Mafic dyke swarms and large igneous provinces in Western Australia get a digital makeover

by

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Digital dyke and LIP layers in the geological map of Western Australia

Since 1894, the Geological Survey of Western Australia (GSWA) has released 14 versions of the 'Geological Map of Western Australia'. The latest in this series, published in December 2015, is the first bedrock geology map compilation in digital form that covers the entire State, and can be viewed online and downloaded at no cost in a variety of formats. The new digital State map includes an updated mafic dyke layer compiled from published geological maps and interpreted from aeromagnetic data. Mafic dyke and sill suites are shown in significantly more detail than on previous State maps, reflecting improvement in the resolution of aeromagnetic datasets, advances in isotopic dating of mafic igneous rocks, and a greater appreciation of the importance of mafic igneous events in interpreting geological history. Most dykes and sills have been assigned to named suites (Figs 1, 2) based on age, orientation, magnetization, composition, and crosscutting relationships. Many dyke swarms are also components of at least seven large igneous provinces (LIP), which range in age from late Archean to early Cambrian (Figs 1, 2).

New developments and new questions

Western Australia is endowed with an impressive number of mafic dykes and sills. In the last few years, there have been several advances in our knowledge of these mafic suites and the large igneous provinces in Western Australia, and some of these are described below.

The 2775–2715 Ma Fortescue large igneous province

The oldest coherent mafic dyke swarm in Australia is the c. 2772 Ma Black Range Dolerite Suite, which fed the Mount Roe Basalt at the base of the Fortescue Group in the northern Pilbara Craton. A new baddeleyite age of 2770 ± 4 Ma for a large north-trending dyke in the Rocklea Inlier (GSWA 205904, Wingate et al., 2017) extends the Black Range swarm more than 200 km into the southwest Pilbara Craton, beneath the Fortescue and Hamersley Groups.

The 2408–2401 Ma Widgiemooltha large igneous province

Much of the Yilgarn Craton is transected by the Widgiemooltha dyke swarm, which includes dykes of two magnetic polarities: those that strike about 075° have upward magnetic inclinations and produce positive aeromagnetic anomalies, and those that strike about 085° have downward inclinations and negative anomalies. Until recently, geochronology and paleomagnetic studies have mainly targeted the first group, yielding U–Pb ages that average 2408 ± 3 Ma (Wingate, 2007, references within, and unpublished data), and paleomagnetic data (Smirnov et al., 2013) that confirm the affinity of dykes well into the northern Yilgarn Craton. Pisarevsky et al. (2015) reported data for 'negative' dykes, including a TIMS U–Pb age of 2401 ± 1 Ma and a mean inclination higher than that of the positive dykes, implying about 10° of poleward motion of the Yilgarn Craton between c. 2408 and 2401 Ma. If additional geochronology corroborates this age difference, it may be necessary to consider the Widgiemooltha dykes as two separate swarms, although perhaps emplaced during a single protracted event.

The c. 1210 Ma Marnda Moorn large igneous province

The c. 1210 Ma Marnda Moorn LIP consists of mafic dyke swarms subparallel to the western, southern, and southeastern margins of the Yilgarn Craton, and in parts of the western Yilgarn interior. However, recent geological mapping, geochemistry, geochronology, and metamorphic studies indicate that this circum-Yilgarn LIP is only one manifestation of a much more widespread event (Fig. 3). The Marnda Moorn LIP coincided with the early stages of the 1220–1100 Ma Maralinga Event (Spaggiari et al., 2016), which included high-strain deformation, extensive ultra-high-temperature reworking, and rapakivi-style granite magmatism in central Australia (Musgrave Orogeny, Howard et al., 2015), and high-temperature magmatism and metamorphism in the Madura and Coompana Provinces and Albany–Fraser Orogen (Spaggiari et al., 2016). There was also magmatism and metamorphism at this time in the Capricorn and Pinjarra Orogens (Fig. 3).

The areal extent of these events suggests the existence of a widespread mafic underplate. The restriction of mafic dykes to the Yilgarn Craton margins at c. 1210 Ma may indicate that the mafic magmas were able to penetrate the cold, dense craton, but remained at depth elsewhere due to their relatively low buoyancy in the presence of extensive partially molten lower crust. The short duration of the LIP may reflect a change in the regional stress regime; plate reorganization at c. 1210 Ma is indicated by a major bend in the apparent polar wander curve for Australia.

