Project summary: LiDAR acquisition and interpretation in northeast Tasmania

by D. C. Green and D. J. Bombardieri

Tasmania
Explore the possibilities
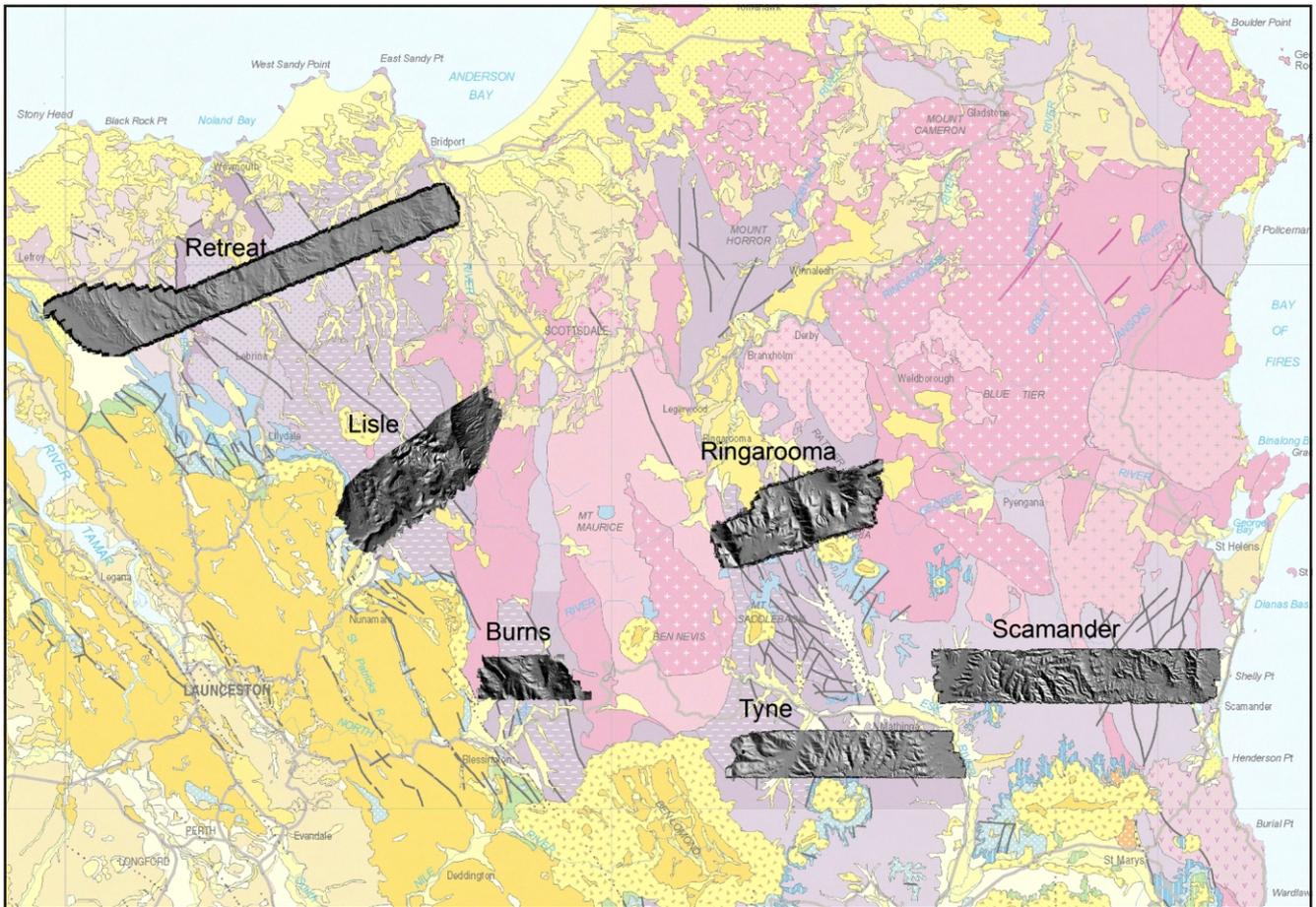
Figure 1
Locality of the LiDAR surveys. Hill shaded DEMs are plotted on 1:500 000 scale geology.

