Environmental impact assessment of a Pb, Zn smelter using soil, slag and tree ring elemental and isotopic geochemistry in Kabwe, Zambia

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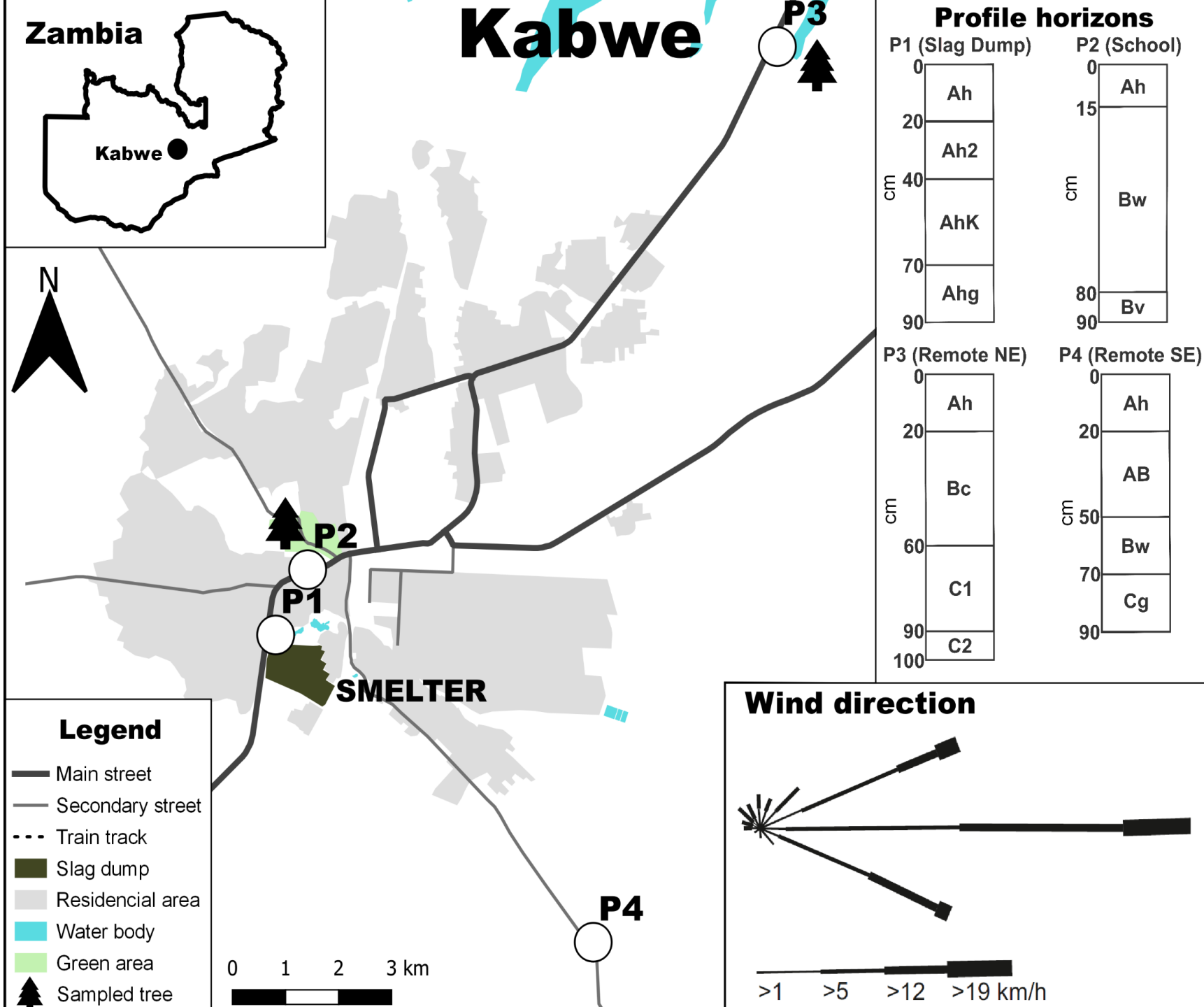
Kabwe

