AN ENVIRONMENTAL MAGNETO-LITHOGENETIC STUDY IN THE LAKES OF THE GORGOVA – UZLINA DEPRESSION (DANUBE DELTA, ROMANIA).

I. INSIGHTS FROM SHORT SEDIMENT CORES

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Abstract. Magnetic susceptibility (MS) represents a high resolution environmental and lithological (LITHO) proxy tool, which is successfully used for the study of recent sediments in freshwater or marine aquatic environments. The studies that we have achieved in the last 40 years in the Danube – Danube Delta – Black Sea hydrosedimentary system have revealed strong connections between the characteristics of sedimentary environment, sediment quality and their magnetic properties. In the present paper are discussed results concerning several lakes from Gorgova – Uzlina Depression (Danube Delta), which are added to the lately published magneto-lithological data for sedimentary environments of Meşteru – Fortuna and Matiţa – Merhei depressions. This work, which represents the first part of a composite paper, is particularly focused on the sediment cores collected in the lakes Gorgova, Cuibeda, Uzlina and Isacova. Their MS characterization, not neglecting the lithological support, defined by the three main components, namely the SILiciclastic/ minerogenic fraction – SIL, Total Organic Matter – TOM and CARbonates – CAR, is approached. Several lithological units are identified, based upon the macroscopic characteristics, magnetic properties and lithological composition. It is interesting to note that although the study area is included in the fluvial delta plain, the recent lacustrine sediments are very thin in some sectors and the short cores (under 60 cm) stop at a level of marine clays (L. Cuibeda). The second part of this study, regarding the surficial sediments from the above-mentioned lakes, and more other ones is published inside of a similar magneto-lithogenetic context. All these data give new evidences for demonstrating the availabilities of the method used to identify the environmental influences on the magnetic susceptibility of lake sediments, and hence to assess the geoecological state of the deltaic area under attention.

Key words: environmental magnetism, lake sediments, magnetic susceptibility, lithology, sediment cores, Danube Delta.

1. INTRODUCTION – STUDY AREA

The magnetic susceptibility tool, which we are using in lacustrine areas since 1977, „offers the possibility of a fast and non-destructive characterization of sediments“ (Egli, 2003), and our MS database, accumulated during such a long time period, accounts for a consistent contribution to the development of „so-called magnetic proxies for the reconstruction of the environmental history“ (Egli, 2003), particularly relating to the Danube Delta. In order to develop a proxy method of recovering and deciphering of the enviromagnetic and sedimentological records archived inside of the lake sediments, we have begun, two years ago, to carry out reviews of data having been gathered by us for the Danube Delta (DD) ecosystems, particularly since 2010. In two previous published papers, we performed synopses relating to the lakes and channels from the Meşteru – Fortuna (I, in Fig. 1) (Rădan et al., 2013) and Matiţa – Merhei Depressions (II, in Fig. 1) (Rădan et al., 2014a). These are two deltaic units located in the northern DD wing, which encompasses the area between the Chilia and Sulina Branches (Fig. 1).
The study area approached in this article is situated within the southern DD wing, which is bordered by the Sulina and Sfântu Gheorghe Branches, and includes the lakes and channels of the Gorgova – Uzlina Depression (III, in Fig. 1). This deltaic unit is placed in the western part of the Danube Delta, having as an eastern border the Caraorman Sand Ridge (Fig. 1), hence, it is also positioned in the fluvial delta plain area, like the above-mentioned previously investigated two depressions.

Magnetic susceptibility (MS) has proved to be a high resolution environmental and lithological (LITHO) proxy tool, being successfully used in lacustrine areas, wherefrom the composite signatures archived inside of surficial sediments and cores are recovered and deciphered in laboratory. The great number of sample collections investigated during the last 40 years in the Danube Delta (DD) gave a clear evidence of „magnetisability“ of the DD lake sediments, particularly concerning the environmental influences on the parameter that measures this geophysical property and the appropriate geoecological response. Consequently, by MS and LITHO characterization of recent sediments, sampled at different time intervals in the same lakes, the changed or unchanged environmental state of deltaic geoecosystems (the anthropogenically modified ones included) has been accurately established by means of a quantitative indicator assessment, complemented by other information, as well.

The magneto-lithological data obtained for nine short sediment cores, collected during the period 2010 ÷ 2014 from four lakes (Gorgova, Uzlina, Isacova and Cuibeda; Figs. 1 and 2), are analysed in this article, as a first part
Sorin - Corneliu Rădan, Silviu Rădan, Inna Catianis, Dumitru Gansu, Albert Scriciu, Iulian Pujar – An environmental magneto-lithogenetic study. I. Insights from short sediment cores

This integrated study concerns the vertical distribution of the magnetic susceptibility ($MS; k$) and of the main lithological (LITHO) components (SIL – Siliciclastic/detrital/mineral fraction, TOM – Total Organic Matter, and CAR – Carbonate fraction). The areal distribution of the magnetic and LITHO parameters measured for the surficial sediments of all 9 investigated lakes from the Gorgova – Uzlina Depression (the Obretinu Mic, Gorgovăţ, Obretinciu, Isăcel and Gorgoștel lakes are added to the four above-specified lakes; Figs. 1 and 2), will be discussed in the second part of the paper.

Some of the magneto-susceptibilometric and lithological/sedimentological data, achieved along the way, have been previously published, e.g., Rădan & Rădan (2011, and the references therein), Rădan et al. (2013, 2014a,b,c,d), and/or were presented at international symposia, e.g., Rădan & Rădan (2007b,c, 2010b), Rădan et al. (2014b, 2015).

2. GEOMATERIALS AND METHODS

The field works were performed by GeoEcoMar, aboard the fluvial research vessel “Istros”, in the framework of the Core Program, Contract no. PN 09-41 03 04. The nine sediment cores have been taken with a Hydro-Bios corer, using a transparent tube of 60 cm length. The thickness of the sedimentary sequences recovered in the cores was 25 - 53 cm. The cores were collected during the period 2010 ÷ 2014 from four lakes: Gorgova (DD 12-278), Uzlina (DD 10-80, DD 12-319 and DD 12-318), Isacova (DD 10-61, DD 11-105 and DD 12-256), and Cuibeda (DD 14-210) (Figs. 1 and 2). Albeit the cores are short, the MS and LITHO variations which were recorded reveal interesting profiles for interpretation in magneto-sedimentological terms. The sediment cores were opened aboard the R/V “Istros” and they were sampled in 1, 2 or 3 cm thick slices; several sediment sub-samples (ranging between 9 - 23 slices) were obtained from each core and, subsequently, they have been directed to different laboratories for specific analyses (e.g., lithological composition, magnetic susceptibility etc.).
The magnetic susceptibility measurements were executed with a KLY-2 Kappabridge, in the laboratory of environmental magnetism of the Geological Institute of Romania. Details concerning the methodology for measuring the magnetic susceptibility (\(MS; k\)) on lake sediments with this equipment were given in numerous unpublished research reports and in several previously published papers (cited in Rădan & Rădan, 2011). The \(k\) values were reported to the classes of a “magnetic susceptibility scale” (Rădan & Rădan, 2007a), so that a \(MS\) calibration of the lake sediments has become feasible.

As regards the determination of the lithological composition of the lake sediments, this was carried out in a dedicated laboratory of GeoEcoMar. The Loss on Ignition method (LOI) was applied, by using the sequential heating at 550°C and 950°C, into a SNOL lab furnace (Dean, 1974; Catianis et al., 2013, 2014). Hence, the contents (in percents) of three lithological components were established, following the order \(TOM\) (Total Organic Matter), \(CAR\) (Carbonates), and \(SIL\) (Siliciclastic/minerogenic/detrital fraction).

The strength of the relationship between the magnetic and lithological parameters was assessed (\(SIL\) versus \(MS\), \(TOM\) vs. \(MS\) and \(CAR\) vs. \(MS\)), the achieved correlation coefficients (\(r\)) being referred to a scale with 6 ranges spanning the interval from (-1) to (+1) (Rădan et al., 2014a).

### 3. RESULTS AND DISCUSSION

The results are presented following the order (Fig. 1) Gorgova (13), Cuibeda (14), Uzlina (15) and Isacova (16).

