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DISTRIBUTION OF LITHOLOGICAL COMPONENTS OF RECENT SEDIMENTS FROM SOME LAKES IN THE DANUBE DELTA; ENVIRONMENTAL SIGNIFICANCE

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Abstract: This study is focused on the lithological pattern of the sediment composition, trying to distinguish the causes of the local sedimentary processes and the differences in terms of hydrological and hydro-biogeochemical particularities. Sediment grab and sediment core samples from 7 lakes located within the Danube Delta were analyzed for the main sediment components: organic matter, carbonates and minerogenic/siliciclastic material. The vertical and areal distribution of the lithological components was studied, in order to establish the main factors which influenced the lacustrine sedimentation in time and in space. As a general remark, there is a constant inverse correlation between the siliciclastic fraction and the organic matter, the main sediment components, and only a minor participation of the carbonate minerals. The results indicate that the distribution of organic matter in sediments is mainly influenced by the *in-situ* organic fluxes and less by the input derived through the hydrological network. The position more or less protected of the lakes within the Delta in relation to the Danube River inputs controls the sediment composition: the lakes directly influenced by the direct riverine inflows contain more siliciclastic sediments as compared with the more confined lacustrine areas, characterized by sediments very rich in organic matter. The carbonates distribution shows relatively low amounts and probably their contents are related to some biochemical processes occurring inside the lake.

Keywords: Danube Delta lakes, environmental significance, lithological components, sediment core, bottom sediment

1. INTRODUCTION

The Danube Delta is one of the largest deltas of Europe (the second after the Volga River), covering an area of 5800 km^2. The region of the Danube Delta is a unique wetland, crossed by many canals, streams, and including swamps and numerous lakes. A part of these lakes are interconnected, presenting a wide variety of basin types and morphologies.

The Danube Delta is subject to a permanent hydrologic and hydrodynamic regime changes in its environmental conditions, due to many factors induced, more or less, by the Danube River, as: anthropogenic upstream changes (water and sediment inflows); degradation of water and sediment quality flowing through the hydrological network of Danube distributaries and canals within the delta; extreme climate events (periods of floods and droughts, storms etc.), sea-level changes etc.

It is well known that the biochemical composition of the sediments has an influence on the environmental quality in the delta ecosystems. The Danube Delta sediments are mainly composed of constantly transported materials *via* the Danube River load. The lake sediments are influenced, more or less, by the direct water intake, loaded with dissolved or suspended solids from the river and by organic matter production inside the lakes, as well. In this respect, sediment samples from different deltaic contexts were collected and analyzed: *dynamic deltaic environments,* strongly influenced by the Danube River supply (lakes linked by a hydrographic network through distributaries, canals, streams etc.), and *confined deltaic environments*, with restrictive conditions (lakes located farther away from the Danube River input or without significant connections with an open water system).

There is not too much published data on the lithological composition of the Danube Delta recent deposits. First important sedimentological map based on grain size characteristics has been presented by Mihăilescu et al. (1983), and concerns the Razelm (Razim) - Sinoie lacustrine complex, situated south of the Danube Delta. As regards the Danube Delta *s.s.*, a number of interesting information, consisting of macroscopic descriptions and grain size classification of sediments in several cores collected from various deltaic lakes, was published by Ghenea & Mihăilescu (1991), Dinescu et al. (1998), Duliu et al. (1996, 1997, 2000). Some sediment quality data (lithology, chemical composition, heavy metal contents) can be found in Rădan et al., (1997). During the last years, numerous papers containing integrated magnetic susceptibility and lithological data included, also, detailed description and classification of the lacustrine recent sediments from the Danube Delta (Rădan & Rădan, 2004, 2004-2005, 2007, 2009, 2010, 2011).

The main purpose of this study is to investigate the areal and vertical distribution of lithological components from lacustrine sediment samples collected from different Danube Delta lakes, in order to provide an overview of the main research results in the last two years (2010 and 2011) in the area.

The lacustrine sediments represent the last stage of both natural and artificial material accumulation generated within the aquatic environment. Therefore, the specific focus of this study is to establish the influence of the fluvial Danubian input and its interrelations within and between lakes. The Danube River carries to the Black Sea huge amounts of allochthonous sediments from the upper, intermediate and lower Danube River catchment area, which are partially dispersed throughout the fluvial-deltaic lakes. Instead, the fluvial-marine lakes can be supplied, in addition, with allochthonous sediments transported by wind currents. All these sediments accumulated during the time on the bottom of the lakes, develop, along with autochthonous material, the total amount of sediments from the lakes.

2. STUDY AREA

The Danube Delta is separated into three main depositional systems: the delta plain, the delta front, and the prodelta. The delta plain consists of two main units: the *fluvial delta plain* (an upper unit situated in the west) and the *fluvio-marine delta plain* (a lower unit located in the east), being separated by the initial littoral ridge: Jibrieni – Letea – Răducu – Ceamurlia – Caraorman – Sărăturile – Perişor – Lupilor (Panin, 1996).

This study is based on the analyses of the sediment samples collected from 7 lakes (Fig. 1), situated in the interdistributary depressions from the Fluvial Delta Plain (Fortuna, Uzlina, Isacova, Babina and Matiţa lakes) and the Fluvio-Marine Delta Plain (Puiu and Roşu lakes).

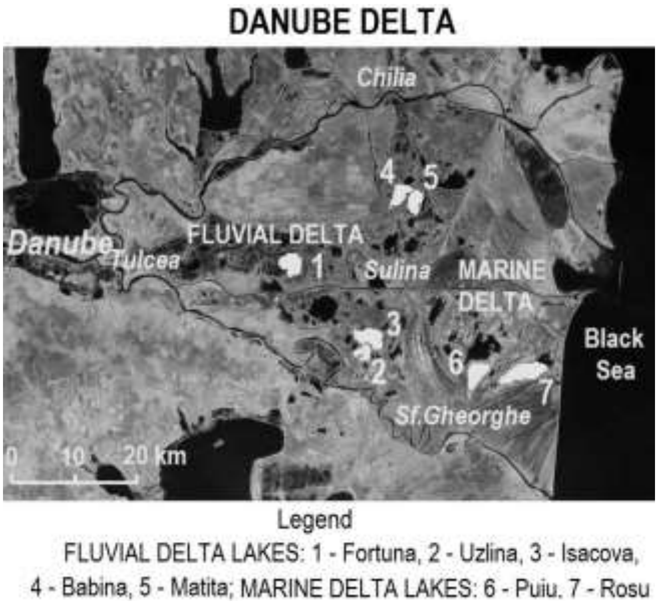

Figure 1. Location of investigated lakes in the Danube Delta (Landsat 2000)

This case study is attempting to correlate the connections between the various lakes defined by different bathymetric characteristics, genesis, inter-distributary depressions and/or hydrographic networks. The Danube Delta branches (*i.e.*, Chilia, Tulcea, Sulina, Sf. Gheorghe), accompanied by the secondary hydrographic network represented by lakes, swamps and other riverine-associated inlet-outlet systems (canals, streams etc.), control the regime of water circulation within the Danube Delta. The water circulation system in the Danube Delta is a very complex process, being in a continuous developing and depending on several factors, as: different phases of the hydric annual regime, the structure and functioning of streams and canal network, the flow direction and the flow distribution of existing hydrographic system etc.

