TABACARIE LAKE – A MODEL OF URBAN POLLUTION

Glicherie CARAIVAN(1), **Dan SECRIERU**(1), **Constantina FULGA**(1), **Florian PĂUN**(1), **Priscila OPREANU**(1)

(1) National Research and Development Institute for Marine Geology and Geoecology - GeoEcoMar - Romania –Constanta branch.
Address: 304 Mamaia bvd., 900581 Constanta, Romania. Tel. +40758.087.000,
e-mail: gcaraivan@geoecomar.ro; dsecrieru@geoecomar.ro; cfulga@geoecomar.ro

Abstract. Tabacarie coastal lake has been surrounded, during the past century, by the fast developing city of Constanta. Consequently, the lake has directly suffered from human interventions, such as dredging, embankments and heavy pollution. The lake surface sediments are generally fine grained: clayey silts and silts, with sands appearing only on dredged bottoms. The review of the chemical composition of upper sediments pointed out the presence of large quantities of certain heavy metals, in particular: Zn, Ba, Cu and Pb, dispersed, mainly, near the discharge points of rainwater pipes.

Key words: lacustrine sediments, bathymetry, geochemistry, heavy metals

1. INTRODUCTION

The Tabacarie lake is situated in the North-Western part of the South Dobrogea, close to the contact with the Central Dobrogea (the Capidava-Ovidiu fault). The lake, situated at the northern limit of the Constanta city and having a surface of approximately 99 ha, was formed by the damming of a river valley; genetically, the lake is a fluvial-maritime creek (Fig. 1). Geologically and sedimentologically, the lake Tabacarie area is closely related to the evolution of the Siutghiol lake, situated northwards and communicating with the Tabacarie lake through a sluiceway equipped with a sluicegate.

Previous studies have been carried out by the main author between 1991-1993, revealing and characterizing the Tabacarie Lake's main features (geography, geomorphology and geology).

2. THE BATHYMETRY OF THE TABACARIE LAKE BASIN

Relatively isolated from natural sources (ground water is insufficient to balance loses), Tabacarie lake has a hydrological level (about +1.20 - +1.70 m above the 1975 Black Sea level) which depends upon the influx of water from Siutghiol lake. The excess water flows out of Tabacarie lake into the sea via a sluice at Pescarie.

Stormwater runoff and rainwater and waste water that flow into Tabacarie lake led to its environmental decline. From 1978 to 1979, the lake basin was dredged and the bank remodelled with walkways.

Bathymetry measurements performed in 1993 allowed the detailed charting of the lake (Fig. 2).

The dredging works intensely affected the northern part of the lake, causing the deepest areas (maximum depth of 3.70 m), where the topography of the bottom includes relatively abrupt drop-offs (Fig. 3).

Bathymetric Maps are made in different years: in 1993, by the main author; in 2007, designed by "Insert" ltd. A slight change is also noticeable (Fig. 1).

Initially, dredging was uniformly conducted across the whole lake area, but the heavily charged with sediments rain and wastewater inflow led to the partial silting of the southern sector. Here, we can identify two steps in the lake basin's bathymetric profile, formed under the influence of the terrigenous sources (sand, gravel) and decomposing organic material (Fig. 3).

Tabacarie lake is situated in an elongated sink, at the mouth of two river valleys stretching from Boulevard Alexandru Lapusneanu and Boulevard Mamaia.

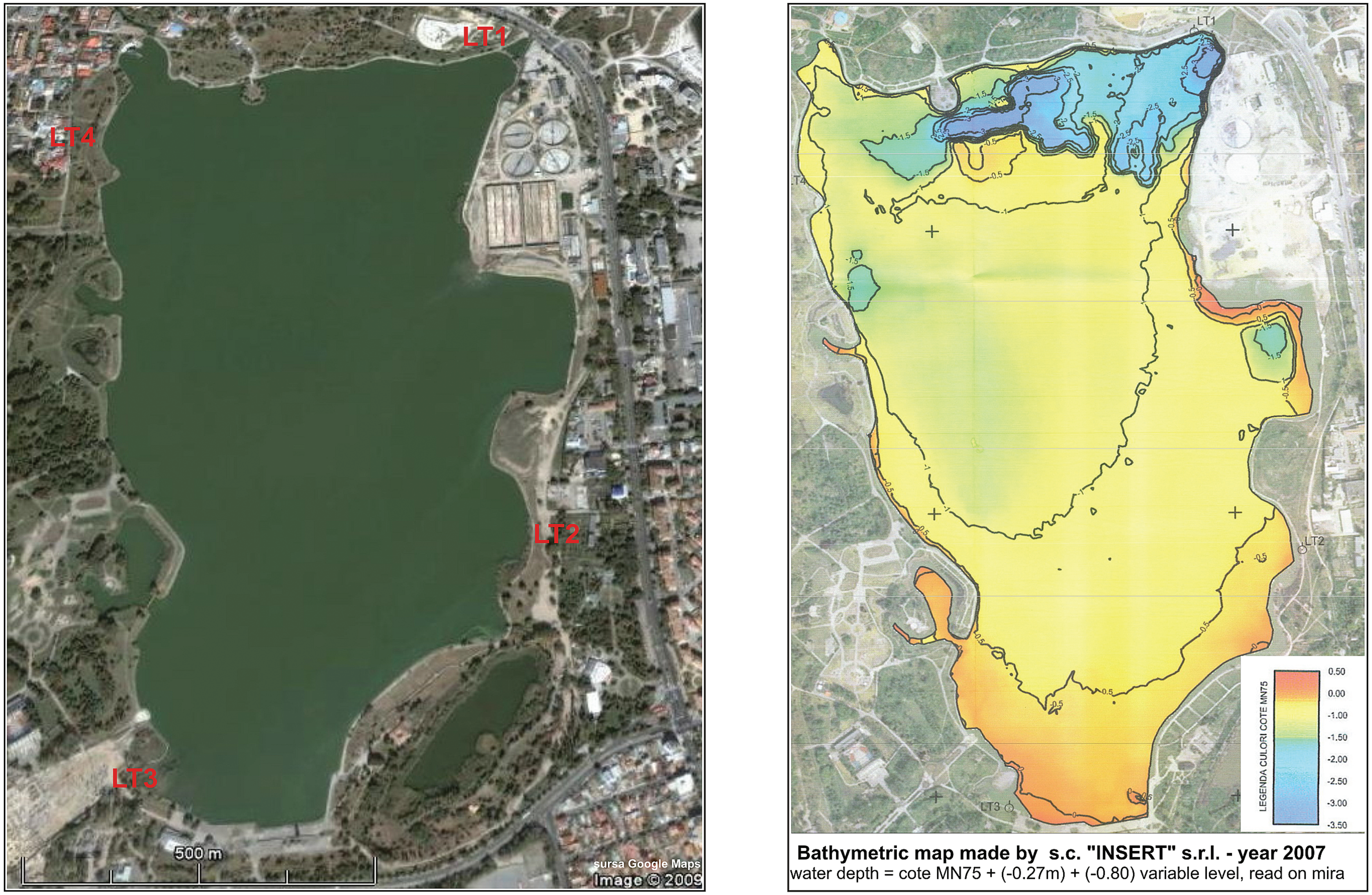


Fig. 1 Tabacarie Lake – Constanta. Topographic marks.

