

Important Acronyms

In Tahoe there are many acronyms floating around and not everyone takes the time to explain what they mean. Scientists in the TCES at SNC examine the SEZ and BMPS from TC to KB. Did you catch all that? Here are a few of the common acronyms you may hear around TERC.

AGP – Algal Growth Potential
AIS – Aquatic Invasive Species
BMP – Best Management Practice
CFL – Compact Fluorescent Lightbulbs
EIP – Environmental Improvement Program
EPA – Environmental Protection Agency
IVGID – Incline Village General Improvement District
JMIE – John Muir Institute for the Environment
KB – Kings Beach
LCT – Lahontan Cutthroat Trout
LEED – Leadership in Energy and Environmental Design
LTIMP – Lake Tahoe Interagency Monitoring Program
LTRA – Lake Tahoe Restoration Act
NASA – National Aeronautics and Space Administration
PPr – Primary Productivity
RV – Research Vessel (TERC has two, the RV John LeConte and the RV Bob Richards)
SEZ – Stream Environment Zone
SNC – Sierra Nevada College (Often confused with the 2-yr junior college Sierra College)
SOTL – State of the Lake Report
SRP – Soluble Reactive Phosphate
SWEP – Sierra Watershed Education Program
TCES – Tahoe Center for Environmental Sciences
TCFS – Tahoe City Field Station
TERC – Tahoe Environmental Research Center
TRG – Tahoe Research Group (Before it became TERC)
TRPA – Tahoe Regional Planning Agency
TINS – Tahoe Institute for Natural Sciences
TRCD – Tahoe Resource Conservation District
TSAC – Tahoe Science Advisory Council
UC – University of California
USFS – United States Forest Service
USGS – United States Geological Survey
VOC – Volatile Organic Compound

Lake Tahoe Vocabulary List

Terminology commonly used by scientists and researchers at Lake Tahoe:

Atmospheric deposition: Pollution from the air may deposit into water bodies and affect water quality in these systems. Airborne pollution can fall to the ground in raindrops, in dust or simply due to gravity. As the pollution falls, it may end up in streams, lakes, or estuaries and can affect the water quality there.

Bathymetry: the measurement of water depth at various places in a body of water

Best Management Practices (BMPs): structural BMPs include infiltration devices, ponds, filters and constructed wetlands and non-structural BMPs include low impact development practices and management measures such as maintenance practices, street sweeping, public education and outreach programs. Section 208 of 1972 Clean Water Act requires every state to establish effective BMPs to control nonpoint source pollution.

Erosion: the group of natural processes, including weathering, dissolution, abrasion, corrosion, and transportation, by which material is worn away from the earth's surface.

Eutrophic: having waters rich in mineral and organic nutrients that promote a proliferation of plant life, especially algae, which reduces the dissolved oxygen content and often causes the extinction of other organisms. Used of a lake or pond.

Eutrophication: the process by which a body of water becomes enriched in dissolved nutrients that stimulate the growth of aquatic plant life usually resulting in the depletion of dissolved oxygen.

Infiltration: to enter, permeate, or pass through a substance or area by filtering; infiltration is the process by which water on the ground surface enters the soil

Limnology: the scientific study of bodies of freshwater (as lakes); the scientific study of the life and phenomena of fresh water, especially lakes and ponds

Non-point Source Pollution (NPS): pollution coming from many small sources

Nutrients: a source of nourishment, especially a nourishing ingredient in a food; specifically, nitrogen and phosphorus

Oligotrophic: lacking in plant nutrients and having a large amount of dissolved oxygen throughout a pond or lake; having a deficiency of plant nutrients that is usually accompanied by an abundance of dissolved oxygen (as in a clear oligotrophic lake)

Phytoplankton: tiny (minute) free-floating aquatic plants; planktonic plant life (in Lake Tahoe these include diatoms, Chrysophytes, Chlorophytes, Cryptophytes and Dinoflagellites)

Plankton: microscopic organisms (see also phytoplankton and zooplankton); the passively floating or weakly swimming usually minute animal and plant life of a body of water

Micron: a unit of length equal to one millionth (10^{-6}) of a meter

Chlorophyll: any of a group of green pigments that are found in the chloroplasts of plants; the green photosynthetic pigment found in plants

Electrical conductivity: the ability to transmit electricity; conductivity is the ability of water to conduct an electrical current (dissolved ions in the water are conductors); conductivity is measured by an electronic probe, which applies voltage between two electrodes

Secchi Disk: an instrument commonly used for measuring the lake's clarity. It is a round, dinner-plate size disk that is lowered into the water. Once it can no longer be seen in the deep water, a scientist measures how far down it was lowered to determine the water's clarity.

Streamflow: discharge of water from a stream; the amount of water flowing in a stream or river

Total Maximum Daily Load (TMDL): Section 303(d) of the 1987 Water Quality Act requires the states to list those water bodies that are not attaining water quality standards including designated uses and identification of relative priorities among the impaired water bodies. States must also develop TMDLs (Total Maximum Daily Loads) that quantify the pollutant load or the impairing pollutants that will bring the waterbody back into attainment.

Thermocline: the region in a thermally stratified body of water which separates warmer surface water from cold deep water and in which temperature decreases rapidly with depth. As you go down farther and farther into the lake, the water stays about the same temperature as at the surface. But once you reach a certain depth boundary (the thermocline), the water's temperature starts decreasing rapidly with depth

Urban Runoff: storm water or non-storm water from urbanized areas (city streets, gutters, etc.) that is dirty and polluted. This water runs down the lake and contributes to the lake's loss of clarity.

Water Clarity: The depth to which light penetrates water. A lake that is composed of clear, clean water will have a much higher level or clarity than one that is polluted.

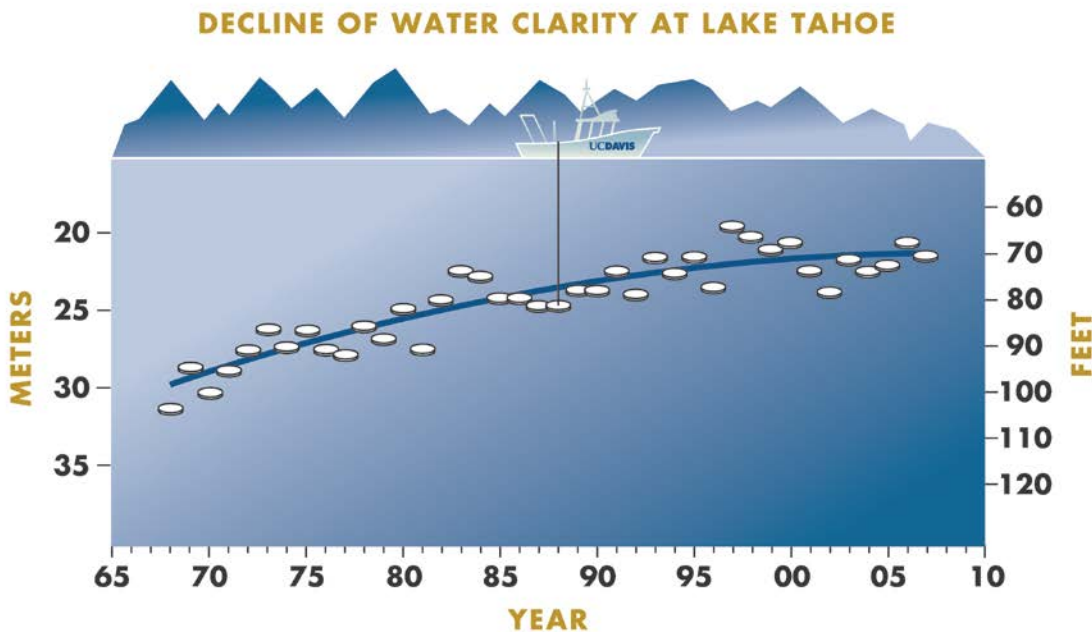
Zooplankton: plankton composed of animals; tiny aquatic animals that live in bodies of water, they are usually microscopic and are an important part of the food chain in water habitats (in Lake Tahoe these include Diaptomus, Epischura, Bosmina, Daphnia, Mysis shrimp, and several types of rotifers)

The Secchi Disk

Father Pietro Angelo Secchi, scientific advisor to the Pope, was asked by Commander Cialdi, head of the Papal Navy, to test a new transparency instrument. This instrument, now named the “Secchi disk,” was first lowered from the papal steam yacht, l’Immacolata Concezione in the Mediterranean Sea on April 20, 1865.

Today, that same instrument is used to measure water clarity at Lake Tahoe. The Secchi disk, a 10-inch opaque white disk, is lowered into the lake until it can be no longer seen by the observer. This depth of disappearance, called the Secchi depth, is a measure of the transparency of the water. Transparency decreases as suspended sediments or algal abundance increases.

Changes in transparency reflect the impact of human activity in the Tahoe basin. Since 1959, the Tahoe Research Group (now called the Tahoe Environmental Research Center) has tracked and recorded the changes in transparency at Lake Tahoe. The data shows that Lake Tahoe’s clarity has decreased.



Using the white Secchi disk to measure water transparency, UC Davis researchers have documented a decline in Lake Tahoe’s water clarity.

Every 10 days, a white plate-like disc called a Secchi disk is used to measure Lake Tahoe’s clarity. The disk is lowered into the lake from the UC Davis research boat (RV John LeConte) until it disappears from view and then raised to the point at which it reappears. The average between these two measurements provides an individual secchi depth measurement to describe the lake’s transparency. The annual clarity value is calculated by taking the average of these individual

measurements over the calendar year. (Note: While other more technologically advanced methods are available, and used, only the Secchi disk data has a long-term record at Lake Tahoe.)

Since 1968, Lake Tahoe's clarity has declined by an average of more than one foot per year. Sediment (microscopic particles of dirt and small debris) and algae suspended in the lake are major contributors to this decline. Although the loss of clarity caused by particles can be reversed once the particles settle on the lake's floor, these particles also carry nutrients that feed algae. Phosphorus from sediment and nitrogen from airborne sources such as vehicle exhaust, have been causing algae to grow at an increased rate.

In May 2008, for the first time since researchers began continuously measuring Lake Tahoe's famed water clarity 40 years ago, UC Davis scientists reported that the historical rate of decline in the lake's clarity has slowed considerably in recent years.

Scientists at the UC Davis Tahoe Environmental Research Center say that by using new, more sophisticated models for detecting trends and, by factoring out the effects of annual precipitation, they have concluded that the historic rate of decline in the lake's clarity has slowed since 2001.

"From 1968 to 2000 there was a near-continuous decline in lake clarity. There were several years at a time when things seemed to improve, but invariably we returned to the same trend," said Geoffrey Schladow, a UC Davis professor of civil and environmental engineering who directs the Tahoe research center. "But since 2001, we have had seven years in which the clarity has consistently been better than the long-term trend would have predicted. This is unprecedented."

Schladow cautioned that the data do not pinpoint a specific cause for the recent improvements, but noted that new modeling results show that runoff of fine particles from both urbanized areas and roadways around the lake are the primary factors that influence clarity levels. Fine particles scatter light and limit how far into the lake we can see.

In addition, Schladow and his UC Davis colleagues cautioned that it is difficult to use data from a small number of years (2001 to 2007) to draw conclusions about when the trend might change from a slowdown in clarity decline to an improvement in clarity. "Only with the commitment to long-term monitoring can we truly evaluate environmental changes over time," he said.

The Research Vessel (R/V) "John LeConte"

*By Robert Richards, UC Davis TERC
February 2007*

The virtual research vessel exhibit "replica" of the R/V John LeConte was fabricated in the Engineering workshop at UC Davis by Bill Sluis, Daret Kehlet, Tom Bell and Mike Banducci. It is an approximate two-thirds sized reproduction of the stern of the real vessel.

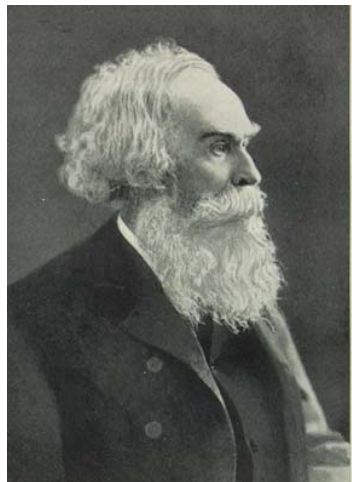
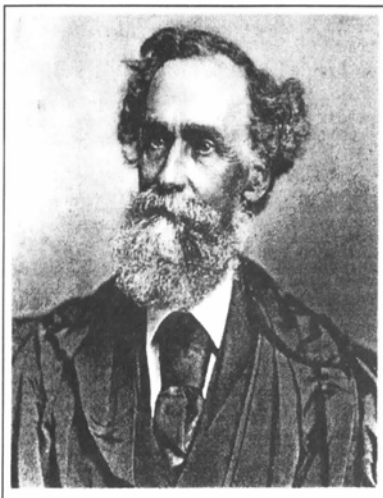
- Custom built in 1976 by Freeman Marine in Gold Beach, Oregon at the mouth of the Rogue River. It was specifically designed to do a broad range of limnological research projects on Lake Tahoe for the UC Davis Tahoe Research Group.
- Cost: About \$75 K from an \$86 K National Science Foundation grant awarded to Dr. Charles Goldman originally intended for the construction of a new research field station and laboratory. Environmental restrictions and land acquisition delays led to re-directing the funds into construction of the LeConte to replace the old, inadequate research vessel "San Giuseppe", a converted wooden horseshoe-stern salmon fishing trolling boat from San Francisco's Fisherman's Wharf.
- Length: 37 ft., Beam Width: 13.5 ft., Draft to Keel: 4.5 ft., Weight: 13 tons. Hull and Superstructure is 1061 Kaiser Aluminum, Heliarc welded. Powered by a Detroit Diesel 6V-53, 180 HP engine driving a 24" diameter stainless steel single propeller. Twin Disc Power Take-Off runs 10 and 20 GPM hydraulic pumps powering a 4-spool Kohlstrand gurdie winch, and two Gearmatic 4000 lb. pull large winches with ¼ " and ½ " wire rope 3000 ft. long to reach the lake bottom.
- Top Speed: 10 knots with a clean hull. Algal growth can reduce speed by at least one third and increase fuel use by 30-40%. Fuel capacity: Port and Starboard aft tanks hold 360 gallons. Fuel use averages 4.5-5 gallons per hour.
- Cabin was built oversize to house research electronics; extra bench space for filtrations and water sample processing. House current (115V) is provided by a 7.5 KW Lima generator powered by a hydraulic motor supplied by two variable-pitch hydraulic piston pumps attached to the camshafts of the boat diesel engine. Transmission is an oil-cooled Twin Disc. Two 12 Volt 8D batteries power the engine, electronics and cabin, deck, flood, navigation and running lights.
- Electronics: VHF multi-channel marine radio, two depth sounders (paper chart), compass, 20 mile-range radar, Global Positioning System, computers, etc.
- Aft work space is well-decked to provide safety rails for researchers and lower center of gravity with hinged stern doors to provide access to the water surface. Overhead boom and

hydraulic "A" Frame are capable of 2000 lb. lift and they are able to swing equipment from the mid-deck storage hold out and over the stern into the water. Buoys, piston corers, multi-probe sensors, etc. are deployed here.

- The LeConte was named for Professor John LeConte, an original faculty member and President (1869-1881) of the University of California, Berkeley. He and his brother, Joseph, came west from the University of Georgia in 1868 to teach at UC. Joseph was known for his geological interpretations of the formation of the Sierra Nevada. John was a doctor, ornithologist and physicist. He published over 100 scientific papers in these fields and was interested in the transmission of light through water. It was, thus, a natural thing for him to come to Lake Tahoe in the 1870's to study its physical characteristics and light penetration. He used one of his wife's white china dinner plates to take the first Tahoe clarity readings and obtained a reading of 33 meters in 1883. He presented his results in a series of papers called "Physical Studies of Lake Tahoe" in the Overland Monthly. This was the same journal used by Mark Twain to publish his writings.



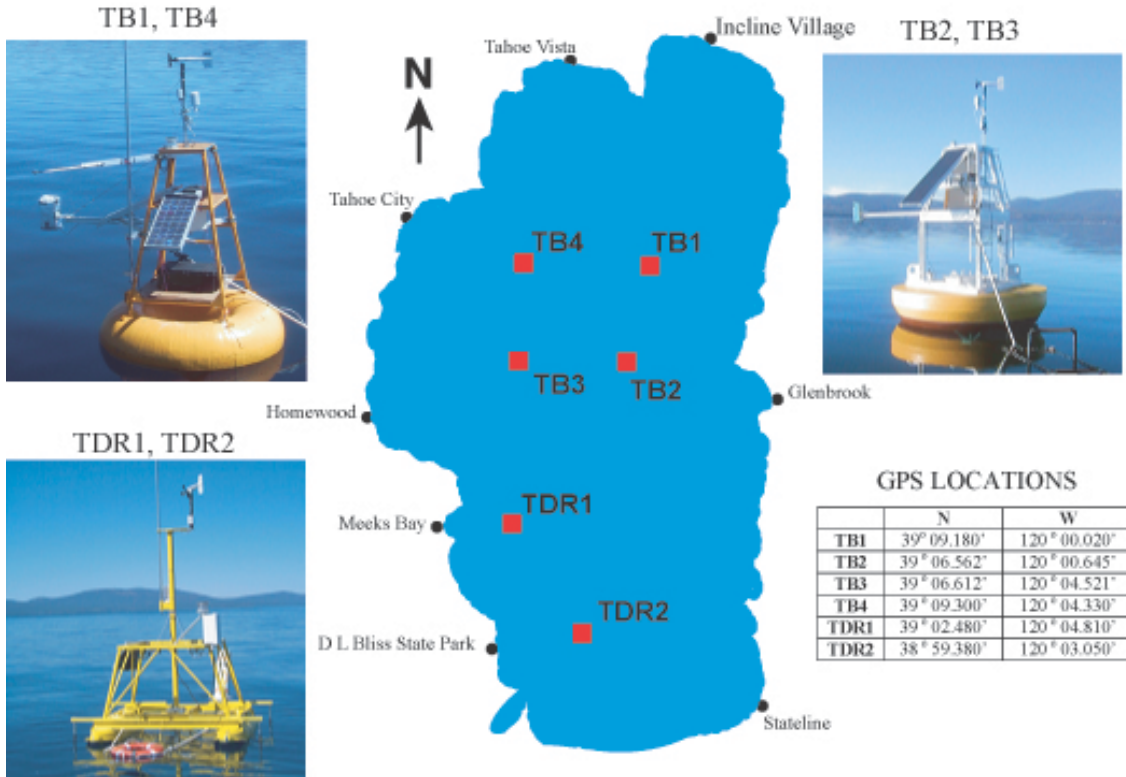
"R\V John LeConte"



John LeConte 1818-1891

Research Buoys on Lake Tahoe

LAKE ADVISORY



The University of California, Davis (UC Davis) and the National Aeronautics and Space Administration Jet Propulsion Lab (NASA/JPL) have 6 large research buoys on Lake Tahoe. Measurements are being used to understand the factors affecting the health of the lake. The locations are shown on the map. Positions may vary by up to 500 ft depending on wind conditions. All are equipped with navigation lights (1 flash every second).

Some of the measurements may be of interest to the Tahoe community and are available over the web. The measurements include wind speed and direction, air temperature, atmospheric pressure and water temperature. They can be viewed at <http://terc.ucdavis.edu/> and <http://laketahoe.jpl.nasa.gov>

The measuring equipment is delicate and there are anchoring and monitoring lines under the buoys. Please maintain a safe distance from the buoys and do not attempt to tie up to them. We appreciate your assistance in maintaining and preserving these resources.

Thank you!

For more information contact:

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Wetlands 101

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Importance of Wetlands

Wetlands, the transitional zones between land and water environments, are among the most biologically fruitful ecosystems, rivaling tropical rainforests in fertility. Scientists and land-use planners have only recently begun to appreciate the critical role played by marshes, swamps, bogs, lakes, estuaries, deltas, floodplains, and other wetlands in maintaining ecological balance.

Wetlands contribute to flood control, for example, by collecting excess rainfall and releasing it slowly over time rather than in a torrent. Wetland soil and vegetation filter contaminants out of water as it percolates through, returning cleaner water to rivers, lakes, and underground aquifers. In addition, wetlands provide indispensable habitat for hundreds of species of amphibians, birds, mammals, and plants.

Wetland Functions

Wetlands are key components in ecosystems, providing many services such as:

- reducing erosion by potentially decreasing floodwater velocity and volume¹
- preventing downstream flood attenuation by spreading excess water flow in floodplains and shallow depressions¹
- improving water quality by removing nutrients and absorbing sediment loads² (this potential benefit is highly dependent on the amount of time that water is retained within wetlands³)
- acting as nutrient sources for fish and other aquatic organisms inhabiting downstream areas in riverine and coastal situations⁴
- providing habitat for a variety of wildlife, such as waterfowl, amphibians, and insects

Loss of Wetlands

In the continental United States, more than half of all native wetlands have been drained, filled, or polluted since colonial times. One estimate puts the rate of wetland loss at 24 hectares per hour (60 acres per hour) since 1780.⁵ With the loss of habitat comes a corresponding decline in flora and fauna: one-third of all endangered plants and animals in the US are wetland species, and some bird populations have fallen to 10 per cent of their historic levels.

Throughout much of the United States, wetland habitat loss has been substantial:

- Between 1780's and 1980's, the lower 48 states have lost 53% of the original wetland habitat, or about 104 million acres.⁵
- Twenty-two states have lost 50% or more of their original wetlands, with California losing the largest percentage (91%) and Florida losing the most acreage (9.3 million acres).⁵
- Most recent losses over the past two decades have been primarily due to agriculture and urban development.⁶
- Most recent losses have been in freshwater wetlands (98%), and 95% of the remaining wetlands are freshwater (as opposed to coastal marshes).⁶

Public perception of wetlands was historically quite negative, with wetlands perceived as swampy wastelands hardly good for anything.⁷ This view shaped wetland policy until the early twentieth century when perceptions began to change slowly with the growing concern about declining migratory bird populations.⁷ Fortunately, a variety of recent U.S. federal and state programs (e.g., the Wetland Reserve Program⁸) have increased wetland protection and provided incentives for habitat restoration.

Wetland Losses in the United States: 1780s to 1980s (US Fish & Wildlife Service Survey)

Region	Land (acres)	Water (acres)	Wetland Area in 1780 (acres)	Percent of Surface Area 1780	Wetland Area in 1985 (acres)	Percent of Surface Area 1985	Percent of Wetlands Lost
California	70,328,960	41,640	487,350	0.7%	236,350	0.3%	-52%
Nevada	100,183,680	1,379,840	5,000,000	4.9%	454,000	0.4%	-91%
Alaska				45.3%		45.3%	-0.1%
United States (contiguous)				11%		5%	-53%
United States (total)						11.9%	-30%

Source: *Wetland losses in the United States: 1780's to 1980's*. U.S. Fish and Wildlife Service, 1990 (5)

Loss of Wetlands at Lake Tahoe

Urbanization of the Lake Tahoe Basin has eliminated 75 percent of its marshes, 50 percent of its meadows, and 35 percent of its stream zone habitats. Approximately 85 percent of all wildlife in the Tahoe Basin uses these habitats.⁹

Lake Tahoe has lost one-third of its transparency in the past thirty years. When Tahoe's clarity was first measured in the 1960's you could see down over 100 feet (annual average). In 2003, you could see down into the lake only 71 feet (annual average). The lake is losing an average of over one foot of clarity each year. Lake Tahoe's water is losing clarity because of very fine (microscopic) sediments entering the lake and algae growth (fueled by nitrogen and phosphorus). Once the very fine

(microscopic) sediments enter Lake Tahoe, they can remain in suspension within the water column. Similarly, once nutrients enter the lake, they can fuel algal growth for decades.

One way to reduce the amount of polluted stormwater getting into the lake is to build new wetlands. These are called constructed wetlands. Our measurements have shown that wetlands can remove most of the pollutants before they enter the lake – turning that polluted (with nutrients and fine particles) water into clean water.

Unfortunately, many of the wetlands in the Tahoe Basin were lost to development. Now the trouble is there simply is not enough flat land around Lake Tahoe to build all the wetlands we would need.

Research has shown how important wetlands and streams are to the health of the lake. That is why local regulatory agencies, such as the Tahoe Regional Planning Agency, have initiated building regulations that now protect these sensitive and important areas from further development.

Sources

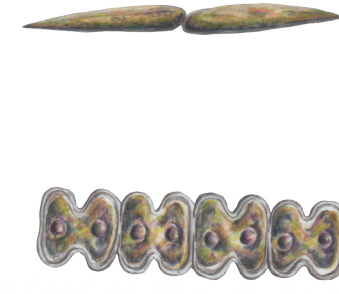
- (1) De Laney, T. A. 1995. "Benefits to downstream flood attenuation and water quality as a result of constructed wetlands in agricultural landscapes." *Journal of Soil and Water Conservation* 50: 620-626.
- (2) Howard-Williams, C. 1985. "Cycling and retention of nitrogen and phosphorus in wetlands: theoretical and applied perspective." *Freshwater Biology* 15:391-431.
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- (5) Dahl, T. E. 1990. "Wetland losses in the United States: 1780's to 1980's." U.S. Fish and Wildlife Service, Washington, DC. 13 p.
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- (9) Murphy, D. D. and Knopp, C. M. (technical editors). 2000. "Lake Tahoe Watershed Assessment: Volume I." Gen. Tech. Rep. PSW-GTR-175. Albany, CA: Pacific Southwest Research Station, Forest Service, US Department of Agriculture.

