The Windimurra and Narndee mafic–ultramafic intrusions: mineralization and geological context

by

TJ Ivanic

Mafic–ultramafic intrusive rocks comprise approximately 40% by volume of the greenstone lithologies within the Murchison Domain of the Youanmi Terrane in the Yilgarn Craton (Fig. 1). Of these, the Windimurra Igneous Complex outcrops over an area of 2500 km^2 and the Nardee Igneous Complex over an area of 700 km^2, of which only about 20% is exposed. The c. 2800 Ma Windimurra and Narndee Igneous Complexes are layered igneous bodies consisting of inward-dipping, concentric layers of largely gabbroic rock. Fractionation trends and discordant layering relationships indicate that these igneous complexes formed from several pulses of magma. Large-scale, strike-slip, amphibolite-facies shear zones transect the region, and the margins of the igneous complexes are sheared and are intruded by granitic sheets (Ahmat, 1986; Scowen, 1991).

New geological mapping, petrography, geochemistry, and geochronological work in the Murchison Domain by the Geological Survey of Western Australia has helped to provide a geological framework for these large intrusions (Van Kranendonk and Ivanic, 2009). In their scheme, the Windimurra and Narndee Igneous Complexes have been assigned to the Annean Supersuite, and are subdivided into two suites based upon lithological association, level of emplacement, and age relationships: i) the Meeline Suite that includes the Windimurra, Barrambie, Atley, Youanmi, and Lady Alma Igneous Complexes, which are largely composed of leucogabbro with notably abundant anorthosite and magnetitite components; and ii) the Boodanoo Suite, which differs from the Meeline Suite in that it contains a significant volume of a hornblende gabbro phase and a larger ultramafic component, and is thus considered to have had a different parent magma (Scowen, 1991). Both these suites intrude the Norie Group (2820–2800 Ma) of the Murchison Supergroup, which locally comprises felsic volcanic rocks, psammitic–pelitic schist, and banded iron-formation. A younger suite of mafic–ultramafic intrusions, the Yalgowra Suite, intrudes into higher levels of the stratigraphy in the Polelle Group (2800–2730 Ma) of the Murchison Supergroup. These intrusions are found primarily in the northern and eastern parts of the Murchison Domain (Fig. 1).

The larger mafic–ultramafic layered intrusions of the Meeline and Narndee Suites — the Windimurra, Narndee, and Youanmi Igneous Complexes — preserve a large part of their original intrusion morphologies with relatively shallowly inward dipping, concentric layers. However, the majority of the other mafic–ultramafic intrusive rocks in the Murchison Domain are steeply dipping and are deformed into parallelism with major shear zones (Fig. 1). Outcrop patterns suggest that most of the magmas were intruded as tabular bodies, i.e. as sills, laccoliths, and lopoliths. The Windimurra Igneous Complex cumulate pile records a 13 km thickness but discordant relationships suggest that the true thickness is approximately 8 km. Primary magmatic layering is well preserved in the larger complexes and comprises megacyclic units of up to 100 m-thick cycles of peridotite–gabbro–anorthosite, with horizons of magnetitite common in the Meeline Suite. Smaller scale modal layering provides readily obtainable way-up information in both the larger and the smaller intrusions. Gabbro is the dominant lithology. However, some intrusions are more ultramafic, containing a higher proportion of peridotite, pyroxenite, and olivine gabbro. Significant vanadium mineralization is present in magnetitite from several intrusions of the Meeline Suite, with the Barrambie and Windimurra Igneous Complexes hosting the principal resources defined to date. A maximum age for the Windimurra Igneous Complex of 2813 ± 3 Ma (Nelson, 2001) is constrained by the age of rhyolite in the overlying Kantie Murdanna Volcanics into which the complex intrudes.

The Yalgowra Suite consists of layered mafic–ultramafic sills up to 4 km thick that are typically emplaced into felsic volcaniclastic rocks and banded iron-formation near the top of the Polelle Group, in the Greensleeves and Wilgie Mia Formations. These sills have been described by Watkins and Hickman (1990) and Van Kranendonk and Ivanic (2009), and are characteristically thick gabbros, with bases of cumulate pyroxenite and peridotite, and tops of leucogabbro and local anorthosite. A layered mafic–ultramafic sill in the Dalgaranga greenstone belt has an interpreted SHRIMP U–Pb zircon magmatic age of 2719 ± 6 Ma (Pidgeon and Hallberg, 2000), which is considered likely to represent of the age of the suite.

Geochemically, the Boodanoo Suite is less Ca- and Al-enriched compared to the Meeline Suite, and lacks vanadium mineralization. The chemistry, together with the presence of a hornblende gabbro phase, suggests that the Boodanoo Suite magma is derived from a hydrous source.