WGS84

LT1 - N 44° 12' 57.67121"	E 28° 38' 23.12521"	LT3 - N 44° 12' 49.82711"	E 28° 38' 6.12684"
LT2 - N 44° 12' 27.74884"	E 28° 38' 29.01260"	LT4 - N 44° 12' 49.82711"	E 28° 37' 51.67993"

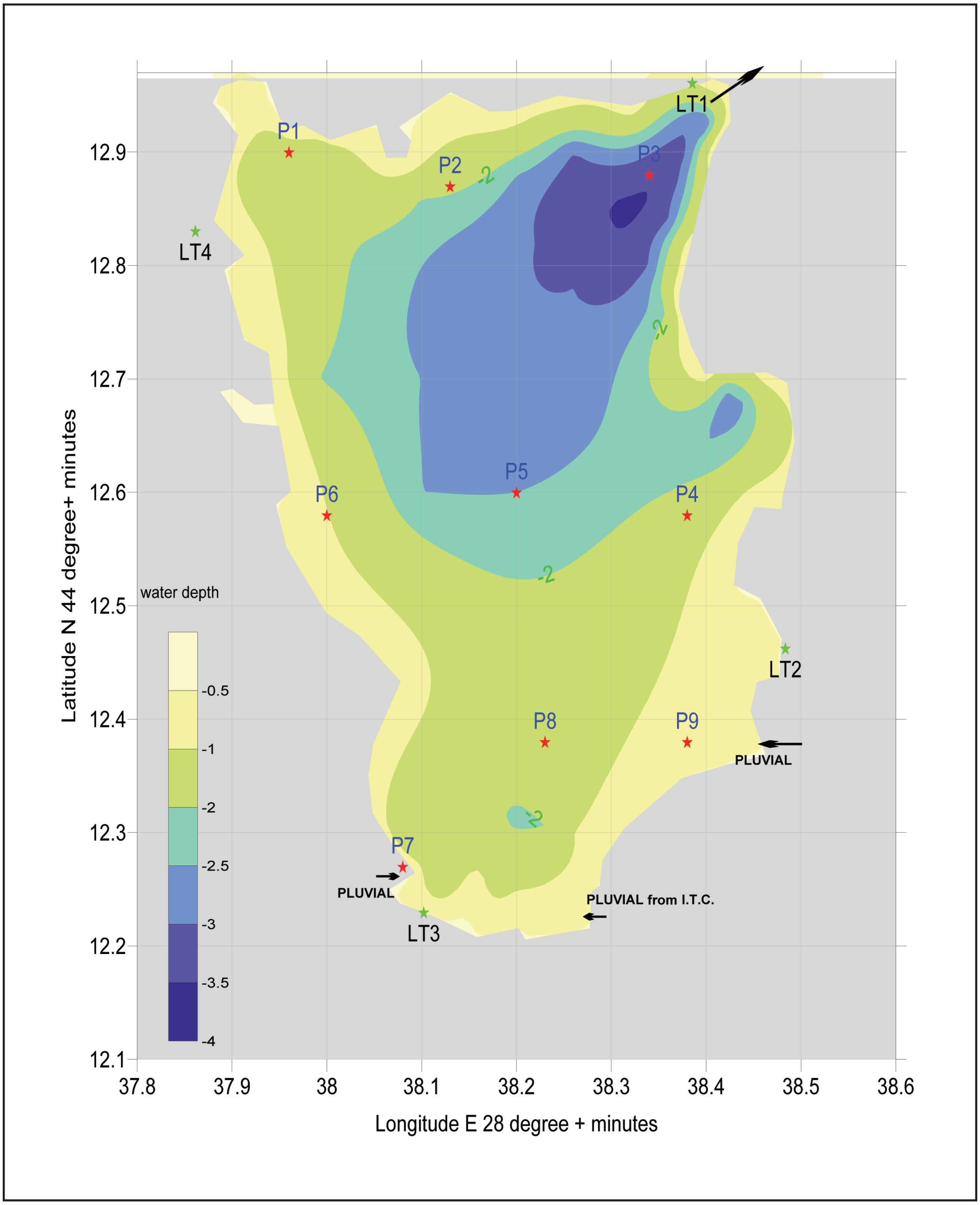


Fig. 2 Bathymetry of Tabacarie Lake in 1993.

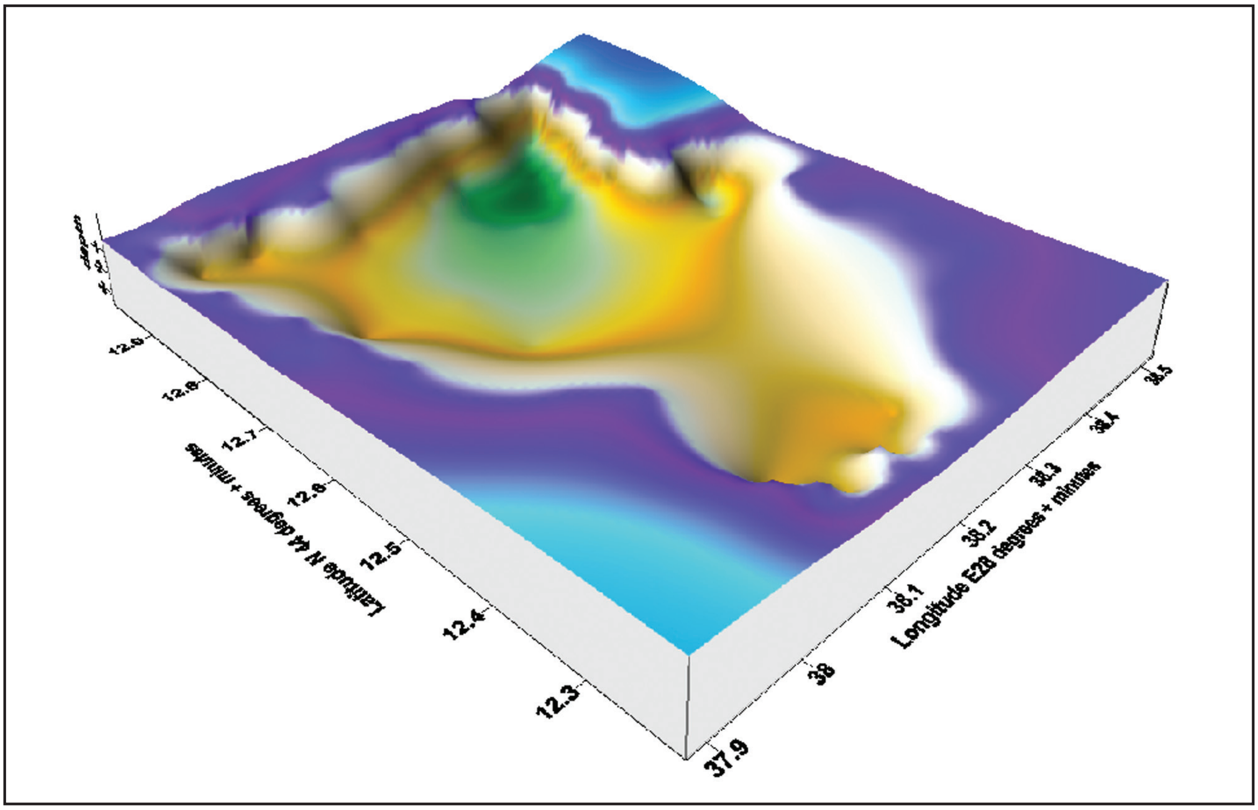


Fig. 3 3D image of the surface of sediments in Tăbăcărie Lake, Constanta.

The present lake shore is entirely straightened and consolidated. The western segment rises to a maximum of 6 - 7 m, while the eastern and southern ones are lower, reaching 2 - 4 m high. The northern sector is the lowest segment of the entire lake area (1 - 2 m).

3. MATERIALS AND METHODS

In order to define the features of the Tabacarie lake bottom sediments, nine samples of superficial sediments were collected with a Van Veen grab from representative locations (Fig. 2).

The granulometric composition of the sediment was determined in the laboratory through the combined method consisting of dry sieving (allowing the separation of the sandy fraction composed from particles with sizes between 2.0 and 0.062 mm – -1 to 4 phi on the Wentworth scale) and the pipetting method (evidencing the silty and clayey fractions, formed from grains with sizes less than 0.062 mm – 4 phi).

The individualized granulometric fractions were weighted and their weights, expressed in grams, percentages and cumulated percentages, were used both for establishing the textural types of the sediment (using the Shepard's ternary diagram) and to determine the granulometric parameters typical for each sediment type.