Although some relatively direct anthropic interventions, as hydrotechnical works carried out over the past years, have influenced the water circulation system, it is estimated that these lacustrine complexes are in a quasi-natural regime, as: Fortuna, Uzlina-Isacova, Matiţa-Merhei, Roşu-Puiu. Many lakes reciprocally maintain exchanges of water both at the surface water (by the hydrographic network) and under reed formations. In each lacustrine complex there are very well defined the pathways that allow both the reception of inputs from the Danube River and the evacuation of waters of surrounding areas. Any disequilibrium arisen into the hydrographic network (*e.g.*, natural - alluvial deposition, human intervention) leads to disturbances in the entire lacustrine complex or in certain parts of it (Driga, 2004).

Further on, there will be marked some general data regarding the water circulation system just in the hydromorphological units investigated within this study.

2.1. Fluvial Delta Plain

Within the Fluvial Delta Plain there were studied five lakes situated in different hydromorphological units, distinguished by diverse hypsometry and genesis (Fig. 1).

2.1.1. Meşteru - Fortuna Depression

The most representative inlets and canals within this interdistributary sub-unit, which is placed between Chilia and Sulina branches, are Sireasa, Şontea, Olguţa, Stipoc, ″35.7 Mile-point″, Păpădia Veche and Păpădia Nouă etc. (Bondar & Panin, 2001).

The *Fortuna Lake* (977 ha) is a lake with a large aquatorium, presenting an active circulation of water, which is supplied by a series of riverine-associated inlet-outlet systems, as: Crânjală Canal (SW of Fortuna L.), Fortuna Canal (NW of Fortuna L.), Şontea Stream (E of Fortuna L.) and Mitchina Canal (W of Fortuna L.).

2.1.2. Gorgova - Uzlina Depression

Within this interdistributary sub-unit, which is located between Sulina and Sf. Gheorghe branches, there are a series of small lakes (110) and a lot of waterways and canals, among the most important being the Litcov Canal (crossing the depression from West to East), the meandering Perivolovca Stream (it flows northward along the initial littoral ridge up to the confluence with the Litcov Canal) and the Ceamurlia Canal (Bondar & Panin, 2001).

Two lakes from this aquatic area were under our attention in the present paper: *Uzlina* and *Isacova*. The *Uzlina Lake* (468 ha) shows active changes of waters due to the direct connection with the Sf. Gheorghe Branch through the Uzlina Canal (S of Uzlina Lake) and with the *Isacova Lake* (to the north). The Isacova Lake (1101 ha) is characterized by relatively stagnant conditions with low water circulation. This couple of lakes is surrounded by a secondary hydrographic network, *i.e.*: the Litcov Canal (N of Isacova L.), Isac 1 (NW of Isacova L.), Isac 2 (NE of Isacova L.), Isac 3 (SE of Isacova L.), Perivolovca Stream (E of Isacova L.) and a short canal between the Uzlina L. and Isacova L.

2.1.3. Matiţa - Merhei Depression

In this sub-unit, which is placed between Chilia and Sulina branches, the related network of inlets and canals is represented by Eracle, Lopatna, Dovnica, Răducu, Bogdaproste, Sulimanca and Roşca (Bondar & Panin, 2001).

The *Babina* and *Matiţa Lakes* belong to the category of lakes with a large aquatorium and relative active changes of waters, including a secondary hydrographic network, too. Although they are geographically located quite close to each other, the Babina Lake (338 ha) is placed in an area with a relatively active circulation of water, while the Matiţa Lake (652 ha) is situated in an area with a poor water circulation, especially during the summer-autumn period, due to the low water levels (Gâştescu & Ştiucă, 2008). There are several canals which provide the inputs and outputs into/from the lake system: Lopatna Stream, Eracle Canal, Rădăcinoasele Canal (NW of Babina L.), Stipoc Canal (W of Babina L.), Canal to the Miazăzi Lake (S of Matiţa L.), Lopatna Canal (N of Matiţa L.) and the Suez Canal (NE of Matiţa L.).

2.2. Fluvio-Marine Delta Plain

Lumina - Roşu Depression

The secondary hydrological network within this sub-unit, which is situated between Sulina and the Sf. Gheorghe branches, is quite well represented, being in connection with the Sulina distributary (*e.g*., Caraorman Canal at Mile 14, Vătafu Canal at Mile 7, Busurca Canal at Mile 2, Pescărie Canal), as well as with the Sf. Gheorghe branch (*e.g*., Erenciuc, Ivancea and Tătaru Canals). The outlets that allow the discharging of water from the depression towards the sea are: Împuţita and Sondei Canals (Bondar & Panin, 2001). Currently, these canals are closed by the Sf. Gheorghe – Sulina roadway.

The *Puiu Lake* (86 ha) and the *Roşu Lake* (1445 ha) are situated farther away from the Danube River distributaries. The riverine-associated inlet-outlet systems are quite well represented by the Caraorman Canal (W of Puiu L.), Erenciuc Canal (S of Puiu L.), Puiu Canal (E of Puiu L.), Ivancea Canal (SW of Roşu L.) and Roşu-Împuţita Canal (NE of Roşu L.).

3. MATERIALS AND METHODS

3.1. Field Methods. Sediment sampling

A series of sediment samples were investigated within four campaigns carried out during 2010 and 2011. The sampling works, the preliminary observations and the *in-situ* measurements were accomplished aboard the ”Istros” Research Vessel (belonging to GeoEcoMar).

The bottom sediments have been usually sampled with a Van Veen - type grab sampler. Several short cores were collected using a Hydro-Bios gravity corer, in order to extend the lithological information up to 50-60 cm under the water-sediment interface. On the R/V ″Istros″ board, both grab and core sediment samples were macroscopically described, sub-sampled, distributed in sterile plastic containers and preserved in cold conditions until their transportation to the laboratory. The cores have been sampled by cutting slices of 1-3 cm thick, using an adequate extruder. Regarding the determination of the bulk sediment properties (wt% of total organic matter, total carbonates and siliciclastic material), approximately 100 g sediment was extracted from the grab sub-samples and the sliced sediments, in order to be used in the laboratory.

3.2. Laboratory analyses

The bulk content of sediment components have been determined by Loss on Ignition Method (Dean, 1974, Heiri et al., 2001, Santisteban et al., 2004), which represents a common procedure used to assess the distribution of organic matter, carbonates and siliciclastic contents of lacustrine sediments. This method is based on the sequential heating of the sediment samples into a SNOL laboratory furnace.

The lacustrine sediment samples are precisely weighed (by using an analytical balance), dried then at 105°C (during more than four hours), in order to remove all the free water, reweighed, and then dried at 550°C for two hours, aiming to remove the organic matter, reweighed again, and finally dried for another two hours, at 950°C, in order to remove the carbonates. In the first phase, the organic matter is oxidized at 500-550°C to carbon dioxide and ash, and then, into the second stage, the carbon dioxide is released from carbonates, at 900-950°C, leaving the oxides. After that, the loss of ignition is calculated as a percentage by using different formulas. In this way, there were determined the organic matter and the carbonate content from the sample. The leftover material of the analyzed sediment is considered the siliciclastic fraction.

