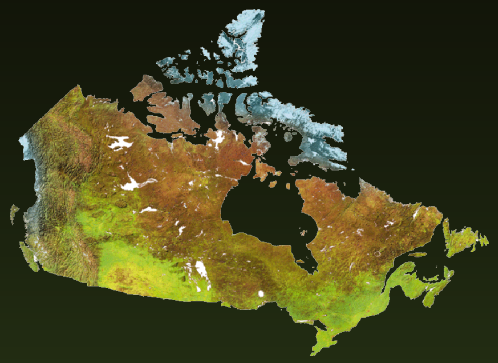
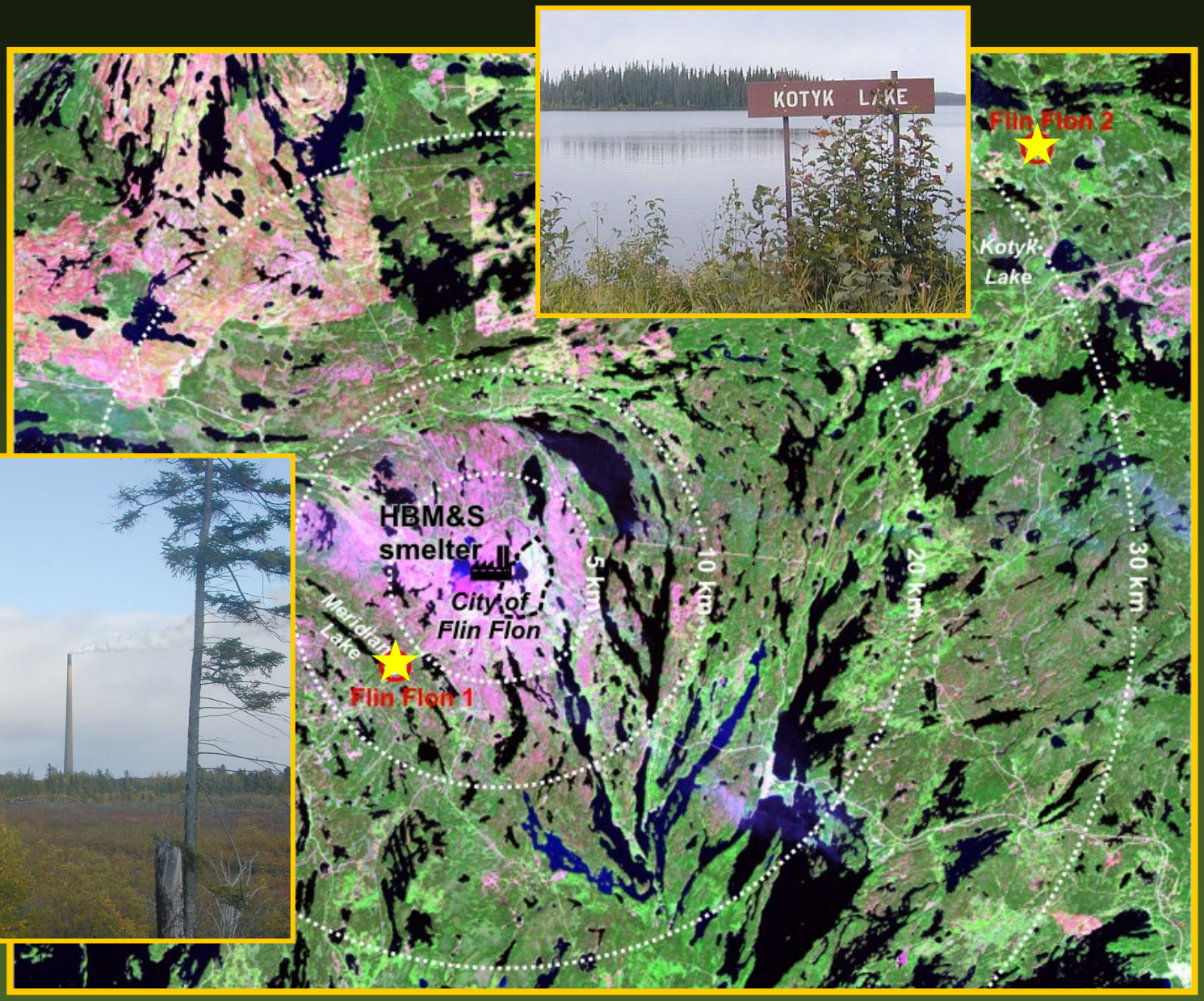


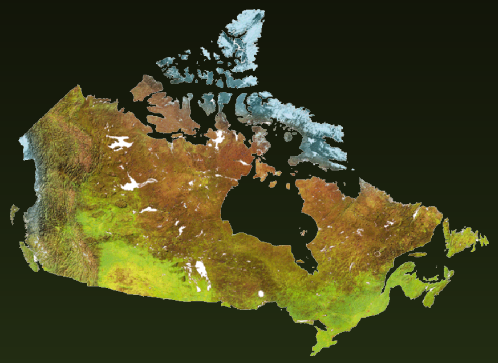
Dendrogeochemical investigation of metal dynamics around the Flin Flon smelter: time perspective and impacts on boreal forest

Objectives:

- Validate the dendrogeochemical approach as a high resolution monitoring tool for pollutant dynamics in the environment - Test the reliability of tree-ring series in preserving historical records of metal loadings
- Provide the historical perspective of environmental changes related to the Flin Flon smelter - Distinguish natural and anthropogenic accumulations of metals
- Investigate physiological processes related to metal accumulation in tree rings (e.g. translocation) - extraction protocols, element mobility, wood components, etc.
- Comparisons with other natural archives (e.g. lake sediments, peat deposits)
- Evaluate the impacts of smelter emissions on boreal forest health (critical metal load, etc.). In collaboration with CFS

Tree-ring activity – Sampling sites





Tree ring activity - Sampling sites

Flin Flon –1 Meridian Lake

Location: **54°44'14"N 101°57'21"W**

Altitude: **335 m**

Distance from smelter: **7 km**

Slope: **facing SSW, 5-6°**

Drainage: **good / moderate**

Soil: **Brunisolic**

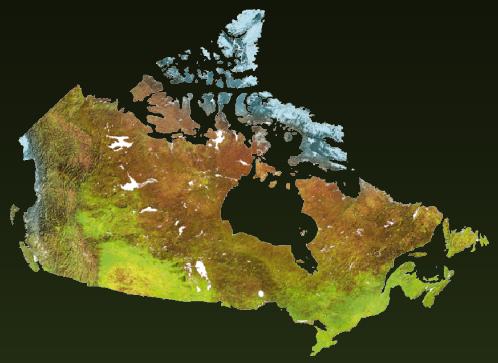
Deposit: **fine matrix-dominated basal till (~1 m), derived from local Precambrian rocks**