The chemical analyses, performed on five of the collected sediment samples, included determinations of major, minor and trace components. The determinations were carried out by using a complex of analytical methods consisting in:

1. a titrimetric method for the $CaCO_3$ determination (Black, 1965)
2. atomic absorption spectrometry with flame atomization for determinations of Co, Cu, Ni, Pb and Zn and graphite furnace atomization for Cd; the analyses were done on a UNICAM SOLAAR 939E double beam atomic absorption spectrometer, with deuterium lamp background correction;
3. total Fe_2O_3, TiO_2, MnO, Ba, Sr, Cr, Zr and V were analyzed by X-ray fluorescence spectrometry on a VRA 30 sequential spectrometer equipped with an X-ray tube with tungsten anode, directly on compacted powders. A LiF 200 analyzer crystal was used to select the wavelengths and the measurements were done with a scintillation detector with Na(Tl)J. The system calibration was done with a series of standard reference materials kindly provided by the US Geological Survey, The National Institute of Standards and Technology – USA and The National Research Council – Canada, using the relation between the element concentration and the difference between the number of impulses recorded at the analytical line and the number of impulses recorded at the background line.

4. DESCRIPTION OF TABACARIE LAKE SURFACE DEPOSITS

4.1. The distribution of sand, silt and clay

Based on the relative frequency of sandy, silty and clayey fractions, Tabacarie Lake surface sediments were classified using Shepard's diagram (1954). Two types of sediments were identified: a) sands and b) silts and clayey silts (Table 1).

Sand was found in the intensively dredged or contaminated by the stormwater runoff areas. The sandy fraction measured up to 93.78% of the sample weights, while silt and clay silt marked a lower ratio (Fig. 4).

The dominant sediments in the studied area are represented by clayey silts and silts, that cover most of the lake bottom. The silty fraction represents between 53.65% - 76.11% and the clayey percentage is between 1.28% - 44.04%, reflecting eolian and anthropogenic material participation (Figs 5 and 6).

4.2. Textural Parameters

Mean Diameter ($Mz_i\Phi$) as a measure of the average size of sedimentary particles, ranges from 0.9 to 2.42 Φ in sand samples and from 6.40 to 7.08 Φ in silt and clayey silt samples (Fig. 7a).

Inclusive standard deviation (σ_i Φ), as a measure size-sorting, gave values varying between 1.59 Φ and 2.23 Φ which indicated a poor and very poor size-sorting, especially in the central area of the lake.

The correlation diagram (Mz_if / σ_i Φ) shows a direct relation between the fineness of sediments and the size-sorting of the present particles.

Inclusive Graphic Skewness (Sk_i) gives only positive values between +0.04 and + 0.62, which indicate an excess of fine particles relative to a normal frequency curve distribution.

The Kurtosis coefficient (K_G) provides the peripheral size range. Most of the K_G values range within the platykurtic field ($K_G = 0.90$). (Fig. 7b).

4.3. Sediment geochemical characterization

The analysis of sediment chemical composition evidenced the presence in large quantities of Zn, Ba, Cu and Pb (Table 2).

Table 1. Grain size composition of surface sediments in Tabacarie Lake

Sample	P_1 (Φ)	P_5 (Φ)	P_{16} (Φ)	P_{25} (Φ)	Md (Φ)	P_{75} (Φ)	P_{84} (Φ)	P_{95} (Φ)	Mz_i (Φ)
P1	2,43	4,12	4,91	5,32	6,35	7,66	8,46	10,08	6,57
P2	0,92	1,60	2,03	2,10	2,29	2,82	2,95	8,55	2,42
P3	4,06	4,73	5,32	5,62	6,75	8,42	9,18	10,10	7,08
P4	4,20	4,69	5,23	5,58	6,68	9,59	10,15	10,58	7,35
P5	1,50	4,35	4,98	6,18	7,24	9,30	9,69	10,31	7,30
P6	2,71	4,26	4,78	5,10	6,31	8,31	9,92	10,49	7,00
P7	1,20	0,80	0,36	0,13	0,82	1,64	2,21	5,50	0,89
P8	2,24	4,21	4,65	4,87	5,86	7,78	8,70	10,32	6,40
P9	3,75	4,44	4,84	5,15	6,48	8,46	9,39	10,37	6,78

Sample	Sand (%)	Silt (%)	Clay (%)	σ_i (Φ)	Sk_i	K_G	Sediment type
P1	4,24	76,14	19,67	1,79	0,22	1,04	Silt
P2	91,58	2,81	5,60	1,28	0,62	3,95	Sand
P3	0,88	69,68	29,44	1,78	0,25	0,78	Clayey Silt
P4	0,50	62,68	36,82	2,12	0,37	0,60	Clayey Silt
P5	2,28	53,68	44,04	2,08	0,04	0,78	Clayey Silt
P6	2,64	70,31	27,05	2,23	0,37	0,80	Clayey Silt
P7	93,78	5,15	1,07	1,59	0,28	1,71	Sand
P8	2,70	73,76	23,53	1,94	0,43	0,86	Clayey Silt
P9	1,06	68,52	30,41	2,04	0,30	0,73	Clayey Silt

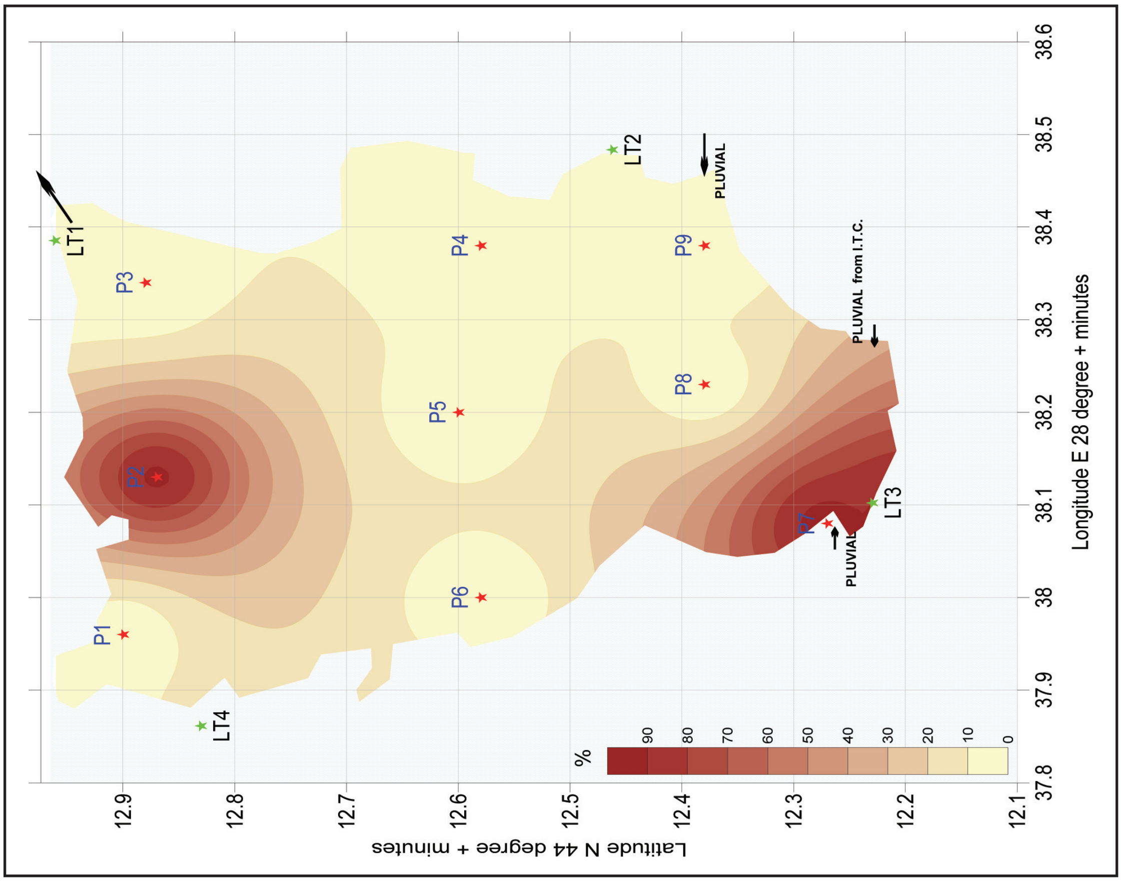


Fig. 4 Distribution of SAND in the sediments of Tabcarie Lake, 1993.

