Origin of Lakes

(Kalff Chapter 6, pp72-84)

A. Introduction

The nature of the physico-chemical and biological events taking place in a lake are related to its shape and size as well as the characteristics of the drainage basin. These characteristics are in turn largely determined by the mode of origin of the lake.

In general the forces forming a lake are:

1. catastrophic, or sudden in geological terms,
2. regional in nature, often giving rise to several similar lakes forming a "lake district", and
3. followed by erosion (of the outlet) and sedimentation of the basin so that lakes are temporary features of the landscape.

Lakes are typically formed by a sudden catastrophic event (at least on a geologic time scale) and eventually end by slow and gradual processes. *[Note however that the metaphor of "lake aging" as equivalent to eutrophication is misleading and should be avoided. Some lakes (Lake Baikal, East African Rift lakes) have endured for millions of years whereas smaller lakes may become extinct after just a few hundred years. i.e. "age" is not equivalent to "trophic status" nor life expectancy.]*

Because the geological forces that create lakes commonly act on a region-wide basis, lakes are often clustered in *lake districts*. Lake districts offer interesting possibilities for comparative studies. The Experimental Lakes Area (ELA) managed by the Canadian Freshwater Institute and the North Temperate Lakes Long-Term Ecological Research Site (LTER) in northern Wisconsin are prime examples of the value of such studies. "By taking a landscape-scale view, in addition to the more usual lake-specific view, it is possible to reach a more robust understanding of lake dynamics and avoid some of the problems associated with extrapolating from single lake results." [Kratz et al, 1997 "The influence of landscape position on lakes in northern Wisconsin", Freshwater Biology **37**:209-217.]

Studies focused on lake districts have gained more attention. [Examples: "Catchment-scale analysis of aquatic ecosystems." 1997 Allan and Johnsons, Freshwater Biology **37**:107-111; "The ecological organization of lake districts: general introduction." 2000 Kratz and Frost, Freshwater Biology **43**:297-299. The results of these studies and others have clearly demonstrated that **landscape-level processes lead to the 'ecological organization of lake districts**.' For example, Riera et al (2000) relate a wide variety of variables (including common ions, nutrients, chlorophyll, fish diversity, etc.) to "lake order" They define lake order as "a metric to analyze the effect of landscape position on limnological features." Lake order is related closely to stream order. (For order 1 and higher, lake order is the same as the order of the stream draining the lake. For lakes without permanent outflow, negative numbers are applied. See reference.) Riera et al 2000 "A geomorphic template for the analysis of lake districts applied to the Northern Highland Lake District, Wisconsin, USA." Freshwater Biology **43**:301-318.

B. Examples of forces forming lake basins.

(For a complete reference, see G.E.Hutchinson, A Treatise on Limnology, Chapter 1, pp1-163)

1. Tectonic lakes (6.3 Kalff)

Tectonic basins are those formed by **movements of the earth's crust**. Although few in number, tectonic lakes include the largest and by far the oldest freshwater lakes. Some principal types are:

a. Tilted fault block

A fault is a break in rock strata that causes a section to become dislocated along the line of fracture. In the case of a tilted fault block, there is vertical movement on either side of a single line of fracture, producing a wedge-shaped basin along the face of the fault. A famous local example is Abert lake.


Abert Lake

b. Graben lake

A graben is..." a depressed segment of the earth's crust bounded on at least 2 sides by faults and generally of considerable length as compared with its width." The deepest lakes in the world are graben lakes: Lake Baikal (1640 meters), Lake Tanganyika (1470 meters). A local example is Lake Tahoe (501 meters).

