THE USE OF THE MAGNETIC SUSCEPTIBILITY RECORD AS A PROXY SIGNATURE FOR THE LITHOLOGICAL COMPOSITION OF LAKE SEDIMENTS: EVIDENCES FROM SHORT CORES IN THE MEŞTERU - FORTUNA DEPRESSION (DANUBE DELTA)

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Abstract. The paper analyses the enviromagnetic results obtained on short cores collected from Danube Delta lakes and channels. A Hydro-Bios type core sampler was used to investigate sediments up to ca. 60 - 80 cm depth from various sedimentary environments located both in the Fluvial Delta Plain (e.g., Lungu L., Cuteşti L., Fortuna L., Crângjăla Canal, Băcăneşti L., Matiţa L., Babina L., Bogdaproste L., Gorgova L., Uzlina L., Isacova L.) and the Fluvio-Marine Delta Plain (e.g., Puiu L. and Roşu L.). In this article, the results achieved for the sediment cores taken in the Meşteru - Fortuna Depression, during the 2010 - 2013 interval, are presented. The data make possible to compare, in some cases, the magnetic susceptibility ($k$; $MS$) characterisation of the bottom sediments (sampled with the grab sampler) with the $MS$ data associated with the first 10-30 cm of sediments collected from the upper half of the cores, taken out from the same places within a lake. More interesting are the variations in the magnetic susceptibility regime along the cores. In many cases, the enviromagnetic parameter “intensity” increased from the upper part towards the core base, but also some well-defined maximum and minimum $k$ anomalies were detected. A clearly higher $MS$ regime was identified along the whole short cores collected from the Crângjăla mid-channel. The data demonstrate the capability of the $MS$ parameter as a sedimentogenetic indicator, being possible to correlate the higher $k$ values with the interception of a silted up zone or of two different sediment sequences within a core as a result of the hydrological regime changes occurred during the time. As regards the lower $k$ values measured at the upper part of the cores, they are usually related to the muds rich in fine vegetal (organic) detritus and/or rich in shell fragments. Based on the values of the enviromagnetic parameter ($k$) and of the contents of the lithological components along the cores, several correlation coefficients ($r$) were calculated, taking into consideration all the possible pairs of magnetic and/or lithological parameters. The vertical distribution of the magnetic susceptibility associated with the cores clearly illustrates the particular characteristics of the “confined sedimentary environments” versus the “dynamic sedimentary environments”.

Key words: environmental magnetism, deltaic lakes, sedimentary environment, short sediment core, bottom sediment, lithological components, enviromagnetic parameter.

1. INTRODUCTION

A number of papers which were published during the last years (see Rădan & Rădan, 2011, for a brief overview and references) dealt mainly with the bottom sediments collected with the “van Veen-type” grab-samplers. So, the first approximately 30 cm beneath the water/sediment interface were the subject of the respective multidisciplinary studies. The magnetic susceptibility vertical variation for six short cores was presented in two of the cited articles (in Rădan & Rădan, 2011). Four cores were taken (in 2006) from the lakes Lungu (Meşteru - Fortuna Depression), Isacova (Gorgova - Uzlina Depression), and Roşu (Lumina - Roşu Depression). Another two short cores (collected in 2010 and 2011) had been originated from the Matiţa - Merhei Depression, particularly from the Babina L. and Matiţa L., respectively.
The present article focuses on the magnetic susceptibility and the lithological composition of 7 short cores collected during the 2010 - 2013 period from 4 lakes and a canal situated within the Meșteru - Fortuna Depression (Fluvial Delta Plain, northern wing) (see Fig. 1).

The magneto-lithological data associated with short cores were firstly presented at several symposia, e.g. the "DEL-TANET International Conference – Deltas and Wetlands" (Tulcea, Romania, 14-16 September, 2011), "13th Castle Meeting. Paleo, Rock and Environmental Magnetism" (Zvolen, Slovak Republic, 17-23 June, 2012), and IGCP 580 - "Magnetic Susceptibility and Gamma-Ray Spectrometry through time" (Graz, Austria, 24-30 June 2012) (e.g., Rădan et al., 2012). Also, a series of results regarding the lithological components only, analysed for 14 short cores taken from 7 deltaic lakes, have been recently published (Catianis et al., 2013).

The present approach is directed towards the study of the existent connections between the magneto-susceptibility regime, identified along the short cores, and the main lithological components of the sediments. In some cases, the MS and the lithological data determined for the surficial sediments, extending, in general, approximately 30 cm beneath the water/sediment interface, are integrated within the study, and the results are compared with the corresponding data provided by the samples sliced from the upper part of the cores. The final goal is to demonstrate the capability of the magnetic susceptibility record to be used as a proxy signature for the lithological composition characterisation of the lake sediments.

2. LOGISTICS, GEOMATERIALS AND METHODS

During the expeditions carried out by GeoEcoMar in the Danube Delta lakes over last four years (2010 - 2013), the field works were focused on the direct observations of the water and sediments, carried out aboard the fluvial vessel "Istros" (Rădan & Rădan, 2011), but also on sampling them (biological samples were added), for different laboratory analyses. A motor-boat "Măriuca" was used in the lakes where the depth was lower than 1.50 m. Besides the physico-chemical and chemical parameters investigated for the surface waters, and the study of the greenhouse gas emissions in different deltaic

![Fig. 1. Location of the lakes from where short cores were collected over the 2010 - 2013 period. I. Meșteru - Fortuna Depression: 1 - Câștigății Lake; 2 - Tătaru Lake; 3 - Bălănești Lake; 4 - Fortuna Lake; 4bis - Crânjală Canal. II. Matița - Merhei Depression: 5 - Babina Lake; 6 - Matița Lake; 7 - Bogdaproste Lake. III. Gorgova - Uzlina Depression: 8 - Gorgova Lake; 9 - Isacova Lake; 10 - Uzlina Lake. IV. Lumina - Roșu Depression: 11 - Puiu Lake; 12 - Roșu Lake. Note: 1 - The area under attention.](image-url)
ecosystems, the lithological and the magnetic susceptibility characterisation of the lacustrine sediments represents an important objective of the respective multidisciplinary campaigns performed in the Danube Delta, at least twice every year.

The present paper is dealing with various aspects of the integrated magnetic and lithological research of the sediments only. As regards the lake sediments, which are further under our consideration, 7 short cores were collected from 4 lakes and a canal located in the Fluvial Delta Plain, particularly, in the Meșteru - Fortuna Depression (i.e., Cucuțchi, Tătaru, Băclănești, Fortuna lakes, and the Crânjală Canal; 1, 2, 3, 4/4bis, respectively, in Fig. 1).

Special attention was paid to choosing the lakes from the deltaic depressions, and then the locations of the cores within the respective lakes, aiming to investigate various ecosystems, and different sedimentary environments.

The sediment cores were collected with a Hydro-Bios corer, with a transparent tube (Fig. 2). The length of the core is up to 60 cm, when the standard corer was used, and up to 80 cm, for a modified version of the corer.

The sediment cores were sliced at 1-3 cm (Fig. 3a), using an extruder, aboard the R/V “Istros”; several sediment samples (Fig. 3b) were obtained from each core, and, subsequently, they were directed to different laboratories for specific analyses (Fig. 3c).

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Fig. 2. Hydro-Bios corer (a), used for taking the short cores, and a transparent plastic tube with sediment inside (b).

Fig. 3. Slicing the sediment core at adequate levels (a), the resulted sediment slice (sample) (b), and a sample within a box (station code, slice number and depth interval are written on its cover), prepared to be send to a lab for analyses (c).
The lithological composition of the sediment samples was determined by sequential heating (up to 950°C) into a SNOL laboratory furnace by the Loss on Ignition Method (Dean, 1974, in Catianis et al., 2013). The lab procedure, which is shortly described in the cited paper, allows the assessment of the contents of the three lithological components, following the order TOM (Total Organic Matter), CAR (Carbonates), and SIL (Silticlastic/mineral fraction).

