Revisiting Radiometric Ratios

Isometric Log Ratio Transforms to Balance Potassium, Thorium, and Uranium Ratios in Regional-Scale Mineral Exploration

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Potassium

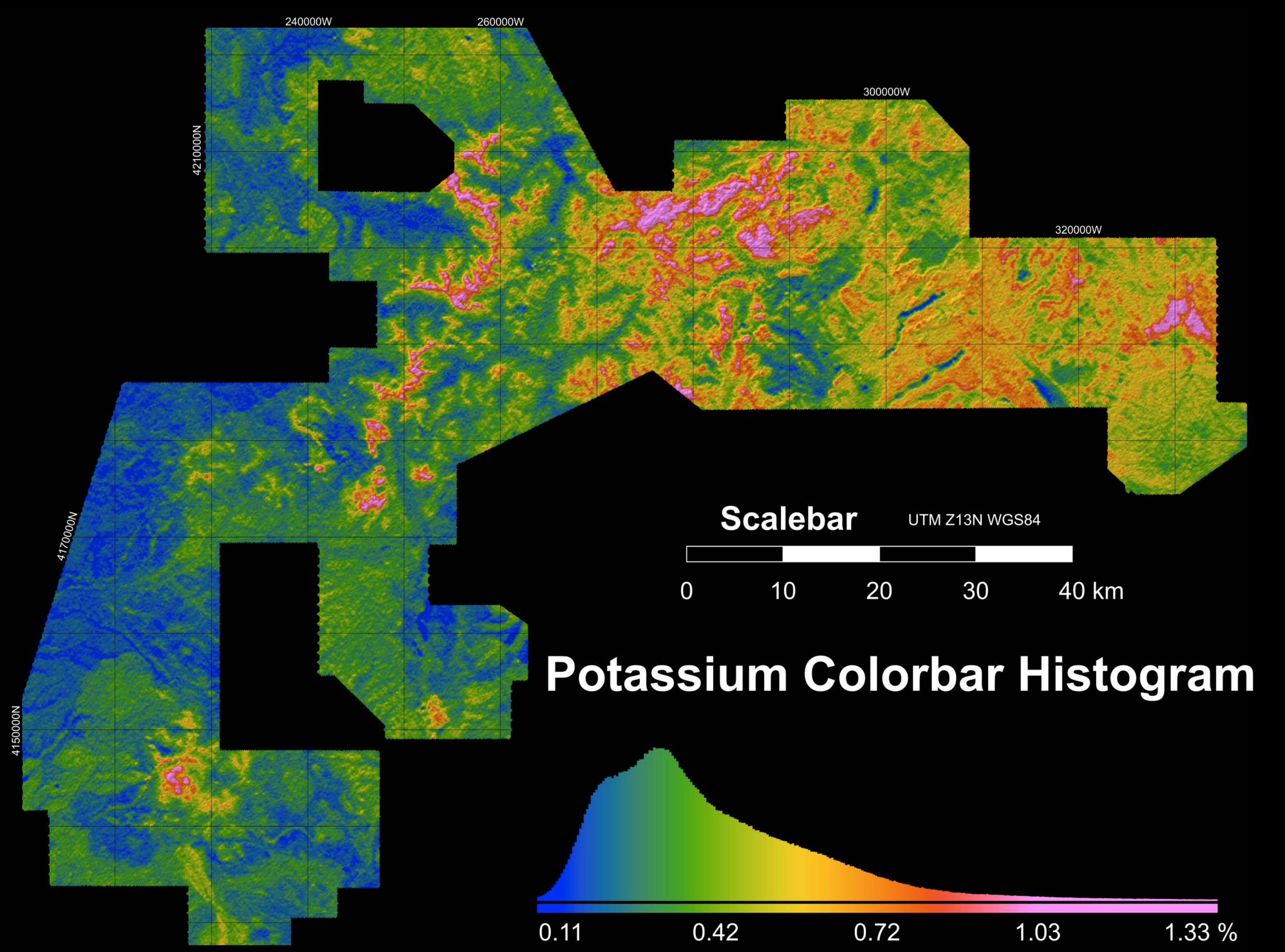


Figure 1 Potassium (K) gridded at 50 m × 50 m in percent. The colorbar is linearly stretched from the first percentile to the 99th percentile. The first and last 0.1% of data points were removed from the distribution shown. All grids are displayed this way.