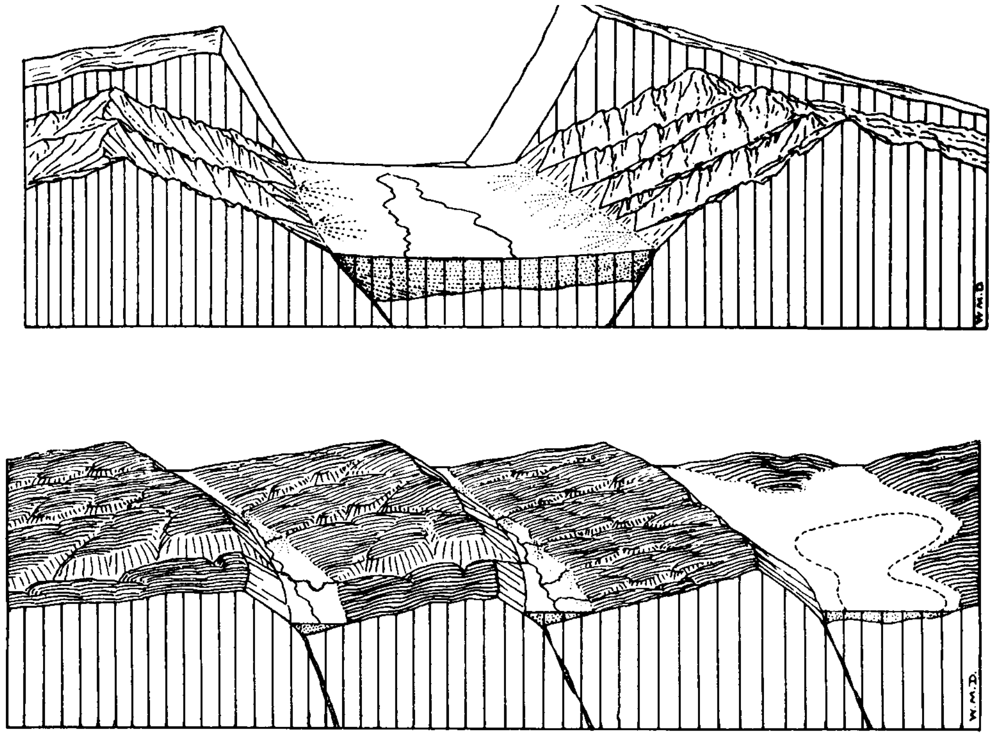


Figure 3-2 Tectonic lake basins. *Upper:* in the background, a depressed fault block between two upheaved fault blocks; in foreground, the same after a considerable period of erosion and deposition. *Lower:* Diagram of the great fault blocks of the northern Sierra Nevada Mountains with the plain of Honey Lake to the east. (From Davis, W. M.: Calif. J. Mines Geol. 29:175, 1933.)

Baikal

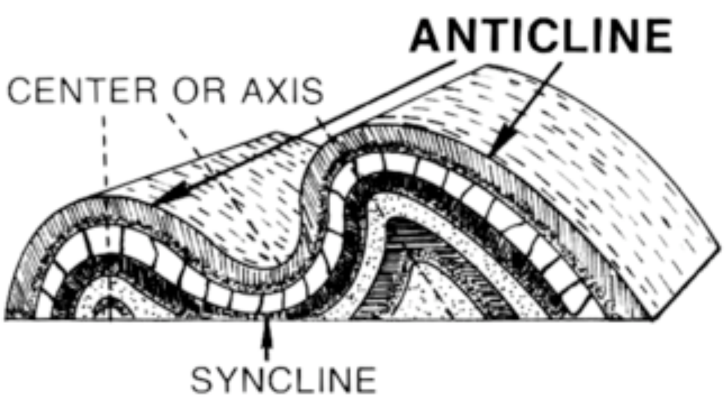
Rift valley lakes in east Africa

Tahoe

c. Other tectonic lakes

Subsidence (Reelfoot lake in Tennessee) and Syncline lakes (Lake Rudolph in East Africa).

(Syncline: ..."a fold of stratified rock inclining upward in opposite directions from both sides of its axis...")



Reelfoot Lake in northwest Tennessee was formed by subsidence in 1811/112 following earthquakes on the New Madrid fault

2. Volcanic lakes (6.6 Kalff)

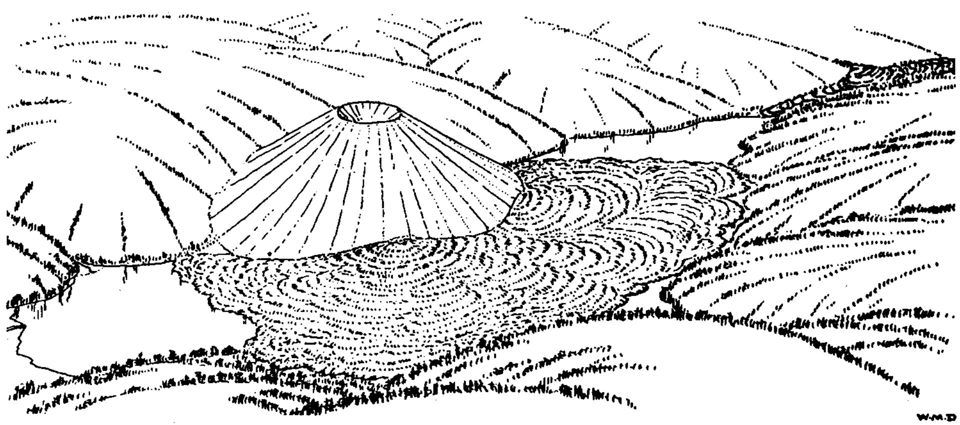


Figure 3-3 Volcanic lakes. A caldera lake within the volcanic cone and several lakes within the valleys dammed by lava flows. (From Davis, W. M.: Calif. J. Mines Geol. 29:175, 1933.)

a. Caldera

A caldera results from the collapse of the surface after subsurface material has been ejected (may or may not be an explosive event). Crater Lake in Oregon is a spectacular example of a caldera lake. It resulted from the explosion of Mt. Mazama about 7000 years ago.

