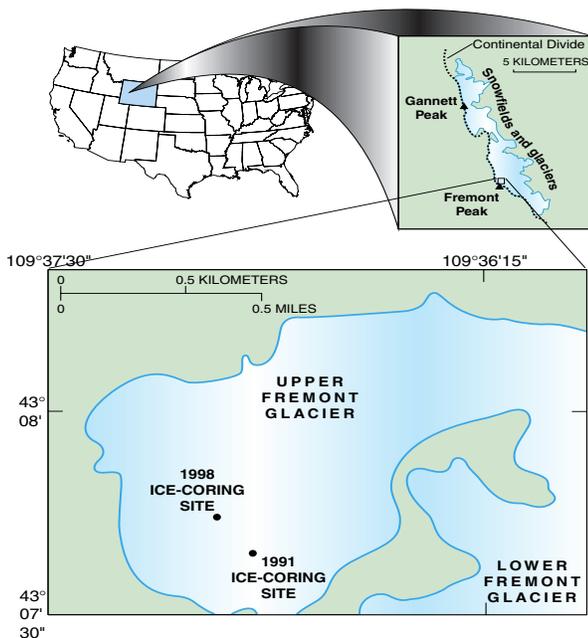


## Glacial Ice Cores Reveal A Record of Natural and Anthropogenic Atmospheric Mercury Deposition for the Last 270 Years

*An analysis of the historical patterns of atmospheric mercury deposition preserved in glacial ice cores from Wyoming indicates major atmospheric releases of natural and anthropogenic mercury from regional and global sources. During the past 270 years, volcanic events contributed 6 percent of total atmospheric mercury input and other natural background sources contributed 42 percent. The percent of total mercury inputs attributed to anthropogenic sources has increased from about 41 percent in the first 170 years (the majority of which was from the 19th century gold rush) to 70 percent during the last 100 years. Significant decreases in total mercury observed in the last 15-20 years of the ice-core record indicate reductions in emissions that correspond to the time period when the Clean Air Act and other emission reduction strategies became prominent.*

**Background:** Mercury is responsible for over three quarters of all contaminant-related advisories for threats to human health. Between 1993 and 1999, the number of mercury-related fish-consumption advisories more than doubled. Today 42 states have advisories. Atmospheric transport and subsequent bioaccumulation of mercury (as methylmercury) can affect aquatic ecosystems in remote areas far from mercury sources. While scientists agree that mercury has many natural and anthropogenic sources, there is no scientific consensus on the amount each source contributes to environmental contamination on local, regional, and global scales. Regardless of the source, previous studies have shown that atmospheric transport is the primary pathway by which mercury is deposited in the environment on regional and global scales.

To gain a better understanding of the long-term history of mercury input and the relative contributions of different sources, U.S. Geological Survey (USGS) scientists analyzed the historical patterns of atmospheric mercury deposition preserved in ice-core samples. Ice cores are valuable tools for reconstructing paleoclimatic and paleoenvironmental records, but cores have not been commonly retrieved from the low and mid-latitude regions of the Earth. The ice cores analyzed in this study were collected from the Upper Fremont Glacier (UFG) in the Wind River mountain range of Wyoming. As a result, the USGS effort to identify the record of atmospheric mercury deposition preserved in these cores is the first of its kind in North America. Atmospheric mercury concentrations in these cores are not likely influenced by local anthropogenic sources. Total mercury in the 97 ice-core samples was determined using trace-metal clean handling methods and low-level analytical procedures.

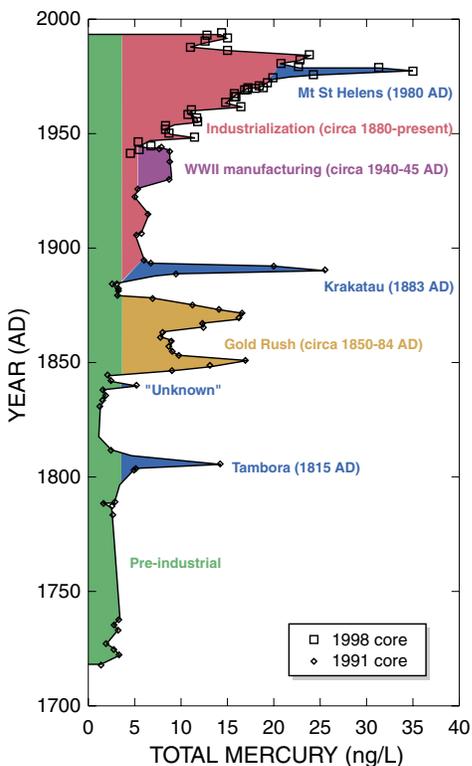


**U.S. Geological Survey scientists collected 97 ice samples from two ice cores, each over 160 m long. The cores were collected in 1991 and 1998 from the Upper Fremont Glacier in the Wind River mountain range of Wyoming.**



