OBSERVATIONS ON THE CORRELATION BETWEEN URANIUM AND THORIUM RADIOELEMENT CHANNELS IN WESTERN AUSTRALIA AIRBORNE RADIOMETRIC SURVEYS.

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INTRODUCTION

In Australia, natural radioelement maps of potassium (K), thorium (Th) and uranium (U) are routinely generated from gamma-ray spectrometry data. Whether airborne or ground, the procedure for converting the gamma-ray spectra from airborne detectors to radioelement concentrations remains the same, as these procedures have been established over the past three decades. The development and acceptance of these procedures has not been one-sided, with various scientists arguing the benefits and shortcomings of many different processing techniques (e.g., Clarke *et al.* 1972, Gunn 1978, Grasty & Minty 1995 Minty 1997, Allyson & Sanderson 1998, Minty *et al.* 1998, Dickson & Taylor 2000, Billings *et al.* 2003). The outcomes of these rigorous scientific pursuits are encapsulated in the International Atomic Energy Agency (IAEA) July 2003 publication *"Guidelines for radioelement mapping using gamma ray spectrometry"*. The radiometric products delivered from all commercial processing companies in Australia reflect these guidelines, with final acquisition products delivered as gridded radioelement maps of %K, eTh, eU, and total count (total gamma-ray dose rate).

Yet, Australian mineral explorers and soil map producers using radiometric data to map regolith are frequently dismayed at the high correlation between the uranium and thorium radioelements in their final data (Bissett *pers. comm.* 2001, George *pers. comm.* 2001). This situation occurs predominately over lateritic terrains. During interpretation, explorers and interpreters rely on the contrast between the radioelement data to highlight boundaries between regolith and soil types, and in combination with digital terrain information, map geomorphological units (Wilford 1992, Bierwirth *et al.* 1996, Cooke *et al.* 1996, Wilford *et al.* 1997, Wilford *et al.* 2001). The strong correlation between the eU and eTh datasets reduces the contrast, and when used to generate a red-green-blue %K-eTh-eU ternary imagery for interpretation, the images tend to be dominated by shades of aqua blue/green and reds (Figure 1).

More perplexing to the explorer/interpreter is the raw data imagery. Raw K, Th and U datasets are generated by summing the count rates within the established (IAEA 2003) energy windows of the K^{40} (%K), Tl^{208} (eTh) and Bi^{214} (eU) elements. This raw data can be presented to the explorer/interpretater as soon as the survey is completed, when instant access to the data is required. The explorer/interpreter treats the raw data in the same manner as final radioelement data, generating ternary red-green-blue imagery from the K-Th-U datasets. While these images are not maps of radioelements, and still contain noise and other contaminants, the overall image contrast is sometimes better in the raw data than in the final processed data (Figure 1).

In this paper, a potential cause for this conundrum is addressed by examining the acquired 256-channel gamma-ray spectrum.

DISCUSSION

During processing, radioelement windows are generated by summing spectra values within specific energy ranges (IAEA 2003). Stripping constants, calculated from annual calibration routines, remove cross contamination between radioelements from the radioelement windows. These radioelement windows provide the basis for determining the equivalent ground values of their radioelements.

Figure 2 highlights the K and U radioelement peak energy anomalies and illustrates the position of the radioelement windows relative to three data sets from Western Australia. Thorium's daughter product Ac^{228} releases gamma-ray energies between 1590 and 1640 keV. This peak lies between the established K and U radioelement windows. However, as demonstrated by Figure 2, the Gaussian distribution of these energies encroaches on the neighbouring radioelement window boundaries under certain geological settings.

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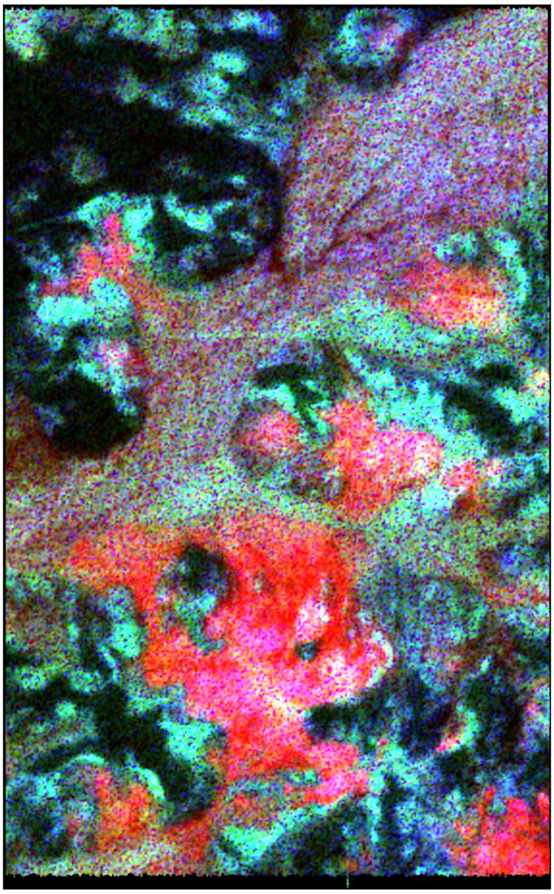