Some characteristics of interest are: circular basin, steep sides, relatively flat floor, and very little drainage basin.

b. Lahar lakes

A lahar is a mudflow containing much volcanic debris. Some local examples of lahar lakes are Castle Lake and Coldwater Lake on either side of the Toutle river valley in the Mt. St. Helens National Monument.

Castle Lake

c. Maars

A maar results from a steam explosion from hot subsurface rocks. Local examples are Blue Lake (in Santiam Pass) and St. Helens Lake near Spirit Lake. Although small in surface area, these lakes may be quite deep, and are often nearly circular.

Spirit Lake

St. Helens Lake

Blue Lake with Mt. Washington in background

3. Landslide lakes

A lake basin may result from the damming of a river valley by a landslide. Some local examples are Bull Run (maybe), Clear Lake and Lost Lake of the Oregon Cascades, and Loon Lake of the Coast range near Reedsport, OR; Eagle Lake in the Warner range of Northern California.

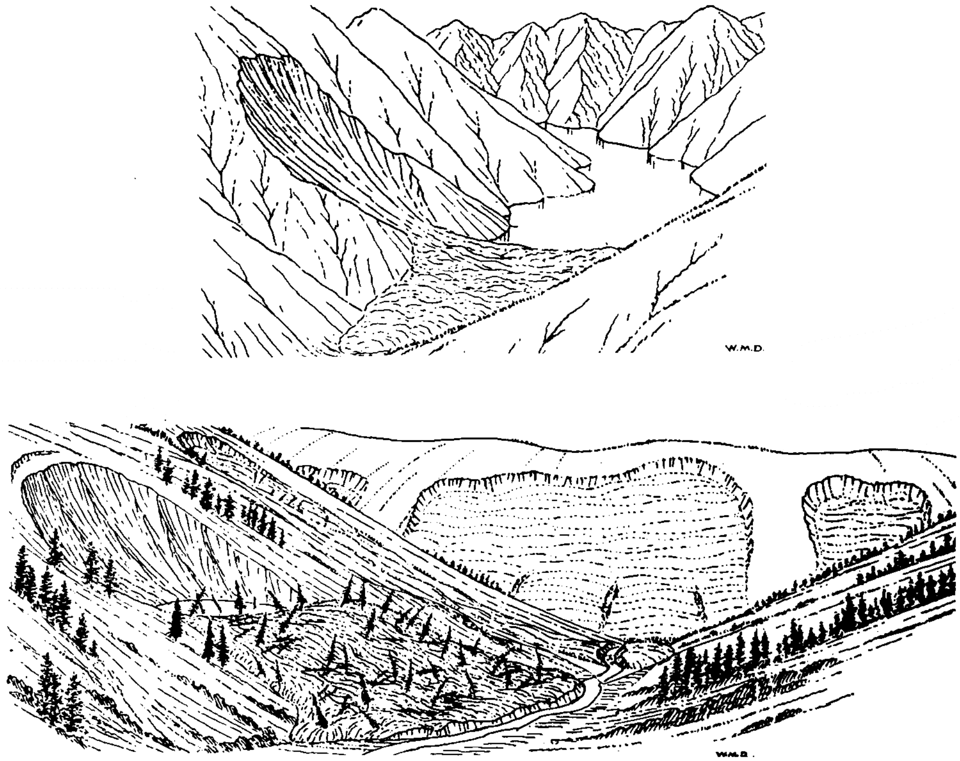


Figure 3-5 Lakes formed by a large landslide into a steep-sided stream-eroded canyon *(upper)* and in a hollow behind a recent slide with tilted trees *(lower)*. Four mountain landslides are shown in the background. (From Davis, W. M.: Calif. J. Mines Geol. 29:175, 1933.)

From Wetzel

Some characteristics: These lakes are often very transitory, depending on the nature of the material forming the dam. The drowned stream valley pattern is similar to man-made reservoirs.

On August 17, 1959 an earthquake in the Madison Canyon River Area, near West Yellowstone, formed Quake Lake. The earthquake created a massive landslide of about 80 million tons of rock, which stopped the flow of the Madison River in the Madison River Canyon gorge.

Quake Lake, Montana

4. Glacial lakes (6.2 Kalff)

Because of the relatively recent Pleistocene glaciations, glacial lakes are the most common kind of lake at this time (at higher latitudes). According to Kalff, about 3/4 of all lakes are glacial in origin. Kalff (p73) describes the various glacial processes responsible for forming lake basins.

a. Cirque lakes

These lakes are formed by the repeated frost-riving due to repeated freezing and thawing. Some local examples are Mirror lake, just south of Mt. Hood and Hanaford, Fawn, Venus and others near Mt. St. Helens. The elevation of these lakes is evidence of the climate characteristic of the time of formation.