Species of Lake Tahoe's Aquatic Food Web

Phytoplankton



Diatoms

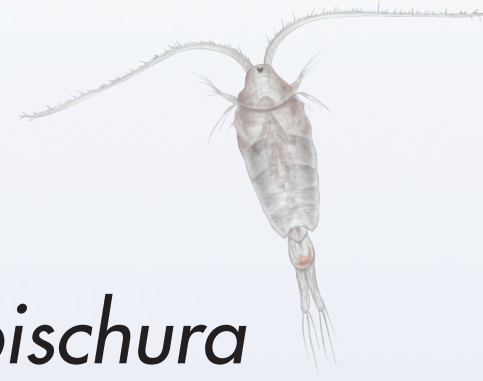


Green Algae

Zooplankton



Diaptomus



Epischura



Mysis Shrimp (Non-native)



Daphnia



Bosmina

Fish

Native



Lahontan cutthroat trout



Paiute sculpin



Mountain whitefish



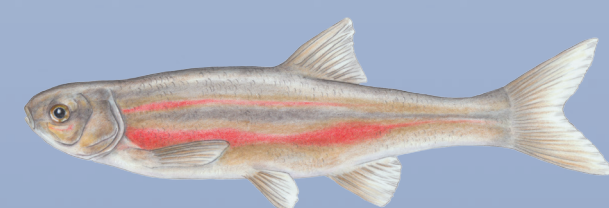
Tahoe sucker



Tui chub



Lahontan speckled dace



Lahontan redbside shiner

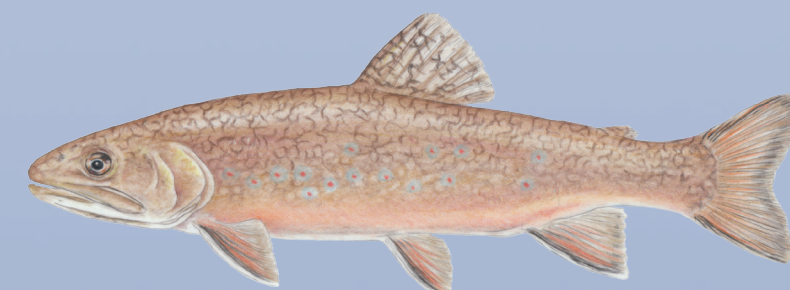
Non-native



Lake trout (Mackinaw)



Rainbow trout



Brook trout



Brown trout



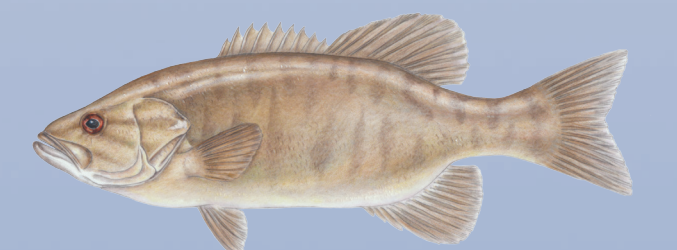
Kokanee salmon



Bluegill



Largemouth bass



Smallmouth bass

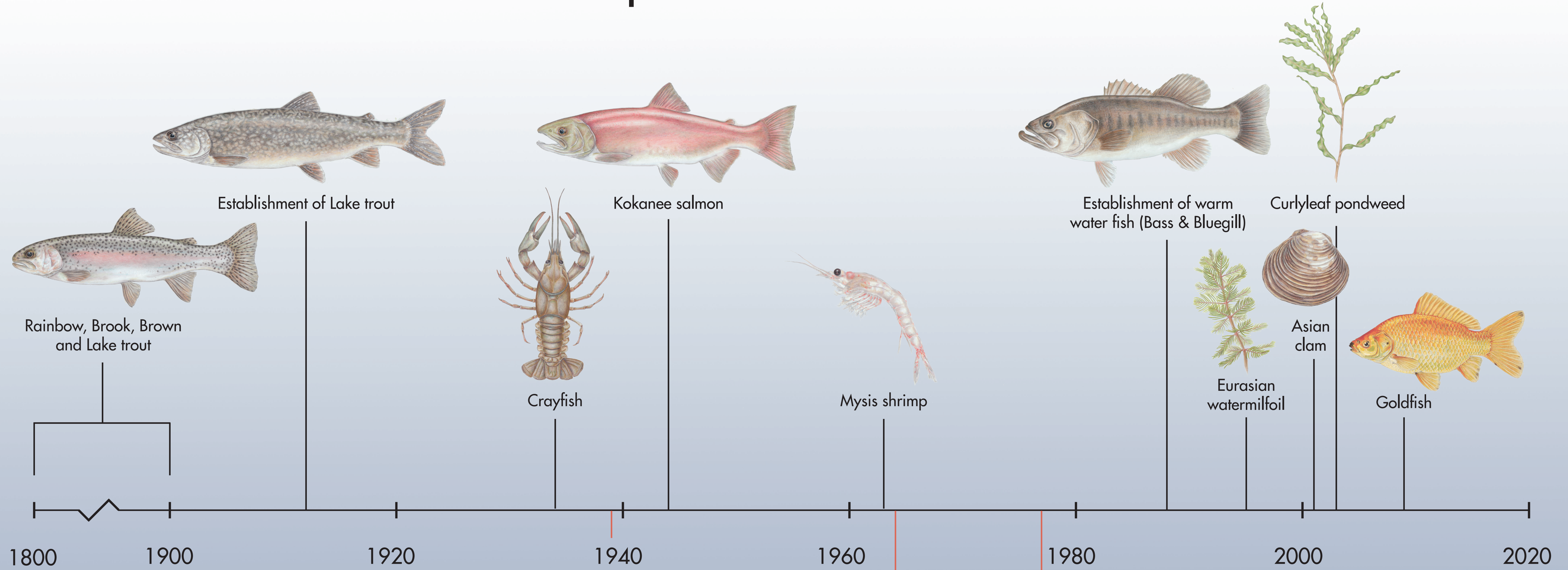


Bullhead catfish



Goldfish

Lake Tahoe Species Introduction Timeline



Extirpation of Lahontan cutthroat trout



Native fish decline (Lahontan redbreast shiner & speckled dace, etc.)



Decline of Daphnia



Help keep these alien invaders out of Lake Tahoe

Quagga mussel Zebra mussel New Zealand mudsnail

Changes in the Aquatic Food Web of Lake Tahoe

Compiled by Heather Segale, 2005

Prior to the influence of Euro-American activities, several species of fish occurred in the lakes and streams of the Lake Tahoe Region (Murphy and Knopp 2000). Of the native fish species, Lahontan cutthroat trout (*Oncorhynchus clarki henshawi*) and the mountain whitefish (*Prosopium williamsoni*) were abundant. Other species included the tui chub, speckled dace and Tahoe sucker (Vander Zanden 2003).

Historical decline of the Lahontan Cutthroat Trout (LCT)

Lahontan cutthroat trout (*Oncorhynchus clarki henshawii*) once dominated Lake Tahoe's waters and produced individual fish weighing more than twenty pounds. This species is no longer present in the lake due to human activities in the basin such as commercial fishing, water and land management practices, and exotic species introductions.

Cutthroat trout, along with whitefish, were abundant in sufficient numbers to support a commercial fishery from 1859 until 1917 (Scott 1957). In one season (1880), 70,000 pounds of LCT were shipped by railroad from Truckee to markets as far away as San Francisco and Chicago. In 1904 up to 80 commercial fishing boats were operating on Tahoe using principles that removed the maximum amount of trout in the minimum amount of time including techniques such as poison, traps, dams, nets, grab hooks, and even dynamite (Scott 1957). This excessive commercial fishing, along with dam construction, disturbance of spawning grounds, obstruction of spawning runs, pollution of the watershed, and competition from introduced species combined to cause the demise of the native cutthroat trout (Lindstrom 1992, 1996; Townley 1980). In addition to these disturbances, it was the introduction of an exotic predator, lake trout, which led to LCT demise in Lake Tahoe.

In the 1860s, a series of laws were enacted to reduce the catchable limit and to place constraints on practices such as dumping sawdust and other pollutants into the waterways. In 1917, the California legislature finally banned commercial fishing at Tahoe to protect the endangered trout, but unfortunately, the irreversible damage was already done. By 1929, the cutthroat trout could no longer migrate up the Truckee River and by 1938 both the Lake Tahoe and Pyramid Lake strains of cutthroat trout were extinct (Murphy and Knopp 2000).

Non-Native Introductions

Since the Comstock Era (circa 1860), 20 additional species of fish have been introduced into Lake Tahoe's aquatic communities (TRPA 2001 Threshold Evaluation, Appendix 1). A number of non-native species have established populations in Lake Tahoe, although two species in particular, lake trout (*Salvelinus namaycush*) and the pelagic crustacean, *Mysis relicta*, have dramatically restructured the Lake Tahoe pelagic food web (Richards et al. 1991).

Signal Crayfish: The signal crayfish (*Pacifastacus leniusculus*) was first introduced into the Lake Tahoe basin in 1895 (Abrahamsson and Goldman 1970) as an early attempt to bolster the production of introduced game fish. Since that time, the crayfish has become widespread throughout the shore region (littoral region) within mean density estimates of 10 individuals per square meter (Flint 1975). Crayfish have appeared in the stomachs of rainbow trout (*Oncorhynchus mykiss*), mountain whitefish (*Prosopium williamsoni*), brown trout (*Salmo trutta*), and lake trout (*Salvelinus namaycush*) in Tahoe studies (TRG unpublished). While little is known about their importance to the other Salmonid species, crayfish were calculated to represent over 13 percent of the annual lake trout diet by weight (Beauchamp et al. 1994). The crayfish is present in all habitat areas of the lake's littoral zone and has been observed to depths of 100 meters (TRG unpublished).

Stocking Sport Fish: With the demise of the native fish populations, attempts were made to restore the sport fishery by stocking exotic aquatic species. Exotic introductions between 1875 and 1920 focused upon top predators, such as Mackinaw and golden trout.

First introduced in 1888, lake trout (*Salvelinus namaycush*) were established in the early 20th century, and there is presently a large, self-sustaining population that supports an important recreational fishery (Cordone and Frantz 1970). Lake trout were only one of at least nine species of fish introduced to the lake between the late 1800s and about 1920. These introductions included Chinook salmon, Atlantic salmon, golden trout, Arctic grayling, Great Lakes whitefish, brook trout, brown trout, and rainbow trout (Cordone 1986). In addition to the lake trout, brook trout, rainbow trout, and brown trout were able to establish self-sustaining populations either in the tributaries to Tahoe or in the lake itself. All other fish species failed to thrive in the Tahoe environment (Murphy and Knopp 2000). By the end of the 1920s, Lake Tahoe's fishery was dominated by deepwater lake trout.

Mysid Shrimp: A second series of introductions starting in the 1940s again were intended to increase the biomass of top predators. These attempts showed a shift in focus from previous introductions. Instead of adding top predators to the food web, managers introduced both zooplankton and lower trophic fish (Murphy and Knopp 2000).

One of the most significant introductions to Lake Tahoe was that of the omnivorous opossum, or mysid shrimp (*Mysis relicta*), in the early 1960s by California and Nevada Fish and Game officials. Mysids were repeatedly introduced into the lake over a three-year period between 1963 and 1965 with the hope that it would supplement the food supply for kokanee and lake trout and produce better sports fishing for the Tahoe angler (Linn and Frantz 1965). Introduction of this organism was successful in a few other lakes (Dodds 2002); however, it was not successful at Lake Tahoe.

This failure of Mysids to supplement food supply for game fish was due to a lack of understanding of (1) the full dietary role of the Mysid shrimp in large and deep oligotrophic lakes, and (2) shrimp behavior, specifically their nightly vertical migration which reduce their utilization by fishes. Mysid shrimp remain near the sediments in daytime and migrate to upper waters at night. In fact, mysids have been shown to migrate enormous distances (400-500 meters) in Lake Tahoe each day (Rybock

1978). Thus, this species has the potential to couple both profundal (dark, deep benthic zone in lakes that do not allow enough light to support photosynthetic organisms) and pelagic (open water) habitats (Chandra 2003).

Mysis introduction was responsible for dramatically changing the makeup of the Lake Tahoe zooplankton food web (Richards et al. 1975; Morgan et al. 1978; Threlkeld et al. 1980; Morgan et al. 1981; Richards et al. 1991). By the early 1970s, a tremendous Mysis population had established (> 300/m²). This freshwater shrimp from eastern North America had been known to prey on other zooplankton; however, this role was underestimated for shrimp living within an infertile lake such as Tahoe. Due to the limited food sources in Lake Tahoe, this large omnivorous shrimp increased predation on native zooplankton (Rybock 1978) and led to near-extinction of prey species (Cooper and Goldman 1980, 1982).

Changes in Lake Tahoe Food Web

“Historically, many of the forage fishes of Lake Tahoe were supported by benthic-derived production, while LCT were the top predator in the pelagic zone, relying on zooplankton and tui chub. Today, Lake Tahoe no longer supports a LCT population, but rather a large lake trout population, which occupies a similar trophic niche to that of historical LCT. In addition, the establishment of Mysis in the late 1960s eliminated large zooplankters such as Daphnia” (Vander Zanden 2002).

The introduction of Mysis in lakes has severely altered the lower planktonic community structure. Two Daphnia species have been virtually eliminated from Lake Tahoe (Morgan et al. 1978, Vander Zanden 2002). An estimate of Mysis reliance on zooplankton between historical time periods (1969) to recent years (1997-99) indicates a dramatic drop in zooplanktivory from 77% to 20% (Chandra et al. Ecology Letters). Following cladoceran disappearance, isotopic analysis shows that Mysis shifted their diets from predominantly cladoceran zooplankton to algae-detritus (Chandra et al. Ecology Letters). The restructuring of the lower biotic community eventually led to a Mysis and copepod dominated zooplankton community. Because of competition for cladoceran food sources, a decline in kokanee population and body size occurred (Morgan et al. 1978).

Sudeep Chandra (UNR) et al. have conducted recent research on trophic level energetics and disruptions within the food web. Chandra compared the Lake Tahoe food web structure for three distinct periods:

1. 1872 – prior to species invasions
2. 1959 – post lake trout establishment and extirpation of cutthroat trout
3. 1998 – post Mysis establishment

Trophic level exchange was determined from stable isotope measurements of archived and modern biotic samples (Chandra et al.). One study describes how “lake eutrophication increases the coupling between pelagic and benthic habitats. Historically, zoobenthos from the pelagic depth zone obtained 32% of their energy from phytoplankton sources. After 43 years of eutrophication they obtained 62%

from pelagic sources" (Chandra et al.). "The resulting export of phytoplankton to the lake bottom and loss of periphyton alter zoobenthic primary consumers energy uptake. These energetics changes are passed to higher consumers that rely on benthic resources. These shifts will alter benthic community composition, size structure, and biomass. This could substantially impact fisheries, since lake food webs are highly dependent on benthic primary production and zoobenthos for their energy."

Long-term declines in forage fish populations have been noted (Thiede et al), which are likely the result of indirect food web effects related to lake trout and Mysis introductions (Chandra et al, unpublished manuscript).

Current Restoration Plans

Though the native Lahontan cutthroat trout went extinct in Lake Tahoe in the 1930s, scientists have begun experimenting with reintroduction of these fish in Fallen Leaf Lake. Since Lake Tahoe has been stocked with the nonnative lake trout, which is now the top predator, and since the primary food source of the cutthroats has been wiped out in Tahoe, scientists do not know if the native fish can survive and reproduce there. Fallen Leaf Lake is a smaller ecosystem. Scientists are using it for a test study to learn what conditions are necessary for successful restoration of the native fish.

Lahontan trout are now among the most endangered western salmonids. Some related strains of the species survive in lakes and streams outside the Tahoe Basin, such as parts of the Carson River's upper watershed. The U.S. Fish and Wildlife Service runs hatcheries to produce cutthroat for restocking the species in its native home range. This effort is part of a recovery plan for the Lahontan cutthroat, which was listed as a "threatened species" in the early 1980s under the Federal Endangered Species Act of 1966.

At Fallen Leaf Lake, the U.S. Fish and Wildlife Service (USFWS) is cooperating with the USDA Forest Service, the California Department of Fish and Game, the University of California Davis' Tahoe Environmental Research Center, and the local community. In this study, USFWS is funding UC Davis to find out how Lahontan trout can feed, grow and spawn in a lake similar to Lake Tahoe but without so many large lake trout. In summer 2002, about 36,000 Lahontan cutthroats were released in to Fallen Leaf Lake, but their average length was only about 7 inches. The nonnative trout consumed most of these. About 6,000 more Lahontan trout, averaging over 11 inches in length, were released in summer 2003. It appears a large proportion of these trout survived the winter (Brant Allen, pers. comm.).

Brant Allen, a scientist with the Tahoe Environmental Research Center, says the goal of the research is to learn how the Lahontan trout interact in the ecosystem and to recommend management strategies that could enable them to become a self-sustaining population. The long-term goal is to create both a sustainable population and a recreational fishery of the native in Fallen Leaf Lake.

As scientists collect and analyze the data, some hope to learn if the Lahontan trout might someday be able to coexist with the lake trout in Lake Tahoe. One promising finding of a study conducted by

Brant Allen, Sudeep Chandra, and M. Jake Vander Zanden, was that the ranges of the two large predators might differ enough for coexistence to occur. By analyzing fish tissue to reconstruct their diet, they found that the Lahontan cutthroats usually stay in shallow waters, feeding on tiny aquatic animals (zooplankton) and minnow. The lake trout feed mostly on fish swimming below 120 feet. Other scientists, however, note that lake trout can enter shallow waters during the cold seasons, when water temperatures are low. The Lahontan cutthroat would still be at risk of predation by lake trout at those times.

For now, much research remains to be done. Allen says it may take 20 years before the native fish can become self-sustaining in Fallen Leaf Lake. Like many of the efforts to restore the ecosystem of the Lake Tahoe watershed, the success of these efforts will be measured over decades rather than years.

Fishes of the Lake Tahoe Basin

The Lake Tahoe Basin is known for its scenic beauty and angling opportunities. Yet many people are surprised to learn that popular game fish such as mackinaw, rainbow, kokanee salmon and browns are not native to the region and that the basin's native fishes are rarely seen and now occupy only a small portion of their historical ranges. Current distribution of native fish bears little resemblance to their distribution before settlement. People dredged creek bottoms, diverted streams and encouraged the introduction of non-native fish – altogether drastically altering aquatic habitats. Most fish communities today are dominated by introduced species.

Lake Tahoe is located within the Pleistocene Lahontan Basin. This basin was drained by the Walker, Carson, Truckee, and Susan rivers. Although the drainages are now isolated from each other, during the Pleistocene they were all tributaries to ancient Lake Lahontan – a gigantic lake that covered 8,665 square miles. Pyramid Lake and Walker Lake are remnants of Lake Lahontan.

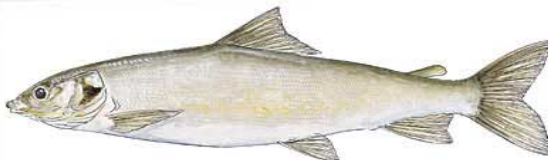
Native

Salmon and Trout Family (Family Salmonidae)

Lahontan Cutthroat Trout (*Oncorhynchus clarki henshawi*) – Historically these fish were the top predators in Pleistocene Lake Lahontan, dating back 70,000 years, and grew up to 50 inches and 40 pounds. LCT can tolerate lower dissolved oxygen and high water temperatures than almost any other trout in western North America. They also persist in highly alkaline waters of Pyramid and Walker lakes. This fish was once abundant in Lake Tahoe. In the early days it was caught commercially to supply mining camps. Overfishing, competition from non-native species, and exotic disease reduced their populations drastically. Measures are being taken to reintroduce populations throughout the basin.



Mountain Whitefish (*Prosopium williamsoni*) – Mountain whitefish bears little resemblance to its relative, the trout. It is the only native game fish left in Lake Tahoe. It is an opportunistic bottom feeder and appears to eat whatever is in abundance, including fish eggs. It is found along the bottom of colder streams and lakes throughout the basin. They tend not to enter smaller streams or small headwaters of big streams. The mountain whitefish is Lake Tahoe's only native game fish. It lives near the bottom to a depth of about 100 feet.



Minnow Family (Family Cyprinidae)

Lahontan Speckled Dace (*Rhinichthys osculus robustus*) – This species is the widest-range native fish in western North America. Body coloration varies between populations. This particular subspecies occupies the Lahontan basin portion of the Eastern Sierra, which includes Lake Tahoe. It occupies a wide variety of habitats, including thermal springs, cool and warm water rivers and streams, swift riffles flowing over cobble-size substrate, quiet backwaters, or shallow, muddy-bottom streams. The success of this species lies partly in its semi-nocturnal, bottom feeding habit. They can be found down to depths of 50 ft and reach about 4 inches in length.



Lahontan Redside (*Rhinichthys egregious*) – This species is thought to be the most beautiful of the California minnows, but only reaching only 4 inches in length. The red streak is present in breeding males and rosy in females. In Lake Tahoe, they remain in large schools throughout most of the year. They are abundant near shore and will consume terrestrial and aquatic insects, plankton, and fish eggs. In streams, the Lahontan redside hold at mid-water to capture insects drifting downstream, and prefer pools with protective cover.



Lahontan Lake Tui Chub (*Gila bicolor pectinifer*) – Tui Chub are widespread throughout the western United States, but this subspecies is endemic to the Lahontan basin and widespread throughout its larger waters. The Lahontan Lake subspecies inhabits mid-water areas of the lake and rarely occupies streams. In deep lakes it can be found down to depths of 100 feet, and can reach up to 18 inches in length. In large, open habitats, like Lake Tahoe, they move in schools, but do so less in shallow habitats with more cover. It feeds mainly on plankton.



Sucker Family (Family Catostomidae)

Tahoe Sucker (*Catostomus tahoensis*) – This fish is endemic to the Lahontan Basin and is found in lakes in streams throughout the Tahoe Basin. Lake-dwellers are larger than those in streams. Breeding males have bright red line on side. It feeds most actively at night – on aquatic plants,

detritus, and invertebrates from substrate. They have a high reproductive capacity and can live up to 15 years.



Lahontan Mountain Sucker (*Catostomus platyrhynchus lahontan*) – This subspecies is endemic to the Lahontan Basin. It is distinguished from the Tahoe Sucker by its smaller size and rounded snout. It does not inhabit lakes and seems to prefer swifter waters and cooler streams. Today, this subspecies is rare. Perhaps the dams and reservoirs constructed during the last 30 years have eliminated their stream habitats. Lahontan Mountain Suckers are herbivorous.



Sculpin Family (Family Cottidae)

Piute Sculpin (*Cottus beldingi*) – It is the most abundant bottom-dwelling fish in the Eastern Sierras. This species is small and drably colored, allowing it to hide between rocks and sticks on the bottom. It is most active at night when it preys upon aquatic insects, snails, and smaller fish hiding between and underneath rocks. This fish usually only gets up to 4 or 5 inches long, where it is usually found over rocky substrate.



Non-Native

Salmon and Trout Family (Family Salmonidae)

Lake Trout aka-Mackinaw (*Salvelinus namaycush*) – Mackinaw can reach well over a meter in length. It was introduced to Lake Tahoe from the Great Lakes in the late 1880s. It prefers lakes that are large, deep, cold, oligotrophic, low in nutrients, and well oxygenated at all depths. Therefore, Lake Tahoe is an ideal mackinaw habitat. As its name implies, it is strictly a lake species and does not even utilize feeder streams for spawning. The Lake Trout is a fall spawner. It is one of the only trout that does not dig a nest in the gravel substrate; instead it spawns in rock rubble areas, where fertilized eggs fall between rocks and boulders. Eggs may take up to 6 months to hatch. As an adult it is exclusively piscivorous, meaning it only feeds on other fish. This feeding habit may well have been responsible for the disappearance of the native Lahontan Cutthroat in Lake Tahoe, replacing it

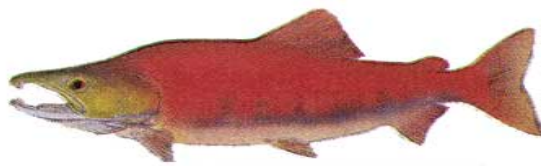
as the top predator in the lake. The Lake Trout now preys upon other native fish, such as the Mountain Whitefish, Tahoe Sucker, and Tui Chub, as well as introduced Kokanee salmon. It can be found at depths to 150 – 300 feet in Lake Tahoe.



Rainbow Trout (*Oncorhynchus mykiss gairdneri*) – Rainbow trout are very ample throughout the basin and the country, but are also one of the most difficult to understand in terms of fish classification. Scientists are trying to fully understand the relationship between the steelhead trout, the anadromous (*fish that live most of their adult life in saltwater but spawn in freshwater*) form of the rainbow and the resident freshwater form. The species is native to the waters along the Pacific coast but has been introduced for food or sport to at least 45 countries, and every continent except Antarctica. Rainbow trout prefer cool, clear streams and lakes, but can survive in lakes or ponds on the prairie, as long as there is cool, oxygenated water in the depths. It prefers water from 55 to 60 °F, and will tolerate temperatures up to 75 °F. The diet consists mainly of insects, plankton, crustaceans, fish eggs, and small fishes. Rainbows are known to hybridize with the native Lahontan Cutthroat trout, diluting genetics of the threatened Cutthroat. In Lake Tahoe, it can be found down to depths of 60 feet.



Kokanee salmon (*Oncorhynchus nerka*) - Kokanee are the landlocked variety of the Sockeye Salmon. It was introduced to the basin in the mid 1900s. It has adapted to spawn in both feeder streams and gravel shallows of lakes, which allows them to mature in lakes rather than in the ocean, although they never reach the full size of sea-going fish. This fish exhibits a strong preference for low water temperature, therefore in summer months it remains in the lower thermocline. In fall they congregate at the mouths of spawning creeks, at which time males undergo a striking color change, acquiring a deep red body hue and black head. All the adults die after spawning, making for a tremendous food source for bald eagles, grizzly bears, and other animals. Kokanee mainly feed on zooplankton. In Lake Tahoe, they are normally found within the top 100 feet of the lake and commonly spawn in Taylor Creek.



Brown Trout (*Salmo trutta*) – This trout is not only introduced to the basin but is not native to the Western Hemisphere. It is the trout of Europe and has acquired adaptations to a wide range of habitat conditions. They have adapted to live in streams with higher temperatures than normally preferred by other trout species. It has been known to grow up to one meter and live up to eighteen years. Brown trout are the most territorial of all trout, but usually appear very sedentary. Brown trout are often described as being the warriest and hardest to catch of all trout. They are drift and bottom larvae feeders and do sometimes feed on other fish. Brown trout are usually found in the top 30- 60 feet of Lake Tahoe.

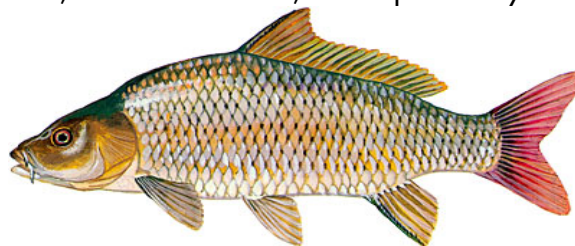


Brook Trout (*Salvelinus fontinalis*) – Brook trout do not exist in Lake Tahoe, but are one of the most abundant fish in the many streams and tributaries throughout the basin. It does however have the ability to spawn in lakes that lack feeder streams. Brook trout favor small, shallow, cold, headwaters streams, small lakes and ponds, particularly those that are spring-fed. Brook trout will eat nearly any living organism, and larger fish can be voracious predators on other fish and even their own young. Due to overpopulation stunting is often a problem in high mountain lakes and rapid cold mountain streams. They may cross with brown trout to produce infertile tiger trout.



Minnow Family (Family Cyprinidae)

Carp (*Cyprinus carpio*) – The carp is native to Asia and was probably the first fish ever to be cultured or farmed by man. It can grow up to approximately 30 inches and can weigh up to 88 lbs. Carp have been introduced, often illegally, into many countries. Due to their habit of grubbing through bottom sediments for food, they destroy, uproot and disturb submerged vegetation causing damage to native fish populations. Thus, in North America, the carp is a very controversial fish.



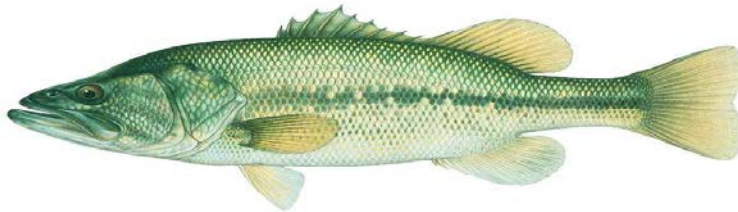
Livebearer Family (Family Poeciliidae)

Bluegill (*Lepomis macrochirus*) – The Bluegill is the most abundant sunfish in the area and as such has been one of the native fishes main competitors. They are extremely prolific, resulting in rapidly

expanding populations in most habitats where it is introduced. This great success has led in some cases to the development of stunted populations: whereas most mammal species experience large die-offs when populations greatly exceed food supply, most fish species adjust simply by growing less.



