# Magnetic mentor

*David Pratt*
*Tensor Research*
**E** david.pratt@tensor-research.com.au

## Colour in magnetic imaging

This is the first in a series of short articles on applied magnetic interpretation for mineral exploration students and early career graduates. You may have a solid foundation in the geosciences, but once you start your first exploration job, there will be an unspoken expectation that you'll be proficient in all but the most advanced geophysical techniques. If you don't have access to a mentor, you will need extra time to master your tools of trade and in exploration, spare time is rare.

I have worked on many geophysical consulting projects around the world and have developed numerous software applications for geophysicists. My long career has given me the opportunity to explore what works and what doesn't when it comes to understanding magnetic data. The ideas that I present in this series are based on my experience and that of my colleagues.

I chose colour as the subject for my first article with the goal of challenging familiar processes. We spend a lifetime training our brains and every day we unconsciously apply built-in weighting (biases) to our geophysical work. The act of writing also challenged my own biases and made me revisit the topic of colour lookup tables.



Future articles will explore topics such as depth of penetration, derivative and integral transformations, magnetic remanence detection, magnetite destruction, depth estimation techniques, modelling, inversion, rock properties and magnetic sensor options.

### *Dynamic range and colour*

Modern magnetometers are typically operating in a practical geological range of 0.1 to 10 000 nT or 1 part in 100 000. Let's look at the dynamic range for colour where millions of colours can be presented using the red, green and blue (RGB) components. But, can we distinguish them when using conventional lookup tables (LUT)? I tested that question many years ago and looked at it again using some modern data over magnetic skarns in a QLD Government survey from the Cloncurry region in Queensland.

The four images in **Figure 1** use the hue, saturation and lightness (luminance) colour model (HSL) each with a different number of discrete colour steps (20, 40, 80 and 160). You can see the individual steps clearly in **(a)**, but they are barely visible in **(b)**, and the maximum perceived geological contrast occurs somewhere between 80 and 160 steps. Each of these images uses a linear colour stretch to map the magnetic data to a discrete RGB colour value. This means that the maximum dynamic range we can see with colour is approximately 1 part in 100 or just 0.1% of the dynamic range required to visualise all aspects of the geology. Different colour models can increase the range slightly, but not enough to make a major difference.

**Figure 1(e)** shows the data range distribution for the data subset and the colour range associated with the magnetic skarns is highlighted by the vertical red bar. The data range in this subset is approximately 1800 nT, but much higher for the full survey area.

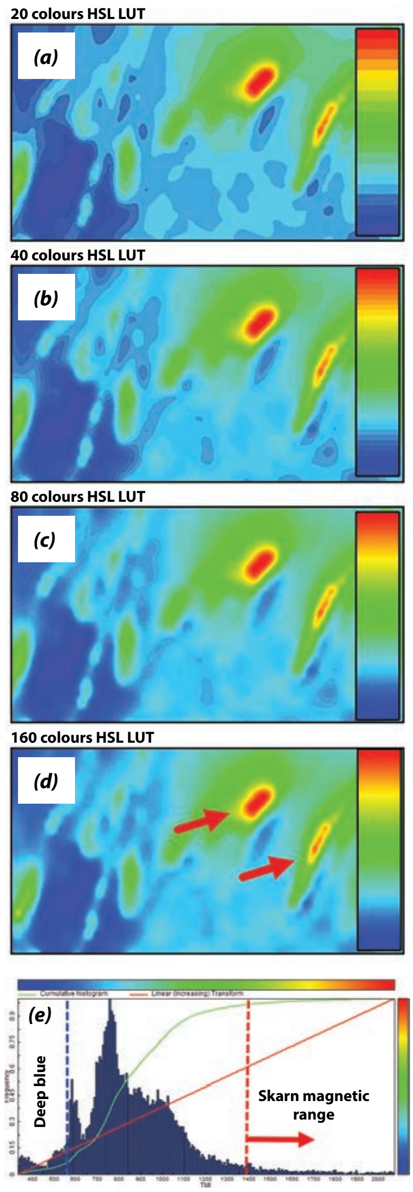


**Figure 1.** *TMI linear colour stretch (HSL LUT) with 20, 40, 80, 160 levels (a, b, c, d). Colour legends are shown on the right of each image. Red arrows (d) show the central location of magnetic skarns. (e) shows the data distribution with the colour mapping versus the magnetic data range where the skarns are mapped to colours from the top of green through to red.*

### *Expanding the dynamic range*

It is obvious already that no colour image can convey all the geological information present in the magnetic grid, so other techniques are required to see more of the geological information within the 1:100 000 dynamic range of the magnetic data. There are many processes in our toolbox to achieve this end.

## Magnetic mentor

A popular way of expanding the perception of detail is the histogram stretch where the data range is allocated according to the data distribution. Typically, large areas of low contrast have a broader colour range allocated to them, and the regions of high amplitude have narrower colour ranges.

**Figure 2(a, b)** shows a comparison between a linear colour stretch and a histogram stretch with the colour legends highlighting the difference in distribution. While useful for the enhancement of low contrast regions of the image, the non-linear stretch in **Figure 2(b)** has reduced our ability to see the edge of the two skarns.