The vertical distribution profiles of the \(MS\) values (in 10\(^{-6}\) SI) and of the \(SIL\), \(TOM\) and \(CAR\) contents (in %), which were recorded along the Cores \(DD\) 12-278, \(DD\) 14-210, \(DD\) 10-79, \(DD\) 12-319, \(DD\) 12-318, \(DD\) 10-80, \(DD\) 10-61, \(DD\) 11-105 and \(DD\) 12-256, are supported by several \(MS\) - LITHO diagrams, all together constituting magneto-lithological models assigned to the nine cores.

#### 3.1. GORGOMA LAKE (13, IN FIG. 1)

Located in the central part of the Gorgova - Uzlina Depression (Fig. 1), the Gorgova Lake was investigated during the expedition carried out by GeoEcoMar during 20 July – 2 August 2012. Besides of the surficial sediments which were sampled from 33 stations, a HydroBios sediment core (DD 12-278) of 44 cm length was collected from the central zone of the lake (Fig. 2). After slicing the core at intervals of 2.0 cm, 23 samples have resulted, which have been then directed for investigation towards different laboratories.

The sedimentary sequence crossed by the Core \(DD\) 12-278 shows a change, from soft organic muds at the upper part to organo-mineral sediments downwards, associated with a slight carbonate increase trend to the base, reflecting the lithological variations in time, during more or less recent evolution of the lake.

The study of this core shows up a series of magnetic susceptibility variations (Fig. 3a), starting from the lowest \(k\) value (20.6x10\(^{-6}\) SI) measured on the first (top) sediment slice (0 - 2 cm), marked by I (‘blue triangle’ in Fig. 3), and reaching the highest value (102.35x10\(^{-6}\) SI) for the sample collected in the middle of the core (depth interval 22.0 - 24.0 cm), element indicated by I in Fig. 3 (‘red triangle’). Actually, a large \(MS\) maximum anomaly is recorded in the central zone of the core, which is extended along ca. 30 cm, up and down of the median ax, above specified. Along the last 6 cm of the core (its base), an enhancement trend is observed, the \(k\) values increasing from 61.49x10\(^{-6}\) SI – which marks a minimum zone (denoted by 2/ ‘blue triangle’, in Fig. 3) – up to 87.94x10\(^{-6}\) SI (at the core base; 42 - 44 cm), \(k\) value signalized by a ‘red triangle’ (III). There is another higher \(k\) value (100.34x10\(^{-6}\) SI), measured on a sample sliced from the central \(MS\) maximum area (interval 28 - 30 cm), a point denoted by II (‘red triangle’). All these elements identified within the \(MS\) 3D bar-chart carried out for the Core DD 12-278 are correlated in Fig. 3 with the corresponding levels from the \(MS\) 2D line-chart (c) and from the \(MS\) 3D bar-chart (f), respectively. We add the observation that the \(MS\) characterization of the core is based on two \(k\) classes only: II (36 %) and III (64 %) (Fig. 3b); moreover, for 71 % of the samples calibrated to class III were measured \(k\) values within the lowest zone of the class III definition interval (75x10\(^{-6}\) – 175x10\(^{-6}\) SI), particularly situated between 75x10\(^{-6}\) and 95x10\(^{-6}\) SI (Fig. 3a), the rest of 29 % being \(k\) values placed between 95x10\(^{-6}\) and 105x10\(^{-6}\) SI (Fig. 3a), i.e., also within the first third of the interval. As regards the contents of the siliciclastic component (\(SIL\)) determined for the muds sampled from the above remarked levels (1 and 2) – related to the lower/minimum values; I, II and III – related to the higher/maximum values), identified along the sediment core, they are as follows: 1 – 11.36 %; 2 – 33.36 %; I – 45.54 %; II – 41.69 %; III – 49.00 %. The calculated correlation coefficients (\(r\)) (Fig. 3j,k,l), which indicate high values (given below), confirm the above observations with regard to the interconnection between the magnetic and the lithological parameters (particularly, \(SIL\) and \(TOM\)):

- \(SIL\) versus \(k\) \(r = 0.89\) (Fig. 3i)
- \(TOM\) vs. \(k\) \(r = -0.81\) (Fig. 3j)
- \(CAR\) vs. \(k\) is lower, but positive: \(r = 0.41\) (Fig. 3k)

The positive correlation \(CAR\) vs. \(k\) is confirmed by the \(CAR\) vs. \(SIL\) correlation, both suggesting a detrital origin of the carbonates in the sediments of the Lake Gorgova:

- \(CAR\) vs. \(SIL\) \(r = 0.72\) (Fig. 3i)

The \(TOM\) 3D bar-chart (Fig. 3g) reflects “in mirror image” the \(SIL\) 3D bar-chart (Fig. 3f), while the \(CAR\) 3D bar-chart (Fig. 3h) shows a relatively similar pattern to \(SIL\) diagram and a general increasing trend of the carbonate contents, starting with the lowest value (3.22 %) obtained on the first mud slice (0 - 1 cm), and reaching the highest one (15.64 %) at the core base (depth interval 42 - 44 cm); a slight minimum zone is visible around the median part of the core, the lowest \(CAR\) content (4.23 %) being given by the mud sample taken from the
Fig. 3. Magneto-lithological model for the Core DD 12-278 (Gorgova Lake). a) Downcore variations of magnetic susceptibility values (MS, k); the bars, representing MS values, are coloured according to k scale classes (Rădan and Rădan, 2007a); b) MS calibration of the core sediments, according to k classes; c) Downcore MS variation curve; d) Downcore variation of lithological composition (SIL, TOM and CAR contents); e) Average lithological composition of the core sediments; f) Downcore variation of SIL contents; g) Downcore variation of TOM contents; h) Downcore variation of CAR contents; i) Scatter plot for SIL versus k; j) Scatter plot for TOM vs. k; k) Scatter plot for CAR vs. k; l) Scatter plot for CAR vs. SIL.

Notes: 1. MS (k) values are expressed in 10^-6 SI; 2. SIL, TOM and CAR contents are expressed in %.
depth interval 16 - 18 cm. The simultaneous vertical distribution of the three lithological components along the sediment core DD 12-278 is best represented by the “area-chart” from Fig. 3d, and the average weights in which they participate to defining the core lithological composition are illustrated by the the diagram of Fig. 3e. So, 61 % are assigned to the organic matter (TOM), 31 % to the siliciclastic fraction (SIL), while the carbonate component (CAR) takes up the remaining 8 % (Fig. 3e).

The magnetic susceptibility variations (Fig. 3a), correlated with the values of the lithological component contents (Fig. 3f,g,h), illustrate an interesting alternance of finer and coarser episodes, which correspond to the temporal variations of the sedimentary supplies. The sediments are quite coarser, more siliciclastic in depth, as compared with the surficial ones, although they remain predominantly of organo-mineral type and are calibrated to k classes II and III.

In the absence of dating information, there are not reliable correlations with known events, but some assumptions in the context, only. Thus, we can consider the maximum MS values recorded at the core base could be correlated with the time period when the Gorgova Canal, located in north, was active. After its closing, in 1982, the sedimentation has become finer and richer in organic material, followed by a new increase with the apex within the depth interval 22 - 30 cm, which corresponds to the active period of the Gârla Filatului Canal; again, a diminishing of the detrital supplies has occurred, after cutting off the Mahmuda Meander, and then, after the temporary closing of the G. Filatului.

3.2. Cuibeda Lake (14, in Fig. 1)

The eastern boundary of the Gorgova - Uzлина Depresion – as regards the studied lakes – is constituted just by the Cuibeda Lake (14, in Fig. 1; see also Fig. 2), investigated by GeoEcoMar during the expedition carried out in the timeframe 25 April ÷ 7 May 2014.

The surficial sediments were sampled from a network of 14 stations, and a short core of 38 cm length (Fig. 4) was taken from the central zone of this lake (Fig. 2), namely from the DD 14-210 sampling station. The core was sampled by extrusion and cutting of sediment slices 2 cm thick; the 19 samples obtained have been analysed for the lithological composition and magnetic susceptibility.

The upper half of the core (0 - 20 cm) consists of grey yellowish muds, fluffy on top and more compact downcore, containing few shell debris (Gastropoda) and some vegetal material (reed fragments). In the next 5 cm, the sediments become coarser and show a peaty aspect. After a thin transition zone (25 - 28), represented by grey clayey to dark grey clayey-silty muds, containing few wood fragments (1 - 3 cm long), the core displays a last sequence (28 - 38 cm), represented by a dark grey silty clay, with a rather plastic consistency, similar to the marine clays identified in cores from Matița - Merhei Depression (Rădan et al., 2014a). The average contents of the main lithological components (Fig. 4e) are in agreement with the above macroscopic core description, the Total Organic Matter (TOM) predominating (69 %) within the sediments, followed by the siliciclastic/mineral fraction (SIL, 26 %), and the carbonates (CAR, 5 %).