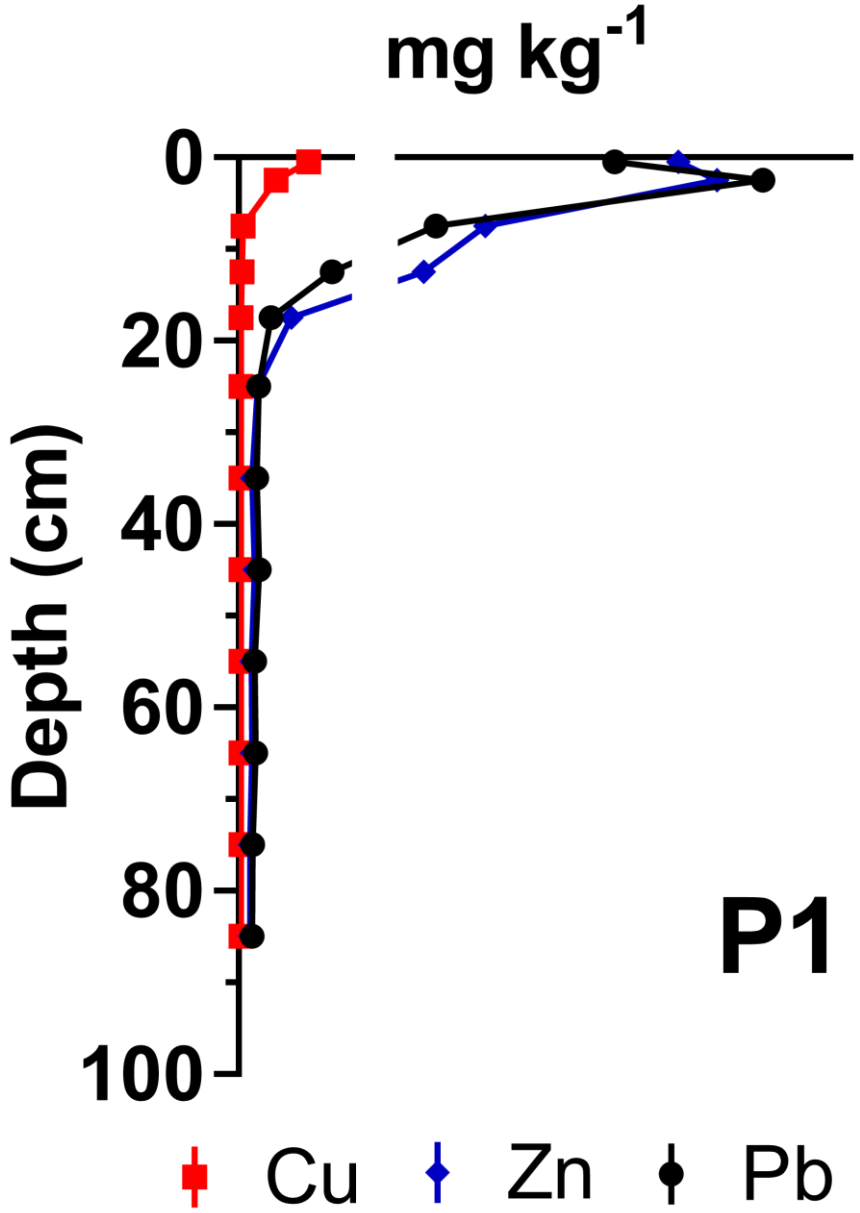
Zambia

P1: soil profile
P2: soil profile + tree
P3: soil profile + tree
P4: soil profile



Soils

- Highest (mg kg^{-1}): 600 Cu, **14000 Zn, 16000 Pb;**
- Remote sites (mg kg^{-1}): 30 Cu, 350 Zn, 100 Pb;