Forest stand

Old-growth boreal stand dominated by Black and White spruces, Jack Pines and Aspens

Evidence of cutting activities (~60 years ago)

Evidence of insect budworm (last 3-5 years)



Tree ring activity - Sampling sites

Flin Flon –2 Kotyk Lake

Location: **54°56'53" N 101°27'10" W**

Altitude: **328 m**

Distance from smelter: **32 km**

Slope: **facing W, 2-3°**

Drainage: **Moderate, locally poor**

Soil: **Ferro-Humic Podzol**

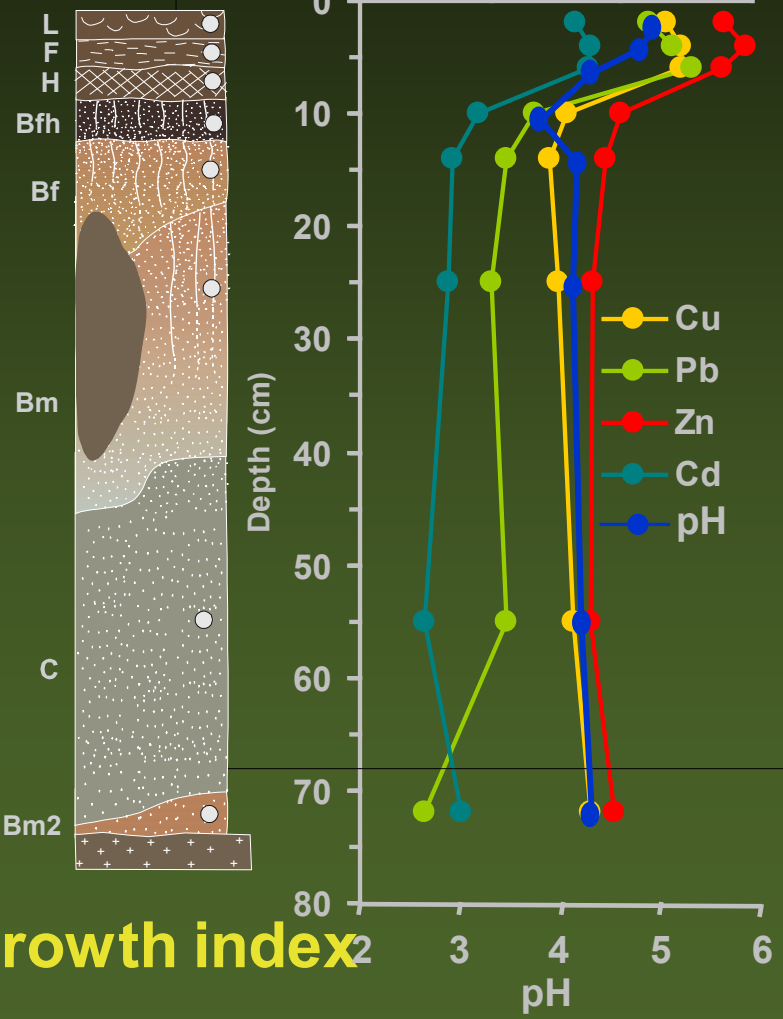
Deposit: **sandy matrix-dominated basal till (~1 m), derived from local Precambrian rocks**

Forest stand

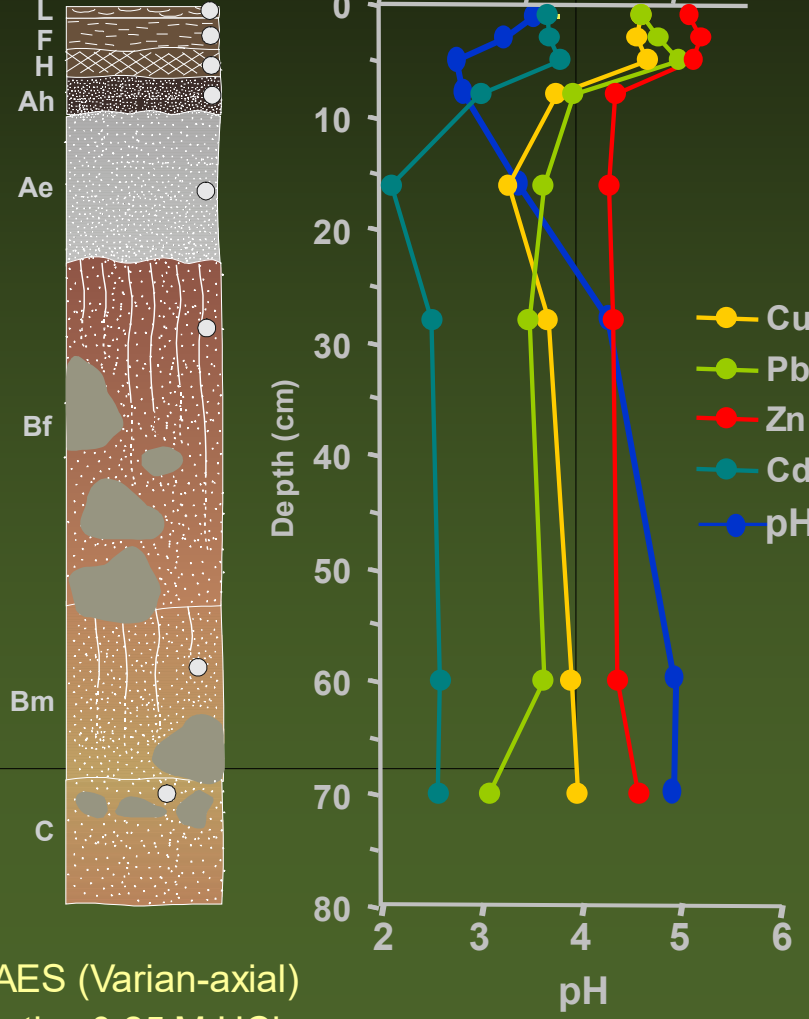
Even-aged boreal stand dominated by Black Spruces and Jack Pines originating from modern natural fire (<200 years ago)

Tree ring activity - Soil studies (metals)

Meridian Lake (7 km)



Kotyk Lake (32 km)



