Rapid Whole-Rock Boron Geochemistry: a Cost-effective Synchrotron Tool for Uranium Exploration

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Uranium exploration is the foundation of Canada's nuclear energy industry and Saskatchewan is a world leader in uranium exploration and production. However, many uranium deposits are located in remote regions, such as northern Saskatchewan and Nunavut, making exploration targeting difficult and expensive. New uranium deposit discoveries require application of novel methodologies and approaches to detect the presence of large-scale ore-forming systems and to vector toward mineralization. Boron is commonly used as a key pathfinder element associated with unconformity-associated uranium deposits; but a genetic relationship has not been rigorously established, although alteration assemblages containing boron are spatially-associated with primary uranium mineralization and are suspected to be coeval with the mineralization. However, in some locations, the host mineral for the anomalous quantities of boron remains cryptic. Tourmaline is the dominant carrier of trigonally-coordinated boron, whereas clay minerals such as illite can substitute boron for silica in tetrahedral sites. Understanding boron coordination chemistry within the alteration haloes will provide insight into the nature of the boron-hosting minerals, the boron-uranium relationship in the mineralizing process, and may provide better-constrained targets for exploration. Synchrotron-source X-ray absorption near-edge structure (XANES) spectroscopy is being used to provide a direct, rapid spectroscopic boron analysis on whole-rock powders. XANES spectroscopy is an element-specific measurement that is sensitive to elemental oxidation state and coordination chemistry, making it uniquely suited for identifying the changing chemistry of boron. New, fast-scan capabilities allow rapid, cost-effective analysis, suitable for uranium exploration. XANES spectroscopy and XRD analyses were conducted to determine the proportions of trigonally-coordinated BO_3 phases (such as tourmaline) and tetrahedrally-coordinated BO_4 phases (such as illite and chlorite clay minerals) in a series of whole-rock drill core samples containing boron concentrations up to 1700 ppm. The uranium mineralization in the study area is associated with distinct clay alteration haloes. The results obtained from the XRD and XANES analyses are consistent, suggesting that the spectroscopic boron signature is robust and a potential exploration vector. While XRD is useful to detect the presence of, and identify, boron-bearing minerals, XANES directly identifies the speciation and relative amount of boron in the complex mineralogical mixtures present in bulk sample materials. Work to date suggests a link between trigonally-coordinated boron phases with uranium mineralization. These results provide additional specific geochemical information that cannot be provided by traditional lithogeochemical analysis. Further research is ongoing to develop this work into a vectoring tool that will be useful in exploration guidance.