Abstract

LiDAR (Light Detection And Ranging) surveys were flown over forested parts of northeastern Tasmania underlain by Mathinna Supergroup rocks as part of the *TasExplore* project in 2008. The surveys were processed to produce six 0.5 m resolution Digital Elevation Models (DEMs) covering a total of 500 km². The DEMs are rich in geological information, including bedding traces, faults, and mineral exploration and mining excavations.

Introduction

As part of the *TasExplore* project of northeast Tasmania, LiDAR surveys were flown over transects of Mathinna Supergroup outcrop (fig. 1). The aim of the surveys was to produce LiDAR Digital Elevation Models (DEMs) of forested terrain and reveal the underlying stratigraphy, folding and faulting in the Mathinna Supergroup.

LiDAR consists of a pulsed laser ranging system mounted in an aircraft equipped with a precise kinematic GPS receiver and an Inertial Navigation System (Wehr and Lohr, 1999). Each laser pulse sent towards the Earth is reflected back towards the aircraft where it is captured. Using a rotating mirror inside the laser transmitter, the laser pulses are made to scan back and forth producing a saw-tooth pattern of LiDAR hits along the flight path.

Accurately timing pulses give the distance to the reflecting features. After correcting for the laser and aircraft orientation and GPS position, the location of the reflector can be determined accurately. The located return pulses create a 3-dimensional 'point cloud' consisting of reflections off a variety of features, which are classified into ground and other features. Ground features can be interpolated to produce a DEM under a forested canopy (Nyborg, Berglund and Triumf, 2007).

Inspection of pre-existing Forestry Tasmania LiDAR DEMs indicated that geological features such as bedding traces could be seen in high resolution DEMs. However it was also noted that historic mechanised forestry or agricultural operations severely degraded the geological features. The northeastern Tasmania surveys were therefore designed to cover significant transects underlain by Mathinna Supergroup (especially areas targeted for geological mapping as part of the *TasExplore* project), while avoiding large areas of mechanised ground disturbance. Google Earth imagery was found to be useful in identifying areas of potential disturbance.

Dimap (Digital Mapping Australia) was contracted to complete the northeast LiDAR surveys through a joint project with Forestry Tasmania. The planned surveys comprised six transects totalling 453 km² (1254 line kilometres), but the resultant area surveyed was somewhat larger due to the contractor incorporating a margin.

The data from these surveys, including processed DEMs and images, are available from Mineral Resources Tasmania.

The surveys

All six surveys were flown in November 2008 using a Lite Mapper 5600 system mounted on a light fixed-wing aircraft. The survey specifications were:

- ☐ LiDAR data capture rate for each area averages two points per square metre.
- ☐ LiDAR point records include spatial position (x, y, z), intensity, number of returns of given pulse, return number, scan angle, point source ID, classification (Unclassified, Ground, Low Vegetation, High Vegetation) and GPS time.
- ☐ Data provided in .las format (www.lasformat.org) and in 1 km ⨉ 1 km tiles.
- ☐ All spatial data supplied in UTM coordinates in the Geodetic Datum of Australia (GDA 94), and using the Australian Height Datum (AHD 1983).
- ☐ Minimum data capture rate for any part of the required areas of one point per square metre.
- ☐ Spatial position of each point within 15 cm of the true position in the x, y, and z dimensions.
- ☐ No more than 0.01% of those points classified as Ground incorrectly classified.
- ☐ Overlap between swathes averages 30%, with a minimum of 10%.
- ☐ Maximum LiDAR scanning angle not exceeding 30° off nadir.
- ☐ No fog, smoke or cloud to interfere with the data capture.

Lines were flown at ~1200 m terrain clearance with 20° maximum off-nadir angle, resulting in a ~900 m swath width. A side lap of ~30% ensured complete coverage and provided additional point density in areas of low relief.

