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Limnology of the Red Lake, Romania

An Interdisciplinary Study

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Preface

Limnology is the border discipline claimed by biology and geography. This is the reason why limnobiology or limnogeography has an ever-increasing use in the field. Though limnology is interdisciplinary by definition, it led to the creation of specializations such as limnogeology, limnogeography, limnoarchaeology, etc.

In this case, we present an interdisciplinary approach based on underlying the geomorphologic characteristics. From this perspective, the authors can definitely say that the approach is new and that it emphasizes the role played by the geomorphologic factors in the distribution and combination pattern of other limnological factors.

The graphics used are exceptional and some representations are new in the field: the map of the lacustrine basin cliffs; the map illustrating the orientation of slopes within the lacustrine basin; the delimitation of wetlands through the correlation between depth, cliffs, and orientation of the slopes; the graphic representation of aquatic bodies, on the vertical, with the corresponding water volume for each level, etc. All these characteristics make this book a statement in the scientific literature of the field.

The existence of numerous lakes, with various origins, makes the Eastern Carpathians an area of main interest for Romanian tourism. The mountain climate—with Baltic and ocean influences, where temperatures are moderate and precipitations are abundant (700–1,400 mm)—favors the existence of lacustrine basins and wetlands (Apăvăloaie 1971).

The Red Lake, through its genesis and landscape, represents one of the most important tourist attractions in Eastern Romania. It is also favored by the existence of a modernized access road, connecting Transylvania and Moldavia. This is another reason why a relevant study was needed to underline its basic features, its national and international individuality, and to spread the information globally.

Most of the corresponding lakes and wetlands are affected by anthropic interventions but also by non-intervention. The decrease in the lacustrine surfaces, as a consequence of normal clogging, is a natural phenomenon. When erosion is accelerated (anthropic intervention), the depth is reduced and, most of the time, the surface increases. For the Red Lake, such a scenario is not possible because the waters in excess are eliminated over the top of a natural dam, towards the Bicaz River. Through clogging, the surface occupied by wetlands increases but the

aquatic surface decreases. The ecologic dichotomy, of maintaining the water surface, or of extending wetlands, is visible.

Wetlands, for the entire planet, have been deeply altered, in different manners, both in space and time. The wetlands and deep waters within the mountain units of the Eastern Carpathians are in an incipient stage of human intervention. For the entire country, the morphometric characteristics and the climatic conditions allowed the formation of a wide variety of wetlands; their preservation was supported by a few possibilities of drainage or by low-habitation density.

In the Eastern Carpathians, research underlines more and more the pollution of streams and of the lacustrine basins, implicitly. As a consequence of low altitudes and of the existence of numerous passes and gorges, the Eastern Carpathians represents an important habitation area, where the population density is relatively high. This has led to the alteration of streams by the building of barrages and dams and by the elimination of floodplains, etc.

The most important argument for the preservation and rehabilitation of lacustrine basins and wetlands is represented by their complex role: regulating the hydrologic cycle; conserving the biodiversity; reducing soil erosion; improving the microclimate; reducing high-water waves; tourist destination, etc.

The lifespan of natural dam lakes has been reduced. This is the reason why these water units attract a large number of tourists. The management of these basins is extremely delicate and an alteration that could seem to bring benefits may lead inevitably to the degradation of other characteristics. In consequence, human intervention is not welcome as the waters of such lakes could be lost.

Ioan Nistor
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Canada

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Introduction

Limnology, as a border science, has long been avoided by the disciplines that are supposed to study the understanding of interdependent phenomena: geography and biology. Unfortunately, even at the international level, the phenomena are not acknowledged due to the lack of main components: the studies are either purely biological or purely geographical.

Most biological studies do not take into account the physical-geographic factors. At the same time, the geographic studies lack the biological component. Those who try to uniform the components get, surprisingly, an elegant rejection: "we regret it, but the subject chosen is not among the themes promoted by our journal". We cannot fully understand the role of each component and its connections with the whole. In limnology, there has always been a "missing link".

The schools in the field fight fiercely in order to impose their perspective in renowned specialties. How many international journals, well known in the field, accept articles with complex, interdisciplinary subjects? How many biologists know what a hydrographic basin is or what its geological constitution comprises? How many specialists take into account the morpho-bathymetric phase as a layering unit for local conditions? The lithological—emersed or submerged—substrate is the development support for the communities on various evolution phases.

Nonetheless, limnologists easily talk about water chemism as if it were part of God's creation. They seem to forget that the chemical parameters are given by the petrologic composition of the hydrographic basin. Through physical and chemical erosion, the elements are taken off, carried and deposited into the lacustrine basin. In this case, the lake becomes the depositary of the elements within the basin of influence—the hydrographic basin, in our case.