The analysis and the interpretation of the integrated magneto-lithological data resulted from the investigation of the 7 cores collected from the above-specified lakes and a canal (Fig. 1) is supported by a number of correlation coefficients (r) which were calculated for SIL vs. MS, TOM vs. MS, CAR vs. MS, or (TOM+CAR) vs. MS. Beside these, the correlation between the other two pairs of lithological components (i.e., SIL vs. TOM, and TOM vs. CAR) has also been tested. A scale with 6 "correlation ranges" (inside the interval defined by the r values spanning from (-1) to (+1)), which was presented in some of the previously published papers and it is redrawn in Fig. 4a, is used to evaluate the size of the correlation.

An important parameter, which has been investigated for the Danube Delta lake sediments since 1977, is the magnetic susceptibility, measured also for the samples sliced from the different levels along the cores. The MS measurements were carried out with a KLY-2 Kappabridge (Instruction Manual for magnetic susceptibility bridge - KLY-2, Geofyzika n.p. Brno, Czechoslovakia, 1981), in the laboratory of environmental magnetism of the Geological Institute of Romania (GIR). Details concerning the methodology for measuring the magnetic susceptibility on lake sediments with this instrument were given in numerous unpublished research reports and in several previously published papers (cited in Rădan & Rădan, 2011). Based on a "Magnetic susceptibility (k) scale" (a version is redrawn in Fig. 4b), the vertical distribution of this magneto-environmental parameter represented by means of 3-D bar charts is complementary illustrated by the colours associated with the five k classes, assigned to each bar, according to the MS value to which the sediment sliced from the respective core depth interval is defined.

<table>
<thead>
<tr>
<th>Correlation coefficients (r)</th>
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<tbody>
<tr>
<td>0.65 - 1.00</td>
<td>Strong positive correlation</td>
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<tr>
<td>0.32 - 0.64</td>
<td>Moderate positive correlation</td>
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<tr>
<td>0.00 - 0.31</td>
<td>No correlation – Weak positive correlation</td>
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<tr>
<td>0.00 - (-0.31)</td>
<td>No correlation – Weak negative correlation</td>
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<tr>
<td>(-0.32) - (-0.64)</td>
<td>Moderate negative correlation</td>
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<tr>
<td>(-0.65) - (-1.00)</td>
<td>Strong negative correlation</td>
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![Fig. 4. Logistics, (geo)materials and methods. a) Scale used to evaluate the size of the correlation (r) between the enviromagnetic parameter (k) and the lithological components (LC), and between LC themselves (SIL, TOM, CAR); b) Magnetic susceptibility (k) scale (Rădan & Rădan, 2007). The k values defining the MS classes must be multiplied by (10 E-06) SI.](image)

Finally, the magneto-lithological models associated with each sediment core are presented, discussed and interpreted. 3-D bar and 2-D line with marker charts showing the vertical distribution of the magnetic susceptibility, and 3-D bar and 2-D 100% stacked area charts, illustrating the contents of the lithological components along the cores, were drawn up. 2-D pie-charts, with the structure of the MS classes, and the distribution of the lithological components’ mean contents, respectively, characterising the sediment cores, were carried out, as well. Diagrams with the graphic correlation between the magnetic parameter and the lithological components, but, also, between pairs of lithological components, are used for data interpretation. Maps with the areal distribution of the magnetic susceptibility, based on sediment samples taken over time, relating to several lakes where from cores were collected, are also integrated in the paper.

3. RESULTS AND DISCUSSION

The magnetic susceptibility and lithological data resulted from the study of the sediment cores are further presented, following the order suggested in Fig. 1. Firstly, the cores collected from the western Meșteru - Fortuna Depression (i.e., DD 10-177 - Cutețchi Lake and DD 12-03 - Tătaru Lake; Fig. 1 and Fig. 5) are taken into consideration, followed by the cores taken from the eastern part of this deltaic area (i.e., DD 13-61 - Băclănești Lake, DD 11-210, DD 13-56 - Fortuna Lake, and DD 13-54, DD 13-55 - Crânjală Canal; Fig. 1 and Fig. 5).

3.1. Sediment cores from the western Meșteru - Fortuna Depression

The core DD 10-177 was collected from the Cutețchi Lake during the expedition carried out by GeoEcoMar in the Danube Delta, in October 2010, while the core DD 12-03 was taken from the Tătaru Lake, during the campaign performed in April - May 2012 (location, in Figs. 5 and 6). In 2006, dur-
ing the July expedition, it had been taken the core DD 06-109 from the southern zone of the Lungu Lake (location, in Figs. 5 and 6); the results of the study of vertical variation of the magnetic susceptibility along this short sediment core (39 cm long) were already published (Rădan & Rădan, 2010).

**a. Cuteţi Lake - Core DD 10-177**

The core DD 10-177, collected in autumn of 2010 from the central zone of the Cuteţi Lake (Figs. 5 and 6), located in the northwestern zone of the western Meşteru - Fortuna Depression (see Fig. 1), is 57 cm long, and is characterised by a varied lithology: an organic, non-cohesive and loose mud on top, passing towards the bottom to a more compact sediment, darker in colour, rich in vegetal fragments, and with 2 - 3 coarser sequences.

The vertical distribution of the magnetic susceptibility values (k) reflects, accurately, the lithological variations, even where the changes are macroscopically less visible. The bar chart from Fig. 7a shows the MS signature of the DD 10-177 core, with each bar coloured according to the k class (Fig. 4b) to which the sediment sub-sample was calibrated.

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**Fig. 5.** Danube Delta, Meşteru - Fortuna Depression (M-F.D.; Fluvial Delta Plain). Location of 8 sediment cores collected from 5 lakes and a canal, in 2006 and in the 2010 - 2013 period.

**Fig. 6.** Danube Delta. Western Meşteru - Fortuna Depression (M-F.D.; Fluvial Delta Plain). Location of the cores taken from the lakes Cuteţi (DD 10-177), Lungu (DD 06-109), and Tătaru (DD 12-03). **a** Location on the magnetic susceptibility (MS) map performed for the western M-F.D on the basis of the bottom sediments sampled in 1980 (Rădan et al., 1999); **b** Location of the core DD 12-03 on the Tătaru Lake MS map, carried out on the basis of the sediments sampled during the Spring 2012 campaign. Notes: The scale used for drawing the 2012 MS map is according to the k scale used to calibrate the lake sediments. The values of MS (k) contours must be multiplied by 10⁻⁶ (SI). The figure (b) support is a Google Earth image.
The MS range is $3.98 \times 10^{-6} - 99.63 \times 10^{-6}$ SI. Most sub-samples (i.e., 68%; Fig. 7e), sliced from the DD 10-177 sediment core, are included within the k class II, followed by the class III (21%) and the class I (11%). The core magnetic susceptibility signature defines, in detail, the lithological modifications, which could be explained by the influence of the hydromorphological conditions within the surrounding area, during the last decades. The two main sequences, which are clearly marked out by the maximum MS anomaly in the core central zone (k class III), and by an increasing trend of the MS values towards the bottom of the core, are represented by coarser sediments, and by silty muds, respectively (in agreement with the k classes and the corresponding lithological categories relieved by the MS scale from Fig. 4b).

