

USING A LIDAR DEM, RADIOMETRICS AND MAGNETICS TO MAP BASALTIC REGOLITH IN THE LAKE CORANGAMITE CATCHMENT, VICTORIA

David Gibson, Andrew Fitzpatrick & Heike Apps

CRC LEME, Geoscience Australia, PO Box 378, Canberra, ACT, 2601

The Lake Corangamite catchment (Figure 1) was chosen for a desktop study of how airborne geophysics can be used to map regolith over areas of Cenozoic basalt flows and underlying Tertiary formations in western Victoria, as:

1. It is an area of saline groundwater with saline playas forming windows in to water table (De Deckker 2003);
2. Agricultural lands are being affected by salinity; and,
3. A high quality Light Detection and Ranging (LiDAR) Digital Elevation Model (DEM), radiometrics and magnetics are available.

The greater part of the catchment is underlain by Cenozoic basalt of the western Victorian Newer Volcanics Province. This study explores the variations in microtopography and radiometric response of basalts to try and predict regolith properties and how these may affect groundwater and salt storage and flow. Magnetics are used to show the distribution of basalt beneath sediment cover.

DATA AVAILABILITY

DEMs

The Corangamite LiDAR DEM was acquired in 2003. The acquisition technique employs an airborne oscillating laser scanner emitting numerous pulses per second. Each reflected pulse is detected, and distance from the scanner and reflectance data are recorded. A ground model is constructed after correcting for the attitude and altitude of the aircraft and elimination of non-earth returns. The Corangamite LiDAR DEM data as supplied to us is extremely detailed and requires storage in a dedicated external hard drive. It consisted of several hundred tiles that had not been edge matched. The elevation data were warped to edge match the tiles, and the DEM 'dumbed down' to 2x2 m pixels to provide a dataset of about 10 gigabytes, which was much more manageable. It has proven to be an extremely powerful tool for mapping basalt landforms as it shows features down to a scale of 10s of metres. The vertical accuracy of the DEM has not been tested. However, traverses plotted across low relief depositional surfaces show variations in elevation of 10-20 cm at a 5-15 m wavelength. At least some of this variation is noise, although ground roughness at this scale has not been studied in the field. In addition, the warping of the tiles in the edge matching process must have introduced some long wavelength errors.

Other DEMs available for the area include the Victorian 20 m DEM based on 10 m contours, spot heights and stream logic (20 m pixels), and the Shuttle Radar Topography Mission (SRTM) DEM with 90 m pixels.

Radiometrics

Radiometrics have been flown over the catchment in two surveys (Colac and Ballarat 1:250,000 sheets), with differing flight line spacing. The original data are available as % K and ppm eTh and eU for Colac, and counts per second for Ballarat, making comparison between areas within each survey difficult. However, a

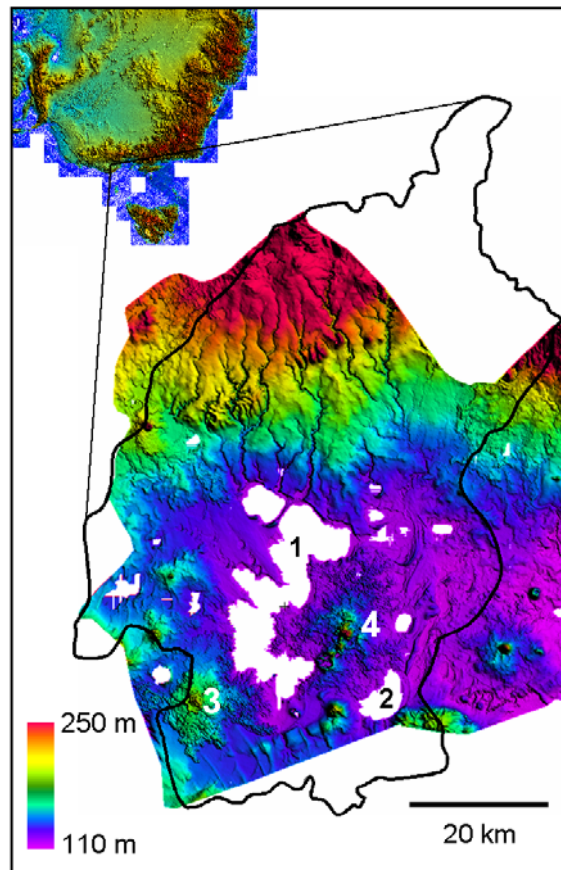


Figure 1: Location of the Lake Corangamite catchment (outlined in black) and part of the LiDAR DEM. 1. Lake Corangamite. 2. Lake Colac. 3. Mount Porndon. 4. Warrion Hill.