4. RESULTS AND DISCUSSIONS

Sediment components

The sediment samples were especially studied in order to assess the bulk sediment characteristics (wt% of total organic matter, total carbonates and siliciclastic fraction). Mostly, the organic matter derived from two main sources - allochthonous (geological substrate of the waterways, plant and animal detritus or other kind of materials carried by water, wind or rainfall), and respectively, autochthonous (microbial-bacterial decomposition and recycling of aquatic plant and fauna remaining). Algal blooms are very intense during the summer and autumn months, contributing, together with the macrophite biomass, to the impressive increase of the biological productivity (Durisch-Kaiser et al., 2011). Generally, the carbonates may have a biogenic origin (mechanical trituration of autochtonous or allochtonous skeletal carbonate) or may come from the chemical precipitation processes. During the laboratory procedures, it has been tried not taking into account the fragments of shells. The investigations have been conducted on several representative lakes of the Danube Delta area, being focused on the litological component variation with depth (core sediment samples), and on their spatial distribution (grab sediment samples).

The areal distribution maps have been elaborated with the program package Surfer 8 (Golden Software, Inc).

4.1. Vertical distribution of lithological components of lake sediments

In general, the lacustrine sediment cores collected from deltaic lakes present an interesting vertical distribution, the depth profiles recording the variations of the lithological components. The core sediments are quite homogeneous in color, with slight variations from light-dark grey to brown, sometimes showing particular gradual colored layers. Apart from this trend are Babina and Isacova Lakes, the sediments being distinguished by color that alternates from light-dark grey to black, predicting high contents of organic matter. In most cores there have been identified fragments of plant residues, shell remains and traces of bioturbation. The water content shows a general decrease with depth, all the cores having a high content of water at the top (fluffy sediments) that decreases downcore, where the sediment becomes more compact. The bottom sediment samples are almost similar in terms of sedimentology (textural and structural). The macroscopic description includes these lacustrine sediments into the category of muds; rarely, the sediments are represented by sandy deposits. Generally, the sediment samples profile exposes three zones: a top horizon rich in organic material, a middle silty horizon, and a bottom clay-rich horizon. In most cases, the sediment cores were collected from the middle of the lakes. The percentage distribution of the lithological components of the core sediments is presented in the table 1.

4.1.1. Fortuna Lake

The results reveal that the organic matter and the minerogenic clastic material (usually siliciclastic) are inversely correlated (a high content of organic matter and a corresponding low content in siliciclastic material, starting from the top and up to the bottom). The diagram (Fig. 2) shows a discontinuous variation, with some peaks and lows in the organic matter and siliciclastic material percentages, which occur at the core depths of 6-8 cm to 14-16 cm, 18-20 cm to 24-26 and 28-30 cm to 34-36.5 cm. This suggests a change in the sedimentary regime and probably, in the depositional environment that facilitated both allochthonous (clastic) and autochthonous (algal, phytoplankton) sedimentary accumulations.

Taking into consideration the core sampling position near the influence area of two canals (one from South – Crânjală Canal and the other from the East – Fortuna Canal), we can say that these variations in organic inputs could have been linked to some processes mainly influenced by the canal inflows or by the underwater current movements that redistribute the sediment particles. The carbonates display low contents with values between 2.68 - 7.54 %.

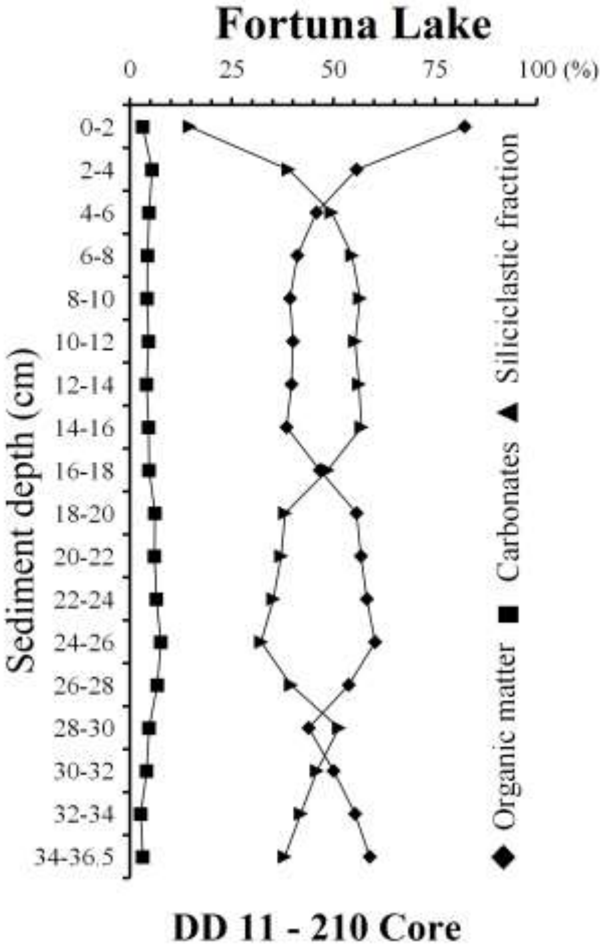

Figure 2. Vertical distribution of lithological components within the sediments of Fortuna Lake

Table 1. The percentage distribution of lithological components of core sediments

Location	Sediment core		Organic matter (%)			Carbonates (%)			Siliciclastic fraction (%)		
	Code	Number of sliced samples	Min. value	Max. value	Mean value	Min. value	Max. value	Mean value	Min. value	Max. value	Mean value
Matiţa	DD10-01	27	4.61	55.58	16.82	5.34	18.17	10.20	34.47	89.99	73.24
Matiţa	DD11-01	23	11.81	85.69	57.35	3.26	12.29	6.57	10.77	79.73	36.21
Babina	DD10-18	25	3.12	69.68	30.33	1.21	31.38	5.45	23.56	93.52	65.04
Babina	DD10-106	21	10.43	79.66	54.63	0.99	9.48	5.45	15.37	88.09	40.08
Babina	DD11-49	15	6.47	83.07	35.95	3.95	9.30	5.74	12.96	88.34	58.53
Isacova	DD10-61	20	2.94	38.52	10.88	6.90	26.73	13.28	45.51	90.15	76.31
Isacova	DD11-105	20	2.42	78.77	31.11	5.49	16.27	10.12	15.73	90.63	59.18
Uzlina	DD10-79	16	2.89	9.22	5.60	5.52	6.70	6.13	84.14	91.08	88.24
Uzlina	DD10-80	10	13.01	25.00	17.80	2.88	12.75	8.43	71.85	78.93	74.12
Fortuna	DD11-210	18	38.51	82.20	52.12	2.68	7.54	4.87	14.70	56.88	43.12
Roşu	DD10-30	23	0.84	49.44	14.55	6.45	49.89	21.16	32.26	90.59	65.37
Roşu	DD11-52	16	11.30	82.61	45.42	6.24	25.21	17.46	11.13	64.87	37.18
Roşu	DD11-60	15	1.19	85.27	46.75	4.05	13.61	9.63	10.67	88.61	43.81
Puiu	DD11-90	12	2.67	83.25	32.00	3.36	26.18	17.53	13.38	76.05	50.81

4.1.2. Uzlina and Isacova Lakes

The cores taken from two lakes of the Gorgova-Uzlina interdistributary depression show almost the same distribution tendency of lithological components in the investigated lakes.

