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LIMNOLOGY, LAKE BASINS, LAKE WATERS

Petre GÂŞTESCU
Hyperion University of Bucharest, Department of Geography
Bucharest, Romania
gastescu_petre@yahoo.com

Abstract
Limnology is a border discipline between geography, hydrology and biology, and is also closely connected with other sciences, from it borrows research methods. Physical limnology (the geography of lakes), studies lake biotopes, and biological limnology (the biology of lakes), studies lake biocoenoses. The father of limnology is the Swiss scientist F.A. Forel, the author of a three-volume entitled Le Leman: monographie limnologique (1892-1904), which focuses on the geology physics, chemistry and biology of lakes. He was also author of the first textbook of limnology, Handbuch der Seenkunde: allgemeine Limnologie,(1901). Since both the lake biotope and its biohydrocoenosis make up a single whole, the lake and lakes, respectively, represent the most typical systems in nature. They could be called limnosystems (lacustrine ecosystems), a microcosm in itself, as the American biologist St.A. Forbes put it (1887).
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Limnology

There are two ways of interpreting the term limnology:

The science which studies lakes (its name comes from the Greek '*limnos*' which means 'lake', 'swamp', 'pond'). Lakes can be classified, according to lake basin genesis, water thermal and chemical .regime, development of floral and faunal associations, relationships with the environment and usefulness for humans.

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Second, limnology is science which studies the biology of continental waters, that is of running waters, stagnant waters and springs, either fresh, brackish or saline. It is, in effect, a subdivision of hydrobiology. The promoters of this study trend were Aug. Thienemann and E. Naumann, who in 1922 had founded the Societas Internationalis Limnologiae (SIL) at Kiel in Germany. This society, which gathers remowned specialists in the field, organizes international congresses every 3 years.

Classification of lakes basins

The lake is a relatively stagnant stretch of water which fills a ground depression. From this point of view, a lake consists of two distinct parts - the basin and the water body.

Lakes may have a very wide range of surface areas, from a few thousands of square meters to hundreds of square kilometers (e.g. the Caspian Sea, the largest lake in the world, 371,000 sq km). Natural lakes cover some 2.7 million sq.km (1.8 % of the Earth's surface), encompassing a water volume of about 176 400 cubic kilometers (0.013% of the planetary water volume).

In 1952 Welch suggested a definition of size distinguishing between lake and pond. According to it, the lake is "*an area of open, relatively deep water, sufficiently large to produce somewhere on its periphery, a barren wave-swept shore*", while the pond is a "*very small, very shallow body of standing water in which quiet water and extensive occupancy by higher aquatic plants are common characteristics*".

In our opinion, the definition of the lake should not be subject to size, depth and annual variability, because these are characteristic features that shape the huge variety of lakes.

In terms of their formation, lakes may be grouped into, *natural lakes* with a great many genetic types of lake basin (formed by tectonic, volcanic, glacial, karst, fluviale, marine and wind action, etc.), and *artificial lakes* created to meet various needs (power generating, fresh water and industrial water supply, navigation, fish farming, agreement, flood control, etc).

Numerous classifications have been made by geomorphologists, geologists and biologist, W.M., Davis (1882), for instance, grouped lake basins according three natural processes-constructive, destructive and obstructive. A few years later, I.C.Russel (1895), considering Davis' classification incomplete, put forward another division 'basedon material agencies which produce depressions in the earth's surface' nine geological and one organic. Much later, in 1957, E. Hutchinson recognized 11 major genetic processes which produce a total of 76 different lake types selected from all the continents of the Earth and provide the best international outlook on lake classification available. Space precludes the enumeration of the Hutchinson's 76 types; however, we shall review in brief 11 categories of natural processes involved in the formation of lake basins.

Tectonic lake basins. Faulting is a major result of tectonic activity and is responsible for the origin of important lake basins (e.g. lakes Baikal, the world's deepest lake, Tanganyika, Nyasa, Albert and Victoria). Submarine structural basins or depressions may become lakes when uplifted above sea level, or isolated from the sea (e.g. Caspian Sea, Aral, Chad, Eyre, Great Salt Lake, Balaton and Neuesiedler).

Lake basins produced by volcanic activity. There are three dominant types among the 13 volcanic group: crater, caldera and dam lakes. The lakes formed in craters are small, because these depressions are changed (enlarged) by explosions, giving birth to calderas. The latter contain the great majority of lakes (e.g. Crater Lake, from Oregon, which is classical caldera). Many such lakes occur in the Central Massif of France, central Italy, Japan, the Philippines, Indonesia and New Zeeland). Volcanic dam lakes are the work of lava barring some valleys (e.g. Chambon, d'Aydat, Cassiere from the Central Massif in France).

Lake basins produced by landsliding. These are formed in the valleys dammed by the superficial movement of earth materials, but since the dam are eroded by streamflow pressure these lakes dissapear rapidly. However, some of them still persist, e.g. Sarez in the valley of the Murgab River, Pamir Mts., Lacul Rosu, on the Bicaz River (Romania).

Lake basins produced by the action of glaciers. These are of several types (in cirgues, valley, or on glaciers between moraines). They are the outcome of erosion and accumulation processes. There is a wide range of glacial lakes, from small ones in mountain glacial cirques to larger ones (the Great Lakes) on the old continental plains and blocks of the subpolar zone (Fenoscandia, Canada).

Lake basins produced by the dissolution of the bedrock. These occur mostly in limestone-based depressions (dolines, poljes), but also on salt deposits. A special case is chemical suffusion, a process developing in loess deposits and generating small, shallow depressions on the ground, in which water gathers. Their incidence is higher in the plain areas, where such deposits do exist (e.g. the Romanian Plain).