Growth index

ICP-AES (Varian-axial)
Extraction 0.25 M HCl

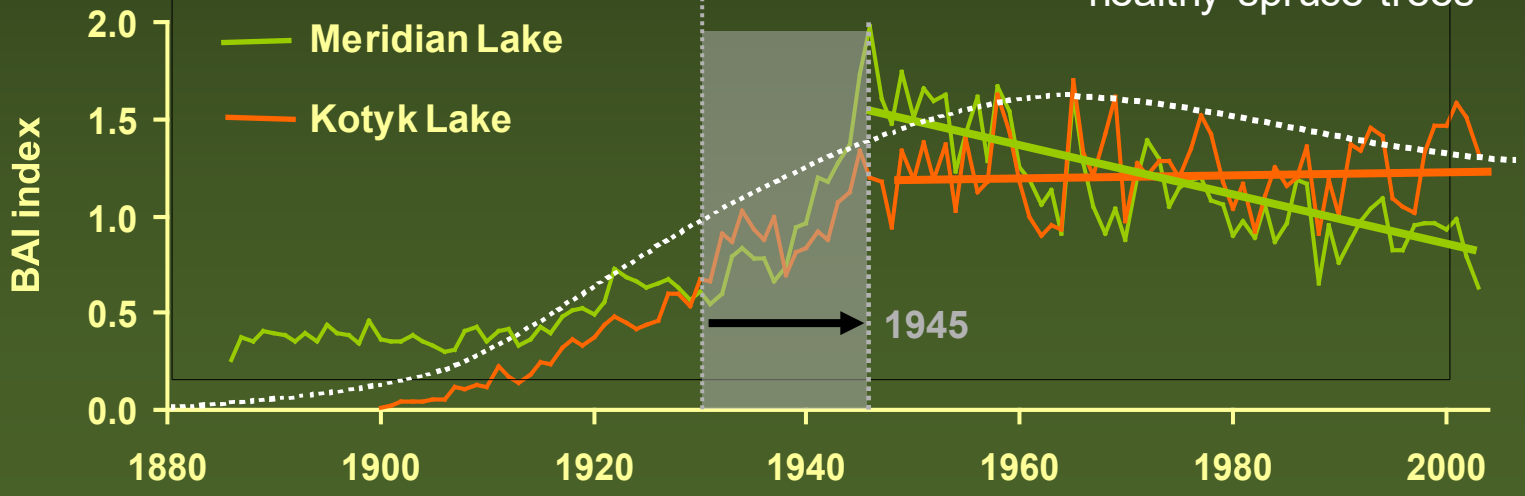
Tree ring activity - Tree growth studies

Impact of smelter on tree growth

	Meridian Lake	Kotyk Lake
Tree species	White spruce	Black spruce
Covered period	1852-2003	1899-2003
Nb trees	16	15
Nb series	41	40
Avg growth (mm)	1.82	1.36

Mean indexed basal area increment

Typical growth model for healthy spruce trees



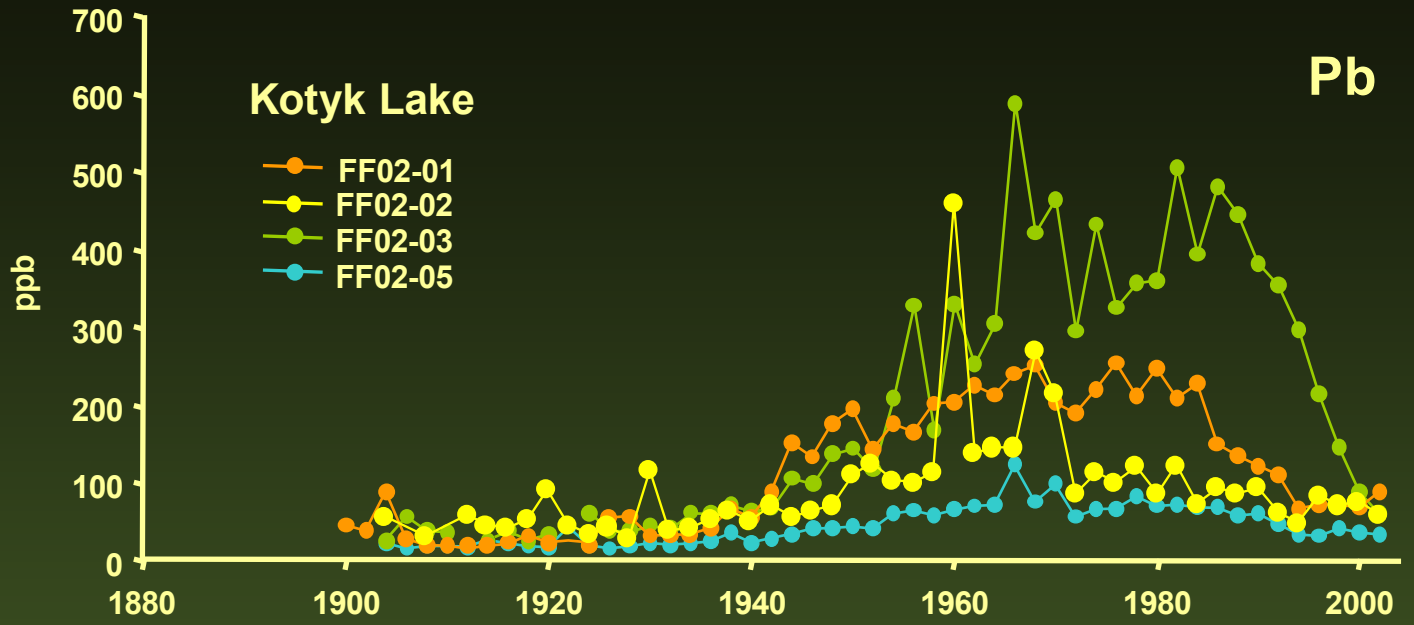
Radial growth decline (15-20%) *ca* 15 years after the smelter onset