Equivalent Thorium

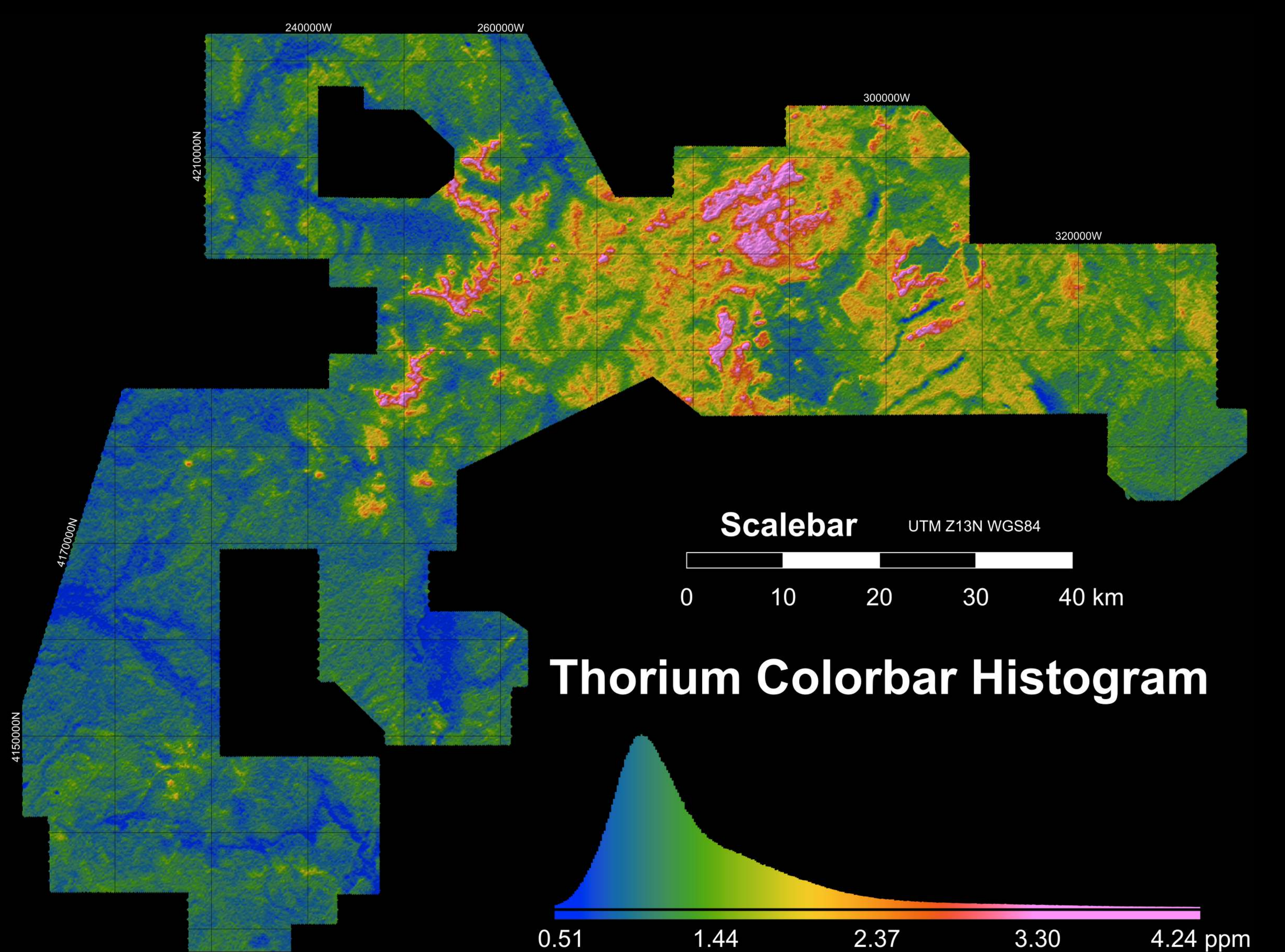


Figure 2 Equivalent thorium (eTh) gridded at 50 m × 50 m in parts per million. Just like potassium, this grid has a strongly skewed parameter space. While anomalously "low" areas are scrunched together, anomalously "high" areas are spread out.

For every compositional measurement, the fractions C_i of the total composition satisfy

$$C_i > 0\%$$

$$\sum C_i = 100\%$$

These constraints pose a major obstacle to interpretation. For instance, fractions C_i cannot vary independently from one another. In radiometrics, this implies an anomaly never occurs just in one grid. Log ratio transforms alleviate this pressure.

Now imagine adding uranium to a rock...

