Geochemical landscape evolution and Pattern Similarity Analysis at tenement scale for gold exploration in Forrestania

Ignacio González-Álvarez,
CSIRO
Perth, WA 6151
ignacio.gonzalez-alvarez@csiro.au

Oscar Rondón-González
Snowden Group
Perth WA 6000
oscar.rondon@snowdengroup.com

Tania Ibrahimi
CSIRO
Perth, WA 6151
tania.ibrahimi@csiro.au

Ian Lau
CSIRO
Perth, WA 6151
ian.lau@csiro.au

Monica leGras
CSIRO
Perth, WA 6151
Monica.LeGras@csiro.au

Dean Goodwin
Classic Minerals Ltd.
Perth, WA 6065
dean_goodwin@outlook.com

Vasek Metelka
CSIRO
Perth, WA 6151
Vasek.Metelka@csiro.au

Tenten Pinchand
CSIRO
Perth, WA 6151
tenten.pinchand@csiro.au

Carmen Krapf
GSSA
Adelaide, SA
Carmen.Krapf@sa.gov.au

SUMMARY

The present study investigates the Forrestania area, located in the Yilgarn Craton, Western Australia, as a case study to combine geochemical landscape evolution and pattern similarity analysis techniques.

In the research area within Forrestania, the dioritic basement is overlain by ~40-~85 m of cover (saprolite and transported sediments). In the basement, Au correlates with As (r^2 = 0.90); in the lower saprolite unit, Au correlates with Ba (r^2 = 0.91); and in the soil Au is associated with carbonates. The saprock and the lower/mottled saprolite unit preserve the basement geochemical footprint. However, metallic vertical dispersion processes in the area are not efficient due to the presence of three geochemical barriers/gradients. These barriers/gradients are (1) the smectite/nontronite and kaolinitic units, (2) the lacustrine and fluvial sediment transported cover, and (3) the soil. Overall, Au mines and prospects in the region are located within erosional landscape regimes, and the main Au soil anomalies are also located on the slopes of landscape erosional landforms.

Pattern similarity analysis (PSA) has highlighted three prospective areas for Au exploration in the Forrestania Greenstone Belt with respect to the best Au drilling intersection at Lady Ada/Blue Haze mine (~70 ppm Au).

This targeting workflow methodology can be applied to any similar mineral exploration context in Australia.

Key words: Mineral exploration, regolith, geochemical dispersion processes, critical zone, gold.

INTRODUCTION

Exploration through the cover (saprolite + transported cover) is a fundamental challenge for the minerals industry in Australia and is driving the restructuring of mineral exploration strategies. Geochemical dispersion/concentration processes throughout the regolith units may be locally efficient, producing metal anomalies corresponding to an ore footprint. In mineral exploration, linking basement orebodies with surficial geochemical signatures is critical. To this end, the understanding of the local cover architecture and its evolution is essential.

The study area for this research is located in the Forrestania Greenstone Belt (FGB), which is the southern extension of the Southern Cross Greenstone Belt, in the SW of the Youanmi terrane (Figs. 1 and 2). This terrane itself lies at the boundary to the west with the South West terrane in the Yilgarn Craton (Cassidy et al., 2006). This area features Archaean granitoids within belts of metamorphosed sedimentary and volcanic rock suites following the N-S trend of the FGB.

The geology of the study area displays a strong structural fabric that follows the lithological trend of the FGB. The greenstone belt is crosscut by faults with NW-SE and NE-SW trends, associated with a mesh of dolerite dykes. The Blue Haze/Lady Ada open pit sits at the intersection of the two dolerite dyke trends (NW-SE and ~NE-SW), as well as the main shear zone trending NW-SE.

The digital elevation model of the area displays a surface that ranges from ~270 m to ~500 m above sea-level to the northeast and southeast (Figs. 1 and 2). Most of the drilling described in the study area is within ~460-390 m above sea-level. The study area is on the margin of a major palaeodrainage system trending NE-SW (Fig. 2), which is the main geomorphological feature of the area. Complete regolith profiles described in previous studies in the NE at the Bounty gold deposit describe a ~40 m thickness cover, with a ferruginous unit at the top, underlain by mottled clays, bleached saprolite, and unweathered basement rocks (Lintern et al., 1990; Lintern, 2005).

The study area is part of the tenement package of Classic Minerals Ltd. These tenements are close to previous deposits such as Bounty (2 Moz) and Yilgarn Star (1.5 Moz; Classic Minerals Ltd, website; http://www.classicminerals.com.au).

