THE LAKES OF THE ROMANIAN BLACK SEA COAST. MAN-INDUCED CHANGES, WATER REGIME, PRESENT STATE

PETRE GÂŞTESCU*, PETRE BREŢCAN**, DACIAN CONSTANTIN TEODORESCU***

Key-words: Black Sea coast lakes, man-induced, water regime, present state.

Abstract. Unlike other regions in Romania, lakes in Dobrogea are marginally positioned – closely connected to the presence of the Danube and the Black Sea. This characteristic/position is the result of paleogeographical evolution in the Quaternary and the current climatic conditions in Dobrogea. The paleogeographical evolution in the Quaternary resulted in the formation of several depressions at the edges of dry land, where fresh and salt/sea water accumulated. The lakes on the Romanian coast line are grouped into two types of genetic depressions, a fact partially reflected in their hydrological and physical-chemical properties – *fluvial-marine limans and marine lagoons*. Regarding *limans*, we would mention the largest one – *Babadag*, grafted into the valley of the two Northern Dobrogea rivers, Taiţa and Teliţa, situated on the western side of the *Razim-Sinoie lagoon* (the largest lacustrine complex in Romania); *Taşaul*, initially located at the mouth of the Casimcea River, flows into the Black Sea; *Techirghiol*, after the conflence of the two tributaries, Urlichioi (Derea) and Biruinţa; *Tatlageac*, at the end of the Dulceşti (Tatlageac) Valley, and *Mangalia*, in the Albeşti Valley. The most notable lagoon, by surface-area, is the *Razim-Sinoie lake complex*; *the Siutghiol Lake*, the old *Comorova Marsh* which drained, resulted in three recreational lakes – *Neptun, Cozia,* and *Jupiter*, as well as the *Herghelia-Mangalia Marsh.* In terms of drainage-basin size, underground water-sources, links to coastal marine waters, and the semiarid, temperate-continental climate of Dobrogea, the spectrum of the chemical composition-mineralisation gradient of lake water, in natural conditions, varied and still varies from *fresh, brackish, salty and hypersalty water*. Man-induced changes of the lacustrine area, of drainage basins and of the links to coastal marine waters have resulted in significant structural modifications of the lacustrine ecosystems, in terms of use.

1. GENERAL CONSIDERATIONS

Background of research. During the first half of the 20th century, significant researches were conducted on a number of littoral lakes: Mangalia (Brătescu, 1915), Techirghiol (Pascu, 1900; Bujor, 1900; Mihăilescu, 1928; Mrazec, Sturza, 1932; Ţuculescu, 1965), Siutghiol (Lepşi, 1933), Taşaul (Brătescu, 1922), and Razim (Brăileanu, 1938; Zemiankovski, 1951; Murgoci, 1912).

During the second half of the 20th century, numerous research-works on the littoral lakes focused on different issues, such as: *the relations between the sea level variations and the genesis of the lacustrine depressions* (Blehu, 1962; Banu, 1964; Coteţ, 1970; Panin, 1983; Vespremeanu *et al.*, 2004); *the present morphobathymetric configuration* which has triggered changes in the hydrological, hydrochemical and hydrobiological regime, and consequently in the lacustrine ecosystems, with impact on their use (Gâştescu, 1971, 1998; Gâştescu, Breier, 1976, 1982; Gâştescu, Nicolae, 1981; Witzel *et al.*, 1964; Bondar, 1970; Nicolae, 1969; Breier, 1976; Romanescu 2006; Breţcan, 2007; etc.).

* Professor, Institute of Geography, Romanian Academy, D. Racoviţă Str., 12, RO-123993 Bucharest 20, gastescu_petre@yahoo.com.

** Lecturer, Valahia University of Târgovişte, Department of Geography, Str. Lt. Stancu Ion, no. 34-36, 130024, Târgovişte, Dâmboviţa, tel: (04) 0245206105, Romania, petrebretcan@yahoo.com.

*** Hydrologist engineer, Dobrogea-litoral Water Basin Administration, Bd. Mircea cel Bătrân, 127 Constanţa, Romania, tdacian@gmail.com.

Rev. Roum. Géogr./Rom. Journ. Geogr., **60**, (1), p. 27–42, 2016, Bucureşti.

Geographical position of the lakes. The marginal position of lakes in Dobrogea, related to the Danube and to the Black Sea (Pontus Euxinus), is the result of paleogeographical evolution during the Quaternary, while their hydrological features have been shaped by the present climatic conditions. On the sea coast eastern side, one can find several important lakes having various hydrochemical features and uses (Fig.1).

The Western-Dobrogea coast of the Black Sea is an area inhabited since the Antiquity, a fact proven by the *ruins of fortified cities* (Calatis-Mangalia, Tomis-Constanţa, Histria-Sinoie, Argamum-Doloşman, and Heracleea-Razim) (Fig. 1).

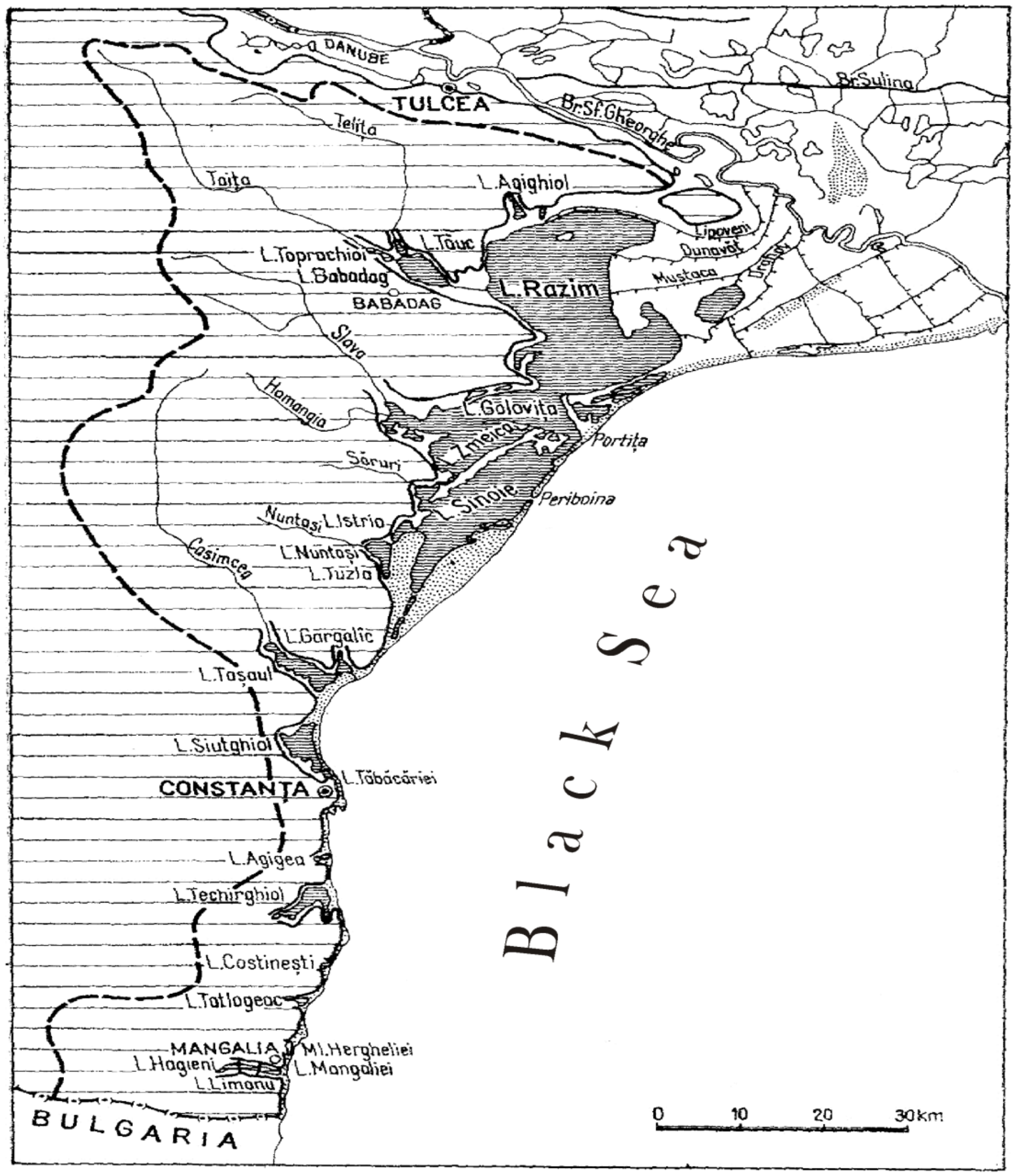

Fig. 1 – Lakes on the Romanian Black Sea coast.