The classifications based upon delimiting the wetlands depending on a set of parameters had satisfactory outcomes. From this perspective, the American school delimits the wetlands depending on hydrologic, geomorphologic, pedologic, and biological parameters. The inter-conditioning of the four parameters leaves no room for ambiguity. Nonetheless, the difficulty of delimitation, the long duration of the research, and the high-analysis costs are still an issue.

The relationship between wetlands and lacustrine basins is extremely close. This is why lacustrine waters are often mistaken for a typical wetland. Most morpho-hydrographic forms, such as wetlands, are only elements of lacustrine basins or stagnant waters. The most important problem is related to the interdependence between morpho-bathymetry and the limno-ecological parameters within various waters.

A mountain unit is mostly known for its altimetric parameters. Each altimetric layer determines a certain type of climate. In their turn, the climatic parameters determine the distribution of plants and animals. The lacustrine basin is the reversed image of a mountain unit. This time, each bathymetric stage corresponds to a cumulus of hydrometric factors. In this case, these are bathymetric layers. Morpho-bathymetry is the edifice on which secondary components are set, just like a house waiting for its dwellers.

The natural dam lakes in Romania have been studied mainly by geographers and less by biologists. Most studies are dedicated to the way they were formed and to emphasizing the evolution of the lake basin in time and space. Most natural dam lakes in Romania are situated in the Eastern Carpathians, where it rains often and the geologic substrate allows landfalls. Most landfalls are favored by the massive deforestations that occurred at the end of the nineteenth century and the beginning of the twentieth century.

The limno-geographic literature until 2012 demonstrated that the Red Lake is the largest natural dam lake in Romania. In 2012, topographic measurements were taken for the most important natural dam lakes and the largest one is Lacul Crucii, measuring 12.95 ha, compared to the 12.01 ha of the Red Lake. As far as the depths are concerned, the situation is the same: 16.3 m for Lacul Crucii and 10.5 m for the Red Lake.

Among the large natural dam lakes in Romania, the Red Lake seems to be the oldest, as it was formed in 1837. Lacul Crucii is the youngest such lake, with two formation stages: in 1978, when a small lake appeared and in 1991, when a big landslide occurred and the landslide body totally blocked the Cuejdul creek.

Because of its relative isolation, the Red Lake caught rather late the attention of interdisciplinary research. The construction of the connection road between Transylvania and Moldavia, over the Eastern Carpathians, meant the end of the lake's isolation. The inclusion of the Red Lake within the transit tourist circuit stimulated the first limno-geographic research. Unfortunately, most studies focused only on the lake basin and on the geologic substrate and less on the physical–chemical parameters and on the water dynamics. The most recent studies focus on the exploitation of the tourist side of the lake and of the surrounding area at the same time. This has brought an invigoration of local tourism, which had suffered a significant decline after 1989, following the Romanian Revolution. The Red Lake exerts a special tourist attraction because the local landscape is ideal for spa-related and climatologic exploitations if community funds can be obtained.

The name of the Red Lake is related to the existence of the reddish limestones on the left bank that often reflect, at sunrise, in the mirror of the lake. The images are also accentuated by the existence of fossil trees bent over and broken from the lake basin.

A chronicle of the second half of the nineteenth century mentions the formation of the Red Lake (Mihaly and Laszlo 2003) as follows: "One night of July 1837, around seven o'clock, from east massive clouds gathered and came rapidly towards our mountains, accompanied by quick lightning, dreadful thunders and, immediately, a heavy rain darkened the entire horizon. The lightnings would not stop, as though foretelling a terrible apocalypse with thunders and endless rains…. People and animals were equally frightened because the lightnings set fire to several households in Gheorgheni and in the surroundings, and the horrible storm went on powerfully until dawn. This caused two landfalls in the Bicaz County, reason for which the Bicaz creek was dammed and it created the Red Lake where, even today, one can find the most beautiful trout".

The origin of this lake also created a very interesting legend related to the interpretation by the local population. In the land of Giurgeu once lived a girl of rare beauty, known by the name of Estera. Her hair was like the feathers of ravens, her eyes were green as olives, and her figure resembled a wind-caressed pine tree.

Estera was extremely hardworking and she was so handy that all the other youngsters asked her favors. One sunny July morning, Estera went to the fair of Gheorgheni. In the market, she met a tall, handsome young man, so strong that he could kill the biggest bear in the area by one stroke. He could also flute like no one else in the land and he was known to have the handiest skills. It was definitely love at first sight, as love comes unexpectedly and it only conquers the hearts of young people.

