Discrimination of Whiskey kimberlite eruptive phases utilizing portable XRF spectrometry data

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Introduction

The purpose of this study was to examine the viability of using a hand-held portable X-ray fluorescence (pXRF) spectrometer to rapidly obtain geochemical data on kimberlite samples, and thus enable discrimination of different kimberlite phases. Potential applications range from augmenting core logging at the exploration stage, to ore grade control during mining. The use of whole rock geochemistry to distinguish different phases of kimberlite within an individual body is well established (e.g. Star kimberlite: Grunsky and Kjarsgaard, 2008; Orion South kimberlite: Kjarsgaard et al., 2009). The samples for this study are from the Whiskey kimberlite, located in the Attawapiskat field, James Bay Lowlands, northern Ontario, Canada (Januszczak et al., 2013).

Analytical Results

A suite of whole rock geochemical analyses (laboratory fusion ICP-ES/MS) were obtained from a selection of Whiskey kimberlite drill core samples; all the raw geochemical data were subdivided into three distinct kimberlite phases (U1VK, U2VK, U3VK) based on core logging and petrographic studies by De Beers geologists. The three phases are easily distinguished on a geochemical basis, e.g. on simple downhole depth versus concentration plots, or x-y plots such as TiO_2 vs Y (Fig. 1a). The whole rock dataset employed provides a sound statistical training set, which consisted of 189 samples (U1VK = 78; U2VK = 75, U3VK = 36). An analysis of variance (AOV) was undertaken to determine elements with the greatest power to discriminate the three phases, in order to examine the potential of using a pXRF, i.e. can a pXRF obtain viable data for the discriminating elements of interest. Note that pXRF spectrometers typically can only provide reliable data for ten to twenty elements, which are concentration dependant.

Based on the AOV for 44 elements from the training set, a subset of 22 elements from the whole rock data set where selected for statistical treatment, with Ti, Ta, Al, Yb, Y and Cr having the greatest discriminating power, and U, Ca and Na the least discriminating power. A principal component analysis (PCA) was applied to the log-centred transformed (Aitchison, 1986) data for 22 elements. The first three eigenvalues account for the majority (71%) of the variance of data. A linear discriminant analysis was carried out (on 22 elements) and a LD1-LD2 plot of the data demonstrates good group separation and the overall accuracy is 99.1%. The discriminating elements of interest (based on the AOV) can be analysed for by pXRF spectrometry.

A sub-set of kimberlite sample powders (previously analysed by laboratory fusion ICP-ES/MS) were analysed with a Niton pXRF in 'Mining Mode' with He gas, and in 'Soil Mode', both using an 8 mm window. An AOV was undertaken on both pXRF data sets. For 'Mining Mode', the best elements to discriminate the 3 kimberlite phases are Ti, Nb, Ba, Al. A bi-variate plot of Al versus Ti distinctly separates the three kimberlite phases (Fig. 1b). In 'Soil Mode', the best elements to discriminate the 3 kimberlite phases are Ti, Cr, Zr. A more comprehensive statistical treatment via principal component and linear discriminant analyses utilizing only 3 (or 4) elements separates out the 3 kimberlite phases into discrete clusters, as summarized by Grunsky et al. (2013).
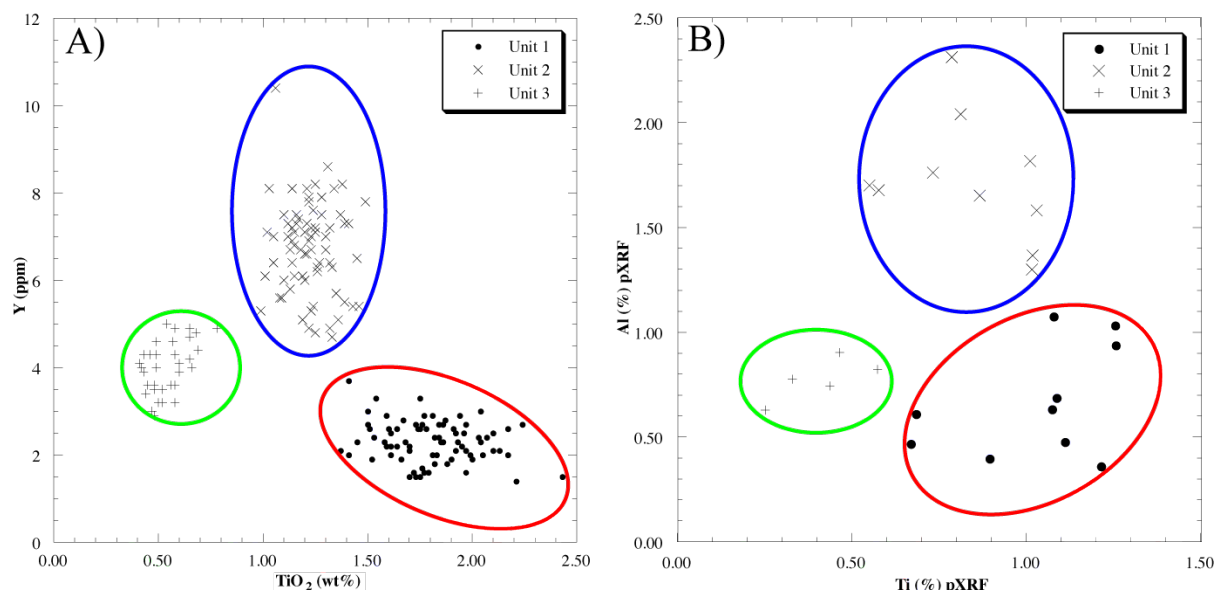
Figure 1: Geochemical separation of the three Whiskey kimberlite phases **(A)** TiO$_2$ versus Y from fusion ICP-ES/MS on whole rocks **(B)** Ti versus Al from hand-held pXRF on kimberlite whole rock powders.

