Using Tree Ring Cores to Map the History of Environmental Pollution – New Jersey Zinc Company Palmerton Smelters

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The Sterling Hill and Franklin Furnace zinc mines are located in northern New Jersey, USA

Mining began in northern New Jersey in the early 1700's.

The various small mines were combined into a single entity, New Jersey Zinc Company, in 1897. Mining ceased at Franklin Furnace in 1954 and at Sterling Hill in 1986.

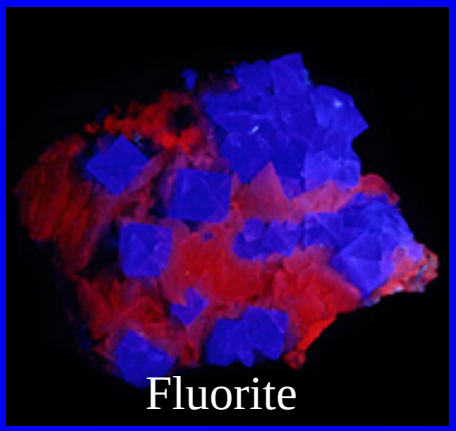
The ore deposits are found in Precambrian marble and are inferred to have originated by high pressure and temperature metamorphism.

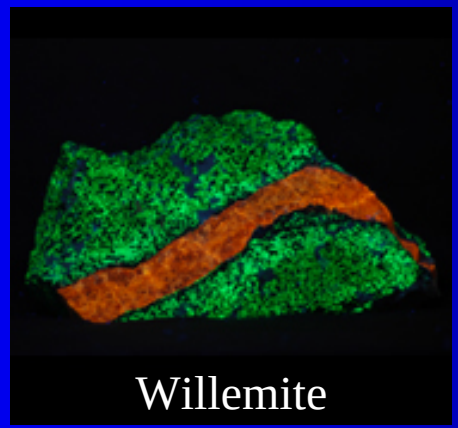
Sterling Hill Mine

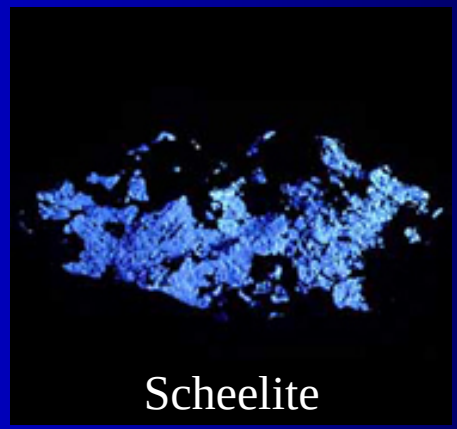
The Sterling Hill and Franklin Furnace Mines are known to mineral collectors the world over.

345 minerals, for 35 of which this is the only known locality, have been identified in the ore deposits.

90 of the minerals fluoresce, the largest number of fluorescent minerals found in any one location.


Fluorite


Willemite


Scheelite

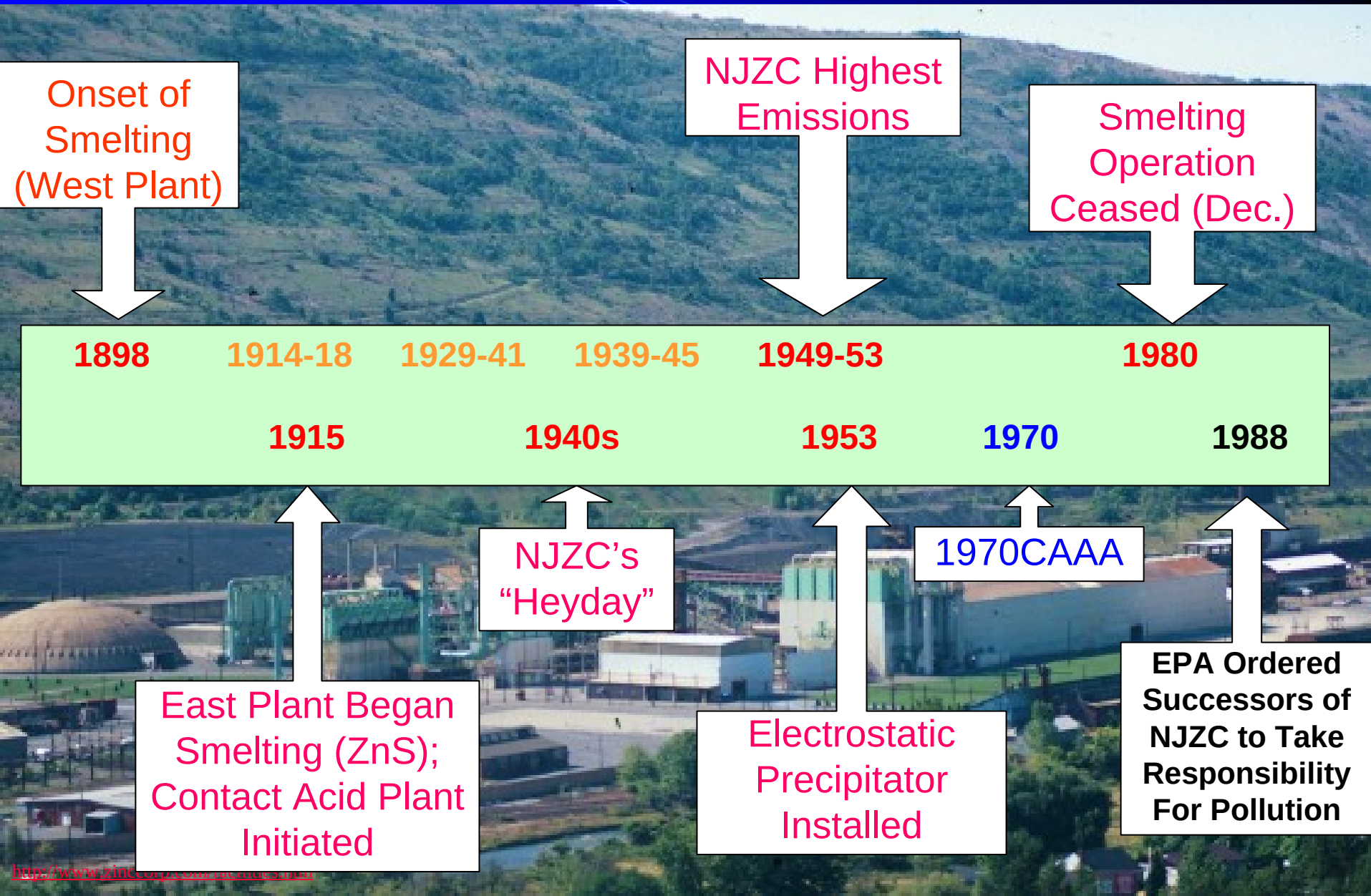

Sphalerite

In 1898 New Jersey Zinc Company built a smelter in Palmerton (named after president Palmer of New Jersey Zinc Company), PA

This location was picked because of the availability of anthracite coal.