Largemouth Bass (*Micropterus salmoides*) – The Largemouth is no doubt the most popular warm-water game fish in North America. It occupies the role of top predator in the vast majority of habitats that it occupies. It can reach up to 37 inches in length and 23 lbs. The largemouth bass has a wide variety of prey. Its diet consists of other fish, worms, grubs, frogs, snakes, crayfish, and insects. It will wait in structure including grass, brush, laydowns, drop-offs, and roots to ambush its prey. Then, it will swallow it whole and digest it. It has recently been found in Lake Tahoe and is a major growing concern for biologist in the Basin. It normally occupies the top 10 feet of the lake in shallows where the water is warmer.



Smallmouth Bass (*Micropterus dolomieu*) – The Smallmouth Bass prefers cooler and clearer water than the largemouth, but can still be found in warmer slow moving waters. Because it is relatively intolerant of pollution, the smallmouth bass is a good natural indicator of a healthy environment, though it can better adjust to changes in water condition than most trout species. Carnivorous, its diet comprises crayfish, insects, and smaller fish, with the young also feeding on zooplankton.



Catfish Family (Family Ictaluridae)

Brown Bullhead Catfish (*Ictalurus nebulosus*) – The Catfish family possesses some unusual characteristics not found in other groups; the most apparent is the lack of scales. They also have barbels, which contain numerous taste buds on their surface. The brown bullhead catfish appears to exhibit the same broad spectrum adaptations to a variety of habitat conditions. It is particularly well adapted to large, eutrophic lakes, but it has been found in Lake Tahoe. Like all members of its

family, it is basically a bottom feeder. The detection of a food item by the barbel triggers an immediate grabbing action by the mouth, allowing it to pick up even the smallest amount of food.



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Lahontan Cutthroat Trout (*Oncorhynchus clarki henshawi*)



Eggs → Egg Sac Fry or Alevin → Fry → Fingerling



The Tahoe Science Center aquariums are home to various ages of LCT. Through the educational Trout in the Classroom project, we receive LCT eggs each April. We are currently home to 1-year old (left) and 2-year old (center) LCT. Our 2-year old LCT, "Lonnie" is a popular feature on our tours.

Description:

- The Lahontan cutthroat trout (LCT) is a member of the Salmonidae (trout and salmon) family, and is thought to be among the most endangered western salmonids.
- The Lahontan cutthroat was listed as endangered in 1970 and reclassified as threatened in 1975.
- Dark olive backs and reddish to yellow sides frequently characterize the LCT found in streams. Stream dwellers reach 10 inches in length and only weigh about 1 lb. Their life span is less than 5 years. In streams they are opportunistic feeders, with diets consisting of drift organisms, typically terrestrial and aquatic insects.
- The sides of lake-dwelling LCT are often silvery. A broad, pinkish stripe may be present. Historically lake dwellers reached up to 50 inches in length and weigh up to 40 pounds. Their life span is 5-14 years. In lakes, small Lahontans feed on insects and zooplankton while larger Lahontans feed on other fish.

- Body spots are the diagnostic character that distinguishes the Lahontan subspecies from the Paiute cutthroat. LCT typically have 50 to 100 or more large, roundish-black spots that cover their entire bodies and their bodies are typically elongated.
- Like other cutthroat trout, they have basibranchial teeth (on the base of tongue), and red slashes under their jaw (hence the name “cutthroat”).
- Female sexual maturity is reached between ages of 3 and 4, while males mature at 2 or 3 years of age.
- Generally, they occur in cool flowing water with available cover of well-vegetated and stable stream banks, in areas where there are stream velocity breaks, and in relatively silt free, rocky riffle-run areas.
- LCT are stream spawners, spawning between February and July. Spawning depends upon stream flow, elevation, and water temperature (41 to 61 °F).
- LCT generally spawn in riffle areas over gravel substrate. They lay their eggs in redds (nests) dug by females and chase intruders away from nest. Eggs generally hatch in 4 to 6 weeks and fry emerge 13 to 23 days later, depending on water temperature.
- Lake populations may travel long distances to spawn. For example, before their demise in the Truckee River system fish migrated from Pyramid Lake more than 60 miles to spawn in tributaries of Lake Tahoe.

History:

- The LCT is endemic or native to the Lahontan basin of northern Nevada, southern Oregon, and the eastern slope of the Sierra Nevada Range in California. This includes the Lake Tahoe Basin, Truckee River, and Pyramid Lake as a biologically connected aquatic ecosystem. The hydrologic connectivity of this system allowed the species to thrive in a wide range of environments, supported by an extensive area of natural reproduction and a vast pool of genetic diversity.
- LCT, like other trout species, are found in a wide variety of cold water habitats including large terminal alkaline lakes, oligotrophic alpine lakes, slow meandering rivers, mountain rivers, and small headwater tributary streams.
- In 1844, there were 11 lake dwelling populations of Lahontans and 400 to 600 stream dwelling populations in over 3,600 miles of streams within the major basins of Lake Lahontan.
- Today, LCT currently occupy between 123 to 129 streams within the Lahontan basin, and 32 to 34 streams outside the basin, totaling about 482 miles of habitat. They are also found in five lakes, including two small populations in Summit and Independence Lakes.
- Self-sustaining populations occur in only 10.7% of the historic stream habitats and 0.4% of the historic lake habitats.
- LCT from Pyramid Lake, Walker Lake, Summit Lake and Lake Tahoe were a major food source for Northern Paiute, Shoshone and Washoe Native Americans. Caught and dried, the trout were stored and eaten during the cold winter months.
- By 1929, LCT could no longer migrate up the Truckee River, and by 1938 the Lake Tahoe and Pyramid Lake strains were no more.

Threats:

Human impacts from the mid 1800's silver rush and the rapid increase in development within the Truckee River watershed, eventually led to the extirpation of LCT by the 1930's. Several factors contributed to their extirpation:

- Dam construction along Truckee River and the outlet of Lake Tahoe forced isolated populations to become self sustaining.
- Between 1872 and 1922 commercial fishing operations harvested 100,000 to 200,000 pounds of Lahontan trout each year from Pyramid, Walker, and Tahoe. They supplied many of the kitchens feeding the Comstock mining boom.
- Degradation of spawning streams as a result of clear cut logging practices and pollution from agriculture, limited juvenile recruitment to the population.
- Improper grazing practices altered much of the riparian habitat along stream banks, reducing habitat and spawning opportunities.
- Genetic hybridization with non-native trout. Rainbow trout are known to hybridize with LCT leading to genetic dilution.
- Introduction of predatory, non-native species (most notably lake trout and brown trout) to Lake Tahoe.

Restoration and Research:

- In the late 1800s, a series of laws were enacted to reduce catchable limit and to place restraints on harmful practices.
- In 1917, the California legislature finally banned commercial fishing at Tahoe to protect the LCT, but unfortunately the damage was already done.
- Attempts to recover LCT began in Pyramid Lake in the 1950's. There has been success in re-establishing a lake population; however it is dependent upon hatchery support.
- In the Lake Tahoe Basin, there have been attempts to reestablish both stream and lake populations. The California DFG has successfully reestablished a stable population of LCT at the headwaters of the Upper Truckee River. While this population exist without supplemental stocking, currently annual maintenance is required for its survival.
- An effort to reintroduce a lake form of LCT in Lake Tahoe was attempted by both the Nevada DOW and California DFG in the late 1960s. Within a few years, it was determined that the LCT had been once again eliminated from the lake due to predation by lake trout.
- During the 1970's, a barrier was constructed on Pole Creek, a tributary to the Truckee River. Following an upstream chemical treatment to remove competitive non-native species, LCT were reintroduced. This population remains successful.
- Independence Lake in Sierra Country, California, has the only completely self sustaining lake LCT Truckee River population. This 700 surface-acre lake located in the Little Truckee River basin supports a small catch-and-release fishery and represents about 0.2 percent of the historic lake habitat. Independence Lake once supported spawning runs of 2,000 to 3,000

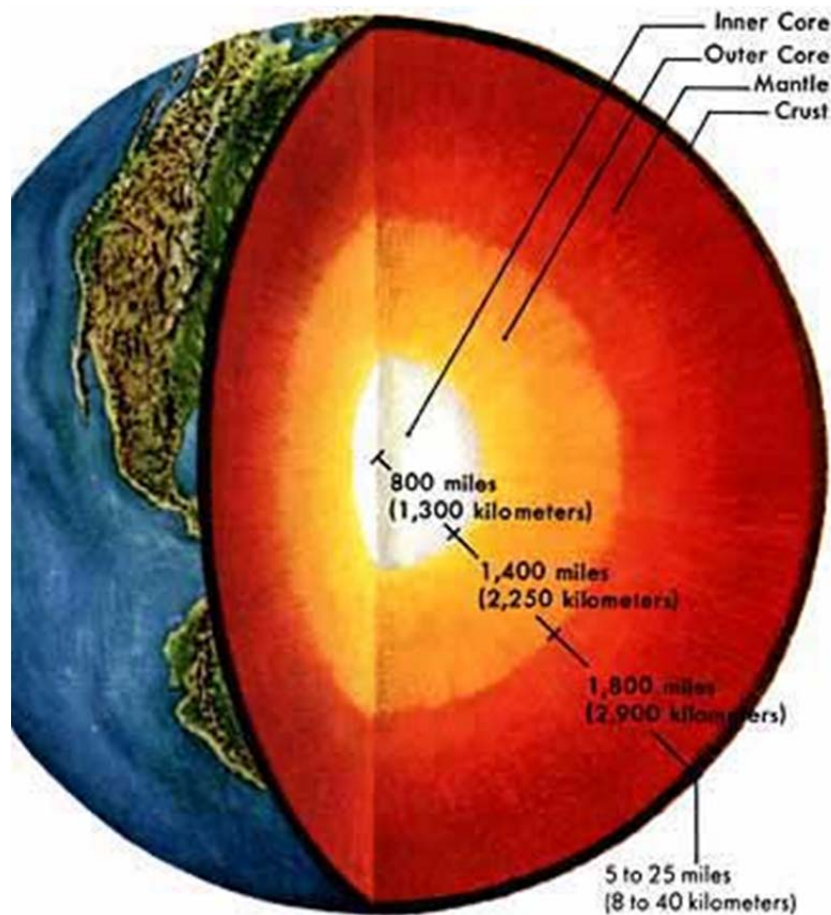
fish. Numbers declined to less than 100 spawners per year by 1960, even though there were numerous attempts to augment this population with hatchery reared populations. Competition with kokanee salmon in the lake and brook trout in the streams are believed to be responsible for the decline.

- The USFWS prepared a recovery plan for the LCT in 1995. The plan outlines the management actions necessary to lead to the eventual delisting of the LCT as the threatened species.
 - The USFWS coordinates recovery plan implementation activities among federal and state agencies, tribal governments, and private land owners to improve, manage, and secure habitats for existing and proposed LCT populations; develop and implement reintroduction plans; regulate fish harvest; manage self-sustaining populations outside historic range; conduct population viability studies and other research; and revise the plan in future when necessary.
- During the summer of 2002, LCT were stocked in Fallen Leaf Lake for the first time in 80 years. The fish plants were collaboration between USFWS, California DFG, USDA Forest Service, and UC Davis Tahoe Research Center. In this study, USFWS funded UC Davis to find out how LCT can feed, grow, and spawn in a lake similar to Lake Tahoe but without so many large lake trout.
 - About 36,000 LCT were released in to Fallen Leaf Lake, with an average length of approximately 7 inches. The non-native trout consumed most of these.
 - About 6,000 more LCT, averaging over 11 inches in length, were released in 2003. It appears a large proportion of these trout survived the winter. Some of these trout are actually spawning up a tributary.
 - The goal of the research is to learn how the LCT interact in the ecosystem and to recommend management strategies that could enable them to become a self-sustaining population. The long term goal is to create both a sustainable population and a recreational fishery of the native fish in Fallen Leaf Lake.

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Structure of the Earth



Beneath Earth's crust are the mantle, the outer core, and the inner core. Scientists learn about the inside of Earth by studying how waves from earthquakes travel through Earth.

Geophysics, which studies the physics of the Earth, has led to many significant discoveries about the Earth and its make-up. Seismologic studies of the Earth have uncovered new information about the interior of the Earth that has helped to give credence to plate tectonic theory.

Geophysical studies have revealed that the Earth has several distinct layers. Each of these layers has its own properties. The outermost layer of the Earth is the **crust**. This comprises the continents and ocean basins. The crust has a variable thickness, being 35-70 km thick in the continents and 5-10 km thick in the ocean basins. The crust is composed mainly of aluminosilicates.

Beneath Earth's crust, extending down about 1,800 miles (2,900 kilometers) is a thick layer called the **mantle**. The mantle, which is composed mainly of ferro-magnesium silicates, is not perfectly stiff but can flow slowly. This is where most of the internal heat of the Earth is located. Large convective cells in the mantle circulate heat and may drive plate tectonic processes. Earth's crust floats on the

mantle much as a board floats in water. Just as a thick board would rise above the water higher than a thin one, the thick continental crust rises higher than the thin oceanic crust. The slow motion of rock in the mantle moves the continents around and cause earthquakes, volcanoes, and the formation of mountain ranges.

At the center of Earth is the **core**, which is separated into the **liquid outer core** and the **solid inner core**. The outer core is 2300 km thick and the inner core is 1200 km thick. The inner core is about four-fifths as big as Earth's moon. The outer core is composed mainly of a nickel-iron alloy, while the inner core is almost entirely composed of iron. Earth's magnetic field is believed to be controlled by the liquid outer core.

Earth gets hotter toward the center. At the bottom of the continental crust, the temperature is about 1800 degrees F (1000 degrees C). The temperature increases about 3 degrees F per mile (1 degree C per kilometer) below the crust. Geologists believe the temperature of Earth's outer core is about 6700 to 7800 degrees F (3700 to 4300 degrees C). The inner core may be as hot as 12,600 degrees F (7000 degrees C)--hotter than the surface of the sun. But, because it is under great pressures, the rock in the center of Earth remains solid.

The Earth is also separated into layers based on mechanical properties in addition to composition. The topmost layer is the **lithosphere**, which is comprised of the crust and solid portion of the upper mantle. The lithosphere is divided into many plates that move in relation to each other due to tectonic forces. The lithosphere essentially floats atop a semi-liquid layer known as the **asthenosphere**. This layer allows the solid lithosphere to move around since the asthenosphere is much weaker than the lithosphere.

Earthquakes

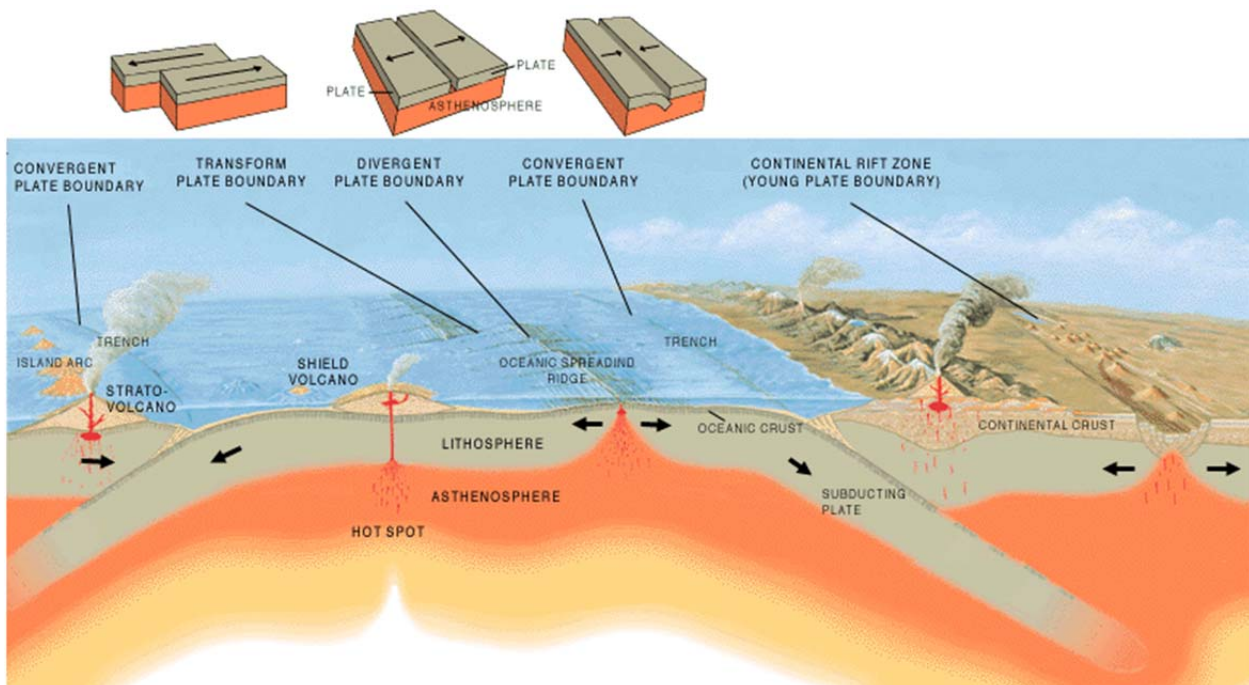
By Kaye M. Shedlock & Louis C. Pakiser

USGS Website (<http://pubs.usgs.gov/gip/earthq1/earthqkgip.html>)

Where Earthquakes Occur

The Earth is formed of several layers that have very different physical and chemical properties. The outer layer, which averages about 70 kilometers in thickness, consists of about a dozen large, irregularly shaped plates that slide over, under and past each other on top of the partly molten inner layer. Most earthquakes occur at the boundaries where the plates meet. In fact, the locations of earthquakes and the kinds of ruptures they produce help scientists define the plate boundaries. There are three types of plate boundaries: spreading zones, transform faults, and subduction zones. At **spreading zones**, molten rock rises, pushing two plates apart and adding new material at their edges. Most spreading zones are found in oceans; for example, the North American and Eurasian plates are spreading apart along the mid-Atlantic ridge. Spreading zones usually have earthquakes at shallow depths (within 30 kilometers of the surface).

Illustration of Plate Boundary Types

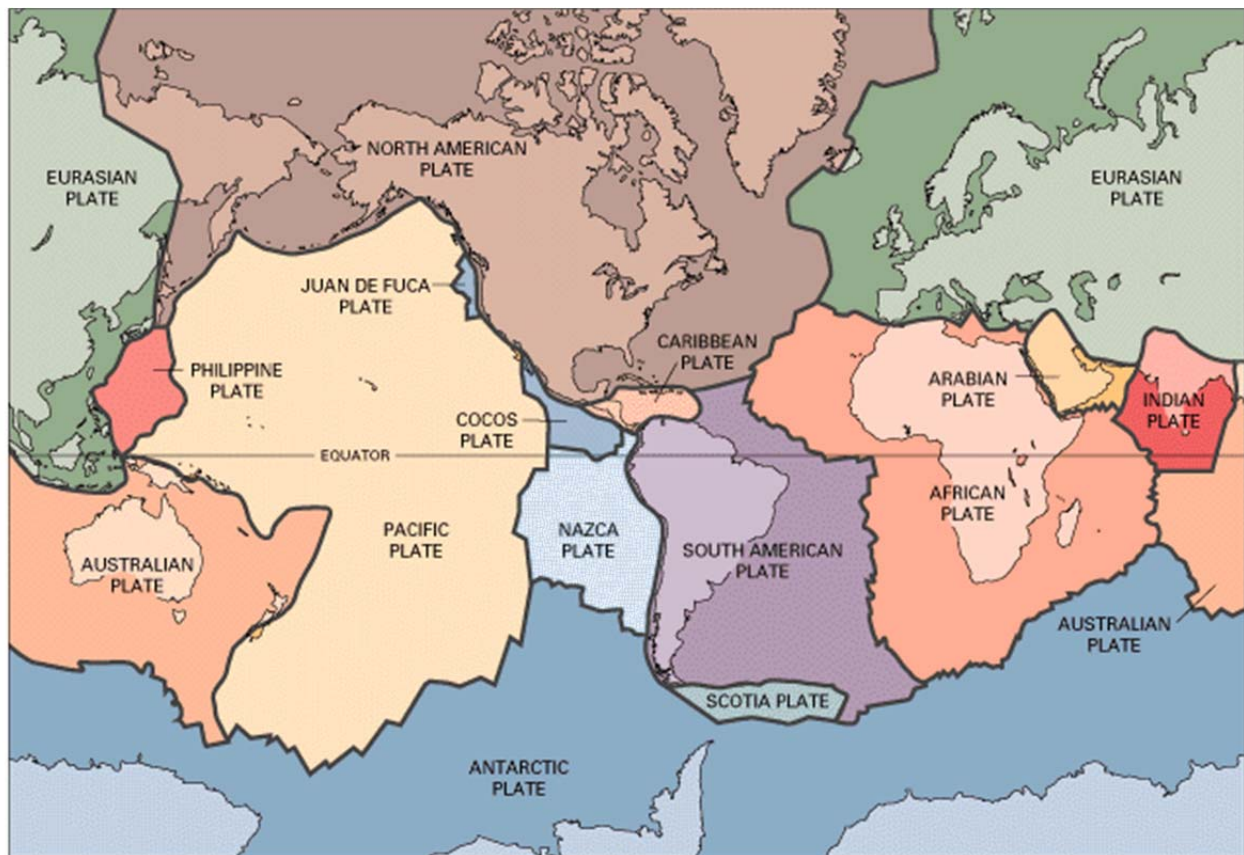


A cross section illustrating the main types of plate boundaries. Illustration by Jose F. Vigil from *This Dynamic Planet* -- a wall map produced jointly by the U.S. Geological Survey, the Smithsonian Institution, and the U.S. Naval Research Laboratory.

Transform faults are found where plates slide past one another. An example of a transform-fault plate boundary is the San Andreas fault, along the coast of California and northwestern Mexico. Earthquakes at transform faults tend to occur at shallow depths and form fairly straight linear patterns.

Subduction zones are found where one plate overrides, or subducts, another, pushing it downward into the mantle where it melts. An example of a subduction-zone plate boundary is found along the northwest coast of the United States, western Canada, and southern Alaska and the Aleutian Islands. Subduction zones are characterized by deep-ocean trenches, shallow to deep earthquakes, and mountain ranges containing active volcanoes.

Map of the Tectonic Plates



Earthquakes can also occur within plates, although plate-boundary earthquakes are much more common. Less than 10 percent of all earthquakes occur within plate interiors. As plates continue to move and plate boundaries change over geologic time, weakened boundary regions become part of the interiors of the plates. These zones of weakness within the continents can cause earthquakes in response to stresses that originate at the edges of the plate or in the deeper crust. The New Madrid earthquakes of 1811-1812 and the 1886 Charleston earthquake occurred within the North American plate.

How Earthquakes Happen



An aerial view of the San Andreas fault in the Carrizo Plain, Central California.

An **earthquake** is the vibration, sometimes violent, of the Earth's surface that follows a release of energy in the Earth's crust. This energy can be generated by a sudden dislocation of segments of the crust, by a volcanic eruption, or even by manmade explosions. Most destructive quakes, however, are caused by dislocations of the crust. The crust may first bend and then, when the stress exceeds the strength of the rocks, break and "snap" to a new position. In the process of breaking, vibrations called "seismic waves" are generated. These waves travel outward from the source of the earthquake along the surface and through the Earth at varying speeds depending on the material through which they move. Some of the vibrations are of high enough frequency to be audible, while others are of very low frequency. These vibrations cause the entire planet to quiver or ring like a bell or tuning fork.

A **fault** is a fracture in the Earth's crust along which two blocks of the crust have slipped with respect to each other. Faults are divided into three main groups, depending on how they move. **Normal faults** occur in response to pulling or tension; the overlying block moves down the dip of the fault

plane. **Thrust (reverse) faults** occur in response to squeezing or compression; the overlying block moves up the dip of the fault plane. **Strike-slip (lateral) faults** occur in response to either type of stress; the blocks move horizontally past one another. Most faulting along spreading zones is normal, along subduction zones is thrust, and along transform faults is strike-slip.

Geologists have found that earthquakes tend to reoccur along faults, which reflect zones of weakness in the Earth's crust. Even if a fault zone has recently experienced an earthquake, however, there is no guarantee that all the stress has been relieved. Another earthquake could still occur. In New Madrid, a great earthquake was followed by a large aftershock within 6 hours on December 6, 1811. Furthermore, relieving stress along one part of the fault may increase stress in another part; the New Madrid earthquakes in January and February 1812 may have resulted from this phenomenon.

The **focal depth** of an earthquake is the depth from the Earth's surface to the region where an earthquake's energy originates (the **focus**). Earthquakes with focal depths from the surface to about 70 kilometers (43.5 miles) are classified as shallow. Earthquakes with focal depths from 70 to 300 kilometers (43.5 to 186 miles) are classified as intermediate. The focus of deep earthquakes may reach depths of more than 700 kilometers (435 miles). The focuses of most earthquakes are concentrated in the crust and upper mantle. The depth to the center of the Earth's core is about 6,370 kilometers (3,960 miles), so even the deepest earthquakes originate in relatively shallow parts of the Earth's interior.

The **epicenter** of an earthquake is the point on the Earth's surface directly above the focus. The location of an earthquake is commonly described by the geographic position of its epicenter and by its focal depth.

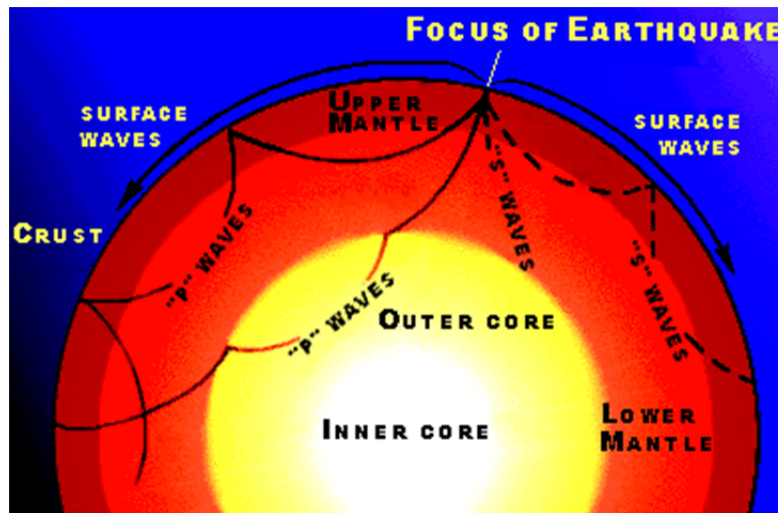
Earthquakes beneath the ocean floor sometimes generate immense sea waves or **tsunamis** (Japan's dread "huge wave"). These waves travel across the ocean at speeds as great as 960 kilometers per hour (597 miles per hour) and may be 15 meters (49 feet) high or higher by the time they reach the shore. During the 1964 Alaskan earthquake, tsunamis engulfing coastal areas caused most of the destruction at Kodiak, Cordova, and Seward and caused severe damage along the west coast of North America, particularly at Crescent City, California. Some waves raced across the ocean to the coasts of Japan.