After the succesful application of the pXRF on the powders, thirteen cut kimberlite slabs were analysed by pXRF in 'Mining Mode' with He gas, and in 'Soil Mode'. The kimberlite matrix was targeted, avoiding xenoliths and megacrysts, with 5 analyses per slab (Fig. 2). Based on an analysis of variance, K, Rb, Fe, Mg, Al, Cu, Zr are the better discriminants, and the three kimberlite phases form distinct clusters on LD1-LD2 plots using these elements (Fig. 3a). Importantly, note that the best discriminating elements from slab matrices are different than from the wholerock powders.
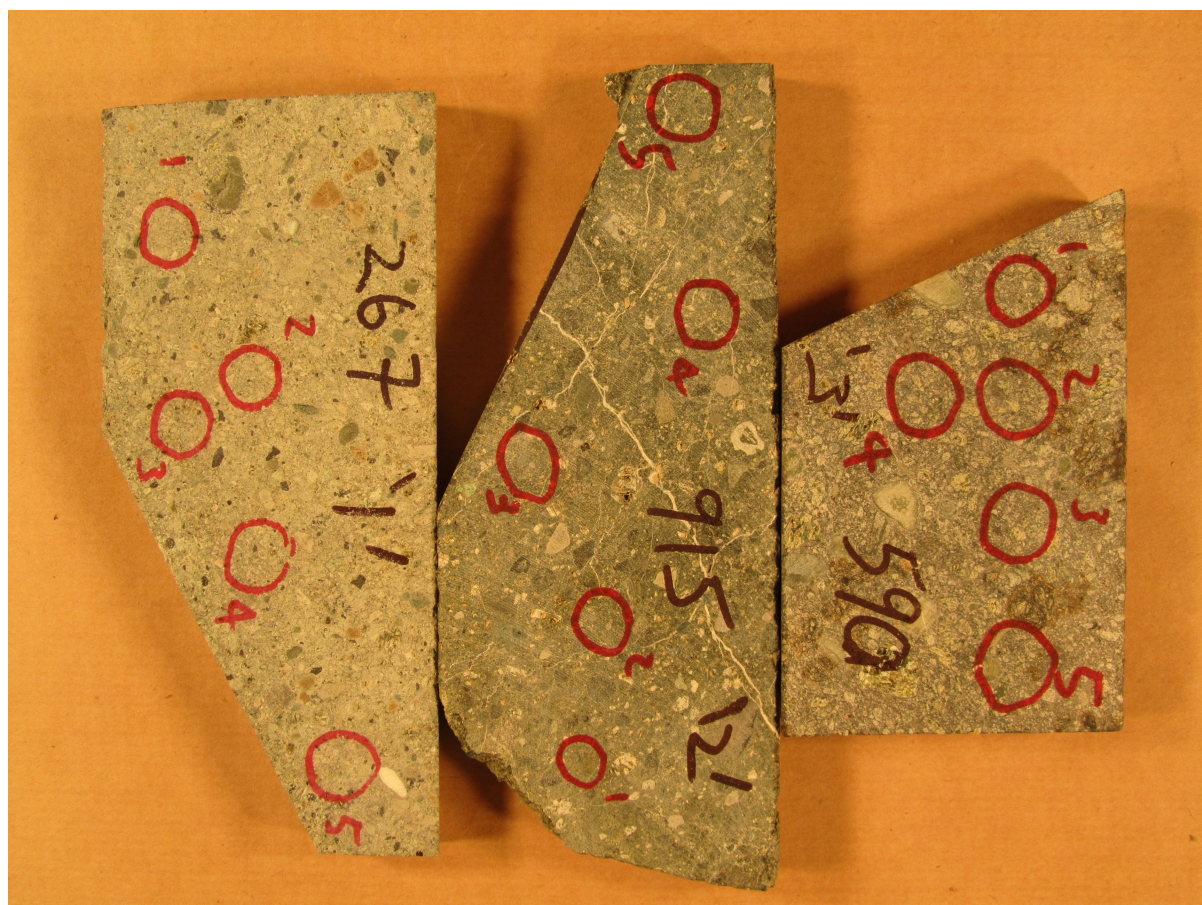
Figure 2: Example of three different phases of the Whiskey kimberlite, with pXRF analysis areas outlined (red).