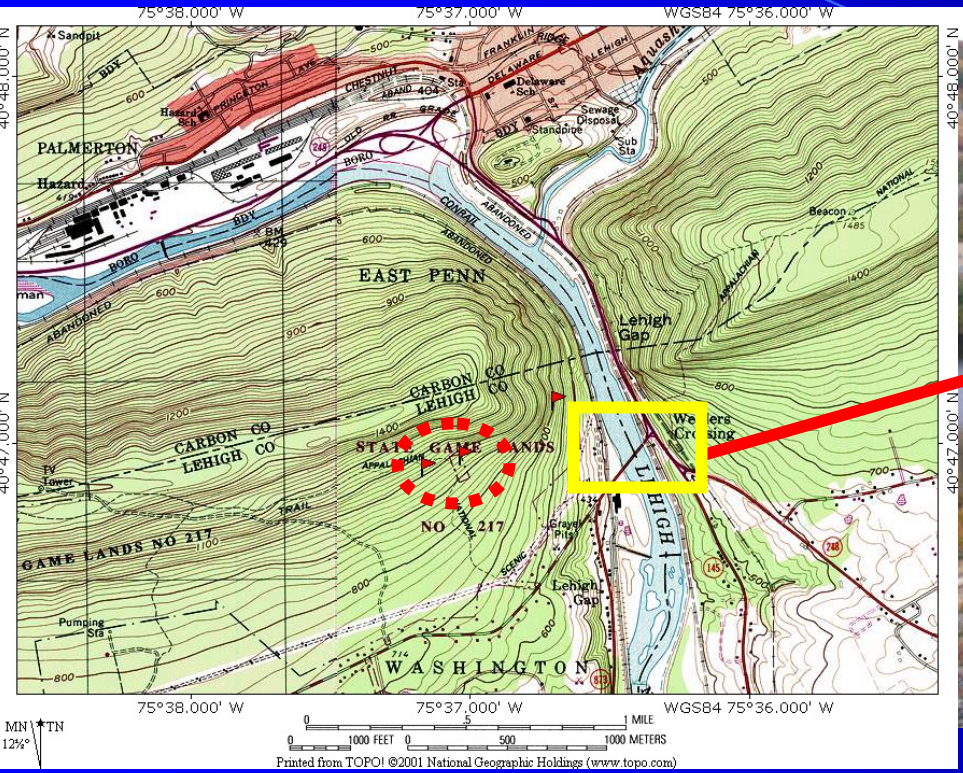
A second smelter was built in 1915. Operations ceased in 1980.

Smelter Operations at Palmerton, PA



http://www.zinc.org/palmerton/index.shtml

Study Area: *Palmerton, PA (Lehigh Gap)*



Sampling: Kittatinny Ridge; adjacent to West Plant

West Plant → Northern bank of Lehigh River

East Plant → Southern bank of Aquashicola Creek

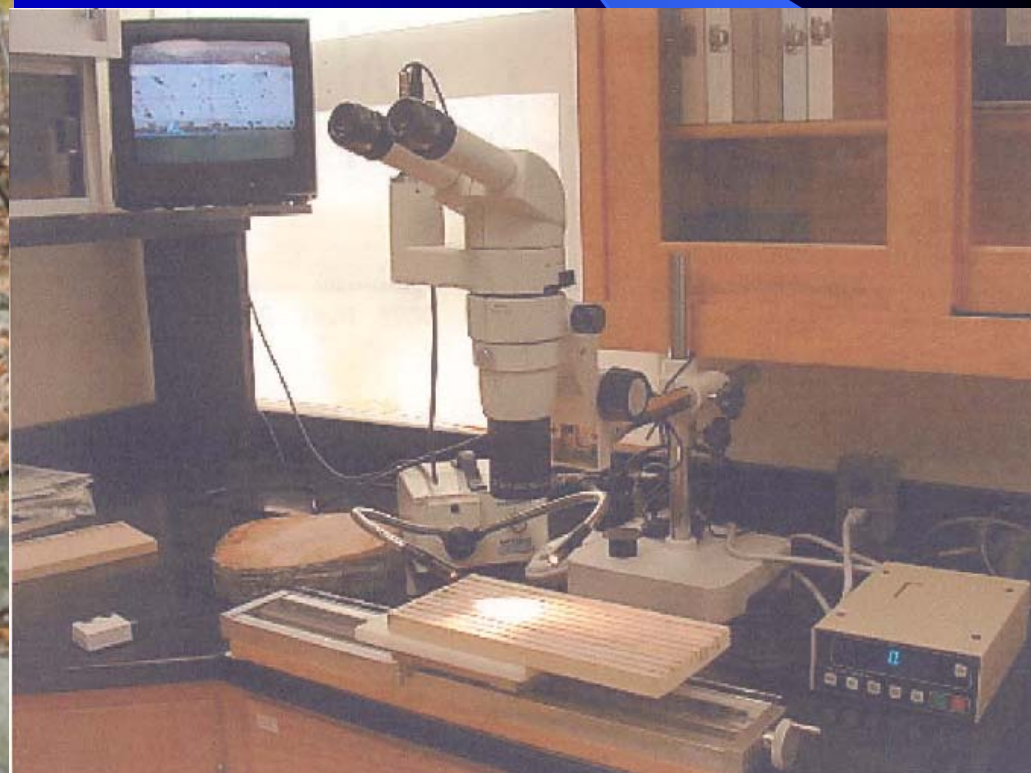
Surrounding Landscape → Severely damaged (multiple causes)