The vertical variation of the contents determined for the siliciclastic/detrital fraction (SIL; Fig. 7b) follows, correspondingly, the MS signature recorded along the core DD 10-177, the lowest values (i.e., 16.1%; 22.67%; 19.9%) coinciding with the lowest k values (i.e., $3.98 \times 10^{-6}$; $23.59 \times 10^{-6}$; $14.54 \times 10^{-6}$ SI) measured on the muds intercepted at the depth levels 0 - 1, 15 - 18 and 40 - 43 cm, respectively (Fig. 7a). The highest k value ($99.63 \times 10^{-6}$ SI; Fig. 7a), corresponding to the highest SIL content (70.39%; Fig. 7b), was measured on the compact silty sediment from the core base (depth 54 - 57 cm). Actually, the correlation coefficient $r$ calculated for SIL versus k is 0.87 (see Fig. 8c), showing the strong positive correlation existing between this lithological component and the enviromagnetic parameter. The reverse situation is that of the vertical variation of the total organic matter content (TOM; Fig. 7c), the correlation between this lithological component and the MS being negative, also a strong one ($r = -0.88$; Fig. 8e). Consequently, the highest TOM content (80.72%; Fig. 7c) was determined for the fine, black mud sampled at the core top (depth 0 - 1 cm), while the lowest TOM content (26.69%; Fig. 8e)
7c) was identified for the silty sediment slice ending the core DD 10-177 (depth 54 - 57 cm). As regards the carbonates, although the correlation coefficients (r) calculated for the CAR vs k (Fig. 8d), SIL vs CAR (Fig. 8g), and TOM vs CAR (Fig. 8h) are very low (-0.08, -0.21, and 0.12, respectively), the vertical variation of the CAR component (Fig. 7d) shows a signature which is slightly similar to that of the environmental parameter (k; Fig. 7a), suggesting - though less evidently - the presence of 2 - 3 episodes within the core sediment sequence (particularly, an extended minimum area within the lower half of the CAR content vertical distribution diagram; Fig. 7d).

The pie-charts drawn for the lithological components and for the k classes to which the core sediment was calibrated show also a very good correlation between the two different characteristics under investigation in our study. Thus, the lithological composition of the core DD 10-177 reveals the highest content of the organic matter and carbonates (62% + 3 %; Fig. 7f), and, on the other side, the lowest k classes I and II represent also the most part (i.e., 11% + 68 %; Fig. 7e) within the pie-chart defining the magnetic susceptibility characterization of the respective sediment core.

**Fig. 8.** Magnetic and lithological parameters related to the DD 10-177 core sediments (Cutetchi Lake). a) Variation of the lithological composition (SIL, TOM, CAR) along the core; b) Variation with depth of the magnetic susceptibility (k); c) Correlation SIL versus k; d) Correlation CAR versus k; e) Correlation TOM versus k; f) Correlation SIL versus TOM; g) Correlation SIL versus CAR; h) Correlation TOM versus CAR.
The parallel presentation of the images drawn for the lithological and the magneto-susceptibilimetric signatures given in Fig. 8a,b stands as a conclusion of the integrated magneto-lithological analysis of the core DD 10-177, taken from the central zone of the Câutechi Lake. The quality of proxy parameter of the magnetic susceptibility with regard to the lithological composition of the lake sediments is clearly demonstrated.

The following core - taking into consideration the spatial location, from north southwards - is DD 06-109, which was taken from the southern zone of the Lungu Lake (Figs. 5 and 6), during the cruise carried out in the Danube Delta, in July - August 2006. A 3D-bar chart with the vertical distribution of the magnetic susceptibility recorded along this core was presented in a previously published paper (Rădan & Rădan, 2010).

Consequently, the next newly analysed sediment core is DD 12-03, which was collected from the Tătaru Lake (Fig. 1, Figs. 5 and 6), situated in the same area, i.e., the western Meșteru - Fortuna Depression.

b. Tătaru Lake - Core DD 12-03

This sediment core (61 cm long; Fig. 9a) was taken from the central-northern part of the Tătaru Lake (Figs. 5 and 6; see also Fig. 1), during the April - May 2012 campaign in the Danube Delta.

At the core bottom, an organic sediment level of brown colour is observed, which is similar to very fine peat; the horizon thickness is ca. 7 cm, and it is characterised by very low magnetic susceptibility values (14.04x10^{-6} - 36.99x10^{-6}) SI, belonging to k class II (Fig. 9a; see also Fig. 4b, for the MS scale). The Total Organic Matter (TOM) content determined for sediment samples taken from this depth interval records values up to 60.72 % (Fig. 10b), while, for the siliciclastic/mineral fraction (SIL), there were determined lower contents (with a minimum value of 36.12 %; Fig. 10a). Above this level, compact, clayey, cohesive muds are present (showing high MS values and SIL contents), which are gradually passing, on the upper part, to more fluffy and richer in organic substance muds, getting to dominantly organic sediments. This transition is very well illustrated by the MS values decreasing upwards; in the upper part of the core, the magnetic susceptibility records values assigned to k class II, which are typical for organic sediments (see Fig. 4b). These remarks are supported by the lithological components of the core sediments: the TOM content is increasing, in the upper part of the core being determined values up to 68.25 %, while the SIL contents are decreasing up to 25.68 % (Fig. 10a,b).

**Fig. 9.** Magneto-susceptibilimetric model for the sediment core DD 12-03 (Tătaru Lake). a) Vertical distribution of the magnetic susceptibility along the core; b) MS calibration of the core sediments according to the k scale classes.
The two higher MS values (up to $115.75 \times 10^{-6}$; k class III), measured at the upper extremity of the core, are not conclusive, as the measurements were performed on very small quantities of geomaterial relating to the standard samples [two thin sediment slices (1 cm thick each) were available for MS measurements]. Instead, the highest magnetic susceptibility (up to $217.73 \times 10^{-6}$ SI, calibrated to k class IV), which was detected in the lower part of the core (Fig. 9a), immediately above the peaty horizon, is clearly explained by the impact on the sedimentation regime after the “Mila 36” Canal opening (see Fig. 5).

The lithological components SIL and TOM determined for the samples sliced from this core depth interval (i.e., 48 - 54 cm), associated with the time since the above-mentioned canal was opened (1982 - 1983), record the highest (71.24 - 78.01 %), and the lowest (14.45 - 15.24 %) values, respectively (Fig. 10a,b), and clearly support the maximum recorded within the magnetic susceptibility vertical variation along the DD 12-03 core (Fig. 9a).

The calibration of the core sediments to the k scale is illustrated in Fig. 9b: most samples (58%) are assigned to k class III, followed by class II (32%) and k class IV (10%). This
“magneto-susceptibilmetric structure” of the core DD 12-03 sediments is supported by their lithological composition (see the average contents of the SIL, TOM and CAR components in Fig. 10d).

The magneto-lithological interpretation of the three 3D-charts with the vertical distribution of the MS, SIL and TOM (Figs. 9a and 10a,b, respectively) is very well argued by the strong correlation coefficients (r) calculated for SIL versus MS, and TOM versus MS (Fig. 10e,f). The correlations (TOM + CAR) versus MS, SIL vs. TOM, and SIL vs. CAR are shown, as well (Fig. 10g,h,i). A low but positive r coefficient, determined for the correlation of the siliciclastic fraction with the carbonates, can be seen; it suggests, anyway, a possible detrital origin of the carbonatic material. The CAR record along the sediment core DD 12-03 is illustrated in Fig. 10c.

The general similarity between the lithological and enviromagnetic signatures recovered from the DD 12-03 core sediments is clearly illustrated in Fig. 11a,b, particularly by the vertical distribution of the siliciclastic detrital component (SIL) and of the magnetic susceptibility parameter (MS; k).