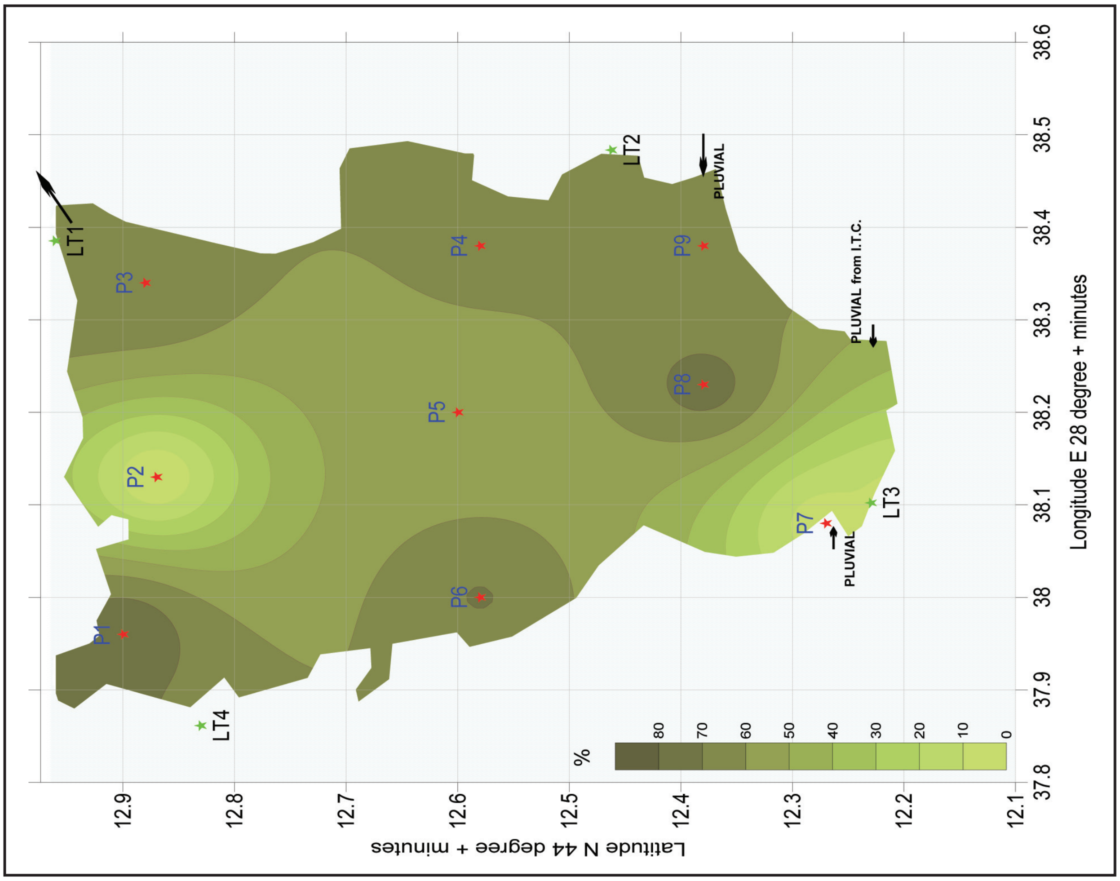


Fig. 5 Distribution of SILT in the sediments of Tabcarie Lake, 1993.

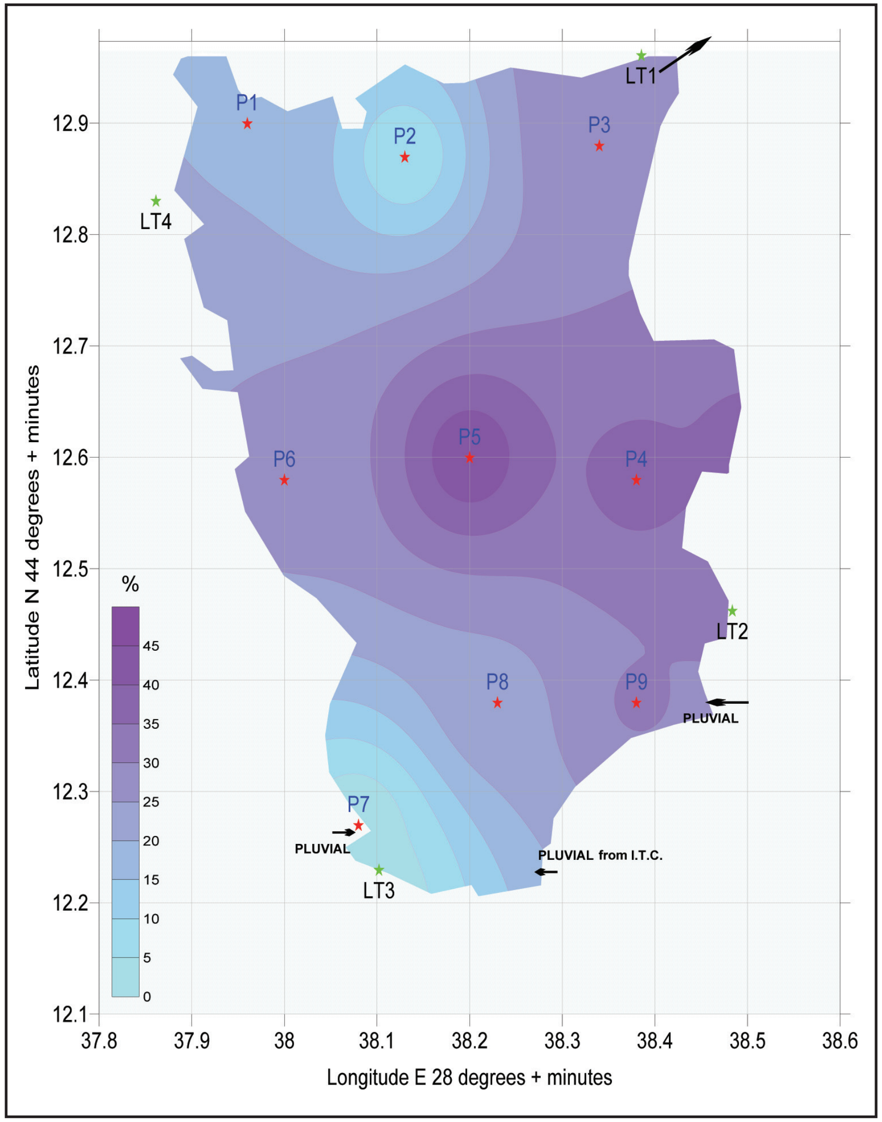


Fig. 6 Distribution of CLAY in the sediments of Tabcarie Lake, 1993.