Tree Coring and Ring Width Measurements

→ **Increment borers**

- ***17 Red Oak trees***
- ***8 Chestnut Oak trees***

2 cores/tree



Metals released during smelter operation can be delivered to trees by

1. Direct deposition on leaves.

2. Through the soil-root interface.

Trace Elements in tree ring core samples were analyses by INAA

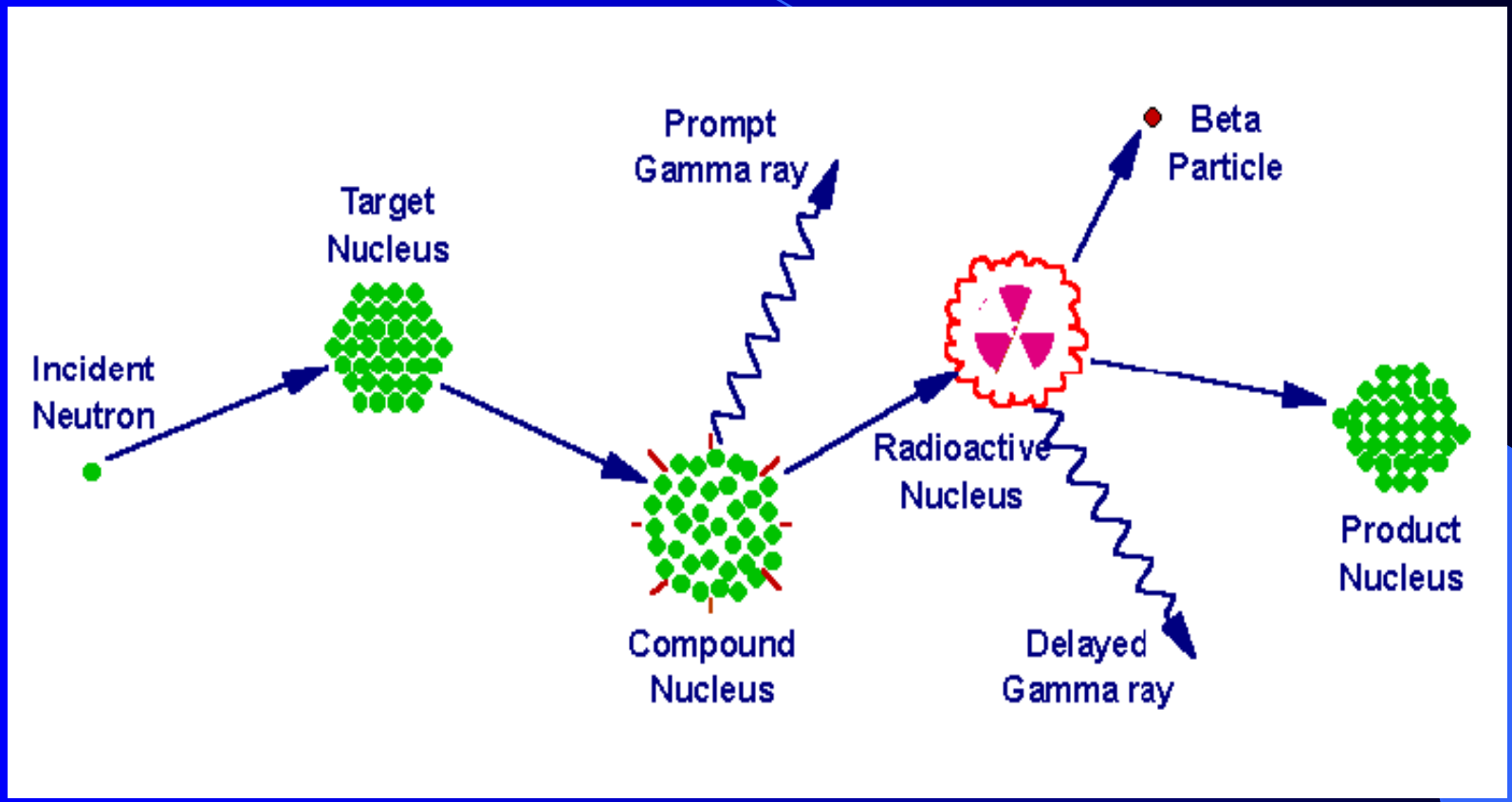
(**I**nstrumental **N**eutron **A**ctivation **A**nalysis)

