CONSIDERATIONS REGARDING THE SALINITY AND WATER TEMPERATURE OF SALTY LAKES OF SOVATA AND OCNA SIBIULUI

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ABSTRACT. The very salty water of the lakes from the studied areas, associated with the reduced capacities of basins and a change of water rather absent, is characterized by a specific variation in time and space of the physical and chemical parameters. In this study we appealed to selective analysis of the most representative parameters (salinity and temperature), which provide jarring feature in analogy with other lakes. No doubt, the variation of salinity establishes various forms of anomaly in the running of all physical and chemical parameters, generating spectacular vertical modifications (heliothermy, transition from acid ph to basic, high reduction of oxygen to the depth associated with the growth of the quantity of H_2S etc.). The stimulation of an intense dynamics of water in the superficial strata the through or local contribution of fresh water comes to complicate even more the distribution on time and space of the salinity and temperature.

Keywords: lake, salinity, temperature, heliothermy, variation in time and space

INTRODUCTION

Ever since the middle of the XIXth century, there has been a certain interest regarding the physical and chemical properties of the water from the salt lakes from the Transylvanian Basin, especially on the temperature and water salinity.

In 1885, P. Schnell made his first notes regarding the physical properties of the salt lakes from Ocna Sibiului, and Friedenfels (1880) undertook an ample study of the biological elements in these waters, noticing the existence of *Artemia Salina*. In this article we can find some field measurements of water temperature made by dr. Stronie – local doctor – who observed, on the 15 December 1879, that when the air temperature was around -19 °C, at the depth of 0.6 m, under the ice sheet of Lakes Horia, Cloşca and Crişan, the water had the temperature of + 7.5 ^{o}C.

In 1901, S. Kalecsinszky made some field measurements on the temperature and salinity in Lake Ursu and Negru (Sovata), which made possible to define the phenomenon of water heating in these salt lakes. Later on, A. Rigler (1902 – Sovata, Ocna Sibiului), F. Schafarzik (1904 – Sovata), M. Rozsa (1910 – Sovata, Ocna Sibiului), had their contribution regarding the stage and evolution in time of water temperatures and concentrations.

A great contribution in the knowledge of salt lakes properties in Transylvania had the papers of Professor I. Al. Maxim, who presents not only scientific researches of his precursors but also his own studies on the lacustrine complexes from Sovata (1926) and Ocna Sibiului (1926, 1930). Also he presents some data about the optical properties of waters – transparency and color.

We can add the researches made by I. Pişota (1955 – Sovata), Al. Bobeică (1965 – Sovata, 1966-1967 – Ocna Sibiului), who studied the vertical distribution of temperatures in the salt lakes.

Some recent researches are the one of T. Pânzaru, made in 1977 and 1982, where he shows some physical and chemical properties of the salt lakes from Ocna Sibiului and those made on the lakes from Ocna Sibiului and Sovata by the authors of this article between 2003-2005 (fig. 1).

In this article, because of the dynamics of the two sectors, due to salt disolvation, we resorted to the analysis of two of the most representative parameters (salinity and temperature), which make the difference to other genetic category of lakes.

The variation of salinity establishes various forms of anomaly and dependences on the running of all physical and chemical elements, generating spectacular evolutions not only on horizontal level, between the contact zones with salt and those influenced by effluents or tributaries, but also on vertical one (heliothermy**,** transition from acid pH to basic, dramatic droppings of dissolved oxygen with depth and the growth of hydrogen sulfide concentrations etc.).

Because of the high dynamics of water in the superficial layers due to bathing and local contribution of fresh water, the distribution in time and space of the analyzed parameters is more complicated.