The proxy parameter magnetic susceptibility confirms this lithological composition of the core sediments, as 63 % of the MS values are represented by the lowest k classes – I (47 %) and II (16 %) -, followed by the class IV (21 %), and class III (16 %) (Fig. 4b).

Very suggestive are the MS line chart (Fig. 4c) and the LITHO area chart (Fig. 4d), as well as the 3D bar-charts (Fig. 4a,f,g), illustrating the vertical distribution of the MS, SIL and TOM parameters along the core DD 14-210. A first general remark is that the downcore gradual increase of the magnetic susceptibility values (Fig. 4a,c) and of the siliciclastic (SIL) content (Fig. 4f), together with the corresponding decrease of the organic matter (TOM) content (Fig. 4g) follow, accurately, the core macroscopic lithological description: the sediments are changing from the fluffy, non-cohesive muds (with vegetal material and shell fragments inside) towards a bit more compact muds ➔ relatively compact muds ➔ clayey muds ➔ clayey silty muds ➔ relatively plastic coarse clays ➔ plastic marine clays. The lithological composition of the core sediments is clearly presented by the area-chart (Fig. 4d), which illustrates, simultaneously, the composite vertical distribution of the three LITHO components. This diagram is supported by three bar-charts performed for the respective components (Fig. 4f,g,h), which present the vertical distribution of their contents. So, regarding the siliciclastic fraction (SIL; Fig. 4f), the increasing trend from the top of the core up to its base is defined by the range 8.01 % ÷ 69.28 %, whose ends come from the first/top sample, a fluffy mud (0 - 2 cm depth), and respectively, from the last/base slice, a marine clay (36 - 38 cm). As concerns the organic matter (TOM; Fig. 4g), also, going downwards, the decreasing trend is defined by the content range 90.24 % ÷ 24.8 %, its ends being given by the same sediment samples as in the SIL case. The carbonates (CAR; Fig. 4h) are defined by the contents interval 1.76 % ÷ 11.51 %, the lowest value being obtained for two samples of muds (0 - 2 cm, and 16 - 18 cm depth intervals), while the highest one is achieved for a marine clay sample taken out from the 32 - 34 cm depth level.

Therefore, the SIL and TOM diagrams (Fig. 4f,g) illustrate – so, graphically – the quantification of the lithological evolution (above specified) that has been inspected by the short sediment core of 38 cm length only, extracted from the Cuibeda Lake central zone.

Coming now to the enviromagnetic parameter – the magnetic susceptibility, this one confirms again its quality of proxy lithological parameter concerning the lake sediments.

So, the MS record shows the lowest level of the k values, having been defined even a „diamagnetic behaviour“ for the muds sampled from the top first 14 cm, which have provided
Fig. 4. Magneto-lithological model for the Core DD 14-210 (Cuibeda Lake). a) Downcore variations of magnetic susceptibility values (MS; k); b) MS calibration of the core sediments, according to k classes; c) Downcore MS variation curve; d) Downcore variation of lithological composition (SIL, TOM and CAR contents); e) Average lithological composition of the core sediments; f) Downcore variation of SIL contents; g) Downcore variation of TOM contents; h) Downcore variation of CAR contents; i) Scatter plot for SIL versus k; j) Scatter plot for TOM vs. k; k) Scatter plot for CAR vs. k; l) Scatter plot for SIL vs. TOM; m) Scatter plot for SIL vs. CAR; n) Scatter plot for TOM vs. CAR. Notes 1 and 2: the same as in Fig. 3.
values between (-4.08)x10^-6 ÷ (-2.67)x10^-6 SI (Fig. 4a). The k values are progressively increasing, but up to the depth of 24 cm they remain inside of the lower ranges of the MS scale, i.e. the classes I and II. The fact that at the base of the sample sliced from the level 24 - 26 cm it has been intercepted a boundary with a clayey mud and a transition zone (up to cm 28) is directly marked out by the magneto-susceptibilimetric parameter, which records an increasing trend, passing to the k class III (the measured value: 83.02x10^-6 SI and 103.07x10^-6 SI; Fig. 4a). Going downwards, along the core, the MS values are progressively increasing, ranging between 146.69x10^-6 (class III) ÷ 220.00x10^-6 SI (class IV). Consequently, the marine clays sampled in the lowest part of the Core DD 14-210, rather inside of the depth interval 30 - 38 cm, are calibrated to class IV, relieving the highest k values measured for the sediments of this core: between 195.50x10^-6 ÷ 220.00x10^-6 SI. This interval is well denoted by two “red triangles” in Fig. 4a→c, while the lowest k value [(4.08)x10^-6 SI], recorded on a fluffy mud (4 - 6 cm depth), is also marked out, but by a “blue triangle” with an inverse position (as compared with the red ones) (Fig. 4a→c).

The relationship of the lithological components with the enviromagnetic parameter/ magnetic susceptibility is remarkable as time as the correlation coefficients are rather inside of the depth interval 30 - 38 cm, are calibrated to class III, the correlation coefficients are rather inside of the depth interval 30 - 38 cm, are calibrated to class IV, relieving the highest k values measured for the sediments of this core: between 195.50x10^-6 ÷ 220.00x10^-6 SI. This interval is well denoted by two “red triangles” in Fig. 4a→c, while the lowest k value [(4.08)x10^-6 SI], recorded on a fluffy mud (4 - 6 cm depth), is also marked out, but by a “blue triangle” with an inverse position (as compared with the red ones) (Fig. 4a→c).

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The vertical distribution of the MS values and of the contents of the LITHO components SIL, TOM and CAR will be further presented, firstly for the cores from the underwater fan area of the Uzlina Canal (DD 10-79, DD 12-319), and then, for the two cores sampled from the southern and the northern extremities of the lake, i.e., DD 12-318, and DD 10-80, respectively (location, in Fig. 2).

a) Core DD 10-79

The Core DD 10-79 was collected in front of Uzlina Canal, at about 230 m from the canal mouth, within the area influenced by the Danubian water and sediment supplies (Fig. 2). From the lithological point of view, at the upper part of the core occurs a yellowish-grey oxidized, coarse silty mud, with sand traces, characteristic to the underwater discharge channel area. The mud is passing downwards to a darker coloured mud, more compact and very cohesive, keeping relatively unchanged up to the core base (48 cm beneath the water/sediment interface), where a cm-scale bedding, as revealed by colour, was observed. Along the whole column, from place to place, Dreissena fragments and rare Viviparus and Unio shells occur. The profile is typical for the zone of influence of a water input channel.

The magneto-lithological model carried out for the core DD 10-79, given in Fig. 5, shows that MS vertical variation is well correlated with the above macroscopic description. The k values are very high, ranging between 188.76x10^-6 SI (class IV) – measured on the lowest sediment slice (45 - 48 cm depth interval), sampled from a finer intercalation, and 441.94x10^-6 SI (class Va) – measured on a sample got from a zone of high k values (34 - 38 cm depth interval), corresponding to the coarser sediments (Fig. 5a), usually present in the discharge areas of the channels. Actually, these two classes only characterize this sediment core (Fig. 5b), 75 % of the samples being calibrated to k class Va, and the remaining 25 % to k class IV. The general image of the MS profile shows an increasing trend of the k values towards the deeper core part, followed by a decrease towards the base. The line-chart from Fig. 5c better illustrates the most significant features recorded by the MS profile, so that two maximum zones are clearly set and defined by the pair of k values marked by I and II (“red triangles”), and respectively, by III and IV (“red triangles”). At the same time, the minimum MS zone located between these two maxima, and the ends (top and base) of the two decreasing arms composing the Core DD 10-79 k profile are marked by 2, 1 (top) and 3 (base) (“blue triangles”), respectively (Fig. 5c).