stitched together and resampled "All Victoria" radiometric coverage with data in % and ppm is also available, and was used in this study.

Dickson & Scott (1991) have shown that weathering of Cenozoic basalt in Western Victoria is accompanied by a decrease in K and a relative increase in Th compared with fresh rock, and that these variations can be demonstrated in both hand specimens of soil and weathered rock and radiometric surveys. Thus it is possible that some indication of the degree of weathering of basalt may be gained from radiometric response, particularly the K and eTh channels and the eTh/K. However, variations in the chemistry of the fresh basalt must be taken into account. As we are not aware of any geochemical data for fresh basalts from different flows in the area, we approach variations in radiometric response with caution.

There are other factors that will also affect the radiometric response over areas mapped as basalt. The sediment in local depositional areas between erosional stony rises may have a different chemical composition from the surrounding rock-dominated areas, depending on the source of the sediment, which could have blown into the area, may be related to old high stands of the numerous lakes in the area, or may be locally derived. In addition, tuff and fragments of country rock from recent explosive eruptions may have added to the sediment.

Magnetics

Magnetic data are also available for the area from the same surveys as the radiometrics. The Colac survey has closer line spacing than the Ballarat, and thus derivatives from the two surveys are not directly comparable. The magnetic data are useful to delineate the full extent of the basalt flows. The first vertical derivative shows high frequency noise over the basalt areas, and the first horizontal derivative shows this even more clearly in the case of the Colac data. However, this is not nearly as clear on the Ballarat data due to the wider line spacing of the survey. The derivative anomalies are slightly larger than the basalt areas, due to edge effects at the margins of the anomalies. At this stage it is thought that the magnetics cannot be used to model the thickness of the basalt, due to the high magnetic response of the basalt.

Geology

Geology of the area is available as digital datasets for the Colac 1:250,000 sheet and the adjoining Ballarat and Skipton 1:100,000 sheets to the north. The geology and geomorphology of the western Victorian Cenozoic basalt province has been described by numerous authors, the most recent compilations being those of Price (2003) and Joyce & Webb (2003). A recent detailed study of basalts from the Werribee Plains to the east of the Lake Corangamite catchment (Hare & Cas 2005, Hare *et al.* 2005) showed that the chemistry, morphology and thickness of various basalt flows vary markedly.

Techniques

So far ER Mapper software has been used solely for study of the datasets, as this allows rapid changes to lookup tables for data layers and the ability to view oblique scenes. Rainbow rather than pseudocolour colour stretches have been used in most cases, as there is a greater variation in colour in intermediate parts of the data ranges. Single channel radiometric data and the Th/K have been studied using stepwise as well as linear relationships and averaging filters used to reduce noise. Boundaries and annotations have been drawn within the software package. These will be migrated to Arc-based products to create a GIS showing the results.

We initially attempted to construct polygons based on radiometric response in basalt areas, but quickly realised that there are many combinations of response from the K and Th channels (the U channel is noisy, and was not studied). The approach we are taking now is to map different genetic basalt packages by details of their landform as seen in the LiDAR DEM, and then study variations in radiometric response within each package. A residuals approach will be used to quantify the variations.

Results

The LiDAR DEM is far superior to the other DEMs for showing detail of microrelief, as illustrated in Figure 2. Areas of smooth and rough (at a scale of 10s of metres) surface morphology are clearly distinguished.