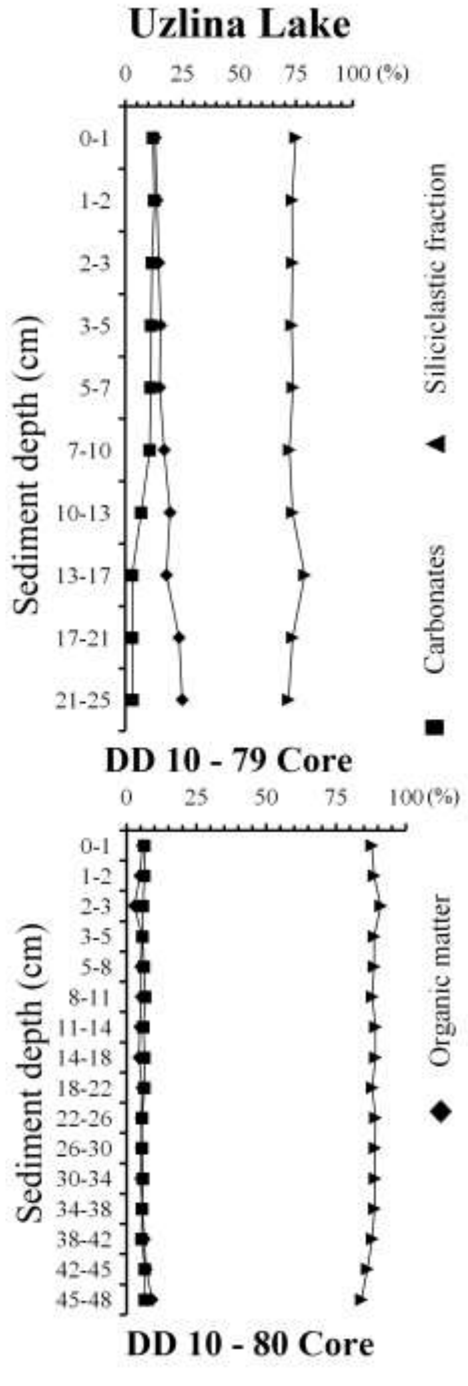

Figure 3. Vertical distribution of lithological components within the sediments of Uzlina Lake

For example, the *Uzlina Lake*, located near the Danube fluvial input, characterized as a dynamic system, remarks lower values of organic matter in comparison with other studied lakes. From this lake, two cores were extracted: one from the middle of the lake (DD10-79), placed near the area of influence of the Uzlina Canal, and the other one from the northern part (DD10-80), near the canal of communication with the Isacova Lake. The graphical representation shows a quite linear distribution of the components across the vertical plane (Fig. 3). There is an inverse correlation between the siliciclastic fraction and the organic matter.

In fact, this represents a typical model of clastic deposition that dominates in the regime of this lake, with low biochemical activity. Here, predominates the clastic sedimentation controlled by the Danube River inflows (allochthonous), through the Uzlina Canal, which is a relatively high velocity watercourse. Regarding the carbonates, they reveal a quite uniform linear distribution, having a mean value of 8.43% and a variation range of 2.88 - 12.75 % (*e.g.*, Core DD10-80; see table 1).

The *Isacova Lake* generally reveals a high content of organic matter, especially at the top of the two investigated cores (Fig. 4). Along the cores we remark a negative correlation between the organic matter and the siliciclastic fraction contents. A decreased percentage of the organic matter and a corresponding increase of the siliciclastic material, especially at the top of the first core (DD10-61), are noticed. At core depths of 3-5 cm we have a peak of the organic matter and a corresponding low of the siliciclastic material; then, as we move downwards, the tendency of these two components decreases (organic matter), respectively increases (siliciclastic fraction). Also, the DD10-61 core shows a peak and a corresponding low in the percentage carbonates content and in the percentage siliciclastic fraction, at depths of 21-24 cm. Otherwise, the carbonates have a quite uniform distribution with some high or low value alternations that occur at different core depths.

From the graphical representation of the second core (DD11-105), we observe the same non-linear distribution of the investigated components.

The distribution of the lithological components shows a lacustrine environment that allowed both organic and inorganic inputs which have occurred through time.

Probably, these variations characterized by alternations of organic and clastic depositions are due to the changes in the water supply system caused by seasonal fluctuations of dry or flooding periods.

4.1.3. Babina and Matiţa Lakes

The results obtained from this sector offer some interesting elements on the investigated lakes. The percentage distribution of the lithological components shows the same general trend, meaning that each core contains a relatively high load of organic matter and a corresponding quota of low siliciclastic material at the core top (inverse correlation; see figure 5).

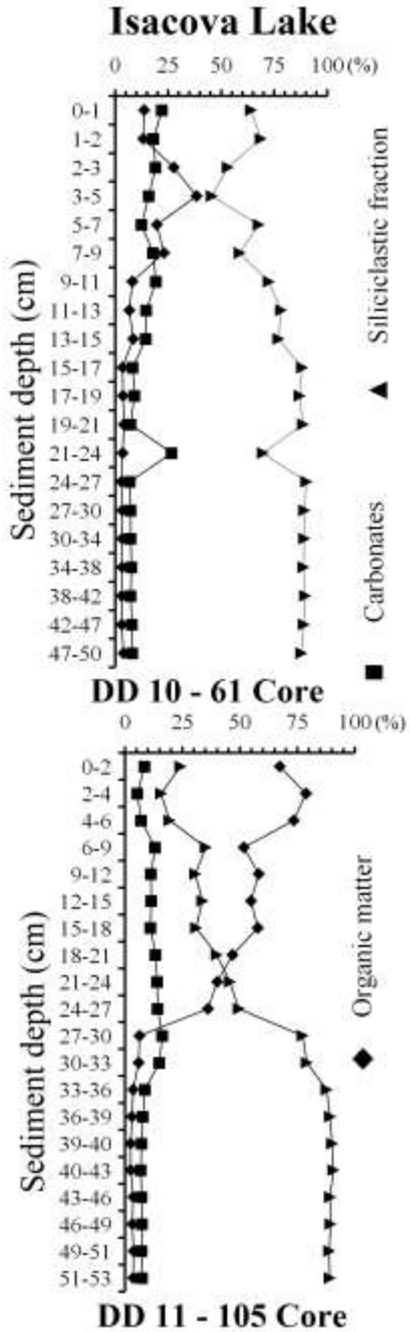

Figure 4. Vertical distribution of lithological components within the sediments of Isacova Lake

The carbonates record low contents. The distribution tendency extends downcore with fluctuations of high and low percentages of lithological component values. In these cores, some peaks and lows in the percentage lithological distribution at analogous depths were noticed. As the amount of organic matter increases, the siliciclastic material gradually decreases.