10 selected subsamples

5-yr incrementally pooled samples from a *Chestnut Oak were analyzed by INAA.*

The n–gamma Reaction

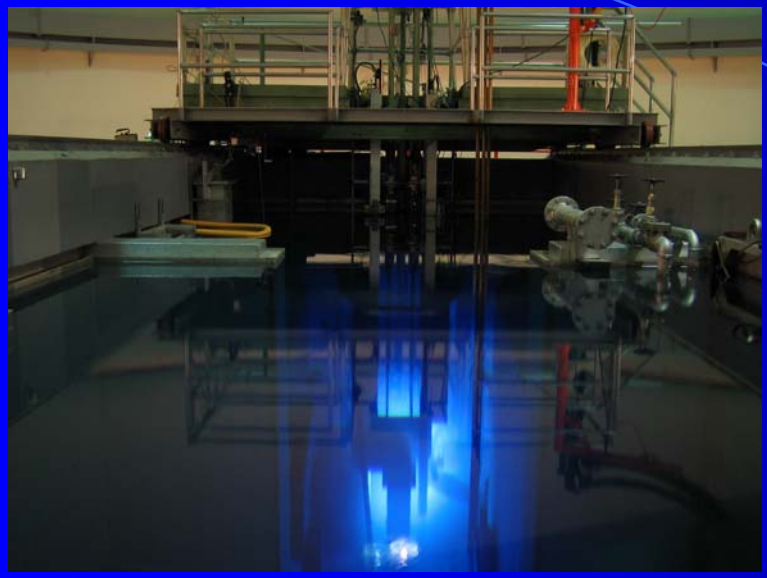
The basic reaction for INAA

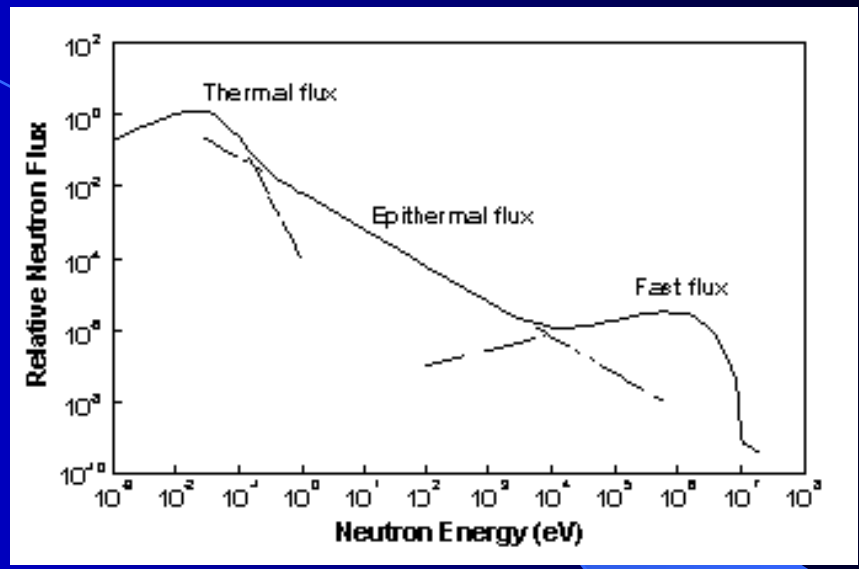


Example: $^{58}Fe + {}^{1}n \longrightarrow {}^{59}Fe + Beta^{-} + gamma\ rays$

Gamma ray energies = 142.4, 1099.2, 1291.6 KeV

Different neutron energies are used for different types of experiments.