Liquefaction, which happens when loosely packed, water-logged sediments lose their strength in response to strong shaking, causes major damage during earthquakes. During the 1989 Loma Prieta earthquake, liquefaction of the soils and debris used to fill in a lagoon caused major subsidence, fracturing, and horizontal sliding of the ground surface in the Marina district in San Francisco.

Landslides triggered by earthquakes often cause more destruction than the earthquakes themselves.

Measuring Earthquakes

The vibrations produced by earthquakes are detected, recorded, and measured by instruments call **seismographs**. The zig-zag line made by a seismograph, called a "seismogram," reflects the changing intensity of the vibrations by responding to the motion of the ground surface beneath the instrument. From the data expressed in seismograms, scientists can determine the time, the epicenter, the focal depth, and the type of faulting of an earthquake and can estimate how much energy was released.



The two general types of vibrations produced by earthquakes are surface waves, which travel along the Earth's surface, and body waves, which travel through the Earth. Surface waves usually have the strongest vibrations and probably cause most of the damage done by earthquakes.

Body waves are of two types, compressional and shear. Both types pass through the Earth's interior from the focus of an earthquake to distant points on the surface, but only compressional waves travel through the Earth's molten core. Because compressional waves travel at great speeds and ordinarily reach the surface first, they are often called "primary waves" or simply "P" waves. P waves push tiny particles of Earth material directly ahead of them or displace the particles directly behind their line of travel.

Shear waves do not travel as rapidly through the Earth's crust and mantle as do compressional waves, and because they ordinarily reach the surface later, they are called "secondary" or "S" waves. Instead of affecting material directly behind or ahead of their line of travel, shear waves displace material at right angles to their path and therefore sometimes called "transverse" waves.

The first indication of an earthquake is often a sharp thud, signaling the arrival of compressional waves. This is followed by the shear waves and then the "ground roll" caused by the surface waves. A geologist who was at Valdez, Alaska, during the 1964 earthquake described this sequence: The first tremors were hard enough to stop a moving person, and shock waves were immediately noticeable on the surface of the ground. These shock waves continued with a rather long frequency,

which gave the observer an impression of a rolling feeling rather than abrupt hard jolts. After about 1 minute the amplitude or strength of the shock waves increased in intensity and failures in buildings as well as the frozen ground surface began to occur ... After about 3 1/2 minutes the severe shock waves ended and people began to react as could be expected.

The severity of an earthquake can be expressed in several ways. The **magnitude** of an earthquake, usually expressed by the **Richter Scale**, is a measure of the amplitude of the seismic waves. The moment magnitude of an earthquake is a measure of the amount of energy released - an amount that can be estimated from seismograph readings. The **intensity**, as expressed by the **Modified Mercalli Scale**, is a subjective measure that describes how strong a shock was felt at a particular location.

The Richter Scale, named after Dr. Charles F. Richter of the California Institute of Technology, is the best known scale for measuring the magnitude of earthquakes. The scale is logarithmic so that a recording of 7, for example, indicates a disturbance with ground motion 10 times as large as a recording of 6. A quake of magnitude 2 is the smallest quake normally felt by people. Earthquakes with a Richter value of 6 or more are commonly considered major; great earthquakes have magnitude of 8 or more on the Richter scale.

The Modified Mercalli Scale expresses the intensity of an earthquake's effects in a given locality in values ranging from I to XII. The most commonly used adaptation covers the range of intensity from the condition of "I -- Not felt except by a very few under especially favorable conditions," to "XII -- Damage total. Lines of sight and level are distorted. Objects thrown upward into the air." Evaluation of earthquake intensity can be made only after eyewitness reports and results of field investigations are studied and interpreted. The maximum intensity experienced in the Alaska earthquake of 1964 was X; damage from the San Francisco and New Madrid earthquakes reached a maximum intensity of XI.

Earthquakes of large magnitude do not necessarily cause the most intense surface effects. The effect in a given region depends to a large degree on local surface and subsurface geologic conditions. An area underlain by unstable ground (sand, clay, or other unconsolidated materials), for example, is likely to experience much more noticeable effects than an area equally distant from an earthquake's epicenter but underlain by firm ground such as granite. In general, earthquakes east of the Rocky Mountains affect a much larger area than earthquakes west of the Rockies.

An earthquake's destructiveness depends on many factors. In addition to magnitude and the local geologic conditions, these factors include the focal depth, the distance from the epicenter, and the design of buildings and other structures. The extent of damage also depends on the density of population and construction in the area shaken by the quake.

The Loma Prieta earthquake of 1989 demonstrated a wide range of effects. The Santa Cruz mountains suffered little damage from the seismic waves, even though they were close to the epicenter. The central core of the city of Santa Cruz, about 24 kilometers (15 miles) away from the

epicenter, was almost completely destroyed. More than 80 kilometers (50 miles) away, the cities of San Francisco and Oakland suffered selective but severe damage, including the loss of more than 40 lives. The greatest destruction occurred in areas where roads and elevated structures were built on stable ground underlain by loose, unconsolidated soils.

The Northridge, California, earthquake of 1994 also produced a wide variety of effects, even over distances of just a few hundred meters. Some buildings collapsed, while adjacent buildings of similar age and construction remained standing. Similarly, some highway spans collapsed, while others nearby did not.

Volcanoes and Earthquakes

Earthquakes are associated with volcanic eruptions. Abrupt increases in earthquake activity heralded eruptions at Mount St. Helens, Washington; Mount Spurr and Redoubt Volcano, Alaska; and Kilauea and Mauna Loa, Hawaii.



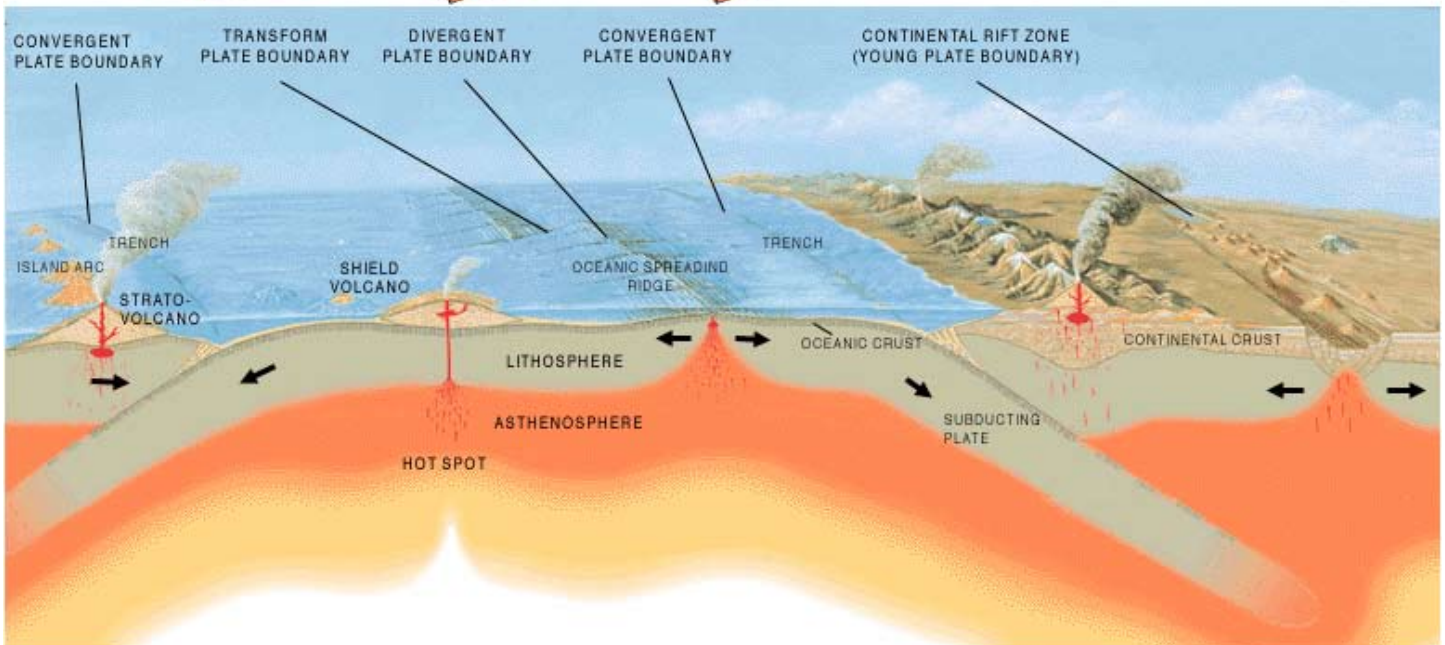
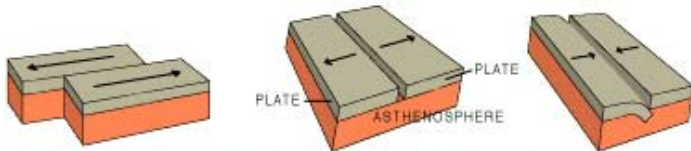
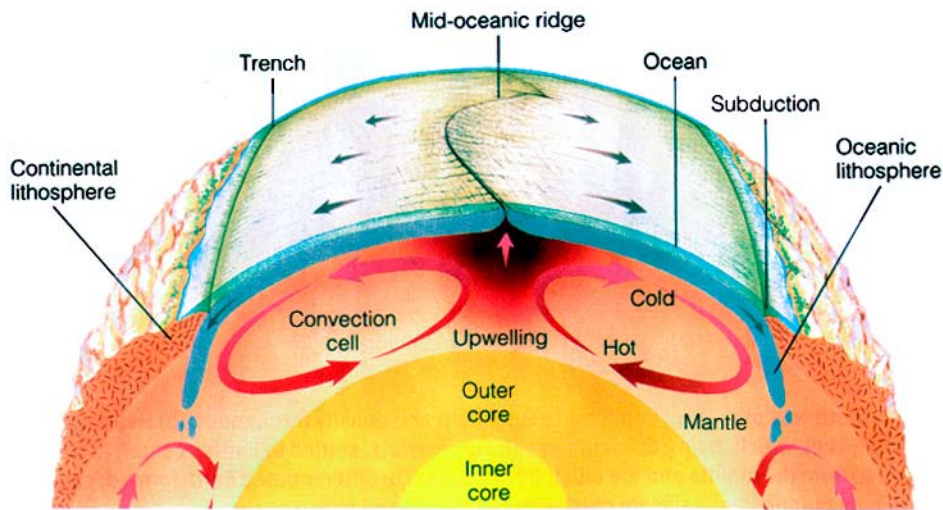
A sudden increase in earthquake tremors signaled the beginning of eruptions at Redoubt Volcano in 1989-90.

The location and movement of swarms of tremors indicate the movement of magma through the volcano. Continuous records of seismic and tiltmeter (a device that measures ground tilting) data are maintained at U.S. Geological Survey volcano observatories in Hawaii, Alaska, California, and the

Cascades, where study of these records enables specialists to make short-range predictions of volcanic eruptions. These warnings have been especially effective in Alaska, where the imminent eruption of a volcano requires the rerouting of international air traffic to enable airplanes to avoid volcanic clouds. Since 1982, at least seven jumbo jets, carrying more than 1,500 passengers, have lost power in the air after flying into clouds of volcanic ash. Though all flights were able to restart their engines eventually and no lives were lost, the aircraft suffered damages of tens of millions of dollars. As a result of these close calls, an international team of volcanologists, meteorologists, dispatchers, pilots, and controllers have begun to work together to alert each other to imminent volcanic eruptions and to detect and track volcanic ash clouds.

Floating Granite: The Uplift of the Sierra Nevada

PLATE TECTONICS



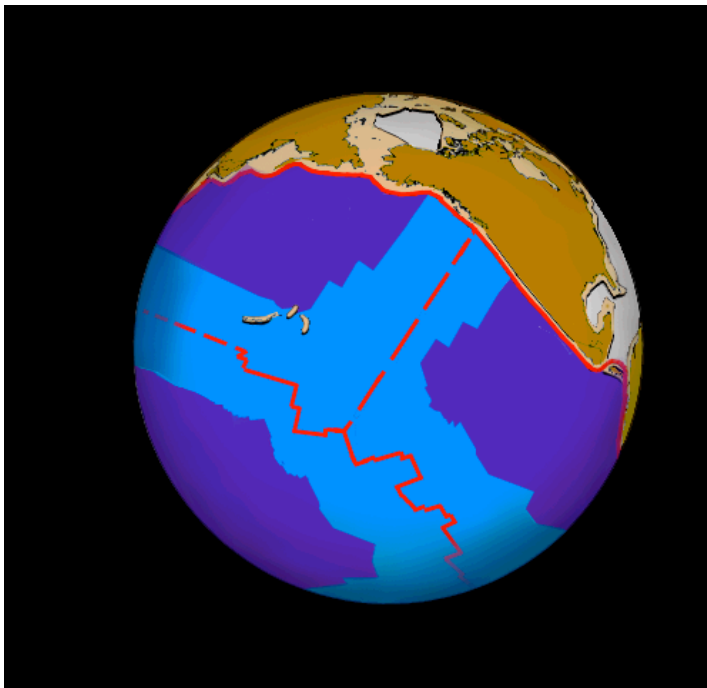
Three types of boundaries exist between the tectonic plates: :

- **Transform plate boundary:** where plates slide horizontally past each other, for example the San Andreas Fault.
- **Divergent plate boundary:** where warm material rises toward the earth surface, pushing two plates apart and adding new material in between. Most divergent boundaries are in the ocean, for example, the East Pacific Rise.
- **Convergent plate boundary:** where one plate dives under another back down to the mantle. You find this type of boundary where deep-ocean trenches parallel volcanic mountain ranges. The northwest coast of the United States is a convergent boundary.

The Earth's surface, called the lithosphere, is a rigid layer of rock about 50 miles thick. It is broken into about a dozen tectonic plates that contain all the continents and oceans.

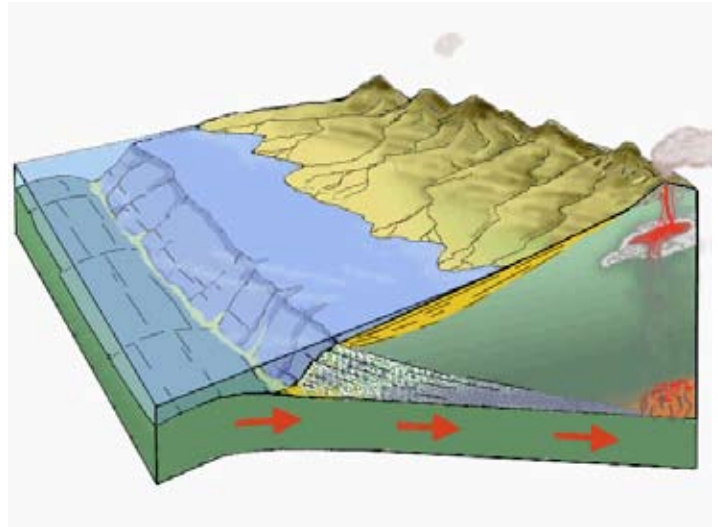
These plates move slowly around because they lie on top of the mantle, a dense and hot layer of semi-solid rock about 1,800 miles thick. The mantle moves in circular convection currents from the core toward the surface, similar to a pot of boiling soup.

130 - 80 MILLION YEARS AGO



130 – 180 million years ago, the Farallon Plate was diving under the North America Plate, forming a convergent boundary. The

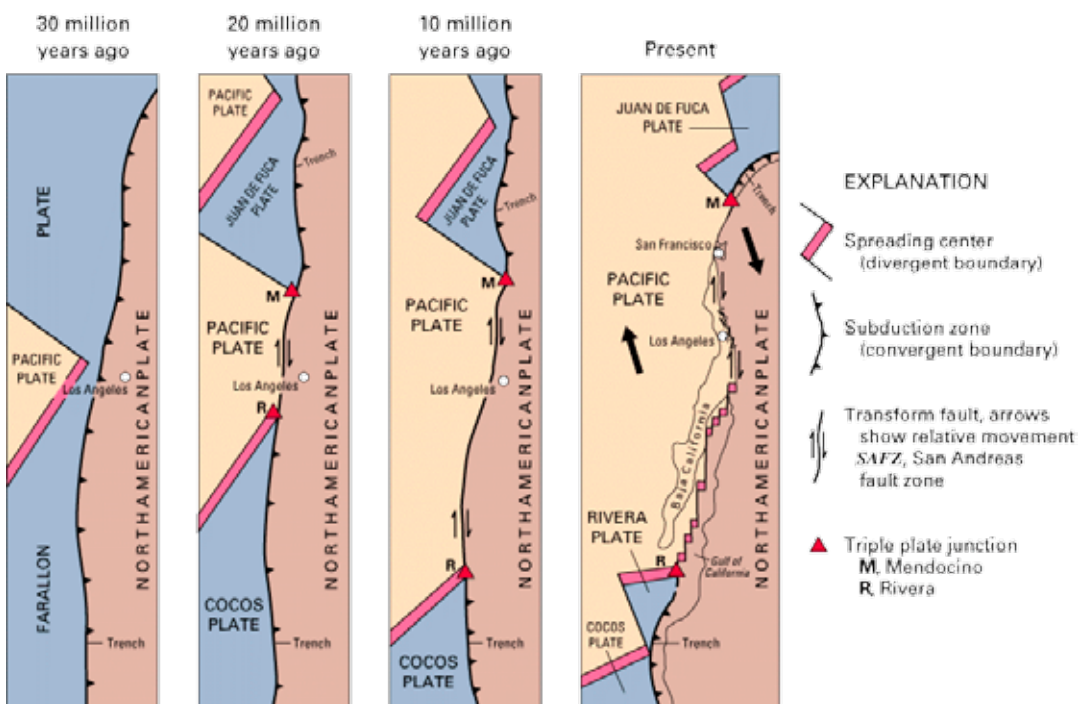
East Pacific Rise (crooked red line in mid-ocean) lay far away, but was spreading rapidly.



As the North American Plate pushed over the Farallon Plate, the Proto-Sierra Nevada Mountains rose. This mountain range predated the current Sierra Nevada and was

much higher. At the same time, globs of magma deep underground fused together and formed the Sierra Nevada granite batholith.

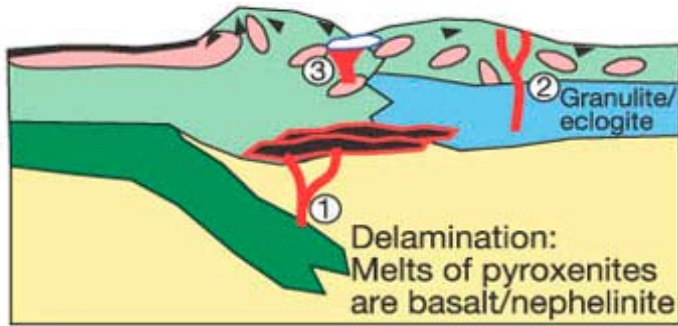
30 - 20 MILLION YEARS AGO



Because the eastern margin of the Farallon Plate dove under the North American Plate faster than it was being

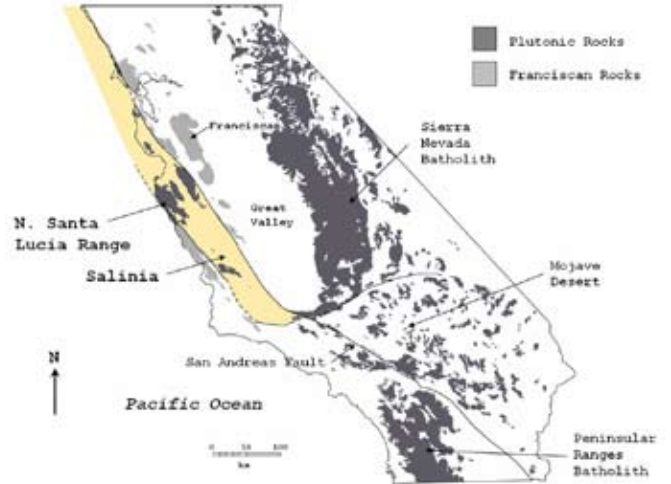
formed at its opposite edge, the East Pacific Rise migrated northeast. As the Farallon Plate shrank it broke into smaller plates, such as the Juan de Fuca, which now lies off the northwest coast of the United States. Where the North American Plate overrode part of the East Pacific Rise, the plate boundary became the transform San Andreas Fault. By this time the Proto-Sierra Nevada Mountains had eroded down to a flat plane.

5 MILLION YEARS AGO



As the East Pacific Rise pushed under the North American continent, it scraped off and melted heavy rocks at the base of the Sierra Nevada

batholith. Without this anchor, the lower density granite rocks tilted and rose, creating today's Sierra Nevada.

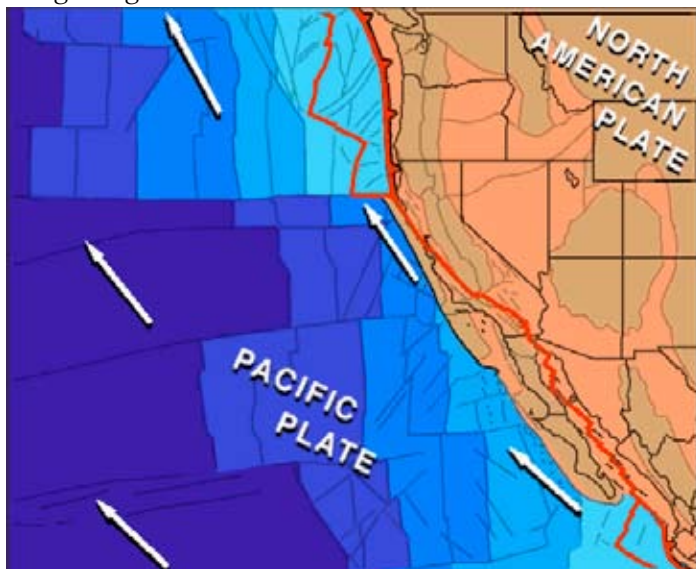


OVER TIME, EROSION REMOVED THE YOUNGER OVERLYING ROCK AND EXPOSED THE SIERRA NEVADA BATHOLITH

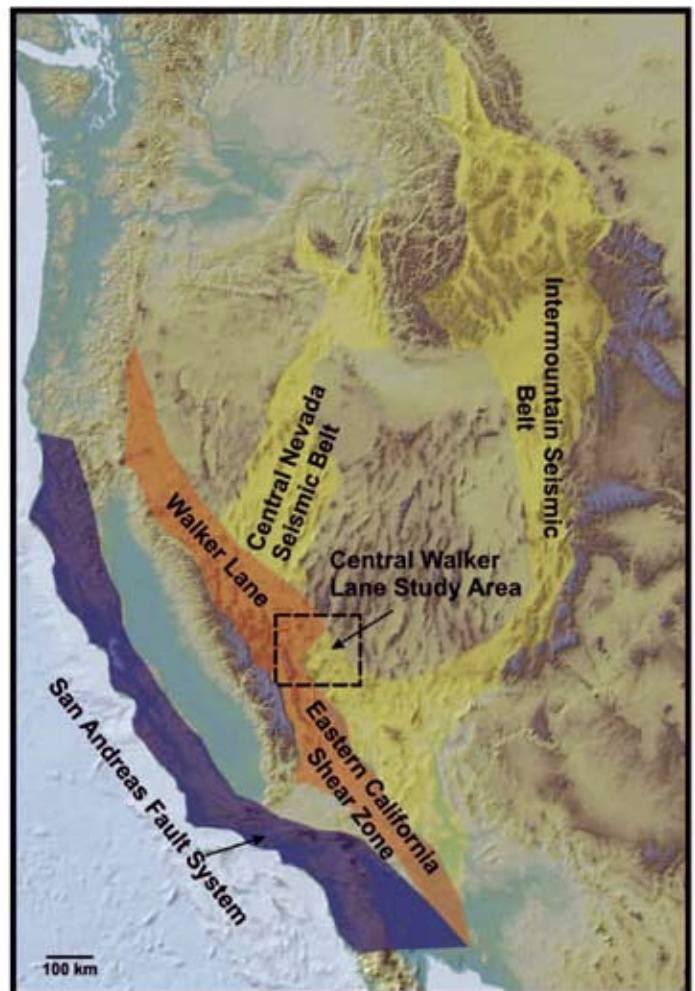
TODAY

Three major zones of active plate movement affect the Sierra Nevada today:

- About 75% of the Pacific Plate movement is along the San Andreas Fault system. Land west of the San Andreas Fault has transferred to the Pacific Plate and is moving northwest.
- About 25% of the Pacific Plate movement is along the Walker Lane-Eastern California Shear Zone. Geologists think eventually a new rift zone may form here.
- The Great Basin Province is expanding into the Sierra Nevada. As it stretches, the Great Basin crust is getting thinner.



THE PACIFIC PLATE IS MOVING NORTHWEST TOWARD ALASKA AND THE PLATE BOUNDARY LIES WITHIN THE CONTINENT

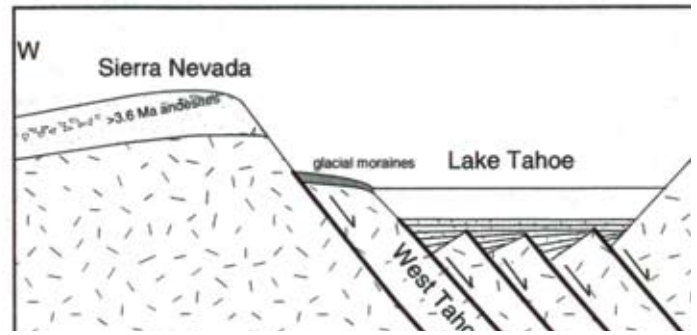


MAJOR ZONES OF ACTIVE PLATE MOVEMENT

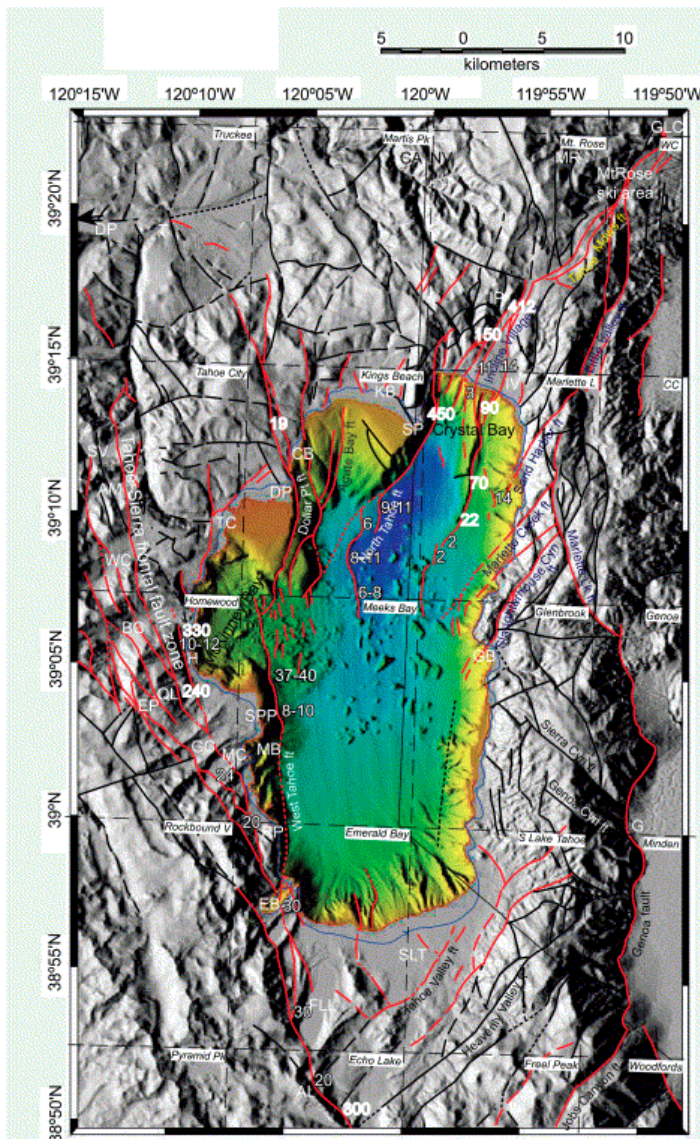
Tilting Dominos: How the Tahoe Basin Was Formed

The Tahoe Basin was formed 2 to 3 million years ago when the Great Basin Province expanded into the Sierra Nevada. Normal faulting lifted the Carson Range on the east and the Sierra Nevada on the west. In between, other blocks

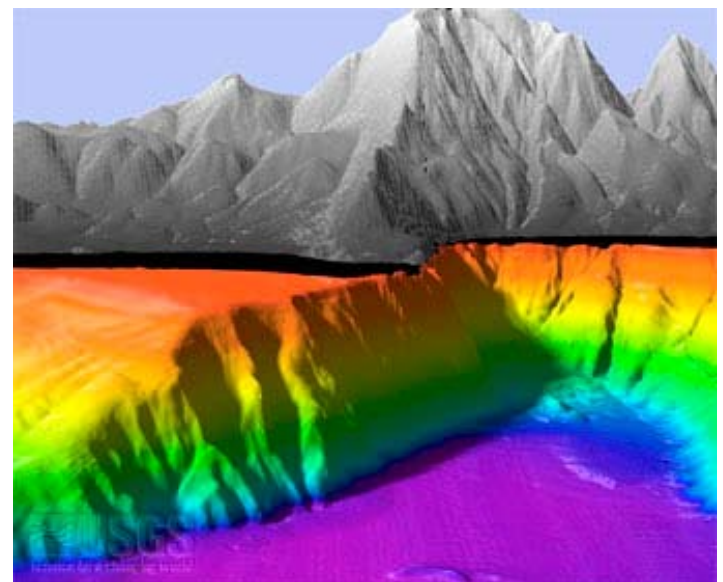
dropped down forming a valley that would become the Tahoe Basin. Initially, the north end was open, allowing snowmelt to flow out of the basin. At least three normal faults run through the Basin.