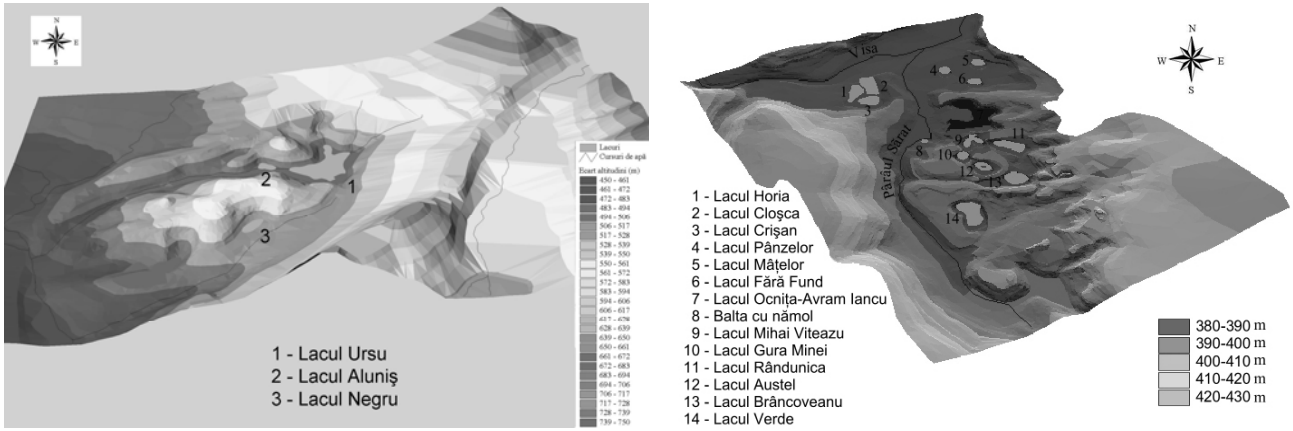

Fig. 1 Salt lakes from Sovata and Ocna Sibiului

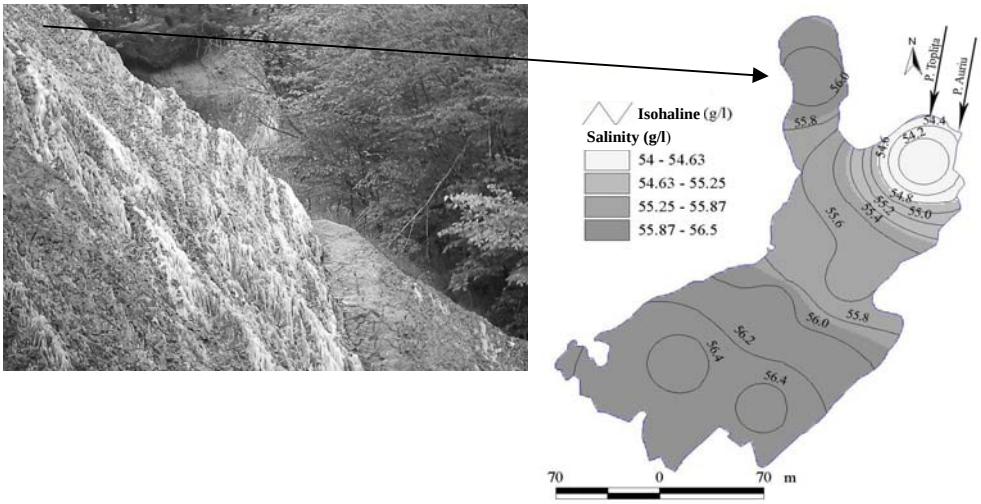

Fig. 2 Distribution of salinity at the surface of Lake Ursu (2004)

SALINITY OF THE LAKES

Regarding the variation of salinity at the surface, we can observe minor differences in the running of the values, excepting the lakes where are contact zones with salt and affluence of some torrents. In the case of Lake Ursu (Sovata), the salinity at the surface in the north-eastern compartment drops with 3 g/l (because of Topliţa and Auriu rivulets), in opposition to the north-western zone where there is a contribution of very salty water from the salt mount (fig. 2).

We can observe the same situations in the case of other salt lakes with direct contact with the salt mount: Lake Roşu (Sovata), Ocniţa-Avram Iancu Complex (Ocna Sibiului). In the absence of permanent contribution of rivulets with fresh water the differences are insignificant.

The vertical variation of salinity differs from one lake to another not only in time but also in concentrations, the lakes formed in ex salt mines present a high stability in this regard.

The vertical distribution of salinity illustrates the existence of three layers with various concentrations (fig. 3):

- the upper layer with the lowest salt concentrations, is characterized by high daily, seasonal and annual variations because of the influence of precipitation, of torrent contribution etc.;
- the middle layer (0,5 – 4 m deep) where the salinity grows to 250 – 300 g/l. This layer is also known as the salt jump layer. In literature it appears under different names: "litocline" (Dussart) or "halocline" (Touchart, 2002). Also this salt jump layer coincides with the mesothermic layer;

the lower layer, from 4-6 m to the bottom of the basins. Here the salinity reaches 250-320 g/l (or even more than 320 g/l) and remains almost constant all the year, rarely being influenced by water dynamics from the upper layers.

Also there are lakes with direct contact with the salt massif beginning from the surface, which determines a homogeneous distribution of salinity up to the bottom (Lake Brancoveanu – Ocna Sibiului). This lake is very salty (310 g/l) starting from the surface.