UML 1 Mw Research Reactor

The Neutron Source

Sample detector spacing

Activated sample

Detector

Preamplifier

Amplify signal

Amplifier

Shape signal

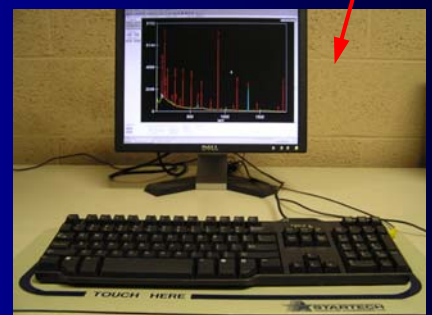
ADC

MCA

Output

ADC = Analog - Digital Converter

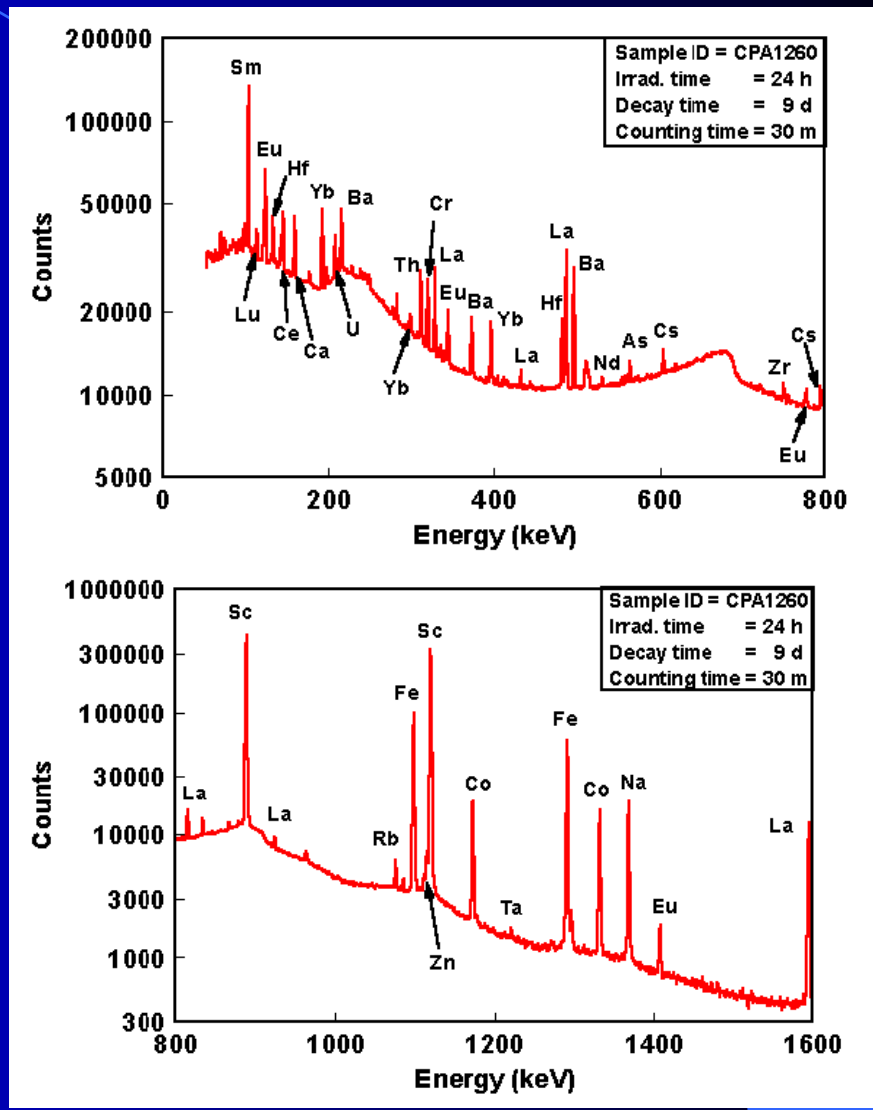
MCA = MultiChannel Analyzer



Data acquisition flow sheet

Gamma ray spectrum for a multi element sample

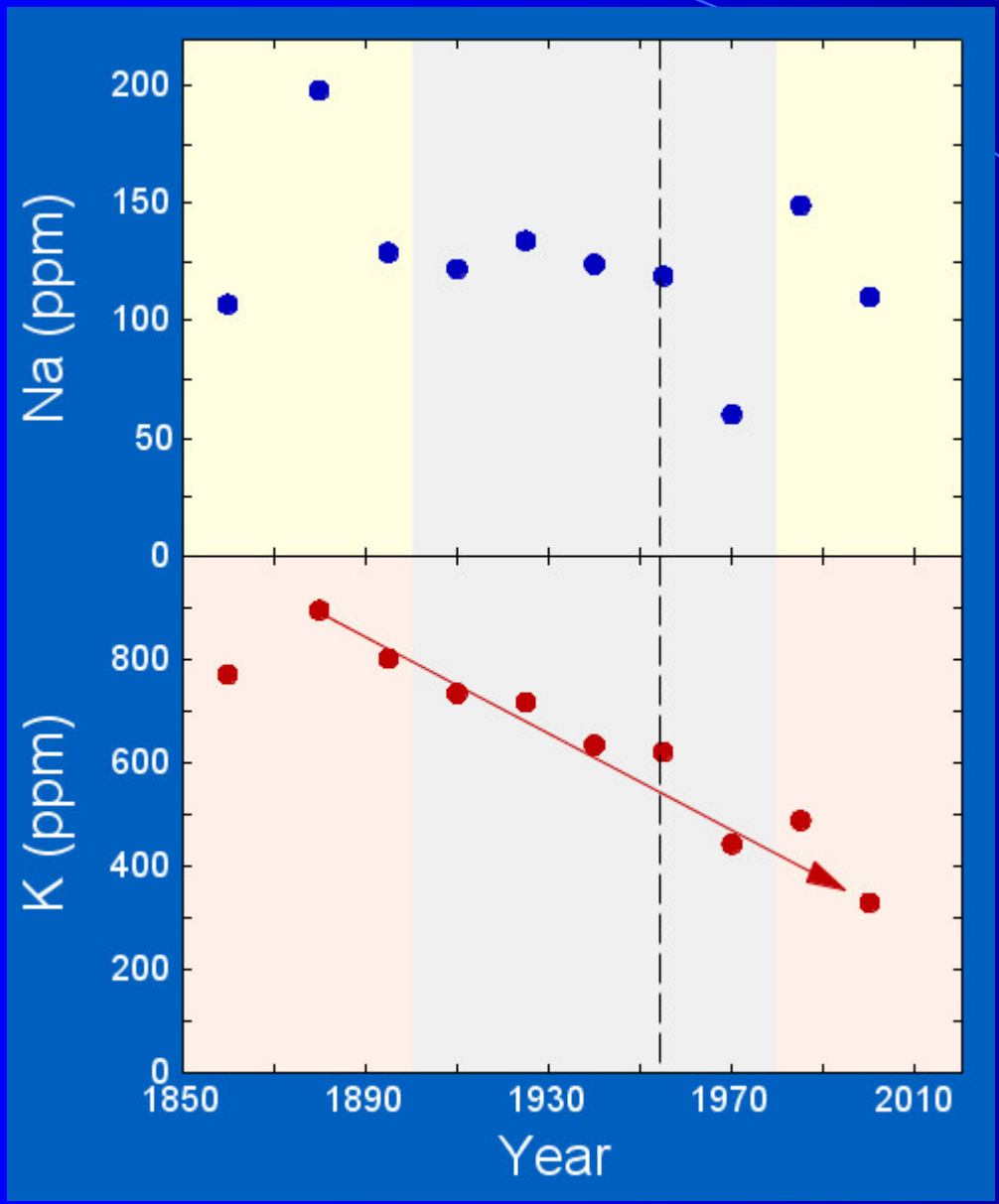
UML INAA Lab



Advantages of INAA

- Can analyze a large number of elements simultaneously
- Very low detection limits for many elements
- Small sample sizes (1 – 200 mg)
- No chemical preparation
- Nondestructive. The material is available for other analytical techniques
- Relatively low entry cost (~$60,000) compared to other high sensitivity analytical methods

Na and K versus Time

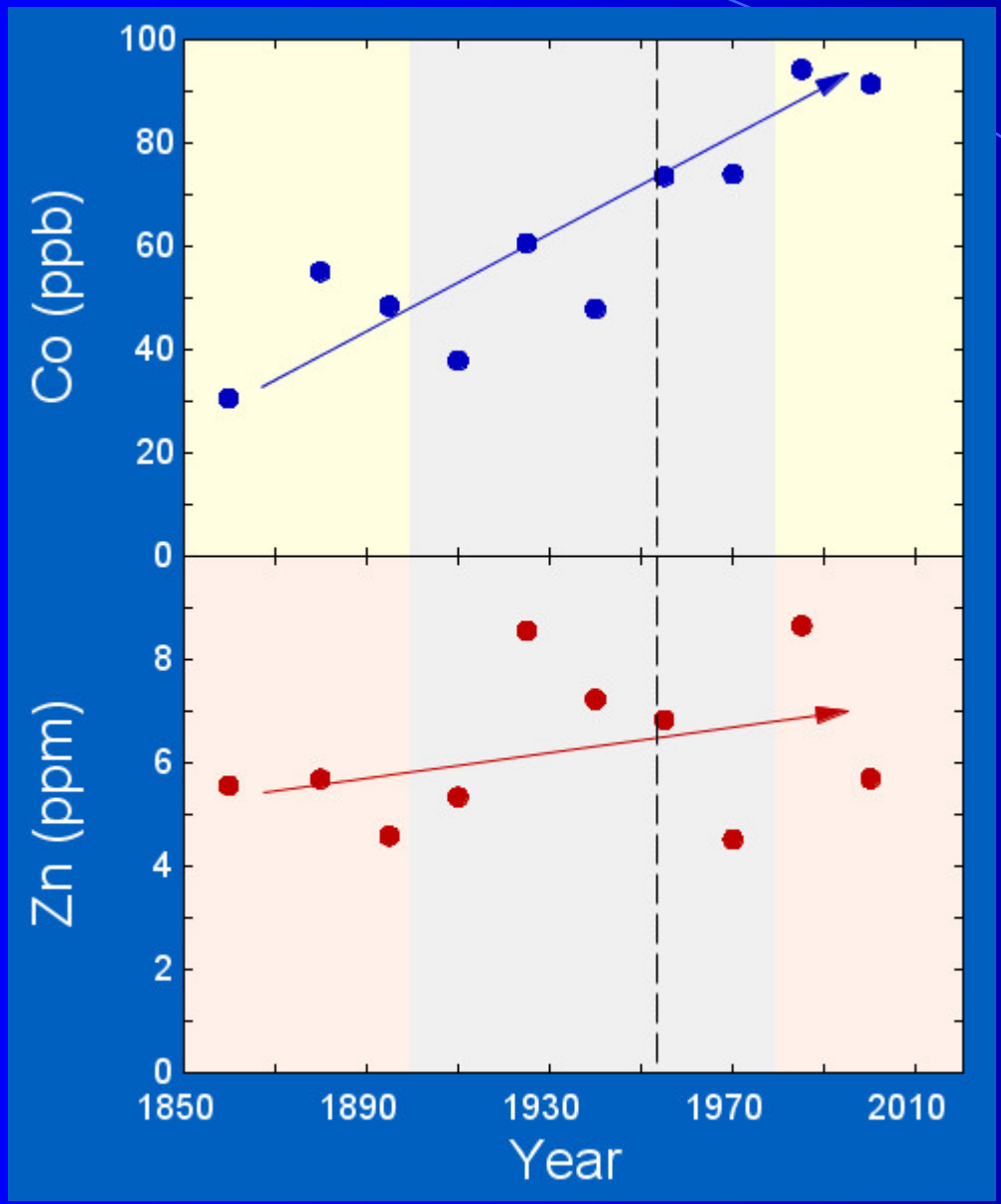


Area shaded gray represents the time during which the smelters were active.