The c. 1075 Ma Warakurna large igneous province

The Warakurna LIP includes layered mafic–ultramafic intrusions and mafic to felsic volcanic rocks and dykes in central Australia, and a 1000 km-long mafic sill province and several mafic dyke swarms in Western Australia. New and recent geochronology and paleomagnetic studies have resolved a c. 1075 Ma age for the Round Hummock dyke swarm (D. Evans et al., written comm., 2016) and mafic sills in the Pilbara Craton, as well as mafic sills in the interior of the Yilgarn Craton, extending the LIP to the north and south and increasing its minimum area to about 2×10^6 km^2. Based on its short duration (1078–1070 Ma, Wingate et al., 2004) and wide extent, the LIP was initially considered to have formed above a mantle plume. However, recent work by GSWA has shown that mantle-derived magmatism in the Musgrave Province continued for >50 Ma and may instead reflect inheritance of the older (1220–1120 Ma), extreme thermal anomaly in central Australia (Fig. 3). Destabilization to produce the widespread 1078–1070 Ma mafic magmatic pulse of the Warakurna LIP may have been triggered by movement on crustal- and continent-scale shear zones (Smithies et al., 2015).

Mafic igneous events at 755–735 Ma

The c. 755 Ma Mundine Well Dolerite Suite is an extensive dyke swarm that intrudes the western Capricorn Orogen and Pilbara Craton, and may be comagmatic with the Northampton dykes of the Pinjarra Orogen (Wingate and Giddings, 2000). A new U–Pb baddeleyite age of c. 735 Ma has been determined for an east-southeastly trending dyke of the Nindibillup swarm that crosscuts Mesoproterozoic rocks of the eastern Albany–Fraser Orogen, and paleomagnetic directions in another east-southeastly trending dyke (Pisarevsky et al., 2014) are similar to those for the Mundine Well dykes. These new results suggest that east-southeastly trending dykes along the southern margin of the Yilgarn Craton and the Mundine Well dykes may have been emplaced during the same event.

The work continues…

There are still many dykes in Western Australia about which very little is known, although most can be grouped into swarms of dykes of similar orientation. Unfortunately, many are not exposed, and can only be identified on aeromagnetic images. However, samples for geochronology and geochemistry continue to be collected when dykes are encountered during regional mapping. Geochemical and isotope data currently being collated are expected to help elucidate the origins and tectonic settings of several dyke suites. The digital dyke layer is regularly updated with new information, and future improvements will include assigning each dyke suite to a unique GIS layer and integration with explanatory notes.

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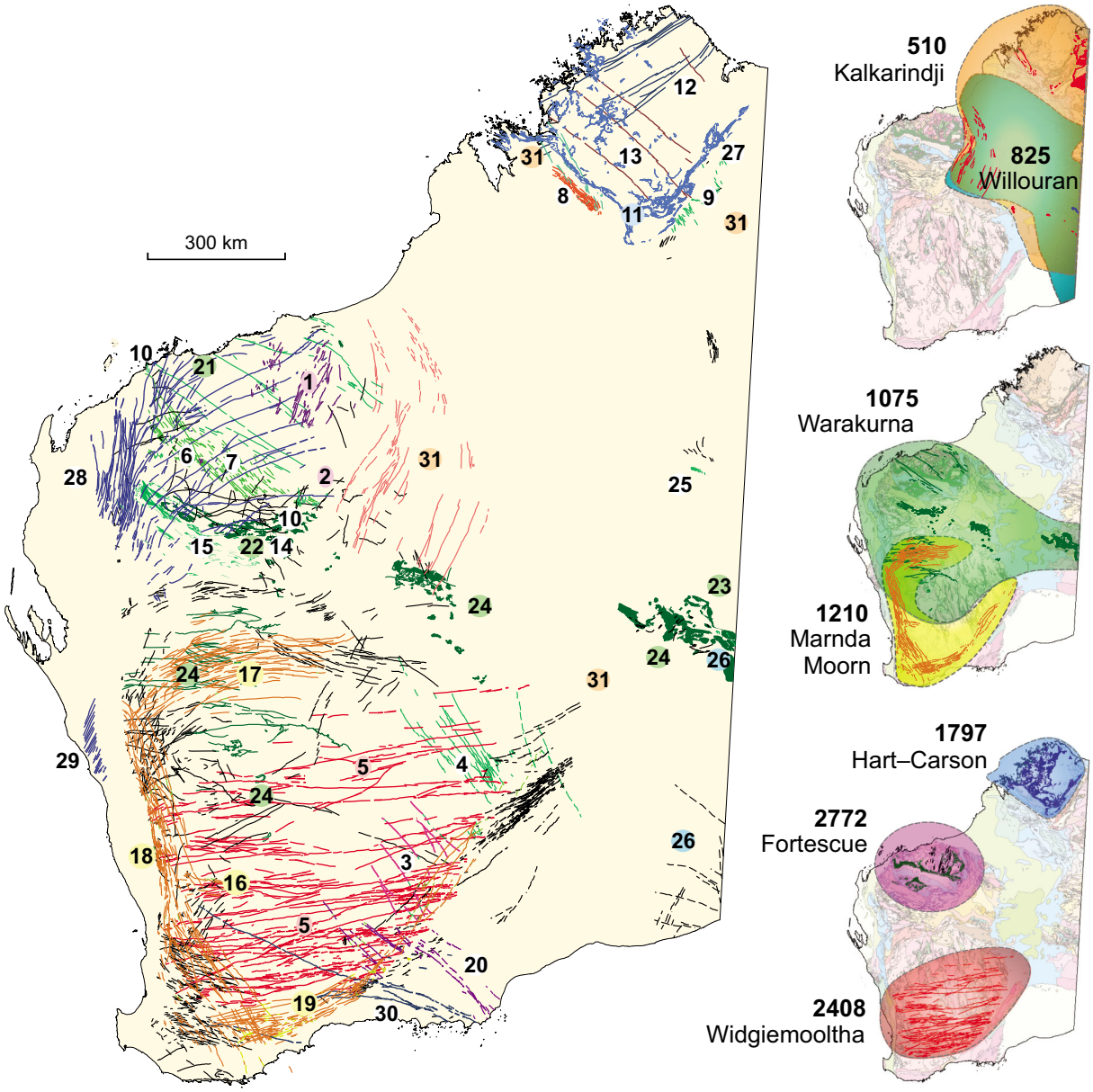

