Gamma-ray spectrometric data: modelling to map primary lithology and later chemical mobilisation

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Whereas the accuracy and detail of gamma-ray spectrometric surveys have improved during the last 10 years, techniques for analysing the geological significance of the absolute abundances of K, Th, and U in the acquired data have not. Commonly the final product is a single image showing the concentrations of K, Th, and U as the intensity of red, green, and blue (RGB). This colour image is qualitatively interpreted either by mapping areas of the same perceived colour, or by classifying (either supervised or unsupervised) the K–Th–U space according to pixel concentrations. Both interpretation techniques largely express distances along the path of the average geochemical variation of the data. Differences from this average variation are poorly expressed, although this is often the main interest to the interpreter.

Modelling the K–Th–U data

For major rock groups, the K–Th–U data correlate with one another. Analysing the data in terms of their geological significance depends on choosing other nearly orthogonal axes in K–Th–U space, such that:

- components along the new axes are largely uncorrelated;
- the new axes have meanings with respect to geological processes; and
- the data analysis is preferentially based on the elements measured with the greatest accuracy relative to their abundance range.

The interpretation method advocated herein considers four major groups of rock separately — sedimentary rocks, and felsic, intermediate, and mafic igneous rocks. For each of these groups, variation diagrams (scattergrams) are plotted to show the distribution of pixels in the planes K–Th, K–U, and Th–U. Importantly, the diagrams show a concentration of points along the line of average geochemical variation in K–Th–U space. The first component is the distance along the path of average geochemical variation. Other components are best defined as the anomalous concentration of other elements with respect to this average variation.

If the objective of the interpretation is to define original lithology to aid the construction of a geological map, the images are made generally to emphasise the variation in the first component — i.e., with many subdivisions along the line of average geochemical evolution, and fewer subdivisions in the direction of other components.

If the objective of the interpretation is to identify areas and types of subsequent change in geochemistry, the interpretation strategy depends on the rock group and its history. One strategy is to model the average geochemical variation of the rock group, and separate and map all pixels with compositions that differ significantly from this model. Another strategy is to map the variation in an element that is independent of primary lithological layering (e.g., U in some mafic igneous rocks), and may indicate a process such as hydrothermal alteration.

The components of the data can be displayed as:

- a single component shown as an intensity image;
- three components shown as an RGB image; or
- a geochemical map produced by dividing components into classification layers, and dividing the area into groups of pixels or into polygons.

In modelling spectrometric data, some experimentation is required to determine the optimal size area for a rock group to be geochemically modelled. Useful results can be obtained by modelling an area the size and complexity of the north Pilbara Craton. However, there are real differences in geochemical evolution between some batholiths, and between some mafic igneous sequences. Modelling is more informative if restricted to a rock group with a single well-defined evolutionary path.

Examples of the method

The following examples relate to a gamma-ray spectrometric dataset of the Marble Bar 1:250 000 Sheet area, which mainly comprises exposed Archaean rocks of the north Pilbara Craton. AGSO surveyed this area along flight lines 400 m apart at an altitude of 80 m above ground level. The data have not been improved by analysing all 256 channels to improve counting statistics, nor have they been downward-continued to ground level.

For intrusive felsic rocks (Fig. 18), the amount of geochemical evolution is difficult to quantify in the traditional display (Fig. 18a), in which the differences from the mean geochemical evolutionary path are seen only for rocks having elements with intermediate concentrations. In displays of the modelled data (Fig. 18b & c), the distance along the geochemical evolutionary path, and differences from the path, are visualised separately. Both batholiths depicted in Figure 18b and c are composed of a mosaic of different plutons that differ in their Th and U contents. Whereas the amount of evolution in the Corunna Downs Batholith (in the northeast) increases systematically to the southeast, the Shaw Batholith (in the west) displays no such systematic evolutionary trend.