The vertical distribution of the magnetic susceptibility (Fig. 9a and Fig. 11b) recorded for the DD 12-03 core reflects a series of very important events occurring in the evolution of this deltaic zone. The peaty sediment identified on core bottom (marked in Fig. 9a through a purple arrow) represents the sedimentation period before the digging of the “Mila 36” Canal, when the Lungu, Meșteru and Tătaru Lakes were isolated from the Danubian direct inputs, being dominated by an organic-type sedimentation. The “Mila 36” Canal opening (in the year 1983) has created a direct connection of these lakes - through the Periteașca Canal - with the Danubian inputs, rich in detrital siliciclastic material, which has radically changed the lithology of the sediments that were deposited in this area. This process led to silting up of the northern sectors of the Lungu and Meșteru Lakes, and any less, of the Tătaru Lake, placed in a more protected position. The islet from the Lungu Lake northern zone was totally incorporated within the lake bank.

The modifications of the magnetic susceptibility fingerprints detected within the bottom sediments sampled from these three lakes during two distinct periods, related to the “opening moment” (1983) of the “Mila 36” Canal, particularly in 1980, and at different times during the period when this canal has exhibited a strong activity (1987, 1993, and 1995 - 1997), were presented in a previously published paper (Rădan & Rădan, 2007). The analysed data confirmed the above presented sedimentogenetic considerations.

**Fig. 11.** Magneto-lithological characterisation of the sediments recovered from the core DD 12-03 (Tătaru Lake). a) Lithological composition (SIL, TOM, CAR) along the core; b) Variation with depth of the magnetic susceptibility (MS; k).
Afterwards, the connection channels of the lakes have silted up, and the Periteașca Canal was dammed upstream, so that, gradually, the lakes have reached again an almost protected regime. The increasing trend concerning the total organic matter (TOM) contents, and the decreasing trend related to the siliciclastic fraction (SIL) contents are suggested by the corresponding maps drawn up for the surficial sediments sampled from the lakes Lungu (Fig. 12a,b) and Meșteru (Fig. 12d,e), during the April - May 2012 campaign. The magnetic susceptibility signatures recovered from the bottom sediments of the two lakes (Fig. 12c, and Fig. 12f, respectively) show, correspondingly, lower intensities than those detected within the sediments sampled, e.g., in 1987: up to 654×10^-6 SI for the Lungu L., and up to 334×10^-6 SI for the Meșteru L. (Rădan & Rădan, 2010).

As regards the Tătaru Lake, with a spatial position that allows a double protection against the direct Danubian supplies, this has not undergone important changes after the severe modifications of the ecohydrological conditions in the area. The two MS maps drawn up for the Tătaru Lake, based on sediments sampled in 1980 (Fig. 6a), and 2012 (Fig. 6b), confirm its particular situation. Anyway, taking into consideration that the calibration of the bottom sediments sampled from this lake in 1980, 1993 - 1997, and 2006 revealed their assignement to k classes II and III only (Rădan & Rădan, 2010), an increasing trend regarding the TOM content is visible even in this lake, as long as the MS values which were measured on all the samples are placed within the k class II (see Fig. 6b) [excepting the station DD 12-48, where, moreover, k is a bit lower, i.e., 9.78×10^-6 SI (class I, a value placed in

Fig. 12. Lithological and magneto-susceptibilimetric maps of the bottom sediments from the Lungu and Meșteru Lakes (April - May 2012 campaign). a) Lungu Lake sediments: a) Total organic matter (TOM) content map; b) Siliciclastic/mineral (SIL) content map; c) Magnetic susceptibility (MS; k) map. b) Meșteru Lake sediments: d) TOM content map; e) SIL content map; f) MS (k) map. Legend: a) to f) Bottom sediment sampling station; 60 TOM content (%) contour (a,d). Similar legend for the SIL content map (b,e); 100 MS (k) contour (c,f). Note: The values of MS contours must be multiplied by 10^-6 (SI). The figures (a to f) support - Google Earth images.
fact at the boundary with k class II). The TOM and SIL maps (Fig. 13) carried out for the Tătaru Lake bottom sediments sampled during the April - May 2012 campaign confirm this observation; they clearly show the higher contents of the organic matter (Fig. 13a) related to those determined for the siliciclastic/mineral fraction (Fig. 13b).

Taking into consideration that, at present, the connection canals with the Periteașca Cn. are reopening, a new modification of the sedimentation regime in the future is presumably.

The magnetic susceptibility model from Fig. 9a is significant, as the sudden change of the MS values at 54 cm beneath the water/sediment interface, simultaneously with the disappearance of the peaty sediment, marks the opening of the “Mila 36” Canal. Relating the thickness of the detrital sequence to the time interval which has passed, i.e. 29 years, a sedimentation rate for the central zone of the Tătaru Lake of 1.9 cm/year is obtained; it is a big value, which suggests even higher sedimentation/silting up rates in the Lungu and Meșteru Lakes.

Fig. 13. Lithological maps of the bottom sediments from the Tătaru Lake (April - May 2012 campaign). a) Total organic matter (TOM) content map; b) Siliciclastic/mineral (SIL) content map. The figure (a,b) support - Google Earth images.

3.2 Sediment cores from the eastern Meșteru - Fortuna Depression

As regards the eastern part of the Meșteru - Fortuna Depression, we focus our attention to the Băclănești Lake (DD 13-61 sediment core), as well as to the Fortuna Lake (DD 11-210 and DD 13-56 cores). Another two cores (DD 13-54 and DD 13-55) were collected from the Crângială Canal microdelta, in the southern part of the Fortuna L. (Figs. 1, 5 and 14).

a. Băclănești Lake - Core DD 13-61

The sediments of the Băclănești Lake, located north of the Fortuna Lake, are dominantly organic (in the first 25 - 30 cm at least), and are not affected by the proximity of the Șontea Canal (Fig. 14a,b). The magnetic susceptibility data, achieved for the sediments taken with a Van-Veen grab sampler, at a time interval of 33 years, that is, in 1980 (Fig. 14b,c; k classes I and II) and 2013 (MS values placed within the range (-2.64)×10^{-5} - 28.2×10^{-6} Sl; k classes I and II; Fig. 14d) proved that the Băclănești Lake surficial sediments are not influenced by a coarser detrital fraction supply via Șontea Canal. The main water and sediment supplies come from northwest through small canals connected with the Stipoc and Băclănești Canals.

In this context, the magneto-lithological data obtained for the core DD 13-61, collected from the lake central zone (Fig. 14a,b), show, also, that in the first 27 cm the MS values are very low (0.19×10^{-6} - 12.69×10^{-6}) SI (Fig. 15a); the siliciclastic/detrital fraction (SIL) records, also, low contents (7.67 % - 17.01 %; Fig. 15b), while the total organic matter component (TOM) reveals high contents along the first half of the core (74.03 % - 91.50 %; Fig. 15c). The carbonates (CAR) show a lower content, too (0.8 % - 2.8 %; Fig. 15d) in the first 27 cm beneath the water/sediment interface. The images carried out for the lithological composition and the magnetic susceptibility vertical variation along the core (Fig. 16a,b) clearly confirm these characteristics of the first part of the recovered signatures.