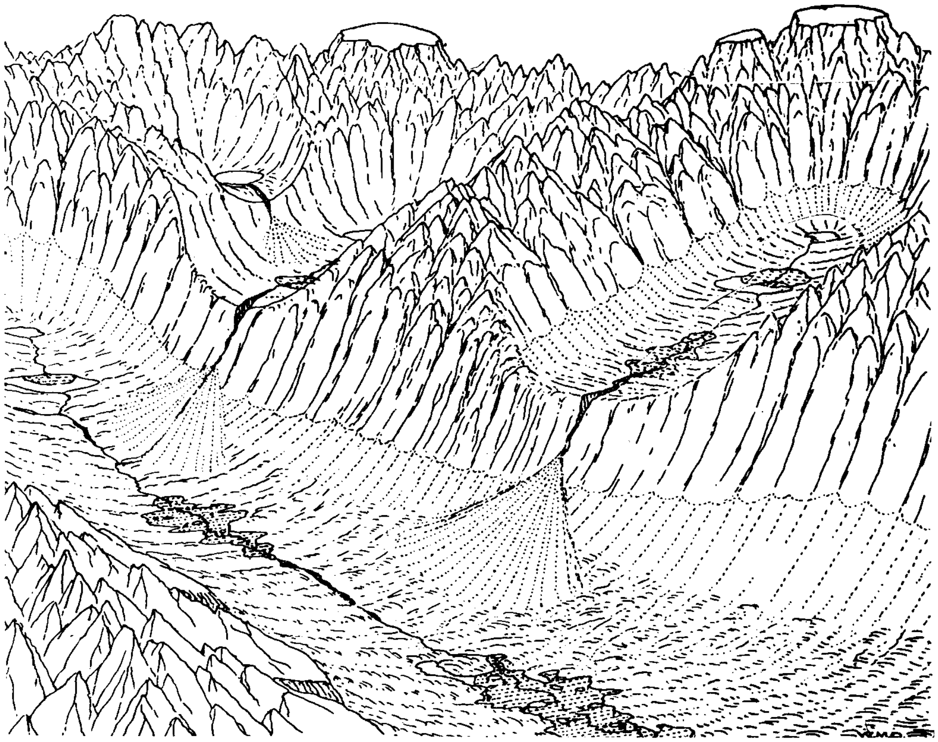


Figure 3-6 Several small cirque lakes within a mountain group from which several converging, cirque-headed branch troughs all join the same trunk trough. (From Davis, W. M.: Calif. J. Mines Geol. 29:175, 1933.)

From Wetzel

Mirror Lake (between Government Camp and Rhododendron)

b. Moraine lakes

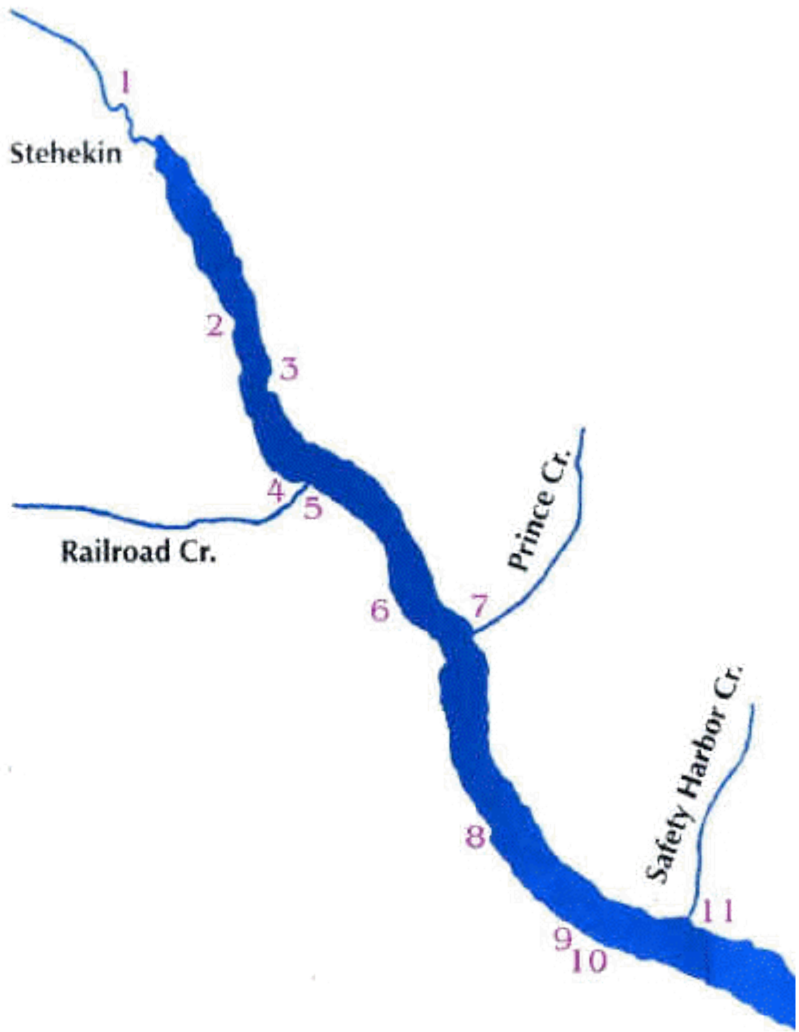
These lakes are formed by damming by glacial moraines. Local example is Wallowa Lake.