The *TasExplore* project benefited from access to Forestry Tasmania LiDAR DEMs for the Ben Nevis area and an extended area at Lisle, and these data are available for purchase from Forestry Tasmania. Dimap also flew a speculative swath of infra-red hyperspectral imagery over the Golden Gate mine. The data has potential for mineral mapping and is available for purchase from Dimap.

Processing

LiDAR returns classified as ground points had an average spacing of 1.0 m (1.0 points per m²). ERMapper and ESRI ArcMap Spatial Analyst tools were initially used to trial a large number of interpolation methods to create DEMs for a 500 m ⨉ 500 m representative area at Joy Creek. The spline method was chosen to optimise micro-topography without resulting in noise that distracted from identifying curvi-linear features.

The interpolation parameters for the spline interpolation were chosen by comparing the results of a large number of

trials on additional representative areas in the Scamander survey and in a 115 m 100 m area southeast of the Golden Gate mine (fig. 2 shows the location of the Golden Gate test area and fig. 3 illustrates the results of some of the interpolation techniques tested). The best interpolation method was determined by empirically choosing the hill shaded DEM that enabled easiest identification of extended bedding features. While most bedding features are obvious in all hill shade images, the most subtle and extended bedding features were found in images of interpolations that included low signal as well as significant noise. The best results allowing identification of the most subtle geological features were provided by interpolating a 0.5 m grid using the ESRI ArcMap tension spline method with tension = 1 and number of neighbours = 30. The number of neighbours was chosen so each local spline included points from at least five down-track scan lines.

Hill shade images were built using the ESRI ArcMap Spatial Analyst hill shade surface tool with sun azimuths of 045 and 315 (true) and an inclination of 45°. Bedding traces are clear in much of the surveyed area, as well as faults and evidence of mineral exploration and mining, such as pits, trenches, access tracks and mullock fans adjacent to adits and shafts.

Results

All six surveys returned useful high resolution DEMs with most hill shaded DEMs characterised by numerous geological features, typically bedding traces. The vast majority of traces were linear, but evidence of folding and faulting was commonly apparent as juxtaposed non-parallel bedding traces as well as occasional traces of fold hinges (fig. 4). Various image processing techniques were used to assist geologists identify geological features, with the most useful being interactive DEM hill shading in the ERMapper environment, images of slope, various effects tools combining complementary DEM hill shades in the Arcmap environment, and superimposing semi-transparent curvature in colour on a DEM hill shade (fig. 5).

Most of the surveyed area was covered in eucalyptus forest with little ground cover, allowing LiDAR light pulses access to the ground surface. The Ringarooma survey featured large areas of rain forest species, probably with significant ground cover, and this particular survey returned a noisy DEM characterised by few obvious geological features.

Cracknell (2009) and Cracknell *et al.* (2013) evaluated the northeast Tasmania LiDAR data for the extraction and interpretation of geological information. The work was partly sponsored by MRT. Cracknell critically appraised the LiDAR ground point data, including an assessment of striping, mound and step artefacts. Cracknell then used image enhancement techniques (e.g. curvature) together with manual identification of geological features and automated plane-fitting to extract structural bedding data, which was used to interpret the three-dimensional geology of the Tyne area (Cracknell, 2009).

Areas of historic mineral exploration and mining activity featured a wide range of man-made ground disturbance features such as tracks, pits, trenches, other excavations and mullock heaps clearly visible in the hill-shaded DEMs (fig. 6). This has allowed MRT to refine the location of mineral prospects and mines and enabled more specific location of individual workings.

References

Cracknell, M. J. 2009. *Remote sensing geological structures using high resolution Digital Elevation Models*. B.Sc. (Hons) thesis, University of Tasmania : Hobart.

Cracknell, M. J.; Roach, M.; Green, D.; Lucieer, A. 2013. Estimating bedding orientation from high-resolution Digital Elevation Models. *IEEE Transactions on Geoscience and Remote Sensing* 51:2949–2959.