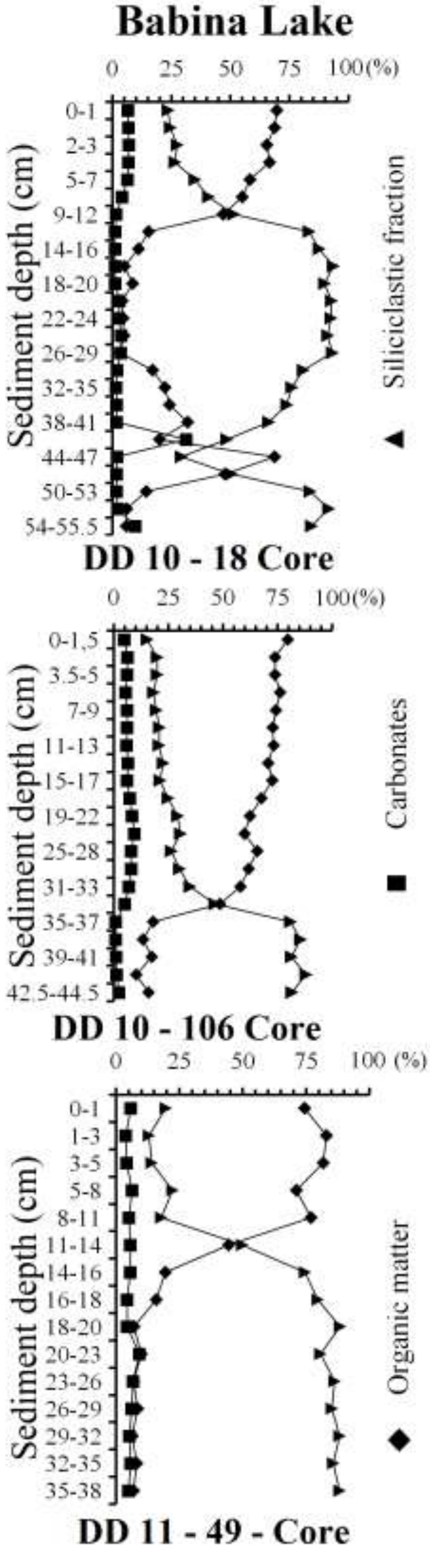

Figure 5. Vertical distribution of lithological components within the sediments of Babina Lake

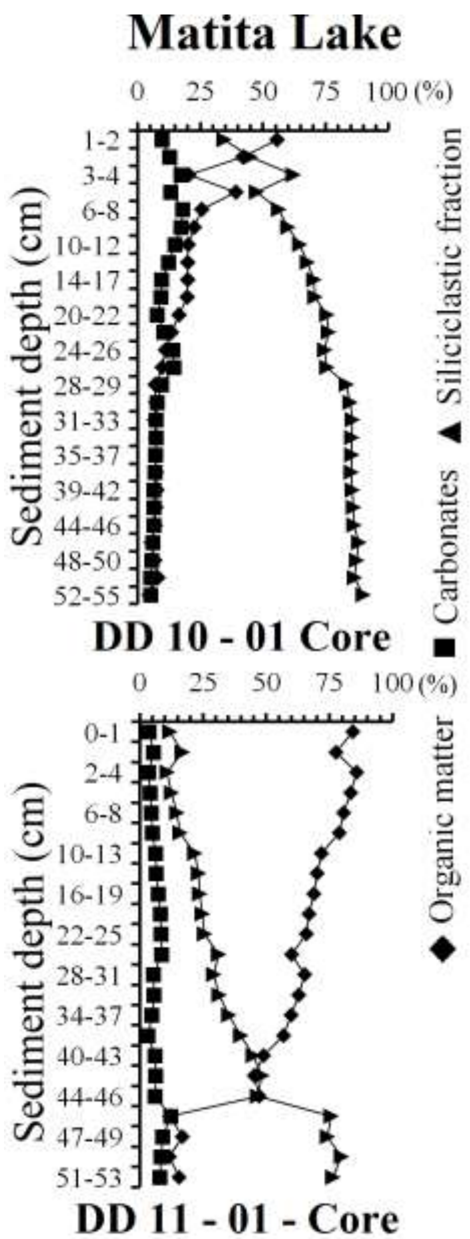

Figure 6. Vertical distribution of lithological components within the sediments of Matita Lake

From the *Babina Lake* there were collected three cores, located in the center of the lake, at a relative short distance one from each other. However, they display a non-linear distribution regarding the lithological components; the organic matter demonstrates some obvious variations in the abundance of organic inputs at different core depths (Fig. 5).

The graphical representation relating to the DD10-18 core may also suggest significant variations of the sedimentation process dynamics in the Babina lake. These variations probably indicate a range of phenomena controlled by the canals inflow regime. As regards the other cores, we can appreciate that the organic deposition dominates, being accompanied by active biological and chemical processes that allowed the settlement of the organic material (vegetal and fauna). Concerning the carbonate content, we observe a quite uniform distribution, with values ranging from 0.99 to 9.48 %, excepting one peak recorded in the DD10-18 core within the depth interval of 41-44 cm, where they registered a value of 31.38 % (Fig. 5).

As concerns the *Matiţa Lake*, there were gathered two cores from the middle of the lake. They display a non-linear distribution, being characterized by a sudden change in the sedimentary regime at different core depths, as: DD10-01, at core depths of 3-4 cm, 4-6 cm and 24-28 cm; DD11-01, at core depths of 1-2 cm and 44-47 cm (Fig. 6). These alternations could be due to some changes in the sedimentation rates, which have been connected to fluctuations in the organic fluxes influenced by the variation of the water level of the canal, which controls the water inflows and the underwater current movements. The carbonates distribution shows values ranging from 3.26 to 18.17 % (see table 1).

4.1.4. Roşu and Puiu Lakes

The percentage distribution of the lithological components relating to the DD10-30 core (Fig. 7), collected from the *Roşu Lake*, shows some clear discontinuities, probably due to the turbulent conditions in the lake sedimentary environments; the alternation of lower and higher values in the upper layers could be linked to serious seasonal changes. The carbonate content is higher than the usual one, within the first 30 cm of the core, suggesting a more carbonatic character of the muds of the Roşu Lake as compared with the sediments from other Danube Delta lakes; then we notice a slight decrease downcore (Fig. 7).

The other two cores from the Roşu Lake (DD11-52 and DD11-60) show evident high values of organic matter in the upper layers, the contents gradually decreasing with the increase in depth (Fig. 7). This suggests a quite moderate sedimentation regime, without significant events, in which the organic deposition prevails. There were favorable conditions for the accumulation of abundant organic matter inputs (algal, phytoplankton, fauna). Overall, the carbonates present an alternation of moderate high and low values from the top down to the bottom. Though, we have to specify some higher contents of carbonates than in the other cases (DD10-30 – 21.16 % mean value, DD11-52 – 17.46 % mean value; see table 1).

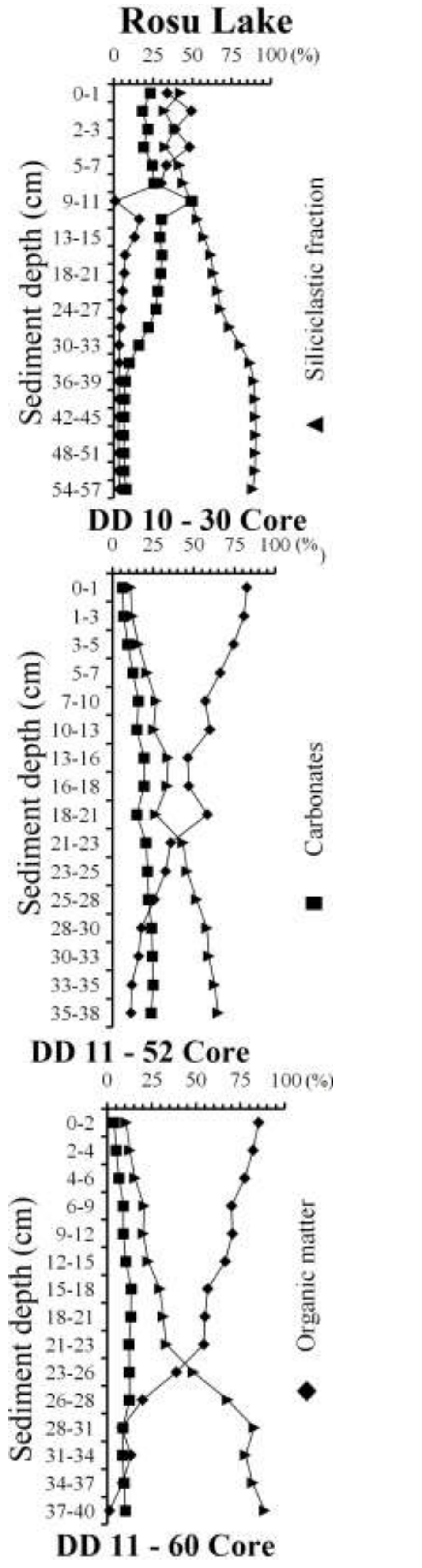

Figure 7. Vertical distribution of lithological components within the sediments of Roşu Lake

