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Identification of sandstones above blind uranium deposits using multivariate statistical assessment of compositional data, Athabasca Basin, Canada

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ABSTRACT

The Athabasca Basin in northern Saskatchewan, Canada, hosts the world's largest high-grade U resources near the unconformity between sandstones and underlying crystalline basement rocks. Finding U deposits is difficult in the interior of the Athabasca Basin where the sandstone cover can reach 1400 m. This study uses the lithogeochemistry of sandstones obtained from drill cores to identify elements associated with U using principal component analysis (PCA) from three areas; samples directly above the Phoenix U deposit, those in Denison Mine's Wheeler River property and background areas in the basin. The sandstone data from the Wheeler River property shows that U is positively associated with Y-Cu-Zn-Na-W-Co-Ni-B-Mg-HREEs-Cr-Sc-Mo-V-LREEs due to uraniferous hydrothermal alteration. In contrast, the principal components derived from the lithogeochemistry of sandstones far from known mineralization in the basin shows that U is positively associated with Th-Ti-Zr-Hf, suggesting that U is hosted in refractory detrital minerals. Linear discriminant analysis (LDA) and random forest (RF) analysis based on principal components of elements associated with U show three classes of sandstones with clear discrimination between samples; those above the Phoenix ore (Class Phoenix), in the Wheeler River (Class Wheeler River), and regional background (Class Regional Background). The class Phoenix contains most of the sandstone samples overlying the Phoenix deposit and a few samples in the Wheeler River property. This study shows that PCA, LDA and RF are able to detect geochemical footprints of uraniferous hydrothermal alteration > 500 m from the ore and differentiate sandstones spatially associated with the mineralization from those in barren areas. Based on the performance of the two discrimination methods, we suggest that RF is a preferred method as it better differentiates altered sandstones from regional background samples. The classification analysis used in this study may be useful in U exploration in Athabasca Basin and other sedimentary basins.

1. Introduction

Many U deposits in the Athabasca Basin occur along the regional unconformity between sandstones and the crystalline basement. The majority of the known U deposits, including the world's largest McArthur River deposit, are located in the eastern margin of the basin (Fig. 1) where the sandstones are relatively thin (< 400 m) compared to the interior of the basin where they are up to 1400 m thick. Geophysical methods, such as radiometric prospecting and electromagnetic surveys, have played important roles in the discoveries of U deposits. However, the thick sandstones pose difficulties for geophysical surveys for U exploration. For example, high gamma rays from the Wolverine Point Formation of ~186 m thick (Ramaekers, 1979) may yield misleading exploration targets. Many deposits are spatially associated with conductive graphitic pelites in the basement, but there are many barren graphitic pelites. In addition, several newly discovered deposits are not associated with graphitic conductors (e.g., Centennial deposit; Reid et al., 2014). Therefore, electromagnetic surveys may not be able to detect these deposits. This prompted a study to identify the geochemical signatures of sandstones overlying buried U deposits. Previous studies reported that concentrations of selected elements, such as Pb, U, Ni, As, REEs and Co, are anonymously high above and close, up to 200 m, to some deposits and prospects (Sopuck et al., 1983; Hoeve and Quirt, 1984; Earle and Sopuck, 1989; Jefferson et al., 2007). Recent studies of sandstone lithogeochemistry suggests that the anomalies extend much farther (Dann et al., 2014; Wright et al., 2015; Guffey et al., 2015; Chen et al., 2017). This study tests the possibility that multivariate statistical methods can distinguish altered sandstones above deeply-buried U deposits from those in barren areas.

We selected the Denison Mine's Wheeler River property in the

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