Application of Gravitational Curvature Analysis to Structural Domaining of Geology

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Introduction

This poster demonstrates theory and practical application of the use of multi-component Gravity Gradiometry data in visual interpretation.

Concepts

- Gravity Gradient data are delivered as a multi-channel data set with 5 independent components, Gxx, Gxy, Gxz, Gyy, Gyz (Figure 1).
- Only 2 components, Gzz (related to Gxx and Gyy) and Gz (vertical gravity, derived from integration of Gzz or several components) are routinely used in interpretation or modelling.
- Information measured from other channels is not being effectively utilised.
- Many combinations and transformations are possible, but they should convey physical meaning to the interpreter.
- Validation of appropriate transformations and combinations for interpretation is performed through 3D synthetic forward gravity gradient modelling of a Basin/'Basement Interface (on right) , then real examples are shown.

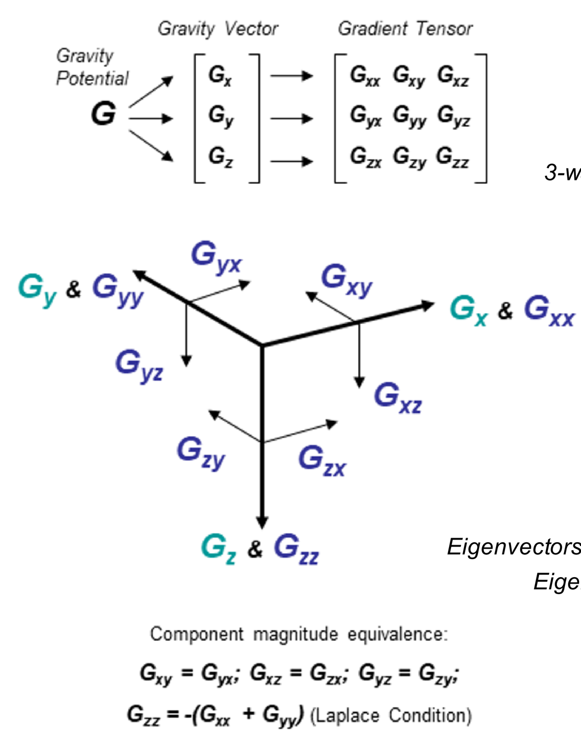


Figure 1. Gravity and Gradient Components

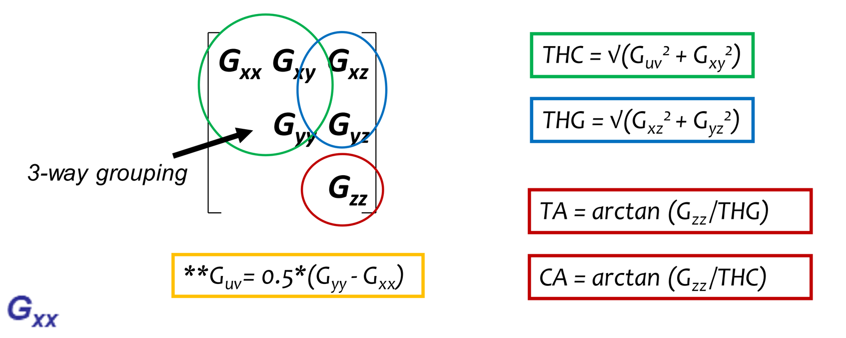


Figure 2. Invariant Groupings of Tensor Components

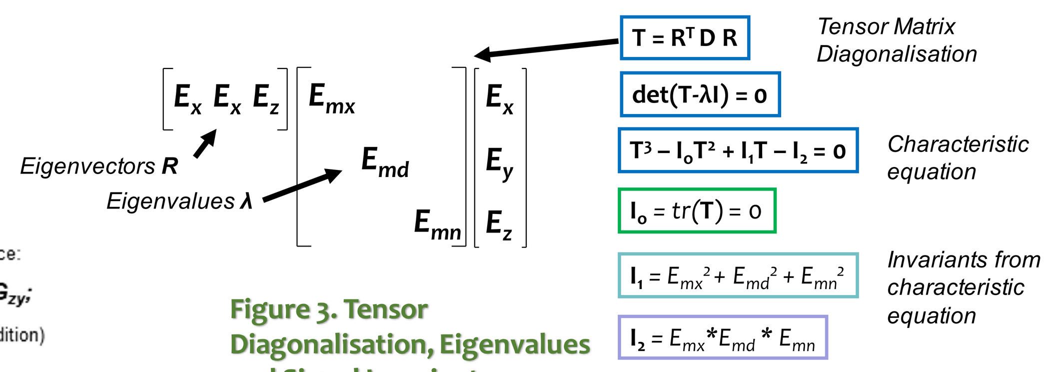


Figure 3. Tensor Diagonalisation, Eigenvalues and Signal Invariants

Gradients and Invariance

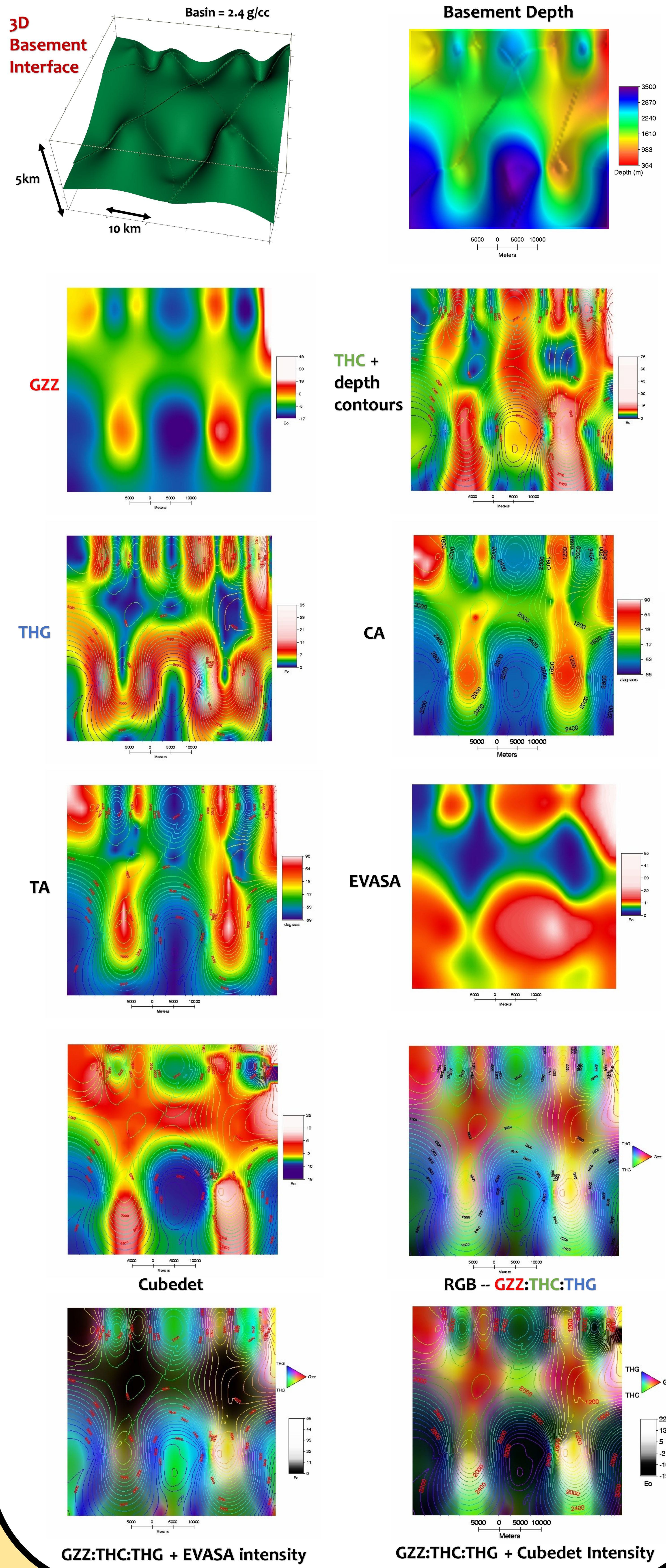
- Makes sense to consider combining horizontal gradient effects
- Combining in certain ways preserves gradient variation – **Invariance**
- Two distinct types together explain horizontal gradient variation:
  - Total Horizontal Gradient (THG)
  - Total Horizontal Curvature (THC)
- In a ratio with the vertical gradient, they explain shape deviation in 3D space (phase)
  - Tilt Angle (TA)
  - Curvature Angle (CA) also known as SHAPE INDEX

