Controls on mineral (gold) distribution in the Yilgarn

by

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Introduction

The Paleoarchean to Neoarchean Yilgarn Craton hosts world-class deposits of gold and nickel, and significant iron and volcanic-hosted massive sulfide (VHMS) base-metal deposits. Acquisition of a variety of new datasets across the craton over the past 25 years has led to major advances in the understanding of its geology at all scales. The new datasets include large amounts of SHRIMP U–Pb zircon geochronology; new geophysical data including aeromagnetic, gravity, passive seismic, deep-crustal seismic reflection and magnetotelluric (MT) data; regional geochemical data; and regional isotopic data. The new data have been particularly enlightening with respect to the crustal-scale architecture of the craton and its consequences for the distribution of mineral deposits.

Yilgarn components

Cassidy et al. (2006) divided the Yilgarn Craton into terranes defined on the basis of distinct sedimentary and magmatic associations (Fig. 1). The Narryer and South West Terranes in the west are dominated by granite and granitic gneiss with minor supracrustal greenstone inliers, whereas the Youanmi Terrane and the Eastern Goldfields Superterrane contain substantial greenstone belts separated by shear zones, granite and granitic gneiss. The Eastern Goldfields Superterrane comprises the Kalgoorlie, Kurnalpi, Burtville and Yamarna Terranes.

The Ida Fault (Fig. 1), which marks the boundary between the western Yilgarn Craton and the Eastern Goldfields Superterrane, is a major structure that extends to the base of the crust. Various geophysical techniques, including deep-crustal seismic, seismic receiver-function analysis, and MT surveys, show the Yilgarn crust to be between 32 and 46 km thick, with the shallowest Moho beneath the Youanmi Terrane. The crust is thicker in the southwest, and thickest in the eastern part of the Eastern Goldfields Superterrane. Seismic and gravity data suggest that the greenstones are 2–7 km thick (Swager et al., 1997; Goleby et al., 2004; Wyche et al., 2013).

Isotopic data, including Sm–Nd data (Fig. 1; Champion and Cassidy, 2007; Champion, 2013; Mole et al., 2015) and Lu–Hf (e.g. Wyche et al., 2012; Mole et al., 2014), show that the terrane subdivisions of the Yilgarn Craton reflect regions with distinctive crustal histories. The Narryer Terrane, which contains both the oldest detrital zircons yet found on Earth (back to c. 4400 Ma: Wilde et al., 2001) and the oldest rocks in Australia (back to c. 3730 Ma: Kinny et al., 1988), shows abundant evidence of very old model ages. The Youanmi Terrane has a more mixed history with a plume event at c. 2800 Ma (Ivanic et al., 2010) followed by at least two cycles of mafic to felsic volcanism (Van Kranendonk et al., 2013). The Eastern Goldfields Superterrane contains a distinctly juvenile zone that broadly coincides with the Kurnalpi Terrane. The c. 2700 Ma komatiite volcanic succession, which hosts world-class nickel deposits, lies mainly along the western side of this zone.

Deposition of supracrustal successions was accompanied by tonalite–trondhjemite–granodiorite (TTG) and local high-silica, enriched high field strength element (HFSE) granite magmatism. The latest period of granite emplacement, after c. 2655 Ma, consisted mainly of widespread low-Ca granite without contemporaneous greenstone deposition (Cassidy et al., 2002). A distinctive belt of alkaline granites, emplaced at this time, is mainly restricted to the Kurnalpi Terrane (Smithies and Champion, 1999).

Deformation histories have been described for the various terranes that comprise the Yilgarn Craton (Blewett et al., 2010a; Wyche et al., 2013). Although there are many common elements, particular regions are characterized by deformation that reflects their overall magmatic and tectonic history.

Large-scale crustal structure and mineral distribution

Begg et al. (2010) and Barnes et al. (2012) proposed that the komatiite distribution in the Eastern Goldfields is controlled by the presence of older blocks within the craton, which are underlain by thick subcontinental lithospheric mantle (SCLM). Lu–Hf data suggest the presence of subtle pro-cratonic blocks in the Youanmi Terrane (Mole et al., 2014). Relatively juvenile crust adjacent to proto-cratonic blocks hosts the major gold and nickel deposits. Some VHMS deposits (e.g. Jaguar–Bentley in the Eastern Goldfields) occur within the

