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MORPHOLOGY OF THE LAKE BASIN AND THE NATURE OF SEDIMENTS IN THE AREA OF RED LAKE (ROMANIA)

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Abstract: Red Lake in Hasmas (Curmaturii) Mountains was formed by the natural barrage of the Bicaz brook in 1837. In a transversal profile, the western bank is steeper and hard (lithologically), and the eastern bank is mild and crumbly (landslide diluvium). In the same way the submerse slopes are maintained as well. The transport of the sedimentary material depends on the immerse slope, but also on the submerse slope. The central sectors, with great depths, have finer sediments, and the sectors situated immediately next to the river mouths have coarser particles. The total organic carbon and humus are distributed in such a way that they reflect a close connection between the development of vegetation and the zone with immediate impact with the river mouths of the brooks tributary to the lacustrine basin. In the spillway sectors of the main brooks, where important amounts of organic silt can be found, large wetlands develop.

Key words: humus, limnosoil, morphology, natural barrage lake, organic carbon

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INTRODUCTION

Due to its genesis and the location within Eastern Carpathians, Red Lake is the most interesting natural barrage lake in Romania. Its long existence, since 1837, induces a balanced hydrological balance. The low silting degree favoured the existence of depths exceeding 10.50 m.

Thanks to very accurate last generation instruments, and to the qualified personnel in taking very fine measurements, a series of measurements on the morphometry and morphology of Red Lake were taken. We hope that these measurements will represent a basis for complex geographical, geological, biological, economic studies, and they will lead to new interdisciplinary research directions – limno-ecological.

A very important problem in the present study is connected to the nature of the lacustrine sediments and to the limnosoil formation, which facilitates the development of large areas with wetlands. From this point of view, samples have been taken in order to determine the total organic carbon and humus content.

The most important studies on the Red Lake and the surrounding area were elaborated by: Begy et al., 2009; Bojoi, I., 1968; Carausu et al., 1971; Ciaglic, V., 2005; Dobrescu et al., Ghenciu, 1970; Ghenciu, I.V., 1968a; Ghenciu, I.V., 1968b; Ghenciu et al., 1969; Ghenciu et al., 1970; Gistescu, P., 1971; Grasu et al., 1980; Pandi, G., 2004; Pandi et al., 2004; Pandi et al., 2003; Pelin, M., 1967, 1971; Pisota et al., 1976; Pisota et al., 1957; Popescu et al., 1950; Preda, I., 1971; Preda et al., 1963; Puscariu, V., 1939; Romanescu, G., 2009a; Romanescu, G., 2009b; Romanescu, G., 2009c; Senchea, N., 1948; Udriste, O., 1963; Xantus et al., 1999.

From the international literature we used only the studies helping in supporting some hydro-geomorphologic ideas: Altunkaynak et al., 2003; Artigas et al., 2004; Christofides et al., 2005; Clague et al., 2006; Della Bella et al., 2007; Gagnon et al., 2008; Gascón et al., 2006; Godeanu et al., 2007; Godet et al., 2009; Holden, H., 1998; Kopácek et al., 2003; Lampert et al., 2007; Mindrescu et al., 2010; Nolan et al., 2007; Penning et al., 2010; Reshef et al., 2007; Rogora et al., 2001; Rzychoń et al., 2008; Sahuquillo et al., 2007; Tassi et al., 2009; Torabay et al., 1991; Wetzel, R., 2001.

GEOGRAPHICAL LOCATION

In the Carpathian Mountains, there are several lakes created as a result of the landslides which created a barrage in the course of the rivers (Vulturilor, Crucii, Balatau, Dracului etc.), but the best known and studied is the Red Lake.

Red Lake is situated in the Central Group of Eastern Carpathians, within Hasmasu Mare (Haghimas) Massif (figure 1) and its main tributaries are Oaia (Oii), Verescheu, Licos and Suhard brooks.