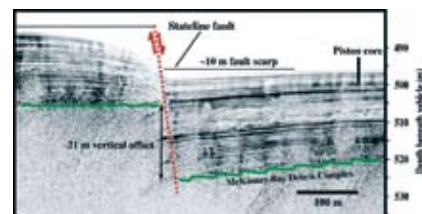
In cross section, the Tahoe Basin looks like a stack of dominos that have tilted and slid past each other.



The West Tahoe Fault starts offshore of Sugar Pine Point and runs past Dollar Point. The Stateline Fault starts in the middle of the lake and runs past Stateline Point. The Incline Village Fault runs through the middle of Crystal Bay.



The Stateline Fault runs along the west shore of Crystal Bay. A very steep, straight 1,400-foot fault scarp trends southwest from Stateline Point. Vertical distance is 3 times the horizontal distance in this image.



In the past 60,000 years, the West Tahoe Fault has slipped about 100 feet and the Stateline Fault (shown here) has slipped about 70 feet.

Plumbing the Depths: Lake Tahoe Bathymetry

The floor of Lake Tahoe remained largely a mystery until scientists used advanced technology to provide a precise map of its bottom.

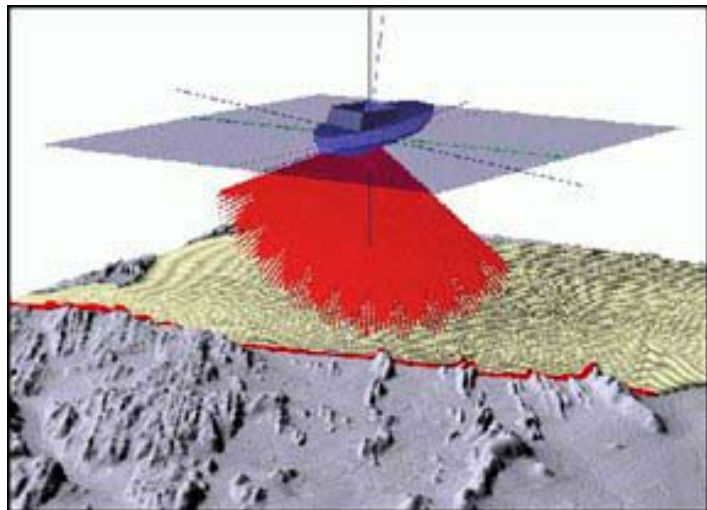
HIGH RESOLUTION MARINE MULTIBEAM-SONAR

In 1998, US Geological Survey used a high-resolution multibeam system to completely scan the lake bottom more than 33 feet

deep. From this data, they developed a set of precise base maps to be used for multidisciplinary research in Lake Tahoe.



INLAND SURVEYOR WITH HIGH-RESOLUTION MARINE MULTIBEAM-SONAR MOUNTED ON BOW

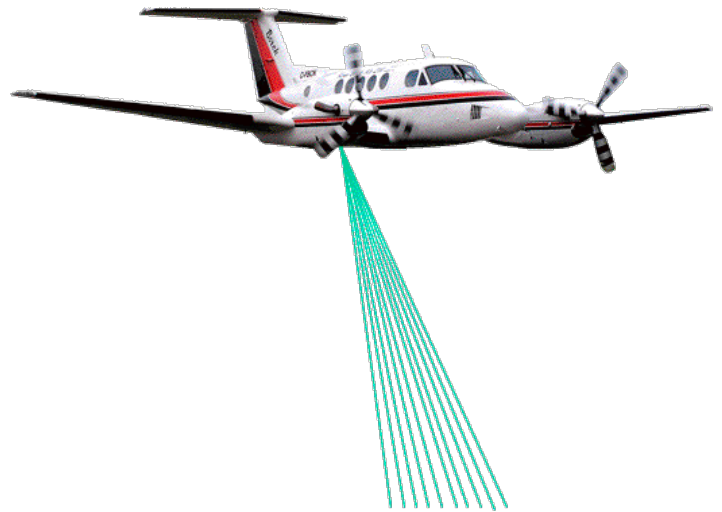


CARTOON OF THE HIGH-RESOLUTION MAPPING SYSTEM

LIDAR (LIGHT DETECTION AND RANGING)

In 2000, the US Army Corps of Engineers flew over Lake Tahoe with LIDAR equipment to map

between the shoreline and water 50 feet deep. Researchers then merged these two datasets.



HIGH-RESOLUTION CHIRP SONAR

In 2002, a third team intensively subsampled using a high-resolution seismic chirp sonar. They then combined this data with the USGS sonar, Corps

of Engineers LIDAR data and data from sediment cores to learn more about the rate at which the Lake Tahoe faults are slipping.

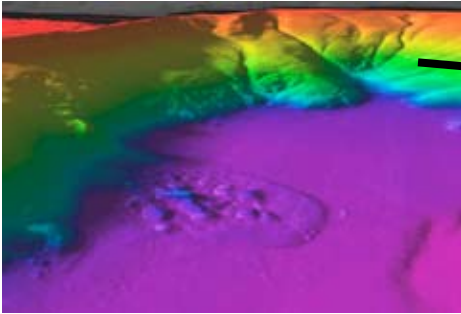


SCIENTISTS PREPARE TO LAUNCH THE HIGH-RESOLUTION SEISMIC CHIRP SONAR

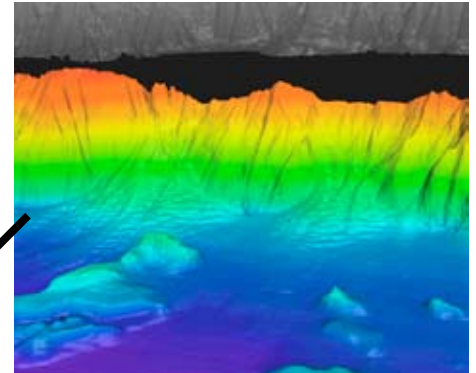
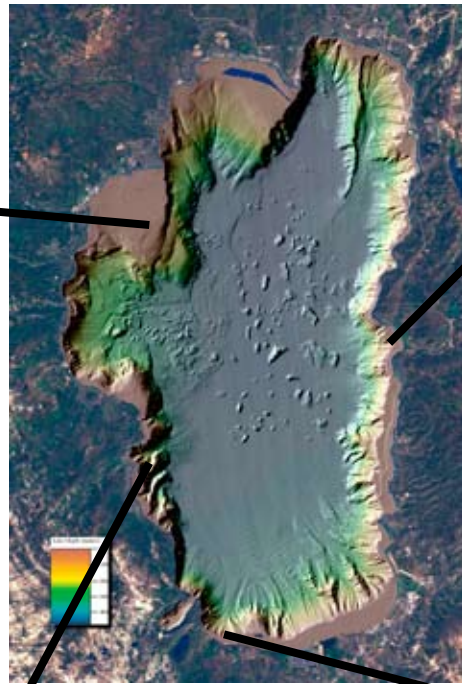
OBLIQUE UNDERWATER VIEWS OF LAKE TAHOE

The high-resolution imagery revealed several submerged terraces that mark periods when Lake level was about 33 feet lower than today. Beyond these terraces, the bottom plunges

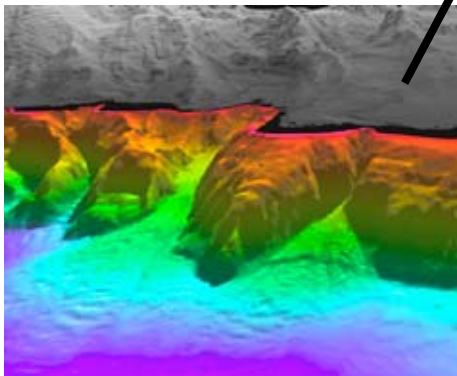
steeply to a relatively flat floor covered with fine-grained sediment. Sediment chutes and debris aprons carry sediment from the near shore areas to the lake floor.



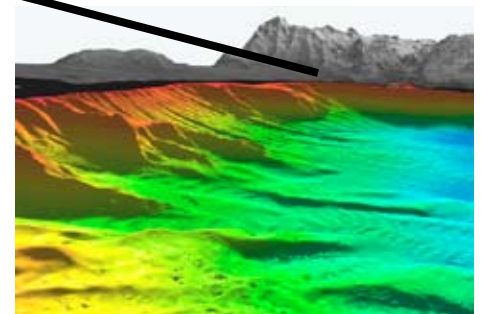
Looking northwest into Carnelian Bay, this image shows a prominent debris flow nearly a mile long and over half a mile wide. Vertical distance is 3 times the horizontal distance in this image.



This view is in the Glenbrook area on the east shore and shows two well-developed sediment aprons. Vertical distance is 4 times the horizontal distance in this image.



This view covers from the northern half or Rubicon Bay on the left to Sugar Pine Point on the right. It shows a series of submerged headlands with well-defined sediment chutes in between. Vertical distance is 3 times the horizontal distance in this image.



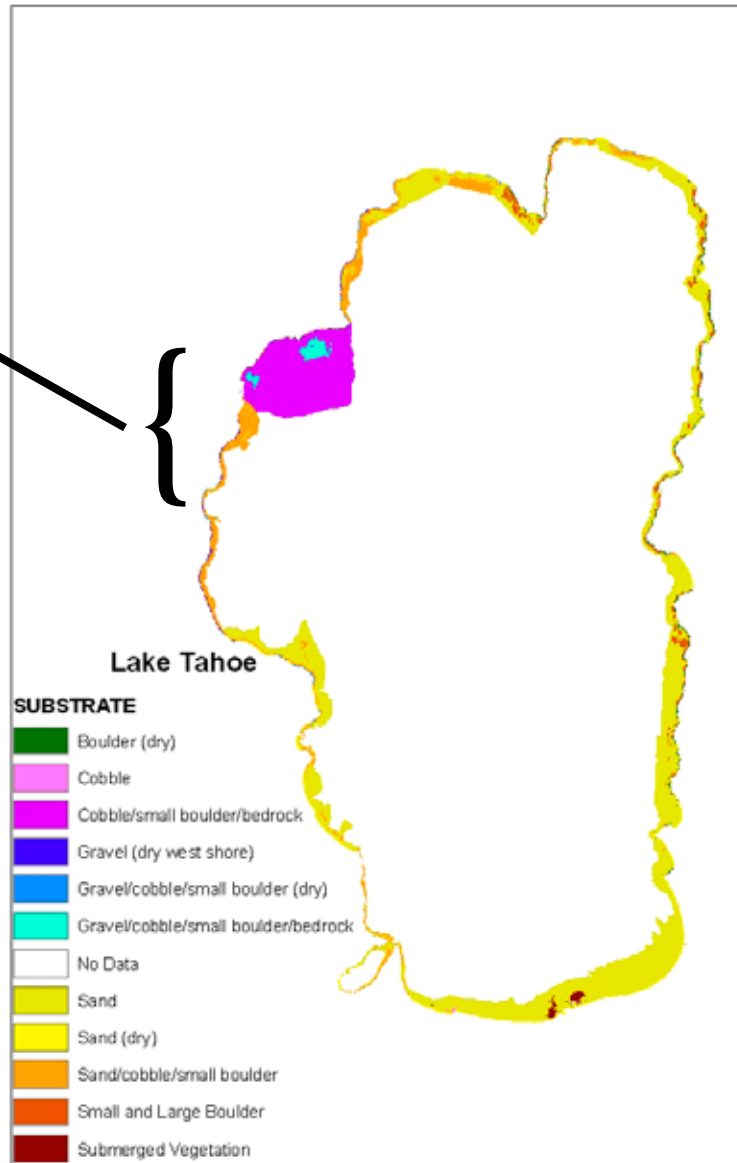
Along the south shore, the bottom slopes relatively gently to the lake floor. Here the lake margin is draped in debris from the Donner Lake glaciation over 131,000 years ago. The lake margin exhibits blocks of sediment pushed here by large glaciers and a layer of glacial outwash over all. Emerald Bay is in the upper right corner of the image. Vertical distance is 3 times the horizontal distance in this image.

NEARSHORE SUBSTRATES: FISH HABITAT

Less than 5 percent, or 9 square miles, of Lake Tahoe's bottom provides good substrate for fish habitat. Fish habitat includes clean gravel, cobble and boulders in less

than 50 feet of water. Fish need these areas to spawn, feed and take cover. This good habitat is scattered around the thin shorezone band that rings the lake.

Pure gravel is essential for spawning. It is the most limited substrate, almost entirely restricted to the west shore and coinciding with favorite recreation areas.



Mixed rocky habitats provide fish places to forage and find cover. These are unevenly distributed around the shorezone, except along the south shore. Boulder fields are prominent along Stateline Point and the east shore.

Sandy bottoms are marginal fish habitat. Most of the shorezone is sandy, and therefore marginal, but especially the south and southeast shores.

Quaking Tahoe: Earthquakes, Landslides and Tsunamis

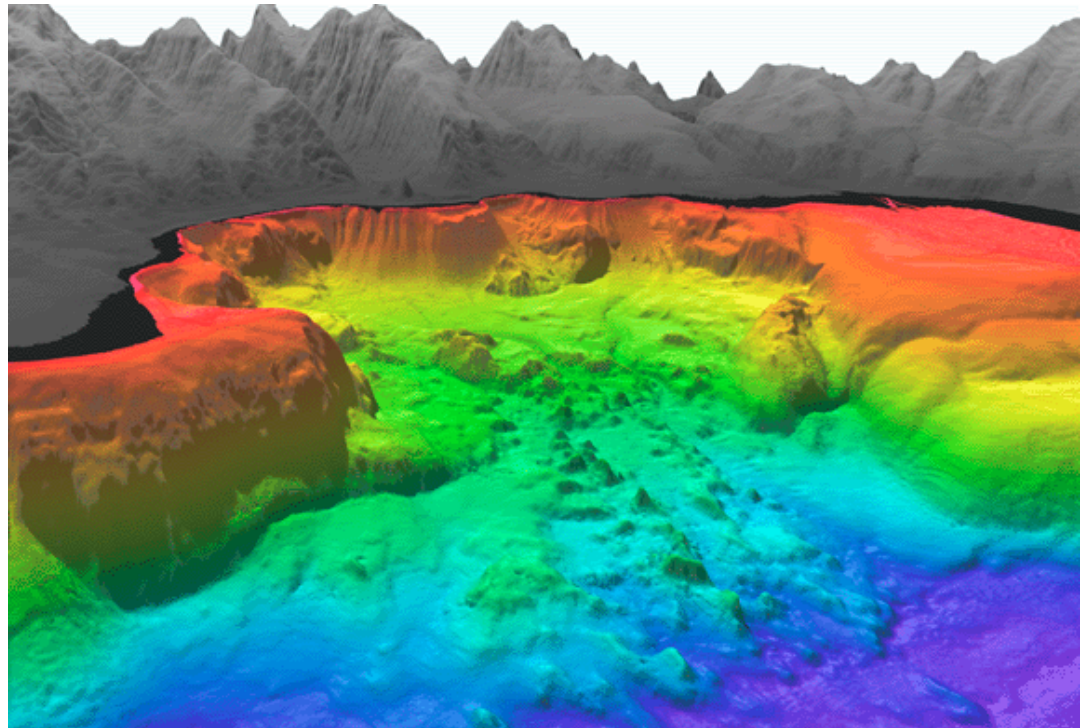
MCKINNEY BAY LANDSLIDE

The 1998 high resolution mapping revealed one of Lake Tahoe's long-held secrets: 60,000 years ago an enormous underwater landslide started in McKinney Bay and sent tons of boulders, rocks and soil plunging 1,500 feet to the lake bottom. The force scattered rock debris all the way across the lake floor.

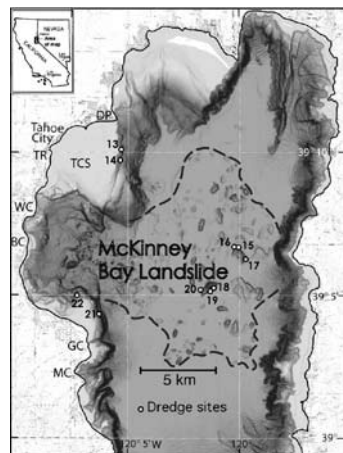
The headwall fracture is over 650 feet tall and the debris tongue is 5 ½ miles long and 4 ½ miles wide.

Scientists believe the landslide was triggered by an earthquake. Similar underwater landslides of this size are found in tectonically active parts of the ocean.

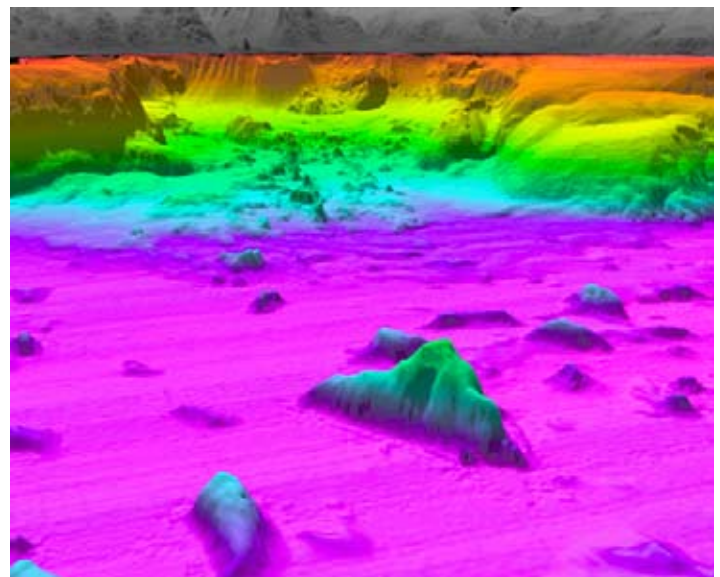
The landslide produced tsunamis that splashed back and forth across Lake Tahoe. Huge waves hit the eastern shore then rebounded back and cut platforms along Sugar Pine Point. They may also have removed glacial moraines at the mouths of Ward Creek and Blackwood Creek.



Oblique view of the McKinney Bay Landslide. In the image, vertical distance is exaggerated 3 times the horizontal distance.



The McKinney Bay landslide scattered debris all the way across to the eastern shore.



Another view of the landslide. In the foreground are large debris blocks, the tallest of which is [460] feet high. In the image, vertical distance is exaggerated 3 times the horizontal distance.

TODAY'S SEISMIC PICTURE

Given Lake Tahoe's seismic origins and the McKinney Bay landslide, what are the chances are that a large earthquake and tsunami could happen again?

California and Nevada lie in one of the most seismically active regions in the United States. The Tahoe area itself accommodates about 2% of the plate boundary budget, accounting for about 1/4 inch of movement per year.

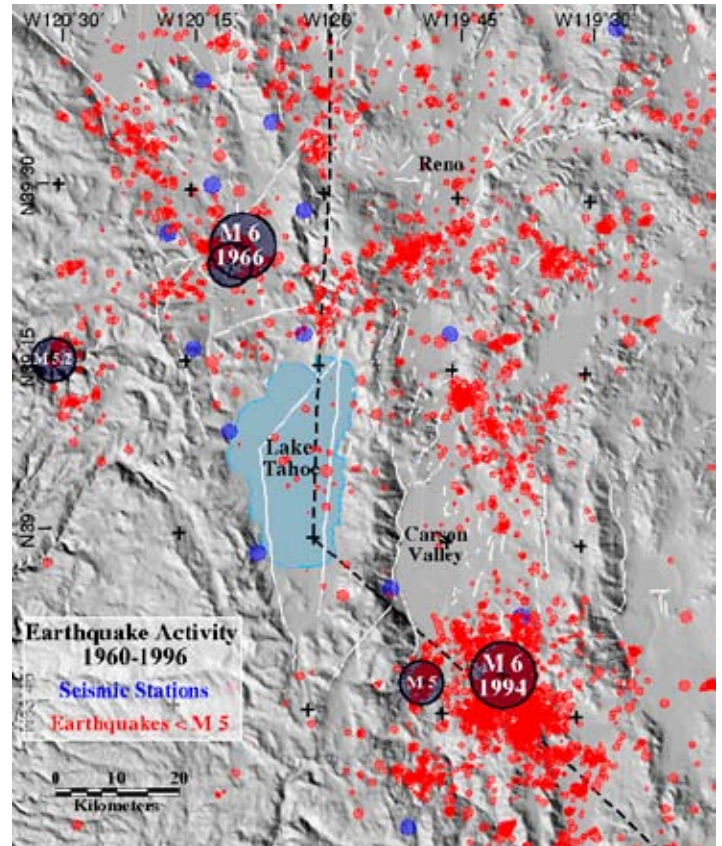
The three normal faults running through the Tahoe Basin have produced large earthquakes in the past 10,000 years.

Today, dozens of minor or moderate earthquakes occur every week at Lake Tahoe, although most are too small to feel. Seismic activity is now focused in Truckee, Mogul, Carson and Gardnerville, where small earthquakes are shortening the crust in the north-south direction.

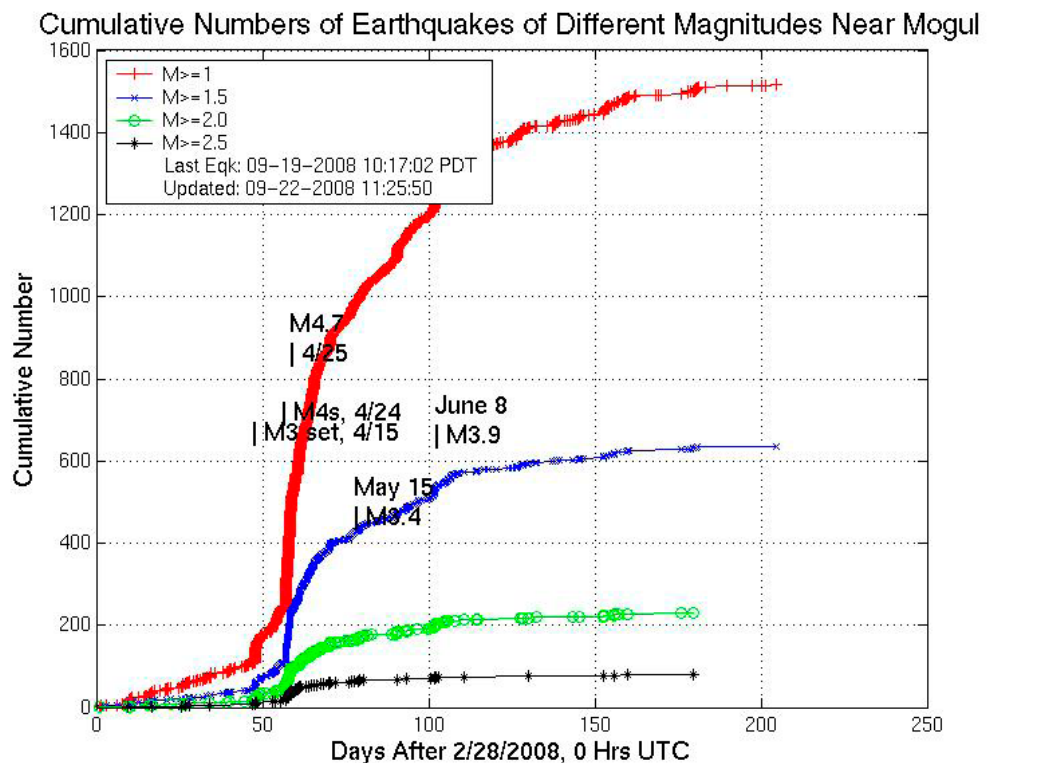
Geologists think that after enough stress is relieved in the north-south direction, another large earthquake could occur in Tahoe. In the past, the Tahoe basin has suddenly dropped about 4 meters every few thousand years.

Scientists don't know when a large earthquake will happen at Tahoe, but they place the chances at between 2 and 4 percent

over the next 50 years. If a large earthquake did occur, it would be followed by a tsunami. Using computer models, scientists estimate that an earthquake under the north end of the lake could send 18-foot waves toward South Lake Tahoe. If the West Tahoe Fault slipped, it could send 30-foot waves into McKinney Bay. In both cases, the tsunami would be followed by seiche waves nearly as high that could slosh back and forth for hours.