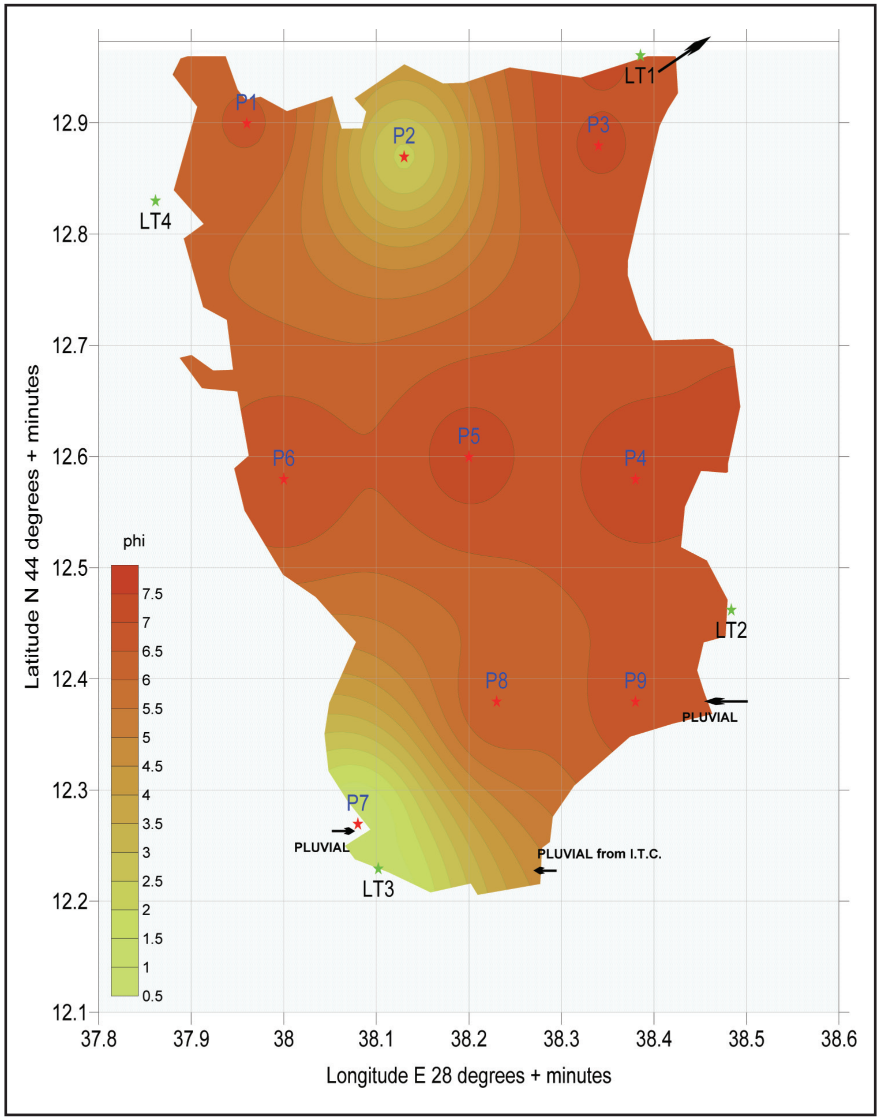


Fig. 7 Distribution of the Mzi-MEAN size parameter in the sediments of Tabcarie Lake, 1993.

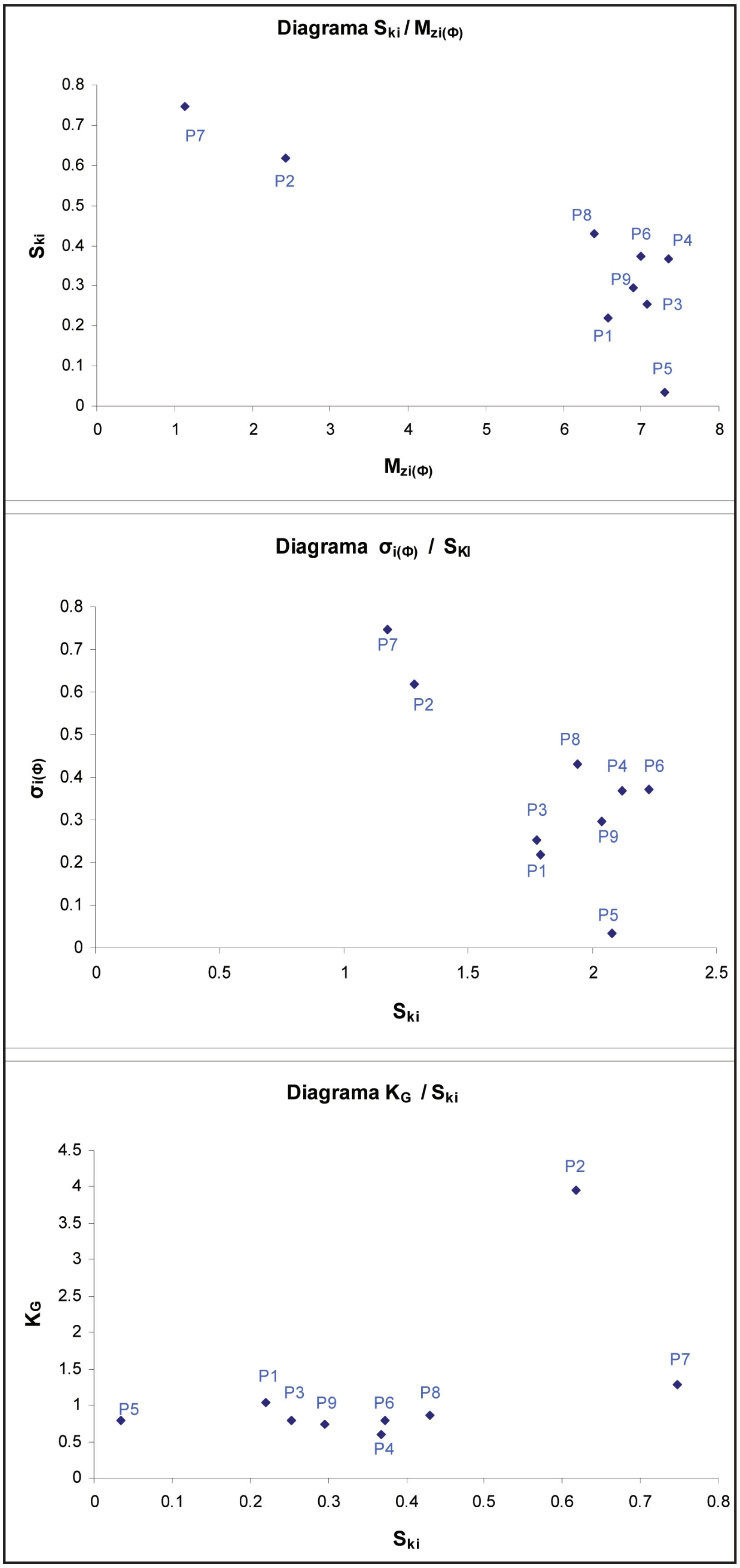


Fig. 7a Correlation of the SK_I, Mzi, KG and σi textural parameters.