As regards the lithological (LITHO) constitution of the core sediments, the area-chart from Fig. 5d presents the composite vertical distribution of the three lithological components: SIL (siliciclastic/mineral/detrital fraction), TOM (total organic matter), and CAR (carbonates). The average lithological composition of the whole core sediments shows a very high SIL content (88 %), the other 12 % being equally divided between the TOM and CAR components (Fig. 5e). Actually, the siliciclastic fraction content determined along the core is quite constant, ranging within a narrow interval, i.e., 84.2 % ÷ 91.1 % (Fig. 5f). The same characteristic is revealed by the carbonates (5.5 % ÷ 6.7 %; Fig. 5h), and by the organic matter content (Fig. 5g), the latter being defined within the interval 2.9 % ÷ 9.2 %, yet, excluding these two extreme values, the variation domain is 4.6 % ÷ 6.5 %.
Fig. 5. Magneto-lithological model for the Core DD 10-79 (Uzlina Lake). a) Downcore variation of magnetic susceptibility values (MS; k); b) MS calibration of the core sediments, according to k classes; c) Downcore MS variation curve; d) Downcore variation of lithological composition (SIL, TOM and CAR contents); e) Average lithological composition of the core sediments; f) Downcore variation of SIL contents; g) Downcore variation of TOM contents; h) Downcore variation of CAR contents; i) Scatter plot for SIL versus k; j) Scatter plot for TOM vs. k; k) Scatter plot for CAR vs. k; l) Scatter plot for TOM vs. CAR; m) Scatter plot for SIL vs. CAR; n) Scatter plot for SIL vs. TOM. Notes 1 and 2: the same as in Fig. 3. Note 3: 1, 2, 3 and I, II, III, IV – see text.
In conclusion, the three components SIL, TOM and CAR have quite constant contents along the core (Fig. 5d), very high for the mineral fraction (an average value of 88.33 %; Fig. 5f), and very low for the organic matter (an average value of 5.56 %; Fig. 5g). As regards the carbonates, the mean content is 6.12 % (Fig. 5h), very close to the TOM content, but a bit higher. Some slight inflexions, that are clearly highlighted by the MS graphs (Fig. 5a,c), but also by the SIL, TOM and CAR charts (Fig. 5f,g,h), suggest an alternation of coarser and finer sediment inflows, characteristic to the areas that are strongly and directly influenced by the Danubian supplies.

Related to the correlations between the lithological components and the enviromagnetic parameter, respectively between pairs of lithological components, the coefficient \( r \) records lower values as compared with those which we have usually presented in our studies. So, with the exception of the extreme cases, particularly for TOM vs. CAR (Fig. 5i), for which the correlation is positive and very weak \( (r = 0.23) \), and SIL vs. TOM (Fig. 5n), for which the correlation is negative and strong \( (r = -0.96) \), in all the other cases taken into consideration the correlations are moderate, namely: SIL vs. k \( (r = 0.49) \); TOM vs. k \( (r = -0.37) \); positive; Fig. 5j), CAR vs. k \( (r = -0.58) \); negative; Fig. 5k), and SIL vs. CAR \( (r = -0.48) \); negative; Fig. 5m), respectively. The relatively weak correlation SIL vs. k reflects the effect of the possible different grain sizes and, maybe, of the heavy mineral content variation within a dominantly siliciclastic sedimentary sequence.

b) Core DD 12-319

After two years, a short sediment core (DD 12-319; 33 cm length) has been taken out at a very small distance (160 m southwest) of Core DD 10-79, apparently closer to the Uzlina Canal mouth (160 m), but at 100 m northwest away from the channel axis (Fig. 2). The magneto-lithological model performed for this core is illustrated in Fig. 6.

This position explains why the vertical distribution of the magnetic susceptibility points out higher levels of the \( k \) values (Fig. 6a), as compared to the Core DD 10-79, characterized by the MS classes III, IV, Va and Vb; 78 % of the sediment samples sliced from the core are calibrated to class Va, and 6 \( \% \) to class Vb (Fig. 6b). Thus, at the core base, is recorded the highest \( k \) value \( (636.75 \times 10^{-6} \ SI) \), assigned to the class Vb (Fig. 6a,c) that was measured on the short cores collected from the deltaic lakes during the last time period. The \( k \) values are increasing with the depth, passing successively through the \( k \) classes III, IV, Va and Vb: the range in which the MS is defined is \( 170.66 \times 10^{-6} \div 636.75 \times 10^{-6} \ SI \) (Fig. 6a). This magneto-susceptibility regime is due to the influence area created by the Uzlina Canal, which is carrying a detrital material supply from the Danube River, particularly from the Sf. Gheorghe Branch. The location of this core, on the underwater alluvial fan, closer to the channel (Fig. 2) could explain the higher \( k \) values measured at the 30 - 32 cm and 32 - 34 cm depth levels (Fig. 6a), whose mean \( k \) value is \( 603.5 \times 10^{-6} \ SI \) (class Vb), as compared with \( 431.57 \times 10^{-6} \ SI \) (class Va), which was recorded for a similar thick slice (30 - 34 cm) cut from the core (DD 10-79; Fig. 5a), previously analysed. As the Core DD 12-319 is shorter than DD 10-79 (33 cm versus 48 cm; Figs. 6a and 5a), the finer sediment horizon (fluffy mud), identified at the lower part of the core taken in 2010, characterized by the decreasing \( k \) values measured within the depth interval 34 - 48 cm (Fig. 5a), has not been intercepted by the core taken in 2012, so that the MS profile is ended with the highest \( k \) value recorded along the Core DD 12-319 (Fig. 6a).

As regards the lithological composition of the sediments of this core, the area-chart from Fig. 6d marks out a “sawtooth” shape of the vertical distribution of the main components SIL and TOM (supported, of course, by the SIL and TOM 3D bar-charts, drawn in Fig. 6f,g). This represents a different, even a contrasting pattern compared to the features denoting steadiness which are revealed by the Core DD 10-79 LITHO area-chart (Fig. 5d). Still the MS profile recorded for the Core DD 12-319 (Fig. 6a,c) shows a shape which does not follow the particular way of the two main LITHO components. The difference between the vertical distribution patterns of the lithological components in the two cores could be explained by their different positions in relation to Uzlina Canal: the Core DD 10-79 is located in the axis of the channel, under the direct and continuous influence of river supplies, and the Core DD 12-319 is placed in a lateral position, which records more accurately the periodic inflows of water and sediments brought by floods. As regards the LITHO content weights (given in Fig. 6d), it can be mentioned that the contents of the carbonates (CAR) from the Core DD 10-79 are close to those determined for the Core DD 12-319: 6.12 % versus 6.26 % (mean values; CAR vertical profiles, in Figs. 5h and 6h), while for the SIL and TOM components (vertical profiles, in Figs. 5f,g and 6f,g), the comparative analysis results in 88.33 % vs. 73.17 % (SIL), and 5.56 % vs. 20.54 % (TOM). It can be concluded, the levels of the LITHO contents relating to the Cores DD 10-79 and DD 12-319, sampled very close one another, look alike, with almost equal CAR contents, and a ca. 15 % difference between the siliciclastic and organic matter contents, particularly, a slight higher SIL content, and corresponding, a slight lower TOM content assigned to the Core DD 10-79.

The particularities of distribution patterns of various parameters observed in the two neighbouring cores could be explained through the role played by yet unmeasured factors, as grain size, heavy minerals in siliciclastic fraction, or the occurrence of greigite within the black organic muds.

c) Core DD 12-318

The sediment core DD 12-318, having a length of 30 cm only (Fig. 7), was collected during the 2012 summer campaign from the southern extremity of the Uzlina Lake, approximately at the half distance between the Uzlina Canal mouth, entering the lake, and its eastern boundary (Fig. 2).
The magnetic susceptibility vertical distribution (Fig. 7a), based on 16 sediment slices cut from the core, shows a general increase of the \( k \) values with the depth, followed by a decreasing trend observed along the last 8 cm towards the core base (interval 22 - 30 cm). Actually, at 22 cm depth, the blackish grey mud, rich in bioturbations, identified from the top core up to this level, becomes more soft and plastic. As compared with the cores DD 10-79 and DD 12-319, taken not far from the mouth of the channel entering the lake (Fig. 6a), in the case of the Core DD 12-318, the \( k \) values are generally lower, passing, successively – from top core to 30 cm depth beneath the water/sediment interface – through the MS classes III, IV and Va, not reaching the class Vb (Fig. 7a,b), corresponding to a magnetic susceptibility range between 121.36×10^{-6} (class III) ÷ 429.00×10^{-6} SI (class Va). For the present analysed core, the most sediment samples (62 %)

![Fig. 6. Magneto-lithological model for the Core DD 12-319 (Uzlina Lake). a) Downcore variation of magnetic susceptibility values (MS; k); b) MS calibration of the core sediments, according to \( k \) classes; c) Downcore MS variation curve; d) Downcore variation of lithological composition (SIL, TOM and CAR contents); e) Average lithological composition of the core sediments; f) Downcore variation of SIL contents; g) Downcore variation of TOM contents; h) Downcore variation of CAR contents. Notes 1 and 2: the same as in Fig. 3. Note 3: 1 and I — see text.](image-url)
are calibrated to k class Va, but the following weights (in size), i.e., 25 % and 13 %, belong to k classes III and IV, respectively (Fig. 7b).