Paleogeographical evolution. During the Quaternary, when liman and lagoon depressions were being formed, the Romanian sea coast and the Black Sea itself aroused the interest of several Romanian and foreign researchers.

By correlating and synthetizing research conclusions, one can see that the Romanian sea coast (which includes *the Danubian liman*, currently the Danube Delta and the *Halmyris Gulf*, occupied by the Razim-Sinoie lacustrine complex), was affected by *three main Black Sea stages* in the Holocene-Quaternary: first stage – *the Flandrian transgression* – Feodorov, 1961); the *Neolithic transgression* (Banu, 1964); and the *Dobrogean transgression* (Coteţ, 1970), the sea level at that time being 3-to-5 m above the present zero-meter one; the second stage – the *Fanagorian, Dacian and Histrian transgressian*, sea level 1-to-5 m below the present one (from the: 7th–6th cc BC to 5th–6th cc/AD); the third stage – *Nimphean, Walachian, Razim transgression*, sea level returned to the current one and the shore separate the present limans and lagoons emerged (the second and third stages are named as such by the above authors – Feodorov, Banu, and Coteţ) (Fig. 2).

Morphological types of lacustrine depressions. In terms of genesis, the lakes of the Romanian sea coast belong *to two categories of depressions*, partially reflected also in their hydro-and-physical-chemical features: *fluvial-marine limans* and *marine lagoons*. Among the *fluvial-marine limans,* the largest one is *Babadag*, situated in the north of Dobrogea, at the western margin of the Razim-Sinoie Lagoon; *Taşaul* at the mouth of the Casimcea River, which once used to flow into the Black Sea; *Techirghiol* after its two tributaries – Urlichioi (Derea) and Biruinţa confluenced; *Tatlageac* at the end point of the Dulceşti Valley (Tatlageac); *Mangalia* along the Albeşti Valley. Quite an impressive *lagoon area,* is the *Razim-Sinoie lacustrine complex***,** occupies the ancient Halmirys Gulf; *Siutghiol Lake*, a *marine lagoon***;** worth mentioning, are also the ancient *Comorova Marsh* (which, drying up, led to the formation of three leisure lakes – Neptun, Cozia, and Jupiter) and the *Herghelia-Mangalia Marsh* (Table 1).

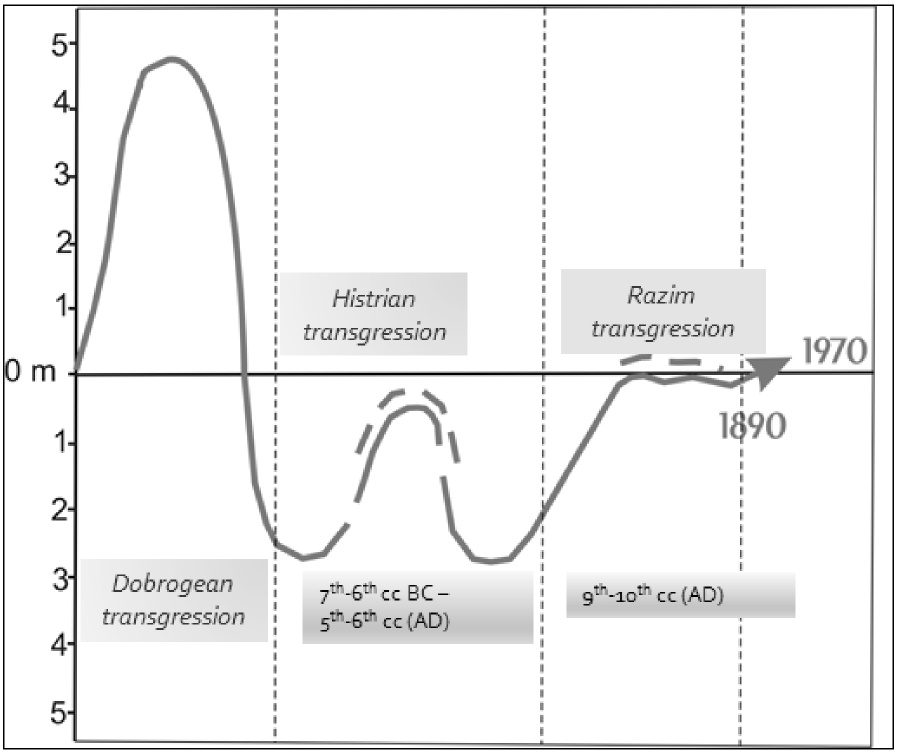

Fig. 2 – The Romanian Black Sea evolution during the Holocene-Quaternary (Coteţ, 1970).

Table 1

The morphohydrographical features of the littoral lakes (Gâştescu, Breier, 1976)

Lake	Genetic types	Altitude (m)	Surface-area (km^2)	Volume (mil.m^3)	Maximum depth (m)	Average depth (m)
Razim -Sinoie	lacustrine complex	0.50	867.7	1440.71	3.5	1.67
Taşaul	liman	1.24	23.35	57.0	3.75	2.40
Gargalâc	liman	0.9	5.20	7.2	1.9	1.40
Siutghiol	lagoon	2.16	19.60	88.7	17.05	4.65
Tăbăcăriei	liman	1.25	0.99	2.1	6.15	2.15
Agigea	liman	0.83	0.60/0.35	0.26	0.7	0.40
Techirghiol	liman	-1.5/1.5	11.61	41.8	9.75	3.60
Costineşti	liman	0.25	0.07	0.02	0.35	0.25
Tatlageac	liman	0.94	1.40	21.5	2.5	1.58
Mangalia	liman	0	3.10	15.7	13.0	6.0
Limanu	pond	4.4	0.52	0.6	2.5	1.1

Present climatic and water features. Low precipitation *(X)* (under 400 mm/year), high evaporation *(Z)* (850-900 mm/year), the accumulation of precipitation waters in the liman *and lagoon* depressions is insufficient to ensure a constant water balance *(X=Z)* and, the formation/persistance of lakes. However, under natural conditions, the presence of the Romanian coastal lakes is due to underground discharge *(U1)*, connections with the marine coastal waters *(Y2)* and the contributions of individual drainage basins *(Y1)*. Therefore, the result is a water balance deficit or surplus, according to the balance equation $(X + Y1 + U1) - (Z + Y2) = \pm \Delta V$.

Under the present local and regional geographical conditions, the water balance structure has changed due to anthropic activities and economic interests.

Chemical charactersistics. The chemical make-up ranges from *fresh water* (Siutghiol), *brackish water* (Sinoie)**,** and *salty water* (Nuntaşi) to *hypersalty water* (Techirghiol), in correlation with drainage-basin size, underground water sources, and connections with the marine coastal waters, against the background of the semiarid temperate-continental climate of Dobrogea.

2. MAN-INDUCED CHANGES IN THE MORPHOHYDROGRAPHICAL FEATURES OF LAKES

The anthropic interventions on the lake pattern, the drainage basins and the connections with the marine coastal waters have significantly changed the *structure and use of the lacustrine ecosystems* (Mangalia, Tatlageac, Techirghiol, Agigea, Siutghiol, Taşaul, and Razim).

Mangalia Lake occupied a 40 m-wide sinewy valley, modified by abrasion, If had a low chemical concentration (3.96‰ in 1906, 1.6‰ in 1933), being influenced by drainage-basin waters (784 km^2) and underground waters. Since 1953, the cutting of the offshore bar led to the formation of three lakes – *Mangalia*, turned into a marine gulf, while *Limanu* and *Hagieni* became fishery ponds; also the hydrological regime and the chemical concentration were essentially modified. Thus, in *Mangalia Lake*, which is connected to the sea waters, mineralization (15–16‰) and the hydrochemical type (chloro-sodic magnesium) are similar; on the other hand, *Limanu* and *Hagieni* lakes have low mineralizations (0.7–1.0‰), being of a bicarbonatted-sodic hydrochemical type, therefore with a tendency to fresh continental waters.

*Tatlagea*c *Lake* occupies the lower, sinewy and enlarged sector of the Dulceşti Valley, drainage basin 144 km^2, being separated from the sea waters by an offshore bar, 60–80 m wide and 2 m high, crossed by the Constanţa-Mangalia railway. Under natural conditions, the lake used to have an opening to the sea, but at present, the lake being used as fishery pond, the opening is under control.

Costineşti Lake, small-sized (0.07 km^2, drainage basin 21 km^2), with insignificant morphobathymetric features; the offshore bar (ca 500 m long and 100-150 m wide), which separates it from the sea, is an important beach used by the spa-and-health resort of Costineşti.