The young man brought Estera a sky-blue headscarf and he asked her to be his loved one. The two lovers could not marry because the young man was enlisted. However, Estera waited for her man impatiently. In the evening, when the proud sun began hiding beneath the tall mountains, Estera took her trug and went to the smooth source at the foot of the mountain, where she would remain for hours, thinking of her beloved. Even the surrounding mountains softened at her sighs and blue songs.

One Sunday morning, an outlaw saw Estera and—conquered by her beauty—he kidnapped the young woman and ran with her up to the stream called Suhardul Mic, between the thousand-faced rocks, where his entire gang dwelled. The outlaw promised Estera gold, silver, and many other treasures, would she become his wife. Nonetheless, Estera rejected him because she wanted to be faithful and wait for her lover.

The outlaw's perseverance made Estera ask the mountains for help. The rocks heard her desperate prayer. One night in July, a very powerful storm came out of

nowhere, dragging along a heavy rain, with horrific thunders and blinding lightning. Making a terrible noise, the mountain fell over and buried the young woman, the outlaw, and also a shepherd and his entire herd.

On the morning of the last Sunday in July, the sun slightly caressed the rocks. The valley, where a day before the clear Vereşcheu creek murmured, was blocked by the landfall, thus creating the Red Lake. If you look in the lake's waters, you can see the red tears and the brightness of the teary, green eyes of Estera (Mihaly and Laszlo 2003). This book tries to underline the role of morpho-bathymetry in the distribution of areas occupied by lacustrine wetlands. At the same time, the physical–chemical characteristics and the water dynamics are underlined, in direct connection with other physical and geographic factors: geologic, geomorphologic, climatic, hydrologic, biologic, anthropic, etc.

In this particular analysis, the Red Lake was chosen because, besides St. Anne's (volcanic) Lake and Lake Bâlea (glacial), it is one of the most important tourist sites in Eastern Romania.

Reference

Mihaly S, Laszlo D (2003) Lacul Roşu şi Cheile Bicazului. Ghid turistic ilustrat. Mark HousePublishing House, Gheorgheni

Apavaloaie M (1971) Contribuţii la cunoaşterea regimului temperaturii aerului din zona Lacului Roşu-Cheile Bicazului. Lucrările Staţiunii de Cercetări Stejaru: 227–237

Chapter 1
Definition of Lakes and Their Position in the Romanian Territory

Abstract Limnology is one of the most important disciplines of hydrology. It studies inland waters and all other standing waters (natural or artificial), including hydrologic phenomena, physical or chemical, in relation to the environment (chemism, thermals, dynamics, development capabilities of the flora and fauna associations, etc.), as well as the way they are valorized by man. From a historical point of view, limnology is only approximately one century old and the founder of limnology is considered to be François A. Forel from the University of Lausanne (Switzerland). It is very important to make a clear distinction between similar terms, such as "lake" and "pool" and define a clear terminology. Out of the grand total of 1 million lakes, distributed all around the world, in Romania, there are currently about 3,450 lakes. There are many types of lakes and numerous classifications are based on several factors, such as: the origin of the lacustrine basin, hydric regime, thermal regime, mineralization degree, trophic potential, geographic position, nature (natural vs. anthropic). The anthropic category is devised into smaller types, depending on the size (the amount of the water reservoir), or on the purpose (hydro-energetic, drinking or industrial water supply, irrigations, pisciculture, recreation, balneotherapeutic, residue cleaning, wet concentration, etc.). The Red Lake is a natural dam lake, which was formed after a huge landslide blocked the Bicaz Valley in 1837. Here, the objective is emblematic, because it is the most well-known natural barrage lake in Romania.

1.1 Concept and Definition

Limnology is the science that studies inland waters and all other standing waters (natural or artificial), including hydrologic phenomena, physical or chemical, in relation to the environment (chemism, thermals, dynamics, development capabilities of the flora and fauna associations, etc.), as well as the way they are valorized by man.

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The word "limnology" comes from the Greek *limne* = lake. In the category of lacustrine waters are included lakes, ponds and mires. More recently, wetlands have also been included in this category.

Through its subject, limnology is a border discipline between geography and biology. It belongs to geography because it studies depressions and the way they were formed; it studies water, with all its characteristics (physical, chemical and dynamics), meaning the biotype—this sub-branch is called physical limnology. It also belongs to biology because it studies the flora and fauna of stagnant waters (biohydrocenosis)—this branch is called biological limnology. As the biotope and biohydrocenosis within a lake form a whole, standing waters in general represent the most typical systems in nature; they may also be called limno-systems (Hutchinson 1957; Dussart 1966, 1992; Gâştescu 1979).