**Total mercury in 97 ice-core samples was determined with trace-metal clean handling methods and low-level analytical procedures.**

**Findings:** The oldest ice recovered from the UFG cores (circa 1700) dates back well before industrialization. Observed mercury concentrations in the oldest samples are similar to those previously documented in ice cores from Antarctica and Greenland. When unaffected by volcanic activity, ice from pre-1850 typically had mercury concentrations in the range of 1 to 4 nanograms per liter (ng/L). Concentrations of mercury preserved in the UFG ice during post-industrial times were much higher than previously documented for the same time period. A maximum concentration of about 20 ng/L was observed in ice samples dating from the 1980's, which was much as 20 times higher than the lowest pre-industrial concentrations. The percent of total mercury inputs attributed to anthropogenic sources has increased from about 41 percent in the first 170 years to 70 percent during the last 100 years; since the industrial maximum (circa 1984), however, mercury concentrations in the UFG ice cores have declined significantly. This recent decrease in atmospheric mercury deposition corroborates previous studies where sediment cores have been used to reconstruct mercury deposition over time.



**Atmospheric mercury deposition corresponds to volcanic and anthropogenic events over the past 270 years. Preindustrial deposition rates can be conservatively extrapolated to present time (4 ng/L; in green) to illustrate the increase during the past 100 years (in red) and significant decreases in the past 15-20 years.**

**Significant events:** The two largest volcanic eruptions in recorded history, Krakatau (1883) and Tambora (1815) account for approximately 6 percent of total mercury deposition. During the gold rush, mercury was used on a large scale to recover gold from mining operations throughout the western United States. The mining operations, which were the most significant anthropogenic source of mercury in the first 170 years of record, peaked around 1860 and then again around 1877. In the twentieth century, increases in mercury input correspond to increases in industrialization. It is important to note, however, that the increase in mercury input during the last 100 years of record is followed by a rapid decrease within the last 15-20 years.

**Significance of findings:** This study, which represents the first effort to estimate rates of atmospheric mercury deposition using ice cores from mid-latitude regions, enabled scientists to clearly discern differences in natural and anthropogenic mercury sources over time. Scientists found that the amount of mercury deposited on the North American continent from atmospheric sources increased significantly during industrialization. In addition, analysis of ice cores indicated a dramatic decrease in atmospheric mercury deposition during the last 15-20 years, reflecting perhaps potential effects of the Clean Air Act and other management practices to reduce emissions. Information of this kind is necessary for establishing baseline levels of mercury in the environment, thereby providing crucial information for scientifically defensible resource-management, policy, and regulatory decisions being made now and in the future.

**Future directions of mercury investigations:** Establishing baselines and inferring changes to mercury emission rates to the atmosphere is only one area of future investigation. USGS scientists are currently working to acquire data sets that will be used to develop regional-to-national scale information on mercury contamination levels in the environment and the factors that control mercury bioaccumulation in food webs. Studies such as this are going on across the country, from the Yukon in Alaska to the Everglades of Florida. Equally important, scientists are developing studies to better understand how ecosystems respond to changing levels of mercury loading, especially in terms of changes to bioaccumulation levels. Currently, USGS scientists are participating in two studies to evaluate the occurrence, fate, and transport characteristics of mercury in the environment including the "old" mercury resulting from emissions over the past 100 years, as well as "new" mercury from current emissions. One of these projects is a large, internationally conducted effort known as **METAALICUS (Mercury Experiment To Assess Atmospheric Loading In Canada and the United States)**, which will assess the effects of intentional applications of experimental doses of mercury to an entire watershed in western Ontario, Canada.

Several USGS programs, including the Toxic Substances Hydrology (TOXICS) Program, National Water Quality Assessment (NAWQA) Program, Placed-Base Studies and the National Research Programs, continue to collaborate on investigations that yield information to assist resource managers on the most effective steps toward minimizing the mercury contamination problem.

**Additional information:** These findings are based on "Atmospheric mercury deposition during the last 270 years: A glacial ice core record of natural and anthropogenic sources", an article published in the June 1, 2002, issue of Environmental Science & Technology, v. 36, no. 11, pages 2302-2310. This and other reports, data, and maps can be accessed on the Internet at <http://toxics.usgs.gov/>.

David Krabbenhoft and Paul Schuster

**Contact for additional information:**

**USGS Toxic Substances Hydrology Program  
412 National Center, 12201 Sunrise Valley Dr  
Reston, VA 20192**

**(703) 648-6862**