Agigea Lake, small-sized, situated south of Constanţa, along the homonymous valley (drainage basin 40 km^2) was separated from the sea by an offshore bar crossed by the Constanţa-Mangalia railway. The construction of the Danube-Black Sea Canal made the last branch to Constanţa-Agigea port go through Agigea Lake, thus reducing its surface-area to 0.35 km^2, affecting an important avifauna reserve and turning the lake into a fishery.

Taşaul Lake, linked to the sea, had formerly two estuaries: the first and the largest occupies a part of the lower Casimcea River sector (69 km long, drainage basin 740 km^2), the second, *Gargalâc Lake*, is situated along the Corbu Valley (7 km long; drainage basin 39 km^2). Both of these lacustrine depressions where much enlarged, first by marine abrasion and later by lacustrine abrasion; the opening to the marine water-bearing structure was dammed by an offshore bar, between Năvodari and Capul Midia.

Nearby these lakes, especially on the offshore bar, important changes have been triggered by the Poarta Albă/Basarabi-Capul Midia branch of the Danube-Black Sea Canal and the PETROMIDIA Refinery with its port. The Canal goes alongside the whole border of *Lake Taşaul*, is an offshore bar that ends up in areas where fluvial barges are moored. At the same time, the lakes are currently used as fisheries, and their opening to the sea is controlled in terms of level variation.

3. HYDROLOGICAL FEATURES

The hydrological features of the lakes have been highlighted and interpreted based on the data recorded by the network that monitors the hydrological parameters and the management of the littoral lakes (levels, precipitation, air and water temperature, evaporation, chemistry, waves) (Fig. 3, Table 2).

Table 2

The main hydrometric stations monitoring coastal lakes

Lake	Hydrometrical station	Surface-area (km^2)	Altitude of lake (RMNm)	Established in
Razim	Sarichioi	415.0	0.50	1956
Goloviţa	Jurilovca	118.7	0.50	1956
Istria	Nuntaşi	5.60	0.80	1979
Nuntaşi-Tuzla	Nuntaşi	10.50	0.78	1979
Taşaul	Luminiţa I	23,35	1.24	1956
Gargalâc/Corbu	Luminiţa II	5.20	0.90	1956
Siutghiol	Mamaia-Băi	19.60	2.16	1956
Tăbăcărie	Constanţa	0,99	1.25	1956
Techirghiol	Techirghiol	11.61	-1.5/1.5	1958

Water-level variation is an important parameter that reflects volume variation, however, it is seasonal and multiannual level variation, that reveals *the general tendency* of climatic factors.

Level variation also depends on the configuration of the lacustrine depression, the wind fetch, seiches on the larger aquatic surface (eg. Razim, Siutghiol lakes), or drainage-basin size, entailing high floods, etc. (Mangalia, Tatlageac, and Techirghiol lakes).

The analysis of water levels covered two different periods: 1967–2005 (Taşaul-Gargalâc, Siutghiol-Tăbăcărie, and Techirghiol); 1979-2005 (Istria, and Nuntaşi). One can note that the average levels in the analysed period are situated 260 cm above the "0" level (Fig. 3).

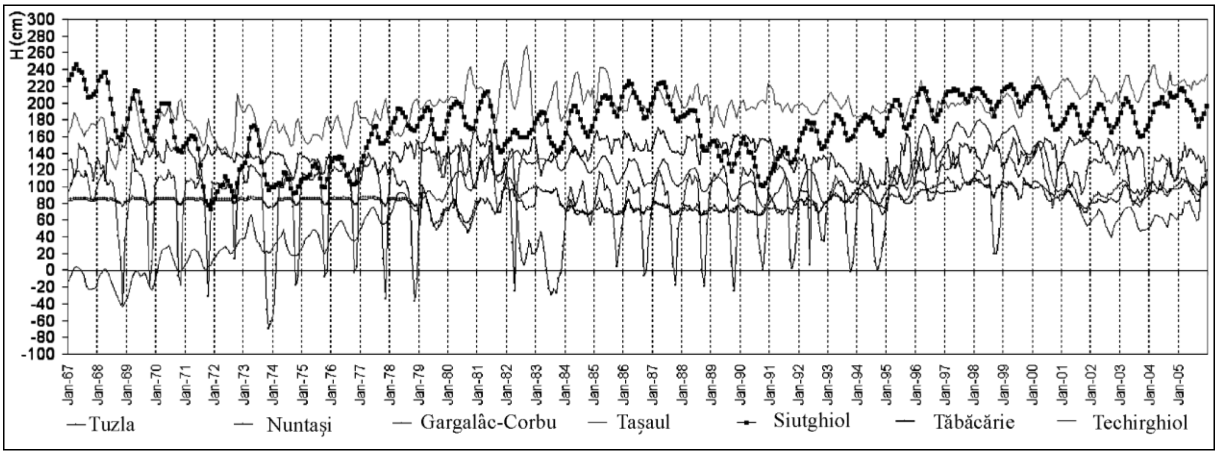

Fig. 3 – Water-level variation.

The multiannual lake-level variation showed a slightly increasing tendency, except for Techirghiol Lake, which kept decreasing after the year 2000.

In the case of the three lakes studied, the most significant level variations were due to direct (Siutghiol and Razim) and *indirect* (Techighiol) anthropic interventions.

4. CASE-STUDIES

Given the man-induced lakes changes, as well as the existing hydrometric data and their importance, our *case-studies* focused on the hydrological parameters of *Techirghiol* and *Siutghiol lakes* and the *Razim-Sinoie lacustrine complex.*

4.1. The Techirghiol Lake

Lake Techirghiol (11.6 km^2, max. depth 9.75 m, area drainage basin 165 km^2 and underground drainage basin 350 km^2) is the most important fluvio-marine liman, separated from the sea by a 200 m-wide and 2,000 m-wide alluvial bank,used as a beach, between Eforie Nord and Eforie Sud. It has come to occupy a much larger depression, initially through karst and marine abrasion processes, and later on lacustrine abrasion processes.

The Techirghiol Lake is a model of semiarid climatic conditions (high evaporation compared to reduced precipitation, isolated drainage basin without any outlet) and of *level variation, hydrological balance and salinity.*

Its level varied from -1.50 m to "0" m in 1909 and to +1.70 m in 1997–1998, followed by a decreasing tendency down to 0.60 m in 2010.

The dramatic level increase of the Techirghsiol Lake was triggered solely by the irrigation systems, which began functioning in the early 1960,s , their influence on the water balance through input on ground and underground basins was started being felt in the 1970s (Fig. 4).

Analyzing the basic water-balance components over 1967–2005 its structure under natural conditions was:

$$(X + Y1 + U1) - (Z + Ii) = \pm \Delta V,$$

where: *X*, rainfall on the lake; *Y1***,** surface runoff influenced by the irrigation system; *U1*, underground discharge; *Z*, evaporation; *Ii*, infiltration from the lake via the offshore bar; $\pm\Delta V$, volume difference.

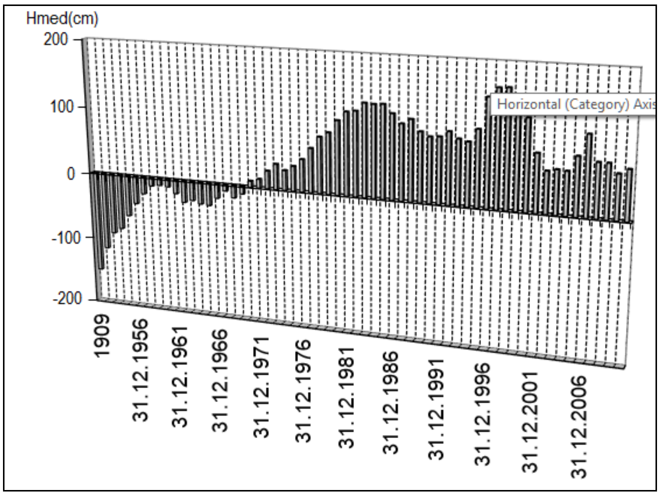

Fig. 4 – The Techirghiol Lake water level variation (1909-2010).

Insofar as the analysed period is concerned, one can notice some extreme values: *precipitation* (*X*) between *225 mm – 1976* and *889 mm – 2005*; *evaporation (Z)* between *587 mm – 1985* and *972 mm – 1971*; therefore *X < Z.*

Yet, during this period, the values recorded in 2005 were *X = 889 mm* and *Z=734 mm*, therefore *X>Z***,** which means an exceptional situation in the specific conditions of Dobrogea.