Figure 1. Dyke and sill suites in the digital map layer (left) and large igneous provinces in Western Australia (right). Ages are in Ma. Numbers identify dyke and sill suites listed in Figure 2.

	Dyke or sill suite	Age (Ma)	LIP	Location
31	Kalkarindji Supersuite	510	**Kalkarindji**	NW Officer Basin, Kimberley
30	Nindibillup Dyke Suite	735		S Yilgarn, Albany–Fraser Orogen
29	Northampton Dolerite Suite	748		Northampton Inlier
28	Mundine Well Dolerite Suite	755		Gascoyne Province, Pilbara Craton
27	Bow Hill Lamprophyre Suite	815		E Kimberley
26	Gairdner Dolerite	825	**Willouran**	Musgrave and Rudall Provinces
25	Central Desert Dolerite Suite	975		W Arunta region
24	Warakurna Supersuite	1075	**Warakurna**	Musgrave Province, Yilgarn Craton
23	Alcurra Dolerite	1075		Musgrave Province
22	Kulkatharra Dolerite (sills)	1075		Capricorn Orogen
21	Round Hummock Dolerite Suite	1075		Pilbara Craton
20	Beenong Dyke Suite	1210–541		SE Yilgarn, Albany–Fraser Orogen
19	Gnowangerup – Fraser Dyke S.	1210	**Marnda Moorn**	S Yilgarn Craton margin
18	Boyagin Dolerite Suite	1210		W Yilgarn Craton margin
17	Muggamurra Dolerite Suite	1210		N Yilgarn Craton margin
16	Wheatbelt Dyke Suite	1210		W & S Yilgarn Craton
15	Narimbunna Dolerite (sills)	1465		Capricorn Orogen
14	Waldburg Dolerite (sills)	1500		Capricorn Orogen
13	Prince Regent Dyke Suite	1797–510		Kimberley
12	Kalumburu Dyke Suite	1797–510		Kimberley
11	Hart Dolerite (mainly sills)	1797	**Hart–Carson**	Kimberley
10	Preston Dolerite Suite	1816		W Pilbara Craton
9	Warmun Dolerite Suite	1860–560		E Kimberley
8	Leopold Downs Dyke Suite	1860–560		W Kimberley
7	Panhandle Dyke Suite	2008		Hamersley region
6	Moodogara Dyke Suite	2208		Hamersley region
5	Widgiemooltha Supersuite	2408	**Widgiemooltha**	Yilgarn Craton
4	Cosmo Newbery Dyke Suite	2500–510		E Yilgarn Craton
3	Lakewood Dolerite Suite	2500–541		E Yilgarn Craton
2	Prairie Downs Dyke Suite	2745	**Fortescue**	S Pilbara Craton
1	Black Range Dolerite Suite	2772		E Pilbara Craton

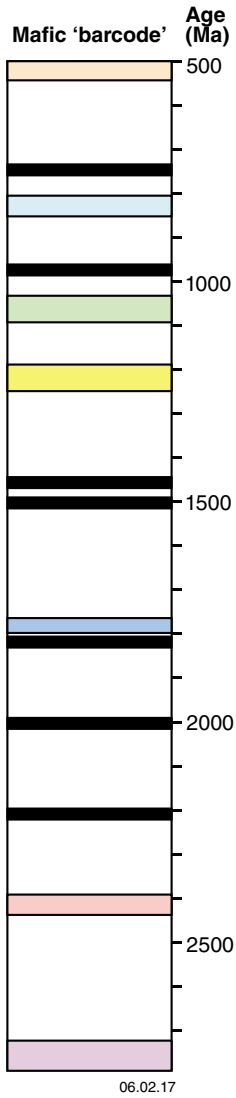

Figure 2. Named mafic dyke and sill suites in Western Australia, and their mafic 'barcode'. Numbers refer to Figure 1.