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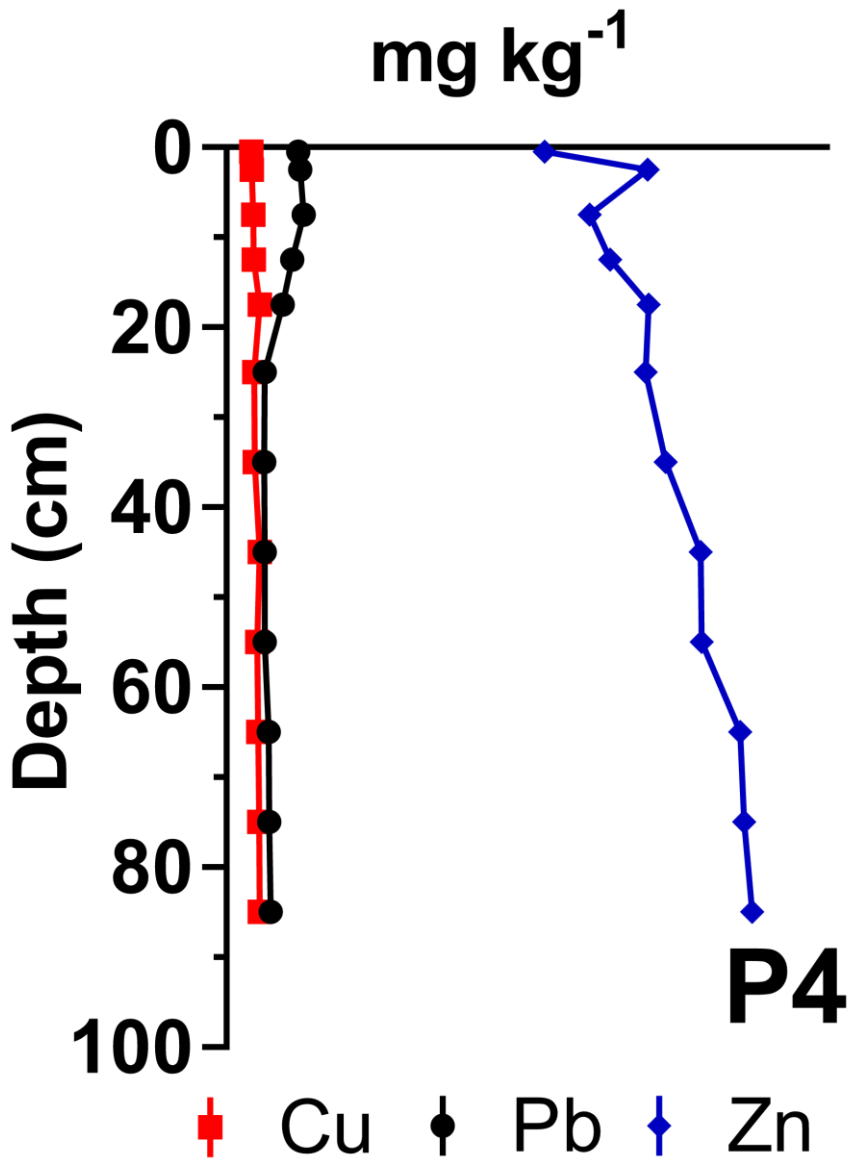
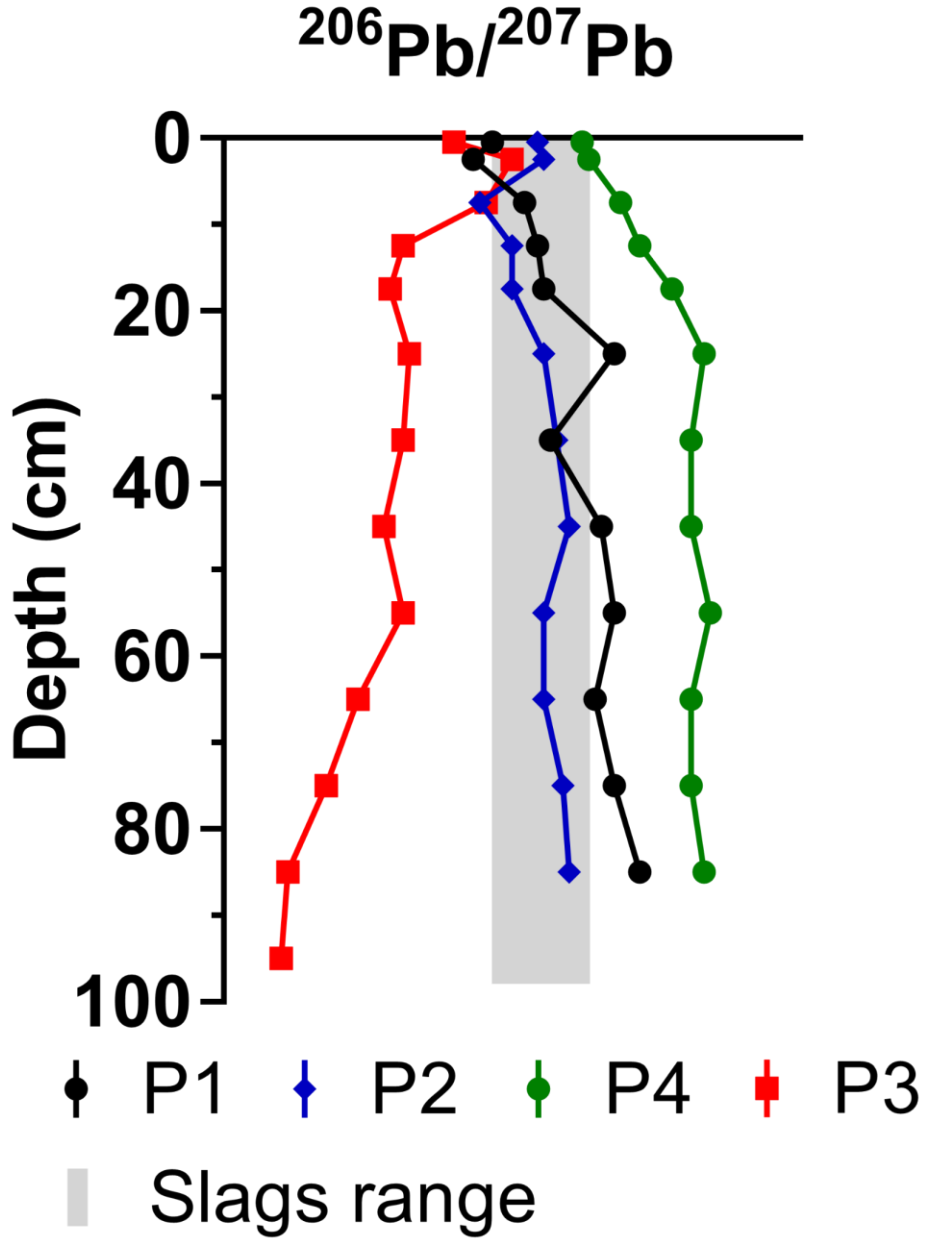