The lithological composition of the core sediments (Fig. 7c) indicates that the siliciclastic/detrital component (SIL) is predominant (70 %) over the organic matter fraction (24 %) and the carbonates (6 %). The SIL contents show a general increasing trend with depth (similar to the k vertical distribution), in this case up to the last two centimeters from the lower part of the core (Fig. 7d); yet, this dominant feature of the SIL profile is interrupted by two higher contents determined at the depth levels 0 - 1 cm and 6 - 8 cm, and by two
lower contents which were reached for the sediment slices cut at the 4 - 6 cm and 14 - 16 cm depth levels (Fig. 7d). The macroscopic description of the samples performed aboard the "Istros" vessel does not explain these divergences from the general trend of the SIL profile, which are more visible if we compare them with the magnetic susceptibility record (Fig. 7a), a proxy lithological parameter tested on thousands of lake sediment samples. Anyway, the correlation coefficient calculated for SIL versus k (r = 0.72) indicates a strong positive correlation (Fig. 7g), according to the scale presented by Rădan & Rădan (2014a). The same evidences, including the exceptions, offer the 3D bar-chart performed for the total organic matter component contents (Fig. 7e), but the general feature of the TOM profile remarks, as usually, a reversed behaviour (as compared with that of the SIL component), i.e. a decreasing trend downcore. Nevertheless, the correlation TOM versus k is a strong negative one, attested by r = -0.70 (Fig. 7h). As regards the carbonates (CAR), the contents are defined within a quite narrow range, between 5.01 % + 8.17 % (Fig. 7f). Like in other cases, the correlation coefficient for CAR versus k is relatively lower (r = -0.44), and shows a moderate negative/reversed correlation (Fig. 7i). As usual, a very strong negative correlation (r = -0.998) was determined for SIL versus TOM (Fig. 7j).

A version of the magneto-lithological model concerning the Core DD 12-318 was firstly included – together with other several short sediment cores – inside of a poster-paper dedicated to the enviromagnetic signatures and their lithological support, in relation with the geocological context associated with the Gorgova – Uzlina aquatic area (Rădan et al., 2015).

d) Core DD 10-80

The Core DD 10-80, a very short one (25 cm length), was collected during the 2010 summer campaign from the northeastern extremity of the Uzlina Lake, 50 - 60 m before entering into the output canal Iasă II, through which the water is discharged from Isacova Lake in Litcov Canal (Fig. 2). The sediments are completely changing. Due to the core position in a more distal zone in regard to the Danubian supplies, the grain size of the cored sequence is finer than those of the above described cores; the MS values are lower, ranging between 32.1×10^{-6} SI (class II; minimum marked by a “blue triangle” in Fig. 8a-c) and 138.07×10^{-6} SI (class III; maximum marked by a “red triangle” in Fig. 8a-c). The core samples calibrated to class II represent 60 %, and the other 40 % belong to the class III (Fig. 8b). The sediments contain reed fragments and a rather poor fauna (some gastropods and a fragment of Anodonta). At 13 - 17 cm depth level, a more compact sediment was identified, having the consistence of a soil; this is remarked by the highest content of the siliciclastic/mineral fraction (78.9 %; Fig. 8f), and correspondingly, by the highest measured magnetic susceptibility value (138.07×10^{-6} SI; Fig. 8a). This zone of maximum, defined by both the magnetic and the lithological parameters (Fig. 8a,c,f), could be explained by the intervention, at a moment, of a major flooding. The SIL 3D-bar chart (Fig. 8f) shows quite constant contents, ranging between 71.9% ± 78.9 %. The decreasing trend illustrated by both the MS and SIL vertical distribution diagrams within the depth interval 17 - 25 cm (Fig. 8a,f) is generated by the relatively soft and fine mud intercepted towards the core base. Actually, the lowest magnetic susceptibility and the lowest SIL content were determined at the core bottom, for the last sediment slice (21 - 25 cm). Opposite to this, the highest organic matter (TOM) content (25.0 %) was shown by the same core interval (Fig. 8h), as compared with the lowest one (13.0 %), which characterizes the uppermost sediment core slice (interval 0 - 1 cm). It can be remarked the general increasing trend of the TOM contents along the Core DD 10-80, from top downwards (Fig. 8g). A general very slight reversed trend is observed for the carbonates of this core (Fig. 8h), the CAR profile indicating a content of 12.8 % for the sediment slice 1 - 2 cm, and around 3 % for the muds from the core lower part (13 - 25 cm). The CAR profile similarity to that of the siliciclastic material suggests a detrital origin of the carbonates. The LITHO area-chart (Fig. 8d) illustrates the composite vertical distribution of the three main components SIL, TOM and CAR along the Core DD 10-80. On the other hand, the diagram of Fig. 8e remarks the clear preponderance of the siliciclastic fraction (74 %), while the organic matter (TOM) represents 17 %, and the carbonates (CAR) – the rest of 9 %.

We add to this presentation of the LITHO profiles an interesting observation with regard to the decreasing trend of the carbonate material downwards the core (CAR, in Fig. 8h), in opposition with the organic component (TOM, in Fig. 8g), which exhibits an increasing trend from the water/sediment interface towards the core base. This situation seems to be atypical, the organic matter usually having a decreasing trend towards the deeper zones of the sediments. In reality, the Core DD 10-80 not being too long, the level relatively rich in organic matter is a normal one for the northern zone of the lake, the covering sediment being influenced by the stronger supplies of sediments, of fluvial origin, which have frequently been present in the last years and which prevail in the Uzlina Lake.

Regarding the relationship between the lithological components and the magnetic parameter MS, only the correlation SIL versus k (Fig. 8i) is characterized by a very high coefficient r = 0.92, which argues a strong positive correlation, while for TOM vs. k (Fig. 8k) and CAR vs. k (Fig. 8l) – according to the MS scale (Rădan and Rădan, 2007a) – the correlations are weak and negative: r = -0.24, and r = -0.19, respectively (Fig. 8k,l). Certainly, if we test the correlation of the contents of these two lithological components together (TOM + CAR) versus the corresponding magnetic susceptibility values (MS; k) (Fig. 8j), the correlation coefficient is very high and negative, namely r = -0.92, opposite to the case of SIL vs. k (r = 0.92), mentioned above.
Fig. 8. Magneto-lithological model for the Core DD 10-80 (Uzlina Lake). a) Downcore variation of magnetic susceptibility values (MS, k); b) MS calibration of the core sediments, according to k classes; c) Downcore MS variation curve; d) Downcore variation of lithological composition (SIL, TOM and CAR contents); e) Average lithological composition of the core sediments; f) Downcore variation of SIL contents; g) Downcore variation of TOM contents; h) Downcore variation of CAR contents; i) Scatter plot for SIL versus k; j) Scatter plot for (TOM + CAR) vs. k; k) Scatter plot for TOM vs. k; l) Scatter plot for CAR vs. k. Notes 1 and 2: the same as in Fig. 3.
3.4. ISACOVA LAKE (16, IN FIG. 1)

During the period 2010 ÷ 2012, three sediment cores were sampled, one in 2010 (DD 10-61), the second in 2011 (DD 11-105), and the third in 2012 (DD 12-256) (location in Fig. 2). Actually, there is another core, DD 06-161, taken from the central zone of the lake (Fig. 2), but in 2006, the magnetic susceptibility profile was analysed or shortly commented in some previously published articles (e.g., Rădan & Rădan, 2010a,b).