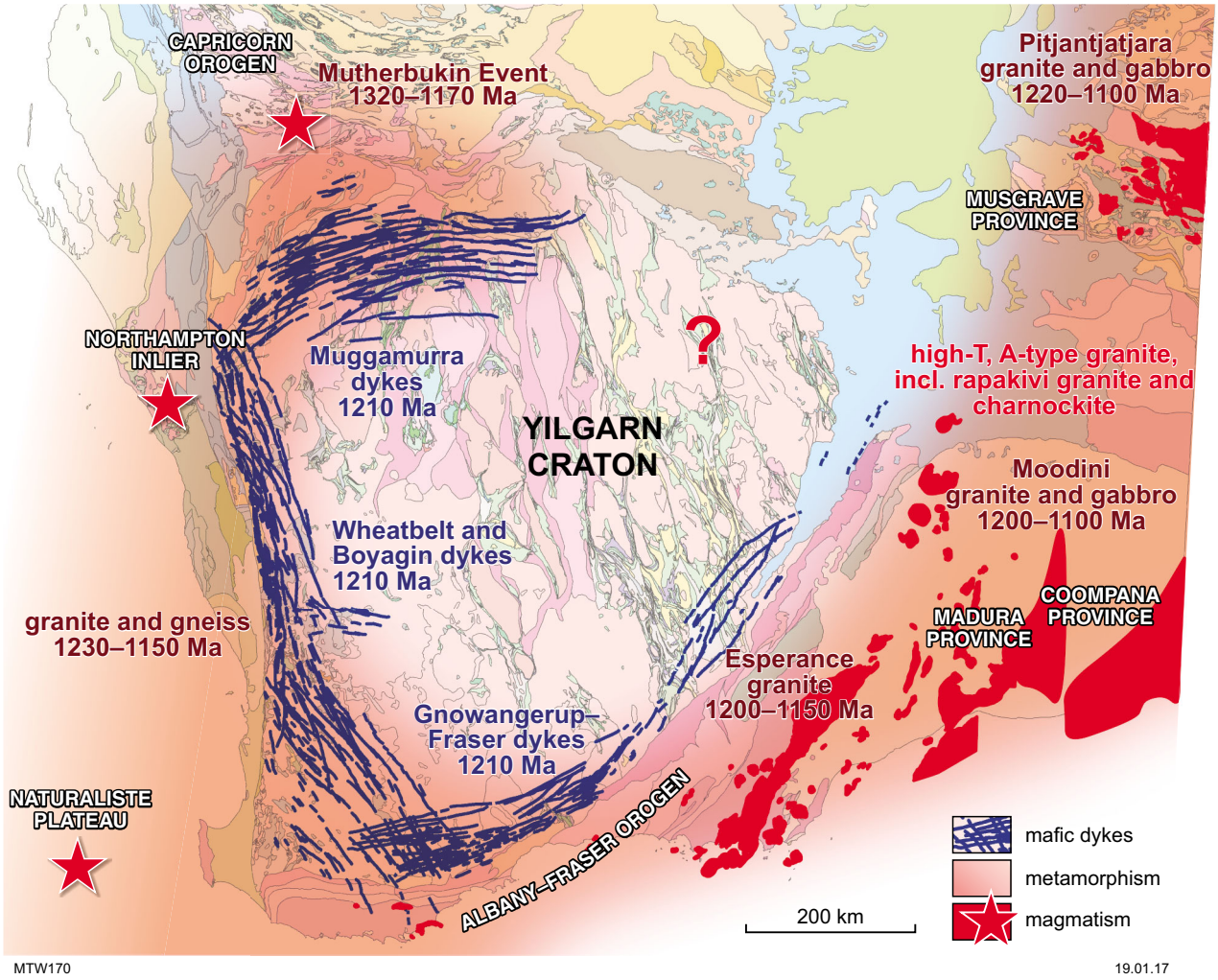

Figure 3. Mafic dyke swarms of the c. 1210 Ma Marnda Moorn large igneous province, and broadly coeval magmatic events in Western Australia