Lake basins formed by fluvitile processes. These are found in the floodplains of large rivers, in meanders and abandoned channels (meanders, scrolls, oxbow lakes), wherever small tributaries become obstructed by the mainstream (fluviatile limans). Such lakes frequently occur on the lower course of lowland streams.

Lake basins formed by shorelie processes. Sea currents and sea waves dislodge sediments along the shore, forming bars which enclose smaller gulfs, turning them into lagoons, or small valleys and engendering fluvio-marine slugs (limans). Examples of lagoon-rich coast is the Gulf of Mexico between Yukatan and Florida, the Bay of Biscaya, the Mediterranean Sea between the extremities of the Pyrenees and the Alps. The largest lagoon, however, is Maracaibo in Venezuela.

Lake basins formed by wind action. They are formed by erosion processes of deflation, by the accumulation of windborne material,but are short-lived. They occur in arid areas after rainfalls.

Lake basins formed by organic accumulation. These include some lakes which emerge when the stream is dammed by vegetal remains or by the accumulation of corals on the shore of tropical and subtropical seas. Typical case are the coral lagoons of the Pacific and Indian oceans.

Lake formed by the impact of meteorites. These are crater - shaped depressions of variousl sizes. The best- known lake in this group is Chubb, situated in the Chubb crater, Ungava region, Canada (3 350 m in diameter, 410 m deep; the lake itself being 251 m long). Other lakes of this type include Bosumtwi in Ghana and Lonar Deccan Tableland, India.

Lake basins formed by human activity. These go back over 4000 years. From ancient Egypt and Syria to this day, people have been building them to meet their various needs. Artificial lake have a wide range of sizes and utilities, but they have also drastically changed some streamflows, producing ecological imbalances in the respective areas (for example Aswan Dam, Egypt and Sudan, has had the strongest ecological impact downstream the Nile, with severe consequences for its delta, in particular).

Water balance

Lake water balance (WB) represents the quantity of inflow (I) and outflow (0) analyzed over a given time interval (day, month, season, year, or several years) and put into a mathematical formula. WB is ***positive*** when I > 0, which means that a certain water volume accumulates in the lake (+ΔV) and the water level rises; and ***negative***, when I < 0, in which case the lake loses a certain volume of water (-ΔV), and its level drops; ***constant (neutral)*** when I = 0, then both the water volume and the level remain constant. The WB model depends on many natural or artificial components, in particular precipitation, evaporation and discharge of drainage basin. Quantitative WB values are related to the geographical (climatic) zone the lake lies in and the local characteristics of the area. In terms of water balance lakes may be classifed into *permanent, temporary* and *ephemeral*, *with* and *without discharge (enclosed)* .

The water level of the lake is an accurate measure of water volume. The WB-governed level hydrograph is given by hypsographic curve changes.The water balance and water level variations are the main expression of climatic conditions, having facilitated medium-and long-term assessment of climate changes in certain regions of the world, following the pattern of some big lakes, especially closed-in lakes (without discharge).

Water chemistry and mineralisation.

Water chemical composition and mineralisation depend on the rock composition of the lake basin and of the drainage basin, and on the climatic zone. The chemical composition accounts for the *hydrochemical type*, reflecting the proportion of major anions and cations. As a rule, three main anion-based hydrochemical types can be distinguished: Cl (*chlorate*, characteristic of saline and brackish lakes); $S0_4$ (*sulphate*, specific to saline and brackish lakes); $HC0_3$ (*carbonate*, *hydrocarbonate*, peculiar to fresh-water lakes). The main cations (Ca^{++}, N^+, and K^+, Mg^{++}) are used to identify hydrochemical subtypes, e.g. sodium-chloride; calcium-bicarbonate, etc.

According to their mineralization (quantity of salts in solution), lakes are grouped into: *freshwater* (up to lg/l); *brackish* (1-24.7 g/l); *saline* (24.7-50 g/l) and *ultrasaline* (over 50 g/l).

Thermal regime and classification

The thermal regime and structure of lakes depend on climatic zone, lake basin pattern and size, water volume, type of water balance and mineralization .Thus there may be *direct thermal stratification*, with higher upper-layer (*epilimnion)* temperatures (temperature variations relate to the air temperature values); a sudden fall of temperature (*thermal leap or thermocline*) in the intermediate layer (*metalimnion),* as well as small, sometimes constant variation, close to 4°C, in the deep layer (*hypolimnion*).Alternatively,there may be *indirect (reverse) sratification*, with low epilimnion and higher hypolimnion temperatures while in shallow lakes, *thermal uniformity* is induced by mechanically (by wind) or by convection (in seasons of transition). It is the so-called *homothermal phase*.

Classifications of lakes into *polar, temperate* and *tropical* (**A. Forel,** 1901) and subsequently into intermediate divisions - *subpolar, subtropical* (**S. Yoshimura**, 1936) - were based on the criterion of water temperature passing through the maximum density threshold (4°C) in the course of one year transition. **G.E. Hutchinson** (1957) divides lake types according to the modality and number of thermal water mixtures: *dimictic* (two mixed phases in the temperate zone), *amictic* (no water mixing), *oligomictic* (low mixing), and *polymictic* (several mixtures). **W.M. Lewis** (1983) divides lake in: *amictic, cold monomictic, continuous cold polymictic, discontinuous cold polymictic, dimictic, warm monomictic, discontinuous polymictic* and *continuous warm polymictic*.

Trophicity

In terms of the quantity of nutrients (mainly nitrates and phosphates), lakes are grouped into *oligotrophic* (nutrient-poor, characteristic of polar, subpolar and high mountain zones), *mesotrophic* (nutrient-rich) and *eutrophic* (nutrient excess, causing water blooming). Several intermediate groups besides these types are also ones are also reported.

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