The influence of the irrigation systems significantly modified the water balance structure:

$$(X+ Y1+U1) – (Z+Ip+Ii) = \pm \Delta V.$$

To diminish the fresh water level in the lake, both via (*Y1)* and (*U1*), the procedure used was the evacuation of significant water volumes by pumping them to the sea and to Constanţa City (*Ip*) (Fig. 5).

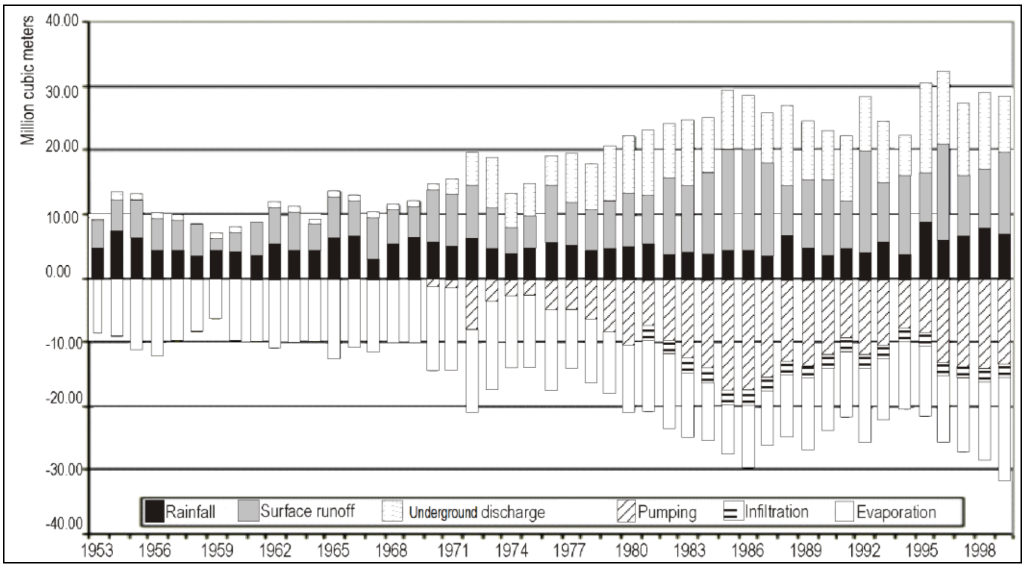

Fig. 5 – The Techirghiol Lake water balance over 1953-1999.

As a consequence, the water volume increased from 57.5 mill. m^3 in 1967 to 80.5 mill.m^3 in 1998, determining a *salinity decrease* from 81.5 ‰ in 1969 to 55.0 ‰ in 2000 that affected the normal genesis conditions of therapeutic mud (peloid), of and the balneo-therapeutic quality of the water (Trică, 1977) (Figs 6, 7).

The relation between lake-level increase and salinity decrease is: $Y = 0.4652 + 108.81$ and $R^2 = 0.5818$.

Beside lower salinity values, the Techirghiol Lake level increase, led to: the flooding of Eforie Sud and Techirghiol spa resorts located on the side of the lake; landslides and bank erosion, especially on the left /southern bank; deterioration of the hygrophile vegetation on the left/northern bank caused by higher water levels.

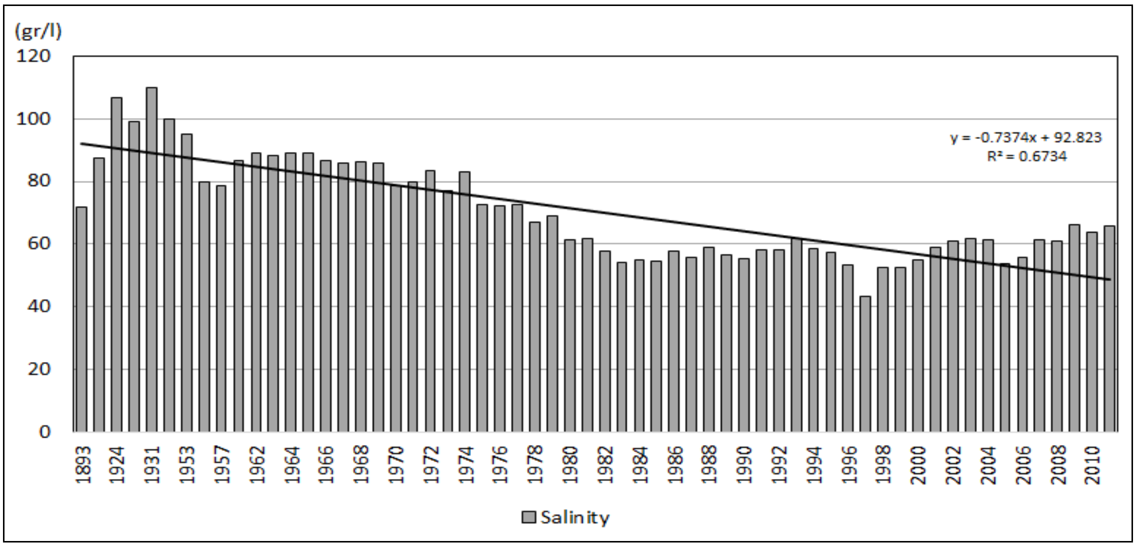

Fig. 6 – Salinity in the Techirghiol Lake (1893–2010).

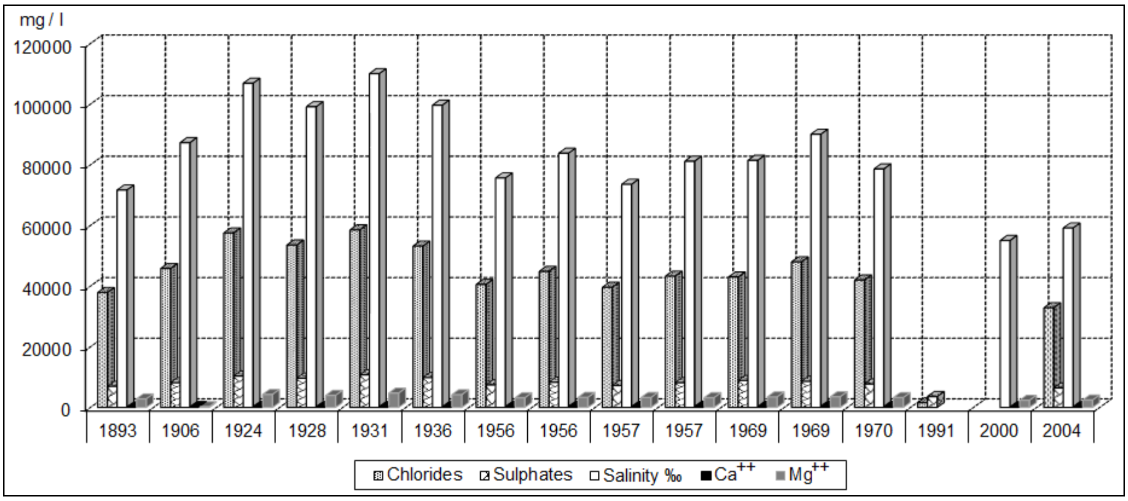

Fig. 7 – The Techirghiol Lake – hydrochemical structure.

The measures taken to diminish the excessive fresh-water intake in the lake by surface runoff *(Y1)* and underground discharge *(U1)*: drillinigs in the drainage basin to pump out the underground water surplus, drains to collect the fresh water in the Urlichioi and Biruinţa Valleys, draining the water towards the Tatlageac Valley; drills around the lake for catching, collecting and pumping the underground intake; building two dams to hold the fresh waters – one at the tail of the lake on the Biruinţa Tributary and another on the Tuzla Gulf; a drainage canal from the lake to the sea via the offshore bar, as a preventive measure in case the water level might rise and affect the facilities between Eforie Nord and Eforie Sud (Fig. 8).