This project was designed to deliver innovative approaches in the use and integration of geology, geochemistry, drilling, geostatistics (PSA), and landscape evolution datasets in mineral exploration, aiming to elucidate the relationship between landscape/cover evolution in Forrestania, geological datasets and the mineralisation at depth, to assist target generation (González-Álvarez et al., 2019).

Figure 1. Landscape view at Forrestania.

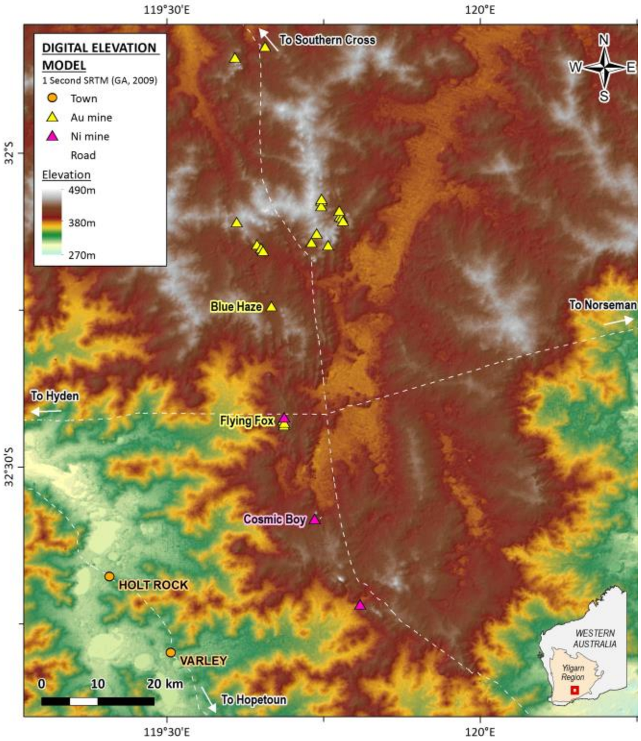

Figure 2. Map of the regional Digital Elevation Model (DEM; Gallant et al., 2011). This Figure displays the main palaeodrainage feature that trends NE-SW to the east of the FGB.

METHODOLOGY

To assess efficient exploration techniques in the area of the Forrestania Greenstone Belt (FGB), we applied the following methodology:

(1) Provide insights on landscape features in relation to mineralised areas through statistical data analytics;

(2) Generate high-quality reference geochemical, mineralogical and HyLogger3™ datasets (major and trace elements; XRD, ICP-MS/OES, M4 Tornado XRF-mineral mapping and HyChips™);

(3) Integrate the geology (e.g., basement lithologies), drilling information, field observations, geochemical analysis and HyLogger3™ results of selected drill holes;

(4) Generate a conceptual model for landscape evolution in the FGB area and determine its implications for geochemical dispersion processes; and

(5) Provide target areas that are the most geologically similar to the site of best Au drill intercept, by applying PSA (Michelena et al., 1998; Rondón and Banchs, 2007) as well as a pattern recognition technique based on a non-supervised neural network developed by Kohonen (2001).

RESULTS

Essential information on the stratigraphy of the cover in the study area was provided by direct field observations and sampling at the Blue Haze/Lady Ada open pit (Fig. 3), along with HyLogger3™ scanning and sampling of drill hole chips supplied by Classic Minerals Ltd. (Fig. 4).

The dioritic fresh basement rock is at ~60-70 m average depth (40 m and 86 m as minimum and maximum depths, respectively; Fig. 3). Mineralogically, the diorite units are made of plagioclase (~60%), amphibole (~35%) and biotite (~5%).

The complete saprolite sequence has a relative average thickness of ~50 m (Figs. 3 and 4). The saprock varies from ~5 to ~30 m in thickness. The lower /mottled saprolite varies from ~1 to ~40 m in thickness and preserves most of the original dioritic basement mineralogy with a relative increase in kaolinite and quartz content. The saprolite units contain hematite, goethite and halite as minor components. Two units may overlie the lower saprolite: (1) a kaolinitic and (2) a smectite/nontronitic saprolite. These units may grade into each other vertically and laterally with variable thicknesses that range from 0 to ~20 m. These two units mainly comprise kaolinite (~60%), quartz (~15%) and halite (<10%). In the smectite/nontronite unit, the goethite content can approach 20%. Capping the saprolite is a pisolitic ferricrete unit, which was identified and sampled outside of the study area. This unit is distributed throughout the landscape, forming topographic highs in the region.

