Geochemical and Nd isotopic signatures of mafic dykes in the western Musgrave Complex

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Abstract

Mafic dykes intruding the Mesoproterozoic granulites and gneisses of the Musgrave Complex in central Australia can be divided into at least six geochemical suites. The oldest belongs to the Pitjantjatjarra Supersuite (c. 1170 Ma), related to the Musgravian Orogeny. The Alcurra dykes form part of the 1070 Ma Giles Event, and with the Giles mafic–ultramafic layered intrusions form part of the Warakurna large igneous province. Post-Giles Event mafic dyke suites include unnamed plagioclase-rich dykes, unnamed olivine dolerite dykes (c. 1000 Ma), the Gairdner Dyke Swarm and Amata Dolerite (c. 800 Ma), and unnamed light rare earth element (LREE)-depleted dykes (c. 750 Ma). Secular trends in geochemical composition of the mafic suites show generally decreasing concentrations of incompatible trace elements and increasing ε_{Nd} with decreasing age.

KEYWORDS: mafic rocks, dykes, geochemistry, Western Australia, Musgrave Complex.

Introduction

The Musgrave Complex, in central Australia, is an east-trending belt up to 800 km long and 350 km wide at the junction of the Archean–Proterozoic West, North, and South Australian Cratons. The complex includes gneisses with protolith ages that pre-date the onset of the c. 1225–1160 Ma Musgravian Orogeny and metamorphosed granites that intruded during that orogeny. It was later intruded, during the c. 1070 Ma Giles Event, by ultramafic to mafic intrusions and by granites, which together form the Warakurna Supersuite. The complex is overlain by volcanic and sedimentary rocks of the Bentley Supergroup, which is coeval with the Warakurna Supersuite.

Several different suites of mafic dykes in the Musgrave Complex have been previously documented based on combinations of their field relationships, petrography, and major element, trace element, and isotope geochemistry (Nesbitt et al., 1970; Clarke et al., 1995; Zhao and McCulloch, 1993; Glikson et al., 1996; Scrimgeour et al., 1999). This geochemical and isotopic study has identified several new suites of mafic dykes within the granulite-facies Fregon Domain of the western Musgrave Complex close to the Northern Territory and South Australia borders (Fig. 1).

The oldest dykes (c. 1170 Ma), which belong to the Pitjantjatjarra Supersuite, are the only pre-Giles Event mafic dykes recognized. During the c. 1070 Ma Giles Event, magmatism associated with the emplacement of the Warakurna large igneous province (Wingate et al., 2004) formed layered mafic–ultramafic intrusions, such as the Hinckley Range, Michael Hills, and Bell Rock intrusions, as well as the Alcurra Dolerite (Zhao and McCulloch, 1993; Edgoose et al., 2004).Unnamed plagioclase-rich dolerite dykes clearly post-date the Giles Event intrusions, but their relationship with younger mafic dyke suites is unclear. Other post-Giles Event intrusions include unnamed olivine- and plagioclase-porphyritic dolerite dykes at c. 1000 Ma, 825 Ma quartz dolerite dykes of the Gairdner Dyke Swarm, and c. 800 Ma dykes of the Amata Dolerite (Zhao and McCulloch, 1993; Glikson et al., 1996; Wingate et al., 1998). A further suite of dykes with trace-element-depleted characteristics may be of similar age or younger than the Gairdner Dyke Swarm. Collectively, these groups of mafic dykes provide an opportunity to trace 400 million years of mantle evolution beneath the Musgrave Complex.

Pitjantjatjarra Supersuite mafic intrusions (1207–1170 Ma)

Mafic rocks within the Pitjantjatjarra Supersuite are distributed both north and south of the Mann Fault on the BATES and BELL ROCK 1:100 000

