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

Sorin - Corneliu RĂDAN[1], **Silviu RĂDAN**[2], **Irina CATIANIS**[2], **Dumitru GROSU**[2], **Iulian POJAR**[2], **Albert SCRIECIU**[2]

[1]*Geological Institute of Romania, 1 Caransebeş St., RO-012271 Bucharest, Romania*
[2]*National Institute of Marine Geology and Geo-Ecology (GeoEcoMar), 23-25 Dimitrie Onciul St., 024053 Bucharest, Romania*
e-mail: sc.radan@yahoo.com; radan@geoecomar.ro; irina.catianis@geoecomar.ro; dan.grosu@geoecomar.ro; pojariulian@geoecomar.ro; albert.scrieciu@geoecomar.ro

Abstract. This paper represents the second part of a larger survey devoted to the enviromagnetic characteristics and to the lithological composition of the lake sediments of the *Gorgova – Uzlina Depression* (*Danube Delta*). A first approach was dedicated to the investigation of nine sediment cores, located in the lakes *Gorgova, Cuibeda, Uzlina* and *Isacova* (Rădan *et al*., 2016). Now, the main aim of the article concerns the magnetic susceptibility (**MS**) of surficial (bottom) sediments from the lakes which have been in our attention in the first part of the study, to which other five more lakes, recently investigated (2014 – 2015), are added (*i.e., Gorgovăţ, Obretinu Mic, Obretinciuc, Isăcel and Gorgoştel*). The lithological (**LITHO**) support related to the magnetic susceptibility characterization of the lake sediments is equally analysed, and it is defined by the three main **LITHO** components: the **SIL**iciclastic/minerogenic fraction (**SIL**), **T**otal **O**rganic **M**atter (**TOM**), and the **CAR**bonates (**CAR**). Consequently, the **MS** data associated to the surficial sediments of each lake are interpreted by integrating them with the specific **LITHO** characteristics. The obtained results are based on collections of samples taken during the 2011 ÷ 2015 period, but also, in some cases, on data concerning the expeditions performed in 2006 (particularly related to the couple of lakes *Uzlina - Isacova*). They represent new proofs which demonstrate 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 investigated area. Besides, the comparison of the latest **MS** results with the magnetic susceptibility data achieved in the first sampling campaign in the *Gorgova*, *Uzlina* and *Isacova Lakes*, in 1979, brings an inedited enviromagnetic information extracted from the lacustrine sedimentary archives, just placed inside of an international context, if we refer to the beginning times of such types of researches in the world (*e.g.*, Thompson *et al*., 1975).

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

1. INTRODUCTION – STUDY AREA

In the present paper, the attention has been focused on the areal distribution of the *magnetic susceptibility* (**MS**; **k**) and of the main lithological (**LITHO**) components (**SIL** – *Siliciclastic/detrital fraction*, **TOM** – *Total Organic Matter* and **CAR** – *Carbonate fraction*), measured for the bottom sediments of nine lakes (*Obretinu Mic*, *Gorgova*, *Gorgovăţ*, *Obretinciuc*, *Cuibeda*, *Isăcel*, *Gorgoştel*, *Uzlina* and *Isacova*; Figs. 1 and 2). Surficial (bottom) sediment sampling was carried out based on networks of stations located so as to accomplish a well-balanced coverage of the investigated surfaces.

Partially, some of the magneto-susceptibilimetric and lithological/sedimentological data relating to the *Gorgova – Uzlina* aquatic area, achieved along the way, were or are to be published, *e.g.*, Rădan (2008), Rădan & Rădan (2007a, 2009, 2010a, 2011), Rădan *et al*. (2016), and/or were presented at international symposia (abstracts published), *e.g.*, Rădan & Rădan (2006a,b, 2007b, 2010b), Rădan *et al*. (2015).

In this paper, the **MS** and **LITHO** results obtained on the samples collected during the period 2011 ÷ 2015 will be particularly analysed and commented. Besides, concerning the couple of lakes "*Uzlina - Isacova*", which have not been covered by networks of stations within the specified time interval, the

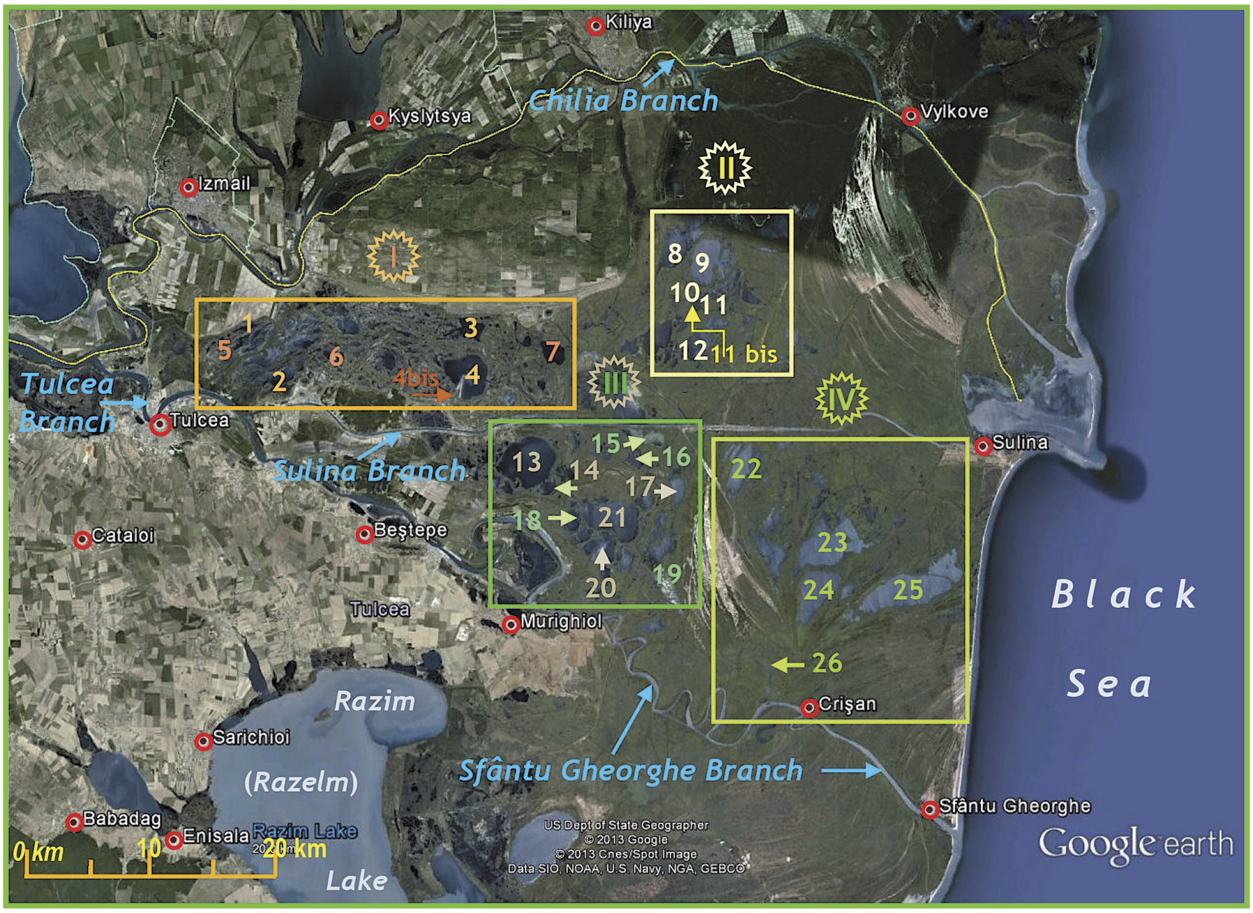

Fig. 1. Location of the interdistributary depressions in the Danube Delta and position of the main water bodies studied during 2010 – 2015 time period. **I**. *Meşteru – Fortuna Depression*: **1** – Cuteţchi Lake; **2** – Tătaru Lake; **3** – Băclăneşti Lake; **4** – Fortuna Lake; **4bis** – Crânjală Channel; **5** – Trofilca Lake; **6** – Belâi Lake; **7** – Lideanca Lake. **II**. *Matiţa – Merhei Depression*: **8** – Babina Lake; **9** – Matiţa Lake; **10** – Polideanca - Lopatna Swamp; **11** – Polideanca Lake; **11bis** – Lopatna - Polideanca Channel; **12** – Bogdaproste Lake. **III**. *Gorgova – Uzlina Depression*: **13** – Gorgova Lake; **14** – Gorgovăţ Lake; **15** – Obretinu Mic Lake; **16** – Obretinciuc Lake; **17** – Cuibeda Lake; **18** – Isăcel Lake; **19** – Gorgoştel Lake; **20** – Uzlina Lake; **21** – Isacova Lake. *Note 1*: **A) 13÷21** – lakes under study in the present article (*Part* **II**), focused on surficial sediments; **B) 13**, **17**, **20**, **21** – lakes under study in the paper's *Part* **I**, focused on sediment cores (Rădan *et al*., 2016; this volume). **IV**. *Lumina – Roşu Depression*: **22** – Iacub Lake; **23** – Lumina Lake; **24** – Puiu Lake; **25** – Roşu Lake; **26** – Erenciuc Lake. *Note 2*: **I** – Area with published data (Rădan *et al*., 2013); **II** – Area with published data (Rădan *et al*., 2014); **III** – Area under attention in the present paper; **IV** – Area for which the results are to be next published. *Note 3*: The figure support – *Google Earth* image.

data achieved in 2006 are used; anyway, some information provided by the small number of sampling stations completed in 2011 (5 locations in *Uzlina L.*, and 4 locations in *Isacova L.*) is included in the main database. Using all these integrated results, feasible **MS** and **LITHO** (**SIL**, **TOM**, and **CAR**) maps have been drawn up. Moreover, inedited magnetic susceptibility maps achieved for sediments collected from networks of sampling stations performed during the 1979 expedition from two "*tandem*" pairs of lakes – *Gorgova - Gorgovăţ* and *Uzlina - Isacova* – are considered for comparison. In our knowledge, such an extended time interval – since 1979 until 2006/2011 –, during which a magnetic susceptibility database for lake sediments has been developed, it is not frequently found in the geophysical - geological literature. It is worth to mark out that only four years before 1979, Thomson *et al*. (1975) have written the paper "*Magnetic susceptibility of lake sediments*", which has opened the way towards the *environmental magnetism* (*e.g.*, Oldfield, 1991; Verosub and Roberts, 1995; Dekkers, 1997), considered by Evans and Heller (2003) – in their book dedicated to the "*Principles and Applications of Enviromagnetics*" – as "*a relatively new science*". In fact, in Romania, we have begun the magnetic susceptibility investigation of the lake sediments even before 1979 (this year regards the *Gorgova – Uzlina Depression*), particularly in 1977, that is closer to the publishing date of the Thompson *et al*. (1975)'s paper; the first results have occurred in an unpublished scientific work/report (Rădan *et al*., 1978, in Mihăilescu *et al*., 1978).

2. GEOMATERIALS AND METHODS

The main elements concerning the logistics, the field and laboratory methods applied to investigate the lake sediments from the *Gorgova – Uzlina Depression* are similar with those that were used in the cases of the two deltaic units (*Meşteru –*

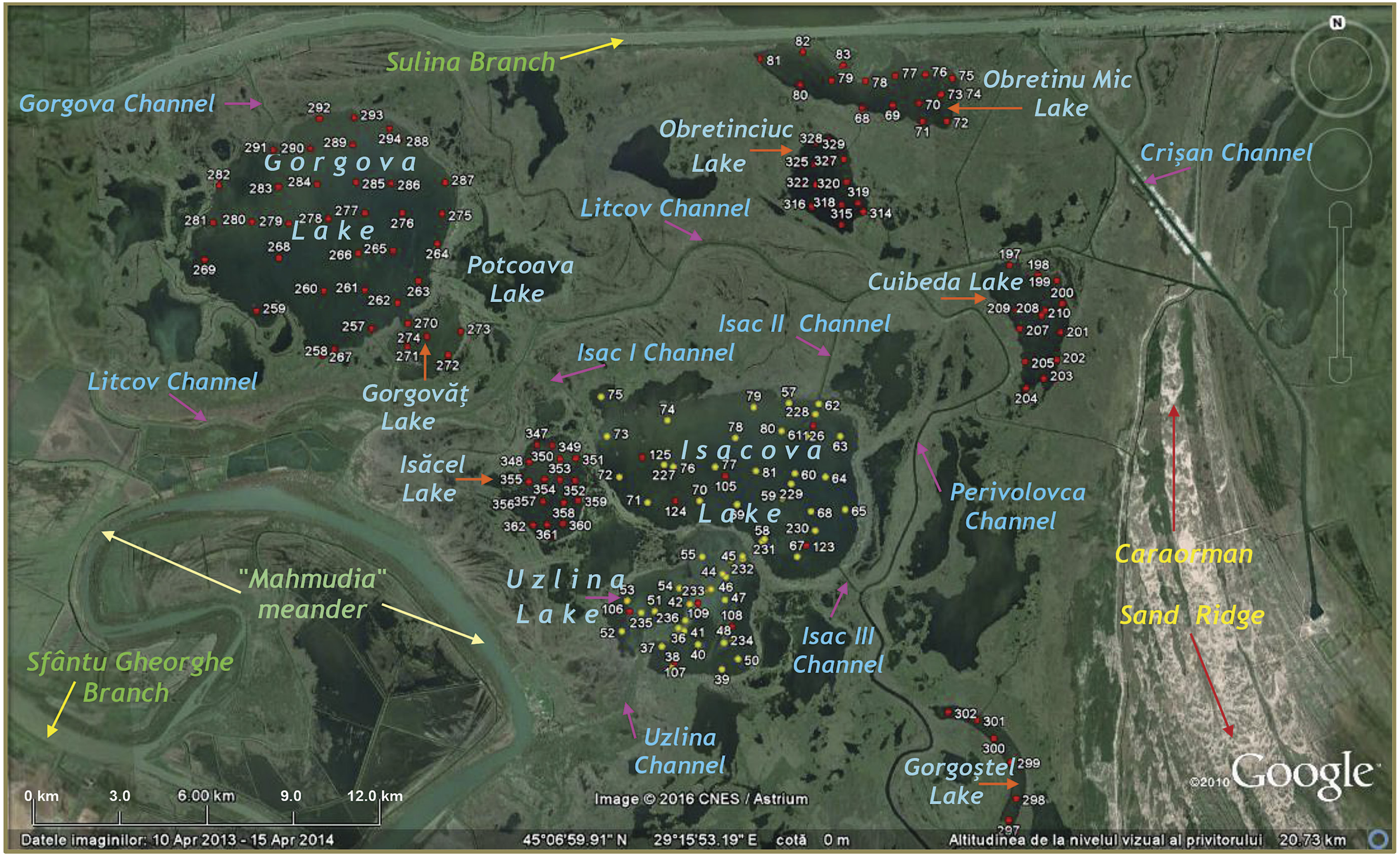

Fig. 2. Locations of the sampling station networks within the lakes of the *Gorgova – Uzlina Depression*, wherefrom surficial sediment samples were collected during 2011– 2015 period ("*red points*"), and whose enviromagnetic characteristics and lithological composition are analysed in the paper. *Note 1*: The stations used for sampling in the *Uzlina* and *Isacova lakes* during two campaigns performed in 2006 are also drawn out ("*yellow points*"). *Note 2*: The figure support – *Google Earth* image.

Fortuna D. and *Matița – Merhei D.*) whose results have already been published (Rădan *et al*., 2013, 2014). Consequently, we refer now just to the specific data concerning the geomaterials, *i.e*., the samples of surficial sediments extracted from the lakes of the area under attention in this article.

TThe sampling works were performed by GeoEcoMar, aboard the R/V "*Istros*", and the motor-boat "*Măriuca*", in the framework of the Core Program, Contract no. PN 09-41 03 04. Relatively undisturbed sediment samples were taken by using a *van Veen*-type grab sampler from around 10 – 15 cm beneath the water/sediment interface. A total number of 109 surficial sediment samples have been collected from the seven investigated lakes, on the basis of adequate networks of stations (Fig. 2): *Obretinu Mic* – 16 (*DD 15-68 ÷ DD 15-83*), *Gorgova* – 33 (*DD 12-257 ÷ DD 12-269* and *DD 12-275 ÷ DD 12-294*), *Gorgovăț* – 5 (*DD 12-270 ÷ DD 12-274*), *Obretinciuc* – 16 (*DD 14-314 ÷ DD 14-329*), *Cuibeda* – 14 (*DD 14-197 ÷ DD 14-210*), *Isăcel* – 19 (*DD 14-345 ÷ DD 14-363*) and *Gorgoştel* – 6 (*DD 15-297 ÷ DD 15-302*). Besides, during an expedition performed in 2011, four samples from the *Uzlina L*. (*DD 11-106 ÷ DD 11-109*) and five from *Isacova L*. (*DD 11-123 ÷ DD 11-126*) were collected. This couple of lakes has already been covered in detail with networks of stations in 1979 and 2006 as well (a general synthesis of results obtained within the 1979 ÷ 2006 period is carried out by Rădan & Rădan, 2010a). During different time intervals (*e.g*., 1992 ÷ 1999; 2003 ÷ 2005), a number of sediment samples (not included in regular networks) have been also collected and investigated in laboratory (see, *e.g*., Rădan & Rădan, 2007a).

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 instrument were given 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) (a version, in Fig. 3a_1), so that a **MS** calibration of the lake sediments has become feasible.

On the other side, the lithological composition of the lake sediments was determined in the specific laboratory of GeoEcoMar, using the *Loss on Ignition method* (*LOI*). The sediment samples were subjected to a sequential heating into a SNOL lab furnace (Dean, 1974; Catianis *et al*., 2014), at two temperature steps (550°C and 950°C, respectively). Hence, the contents (in percents) of three lithological components were established, following the order **TOM** (**T**otal **O**rganic **M**atter), **CAR** (**CAR**bonates), and **SIL** (**SIL**iciclastic/minerogenic fraction).

Usually, the values of **MS** vary directly proportional to the detrital/siliciclastic material (**SIL**) contents, leading to strong positive correlation coefficients (close to 1). This relationship allowed the elaboration, on the basis of **SIL** contents, of an analogous lithological (**LITHO**) scale (Fig. 3a_2), well correlated to the **MS** scale (Fig. 3a_1).

The relationship between the magnetic and lithological parameters (**SIL** *vs*. **MS**, **TOM** *vs*. **MS**, and **CAR** *vs*. **MS**) measured for each lake was assessed by calculating the correlation coefficients (**r**), whereas for their interpretation we have referred to a scale with 6 ranges spanning the interval from (-1) to (+1) (Fig. 3b).

3. RESULTS AND DISCUSSION

The results of the study undertaken on the magneto-susceptibility and lithology of the lake sediments are presented following the order of the lakes that is shown in **Ch. 2** (Fig. 2), *i.e*., *Gorgova*, *Gorgovăț*, *Obretinu Mic*, *Obretinciuc*, *Cuibeda*, *Isăcel*, *Gorgoştel*, *Uzlina* and *Isacova*. The areal distribution of the four above-mentioned geophysical and lithological parameters is presented, for each lake, by contour maps, with **k** isolines, and, respectively, with **SIL**, **TOM** and **CAR** contents isolines.

Related to the data presentation manner, the mentioned specific maps have been elaborated in two versions: **a)** maps with contour lines and colours according to the **k** and **LITHO** scales (see the two scales in Fig. 3a_1,a_2); **b)** maps with **k**-cubs, and **SIL**-, **TOM**- and **CAR**-cylinders, coloured conforming to the **MS** sediment calibration to five **k** *classes* (from **I** to **Va**; Rădan & Rădan, 2007a; see also Fig. 3a_1), and respectively, according to a preliminary **LITHO** scale (Fig. 3a_2), also with five *classes* (**1** to **5**, spanning the 0 % - 100 % percentage interval, assigned to **SIL** contents, the lithological parameter that show always a very strong positive correlation with the **MS** values).

3.1. Gorgova and Gorgovăț Lakes (13 and 14, in Fig. 1; see also, Fig. 2)

Located in the northwestern part of the *Gorgova – Uzlina Depression* (Figs. 1 and 2), the *Gorgova - Gorgovăț* couple of lakes were investigated during the expedition that was carried out during 20 July – 02 August 2012, the networks of sampling stations being illustrated in Fig. 2.

