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Proximal and remote spectroscopic characterisation of regolith in the Albany–Fraser Orogen (Western Australia)

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ABSTRACT

Vast parts of the Australian continent are prospective for precious and base metal mineralisation, but exploration is hindered by extensive cover of often deeply reaching regolith. New operational exploration methods are required that can help to characterise the cover and provide information about bedrock signatures. This paper shows how mineral mapping information from a combination of satellite multispectral Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) imagery and drill core hyperspectral profiling data (HyLogging™) can be used to unravel the regolith stratigraphy and to describe regional variations of regolith landforms, delivering important information for mineral exploration.

The case study is located in the Neale tenements in the northeastern Albany–Fraser Orogen (Western Australia), which is prospective for Tropicana-style gold mineralisation. By interpretation of indicator minerals from hyperspectral drill hole logging data the regolith stratigraphy atop a metamorphic basement, comprising saprock, ferruginous saprolite, kaolinitic saprolite, silcrete and transported cover, is recorded in cm-detail. Important mineralogical parameters extracted from the hyperspectral subsurface data and validated by XRD and FTIR, are 1) the abundance and type of iron oxides, 2) the abundance and crystallinity of kaolinite, 3) the abundance and composition of primary minerals, such as white mica, and 4) the abundance of quartz.

The HyLogging™ data served as ground control points for mineral mapping information provided by CSIRO's ASTER Geoscience Products, which are a collection of mineral maps that highlight variations in the abundance, type or chemistry of selected mineral groups. Key ASTER Geoscience Products for regolith characterisation were the Ferric Oxide and AlOH abundance and composition images. The comparison of the surface with the subsurface data suggests three major different regolith landforms, including erosional, depositional and relict areas, which were used to generate a map showing transported versus relict and erosional areas. Erosional domains were mapped out in great detail, providing important information for exploration in saprolite dominated areas. Furthermore, source areas of transported material could be identified, which may help to understand the distribution of geochemical signatures collected during, for example, geochemical soil sampling projects.

1. Introduction

An emerging generation of optical sensing technologies, operating from drill core to space based platforms, provides the opportunity for explorers to use the derived mineral information for more efficient mineral deposit discovery, including in areas obscured by regolith cover. Operational technologies to date include the satellite multispectral imaging sensor ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer; Yamaguchi et al., 1999) and the hyperspectral drill core logging system HyLogging™ (Huntington et al., 2005), providing detailed information to explorers about the abundance and composition of minerals. The multispectral ASTER data can help to characterise regolith environments and mineral systems from the continent to the prospect scale down to 15 m/pixel spatial resolution (Rowan et al., 2003; Hewson et al., 2005; Hewson and Cudahy, 2010; Laukamp, 2013). Examples of successful application of ASTER data for mineral exploration range from targeting iron ore in banded iron formations (Duuring et al., 2012) to delineation of hydrothermal alteration associated with gold mineralisation (Witt et al., 2013). The HyLogging™ system provides spatially dense (down to 1 cm) drill hole information about the abundance, composition and/or crystallinity of visible and infrared active mineral species (Haest et al., 2012a). This detailed mineralogical information can be applied for the characterisation of regolith and bedrock lithologies, such as the separation of saprolite and transported material, depth to bedrock or hydrothermal alteration patterns (Cudahy et al., 2009; Haest et al., 2012a, 2012b; Tappert et al., 2013). The characterisation of regolith landforms is paramount for explorers in regions such as the Albany–Fraser Orogen.