"Lakes, moreover, form more or less closed systems, so that they provide a series of varying possible ecologic worlds which permit a truly comparative approach to the mechanisms of nature" (Hutchinson 1957). The American biologist Forbes (1887) compares the lake with a microcosm—hence the importance of lake studies to reveal the geographic evolution of an area.

In a broader perspective, limnology is "the interdisciplinary science which studies water basins with slow water exchange—natural or artificial—historically, meaning dynamically in time and regionally in space, the current physical and biotic process, on the grounds of energy and matter transformation within the water body. It also studies the laws of their evolution and geographic status, their natural resources, and possibility of use by mankind" (Gâştescu 1971).

1.2 Limnological History

The Swiss naturalist and professor of medicine, François A. Forel, at the University of Lausanne (Switzerland) (1841–1912) is considered to be the founder of limnology. His first study was "Matériaux pour servir à l'étude de la faune profonde du lac Léman" (1869). The founding book of limnology is "Le Léman: Monographie limnologique," Lausanne, (1892, 1895, 1904) (3 volumes).

Murray (1900) introduces a methodology specific to oceanography and hydrology in his exhaustive research regarding Scottish lakes. Halbfass (1903, 1923) published his treatise on the geography, physics and chemistry of lakes (Berlin), a true basis for modern limnology. Thienemann (1925, 1926) is the first to have studied the insects of streams; he is the most important representative of European limnology (Arlinghaus et al. 2008).

For better organization, on 1st January, 1922, in Kiel (Germany), Thieneman August and Nauman Einar founded the International Society of Limnology (S.I.L.—Societas Internationalis Limnologiae). It comprised 103 specialists from various countries.

The first systematic observations on the lakes in our country truly appeared after 1950. For this organized start, the following geographers should be

mentioned: Vîlsan G., Brătescu C., Martonne Emm. de., Morariu T., Coteţ P., Mihăilescu V., etc. There have also been geologists, such as Munteanu-Murgoci Gh., Mrazec L., Maxim I., etc.; biologists: Antipa Gr., Borcea I., Lepşi I., Antonescu C.S., etc.; chemists: Poni P., Petreanu P., etc.

Among the most important geographic limnology works, the following papers, genuine regional monographs must be cited: "Câteva aspecte privind bilanţul hidrologic al lacurilor din Câmpia Moldovei" (Schram 1968); "Lacurile dulci din Câmpia Transilvaniei" (Săndulache 1970); "Lacurile din România" (Gâştescu 1971); "Lacurile glaciare din Carpaţii Meridionali" (Pişota 1971); "Lacurile de pe litoralul românesc al Mării Negre" (Breier 1976), etc.

1.3 Definition of the Terms Lake and Pool

Lake is "a body of standing water occupying a basin and lacking continuity with the sea" (Forel 1892). The term lake applies to all natural or artificial depressions containing water, "with their own life and certain autonomy" (Dussart 1966, 1992).

One of the simplest definitions of the term lake says that it is "an inland body of water of considerable size" (International Glossary of Hydrology 1992). At the same time, lake is "a sweet or salt water body which occupies a closed depression on the surface of a continent" (Dictionnaire Encyclopédique Alpha 1983).

In defining the notion of lake, the main criteria should be the basin and water body—which are inseparable—on the one side and the hydric characteristic of the relatively stagnant water, on the other. Consequently, "a lake is a relatively stagnant water volume, cantoned in an inland depression, with no continuity with the Planetary Ocean" (Gâştescu 1971). According to this definition, the natural and artificial basins also fall into the category of lakes (Bratsk, Assouan, The Iron Gates I and II, etc.), as well as the water bodies of thousands of square meters and thousands of square kilometers (Caspian Sea, Aral, Baikal, Victoria, etc.). In the category of lakes the authors also included the water bodies above or below the Planetary Ocean level (Dead Sea, Lake Tiberias, etc.), at a depth of several dozen meters or thousands of meters (Baikal, Tanganyika, Malawi, etc.). They are called lakes regardless of their emersed or submerged vegetation, productive or unproductive bottom, whether they are salty (Dead Sea, Caspian Sea, Techirghiol, Ursu, etc.), brackish (the Razim-Sinoe lagoon complex) or sweet, if they are permanent or temporary, etc. For this definition, the authors are interested in the form of the depressions where the water is cantoned (circular, oval, elongated, digital, etc.). The main characteristic is that of the slow water exchange with the environment; it triggers a series of particularities, of the hydric, thermal and hydrochemical regime, of the lake-specific hydrocenoses, etc.