In the *Gorgova Lake*, the surficial sediments were sampled from 33 stations (*DD 12-257 ÷ DD 12-269* and *DD 12-275 ÷ DD 12-294*), and in the *Gorgovăț Lake* from 5 stations (*DD 12-270 ÷ DD12-274*) (Fig. 2). The maximum thickness of the sediment sequence extracted from the lake bottom – by using a *van Veen*-type grab sampler – was of 10 cm; sometimes, within the grab sample have been identified several distinct layers in terms of lithology, which were marked from top downwards with the letters **a**, **b**, **c** ... etc. For this sample collection, 15 % of them show two layers ("**a**" and "**b**"), the others 85% only one ("**a**").

First time when a magnetic susceptibility study has been carried out on a collection of bottom sediments sampled from these two lakes concerns the expedition of 1979 year (Rădan *et al.,* 1980, in Mihăilescu *et al*., 1980). These old

a

Magnetic susceptibility scale a1) (MS; k)		Lithology of lake sediments	Lithological scale a2) (LITHO)	
Classes	MS ranges [× 10^{-6} SI]	Lithological types	Classes	SIL ranges [%]
Vd	> 1000	Coarse silts and sands	5	70 ÷ 100
Vc	675 ÷ 1000			
Vb	575 ÷ 675			
Va	275 ÷ 575			
IV	175 ÷ 275		4	60 ÷ 70
III	75 ÷ 175	Clayey to silty sediments	3	50 ÷ 60
II	10 ÷ 75	Fine sediments, usually rich in organic matter and / or carbonates	2	15 ÷ 50
I	< 10		1	0 ÷ 15

b

Correlation coefficient (r)		
(red)	0.64 ÷ 1.00	Strong positive correlation
(orange)	0.31 ÷ 0.64	Moderate positive correlation
(light orange)	0.00 ÷ 0.31	No correlation – Weak positive
(yellow, crossed)	0.00 ÷ (- 0.31)	No correlation – Weak negative
(green)	(- 0.31) ÷ (- 0.64)	Moderate negative correlation
(light blue)	(- 0.64) ÷ (- 1.00)	Strong negative correlation

Fig. 3. Scales used in the magneto-lithological study of the surficial sediments. **a)** Magnetic susceptibility (**MS**; **k**) and lithological (**LITHO**) scales. **a1) MS** scale, with 5 ranges/classes (**I** to **V**), the class **V** with 5 sub-classes (**Va**, **Vb**, **Vc**, **Vd**), used to calibrate the lake sediments. **a2) LITHO** scale used to assess the lithological composition (contents in %) of the surficial sediments, according to five **SIL** ranges/classes (**1** to **5**), correlated with the **MS** scale. **b)** Scale used to evaluate the degree of the correlation (**r**) between the enviromagnetic parameter (**k**) and the lithological components (**SIL** – siliciclastic/minerogenic/detrital fraction; **TOM** – total organic matter fraction; **CAR** – carbonate fraction; **r** – correlation coefficient).

MS data were re-analysed – together with the other results achieved along the period 1979 ÷ 2003 – in the framework of a "*CERES*" Project, dedicated to the elaboration of a magneto-environmental method for characterizing sedimentary systems in the *Danube Delta* and the *Razelm (Razim) – Sinoie Lagoon Complex* (*e.g.*, Rădan & Rădan, 2003). The **k** maps based on the network of 23 stations in the *Gorgova L.*, and 5 stations in the *Gorgovăț L.*, wherefrom sediment samples were collected in 1979, are illustrated in Fig. 4a, together with the **MS** maps of the *Uzlina* and *Isacova Lakes*, which were investigated in detail during the same expedition (some information, in Ch. 3.7). As regards the surficial sediments of the *Gorgova* and *Gorgovăț Lakes*, a general observation is that the **k** values decreasing trend from the *Gorgovăț Lake* towards the *Gorgova Lake* reflects the water influx from the *Danube River* (on the track *Gârla/Brook Filatului* ➔ *Litcov Channel* ➔ *Gorgovăț L.*), loaded with suspensions which are partially settled down in the latter, before passing into the *Gorgova Lake*. A close connection was remarked between the **k** maps (Rădan & Rădan, 2003) and the *grain size* distribution maps (*Md*, *φ*, *silt*, *sand*; Mihăilescu *et al.*, 1980); at the same time, the close correlation with the outlet mouths of the channels has been pointed out, as well. In the *Gorgova Lake* northwestern zone (Fig. 4a) it is easily observed a **MS** decreasing gradient, which is well marked out by the **k** contours, going from the *Gorgova Channel* mouth inward. Also, in south, the *Gorgovăț Lake* presents the same distribution model, the strongly decreasing gradient being directed from the access channel mouth (from *Danube, via Filat* and *Litcov* channels) towards the connection channel with the *Gorgova L.* (Fig. 4a). Looking to the new **MS** map (Fig. 6a), based on the **k** values measured on sediments sampled after 33 years (*i.e.*, during the July - August 2012 expedition), it is very interesting to remark the location of two anomaly zones in the same areas, in northwest and south, with the associated gradient regimes defined by the **k** contour lines that are similarly directed, inside of the *Gorgova L.* in relation with the *Gorgova Channel* mouth (even if this channel was closed in 1982), and respectively, inside of the *Gorgovăț L.*, related to the mouth of *Gârla Filatului Channel*.

Therefore, passing now to the latter *magnetic susceptibility* model (Fig. 5), the **MS** calibration of the *Gorgova Lake* sediments (to **k** scale from Fig. $3a_1$) has shown that 73 % of samples (fine sediments, rich in organic matter) are defined by the **MS** *class* **II**, and 3 % of them are assigned to the *class* **I** (Fig. $5a_1$), they corresponding to the *organo-mineral muds* (in

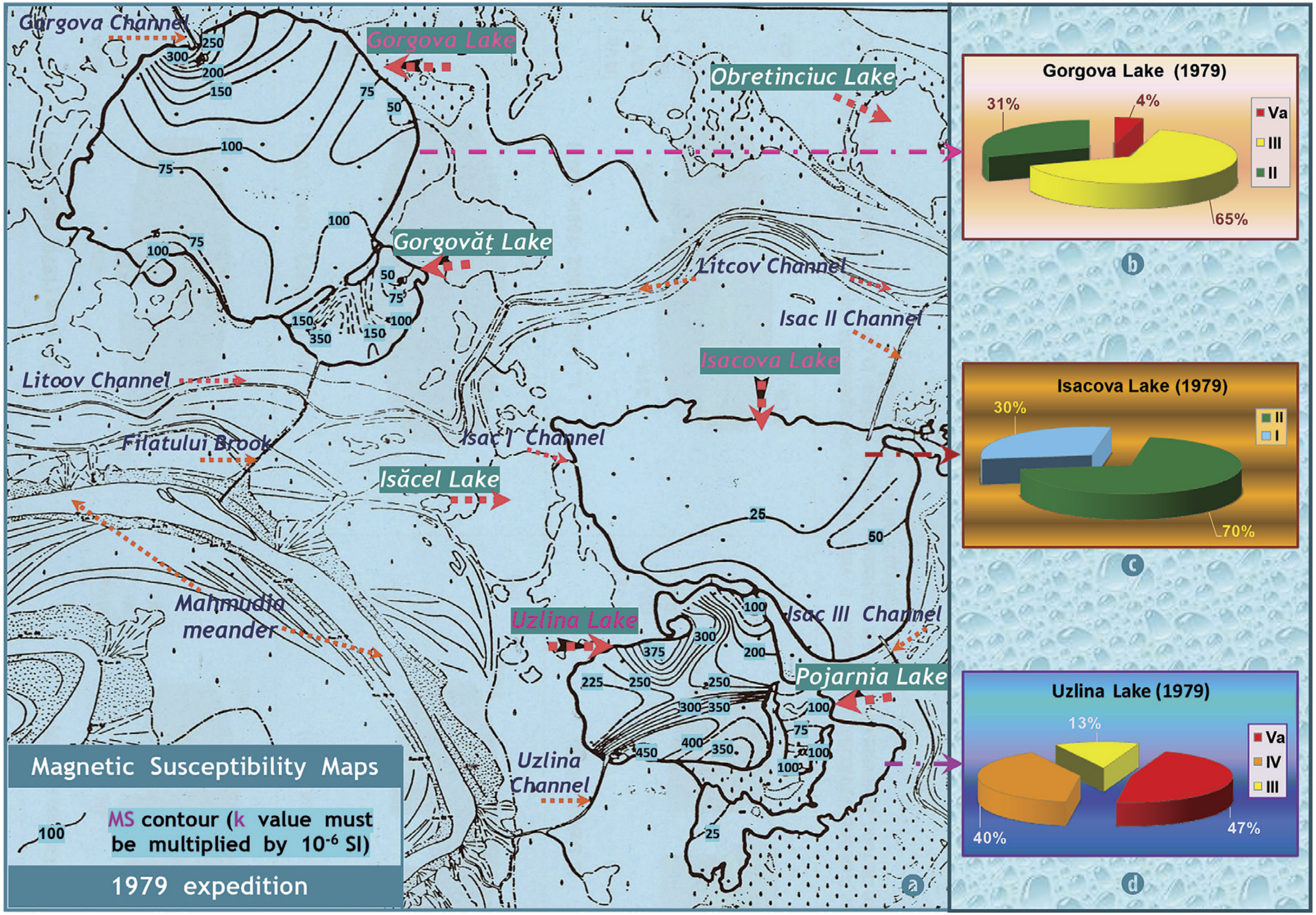

Fig. 4. Magnetic susceptibility data for the surficial sediments sampled from the *Gorgova - Uzlina Depression* during the campaign carried out in 1979. **a) MS** (**k**) maps for the bottom sediments of the *Gorgova*, *Isacova*, *Uzlina* and *Pojarnia* lakes. **b), c), d)** Diagrams showing the **MS** calibration (by using the **k** scale classes) of the surficial sediments sampled in the *Gorgova Lake*, *Isacova Lake* and *Uzlina Lake*, in 1979.

Fig. 5. Synoptic magneto-lithological model showing the **MS** calibration (by using the **k** scale classes) and the lithological composition (based on the contents of **SIL**, **TOM** and **CAR** components) of the surficial sediments sampled in the lakes from the *Gorgova – Uzlina Depression* over the 2011 – 2015 period. Detail concerning the assessment of the siliciclastic/detrital component (**SIL**) contents according to the **LITHO** scale. *Legend* : **A) MS** (**k**) scale; **B) LITHO** scale; **C) MS** cub, coloured according to the **k** scale class to which the sediment sample was calibrated (based on the **k** value measured in the laboratory and its correlation to the **MS** scale); **D) LITHO** cylinder, coloured according to the **LITHO** scale class to which the **SIL** component content, determined for a sediment sample was assigned. *Note*: The figure support – *Google Earth* image.

accord with the lithological classification). These *muds* cover the largest part of the lake bottom, and taking into consideration the weights of the main lithological components (Fig. 5a_2), the *organic matter* records 68 %, the *mineral material* (predominantly detrital, siliciclastic) 26 %, whereas the *carbonates* represent 6 %. Some exceptions are constituted by the samples *DD 12-257* and *DD 15-291*, which are assigned to the *mineral-organic muds* category, containing 52.1 % and 54.8 % *mineral material*, respectively. They were collected from the mouths of the *channels Gârla/Brook Filatului* (in south) and *Gorgova* (in north), respectively, through which the lake was supplied with sedimentary material of *Danubian* origin. The magnetic susceptibility confirms these lithological-mineral characteristics and indicates high **k** values (both assigned to **MS** *class* **IV**; **k** scale, in Fig. 3a_1): 221.63×10^{-6} SI and 297.82×10^{-6} SI (the latter, a *compact grey mud* – layer "**b**"). There are two more other exceptions, namely the samples *DD 12-281* – an *organic mud* (with over 80 % organic material), and *DD 12-264* – a *carbonate organo-mineral mud* (with over 10 % carbonates), which are originated from the western and eastern lake extremities, respectively (Fig. 2). The magnetic susceptibility records a very low **k** value (7.4×10^{-6} SI – **k** *class* **I**) for the first sample (actually, the lowest value in the *Gorgova Lake*), and a very high **MS** value for the second sample (477.19×10^{-6} SI – **k** *class* **Va**, in fact, the highest value in this lake). Yet, if the mentioned low **k** value is "normal" for an *organic mud*, the remarked high **k** value cannot be explained in the hydromorphological context which is known for the *Gorgova L.*; the sample is probably "contaminated" with a material from basement, characterized by a very high magnetic susceptibility, comparing with the specific sediments of the *Gorgova Lake*. Actually, at the bottom of the sediment taken with the grab sampler were observed some fragments of a compact clayey material, harder, similar to a soil. Excluding this sample, and also not taking into attention the layer "**b**" separated within the sample *DD 15-291*, we can say the magnetic susceptibility of the surficial sediments (so, referring to the layer **"a"**), collected from the *Gorgova* and *Gorgovăţ Lakes*, is defined by the interval 7.74×10^{-6} ÷ 221.43×10^{-6} SI, which means a range that has as ends the *class* **I** and the *class* **IV**, respectively. The weights of the four **MS** *classes* to which the bottom sediments of the two lakes are calibrated are shown by the **k** pie-chart from Fig. 5a_1: 3 % – *class* **I**, 73 % – **II**, 19 % – **III**, and 5 % – *class* **IV**. One can add that the five sediment samples of the *Gorgovăţ Lake* (*DD 12-274 ÷ DD 12-270*) are characterized by **k** values placed within a very narrow interval (57.58×10^{-6} SI ÷ 78.68×10^{-6} SI).

Instead, the **MS** pie-chart performed on the basis of the "1979-year" data indicates a preponderance of sediment samples calibrated to the *class* **III** (65 %), followed by the *class* **II** (31 %) and the *class* **Va** (4 %) (Fig. 4b). We can observe that concerning the "1979" and "2012" collections of samples, the composite weights for the *classes* **II** and **III** are comparable, 96 % *versus* 92 % (Fig. 4b *vs*. Fig. 5a_1), but separately, the weights are reversed as size order: "1979" (**II** – 31 %; **III** – 65 %) *versus* "2012" (**II** – 73 %; **III** – 19 %). This means a state of enrichment in organic matter of the sediment composition in 2012 as compared with 1979. Actually, no *class* **I** is present relating to the calibration of the sediments sampled in 1979. As concerns the 2012 magneto-lithological study, if we compare the magnetic susceptibility data with the lithological ones, we remark that 76 % of samples are calibrated to the *classes* **I** and **II**, and 24 % to the *classes* **III** and **IV** (Fig. 5a_1). Thus, corresponding to this percentage distribution, the organic component (**TOM**) and the carbonates (**CAR**) summarize 74 %, while the remaining 26 % represent the participation of the mineral/detrital (**SIL**) fraction (Fig. 5a_2). If the **LITHO** scale from Fig. 3a_2 is used, then 97 % of samples have the **SIL** component defined by the *class* **2** (*i.e.*, **SIL** contents between 15 % - 50 %), and only 3 % by the *class* **3** (*i.e.*, 50 % - 60 %) (Fig. 5a_3).

It is interesting to point out the **MS** areal distribution pattern (Fig. 6a) is practically identical with that of the *siliciclastic* (lithological) component (**SIL**) (Fig. 6b), a similarity which clearly demonstrates the quality of *proxy-parameter* of the magnetic susceptibility for sedimentological interpretations. Numerous previous papers (*e.g.*, Rădan *et al*., 2013, 2014) and scientific reports, approaching other areas of the *Danube Delta*, as well as the *Razim - Sinoie Lagoon Complex*, have proved the high resolution of the lithological-sedimentological signatures of the magneto-susceptibilimetric records.

Thus, the magneto-susceptibility and lithological data obtained for the surficial sediments of the *Gorgova* and *Gorgovăţ Lakes*, particularly the **MS**, **SIL** and **TOM** maps with contour lines (Fig. 6a,b,c) reflect accurately the hydrodynamic and sedimentogenetic processes having place in this deltaic area. The maps of the lithological parameters (Fig. 6b,c,d) reveal very interesting and suggestive distribution patterns, which point out the influences of the different supply sources that have contributed to accumulating of the sediments in these lakes. It can be perceived as the main sources of *detrital-siliciclastic* sediments are located in north, in front of the *Channel Gorgova* mouth, – at some other time (until 1982) this being connected with the *Sulina Branch* –, and also in south, where the water and sediments enter through *Gârla/Brook Filatului*. This channel connects the *Sfântu Gheorghe Branch* ("*Mahmudia Meander*") with the *Gorgova* and *Gorgovăţ Lakes* (the channel is bifurcating), after it is crossing the *Litcov Channel* (another *Danubian* origin source of water and sediments) (Fig. 6b). The magnetic susceptibility (**MS**) map (Fig. 6a) reveals the same characteristics as the **SIL** map (Fig. 6b), the **MS** contours "following" with a great similarity the **SIL** isolines: very well defined **k** and **SIL** maximum zones in north, and respectively, in south. The *organic matter* distribution (Fig. 6c) reflects "in mirror image" the *siliciclastic* material distribution pattern, the **TOM** maximum areas being situated in the central zone of the *Gorgova Lake,* and in the *Gorgovăţ Lake*. These results constitute an excellent example for demonstrating the quality of the magnetic susceptibility as a *proxy* signature for the lithological composition of the lake sediments (*e.g.*, Rădan *et al*., 2013). As regards the *carbo-*

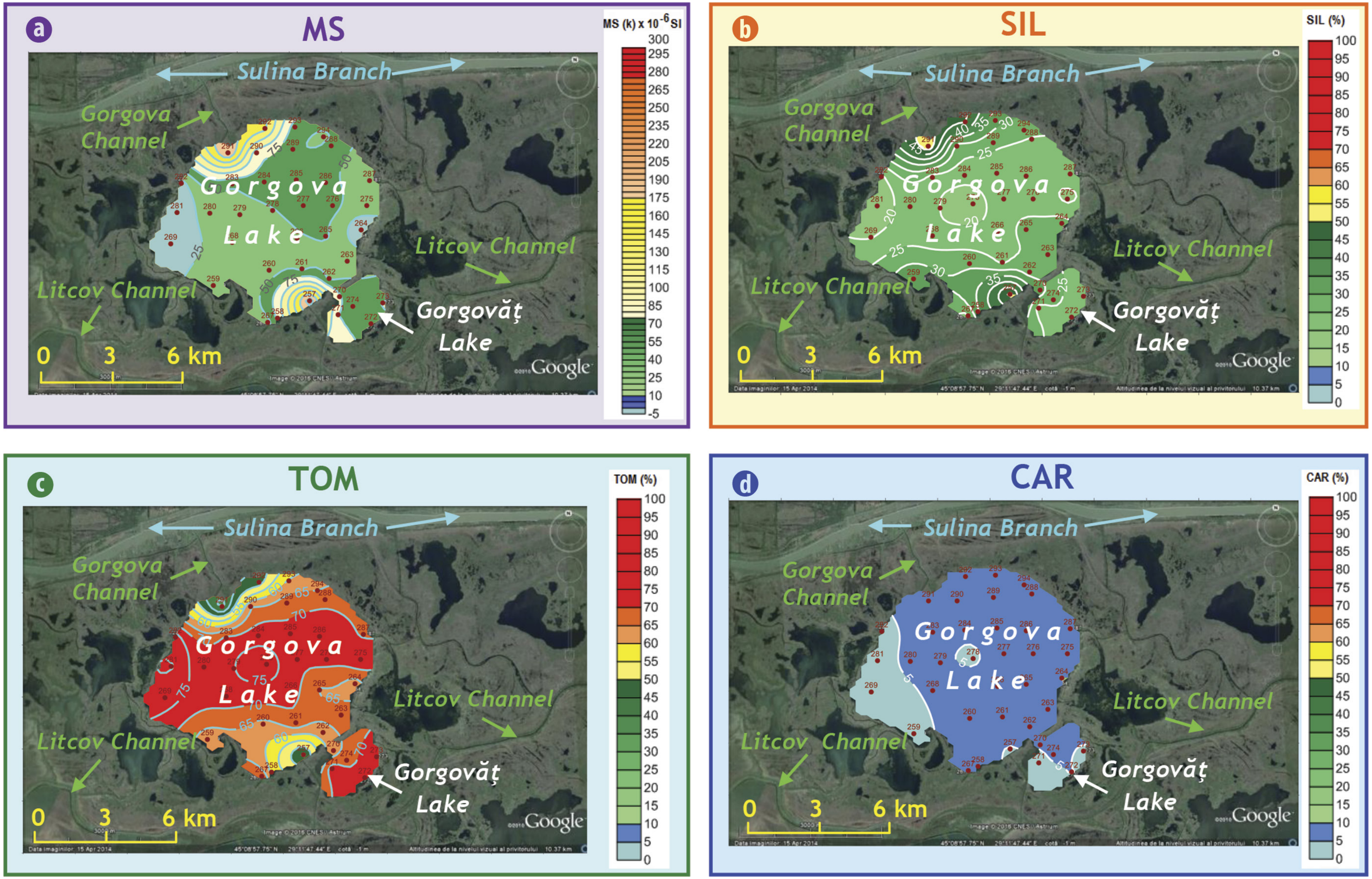

Fig. 6. Magnetic susceptibility and lithological maps of the bottom sediments from the *Gorgova* and *Gorgovăț Lakes* (20 July – 2 August 2012 expedition). **a) MS** map; **b) SIL** content map; **c) TOM** content map; **d) CAR** content map. *Note 1*. **MS** isolines: **k** values, in 10^{-6} SI; **SIL**, **TOM**, **CAR** isolines: **LITHO** component contents, in %; *Note 2*. The background support for the maps (**a**, **b**, **c**, **d**) – *Google Earth* image.

nates (Fig. 6d), they have an enrichment trend in the eastern half of the lake, towards the *Potcoava Lake*.