In the Puiu Lake, the graphical representation of the vertical distribution of the lithological components determined for the DD11-90 core (Fig. 8) depicts, in the upper part, a higher organic matter content, and correspondingly, low contents of the siliciclastic fraction.

We suppose that there was a normal rate of sedimentation without significant disturbances that allowed the deposition of organic fluxes in this lacustrine environment. The carbonates show contents between 3.36 – 26.18%, with 17.99% average value. The higher values of the carbonate contents, relating to the Roşu and Puiu lakes, may be related to *in-situ* carbonate precipitation processes, but further investigations should be made to support the origin of carbonates in these lakes.

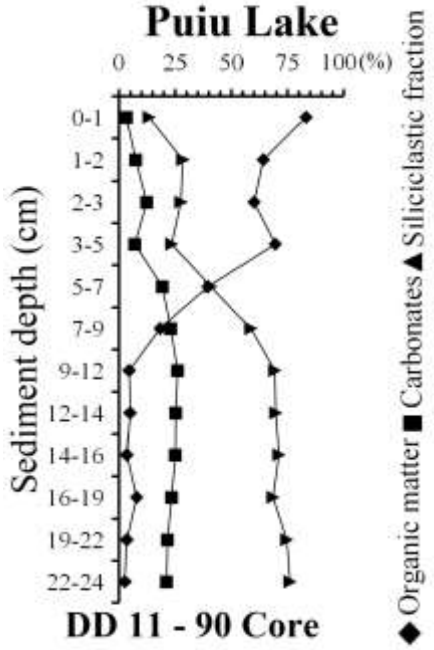

Figure 8. Vertical distribution of lithological components within the sediments of Puiu Lake

4.2. Areal distribution of lithological components of lake sediments

Generally, three categories of lakes are present within the Danube Delta: (a) lakes strongly influenced by the Danube River fluvial input (*e.g.*, Uzlina, Fortuna); (b) lakes that are situated farther away from the Danube River supply (*e.g.*, Matiţa, Babina) and (c) lakes with intermediate conditions (*e.g.*, Puiu). The lakes which are influenced more or less by the direct fluvial inputs loaded with solid suspensions from the Danube River are characterized by grey or blackish mineral silts, with unctuous aspect and bioturbation structures, usually presenting a grey-yellow fluffy layer at the top. In these recent sediments frequently appear shells and live specimens of *Unio pictorum*, *Anodonta cygnea*, *Dreissena polymorpha* and *Viviparus viviparus* (*e.g.,* Uzlina and Fortuna lakes). The lakes that are not influenced by direct fluvial inputs are characterized by porous uncompacted and non-cohesive silts, of grey-blackish or yellow color, quite rich in organic material and carbonates. Sometimes, these silts contain fragments of reeds and rare shells or live specimens of mollusks (*e.g.,* Isacova, Matiţa, Babina, Roşu, and Puiu) (Rădan et al., 1997). The percentage distribution of the lithological components of the surface sediments is presented in the table 2.

4.2.1. Fortuna Lake

This lake belonging to the Meşteru – Fortuna Depression, that is situated between Chilia, Tulcea and Sulina distributaries, is strongly influenced by the Danube River input, especially after the achievement of some hydrotechnical works within the Danube Delta. The environmental conditions relating to the Fortuna Lake are dominated by the relatively large amounts of sediment inputs received from the Sulina distributary, especially through the Crânjală Canal.

In the *Fortuna Lake,* the areal distribution of the organic matter content exposes two zones of maximal concentration, situated in the northwestern and northern parts of the lake (Fig. 9). Here, it prevails the abundance of the organic settlement due to the quite moderate sedimentation regime. As regards the carbonate content, also, we found two areas of maximal concentration, but these are located in the central-eastern and southern parts of the lake. The highest siliciclastic fraction content occurs in the central and southwestern parts of the lake, and this could be linked with the Crânjală Canal inflow (situated in the southern part of the lake), which is in connection with the Danube River direct supply. The dynamic conditions are suggested by the clastic settlement which dominates these areas of the lake.

4.2.2. Uzlina and Isacova Lakes

The couple of lakes Uzlina-Isacova investigated within the Gorgova – Uzlina Depression represents a particular case due to the fact that although the two lakes are placed one after another, they are characterized by different environmental conditions. So, the *Uzlina Lake* is strongly influenced by the Danube River input, while the *Isacova Lake* is individualized by relative stagnant conditions. The small number of samples was not sufficient to elaborate the areal distribution maps relating to the lithological components of the surface sediments in these investigated lakes. However, the values obtained suggest certain trends.

The surface sediments collected from the *Uzlina Lake* are mainly mineral-organic muds and those sampled from the *Isacova Lake*, are organic - mineral muds, quite richer in carbonates. The southern part of the Uzlina Lake is dominated by moderate values of the organic matter content in comparison with the previous investigated lakes. The carbonate content (5 - 9.2%) is mainly concentrated in the northern part of the lake. Regarding the siliciclastic material, the higher content is noticed in the median-southern part of the lake. Generally, the sedimentary deposits from the Uzlina Lake are of allochthonous origin (organic and inorganic detritus etc.) that is introduced from rapid water inflows through the Uzlina Canal. It is important to specify the formation of a ″micro-delta″ at the end of the Uzlina Canal, due to the sediment supply from the Danube River, that is very high within this lake.

With regard to the areal distribution of the lithological components of the surface sediments in the *Isacova Lake*, we remark some higher values of organic matter contents occurring in the southern part of the lake up to the median part, and higher contents of carbonates (22 - 26 %), and respectively, of siliciclastic material (60 - 64 %), in the northern part of the lake.

The sedimentation processes from the Isacova L. present intermediate conditions, which have been connected with both autochthonous (aquatic plants, phytoplankton and benthic algae etc.) and allochthonous origin.