Dashed line denotes the year in which precipitators were installed and the Franklin mine closed. Franklin Furnace ores were no longer smelted in Palmerton

Na shows no trend, but during the time smelting was done at Palmerton **K** declined. This decline continued after smelting ceased. **K** is a nutrient element and the data suggest that this element was depleted with time. Such a depletion would lead to stress on the tree. Stable isotope and tree ring widths also indicate that the tree was under stress during the time of smelter operation.

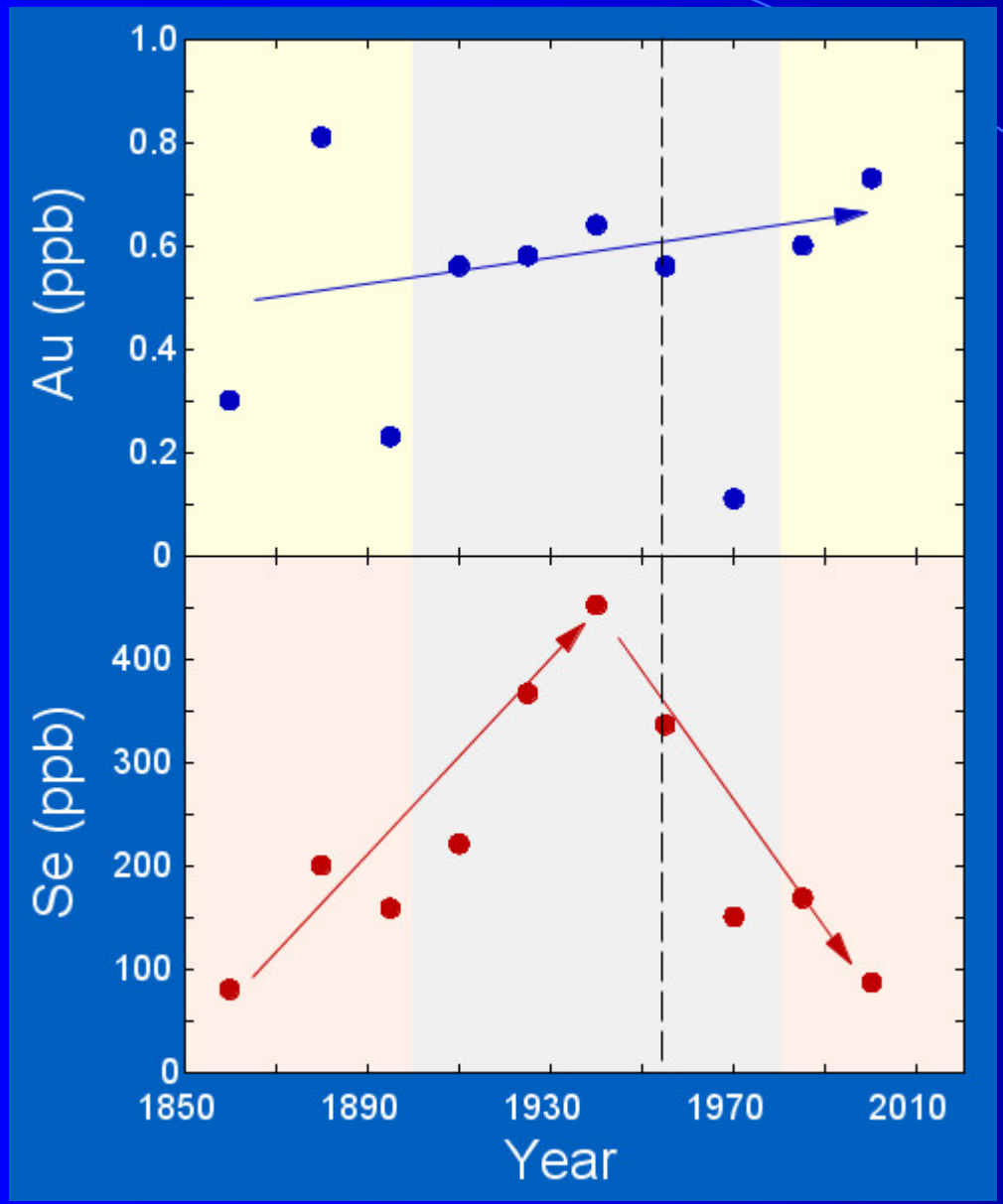
Co and Zn versus Time



Co increases throughout the time of smelter operation and the increase continues after cessation of smelting.

Zn, which was the major metal emission, shows an irregular pattern but general increase with time. The most recent tree ring increment indicates that **Zn** uptake is decreasing.