Actually, even the core DD 10-61 is a short one, the extracted sediment column (52 cm thick) shows a rather complex situation. The magneto-lithological charts, presented in Fig. 15a,b,c,d and Fig. 16a,b, emphasise the existence of two distinct sequences: a) the upper one (ca. 27 - 28 cm thick) is constituted of organic muds, with a net subordinate participation of the detrital mineral material and a very reduced presence of the carbonates; b) the lower one, which is visible along ca. 24 cm, is characterised by a relatively balanced participation of the siliciclastic (45.91 % - 56.73 %; Fig. 15b) and organic (38.46 % - 50.28 %; Fig. 15c) components, to which the carbonates are added, with relatively higher contents (3.81 % - 4.93 %; Fig. 15d) comparing with those from the upper sequence (but very reduced, anyway).
Fig. 14. Location of the sediment cores - in magneto-susceptibilimetric context - collected from the Băclănești Lake, Fortuna Lake and Crânlăi Canal (eastern Meșteru – Fortuna Depression). a) Location of all the cores on a Google Earth image-support; b) Location of the cores on the magnetic susceptibility maps of the bottom sediments sampled from the Băclănești and Fortuna lakes in 1980 (Rădan et al., 1999). Note: The k values shown on the MS contours must be multiplied by $10^{-6}$ SI; c) MS calibration (according to k scale classes) of the surficial sediments from the Băclănești Lake, sampled in 1980 and 2013, respectively; d) Location of the core in the Băclănești Lake, on the MS map of bottom sediments sampled in 2013, drawn up by using coloured cubes, according to k scale from Fig. 4b; e) Location of the cores in the Fortuna Lake, on the magnetic susceptibility map of the bottom sediments sampled in 2011. Note: The colour scale used for the MS map is in agreement with the k scale.
These characteristics prove a lithological composition corresponding to the (slightly dominant) mineral-organic and organic-mineral muds. The upper mud is grey-yellowish-brown, sometimes, slightly greenish, non-cohesive, fluffy, rich in fine organic material; the lower mud is grey, cohesive, and contains vegetal material, too. In the depth interval 27 - 31 cm, the mud shows transition characteristics between the above-described sequences (Figs. 15 and 16). The similarity between the vertical distribution of the siliciclastic detrital component and of the magnetic susceptibility parameter related to the DD 13-61 core sediments is evidently illustrated in Fig. 16a,b.
The correlation diagrams (Fig. 16c,d,e) clearly reflect the existence of two different sets, corresponding to the two sequences. If the correlations are analysed in detail, separately for each sediment sequence (Fig. 17), it can be observed that, in the both groups, the carbonates (CAR) are positively correlated with the siliciclastic fraction (SIL), namely $r = 0.69$, related to the upper sequence (Fig. 17c), and $r = 0.77$, regarding the lower one (Fig. 17d), suggesting the detrital origin of the carbonatic material.
The separation of the two distinct “sediment packets” in the Băclănești Lake points out a significant change in the hydrological regime of the area, possibly connected to the diminution of northwestern supplies after the building of Pardina polder (1983).

b. Fortuna Lake - Cores DD 11-210 and DD 13-56

Core DD 11-210

The DD 11-210 core was collected from the southern zone of the Fortuna Lake (eastern Meșteru - Fortuna Depression, Danube Delta; Figs. 5 and 14).

The vertical distribution of the magnetic susceptibility offers interesting information on the sedimentation process in the southern half of the Fortuna Lake. In Fig. 14a, the core location is represented within the MS map constructed on the basis of the bottom sediment samples collected during the 1980 campaign (Rădan et al., 1999), that is when the Crânjală Crn. - a short artificial canal, which connects the Sulina Branch and the Fortuna L. - was very active. The MS anomaly (k values up to 581×10⁻⁶ SI), revealed by the contour map from Fig. 14a, shows the morphology of the underwater fan zone of the solid discharge provided by the Danube River. In the 3D-chart from Fig. 18a, two maxima are visible, one (with the highest k value of 145×10⁻⁶ SI) at ca. 30 cm under the water (w) / sediment (s) interface, the second one (with the highest k value of 452×10⁻⁶ SI) at ca. 12 cm beneath the w/s interface. The same pattern can be recognised in the similar diagrams for the lithological components (Fig. 18c,d,e). Actually, the MS calibration of the core sediments reveals that 44% of the sliced samples belong to k class Va (Fig. 18b), which mostly defines the upper maximum (Fig. 18a), 44% to class III (Fig. 18b), which mostly describes the lower maximum (Fig. 18a), and finally, 6% each to class IV and class II, respectively.
Fig. 18. Vertical distribution of the environmagnetic parameter and the lithological components along the DD 11-210 core. a) Vertical distribution of the magnetic susceptibility; the bars are coloured according to the $k$ scale; b) MS calibration of the core sediments according to the $k$ scale classes; c) Vertical distribution of the siliciclastic/detrital fraction ($SIL$); d) Vertical distribution of the total organic matter content ($TOM$); e) Vertical distribution of the carbonate content ($CAR$).
(Fig. 18b), which belong to the decreasing arms of the upper and lower maximum, respectively (Fig. 18a). The two maxima represent two evolution phases of the detrital inputs, which could be found within the history of the canal activity. The \( MS \) maxima located in the upper part of the DD 11-210 core could be correlated with the high solid discharge characterising the Crânjală Canal activity in the ’80s (the \( k \) map from Fig. 14a, as we mentioned above, is based on bottom sediments sampled in 1980). More information data are needed with regard to the time interval when the canal has acted at a maximum discharge to allow calculation of the sedimentation rate for the southern zone of the Fortuna Lake.

The sedimentogenetic significance of the magnetic parameter \( MS \) is supported by the high correlation coefficients (\( r \)) which were determined for \( MS (k \) values in Fig. 18a) versus the lithological components \( SIL \) (siliciclastic/detrital fraction; the vertical distribution along the DD 11-210 core, in Fig. 18c, and the average content, in Fig. 19a), \( TOM \) (Total Organic Matter content; Fig. 18d; Fig. 19a), and (\( TOM+CAR \)) (\( CAR \) - Carbonates, Fig. 18e, Fig. 19a). So, \( r = 0.73 \) (i.e., a strong direct/positive correlation, according to the scale given in Fig. 4a), in the case of \( SIL \) vs. \( MS \) (Fig. 19b), and \( r = 0.72 \) (i.e., a strong indirect/reversed correlation), when referring to \( TOM \) vs. \( MS \) (Fig. 19c). The correlation between the \( MS \) and \( CAR \) is insignificant (\( r = -0.15 \); Fig. 19d), due to their reduced weight (Fig. 18e; Fig. 19a) to the sediment constitution. When the contents of carbonates and organic matter are taken together, \( r = -0.73 \), i.e., a strong negative/reversed correlation for (\( TOM+CAR \)) versus \( MS \) (Fig. 19e).

The magneto-lithological study of the core DD 11-210 shows a diminution of the coarse siliciclastic component towards the base (\( SIL \); Figs. 18c and 20a), which is even better illustrated by the magnetic susceptibility record (Figs. 18a and 20b), suggesting that the upper unit is the result of the lake silting up due to the influence of the Crânjală Canal sedimentary supplies.

Fig. 19. Correlation diagrams of the lithological components (\( SIL \), \( TOM \), \( CAR \)) and the magnetic susceptibility enviromagnetic parameter (\( MS \), \( k \)), related to the DD 11-210 sediment core. a) Lithological composition of the core sediments, based on the \( SIL \), \( TOM \) and \( CAR \) average contents; b) Correlation \( SIL \) versus \( MS \); c) Correlation \( TOM \) versus \( MS \); d) Correlation \( CAR \) versus \( MS \); e) Correlation (\( TOM+CAR \)) versus \( MS \).
Core DD 13-56

This core was collected from the Fortuna Lake central zone, northwest of the previously presented core (DD 11-210), not far from this, but outside of the former Crânjală Canal (Fig. 14a,b). Consequently, the magnetic fingerprints recovered from the sediments of the two cores are similar in morphology, but different in intensity (see Figs. 18a, 20b and Figs. 21a, 22b). The upper maximum zone recorded in the Core DD 11-210 registers the highest MS value of 452×10⁻⁶ SI (k class Va) at ca. 12 cm beneath the water/sediment interface (Fig. 18a), while the maximum k value related to the upper maximum zone characterising the MS fingerprint extracted from the DD 13-56 core sediments is 239.17×10⁻⁶ SI (k class IV; Fig. 21a), and it was measured on cohesive muds from about the same depth.