The magnetic data, in conjunction with geological polygons, indicate areas where the basalt is covered by younger sediments, as contrasted with areas where sediments have been deposited in low-lying areas that result from 'windows' in the basalt (Figure 3). For example, the data show that a large area mapped as young sediments northeast of Lake Colac is underlain by basalt, but that there are adjacent areas where the basalt is absent, and young sediments directly overlie older Tertiary Otway Basin sediments.

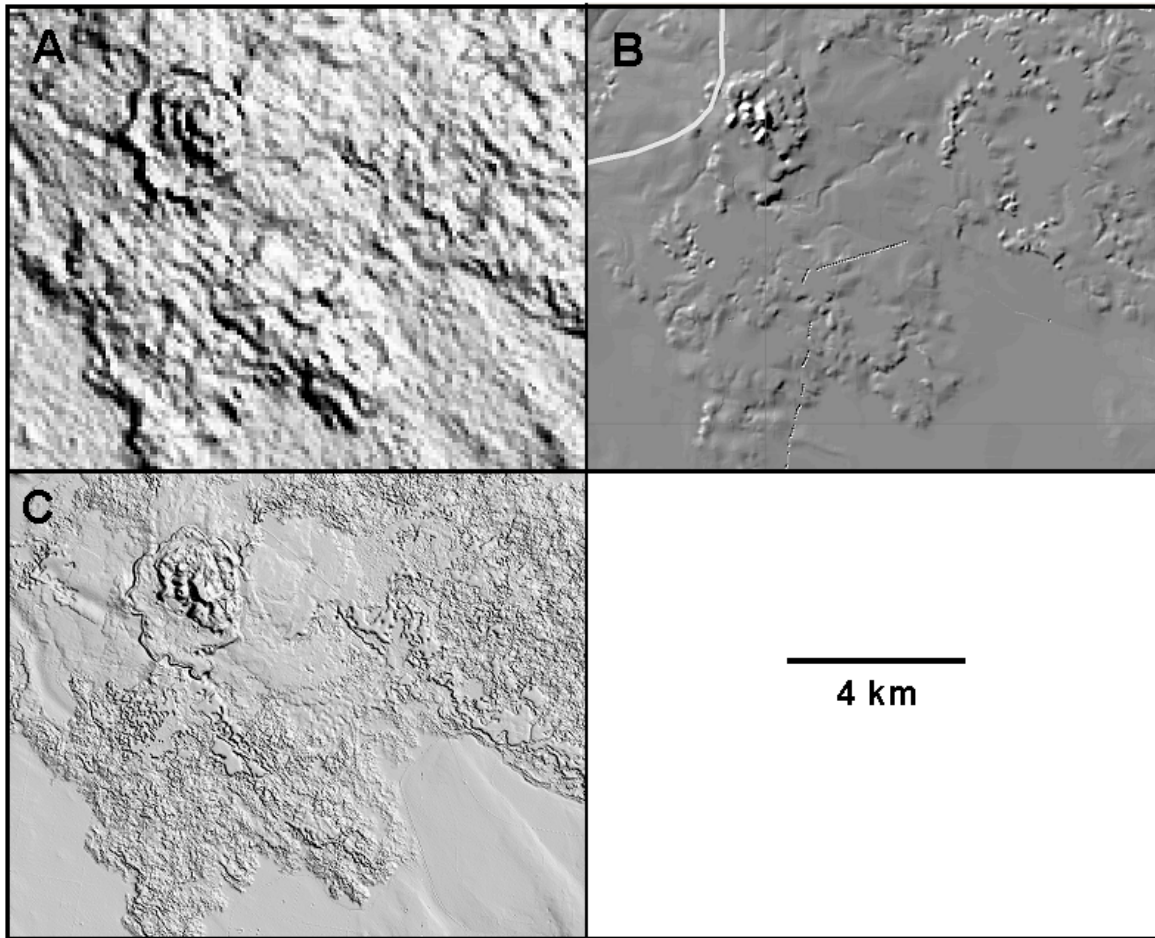


Figure 2: Comparison of different DEMs, showing the area of basalt flows around Mt Porndon in the southwest of the catchment, using intensity images with sun shading. **A:** Shuttle radar DEM with 90 m pixels. **B:** Victoria 20 m DEM. **C:** LiDAR DEM with 2 m pixels.