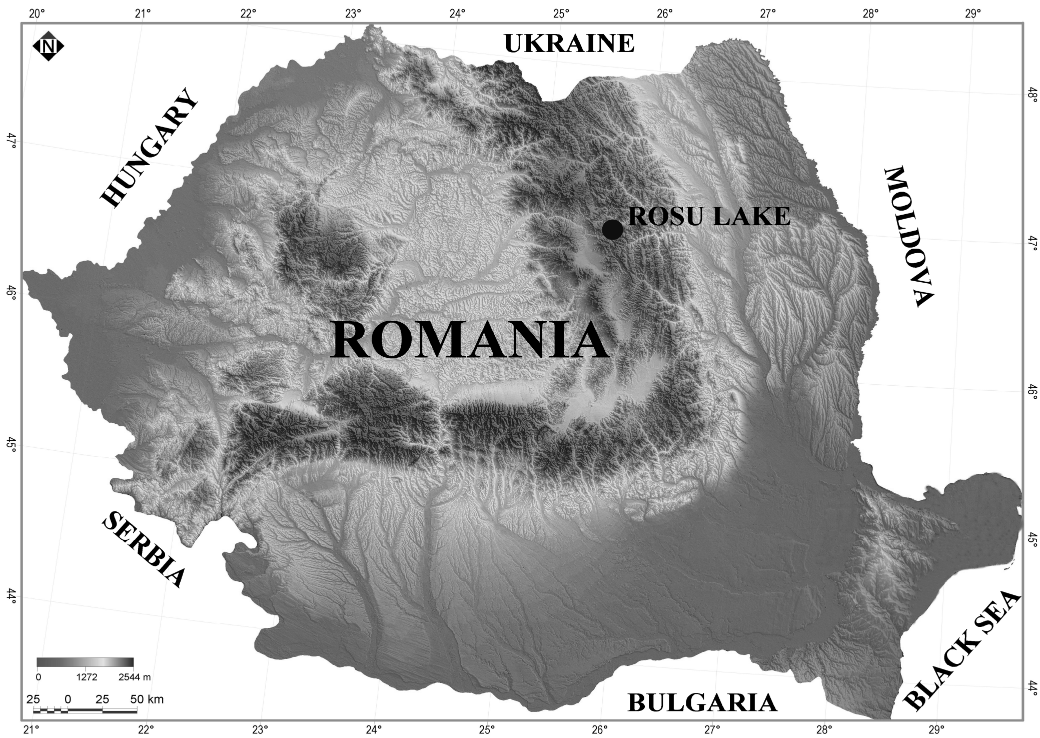

Figure 1. Geographical Location of Red Lake on the territory of Romania

It is a natural barrage lake. It was created in the summer of 1837, when, following a period of abundant rains, a landslide diluvium detached from Ghilcos (Ucigasu) Mountain and created a barrage in the course of Bicaz brook. Behind the landslide wave, a lake was created and this lake inherits the tree trunks of the forest covering the sliding slope (e.g., Bojoi, I., 1968; Pisota et al., 1957).

The mathematical coordinates of the lake are: 46º47’0’’ N latitude in the southern sector, 46º47’37’’ N latitude in the northern sector, 25º47’0’’ E longitude in the north-western sector and 25º47’30’’ E longitude in the eastern sector.

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The name „rosu” (red) comes from the fact that at sunrise, the sunrays fall directly on the reddish clays of the western slope (Piciorul Licos), and it reflects on the relatively clear waters of this aquatorium.

METHODS AND TECHNIQUES

We have used instruments in order to realize topographic and bathymetric measurements and to collect silt samples in order to determine the total organic carbon and humus content.

The field measurements were taken by using LEICA TCR 1201 total station, which, together with LEICA GPS 1200, is part of SYSTEM 1200 LEICA. The Topographic Headquarters in Gheorgheni gave us the coordinates of the topographical marks. The measurements were taken starting from the Topographic Mark number 15, situated on the right side of the lake, at 986.275 m altitude, and the orientation was done towards the mark on the Suhardului peak, at 1,507.0 m altitude. From Topographic Mark number 15 the measurements started effectively. Seven station points were radiated, by using wood stakes in different zones of the lake, for an optimum cover of the whole area. After finishing the measurements the data were processed by using AutoCAD software.

At the same time, a GPS was used in order to establish the exact perimeter of the lacustrine basin and of the typical humid zones in the Red Lake.

The bathymetric measurements were taken by using Valeport Midas Surveyor echo sounder (Bathy-500DF Dual Frequency Hydrographic Echo Sounder). The resolution of this echo sounder is 1 cm/1 cm and it includes GPS navigation.

The contour of the lake was established on the basis of the topographical measurements and GPS. The whole lacustrine surface was scavenged by using the sonar. In this case, over 80,000 points were inventoried and about 50,000 were graphically interpolated.

A certain difficulty in establishing the correct depths was generated by the fact that the signal of the echo sounder can easily penetrate the extremely watery silt from the bottom of the lake. In this case, the thickness of the sediment is added to the depth of the lake, instead of being considered a consolidated layer. That is why several corrections were done and supplementary measurements were done by using string and weights.

As a result of the fact that the lake still preserves a multitude of tree trunks, the bathymetric measurements were affected. In order to avoid errors, the „parasites” which frequently appeared in the measurement operation were eliminated.

In order to process the bathymetric data and realize the thematic maps, TNTMips v.7.2 and ArcGis v.9.3 software was used. Therefore, the numeric model of the land was realized and it was graphically used for different purposes. These are new graphical representations in the mathematic modelling of the lacustrine basins.

In the Total Organic Carbon determination to obtain the percent carbon content from soil, first we have to standardize the titrant solution ($FeSO_4 \cdot 7H_2O$) before the sample analysis are made, as result we obtain some data which have to be reduced in order to obtain the results we need , and to do this, we use the next equation:

Titrant normality equation:

$$N_2 = \frac{N_1 V_1}{V_2}, \tag{1}$$

In which:

N_1: $K_2Cr_2O_7$ normality,
V_1: $K_2Cr_2O_7$ volume (mL),
V_2: $FeSO_4$ volume (mL).

Organic carbon percentage:

$$\%Carbon = \frac{(A-B)\times 0.3\times 1.33}{C}, \quad (2)$$

In which:

A: meq $K_2Cr_2O_7$ = (mL $K_2Cr_2O_7$ x N $K_2Cr_2O_7$),
B: meq $FeSO_4{\bullet}7H_2O$ = (mL $FeSO_4{\bullet}7H_2O$ x N $FeSO_4{\bullet}7H_2O$),
C: grams of sample,
0.3: Conversion factor to carbon weight.

We have milli-equivalents as result of the difference between A and B, and they need to be converted to carbon milli-equivalents in order to get the units we need, for that it is necessary to do the next operation:

meq x (1eq/1000meq) x ((1/4)molC) x (12g/1molC) x 100 = 0.3gC(%) (3)

The 0.3 conversion factor has units of carbon grams and involves the constant to convert a fraction to percent units; hence equation 2 does not have the factor 100. Walkey-Black constant for sediment 75 % is the mean recuperation of carbon in solids and sediments by using this method, that's why the final results has to be multiplied by 1.33 in order to get the real value, this constant is not used when determining carbon in KHP standard because almost all its carbon content is recovered.