To evaluate the connections between the previous **MS** and **LITHO** data presented for the surficial sediments investigated in the *Gorgova* and *Gorgovăț Lakes*, we have calculated the correlation coefficients (**r**) for **SIL** *vs*. **MS**, **TOM** *vs*. **MS** and (**TOM**+**CAR**) *vs*. **MS** (Fig. 7). The results quantify, in fact, the above observed connections, the **r** values being significantly positive (**r** = 0.91) for the relationship between the lithological *siliciclastic component* (**SIL**) and the *magnetic susceptibility* (Fig. 7a), and significantly negative (**r** = - 0.89) for the other case, when the correlation between the *total organic matter* (**TOM**) component and the *magnetic parameter* was assessed (Fig. 7b). Also, a very high negative correlation coefficient (**r** = - 0.91) has been achieved for (**TOM**+**CAR**) *vs*. **MS** (Fig. 7d), but a weak, practically no correlation, concerning **CAR** *vs*. **MS** (**r** = 0.05; Fig. 7c).

3.2. Obretinu Mic Lake (15, in Fig. 1; see also Fig. 2)

Situated in the northernmost position within the *Uzlina - Isacova Depression*, the *Obretinu Mic Lake* is a part of the great *Lake Obretin*, which was cut-off into two units during the digging of the *Sulina Canal* between 1857 - 1902. It has been investigated during the expedition carried out between 20 February – 4 March 2015, the surficial sediments being sampled from a network of 16 stations (*DD 15-68 ÷ DD 15-83*; Fig. 2).

The bottom sediments (the first 5 - 8 cm beneath the water/sediment interface) are represented by fine, sporadically silty coarse, cohesive, black or dark grey-blackish muds; often, the blackish muds are passing, gradually, at the lower part of the sampled sequence, to dark grey, sometimes yellowish, a bit more compact and cohesive silty muds. Many bioturbation canals full with yellowish mud are observed, and within the sediment mass occur frequent fructifications of *Trapa*, sometimes *Chironomidae*, fragments and complete shells of *Limnaea* (very frequent), *Planorbis* (frequent), and seldom *Viviparus* and *Anodonta* (fragments). Below this level of soft to fluffy, lacustrine mud, it has been intercepted, in some sampling stations, a compact level of plastic, cohesive, coarse silty grey clay, sometimes containing shell detritus, probably representing a result of the older fluviatile influxes from the *Sulina Canal*. In the whole sediment mass, millimetric (rarer centimetric) fragments of vegetal material are observed.

From the lithological point of view, the sediments of the *Obretinu Mic Lake* are assigned to the category of the *organo-mineral*, *mineral-organic* and *organic muds*, with contents of 55.32 % ÷ 87.14 % *organic matter* (**TOM**), 12.00 % ÷ 40.66 % mineral/detrital/siliciclasic material (**SIL**), and a participation of 0.86 % ÷ 4.01 %, *carbonates* (**CAR**). The average weights of the lithological components are 73.79 % (**TOM**), 24.27 % (**SIL**), and respectively, 1.94 % (**CAR**) (Fig. $5b_2$). The grey, coarse silty clays, which were differentiated as the *layer* „**b**" within the samples *DD 14-78* and *DD 14-82*, have revealed much higher **SIL** and higher **CAR** contents than the maximum ends of the above mentioned general definition ranges (relating to *layer* **"a"**), and on the other hand, much lower **TOM** contents than the minimum ends of the respective specified definition intervals. These characteristics, to which will be further given some information, enclose the clays of the *layer* „**b**" within the category of the *mineral-organic*, and even *mineral* sediments, dominantly *siliciclastic*.

Passing now to the magnetic susceptibility (**MS**) of the bottom sediments, we remark that the **k** values reflect very well the same trends identified for the lithological components.

A first remark is that the greatest part of the muds are calibrated to **MS** *class* **II** (Fig. $5b_1$). Yet, close to the northern boundary of the lake, coarser muds were found, in some cases a grey coarse clay, with frequent fragments of shells, being intercepted as *layer* „**b**" (*e.g.*, the samples *DD 15-78* and *DD 15-82*), as we have previously pointed out. The **MS** values measured on these *clays* are 284.68×10^{-6} SI and 308.56×10^{-6} SI, respectively, both belonging to the **k** class **Va** (Fig. 5; scale **k**, in Fig. $3a_1$). The siliciclastic fraction of these *clays* dominates their lithological composition, the **SIL** contents having weights of 78.14 % and 75.07 %, respectively. Likewise, the highest **CAR** content (6.50 %) was recorded for the sample *DD 15-78b*. The coarser muds, separated as *layer* „**a**" in these samples, have also indicated some higher susceptibilities (*class* **IV**, and respectively, *class* **III**, namely 200.31×10^{-6} SI and 125.00×10^{-6} SI), comparing with the general level (*class* **II**; 62 %) (Fig. $5b_1$), defined by the range 22.67×10^{-6} SI ÷ 74.08×10^{-6} SI, shown by the bottom sediments of the *Obretinu Mic*. Alongside of these cases, we must mention the coarse mud that was sampled from the station *DD 15-83*, placed also on the northern lake boundary, just between the above remarked sampling points *DD 15-82* and *DD 15-78*; the measured **k** value is 209.25×10^{-6} SI (*class* **IV**) (Fig. $5b_1$).

If we compare the magnetic susceptibility data with the lithological ones, we note that 62 % of samples are calibrated to the **MS** *class* **II**, and 38 % to the *classes* **III** and **IV** (Fig. 5 b_1), and, corresponding to these weights, the *organic* component (**TOM**) and *carbonates* (**CAR**) summarize 76 %, while the remaining 24 % represent the participation of the *mineral/detrital* (**SIL**) fraction (Fig. $5b_2$). If the **LITHO** scale from Fig. $3a_2$ is used, 81 % of samples have the **SIL** component defined by the *class* **2** (*i.e.*, contents between 15 % - 50 %), and the remaining 19 % by the *class* **1** (*i.e.*, 0 % - 15 %) (Fig. $5b_3$).

As regards the connections between the **MS** (**k**) and **LITHO** data presented for the surficial sediments investigated in the *Obetinu Mic Lake*, the correlation coefficients (**r**) for **SIL** *vs*. **k**, **TOM** *vs*. **k** and **CAR** *vs*. **k** (Fig. 8) point out a very high level of the strength of the specified analysed correlations. Generally speaking, this clearly illustrates a lithological control on the magnetic susceptibility characterizing the lake sediments.

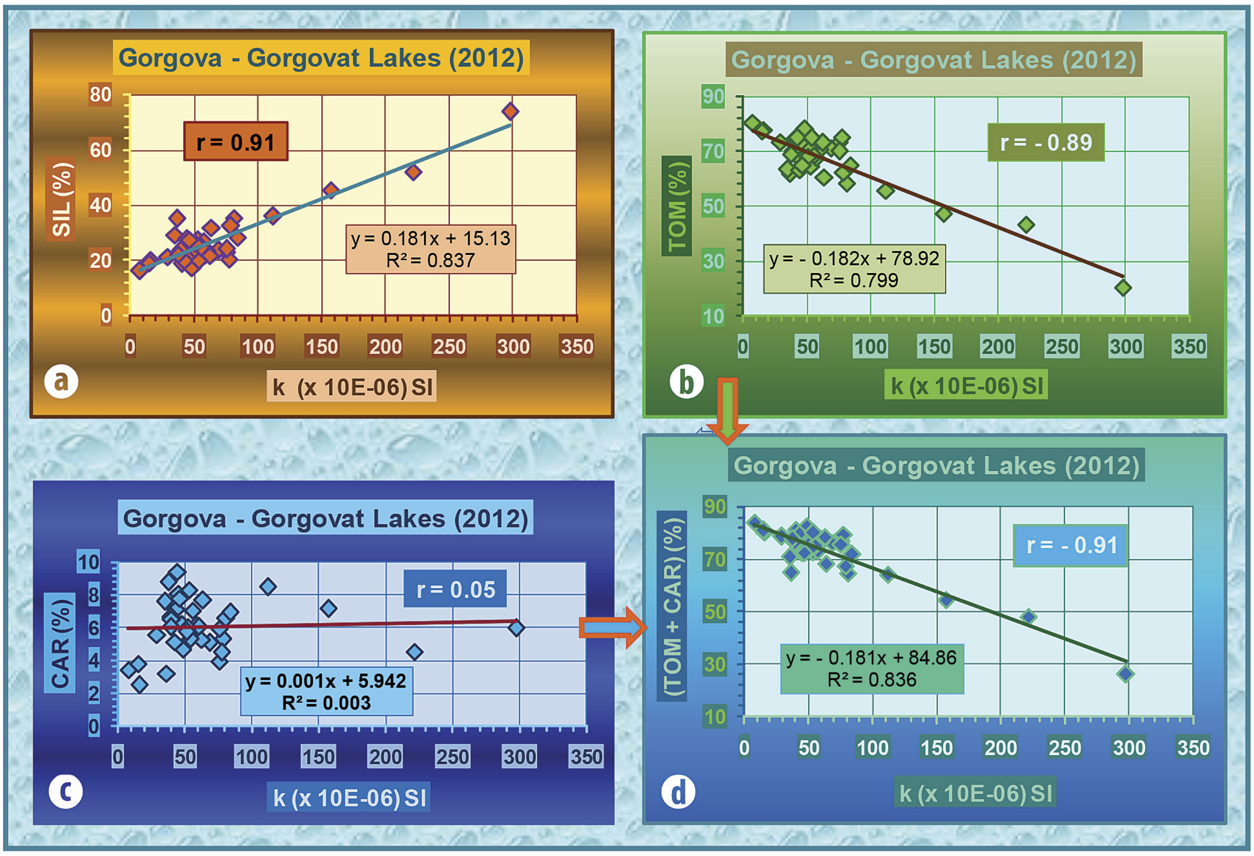

Fig. 7. Diagrams of correlations between the enviromagnetic parameter (**MS**; **k**) and the lithological components (**SIL**, **TOM**, **CAR**), which characterize the surficial sediments of the *Gorgova – Gorgovăț* couple of lakes. **a) SIL** *versus* **k** scatter plot; **b) TOM** *vs.* **k** scatter plot; **c) CAR** *vs.* **k** scatter plot; **d)** (**TOM** + **CAR**) *vs.* **k** scatter plot. *Note*: **r** is the correlation coefficient calculated on the basis of the equation displayed on each scatter-chart.

The **r** value is significantly positive (**r** = 0.90) for the relationship between the *magnetic susceptibility* and the lithological *siliciclastic component* (**SIL**), and significantly negative (**r** = - 0.91), for the case **TOM** *vs*. **k** (Fig. 8a,b). These correlation coefficients are in agreement with the results existing in the huge database that we have for the recent sediments from the *Danube Delta*.

We wish to remark, yet, the surprising high **positive** correlation coefficient (**r** = 0.91) that was reached between *carbonate contents* (**CAR**) and the *magnetic susceptibility* values (**MS**; **k**) (Fig. 8c), which denotes a genetic signification, demonstrating in this case that the *carbonates* are of detrital origin, and not of biochemical one, they being brought along with the *siliciclastic material* from the *Danube River*. This conclusion is even more argued by the correlation coefficient **r** = 0.91, which we have calculated to quantify the relationship between the *siliciclastic* (**SIL**) and the *carbonate* (**CAR**) components that are present within these lake sediments (Fig. 8d). We add the very high correlation coefficients determined for **TOM** *vs*. **CAR** (**r** = - 0.93; Fig. 8e), and surely, for **SIL** *vs*. **TOM** (**r** = - 0.998; Fig. 8f).

The strong positive correlation shown by **SIL** *vs*. **MS** (**r** = 0.90) could explain the aspect of the areal distribution magnetic susceptibility model (Figs. 5 and 9a) and its significance as concerns the sedimentary dynamics in the *Obretinu Mic L*. This lake, placed in the proximity of the *Sulina Branch* (Fig. 5), is influenced by the more or less regular influxes coming from the *Danube River*, and, as we have above presented, the sediments were characterized by the **k** *classes* **II**, **III** and **IV** (Figs. $5b_1$ and 9a). The higher **MS** classes were especially provided by the samples collected from the northern lake border (Figs. 2 and 9a), at the boundary of the microdeltas generated by the *Danubian* influxes, as well as at the channel mouth from the eastern extremity, showing that this is working as a supply pathway of water and sediments from the *Danube*, through the small canal connecting with the main *Crişan - Caraorman Channel*. The **SIL** (Fig. 9b) and **TOM** (Fig. 9c) maps, with content (%) contour lines, support, correspondingly, the **k** regime shown by the **MS** map (Fig. 9a). Thus, the higher **SIL** contents have been obtained for the sediments sampled close to the northern lake border, which are particularly characterized by the **MS** classes **III** and **IV**. So, the contour lines mark out an increasing gradient, from the **SIL** content isoline of 25 %, drawn up in the southern lake zone (even of 15 % in the southern extremity), up to the contour line of 45 %, even higher (50 %) around two sampling points located in the northern lake extremity (*DD 15-82* and *DD 15-78*; Fig. 9b),

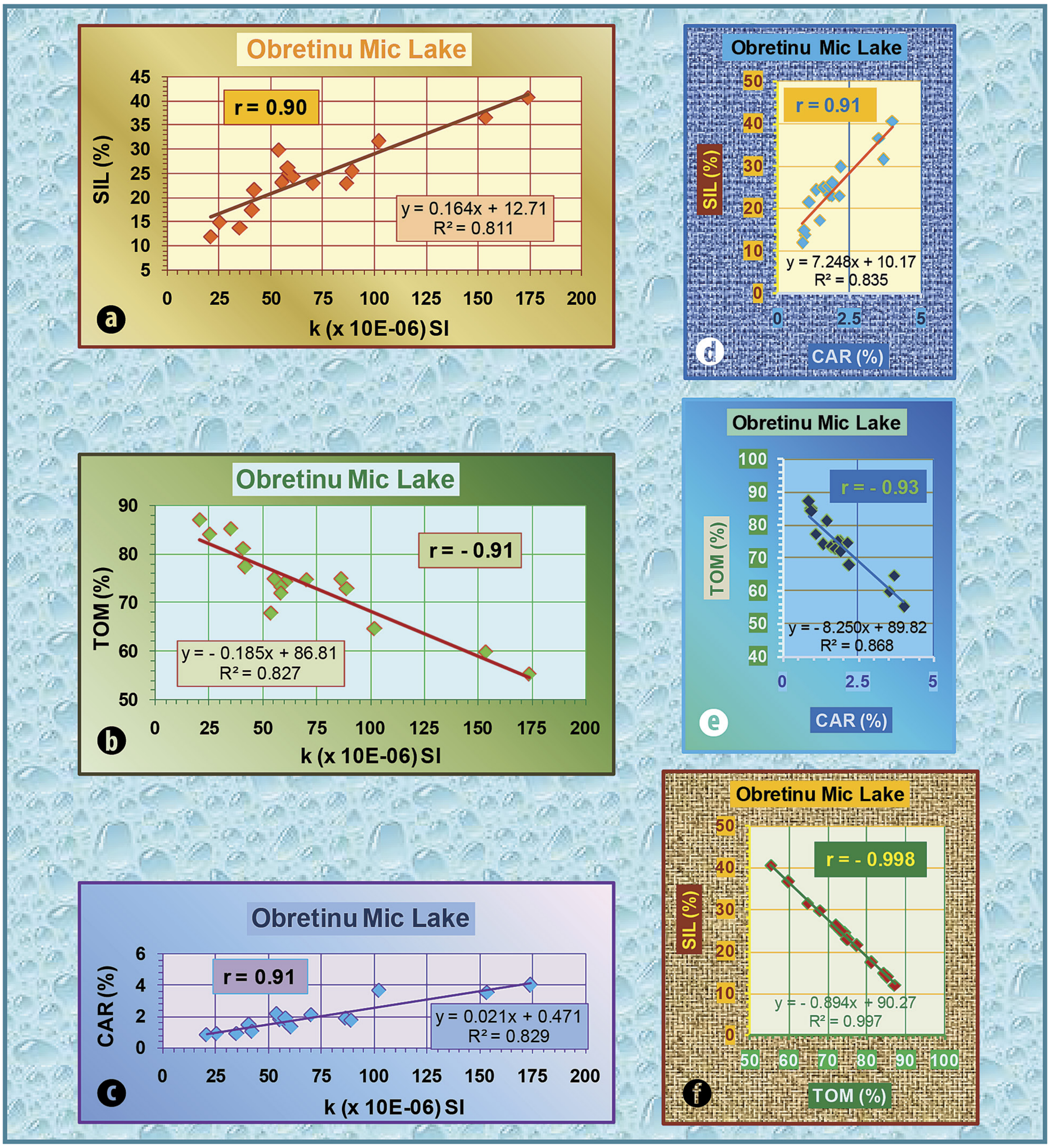

Fig. 8. Diagrams of correlations between the enviromagnetic parameter (**MS**; **k**) and the lithological components (**SIL**, **TOM**, **CAR**), as well as between the **LITHO** components themselves, which characterize the surficial sediments of the *Obretinu Mic Lake*. **a) SIL** *versus* **k** scatter plot; **b) TOM** *vs*. **k** scatter plot; **c) CAR** *vs*. **k** scatter plot; **d) SIL** *vs*. **CAR** scatter plot; **e) TOM** *vs*. **CAR** scatter plot; **f) SIL** *vs*. **TOM** scatter plot. *Note*: same as in Fig. 7.

