Synchrotron Micro X-ray Fluorescence and Metal Distribution Across the Sapwood/Heartwood Boundary

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Introduction: Dendroanalysis is the study of the metal distribution in the annual growth rings of trees. Dendroanalysis can, in principle, be used to provide a chronological record of pollution events. Interpretation of data is often compromised by limited knowledge of both the method of sequestration and lateral mobility of metals in stemwood. In this work we have used synchrotron radiation induced x-ray emission (SRIXE) to probe the distribution of metals in a tree stem cross section. The results show that some metals are enriched in both darkwood and heartwood. Recognition of this anomalous distribution might increase the reliability of metal records obtained from tree rings.

Methods and Materials: The sample was a stem cross section cut from a 106-year old black spruce (Picea mariana) collected in the Hudson Bay Lowlands. The severe growth conditions (short season and low nutrient availability) produce very narrow growth rings so that the entire inside diameter of the tree stem could be conveniently scanned using SRIXE. The sample from the tree was in the form of a disc as shown in Figure 1. It was polished with SiO_2 sandpaper prior to analysis. The analysis was performed with white beam collimated to a 0.015 mm spot size. The specimen was scanned twice in parallel lines 1 mm apart at intervals of 0.025 mm across the entire stem diameter. Data were collected for a live time of 10 seconds at each point. X-ray fluorescence intensities for K, Ca, Mn, Fe, Cu, and Zn were obtained.

Results: The results obtained during the scan for Zn are shown in Figure 2. There is a clear enrichment within the heartwood, and Zn is also enriched in the so-called darkwood, which is associated with early frost events. The pith is off-center as noted in Figure 1. The Zn concentration rises more rapidly with distance (time) on the narrow side of the stem. This is probably the result of compression of the rings. Finally, the metal is enriched in the outer two-three rings. This observation is consistent with transport of nutrient metals from the later rings into actively growing xylem immediately under the bark.

Conclusions: SRIXE shows the Zn distribution throughout the life of the tree, a result not readily achieved using any other technique. The zinc distribution reveals most of the anomalies in dendroanalysis and thus provides confirmation for several observations in the literature, specifically:

1. Zn is enriched in heartwood implying lateral transport of this metal.
2. Zn is also enriched in the heartwood, believed to be associated with early frosts and/or insect damage.
3. The Zn concentration is locally enriched in the most recent rings, in agreement with the suggestion that metals are transported from recent rings to the rapidly growing ring of the current growth year.
4. Chronological records of metal deposition must avoid the most recent tree rings, darkwood, and heartwood if accurate records are to be achieved.

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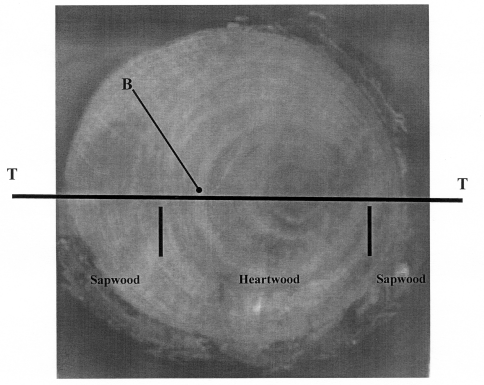

Figure 1. Picture of the black spruce cross section. The line T-T represents the approximate location of the x-ray transect. The heartwood and sapwood are indicated. B) indicates a region of lightwood within the heartwood.

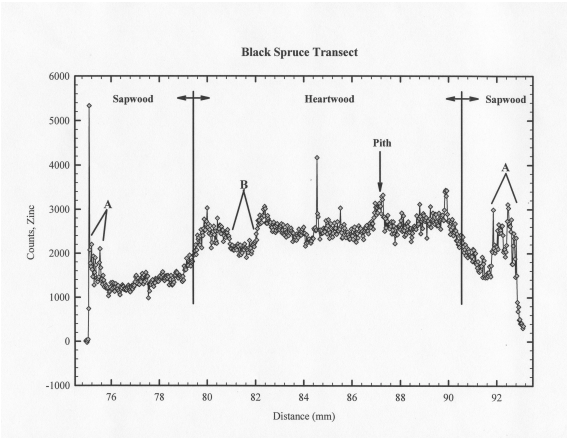

Figure 2. Zn x-ray intensities along the transect indicated in Figure 1. The approximate positions of the heartwood, sapwood, and pith are indicated. A) indicates regions of Zn enrichment in the outer few rings. B) indicates a lightwood region within the heartwood with decreased Zn content.