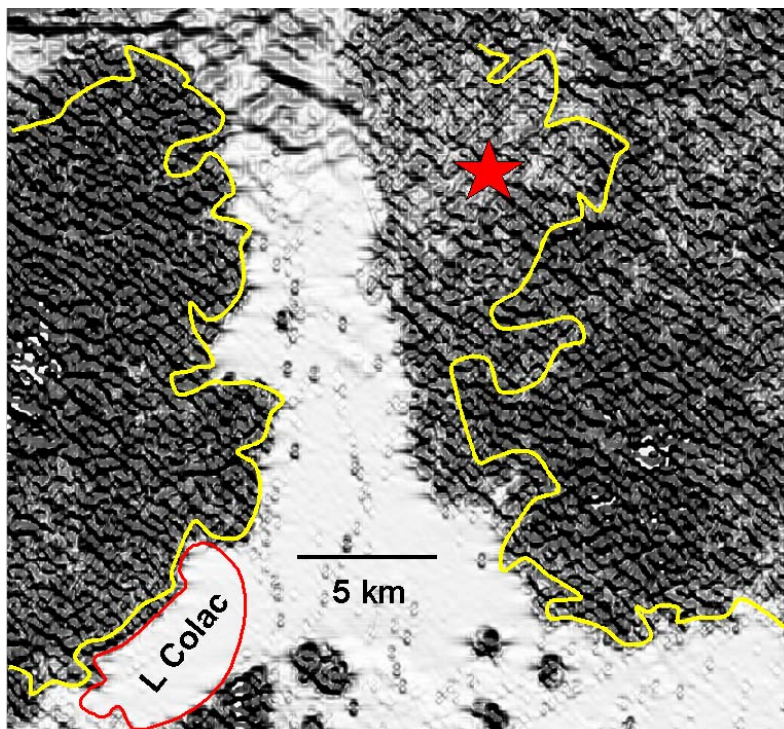


Figure 3: First horizontal derivative of magnetics, with basalt characterised by heavy texture. Approximate boundary between mapped basalt and young lacustrine and alluvial sediments shown by the yellow line. Most of the sedimentary areas are not underlain by basalt, but there is a significant area (marked with the star) where the sediments are underlain by basalt, which will alter local hydrodynamics. The outline of Lake Colac (see Figure 1) is shown in red.

The existing geological maps of the area show very little information about different basalt flows or types of flow. A four-fold subdivision is used, with stony rise basalt, undifferentiated basalt, scoria cones, and areas of tuff being differentiated. Large areas north of Lake Corangamite have been mapped as undifferentiated lava flows. The topography of these as shown by the LiDAR DEM is a very smooth south-facing low slope, punctuated by incised drainage and farm dams. Radiometric response shows that there is a broad gradation from higher eTh and lower K in the north to lower eTh and higher K in the south. Figure 4 shows the eTh/K (ppm/%) decreasing from north to south. This may indicate a broadly varying degree of weathering, which may be related to regolith thickness, and hence the total amount of regolith available for storage of moisture and salt.

The LiDAR DEM has allowed us to map areas of different surface morphology in areas of younger flows, which may relate to flow type and chemistry. In addition, an estimate may be made of the amount of depositional material within a given area. Thus a distinction has been made between: areas that are mainly erosional; areas with some depositional sumps; and areas dominated by sediment, but with local basalt outcrops. In addition, areas with lake sediment (related to former higher water levels of the palaeo Lake Corangamite) are differentiated from areas with what appear to be locally derived sediment. There are variations in radiometric response between areas of different morphology, and also within the one morphology.

For example, flows around Mt Porndon can be divided into two broad classes with different morphology on the LiDAR DEM: smooth (but with discrete flow edges visible); and rough (mainly due to collapse of flows) (Figure 5). The smooth areas have higher eTh and lower K than the rough, resulting in clear distinction between these areas on the eTh/K diagram. As the areas have not been field checked, it is not known whether this relates to original flow chemistry or degree of weathering. In addition some variability is apparent within the rough textured areas. Again this may relate to weathering.