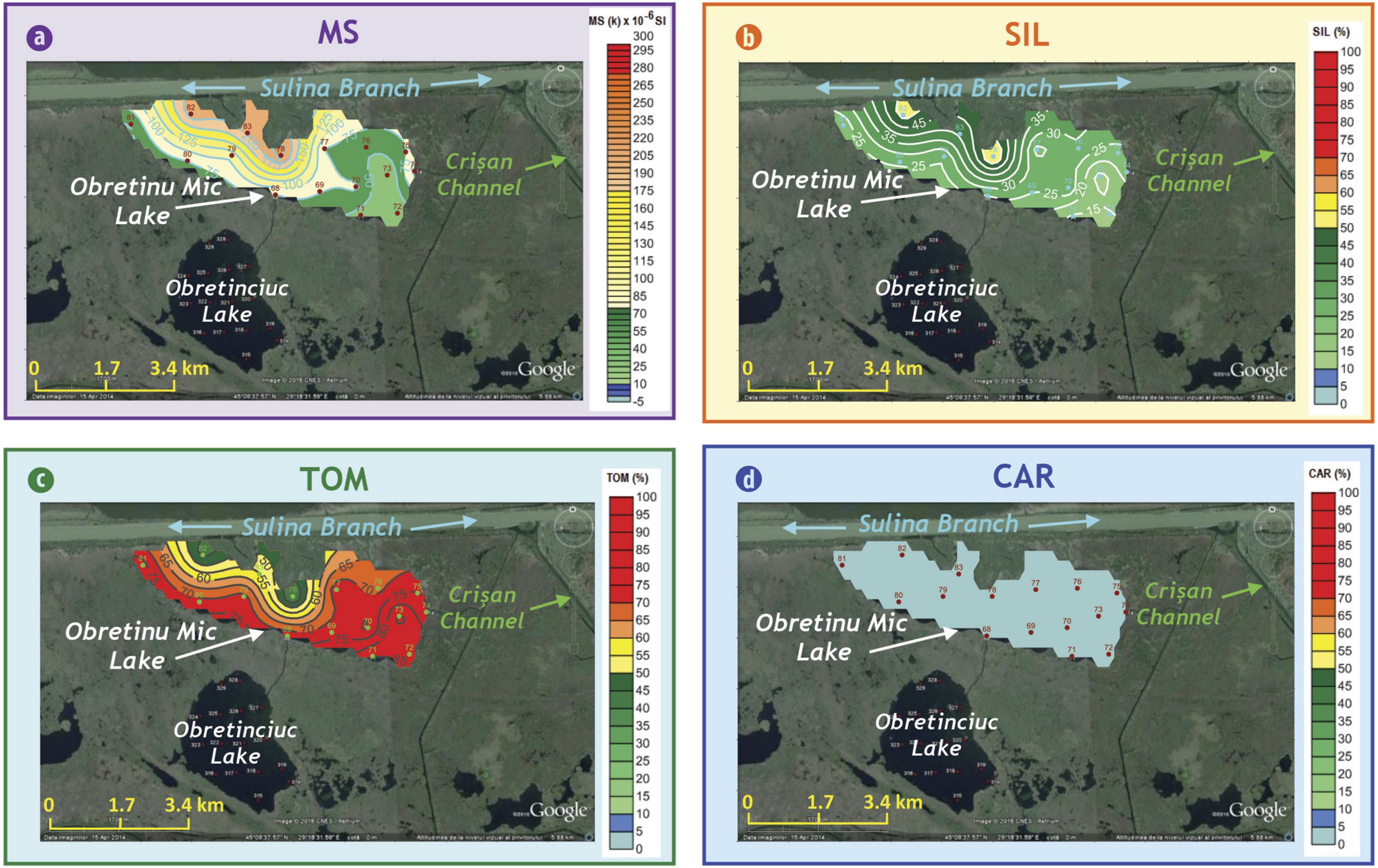

Fig. 9. Magnetic susceptibility and lithological maps of the bottom sediments from the *Obretinu Mic Lake* (20 February – 4 March 2015 expedition). **a) MS** map; **b) SIL** content map; **c) TOM** content map; **d) CAR** content map. *Notes* (*1* and *2*): same as in Fig. 6.

where the sediment samples have shown the presence of two layers ("**a**" and "**b**"). Complementary, the **TOM** map illustrates a decreasing content gradient from south northwards (Fig. 9c): from 75 % **TOM** isoline in the southern zone (even 85 %, in the southern extremity), up to the 50 % close to the northern lake border (even a contour line of 45 % traced around the same two sampling stations previously specified). As regards the **CAR** map (Fig. 9d), if only the layer "**a**" is taken into consideration, no **CAR** contour line is drawn up, all the contents being lower than 5 %.

3.3. Obretinciuc Lake (16, in Fig. 1; see also Fig. 2)

The **Obretinciuc Lake** is situated to north of *Uzlina - Isacova* couple of lakes, between the *Litcov Channel* and the *Obretinu Mic Lake* (Fig. 2). Its position is well protected by the *Danubian* supplies, the influxes of water from *Litcov Ch*. being filtered through a network of small channels and swamps; northwards, the lake is connected through a narrow channel to the *Obretinu Mic L*. The lake was investigated during the expedition carried out between 12 – 21 August 2014. The surficial sediments were sampled from a network of 16 stations (*DD 14-314* ÷ *DD 14-329*; Fig. 2).

The lake sediments are represented by dark grey-yellowish up to brown soft muds, fluffy/fluid at the upper part, non-cohesive, containing fine to coarse vegetal material. Usually, the muds emanate a H_2S smell, with a different intensity in various sectors of the lake. Towards the base, the muds become more consistent and compact. The fauna that was found in the collected samples is constituted by fragments, seldom by complete shells of *Viviparus*, and accidentally, *Planorbis*, *Bithynia, Anodonta, Valvata*, and such like, usually depigmented and friable. In the *DD 14-320* sampling station (Fig. 2), a living specimen of *Anodonta* (of exceptional dimensions, *i.e.*, 23 cm × 15 cm) has been found.

As regards the lithological composition, the sediments of the *Obretinciuc Lake* are placed within the category of the *organic* and *organo-mineral muds*, with very high *organic* matter contents (**TOM**; 83.1 % ÷ 94.0 %), a very low *siliciclastic* material percentage (**SIL**; 5.1 % ÷13.5 %), and insignificant contents of *carbonates* (**CAR**; 0.4 % ÷ 4.1 %). The average lithological contents of these lake sediments (Fig. $5c_2$) are 89.3 % (**TOM**), 8.8 % (**SIL**) and 1.9 % (**CAR**), reflecting the isolated character of this lacustrine environment, protected by direct fluviatile supplies, and in which the autochthonous organic sedimentation is clearly dominant. The magnetic susceptibility characterization of the *Obretinciuc Lake* bottom sediments confirms this predominance of the *Total Organic Matter* component within the lithological composition, their calibration to the **MS** scale resulting in the assignment of the **k** *class* **I** to all the investigated samples (100 %; Fig. $5c_1$ and Fig. 10a). Moreover, 81 % of the samples have susceptibilities which can be assigned to *diamagnetic materials*, the **k** values ranging between (- 4.32)×10^{-6} ÷ (- 0.35)×10^{-6} SI; the ends of the definition interval were measured on the samples *DD 14-323* and *DD 14-320*, respectively, collected from the median zones in the western, and respectively the eastern lake boundaries. As regards the remaining 19 % of samples, their **MS** values are very low and positive, being enclosing within the interval 0.65×10^{-6} ÷ 4.59×10^{-6} SI; they can be assigned to *paramagnetic materials*. These very low **k** values are in agreement with the lithological characterization of the *muds* sampled from the *Obretinciuc Lake*, which could be "quantified" by the calibration of the *muds* to the (preliminary) **LITHO** scale (Fig. $3a_2$). Consequently, percentages of 100 % were achieved for the *class* **1**, concerning the *siliciclastic/mineral/detritic* (**SIL**) component (Fig. $5c_3$).

The areal distribution of the lithological components (**SIL**, **TOM**, **CAR**) of the *Obretinciuc Lake* surficial sediments (Fig. 10b,c,d) reveals a gradual passing from west towards east, from very organic sediments towards sediments within which the siliciclastic fraction percentage is going to become more important in the muds. The lake eastern zone is closer to the connection channel named *Canalul Lung* (*Malafeica*) that branches off the *Litcov Channel* northwards, to Crişan village, which could explain a more significant siliciclastic allochthonous supply in this area, mainly in the high flood periods.

The **SIL** contents are increasing from the range (5.1 % ÷ 6.8 %) – defining the sediments sampled in the three stations from the lake western part – to the range (11.3 % ÷ 13.5 %), which characterize the muds sampled from the five stations placed in the lake eastern margin (Fig. 10b). Surely, the gradient is reversed relating to the **TOM** map (Fig. 10c), and although the *total organic matter* shows contents which range inside of a very narrow interval (83.1 ÷ 94.0%), a decreasing trend from west eastwards is well described by the **TOM** contour lines (Fig. 10c). As concerns the *carbonates*, the extremely low difference between the **CAR** contents, ranging between 0.4 % ÷ 4.1 %, results in the absence of any contour line in the *carbonate* (**CAR**) distribution map (Fig. 10d), if the same equidistance as in the other two **LITHO** maps is kept up (*i.e.*, 5 %).

The **MS** map (Fig. 10a), based on the **k** values above commented (81 % of them assigned to the diamagnetic susceptibility) confirms the **SIL** and **TOM** maps, respectively, the **k** contour line of zero being the only one available for drawing up within the map. This *magnetic susceptibility* isoline separates two **MS** fields, both of them defined by **k** values assigned to *class* **I**, and is similarly oriented (*NW - SE*) to the **SIL** and **TOM** contour lines from the respective **LITHO** maps (Figs. 10b and 10c, respectively).

Actually, the tests performed for the strength evaluation of the relationship between the lithological composition and the magnetic susceptibility have shown very high correlation coefficients (**r**), albeit the **MS** values submitted to this analysis are extremely low. Thus, regarding **SIL** *vs*. **k**, the coefficient **r** is 0.89 (Fig. 11a), while for **TOM** *vs*. **k**, we achieved **r** = - 0.82 (Fig. 11b). As in many other cases, the coefficient **r** records lower values for **CAR** *vs*. **k**; anyway, in the present situation, **r** = 0.47 (Fig. 11c). But, testing the correlation of the litholog-

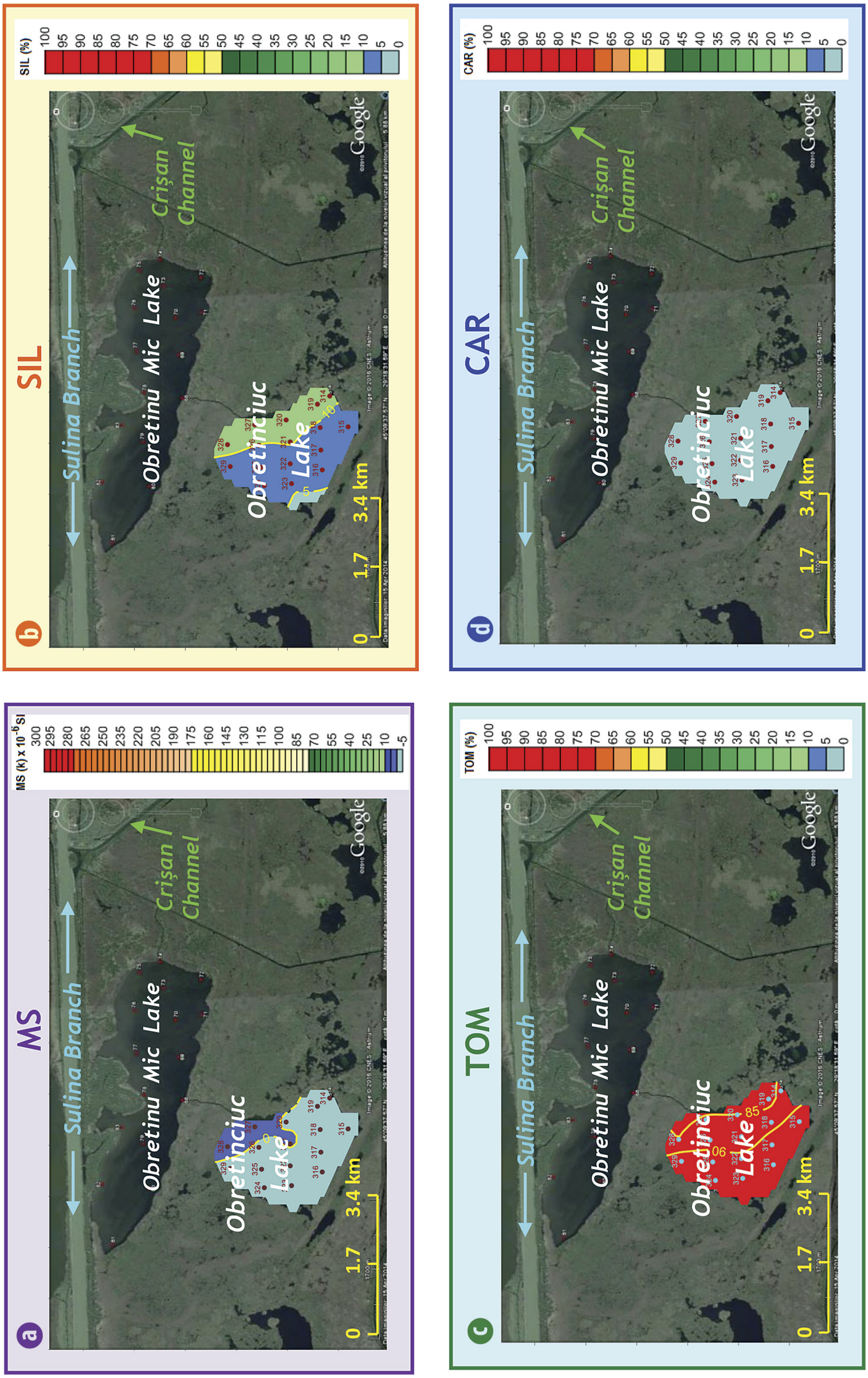

Fig. 10. Magnetic susceptibility and lithological maps of the bottom sediments from the *Obretinciuc Lake* (12 – 21 August 2014 expedition). **a) MS** map; **b) SIL** content map; **c) TOM** content map; **d) CAR** content map. *Notes* (*1* and *2*): same as in Fig. 6.

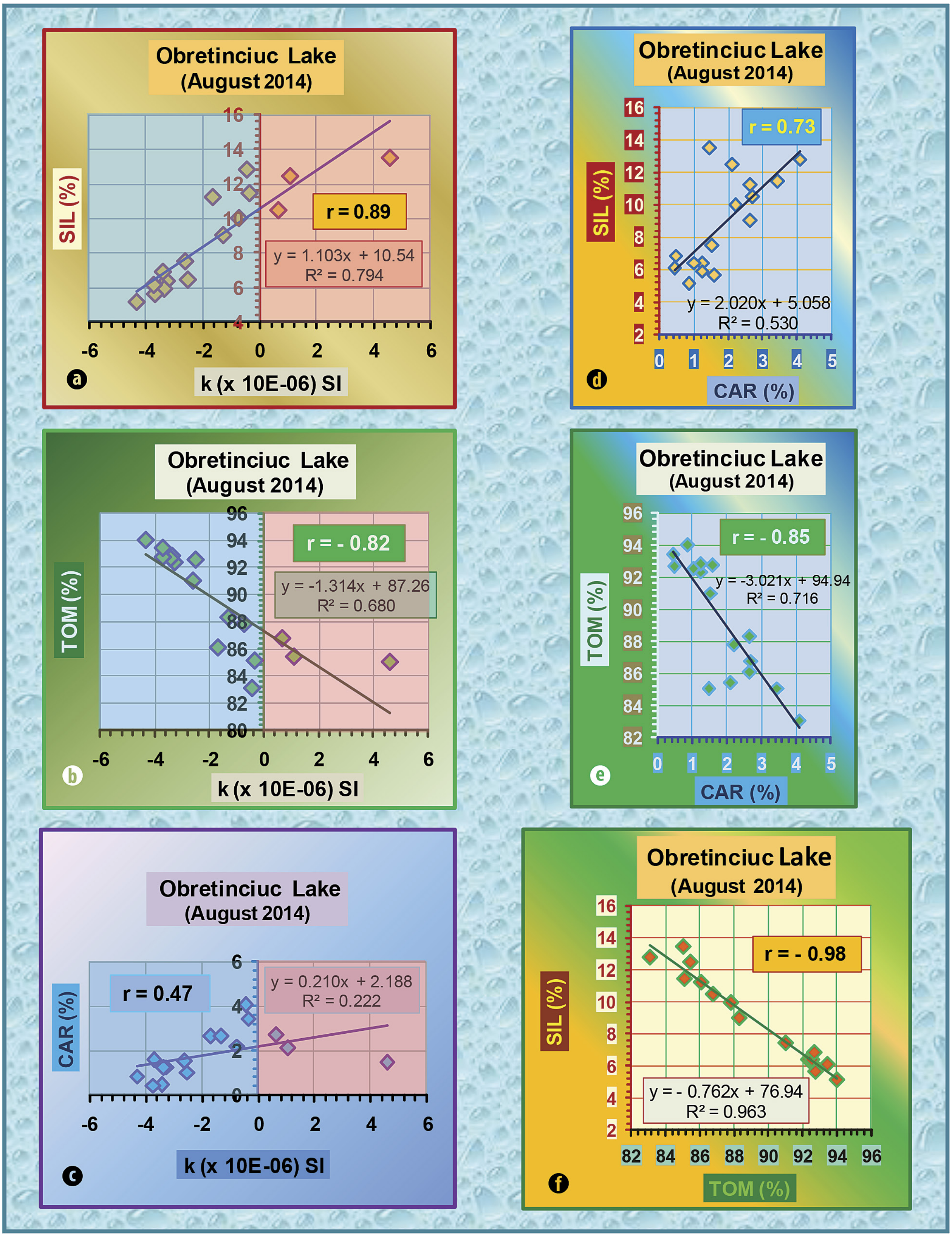

Fig. 11. Diagrams of correlations between the enviromagnetic parameter (**MS**; **k**) and the lithological components (**SIL**, **TOM**, **CAR**), as well as between the **LITHO** components themselves, which characterize the surficial sediments of the *Obretinciuc Lake*. **a) SIL** *versus* **k** scatter plot; **b) TOM** *vs*. **k** scatter plot; **c) CAR** *vs*. **k** scatter plot; **d) SIL** *vs*. **CAR** scatter plot; **e) TOM** *vs*. **CAR** scatter plot; **f) SIL** *vs*. **TOM** scatter plot. *Note*: same as in Fig. 7.

ical components between themselves, the results show very good correlations, even in the cases when the **CAR** component is involved in the analysis. Therefore, for **SIL** *vs*. **CAR**, the coefficient **r** = 0.73 (Fig. 11d), and for **TOM** *vs*. **CAR**, **r** = - 0.85 (Fig. 11e). The positive correlations of *siliciclastic material* (**SIL**) *vs. carbonates* (CAR) and, respectively, *vs. magnetic susceptibility* (MS) suggest the same dominant detrital origin for carbonate minerals in the *Lake Obretinciuc* sediments. Certainly, the reversed relation between the main lithological components, *i.e.*, **SIL** and **TOM**, particularly the "mutual interdependence", which is present in the greatest majority of the investigated cases, is self-evident, and is clearly expressed by the correlation coefficient: **r** = - 0.98 (Fig. 11f).

3.4. Cuibeda Lake (17, in Fig. 1; see also Fig. 2)

The *Lake Cuibeda*, located within the easternmost area of the *Gorgova - Uzlina Depression*, has been investigated by the GeoEcoMar team in the course of the expedition carried out in the *Danube Delta* during 25 April – 7 May 2015. The surficial sediments were sampled from a network of 14 stations (*D 15-197 ÷ DD 15-210*) (Fig. 2).

The *Cuibeda Lake* bottom sediments are represented by grey-yellowish to soft brown *muds*, fluffy at the upper part, non-cohesive, rich in fine up to coarse vegetal material (also including reed fragments with a carbonization tendency and long vegetal fibres, probably macrophytes roots). The *muds* present a H_2S smell, with various intensities in the different sectors of the lake. Towards the base, the *muds* become more consistent and more compact, in patches mixed with a grey clayey material, dense and cohesive, similar to the marine sediments. The fauna that has been found within the collected samples is represented by fragments, rarely complete shells of *Unio*, *Hydrobia*, and such like. The benthic biocenosis could include *Chironomidae* and *Oligochaeta*.

The above description of the surficial sediments sampled from the *Cuibeda Lake* (particularly, the richness in vegetal material) is confirmed by the lithological analyses; the average contents determined for the organic matter (**TOM**), the *mineral/detrital* fraction (**SIL**), and the *carbonate* (**CAR**) components are as follows: 90 % – **TOM**; 8 % – **SIL**; 2 % – **CAR** (Fig. $5e_2$). Moreover, the predominance of the *organic matter* over the *siliciclastic/detrital fraction* within the surficial sediments of the *Cuibeda Lake* is clearly illustrated by the corresponding specific diagrams shown in Fig. 5. So, if we refer to the preliminary **LITHO** scale from Fig. $3a_2$, all the samples are characterized by the lowest **SIL** *classes*: 93 % –*class* **1**, and 7 % –*class* **2** (Fig. $5e_3$). The magnetic susceptibility values measured for the same 14 samples collected from this lake support the **LITHO** percentage structure, the **MS** calibration to the **k** scale (Fig. $3a_1$) providing the following results: **MS** *class* **I** – 86 %; *class* **II** – 14 % (Fig. $5e_1$). We must remark the sample *DD14-207*, for which the sediment has indicated two layers in its structure: "**a**" – a coarse, soft *mud*, fluffy at its higher part, and more compact at the lower part; layer "**b**" – a *clayey mud*, coarse, compact, a possible transition towards a *marine sediment*. The **LITHO** contents (particularly, relating to **SIL** and **TOM** components) determined for the layer "**b**" show, distinctly, different percentages as compared with the average content calculated for the layer "**a**", based on all samples collected from the lake area, *i.e.*: 55.74 % – **TOM**; 42.11 % – **SIL**; 2.15 % – **CAR** (layer "**b**") *versus* 89.92 **% – TOM**; 8.48 % **– SIL**; 1.6 % **– CAR** (layer "**a**"). A much higher **SIL** content and a much lower **TOM** content, respectively, characterize the *clayey mud* (layer "**b**") comparing to the *soft muds*, rich in vegetal material, which represent the layer "**a**" of the surficial sediments. Correspondingly, the *clayey muds* are defined by a higher magnetic susceptibility (**k** = 83.52×10^{-6} SI; *class* **III**), while the upper soft *muds* have shown a very low average **MS** value, namely 0.68×10^{-6} SI (*class* **I**).