Table 2. The percentage distribution of lithological components of surface sediments

Location	Number of samples	Organic matter (%)			Carbonates (%)			Siliciclastic fraction (%)		
		Min. value	Max. value	Mean value	Min. value	Max. value	Mean value	Min. value	Max. value	Mean value
Fortuna	25	3.46	67.30	40.72	2.92	10.97	7.48	26.4	90.27	52.25
Matiţa	25	53.20	82.25	72.54	2.69	8.55	5.73	13.26	42.48	21.81
Babina	33	34.35	84.57	67.16	1.05	13.88	5.09	12.87	63.74	28.04
Roşu	10	51.43	79.29	67.45	3.38	12.92	8.77	14.10	44.45	24.23

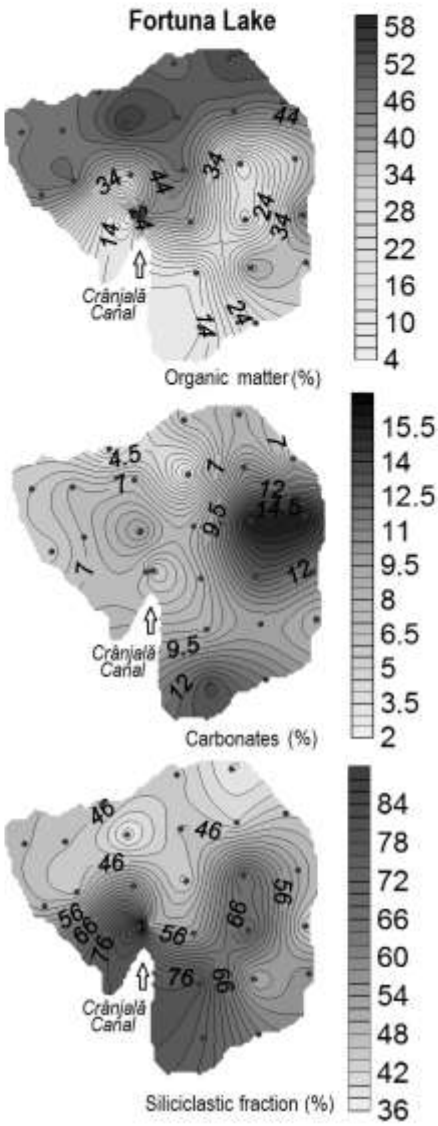

Figure 9. Areal distribution of lithological components characterizing the Fortuna Lake sediments

4.2.3. Matiţa and Babina Lakes

The lakes within this hydrographic unit are situated farther away from the Chilia and Sulina Danube River Branches. The secondary hydrographic network is not very well developed, so that relatively stagnant environmental conditions prevail, being the subject of *in-situ* biological and chemical processes *versus* allochthonous input. This sector is dominated by sediments rich in organic matter. The sediment samples collected from these lakes are represented by porous organic muds, more or less coherent, being remarked an abundance of underwater vegetation.

In the *Matiţa Lake*, we observe a great variability regarding the areal distribution of the lithological components. For example, the organic matter content presents some maximal concentration areas in the northwestern part and in the south-central part (Fig. 10), which may be related to different sedimentation rate conditions.

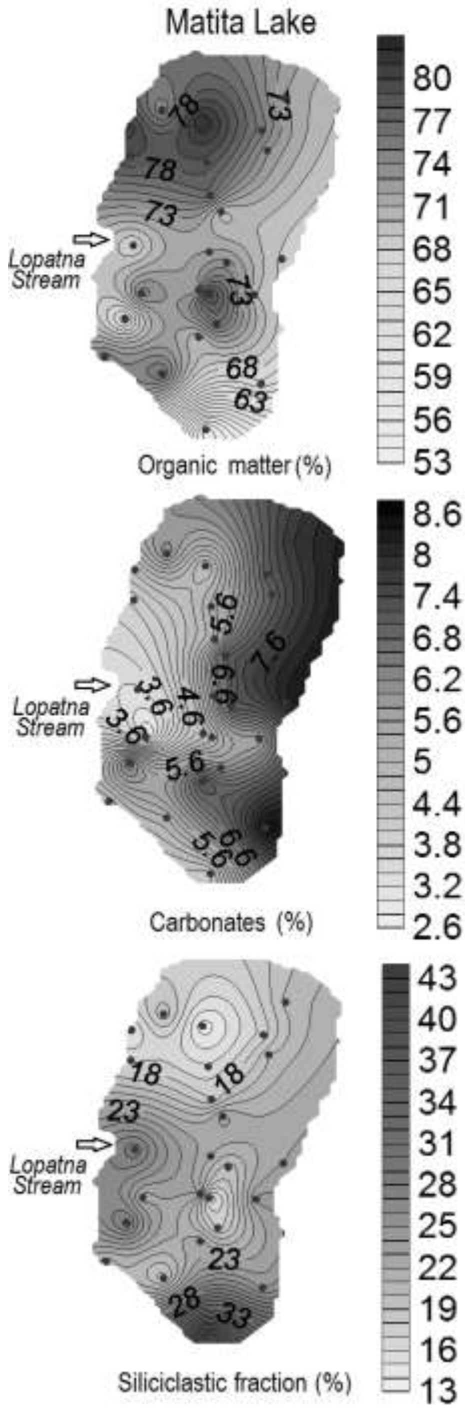

Figure 10. Areal distribution of lithological components characterizing the Matiţa Lake sediments

As we have mentioned before, there is a substantial load of subaquatic vegetation and there is a little connection with an open water system. The carbonate content is quite low (2.69 - 8.55 %), the maximal values being distributed from the eastern part of the lake up to the median and the western part of the lake. The highest content of siliciclastic fraction was found in the southern and western parts of the lake and it could be linked to the Lopatna Stream inflow.

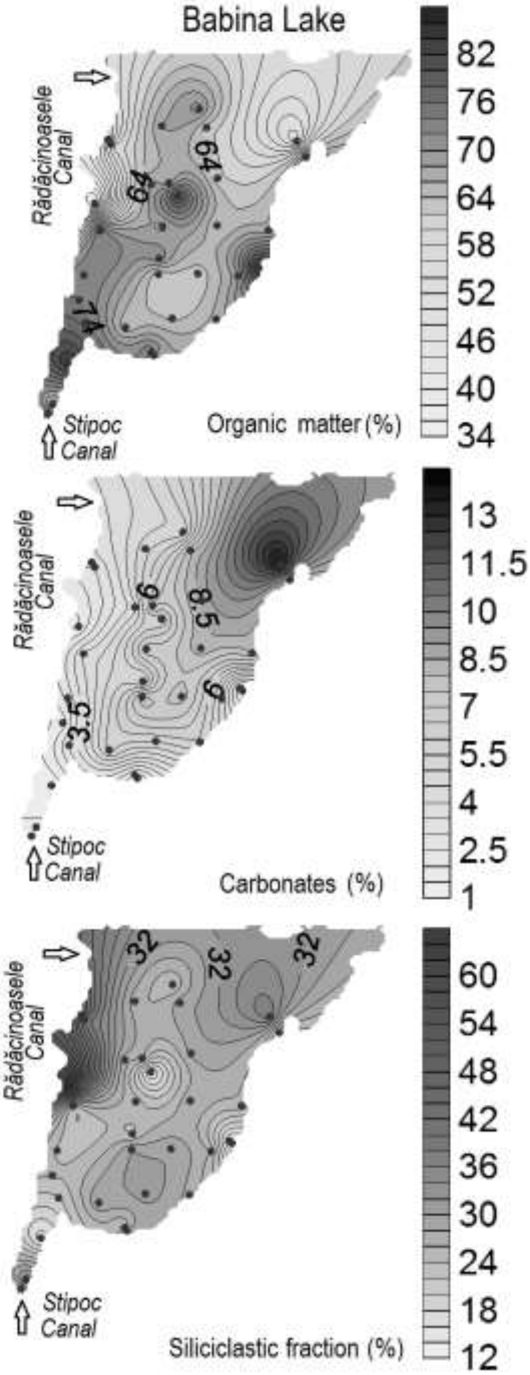

Figure 11. Areal distribution of lithological components characterizing the Babina Lake sediments

The areal distribution of organic matter contents in the *Babina Lake* indicates high values that occur in some distinct sectors, namely in the central, eastern and southern parts of the lake. The carbonate contents (1.05 - 13.88%) present the maximum concentration in the east-northern part of the lake (Fig. 11). The maximum concentration of the siliciclastic fraction occurs in the western-central and southern parts of the lake. These trends of the lithological components distribution are probably due to the autochthonous origin that prevails and may be a consequence of the fact that the lake is quite isolated from an open water system.