Vertical salt concentration is being modified not only by the hydrologic balance or free or forced convection, but also by anthropic influence, especially in summer, when in the upper layer the concentration is higher than in the rest of the year because of bathing (fig. 4).

Before the bathing season, the values are 15-20 % lower than in the period of activity, when the concentrations increase to the depth of 1-3 m and the lowering of the jump layer with 0.5 – 1 m. After this season, the concentrations are back to normal.

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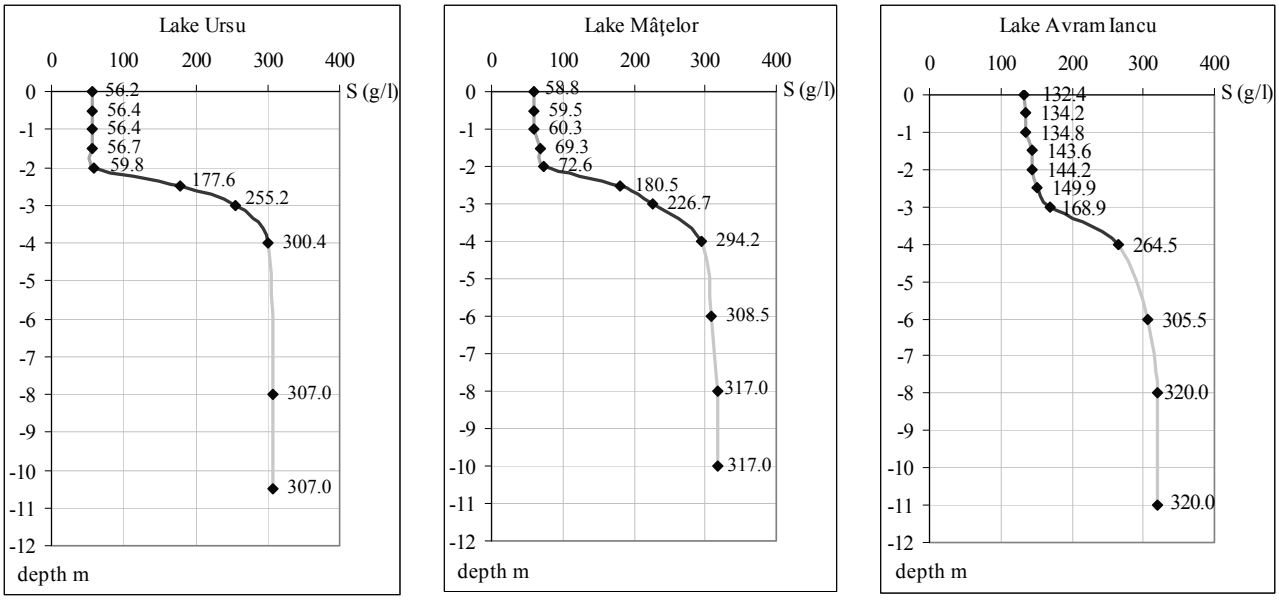

Fig. 3 Vertical distribution of salinity in the case of the most representative salt lakes from Sovata and Ocna Sibiului

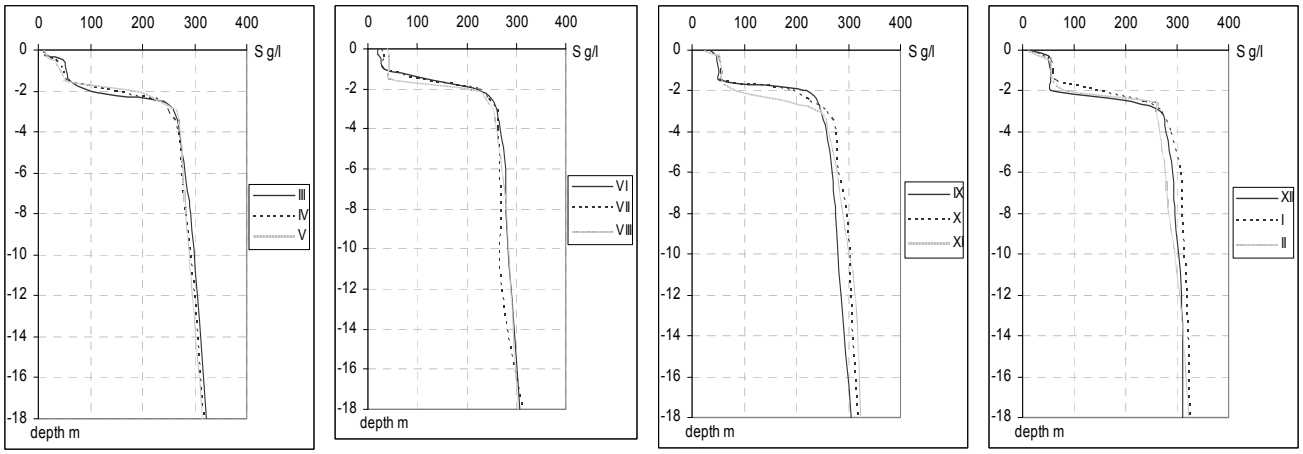

Fig. 4 Seasonal variation of salinity in the case of Lake Ursu (1992)