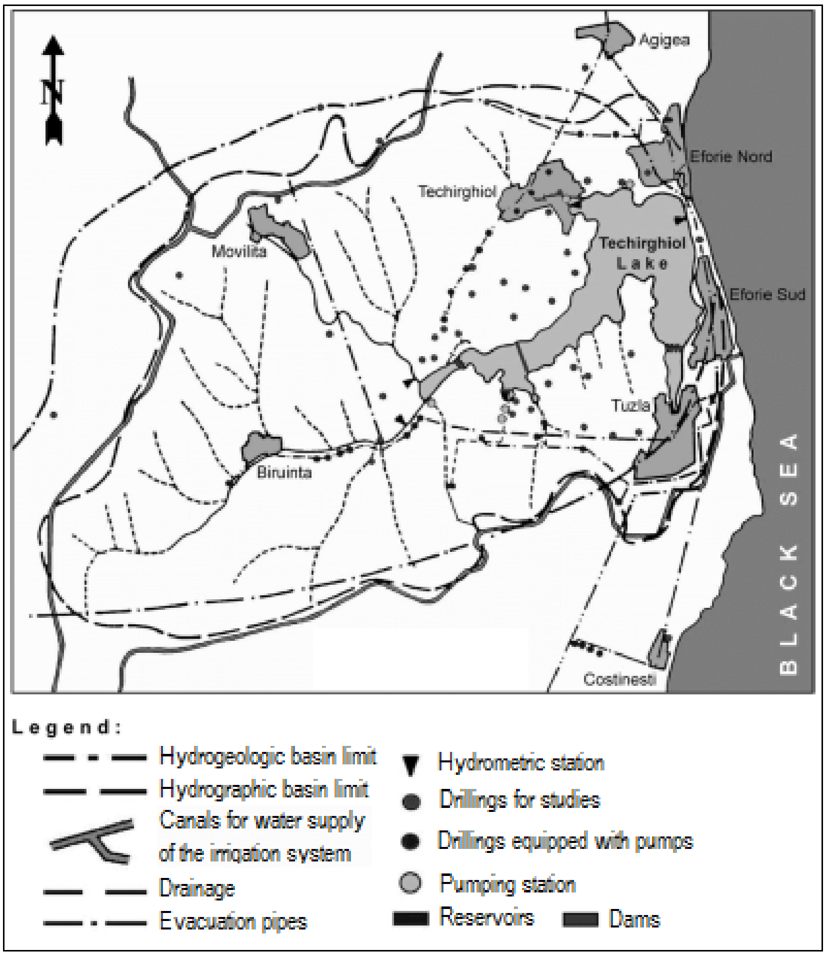

Fig. 8 – Hydrographic basin of the Techirghiol Lake.

4.2. The Siutghiol Lake

The Siutghiol Lake depression, a marine mini-lagoon, emerged in the wake of the Capidava-Ovidiu fault, which separates the Jurassic limes from the Cretaceous limes, affected by karst processes and favouring a significant underground water supply from submerged springs, determining the water-balance structure, the waters being usually in excess and fresh.

The lake is separated from the Black Sea by an offshore bar made up of fine sands, 300 to 600 m wide and about 15 km long, between Constanţa City and Mamaia (village), where Mamaia spa-and-health resort has developed (Gâştescu, 1971).

The Siutghiol Lake, which covers 19.6 km^2, maximum depth 17.15 m, is situated in one of the karst dolines present on the almost plain bottom at an average depth of 4.6 m. In the lake area stands Ovidiu Island – close to the homonymous town. This abrasion witness, made up of Jurassic limestone, covers a 2.6 ha area of reaches (max. 5 m high). It represents a complementary tourist objective for those who visit Mamaia resort (Fig. 9).

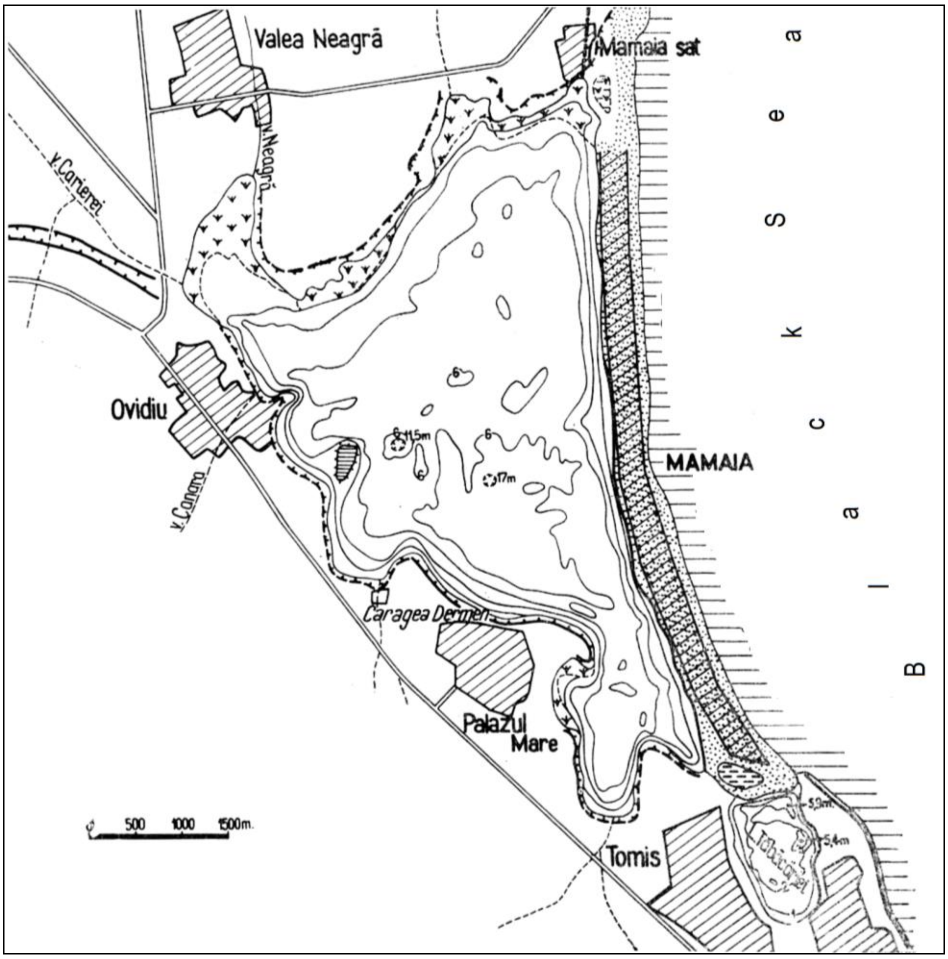

Fig. 9 – The Siutghiol Lake-bathymetric map (Gâştescu, 1971).

Due to the underground discharge via numerous submerged springs, the water balance is above zero and the multiannual average level around 2 m, determines the drainage towards the Black Sea via the Tăbăcărie Lake (Fig. 10).

In natural regime, the water balance has the following structure:

$$(Y1 + X + U1) - (Z + Y2 + Ii) = \pm \Delta V$$

where: ***Y2,*** discharge into the Black Sea; *Ii* seaward infiltration through the offshore bar.

In the 1967–2005 period, these two fundamental components registered the following values: *X* = 386 mm and *Z* = 844 mm with significant variations (*X* between 214 mm in 1983 and 692 mm in 2004; *Z* between 625 mm in 1985 and 1,015 mm in 1970).

The compensation of the water deficit, resulting from the values of components (*X)* and (*Z),* in the case of a small drainage basin (92 km^2), is due to the underground discharge *(U1)* and also discharge into the Black Sea *(Y2).*

Before anthropic interventions, underground supply *(U)* reached 89% of the values of water balance components (47.6 mill. m^3 in the hydrological year 1958–1959).

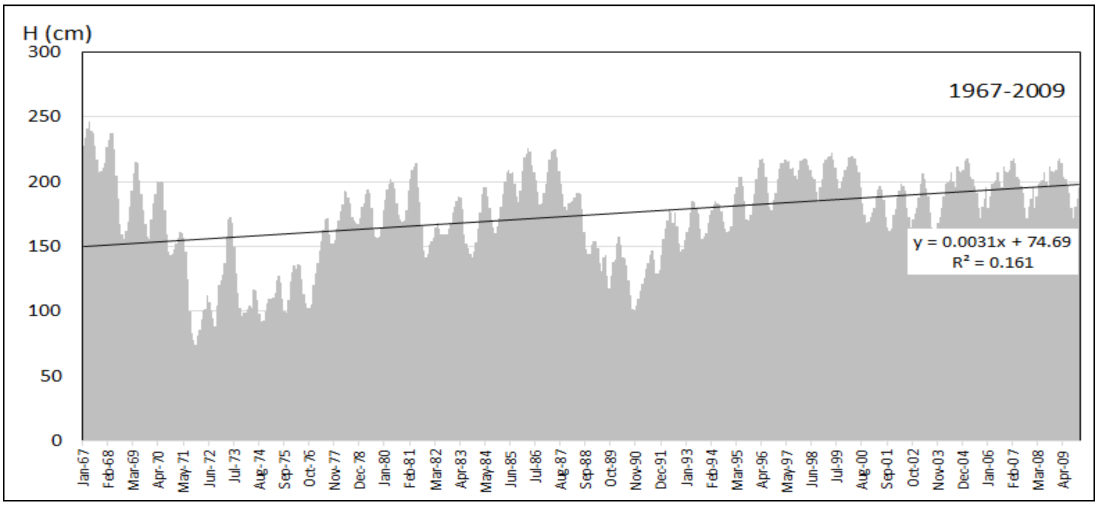

Fig. 10 – Water-level variation –Siutghiol Lake (1967–2009).