First, the fraction of eU *will increase.*

In response the fractions of K, eTh, *and the non-radioactive portion decrease; however, these do not necessarily decrease by the same amount.*

Thus, variation in eU *can produce an anomaly in* K / eTh. *This is undesirable behavior, and difficult to interpret.*

Log ratio transforms also tackle this issue. The isometric log ratio transform ilr on a 4-D C is

$$\operatorname{ilr} C = \operatorname{clr} C \cdot \Psi^T \in \mathbb{R}^3$$

$$\operatorname{clr} C = \left(\log \frac{C_i}{\operatorname{geo} C} \right) \in \mathbb{R}^4$$

Log Ratio Balanced K vs eTh

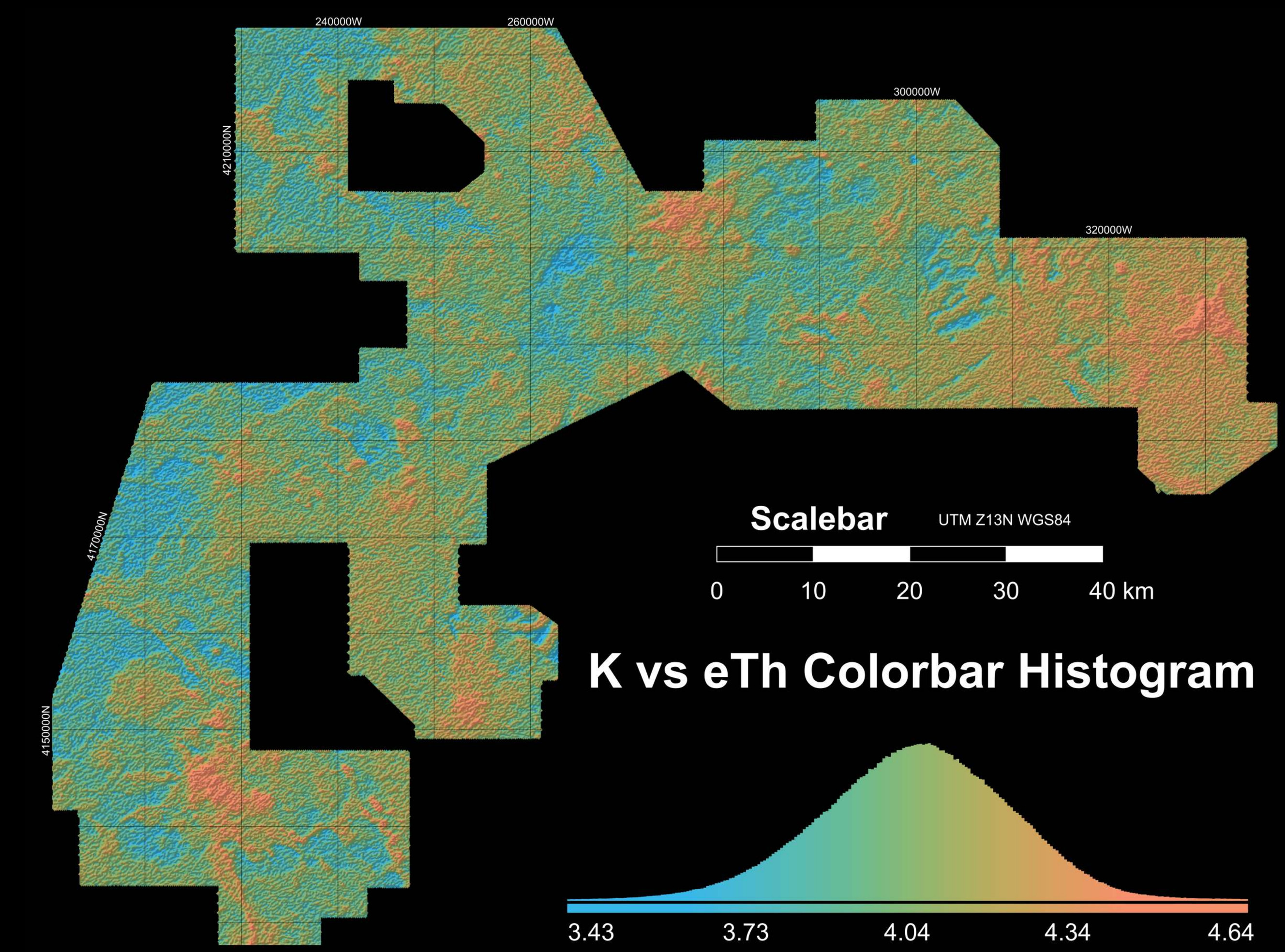


Figure 3 The projection of the ilr transform balancing the contribution of K and eTh fractions. The values are unitless; high values indicate relative high contribution of K; low values indicate relative high contribution of eTh. This quantity is orthogonal (or independent) to variations in eU and non-radioactive rock fractions.