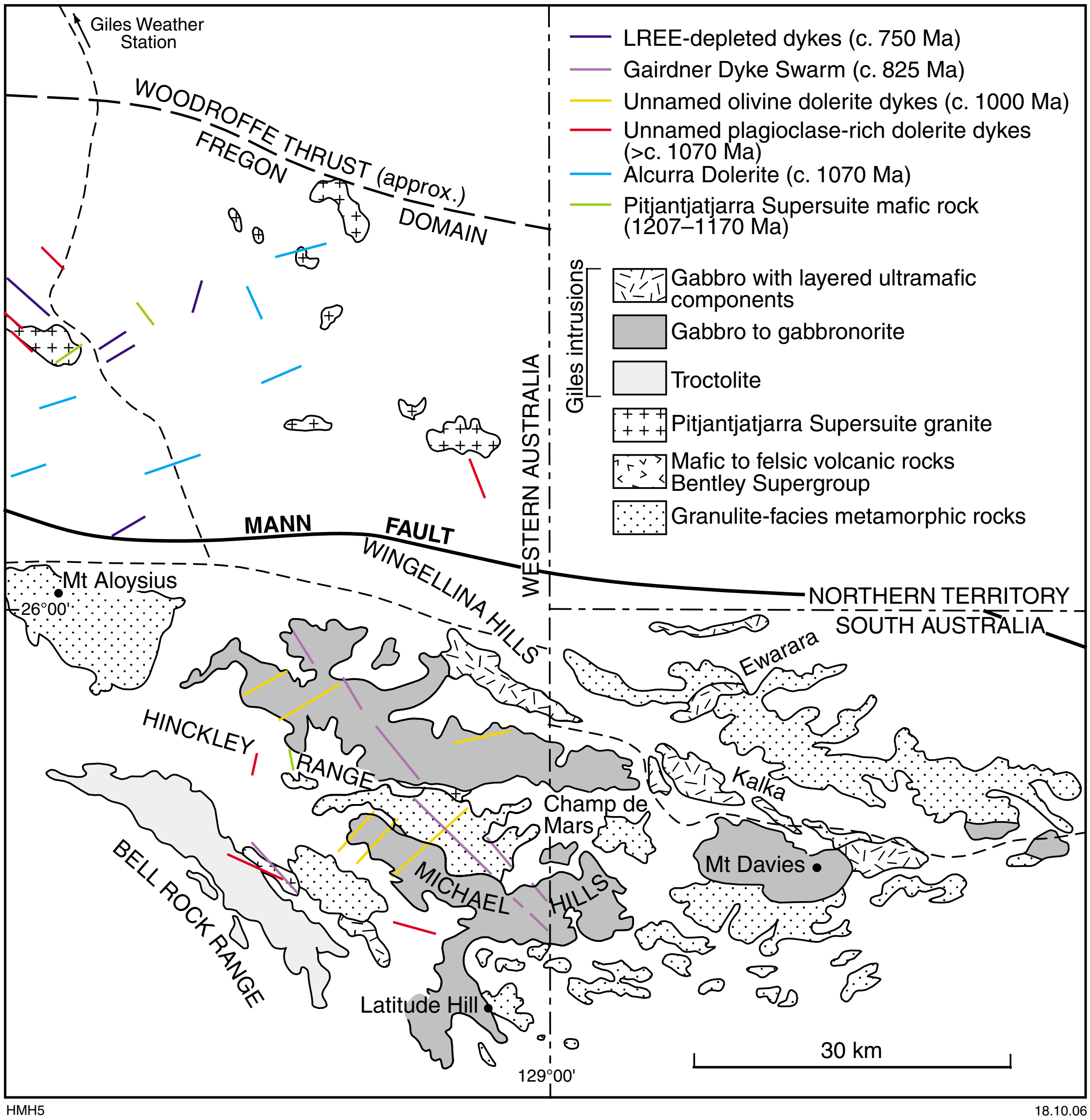

Figure 1. Distribution of mafic dyke suites on the Bates and Bell Rock 1:100 000 map sheets

map sheets. A large biotite gabbro intrusion south of the Hinckley Range yielded a sensitive high-resolution ion microprobe (SHRIMP) U–Pb zircon age of 1176 ± 5 Ma (Glikson et al., 1996) and a layered leucogabbro north of the Mann Fault yielded a SHRIMP U–Pb zircon age of 1190 ± 7 Ma (Geological Survey of Western Australia, in prep.). Several mafic dykes are included in this group based on their field relationships. For example, some dykes at Mount Fanny intrude and in places appear to be interleaved with 1207 Ma granites of the Pitjantjatjarra Supersuite, but are also intruded by c. 1170 Ma granite of the Pitjantjatjarra Supersuite. The orientations of the dykes are variable.

The dykes are typically medium grained, massive, and most have a polygonal granoblastic texture. Locally, they contain large (up to 5 mm) clinopyroxene oikocrysts. A typical mineral assemblage consists of plagioclase (45%), orthopyroxene (25%), clinopyroxene (25%), quartz (5%), late-stage brown biotite, green hornblende (replacing pyroxene), and garnet. Some dykes contain abundant disseminated ilmenite grains. Reaction textures include brown biotite and quartz coronas on orthopyroxene, clinopyroxene and garnet coronas on orthopyroxene, and garnet coronas on clinopyroxene and opaque minerals.