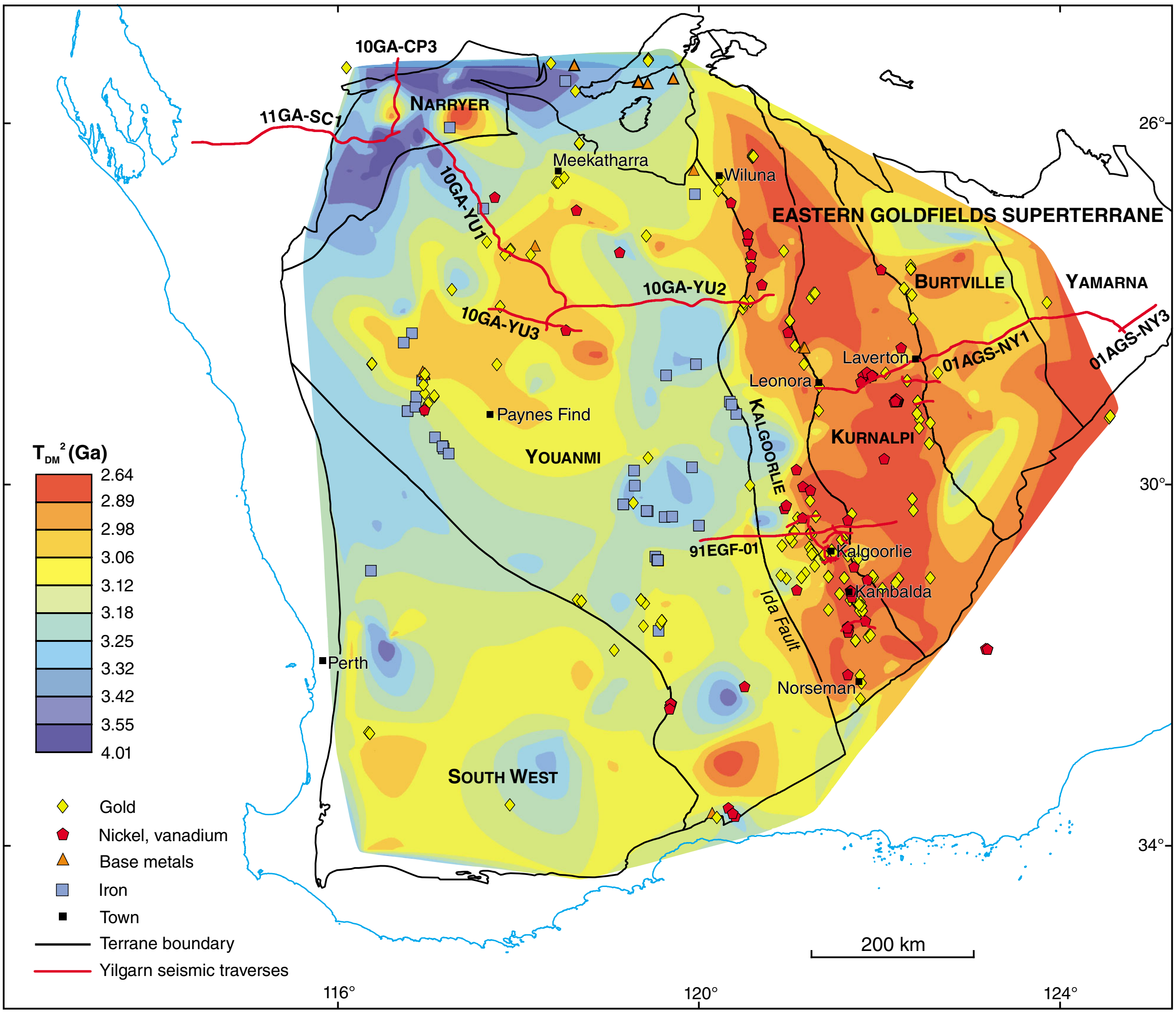

Figure 1. **Neodymium depleted-mantle model age map for the Yilgarn Craton showing terrane subdivisions and locations of major mineral deposits. Modified from Champion and Cassidy (2007) with additional data from Champion (2013), Mole et al. (2015) and the GSWA GeoChem Extract database.**

juvenile zones but deposits in older successions, such as Golden Grove, have more cryptic settings (Hollis et al., 2015). All economic iron deposits are in areas of old, reworked crust and are restricted to the western half of the craton.

Blewett et al. (2010a,b) described the key elements in the crustal architecture that play a role in the localization of gold deposits. In particular, they recognized that crust-penetrating shear zones are potentially important pathways for fluids, but that not all apparently prominent structures penetrate deeply into the crust. Blewett et al. (2010b) suggested that the best endowed areas are those that have a long history of structural preparation through repeated deformation, perhaps back to the earliest basin-forming events (e.g. Miller et al., 2010). In these places, there are likely to have been multiple episodes of mineralization. The largest gold deposits appear to be related to structures that were able to directly access deeply penetrating structures in relatively juvenile crust. These structures are broadly contemporaneous with TTG-style granites, which may form structurally favourable depositional traps through the development of features such as domes.