Growth index

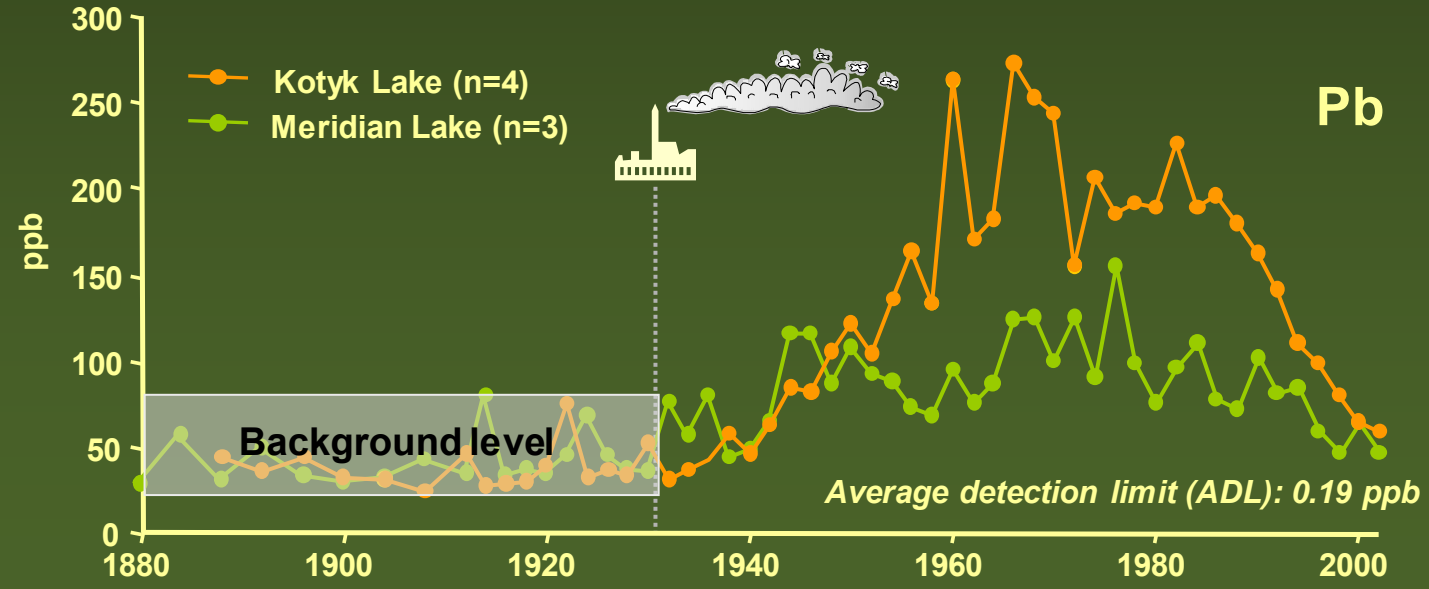
Natural Resources Canada | Ressources naturelles Canada