The Pitjantjatjarra Supersuite mafic dykes have primitive mantle-normalized incompatible trace-element profiles that are light rare earth element (LREE) enriched, (Table 1, Fig. 2a) with La/Sm values of 4.1 to 4.5 and Gd/Yb values of 1.4

to 1.9. They also have high Th/Nb values, suggesting either enrichment of the mantle source or crustal contamination. Negative titanium anomalies and corresponding low iron contents may reflect ilmenite fractionation. Two Nd isotopic analyses give epsilon Nd (ε_{Nd}) values of –2.42 and –6.20 (calculated at t = 1207 Ma, their maximum age) also suggesting crustal contamination.

Alcurra Dolerite (c. 1070 Ma)

The c. 1070 Ma dykes in Western Australia are contemporaneous with the Alcurra Dolerite and Stuart Pass Dolerite of Northern Territory and show geochemical similarities with the former. In Western Australia the mafic dykes of the Alcurra Dolerite have so far only been identified north of the Mann Fault (on the BELL ROCK 1:100 000 map sheet). They intrude felsic rocks of the Pitjantjatjarra Supersuite, but typically have mylonitic contacts. Most of these mafic dykes are oriented east-southeast and dip 40° to 60° to the south.

The dykes of the Alcurra Dolerite are medium to coarse grained and have a distinctive ophitic texture with oikocrysts several centimetres in diameter. Primary minerals include pink cloudy plagioclase, augite, and minor orthopyroxene symplectite oikocrysts, subhedral olivine, magnetite, and sulfide minerals. Pyrrhotite and pentlandite crystallized in late penetrating fractures in other minerals. Secondary biotite and chlorite rim opaque minerals and garnet forms rims on augite. Olivine has rims of both chlorite and plagioclase or intergrowths of plagioclase–clinopyroxene.

The Alcurra Dolerite has MgO contents of 5.2 to 6.8 wt% and higher TiO_2 and P_2O_5, and lower SiO_2 than the other suites of dykes. They are LREE-enriched (La/Sm = 2.6 to 3.3, Gd/Yb = 1.5 to 2.0) with slight negative Nb anomalies (Fig. 2b). Values for ε_{Nd} range from +0.89 to –0.92 (calculated at t = 1075 Ma), inside the range of +0.1 to –1.3 for Alcurra Dolerites dykes of the Northern Territory (Scrimgeour et al., 1999).

Michael Hills, Hinckley Range and Bell Rock intrusions (c. 1070 Ma)

Most of the large layered Giles Event intrusions, including the Hinckley Range, Michael Hills, and Bell Rock Range intrusions, are south of the Mann Fault. The Hinckley Range and Michael Hills intrusions consist of interlayered gabbros, gabbronorites, and anorthosites, whereas the Bell Rock intrusion is dominantly composed of troctolite and gabbro.

The Michael Hills and Hinckley Range intrusions show a range of trace-element abundance patterns (Fig. 2c), interpreted to be influenced by cumulate processes. Nevertheless, the overall trend shows little to no LREE enrichment compared with the LREE-enriched troctolites and gabbros of the Bell Rock intrusion (Fig. 2d). The trace element profiles for the Hinckley intrusion gabbros and the Michael Hills intrusion gabbronorite are similar. The possibility that these two intrusions might be remnants of a larger igneous body is consistent with gravity data indicating that the two are connected at depth (Shevchenco, S., 2006, written comm.). The ε_{Nd} values for the three intrusions fall within the range 0.89 to –2.75 (calculated at t = 1075 Ma), slightly more negative than the range for the Alcurra Dolerite dykes.

Unnamed plagioclase-rich dolerite dykes (post-c. 1070 Ma)

Northwestly to north-northwesterly trending plagioclase-rich dolerite dykes have been identified both north and south of the Mann Fault. North of the Mann Fault (BATES 1:100 000 map sheet) they intrude granites of the Pitjantjatjarra Supersuite and paragneiss of the Birksgate Metamorphics. South of the Mann Fault they cut the Bell Rock intrusion and c. 1300 Ma granite at Mount West.

