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Integrating hyperspectral and radiometric remote sensing, spatial topographic analysis and surface geochemistry to assist mineral exploration

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SUMMARY

Exploration and mining companies in Australia are faced with the challenge of locating deep ore deposits potentially buried under hundreds of metres of cover sequence materials. This research aims to investigate how the integration of hyperspectral remote sensing and surface geochemistry can be used to recognise signatures of alteration potentially associated with buried mineralisation. While each of these methods are individually mature, their combination for the purpose of mineral exploration is novel. Integration of methods including classification of spatial data and radiometric imagery, hyperspectral alteration mineral mapping and lithogeochemical analysis has produced results that might benefit exploration within the study area of the Central Gawler Gold Province. Further, the methods developed have the potential to be applied in other areas and therefore benefit the wider Australian and international minerals industry, especially in areas where there is no obvious expression of alteration at the surface.

Key words: mineral exploration, remote sensing, geochemistry, regolith

INTRODUCTION

Mineral exploration is becoming increasingly difficult and expensive as the need to explore deeper, buried terranes becomes vital to discovering new ore deposits (Schodde, 2017). Hence, there is a need to extract more from current data and methods available to the minerals industry.

Regolith, which is included in the Critical Zone (Richardson, 2017), encompasses geological, chemical and biological processes above bedrock (Brantley et al., 2007; Eggleton et al., 2001). Remote sensing to produce surface maps of regolith materials has been used for over 30 years for mineral exploration (Goetz and Rowan, 1981; Sabins, 1999). Advancements in spectral and spatial resolution of hyperspectral data is particularly conducive to surface mineral mapping (Kruse, 2012; Kruse, 1988; Laukamp et al., 2011). However, although surface mapping of the landscape, regolith and associated elements is commonly conducted for mineral exploration purposes in Australia via standardised methods (e.g. Pain et al., 2007), there are still a number of subjective decisions made by individual mappers. Geochemical sampling of regolith materials is also commonly undertaken in mineral exploration. These data are typically used to identify anomalous or elevated element concentrations to characterise a signature of a possible buried ore deposit. Surface mapping and geochemical analytical methods each have demonstrable individual use as exploration tools (e.g. Brown et al., 2006; Metelka et al., 2018; Salama et al., 2016), however combination of these tools has been examined to only a limited extent.

The broad objective of this work is to evaluate the potential of using a combination of pre-existing spatial, remote sensing and traditional mineral exploration data to identify surface indicators of buried ore deposits. Here we present a brief overview of methods and outcomes demonstrated in a regolith dominated terrain with a summary of their benefits and potential usage in the Australian minerals industry.

METHODS

This research was conducted at the southern margin of the Gawler Range Volcanics in South Australia (Figure 1). The basement rocks are Archean and Paleoproterozoic age and are extensively overlain by younger sediments. This region is prospective for base metal and gold deposits and proximal to several known mineral occurrences.

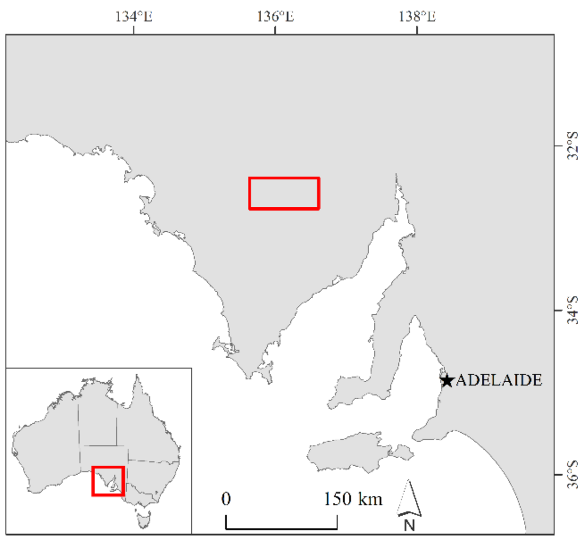

Figure 1. Location of study area.

Objective Regolith-Landform Mapping

An objective Regolith-Landform map was produced using a 1 Second Digital Elevation Model (DEM), airborne radiometrics (potassium, thorium and uranium, obtained from Geoscience Australia), and a Topographic Position Index (TPI) generated from the DEM at two different radii (300 m and 2000 m) to characterise two different scales of landscape variation (Caruso et al., 2018). An Iso Data Unsupervised Classification produced 30 classes which were then aggregated to 8 broad classes (most similar classes merged first). These classes were compared to a traditionally derived regolith-landform map by the Geological Survey of South Australia (Krapf, 2016) which was itself aggregated to 8 classes based on formation processes.

Statistical Methods

Mapcurves (Hargrove et al., 2006), a measure of 'Goodness of Fit' (GOF) was used to evaluate the spatial concordance between the objective and traditional mapping methods (Caruso et al., 2018). Specific implementation of van Loon (2011) was applied using 400 iterations of the Mapcurves algorithm with a random subsample of 500 of 5000 randomly generated points across the study area.

Hyperspectral Methodology

HyMap™ hyperspectral imagery was flown over the study area in April 2011. This sensor collected data over a 375 km^2 area in 124 contiguous wavebands from 450-2500 nm delivered as a mosaicked image of ten 2.5 km swaths calibrated to apparent surface reflectance.

