REGOLITH GEOCHEMISTRY OF THE NORTH KIMBERLEY, WESTERN AUSTRALIA: A STRONG PROXY FOR BEDROCK

Paul A. Morris[1]

[1]Geological Survey of Western Australia, 100 Plain Street, East Perth 6004, Western Australia; Paul.MORRIS@dmp.wa.gov.au

Introduction

In many parts of Western Australia, such as the Archean Yilgarn Craton, regolith is often thick, contiguous and transported, and is genetically unrelated to the underlying bedrock (Anand & Butt 2010). However, regolith found on Paleoproterozoic rocks of the Kimberley area in northern Western Australia is commonly thin, subordinate in area to outcropping bedrock, and of local derivation. Here, the opportunity exists to examine regolith resulting from the early stages of physical and chemical weathering (Fig. 1), and to test the usefulness of regolith chemistry as a proxy for bedrock composition.

Due to its remoteness and difficulty of access, relatively little is known about the geology of northern Western Australia, particularly the regolith. As part of a multi-agency State government program to better understand the Kimberly region, the Geological Survey of Western Australia (GSWA) carried out three regional regolith and rock sampling programs in the Kimberley area. Regolith programs involved collection of samples on a 5-km grid, followed by multi-element chemistry (Scheib in press; de Souza Kovacs in press). Some results of the first program from the Balanggarra area in the north Kimberley (Fig. 2) are discussed here.

The Balanggarra project area covers approximately 10 300 km^2 in the north Kimberley. Rock units in the project area comprise quartz-rich siliciclastic rocks of the King Leopold, Warton and Pentecost sandstones, mafic volcanic rocks of the Carson Volcanics, and sandstones and siltstones of the Elgee Siltstone (Fig. 2). This essentially undeformed and unmetamorphosed succession strikes roughly NNE and dips gently to the ESE. Regolith samples from 406 sites have been collected, and an interpretive regolith map was compiled at 1:100 000 scale (GSWA 2014). About 60 % of the project area consists of thin regolith (often < 20 cm thick) in areas of exposed bedrock, with a further 10% consisting of duricrust derived by in situ weathering. Of the transported component, 20% comprises colluvium found close to outcrop, and only 7% is accounted for by alluvium in drainage channels. Thus, most regolith is found either on or close to bedrock.

Methodology – chemical analysis

As regolith is poorly sorted, the < 10 mm fraction was selected for analysis. Approximately 2 kg of each sample was dry screened to < 10 mm, and a representative part crushed and milled to < 75 µm in a low-Cr steel mill. Sixty four analytes were determined as either major element oxides, trace elements, or rare earth elements (REE; La - Lu) by either XRF or ICP (following fusion ± acid digestion), as well as ignition loss, pH and total dissolved solids (TDS). Gold, Pt and Pd were determined by fire assay collection and ICP. The data are available from the Department of Mines and petroleum website (www.dmp.wa.gov.au/geochem).

Results

Multi-element spider diagrams (e.g., Fig. 1) normalised to fresh bedrock show the extent of chemical weathering. Residual regolith from the Carson Volcanics is depleted in labile elements (Ba – Na), the rare earth elements (REE) La – Y, and Ni and relatively enriched in Fe, Th, the high-field strength elements (HFSE) Hf, Nb and Zr, and V and Cr. Colluvium shows a broadly similar pattern for the interval Ba – Na, but other elements are similar to regolith from areas of outcrop (Fig. 1).

The behaviour of Ba – Na and Ni is consistent with the alteration of pyroxene, olivine and feldspar. Extreme weathering to produce residual regolith involves ferruginization, the concentration of resistate phases (elevated HFSE, Cr, V), and the loss of REE. The overall similarity of colluvium and regolith from areas of outcrop (except Ba – Na) indicates chemical weathering is largely limited to the alteration of parent rock phenocrysts, especially feldspar.

A bubble plot (Fig. 2) shows the interpreted bedrock geology of the project area and the concentration of Cr (ppm) in regolith. There is clear separation of the Carson Volcanics (high Cr) from siliciclastic sedimentary units (low Cr). By combining knowledge about the extent of chemical weathering and lithology, variations within bedrock units can be examined using regolith chemistry.