The plagioclase-rich dykes are mostly fine to medium grained, either with subophitic to ophitic textures or with polygonal to elongate granoblastic textures where they are foliated. They contain clinopyroxene and a high proportion of plagioclase (60–65%) and opaque minerals. Clinopyroxene has poorly developed coronas of garnet, amphibole, and quartz. This dyke suite is poorly defined, in that the dykes do not have consistent orientations and are of limited distribution.

The dykes have flat, unfractionated, primitive mantle-normalized trace element patterns with generally slightly negative Nb anomalies (Fig. 2e). MgO contents are similar to or higher than those of the other dyke suites, ranging from 7.9 to 10.1 wt%, and Ni contents are similarly high, ranging from 170 to 240 ppm. Two dykes have ε_{Nd} values of 0.58 and –2.06, calculated at t = 1075 Ma (the maximum age of the unnamed plagioclase-rich dolerites).

Unnamed olivine dolerite dykes (c. 1000 Ma)

A suite of unnamed olivine dolerite dykes (referred to by Glikson et al., 1996, as Type C dykes) are mostly northeast trending and are most common in the Michael Hills and the Hinckley Range intrusions. They have so far only been identified south of the Mann Fault. They crosscut the igneous layering of the Giles Event intrusions and are crosscut by 825 Ma dykes of the Gairdner Dyke Swarm. A poorly constrained Sm–Nd mineral isochron age of 1000 Ma was obtained for one of the dykes (Glikson et al., 1996).

The unnamed olivine dolerite dykes have textures that distinguish them from the other dyke suites. They have a fine-grained groundmass and a porphyritic texture, containing phenocrysts of plagioclase (up to 10%) and olivine (5%). The groundmass contains plagioclase (50–60%), clinopyroxene (20–30%), opaque phases (5%), and accessory biotite, Fe–Ti oxides, and spinel. The opaque minerals crystallized late and include ilmentite, pyrrhotite, pentlandite, and pyrite. The texture is dominantly igneous; however,

Table 1. Whole-rock analyses of dolerites dykes, Hinckley Range gabbro and Bell Rock gabbro