a) Core DD 10-61

The Core DD 10-61 was sampled from the Isacova Lake central zone (Fig. 2), during the expedition that was carried out during 16 ÷ 30 June 2010. The core has a length of 50 cm. Normally, the sediments from this lake are finer and richer in organic matter than those from the Uzlina Lake. These characteristics are preserved in the core to the depth of 10 cm beneath the water/sediment interface. The organic, non-cohesive muds from this upper part of the core (first 6 slices, up to 9 cm depth) are characterized by very low magnetic susceptibility values, ranging between $14.11 \times 10^{-6}$ - $35.57 \times 10^{-6}$ SI (Fig. 9a). The siliciclastic/mineral fraction (SIL) and the organic matter (TOM) support the environmental indication, recording within this depth interval the lowest contents (45.5 % ÷ 68.6 %; Fig. 9d), and respectively, the highest ones (13.3 % ÷ 38.5 %; Fig. 9e) that were measured for these sediments. Starting with the core slice cut from the depth level 9 - 11 cm, the lithological composition is changing, the muds become coarse silty and take the aspect of a compact soil or clay, having a clearly different texture related to the typical lacustrine sediments. The magnetic susceptibility confirms its proxy quality, and records – going downwards along the core – a stepwise increasing, the MS values passing through k classes III, IV and Va (Fig. 9a), to reach the highest level (292.32 $\times 10^{-6}$) at depth 24 - 27 cm (Fig. 9a), where a coarse silty mud has been intercepted. Yet, as the core is constituted of such sediments up to its base, the high level of the magnetic susceptibility is actually characteristic for more than a half of the core. Along the depth interval 19 - 50 cm/core base, the k values are ranging between 270.69 $\times 10^{-6}$ (very close to the upper limit of class IV) and 292.32 $\times 10^{-6}$ SI (class Va) (Fig. 9a). There is an exception – the slice cut from the level 21 - 24 cm –, which is characterized by a slightly lower value, i.e., 233.26 $\times 10^{-6}$ SI (marked by a “blue triangle” in Fig. 9a), so, also belonging to class IV. It is useful to highlight at this point of the analysis that this sample has also shown anomalous SIL and CAR contents, namely a minimum for the siliciclastic/mineral fraction, i.e., 69.7 % (marked by a “blue triangle” in Fig. 9d), and a maximum for the carbonate component, i.e., 26.7 % (marked by a “red triangle” in Fig. 9f). The unusual carbonate content is due, almost certainly, to a fragment of shell included accidentally within the mud sample (usually, the observable shell fragments are removed from the samples before performing analyses). This magneto-lithological anomaly, occurred at the depth level 21 - 24 cm, is very well illustrated by the profiles MS (Fig. 10a) and CAR (Fig. 10c), as well as by the area-chart (SIL, TOM, CAR) from Fig. 10b: the minimum MS, minimum SIL and the maximum CAR are correlated by a blue dotted line relating to the interconnection MS $\rightarrow$ SIL, and further, by a red dotted line, for the connection with the CAR record (Fig. 10a$\rightarrow$b$\rightarrow$c). It can also be seen in Fig.10, at the 3 - 5 cm depth level, where it has been sampled a grey-dark yellowish organic non-cohesive mud (with rare shell fragments), a dotted blue line which correlates the minima MS and SIL (Fig. 10a$\rightarrow$bb), in fact the lowest k value (16.07 $\times 10^{-6}$ SI; class I) and the lowest SIL content (45.5 %), respectively, which were recorded relating to the whole sediment core.

Looking to the 3D bar-charts performed for the three lithological components (Fig. 9d,e,f), in the upper core part, that is along the first 15 cm, we can observe, as a general characteristic – corresponding to the magnetic susceptibility profile –, the siliciclastic fraction records lower contents (Fig. 9d), while the organic matter (Fig. 9e) and the carbonates (Fig. 9f) are defined by higher contents.

The general trends indicated by the four profiles associated with the Core DD 10-61 point out a downcore increasing of the magnetic susceptibility (Figs. 9a and 10a), and of the siliciclastic component content (Figs. 9d and 10b), in parallel with a decreasing of the organic matter (Figs. 9e and 10b) and of the carbonate fraction (Figs. 9f and 10b,c) contents. It is considered, in the lower half of the core, the sediment sequence is a coarser and more compact mud, which often contains carbonaceous material, small peat fragments and plant remains, suggesting an old littoral lake facies. The sequence is defined by these characteristics: k values higher than $270 \times 10^{-6}$ SI, SIL contents higher than 87.9 %, and TOM contents lower than 3.9 %; Fig. 9a,d,e).

The asserted trends could be explained by the diminishing of the detrital supplies in this zone in the last three decades, by cutting of the Mahmudia Meander, and afterwards, by the temporary closing of the Uzlina Channel. Albeit the dam from this channel has been moved away, the turbidity of the supplies coming from the Mahmudia Meander is lower than that of the channel which is shortening it.

Anyway, related to the lithological composition of the core sediments (Fig. 9c), the predominance of the siliciclastic fraction is clearly argued by the SIL content (77 %), while the organic matter (TOM) and the carbonates (CAR) represent 10 %, and 13 %, respectively. The magnetic susceptibility characterization of the Core DD 10-61 supports this distribution of the lithological components within the core sediments, 70 % of the investigated samples being calibrated to classes III (15 %) + IV (20 %) + Va (35 %), and the remaining 30 % are assigned to the lower class II (Fig. 9b).

The general trends, comparable concerning the four characteristics of the core sediments, could anticipate the level of their correlations. So, as regards the connection of the LITHO components with the enviromagnetic parameter, the correlations are strong and positive for SIL vs. k ($r = 0.88$; Fig. 9h),

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Fig. 9. Magneto-lithological model for the Core DD 10-61. Part I (Isacova Lake). a) Downcore variation of magnetic susceptibility values (MS; k); b) MS calibration of the core sediments, according to k classes; c) Average lithological composition of the core sediments; d) Downcore variation of SIL contents; e) Downcore variation of TOM contents; f) Downcore variation of CAR contents; g) Scatter plot for SIL vs. TOM; h) Scatter plot for SIL vs. k; i) Scatter plot for TOM vs. k; j) Scatter plot for CAR vs. k; k) Scatter plot for SIL vs. CAR; l) Scatter plot for TOM vs. CAR. Notes 1 and 2: the same as in Fig. 3.
and strong and negative for TOM vs. k (r = - 0.81; Fig. 9i), and for CAR vs. k (r = - 0.69; Fig. 9j). We have also tested the correlations between pairs of lithological components, and the highest correlation coefficient (r) was obtained – as it is the case in the great majority of the studied cases – for SIL vs. TOM (r = - 0.92; Fig. 9g); a strong negative correlation for SIL vs. CAR (r = - 0.77; Fig. 9k) was determined, as well. It is not the case of the relationship of the organic matter with the carbonates, the correlation TOM vs. CAR being moderate and positive (r = 0.47; Fig. 9l), the latter characteristic not being frequently determined in our studies.

b) Core DD 11-105

The Core DD 11-105 was collected from the Isacova Lake central zone (Fig. 2), at about 150 m east from the Core DD 10-61, during the expedition carried out in April 2011. The core has a length of 53 cm. As concerns the lithological composition, it has been observed an upper mud sequence of ca. 20 cm, blackish-grey at its upper part, and yellowish-grey at the lower one, fluffy on top, generally soft, non-cohesive, bioturbated, with a slight smell of H₂S, and with rare depigmented and very brittle shells. The muddy sediments are passing quite rapidly downwards to a more and more compact and plastic clay, showing a grey to dark grey colour, coarse silty to fine sandy, with frequent carbonized vegetal remains. The sedimentary succession and the lithological composition of the cored sequence are quite similar to those of the Core DD 10-61.

The magneto-lithological pattern presented in Fig. 11 illustrates – by the magnetic susceptibility (MS) record, and at the same time, by the parallel siliciclastic (SIL), organic matter (TOM) and carbonate (CAR) profiles – the above macroscopic description.