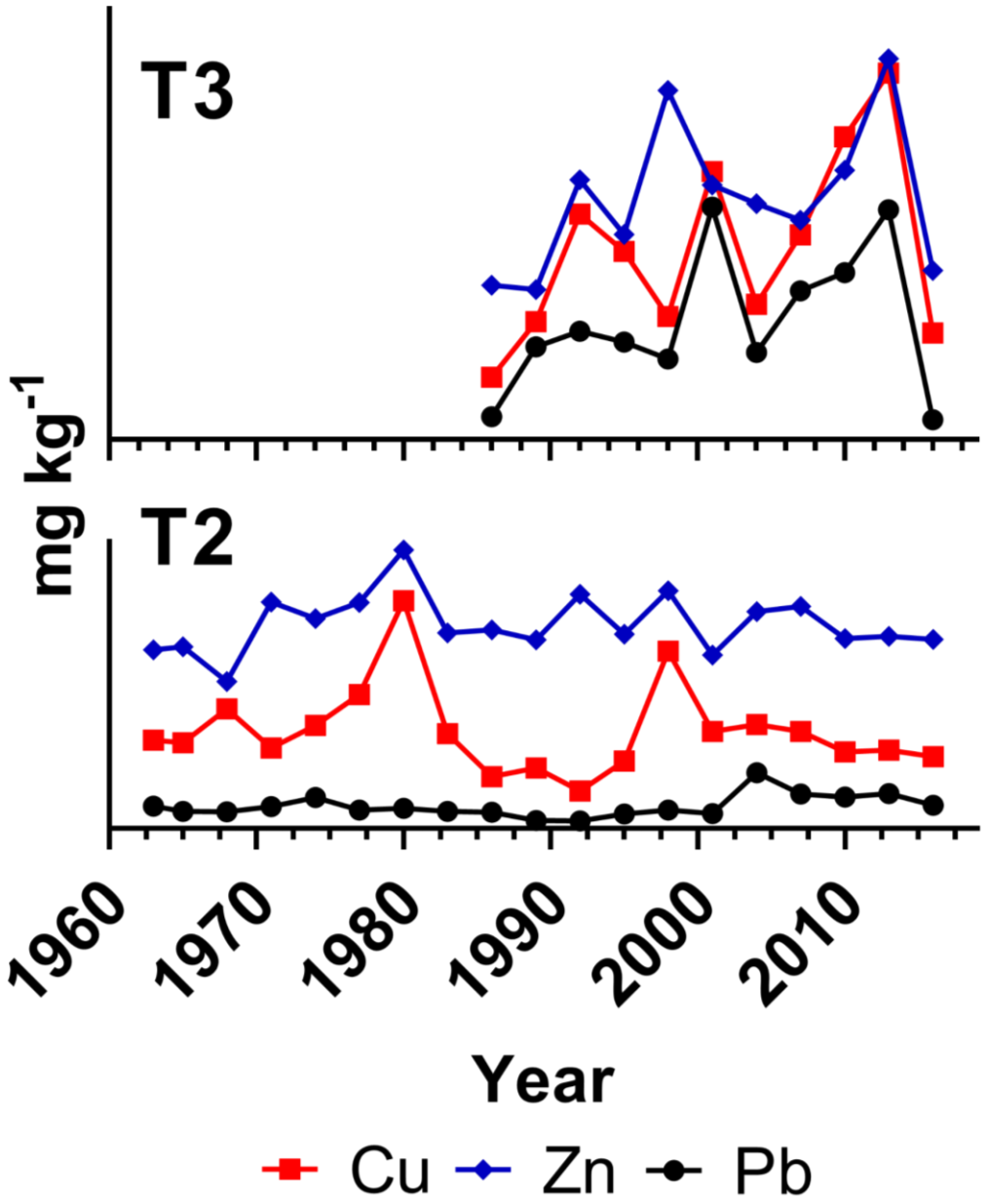
Soils

- Slag signature is similar to topsoils and local galenas;
- The mining/smelting activities are the sources of contamination.



Tree rings

- Highest (mg kg^{-1}): 10 Cu, 29 Zn, 6 Pb;
- More Pb in the remote site, **Why?**;
- Due to small size (<1 µg) of airborne particles?