Wallowa Lake

b. Fjord lakes

Fjord lakes are formed when a glacier scours out a pre-existing stream valley. A local example: Lake Chelan.

These lakes characteristically are elongate and have a U shaped bottom profile. Many such basins are open to the ocean (hence the Norwegian name).



Lake Chelan

c. Continental scour lakes

The North American Great Lakes are an outstanding example of continental scour lakes (but there are many smaller lakes of this type). These lakes collectively represent the single largest body of freshwater in the world (approximately equaled in volume by Lake Baikal).

Characteristics include: an irregular bottom due to the differential resistance to scouring by the parent rock, and an ongoing tilting of the shorelines because of isostatic rebound.

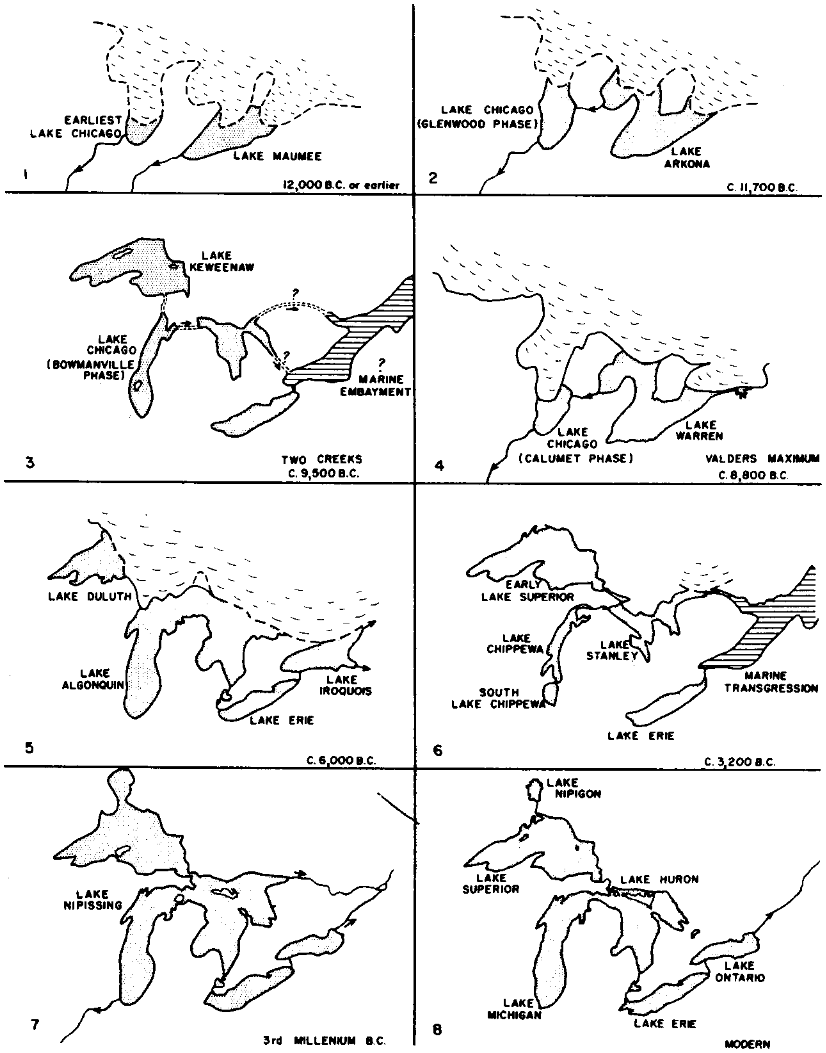


Figure 3-7 The history of the Laurentian Great Lakes. *1*, Cary substage; *2*, Late Cary; *3*, Cary-Valders interstadial, low water in eastern basins, marine transgression in Ontario Basin; *4*, Valders maximum; *5*, Post-Mankato retreat; *6*, Postglacial thermal maximum; *7*, Lake Nipissing with triple drainage; *8*, Modern lakes. (From Hutchinson, G. E.: A Treatise on Limnology. Vol. 1, New York, John Wiley & Sons, Inc., 1957, after various sources; see Hough, 1958, for details.)

From Wetzel

d. Kettles

Kettle lakes result from the collapse of overlying material after a block of relict ice melts. As expected, Kettles are small and nearly circular. Kettles are common in some areas of the upper Mid-west.