In the **MS** map (Fig. 12a), an increasing trend, westwards, and in a lesser degree, to the north, is indicated by the **k** isolines (10×10^{-6} SI ➚ 15×10^{-6} SI); even a small positive anomaly is suggested close to the western median lake border, around the sampling station *DD 14-207*. The magnetic signature is supported by the **SIL** and **TOM** distribution maps, which reveal a maximum anomaly and an increase trend northwards for the *siliciclastic material* contents (Fig. 12b), yet defined by low content contour lines (10 % ➚ 25 %), and respectively, a minimum anomaly for the *organic matter* (Fig. 12c), defined, reversely, by high content isolines (90 % ➘ 75 %), both located in front of the mouths of two short canals, connecting the lake to *Perivolovca* (west) and *Litcov* (north) *Channels*, respectively. As regards the **CAR** map (Fig. 12d), the very low contents characterizing the *carbonate* component result in no contour line present within the map, which is entirely coloured in *blue*, accordingly to the lowest contents (up to 5 %) from the **LITHO** scale (Fig. $3a_2$).

The excellent connection between the main *lithological* components and the *enviromagnetic* parameter **MS** is clearly illustrated and pointed out by the **MS** *versus* **LITHO** correlation diagrams from Fig. 13. The coefficients **r** show very strong correlations for **SIL** *vs*. **k** (Fig. 13a) and **TOM** *vs*. **k** (Fig. 13b), *positive* (**r** = 0.98), respectively *negative* (**r** = - 0.96), and a very weak towards *no correlation* for **CAR** *vs*. **k**. (**r** = 0.08; Fig. 13c), according to the scale used to evaluate the correlation degree (Fig. 3b). Actually, the interconnection of the main lithological components, **SIL** and **TOM**, with the *carbonates* (**CAR**) shows a *weak* positive correlation for **SIL** *vs*. **CAR** (**r** = 0.24; Fig. 13d), and a *moderate* to *weak* negative one for **TOM** *vs*. **CAR** (**r** = - 0.33; Fig. 13e). If the sample *DD 14-207b* is excluded from the analysis, and only the layer "**a**" identified in the *Cuibeda Lake* sediments is taken into consideration, the correlation coefficient "**r**" is increasing in both cases: **r** = 0.33 (for **SIL** *vs*. **CAR**), and **r** = - 0.57 (for **TOM** *vs*. **CAR**), suggesting a partially detrital origin for carbonates. Certainly, the correlation between the two main lithological components, **SIL** *vs*. **TOM**, is, as usually, a very strong one, even in the case when the sample *DD 14-207b* is included in the analysis: **r** = - 0.996 (Fig. 13f).

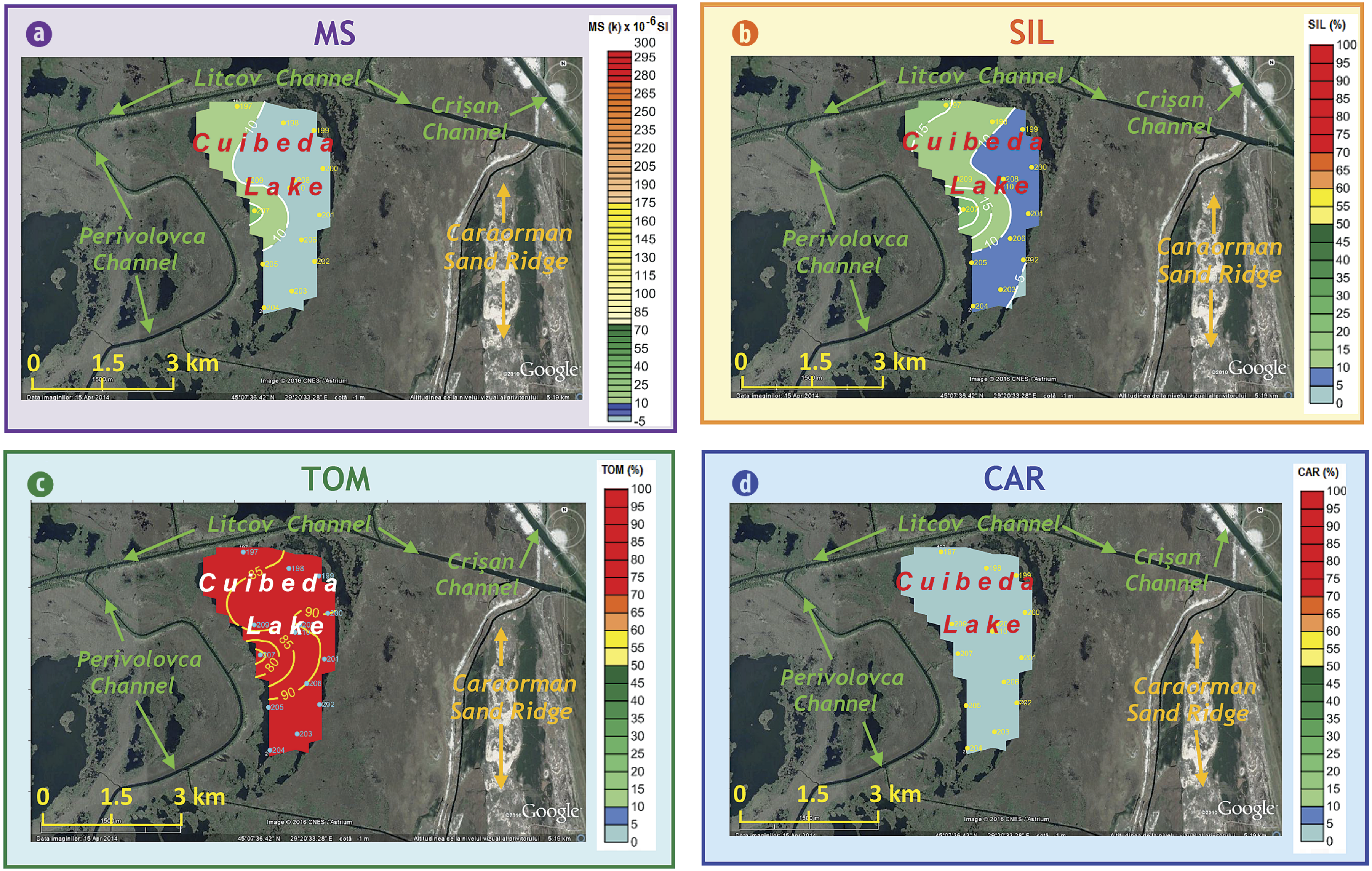

Fig. 12. Magnetic susceptibility and lithological maps of the bottom sediments from the *Cuibeda Lake* (25 April – 7 May 2014 expedition). **a) MS** map; **b) SIL** content map; **c) TOM** content map; **d) CAR** content map. *Notes* (*1* and *2*): same as in Fig. 6.

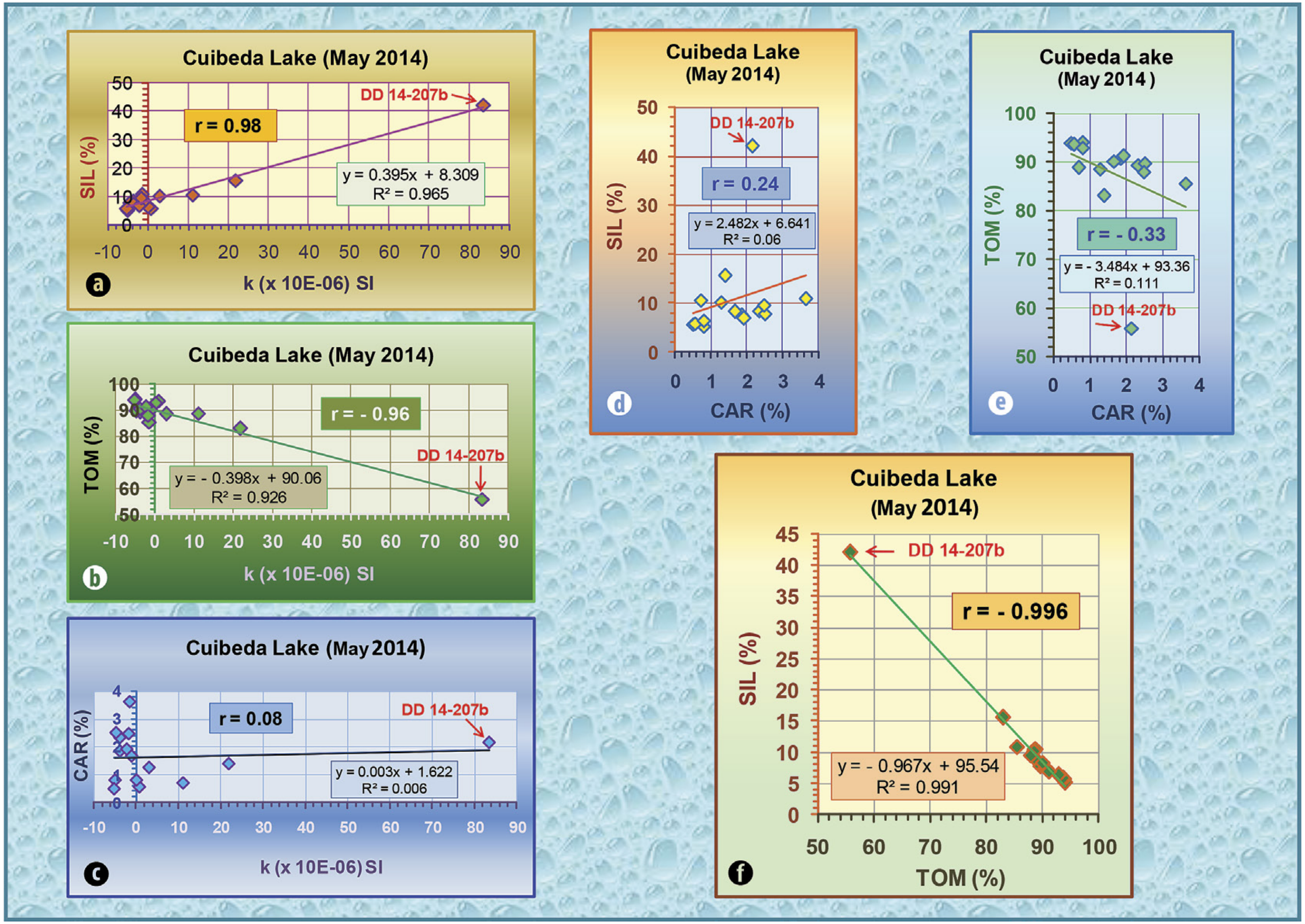

Fig. 13. Diagrams of correlations between the enviromagnetic parameter (**MS**; **k**) and the lithological components (**SIL**, **TOM**, **CAR**), as well as between the **LITHO** components themselves, which characterize the surficial sediments of the *Cuibeda Lake*. **a) SIL** *versus* **k** scatter plot; **b) TOM** *vs*. **k** scatter plot; **c) CAR** *vs*. **k** scatter plot; **d) SIL** *vs*. **CAR** scatter plot; **e) TOM** *vs*. **CAR** scatter plot; **f) SIL** *vs*. **TOM** scatter plot. *Note*: same as in Fig. 7.

3.5. Isăcel Lake (18, in Fig. 1; see also Fig. 2)

The *Isăcel Lake*, situated close to the *Isacova L.*, between this lake and the *Mahmudia Meander* (Fig. 2), has been investigated during the expedition performed by GeoEcoMar between 12 ÷ 21 August 2014. The surficial sediments were sampled from a network of 19 stations (*DD 14-345* ÷ *DD 14-363*; Fig. 2).

The *Isăcel* bottom sediments are dominated by grey-yellowish up to grey-brownish *muds*, fluid (fluffy) at the upper part, with a darker colour, and more compact at their lower part, usually soft, non-cohesive or slightly cohesive, frequently with a H_2S smell. The fauna is rare, sometimes occurring fragments and even intact specimens of *Viviparus, Bithynia* or *Anodonta,* usually depigmented and friable. At the mouth of the *Isac I Channel* (Fig. 2), a coarser, dark grey, compact, cohesive *mud* occurs, with vertical and horizontal active bioturbations.

From the lithological point of view, with the exception of the *mud* from the *Isac I Channel* mouth, that is of *mineral-organic* type, all the others could be placed within the category of the *organo-mineral* and *organic* sediments. The **LITHO** diagram from Fig. 5 clearly illustrates this characterization, the average contents revealing the highest weight (84 %) for the *total organic matter* (**TOM**) lithological component, 13 % only for the *siliciclastic/mineral* (**SIL**) fraction, and 3 % for the *carbonates* (**CAR**). Actually, for 89 % of the *Isăcel L. muds*, the **TOM** contents are ranging between 80 % ÷ 95 %. As regards the **SIL** lithological component, 89 % of the samples (layer „**a**") are characterized by contents included within the *class* **1** (0 % ÷ 15 %), and 11 % are defined by the **LITHO** *class* **2** (15 % ÷ 50 %), both corresponding to the category of fine sediments, rich in organic matter (Fig. $5d_3$).

The *magnetic susceptibility* (**MS**; **k**) demonstrates once again the *proxy* parameter quality for the lithological composition of the surficial sediments. Correspondingly to the dominance of the very low **SIL** contents, respectively of the very high **TOM** ones, the *muds* collected from the *Isăcel Lake* are almost totally (95 %; Fig. $5d_1$) calibrated to the *class* **I** (**k** values lower than 10×10^{-6} SI; the **MS** scale, in Fig. $3a_1$). The exception (the other 5 %) is represented by two samples: the first one, collected from the station *DD 14-345* (a coarse silty *mud* with two identified layers "**a**" and "**b**"), located at the *Isac I Channel* mouth (Fig. 2 – *Isăcel Lake*), which has recorded a **k** value of 222.72×10^{-6} SI for the layer "**a**" (**MS** *class* **IV**), and respectively, of 386.34×10^{-6} SI (*class* **Va**) for the layer "**b**"; the other sample (*DD 14-351*), placed in the vicinity of *DD 14-345*, southwards, close to the lake border, has provided a **k** value that is a bit over the *class* **I** upper boundary, namely 13.3×10^{-6} SI (**k** *class* **II**).

The areal distribution of the main lithological components, **SIL** and **TOM** (Fig. 14b,c), clearly outlines the discharge zone (underwater fan) of the western branch of the *Isac I Channel*, marked out in the **LITHO** maps by the contents contour lines: a strong local **SIL** maximum anomaly in the north of the lake, and a **TOM** minimum one, respectively. Further, the **SIL** map suggests that the detrital material is redistributed then southwards and eastwards, in the water flowing direction through channels and swamps, towards the *Uzlina* and *Isacova Lakes*. The western area of the *Isăcel Lake* is more protected, and therefore, it is the richest zone in organic matter. So, the *organic muds* are dominating there, the **TOM** contour lines defining an increasing gradient from east - north-east towards that lake border**.** The quality of *proxy* parameter that was remarked above is excellently illustrated by the **MS** map (Fig. 14a), if compared with the **SIL** and **TOM** maps (Figs. 14b,c). The **k** isoline of 0×10^{-6} SI and the contour lines of 10 % in the **SIL** map, and of 85 % in the **TOM** map, respectively, show similar forms. As regards the **CAR** map (Fig. 14d), the very low content of the *carbonates* in the surficial sediments explains the absence of any content contour line; the blue colour that covers the entire **CAR** map is in agreement with the contents lower than 5 % which were determined for the *carbonates* in the bottom sediments.

The very good connection between the enviromagnetic *proxy* parameter and the lithological components, mainly the siliciclastic/detrital material and the organic matter, is correspondingly proved by the correlation coefficients (**r**) calculated for the respective pairs of parameters. Therefore, for **SIL** *vs*. **k** (Fig.15a), a very strong positive correlation is shown by **r** = 0.99, and respectively, a very strong negative correlation (**r** = - 0.97) for **TOM** *vs*. **k** (Fig. 15b). It is not the case regarding the relationship **CAR** *vs*. **k** (Fig. 15c), the correlation coefficient indicating no correlation (**r** = 0.045). Interesting data were obtained by analysing the correlation between different pairs of lithological components. So, taking into consideration all the collection (including the *DD 14-345* coarse *mud* sample, with the two layers "**a**" and "**b**"), the coefficient **r** has shown, as usually, a very strong correlation (**r** = - 0.99) for **SIL** *vs*. **TOM** (Fig. $15f_1$), but a (very) weak correlation (positive, respectively negative) for each of these two principal lithological components (**SIL** and **TOM**, respectively) *versus* carbonates (**CAR**). Consequently, **r** = 0.16 for **SIL** *vs*. **CAR** (Fig. $15d_1$), and **r** = - 0.28 for **TOM** *vs*. **CAR** (Fig. $15e_1$). If the sample *DD 14-345* is not taken into consideration in the correlation analysis, the results are totally changed. So, the correlations for **SIL** *vs*. **CAR** and **TOM** *vs*. **CAR** become very strong: **r** = 0.73 (Fig. $15d_2$), and **r** = - 0.89 (Fig. $15e_2$), respectively, indicating a detrital origin of the carbonate minerals in the surficial lake sediments; certainly, regarding the relationship **SIL** *vs*. **TOM**, the correlation remains very strong and negative (**r** = - 0.96; Fig. $15f_2$), a result very close to that obtained when the whole collection of samples has been taken into consideration.

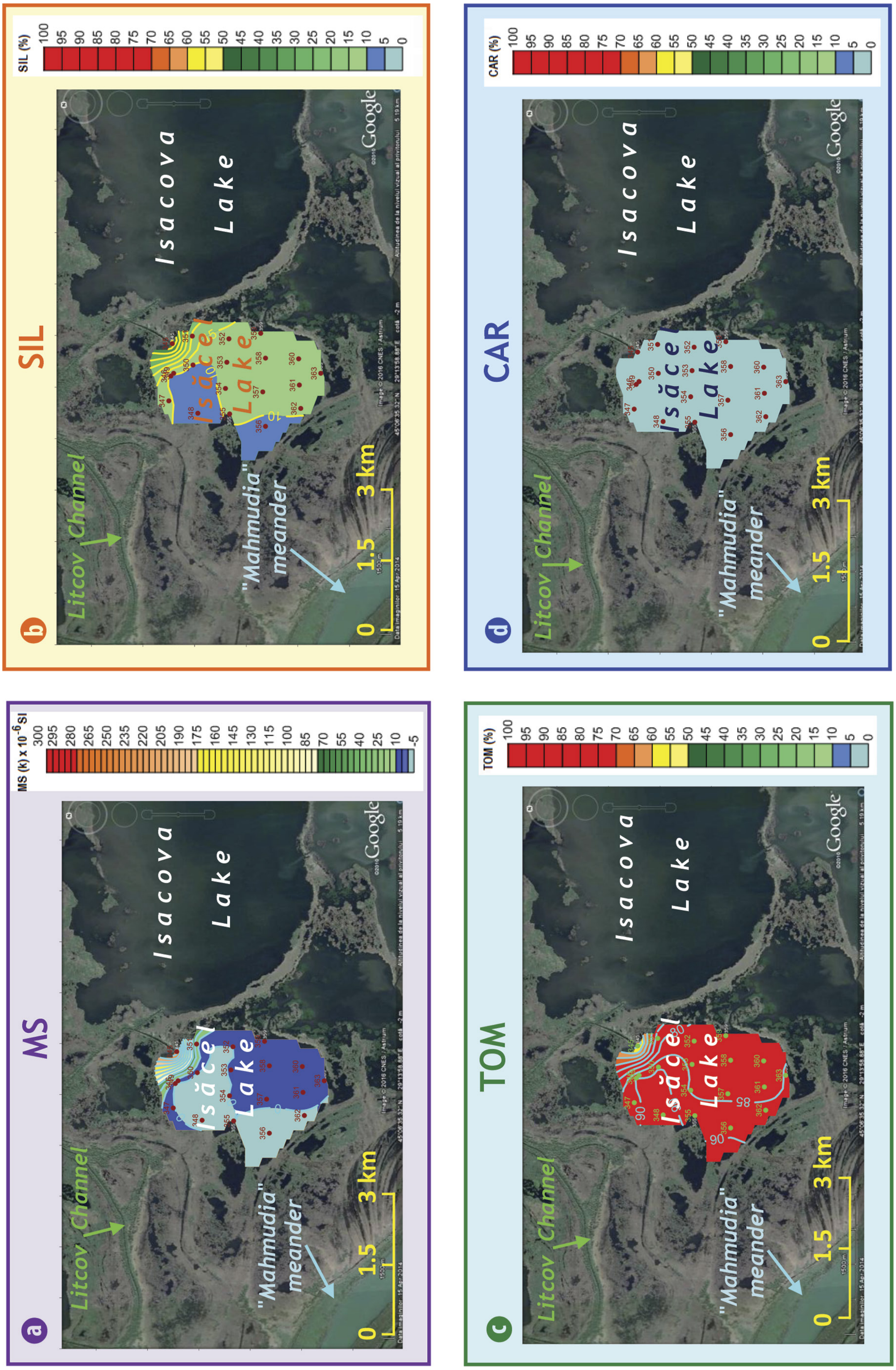

Fig. 14. Magnetic susceptibility and lithological maps of the bottom sediments from the *Isăcel Lake* (12 – 21 August 2014 expedition). **a) MS** map; **b) SIL** content map; **c) TOM** content map; **d) CAR** content map. *Notes* (*1* and *2*): same as in Fig. 6.