Canada

Reproductibility of dendrochemical series – trace metals

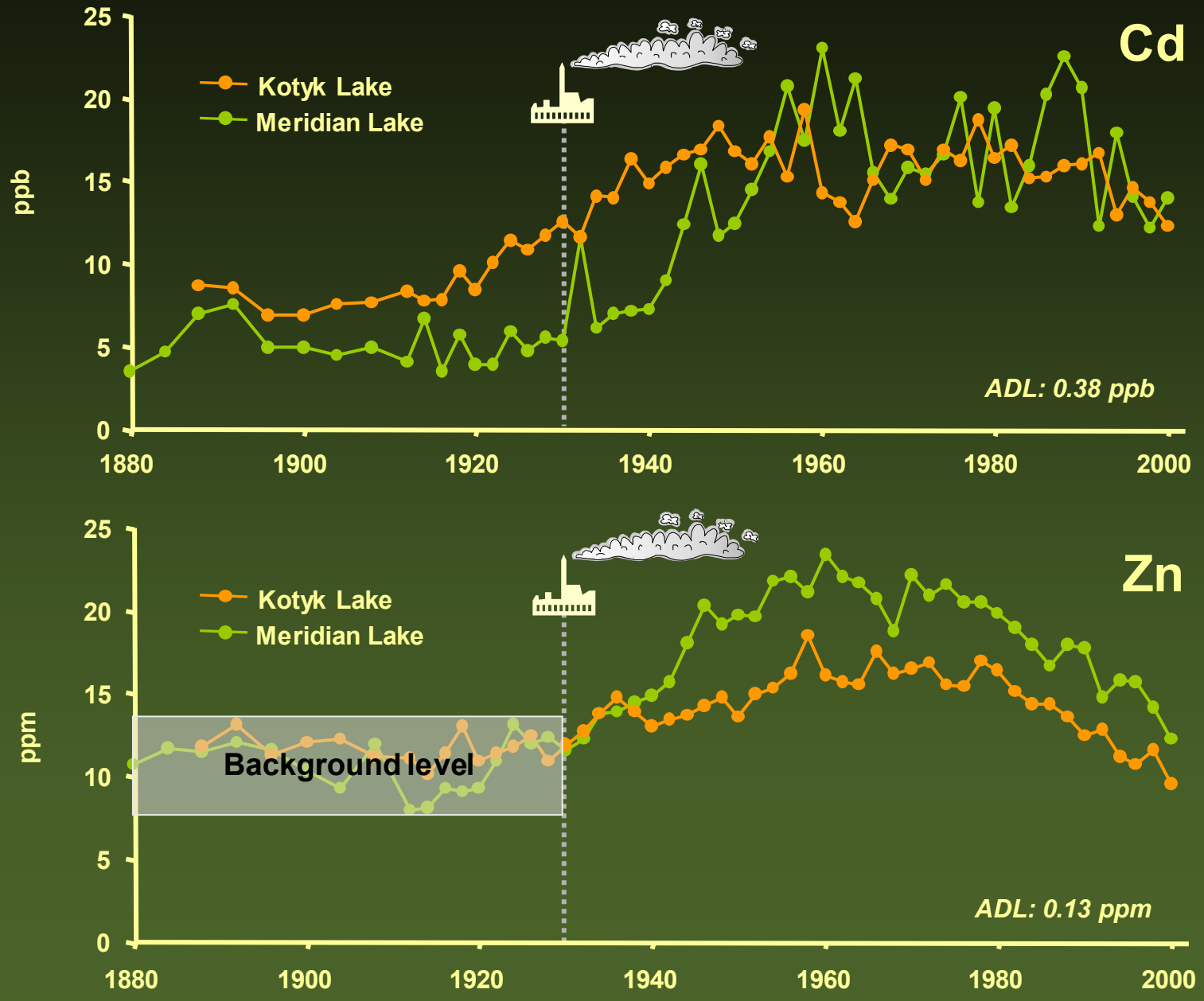


Similar trends / different amplitude: Individual response to environment changes

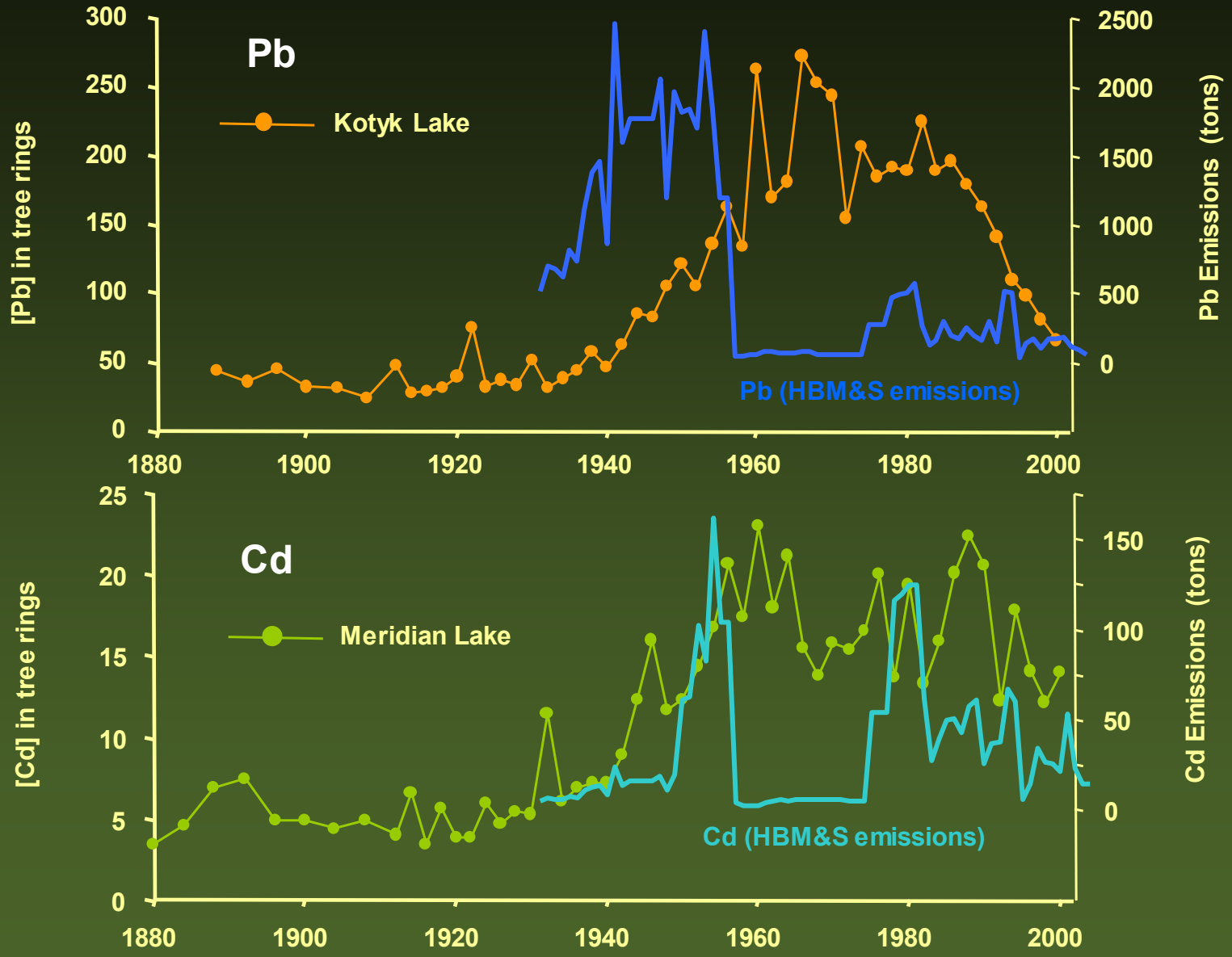


Increasing concentrations 14 years after the smelter onset