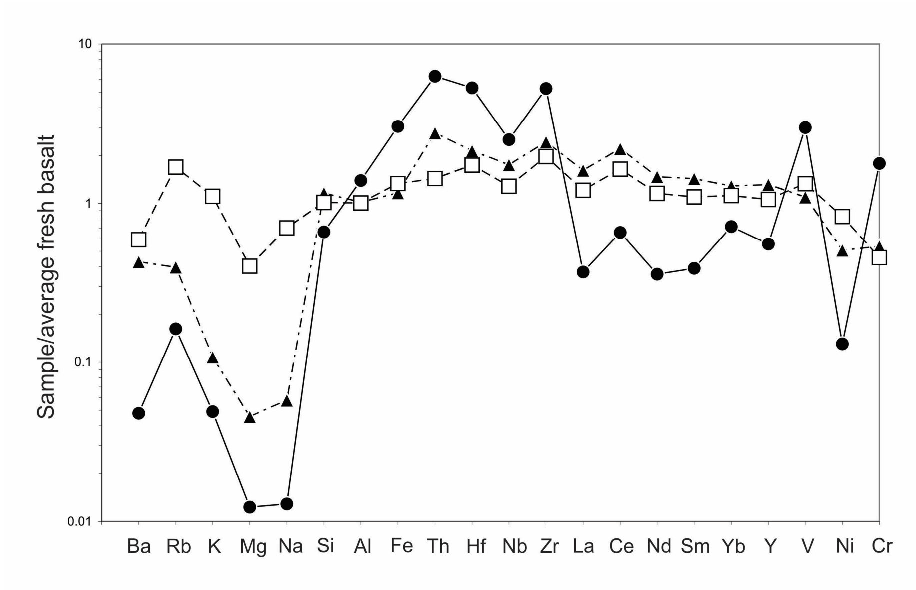

Figure 1. Spider diagram for regolith from the Carson Volcanics. Composition of Carson Volcanics regolith from an area of outcrop (open squares), colluvium (closed triangles) and residual regolith (closed circles) normalised to the average of 37 analyses of fresh Carson Volcanics basalt (data from Karin Orth).

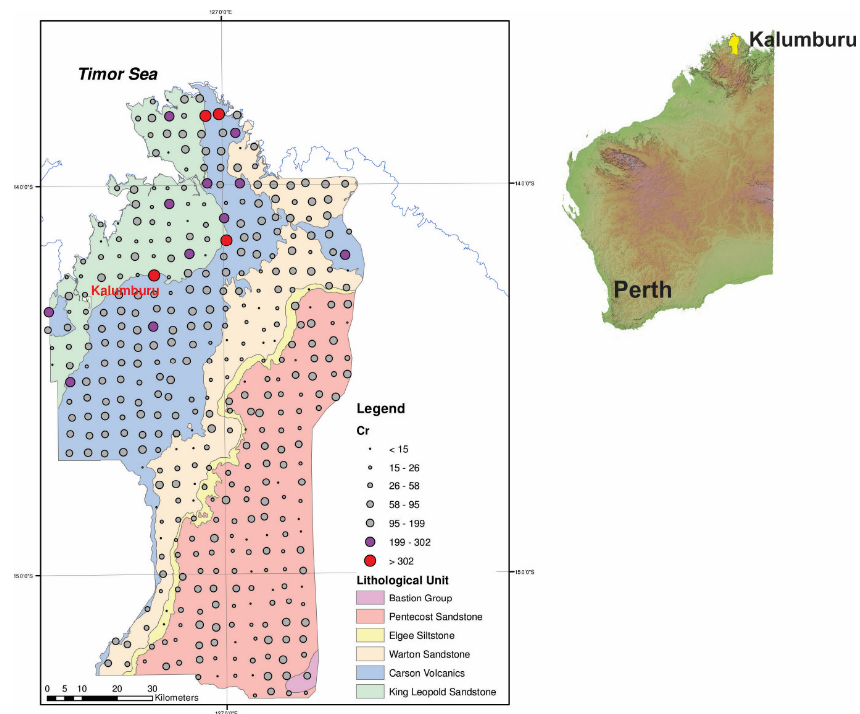

Figure 2. Chromium (ppm) in all regolith samples. Anomalous concentrations are shown as purple (outlier) and red (extreme) closed circles.