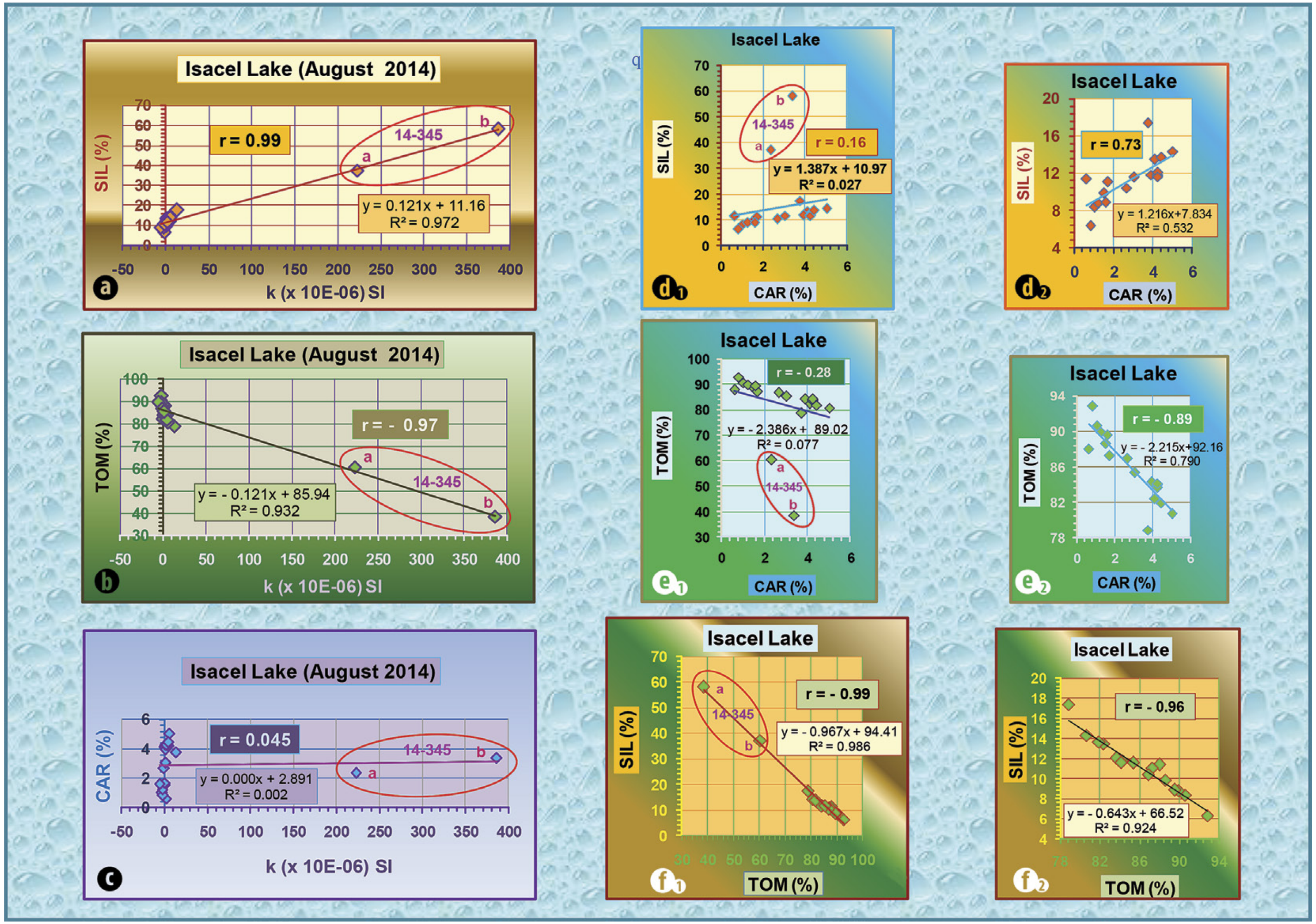

Fig. 15. Diagrams of correlations between the enviromagnetic parameter (**MS**; **k**) and the lithological components (**SIL**, **TOM**, **CAR**), as well as between the **LITHO** components themselves, which characterize the surficial sediments of the *Isăcel Lake*. **a) SIL** *versus* **k** scatter plot; **b) TOM** *vs*. **k** scatter plot; **c) CAR** *vs*. **k** scatter plot; **d1) SIL** *vs*. **CAR** scatter plot (all samples); **e1) TOM** *vs*. **CAR** scatter plot (all samples); **f1) SIL** *vs*. **TOM** scatter plot (all samples); **d2) SIL** *vs*. **CAR** scatter plot (selected samples); **e2) TOM** *vs*. **CAR** scatter plot (selected samples); **f2) SIL** *vs*. **TOM** scatter plot (selected samples). *Note 1*: same as in Fig. 7. *Note 2*. **a**, **b**, **c**, **d1**, **e1**, **f1**: *DD 14-345 mud* sample (with two layers "**a**" and "**b**") included. *Note 3*. **d2**, **e2**, **f2**: *DD 14-345 mud* sample not included.

3.6. Gorgoştel Lake (19, in Fig. 1; see also Fig. 2)

Throughout its evolution, the network of branches and channels of the *Danube Delta* has undergone many changes. Among them, the processes of cutting off and abandonment of meanders, followed by sediment deposition and sealing off the ends of river bend remnants, leads to the formation of stagnant U-shaped or crescent-shaped water bodies called *horseshoe* lakes, *loop* lakes, *cutoff* lakes, or oxbow lakes (due to their shape suggesting a horseshoe, a ring or a bow of an oxen yoke). There are three major lakes of oxbow type in the *Danube Delta*: *Belciug*, *Erenciuc* and *Gorgoştel*. The first two have been generated by cutting off old meanders of *Sfântu Gheorghe Branch*, and the last one is an abandoned meander of *Perivolovca Channel*. The *Gorgoştel Lake* is located within the southeastern extremity of the *Gorgova - Uzlina Depression*, between *Perivolovca Channel* to the west and *Caraorman Ridge* to the east (Fig. 2).

Ishii and Hori (2016) have examined cores from four oxbow lakes in the *Ishikari* lowland, in the northern Japan. By using ^{14}C ages, ^{137}Cs measurements, and the position of a tephra layer, information on the detailed chronology of oxbow fills has been achieved, and their sedimentation rates have been evaluated; the persistence of oxbow lakes in the landscape has been described, as well. The authors described three characteristic units in the structure of the oxbow sedimentary deposits: a basal coarse-grained streambed deposits, generated during the normal water flow of the river (*Unit 1*), followed by channel fill sediments settled down before the complete cutting off (*Unit 2*) and overbank deposits, after the complete separation of the lake (*Unit 3*).

As concerns the *Gorgoştel Lake*, its bottom sediments have been investigated by collecting grab samples, no cores being taken out, so our sedimentary sequence is limited to the *Unit 3*; two cores from the other two *oxbow* lakes, *i.e*., *Erenciuc* and *Belciug*, have been collected, but these lakes are not in our attention in the present paper.

During the expedition carried out between 6 ÷ 23 October 2015, the surficial sediments of the *Gorgoştel L.* were sampled in 6 stations, situated along the axis of this very "narrow" lake.

The *Gorgoştel Lake* bottom sediments show a transition from fine *muds* – of *Danubian* type, grey-blackish, cohesive, with bioturbations, which are located at the mouth of the connection channel with the *Gârla/Brook Perivolovca* (*e.g*., samples *DD 15-297* and *DD 15-298*; Fig. 2) – to yellowish-brown *muds*, sometimes with a blackish cover, loose, slightly cohesive, with a H_2S smell, and shell fragments (*e.g*., *Anodonta*), which could accidentally occur.

The *Gorgoştel Lake*, albeit is a small one, presents an interesting variation of the lithological components (**SIL**, **TOM**, **CAR**) and of the enviromagnetic parameter **MS**, which show, and respectively confirms a transition from *organo-mineral muds,* found in south, towards the predominantly *organic muds*, identified in the northern end of the lake. The *siliciclastic material content* (**SIL**) (Fig. 5f) is increasing from north southwards, *i.e*., from the contents of 11.13 % and 10.41 % (*class* **1**; "**LITHO** scale", in Fig. $3a_2$), assigned to the organic *mud* samples *DD 15-302* and *DD 15-301*, respectively, to **SIL** contents of 33.59 % and 23.82 % (*class* **2**), determined for the *organo-mineral muds* (samples *DD 15-297* and *DD 15-298*; Fig. 5f). The *lithological component* **TOM** offers, of course, a "reversed" situation, so that the highest contents are obtained for the *organic muds* from north (87.36 % and 87.87 %, respectively), whereas the lowest **TOM** contents (63.79 % and 74.29 %) are shown by the *organo-mineral muds* from south. As regards the *carbonates*, the **CAR** contents are ranging between 1.52 % (sample *DD 15-302*, in north) and 2.62 % (sample *DD 15-297*, in south).

The magnetic susceptibility values measured on the six samples collected from the *Gorgoştel Lake* strictly follow the lithological transition, above commented and argued, and reveal a successive increase from north southwards, *i.e*., from the *organic muds* towards the *organo-mineral muds*: *class* **I** ➔ *class* **II** ➔ *class* **III** (Fig. 5f). The lowest **k** value, a negative one (-3.05×10^{-6} SI) was recorded for the sample *DD 15-302,* and the highest one (106.39×10^{-6} SI) for the sample *DD 15-297* (location of the samples along the "2015 profile", also in Fig. 17b). The **MS** map (Fig. 16a) illustrates the transition from the *organo-mineral muds* from south, generated under the influence of the fluvial supplies from the *Perivolovca Channel* mouth, towards the *organic muds* from the northern lake zone. The **SIL** map (Fig. 16b) supports the **MS** image, and, by means of a "reversed" contour gradient, the **TOM** map (Fig. 16c) confirms the transition direction, as well. As regards the **CAR** map (Fig. 16d), no contour line has been possible to be drawn, as result of the narrow range within which the contents of the *carbonates* are defined.

Yet, regarding the *Gorgoştel Lake*, located in our study area, is worth pointing out a remarkable situation, namely, we take advantage of having magnetic susceptibility results provided by surficial sediments sampled in this lake during two expeditions which have been performed at a temporal distance of 36 years: 1979 and 2015 campaigns (Mihăilescu *et al*., 1980; Rădan *et al*., 2015). It is worth pointing out the magnetic susceptibility data which we have obtained in our first expedition in the *Gorgova - Uzlina Depression*, in 1979 (Rădan & Rădan, in Mihăilescu *et al*., 1980), when the surficial sediments were also sampled in 6 stations (*DD 1422 ÷ DD 1427*), placed along the lake longitudinal axis. These data were re-analysed in the framework of a "CERES" Project, in an unpublished scientific Report (Rădan & Rădan, 2003). The location of the 1979 sampling stations is very close to the sampling points composing the recent profile (carried out in October 2015) (see a parallel location of the sampling stations used in 1979 and 2015, respectively, in Fig. 17a,b). The **k** values are also progressively increasing, from north southwards. The lowest **MS** value (5.81×10^{-6} SI, *class* **I**) was measured for the sample

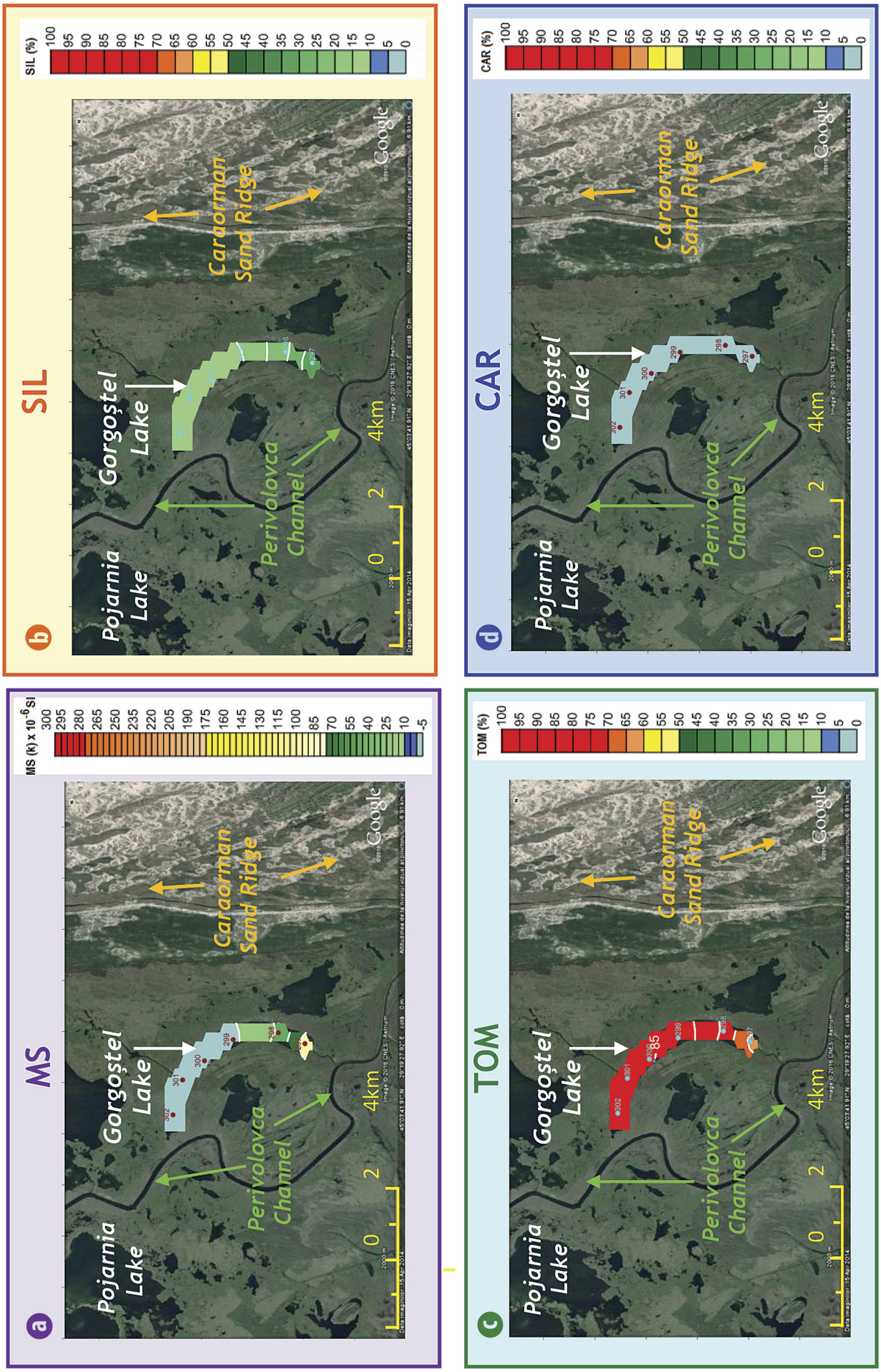

Fig. 16. Magnetic susceptibility and lithological maps of the bottom sediments from the *Gorgoştel Lake* (6 – 23 October 2015 expedition). **a) MS** map; **b) SIL** content map; **c) TOM** content map; **d) CAR** content map. *Notes* (*1* and *2*): same as in Fig. 6.

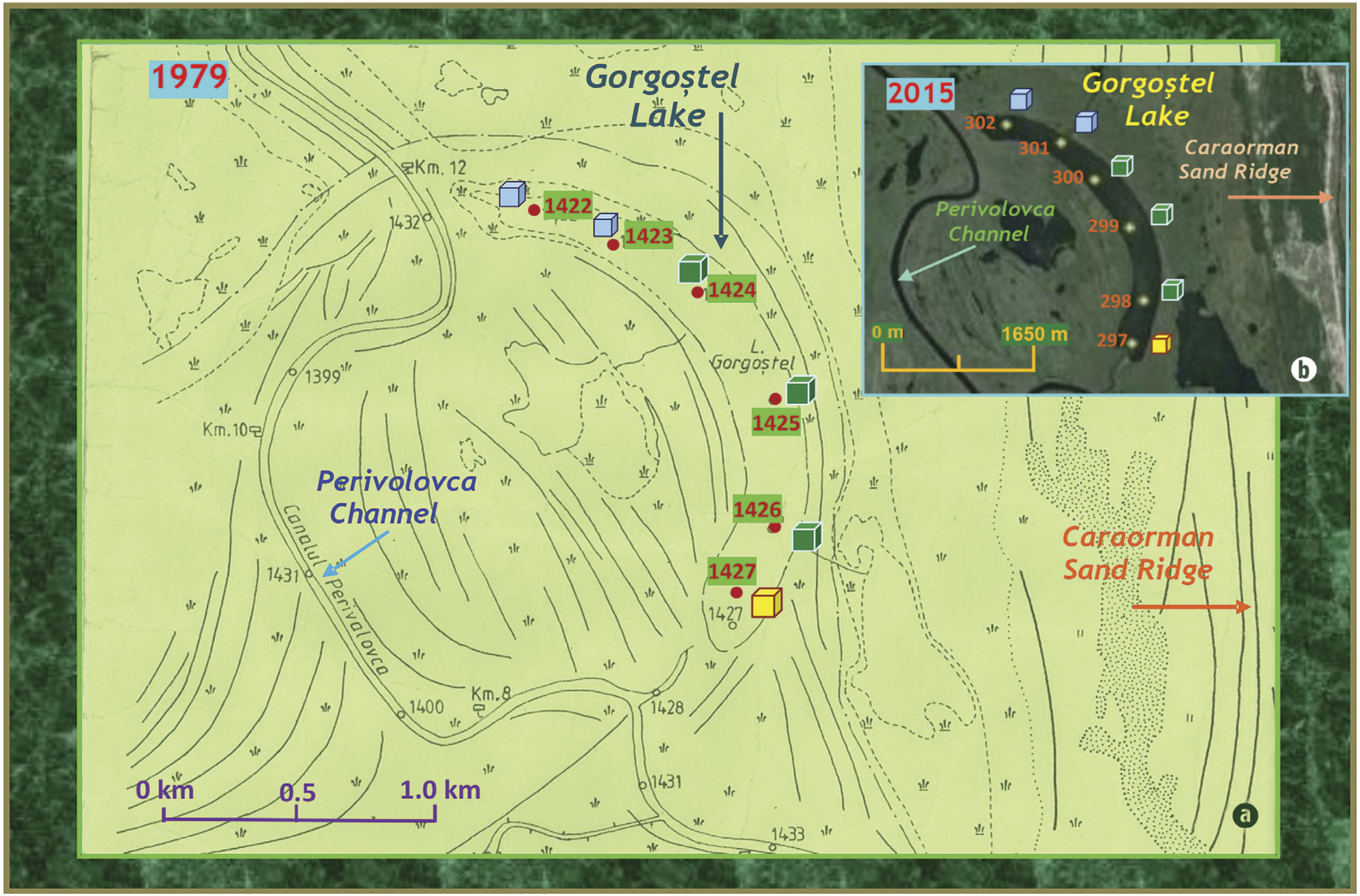

Fig. 17. Comparative magnetic susceptibility data concerning the surficial sediments of the *Gorgoştel Lake*, sampled during two expeditions carried out at the ends of a time interval of 36 years (*i.e.*, 1979 and 2015, respectively). **a)** map with **MS** cubs, coloured according to the **k** scale from Fig. 3a$_1$ (1979 expedition); **b)** map with **MS** cubs (6 – 23 October 2015 expedition).