The vertical distribution of the MS (k) values measured along the core marks out the two types of sediments, the transition between them being a short one (Fig. 11a). So, the muds from the upper 21 cm are calibrated to MS class II, the k values ranging between 20.16×10⁻⁶ and 45.43×10⁻⁶ SI (Fig. 11a), followed, downwards, up to 33 cm depth level, by a sequence of coarse silty muds, calibrated to MS class III, specifically with k values within the interval 80.00×10⁻⁶ and 133.37×10⁻⁶ SI. This could be considered the transition zone between the two clearly different categories of sediments. The following and at the same time the last 20 cm of the Core DD 11-105, i.e. from 33 cm depth up to the core base (53 cm), constituted of coarse silty-clayey sediments, passing to coarse silty to sandy clays along the last 7 cm, are characterized by the highest k values, belonging to the MS classes IV and Va: the range is defined by 216.21×10⁻⁶ (class IV) + 287.68×10⁻⁶ SI (class Va) (Fig. 11a). The highest k value was measured for the sample collected from the 43 - 46 cm depth interval, a sample of mixed clayey, coarse silty and sandy sediment. A general remark, provided by this detailed magneto-susceptibility analysis, regards the stepwise passing from top core downwards, along 40 cm, through k classes II, III, IV and Va. In the last 13 cm, where a sequence of clayey (+ sandy) sediments and clays has been intercepted, the class IV is the characteristic MS range for 4 of 5 slices, excepting, thence, the highest k value that has just been above discussed. The weights in which the four k classes occur are as follows: II – 37%; III – 21%; IV – 32%; Va – 10% (Fig. 11b).
Fig. 11. Magneto-lithological model for the Core DD 11-105. Part I (Isacova Lake). a) Downcore variation of magnetic susceptibility values (MS; k); b) MS calibration of the core sediments, according to k classes; c) Downcore MS variation curve; d) Downcore variation of lithological composition (SIL, TOM and CAR contents); e) Average lithological composition of the core sediments; f) Downcore variation of SIL contents; g) Downcore variation of TOM contents; h) Downcore variation of CAR contents. Notes 1 and 2: the same as in Fig. 3.
The vertical distribution of the lithological components (Fig. 11d,e,f,g,h) support the magnetic susceptibility profile that is also illustrated in Fig. 11a,c. The SIL 3D bar-chart (Fig. 11f) marks out the two types of sediments composing the Core DD 11-105, and also a short transition zone, as it has previously been mentioned. We present further the characteristic zones in keeping with the groups shown by the SIL, TOM, CAR contents provided by the lithological analyses. So, the SIL contents within the upper mud sequence, more exactly, in this case, within the 0-18 cm depth interval, are ranging between 15.73% ± 35.19% (Fig. 11f). A short transition zone could be suggested by the SIL contents ranging between 39.92% ± 49.61%, which are assigned to the samples collected from the 18-27 cm depth interval. The coarse silty mud identified in the following two samples (27-30 cm and 30-33 cm) indicates higher SIL contents (77.30% and 79.12%, respectively), very close to those which are pointed out by the coarse silty clays, which were intercepted along the lowermost 20 cm. Therefore, the core sequence from 33 cm beneath the water/sediment interface up to the core base (53 cm) is characterized by the highest SIL contents, placed within the interval 87.72 % ± 90.64 % (Fig. 11f). This situation is in agreement with the magnetic susceptibility profile, namely the calibration of these sediments to the highest k classes of the MS scale, i.e., IV and V (Fig. 11a). Of course, the vertical distribution of the organic matter fraction (TOM) (Fig. 11g) shows a reversed situation: high contents (51.72% ÷ 78.77%) for the muds from the first 18 cm of the core, followed by a transition zone defined by intermediary TOM contents, which decrease from 5.5% (18-21 cm; a dark yellowish grey mud, without a H₃S smell, as it has been felt above it) up to 36.17% (24-27 cm; a coarse silty mud). The next two samples (27-30 cm; 30-33 cm) show a sharp organic matter content decreasing, defined by 6.42% and 5.96%, respectively, very close to the following range of TOM contents (2.42% ± 3.85%), characterizing the coarse silty clays, crossed along the lowermost 20 cm of the core (33-53 cm) (Fig. 11g).

We can remark in this point of the analysis of the magneto-lithological characteristics the congruence of the diagrams from Fig. 12a,b. It is easily observed the very strong and positive correlation shown by SIL vs. k (r = 0.95), and, respectively, the very strong and negative correlation for TOM vs. k (r = -0.92). As usual, the correlation between the two lithological components SIL and TOM is negative, in the present case reaching an extremely high degree: r = -0.99 (Fig. 12c).

Referring to the third lithological component – the carbonates, it is interesting to note that the CAR profile (Fig. 11h) shows up two significant characteristics. Thus, in the first part, extending from the core top up to 33 cm beneath the water/sediment interface, the CAR contents indicate a general increasing trend (5.5% ➔ 16.28%), but with a few small deflections, that is quite similar with the corresponding interval from the SIL profile (Fig. 11f), and also from the MS record (Fig. 11a). It follows, downwards, from 33 cm depth up to the core base, a clearly lower level of the CAR contents, defined within a narrow range: 6.94% ± 8.65% (Fig. 11h), a characteristic indicated along this core fragment by the TOM profile, as well (Fig. 11g).

A general observation with regard to the carbonate profile reveals that the increasing trend of the CAR contents, in the first part of the Core DD 11-105 (0-33 cm), is following up the lithological succession, starting from the upper sequence of muds with a H₃S smell, with rare depigmented and very brittle shells, and going towards the sequence of coarse silty muds; then it is recorded a sudden change, to a lower level of the CAR contents, from 33 cm depth up to the core base, where is intercepted the sequence of coarse silty clays (denoted as “clay” in the diagrams of Figs. 11 and 12).

This particular feature of the CAR profile recorded along the whole Core DD 11-105 could support the moderate correlation that is indicated by the coefficient r = -0.48 (Fig. 12d) for CAR vs. k (a negative correlation).

A more detailed analysis shows that the CAR vs. MS diagram of the upper mud sequence (0-33 cm) displays a clear strong positive correlation (r = 0.75; Fig. 12e), suggesting an association of carbonates with the siliciclastic fraction of sediments, which would indicate their predominantly detrital origin. The same type of chart obtained for the lower clay sequence (33-53 cm) presents, instead, a strong negative correlation (r = -0.81; Fig. 12f), which highlights the lithological, and probably, a genetic difference between the two sequences.

The diagram of Fig. 11e reveals the preponderance of the siliciclastic component (60%), followed by the organic matter fraction (30%), and the carbonates (10%). If we compare with the result of the calibration of the core sediments to the “MS scale” (Rădan & Rădan, 2007a), it appears a corresponding structure of the MS values distribution (Fig. 11b): the majority of the samples (63%) are characterized by higher k classes, i.e., 21% (class III) + 32% (class IV) + 10% (class Va), while 30% represent the core sediment slices to which the lower k class II is asserted.

Finally, we add that a composite LITHO image (a 2D area-chart) is presented in Fig. 11d, and a line graph (Fig. 11c) illustrates the recorded MS profile (along the Core DD 11-105), in parallel with the MS bar-chart (Fig. 11a). The correlation of the k minimum value (class II), as well as of the highest two k values (class Va) from the MS bar diagram with the corresponding levels from the MS line-chart is illustrated in Fig. 11a ➔ c by the connection lines which are drawn out, particularly a blue line with a “blue triangle” (1) inserted, respectively by two red lines with a “red triangle” each inserted (I and II).

c) Core DD 12-256

The DD 12-256 sediment core was collected from the Isacova Lake southeastern area (Fig. 2), at about 1200 m north-east from the Ușlina-Isacova Canal mouth, in the 2012 summer campaign. With a length of 38 cm only (Fig. 13), this core has pro-
provided very interesting magneto-lithogenetic characteristics. The core shows an upper sequence of ca. 26 cm, consisting of soft, blackish sediments, presenting a thin layer (2 cm) of fluffy oxidised mud on top, and passing downcore to a dark grey and dark yellowish grey compact mud. There are frequent bioturbations within the upper 18 cm, usually filled with a yellowish soft mud. Small fragments of shells and tiny gastropods are observed in divers places, but, also, a few larger shells can be found (Viviparous sp. at cm 6 – 8, Dreissena sp. at cm. 20 – 22).

From 26 cm depth beneath the water/sediment interface, downwards, the muds become more and more coarser and compact, turning into even silty-sandy muds or clays along the lowermost 4 cm (34 - 38 cm), where a small Dreissena shell was found.

The envirromagnetic parameter MS offers very clear quantitative proofs for the existence of two distinct sequences within the Core DD 12-256 (Fig. 13a). The net boundary between them is located at 26 cm depth, as was inferred from the above.