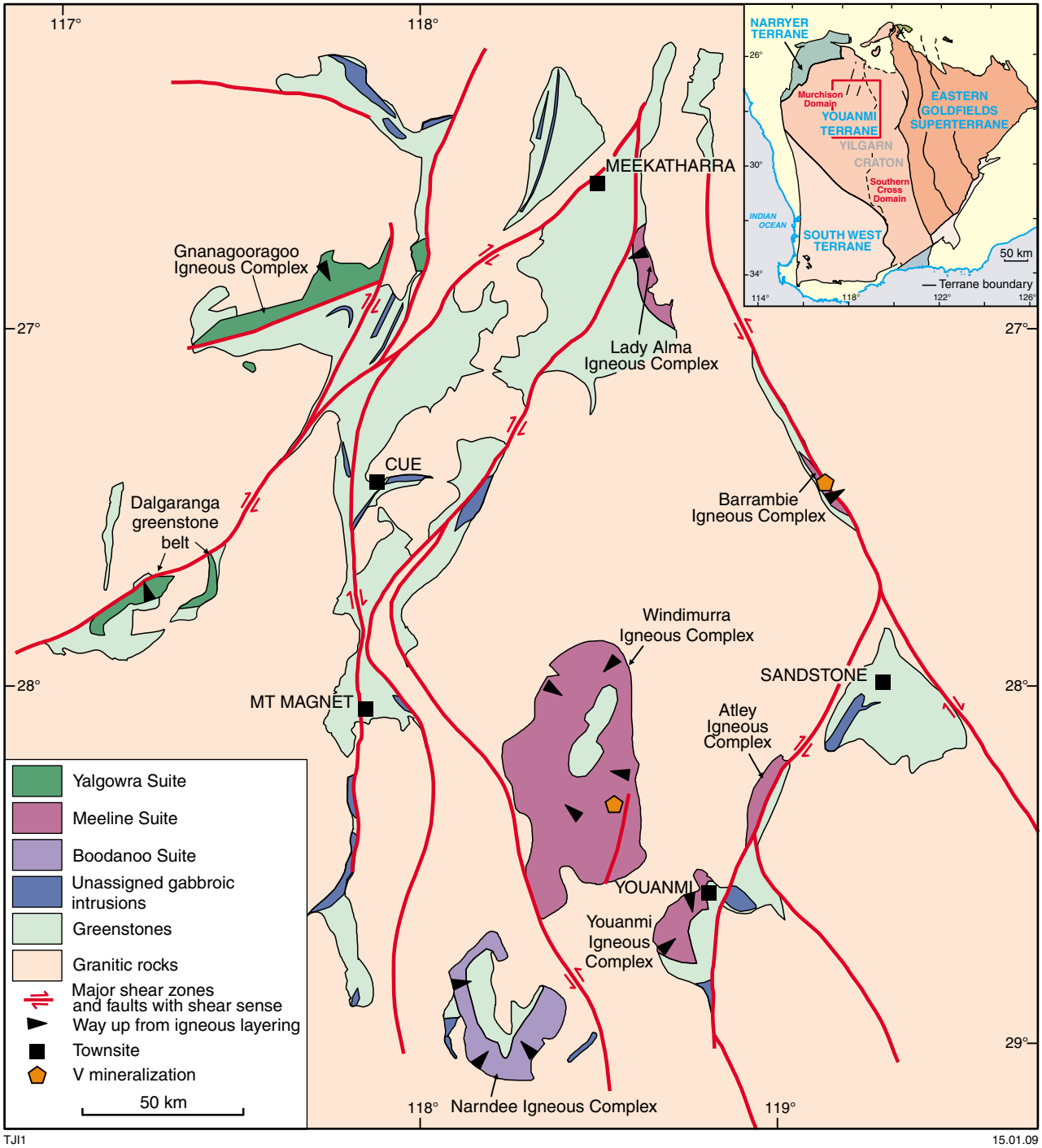

Figure 1. Simplified geology of the Murchison Domain, showing the mafic–ultramafic suites relative to major shear zones, greenstones, and granitic rocks

However, these features could also reflect a larger degree of crustal assimilation. An arc setting or a hydrous plume may also explain the hydrous nature of the Boodanoo Suite magma. No clear calc-alkaline affinities are indicated by the geochemistry, and further work is required to elucidate the origins for the two magmatic suites. Ahmat (1986) showed that at least 14 reversals of fractionation trends are present in the Windimurra Igneous Complex, and that the relatively long-lived source was continuously replenished with primitive magma.

Vanadium is concentrated in the lowermost magnetitite units of the Windimurra Igneous Complex with V_2O_5 grades commonly in excess of 0.46% (Windimurra Vanadium Limited, 2008). The mineralization style is very similar to that found in the Barrambie Igneous Complex. PGE–sulfide mineralization is found in both the Windimurra and Narndee Igneous Complexes. However, PGE geochemistry reveals that a significant quantity of sulfides have segregated at depth, leaving the higher structural levels of the igneous complexes that are exposed at the surface relatively depleted in Pt and Pd. Cu and Ni are not significantly depleted, but no resources have been found to date. Ni–Cu mineralization is present in ultramafic lithologies in the Milgoo area at Narndee, where it is linked to a suite of cross-cutting leucogabbro sheets. Several chromitites and chromite dunites within the Windimurra Igneous Complex are thin and relatively Cr poor.

The ages of the Murchison Domain mafic–ultramafic igneous complexes overlap with a very important time for crustal evolution in Archean cratons. A huge volume of mafic magmatism occurs in greenstone belts between 2800 and 2700 Ma and includes the Neoarchean thermal spike on mantle temperature evolution curves (e.g. Condie, 1998). Furthermore, the Sm–Nd model age distribution of the Yilgarn Craton granites (Champion and Cassidy, 2007) provides evidence for a large-scale north-northeasterly trending rift between Meekatharra and Mount Magnet. This implies the input of a large amount of juvenile material into the crust between c. 2960 and c. 2700 Ma. Mafic magmatism in the Murchison Domain may be the result of at least two long-lived mantle-plume and rifting events, where early greenstones were deposited onto a >2950 Ma basement and subsequently intruded by successive plume-derived mafic magmatic suites.

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