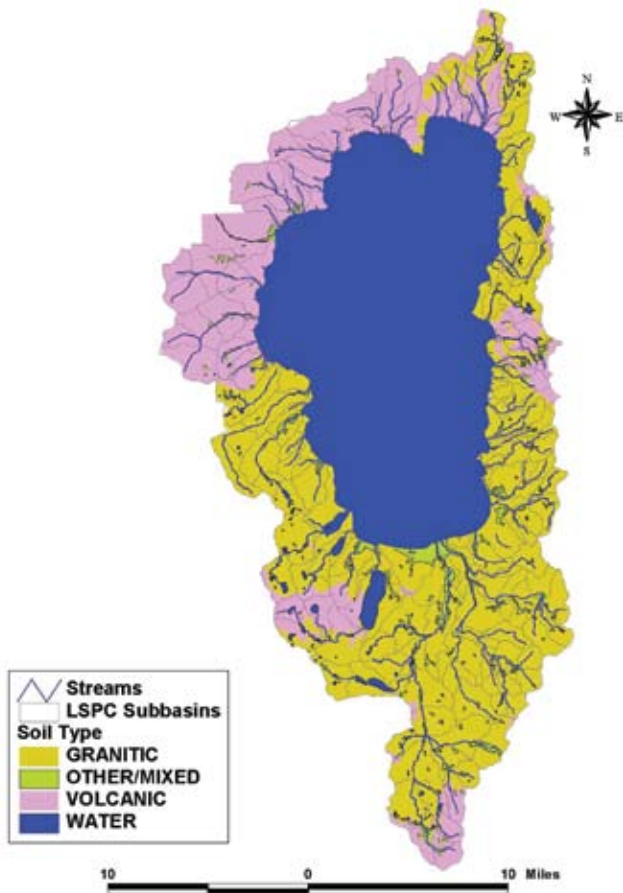


EARTHQUAKE ACTIVITY IN THE TAHOE REGION, 1960 - 1996. DOZENS OF EARTHQUAKES OCCUR EVERY WEEK, ALTHOUGH MOST ARE TOO MINOR TO FEEL.



CUMULATIVE NUMBER OF EARTHQUAKES NEAR MOGUL, NV, FROM MARCH 1, 2008.

Erupting Lava: Closing the Tahoe Basin



The valley basin became a lake basin two to three million years ago when several large volcanic eruptions occurred in its northwestern corner. Much of the terrain between Ward Creek, Mount Rose, and Castle Peak is volcanic, including Martis Peak, Mount Pluto, Mount Watson and Squaw Peak. When Mount Pluto erupted, it poured lava and volcanic mudflows into the northern outlet of the basin, blocking the ances-

tral Truckee River and impounding Lake Tahoe. Over time, snowmelt and rain filled the basin.

Notable local eruptions include:

- Mt. Lincoln: 13 - 7 million years ago
- Martis Peak: 7 - 5 million years ago
- Squaw Peak: 5 - 3 million years ago



This picture is of the “Ward Badlands,” an area of fine volcanic mudflow. Located in the south fork drainage of Ward Creek, the deep rills and gullies were caused by past land use practices, such as grazing and timber harvest.

Sculpting Glaciers: Carvings From the Ice Age

PLEISTOCENE ERA: 1.8 MILLION TO 10,000 YEARS AGO

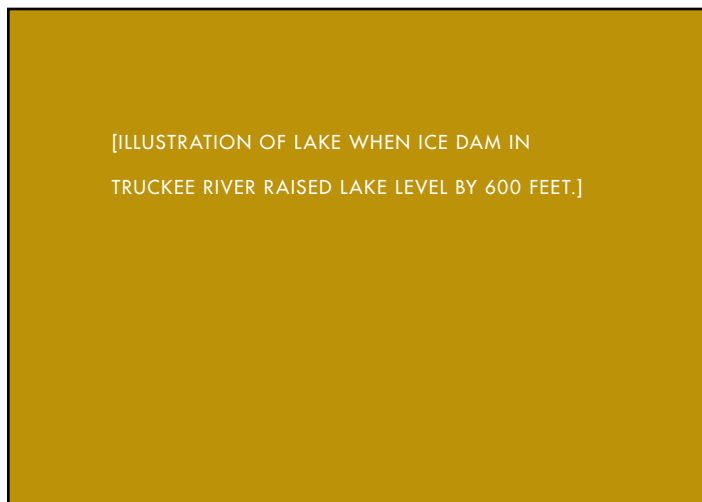
During the Pleistocene, an ice cap covered the Sierra Nevada from Portola to Kings Canyon. On the west shore of Lake Tahoe, glaciers advanced and retreated several

times, carving U-shaped valleys down drainages from the Upper Truckee River to Ward Creek. The Carson Range had much smaller glaciers because of the rain shadow, but

glacial evidence exists in the northeast corner near Incline Lake and the

southeast corner along Trout and Cold Creeks.

DONNER LAKE GLACIATION: >131,000 YEARS AGO



[ILLUSTRATION OF LAKE WHEN ICE DAM IN TRUCKEE RIVER RAISED LAKE LEVEL BY 600 FEET.]

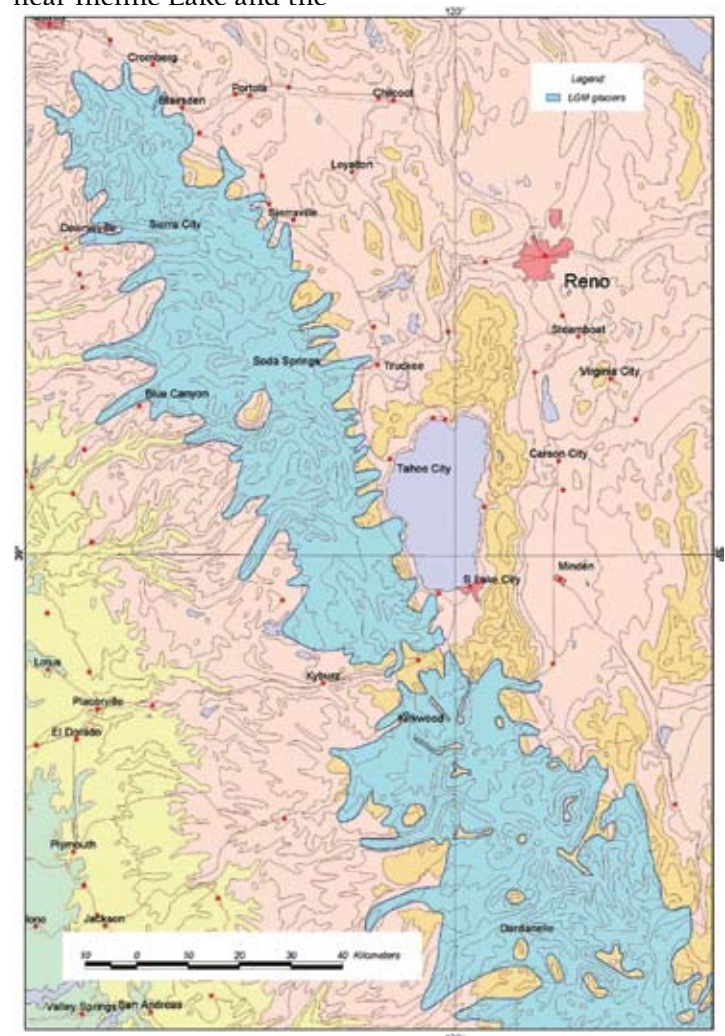
During the Donner Lake Glaciation, a large glacier flowed down from Alpine Meadows and dammed the Truckee River, raising Lake Tahoe by 600 feet. Once the ice dam was breached, a cataclysmic flood swept

boulders and sediment down the Truckee River to Reno. Few deposits from the Donner Lake Glaciation remain in the Tahoe basin because they have been obscured by later events.

TAHOE GLACIATION: 56,000 TO 118,000 YEARS AGO

The oldest glacial till in the Tahoe basin dates from the Tahoe Glaciation. A large valley glacier along Squaw Creek dammed the Truckee River and raised

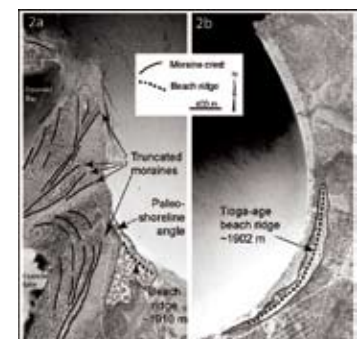
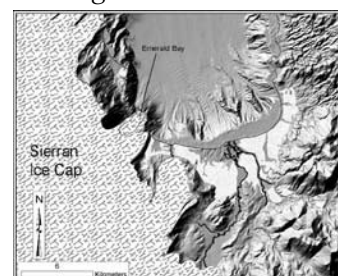
Lake Tahoe by 90 feet. Once again, the ice dam broke, sending catastrophic floods down the Truckee River.



TIOGA GLACIATION: 10,000 TO 25,000 YEARS AGO

Till from the Tioga Glaciation is very fresh in the Tahoe Basin. This was the mildest glacial period, although an ice dam across

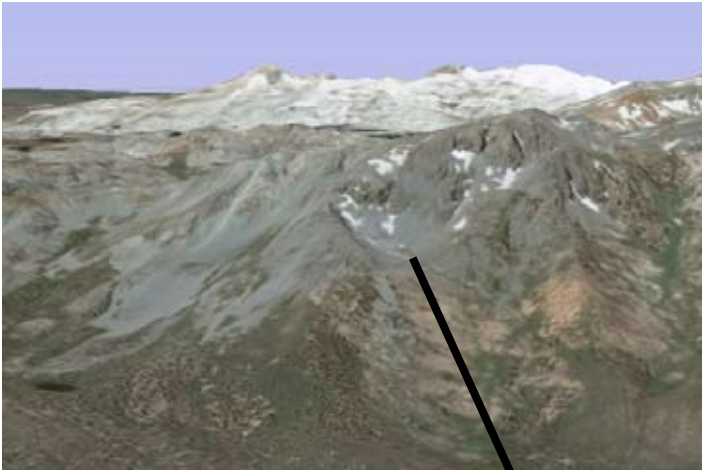
the Truckee River may have raised Lake Tahoe by 15 feet.



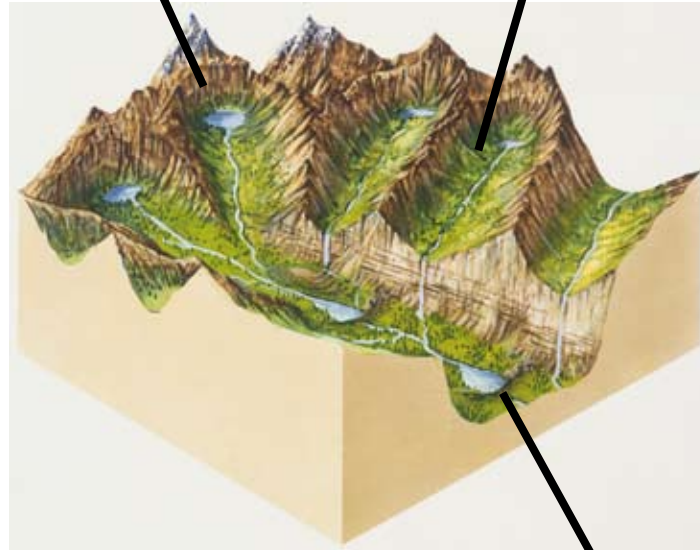
Additional Resources

READING TAHOE'S GLACIAL HISTORY

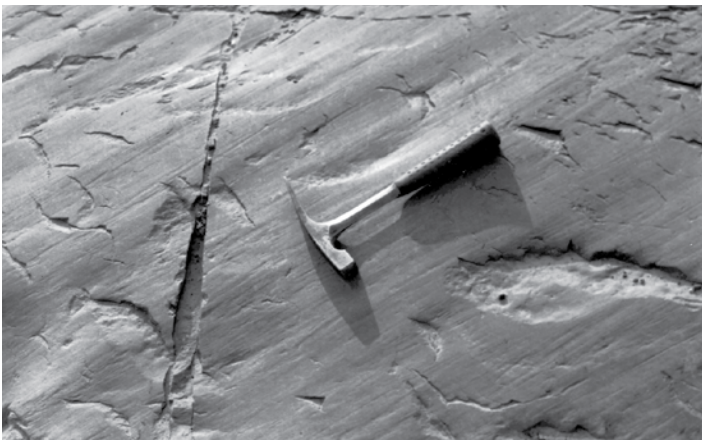
Cirque: A deep, semi-circular basin eroded by an alpine glacier, for example, the northwest face of Mt. Tallac.



U-shaped valley: a valley with steep sides and a broad floor carved by a glacier, for example, Cascade Creek and Eagle Creek.



Lateral moraine: a mixture of angular and rounded rocks deposited along the sides of a glacier, for example, the ridge between Emerald Bay and Cascade Lake.



Glacial polish, striations and chatter: markings in bedrock formed when a glacier drags rocks across the landscape. The parallel grooves indicate the direction of travel.



Paternoster Lakes: a string of lakes connected by a stream, for example, Lake Genevieve, Crag Lake, Shadow Lake and Stoney Ridge Lake connected by Meeks Creek.

Rocks and Soil



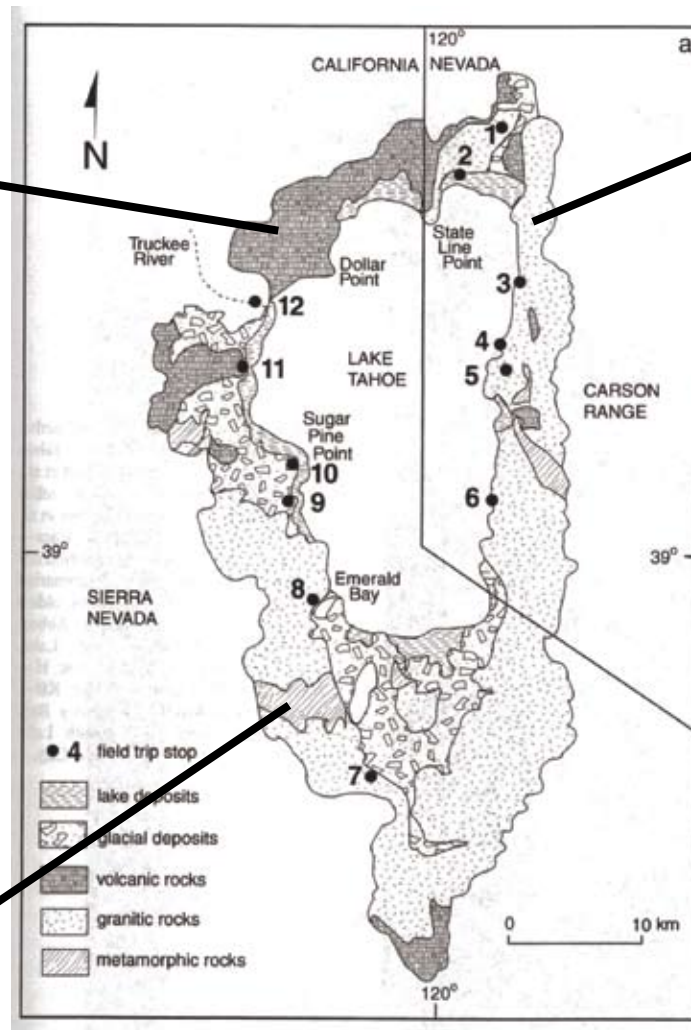
Volcanic Rock: Andesite

The volcanic rocks in the northwestern corner of Tahoe basin are primarily andesite. The molten rock was extruded aboveground where cooled quickly, which gave it a very fine grain. Much of the basin from Blackwood Canyon to Stateline is volcanic. Soils that develop from these rocks generate the most sediment and nutrients, especially when disturbed or left bare like the Ward Badlands.



Metamorphic Rock: Hornfels

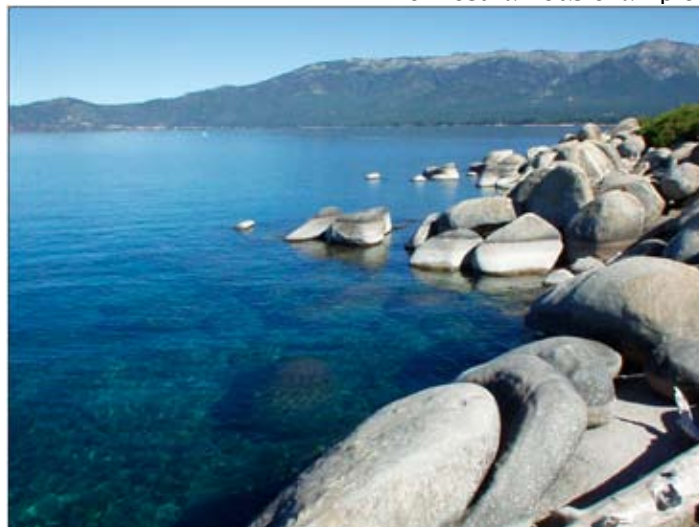
Metamorphic rocks are the oldest rocks in the Tahoe basin. They were formed deep underground 180 million years ago when hot magma came into contact with ancient volcanic island arcs and submarine sedimentary rocks. Consisting primarily hornfels, they are remnants of layers that have eroded away. Called roof pendants, they can be found at Mount Tallac, Barker Pass, near Spooner Lake and Genoa Peak.



Granite

The granitic rocks that underlie most of the Tahoe basin are part of the Sierra Nevada batholith that formed 144 to 65 million years ago. It ranges from granite, a light rock, to a darker granodiorite that contains more iron and magnesium. Soils that develop from this granite tend to be low in nutrients and have larger particle sizes. They contribute relatively less to the loss of lake clarity, except when highly disturbed and lacking vegetation.

Spheroidal weathering is common in Sierra Nevada granite, reaching its height of beauty at Sand Harbor. The most famous example is Half Dome in Yosemite



National Park. Spheroidal weathering occurs when rock formed underground comes to the surface where heat and pressure are dramatically reduced. Because angular edges have greater surface area than flat surfaces, they weather more quickly. Over time the differential rates of weathering produce a spherical shape.

Reading History: Bottom Sediments

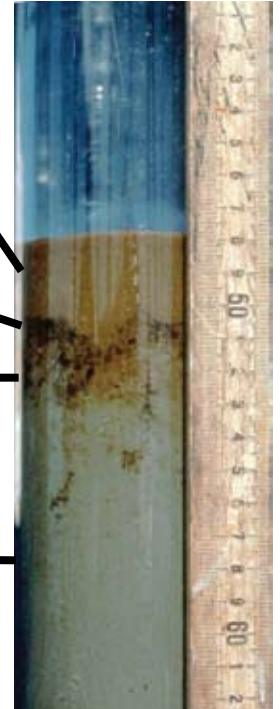
The history of Lake Tahoe is recorded in its bottom sediments, which accumulate in layers like tree rings. Every particle entering Lake Tahoe -- whether from air, land or water -- eventually falls to its bottom and mingles with dead algae and zooplankton. A typical core from Lake Tahoe has these five layers:

1. **Dead Zooplankton:** fall to the bottom and eventually become part of the sediments.
2. **Oxidized Top Layer:** Lake Tahoe's water is unique because it has oxygen all the way down to its bottom. This oxidizes iron in the top layer of sediment, giving it a "rusty" orange color. The oxidized layer acts like a cap that prevents phosphorus in the sediments from returning to the water during deep mixing events or turbulent storms.
3. **Redox Layer:** The redox layer accumulates black precipitates of manganese and reddish-brown precipitates of iron.
4. **Comstock Period:** Sediment rates increased 7 to 12 fold, adding one to two inches of sediment, during the Comstock Era when 60 percent of the Basin was clear-cut. This layer includes perfectly preserved sawdust from the Glenbrook mills, along with pine needles and charcoal from burned slash.
5. **Natural Lake Sediment:** Below the Comstock Era lies sediment with a greenish cast because iron has lost oxygen to decompose organic matter. This is how sediment appears from the natural disturbance regime.

Two other layers are sometimes found:

6. **Mt. Mazama Ash:** A white ash layer of tephra (fragments of volcanic rock and lava) from the cataclysmic eruption that destroyed Mt. Mazama about 7,700 years ago. Crater Lake, the deepest lake in the United States, formed in the collapsed caldera of the volcano. The eruption is estimated to have been 42 times more powerful than the 1980 Mount St. Helens blast, spreading ash over 500,000 square miles. Crater Lake is part of the Cascade Range Volcanic arc, which stretches from British Columbia to Northern California.

7. **Turbidites:** Sometimes cores reveal turbidites, layers of coarse sediment deposited when turbid water races down the steep side slopes like a snow avalanche. Researchers have found turbidites throughout the lake bottom and correlated them with submarine landslides from McKinney Bay, the northern and southeastern parts of the lake. Scientists estimate that events that create turbidites occur about every 1,000 years.

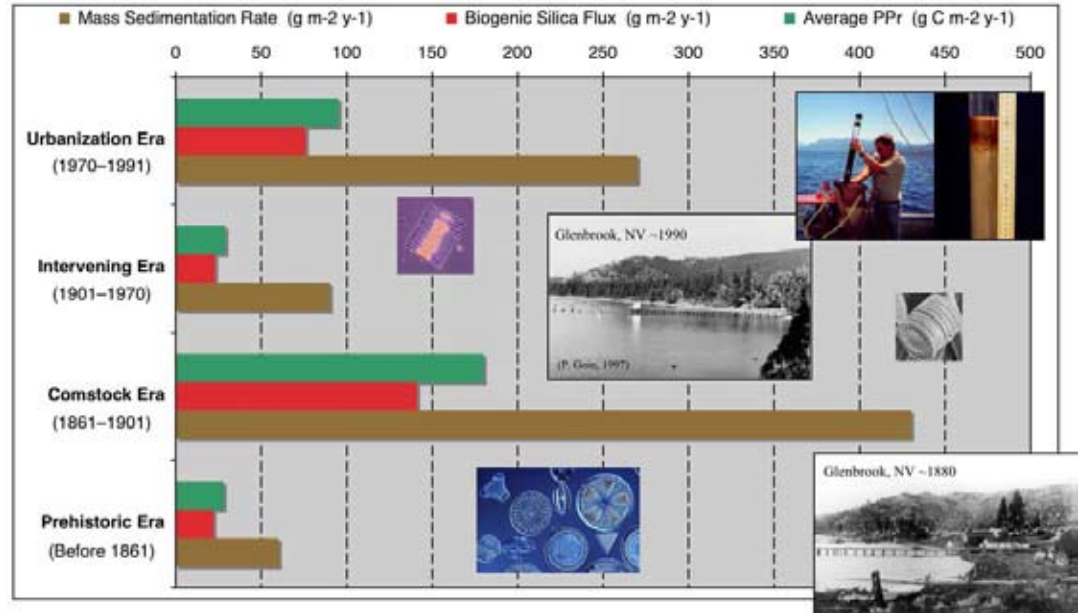


A WHITE ASH LAYER WAS DEPOSITED WHEN MT. MAZAMA ERUPTED 7,700 YEARS AGO, FORMING CRATER LAKE

Erosion: Present and Future

Soil erosion is a natural process of wearing away the earth's surface that, given millions of years, reduces mountains to sea level. It always has been, and always will be, a force that shapes the Tahoe basin.

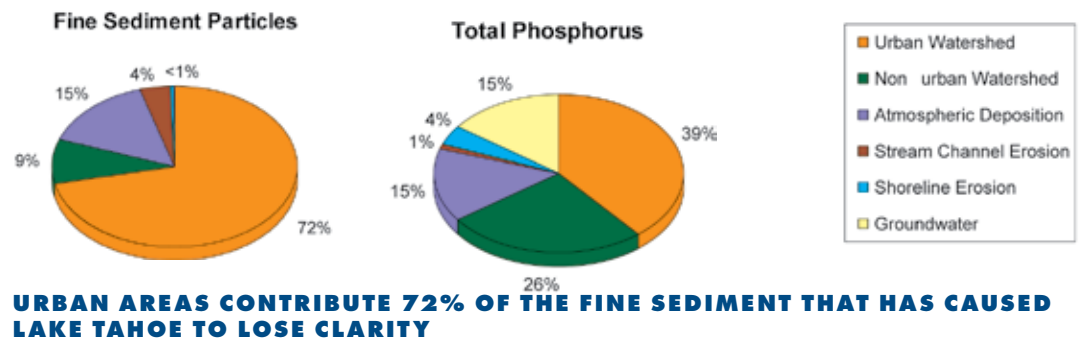
But researchers have identified two periods in which humans have accelerated erosion enough to spoil Lake Tahoe's famed clarity. The first was the Comstock Era, when 60 percent of the Tahoe basin was clear-cut. Sawdust from the mills at Glenbrook along the east shore is



still perfectly preserved in the sediment. The second began with post-World War II development and continues today.

Between the Comstock and the modern era, erosion returned to pre-disturbance rates and Lake Tahoe's clarity completely

recovered. Scientists conclude from this that if erosion slows down again, Lake Tahoe's clarity can be restored.



Fine particulates are the leading culprits in the lake's clarity decline. Nearly three-quarters of these particulates come from the urban areas (72%), even though urban areas represent only 10% of the Tahoe Basin. Phosphorus is attached to soil particles and thus 39% comes from the urban areas, while non-urban

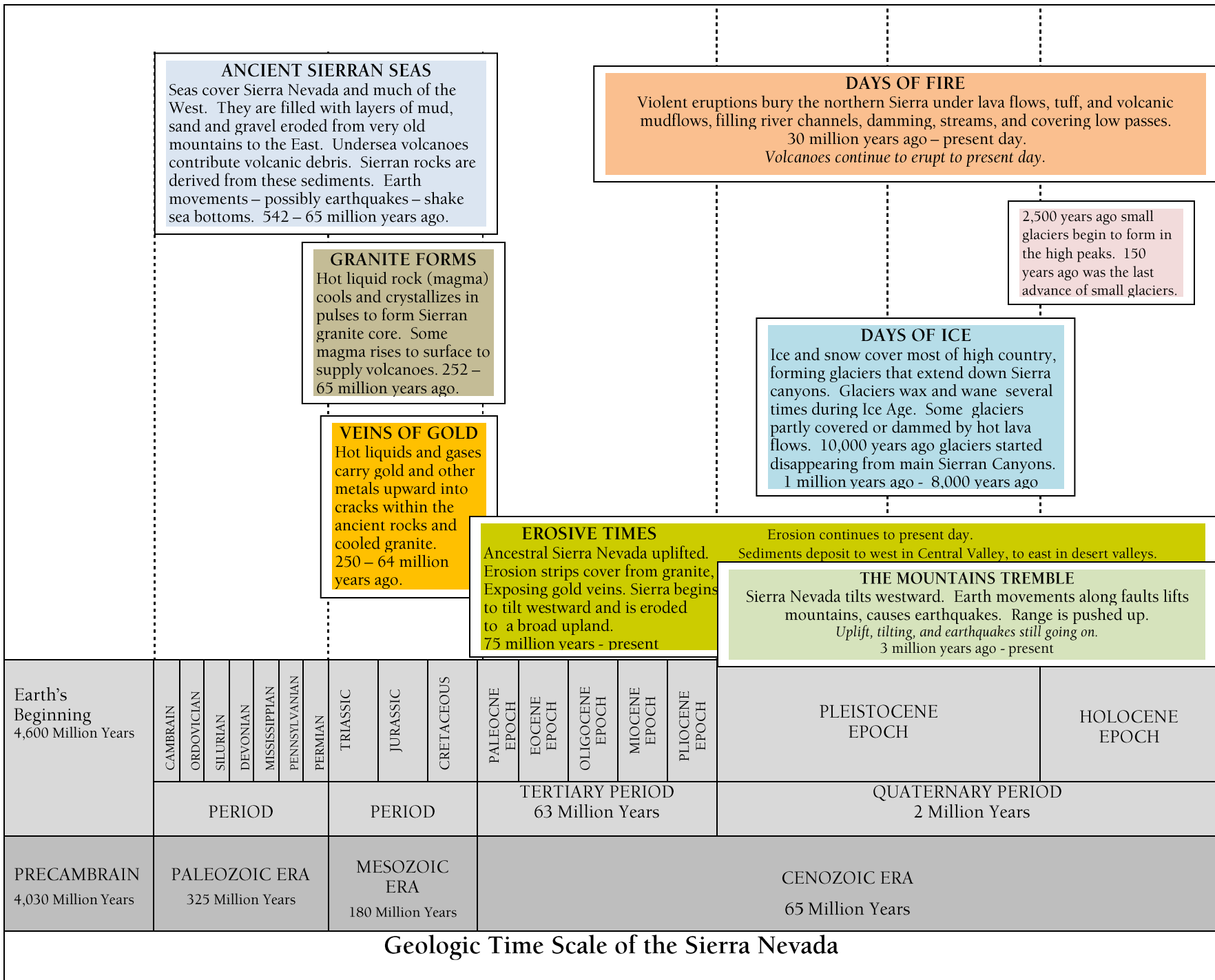
lands contribute 26%. The primary sources of urban particulates are developments, roads and dirt trails. Roads and trails also collect and convey sediment to the lake. Motor vehicles compound the problem by grinding soil into small particles that can remain suspended in Lake Tahoe for years.