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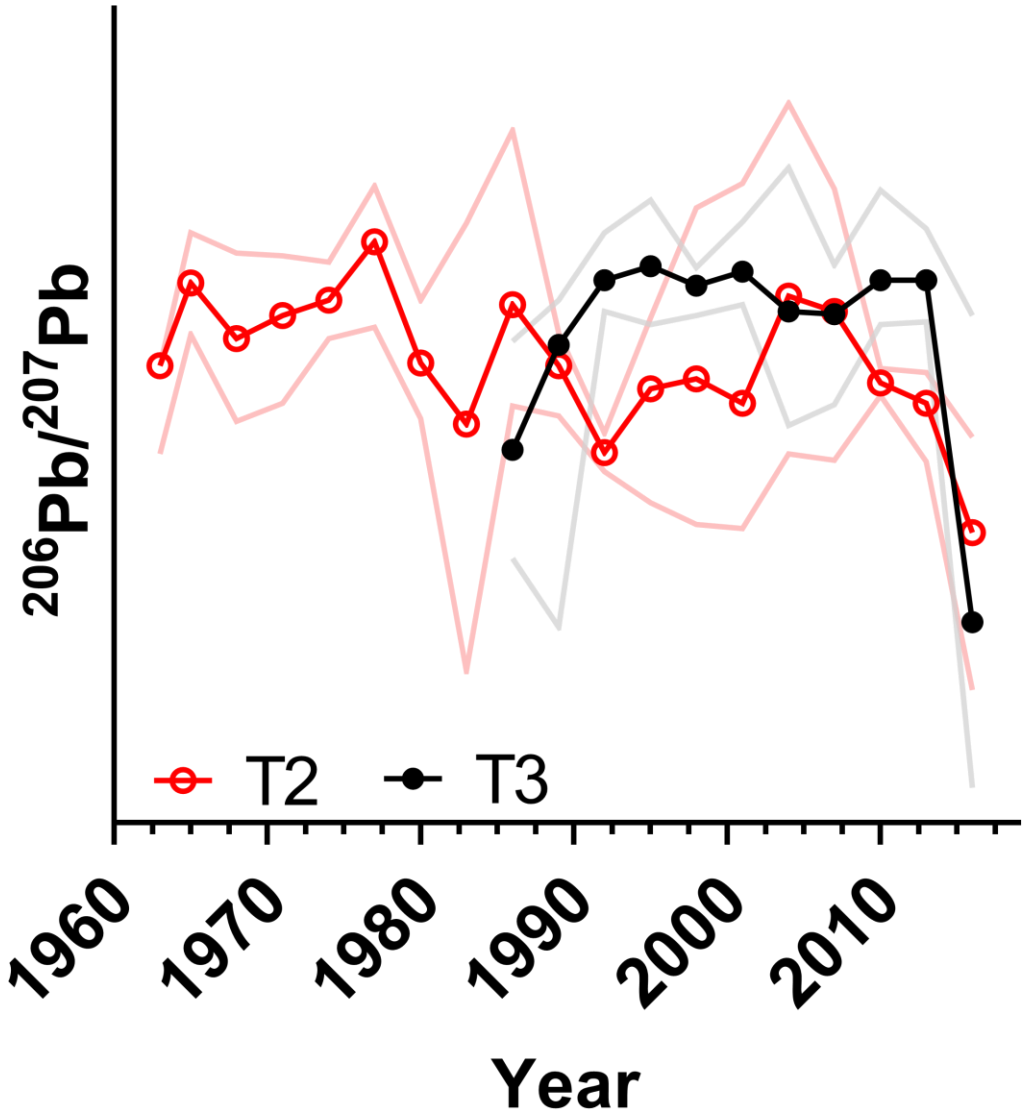
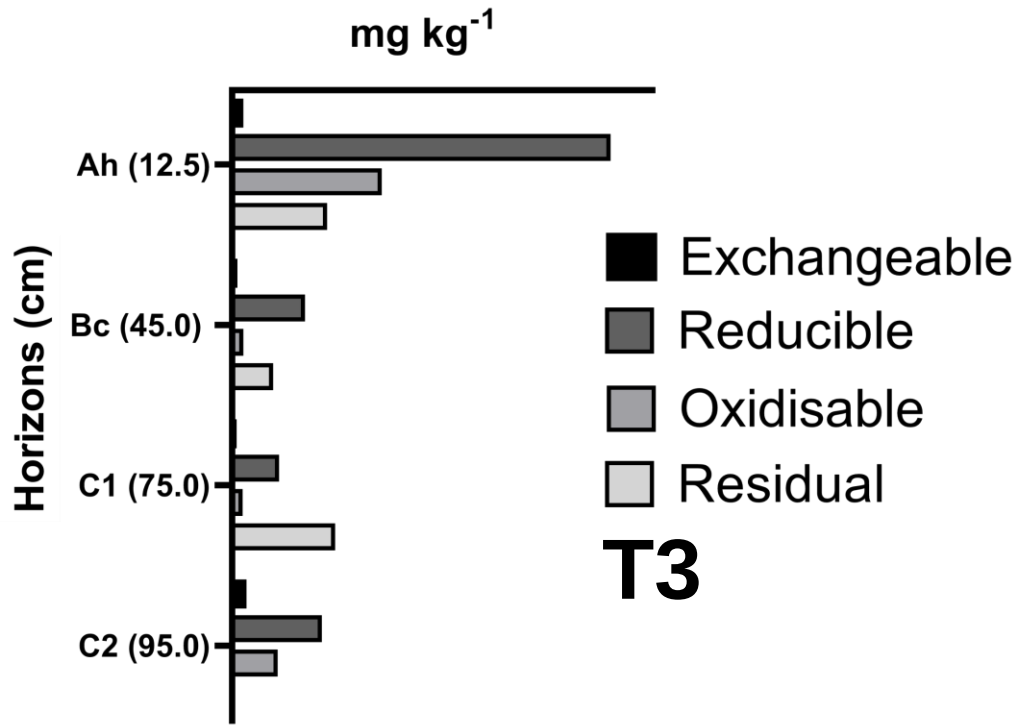


Sequential extraction

- Mobile Pb is found in the reducible fraction;
- That Pb is **not** from anthropogenic origin.