After 1970, the water supply of Constanţa City from underground sources (Caragea Dermen and Cişmea) reduced the volume of the underground component (*U1*) part of the water balance. Besides, water used to be taken directly from the lake for irrigation and for some industrial companies.

In this situation, the water balace structure equation was:

$$(X + Y1 + U1) - (Z + Y2 + Ii + C) = \pm \Delta V$$

where: *C* represents the water consumption / extractions from the lake.

The anthropic interventions triggered up to 1 m lake-level decrease, even cutting off discharge into the Black Sea *(Y2)*. In order to avoid the seaward infiltration through the offshore bar (*Ii*), jeopardising the quality of fresh lake water, all water extractions were forbidden (Fig. 11).

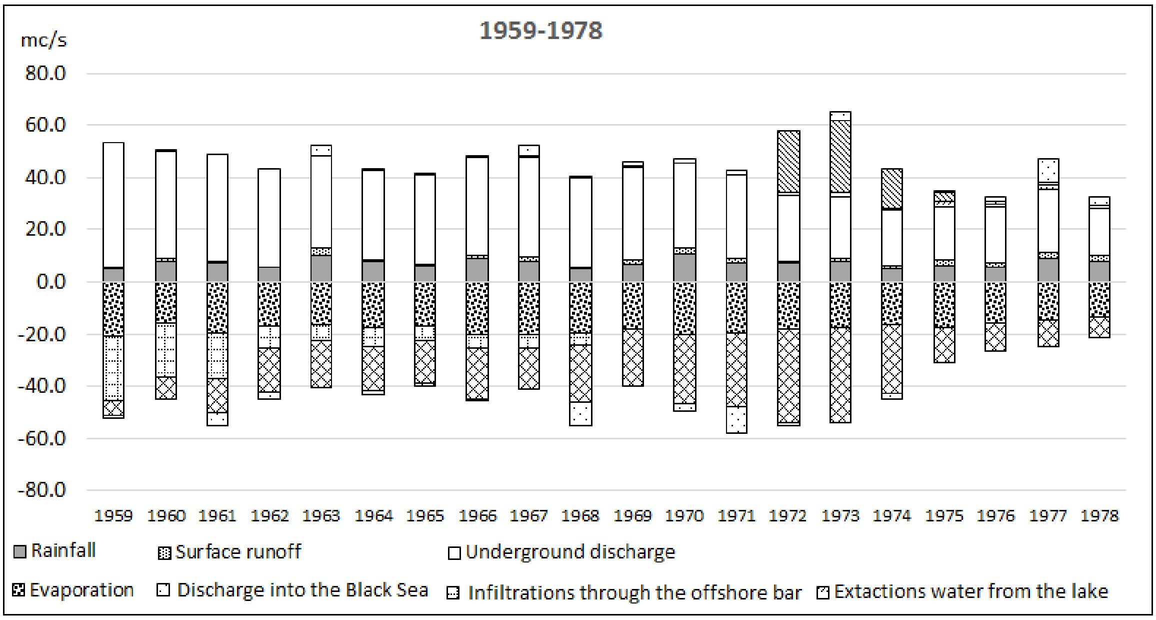

Fig. 11 – The Siutghiol Lake – water balance.

Due to the quantitative values of the water balance component, under both natural conditions and anthropic intervention, the Siutghiol Lake water was and remained fresh water, with under 1‰, mineralization, except for the years 1961–1963 when this threshold was slightly exceded, being of the bicarbonated sodium-magnesium towards the chlorinated sodium-magnesium type (Fig. 12).

This hydrochemical structure reflects a twofold influence: on the one hand, the dominantly underground water imput and, on the other hand, the reversible relation with the Black Sea via the offshore bar.

Having in view the morphobathymetric and hydrological features, as well as its geographical location near Constanţa City and Mamaia spa-and-health resort, the Siutghiol Lake is used mainly for nautical competitions and leisure sports, sporting fishing and amateur fishing (Gâştescu, Nicolae, 1981, Gâştescu, Breţcan, 2003).

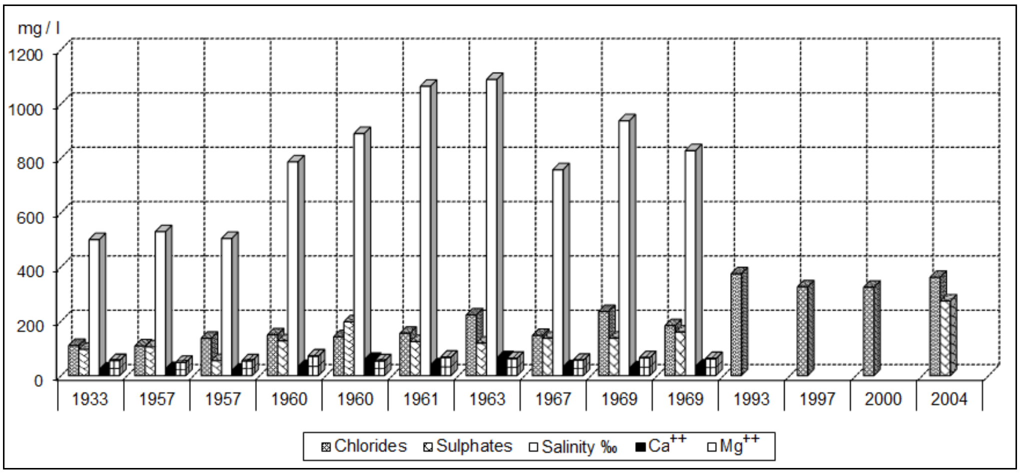

Fig. 12 – The Siutghiol Lake – hydrochemical structure.

4.3. The Razim-Sinoie lacustrine complex

The largest lacustrine complex on the Romanian sea coast and in this country (863.5 km^2), the Razim-Sinoie comlex includes several lakes: Razim (415 km^2), Sinoie (171.5 km^2), Goloviţa (118.7 km^2), Zmeica (54.6 km^2), Babadag (23.7 km^2), Nuntaşi-Tuzla (10.5 km^2), Istria (5.6 km^2) and a few more satellite lakes (Breier, 1976) (Fig. 13).

This complex occupies the former Halmyris Gulf, which started being gradually separated from the Black Sea about 2000 years ago. The hydronym Halmyris has been "borrowed" from the homonymous fortified city of the Antiquity, situated north of the Razim Lake area.

The lacustrine complex is separated from the Black Sea by a series of offshore bars, several of them fragile – Perişor, Periteasca, Periboina, while the largest one being Chituc; the western shore of the Razim Lake represents a *"fossil"* cliff of the former Halmyris Gulf.

The complex encompasses are three islands – Grădişte, Bisericuţa and Popina, the last one, which is also the largest, represents a 47 m-tall outlier of north-Dobrogea, whose steppe vegetation and fauna entitled it to being declared strictly protected area of the Danube Delta Biosphere Reserve.

The maximum depth of 3.5 m in the midst of the Razim Lake is the result of the clogging and closure of the Halmyris Gulf by the offshore bars, a situation that determined the abandonment of the *Greek city of Histria,* situated on a cape formed of green schists, on the border of Sinoie Lake, and which was inhabited between the 7th century B.C and the 5th century (AD) (Bleahu, 1962).