Regolith landforms in the northeastern Albany–Fraser Orogen are similar to those of the Yilgarn Craton (González-Álvarez et al. (in this issue-a)), where they can be separated according to Anand and Paine

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(2002) into three major regolith landform units for the Yilgarn Craton: 1) Sands, ferruginous gravels and duricrust-dominated terrains (relict), 2) Saprolite and bedrock-dominated terrains (erosional) and 3) Sediment-dominated terrains (depositional). These three regolith landforms are not only characterised by a distinct morphology, but also by a distinct mineralogy. In regolith systems, clay minerals and iron oxides develop in certain levels of the regolith stratigraphy, depending on the source/bed rocks and the physicochemical conditions of the environment (e.g. ground water chemistry). Kaolinite and halloysite for example are typical weathering products of feldspars (± muscovite) and are more abundant in regolith materials sourced from mafic and felsic rocks than from ultramafic rocks (Anand and Paine, 2002). This is in contrast to smectites, which form especially at the base of deeply weathered profiles in dry or poorly drained conditions (Anand and Paine, 2002). Smectites are weathering products of "primary" minerals, with high Fe/Al smectites forming from mafic rocks. In upper levels of the regolith smectite weathers to kaolinite and goethite.

Regolith cover in the Albany–Fraser Orogen is extensive and outcrops of bedrocks are scarce. Locally, only breakaways provide ready insights into bedrock lithologies, though the respective material is usually heavily weathered. An advanced mineralogical characterisation and understanding of the regolith materials and landforms (including weathered bedrock) is crucial in order to 1) help distinguishing transported from residual material (important for mineral exploration), and 2) characterise mineral assemblages at a district to regional scale distribution that reflect the type of concealed bedrock and/or alteration systems. These can provide insights into the mechanisms behind the lateral and vertical distribution of indicator minerals in weathering profiles.

The present study is focused mainly on the characterisation of regolith landforms and associated mineralogical variations in a selected area in the northeastern Albany–Fraser Orogen using reflectance spectroscopic techniques, validated by FTIR, XRD and geochemistry. For this, mineral group maps, derived from multispectral remote sensing data (i.e. ASTER), and hyperspectral subsurface data (i.e. HyLogging™) were acquired from the south part of the Neale tenement (held by Beadell Resources Ltd.) located about 385 km southeast of Kalgoorlie and 60 km northeast from the Tropicana gold deposit, in the Eastern Biranup Zone of the northeastern Albany–Fraser Orogen (Fig. 1). This study evaluates 1) whether the detailed mineralogy obtained from the HyLogging™ data can be extrapolated to mineralogical expressions at the surface using the ASTER data, and 2) if the remote sensing data can be used to generate regolith maps, that may assist mineral exploration in regolith-dominated terrains (RDT; Anand, in this issue; Butt, 2016–in this issue; González-Álvarez et al. (in this issue-b)). For validation of the reflectance spectroscopic data, HyLogging™ results were compared with XRD and FTIR analyses, providing a detailed understanding of the mineral assemblages in the regolith profile.

2. Geological setting

The study area is located in the Eastern Biranup Zone (Kirkland et al., 2011) of the northeastern Albany–Fraser Orogen. The Eastern Biranup Zone comprises intensely deformed orthogneiss, metagabbro and paragneiss (Spaggiari et al., 2011). Kirkland et al. (2011) described the Albany–Fraser Orogen as a Mesoproterozoic continent–continent collision zone between the Archaean Yilgarn Craton to the northwest and the Gawler Craton to the east. The area in contact with the Gawler Craton is covered by Cenozoic sediments of the Eucla Basin.

In the study area (Fig. 1), the Palaeoproterozoic Bobbie Point Metasyenogranite is thrusted northwest upon the Palaeozoic Paterson Formation along the northeast trending Cundeelee fault (Spaggiari et al., 2011, 2014a). Northeast trending shear zones separate the Bobbie Point Metasyenogranite from the Atlantis prospect located in the McKay Creek Metasyenogranite, and metagranites of the Biranup zone further southeast (Fig. 1). The McKay Creek Metasyenogranite (Fig. 1), hosting the Hercules and Atlantis prospects, can be mingled with metagrabbro and may include intrusions of the Bobbie Point Metasyenogranite and remnants of Archaean rocks (Spaggiari et al., 2014b and references therein). Doyle et al. (2015) described subeconomic gold mineralisation in the Voodoo Child domain further to the southwest.