Nyborg, M.; Berglund, J.; Triumf, C. 2007. Detection of lineaments using airborne laser scanning technology: Laxemar-Simpevarp, Sweden. *Hydrogeology Journal* 15:29–32.

Wehr, A.; Lohr, U. 1999. Airborne laser scanning — an introduction and overview. *ISPRS Journal of Photogrammetry and Remote Sensing* 54:68–82.

[15 November 2013]

Figure 2

*Locality of the small area southeast of the Golden Gate mine used to test interpolation methods
is illustrated by a DEM hill shade outlined in red on a 1:25 000 scale geology background.
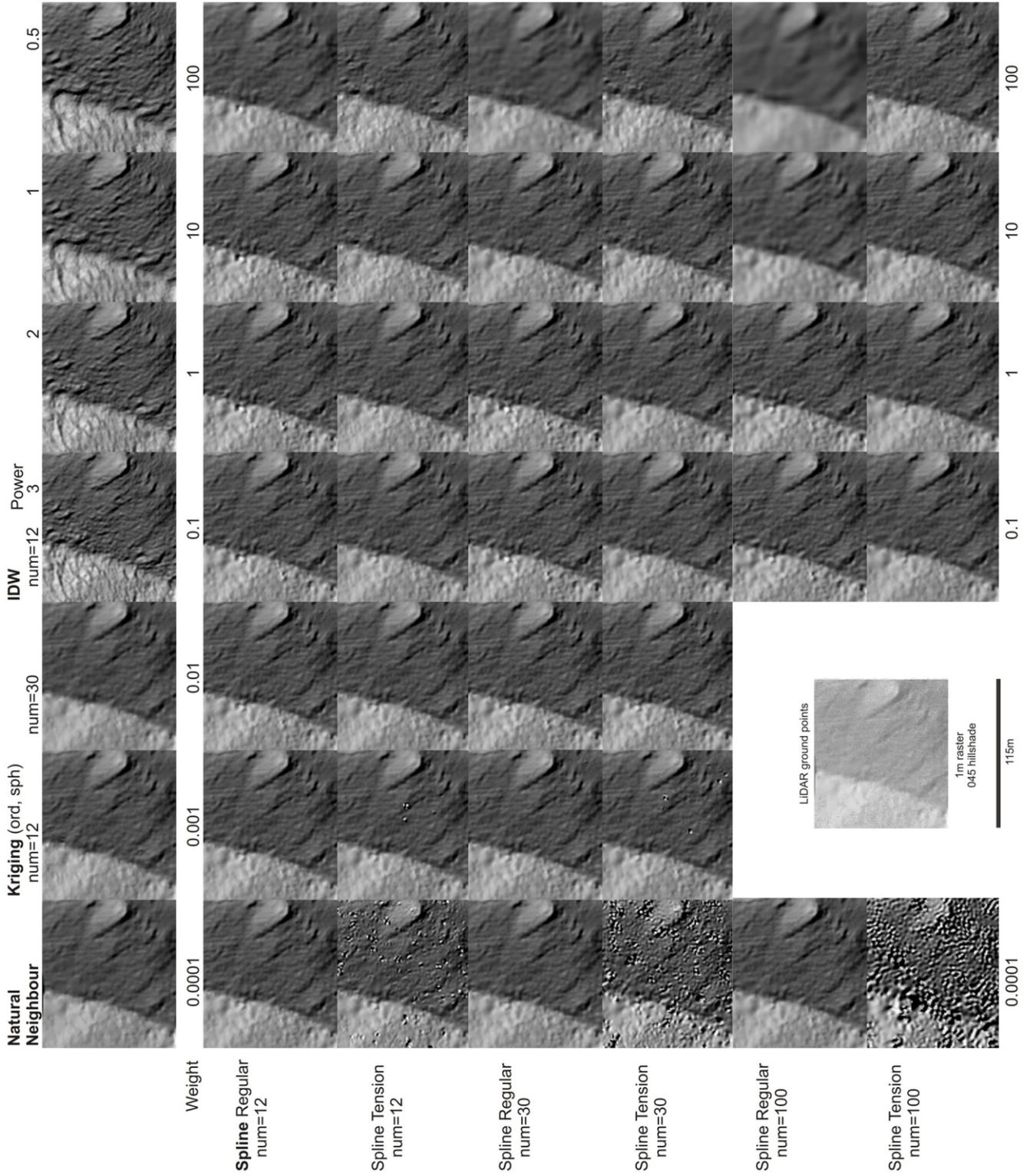The area is bounded by 576027 mE, 5405868 mN; 576144 mE, 5405971 mN (GDA94).*