Stratigraphic variations in the Carson Volcanics

Statistical treatment of regolith geochemical data shows that several samples with anomalous Cr concentrations (i.e., > 199 ppm; Fig. 2) are found at or near the base of the Carson Volcanics. These samples also have elevated Ni, MgO and chalcophile element contents. Although only seven of the 116 regolith samples from this unit have detectable Pt (LLD = 1 ppb), four of these samples are located within 1 500 m of the lower contact.

High Cr could reflect the concentration of chromite as a result of chemical weathering, but this is inconsistent with the high MgO and Ni; even small degrees of chemical weathering results in marked depletion in MgO and Ni due to the breakdown of olivine and pyroxene (Fig. 1). Instead, the high MgO, Cr, and Ni of these samples indicate less fractionated rocks at the base of the unit. The higher chalcophile element contents and presence of detectable PGEs in these regolith samples indicates the likelihood of mineralization.

Strandline deposits in the Pentecost Sandstone

The elevated SiO_2 (median 87.75 wt%) and low lithophile element content (e.g., median Sr = 7.6 ppm; n = 141) of regolith from siliciclastic sedimentary rocks is consistent with a chemically mature source, and it is likely that resistate minerals will be more common in both bedrock and regolith.

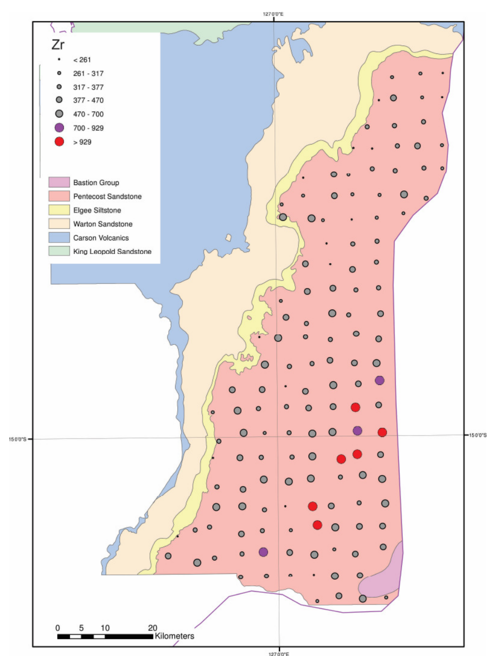

Figure 3. Zirconium (ppm) in all regolith samples from the Pentecost Sandstone. Anomalous concentrations are shown as purple (outlier) and red (extreme) closed circles.

Nine regolith samples from the southeast part of the Pentecost Sandstone (Fig. 3) have anomalous concentrations of Zr (> 654 ppm), including one sample with the highest concentration recorded from the project area (1046 ppm). The same nine samples also have anomalous concentrations of Hf, but not of other HFSE such as Nb and Ta. All regolith samples are from areas of outcrop, so their Zr and Hf contents are more likely to represent the bedrock rather than the effects of chemical weathering. The samples form a linear belt roughly parallel to strike, and are interpreted as the regolith representation of a zircon-enriched heavy mineral unit within the Pentecost Sandstone. The restriction of heavy minerals to zircon is attributed to the mineralogy of the source region, coupled with density sorting during sediment transport.

Discussion and Conclusions

In areas of thin regolith where transportation distances are minimal, regolith geochemistry can be used as a reliable proxy for bedrock as long as the effects of chemical weathering can be accounted for. In the north Kimberly of Western Australia, regolith geochemical data mimics bedrock, and statistical treatment of regolith geochemical data reveals compositional variations within individual lithological units that have implications for mineralization.

References

ANAND, R. R. & BUTT, C. R. M. 2010. A guide for mineral exploration through regolith in the Yilgarn Craton, Western Australia. *Australian Journal of Earth Sciences*, **57**, 1015-1114.

DE SOUZA KOVACS, N. in press. Regolith-landforms of the west Kimberley: distribution and composition. Geological Survey of Western Australia Record.

GSWA 2014. Kimberley Geological Information Series, 2014 update. Geological Survey of Western Australia.

SCHEIB, A. J. in press. The regolith sampling program in the Kimberley: an overview. Geological Survey of Western Australia Record.