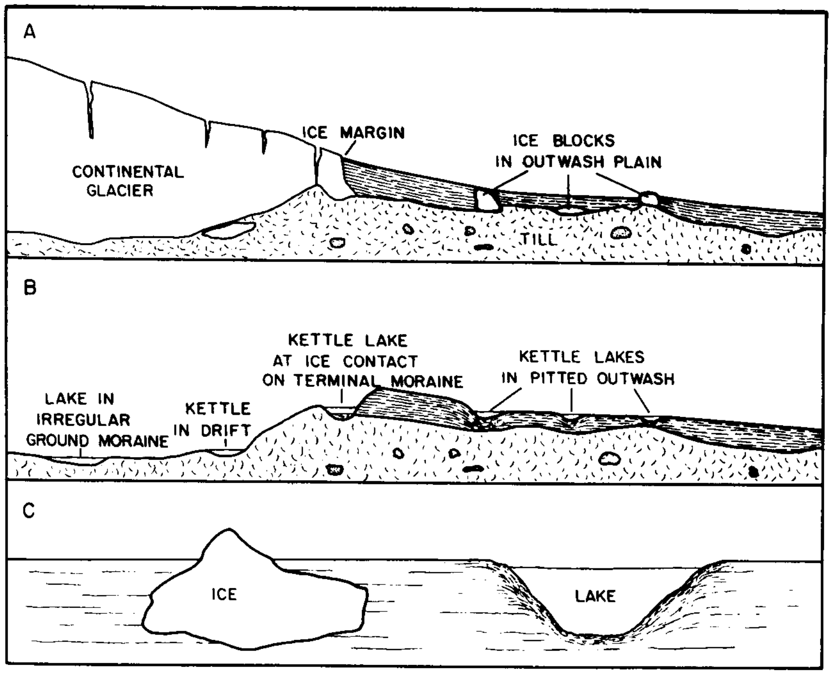


Figure 3-8 The formation of various types of kettle lakes. *A*, An outwash plain of retreating continental ice containing ice blocks; *B*, Lakes formed in the outwash plain and morainal till; *C*, Irregular slopes and shelves of a kettle lake formed by deposition of overburden till on an irregular block of ice. (From Hutchinson, G. E.: A Treatise on Limnology, Vol. 1, New York, John Wiley & Sons, Inc., 1957, after Zumberge, 1952.)

5. Solution lakes (6.7 Kalff)

Solution lakes result from the dissolution of soluble rock, usually carbonates. The dissolution results from:

$CaCO_3 + H_2O + CO_2$ -----> $Ca^{+2} + 2\ HCO_3^-$

The most important region in the US of solution lakes ("Karst topography") is in Florida. Many solution lakes drain through underground connections. Some may be funnel shaped (dolines).

Lake Jackson (Tallahassee), is known nationally as a premiere bass fishing lake. And over the years, aquatic weed and water quality concerns in the lake have been the subject of countless homeowners' meetings and of primary interest to lake management personnel. However, its bass reputation and aquatic weed problems became much less consequential on September 16, 1999 when a sink hole suddenly drained more than half the lake of every last gallon of water, not to mention every last fish and alligator. It is now possible to walk from shore to shore--but steer clear of the sink hole.

Jess Van Dyke, long-time regional biologist with the Bureau of Invasive Plant Management (Florida Department of Environmental Protection) was there when it happened. "It was spectacular: animals trying to scramble out; a whirlpool of gators, birds and bass went down the hole," said Van Dyke. Lake Jackson is one of Florida's disappearing lakes, lakes with sinkholes that are known to drain periodically. Lake Jackson, for example, has drained 4 times previously in the 20th century, in 1907, 1933, 1957, 1982 and 1999

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before

after

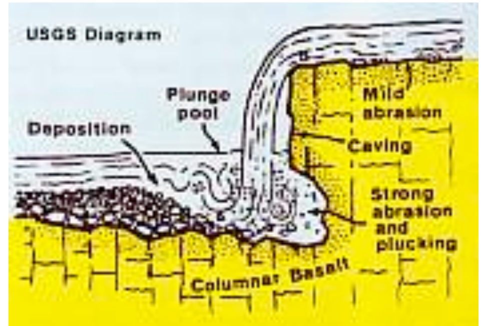
the hole

6. Fluviatile lakes (6.5 Kalff)

Lakes formed by the action of rivers are fluviatile lakes. Some examples are:

a. Plunge pool lakes

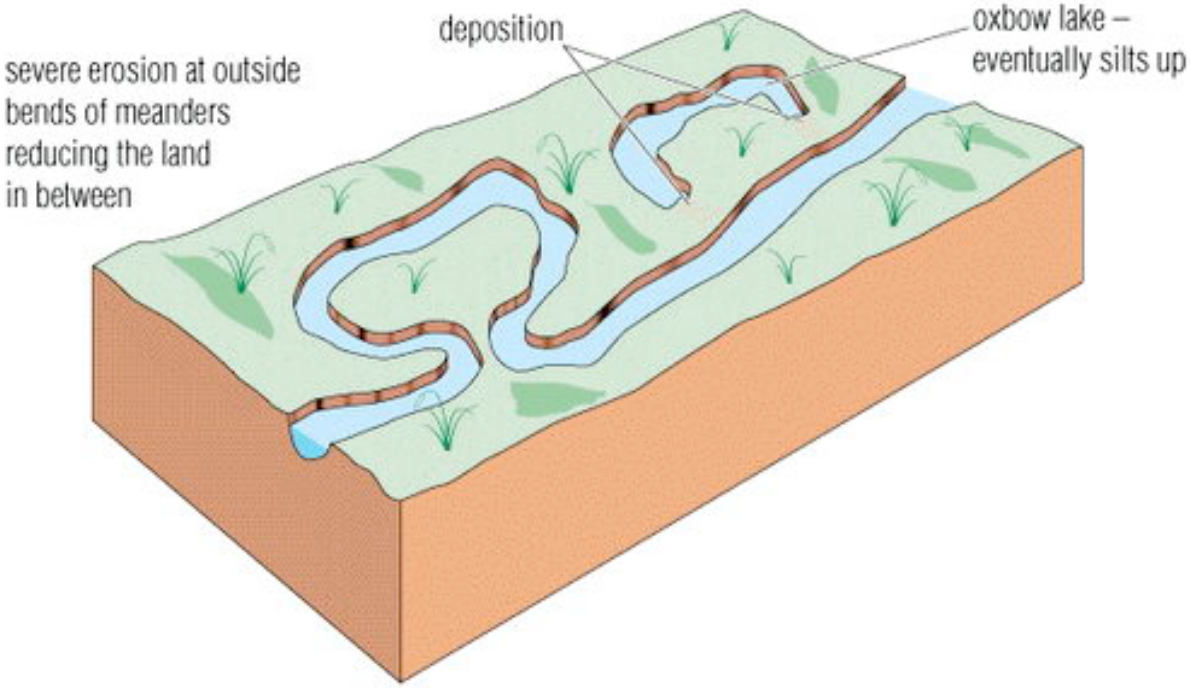
There are plunge pool lakes in Eastern Washington where the Columbia once flowed over a cliff (Soap lake, etc.) and in Idaho.

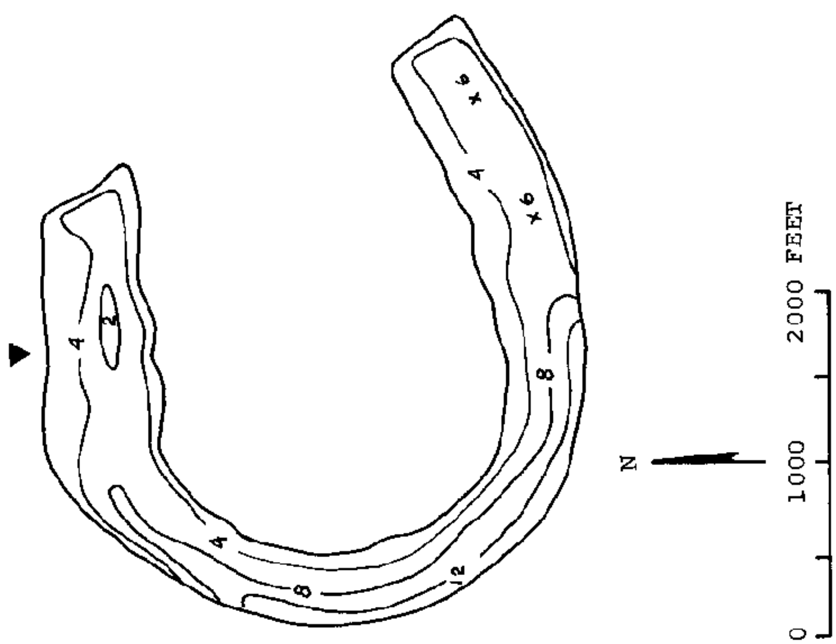


Dry Falls, Washington

b. Oxbow lakes

Oxbow lakes are common features on the flood plain of a mature river valley. Local examples are Blue lake and Vancouver lake.





Horseshoe Lake, Woodland, WA. Formed on Lewis River.

Varzea (Amazon) or Cienaga (Magdalena) lakes in South America (see Kalff, p79).

A large number of shallow lakes emerge during the wet cycle of large tropical rivers. These lakes commonly dry up during the dry season, but can be extremely important to the biology of the region (see figure 6.6, p79 of Kalff).