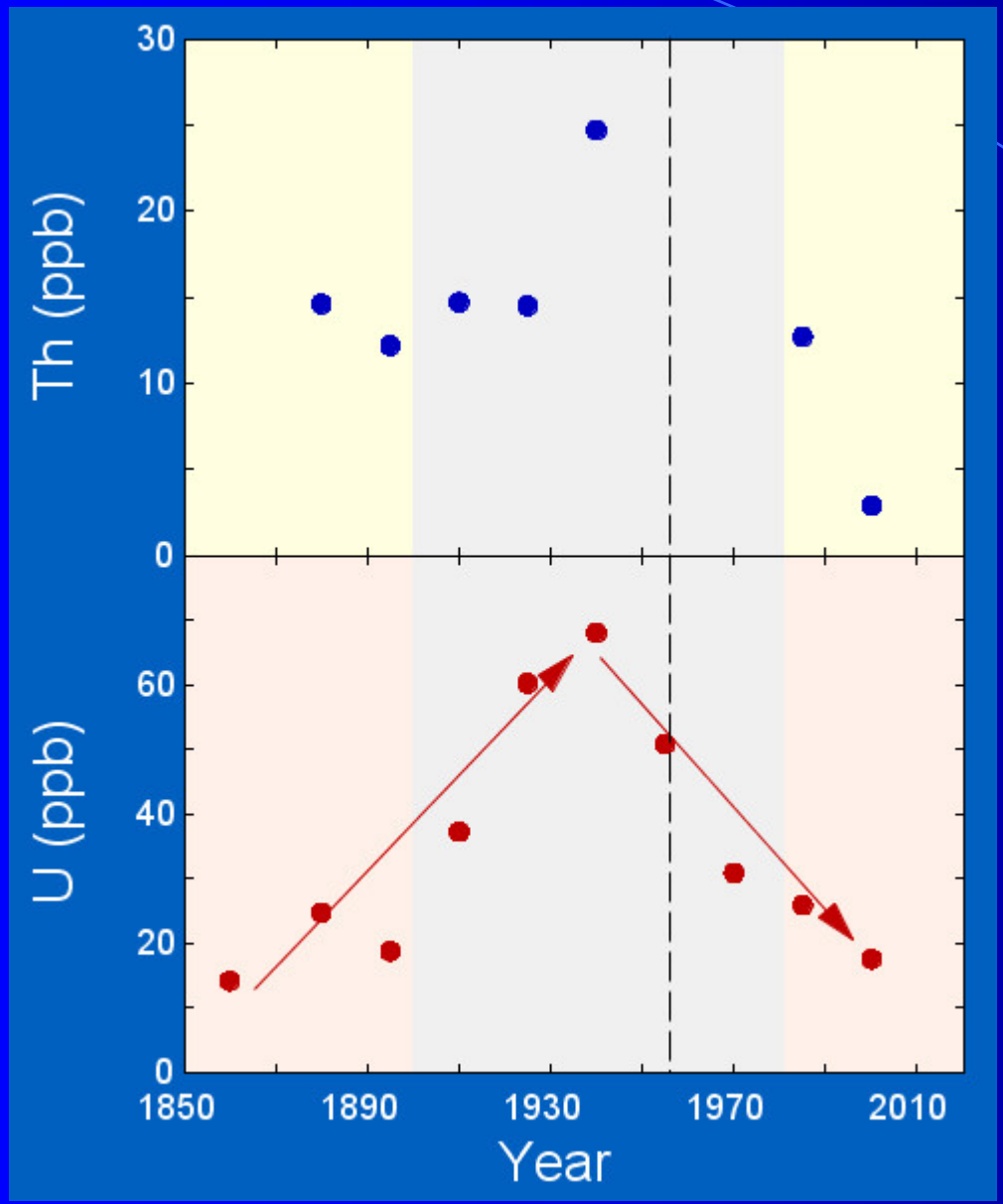
Au and Se versus Time



Au generally increases during the period of smelter operation.

Se, as do a number of other metals (subsequent slides) initially shows an increase and then a decrease. The change in behavior roughly corresponds to the time when (1) precipitators were installed and (2) ores from Franklin Furnace were no longer smelted at Palmerton. After cessation of smelter operation **Se** returns to pre-smelter levels.