Distribution patterns of trace metals in tree rings

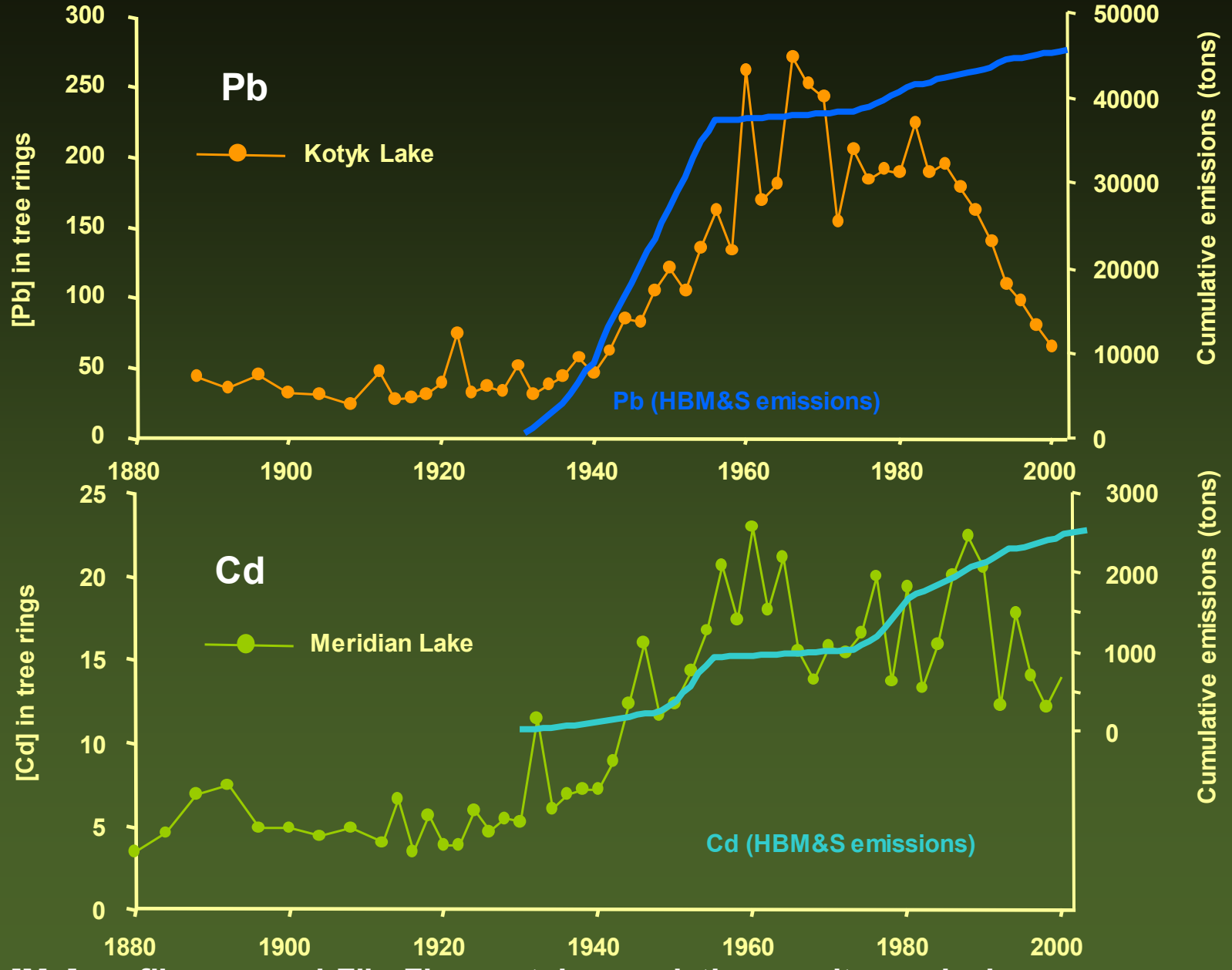


[Me] in tree rings vs. HBM&S smelter emissions



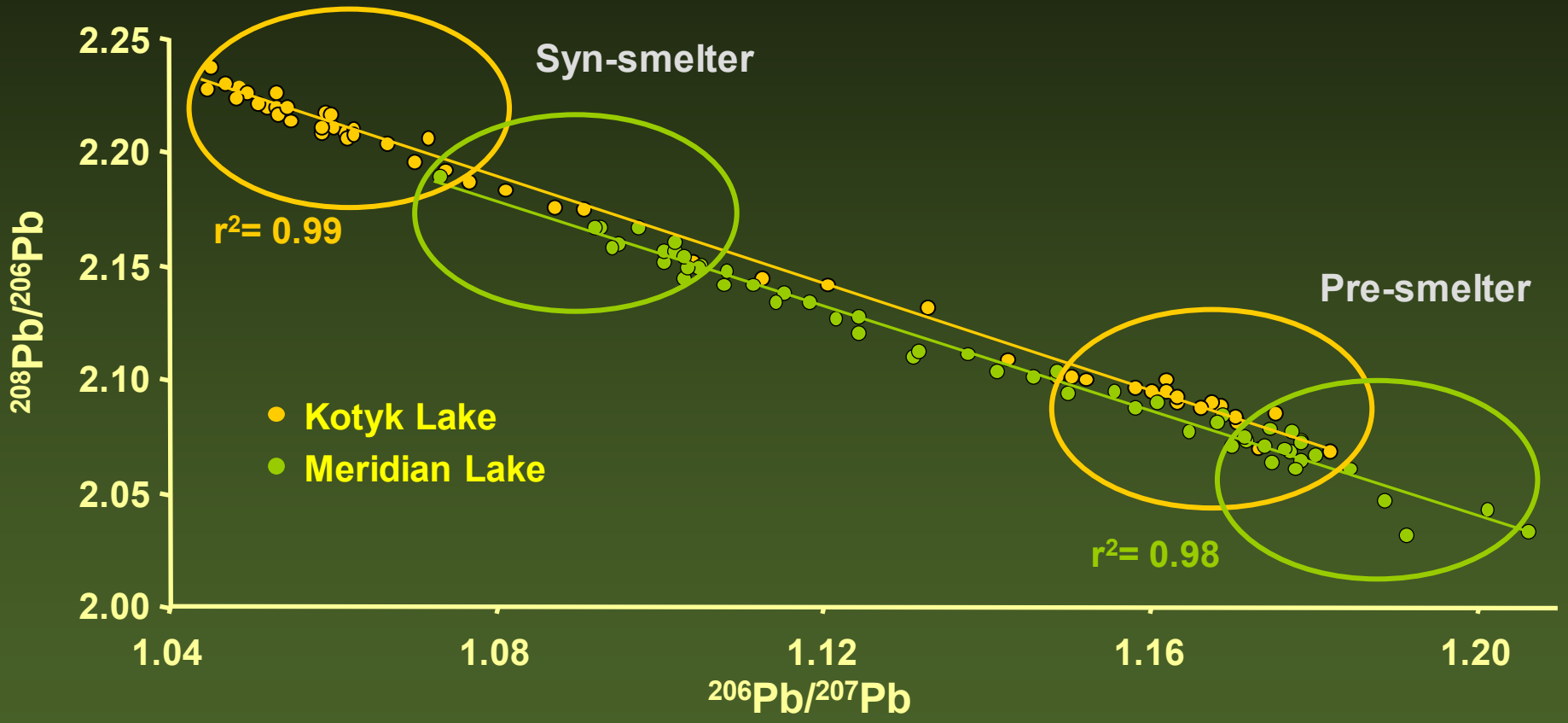
[Me] profiles around Flin Flon also seem to reflect changes in smelter emissions

[Me] in tree rings vs. HBM&S smelter emissions (Cumulative)



