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Sea-level changes and buried islands in a complex coastal palaeolandscape in the South of Western Australia: Implications for greenfield mineral exploration

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ABSTRACT

Weathering intensity changes due to climatic variability across tectonically stable portions of continental crust can generate a thick and extensive weathered cover, resulting in regolith-dominated terrains (RDTs). Mineral exploration in RDTs is challenging because of the lack of bedrock outcrop, and the difficulty of linking surface regolith geochemistry to the geology at depth. Complex weathering obscures the expression of the basement geochemistry in the regolith, and therefore the footprints of mineral systems are difficult to detect. The southeast of the Yilgarn Craton and the Albany–Fraser Orogen (AFO) in the south of Western Australia is an RDT that extends along the coastline and the Eucla basin.

This study proposes a landscape evolution model of the AFO, driven by transgression–regression sea-level changes that resulted in the formation of numerous islands and development of estuarine zones. This model contrasts with the river system-dominated landscape evolution present in the Yilgarn Craton. This difference has significant implications for mineral exploration and geochemical interpretation of the regolith in this region.

Weathering profiles developed “on inland” and “on island” are thicker and more mature than those developed in sea-inundated areas. Even if in the Yilgarn Craton local areas display reworking of weathering profiles and other complexities from Permian, non-marine Tertiary sediments and Quaternary fluvial and aeolian sediments, at a regional scale, if vertical geochemical mobility of elements has occurred, “on inland” and “on island” are more reliable for understanding geochemical anomaly-basement relationships, whereas the “marine inundated” areas require a more detailed investigation, because of the role of marine reworking of weathering profiles and possible mixture of sediments from different provenances.

Landscape changes from the topographically high, dissected Yilgarn environment with thick saprolite development and uneven basement topography, to the nearly flat regions dominated by sand dunes and thin saprolite development at the coastline. These regions are the result of the erosional and depositional effects of successive sea-level transgression–regression cycles. Within this framework, the following four different regolith settings have been identified in a progressive change from Yilgarn Craton environments to the modern coastline: (1) Albany; (2) Kalgoorlie–Norseman; (3) Esperance; and (4) Neale.

Mapping the palaeocoastlines, islands and estuarine zones, as well as the region of influence of marine limestones and sediments, can significantly improve the understanding of how surface geochemistry relates to the landscape, and how it links with the geology at depth, and therefore, how it may reflect the presence of mineral systems. Understanding the difference in the landscape evolution between the AFO and Yilgarn Craton is essential to properly calibrate mineral exploration protocols in both regions.

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1. Introduction

Deeply weathered landscapes are associated with tropical and subtropical environments. They extend throughout large continental regions, mainly between the 30° south and north meridians (e.g., Strakov, 1967). Many of these regions display thick weathered profiles that were developed during several climatic shifts that overprinted each other, resulting in landscapes with low relief and a lack of fresh bedrock outcrop. In addition to the in situ cover, these weathering profiles may be thickened with sedimentary packages with diverse provenances that bury the in situ weathered profiles. Thus the geological understanding of these terrains is challenging because of the difficulty in linking the accessible surface geochemistry to the fresh rock at depth (González-Álvarez et al., 2015a).

The concept of landscape preservation or ancient landscape has been largely discussed and studied in regions such as South America, West

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Africa and Australia were duricrusted plains and plateaux of a wide a variety of ages are widely preserved (e.g., Twidale and Campbell, 1995; Geological Survey of Western Australia, 2003; Ollier, 2001; Pillans, 2005; Butt et al., 2005; Anand and Butt, 2010; Ollier, 2014). This implies that regolith history spans at the similar timescale as tectonics and biological evolution (Ollier, 2014). This study is framed within this paradigm.

Dating of hematite from many areas in the Yilgarn suggests that extensive areas of the landscape in the Yilgarn Craton in Western Australia are Palaeogene in age (~65–25 Ma; Pillans, 2005 and references therein). Residual clays dating back to the Late Palaeozoic and Mesozoic have also been reported (>250 Ma and <145 Ma respectively; Bird and Chivas, 1988, 1989). This indicates that in some areas of Western Australia weathering profiles have been developing for at least the last ~65 Ma, and up to ~260 Ma, which has resulted in weathering profiles reaching depths of up to 150 m (e.g., Butt et al., 2000; Anand and Paine, 2002; Pillans, 2005 and references therein). Thus these regions represent ancient, stable and weathered landscapes.

Sea-level changes are mainly described as the result of transgressions and regressions, which refer to coastline positional changes linked to glaciations, eustatic sea-level changes or crustal isostasy (e.g., Bokuniewicz, 2005). Transgression–regression cycles significantly affect coastal sedimentary dynamics, driving: erosion, redistribution of continental sediments along the changing shoreline, and addition of new exotic marine sediment. The southwest coastline of Australia records major depositional events during the Palaeocene–Quaternary, as a result of eustatic sea-level variations that inundated the AFO, flooding palaeovalleys and palaeodrainages to up to 400 km inland of the present coastline (Hou et al., 2008).