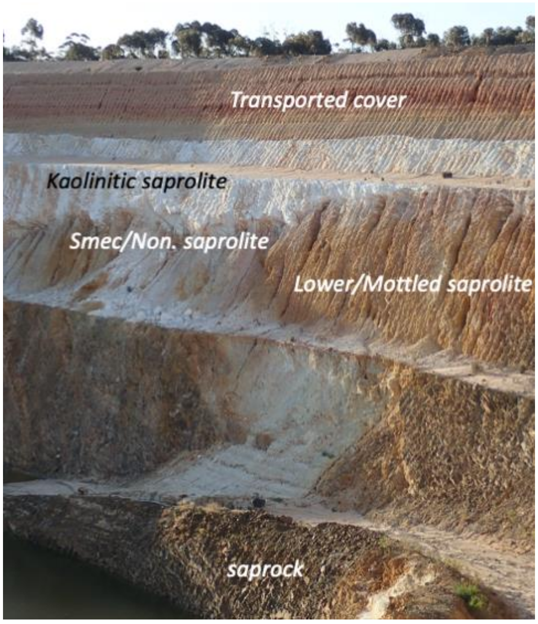

Figure 3. Main stratigraphic units of the cover at the Blue Haze/Lady Ada open pit, Forrestania, Western Australia.

Overalying the saprolite or the ferricrete is the transported cover unit, which blankets all the area with a maximum thickness of 15 m, mostly varying between 5 and 9 m thickness (Figs. 3 and 4). The lower unit of the transported cover is composed of quarzitic fluvial sediments that have an erosional contact with the underlying saprolite. These fluvial sediments are overlain by kaolinite-dominated lacustrine clays that can be divided into three units based on colour: bottom(grey), middle(yellow) and top(red). These units are horizontally and laterally continuous at the Blue Haze/Lady Ada open-pit exposure (Figs. 3 and 4). These lacustrine sediments are topped by a ~1 m thick soil rich in carbonate (up to 80%) with a topsoil horizon rich in organic matter with little to no carbonate.

The dioritic basement rocks preserve their geochemical signature in the saprock and lower/mottled saprolitic unit (Figs. 3 and 4). This is strongly supported by similar rare earth element and transition metal patterns detected in the stratigraphic unit.

Figure 4. Is at the end of the abstract to have a font readable size.

Vertical geochemical dispersion processes are not efficient due to several geochemical resetting events, or barriers, such as the upper saprolite unit, the lacustrine units and the soil unit (e.g., Fig. 5). However, Au can still be detected due to its redistribution to the soil at the landscape surface. This is interpreted to be the result of biological dispersion processes. Salmon Gum trees are extensively present in the area. By sampling the tree material, it was established that Au is absorbed and distributed within the tree, reaching the leaves (0.83 ppb Au in one of the Salmon Gum trees sampled). Inherently, the trees absorb groundwater that has interacted with stratigraphic units that contain Au and remobilised Au as well as other elements. This implies that roots were able to rich vertically or laterally the mottled or lower saprolite units, which contain Au, bridging the geochemical barriers that vertical inorganic geochemical processes encounter in the stratigraphic sequence (e.g., transported cover and kaolinitic saprolite). The recycling of leaves and bark within the soil can consequently cause Au anomalies (Fig. 5). The efficiency of trees as a sample media is linked to their distribution in the landscape, cover stratigraphy variability, water table depth, groundwater salinity, and cover thickness (e.g., Reid and Hill, 2010).

Two main observations made by assessing the landscape regimes and Au mineral exploration relationships in the Forrestania area around Blue Haze/Lady Ada open pit are:
the gold mines in the region are on erosional landscape regimes (Fig. 2), and the main Au anomalies detected in the Classic Minerals Ltd. soil geochemical dataset are located primarily on the slopes and at the edges of erosional landscape domains (Fig. 2).