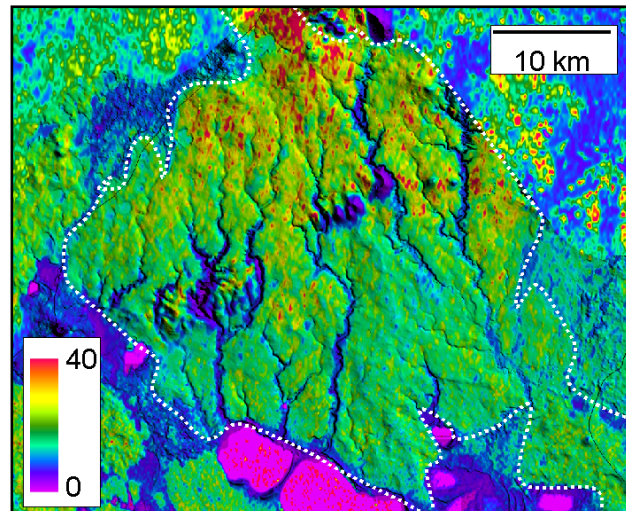


Figure 4: Area of undifferentiated weathered basalt north of Lake Corangamite (enclosed by white dotted line) showing gradation from high eTh/K (red and yellow) in north to lower ratio in south. Basement inliers and alluvium have low ratio (blue to purple).

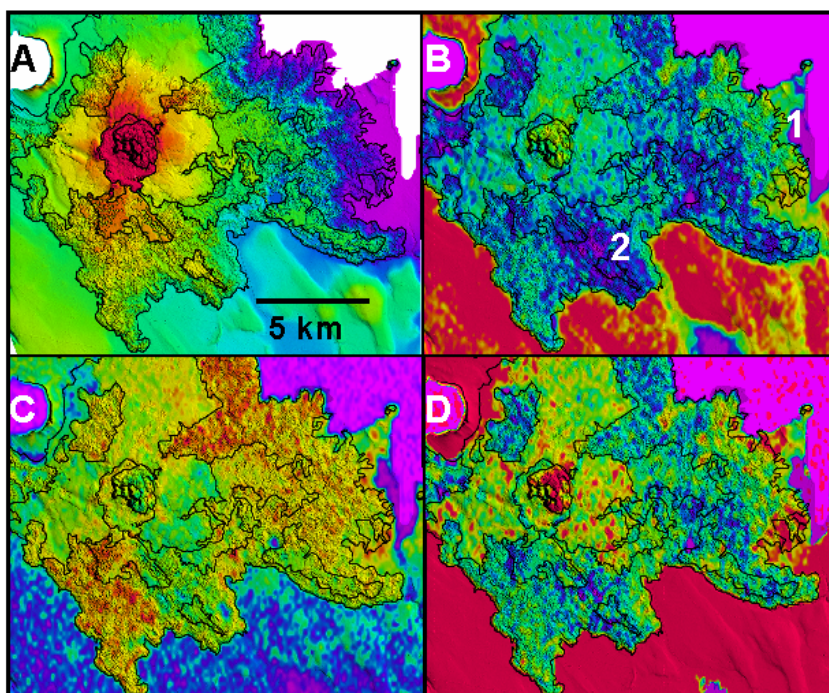


Figure 5: Area of basalt flows around Mt Porndon; smooth-textured areas in south with NW trends are Pliocene sands. **A:** LiDAR DEM annotated with polygons of smooth and rough flow surface morphology, colour stretch 115-180 m. **B:** eTh, 0-10 ppm. **C:** K, 0-1%. **D:** eTh/K, 0-10 ppm/%. There is a sharp variation in response at the edge of the smooth flows. However, there are also variations within the rough areas (as at 1 and 2), which may relate to weathering.

CONCLUSIONS

The geophysical datasets appear to be of use in mapping basalts and regolith in this area. The LiDAR DEM is particularly useful for showing fine-scale surface morphology and there are variations in radiometric response that may relate to weathering. The magnetics can be used to determine the extent of the basalts, even where covered by younger sediment. Any conclusions from the study will need to be field checked before results are applied to groundwater modelling in the area.

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