The pie-charts in Figs. 18b and 21e point out the different intensities of the two MS fingerprints recovered from the DD 11-210 and DD 13-56 cores, respectively: a range extended from k class II (6%) up to class Va (44%), with an average k value of 236.93×10⁻⁶ SI in the first case, and a range covering an interval from k class I (9%) up to class IV (29%), in the second one, with an average k value of 110.60×10⁻⁶ SI. The magnetic susceptibility calibration of the DD 13-56 core sediments shows - beside the mentioned k classes I and IV - the MS classes II (38%) and IV (24%) (Fig. 21e).

The lithological composition of the DD 13-56 core supports the magnetic susceptibility signature characterising the sediments: a maximum zone in the upper-central part of the SIL record (Fig. 21c), followed by a narrower minimum zone towards the base, and vice versa relating to the TOM component (Fig. 21b), i.e., a large minimum zone in the upper-central part of the core, and a narrower maximum zone towards the core base. Still, the contents determined for the carbonates existing within the core sediments show a slightly similar vertical distribution (Fig. 21d), with an increasing trend in the upper-central part, followed by a minimum zone in the basal part. The correlation coefficients r calculated for SIL versus k, TOM vs. k, CAR vs. k, as well as SIL vs. TOM (Fig. 22c,d,e,f) assert that the magnetic susceptibility is strongly positively correlated (according to the scale from Fig. 4a) with the lithological components SIL and CAR (Fig. 22c,e), and strongly negatively correlated with the TOM component (Fig. 22d). Strong negative correlations (i.e., r = -0.99, and r = -0.71) are also shown by SIL vs. TOM, and TOM vs. CAR, respectively (Fig. 22f,h).

The SIL and CAR lithological components are moderately positively correlated (r = 0.62; Fig. 22g), suggesting a detrital origin of the carbonates found within the core sediments; a similar situation was found for the core DD 13-61 collected from the Bâclăneşti Lake (see Fig. 17c,d). This assertion is confirmed by the correlation CAR vs. k, which points out a strong positive correlation (r = 0.72; Fig. 22e).
Fig. 21. Vertical distribution of the enviromagnetic parameter and of the lithological components along the core DD 13-56 (Fortuna Lake). a) Variation with depth of the magnetic susceptibility (MS; k); the MS bars are coloured according to the k scale classes; b) Variation with depth of the total organic material content (TOM); c) Variation with depth of siliciclastic/detritial fraction content (SIL); d) Variation with depth of the carbonate content (CAR); e) MS calibration of the core sediments according to k scale classes; f) Lithological composition of the core sediments, based on the SIL, TOM and CAR average contents.
Finally, concerning the core DD 13-56, the parallel diagrams for the lithological composition (SIL, TOM, CAR) and the enviromagnetic signature (MS; k), respectively (Fig. 22a,b), are noteworthy. Their morphology analysis is supported by the above-presented correlation coefficients, determined for the two categories of characteristics defining the recovered 38 cm thick column of sediments, extracted from the central area of the Fortuna Lake.

c)  Crânjală mid-channel/Fortuna Lake - Cores DD 13-55 and DD 13-54

During the April 2013 campaign, two cores from the Crânjală mid-channel were taken, namely the DD 13-54 and DD 13-55 (location, in Fig. 14).

In the ‘80s, the influence of the Crânjală Canal on the Fortuna Lake sediments was very important, the direct solid discharges from the Danube contributing to the formation of a "microdelta" in the canal mouth area, providing a progressive silting of the lake. The magnetic susceptibility map performed on the basis of the sediments sampled in the year 1980 (Fig. 14b) clearly reflects the morphology of the underwater fan zone generated by the Crânjală Canal intense activity. The sediments were of fluvio-lacustrine type. Afterwards, in the ‘90s, when the canal closed, the sedimentation became predominantly organic, simultaneously with the change of the lake hydrological regime, nowadays filled up with water from north, through a connection canal with Şontea Cn. (Fig. 14a). The magnetic susceptibility map carried out on the basis of the surficial sediments sampled in 2011 (Fig. 14e) emphasises these changes, the measured maximum k value being 329.68×10^-6 SI (a maximum k contour of 300×10^-6 SI); 30 years ago, the maximum k value recorded on a sediment
sampled, roughly, in the same area (Fig. 14b), has reached 581\times 10^{-6} \text{SI} (a maximum k contour of 575\times 10^{-6} \text{SI} was drawn; Râdan \textit{et al.}, 1999).

Taking into account these short comparative considerations, based on MS data obtained at the ends of a 31 year interval, the information given by the two cores collected in 2011 from the \textit{Crânjală mid-channel} (Fig. 14a,b) is relevant. The sequences, though not too thick (i.e., 32 cm in the core DD 13-55, and 27 cm in the core DD 13-54), penetrated by the two cores, reflect the sedimentation conditions existing, anyway, during an earlier period.

\textbf{Core DD 13-55}

The sediments penetrated by the core DD 13-55, collected from the \textit{Crânjală mid-channel} (Fig. 14), show, as expected, a lithological composition dominated by the siliciclastic detrital material/SIL (ranging between 51.69 - 68.23%; average content: 61%; Fig. 23b,f), to which are added, subordinately, the organic material/TOM (26.71 - 44.54%; 35%; Fig. 23d,f), and a small amount of carbonates (3.67 - 5.06%; 4%; Fig. 23c,f). The sediments belong to the category of the mineral-organic muds, and are represented by coarse siltic muds, sometimes with sand traces, grey and grey-yellowish in the upper half core, and blackly towards the base. The vertical variations have not a big amplitude, being probably connected with the seasonal changes of the \textit{Danubian} supplies since the \textit{Crânjală Canal} had been active.

The magnetic susceptibility variations along the core (Fig. 23a, Fig. 24b), which perfectly correlate with the main lithological components determined for the analysed sediments (Fig. 23b,c,d; Fig. 24a), pointing out even in more detail the detrital sequences, assert its quality of proxy parameter for the lithological composition. Particularly, referring to the siliciclastic fraction (SIL) and the organic matter (TOM), the correlation coefficients are \(r = 0.91\) for SIL versus k (Fig. 24c), and \(r = -0.90\) for TOM versus k (Fig. 24d). The dominance of the mineral fraction (Fig. 23f), and the fact that the sediments are mainly constituted of coarse siltic muds (with sand traces) are reflected by the calibration of the most samples (88%) to the k class Va (Fig. 23e), the rest of 12% being assigned to the class IV (k scale, in Fig. 4b). The high intensity of the magnetic fingerprints recovered from all the core sediment slices is defined by the range 263.61\times 10^{-6} - 376.11\times 10^{-6} \text{SI} (Fig. 23a) within which all the MS values are concentrated.

It is worth a remark concerning the strong correlations between the lithological components. So, for SIL versus TOM, \(r = 0.999\) (Fig. 24f), but very interesting are the correlations SIL vs. CAR (\(r = 0.79\); Fig. 24h) and TOM vs. CAR (\(r = 0.82\); Fig. 24g); the strong positive and negative correlations, respectively, point out the connection of the carbonate fraction with the siliciclastic mineral material, suggesting a detrital origin of the carbonates, and not a biochemical one, as it has been recognised within some very organic muds. The enivromagnetic parameter MS confirms this inference, the correlation coefficient for CAR versus k being also positive (\(r = 0.61\); Fig. 24e).