Of the various definitions so far, there is not a clear-cut distinction between lake, pond and pool. The transition of these lacustrine categories is not entirely transparent. The size cannot be the only main criterion, as a pond can be much

larger than a small lake. Depth has also been used as a distinction index, which, through the physical-geographic indices, allows a definition of the classification limits.

The consensus is that (Imboden 1976) a lake presents, besides the littoral area, a deep area with no light and where the bottom is covered by vegetation. Its water is often stagnant, as the currents are present mostly when the water stream has tributaries or important emissaries (Fig. 1.1). Certain Romanian authors have also accepted this definition, such as Antonescu (1967). He states: "We call lake a standing water, so flat and deep, that we have two distinct areas: (1) a bank (littoral) area covered by aquatic emersed and submerged vegetation, hence with a productive bottom, and (2) a deep (profound) area, obscure, with no plants and covered, on the unproductive bottom, with a fine, uniformly structured silt." "According to this limnological definition, Romania has only a few lakes, given the above mentioned meaning: Snagov (11 m deep) and certain standing waters in the Carpathians (Zănoaga, Bucura, and Galeş—the first 27 m deep), the Red Lake and the Big Bicaz Lake (around 93 m). Nonetheless, Romania has numerous standing water surfaces, some very large but not at all deep—this is why the vegetation can grow anywhere on their bottom. These waters are called ponds, or sometimes tarns and mires."

With regards to ponds, they are never deeper than 3 m and they can have their entire bottom covered with aquatic plants that do not need sunlight. Standing waters, because of their small sizes and volume, are sensitive to the variations in external influences. If the accumulations are artificial, a device is needed to make sure there is always a level-up. In Romanian geographic literature, a pond is, most

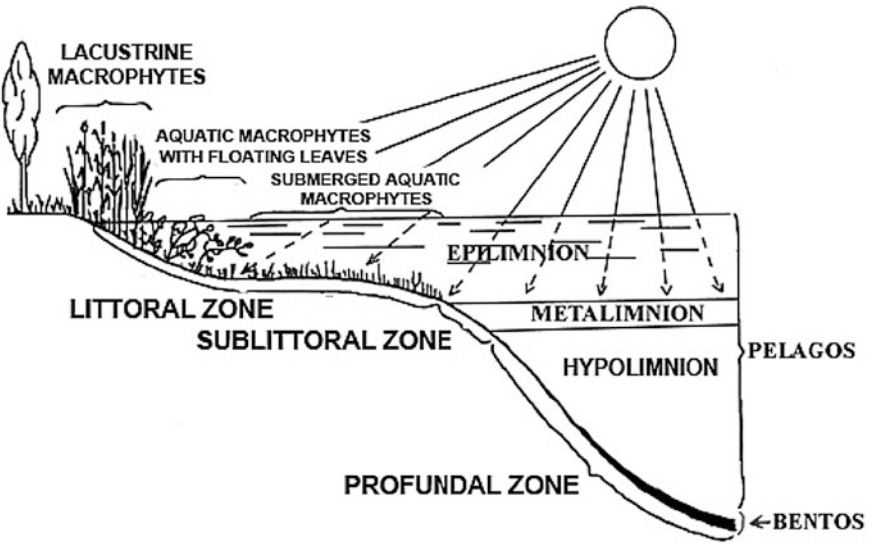

Fig. 1.1 Zoning of the lacustrine environment

of the times, an artificial lake. The pool of water is a small inland water body, usually not deeper than 80 cm, where the sun affects all the water layers; in this case, there are daily variations in the temperature. The smallest water surfaces are called puddles; during the dry season most of them disappear. In the case of our country, the term pool should be used in its broader, popular meaning only for the water surfaces within floodplains. In this case, it is not about a certain lake but about a geographic area, a natural unit with several elements: geographic units, hydrography, i.e., vegetation, fauna, economic use, etc. It may have two meanings: a toponym specific to floodplains (the Danube or Siret Floodplain, etc.); or a toponym limited to plain lakes of genetic type but not as an evolution phase (it is not widely known for this meaning). de Emm (1902) mentions that "At Călăraşi begins what people name the Pool."

"The Romanian people (the ones near the Danube, and also the shepherds from Ardeal who have taken their sheep there for centuries) name the Danube Floodplain the Pool, meaning the natural geographic area within the country… a natural unit with a similar role to that of the Carpathians in the history of our people" (Conea 1965).

From the definitions given to lakes and to standing waters in general several conclusions have resulted. The most important feature is the stagnant character of the water, which is also relative. This is the main difference compared to streams.

Dimensions (surface and depth) represent the second feature. From this perspective, the definitions of Imboden and Antonescu are based on biological criteria (Gâştescu 1998). In this case, the Sea of Azov, with only 9 m depth and without a profound area, should be included in the category of ponds or pools.