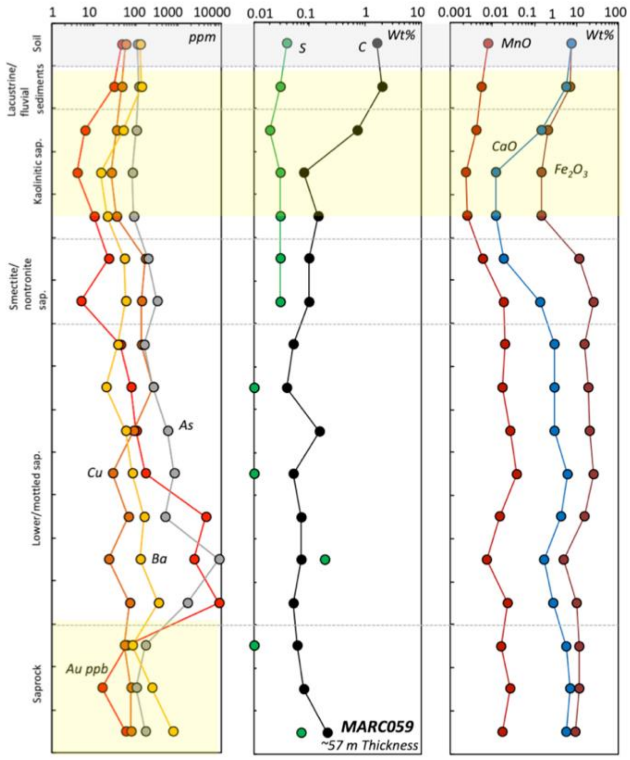

Figure 5. Vertical distribution of selected elements and oxides in drill hole MARC059. Gold correlates with As in the saprock and lower/mottled saprolite unit and is associated with pedogenic carbonate (calcrete) in the soil unit.

The assessment for PSA utilised the point MARC023 as a reference. Point MARC023is the drill hole with the best Au intersection in the area (76.8 g/t at 116 m depth). The PSA comprised eight datasets: DEM, tree density, drainage, flatness, geology, structure, geochemical analysis of the soil samples, and magnetic intensity of basement geology. This analysis resulted in several maps, which display the distribution of areas similar to MARC023. Warm colours and cold colours indicate high and low similarity indices, respectively (Fig. 6).

CONCLUSIONS

(1) The saprock and the lower/mottled saprolite unit preserves the basement geochemical signature. However, vertical dispersion processes for metals in the area are not efficient due to the presence of three geochemical barriers/gradients.
(2) Au mines and prospects in the region are located within erosional landscape regimes, and the main soil Au anomalies are also located on the slopes of landscape erosional landforms.
(3) Three areas are highly prospective for Au exploration in the Forrestania Greenstone belt based on Pattern Similarity Analysis (Fig. 6).

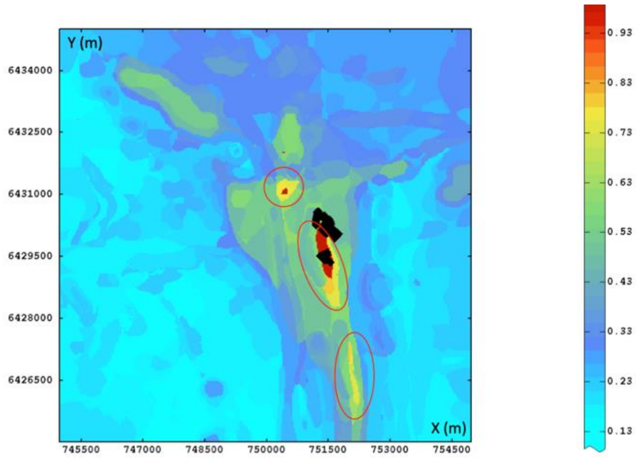

Figure 6. Similarity pattern map highlighting three areas (white dashed line ellipsoids) that display high similarity to the highest drill hole Au intersection (MARC023, ~70 ppm) when combining five geochemical, geological, geophysical and geomorphological datasets.

ACKNOWLEDGMENTS

We would like to thank the Noongar people, who are the traditional owners of the land, for granting access to the ground for this study. Classic Minerals Ltd. is thanked for providing access to the Forrestania mine site and provisioning the data for this project. This project received funding from Classic Minerals Ltd., Innovation Connections, and CSIRO.

REFERENCES

Cassidy, K.F., Champion, D.C., Krapev, B., Barley, M.E., Brown, S.J.A., Blewett, R.S., Groenewald, P.B., and Tyler, I.M., 2006, A revised geological framework for the Yilgarn Craton, Western Australia: Western Australia Geological Survey, Record 2006/8, 8p.

Gallant, J.C., and Dowling, T.I., 2003. A multi-resolution index of valley bottom flatness for mapping depositional areas, Water Resources Research 39, 1347, 4-1/4-13.

Gallant, J., Wilson, N., Dowling, T., Read, A., Inskeep, C. 2011. SRTM-derived 1 Second Digital Elevation Models Version 1.0. Record 1. Geoscience Australia, Canberra. https://ecat.ga.gov.au/geonetwork/srv/eng/catalog.search#/metadata/72759

González-Álvarez, I., Rondón-González, O., Ibrahimi, T., LeGras, M., Lau, I., Metelka, V., and Pinchand, T., 2019. Insights on gold exploration in Forrestania, Western Australia. CSIRO Report, restricted, EP EP191651, 78 pp.

Reid, N., Hill, S.M., 2010. Biogeochemical sampling for mineral exploration in arid terrains: Tanami Gold Province, Australia. Journal of Geochemical Exploration 104, 105–117.