Figure 3

Poster illustrating hill shades for DEMs derived from LiDAR ground points by a number of interpolation methods. The nomenclature follows ESRI documentation. The location of the test area is illustrated in Figure 2.
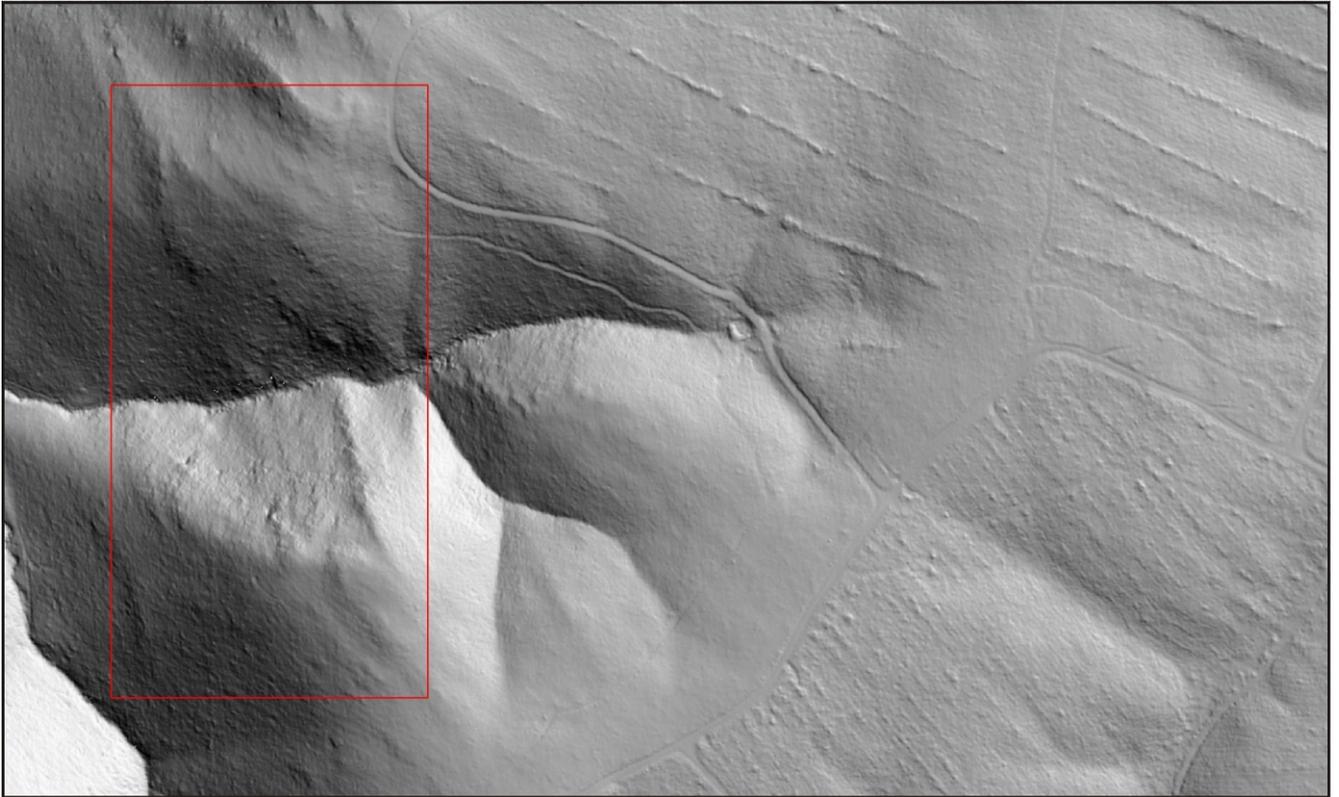
Comparison of hill shades illustrating various ArcMap interpolaters
LiDAR DEM: East Golden Gate area, Mathinna