DD 1422, situated in the northern *Gorgoştel Lake* (Fig. 17a), and this has presented a little higher level as compared to the corresponding 2015 value (-3.05×10^{-6} SI) recorded for the sample *DD 15-302*, while the highest **k** value (97.26×10^{-6} SI, *class* **III**) was provided by the sample *DD 1427*, located in the southern zone (Fig. 17a), a little lower than the equivalent 2015 sample (Fig. 17b*), i.e. DD 15-297* (106.39×10^{-6} SI). So, the same **MS** increasing trend – as it has been above specified – was recorded 36 years ago, from north southwards: *class* **I** ➔ *class* **II** ➔ *class* **III;** three sediment samples were calibrated to the *class* **II**, this being the case relating to both the sampling campaigns – 1979 (*DD 1424 ÷ DD 1426*; Fig. 17a), and 2015 (*DD 15-300 ÷ DD15-298*; Fig. 17b). The small differences suggest a very stable environment, presenting only a slight increasing trend of organic matter accumulation in the northern, confined part of the lake.

Finally, we can conclude the distribution patterns presented for the enviromagnetic parameter **MS**, and for the **SIL** and **TOM** lithological components show that, in south, the silting process of the lake is controlled by the allochthonous supplies of *Danubian* origin, and in north, by the autochthonous organic productivity. The **MS** results achieved at the ends of a 36 years time interval hold this concluding remark.

3.7. Uzlina and Isacova Lakes (20 and 21, in Fig. 1; see also Fig. 2)

We approach together these two important lakes of the *Gorgova - Uzlina Depression*, particularly as the "*couple of lakes Uzlina and Isacova*" (Fig. 2), in fact a very interesting aquatic ecosystem for the study of the differential settling, filtering and sedimentation processes produced during the transport of water and sediment from the Danube towards the inside of the Delta.

The *Uzlina Lake* is directly supplied with water and sediments from the *Danube* (*Sf. Gheorghe Branch - Mahmudia Meander*), through the *Uzlina Channel* (Fig. 2 and Fig. 5). The *Isacova Lake* is receiving from the *Uzlina L.* water already depleted of coarser suspended fractions, which determines a differentiation of the characteristic sediment types, but also an evolution of the water quality along the main flowing flux. At the same time, the *Isacova L.* is also directly supplied from the *Litcov Channel* through the *Isac I Channel* (Fig. 2). The latter has been deepened and enlarged in recent years, so that at the expedition moment (August 2014), the *Isacova Lake* northwestern zone was receiving a rather strong supply of water charged with suspended sediments. This channel bifurcates before entering into the *Isacova Lake*, the right arm supplying the *Isăcel Lake* (Fig. 2).

During the period to which this paper is focused, *i.e.*, 2011 ÷ 2015, there have not been carried out networks of stations for sampling surficial sediments from the couple of lakes *Uzlina - Isacova*. The last expedition in which there were covered in detail these two lakes was in 2006, another one performed in the same year adding up the networks. The results achieved on the basis of 17 expeditions carried out in the *Uzlina* and *Isacova Lakes* during the 1979 - 2006 period were presented by Rădan & Rădan (2010a). The paper illustrates the net difference between the *Isacova Lake* magnetic susceptibility characterization, supported by low and very low **k** values (not higher than the *class* **II**, excepting two stations placed at a channel mouth), and the *Uzlina Lake* **MS** description, based on much higher **k** values (*class* **Va** included). Actually, the two distinctly different magnetic susceptibility definition ranges evidence two peculiar environments: *confined* – associated with the *Isacova L.*, and *dynamic* – assigned to the *Uzlina L.*, which is strongly influenced by Danubian sediment supplies transported by the *Uzlina Channel* from the *Danube River*. The **MS** model simulates, and actually evaluates the natural threshold existing between the two "coupled lakes", and the briskly water transit, respectively. In the above cited article, very suggestive **MS** maps point out – by the **k** contour lines – the corresponding different magnetic susceptibility regimes, a *dynamic/turbulent* one, with very significant **MS** gradients/anomalies (**k** isolines of even 400×10^{-6} SI) – in the *Uzlina L.*, and a *very quite* **MS** regime, defined by two **k** contour lines only (of 25×10^{-6} SI and 50×10^{-6} SI, respectively) – in the *Isacova L.* (Rădan & Rădan, 2010a). This net difference is also clearly illustrated and argued by the **MS** diagrams generated by using the results given by the first two sediment sample collections taken from these important lakes in 1979. In Fig. 4c, the **k** pie-chart related to the *Isacova Lake* shows a very simple **MS** definition structure: 30 % – *class* **I**, and 70 % – *class* **II**, while the **MS** diagram for the *Uzlina Lake* (Fig. 4d) evidences the characterization of its sediments by the other three classes of the **k** scale, located in its upper half, defining, hence, the intermediate and the highest **MS** ranges (**k** scale, in Fig. $3a_1$): *class* **III** – 13 %; *class* **IV** – 40 %; *class* **Va** – 47 %.

As concerns the time interval to which this paper is focused, we mention that on the occasion of the expedition carried out in the *Danube Delta* in April - May 2011, the surficial sediments have been sampled only from 4 stations in the *Uzlina Lake* and 5 in the *Isacova Lake* (their locations, drawn out by red points, in Fig. 2). The highest **k** value (227.30×10^{-6} SI; *class* **IV**) was measured on a *compact mud* sampled from the *Uzlina L.* – *DD 11-109* station, located in the lake central zone (Fig. 2 and Fig. 5). The lithological composition determined for this *mud* confirms the **MS** characterization, revealing the highest **SIL** content (79.79 % – *class* **5**; Fig. 5 – *Uzlina Lake*), respectively the lowest **TOM** content (12.58 %). The lowest **MS** value was provided by a *mud* sampled from the *DD 11-106* station (100.40×10^{-6} SI; *class* **III**), situated in the lake western part (Figs. 2 and 5 – *Uzlina Lake*). It is very interesting to note that the **MS** values are very well integrated inside of the **k** map that was drawn up on the basis of the samples taken during the expedition carried out in 1979 (Fig. 4a). As regards the 5 samples taken from the *Isacova Lake* in 2011, the **MS** range characterizing them is very narrow, and defined by low **k** values (*class* **II**; Fig. 5 – *Isacova Lake*): 19.66×10^{-6} ÷ 44.84×10^{-6} SI. Actually, it must be emphasized that in all the

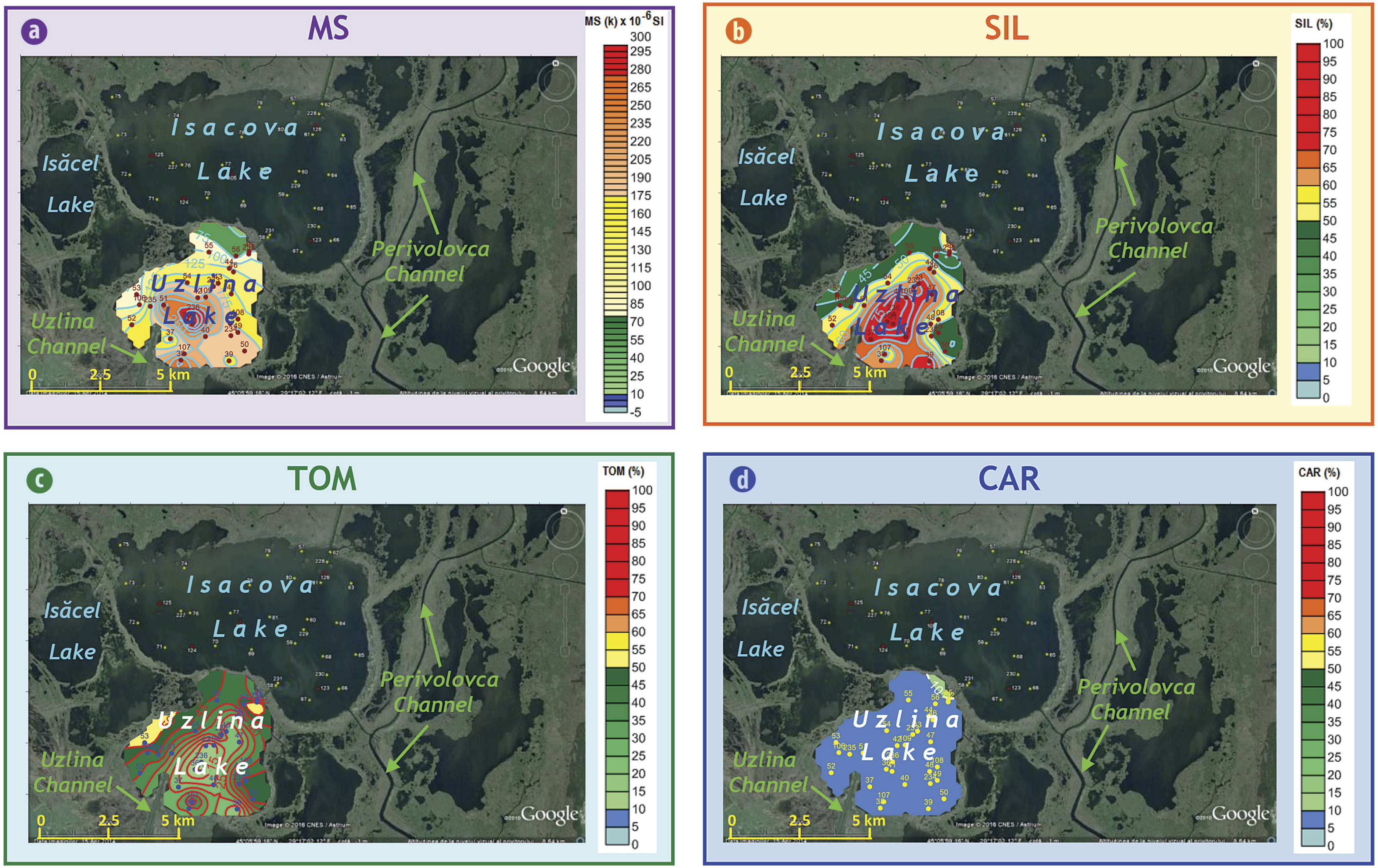

Fig. 18. Magnetic susceptibility and lithological maps of the bottom sediments from the *Uzlina Lake*, based on samples collected during 3 expeditions: 15 – 28 May 2006; 27 September – 8 October 2006; 29 April – 12 May 2011. **a) MS** map; **b) SIL** content map; **c) TOM** content map; **d) CAR** content map. *Notes* (*1* and *2*): same as in Fig. 6.

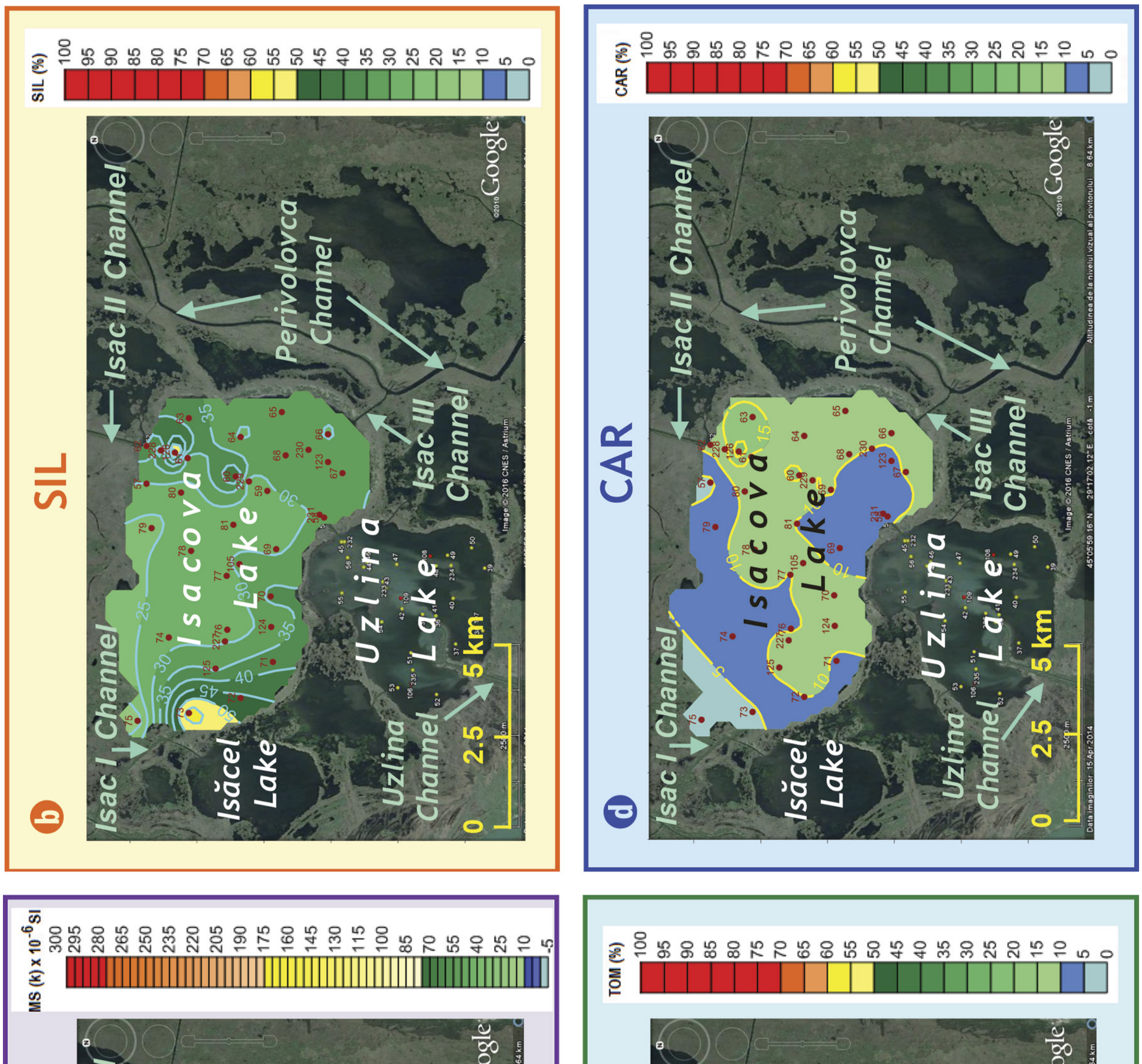

Fig. 19. Magnetic susceptibility and lithological maps of the bottom sediments from the *Isacova Lake*, based on samples collected during 3 expeditions: 15 — 28 May, 2006; 27 September – 8 October 2006; 29 April — 12 May 2011. **a) MS** map; **b) SIL** content map; **c) TOM** content map; **d) CAR** content map. *Notes* (1 and 2): same as in Fig. 6.

cruises reaching the *Isacova Lake* during the 1979 – 2006 period, no **k** value correlated with the *class* **III** was measured on the surficial sediments collected from this relatively stagnant aquatic environment (except for two **k** values determined for the sediments sampled in May 2006 from the mouths of two channels entering into the *Isacova L.*).

Relating to the 1979 expedition, when the networks of sampling stations have entirely covered these two lakes, it is worth mentioning the great difference between the two ranges of **k** values which characterize the surficial sediments. Thus, the **MS** enviromagnetic parameter measured for *Isacova Lake* sediments is defined between (-2.30)×10^{-6} (*class* **I**) ÷ 52.01×10^{-6} SI (*class* **II**), with an average value of 20.51×10^{-6} SI (*class* **I**), while for the *Uzlina Lake*, the **k** range is 131.26×10^{-6} (*class* **III**) ÷ 488.36×10^{-6} (*class* **Va**), with an average value of 283.06×10^{-6} SI (*class* **Va**). In the *Isacova Lake*, characterized by a low **MS** regime (Fig. 4a), a bit higher **k** values are provided by the samples collected from the eastern extremity, namely the area between the mouth of the *Isac II Channel* in north (connection with the *Litcov Channel*) and the mouth of the *Isac III Channel* in south (connection with the *Perivolovca Channel*) (Figs. 2 and 4a). It was considered that the **MS** variation regime could have been influenced by the abundant vegetal biomasses from the western part of the lake (Rădan & Rădan, 2003). As regards the *Uzlina Lake*, coupled in south with the *Pojarnia swamp* (Fig. 4a), the surficial sediments present totally different characteristics comparing with those of the *Isacova Lake*. The **k** map shows a very agitated magnetic susceptibility regime, suggestively illustrated by the high **MS** contour lines. In north, a maximum **k** zone is revealed, which is developed parallel with the bar placed between the *Uzlina* and *Isacova Lakes*. A second maximum zone, stronger, is in the southern area, and it is transversally extended between the two lake banks (Fig. 4a).

Actually, all the time the *Uzlina Lake* was under the influence of the direct sediment supplies from the *Danube*, which explains the general very high magnetic susceptibility background in the lake. On the other hand, the progradation of a small and narrow *delta* created by the *Uzlina Channel* in the southwestern zone of the lake, and which presently almost reached the middle of the lake, was able to influence a large part of the lacustrine area.

The net difference between the two **MS** regimes characterizing the *Uzlina* and the *Isacova Lakes* is also clearly illustrated by the corresponding **k** maps (Figs. 18a and 19a), performed for them on the basis of the magnetic parameter measurements carried out on the bottom sediments sampled during the 2006 and 2011 expeditions in the area. An important maximum **MS** anomaly, with two apices, is located in the *Uzlina Lake* central - southern area, described by **k** contour lines of 125×10^{-6} SI up to 325×10^{-6} SI (Fig. 18a), while a minimum **MS** zone is placed in the northern *Uzlina Lake* part, where the **k** isoline values are decreasing from 125×10^{-6} SI up to 50×10^{-6} SI. The *siliciclastic/detrital* and the *total organic matter* contents maps support with a great resolution the **MS** map morphology, defining two maximum **SIL** anomalies, and respectively, two minimum **TOM** anomalies, also directed along a northeast - southwest alignment; the highest **SIL** content isoline of 80 %, and respectively, the lowest **TOM** content contour line of 15 % are drawn up around the same group of sampling stations located in the central - southern zone, in the proximity of the apex of the *Uzlina Channel* microdelta (Figs. 18a,b,c and 19a,b,c). As regards the decreasing trend revealed by the **k** isolines in the western and northern parts of the *Uzlina Lake* (Fig. 18a), again the **MS** regime is supported by the main **LITHO** maps: the **SIL** contour lines (Fig. 18b) show a decreasing gradient of the *siliciclastic/detrital* contents, coupled with an increasing gradient of the *organic matter* contents defined by the **TOM** isolines, following the same directions, *i.e.*, directed northwards and westwards, respectively (Fig. 18c). Finally, referring to the **CAR** map (Fig. 18d), as the *carbonate* contents determined for the surficial sediments sampled in the expeditions carried out in 2006 and 2011 in the *Uzlina Lake* are ranging – with one exception (*DD 06-45* station) – within the interval 5 % - 10 %, no **CAR** contour line has been drawn up, except for the zone located around the sample collected from the previously specified station, located in the northeastern lake extremity, where the content isoline plotting of 10 % has been feasible (Fig. 18d). Therefore, the blue colour corresponding to the range 0 % - 15 % from the **LITHO** scale (Fig. $3a_2$) covers almost totally the *Uzlina Lake* surface (Fig. 18d). Passing to the *Isacova Lake* magnetic susceptibility map (Fig. 19a), the general characteristics show a clearly lower level of the **MS** isolines values (comparing to the coupled lake located before it – *Uzlina L.*) which is defined by the 25×10^{-6} SI and 50×10^{-6} SI **k** values (a 0 **k** contour is also visible in the northern lake extremity). Yet, in the northwestern and southwestern zones, at the mouths of the *Isac I Channel* and a very short connection *channel* with the *Uzlina Lake*, respectively, two **MS** anomalies occur (Fig. 19a): the first one is generated by the sediment sampled from the *DD 06-73* station, which provided a **k** value of 247.42×10^{-6} SI, and the second **MS** anomaly is of lower intensity and spatial extension, *i.e.* 158.80×10^{-6} SI, located around the *DD 06-058* sampling station. The *siliclastic/mineral* and the *total organic matter* component maps (Fig. 19b,c) support the northwestern **k** anomaly by the presence of a maximum **SIL** content zone (contour lines of 40 % up to 55 % around the above mentioned station), and respectively, by a minimum **TOM** content zone (isolines of 40 % up to 15 % around the same sediment sampling point *DD 06-073*). As regards the second **k** anomaly (of lower intensity) from the southwestern zone (Fig. 19a), the **SIL** and **TOM** content maps do not support it by corresponding anomalies (Figs. 19b, c). Instead, in the north-northeastern zone of the *Isacova Lake*, a maximum **SIL** content anomaly and a minimum **TOM** content one occur, having two apices each (Figs. 19b, c); even in the **CAR** content map (Fig. 19d) there can be identified two anomalies with similar locations (the northeastern one being better defined by contour lines of 15 % and 20 %). In this case, the **LITHO** anomalies are not reflected by any corresponding **MS** anomalies (Fig. 19a).