Analysis of spectrometric data of the mafic flows is complicated by flows being thinner than the pixel size, by adjacent flows commonly differing in composition, by the presence of sedimentary and other volcanic rocks intercalated with the flows, by the terrain effects of float material near strike-ridges, and by the larger analytical errors due to moderately low concentrations of K, Th, and U. For the mafic volcanics of the Coongan Syncline, the deficiencies of a traditional RGB display of K–Th–U data (Fig. 19a) are apparent in a comparison with displays of modelled data (Fig. 19b–d). A measure of geochemical evolution (Fig. 19b) shows significant differences across strike both regionally and locally. Anomalous Th (Fig. 19c) shows that the mafic sequences have characteristic mean Th differences from the mean geochemical evolutionary path. Anomalous U (Fig. 19d) is a measure of geochemical mobilisation, and the high and low values may reflect the location of hydrothermal systems. This figure highlights the area of anomalously high U in the northeast. Note the increasing image degradation from Figure 19b–d owing to low spectrometer count rates over areas of low concentration of Th and U.

The above examples show the power of displaying the spectrometric data analyses with respect to the average geochemical evolutionary path. The data and displays should be useful for analysing geochemical evolution, for lithological mapping, and for identifying areas of subsequent geochemical change.

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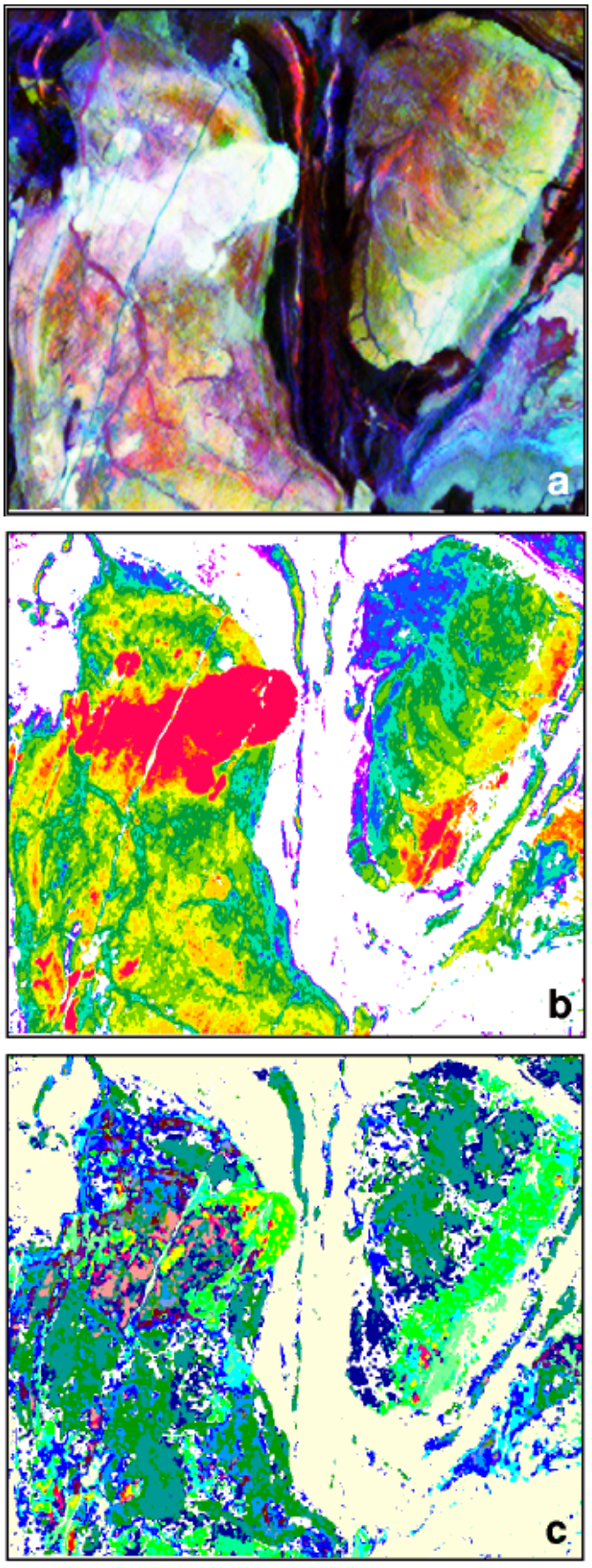