In the northern Yilgarn Craton, the Youanmi Terrane includes several distinct crustal elements, evident on the Yilgarn Sm–Nd model-age map (Fig. 1), some of which correspond to high gold endowment. The 2010 Youanmi seismic and MT lines (Fig. 1; Wyche et al., 2013) form a traverse from the juvenile crust of the Eastern Goldfields Superterrane in the east, across the terrane-bounding Ida Fault to the old, reworked crust in the eastern Youanmi Terrane, across the Meekatharra – Paynes Find structural corridor that is characterized by relatively juvenile crust,

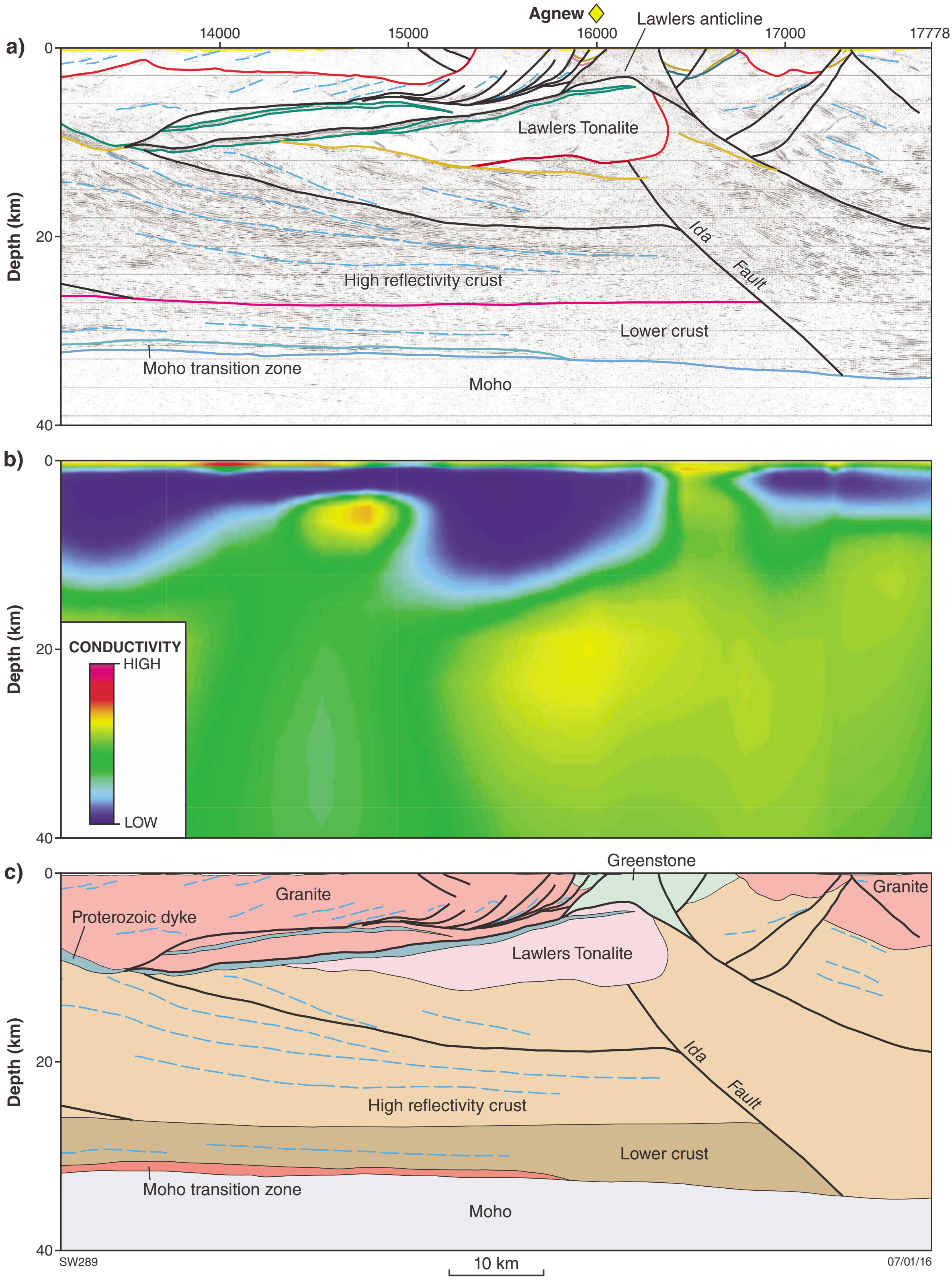

Figure 2. Eastern end of seismic line 10GA-YU2: a) seismic image with interpretation overlay showing position of the Agnew gold deposits; b) magnetotelluric image; c) simplified geological interpretation. Modified from Wyche et al. (2013)

and then into the old, reworked crust of the Narryer Terrane. The Meekatharra – Paynes Find corridor, which is occupied by greenstones of the Murchison Supergroup and associated granites (Van Kranendonk et al., 2013), contains significant gold deposits, as well as large, layered mafic–ultramafic igneous complexes that host vanadium and minor PGE mineralization (Ivanic et al., 2010).

Relating specific features in the seismic and MT data to gold mineralization, the highly endowed Agnew area at the eastern end of the 10GA-YU2 seismic line shows features such as the granite-cored Lawlers Anticline and the crust-penetrating Ida Fault (Fig. 2). To the west, newly recognized structures, such as the Wattle Creek Shear Zone on the western side of the well-endowed Meekatharra – Paynes Find corridor, are visible in lines 10GA-YU1 and 10GA-YU3 (Wyche et al., 2013).

Large-scale datasets provide insights into the distribution of known mineralization in the Yilgarn Craton, and may highlight underexplored areas, particularly those under regolith and post-Archean cover.

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