In order to transform the organic carbon into humus, we have to multiply ii with the factor 1.724.

RESULTS AND DISCUSSIONS

In 1837, as a result of continuous summer precipitation, an immense landslide occurred on the western slope of Ucigasu Mountain, creating a barrier in the course of Bicaz brook. The landslide wave favoured the appearance of a natural barrage lake, which extended on the courses of Oaia (Oii) and Suhard valleys. It has a total area of 12.1 ha (120,134.44 sqm) and a water volume of 721,404.87 sqm.

At water level, in a longitudinal profile, one can notice a more reduced slope in the sector of Oaia (Oii) valley, from 965.199 m upstream, to 965.051 m downstream, at the river mouth, and a higher slope on the Suhard valley, from 966.041 m upstream, to 965.051 m downstream, at the river mouth (figure 2). The situation is similar at the level of the lake bottom, with the difference that, at the river mouth, the altitude is 954.55 m, 10.5 m lower – which is an equivalent of the lake maximum depth (figure 3). The general slope of the lake bottom profile has the value of 11º on the alignment of Oaia brook and the river mouth, 26º between Suhard brook and the river mouth, and 56º on the alignment of the confluence between the two sectors and the main spillway (figure 4).

The silt samples from the bottom of the lake were taken in 17 points covering the whole surface of the lake (figure 5). These points are representative for the erosive processes at the surface, as well as for the alluvionary processes within the lake basin.

As water flowing speed reduces, the brooks tributary to the Red Lake gradually deposit alluvia: first, the rolled and dragged ones and then the suspension ones. The former are deposited mainly next to the source, and the latter are deposited further away. The lacustrine sediments in the area of Oaia (Oii) brook spillway have grey colours, with grey-blackish colours towards the surface. The darker colour at the surface is a result of higher humus content. Next to Suhard brook and abundance of craggy elements is registered. In this case the slope of the river is greater as well. The sediments in the Red Lake present the characteristics of the fine micaceous sand.