The third feature is that of the lake position compared to a marine basin. If the definitions imply that the lake has nothing to do with the sea, lagoons should also be eliminated. Most of the times, lagoons may be classified within transition systems or they may be clearly delimitated, in which case they are included in the category of lakes. Their features have been strongly altered by anthropic activities (the level of the Razim-Sinoe lagoon complex is 50 cm higher than that of the Black Sea, the water salinity is down by 2–5 ‰, etc.). According to the last feature, the Caspian Sea is truly a lake.

1.4 Distribution of Lakes

There are around 1 million lakes in the world, which represent between 2.1 and 2.7 million km^2 (1.4–1.8 % of the land, meaning the size of the Mediterranean Sea). The total volume is approximately 700,000 km^3 (Pisota and Nastase 1957; Pişota 1995; Zăvoianu 1999).

In Romania there are around 3,450 lakes (of which 2,300 are natural and 1,150 are artificial), with a 2,620 km^2 surface (Gâştescu 1971).

- The lakes within areas with a humid and temperate climate

They have large volumes of water and they are the most numerous, with a pluvial, pluvio-nival, nivo-pluvial or nival supply regime. Most of them become sweet and they present surface outflows. They form the category of outflowing lakes because they are connected to the Planetary Ocean (e.g., Onega, Ladoga, Baikal, Biwa, Tanganyika, Victoria, Huron, Ontario, Titicaca, Balaton, Zănoaga, etc.).

- The lakes within arid and dry areas

They are not numerous and they present no outflows. They have a small water volume; most of the time they are salty, with a pluvial or pluvio-nival supply regime. They are not connected to the Planetary Ocean and they form the category of non-outflowing lakes.

In Africa they are called chotts (salt water lakes or big *sebkha*); *sebkhaouri* (*sebka*) (arid saline depressions found in northern Africa and Arabia; geologically speaking, they represent deposits of gypsum and anhydrite mixed with sand and silt); and salt pans (ex: Ciad, el Hodna, Chott el Jerid, the Dead Sea, Aral, the Caspian Sea, etc.).

1.5 Types of Lakes

Since the first hydrologic books in general and limnological in particular, lakes have been categorized depending on their dominant characteristics.

The best-known classifications are the following:

(a) depending on the origin of the lacustrine basin: resulting from the action of internal factors (tectonic, volcanic); resulting from the action of external factors (from streams; from water dissolution; glacial; of wind depressions; of sea and ocean banks, etc.);
(b) depending on the hydric regime: permanent; temporary; with outflow; without outflow (closed);
(c) depending on the thermal regime: polar; temperate; tropical; cold; mesothermal; thermal;
(d) depending on the mineralization degree and on the chemical composition: sweet; brackish; salty; hydro-carbonated; sulphated; chlorinated;
(e) depending on the trophic potential: oligotrophic; eutrophic;
(f) depending on the geographic position within various landforms: mountainous; plateau; plain; littoral, etc.;
(g) depending on their nature: natural; anthropic (artificial).

For the artificial (anthropic) lakes, the following characteristics are taken into account as classification criteria:

- the purpose (hydro-energetic, drinking or industrial water supply, irrigations, pisciculture, recreation, balneotherapeutic, residue cleaning, wet concentration, etc.);
- the size (the amount of the water reservoir).

Depending on the origin of the lacustrine basin

This classification is specific to geography and geology. Most classifications of this type have as grounds the works of Penck (1882), von Richtofen (1886), Davis (1887), Russell (1895), Delebecque (1898), Geikie (1905), de Emm (1909), Collet (1925), Mehedinţi (1930), Hutchinson (1957), Dussart (1966, 1992), Gâstescu (1971), Guilcher (1979), Pişota and Buta (1983), etc.

At the beginning, the geomorphologists took into account the constructive, destructive and obstructive factors. Another element to be taken into consideration is time (Davis 1887). Consequently, a lake cannot be permanent; it appears, it develops and then it disappears (Wetzel 2001).

Hutchinson (1957) made the most complete classification by the origin of the lacustrine basin. The author determines the existence of 76 genetic types of lacustrine basins, classified into 11 groups of natural processes:

I. Tectonic Basins

1. Relict lakes isolated from the sea by epirogenetic movements;
2. Gentle epirogenetic uplift of irregular marine surfaces;
3. Reversal of the hydrographic pattern by tilting or folding;
4. Large-scale basins formed by warping;
5. Earth movements producing local subsidence;
6. Lakes in basins in tectonically dammed synclines;
7. Old peneplain surfaces as intermontane basins;
8. Basins associated with fault scarps in a tilted terrain (half-graben);
9. Basins associated with fault scarps in an elongated depression (graben or series of half-grabens).