Mafic suite	*Pitjantjatjarra Supersuite dolerite*	*Alcurra Dolerite*	*Hinckley Range gabbro*	*Bell Rock gabbro*	*Plagioclase-rich dolerite*	*Olivine dolerite*	*Gairdner Dyke Swarm dolerite*	*LREE-depleted dolerite*
Sample ID	*174793*	*174547*	*183532*	*183431*	*183411*	*174570*	*174564*	*174751*
				Weight percentage				
SiO_2	50.94	48.33	48.43	47.38	47.90	49.05	49.95	48.03
TiO_2	1.03	2.11	0.55	0.46	0.85	1.33	1.38	0.86
Al_2O_3	15.73	15.45	19.37	22.00	17.37	16.71	14.08	16.55
Fe_2O_3	2.07	1.97	1.58	1.44	2.25	2.10	2.17	1.84
FeO	8.69	11.47	6.15	7.08	9.31	8.60	9.67	7.74
MnO	0.19	0.20	0.12	0.11	0.19	0.17	0.20	0.17
MgO	7.62	6.07	8.58	7.59	8.31	8.06	8.11	9.42
CaO	9.77	8.32	11.68	10.57	10.68	9.90	12.04	12.06
Na_2O	2.49	2.79	2.25	2.57	2.24	2.66	1.91	1.86
K_2O	0.82	1.09	0.36	0.24	0.24	0.66	0.21	0.21
P_2O_5	0.16	0.42	0.06	0.05	0.10	0.31	0.11	0.08
LOI	-0.74	0.21	-0.14	-0.46	-0.81	-0.94	-1.07	0.04
SO_3	0.22	0.10	0.15	0.03	0.20	0.24	0.03	0.15
Total	**98.99**	**98.53**	**99.14**	**99.06**	**98.83**	**98.85**	**98.79**	**99.01**
				Parts per million				
Ag	0.2	0.23	0.01	0.18	0.46	0.05	0.2	0.1
As	2.7	4.9	0.9	3.5	5.4	1.9	2.9	1.9
Ba	255	400	173	71	94	297	44	26
Be	0.6	1.4	1.0	0.3	0.8	0.4	0.3	0.3
Cr	188	60	260	232	176	288	149	332
Cs	0.22	0.68	0.01	0.03	0.03	0.07	0.12	0.11
Cu	55	76	96	42	132	68	184	120
Ga	16.3	20.9	16.6	22.4	17.5	18.2	18	14.7
Ge	1.4	1.4	1.1	1	1.7	1.1	1.7	1.5
Hf	2.9	4.1	0.9	0.4	1.5	2.5	2.1	1.4
Mo	0.9	1.2	0.5	0.6	0.8	1.1	0.6	0.4
Nb	3.9	10.8	1.0	0.8	2.2	6.3	4.5	1.1
Ni	98	108	248	269	173	132	115	193
Rb	26.2	31.1	7.1	5.0	6.9	14.8	11.1	15
Sb	0.2	0.1	–	0.2	0.3	5.4	0.2	3.3
Sc	28	22	24	8	27	22	32	33
Sr	155.1	267.1	371.8	385.2	185.2	348.8	165.6	151.2
Th	3.4	2.8	0.4	0.4	0.3	1.8	1.2	0.5
Ti	6 186	12 678	3 282	2 730	5 082	7 968	8 292	5 160
V	200	234	108	87	206	204	347	248
Y	31.2	24.5	12.9	4.3	11.7	29.3	26.4	23.7
Zn	90	128	54	56	78	87	82	66
Zr	128.1	160.1	30.2	17.3	51.5	125.3	82.9	51.4
La	16.42	19.47	4.92	2.78	4.79	15.84	5.97	2.71
Ce	33.42	45.16	9.37	5.66	11.56	32.39	14.28	6.73
Pr	4.13	5.81	1.38	0.75	1.57	4.23	2.15	1.06
Nd	17.43	26.29	5.85	3.41	7.42	19.08	10.64	5.64
Sm	3.74	5.87	1.72	0.76	2.14	4.13	3.31	2.01
Eu	1.122	1.971	0.751	0.643	0.837	1.541	1.164	0.769
Gd	3.77	5.95	1.9	0.72	2.54	4.31	3.64	2.71
Tb	0.68	0.97	0.3	0.12	0.47	0.75	0.68	0.50
Dy	4.33	5.85	1.94	0.73	2.97	4.38	4.00	3.36
Ho	0.92	1.16	0.4	0.13	0.65	0.86	0.86	0.73
Er	2.89	3.42	1.18	0.40	1.95	2.52	2.49	2.22
Yb	2.70	2.83	1.13	0.31	1.64	2.21	2.02	1.99
Lu	0.41	0.42	0.16	0.04	0.26	0.34	0.31	0.31
La/Sm	4.39	3.32	2.86	3.66	2.24	3.84	1.80	1.35
Gd/Yb	1.40	2.1	1.68	2.32	1.55	1.95	1.80	1.36
La/Nb	4.21	1.8	4.92	3.48	2.18	2.51	1.33	2.46
ε_{Nd}	-6.43	-0.34	-2.65	0.59	0.58	-2.84	2.39	4.58
Age	1 180	1 075	1 075	1 075	1 075	1 000	800	750

NOTES: ε_{Nd} calculated using the crystallization age (T) of the mafic suite. Analytical procedures are outlined in Morris and Pirajno (2005)