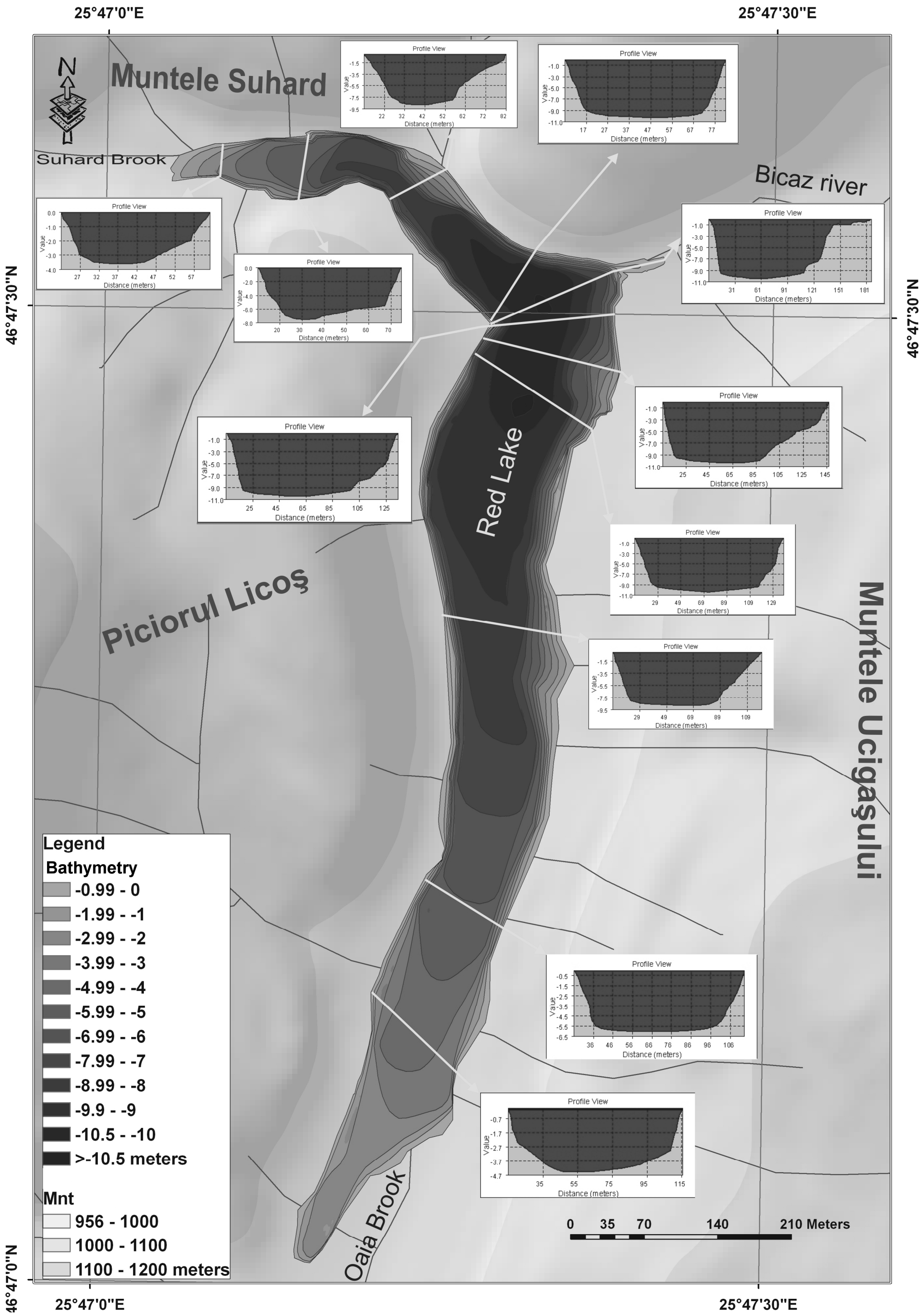


Figure 2. Transversal profiles in Red Lake lacustrine basin

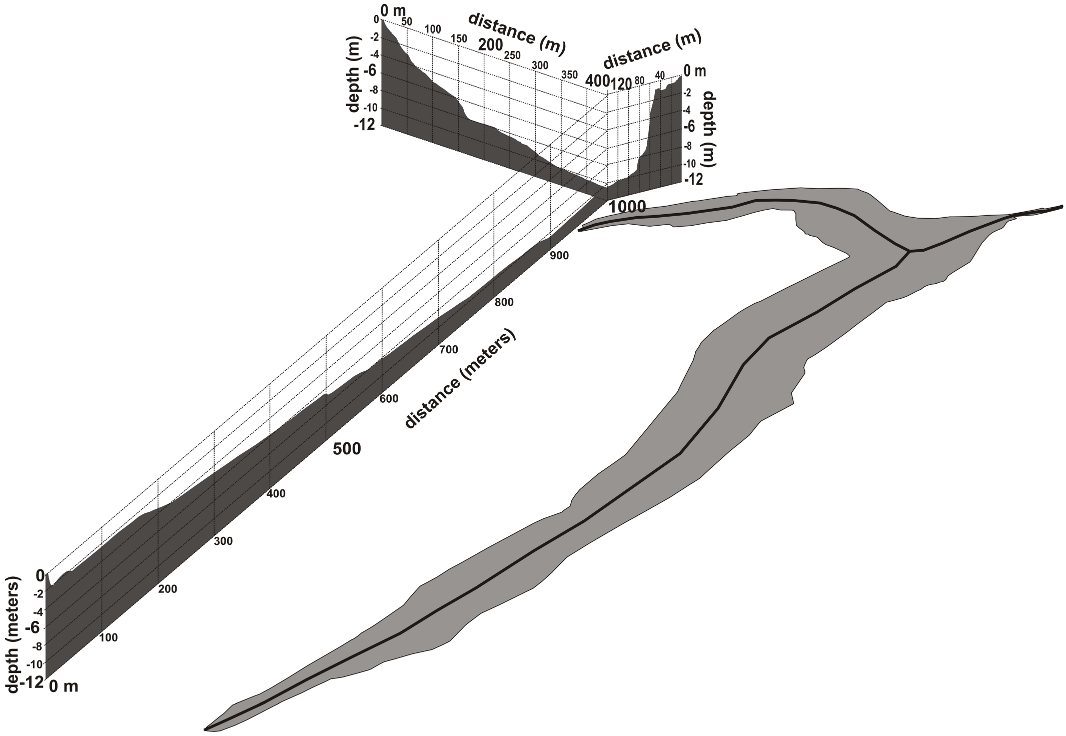
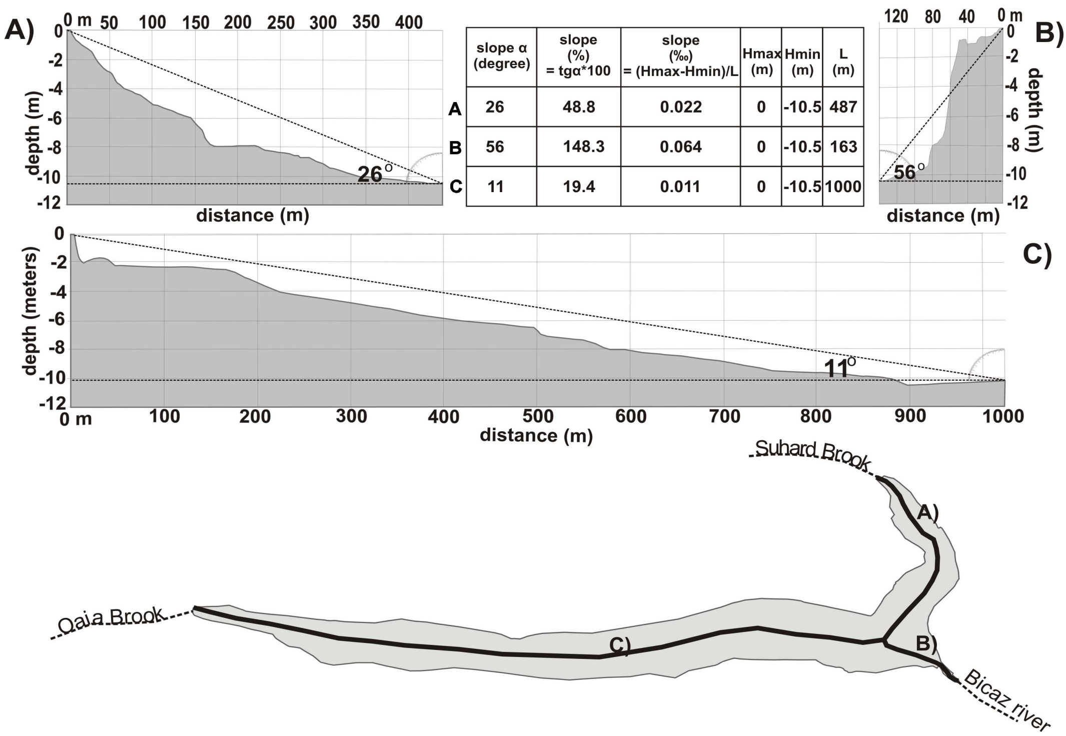