Standard K / eTh

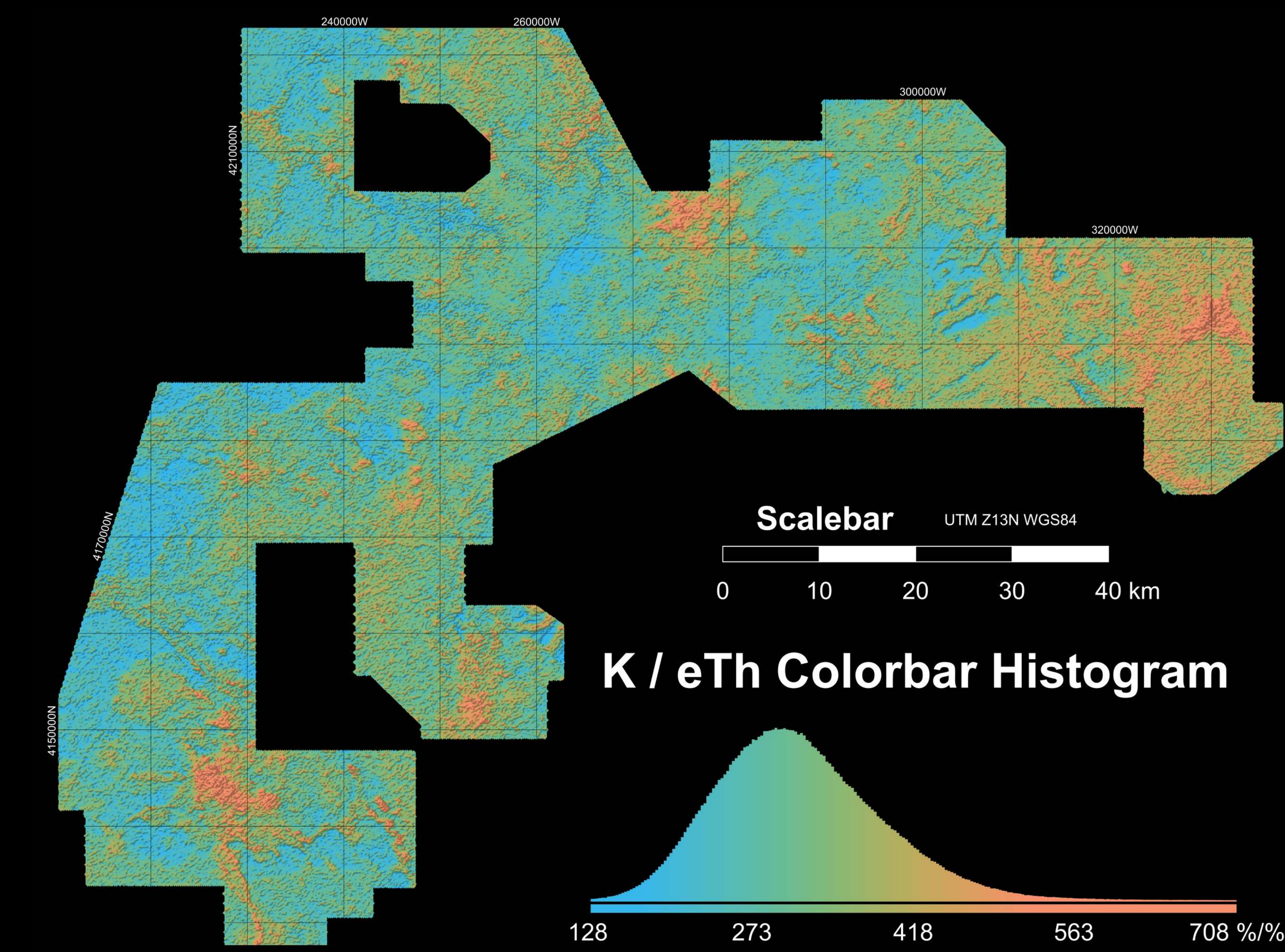
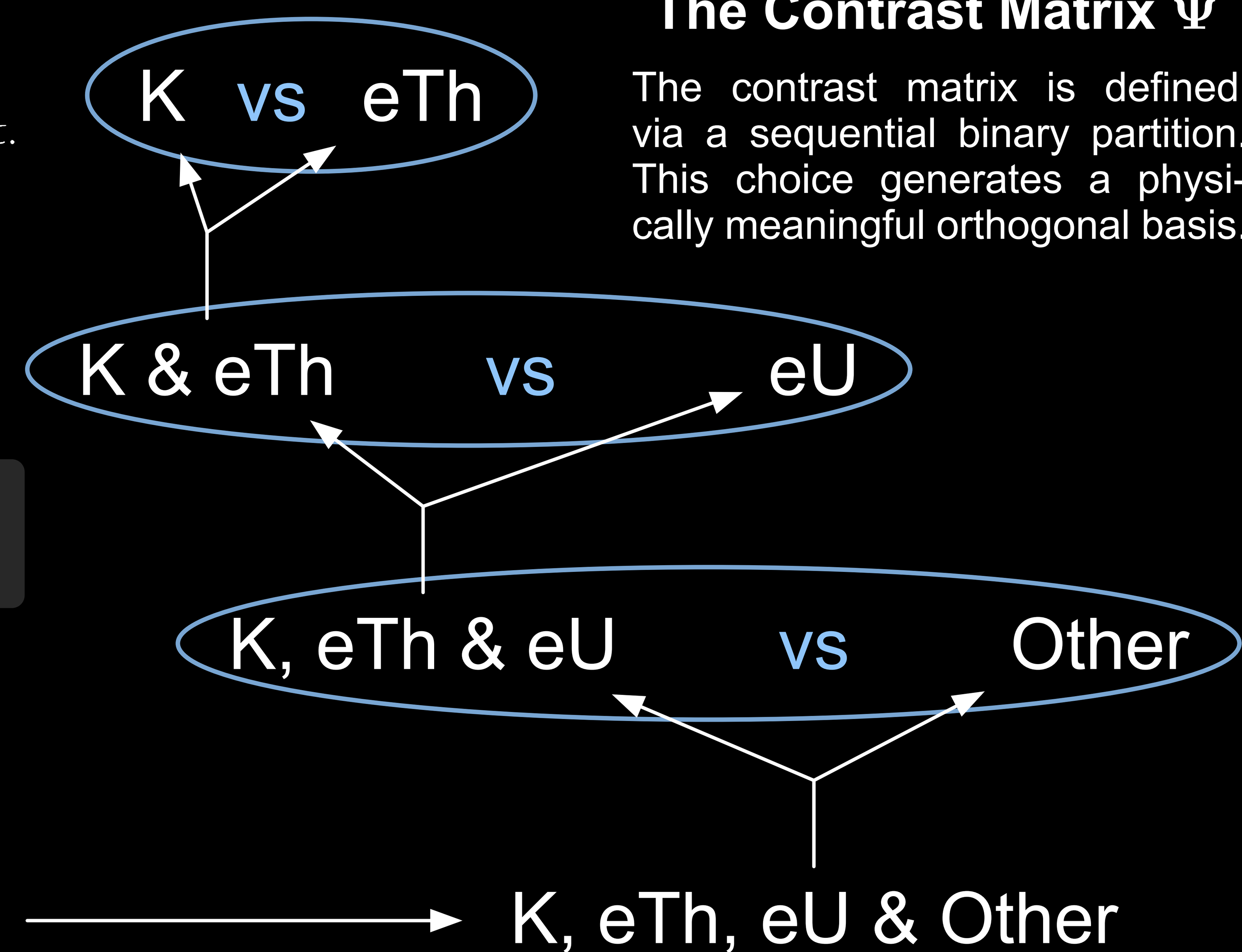


Figure 4 The ratio of K over eTh, a classic metric used to identify hydrothermal alteration in mineral exploration. The distribution of data points remains long tailed. Accordingly, texture of high anomalies are artificially exaggerated relative to the texture of low anomalies. This grid is influenced by eU and non-radioactive rock.

The Contrast Matrix Ψ

The contrast matrix is defined via a sequential binary partition. This choice generates a physically meaningful orthogonal basis.



Conclusions

Familiar radiometric ratio analogues are embedded in isometric log ratio transform space. Extracting these values yields balanced ratios. Experienced interpreters can immediately use the balanced ratios — they look nearly the same as standard ratios! Balanced ratios are normally distributed, not biased high, and completely independent of other components (e.g., eU).

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Computational Statistics in the Earth Sciences
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