[Me] profiles around Flin Flon match cumulative smelter emissions

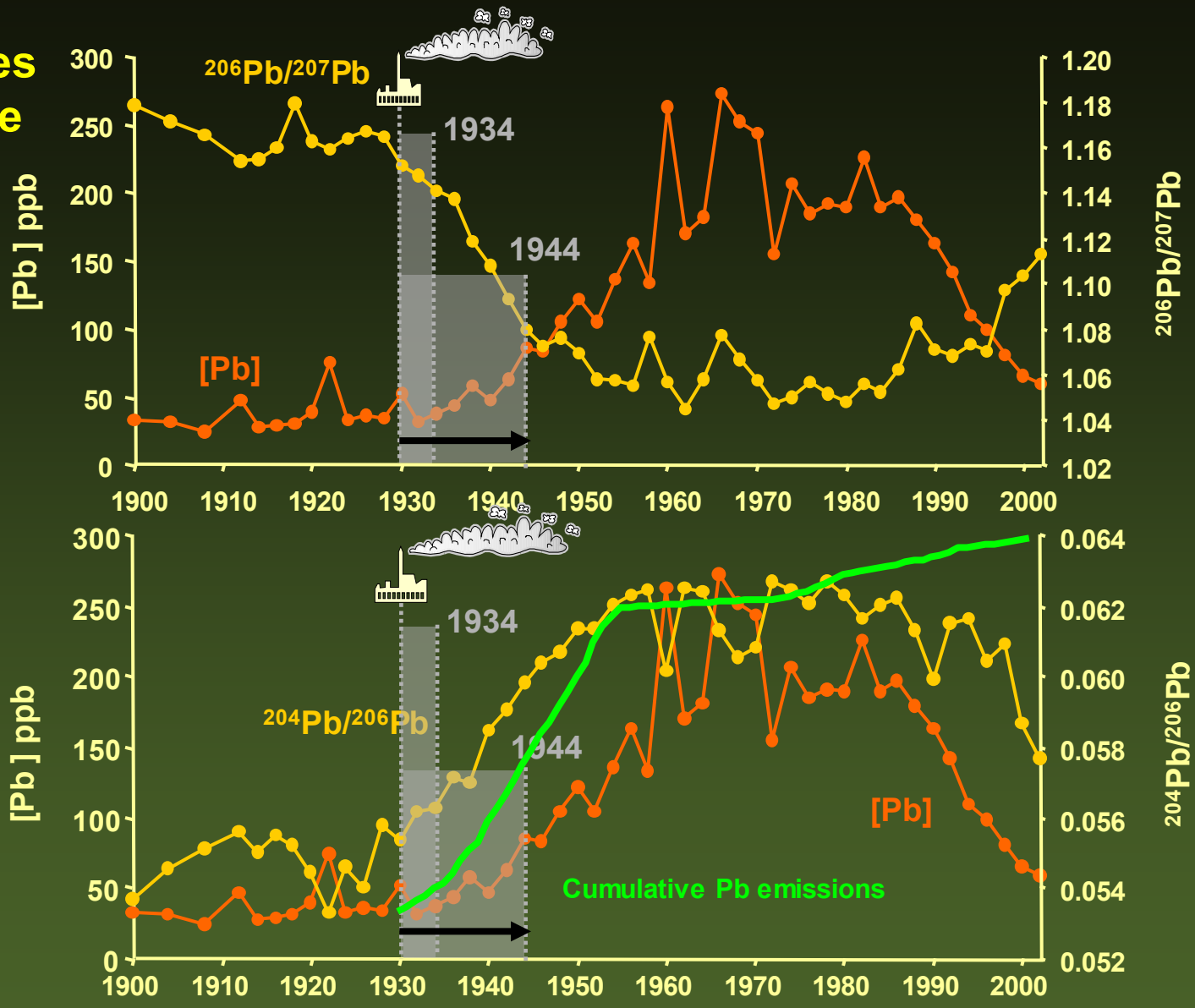
Pb isotopes ratios in tree rings – Flin Flon region



Pb isotopes in tree rings have broad ranges of ratios, well distributed and forming mixing lines for syn- and pre-smelter rings

Difference between the two sites reflects influence of local sources (geogenic)

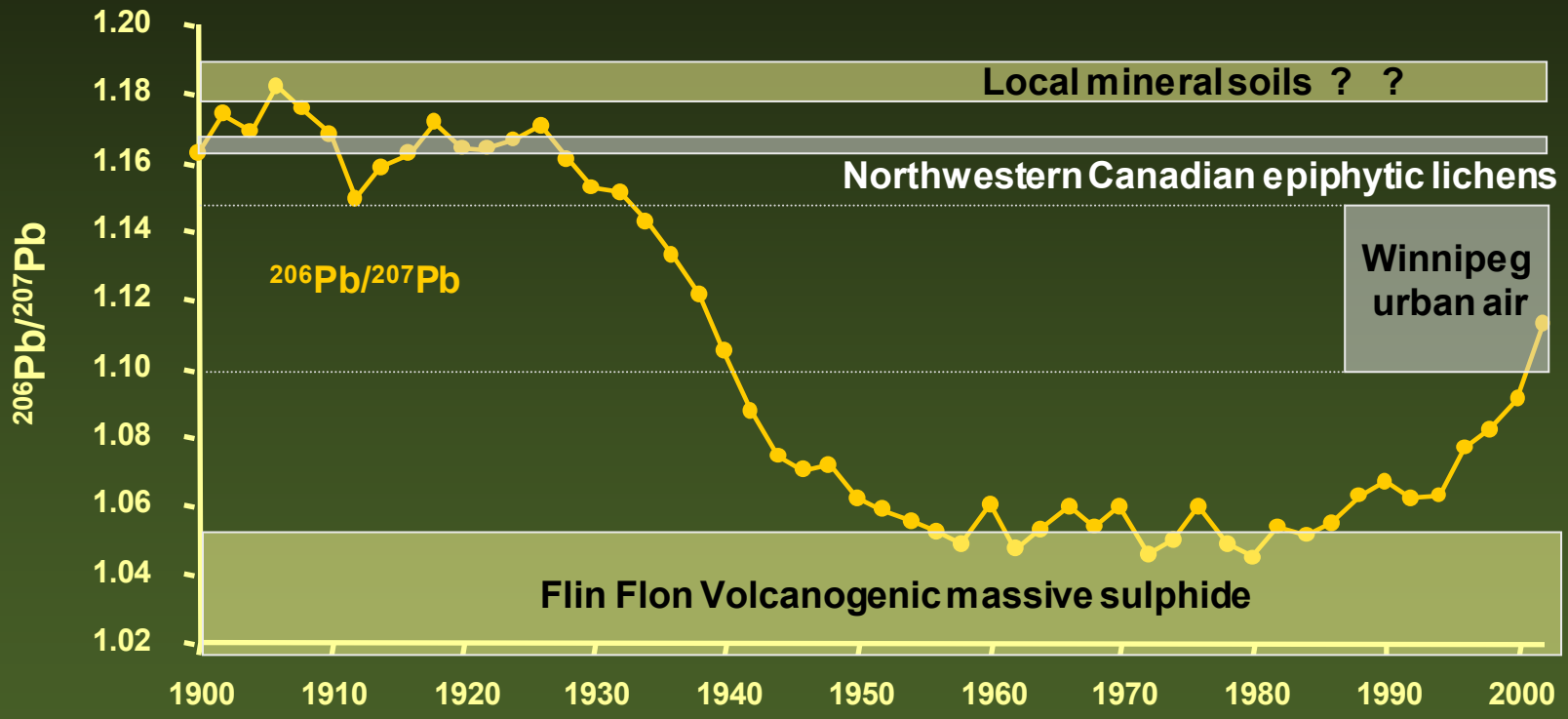
Pb isotopes
Kotyk Lake



The increasing [Pb] 14 years after the smelter onset correspond to a major change in Pb isotopic ratios, thus indicating the integration of a new type of Pb in tree rings
A new source of Pb is accumulated in tree rings shortly after the smelter has started its activity