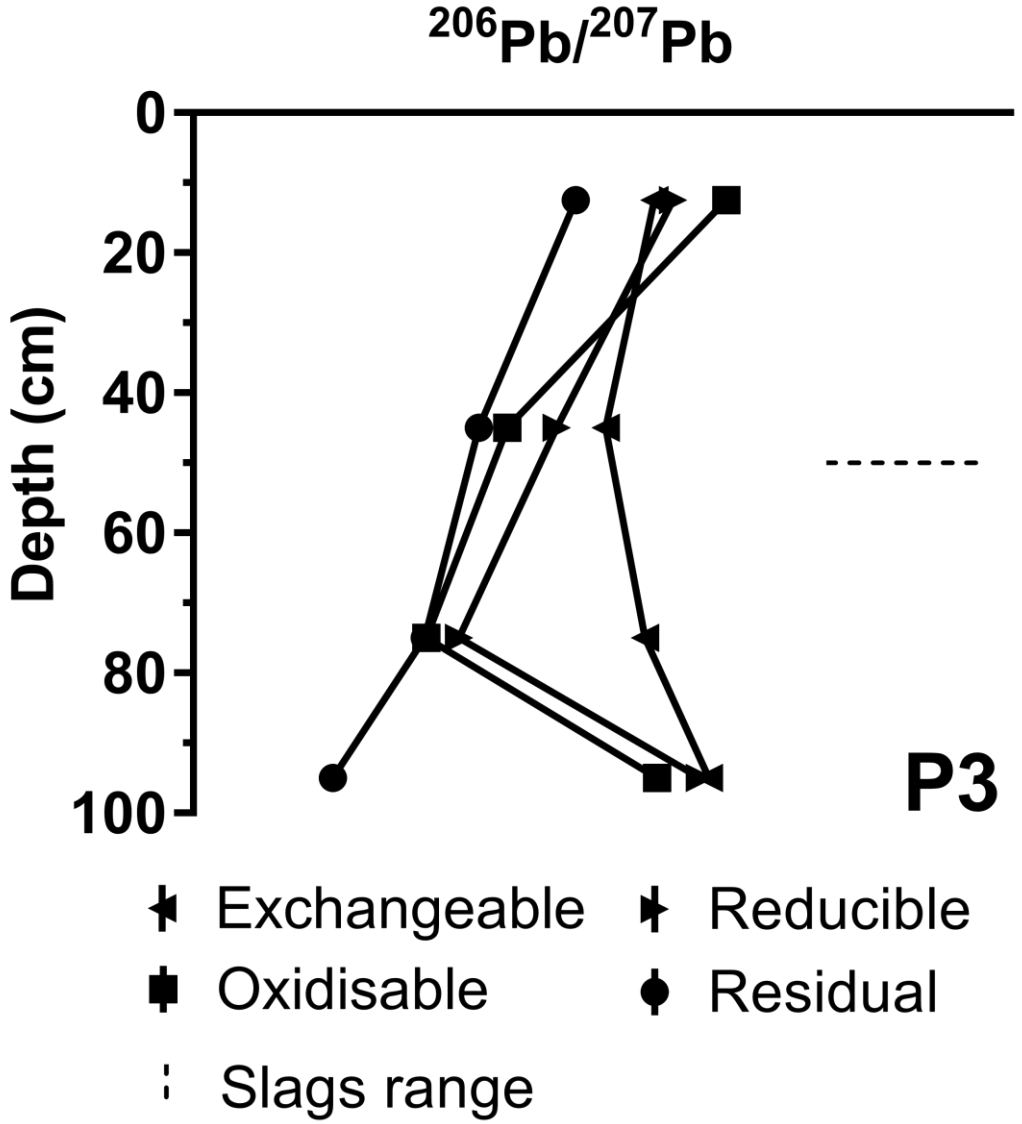


Step 1 – exchangeable/acid extractable fraction (soluble/exchangeable metals and carbonates), 0.11 mol l^{-1} CH_3COOH;

Step 2 – reducible (Fe-Mn oxyhydroxides), 0.5 mol l^{-1} $NH_2OH.HC_l$ at pH 1.5;

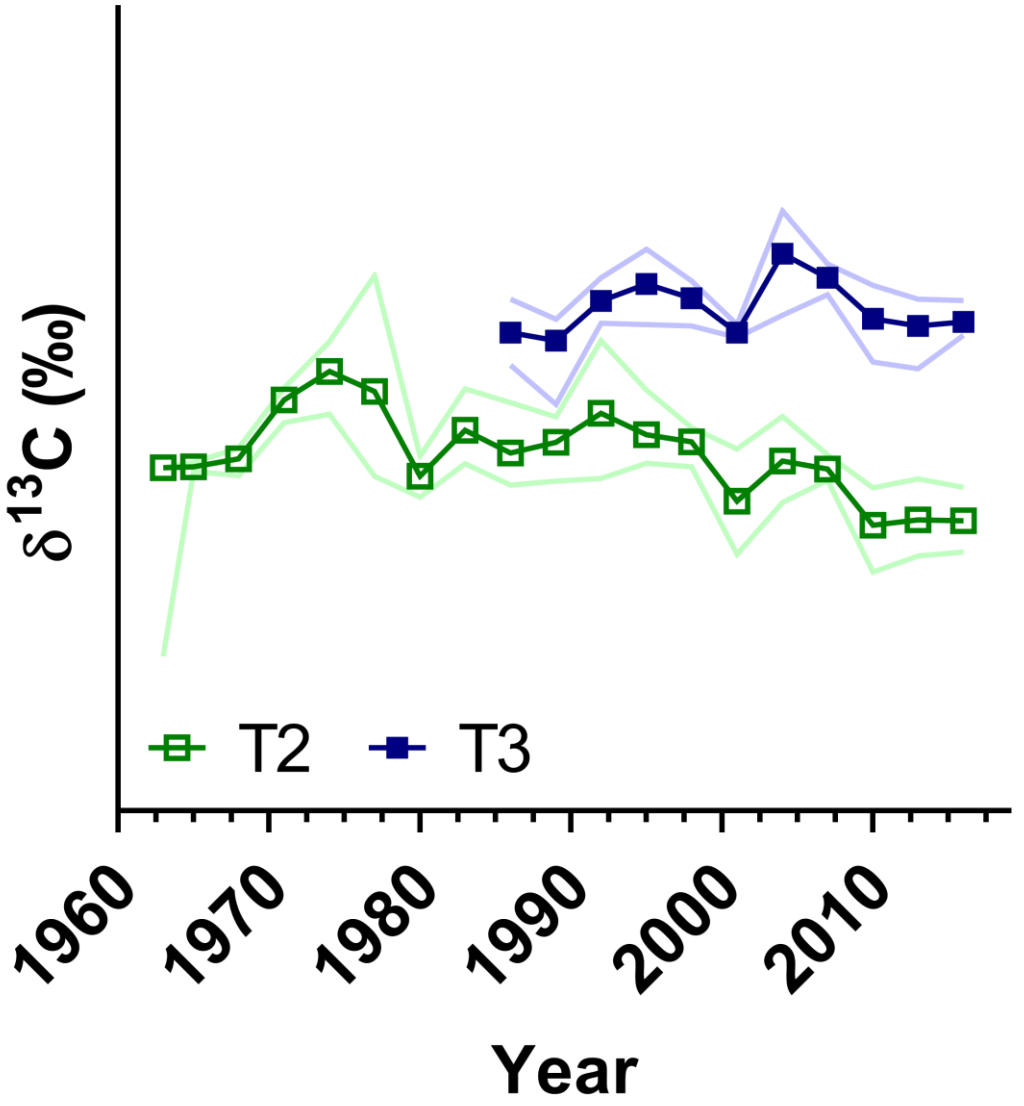
Step 3 – oxidizable (organic matter and sulphides), H_2O_2 (85 ºC) then 1 mol l^{-1} $CH_3COONH_{4;}$