The stability of stratification and extension of the heliotherme layer can be disturbed not only by anthropic influence but also by natural ones, all the year long (fig. 5).

In the case of Lake Ursu, for example, the whole north-eastern compartment is influenced by inflow of fresh water from Topliţa and Auriu rivulets. As a result we can observe the pushing over 0.5 m of the heliotheme layer (begins at 2.5 m unlike 1.75 m in the north-western compartment and 2 m in the rest of the lake).

In the case of some salt lakes from the Transylvanian Basin we noticed a general process of water sweetening. This is caused by the interruption of the direct contact between the lake and the salt mount due to the collapse of clastic rocks. Lake Verde (Ocna Sibiului) is a good example in this case, which has a salinity of 8 – 9 g/l.

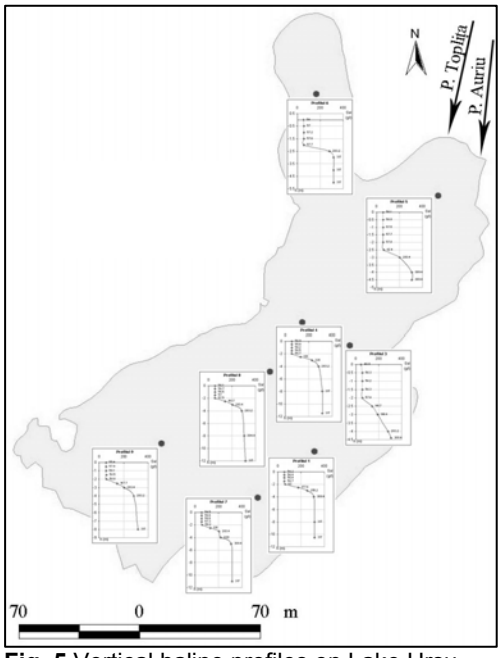

Fig. 5 Vertical haline profiles on Lake Ursu, Sovata – July 2004

TEMPERATURE OF WATERS

A special place among the phisical properties is taken by temperature. On the basis of the gathered data we can say that the evolution of temperature at the surface of salt lakes is the same as in the case of mild lakes because of the influence of air temperature. The amplitude of water temperature is lower than air temperature.

Obvious differentiations in the vertical distribution of temperatures are in the case of deep lakes and in concordance with the existence or inexistence of a superficial layer of fresh water, which would fulfill the role of thermal insulator. Because of the high concentrations of salt and great depths, the distribution of temperatures is very complex, with different variations from one basin to another and from one season to another.

The salt lakes over 5-10 m deep and with a fresh water layer at the surface, present a special thermical structure, also known as ”paradoxical structure” or ”thermical anomaly” (Touchart, 2002). It is about *mesothermy*, which can be defined as the existence of a 2-3 m deep layer in metalimnion with higher temperatures than in the one from the surface (epilimnion) and the one below (hipolimnion), with maximum concentrations of salt, witch remains almost the same to the bottom of the lake (fig. 6).