Fig. 12. Magneto-lithological model for the Core DD 11-105, Part II (Isacova Lake). Scatter plots showing the correlation between the SIL, TOM and CAR contents and the magnetic susceptibility (MS, k) values. a) SIL versus k; b) TOM vs. k; c) SIL vs. TOM; d) CAR vs. k (whole core); e) CAR vs. k (mud sequence: 0-33 cm); f) CAR vs. k (clay sequence: 33-53 cm).
Fig. 13. Magneto-lithological model for the Core DD 12-256. Part I (Isacova Lake). a) Downcore variation of magnetic susceptibility values (MS; k); b) MS calibration of the core sediments, according to k classes; c) Downcore variation of SIL contents; d) Downcore variation of TOM contents; e) Downcore variation of CAR contents; f) Average lithological composition of the core sediments; g) Scatter plot for SIL versus k; h) Scatter plot for TOM vs. k; i) Scatter plot for CAR vs. k; j) Scatter plot for SIL vs. TOM; k) Scatter plot for TOM vs. CAR. Notes 1 and 2: the same as in Fig. 3.
specified macrosopic description, which suggests a change of the lithological features, namely from the upper soft muds to the silty, coarse silty, and even fine sandy muds downcore. The vertical distribution of this proxy lithological parameter – magnetic susceptibility (MS) – shows an interesting profile of the upper sequence (Fig. 13a), particularly, a large maximum zone, with the apex (56.13×10^{-6} SI) centred on the sediment sample cut from the 10 - 12 cm depth level, bordered by two zones of minimum; the upper one is centred on the mud slice cut from the 1 - 2 cm level interval (30.39×10^{-6} SI), while the underlying minimum zone is located on the mud sample deriving from the 20.0 - 22.0 cm level (39.58×10^{-6} SI). The MS record points out a sudden change of the magneto-susceptibility regime, beginning with the silty mud sampled from the 26 - 28 cm depth level, which is calibrated to the MS class III; the k values jump from 49.49×10^{-6} SI (class II), measured for the sample taken from the 24 - 26 cm level, to 89.08×10^{-6} SI (class III), value provided by the silty mud sampled from the 26 - 28 cm level (Fig. 13a). Hereinafter, the magnetic susceptibility profile remarks an increasing trend up to the core bottom (all k values assigned to class III), the last two slices – silty-sandy muds – generating the highest k values measured on the Core DD 12-256: 114.35×10^{-6} SI and 114.75×10^{-6} SI (Fig. 13a). The diagram of Fig. 13b illustrates the distribution of the core sediments according to the susceptibility scale: 70 % of samples – class II, and 30 % – class III. The magnetic susceptibility profile along the Core DD 12-256 is also illustrated in Fig. 14a, where the characteristics outlined above are represented by the appropriate MS value markers. Next to this is drawn the LITHO area-chart (Fig. 14b), which brings together the SIL, TOM and CAR vertical profiles, showing, graphically, their different contents, which are in detail analysed below.

The main lithological components – siliciclastic and organic matter – indicate, correspondingly, a general increasing, and respectively, a decreasing trend of the contents with the depth, along the core (Fig. 13c,d), with a few exceptions, among which the most visible are the higher SIL contents, and the lower TOM contents, respectively, determined for the muds sliced from the 1 - 2 cm and 8 - 10 cm depth levels. It is also worth to remark that the highest SIL contents (66.97 % and 69.49 %) and the lowest TOM contents (13.21 % and 10.44 %) were obtained for the silty-sandy muds sampled from the core bottom (34 - 36 cm, and 36 - 38 cm, respectively; Fig. 13c,d). As regards the carbonates, it is remarked an increasing trend of their contents with the depth, with two more visible divergences generated by the same mud slices cut from the 1 - 2 cm and 8 - 10 cm levels (Fig. 13e). The CAR contents range between 7.92 % ÷ 20.08 %, the highest weights (19.83 % and 20.08 %) being provided by the two silty-sandy samples from the core bottom (Fig. 13e).

The average lithological composition of the cored sediments (Fig. 13f) reveals a balanced distribution of siliciclastic and organic components (43% and 43%), associated with a subordinate, but quite high content (as compared to all cores previously discussed) of carbonates (14%).

All the three lithological components (SIL, TOM and CAR) show interesting correlations with the proxy magnetic pa-
rameter (MS; k). Thus, for SIL versus k, the coefficient r shows a strong positive correlation (r = 0.85; Fig. 13g), and for TOM versus k – a strong negative/reversed correlation (r = -0.84; Fig. 13h). It is interesting to remark a strong positive correlation for CAR versus k (r = 0.76), clearly expressed for the lower silty-sandy clay sequence, suggesting a detrital origin of the carbonates (Fig. 13i). We also checked the correlation of the lithological components in the cases SIL versus TOM, and TOM versus CAR, and we obtained very strong negative correlations in both situations: r = -0.995 (Fig. 13j), and r = -0.95 (Fig. 13k), respectively, the last one supporting, also, the detrital origin of the carbonates. In the same time, the diagrams of Fig. 13g,h,i highlight a clear distinction between the two lithological sequences described above. The two cluster groups, having distinct locations in the correlation diagrams, are associated with the muds (and marked on graphs by a “blue rectangle”), respectively with the silty, coarse silty and silty-sandy muds (“red rectangle”).

4. CONCLUSIONS

The variety of the aquatic ecosystems and the diversity of the sediments deposited in different environments from the Danube Delta are well characterised by specific magnetic susceptibility (MS) fingerprints, recovered from surficial and core sediments sampled in the lakes of a series of deltaic deposits. Continuing this approach, this paper makes available a new magneto-lithological database – assigned to the Gorgova - Uzlina Depression –, which is added to another two important systematised series of results, previously published, relating to the Mestețu - Fortuna (Rădan et al., 2013) and Matița - Merhei Depressions (Rădan et al., 2014a).

The present article – as the first part of the paper concerning the aquatic unit above specified – is dealing with the magneto susceptibility bilimetric (MS) and lithological (LITHO) signatures recovered from short cores only, the surficial sediments being the objective of the second part to be next fulfilled (Rădan et al., 2016; this volume).

The vertical distribution of the MS (k) values, recorded for nine sediment cores, collected from four deltaic lakes (Gorgova, Cuibeda, Isacova and Uzlina), reflects, accurately, the lithological variations, which sometimes are macroscopically less visible. Moreover, the integrated magneto-lithological study of the cores, taken out during the time period 2010 ÷ 2014, has resulted in the detection, in some investigated cases, of marine deposits located very close of the water/sediment interface (Lake Cuibeda). The presented data remark distinct magnetosusceptibility fingerprints recovered from the muds observed in the upper part of the cores, and from the marine clays or coarser shallow water deposits, respectively, intercepted towards the bottom of the cores. The main lithological components, particularly defined by the contents of siliciclastic/mineral/detrital (SIL) and of total organic matter (TOM) fractions, support the above mentioned MS signatures. More specifically, the intensity of the MS fingerprints recovered from muds (lacustrine deposits) is very low (e.g., k classes I and II), supported by low SIL and high TOM contents, while the MS fingerprints of marine clays and shallow water sediments (representing old marginal lacustrine or underwater fan deposits) show higher intensities (e.g., k classes IV and Va), supported by high SIL and low TOM contents.

These new proofs of identification of some marine deposits very close to the actual water/sediment interface, which are added to the previously published examples (e.g., Rădan et al., 2014b), help to improve the deltaic system evolution knowledge, taking into consideration that the area under attention in the present study is located behind of the initial Jibrieni – Letea – Caraorman sand ridge, and thence older than this one. Besides, it is worth to point out that the cores in which it has been stated the existence of a marine episode at west of this initial belt were collected from lakes situated in the Gorgova – Uzlina Depression, which, at present, is a part of the Fluvial Delta Plain.

To clarify some aspects of the controversy relating to the development in time of the different events, which led to the deltaic edifice building up, some absolute dating information, complemented with fauna identification within some cores are needed.

Certainly, the presented magneto-lithological results give new proofs for demonstrating the availabilities of the method used to identify the environmental influences on the magnetic susceptibility of lake sediments, and hence to assess the geocological state of the delta area.

This new case-study developed with regard to the lakes of the Gorgova – Uzlina Depression confirms that the magnetic susceptibility is a useful sedimentogenetic, lithogenetic and environmental proxy indicator, as well as a challenging stratigraphic tool (Rădan et al., 2014c). The obtained data are important in the context of deciphering the spatial and the temporal evolution of the deltaic geosystem.

An important direction that could be approached by comparing the profiles showing the vertical distribution of the magnetic susceptibility and of the lithological components, recorded along the sediment cores extracted from different lakes, is the stratigraphic correlation of the recent sediment sequences. Albeit the studied cores are short, some distinct features are seen in most of them. Even the use of the MS as a correlation tool is positively discussed in the literature, in a series of cases, to match the k peaks identified in some cores within a lake or in several cores from different lakes is difficult to really carry out (e.g., Trodahl, 2010, and references therein). In order to fulfill the stratigraphic goal, the MS records must be supplemented with data provided by other proxy parameters, including the radiometric dating.
REFERENCES