Figure 4

Hill shaded DEM of an area southeast of the Golden Gate mine illustrating wind rows characteristic of mechanised forestry operations. Geological features within the red outline include dipping beds crossing a small valley and a fold hinge towards the top. The width of the image is 1.2 kilometres.

Figure 5

Images illustrating the revealing nature of LiDAR in the Joy Creek area.

(a) *1991 1:25 000 scale geology showing little detail.*

(b) *Aerial photograph showing the continuous forest cover in the area.*

(c) *LiDAR DEM coloured by elevation (432 to 794 m) with superimposed 8 m contours.*

(d) *Image of the DEM illuminated with a Lambertian hill shade from the southeast, illustrating typical linear bedding features.*

(e) *Image of the slope derivative of the DEM, illustrating how the technique highlights many geological features. In this image slope increases from white to black.*

(f) *Bedding features are highlighted in this image combining coloured DEM curvature (clipped to data with positive curvature only) with 75% transparency and grayscale DEM hill shade. The width of each image is 1.5 km.*
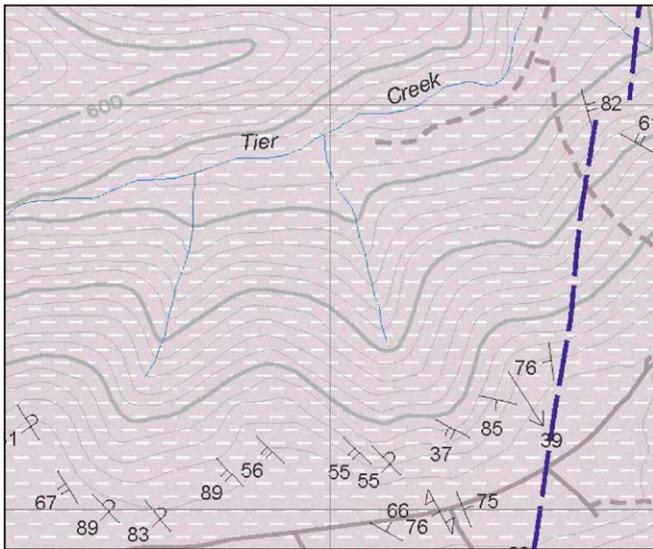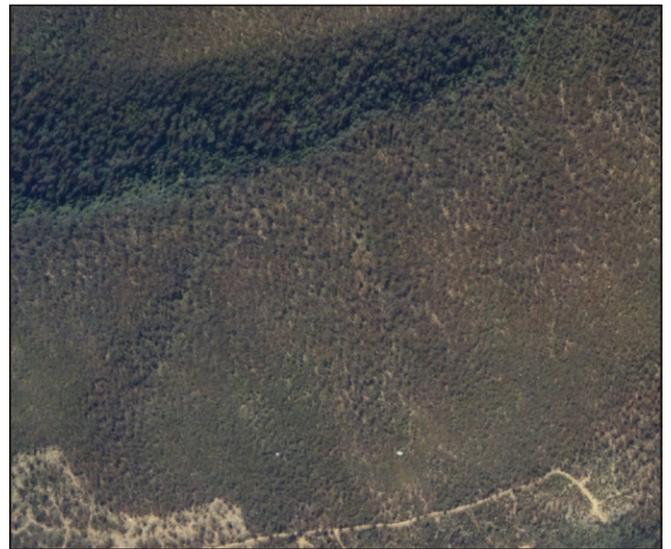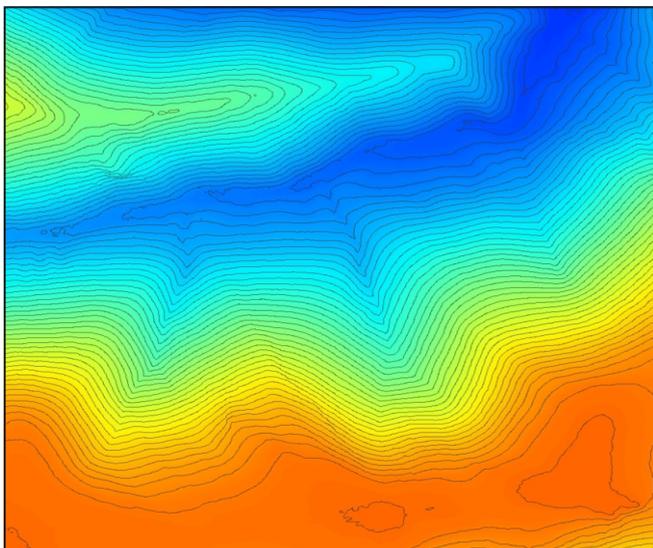
Figure 5a