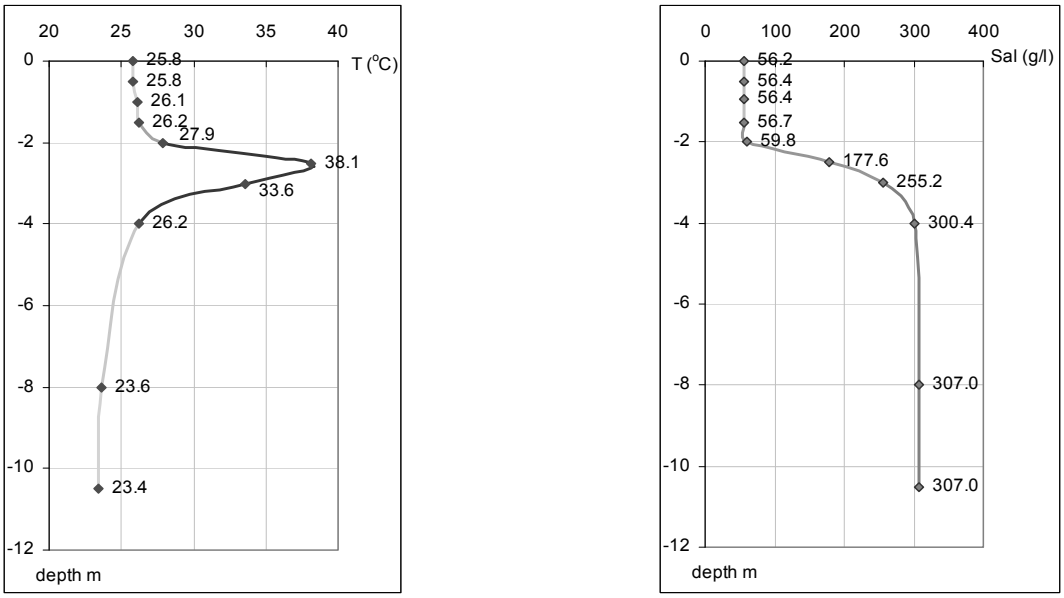

Fig. 6 Relation between vertical distribution of salt and temperatures – Lake Ursu, July 2004

In fact we can talk about a double thermical stratification: one is *inverse stratification* (from the surface to 1.5 – 3.5 m deep) and the other is *direct stratification* (from the mesothermic layer to the bottom), with gradual lessening of temperatures.

Also we have to specify that the double thermical stratification is observed mainly in summer, but sometimes can appear in spring and remains active until October.

Physical, chemical and hydric aspects of water establish a thermical characteristic of these kinds of lakes known as *heliothermy*. This represents the accumulation of caloric energy from the sun and the transmission of this energy to the inferior layers. This phenomenon is conditioned by many factors: the presence of a thin layer of fresh water at the surface and a salty layer under it, the growth of salinity with depth, high concentrations of salt, the diminishing of bath and wind influence not to disturb the distribution of salinity and the fresh water layer (Gâştescu et al., 1985).

The highest temperature is at 2-3 m deep, in the layer above the one with maximum concentrations of salt, witch remains almost the same to the bottom of the lake.

Heliothermy was observed even in winter, under the ice sheet, as a result of the maintenance of it from the warm season (Lake Fara Fund – Ocna Sibiului), or from the thermical reorganization of the epilimnion, because of the cooling of the water from the surface. The maintenance of the double stratification is explained by the transformation of the energy from the surface in caloric energy, but also by the thermal insulator effect of the fresh water layer from the surface (Pisota, Trufas, 1971).

From the investigations taken up to now on the salt lakes in the Transylvanian Basin we came to the conclusion that Lake Ursu has the highest temperature of the heliotherme layer. This is due to the fact that there is always a thin layer of freshwater on the surface of the lake coming from the imission of rivulets. The bathymetric profiles realized in the summer of 2004 (beginning of July) revealed the existence of a thermocline layer between 2-4 m deep, with a maximum of temperature at 2,5 m deep (38,1 ^{o}C).

Then follows a gradual lessening of temperatures to the bottom of the lake, but maintaining them at high values (over 20 ^{o}C) (fig. 6).

The same variation is observed in the case of Lake Negru (Sovata), but the highest temperature does not

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exceed 31.5 °C and those from Ocna Sibiu reach 32 °C (fig. 7).

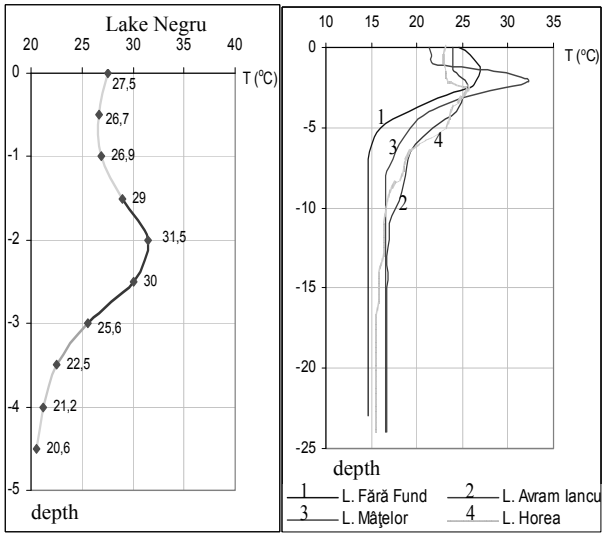

Fig. 7 Vertical thermic profiles – Lake Negru (Sovata, July 2004) and some lakes from Ocna Sibiului (July 2003)

In the case of lakes formed in ex salt mines**,** with high deeps, where the temperature in the heliotherme layer is not so high, we can observe that under 10 – 11 m deep, the temperatures are around 15 – 16 °C.