\textbf{Core DD 13-54}

This second core taken from the \textit{Crânjală mid-channel}, which is 5 cm shorter than the previously presented one, is located closer to the channel entry into the Fortuna Lake (Fig. 14). The magneto-lithological models achieved for the two cores (Figs. 23 and 24, and Figs. 25 and 26, respectively) are, generally, similar. Yet, the maximum zone identified in the upper half of the core DD 13-54 is thinner, but more intense than that recorded for the core DD 13-55, while the minimum zone, observed in the lower half of the two cores, is larger, but less intense for the first mentioned core as compared to the second one. The measured magnetic susceptibility values on the 15 sediment samples sliced from the core DD 13-54 are defined within a slightly more extended range than that concerning the core DD 13-55, namely 213.0\times 10^{-6} - 423.75\times 10^{-6} \text{SI} (Fig. 25a). Additionally, the average k values which characterise the intensity of the recovered MS fingerprints are very close (almost the same), i.e. 327.40\times 10^{-6} \text{SI} for the core DD 13-54, and 328.88\times 10^{-6} \text{SI} for the core DD 13-55. This fact could indicate the quite similar magneto-mineralogical and geochemical constitution of the two core sediments. The pie-chart from Fig. 25e illustrates the calibration of the sediments penetrated by the core DD 13-54 to the same two k classes of the MS scale (Fig. 4b), with slightly different weights, i.e., k class Va (73%), and class IV (27%) (see, for comparison, Fig. 23e).

The position of the core DD 13-54 towards the upper part of the sediment fan developed into the lake at the channel mouth - as compared to the location of the core DD 13-55 - results in a slightly more intense magneto-lithological signature assigned to the sequence from the upper half of the core. This small difference recorded within the vertical variation of the magnetic parameter could give a complementary information to the macroscopical description of the cores made aboard the vessel.

The lithological composition of the core DD 13-54 is dominated, as for the previously analysed one, by the siliciclastic mineral material/SIL (66%), followed by the organic matter (29%), and carbonates (5%) (Figs. 25f and 26a). The sediments are placed into the category of the mineral-organic muds, and are represented by coarse siltic muds, dark grey in the core upper half, and light grey in the lower one, quite rich in vegetal material. This macroscopic description of the sediments is confirmed by the MS (k), SIL and TOM charts from Fig. 25a,b,d. Consequently, a maximum zone in the upper half is well-defined for the MS and SIL parameters, and a minimum one for the TOM lithological component; in the lower half, a minimum zone is outlined within the MS and SIL records, and a maximum zone within the TOM content vertical variation chart. These relations between the enivromagnetic parameter MS and the lithological components determined for the core DD 13-54 sediments are quantified by the
Fig. 23. Vertical distribution of the enviromagnetic parameter and the lithological components (core DD 13-55). a) Variation with depth of the magnetic susceptibility (MS; k); the MS bars are coloured according to the k scale classes; b) Variation with depth of the siliciclastic/detritial fraction content (SIL); c) Variation with depth of the carbonate content (CAR); d) Variation with depth of the total organic material content (TOM); e) MS calibration of the core sediments according to the k scale classes; f) Lithological composition of the core sediments, based on the SIL, TOM and CAR average contents.
correlation coefficients \((r)\) calculated between pairs of these magnetic and lithological characteristics. Thus, regarding \textit{SIL} versus \(k\), \(r = 0.65\) (Fig. 26c), and for \textit{TOM} versus \(k\), \(r = -0.64\) (Fig. 26d), which confirm a positive/direct correlation between the siliciclastic detrital fraction and the magnetic susceptibility, and a negative/reversed correlation between the organic matter and the enviromagnetic parameter, respectively. Regarding the carbonates, present in small amounts in sediments (3.88 - 5.71 %; Fig. 25c,f), the correlation with the magnetic parameter is positive, but weak \((r = 0.30;\) Fig. 26e),
actually, close to the boundary which separates the weak and moderate correlation ranges (see Fig. 4a).

A suggestive illustration of the lithological characterisation and of the magnetic susceptibility signature related to the core DD 13-54 sediments is given by the 2D-area chart from Fig. 26a, and the 2D line-chart from Fig. 26b, respectively. The parallel analysis confirms the above comments and adds even more details relating to the vertical distribution of the four parameters along the short core (only 27 cm long). It is also demonstrated the quality of magnetic susceptibility as a proxy parameter for the lithological composition of the lake sediments, even we are in a rarer case, referring to our investigated cores, when some \( r \) coefficients showed correlations placed - according to the scale from Fig. 4a - at the moderate/strong boundary (for SIL vs. \( k \) and TOM vs. \( k \)), or even at

Fig. 25. Vertical distribution of the enviromagnetic parameter and the lithological components (Core DD 13-54, Cranjală Canal). a) Variation with depth of the magnetic susceptibility (MS; \( k \)); the MS bars are coloured according to the \( k \) scale classes (see Fig. 4b); b) Variation with depth of the siliciclastic/detritial fraction content (SIL); c) Variation with depth of the carbonate content (CAR); d) Variation with depth of the total organic material content (TOM); e) MS calibration of the core sediments according to the \( k \) scale classes; f) Lithological composition of the core sediments, based on the SIL, TOM and CAR average contents.
the weak/moderate one (for CAR vs. $k$). Anyway, these two images (Fig. 26a,b), compared to the corresponding ones for the core DD 13-55 (Fig. 24a,b), collected also from the Crânjală mid-channel, provide an useful tool to observe the similarities and the slight differences between the two cores from a canal with an intense activity in the ‘80s, and closed afterwards, in the ‘90s. If the cores have the availability to point out the intense activity from the first mentioned period and before, the magnetic susceptibility maps from Fig. 14b,f, based on the surficial sediments sampled in the years 1980 and 2011, respectively, clearly illustrate the difference between the sedimentation process characteristics, as a result of the hydrological regime change, related to the two periods, before and after closing the Crânjală Canal.

Fig. 26. Magneto-lithological characteristics of the DD 13-54 core sediments (Crânjală Canal). a) Lithological composition (SIL, TOM, CAR) along the core; b) Variation with depth of the magnetic susceptibility (MS; $k$); c) Correlation SIL versus $k$; d) Correlation TOM versus $k$; e) Correlation CAR versus $k$; f) Correlation SIL versus TOM; g) Correlation SIL versus CAR; h) Correlation TOM versus CAR.
4. CONCLUSIONS, INFERENCES, AND FUTURE WORK

The variety of the aquatic ecosystems and the diversity of the sedimentation environments in the Danube Delta are well characterised by specific magnetic susceptibility fingerprints, recovered from the sediments of the investigated lakes. The vertical distribution of the magnetic susceptibility values, recorded for numerous short sediment cores, collected during the 2010 - 2013 period from 12 lakes and a mid-channel, reflects, accurately, the lithological variations, which sometimes are macroscopically less visible. The integrated magneto lithological study of the sediment cores concerns the main interdistributary depressions, situated in both the Fluvial Delta Plain and the Fluvio-Marine Delta Plain.

In this paper, the magnetic susceptibility (MS) characterisation and the lithological composition of 7 short cores from 4 lakes and a mid-channel from the Mesturu - Fortuna Depression (Fluvial Delta Plain) were presented. In the western area of this depression, a sediment core (57 cm long) from the Cucetchi Lake (DD 10-177), and another one (61 cm long) from the Tătaru Lake (DD 12-03), collected in 2010 and 2012, respectively, were taken. As regards the eastern part of the aquatic depression, a core (with a length of 52 cm) from the Băclănești Lake (DD 13-61), two cores (36.5 cm, and 38 cm, respectively) from the Fortuna Lake (DD 11-210 and DD 13-56, respectively), and other two short sediment cores (32 cm, and 27 cm, respectively), from the Crânjăla mid-channel (DD 13-55, and DD 13-54, respectively), were collected. Apart from the core DD 11-210, taken in the year 2011, the other 4 cores from the eastern Mesturu - Fortuna Depression have recently been collected, during the campaign carried out by GeoEcoMar in the Danube Delta in April 2013.