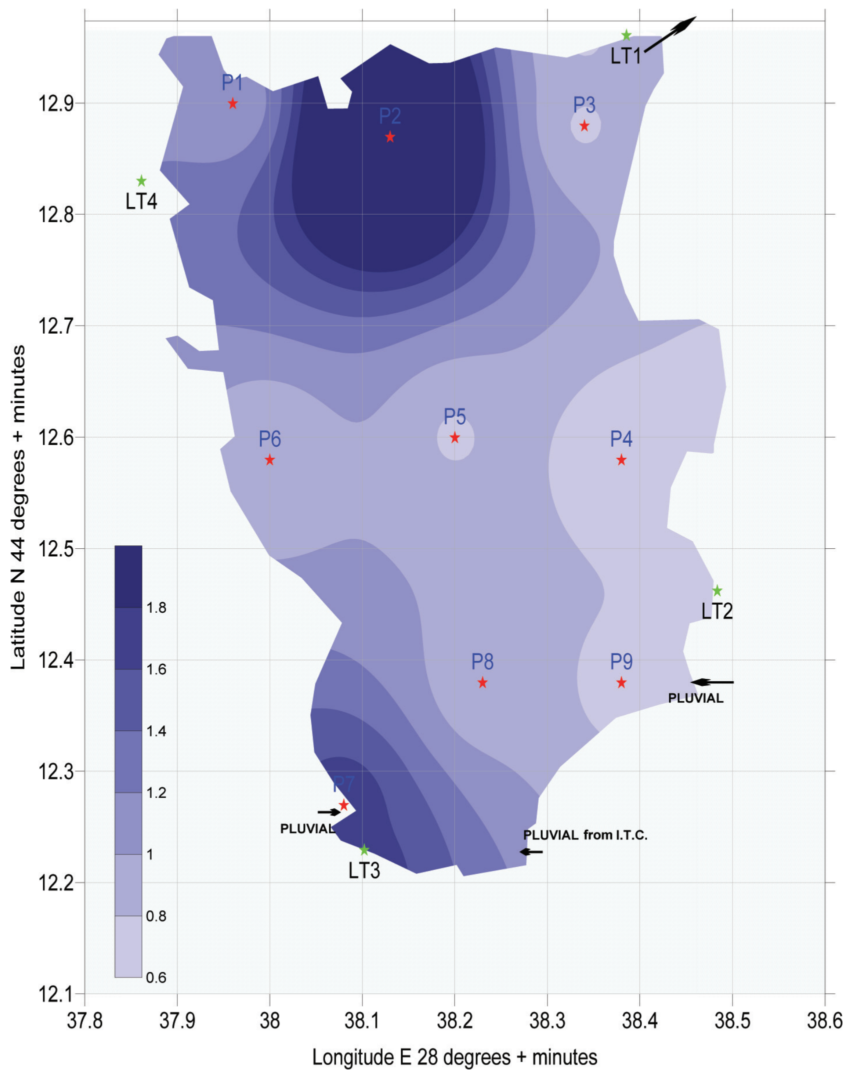
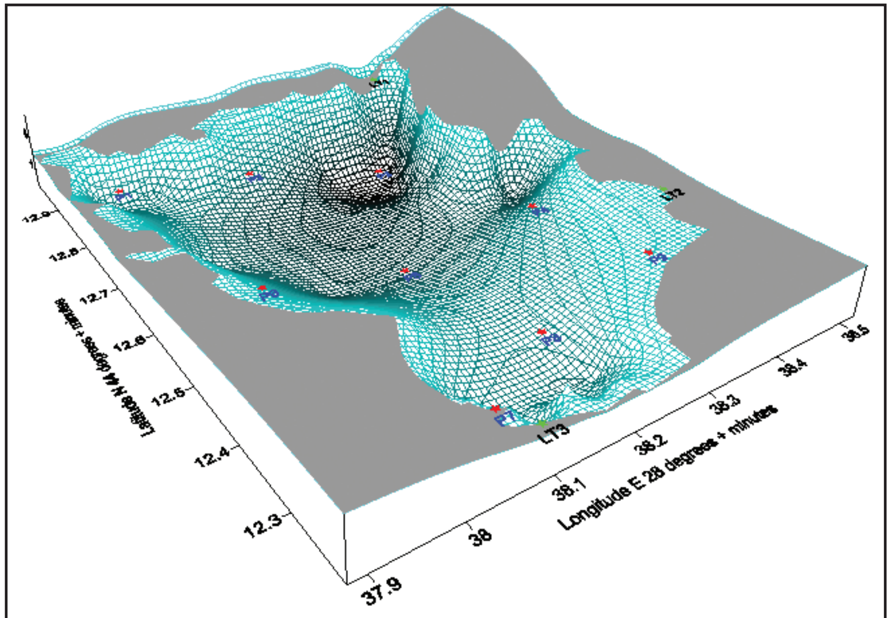


Fig. 7b Distribution of the Kurtosis coefficient parameter in the sediments of Tabcarie Lake, 1993.



Sampling location placement depending of the depth of Tabacarie Lake, 1993.

Table 2. The chemical composition of sediments in Tabacarie Lake

Sample Parameter	P1	P3	P5	P7	P9
$CaCO_3$, %	18,43	20,53	16,55	30,04	18,13
Fe_2O_3, %	4,62	4,70	5,12	3,69	4,79
TiO_2, %	0,64	0,64	0,61	0,39	0,70
MnO_2, %	0,076	0,086	0,089	0,063	0,083
Ni, ppm	65	64	76	41	68
Co, ppm	10	14	16	11	10
Ba, ppm	398	339	430	512	468
Sr, ppm	412	326	352	343	289
Cu, ppm	89	47	115	380	90
Pb, ppm	75	44	92	376	74
Zn, ppm	743	307	894	788	808
Cd, ppm	1,16	0,95	0,57	1,20	0,80
Cr, ppm	98	85	102	128	112
Zr, ppm	185	176	153	136	186
V, ppm	82	93	77	42	62

Table 3. Statistical parameters of samples analysis

Parameter	X_{min}	X_{max}	X	S	C_v %
$CaCO_3$, %	16,55	30,04	20,74	5,39	26,00
Fe_2O_3, %	3,69	5,12	4,58	0,54	11,67
TiO_2, %	0,39	0,70	0,60	0,12	20,13
MnO_2, %	0,063	0,089	0,0794	0,0104	13,10
Ni, ppm	41	76	62,8	13,1	20,8
Co, ppm	10	16	12,2	2,7	22,0
Ba, ppm	339	512	429,4	66,1	15,4
Sr, ppm	289	412	344,4	44,8	13,0
Cu, ppm	47	380	144,2	134,1	93,0
Pb, ppm	44	376	132,2	122,9	93,0
Zn, ppm	307	894	708	230,8	32,6
Cd, ppm	0,570	1,200	0,936	0,261	27,88
Cr, ppm	85	128	105	16,1	15,33
Zr, ppm	136	186	167,2	21,9	13,11
V, ppm	42	93	71,2	19,8	27,76

The main parameters of the component distribution's statistical analysis are presented in Table 3, where:

Xmin = component minimum concentration

Xmax = component maximum concentration

X = component mean concentration

S = standard deviation of concentrations

Cv = concentrations' coefficient of variation, C_v = 100 S/X

The values of the variation coefficients recorded for Fe_2O_3, MnO, Sr, Cr, Zr and, in a lesser measure, for TiO_2 and Ni, indicate the compositional uniformity of the upper sediments covering the lake bottom. The slightly higher $CaCO_3$ variation coefficient may be connected to the high natural variability of the biological activity (Fig. 8).

For the other elements (Cu, Pb, Zn, Cd, V), the high coefficients of variation indicate the existence of perturbing phenomena; most likely a massive technogenic influx is affecting the concentrations of these elements in the sediments, with notable effects in Cu (Cv = 92.97 %) and Pb (Cv = 92.95 %) amounts.

The extremely high values of the Cu and Pb variation coefficients are the consequence of very high local concentrations, pinpointing their main source, the urban storm water runoff pipe, situated in the south-western extremity of the lake (Fig. 9).

The localisation of the high concentrations can be explained by the particular affinity of Pb and Cu for organic and clayey detritic material, on whose surface they fasten rapidly through adsorption processes. The decrease of the transport speed and the physical-chemical parameters (pH, Eh, etc.) change at the lake entrance favor a massive accumulation of terrigenous material close to the entrance point. Meanwhile, the Pb and Cu quantities entering the lake in solution, are rapidly adsorbed by the sediments; only a small part of the total quantity diffuses in the lake waters to be captured by the sediments from other areas. The two processes (the accumulation of detritic material and the adsorption at the water-sediment interface) determine the localization of the high concentrations of the two elements in the sediments from the access point zone, precisely identifying the entrance.

High concentrations of Ba (Fig. 10), Cd and V were also measured here, but the variation coefficients these elements are significantly lower.

Although Zn concentrations in sediments were very high, they were a lot more homogenous, varying between 750 and 900 µg/g, with the exception of the area through which the lake waters discharge into the sea.

The uniformity of Zn concentrations might be the result of either a similar Zn input through all the water feeding points of the lake, or to its introduction through one or more access ways, predominantly in dissolved form. The zinc great mobility and its long residence time in the water determine a homogenous dispersion of zinc in the lake waters, before it sinks into the sediments. The presence of Zn maximum concentrations in the central zone of the lake characterizes a slow circulation of lake waters. The explanation is also valid for the rather homogenous distributions of Cd and V, previously mentioned.

However, the sample analyses reveal that Ni, Cr and Zn exceed in all, or almost all, the analyzed samples, the concentration levels of probable biological effects (PEL) for freshwater sediments (Buchman, 1999) – Ni_{PEL}=35.9 µg/g, Cr_{PEL}=90 g/g, Zn_{PEL}=315 µg/g. Despite this, considering the low relative pollution indices (Föstner and Müller,1973), and especially the high natural background concentrations typical for Ni and Cr, it is unlikely that their high concentrations are the result of anthropogenic influences. This is not the case of Zn, whose concentrations exceed 3-8 times the concentrations of the natural geochemical background.