II. Volcanic Lakes

10. Unmodified craters in a cinder cone;
11. Explosion craters;
12. Maars (abortive embryonic volcanic depression);
13. Calderas;
14. Conche (series of craters producing terraces);
15. Modification of caldera lakes by secondary activity;
16. Volcano-tectonic basins;
17. Lakes on collapsed or irregular lava flows;
18. Lakes formed through volcanic damming by peaks or secondary peaks;
19. Lakes formed through volcanic damming by a lava stream or mudflow.

III. Landslide Lakes

20. Lakes formed through dams formed by rock flows, mud flows and debris flows (Lake Quake-California, Clear-California);
21. Lakes formed between the mass of a slide and a detached valley wall (Red Lake, Lake Crucii - Romania; Lake Brazeau-Alberta (Cruden 1982), Sarez-Pamir, Chaillexon-Franţa, Busyû-Japonia) (Gâştescu 1979);
22. Lakes formed by the building of scree dams across valleys (Lake Arrowhead-California).

IV. Glacial Lakes

23. Lakes on or in ice;
24. Glacier-dammed lakes;
25. Damming by moraines of existing glaciers;
26. Ice-scour lakes;
27. Cirque lakes;
28. Paternoster lakes, fiords and piedmont lakes (valley rock basins);
29. Glint lakes (ice cauldrons);
30. Damming by terminal or recessional moraines (no glacier);
31. Damming by outwash in a valley;
32. Lateral valley dammed by a terminal or lateral moraine in the main valley;
33. Lakes between terminal deposits;
34. Lakes formed in irregularities in ground moraine;
35. Kettle lakes following the valley drainage pattern from an ice block with outwash;
36. Kettle lakes from stagnant ice blocks within outwash (no pattern);
37. Kettle-hole lakes (ice blocks within an outwash in an unglaciated valley);
38. Kettle lakes in till;
39. Kettle lakes associated with esker development;
40. Glacial tunnel lakes;
41. Lakes formed due to local thawing of permafrost;
42. Lakes formed by melting of ice wedges on permafrost.

V. Solution Lakes

43. Karstic depressions (dolines (funnel), uvala (compound funnel));
44. Poljes (tectono-karstic depression);
45. Underground lakes in caverns;
46. Solution lakes in gypsum;
47. Solution lakes in ferric hydroxide and hydrous aluminum silicate.

VI. Fluviatile Lakes (From Running Water)

48. Plung pools and evorsion lakes;

49. Lakes formed by fluviatile dams;
50. Fluviatile damming within lakes;
51. Strath lakes (parallel sediment ridges formed in a long narrow basin);
52. Lateral lakes (lateral valleys dammed by deposits of a main stream);
53. Deltaic levee lakes;
54. Meres (levee lakes influenced by tidal forces);
55. Oxbow lakes;
56. Lakes formed by uneven aggradation in a floodplain;
57. Lakes formed by the abandonment of well-defined channels;
58. Lakes formed between a scarp (edge of floodplain) and a levee;
59. Crescentic levee lakes.

VII. Wind Lakes

60. Lakes formed by damming through sand dunes;
61. Lakes formed through uneven deposition of loess;
62. Interdunal lakes;
63. Deflation basin lakes.

VIII. Coastal Lakes

64. Lagoonal or coastal lake (river discharge vs. constant tide level);
65. Lakes formed when two tombolos connect an island to the coast;
66. Lakes formed along a lake shore when a bar is built across a bay;
67. Lakes formed when a lake is bisected by two spits;
68. Lakes formed behind a cuspate spit of a larger lake.

IX. Organic Accumulation Lakes

69. Phytogenic dam lakes (peat bogs);
70. Closed phytogenic basin lakes (peat bogs);
71. Lakes in coral atolls.

X. Mammal-Constructed Lakes

72. Beaver dammed lakes;
73. Reservoirs;
74. Lakes in artificial depression.

XI. Meteoritic Impact Lakes

75. Lakes formed in craters formed by meteoritic impact;
76. Bay lakes formed through compression waves of impact.

Throughout time, the classification made by Hutchinson in 1957 has been completed or simplified depending on the factors considered. Most classifications after 1957 had this classification as a reference point. The Romanian literature borrowed integrally the directives of English literature (Romanescu 2003).

Of the entire lake surface, the glacial and periglacial lakes (1,247,000 km^2) were underlined, followed by tectonic lakes (524,000 km^2). As for the volume, the

first are the tectonic lakes (56,600 km^3) and the second the glacial and periglacial lakes (38,400 km^3; Cohen 2003) (Table 1.1). As far as volume is concerned, Lake Baikal is the largest, with 23,615 km^3, which represents 20 % of the global freshwater volume.