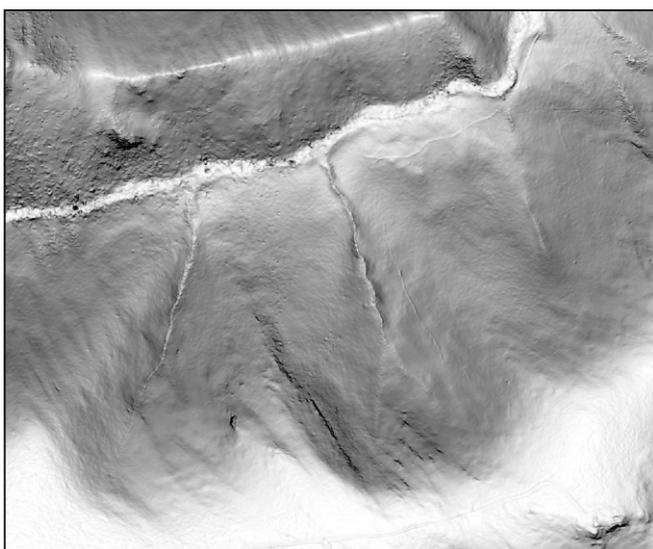

Figure 5b

Figure 5c

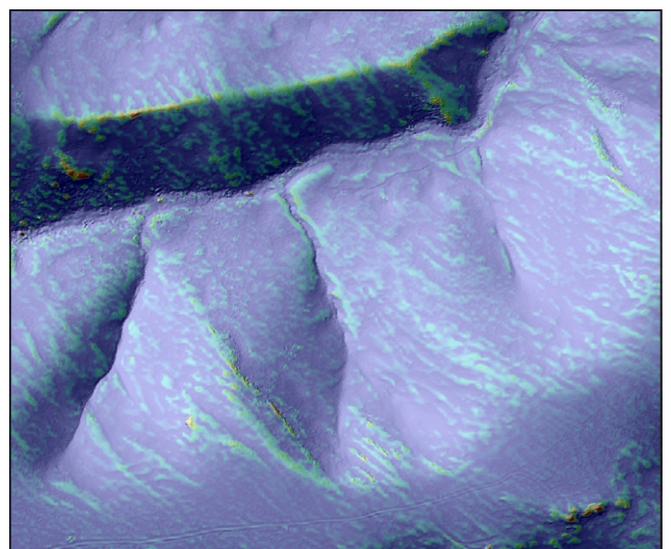

Figure 5d

Figure 5e

Figure 5f

Figure 6

Tracks, mullock heaps, pits, trenches and other excavations are evidence of historic mineral prospecting and mining activities widespread in the area around the Golden Gate mine (which is located amongst the extensive earthworks in the northeast of the image). Bedding features striking SSE become more apparent as the lithologies coarsen from mudstone in the northeast to sandstone in the southwest. The width of the image is two kilometres.