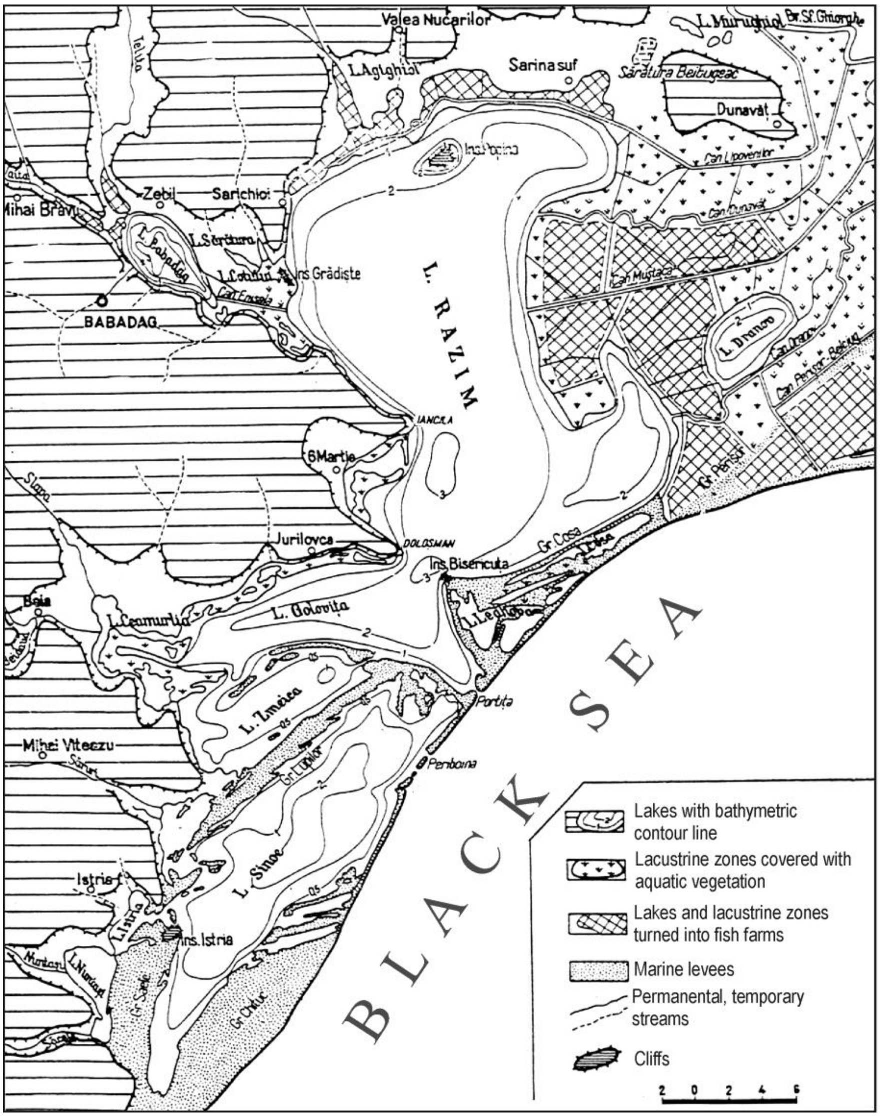

Fig. 13 – The Razim-Sinoie lacustrine complex.

To provide a solution to the water deficit, the Dunavăţ and Cerneţ backwaters were extended (in 1905, 1912 and 1933) by connecting the Dunavăţ and Dranov canals to the Sfântu Gheorghe Arm and the Razim Lake.

An important change in the Razim-Sinoie complex ecosystems took place 1970, when Gura Portiţei, the main connection with the sea, was dammed; the whole complex has only one connection through Periboina (Sinoie Lake).

When this lacustrine environment was in a natural state, that is, before human intervention, the lake complex was connected to the Black Sea through a breach in the marine levee, a kind of gateway (‘periboine’ and ‘portiţe’). A major link between the Black Sea and the Lake Razim was Gura Portiţei, which enabled very close permanent exchange between lake and sea levels.

The dam, built in 1970, destroyed the link, and Lake Razim remained a fresh water basin used for irrigation in the adjoining area. Irrigation water is supplied by the Danube through the Sfântu Gheorghe Arm.

These man-induced changes (water coming in from the Danube in the north- Lake Razim-and from the sea in the south-Lake Sinoie) have altered the mineralization, i.e. fresh water turning to brackish and saline in the more isolated lakes of the south (Nuntaşi-Tuzla).At the same time, the area was put to new uses, e.g. fish farming, irrigation, spa-and-tourism.

The *unmodified water balance model* over 1956-1970**:**

$X + Y1 + YD - Z - I2 = \pm \Delta V$, where: *X*, rainfall; *Y1*, surface runoff, ***YD*,** runoff from the Danube via canals; *Z* evaporation, *Y2* discharge into the Black Sea and $\pm \Delta V$ lacustrine complex water volume stocked or evacuated within a certain time interval (Fig. 14).

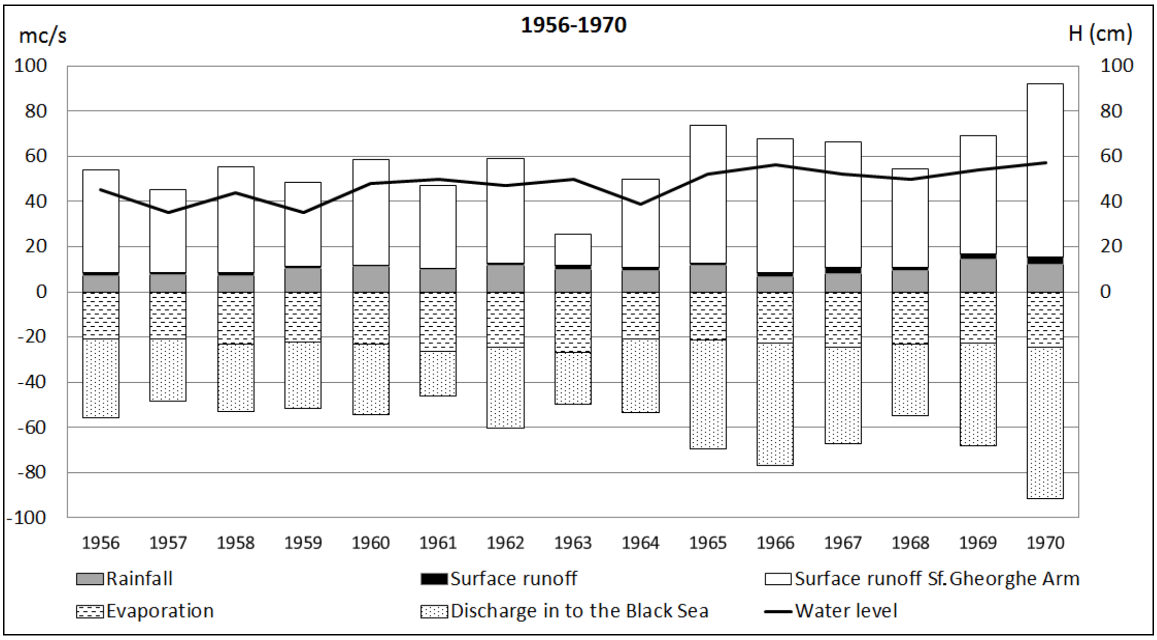

Fig. 14 – The unmodified water balance (1956–1970).

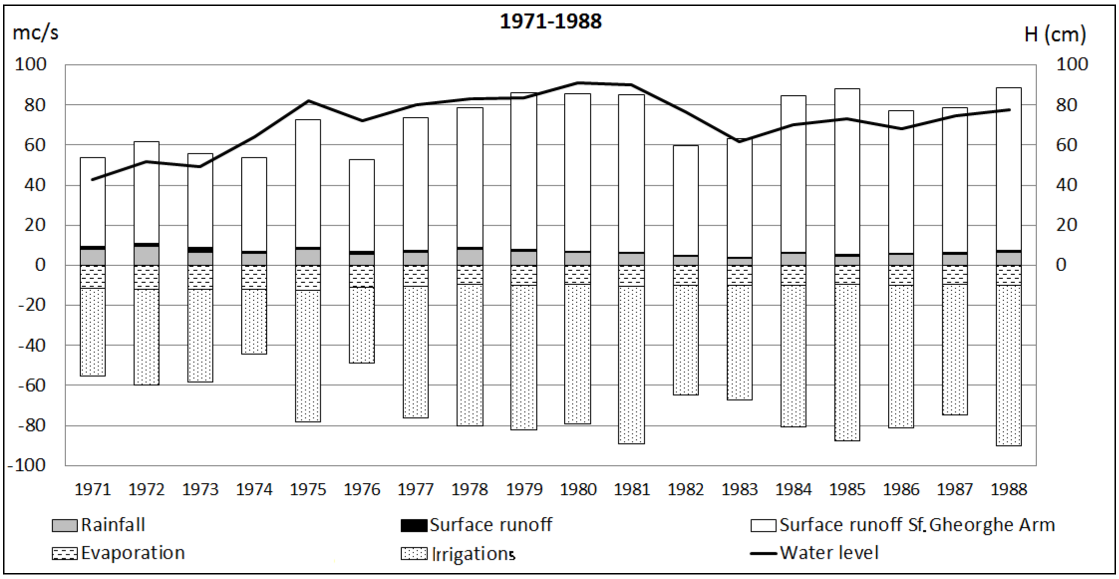

Fig. 15 – The modified water balance (1971–1988).