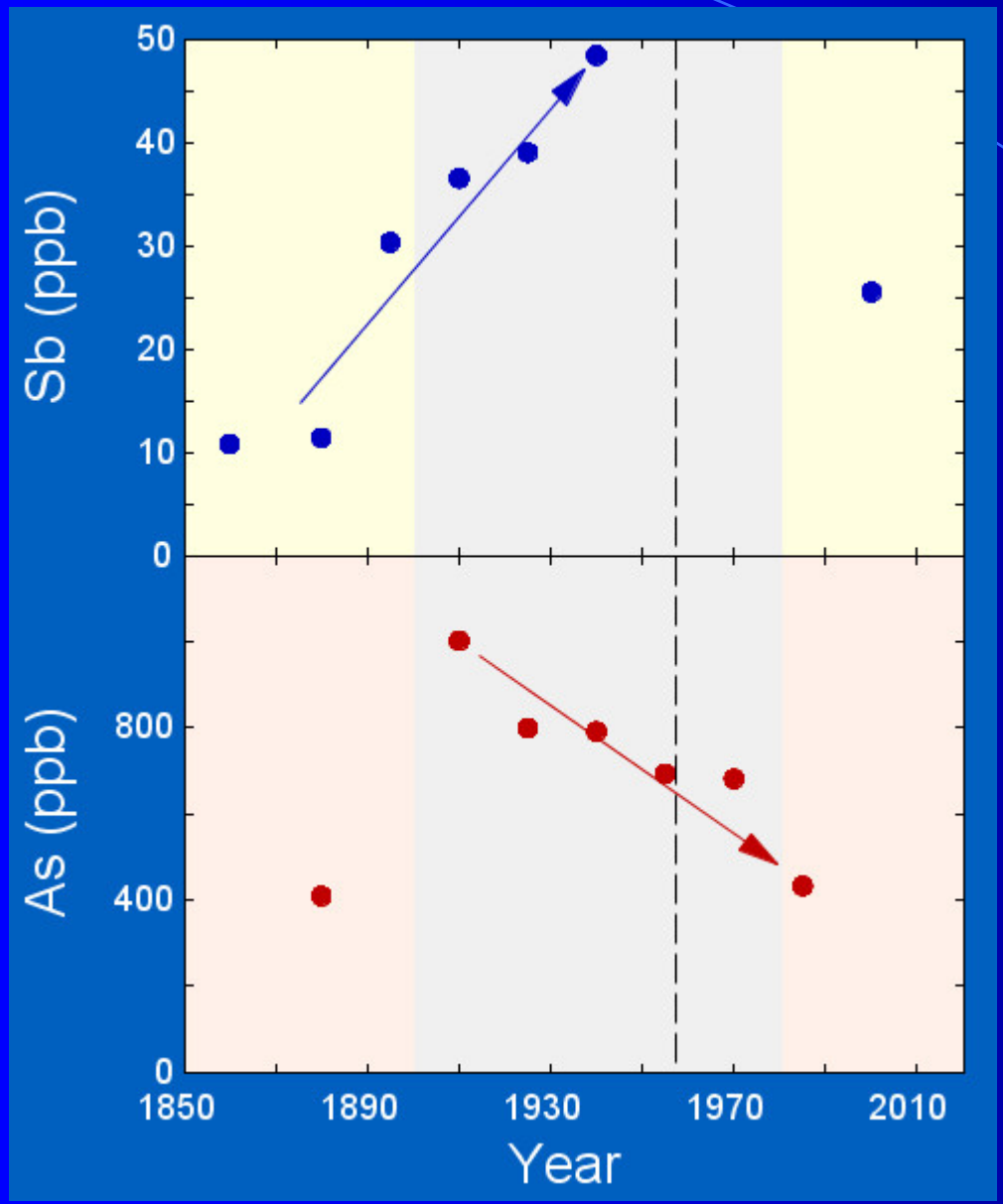
Th and U versus Time



Th variations with time are erratic.

U initially shows an increase and then a decrease. A similar pattern to that shown by **Se**. After cessation of smelter operation, **U** returns to pre-smelter levels.

Sb and As versus Time



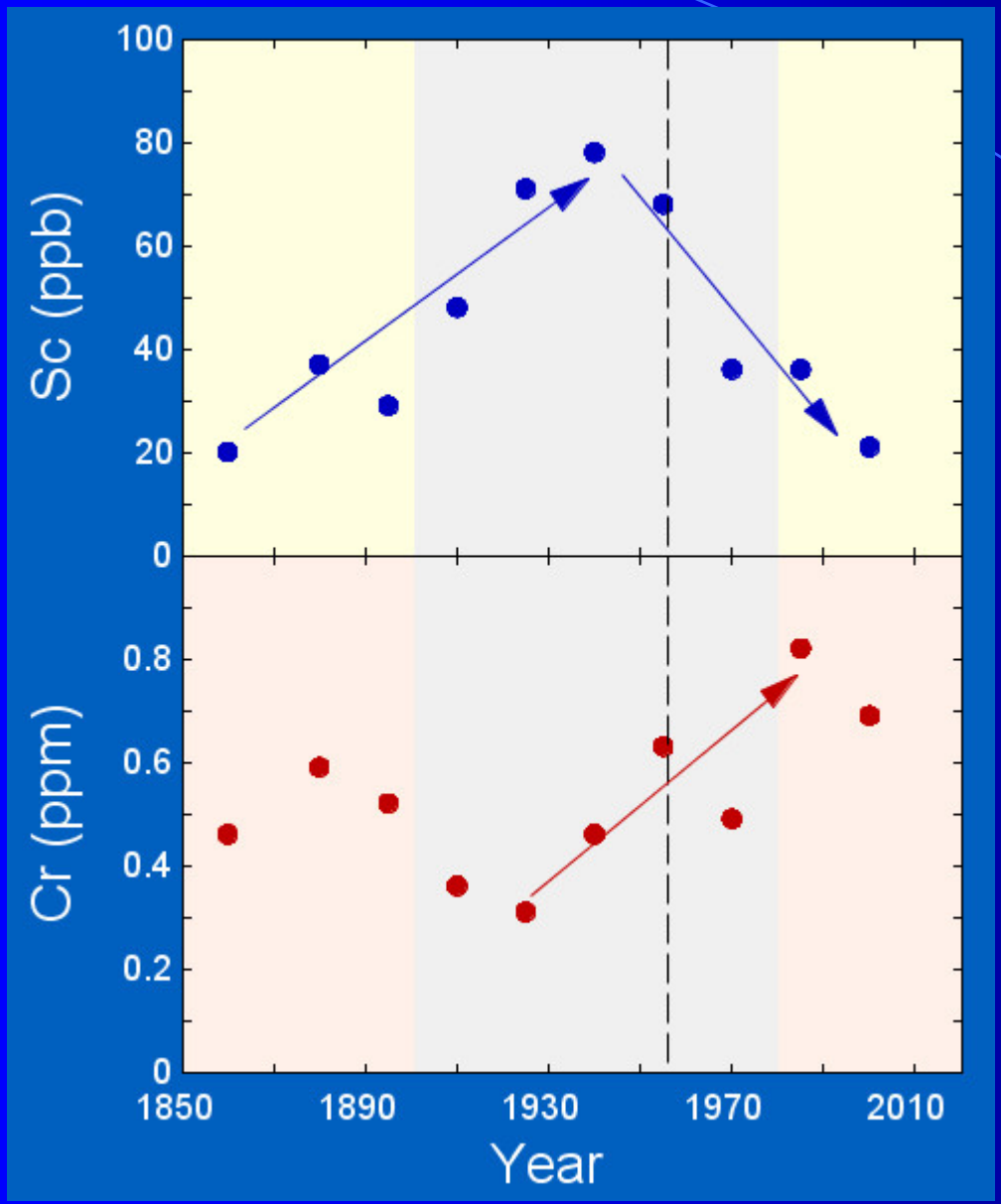
Sb and **As** show antithetical behavior with time.

Sb gradually increases over the time of smelter operation, although we do not have data for the later time periods.

As shows a sharp increase at the start of smelter operation and then decreases with time. This may reflect rapid removal of **As** from the soil.

After cessation of smelter operation, both elements return to near pre-smelter levels.

Sc and Cr versus Time



Sc initially increases and then decreases to pre-smelter operation concentrations.

Cr initially shows irregular variation with time and then increases towards the present.

Summary

- Variations in trace metal concentrations in tree rings reflect anthropogenic inputs. These variations can be complex.
- Decrease in K during the entire time of smelter operation most likely represents leaching of K from the soil. Large amounts of sulfur dioxide were emitted during smelter operation which led to local acid rain.
- Se, U, and Sc show a complex behavior initially increasing and then later in the tree ring record decreasing in abundance. This change in behavior roughly corresponds with the installation of precipitators and the cessation of smelting of Franklin Furnace ores. If these trace metals largely enter the tree by deposition on leaves the installation of the precipitators may account for the decrease in metal concentration.
- Co, Cr, and Zn generally increase throughout the period of smelter operation.
- In the 20+ years since the cessation of smelter operation, As, Sc, Se, U, and Zn have returned to pre-smelter concentrations. The other trace metals are still found at elevated levels in the tree rings.