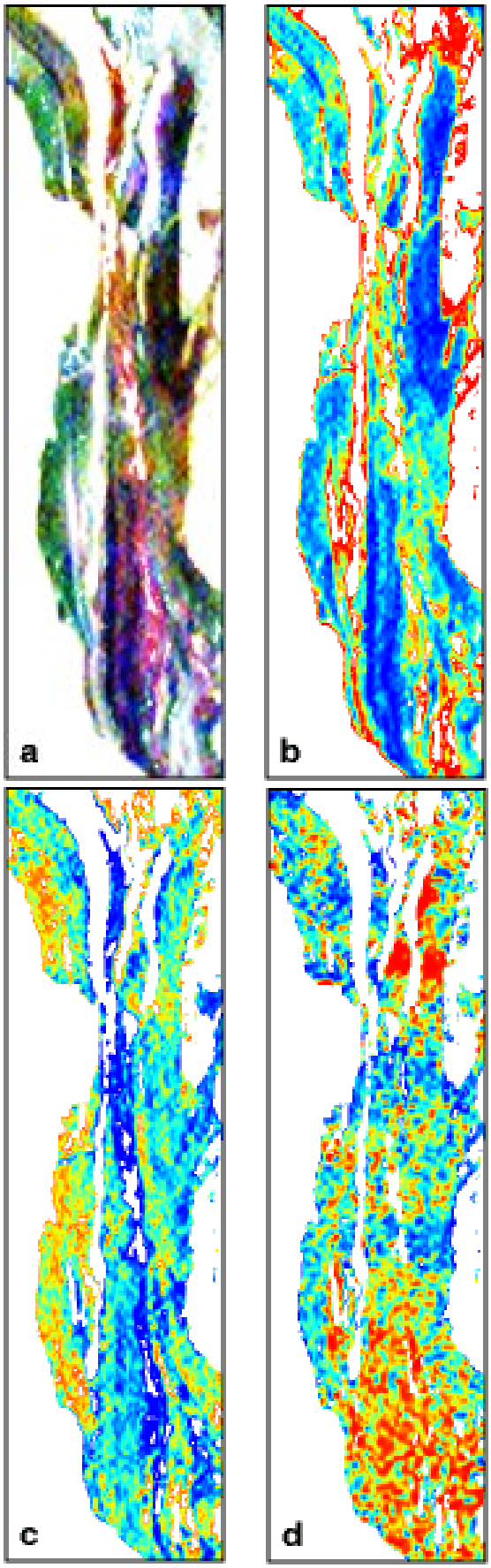

Click on each image for a larger version (Fig. 18. a–156k ; b–122k ; c–136k : Fig. 19. a–74k ; b–68k ; c–60k ; d–66k)

Fig. 18. Felsic igneous rocks of the Shaw and Corunna Downs Batholiths. *(a)* Traditional RGB display of K, Th, and U concentrations. *(b)* Component showing the amount of differentiation: low differentiation shown as blue, and high differentiation shown as red. *(c)* Components showing differences of plus or minus more than one standard deviation from the mean geochemical evolutionary path: K, Th, and U are red, green, and blue respectively. The area in the figure is 84 km wide.

Fig. 19. Mafic igneous rocks of the Coongan Syncline. (*a*) Traditional RGB display of K, Th, and U concentrations. Fig. 19b–d shows separate components as intensity — low values are blue; high, red. (*b*) Component showing the amount of geochemical evolution. (*c*) Component showing difference in Th content from the mean geochemical evolutionary path. (*d*) Component showing difference in U content from the mean geochemical evolutionary path. The area in the figure is 18 km wide.