ROADS AND ROADCUTS ARE A MAJOR SOURCE OF SEDIMENT

Tahoe Basin Geologic Timeline

670 million years ago	California and Nevada are covered by the waters of an ocean. The western edge of the continent is in the vicinity of present day Utah.
70 million years ago	A long-lived subduction zone is located to the west. Magma continues to intrude the earth's crust below the present location of the Sierra Nevada, forming a vast batholith of granitic bedrock.
10 million years ago	Continuing movement of tectonic plates cause blocks of earth to slide up, down, and past one another along fractures in the earth's crust, forming hills 2000 to 3000 feet high—the future peaks of the Sierra Nevada. Active Volcanoes are present.
5 million years ago	Major uplift of the Sierra Nevada range continues and formation of the Tahoe graben (fault-bounded valley) begins. Volcanism continues at north end of the basin.
2 million years ago	Volcanism at north end of the basin continues, potentially damming the basin at present site of Tahoe City. The Ice Age begins.
800,000 years ago	One of the largest glaciations occurred (Donner Lake Glaciation), choking the Truckee River Canyon downstream of Tahoe City with ice and potentially raising the elevation of Lake Tahoe to 6800 ft. before the ice dams failed and sent a wall of water and debris downstream.
10,000 years ago	The last glaciation (Tioga) ends. The jagged peaks of Mt. Tallac and Squaw Peak, as well as the other alpine features seen around Lake Tahoe, represent the sum total of as many as 10-15 glaciations over the last 2 million years. The two most recent (Tioga and Tahoe) also periodically dammed the outlet of Lake Tahoe, causing lake-levels to rise and large floods when ice dams failed.



Hill, Mary. 2006. *Geology of the Sierra Nevada, revised edition*. Berkeley, CA: University of California Press.

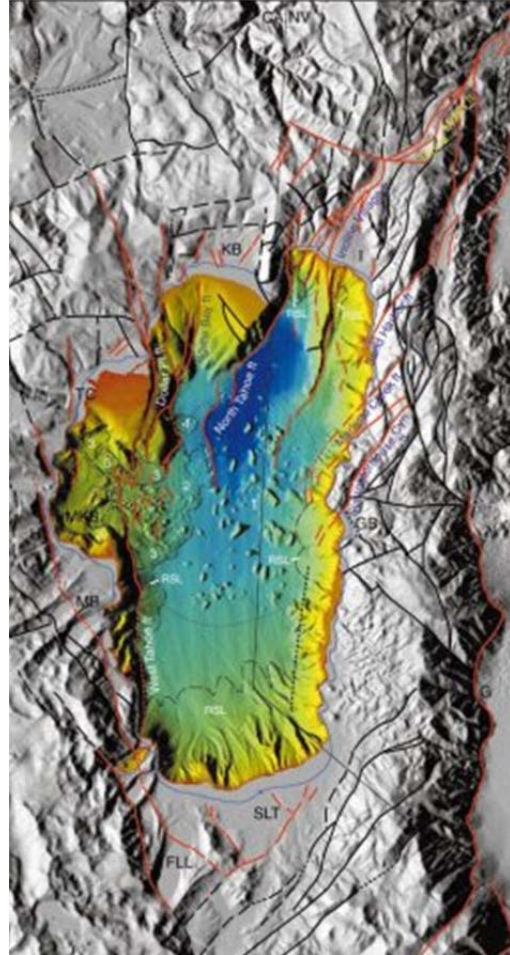
Additional Resources

Tsunami in Lake Tahoe?

Lake Tahoe had a very dramatic beginning when its bottom fell out and the Carson Mountain range and the Sierra Nevada Mountain range rose up. There were volcanic eruptions that created an earthen dam on the west shore. Over the years, rain and snow accumulated in the newly formed basin to create what is now Lake Tahoe. During the Ice Age, glaciers carved the landscape of the west shore into what we see today. Emerald Bay and Cascade Lake provide excellent evidence of past glaciers. It is this dynamic geological past that leads some researchers to hypothesize that a tsunami could form in Lake Tahoe.

Tsunamis generally occur in oceans, not lakes. What makes a tsunami feasible in Lake Tahoe is its size (2nd deepest in the United States, 11th deepest large-lake in the world) and location. Lake Tahoe is nestled in the middle of fault-ridden California and Nevada. More importantly, there are several active faults running through the bottom of Lake Tahoe. The Earth's plates are constantly moving, making an earthquake possible along any of these faults. The two faults of most concern in Lake Tahoe are the West Tahoe Fault/Dollar Point Fault and the North Tahoe Fault/Incline Village Fault.

Geologists predict it would take an earthquake with a magnitude of 6.5 or greater to create a tsunami in Lake Tahoe. When an earthquake occurs, the lake floor would either drop (like a trapdoor opening) or lift. This action would displace the water above the lake floor, causing a wave. Some geologists hypothesize that the tsunami could reach up to 10 meter (33 ft) at the shore. An earthquake along one of the underwater faults could also trigger a landslide which, in turn, could cause a tsunami. This occurred an estimated 10,000 years ago; in what is now McKinney Bay.



Using USGS bathymetry data, a preliminary fault map of the Lake Tahoe basin reveals several active faults (in red) beneath and around the lake.

Rich Schweickert, Ph.D., UNR

(Visitors can see debris on the lake floor from this underwater landslide in the 3-D visualization lab.)

Most tsunamis are generated in the ocean and travel many miles before they reach shore and dissipate. However, Lake Tahoe is in a basin surrounded by mountains so the waves are left with nowhere to go. If a tsunami were to occur in Lake Tahoe, the waves would travel from shore to shore (crisscrossing the lake) for hours. Geologists refer to this particular type of wave as seiche waves. (In an enclosed basin, geologists refer to the tsunami as the initial wave directly produced by the earthquake while the seiche waves are the harmonic resonance within the lake.)

Inland tsunamis are extremely rare, but it is important that we look at Lake Tahoe's past so we can prepare for its uncertain future. "The good news," geologists say, "is that a magnitude-7 quake under Lake Tahoe only has a 3 to 4 percent probability of striking in the next 50 years, given the 1,500-year quake-recurrence interval inferred from tremors along the Genoa fault."

#

Information obtained from Ken Adams, Ph.D., Desert Research Institute (DRI) & Science News Online: <http://www.sciencenews.org/articles/20000610/bob9.asp>, Article by Kathryn Brown

References:

Driscoll, N.W., J.K. Weissel, and J.A. Goff. 2000. Potential for large-scale submarine slope failure and tsunami generation along the U.S. mid-Atlantic coast. *Geology* 28(May):407-410. Abstract.

Ichinose, G.A., J.G. Anderson . . . R.A. Schweickert, et al. 2000. The potential hazard from tsunami and seiche waves generated by large earthquakes within Lake Tahoe, California-Nevada. *Geophysical Research Letters* 27(April 15):1203-1206. Available at <http://www.seismo.unr.edu/htdocs/WGB/LakeTahoeTsunami/>.

Schweickert, R.A., et al. 1999. Preliminary fault map of the Lake Tahoe Basin, California and Nevada. *Seismological Research Letters* 70(May/June):306-312.

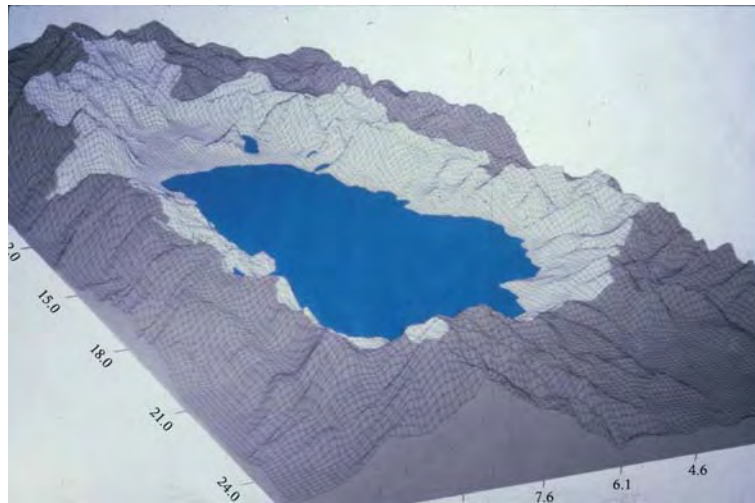
What do Watersheds Matter?

By John Cobourn and Heather Segale,
University of Nevada Cooperative Extension

Date: Feb. 8, 2003

Most Tahoe residents know what a watershed is. Our region is called the Lake Tahoe Basin because the water that fills our spectacular lake comes entirely from precipitation that falls within our watershed as rain or snow. The high peaks and ridgelines surrounding our communities form a huge bowl. They act like a local continental divide, separating Tahoe's water from the water that flows to the Carson River, the American River, Steamboat Creek, and Martis Creek, near the town of Truckee.

Our entire continent is made up of watersheds, which often contain smaller sub-watersheds. In nearly all watersheds that have not been disturbed by heavy natural resource use or urbanization, natural filtration processes tend to keep the water that is in streams, lakes and underground clean. Watersheds naturally adjust to their climate and soil characteristics over time, and collect, store and safely release clean water.



Catastrophic floods occur much less frequently in undisturbed watersheds than in those with urban development and many roads.

Understanding the watershed concept is useful because the main way to stop the decline in Tahoe's water quality is to prevent pollution from many small soil disturbances, and to repair those disturbances by restoring or mimicking natural watershed functions. Since Lake Tahoe has no factories or wastewater treatment plants that discharge polluted water inside the watershed, most of the pollution entering the lake comes from many small, seemingly insignificant disturbances to the natural watershed. We call these small disturbances – a little eroded soil here, a little spilled fertilizer there – nonpoint sources of pollution.

Even water pollution caused by poor air quality or atmospheric deposition can be reduced if the watershed's natural filtration processes are functioning properly.

Since the 63 Tahoe sub-watersheds sometimes carry dirty water to the

(Continued on page 2)



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(Continued from page 1)

lake, all these small impacts (plus atmospheric deposition directly into the lake) add up to what we call the cumulative impacts to the lake. These can be tracked over time, and the results can be displayed with graphs, such as the UC Davis Tahoe Research Group's Secchi Depth Chart. This chart tracks the average water clarity of Lake Tahoe – the distance you can see objects below the lake's surface. It shows that Lake Tahoe's clarity has decreased from 105 feet in 1968 to about 65 feet to 70 feet today.

The cloudiness in the lake's water is caused by a combination of small soil particles, called suspended sediments, and tiny single-cell algae plants that also remain suspended in the water. They are too small to settle out, but numerous enough to block the light.

Best management practices (BMPs) are basically repairs that prevent pollution by restoring our residential lots, so they act more like a natural watershed. We want rain and snowmelt to soak into the soil, not run off. Runoff collects and carries tiny soil particles and phosphorus, the most harmful of the nutrients that feed the single-cell algae plants in the lake. Properly installed and maintained BMPs can prevent small amounts of pollution from leaving our properties throughout the watershed and entering the Lake. When our repairs outweigh our adverse cumulative impacts, our lake's water quality will slowly return.

FACTS:

- Everyone lives in a watershed. Watersheds are those land areas that catch rain or snow and drain to specific marshes, streams, rivers, lakes or groundwater.
- Watersheds are not defined by jurisdictional boundaries. Watersheds near us include the Lake Tahoe Basin, Truckee River, Carson River and Walker River watersheds.
- Within Lake Tahoe there are 64 sub-watersheds, with 63 streams draining into the Lake and only the Truckee River carrying water out.
- Tahoe does not have any polluting factories. All of the pollution comes from our daily activities and impacts. Pollution comes from our properties, recreation, transportation, and other human activity.
- All of the activities that take place within the watershed, including those that occur far from the lake, have an impact on our water clarity and water quality. What you do on your property, no matter how far from the Lake, makes a difference.

How the Lake Interacts with its Watershed and Ecosystem

By John Cobourn, Water Resource Specialist, and Heather Segale, Environmental Education Coordinator
University of Nevada Cooperative Extension

Lake Tahoe's watershed is the natural drainage system that supplies the lake with water. From the high peaks and ridgelines all the way to the shore, rain and snowmelt flow in creeks or through the ground into the lake.

Water that is conveyed to a lake by an undisturbed watershed is usually quite pure, because the watershed's soils, plants and organisms act as a natural water purification system. In fact, in many undisturbed forests, more than 95 percent of rain and snowmelt percolates into the ground, where it is filtered on its way to the nearest stream.

The exceptional clarity of Lake Tahoe's water is a result of the relative absence of suspended sediment and free-floating, single-celled algae in the water. Very few plant nutrients are present in the water to feed algae. Given undisturbed conditions, the lake's water quality would be expected to change so slowly that the changes would be imperceptible over a human lifetime.

However, Lake Tahoe's water quality has deteriorated since settlers arrived in the mid-1800s. Its clarity has decreased by more than 33 percent since the 1960s. In 1968, scientists could routinely see objects lowered into the lake at depths of over 30 meters (100 feet). By the end of the twentieth century, they could see only about 20 meters (65 feet) into the lake's water (see graph).

Water quality deterioration has occurred primarily because we've disturbed the watershed by building roads and urban areas in the basin. The pavement, rooftops and other impervious (hard) surfaces we've created shed over 90 percent of all precipitation. Instead of being filtered by the soil, the water runs off the surface rapidly. Surface runoff typically concentrates in ditches and gullies, causing soil erosion. When these higher-than-natural flows reach streams, increased streambank erosion occurs.

The lake's natural biological cycle has been disturbed over the past 50 years due to these influences. Lake Tahoe suffers from increased loads of fine sediment and dissolved nutrients. The nutrient inflows, mostly phosphorus and nitrogen, are literally fertilizers, which boost the growth of free-floating algae, diminishing water clarity. This process, called eutrophication, is accelerating from the increased input of nutrients.



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How Erosion Hurts Water Quality

By John Cobourn, Water Resource Specialist, and
Heather Segale, Environmental Education Coordinator
University of Nevada Cooperative Extension

Soil erosion occurs when soil particles are detached and moved from their original location, usually by water, wind or gravity. Though soil erosion is a natural process, accelerated erosion, caused by poor drainage, construction or other human activity, causes serious environmental problems. Soil erosion can degrade water quality and fish habitat if the eroded soil finds its way into streams and to the lake.

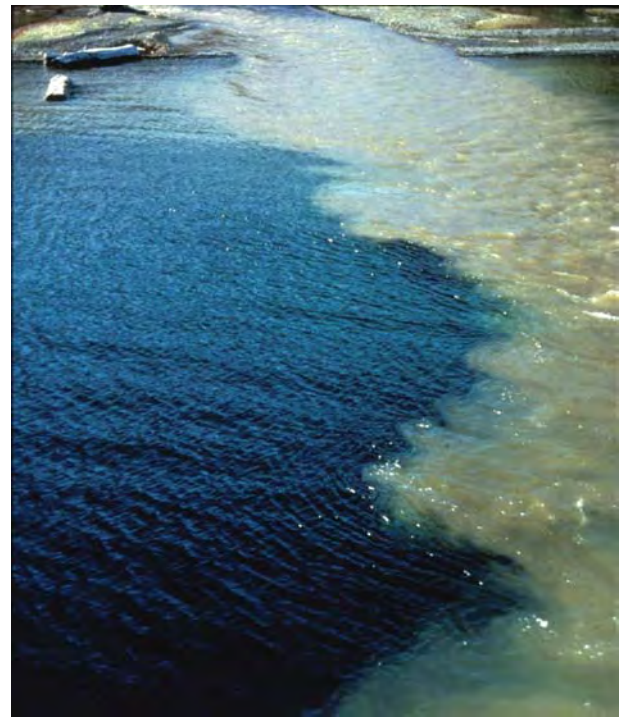


During rainstorms, snowmelt or irrigation, flowing water moves eroded soil, called sediment. Moving water transports sediment to Lake Tahoe via ditches, creeks and storm drains. Once in a creek or river, sediment buries aquatic organisms, smothers fish eggs, clogs fish gills and spawning gravels, and muddies clean waters. Eroded sediment also carries fertilizers, pesticides and other chemicals, any of which cause additional pollution

concerns for the lake. Sediment, especially fine particles and dust, carry phosphorus, the key nutrient stimulating the growth of algae that clouds the lake's waters. Fine sediment also remains suspended in the water rather than settling out, further reducing clarity.

What we do in our landscapes has a huge impact on the future of Lake Tahoe. If we allow sediment, fertilizers, pet waste or other pollutants to run off properties and roadways into the lake, its

(Continued on page 2)



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beauty could be destroyed in our lifetime.

To keep Lake Tahoe clear and blue, everyone must prevent water pollution. Since household sewage is treated at plants and pumped outside the basin, the real concern is non-point source pollution caused by activities at home, work and in our communities. This pollution comes from streets and properties rather than a single point such as the discharge pipe of a factory or wastewater treatment plant. It all adds up, whether it's litter out of a car window, soil erosion or fertilizer that washes off a landscaped area.

The first line of defense against nonpoint-source water pollution, or polluted runoff, is to follow guidelines known as Best Management Practices, or BMPs. The most challenging BMP at Lake Tahoe is erosion control.

Best Management Practices (BMPs)

Best Management Practices (BMPs), designed to prevent nutrient and sediment loading to Lake Tahoe, are required on all commercial properties, on the public roadways, and yes, even on our own private property. Typically, a BMP retrofit for a residential property entails measures such as spreading mulch over exposed soil areas, paving dirt driveways, and in some cases installing infiltration systems next to driveways and under roof driplines. To schedule a free BMP Site Evaluation, call your local Conservation District, (530) 573-2210. The University of Nevada Cooperative Extension 160-page book, Home Landscaping Guide for Lake Tahoe and Vicinity, is included free as part of your BMP site evaluation.

Fertilizer Usage

When you're fertilizing the lawn, remember you're not just fertilizing the lawn. The rain washes fertilizer along the curb, into the storm drain, and directly into our streams and Lake Tahoe. This causes algae to grow, which decreases the clarity of the lake. So if you fertilize, please follow directions and use sparingly.

Water Conservation

Please don't waste water - To irrigate your lawn efficiently and avoid over watering, you should perform an "irrigation audit" (or "can" test) on your sprinkler system. If you are applying more than 1 and one-half inches of water per week in spring or fall, or more than 2 inches per week in July and August, you are over watering and perhaps leaching nutrients down into the groundwater. For more information, call Bill Carlos, (775) 784-4848, or Waste Not Incline Village GID, (775) 831-8603.

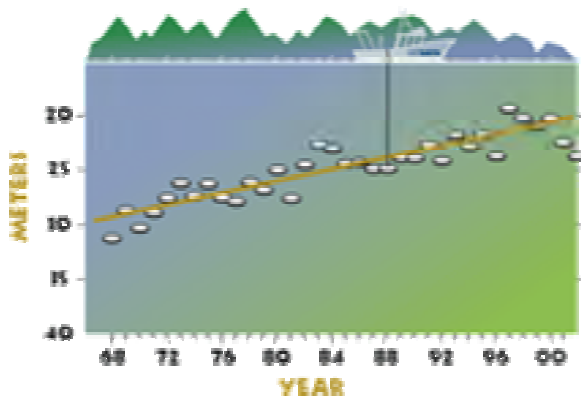
Why Measure Water Quality at Lake Tahoe?

By John Cobourn, Water Resource Specialist, and
Heather Segale, Environmental Education Coordinator
University of Nevada Cooperative Extension

Date: Feb. 14, 2003

Scientists have been measuring water clarity in Lake Tahoe continuously since mid-1967. A simple measurement of how far down into a lake a white Secchi Disk can be seen tells lake specialists, called limnologists, a great deal about a lake's ecological condition.

Charles Goldman, Ph.D., founder of the UC Davis Tahoe Research Group, is the limnologist who had the foresight to begin scientifically accurate measurements of Lake Tahoe's clarity 35 years ago. Because of this, we know that the Lake's clarity has decreased at an average rate of more than a foot a year, declining from a clarity of approximately 105 feet in 1968 to a clarity of only about 70 feet in 2001. These measurements are summarized in the Lake Tahoe Secchi Depth chart, as shown.



Unlike most graphs, this chart shows the measurements reading down from the top. This corresponds with the fact that water clarity is measured by how far down into the lake the disk can be seen by Bob Richards, UC Davis researcher, from the deck of the John LeConte, the UC Davis research vessel. Note that while the Secchi depth fluctuates depending on the weather, storm patterns and amount of precipitation each year, the trend is unmistakably toward lower clarity over the years. The rising trend line indicates decreasing Secchi depth, or water clarity.

Water clarity is an indicator of the ecological condition of a lake. When Mark Twain spoke of his amazement at seeing objects clearly on the bottom of Lake Tahoe in over a hundred feet of water, he was describing what a rare circumstance it was even 130 years ago to encounter a lake this clear. The lake was then, as it is now, an "oligotrophic" lake. That means it is exceptionally clear because there is very little suspended sediment and suspended algae in the water. Such lakes tend to be naturally clear, because their watersheds are relatively small compared to the volume of water in the lake.

The Secchi chart is telling us that we are destroying the Lake's natural clarity. Our urbanization of Tahoe's watershed and our pollution of the air

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Basin. The construction boom disrupted the watershed's natural water filtration processes, and the combined effects of soil erosion, nutrient pollution, and air pollution caused the decline we have measured since the 60s.

Because watershed restoration efforts to date have not reversed the downward trend of water quality, and because Tahoe is considered a national treasure, state, federal and local governments have committed to a new level of cooperative effort to save the lake from turning green. The Lake Tahoe Environmental Improvement Program (EIP) is a model for collaboration between public agencies and the private sector to stop the inflow of pollutants into the lake. Over 800 restoration projects are being planned, and millions of dollars are being raised to fund this massive cooperative effort.

While experts agree that the lake can recover if we greatly reduce pollution, they urge citizens to be patient. We must continue our efforts to repair the soil disturbances of urbanization, so the watershed can recover as it did when the forests grew back in the early 1900s. If we can greatly reduce the amounts of nutrient and fine sediment pollution that reach the lake, Heyvaert's research indicates that water quality could improve within 20 or 30 years.

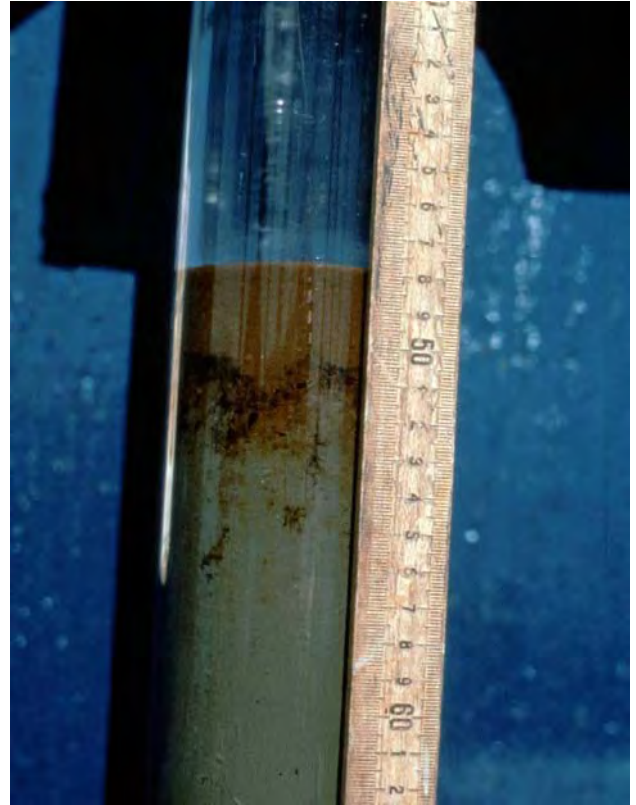
Can Lake Tahoe Be Saved?

By John Cobourn, Water Resource Specialist, and
Heather Segale, Environmental Education Coordinator
University of Nevada Cooperative Extension

Date: Feb. 24, 2003

No one knows if we can restore Lake Tahoe's remarkable water clarity or even what it would take to halt the decline in that clarity. As we described in last week's article, there has been a fairly steady reduction in water clarity (the distance one can see objects such as a Secchi Disk below the surface) since scientific measurements began in 1968. The depth we could see in 1968 was 105 feet, or about 50 percent greater than today's depth of about 70 feet. The considerable protection efforts by the federal government and California and Nevada since the late 70s have not yet shown a positive effect in reducing the rate of water quality decline.

But Alan Heyvaert, a researcher from University of California, Davis, has found evidence in the sediments on the lake bottom that the lake has recovered from pollution before. He has taken core samples of the layers of sediment on the floor of the lake which indicate that water quality was likely reduced during the Comstock silver mining boom of the late 1800s, when most of the forests of the Lake Tahoe basin were clear cut to provide timber for the mines. When the boom died out and the logging stopped, the forests in the Basin grew again, and the soil disturbances healed over time. During the first half of the 20th century, the lake's water quality and clarity actually improved.



Given this evidence, there is hope that we can stop Tahoe's decline if we can reduce the unnaturally high levels of nutrients and fine sediments that enter the lake due to human disturbances. Tahoe's current problems began in the 1960s when the popular Squaw Valley Olympics triggered a new boom—a sharp rise in urbanization in the Tahoe

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quality over the lake have created millions of small human impacts that have added up over time. These cumulative impacts have caused more nutrients to enter the Lake and feed the free-floating algae, and more small soil particles to become suspended in the water.

Goldman is still working on Lake Tahoe. He is telling us that the water quality may move from spectacular to merely average in our lifetimes, with the color changing from blue to green. Restoration of our air quality and watershed is the only likely means to prevent this decline.

Preventing further deterioration is not just important for aesthetic reasons, but it is also important for Tahoe's recreation-based economy, property values and the quality of our drinking water.

Where Does Tahoe's Water Pollution Come From?

