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Boron in tree-ring as an indicator of forest disturbances in the Lower Athabasca Oil Sands region, Northeastern Alberta, Canada

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Industrial activities related to oil sands (OS) extraction in northeastern Alberta (Canada) have generated, since 1967, important quantities of NO_x and SO_2 emissions that can lead to several negative effects on forest ecosystems including the potential for soil acidification. In addition, mining processes, tailing pond treatments and heavy transport (haul roads) in mining areas are considered important sources of air contaminants that have the potential to impair forest health by affecting the nutrient balance and physiology of trees. In this study, we analysed micronutrients (B, Fe, Zn, Na, Cu) and macronutrients (Ca, Mg, Mn, K) in the tree-ring series of jack pine (Pinus banksiana) and spruce (Picea glauca and Picea mariana) trees growing at different distances from the heart of mining operations (two sites for each species). Based on tree-ring records, our aims were to provide a historical perspective on the nutritional status of forest ecosystems and to identify temporal changes in tree-ring chemistry that can be attributed to OS activities.

One of the key findings of this research is the direct and immediate response of boron (B) in woody tissues of all studied species to mining operations. During the pre-mining period (prior to 1967) [B] variations in tree-rings of the three species covary with other elements such as Na and Fe and are likely controlled by environmental factors, namely climatic conditions. After 1970, [B] increases and strongly departs from trends of other elements. In jack pine trees (54 km NNE of the centre of industrial operations) the increasing trend is abrupt with mean [B] increasing from 11.7 mg/kg during the pre-industrial period to 14.3 mg/kg during mining period. In spruce trees at the proximal site (14 km NE), [B] increases gradually and nicely reproduces the historical pattern of industrial emissions with mean pre-mining [B] of 29.5 mg/kg increasing to 92.1 mg/kg during the mining period. At the four spruce sites, the increasing rate of B decrease with distance and no specific trend in [B] was found at the distal site (135 km E). Finally, a significant negative correlation was found between [B] and tree growth within the mining area suggesting a potential negative role of anthropogenic emissions on forest productivity.

Mining and associated industrial activities in the Alberta OS region are known to have the potential of releasing substantial quantities of B in the environment. Even if B specific emissions remain poorly documented in the area, the high [B] in top organic soil horizons at all sites confirm the atmospheric source for B. Rarely investigated in dendrogeochemical studies, B in the tree-rings, along with other associated nutrients, appears to be an excellent biogeochemical indicator of disturbances in nutritional status of forests in the vicinity of Alberta OS mining activities.