On the basis of the old measurements we can observe an evolution in time of the heliotherme phenomenon. In the case of Lake Ursu, the highest temperatures were over 60 °C (Kalecsinsky, 1901), after that have diminished a lot (31.5 °C – I.Al. Maxim, 1932), reaching nowadays the value of 40 °C (fig. 8).

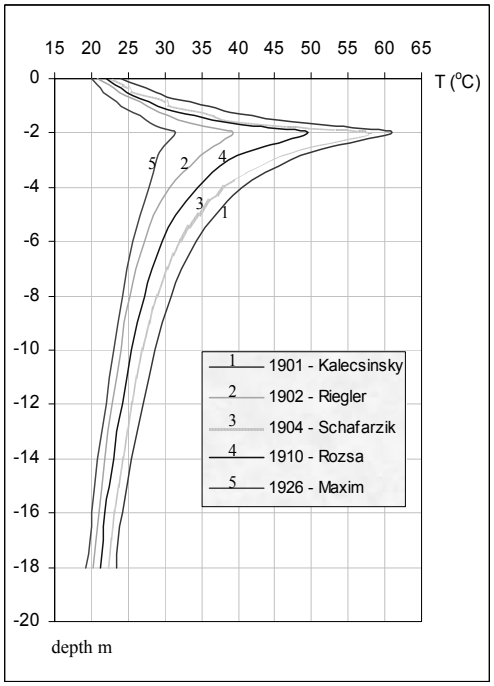

Fig. 8 Evolution in time of the heliotherme phenomenon – Lake Ursu, Sovata (after Maxim, 1926)

The main cause is supposed to be the intense exploitation of the lake through bathing and the usage of waters in many disease treatments. Not a long time ago, from the same lake, they collected a great quantity of salt water and restored it with reduced salinity, which led to the perturbation of the natural stratification of the water. Another modification in the stratification of water was influenced by the infiltration of fresh water from Lake Tineretului. In 1997 this lake drained.

To prevent the loss of heliothermy (Lake Ursu), the bathing programme is very well controlled, with a break of 2 hours (between $13^{oo} – 15^{oo}$). During the field campaign in the summer of 2004 we tried to verify the efficiency of this method. Thus, we realized a vertical thermic profile before the break, observing that the temperature of water is around 28 °C until 2 m deep, and the layer with the maximum temperature "migrating" to 3 m deep. After 2 hours, the temperature on the first 2 m remained the same, but the heliotherme layer went up with 0.5 m.

Although the 2 hour break is not enough to the restoration of the normal distribution of the layers, we consider that this break is useful, preventing an excessive mechanical mixture of waters. It is more a prophylactic measure than one that "remedies" the effect of bathing (Alexe et al., 2006).

Till the end of September and the beginning of October, the natural stratification is restored and although the air temperature is dropping, the temperature of water can increase again.

There are situations when the intense utilization of lakes for bathing can lead to the disappearance of this stratification (Lake Aluniş – fig. 9) or, contrary, to the "conservation" of this phenomenon in the absence of bathing (Lake Mâţelor – Ocna Sibiului, Lake Negru – Sovata).

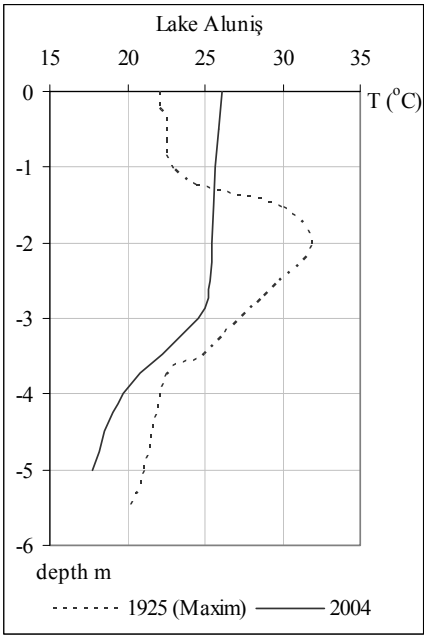

Fig. 9 Vertical thermic profile – Lake Aluniş, Sovata

In summer, in the lakes where there is not a layer of fresh water on the surface or in the ones not so deep, the vertical *direct thermic distribution* is observed. This phenomenon is a result of the presence of a warmer layer at the surface, a layer of thermic jump with high gradients (2-5 °C/m), which makes the

connection with the colder waters from deeper layers (over 4 m). The thermic jump layer is distinct from one lake to another, migrating on the vertical, depending on the depth of lakes.