Terrestrial or marine sedimentary packages, with exotic mineral and geochemical features deposited on top of in situ weathering profiles, become part of the cover and contribute to increase its total thickness. These overburden units act as filters or even impermeable barriers to vertical geochemical dispersion, which can significantly reduce, if not prevent, any ore pathfinder element or anomalous geochemical proxy from reaching the surface and being detectable in exploration campaigns (e.g., Smith et al., in this issue; Butt, 2016–in this issue; Anand et al., 2016–in this issue). The understanding of weathering processes in these regions requires an approach different from its counterparts in more recent glaciated environments. This is because of the much longer time scales involved, and the intricate overprinting of the mineral deposit footprint from different climatic shifts (González-Álvarez et al., 2015a).

The southeast of Western Australia is a regolith-dominated terrain that primarily includes the southeast margin of the Yilgarn Craton and the Albany–Fraser Orogen (Fig. 1). Cratonic margin complexities of basement lithologies, such as reworking and remelting of mixed rock suites of diverse ages, and high grades of metamorphism variably affecting basement units, have increased the difficulties of geological understanding (e.g., Cawood and Korsch, 2008; Kirkland et al., 2011; Cawood et al., 2011), and mineral exploration. Exploration protocols for the regolith cover in the Yilgarn Craton are understood (Anand

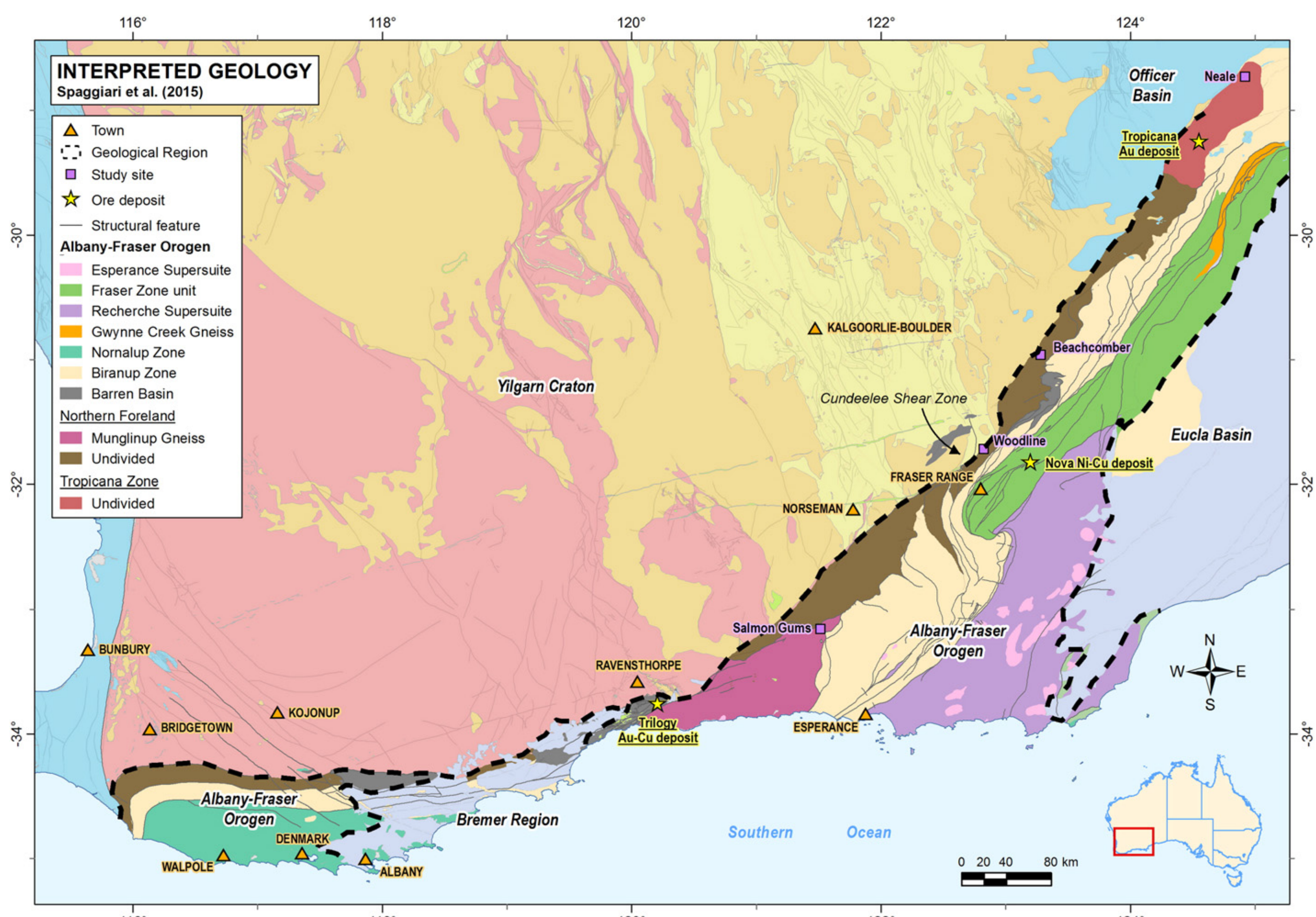

Fig. 1. Simplified geological map of the Albany–Fraser Orogen and Yilgarn Craton margin modified after the Geological Survey of Western Australia (GSWA) 500 K geological map of GSWA (2008) and Spaggiari et al. (2015).

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