pandi G., 2004. *Lacul Roşu. Studiu hidrografic.* Editura Casa Cărţii de Ştiinţă, Cluj-Napoca.
16. Pânzaru, Th., 1969. *Lacurile antropice de la Ocna Şugatag, Maramureş. Aspecte morfologico-morfometrice,* Lucrările ştiinţifice ale Institutului Pedagocic, Oradea, pp. 249-268.
17. Pânzaru, Th., 1969. *Lacurile carsto-saline din complexul lacustru de la Ocna Şugatag-Maramureş. Aspecte morfologice şi morfometrice*, Studia Universitatis „Babeş-Bolyai", Cluj-Napoca, pp. 103-116.

18. Pop, P. Gr., 2000. *Carpaţii şi Subcarpaţii României*. Editura Presa Universitară Clujeană, Cluj-Napoca, 264 p.
19. Popescu-Voiteşti, I., 1953. *Sarea regiunilor carpatice româneşti.* Comitetul Geologic, Bucureşti.
20. Simon, Zs., 2006. *Mineritul de sare în Evul Mediu în Transilvania şi Maramureş.* În volumul "Sarea, Timpul şi Omul", Editori Cavruc, V., Chiricescu, Andrea, Editura Angustia, Sf. Gheorghe (CV), 250 p.
21. Sorocovschi, V., 2005. *Câmpia Transilvaniei. Studiu hidrogeografic*, Editura Casa Cărţii de Ştiinţă, Cluj-Napoca, 212 p.
22. Şerban, Gh. 2007. *Lacurile de acumulare din bazinul superior al Someşului Mic. Studiu hidrogeografic.* Editura Presa Universitară Clujeană, Cluj-Napoca, 236 p.
23. Şerban, Gh., 2008. *Anthropo-saline and karsto-saline lakes from Ocna Şugatag – Maramureş (Romania)*. „Lakes, reservoirs and ponds", Romanian Journal of Limnology, 1-2, Ed. Transversal, Târgovişte, pp. 80 – 89.
24. Şerban, Gh., Alexe, M., Touchart, L., 2005. *L'evolution du modele lacustre et la salinite des lacs de Cojocna (Plaine de Transylvanie, Roumanie),* Bulletin de l'Association de Geographes Francais, No 2, Juin, 82e annee, Section II: Lacs, etangs et zones humides: une demarche de geographie limnologique, Paris, France, pp. 234 - 245.
25. Touchart, L., 2000. *Les lacs. Origine et morphologie.* Editure de L'Harmattan, Paris, 210 p.