For Cu, Pb and Cd, the PEL concentration levels are exceeded, either occasionally (Cu, Pb), or not at all (Cd). For Cu and Pb, PEL is exceeded in the sample from station P7, where the concentrations are one order of magnitude higher than PEL (PEL_{Cu} = 197 µg/g, PEL_{Pb} = 91.3 µg/g).

In all samples, the concentrations above which biological effects may appear (threshold effects level – TEL – Buchman, 1999) are exceeded by all three elements (Cu_{TEL}=35.7 µg/g, Pb_{TEL}=35.0 µg/g, Cd_{TEL}=0.596 µg/g). Since they are characterized by high relative pollution indices and relatively low geochemical backgrounds, it is possible to consider that a good part of their total concentration of the three metals is the result of substantial anthropogenic inputs.

The presented data indicate that the Tabacarie lake is the subject of significant technogenic influences, affecting the heavy metal content of the sediments, some of them, such as Cu, Pb and Zn, being highly toxic. The main source of these elements is represented by the pluvial discharge located in the South-Western extremity of the lake

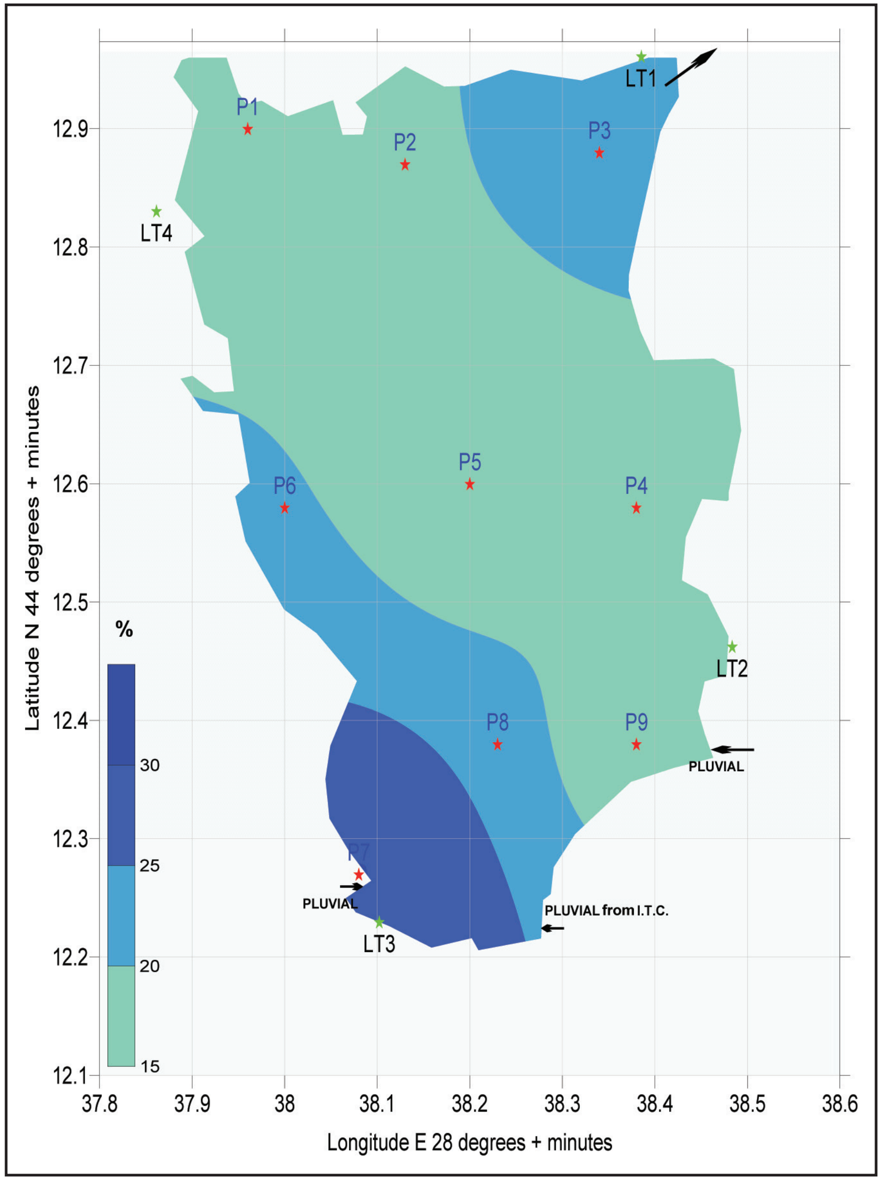


Fig. 8 Distribution of Calcium carbonate content in the sediments of Tabcarie Lake, 1993.

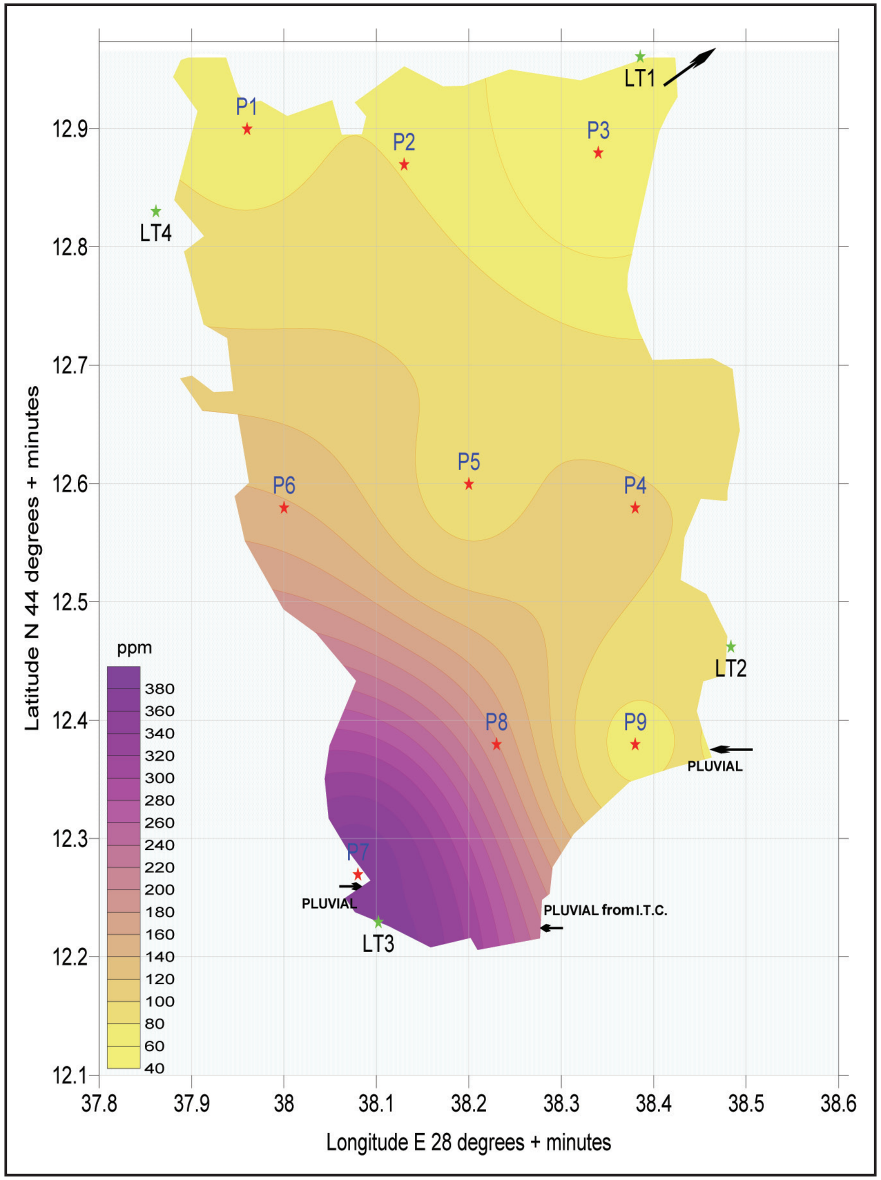


Fig. 9 Distribution of Pb content (similar of Cu) in the sediments of Tabcarie Lake, 1993.