A special situation is in the case of the lakes with high concentrations and equally distributed on the vertical (Lake Brâncoveanu – Ocna Sibiului). The stratification in this lake is influenced by the great mixture of waters through bathing. From the surface to 2 m deep we can observe an isotherm layer (25 ^{o}C), then follows the direct stratification and the temperatures are over 15 ^{o}C even in deep areas.

In the greatest part of spring, autumn and during winter, the deep salt lakes have an *inverse thermic stratification*. In this case the temperatures are higher in the deep areas (14 – 18 ^{o}C). In the case of the lakes with fresh water or salt lakes not so deep and great surface, the temperatures in the deep zones are between 4-8^{o}C.

The monthly bathythermic profiles (fig. 10) reveal a detailed situation for Lake Ursu (values from 1992). We observe that if in the cold season the inverse stratification is a usual phenomenon, in the transitory seasons is observed at the beginning of spring (March) and the end of autumn (November).

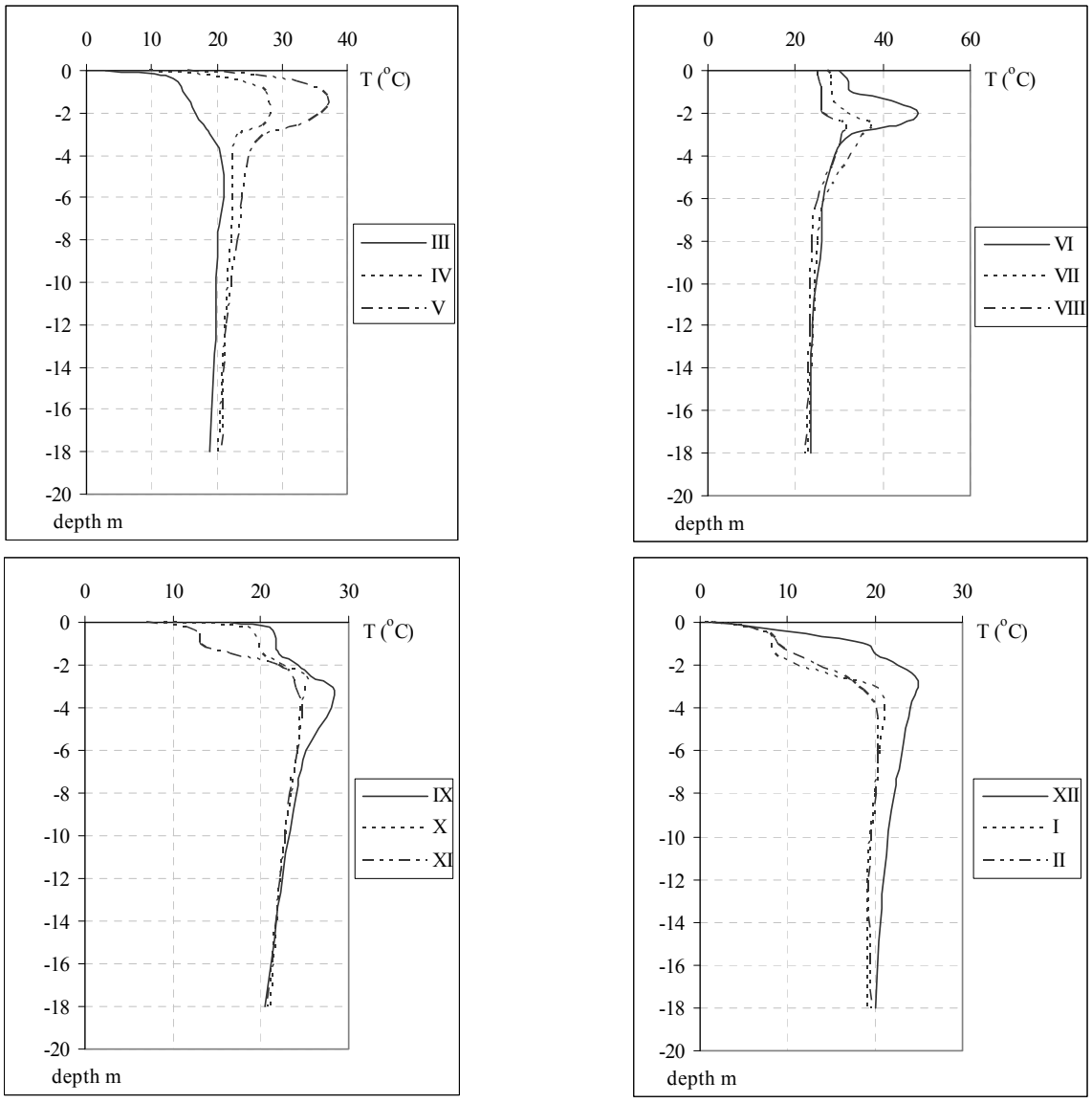

Fig. 10 Monthly vertical variation of temperatures in Lake Ursu (1992)