Figure 3. Diagram of the longitudinal profile in Red Lake (the proportion of shapes and lengths for the two components – Oii stream and Suhard stream - is maintained)



	slope α (degree)	slope (%) = tgα*100	slope (‰) = (Hmax-Hmin)/L	Hmax (m)	Hmin (m)	L (m)
A	26	48.8	0.022	0	-10.5	487
B	56	148.3	0.064	0	-10.5	163
C	11	19.4	0.011	0	-10.5	1000

Figure 4. General slope of the lake bottom in the three sectors of Red Lake

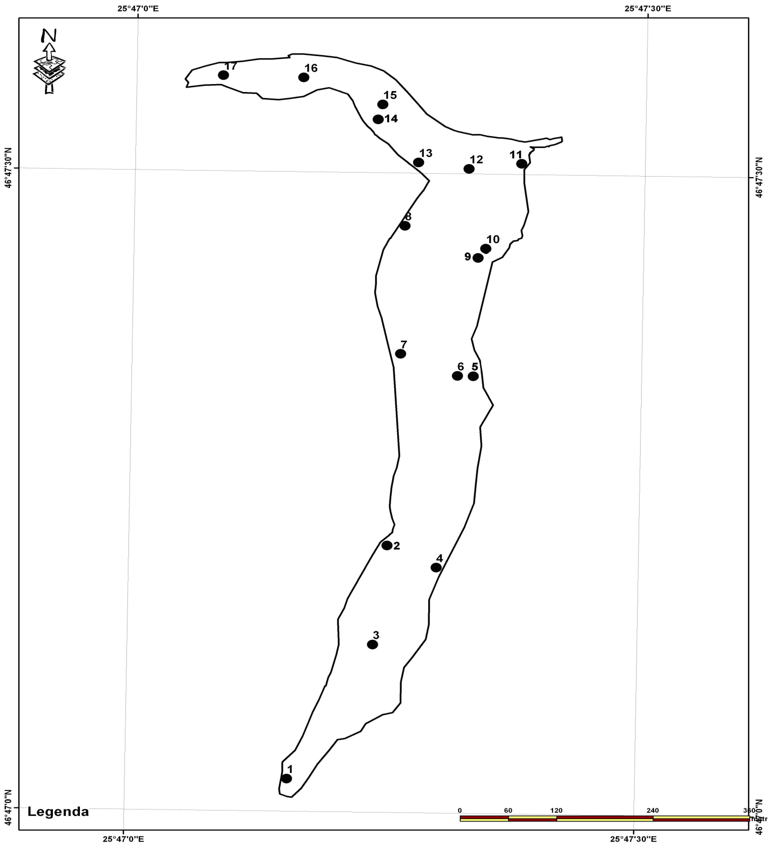


Figure 5. Distribution of the points where samples of silt were taken from the bottom of Red Lake

The thickness of the lacustrine sediments varies in extremely large limits, reaching a maximum of over 6m in the spillway sectors of the two important brooks: Oaia (Oii) and Suhard.

One can notice a logical correlation between the existence of the total organic carbon and humus quantities (Table 1, Figure 6).

Table 1. Amount of total organic carbon and humus in the sediments of Red Lake

Sample	Total organic carbon %	Humus %
1	7.31	12.7
2	6.61	11.39
3	4.03	6.94
4	3.82	6.58
5	6.65	11.46
6	4.49	7.74
7	4.26	7.34
8	4.21	7.25
9	3.92	6.75
10	3.73	6.43
11	4.80	8.27
12	3.82	6.58
13	4.78	8.24
14	4.21	7.25
15	5.06	8.72
16	5.39	9.29
17	6.10	10.53

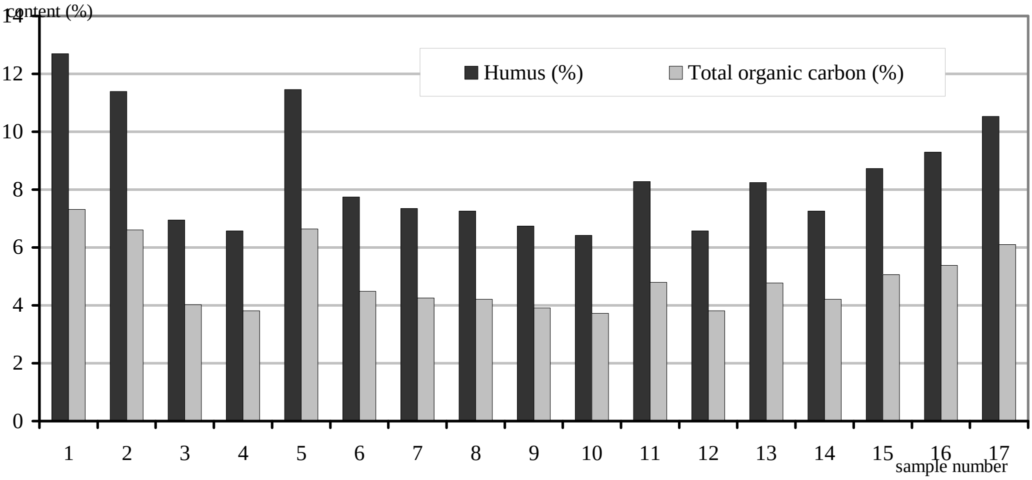


Figure 6. Histogram of the distribution of total organic carbon and humus proportions in the sediments of Red Lake

The more reduced the slopes and depths are, the higher the concentration of organic carbon and humus is (sample taking points 1, 2, 3, 4, 5 and 15, 16, 17 respectively). In the deeper sectors, especially towards the river mouth, the smaller quantities are found as well (figure 7). This fact is due to the great distance to the alluvia source and to the existence of a weak aquatic current which transports a reduced amount of alluvia. The alluvia are stopped at the two extremities of the lake by the existence of immerse and submerse vegetation, extremely well developed in the torrential rain season.