The concept of hill shading for geophysical data was introduced in the 90s to increase the dynamic range and then extended to include illumination so that edges and linear features could be enhanced from two directions. The effect is similar to a horizontal derivative, but the dynamic range is limited by using the angular difference between the illumination and terrain surface normal vectors. A user-controlled amplifying factor is applied to assist with geological detail across the data range. You can literally make an ant hill look like Mt Everest, which is useful for examining detail, but distorts your perception of the high amplitude areas.

Note that the hill shading modifies your perception of colour by modifying the luminance. It is also easy to exaggerate the perception of amplitude which causes a loss of fine detail in shadows and highlights as seen in **Figures 2(c)** and **2(d)**. How you use shading depends on the geology, but I would recommend using the least exaggeration required to visualise the target features.

### *Exploring colour lookup tables*

While preparing this first article on applied magnetic methods, I decided to take another look at the work done by Peter Kovesi at the Centre for Exploration Targeting on CET Perceptually Uniform Colour Maps. His LUTs are available in many imaging applications. Peter's site is worth a visit because he illustrates explanations of colour perception. On reading and testing Peter's example LUTs, I was shaken out of my comfort zone of years working with the pure HSL colour model, which has two important limitations:

- Deep blue is too dark and limits visualisation in magnetic lows and subtle remanence detection in lows.
- Light green occupies more than 30% of the colour range.

By way of example, **Figure 3** compares a grid from the South Australian Gawler Craton survey imaged using the HSL **(a)** and CET-R4 **(b)** LUTs. I made minor modifications to both LUTs by decreasing the deep blue range and increasing luminance in CET-R4, which decreases the slightly dull or muddy perception. You can see there is more interpretable geological information with the CET-R4 lookup table. This improvement is partly due to the perceived colour linearity and also the ability to increase the shading and illumination contrast.

### *Summary*

What can we learn from these examples?

- Colour is excellent for comparison of TMI amplitudes from one part of the survey to another.
- It provides a useful separation of magnetic rock units.
- The dynamic range of colour for recognition of geological features is ~ 1 part in 100, compared with the dynamic range of magnetic data of ~ 1 part in 100 000.
- The contrast can be increased slightly with different colour lookup tables.
- Local enhancement technique is driven by geological objectives such as direct target detection, structures, geological boundaries, alteration or magnetic remanence.

If you are reading the printed copy of *Preview*, I would recommend checking the online version because colours and shadows may be more vibrant on screen. Also, the data used in these examples is available to download from the Geoscience Australia GADDS site.

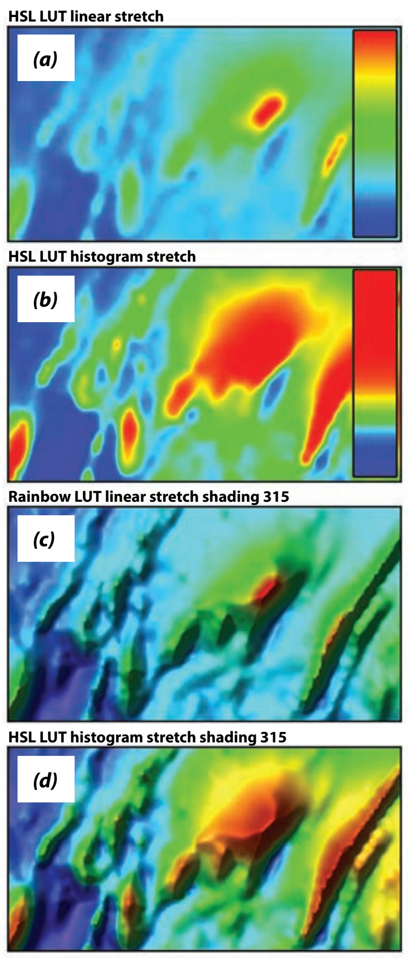


**Figure 2.** *Comparisons of linear and histogram colour stretches without shading (a, b) and illuminated from 315º (c, d).*

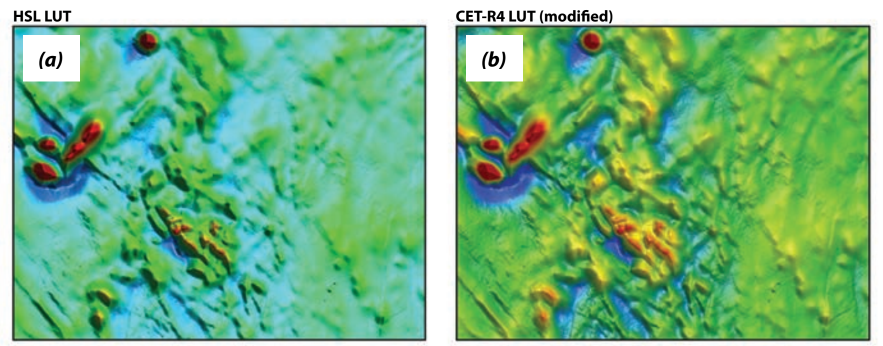


**Figure 3.** *Comparison of -Bzz tensor grid data derived from the South Australian Gawler Craton magnetic survey comparing the HSL (a) and CET-R4 (b) colour LUTs.*