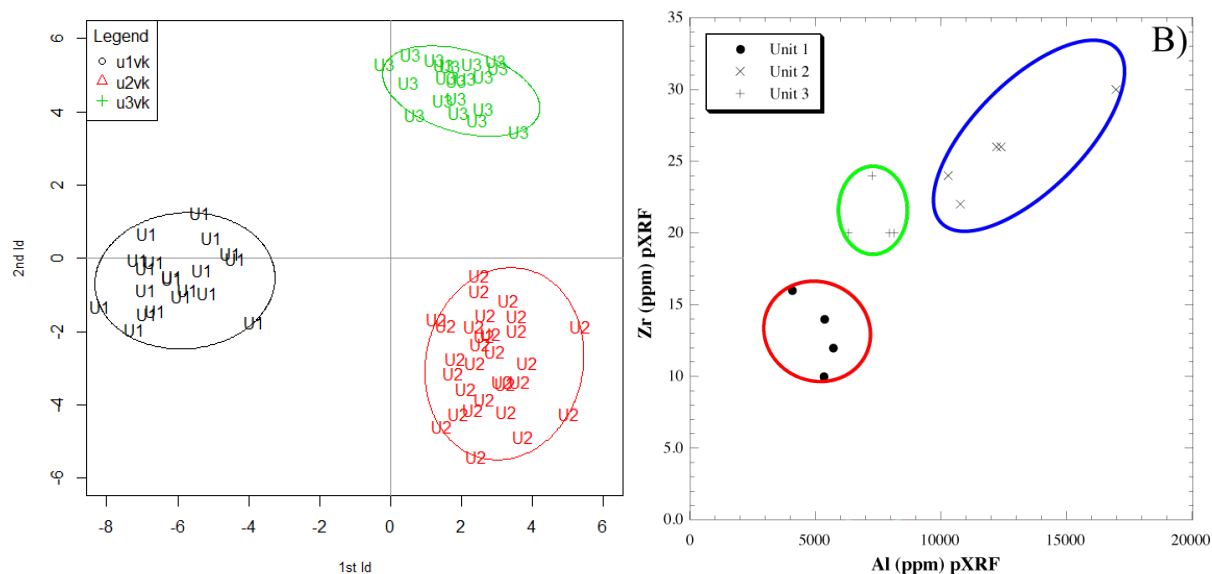
Figure 3: (A) Four element linear discriminant analysis (Fe, Cu, Mg, Al from mining mode), all individual pXRF cut slab analyses plotted: **(B)** Al versus Zr from pXRF mining mode, average of 5 analyses per cut slab.

Summary

We summarize that hand-held pXRF spectrometry can be an effective tool for discriminating kimberlite phases, with pXRF on cut slabs potentially useful to assist in exploration core logging, and pXRF on whole rock powders providing better quality data that would be best applied for ore grade control situations.

References

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