❖ Tensor is now grouped in only 3 ways!!! – **Figure2.**

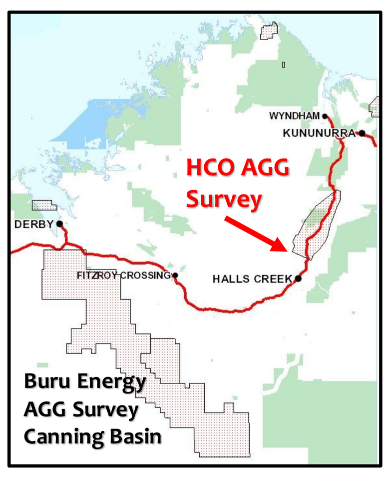
- Symmetric Tensors can be decomposed using diagonalization to produce a form invariant of measurement reference frame – **Figure 3.**
- Eigenvalues represent invariant gradient signal amplitudes of tensor, based only on variance
- Three Signal Invariant functions arise from solution of characteristic equation for diagonalizing a tensor
  - I_0 is the trace of the tensor (Laplace Equation = 0)
  - I_1 is sum of squares of eigenvalues of tensor
  - I_2 is determinant of tensor = product of eigenvalues
- *Taking square root of I1 and cube root of I2 normalises signal to being same as Eötvös*
  - EVASA is square root of I1 and is equivalent to Analytical Signal Amplitude of eigenvalues.
  - CUBEDET is cube root of I2

❖ ALL INVARIANT GRADIENT AND SIGNAL COMPONENTS HAVE A PHYSICAL MEANING AND CAN BE USED IN INTERPRETATION!!!