Even this synopsis refers to the sediment cores taken from a single deltaic depression, the magneto-lithological results point out the various ecosystems and sedimentary environments which arise in the approached area.

From the very beginning, a noteworthy conclusion is the generally strong correlation existing between the magnetic susceptibility and the contents of the main lithological components, i.e. the silicilastic/mineral-detrital fraction (SIL) and the total organic matter (TOM); these usually cover (together) more than 95 - 97% of the total content, while the rest is occupied by the carbonates (CAR). To evaluate the correlation between the two categories of characteristics investigated for the core sediments, a scale with steps [3 in the positive part, i.e. 0 - 1, and 3 in the negative part, i.e. 0 - (-1)] was used. In all the cases, the SIL lithological component is strongly positively correlated with the environmagnetic parameter MS, the correlation coefficient (r) recording values within the interval 0.73 - 0.98 (a lower value for DD 13-54 core, where r = 0.65), while the TOM component is strongly negatively correlated, with r ranging from (-0.72) to (-0.98), excepting the same core, where r = 0.64. As regards the minor lithological component, the carbonates (CAR), the correlation with the magnetic parameter was either positive or negative, covering all the 3 main classes: weak, moderate and strong. Yet, it is worth pointing out the direct correlations for CAR versus k (0.30 - 0.94), and for SIL versus CAR (0.62 - 0.80), which were determined for the cores taken from the eastern Mesturu - Fortuna Depression, namely from the lakes Băclănești and Fortuna, as well as from the Crânjăla mid-channel. These results argue the dominant detrital origin of the carbonate material which is present within the sediments penetrated by the four investigated cores.

Another remark regards the proxy characteristics of the enviromagnetic signature in connection with the lithological composition, with a special view to some methodological aspects. Thus, performing the correlation charts relating to SIL versus k, and TOM versus k, in some cases, samples placed farther from the trendline were identified. They were analysed again for their lithological composition, by choosing new samples from the original sediment slices. The results are very stimulating, the correlation coefficients becoming much higher; e.g., for SIL vs. k, an increase from r = 0.59 (first analyses) to r = 0.80 (after 8 samples were analysed again) has resulted, for TOM vs. k, from r vs. k, from r = 0.24 to r = 0.72. The effect was visible for the correlation of lithological component pairs, as well; e.g., for SIL vs. CAR, a change from a weak negative correlation (r = -0.13) to a nearby strong positive (l) one (r = 0.62) was recorded, for TOM vs. CAR, from r = -0.15 to r = -0.71, and for SIL vs. TOM, from r = -0.96 to r = -0.99. Other tests have also confirmed this very important inference concerning the use of the magnetic susceptibility as a proxy parameter to improve the quality of the lithological analyses, particularly with regard to optimize sampling the most adequate material from the sediment core slices. This methodology is feasible, of course, to be applied to sub-sampling the surficial sediments collected with a grab sampler. In this respect, a first test has already been successfully done, too.

As regards a general view on the magnetic susceptibility calibration of the sediments investigated in the Mesturu - Fortuna Depression, this time by extracting short cores from the lakes, the use of the MS scale applied till now in the various ecosystems and sedimentary environments of the Danube Delta and the Razim (Razelm) - Sinoie Lagoonal Complex (Rădan & Rădan, 2007) led to new and practical results. These data confirmed the good functionality of the scale and its usefulness to characterise the lake sediments in a vertical direction, in the analysed cases up to 61 cm depth beneath the water/sediment interface. As result of the calibration process application, all the 5 main k classes (from I to Va) were identified. Higher weights of the classes I and II (together) were determined for the cores collected from the lakes Cucetchi (DD 10-177; 79%) and Băclănești (DD 13-61; 55%), followed by Tătaru (DD 12-03; 32%), while greater percentages for the highest main classes (IV and Va) were identified for the sediment slices of the two cores taken from the Crânjăla mid-channel (DD 13-54 and DD 13-55; 100% in both cases). These
were followed by the core DD 11-210 sampled from the silted zone relating to the Crângulă Canal (within the Fortuna Lake), the total percentage for the classes (IV + Va) reaching 50%, a big weight (44%) showing also the class III. These results suggest that the vertical distribution of the magnetic susceptibility of the core sediments, nevertheless, integrates the particular characteristics of the sedimentary environments from lakes, to a certain extent, protected by the direct Danubian influence versus the lakes which are/or were directly influenced by the riverine supplies (see, e.g., Rădan & Rădan, 2011).

Although the cores were very short (less than 61 cm), they brought an interesting information on the respective sediment sequences, providing, anyway, more information than the bottom sediments taken with the grab sampler. A good example is the Fortuna Lake, in which case the two short cores (DD 11-210 and DD 13-56) collected from the “yellow zone” of the MS map, that is the “band” in which the surficial sediments are calibrated to the k class III (k values range: 75×10⁻⁶ - 175×10⁻⁶ SI), show in their upper half (first ca. 18 cm) MS values assigned to k class Va (higher than 275×10⁻⁶ SI), and IV (range 175×10⁻⁶ - 275×10⁻⁶ SI). The respective maxima represent an evolution phase relating to the detrital inputs, which could be found within the history of the Crângulă Canal activity, possibly around the years ’80, when it has acted at a higher discharge. Actually, the other two cores (DD 13-54 and DD 13-55), taken in 2013 from this canal, which had made - along a short distance - the connection between the Sulina Branch and the Fortuna Lake, point out this assertion, the 27 - 32 cm thick sediments being entirely calibrated to the high k classes IV and Va. The lithological components, particularly the siliciclastic/detrital, and the organic matter fractions - directly (maximum zones/high SIL contents), and indirectly (minimum zones/low TOM contents), respectively - support this inference. If more information data are brought with regard to the time interval when the canal has acted at a maximum discharge, a sedimentation rate calculation - based on the magneto-susceptibilimetric model - relating to the Fortuna Lake southern area could be possible. When such conditions were fulfilled, as in the case of the western Meşteru - Fortuna Depression, particularly concerning the Tătaru Lake, the sedimentation rate was determined (i.e., 1.9 cm/year).

The magneto-lithological data provided by the short cores collected from different sedimentary environments and ecosystems of the Meşteru - Fortuna Depression are very important in the context of deciphering the spatial and temporal evolution of the deltaic geosystem. Several examples have been already presented, and they support a series of conclusions and are resulting in interesting inferences, which have partially been pointed out above. Another one regards the case of the Băclănești Lake, where the taken core (i.e., DD 13-61) has clearly illustrated - by means of the vertical distribution of the proxy environmental magnetic parameter (MS) and of the main lithological components (SIL and TOM) - the existence of two different sediment sequences (at least, in the first 52 cm beneath the water/sediment interface). Consequently, the problem of the sources supported by this lake over the time must be taken into consideration. It seems a sudden change of the sedimentation regime has taken place. It could be said the lower sequence corresponds to a period characterised by a more agitated hydrological regime, with stronger fluvial influences. This action has almost suddenly closed down, when a barrier occurred, which has isolated the lake area from the supplies, the lake passing to a regime similar to that from nowadays.

As regards the spatial evolution of the deltaic geosystem, such an approach will be initiated by a parallel analysis of the magneto-lithological models achieved for the short cores collected in the Meşteru - Fortuna Depression (commented in the present paper); to this, a number of cores taken from other three important Danube Delta sub-units, i.e. the Matiţa - Merhei, Gorgova - Uzlina and Lumina - Roşu Depressions, will be added. The results of the study of the 17 short cores, which have already been investigated in the specific laboratories for the magnetic susceptibility and the lithological composition of their sediments, are to be the subject of the following parts of the composite paper. It seems the last one will be adequate for including a synopsis within the attempt to contribute towards deciphering the spatial and temporal evolution of the deltaic geosystem.

REFERENCES