Pb isotopes ratios ($^{206}Pb/^{207}Pb$) – Kotyk Lake

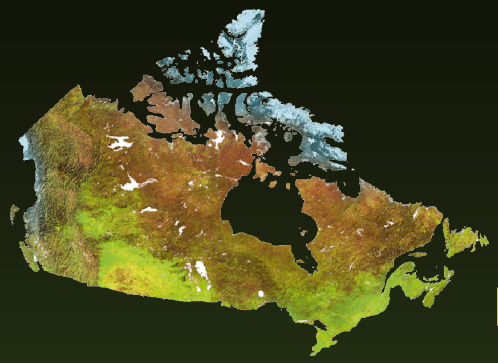
Temporal changes



Complex and changing history of Pb sources

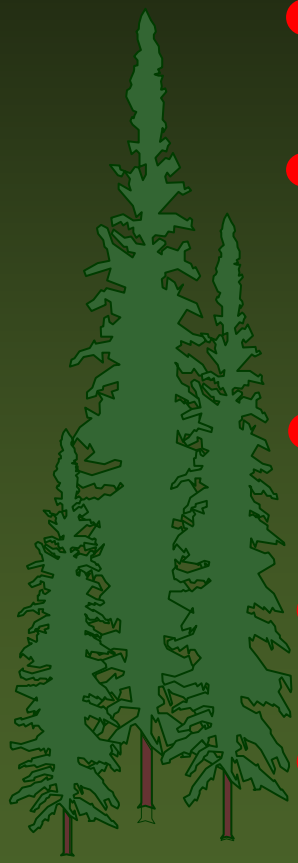
Natural pb signature in pre-smelter tree rings

Lack of local natural Pb signatures



Dendrogeochemical investigation of metal dynamics around the Flin Flon smelter: Time perspective and impacts on boreal forest

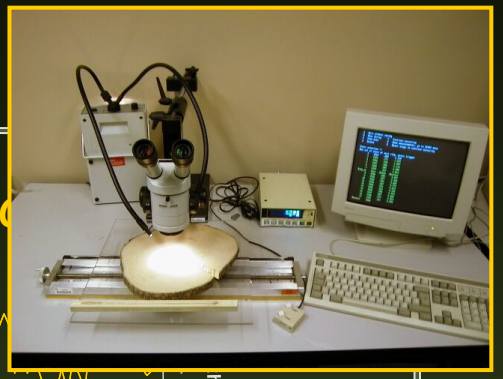
Highlighs



- **Environment changes related to HBM&S smelter activities are recorded in different tree ring tracers (physical & chemical); up to 32 km**
- **Radial growth rate (BAI), [Cd and Pb], and Pb isotope ratios in tree rings appear to be accurate tracers of anthropogenic changes. Pb/Pb in tree rings can provide the history of sources of metals in the investigated area**
- **Tree ring profiles reflect the history of the HBM&S smelter (in term of emissions)**
- **HBM&S smelter emissions do not have significant effect on nutrient accumulated in woody tissues**
- **HBM&S smelter emissions have a negative impact on radial growth (15-20% reduction); decreasing growth rate start *ca.* 15 years after the smelter onset, when emissions increase**

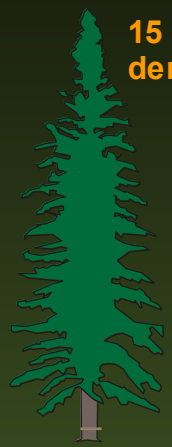
Additionnal information

Methods – Lab analysis

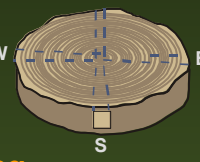


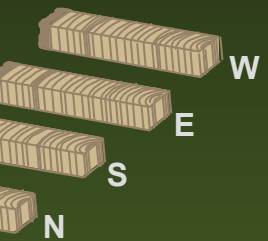
15 trees used for dendrochronology

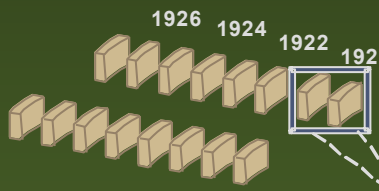
DENDROCHRONOLO



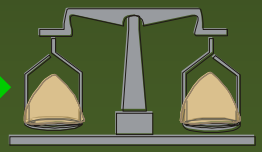
healthy tree growing on unreworked till







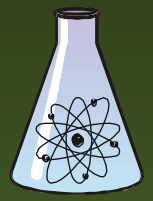
1920-1921



150 mg of wood

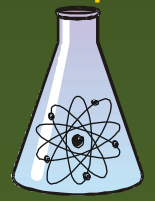
Autoclave digestion

Major elements

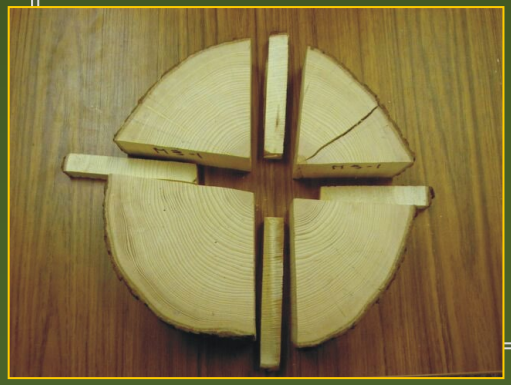


ICP-AES Varian Vista

Trace metals
Pb isotopes



ICP-MS
Thermo instrument
model X7



DENDROGEOCHEMISTRY

Reducing the influence of complicating factors…

- Selection of tree species (ecological, anatomical and chemical criteria)

  Wide geographic range, wide ecological amplitude, long-lived species

  Distinct heartwood/sapwood boundary, low number of sapwood rings, low xylem moisture, low radial permeability, limited number of ray cells

  High potential of conifer trees –primitive nature of wood

- Selection of element to be analyzed (mobility of elements)

  Depends on element solubility, its charge and its diameter (ion size)

  High mobility: As, K, Na, Mg, P, N, S, Cl, B

  Moderate mobility: Ca, Sr, Mn, Zn, Rb, Cu, Mo

  Low mobility: Fe, Ni, Sn, Sb, Ba, Al, Pb, Cd

Essential elements (macro and micronutrients): Ca, Mg, H, C, N, S, Cr, Mn, Fe, Zn, Ni, Cu, Mo, Se

Non-essential elements: As, Hg, Th, Pb, Cd, Ar

Low physiological control on non-essential elements; passively assimilated with bulk sap flow; relationship of soil/tree chemistry less affected