Synthetic Examples

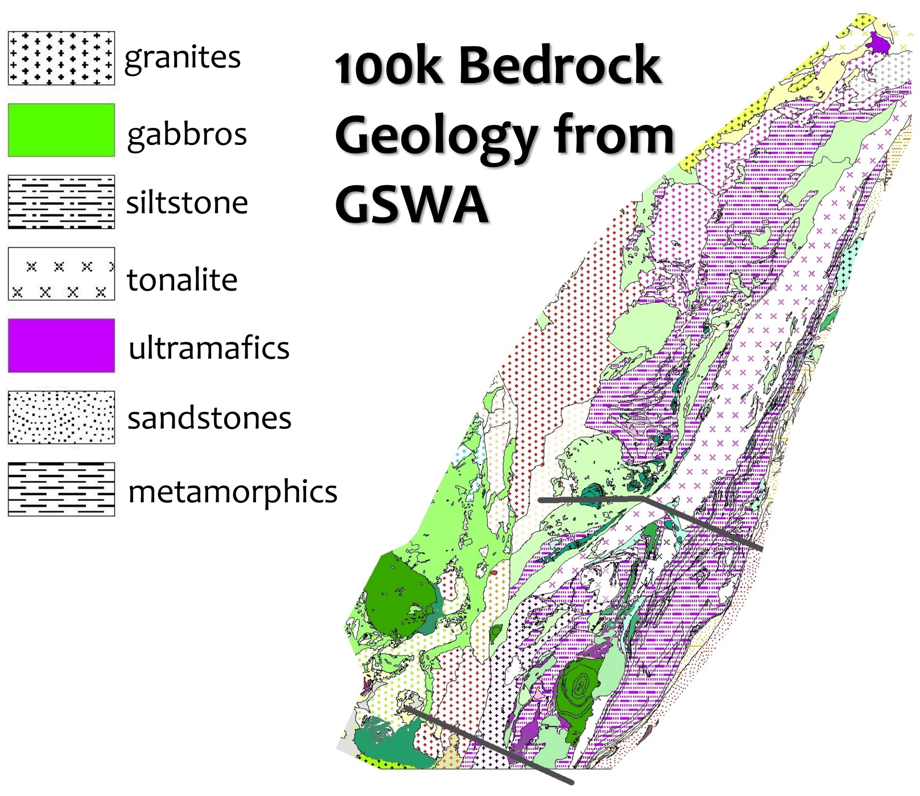


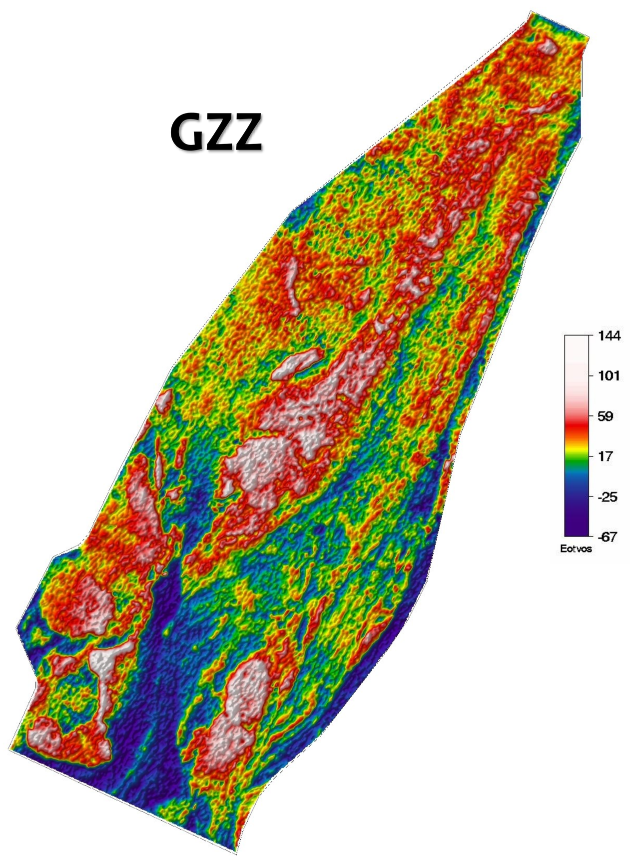
Gravity Gradiometry Imaging Examples

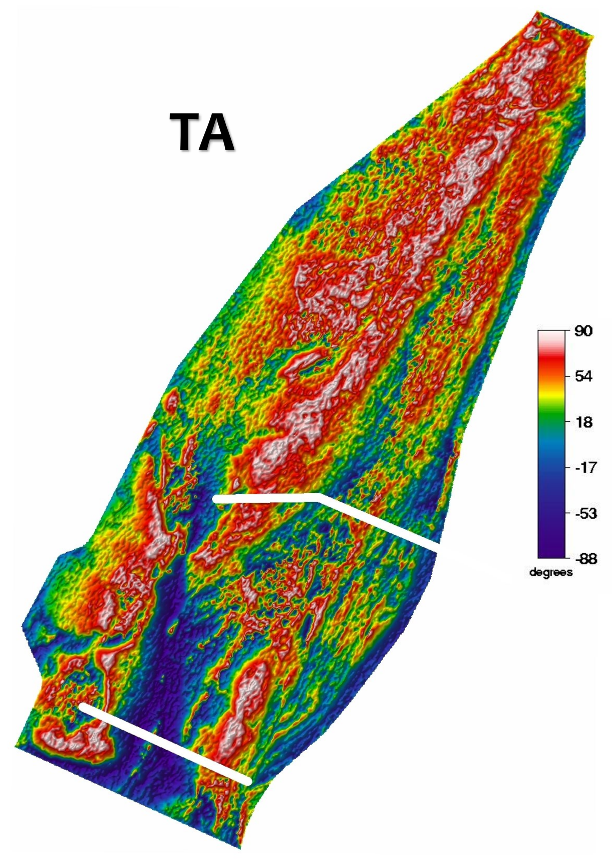


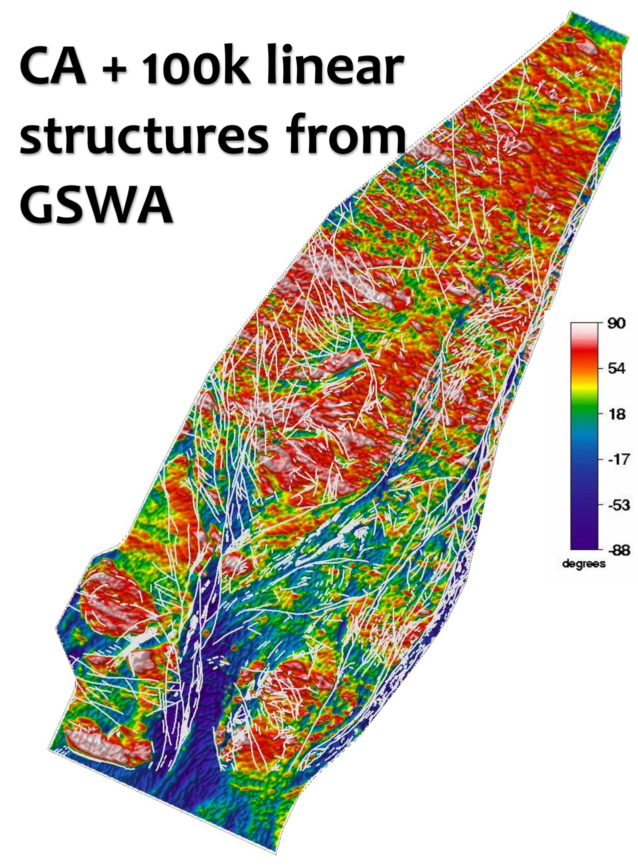
Halls Creek Orogen Falcon AGG Survey

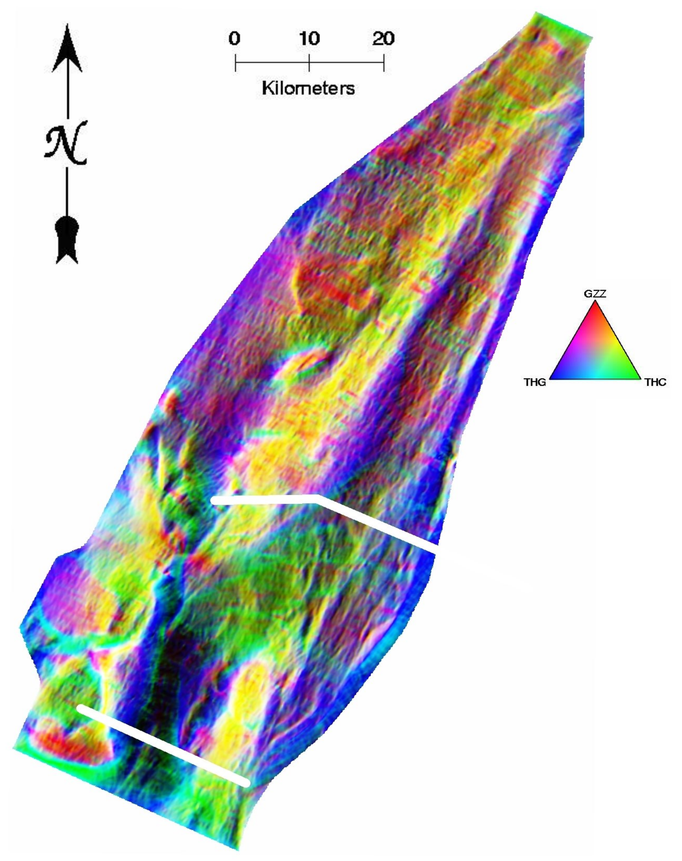
- To evaluate the transformation images, an AGG/FTG dataset had to be chosen that was both publicly available and had well-mapped geology and a structural interpretation.
- Unfortunately, a basin example was not available that met all three criteria, however, the same principles apply and plenty of data now exist.
- Data chosen was from the Halls Creek Orogen between Kununurra, flown as Falcon AGG Survey by Fugro Airborne Surveys in 2009.
- Data is 500m line-spaced and approx. 50km x 140km in dimension. It was reprocessed and imaged by Gondwana Geoscience.