Prior investigations of drill core and surface mapping have shown that the region has been affected by high-sulphidation epithermal conditions resulting in development of advanced argillic, argillic and propylitic alteration mineral assemblages. The selected suite of alteration minerals to conduct mineral mapping using the Spectral Feature Fitting (SFF) algorithm therefore included alunite, pyrophyllite, kaolinite and dickite.

Field Evaluation

Direct surface ground-truthing was undertaken using an ASD Field Spectroradiometer Pro® 3 at several locations. Field sites were selected based on being deemed 'high', 'medium', or 'low' likelihood of presence of alteration mineral(s) from SFF mineral mapping.

Geochemistry

Soil samples sent for geochemical analysis were collected during July and November 2017. Analysis for a suite of 62 elements were attained via three methods: Peroxide Fusion (Si), Aqua Regia (Au) and 4 Acid Digest (Ag, Al, As, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cs, Cu, Dy, Er, Eu, Fe, Ga, Gd, Ge, Hf, Ho, In, K, La, Li, Lu, Mg, Mn, Mo, Na, Nb, Nd, Ni, P, Pb, Pr, Rb, Re, S, Sb, Sc, Se, Sm, Sn, Sr, Ta, Tb, Th, Ti, Tl, Tm, U, V, W, Y, Yb, Zn, Zr). This geochemical data was analysed in ioGAS software for major and trace element relationships using a workflow devised by (Tiddy et al., in review).

The potential use of trace elements as pathfinder elements was assessed based on their known association with previously established mineralisation and alteration styles in the area, and their relationship with surface mineralogy as established from SFF mineral mapping.

RESULTS

Objective Regolith-Landform Mapping

The objective regolith-landform map produced from this work is shown in Figure 2 (see also Caruso et al., 2018). The overall GOF score illustrated a 26.4 % spatial concordance between the objective and traditional regolith-landform mapping methods. This concordance indicates two main points, that there is a relationship between the traditionally derived and objective mapping and, the objective mapping is providing a great deal of additional information that is geologically meaningful based on the input data. Outcomes such as this could be useful as a first pass regolith-landform map for mineral exploration in a new region. Further results are described in Caruso et al. (2018) demonstrating the success of using Mapcurves in this scenario.

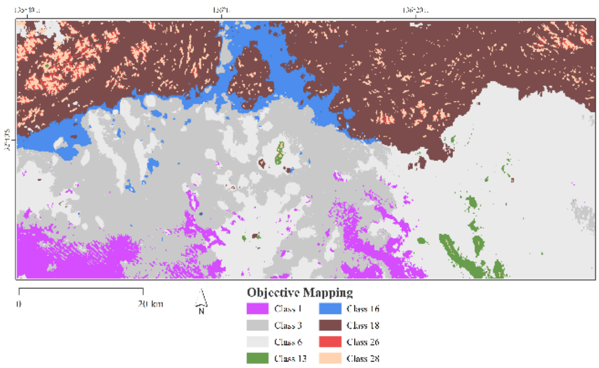

Figure 2. Objective Regolith-Landform Map reproduced from Caruso et al. (2018).

Alteration Mineral Mapping

Mineral mapping with SFF found a number of key minerals present in the study area. Notably, alunite and pyrophyllite were clearly identified, which strongly indicate the presence of advanced argillic alteration in this area. The spatial distribution of alunite corresponds with a geological exposure comprising an alunite breccia (Figure 3). Pyrophyllite was identified to the north of this breccia and its presence is consistent with the understanding of advanced argillic alteration in this region.

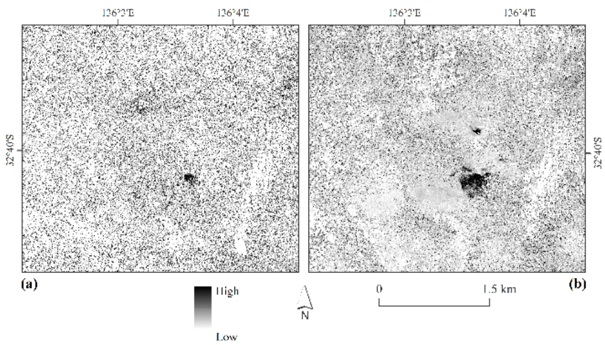

Figure 3. Alteration mineral mapping result; (a) Alunite, (b) Pyrophyllite

From this work, we can locate unique alteration, and this may indicate a nearby buried ore deposit, hence assisting the explorer in drilling target definitions.

Geochemistry

The mineralogy as identified from SFF mineral mapping is identified to have control on concentrations of several major elements including Fe_2O_3 and MgO. A linear relationship was observed between SiO_2 and Al_2O_3, allowing discrimination of quartz sand-rich versus clay-rich siliciclastic material. Relationships between major and trace elements (e.g. Zn, Cu, Pb) demonstrates potential use as pathfinder elements for alteration this region. Preliminary results indicate that the clay-rich siliciclastic material potentially hosts higher concentrations of pathfinder elements.

CONCLUSIONS

This research has demonstrated that integrated remote sensing and spatial analyses with geochemistry can provide information relevant to the needs of mineral exploration. In many regions, the data for these methods already exist and implementation could be done relatively quickly and inexpensively. Across Australia, interdisciplinary methods such as those in this research have the potential to increase understanding of prevalent regolith dominated landscapes and the ore deposits potentially buried beneath them.

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