The greatest value of organic carbon is 7.31 % at the spillway of Oaia (Oii) brook and 6.10 % at the spillway of Suhard brook. The most reduced value (3.73) is recorded next to the river mouth, where the greatest depths are recorded as well.

In the literature in the field, values of over 25 % are cited at the river mouth of Oaia (Oii) brook and 18% at the spillway of Suhard brook (e.g., Bojoi, I., 1968). In the present case, it seems that these values are exaggerated.

The high values of humus are caused by the existence of rich vegetation in the sectors with reduced depths. In these areas, the water mass is totally lighted and the roots of the plants can penetrate the soft layer. These are the most impotent wetlands around the lake.

The humus in the sediments of the lake comes from two sources: eroded soil from the slopes; accumulation produced by plant decomposition. In this way a typical limnisoil is formed.

During summer, when torrential rains occur, the brooks transport an important amount of alluvia material. The yellow colour, which indicates the high amount of alluvia, is specific only to the sectors next to the riveran spillway. The rest of the lake remains clear, with extremely weak turbidity. The transparency degree reduces to several centimetres next to the banks and in the area of abundant vegetation (10-20 cm), while the sectors close to the river mouth and the sectors with the greatest depths have a transparency of 2-3 m.

The greatest values of humus are 12.7 at the spillway of Oaia (Oii) brook and 10.53 at the spillway of Suhard brook. The lowest value is 6.43 and it is recorded at the river mouth, where the greatest values of depth are also recorded.

The existence of a significant amount of humus, and of a typical limnisoil, implicitly, facilitated the development of immerse and submerse vegetation (Fig. 8). This fact is normal for depths up to 2-3m. For greater depths, light hardly penetrates and therefore, the bottom of the lake is lacking such life forms. This is the domain of the bacteria and animals which can resist under such conditions created by the oxygenation, pH, salinity, pressure etc.