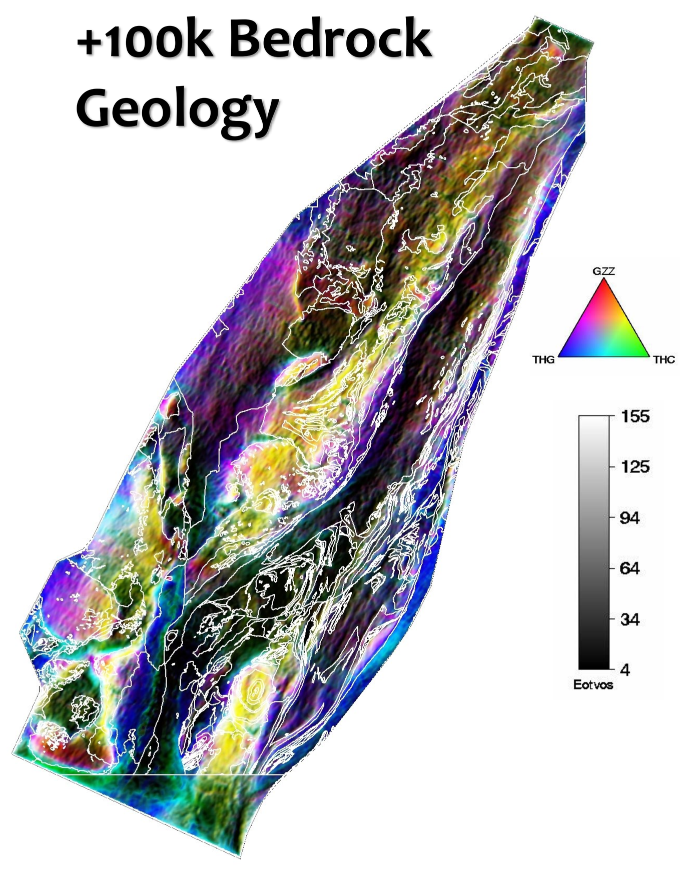




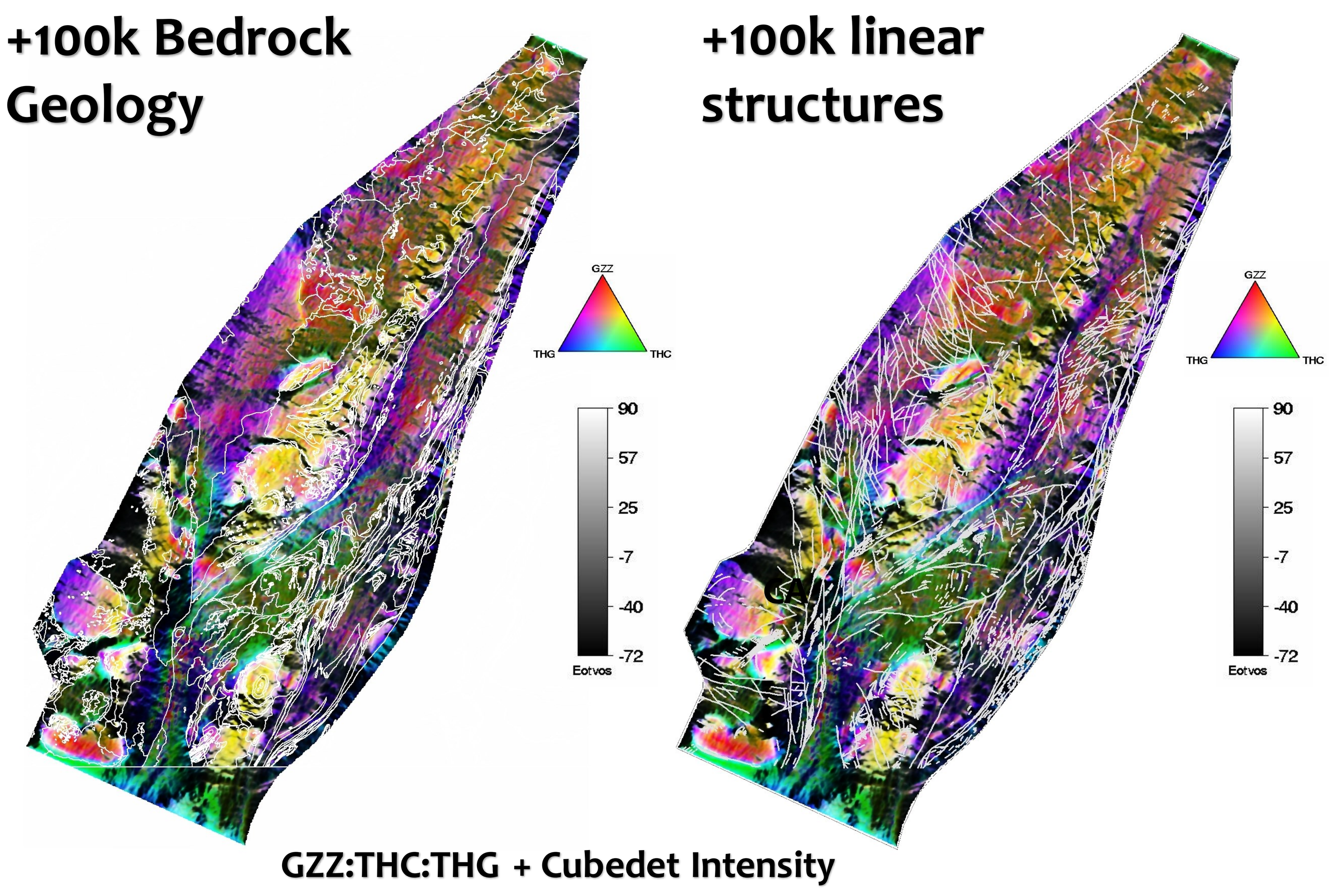




RGB – GZZ:THC:THG

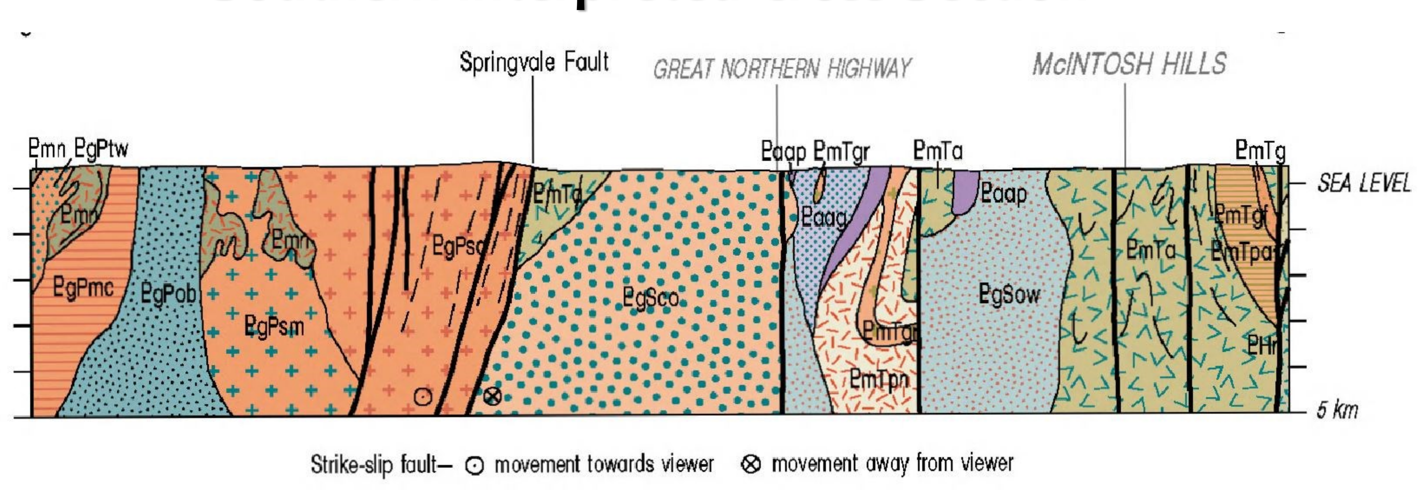


GZZ:THC:THG + EVASA intensity

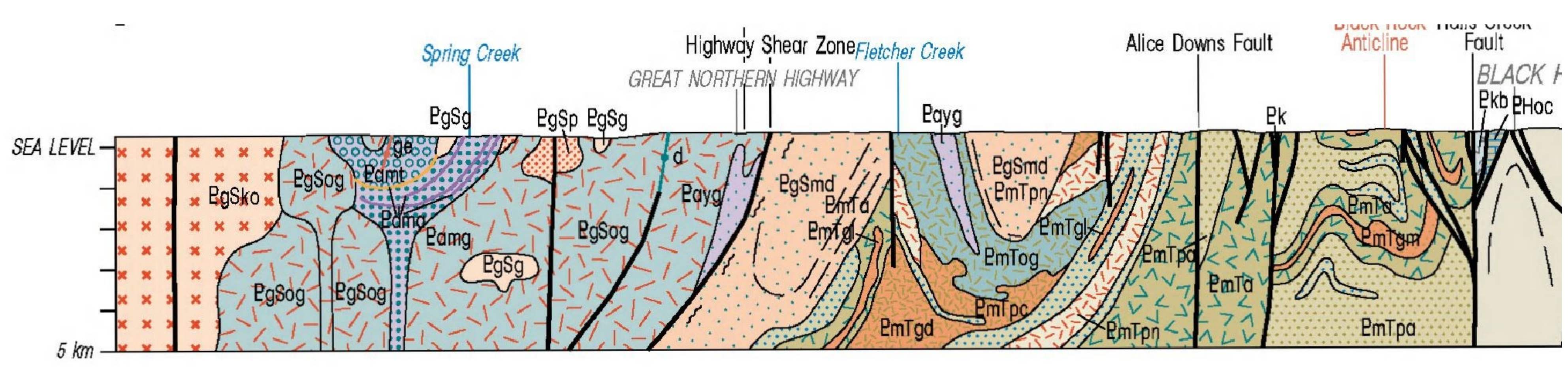


GZZ:THC:THG + Cubedet Intensity

Southern Interpreted Cross-Section



Northern Interpreted Cross-Section



Comments and Conclusions

- The RGB images perform an extraordinary job of domaining the geology, particularly as it was a completely independent mapping exercise performed by the Geological Survey of Western Australia (GSWA) a number of years ago.
- A similar remark pertains to the GSWA 100k structural interpretation.
- Much of the interpretation by the GSWA is based on both airphoto and aeromagnetics as much as ground mapping. Therefore it is clear that the interpretation can be only improved by using the gradiometry data.
- The domaining from the RGB and Intensity images even appears to be differentiating different types of granite!!!
- It is clear that yellow and white colours correspond to high density and anticlinal features
- Cyan/green colours are low density or synclinal features
- Blue colours are steeper slopes and lower density rocks
- Red areas are moderately dense or saddle zones
- Black areas are flat geology and fractures of low density
- Differences in the CA and TA are due to variances in gross morphology from vertical to sub horizontal.

References

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