The most usual classification in Romania targets the geographic position of a lacustrine basin within the main landforms. The primordial elements concern the altitude and the thermal gradient. Depending on this criterion, the lakes are classified into the following groups:

- mountain lakes: Red (Roşu) (Fig. 1.2), Bolătău, Ştiol (of a natural dam), Bucura, Zănoaga, Lala, Buhăescu, Bâlea (glacial), St. Ana (volcanic), Ocna Şugatag, Telega, Vintileasca (clasto-karstic), Izvorul Muntelui, Vidraru, Vidra, Călineşti-Oaş, Firiza, Bodi-Mogoşa, Colibiţa, Bâtca Doamnei, Mesteacănu, Frumoasa, Poiana Uzului, Săcele, Brădişor, Siriu, Măneciu, Paltinu (anthropic) (Fig. 1.3), etc.;
- hill and plateau lakes: Ursu, Cojocna (clasto-karstic), Crucii (natural dam), Balta Vulturului, Balta Roşie (of subsidence), Dracşani, Podul Iloaiei (ponds), etc.;
- plain lakes: Sărat, Amara, Lătenilor (of meandre); Movila Miresii, Ianca, Strachina (sinkholes), Băneasa, Herăstrău, Mogoşoaia (anthropic), etc.;
- littoral lakes: Razim, Sinoie, Siutghiol (lagoons), Mangalia, Tatlageac, Agigea, Techirghiol (fluvio-marine limans);
- floodplain lakes and the Danube Delta: Bugeac, Oltina, Mârleanu (fluvial limans), Crapina, Brateş (floodplain lakes), Sireasa, Dranov, Gorgova, Furtuna (delta lakes), Erenciuc, Belciug (of meander) etc.

The Red Lake is part of the water bodies formed after damming streams to prevent landslides. Landslides may be caused by heavy rains or by earthquakes. In our case, the issue is still undetermined, even though rain is more likely the cause.

On the Romanian territory there are lakes formed because of landslides only in the Eastern Carpathians and Subcarpathians: Crucii, Ştiol, Vulturilor, Bolătău, Iezer, Dracului (Romanescu 2003; Mîndrescu et al. 2010). It appears that the oldest natural dam lakes in Romania are over 400 years old (Bolătău, Iezer). They are situated in the Eastern Carpathians and they were caused by landfalls (Mîndrescu et al. 2010).

Table 1.1 Aggregate areas and volumes of the major lake classes at the global scale [After Meybeck (1995) and Herdendorf (1990)] (Cohen 2003)

No	Lake type	Aggregate area (km^2)	Aggregate volume (km^3)
1	Glacial and periglacial lakes	1,247,000	38,400
2	Tectonic lakes[a]	524,000 (893,000)	56,600 (134,900)
3	Fluvial lakes	218,000	580
4	Coastal lakes	40,000	130
5	Volcanic lakes	3,150[b]	580[b]
6	Other lake types	88,000	300

[a] Values including the Caspian Sea are shown in brackets
[b] Crater lakes only

Fig. 1.2 The Red Lake and the Suhard Mountain

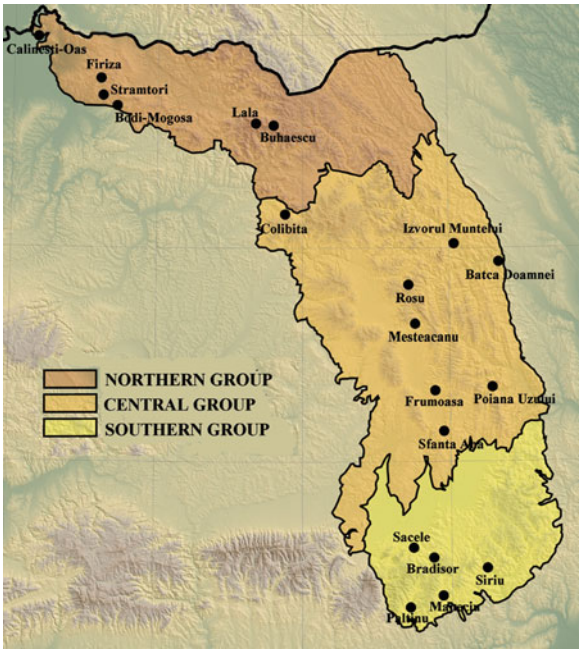

Fig. 1.3 Geographic position of the main lakes in the East Carpathian Mountains