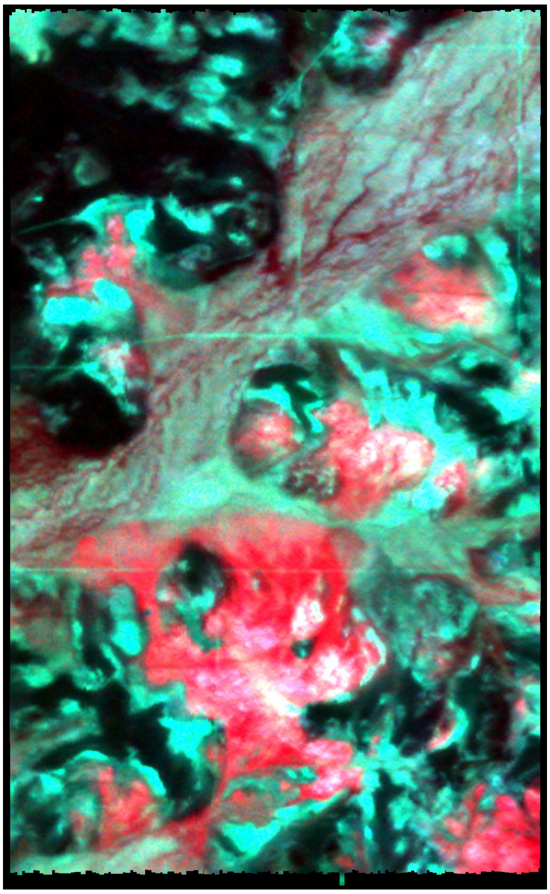

Figure 1: Raw (**left**) and final (**right**) ternary radioelement maps, Yilgarn dataset, Western Australia: potassium in red channel, thorium in green channel, and uranium in blue channel.

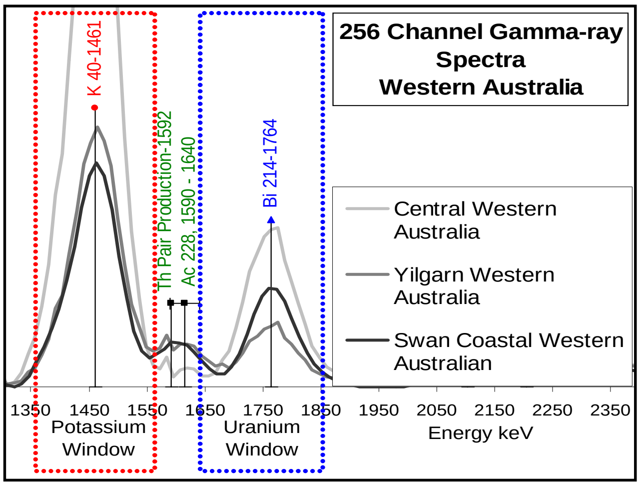

Figure 2: Part of the 256-channel gamma-ray spectra for three datasets in Western Australia: Central, Yilgarn and Swan Coastal areas. Potassium and uranium radioelement window extents are illustrated using broken red and blue lines respectively. The location of radioelement decay peaks are illustrated using solid vertical lines. Amplitude of the spectra has been normalised by the thorium window.

Of the three spectra illustrated in Figure 2, the Yilgarn and the Swan Coastal datasets experienced the colour contrast reduction to shades of aqua blue/green and reds as described previously. The Central Western Australian dataset did not exhibit this problem, and demonstrated good contrast between the radioelement windows. Examining the spectra in Figure 2 with respect to the Ac^{228} peak, in the Yilgarn and Swan Coastal datasets the Ac^{228} peak encroaches into the Uranium window, while in the central Western Australian data set the Ac^{228} peak does not. Note that the spectra in Figure 2 is normalised to Th, such that the height of the Th radioelement window is equal for all spectra. Consequently, the magnitude of the Ac^{228} peak is not dependant on the amplitude of the Th radioelement window, and differs over geological settings. Therefore, the reduced colour contrast expressed in some datasets in Western Australia can be attributed to the failure of the stripping ratio routines to totally remove the variable influence of the Ac^{228} peak from the uranium window.

CONCLUSIONS

In ancient terrains, such as the Yilgarn Craton in Western Australia, there exists a naturally strong relationship between the radioelements Th and U (Dickson & Scott 1997). However, this influence does not explain the observed difference between U and Th radioelements in raw and stripped/processed data.

An examination of the 256 channel spectra from three different geological terrains in Western Australia highlighted an inconsistency between the amplitude and width of the Ac^{228} peak and the amplitude of the Th window. The Ac^{228} peak, located between the K and U windows, is a daughter product $Tl^{208}$of the Th decay series, and was expected to vary with respect to the Th window. However, in Th normalised data, the amplitude and width of the Ac^{228} peak varied independently.

In two Western Australian airborne radiometric datasets, the width of the Ac^{228} peak significantly encroached into the U window. Stripping ratios should remove the influence of the Th decay series from the U window. However, as the influence of the Ac^{228} peak was independent of the Th window, in these examples, existing stripping routines failed to remove these influences, and instead heighten the correlation between Th and U windows.

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