Kohonen, T., 2001. Self-organizing Maps. Springer-Verlag.

Michelena, R. Gonzalez, E. Capello, M., 1998. Similarity Analysis: A new tool to summarise seismic attributes information. The Leading Edge 17, 545–548.

Lintern, M.J., 2005. Bounty gold deposit, Forrestania Greenstone belt, Western Australia. CRC LEME, 3 pp.

Lintern. M.J., Churchward, H.M., and Butt, C.R.M., 1990. Multi-element soil survey of the Mount Hope area, Western Australia. Report 40 CSIRO Division of Exploration Geoescience, Perth, 83 pp.

Rondón, O., and Banchs, R., 2007. Seismic Similarity Analysis through to Self-Organising Maps. Exploration Geophysics, 38, 184–188.

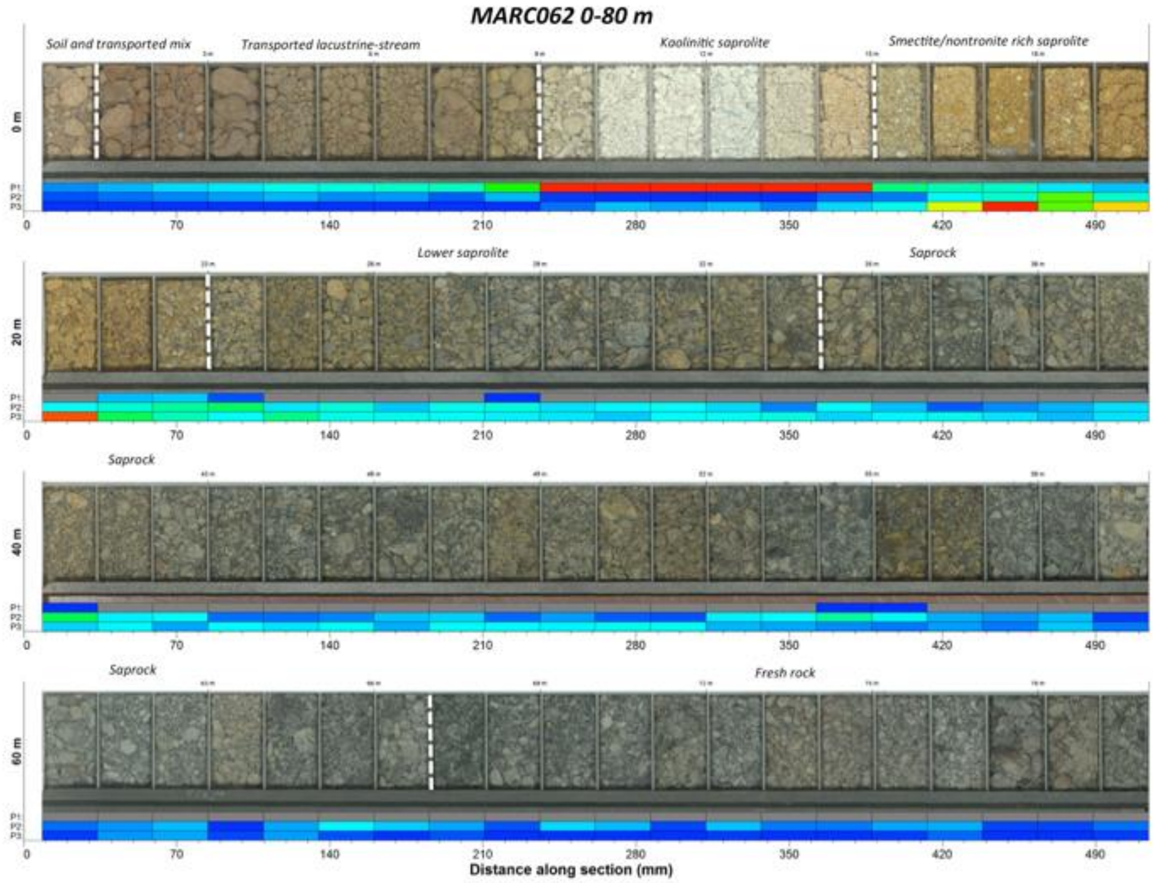

Figure 4. Example of HyLogger3^{TM} data interpreted to define the stratigraphic units and mineralogical changes. The top row of HyLogging information (P1) crystallinity of kaolinite: cold colours indicate low crystallinity and warm colours indicate high crystallinity. The middle row (P2) displays goethite/hematite ratio: cold colours indicate hematite and warm colours indicate geothite , and the bottom row (P3) displays the relative amount of water in the rock/cover unit.