CONCLUSIONS

The values of salinity from the surface vary between some g/l and depend on the existence of a direct contact with salt, water dynamics in the superficial horizon, imission of fresh water etc.

The vertical distribution of salinity illustrates the existence of three different layers: *the upper layer* with the lowest salt concentrations (20-60 %) and 1.5 – 2.5 m deep, *a middle layer*, also known as the salt jump layer, and a *hiperhaline layer* (over 300 g/l), which is very thick depending on the depth of the lake. We can add the thin sheet (20 cm) of fresh water from the surface, which came from rainfall or rivulets, which can become an ice sheet in winter (5 – 15 cm).

The distribution of temperatures on the surface is homogeneous, being influenced by local factors. On the vertical, the relation between the variation of salinity and temperature is very tight, which allows us to find three thermical horizons: an upper one, with huge oscillations of temperatures, depending on

season, the heliotherme layer with some oscillations, but little amplitudes and a deep horizon with no variations in time of temperatures.

REFERENCES

Alexe M., Şerban Gh., Fülöp-Nagy J., *Lacurile sărate de la Sovata*, Editura Casa Cărţii de Ştiinţă, Cluj-Napoca, 2006.

Bobeică A., *Cercetări privind lacurile de la Ocna Sibiului,* Hidrotehnica, Gospodărirea apelor, Meteorologia, vol. 14, nr.4, Bucureşti, pp.179-187, 1969.

Gâştescu P., *Lacurile din România. Limnologie regională,* Editura Academiei RSR, Bucureşti, 1971.

Gâştescu P., Driga B., Anghel Cornelia, *Noi posibilităţi în valorificarea lacurilor helioterme din România,* Studii şi cercetări de geologie, geofizică, geografie, Seria geografie, tom XXXII, Bucureşti, 1985.

Kalecsinszky S., *A Szovátai meleg és forró konyhasóstavakról mint természetes hőaccumulátorokról. Meleg sóstavak és hőaccumulátorok előálitásárol,* Földrajzi Közlemény, XXXVII, Budapest, 1901.

Maxim I. Al., *Contribuţii la explicarea fenomenului de încălzire al apelor sărate din Transilvania. Lacurile de la Sovata*, Revista Muzeului Geologic-Mineralogic al Univ. din Cluj, vol. III, Cluj-Napoca, pp. 49-84, 1929.

Maxim I. Al., *Contribuţii la explicarea fenomenului de încălzire al apelor sărate din Transilvania. Lacurile de la Ocna-Sibiului*, Extras din Revista Muzeului Geologic-Mineralogic al Univ. din Cluj, vol. IV, nr.1, Cluj-Napoca, pp. 47-105, 1931.

Panait I., Sişman I., Bobeică Al., *Studiu privind protejarea fenomenului helioterm al Lacului Ursu – Sovata*, Studii de hidrologie, XXVII, Bucureşti, pp. 63-88, 1969.

Pânzaru T., *Complexul lacustru de pe masivul de sare de la Ocna-Sibiului (I). Sectoarele lacustre "Incinta Băilor" şi "Parcul Public"*, Lucrări Ştiinţifice, seria A, Geografie, Institutul Pedagogic Oradea, pp. 185-204, 1977.

Pânzaru T., *Complexul lacustru de pe masivul de sare de la Ocna Sibiului (II), sectoarele lacustre "Ocniţa-Avram Iancu" şi Ignaţiu*, Studia Univ. „Babeş-Bolyai", Geologia-Geographia, 27, nr. 1, Cluj-Napoca, pp. 46-60, 1982.

Pişota I., *Noi date hidrologice asupra lacurilor din Depresiunea Sovatei*, Probleme de geografie, vol. VII, Bucureşti, pp. 179-192, 1960.

Pişota I., Trufaş V., *Regimul termic al lacurilor sărate din R. S. România*, Lucr. şt., Seria A., Institutul Pedagogic, Oradea, pp. 173-178, 1969.

Touchart L., *Limnologie physique et dinamique. Une géographie des lacs et des étangs*, L'Harmattan, France, 2002.

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