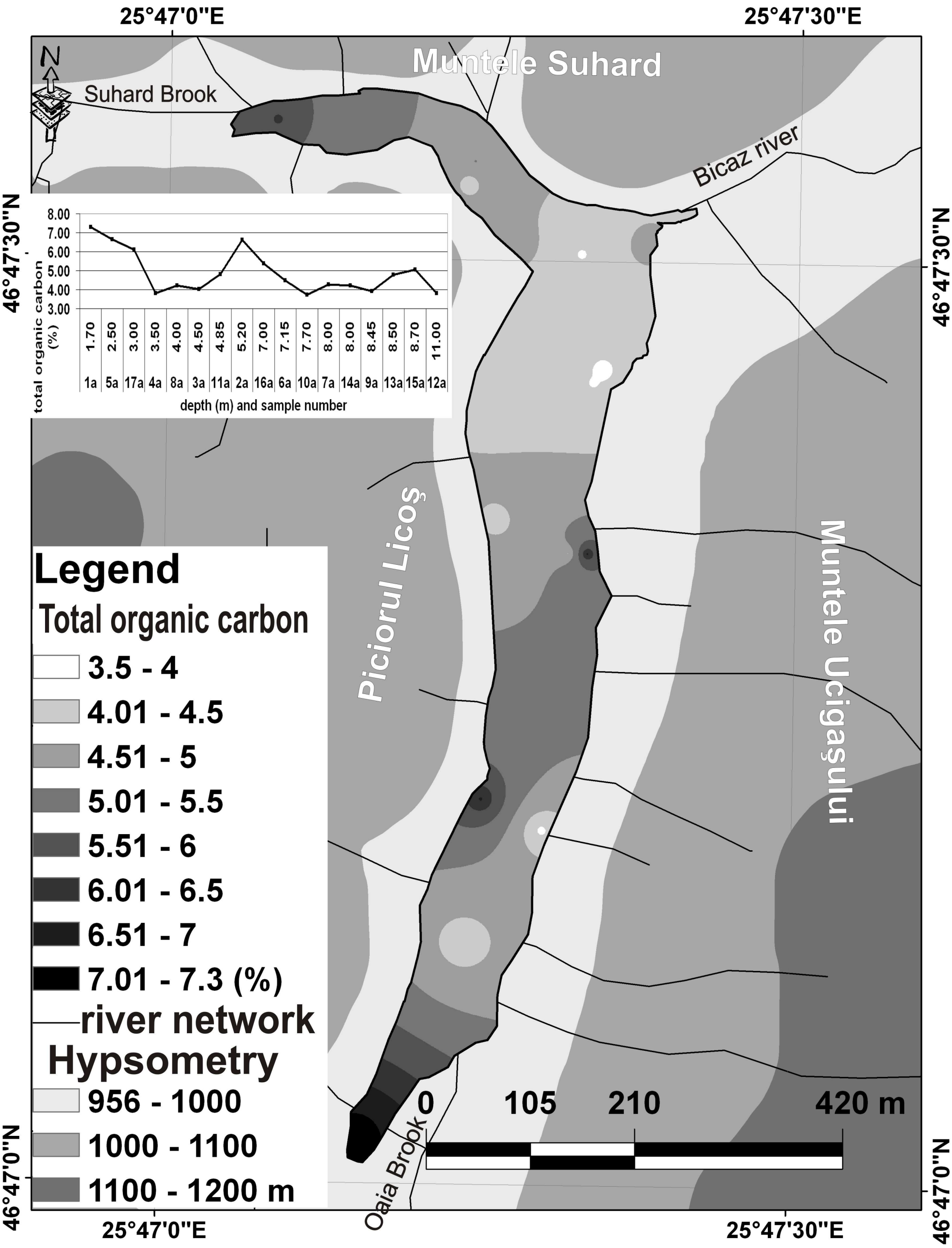


Figure 7. Map of total organic carbon distribution in the surface sediments of Red Lake

On the lithological slopes (western and northern) where the slopes are greater and the depths are also greater, the lowest quantities of organic carbon and humus are found. This fact is due to the weak erosion of the slopes (perfect forest cover) and to the lack of brooks (therefore a lack of supplementary alluvia).

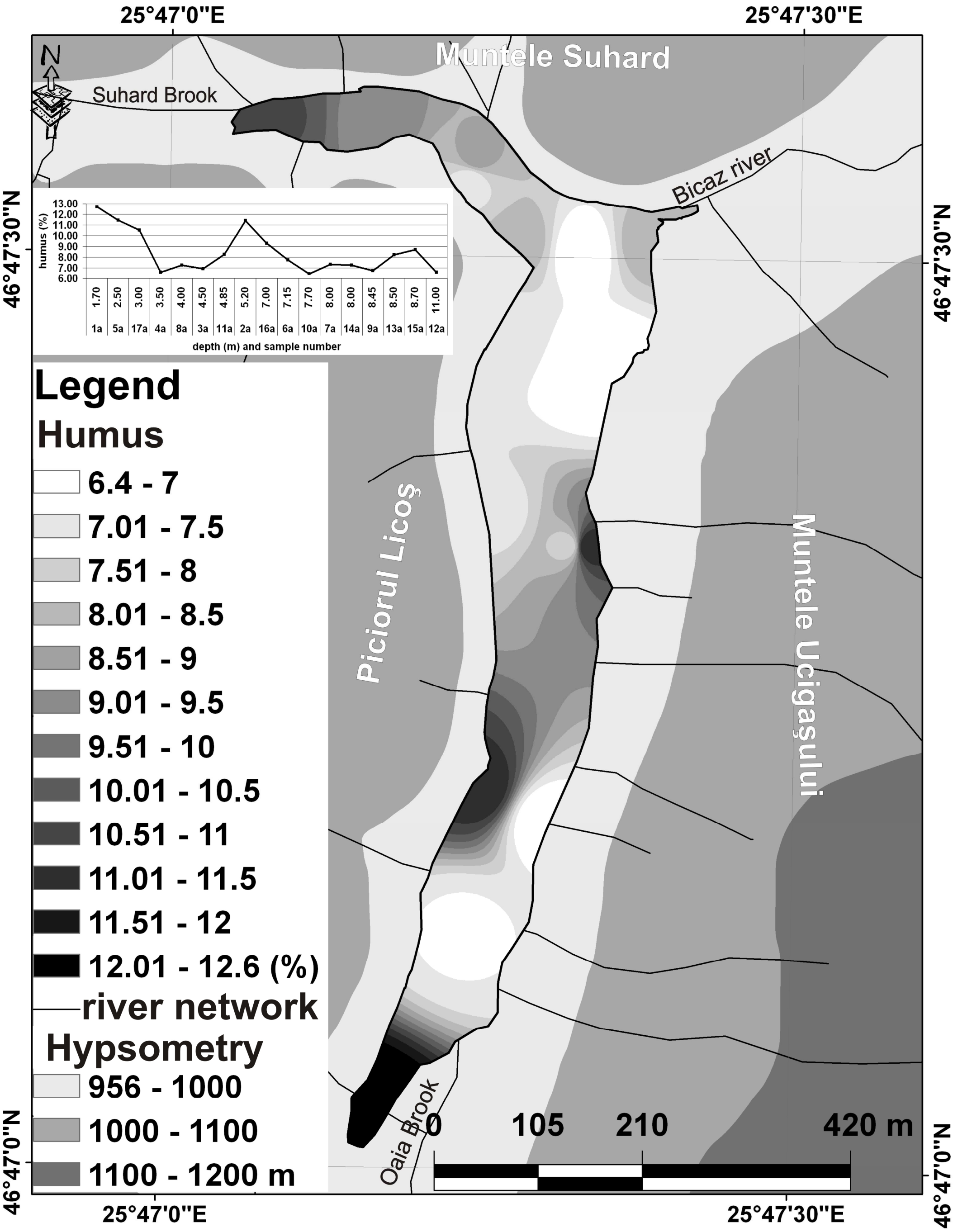


Figure 8. Map of humus distribution in the surface sediments of Red Lake

The deposition of the alluvia material coming from the slopes and from the organism decomposition, contributes to the silting of the lacustrine basin and to the changing of the whole morphology of Red Lake implicitly.

The sedimentary deposit in the Red Lake basin represents a formation specific to the mountain valley lakes. An important characteristic of these alluvia is represented by the existence of sands with intercalations of coarse fragments, specific to the changes in the sedimentation process.