By John Cobourn, Water Resource Specialist, and
Heather Segale, Environmental Education Coordinator
University of Nevada Cooperative Extension

Class	Examples	Major Sources	Major Effects
Nutrients	Nitrogen, phosphorus	Fertilizers, leaking sewer pipes, animal wastes, soil erosion	Slow, steady increase of single-cell algae reduces the lake's famed clarity
Sediments	Soil, sand, silt, dust, gravel	Erosion of soil by water or wind, road de-icing, storm drains	Carries attached phosphorus into the lake. Suspended sediment reduces water clarity
Pathogens	Bacteria, viruses, parasites	Animal and human wastes, leaking sewer pipes, storm drains	Makes water unsafe for human consumption
Toxins	Hydrocarbons, heavy metals, petroleum products	Chemical spills, automobile products and emissions, watercraft, street runoff, leaking underground petroleum storage tanks, improper use of pesticides	Harms wildlife and fish, contaminates human drinking water
Salinity	Total dissolved solids (TDS), salts	Road de-icers	Accumulates in lakes
Thermal Pollution	Increased water temperature	Loss of streamside tree canopy	Water holds less dissolved oxygen; harms aquatic life

Excerpted from "Home Landscaping Guide for Lake Tahoe and Vicinity," University of Nevada Cooperative Extension

Date: March 21, 2003

Of the six main types of water pollution, Lake Tahoe is affected most seriously by nutrients and sediments. The table shows the six types of pollution, their major sources, and their effects.

Nutrient pollution occurs when phosphorus and nitrogen enter the lake in dissolved or particulate forms. These chemicals are commonly found in fertilizer. They are literally food for plants, in-

cluding the algae that are beginning to turn Lake Tahoe green. While fertilizer is beneficial to your landscape plants if your soils are poor, it is detrimental to the lake when it is carried off your property and into roadside ditches or nearby streams. Other sources of nutrient pollution include auto, factory and wood stove emissions; human and animal wastes; and fine sediments, which usually carry phosphorus with them.

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Sediments are small and very small particles of eroded soil, including dust and pulverized road sand. When these particles are washed or blown into our streams and the lake, the larger grains settle to the bottom, but the tiny, fine particles remain suspended in the lake water. Since one of the main sources of phosphorus pollution is sediment, the control of soil erosion in the Tahoe Basin has become a major priority of scientists and agency officials who are trying to prevent further pollution of the lake.

In the \$2 million scientific study, the Lake Tahoe Watershed Assessment, water quality researchers blamed the steady loss of Tahoe's famed water clarity on the combination of fine suspended sediment and equally tiny, single-celled algae, called phytoplankton, which are also suspended in the lake's water and do not settle out. These algae will continue to grow in Lake Tahoe until we reduce the amounts of nutrients that feed them. Since some nutrients and fine sediments enter the lake through air pollution, our basic strategy to save the lake's clarity is to improve air quality in the basin while reducing the rate of soil erosion.

While pollution by pathogens and toxins are serious events when they occur, these problems are not widespread. Salinity and thermal pollution are even less often problems for the lake, although road de-icing salt can increase lake salinity in areas where road runoff and improperly stored snow can make their way into nearby streams or the lake itself.

What Kinds of Best Management Practices Work Best?

By John Cobourn, Water Resource Specialist, and
Heather Segale, Environmental Education Coordinator
University of Nevada Cooperative Extension

Date: July 8, 2003

Most Lake Tahoe residents and second-homeowners know that best management practices (BMPs) are required on all private and public properties at Lake Tahoe. They also know that these land management practices are designed to prevent the kinds of water pollution that are slowly but steadily reducing Lake Tahoe's world famous water clarity. But, property owners want to know what kinds of BMPs they should install.

As we have discussed in previous articles, property owners need to evaluate their properties to learn if polluted runoff escapes the boundaries during a heavy rainstorm. It should not do so. The main goal of BMPs is to keep precipitation that falls on a property from running off, even during an intense rainstorm that drops an inch of rain in an hour. The rain should soak into the ground instead of running off the driveway and onto the street or down a hill toward a creek or roadside ditch.

The good news is that homeowners can receive a free BMP site evaluation by calling the Nevada Tahoe Conservation District in Nevada, (775) 586-7223, Ext. 1; or the Tahoe Resource Conservation District in California, (530) 543-1501, Ext. 6. You can schedule the free inspection when you are at home or away from home. If you are a business owner, you can call the TRPA, (775) 588-4547, Ext. 205. The evaluators are not looking for infractions of local rules. Their purpose is to prepare a written recommendation to send back to

you, explaining which BMPs you can install to reduce the likelihood of creating water pollution.

The site evaluation report will categorize BMPs into four basic categories:

- **Paving Driveways and Parking Areas:** A driveway permit and a professional design are required to ensure that runoff will not flow to the street or roadside ditch. The reason we pave driveways at Tahoe is to prevent unpaved driveways from being sources of soil and mud to be tracked onto the street by departing cars. This mud is washed into the storm drain system. In addition, during rainstorms water containing harmful sediment will run off the compacted dirt surface and often enter the street drain system, which carries the dirty water eventually to the lake. Runoff from the impervious surface must be conveyed to an infiltration system, which is the next category.
- **Infiltration Systems:** Since water from a rainstorm or melting snow will run off all the rooftops, patios, walkways and driveways on your lot, your soil usually is not capable of soaking up all that water. Infiltration systems are merely devices that catch and store the runoff, often underground, from your "impermeable" surfaces so that it has time to percolate down into the soil. Since most runoff from homes is relatively nontoxic, its pollutants are easily filtered by the soil. The clean

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water reaches the water table, which can eventually return it to streams or the lake. One important exception is plant fertilizer. If you overfertilize your landscape, the nitrogen and phosphorus that sinks to the water table will eventually reach and pollute the lake.

- **Vegetation and Mulch on Bare Soil:** Most people realize that heavy rainfall on bare soil is a recipe for soil erosion. The BMPs in this category include planting native and adapted plants, as listed and pictured in Chapter 7 of the “Home Landscaping Guide for Lake Tahoe and Vicinity.” This book comes free with the site evaluation described above. Mulch is a material such as wood chips, bark chips, composted pine needles, or gravel that is spread on top of the soil to protect it. Both vegetation and mulch promote the infiltration of water into the soil and reduce the ability of raindrop impact to erode soil particles.
- **Slope Stabilization:** This category includes the planting of erosion-control vegetation on gentle slopes. It also includes the installation of structures such as terraces, retaining walls, or gravity block walls, or using bioengineered methods on slopes greater than 50 percent. Bioengineered methods involve placing cuttings of dormant willow shrubs into slopes, often horizontally along the contour, and irrigating the cuttings so that they grow to form a strong, vigorous stand of willow bushes that keep even, steep slopes from eroding. This method can provide a unique gardening challenge for full-time residents with a green thumb.

From Under the Water – Part One

By John Cobourn, Water Resource Specialist, and
Heather Segale, Environmental Education Coordinator
University of Nevada Cooperative Extension

Date: May 6, 2003

Lake Tahoe is naturally an ultra-oligotrophic lake, meaning that it has extraordinary clarity in part because of extremely low rates of algae growth in its water. In lakes, microscopic free-floating algae plants are the primary producers of food for other lake organisms. Tahoe has a naturally unproductive aquatic ecosystem, compared to the vast majority of lakes in the world. That is one of the reasons its water is among the clearest and most transparent of any large lake in the world.

Does that mean the aquatic ecosystem is barren or uninteresting? Well, not if you like ecology and find out what is actually there. There are many different species of free-floating microscopic algae, called phytoplankton, in Lake Tahoe. One of the most abundant types of algae here is the diatom. Diatoms have a hard glass-like silica shell surrounding their biomass, and when they die and sink to the bottom, they make deposits that have been mined as diatomaceous earth where shallow seas have dried up.

Some microscopic algae plants have a tiny whip-like flagellum, allowing them to swim in search of nutrients. In the summer, throughout the lake, various species of algae stratify into layers from the warm bright surface of the water to the lowest edge of the zone of light penetration, more than 350 feet below the surface. Some algae swim up to the surface for photosynthesis during the daylight and back down to harvest nutrients each night.

The favorite foods of these plants are dissolved Nitrogen and Phosphorous. Scientists have learned that phytoplankton generally thrives and grows fastest when it can find 16 atoms of nitrogen for each atom of Phosphorus. This atomic ratio of 16:1 forms the balanced diet for algae.

Since Tahoe has relatively low concentrations of plant nutrients in its water, the growth of algae throughout the lake is limited. As more nitrogen and phosphorus are added to the lake through erosion and other forms of pollution, growth will increase. Currently, because so much nitrogen is deposited into the lake out of the atmosphere, there is a slight excess of nitrogen with regard to the 16:1 ratio (called the Redfield Ratio). Because of that, many species of algae will not increase their growth rate unless we add more Phosphorus to the water. The lake is currently “phosphorus-limited”.

Scientists reported in the Lake Tahoe Watershed Assessment (2000) that the most effective way to limit the decline in lake clarity is to reduce the amount of phosphorus and fine sediment particles that are delivered into the lake each year. Fine sediment particles not only absorb and scatter light like phytoplankton, but they also carry attached phosphorus that becomes available as food for algae. To reduce phosphorus and fine sediment inflow, scientists recommend best management practices (BMPs), which are land management practices that reduce erosion, promote infiltration of runoff down into the ground, and prevent fertilizers or other sources of plant nutrients

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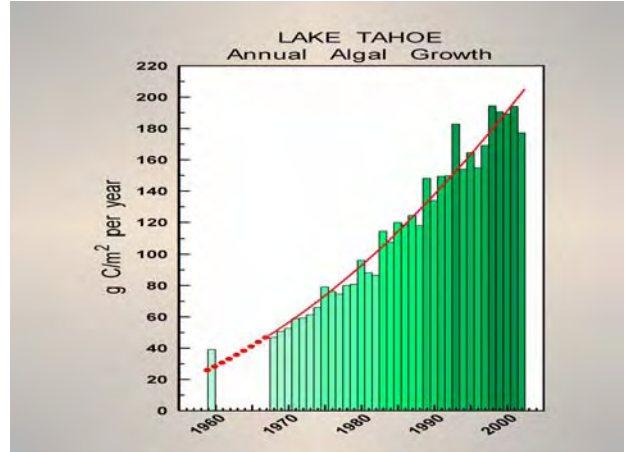
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from moving from the land to the lake.

Scientists have shown that the rate of algal growth has been steadily growing in Lake Tahoe. While most residents have seen the Tahoe Research Group's Secchi Depth chart, not as many have looked at the chart showing the rise in the algal growth in the past 40 years. In fact, the rate of algae growth in Lake Tahoe has quadrupled since 1959. This trend continues to increase at a rate of approximately 5 percent to 6 percent per year.

Kendrick Taylor of the Desert Research Institute (DRI) is one of many scientists currently studying Tahoe's water. He measures near-shore water quality several times each month in order to identify areas with poor water quality and to determine how different weather conditions influence water quality. He has measured the turbidity, or lack of clarity, of the water at the mouths of most of Lake Tahoe's 63 tributary streams. His near-shore turbidity measurements show the combined effects of the fine suspended soil particles and the microscopic algae that cloud the water in locations around the lake. One of the most significant findings of his research is that the lake exhibits plumes of turbid water near the outlets of streams that drain urbanized land, such as Tahoe City, South Lake Tahoe, Incline Village and Kings Beach. This provides further evidence that it is human land use that contributes the pollutants that are causing the loss of Tahoe's clarity.



Source: Charles Goldman, Ph.D., UC Davis

Dr. Charles Goldman and other authors of the Watershed Assessment have stated that current rates of pollution will, if continued, result in a lake that is turning green and of merely "ordinary" clarity by the year 2030. The algae are bent on surviving and reproducing. It is up to us to slow down the rate at which we are providing the food for their growth.

From Under the Water – Part Two

By John Cobourn, Water Resource Specialist, and
Heather Segale, Environmental Education Coordinator
University of Nevada Cooperative Extension

Date: May 13, 2003

The future of Lake Tahoe's water is being shaped by living organisms, both microscopic and macroscopic. The microscopic life forms that will determine the future health and clarity of the lake are influenced by the actions of much larger, macroscopic life forms – humans.

Remember the phytoplankton algae we described last week? It can be difficult to see with a naked eye, but sometimes during a particularly productive period, known as an "algae bloom," the water will appear greenish. Researchers can either measure the chlorophyll in the water to detect this type of algae, or, lower the Secchi disk to a depth where the millions of suspended microscopic plankton and soil dust in the water actually make the disk disappear out of view.

By comparison, the attached algae, also known as periphyton, is very easy to see. In fact, in some locations it can be hard to miss. This is the type of algae most people are familiar with and it occurs mainly near the shore where the sun can warm the water and these furry green plants can attach to rocks and grow. This attached algae coats the rocks with colonies of hair-like filaments that feel slimy and can be slippery if you step on them on your way to go swimming. In some areas of the lake, these attached algae can grow many inches in length. The larger mats of these algae seem to be especially common in areas where developed residential and urban areas drain into the lake. If phytoplankton or suspended sediment doesn't

cloud the water, you can sometimes see periphyton algae on rocks 30 feet deep.

Periphyton, or attached algae, has noticeable blooms, when their growth rate speeds up, particularly in spring and to a lesser extent in the fall. The best time to look for algae-covered rocks is usually during April or May, when spring runoff is generally greatest. During the summer, the periphyton population dies back as part of its natural life cycle, and mats of decaying algae accumulate at the shoreline.

While there has been significant attention paid to the algae that live in Lake Tahoe, the tiny animals that graze on the phytoplankton receive much less press. These microscopic consumers are known as zooplankton and have been the subject of considerable study by the Tahoe Research Group. In general, the zooplankton graze on the phytoplank-

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Periphyton in Lake Tahoe



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ton. And of course, the larger lake shrimp and many fish feed on the smaller zooplankton. The Tahoe food web is relatively simple, but this simplicity makes the lake vulnerable if a change should cause even a single species to enter or leave the lake. This is why resource managers from both Nevada and California are very concerned about the introduction of exotic species to Lake Tahoe and why efforts are taken to prevent this from happening.

Because most residents agree the relatively clear water in the lake is desirable, they are instructing their property managers to go easy with the fertilizer. The impact of fertilizers draining into the Lake and causing attached algal growths can be startling. In a study by the Tahoe Research Group in the 1980s, significantly more periphyton growth was observed in an area where a lawn received fertilizer than was observed at a section of shoreline just 300 feet away that did not receive fertilizer. Property managers are being encouraged by publications such as *The Home Landscaping Guide for Lake Tahoe* to apply no more fertilizer to lawns than is needed for plant health – generally a light application of fertilizer in May and just one more in September. Lawn-care companies that strive for deep green color can cause the inadvertent escape of excess nitrogen and phosphorus into local rain ditches, streams, or even beach gravel and sand and directly into the lake. Humans adding nutrients into lakes can lead to “cultural eutrophication.” This gloomy term means humans can turn clear lakes into highly productive green ponds, with slimy bottoms and a wide variety of pond life and insects, such as mosquitoes.

The microscopic organisms that will ultimately shape the future of Tahoe’s waters can only react to the conditions they live in – they have no choice or awareness. We, the macroscopic life forms, do have awareness and do have choice. Lake Tahoe is truly fortunate to have such an aware population that knows and cares about the need to reduce erosion and nutrient inputs to its water. We are beginning to see that the choices



Decaying algae along the shoreline of Lake Tahoe

we make can have a positive effect, and that an algae-green Lake Tahoe does not have to be inevitable.

Attached algae are good indicators of localized nutrients entering the lake. Researchers at the UC Davis – Tahoe Research Group have been studying the attached algae in the shore zone of Lake Tahoe for the past 20 years. While the steady loss in lake clarity is sometimes difficult to visualize, the proliferation of periphyton is a readily apparent indicator to the public that the lake is changing in a detrimental way. The monitoring has indicated that there is a greater amount of growth in lakeshore areas where the upland is more developed. Current efforts are focusing on how periphyton growth has changed since the monitoring started. This includes determining how much is present at different locations around the lake and how long it persists. Generally, the heaviest growth occurs in the spring (March – May) and is associated with water flow into the lake as streams, groundwater, or

Take a Glimpse of Tahoe's Natural History

By John Cobourn, Water Resource Specialist, and
Heather Segale, Environmental Education Coordinator
University of Nevada Cooperative Extension

Date: April 4, 2003

Geologic time is hard to imagine, with vast stretches of time measured in millions of years. Lake Tahoe, on such a geologic time scale, is actually not very old. North America has been adding new blocks of crust to its western margin for hundreds of millions of years. Enormous blocks



of stone have pushed and collided, generating so much pressure and heat, that they caused a series of meltdowns of the solid rock, deep below the surface. About 70 million years ago, chambers of liquid magma rose slowly toward the surface like gigantic underground hot air balloons. Most cooled and solidified, never reaching the surface. These formed the hard granite core of the future Sierra. Others erupted as volcanoes. For tens of millions of years, erosion and weathering wore away most of the old rock of the ancestral Sierra, and about 10 million years ago, the Sierra Nevada was a low range of granite hills, perhaps 2000 feet to 3000 feet high.

Then, the real period of mountain building began. Volcanoes began erupting, and huge blocks of crust began rising and falling to the beat of thousands of earthquakes. By about 5 million years ago, the Carson Range on today's east shore, and the Sierra Block on today's west shore had risen many thousands of feet in elevation. Another enormous block between these sank downward creating a trough thousands of feet deep. Volcanoes built high mountains across the north end of the trough, creating a natural dam. Mount Watson, Mount Pluto and Martis Peak the remnant cores of these volcanoes. Over time, waters filled the trough, and created Lake Tahoe. Yet, it would be many years before it looked like the lake we

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see today.

Over the next 3 million years, a series of ice ages created huge snowpacks, thousands of feet thick. Over time, these snowpacks grew into glaciers, and then melted, only to grow into giants once more. Slowly flowing rivers of ice ground their way from the Sierra crest to the lowlands, and some reached into the young Lake Tahoe. Emerald Bay is the footprint of such a glacier.

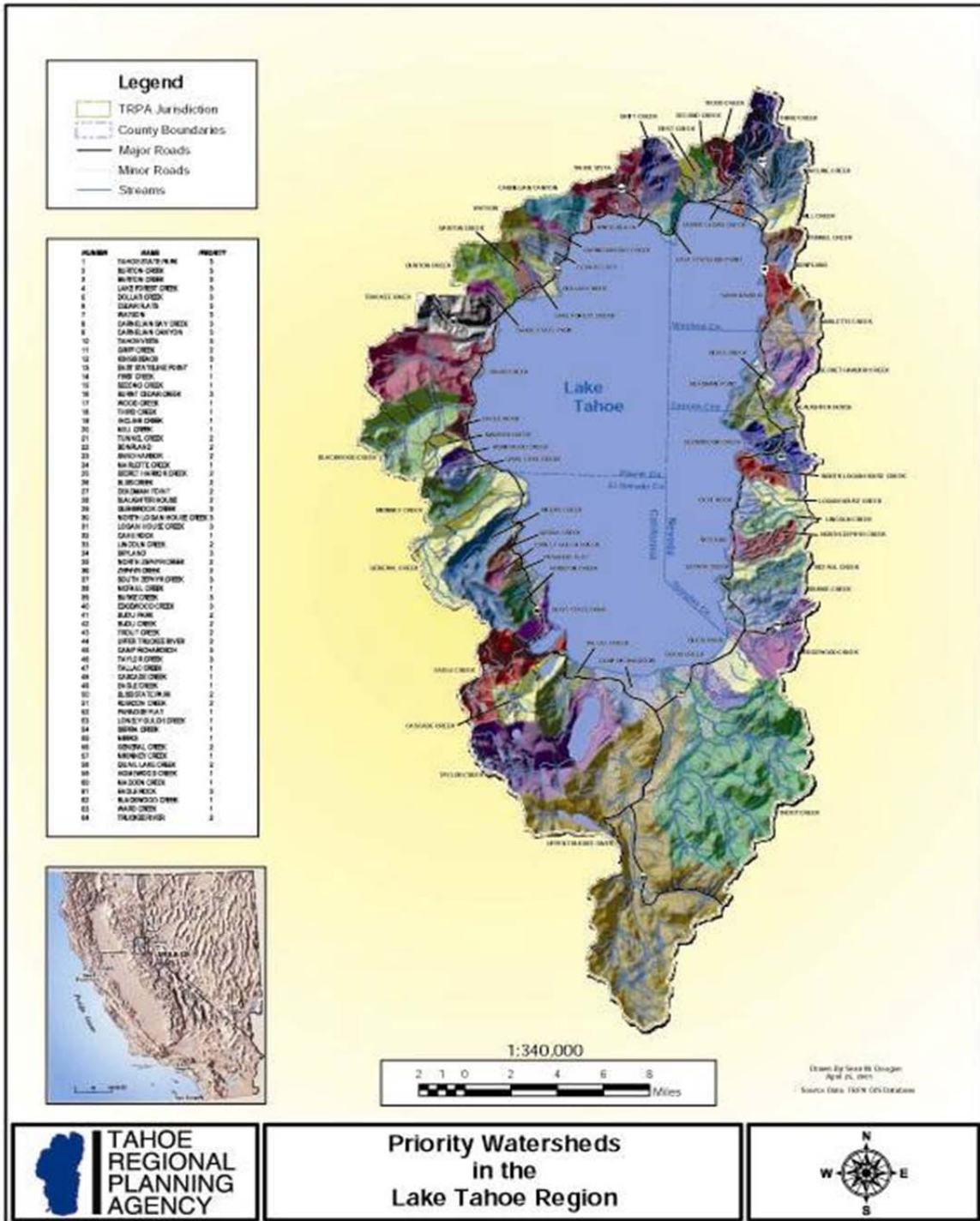
The summits and ridgelines of the Carson Range on Tahoe's east side received less snow than the Sierra Range to the west, just as they do now. They appear graceful and rounded in contrast to the shapes of Mount Tallac, Squaw Peak, and other west shore peaks, which were sculpted into their present shapes by the scour of millions of tons of moving ice. Twelve thousand years ago, the glaciers melted, leaving boulders called "erratics" scattered about the landscape. The rocky, gravelly debris left with the boulders began to be weathered into soil, and pioneering species of plants, microbes and animals began to claim the rock piles. In some places, topsoil took thousands of years to develop sufficient depth to nourish the great forests that would later grow in the basin.

When John Fremont, the first European-American credited as having seen Lake Tahoe, passed

through in 1844, he was looking at an ecosystem that had been developing and changing continually since the glaciers melted. The soils were deep, and all the plants were well-adapted to the conditions of their niches. Natural disturbances from avalanches and earthquakes were rare enough and healed quickly. Fremont saw a forest system largely shaped over millennia by repeated low-intensity fires, sparked by lightening and Native Americans. These regular fires often cleaned out the forest floor without killing the mature trees, in fact contributing to forest health. The natural and undisturbed watersheds, many thousands of years old, prevented large quantities of nutrients or sediments from being carried into the lake itself.

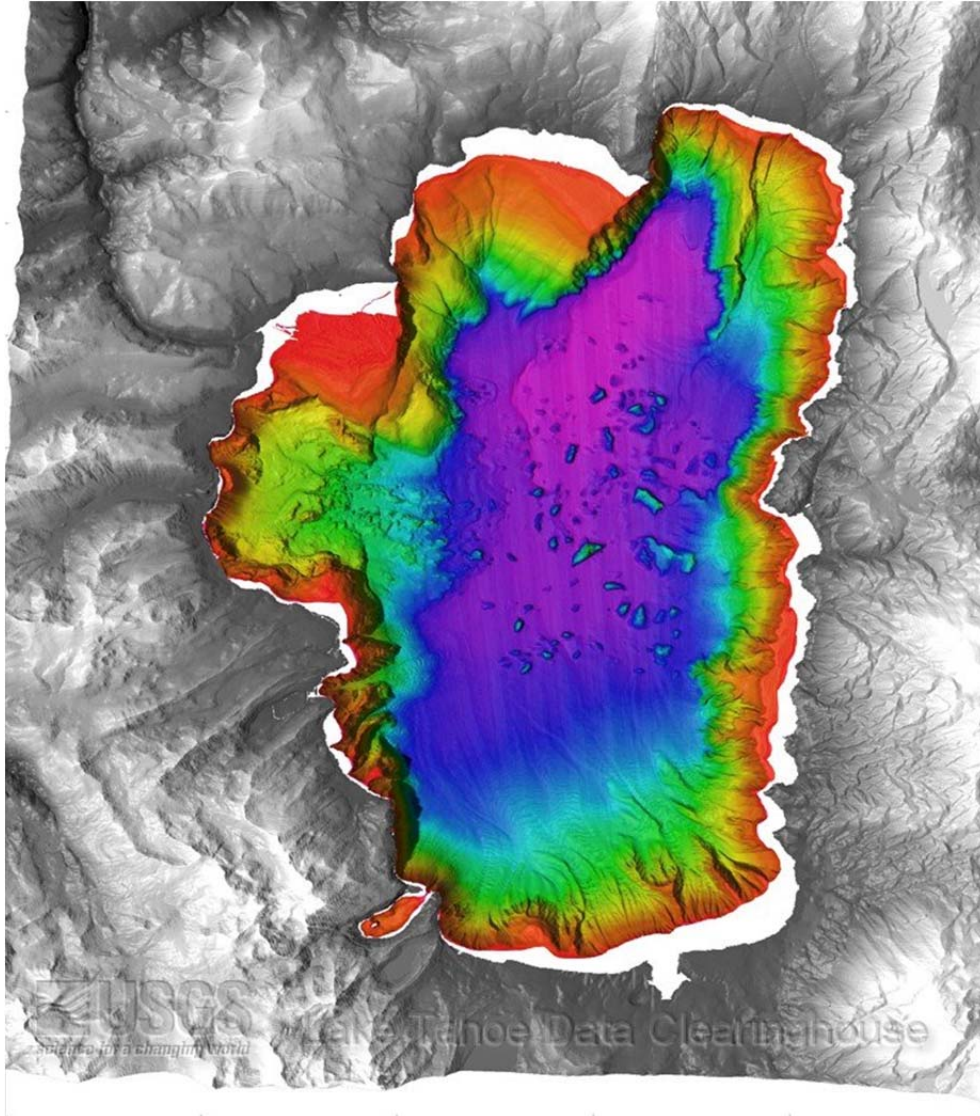
Over millions of years, nature has created an extraordinary place, the Tahoe Basin, and set the conditions for its famously clear waters. Erosion and disturbance have always been a part of the forces that have shaped the Tahoe Basin. In the past, change was slower; nature and time allowed the lake to recover from such disturbances. However, human changes to the Tahoe ecosystem are not measured in geologic time. Since settlement and development began in the mid 19th century, we have become the single most important force that can either break or restore the ecosystem and determine the fate of the lake.

Map of Watersheds in the Lake Tahoe Basin



The Lake Tahoe watershed is composed of 63 subwatersheds, each resulting in a stream carrying water into the lake. The Truckee River watershed is the only outflow and carries water away from Lake Tahoe and into Pyramid Lake.

Lake Tahoe Bathymetry (Depth)



United States Geological Survey

A bathymetric survey of Lake Tahoe was conducted on August 1998 using the latest-generation multibeam system. The multibeam mapping system records both the bathymetric data (depth information) and the backscatter data (the strength of sound energy that bounces back). This information can help scientists identify the materials that make up the lake floor, such as rock, sand, or mud. New data can shed light on the history hidden by the waters of Lake Tahoe.

For more information visit <http://tahoe.usgs.gov/bath.html>

Lake Tahoe Geologic Map



Geologic Map of the Lake Tahoe Basin, California and Nevada
California Geological Survey (CGS)

http://www.conservation.ca.gov/cgs/rghm/rgm/preliminary_geologic_maps.htm