Step 4 – residual, total digestion (targeting metals bound to silicates).

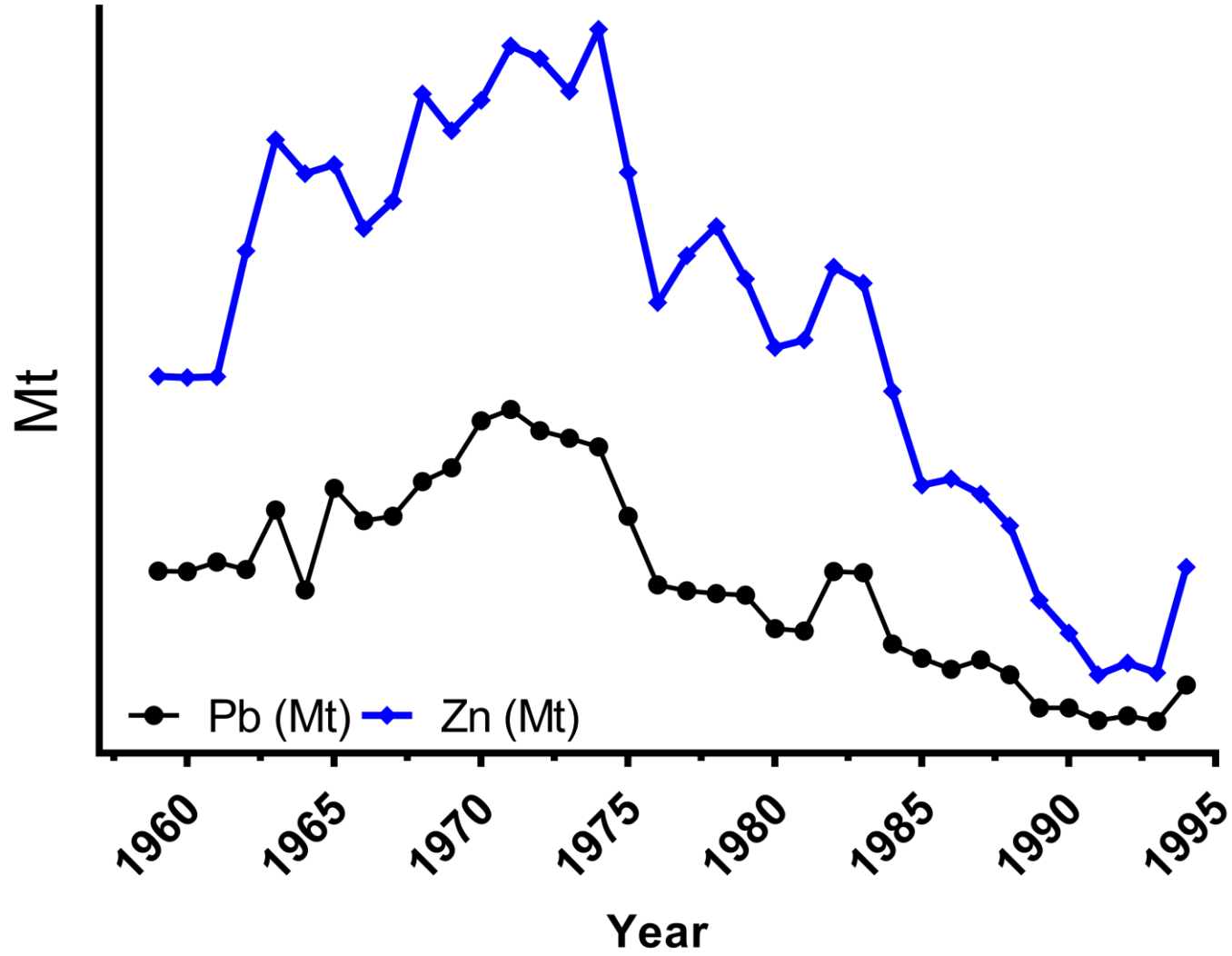


Tree rings

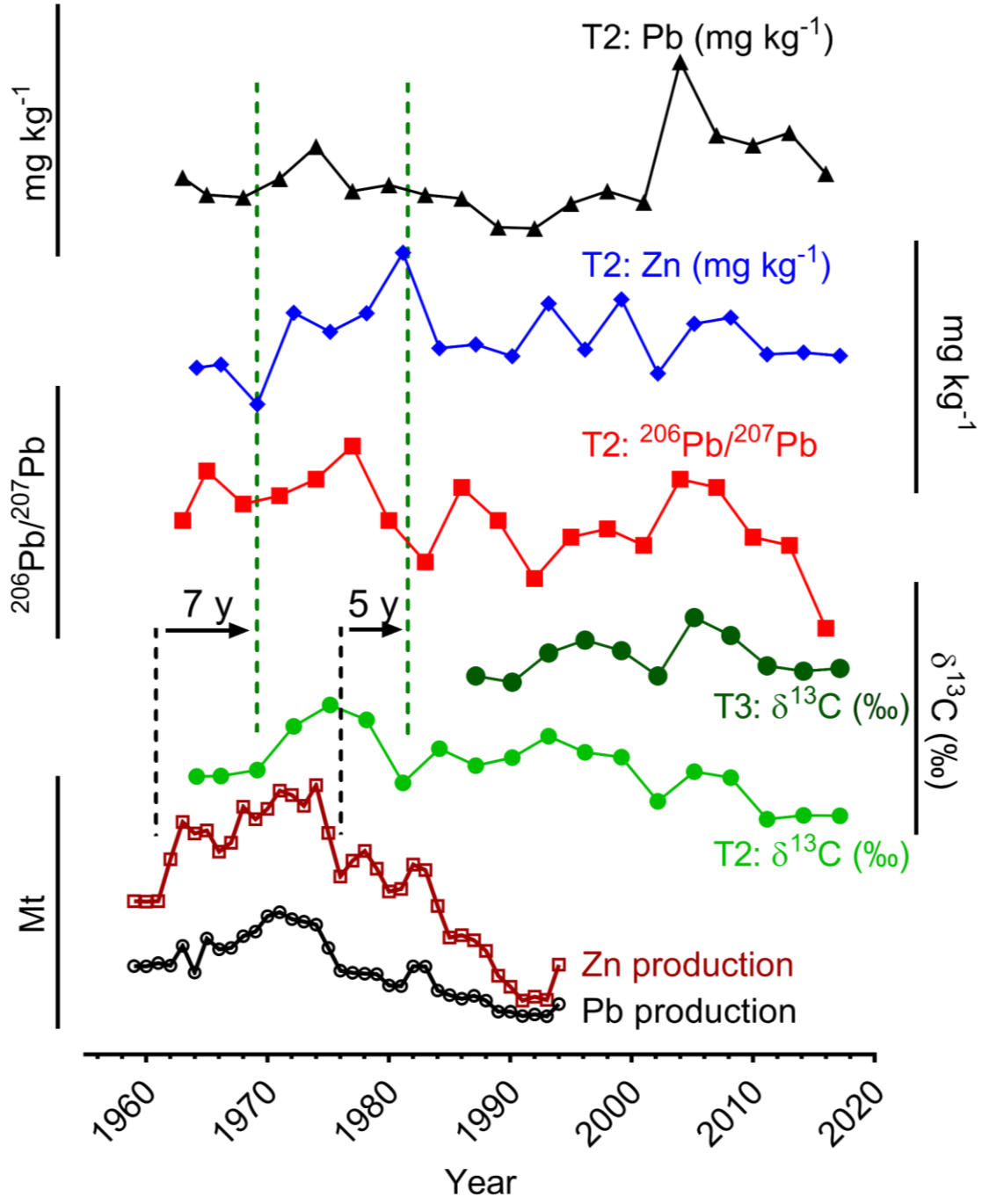
- Peaks in $\delta^{13}C$ correspond to peaks in major cations and metals.
- Increase in smelter **SO_2** and **NO_x** allowing for higher mobilization?



Production records



Combining it all


T2: Pb (mg kg-1)
T2: Zn (mg kg-1)
T2: 206Pb/207Pb
T3: δ13C (‰)
T2: δ13C (‰)
Zn production
Pb production
7 y
5 y
mg kg-1
206Pb/207Pb
δ13C (‰)
Mt
1960
1970
1980
1990
2000
2010
2020
Year

Conclusions

- The topsoils in Kabwe are highly contaminated. Lead values are also high in local pine trees;
- Pb isotopes show that the contamination in Kabwe soils and trees is of anthropogenic origin;
- The entry-point of Pb in the trees is through the bark and leaves and not through the roots;
- Tree ring C and Pb isotopes reflect the yearly production values of the smelter within a 5-10-year shift;
- Local pine tree (*Pinus montezumae, L*.) rings are adequate to be used as environmental archives.

References:

Kamona A. F., Leveque J., Friedrich G., Haack U., 1999. Lead isotopes of the carbonate-hosted Kabwe, Tsumeb, and Kipushi Pb-Zn-Cu sulphide deposits in relation to Pan African orogenesis in the Damaran-Lu®lian Fold Belt of Central Africa. Mineral. Dep. 34, 273-283

Bollhöfer, A., Rosman, K.J.R., 2002. The temporal stability in lead isotopic signatures at selected sites in the Southern and Northern Hemispheres. Geochim. Cosmochim. Acta 66, 1375–1386.

Thank you!

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