There is a limit on the amount of fish you consume from the San Francisco Bay. Why? The fish are contaminated with Mercury, a neurotoxin that accumulates in your body, and at high doses could cause death. The Environmental Protection Agency (EPA) recommends that the daily intake of mercury be limited to 15 ppb (parts per billion). The consumption of a typical 6.5 ounce can of tuna contains 250 ppb of methylmercury, which exceeds the recommended intake by a factor of 16. Methylmercury is the most dangerous form and people are exposed to it almost entirely by consuming specific types of food. The population at highest risk of Methylmercury contamination is those who eat a large amount of fish that contain a significant amount of mercury such as tuna, swordfish, shark, and Orange roughy.

### Mercury Methylation and Biomagnification

Mercury occurs in several different geochemical forms, including elemental mercury (Hg(0)), ionic (or oxidized) mercury (Hg(II)), and a suite of organic forms, the most important of which is methylmercury (CH₃Hg⁺). Methylmercury is the form most readily incorporated into biological tissues and most toxic to humans. The transformation from elemental mercury to methylmercury is a complex biogeochemical process that requires at least two steps, as shown in figure 9: (1) Oxidation of Hg(0) to Hg(II), followed by (2) Transformation from Hg(II) to CH₃Hg⁺; step “2” is referred to as methylation. Mercury methylation is controlled by sulfate-reducing bacteria and other microbes that tend to thrive in conditions of low dissolved oxygen, such as the sediment-water interface or in algal mats. Numerous environmental factors influence the rates of mercury methylation and the reverse reaction known as demethylation. These factors include temperature, dissolved organic carbon, salinity, acidity (pH), oxidation-reduction conditions, and the form and concentration of sulfur in water and sediments.

The concentration of CH₃Hg⁺ generally increases by a factor of ten or less with each step up the food chain, a process known as biomagnification. Therefore, even though the concentrations of Hg(0), Hg(II), and CH₃Hg⁺ in water may be very low and deemed safe for human consumption as drinking water, CH₃Hg⁺ concentration levels in fish, especially predatory species such as bass and catfish, may reach levels that are considered potentially harmful to humans and fish-eating wildlife, such as bald eagles.

### Fish Consumption Advisories for Mercury

Methylmercury (CH₃Hg⁺) is a potent neurotoxin that impairs the nervous system. Fetuses and young children are more sensitive to methylmercury exposure than adults. Methylmercury can cause many types of problems in children, including brain and nervous system damage, retardation of development, mental impairment, seizures, abnormal muscle tone, and problems in coordination. Therefore, the consumption guidelines in areas where CH₃Hg⁺ is known to occur in fish at potentially harmful levels tend to be more restrictive for children as well as for pregnant women, nursing mothers, and women of childbearing age.

In the United States, as of 1999, there were a total of 2,506 fish and wildlife consumption advisories for all substances, of which 1,931 (more than 75 percent) were for mercury. Forty states have issued advisories for mercury, and ten states have statewide advisories for mercury in all freshwater lakes and (or) rivers.

In California, as of 1999, there were fish consumption advisories for mercury in 13 waterbodies, including the San Francisco Bay and Delta Region and several areas in the Coast Ranges affected by mercury mining (fig. 10; compare with fig. 4). Data on CH₃Hg⁺ levels in fish are presently insufficient for public agencies to determine whether advisories are warranted for lakes and rivers in areas affected by historic gold mining, such as the Sierra Nevada foothills.

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**Figure 10.** Locations of health advisories for mercury in sport fish consumption in California. Source: California Office of Environmental Health Hazard Assessment, 1999. Lake Pillsbury has interim advisory by Lake County; state advisory pending, as of May 2003.
How Mercury is deposited

The plate tectonic theory explains the various types of igneous activity (heating and cooling of rocks and minerals) in terms of the interactions of plates at boundaries where they separate and collide. Because igneous processes bring chemical elements and their mineral compounds from the interior of the Earth to the surface, the theory of plate tectonics provides a foundation for understanding the origin of ore deposits (ore is a rock that contains a desired mineral).

In 1979 Geologists exploring a spreading center along the seafloor discovered hot springs, laden with dissolved minerals, venting on the seafloor. The seawater is heated to temperatures of several hundred degrees Celsius when it comes into contact with magma or hot rocks deep in the crust. The heated seawater, which is also called a hydrothermal solution, leaches minerals from the hot rocks and rises to the seafloor. When the hot waters, now loaded with minerals, reach the cooler upper crust and near freezing Ocean bottom water, the minerals precipitate (come out of the solution). In this manner, enormous quantities of sulfide ores rich in zinc, copper, iron, and mercury are being deposited along mid-ocean spreading centers.

When current spreading centers were recognized as rich sources of mineral deposits, geologists began to look on land for the remains of ancient seafloor, which also might contain valuable minerals.

Where might there be remnants of ancient seafloor on land (hint: think about plate boundaries)?

One hypothesis proposes that some of the ore found at plate boundaries was deposited in 2 stages. The first stage is the creation of minerals ore by hydrothermal activity (described in the second paragraph). The second stage, which would occur a period of time later, is the subduction and partial melting at a collision zone of oceanic sediments and crust containing the previously concentrated minerals, such as mercury.

Use the diagram above depicting the geologic origin of mercury within the New Almaden region to help answer the following:

What is the name of the plate that use to subduct under the North American plate?

Subduction is no longer taking place in this region, what type of plate boundary currently exists along the coast of California?

What type of magma created the batholith that is near New Almaden?
What other evidence in the diagram represents that there is still magma underneath the crust?

After the slab fragment stopped subducting underneath the North American plate what appears to have happened to the slab?

The slab fragment acted like a blanket and once it broke heat from the interior of the Earth was able to rise and heat the lower crust above the fragment. How would this action result in the creation of mercury containing ore? (hint: the above reading of stages 1 and 2 should help you to successfully answer this question).

If volcanic belts contain the most mercury bearing rocks, what does this suggest about the type of geologic activity that is necessary to create mineral rich rocks?

Resources and Credits:

- How Mercury is Deposited:
  Press F., Siever R. Understanding Earth; Freeman and Company, 2001; 3rd edition

- Mercury Contamination Key Issues:
  Alpers, Charles N., Hunerlach, Michael P. "Mercury Contamination from Historic Gold Mining in California." USGS fact sheet FS-061-00; May 2000

- Geologic Origin of Hg:
  Slide image taken from PowerPoint titled "Mercury: Who, What, Why" by Gordon Brown, EMSI

Worksheet designed and created by Heather Johnson, EMSI participant 2008