The amount of organic carbon, and humus implicitly, increase towards the surface. This can be explained by the development of the vegetation, while the depth gets lower.

In order to study the temporal evolution of the lacustrine basin, a hypsometric integral specific to the immerse landform units was made (figure 9). This is based on the estimation of the landforms erosion degree. The whole area of the graph represents the initial volume of the landforms. The area situated under the hypsometric curve represents the present volume of landforms. The ratio between the two volumes indicates the value of the hypsometric integral (e.g., Strahler, A., 1952).

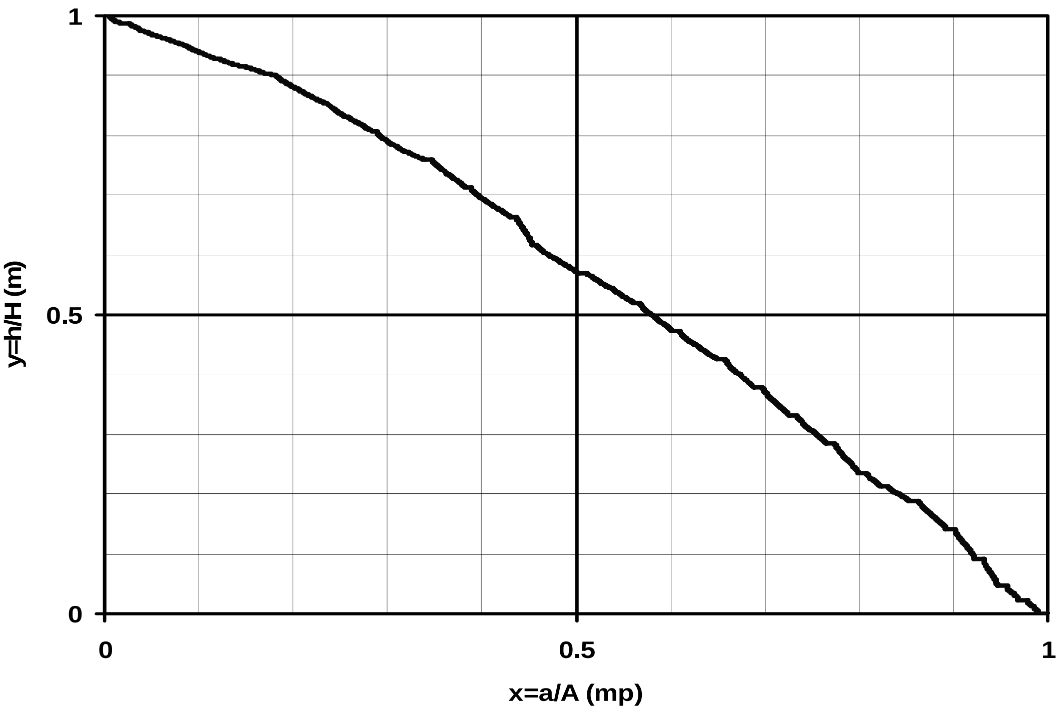


Figure 9. Hypsometric integral of Red Lake lacustrine basin

At the surface, the situation is the following: a concave curve reveals old landforms, and a convex curve indicates young landforms, with weak erosion phenomena. For Red Lake the values are higher than 1 (convex curve), which demonstrates a permanent accumulation of material and an aging of landforms. The phenomenon is exactly the opposite of the one occurring on the land.

The hypsometric integral is a graphical representation of the relationship between altitude and area. The calculation formulas for the two axes are:

For oYaxis: y=h/H, in which h = altitude of a point in a horizontal-transversal section (meters) and H = maximum altitude of the studied area (meters). For oX axis: x=a/A, in which a = the relative surface occupied by (square meters), A = total area (square meters).

By analysing the hypsometric integral for the Red Lake lacustrine basin, one can notice a permanent accumulation and a continuous modification of the submerse slopes as a result of the accretion (bottom and lateral).

The human induced changes around the lake – as important sources of sediments – are extremely rare. We can mention only several deforested areas on the south-western slope and an area with several tourist constructions on the north-eastern sector.

CONCLUSIONS

Red Lake is the best known natural barrage lake in Romania and it represents, together with the Bicaz Gorges, the main tourist attraction in the area of Hasmasu Mare (Haghimas) Mountains. The geomorphologic, hydrological, ecological, landscape, tourist etc of this lake will cause radical changes in the neighbouring environment, and therefore, important impact on the lacustrine basin.

For a correct understanding of the morphometric data, the geomorphologic methodology specific to positive, immerse landforms, has been applied. The methodology is similar for the negative landforms, such as the lacustrine basins.

Most of the morphometrical data, mentioned by different authors already mentioned in this paper, were wrongly recorded. The existence of morpho-metrical data and their correct interpretation could lead to a new re-evaluation of the hydrological, biological, ecological, economical parameters etc. Morpho-bathymetry of a lacustrine basin represents the base for the limno-ecological interpretation.

The existence of such an aquatorium is due to balanced hydrological balance, favourable from this point of view, but also to a reduced silting. The reduced silting index is a direct result of the continuous presence of vegetation layer, especially the coniferous forests, in the surrounding area, and of the high hardness of the geological layer (crystalline schists and limestone).

The total organic carbon and humus from the lake bottom come from the immerse slopes and by aquatic organism decomposition. The most important amounts are found in the waters with reduced depth and next to the river mouths of the affluent brooks.

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