The *modified water balance model* over 1971–1988:

$$X + Y1 + YD - Z - IR - I2 = \pm \Delta V,$$

where: *IR* is the water volume for irrigation (Fig. 15).

The great diversity of the Razim-Sinoie lake complex ecosystem, as well as the vicinity of the Danube Delta, made the authorities declare the area a nature reserve in 1990- the *Danube Delta Biosphere Reserve*, which encompasses both geographical units.

5. CONCLUSIONS

- The geographical position of Dobrogea's coastal lakes is the result of paleogeographical evolution during the Quaternary, their hydrological features having been shaped by the present climatic conditions.
- In the present semiarid conditions – low precipitation *(X)* (under 400 mm/year), and high evaporation *(Z)* (850–900 mm/year), the accumulation of meteoric waters in the lacustrine depression is insufficient to ensure a constant water balance *(X=Z)*.
- The persistence of the Romanian coastal lakes is due especially to the underground discharge *(U1)*, their connections with the coastal waters *(Y2)* and the intake from individual drainage basins *(Y1)*.
- In harmony with drainage basin size, underground water sources, and coastal waters connections against the background of the semiarid temperate-continenental climate of Dobrogea, the chemical composition of lake waters ranges from *fresh to brackish, salty* and even *hypersaline*.
- Human intervention on the lacustrine water-bearing structure, on drainage basins and on the connections with the coastal sea waters has determined significant changes in the *structure and uses of the lacustrine ecosystems*.
- Under the present local and regional geographical conditions, the water balance structure of lakes has been changed by anthropic activities, in terms of hydrochemical features and economic interests.
- Seeing the modifications occurred in the morphohydrographical configuration of the lacustrine depressions, influencing also the water regime, especially level the variation and the structure of the water balance components, the *case-studies* analyzed herein are Techirghiol, Siutghiol şi Razim-Sinoie lakes.
- *The Techirghiol Lake* (–1.50 m), isolated from the sea, hypersaline water (110‰), has special spa qualities; irrigation waters (after 1960) rose the lake level by +1.5 m, salinity decreasing to 55‰ (in 2000). In order to protect its spa qualities, a project limiting the intake of fresh ground and underground water was elaborated and implemented, the situation improving after the year 2000.
- The *Siutghiol Lake*, with a special underground water intake, had and still has fresh water, yet it has experienced volume and level variations, because of the diminution of underground sources and the extraction of water for irrigation and other uses.
- The *Razim-Sinoie lacustrine complex*, being connected with the sea, is a *brackish water*, used only for fish breeding; once the connection with the Black Sea was cut, *fresh water* for irrigating the riverside area was taken from the Danube, thus changing the hydrochemical and faunistic composition of this lake complex.

REFERENCES

Banu, A.C. (1964), *Date asupra unei transgresiuni de vârstă istorică în bazinul Mării Negre şi al Dunării inferioare,* Hidrobiologia, vol. **V**, Bucureşti.

Bleahu, M. (1962), *Observaţii asupra evoluţiei zonei Histria în ultimile trei milenii,* Probl. geogr. **IX**, Bucureşti.

Bondar, C. (1970), *Date noi privind morfometria complexului lagunar Razim - Sinoie,* Lucr. colocviului de limnologie fizică, Inst. Geografie, Bucureşti.

Brăileanu, Al. (1938), *Lacul Razim. Geneza şi evoluţa lui*, Bul. S.R.G., **LVII**, Bucureşti.

Brătescu, C. (1915), *Lacul Mangalia,* Bul. Soc. Rom. Regale de Geografie, vol. **XXXVI**, Bucureşti.

Brătescu, C. (1922), *Lacul Taşaul (note dintr-o călătorie),* Anal. Dobrogea, **III**, *4*.

Breier, Ariadna (1976), *Lacurile de pe litoralul românesc al Mării Negre. Studiu hidrogeografic,* Edit. Academiei Române, Bucureşti.

Breţcan, P. (2007), *Complexul lacustru Razim-Sinoie. Studiu de limnologie*, Edit. Transversal, Târgovişte.

Bujor, P. (1900), *Contribution à l'étude de la faune des lacs salés de Roumanie (Techighiol et Lacul Sărat),* Ann. Sci. Univ. Jassy, **I**, *1*, 36.

Coteţ, P. (1970), *Lacurile litorale dobrogene şi raporturile genetice cu schimbările de nivel ale Mării Negre,* Lucr. colocviului de limnologie fizică, Inst. Geografie, Bucureşti.

Feodorov, P.V., Skiba, L.A. (1961), *Oscilaţiile nivelului Mării Negre şi Mării Caspice în holocen,* Anal. rom-sov., seria geol-geogr., **1**.

Gâştescu, P. (1971), *Lacurile din România. Limnologie regională*, Edit. Academiei Române, Bucureşti.

Gâştescu, P. (1998), *Razim-Sinoie lake complex,* Enciclopedia of Hidrology and Water Resources, Edited by Reginald W. Herschy and Rhodes Fairbridge, Academic Publisher, London-Dordrecht-Boston.

Gâştescu, P., Breier, Ariadna (1976), *Le complexe lacustre Razim-Sinoie (Roumanie). Genèse, morphométrie et régime hydrique*, în Scritti geografici in onore di Riccardo Riccardi, I, Mem.Soc. Geogr. Ital., Roma.

Gâştescu, P., Breier, Ariadna (1982), *Les lacs littoraux roumains-particularités hydriques, modifications anthropiques et leur utilisations,* RR GGG-Géographie, T. **26**.

Gâştescu, P., Nicolae, Tatiana (1981), *Influenţe antropice asupra regimului hidric al lacurilor Siutghiol şi Techirghiol,* SC.GGG, Geografie, T. **XXVIII**.

Gâştescu, P., Breţcan, P. (2003), *Aspecte privind starea actuală a lacurilor Siutghiol şi Techirghiol,* Anale Seria geografie, Tomul **3**, Univ."Valahia", Târgovişte.

Lepşi, I. (1933), *Zur Biologie des Siut-Ghiol,* Bull. Sect. sci. Acad.Roumanie, **16**.

Mihăilescu, V. (1928), *Regiunea Techirghiolului*, Anal. Dobrogea, **II**.

Mrazec, L., Sturza, M. (1932), *Regiunea balneară a lacului Techirghiol*, Viaţa medicală, România, **1-32**.

Murgoci, Gh. (1912), *Studii de geografie în Dobrogea de nord*, Bul. Soc. Reg. Române de Geografie, vol. **XXXIII**, Bucureşti.

Nicolae, Tatiana (1969), *Consideraţii asupra regimului hidrologic al lacurilor de pe litoralul românesc al Mării Negre,* Hidrot. gosp. ape., meteor., **14**, *4*.

Panin, N. (1983), *Black Sea coast line changes in the last 10,000 years. A new attempt at identifying the Danube mouths as described by ancients,* Dacia, Rev.d'arch.et d'hist. anc., nouv. série, **XXVII**, *1-2*, Bucureşti.

Pascu, R. (1900), *Recherches préliminaries sur lac de Techighiol, avec un plan et des profiles*, Ann. Inst.géol. Roum., **4**, 1.

Romanescu, Gh. (2006), *Complexul lagunar Razim-Sinoie. Studiu morfohidrografic*, Edit. Univ. "Al.I.Cuza", Iaşi.

Teodorescu, D.C. (2009), *Particularităţi climatice care influenţează evapotranspiraţia potenţială în spaţiul hidrografic continental dobrogean,* Anal. Univ. Spiru Haret, Seria Geografie, nr. **12**, Bucureşti.

Trică, Valeria (1977), *Les corrélations entre les conditions de milieu et les organismes qui prennent part à la formation des boues des lacs salés de Techirghiol et d'Amara-Roumanie,* Hidrobiologia, Tomul **15**, Bucureşti.

Ţuculescu, I. (1965), *Biodinamica lacului Techirghiol. Biocenozele şi geneza nămolului*, Edit. Acad.Română.

Vespremeanu, E., Vespremeanu-Stroe, A., Constantinescu, S. (2004), *The Black Sea level oscillations in the last 150 years,* Analele Universităţii Bucureşti, seria Geografie, **LII**, Bucureşti.

Witzel, E. şi colab. (1957), *Studii topometrice şi geologice pentru determinarea cantităţii de nămol care se găseşte în lacul Techirghiol*, Lucr. balneol., climatol., Bucureşti.

Zemiankovski, Vl. (1951), *Regimul de salinitate şi producţia piscicolă a lagunelor Razelm-Sinoi*e, Bul.I.C.P., **X**, *1*.

Received June 16, 2015