4.2.4. Puiu and Roşu Lakes

The investigated lakes within the Lumina – Roşu Depression are less influenced by the Danube River intake. The *Puiu Lake* receives appreciable inputs through the Crişan-Caraorman Canal, while the Roşu Lake, located farther away from fluvial supply, receives water inputs, in the western part, from the Puiu Lake (through the Roşu-Puiu Canal). Generally, the sediments collected from the Puiu and Roşu lakes are characterized by organic-mineral muds.

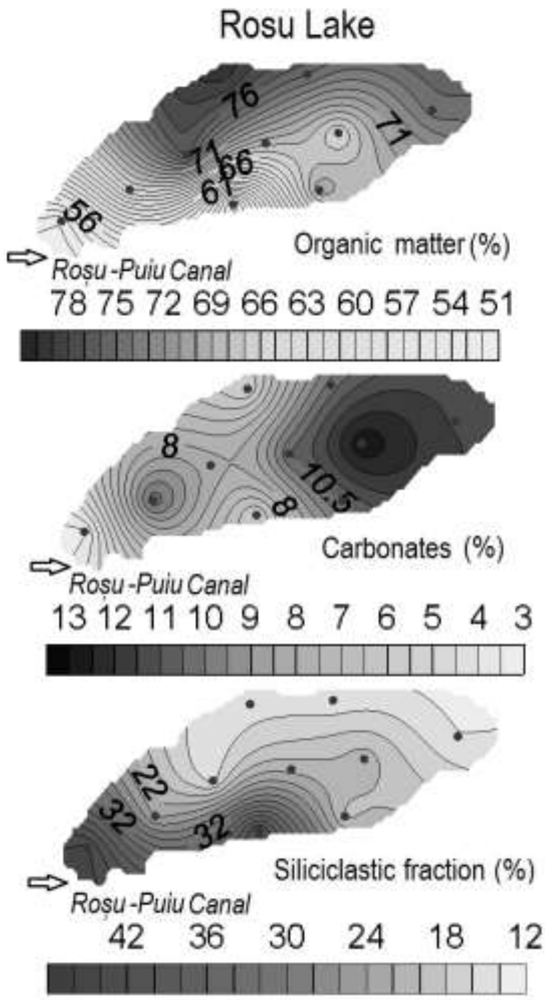

Figure 12. Areal distribution of lithological components characterizing the Roşu Lake sediments

The organic matter spatial distribution within the *Roşu Lake* is characterized on the entire area by high values varying from 51 to 79% (Fig. 12; Table 2). This indicates relatively calm environmental conditions, without significant variations regarding the abundance of organic matter input (especially, the settlement of vegetal and fauna contents). The sector with the maximal carbonate content appears in the eastern-central part of the lake (Fig. 12), and the maximal content of the siliciclastic fraction occurs, especially, in the western part and in the southern extremity of the lake (Fig. 12), as a result of the Roşu-Puiu and the Ivancea Canal inflows.

Due to the low number of samples it was not possible to elaborate a relevant distribution map for the *Puiu Lake*. Anyhow, from the obtained results, we observed that in the Puiu Lake two areas of maximal organic matter content are revealed, namely in the eastern and southern parts of the lake. The highest content of carbonates is found in the northern part. Concerning the siliciclastic material, the maximal content occurs in the western-median part of the lake, probably due to the water and sediment inputs through the Crişan-Caraorman Canal.

5. CONCLUSIONS

The sediment accumulations in the investigated lakes are strongly influenced by the characteristics of their source components – allochthonous and autochthonous materials – that allow interactions between the internal elements and the lacustrine depositional environment.

In the lakes that are situated farther from the Danube River intake or in more restricted areas prevails the distribution of the autochthonous materials; here, the sediment deposition is characterized by limited conditions, as the diminished water and sediment supply, due to the long distance transport and the differential sedimentation during the way to the deposition area. Probably, the inner transportation of resuspended sediment particles and the biological processing of materials represent the main characteristics of these lakes.

In the lakes that are directly affected by the Danube River supply predominate the allochthonous materials; the accumulation is conditioned by active processes of erosion – transportation – deposition of dissolved or particulate sediments associated with a relatively high sediment input.

Finally, we can say that the vertical distribution of organic matter, carbonates and siliciclastic fraction indicate that the sediment accumulation is distinct between all the studied lake systems, and even more than that, this varies within the same lake. This statement is supported by the high degree of the lithological component variation that shows some changes at different layers with respect to a constant rate of sedimentation, such as the organic matter that recorded different values (*e.g.*, higher values both in the upper and in-depth layers) that fall into a wide range in the majority of investigated cores. The possible fluctuations in organic inputs could be due to the high productivity (algal, phytoplankton and fauna activities) or to the anthropogenic influences (opening and closing of various artificial canals within the Danube Delta), that have had repercussions in the deposition rate at a moment in time. The higher values of the carbonate contents found out in the Roşu and Puiu cores may be related to *in-situ* carbonate precipitation processes, but further investigations should be made to support their origin in these lakes. With regard to the clastic deposition, we mention that its variability indicates a wide range of processes that are influenced by external factors as: the water flow through the Danube River or riverine-associated inlet-outlet systems, underwater current movements (sediment recirculation), climate changes (floods or droughts), anthropogenic inputs and outputs etc.

The areal distribution analyses generally separate these types of recent sedimentary deposits:

- Sediments rich and very rich in organic matter (organic muds subsequently followed by organic-mineral muds*)*, which occur especially in the areas located far from the Danube River intake or in more restricted areas;

- Sediments loaded with a high content of the siliciclastic material (mineral muds passing into mineral-organic muds) characteristic especially in areas directly affected by the Danube River supply.

It should be noted that these types of identified accumulations do not dominate the entire surface of a lake and within these aquatic areas may exist variations of these categories; they depend on several factors which control the recent sediment transport and deposition, being very different from one sector to another or may vary over time due to natural or anthropogenic causes. Thus, the artificial closing and reopening after few years of Uzlina Canal influenced the sedimentation conditions within the Uzlina and Isacova lakes in the last two decades, the closing of the Crânjală Canal, many years ago, converted the Lake Fortuna from a dynamic to a quite restricted aquatic environment, modifiyng the quality of sediments, and the seasonal natural closing of Roşu-Puiu Canal by the floating reed influences the sedimentation process in the Roşu Lake.

The acquired results reveal significant variations of the main lithological components (total organic matter, carbonates and siliciclastic fraction) of the sediments in the investigated lakes. As it was expected, the sediment differentiation between the investigated lakes was evidenced by the relations between the external sources of sediments (suspended or particulate) brought by the Danube River input and by the local lacustrine environmental conditions (*in*–

situ bio-chemical processes). Thus, organic and inorganic particles resulted from inside and outside the lake system are progressively stored.

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