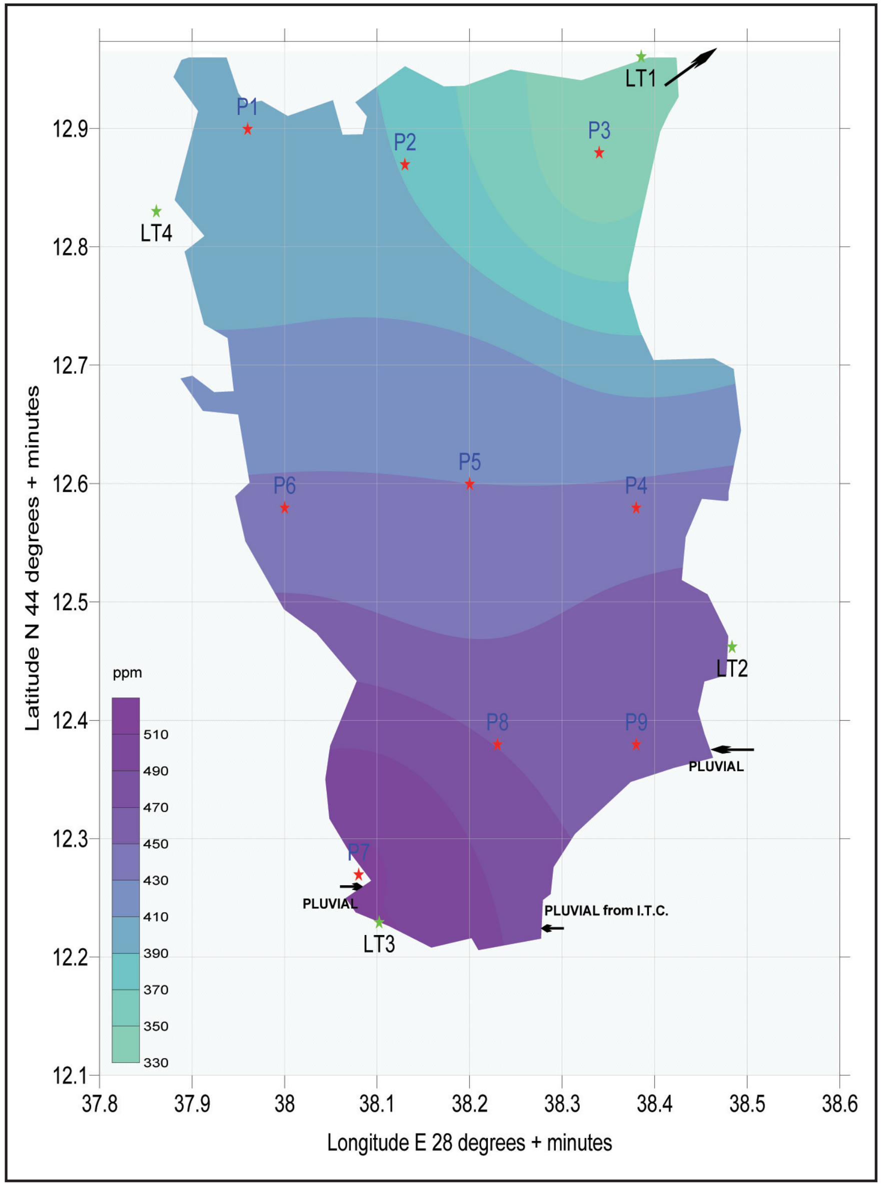


Fig. 10 Distribution of Ba content in the sediments of Tabcarie Lake, 1993.

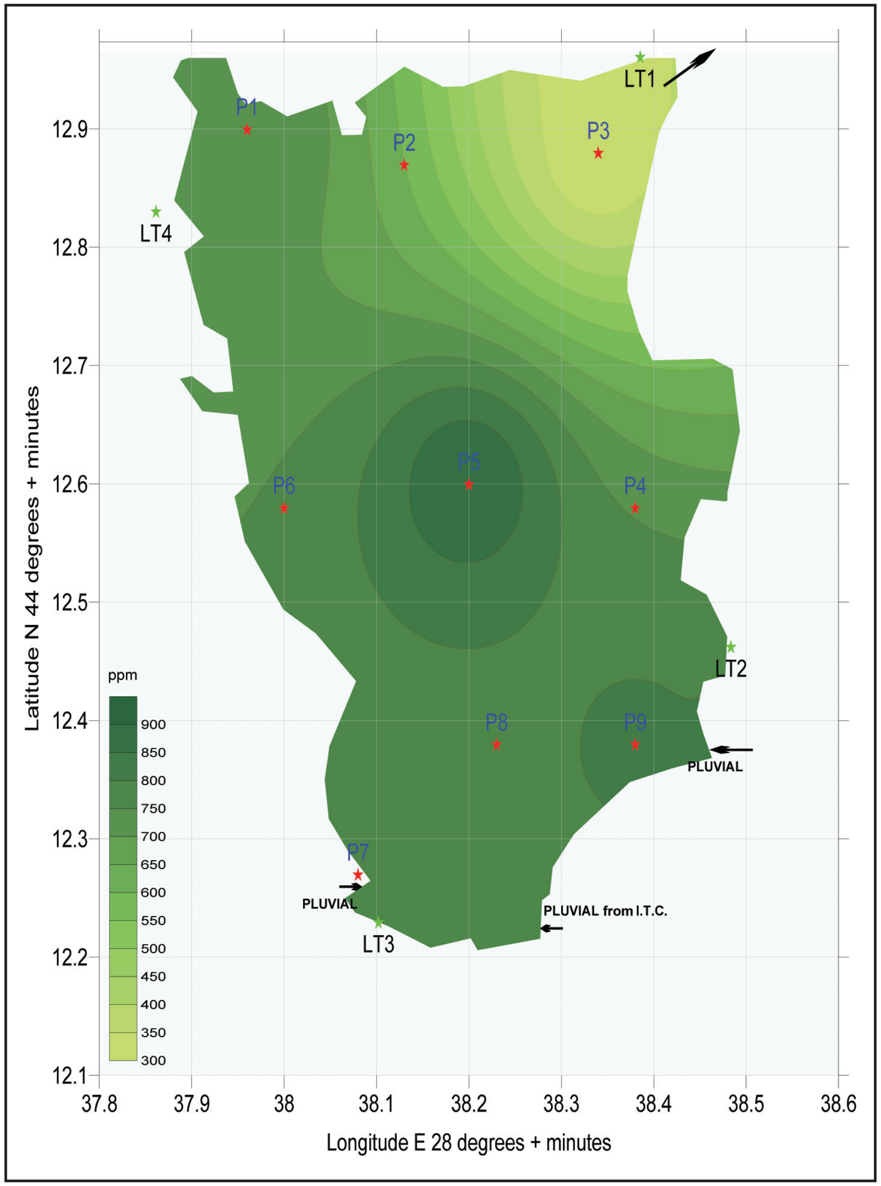


Fig. 11 Distribution of Zn content in the sediments of Tabcarie Lake, 1993.

REFERENCES

Black C. A., 1965. Methods of Soil Analysis – American Society of Agronomy, Monograph , Madison, Wisconsin, 1572 p.

Buchman M. F., 1999. NOAA screening quick reference tables – NOAA HAZMAT report 99-1, Seattle WA, Coastal protection and Restoration Division, National Oceanic and Atmospheric Administration, 12 p.

Caraivan Gl., Secrieru D., 1993. Geographical, geomorphologic and geological study of Lake Tabacarie (Constanta county): study phase, CCTE Archive.

Caraivan Gl., 1993. Sedimentological studies of Mamaia Lake and assessment of the Mamaia village sands exploitation possibilities, archive CCTE Archive.

Föstner U., Müler G., 1973. Heavy metal accumulation in river sediments, a response to environmental pollution. Geoforum V. 14, p. 53–62.

Shepard F.P., 1954. Nomenclature based on sand-silt-clay ratios – Journal of Sedimentary Petrology, V. 24, p. 151-158.

Shepard, F.P., 1954. Nomenclature based on sand-silt-clay ratios – *Journal of Sedimentary Petrology*, V. 24, p. 151-158.