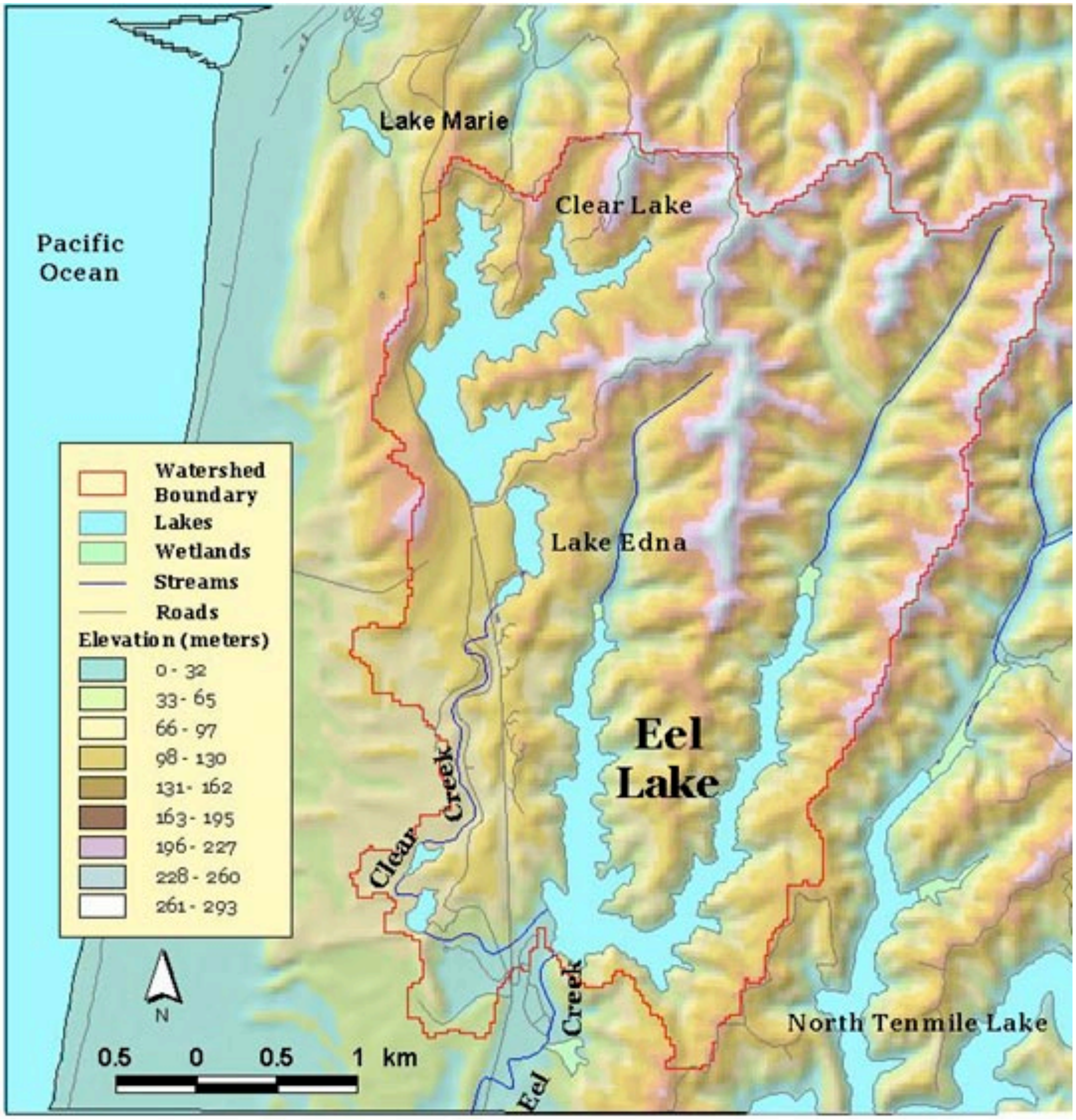
7. Wind lakes

Lake basins may be formed by the action of the wind. Moses Lake in Eastern Washington is said to be the result of wind action. There are many small bodies of water along the Oregon coast which are the result of deflation of sand down to the water table.

Taylor Lake, Oregon Dunes NRA

8. Shoreline lakes (6.4 Kalff)

Lake basins may result from the growth of spits across the mouth of bays or estuaries. If the passage to the sea becomes narrow enough, a freshwater basin is formed. There are several examples in Lane County, Oregon (Eel Lake, Siltcoos, Mercer). Lakes have also formed in the swales between accreting dunes (e.g. Sunset, Coffenbury Lakes in Clatsop County Oregon).



9. Lakes formed by dams (6.9 Kalff)

Two species of vertebrates build dams: humans and beavers. Reservoirs are of course very young in geological terms. Some characteristic features include: shorelines which are subject to active erosion (especially with fluctuating water levels) and (usually) a dendritic shape.

Other human activities can also produce lakes: quarries, subsidence over subsurface mines.

Grand Coulee

Bonneville Dam

10. Meteorite impact craters

    Rare and dramatic. The only well documented example is the New Quebec Crater in northern Quebec. The basin was formed by the explosion of gases following the impact of a meteorite.