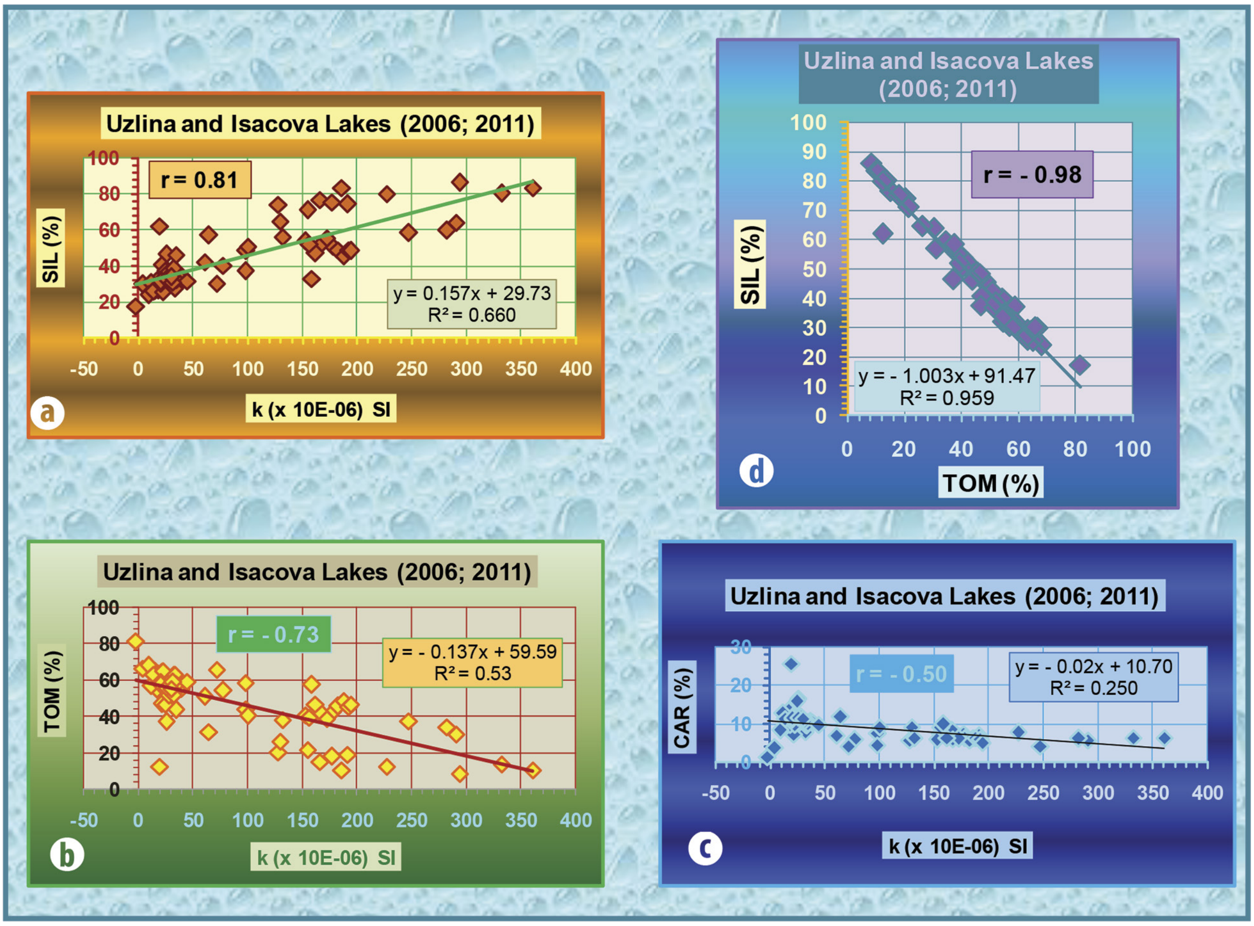

Fig. 20. Diagrams of correlations between the enviromagnetic parameter (**MS**; **k**) and the lithological components, as well as between the **LITHO** components themselves, which characterize the surficial sediments of the *Uzlina* and *Isacova Lakes* (related to all the three sampling expeditions: 15 – 28 May, 2006; 27 September – 8 October 2006; 29 April – 12 May 2011). **a) SIL** *versus* **k** scatter plot; **b) TOM** *vs*. **k** scatter plot; **c) CAR** *vs*. **k** scatter plot; **d) SIL** *vs*. **TOM** scatter plot. *Note*: same as in Fig. 7.

With regard to the correlation of the **MS** and **LITHO** results achieved for the *Uzlina - Isacova* couple of lakes, and taking into consideration for analysis together, both lakes, we have obtained the **SIL** *vs*. **k**, **TOM** *vs*. **k**, **CAR** *vs*. **k**, and **SIL** *vs*. **TOM** diagrams from Figs. 20 a,b,c,d. The correlation coefficients are lower than we have previously presented for other lakes of the *Uzlina – Isacova Depression*, but, anyway, they show – according to the "**r** *scale*" (Fig. 3b) – a *strong positive correlation* for **SIL** *vs*. **k** (**r** = 0.81; Fig. 20a), and *strong negative correlations* for **TOM** *vs*. **k** (**r** = - 0.73; Fig. 20b) and **SIL** *vs*. **TOM** (**r**= - 0.98; Fig. 20d), respectively a *moderate negative correlation* for **CAR** *vs*. **k** (**r** = - 0.50; Fig. 20c).

An overview on the information provided by the magnetic and lithological characteristics measured on bottom sediments reveals a good correlation between these parameters and shows up a pattern of water circulation and sediment distribution under the control of the *Danubian* inputs: the *Channels Uzlina* and *Isac I* are proved as the main water and sediment suppliers, and the *Channels Isac II* and *III* are the main discharging waterways; the images provided by the distribution maps reflect the major water flow and sediment transport directions within the system of the *Uzlina - Isacova* couple of lakes.

4. CONCLUSIONS

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

Actually, this article represents the second part of the paper concerning the *Gorgova - Uzlina Depression*, and it is regarding the synopsis of the **MS** and **LITHO** characteristics of the surficial sediments from the main lakes of this aquatic area. The present contribution fills up the magneto-lithological database assigned to it, in which till now it has already been introduced the information achieved from discrete points placed in four lakes wherefrom nine short cores have been collected (Rădan *et al*., 2016; this volume).

The surficial sediments to which the present paper is referred to were sampled from networks of stations that have been carried out in 9 lakes of the *Gorgova - Uzlina Depression* on the occasion of the expeditions in the *Danube Delta* performed during 2011 - 2012 and 2014 - 2015 time intervals. A special mention is needed for the *Uzlina – Isacova* coupled lakes, in which only a low number of sampling stations have been added during the period under attention in the paper (4 locations in the *Uzlina L*., and 5 locations in the *Isacova L*.), so that the **MS** and **LITHO** data achieved from detailed networks of sampling points carried out in the 2006 campaigns (26 sampling locations in the *Uzlina L*., and 30 locations in the *Isacova L*.) were considered. The integrated data led to feasible results, making available the elaboration of suggestive **MS**, **SIL**, **TOM** and **CAR** maps.

The net difference between the two **MS** regimes characterizing the *Uzlina* and *Isacova Lakes* is clearly illustrated by the corresponding **k** maps. A general very high magnetic susceptibility background is recorded in the *Uzlina Lake*, which is explained by the influence of the direct sediment supplies from the *Danube*. The normal situation relating to such *in tandem* positioning, as in the case of these coupled lakes, reveals that the sedimentary material of mineral origin (*e.g*., coarse silty muds) coming (by a short channel) from the *Danube River* into the first lake is settled down on the way, so that the major lithological component of the sediments from the second lake is represented by the organic matter, the *muds* being very soft and fine, usually non-cohesive.

The **MS** characterization – not neglecting its lithological support – of surficial sediments from the *Gorgova*, *Uzlina*, *Isacova* and *Cuibeda lakes*, wherefrom the sediment cores, which have constituted the subject of the previous paper (Rădan *et al*., 2016), were collected, has been completed with a similar approach of more five small lakes, investigated in recent years (2014 – 2015) for the first time, *i.e*., *Gorgovăţ*, *Obretinu Mic*, *Obretinciuc*, *Isăcel* and *Gorgoştel lakes*. The resulted database gives 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 geoecological state of the deltaic area under attention.

An interesting part of the paper is constituted by the approach of the two interconnected pairs of lakes present in the area, placed very close to one another, and forming the couples of lakes *Gorgova – Gorgovăţ* and *Uzlina – Isacova*.

The comparison of the **MS** results with the magnetic susceptibility data achieved in the first sampling field trip in the *Gorgova*, *Uzlina* and *Isacova Lakes*, in 1979, brings original enviromagnetic information extracted from the lacustrine sedimentary archives, just placed inside of an international context, if we refer to the beginning times of such types of researches in the world.

Based on the values of the enviromagnetic parameter (**k**) and of the lithological components contents obtained for the surficial sediments, several correlation coefficients (**r**) have been calculated: *siliciclastic fraction* (**SIL**) *vs*. **MS**, *carbonates* (**CAR**) *vs*. **MS**, *total organic matter* (**TOM**) *vs*. **MS**, **SIL** *vs*. **TOM** *etc*. Generally, strong positive/negative correlations were determined. The high correlation coefficients, which characterize the relationships concerning the *susceptibility* (**MS**) and the *siliciclastic/detrital material* (**SIL**), can constitute arguments towards the *proxy* quality assignment of the **magnetic parameter** as *environmental and minerogenic fingerprinting tool*. This represents one of the main objectives towards which our new contributions are and will be directed at present and in the future, respectively. The composite signatures archived inside of surficial sediments are retrieved and decoded in the laboratory.

So, by the **MS** and **LITHO** characterization of recent sediments, sampled in the same lakes at different time intervals since 1979, the changed or unchanged environmental state of the deltaic geoecosystems (the anthropogenically modified ones included) has been harshly established by means of a quantitative indicator assessment, complemented by other information, as well. Thence, our **MS** database accounts for a consistent contribution to the development of "*so-called magnetic proxies for the reconstruction of the environmental history*" (Egli, 2003) in the *Danube Delta*.

The magnetic susceptibility data achieved on collections of samples taken more than 35 years ago from the surficial sediments of the main lakes of the *Gorgova - Uzlina Depression* and analysed together with the results obtained during the last decade or so, in a magneto-lithological and geoecological framework, demonstrate the practical validity of the Verosub & Roberts (1995) statement, *i.e*. "*many types of studies that are now classified as environmental magnetism have been in existence for some time*". Consequently, the enviromagnetic archives recovered from the *Danube Delta* modern sediments are continuously enriching, making place among the most developed and temporally extended databases known in the world associated to such aquatic environments.

REFERENCES

Catianis, I., Rădan, S., Grosu, D. (2014) – Loss of ignition as a proxy indicator for assessing the lithological composition of the recent sediments accumulated in some freshwater lakes from the Danube Delta, Romania, *Inter. J. of Innov. and Appl. St.*, ISSN 2028-9324, **9**, *1*, 260-278.

Dean, W.E. (1974) – Determination of carbonate and organic matter in calcareous sediments and sedimentary rocks by loss on ignition: comparison with other methods, *Journal of Sedimentary Petrology*, **44**, 242-248.

Dekkers, M.J. (1997) – Environmental magnetism: an introduction, *Geol. Mijn*., **76**, 163-182.

Evans, M.E., Heller, F. (2003) – *Environmental Magnetism. Principles and Applications of Enviromagnetics,* Academic Press, Elsevier Science, USA, 299p.

Oldfield, F. (1991) – Environmental magnetism – a personal perspective, *Quater. Sci. Rev.*, **10**, 73-85.

Egli, R. (2003) – *Environmental influences on the magnetic properties of lake sediments*, PhD Thesis, Swiss Federal Institute of Technology, Zurich, 328p. (with an *Appendix*).

Ishii, Y., Kazuaki Hori, K. (2016) – Formation and infilling of oxbow lakes in the Ishikari lowland, northern Japan, *Quaternary International*, **397**, 136-146.

Rădan, S. (2015) – *Field campaign for monitoring, review and completion in the master areas from the Danube Delta, the Razim - Sinoie Lagoon Complex*, *and the marginal lakes*, "Phase no. 22" Report (*PN 09-41 03 04* Project), 50 p., GeoEcoMar, Bucharest, Romania (unpublished Scientific Report; *in Romanian*).

Rădan, S.-C. (1981) – Magnetometric and petromagnetic researches in the lacustrine area, *Bul. Inf. Ştiinţ. Tehn.,* **I**, *1,* Inst. Geol. Geofiz., Bucureşti, 9-11 (*in Romanian*).

Rădan, S.-C. *(*2008*)* – The direct problem and the inverse problem in Petromagnetology and Palaeomagnetology; a discussion, with exemplification in Geophysics, Geology and Geoecology, *Geo-Eco-Marina*, **14**, Suppl. no. 1, Bucureşti - Constanţa, 201-215 (with 3 *plates*) (*in Romanian*).

Rădan, S.-C. Rădan, S. (2003) – *Magneto-susceptibilimetric models drawn up for bottom sediments sampled in different phases from lakes of the Gorgova – Uzlina Depression*, in S.C. Rădan and S. Rădan (2003) – *The elaboration of an enviromagnetic method to characterize the sedimentary systems in areas covered by water. Experimentation in the Danube Delta and the Razelm (Razim) - Sinoie Lagoon Complex. Phase II* ("CERES" Project), G.I.R. – GeoEcoMar Archives, Bucharest, Romania (unpublished Scientific Report; *in Romanian*).

Rădan, S.-C., Rădan, S. (2006a) – 30 years of magnetic susceptibility measurements on the Danube Delta lake sediments (Romania, 1976 - 2006). Sedimentologic applications to Environmental Magnetism, *10th Castle Meeting "New Trends in Geomagnetism – Palaeo, Rock and Environmental Magnetism",* September 3 – 8, 2006, Castle of Valtice, Czech Republic; Abstract, *Travaux Géophysiques*, **XXXVIII**, 2006, ISSN 0231-5548, Geophysical Institute, Academy of Sciences of the Czech Republic, Prague, 94-95.

Rădan, S.-C., Rădan, S. (2006b) – A magnetic susceptibility scale with a lithological support originated in the lake sediments from the Danube Delta and the Razim – Sinoie Lagoonal Complex (Romania). An environmental and geoecological approach*, 10th Castle Meeting "New Trends in Geomagnetism – Palaeo, Rock and Environmental Magnetism"*, September 3 – 8, 2006, Castle of Valtice, Czech Republic; Abstract, *Travaux Géophysiques*, **XXXVIII**, 2006, ISSN 0231-5548, Geophysical Institute, Academy of Sciences of the Czech Republic, Prague, 96-97.

Rădan, S.-C., Rădan, S. (2007a) – A magnetic susceptibility scale for lake sediments; inferences from the Danube Delta and the Razim – Sinoie Lagoonal Complex (Romania), *Geo-Eco-Marina*, **13**, Bucureşti - Constanţa, 61-74.

Rădan, S.-C., Rădan, S. (2007b) – Modern Sediments as Enviromagnetic Archives. A Case Study: Danube Delta and Northwestern Black Sea, *American Geophysical Union Fall Meeting*, 10 – 14 December, 2007, San Francisco, USA (*Poster Presentation*); *EOS Transactions, American Geophysical Union*, **88** (*52*), Fall Meet. Suppl., San Francisco, USA, Abstract GP53B-1220.

Rădan, S.-C., Rădan, S. (2009) – Integrated magnetic susceptibility and lithological studies on lacustrine recent sediments from the Danube Delta, *Geo-Eco-Marina*, **15**, Bucureşti - Constanţa, 177-197.

Rădan, S.-C., Rădan, S. (2010a) – The use of the magnetic susceptibility to study hydrosedimentary environments and processes in Danube Delta, *Geo-Eco-Marina*, **16**, Bucureşti - Constanţa, 37-46.

Rădan, S.-C., Rădan, S. (2010b) – Lake sediments fingerprinting in the Danube Delta, using composite magneto-lithological signatures; an environmental approach, *Travaux Géophysiques*, **XXXIX**, Abstracts of the *„12th Castle Meeting – New Trends in Geomagnetism. Palaeo, Rock and Environmental Magnetism"*, Castle of Nové Hrady, Czech Republic, August 29 - September 4, 2010, 68-69.

Rădan, S.-C., Rădan, S. (2011) – Recent sediments as enviromagnetic archives. A brief overview, *Geo-Eco-Marina*, **17**, Bucureşti-Constanţa, 103-122 (with a *double plate*).

Rădan, S.-C., Rădan, M., Rădan, S. (1978) – *Magnetic susceptibility of bottom sediments*. In: N. Mihăilescu *et al*. (1978) – *The geological and geophysical study of the Danube Delta to assess its economical potential* (*Goloviţa L. – Sinoe L. sector*), Archives *of* Institute of Geology and Geophysics (in present, Geological Institute of Romania), Bucharest, Romania (unpublished Scientific Report; *in Romanian*).

Rădan, S.C., Rădan, M., Rădan, S. (1980) – *Petromagnetic characteristics of the bottom sediments*. In: Mihăilescu, N. *et al*. (1980) – *The geological and geophysical study of the Danube Delta in order to evaluate its economical potential* (*Gorgova – Uzlina – Isacova sector*), Archives of Institute of Geology and Geophysics (in present, Geological Institute of Romania), Bucharest, Romania (unpublished Scientific Report; *in Romanian*).

Rădan, S.-C., Rădan, S., Catianis, I. (2013) – The use of the magnetic susceptibility record as a proxy signature for the lithological composition of lake sediments: Evidences from Danube Delta short cores in the Meşteru – Fortuna Depression (Danube Delta), *Geo-Eco-Marina*, **19**, Bucureşti - Constanţa, Romania, 77-105.

Rădan, S.-C., Rădan, S., Catianis, I. (2014) – Relationship between the magnetic susceptibility and lithological composition in sediment cores from lakes of Matița – Merhei Depression (Danube Delta, Romania): Towards a proxy method of sedimentological and environmental fingerprinting, *Geo-Eco-Marina*, **20**, București - Constanța, ISSN: 2248–2776 ISSN-L: 1224–6808, 45-86.

Rădan, S.-C., Rădan, S., Catianis, I., Grosu, D., Scrieciu, A., Pojar, I. (2016) – An environmental magneto-lithogenetic study in the lakes of the Gorgova – Uzlina Depression (Danube Delta, Romania). I. Insights from short sediment cores, *Geo-Eco-Marina,* **22**, București - Constanța, ISSN: 2248–2776 ISSN-L: 1224–6808 (*this volume*).

Rădan, S.-C., Rădan, S., Scrieciu, A. (2015) – Environmental influences on the magnetic susceptibility of recent sediments in Danube Delta, in geoecological context: insights from lakes of Gorgova – Uzlina Depression, Abstract, p. 29, in L. Török (ed.) – *2015 Deltas and Wetlands* (Book of abstracts), vol. **3**, 45 p., Danube Delta Technological Information Center Publishing House, Tulcea, Romania, ISSN 2344-3766.DOI:10.14592/DDI.D.W.03.2015

Thompson, R., Battarbee, R.W., O'Sullivan, P.E., Oldfield, F. (1975) – Magnetic susceptibility of lake sediments, *Limnol. Oceanogr.*, **20**, *5*, 687-698.

Verosub, K.L., Roberts, A.P. (1995) – Environmental magnetism: Past, present, future, *J.Geophys. Res.*, **100**, *82*, 2175-2192.