Gold mineralisation is associated with "silica sericite alteration" along the Hercules Shear Zone and along a major granite gneiss/paragneiss contact (Spaggiari et al., 2014b). The Hercules trend is prospective for Tropicana-style mineralisation and is characterised by a metachert intersected close to the contact between a garnet gneiss in the east and a granite gneiss in the west. According to Beadell Resources Ltd., about 30 to 40 m of transported regolith can cover the mineralised

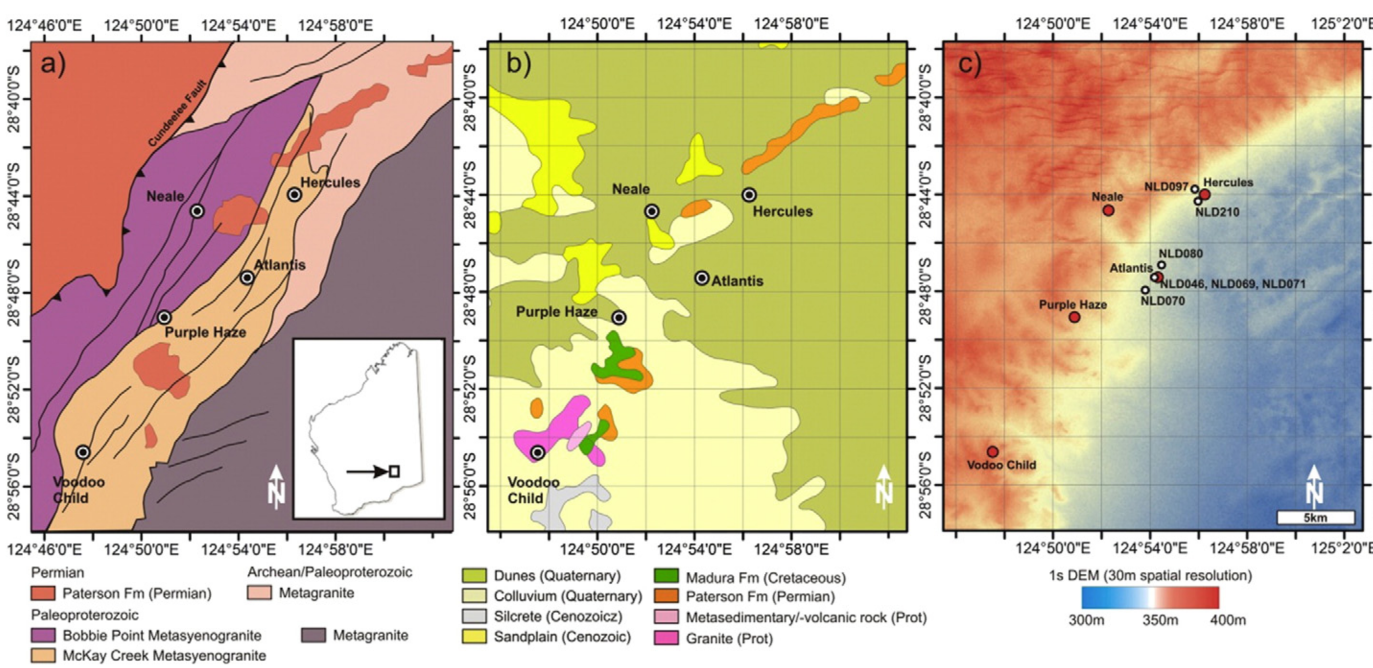

Fig. 1. a) Basement geology of the case study area (modified after Spaggiari and Pawley (2012); b) Surface geological map (1 M, Stewart et al., 2008); c) DEM (Gallant et al., 2011) showing location of drill cores (NLD046 to NLD210) from the Hercules and Atlantis sites, scanned with the HyLogging™ system. Neale, Purple Haze and Voodoo Child are further exploration sites.