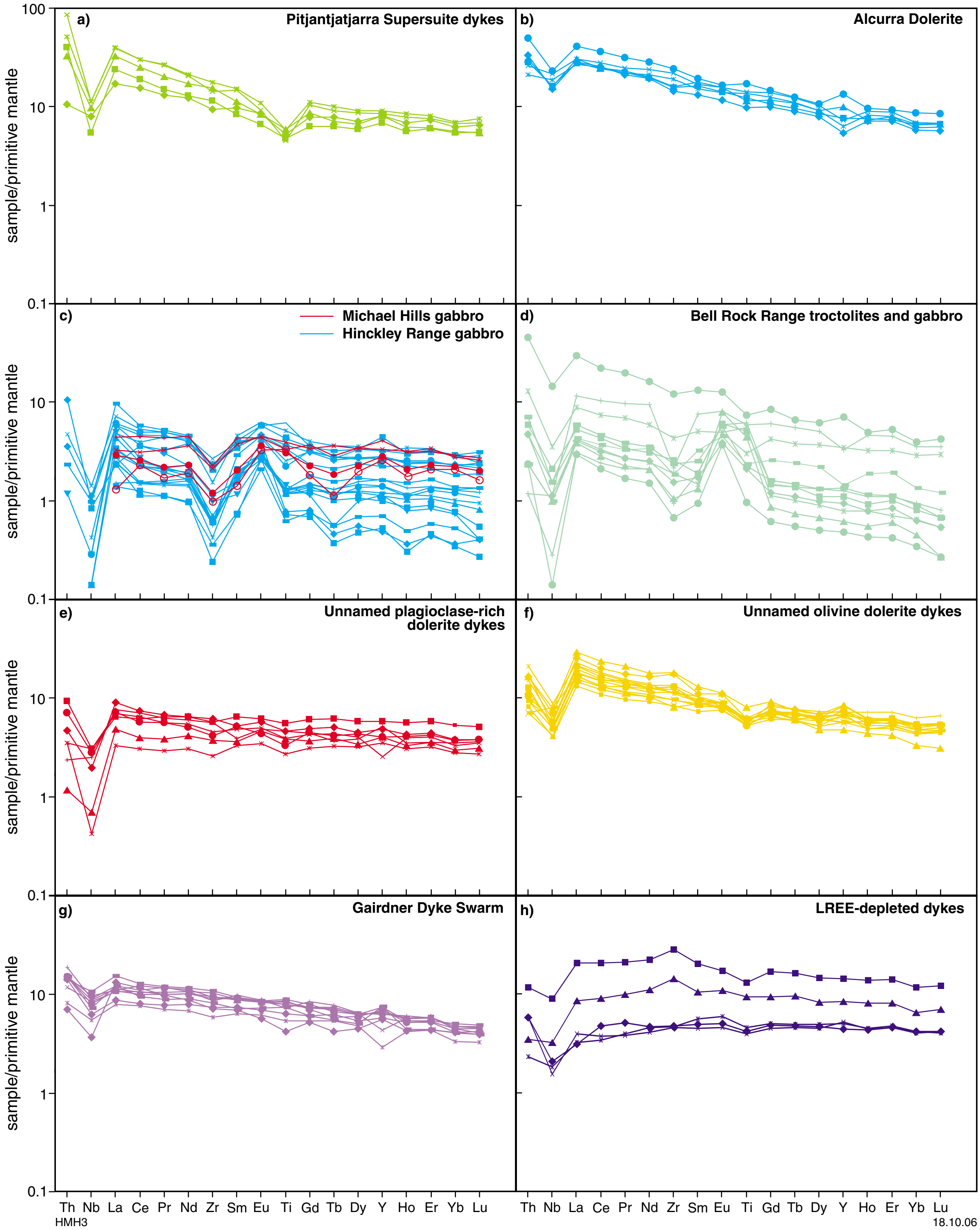

Figure 2. (a–h) Primitive mantle-normalized trace element plots for the mafic dyke suites, and the Hinckley Range and Bell Rock intrusions of the western Musgrave Complex. Normalizing values from Sun and McDonough (1989).

many of the dykes show recrystallized clinopyroxene, and in some cases where the entire groundmass has been recrystallized, a polygonal granoblastic texture is seen. Plagioclase coronas on olivine phenocrysts are common.

The dykes are chemically more primitive than many of the other suites, with high MgO (mostly 9 to 13 wt%), and Ni (132–291 ppm) reflecting their high olivine content. They nevertheless have LREE-enriched profiles [La/Sm = mostly 2.8 to 3.5, slightly lower than that of the Alcurra Dolerite], high Gd/Yb ratios (1.6 to 2.0), but at significantly lower REE abundances than the Alcurra Dolerite (Fig. 2f). They have a slight negative Nb anomaly, suggesting limited crustal contamination. The olivine dolerite dykes have ε_{Nd} values ranging from 0.65 to –2.84 when calculated at t = 1000 Ma.

Gairdner Dyke Swarm and Amata Dolerite dykes (c. 825 Ma)

The Gairdner Dyke Swarm (Type B dykes of Glikson et al., 1996) contains mostly northwest- to north-trending dykes that so far have only been identified south of the Mann Fault. One dyke in Western Australia yielded a zircon U–Pb age of 824 ± 4 Ma (Glikson et al., 1996), similar to the baddeleyite U–Pb age of 827 ± 6 Ma for a Gairdner Dyke Swarm dyke on the Stuart Shelf (Wingate et al., 1998). An Amata Dolerite dyke gave a less precise Sm–Nd age of 790 ± 40 Ma (Zhao et al., 1994). The Gairdner Dyke Swarm, Type B dykes and Amata Dolerite dykes have been linked on the basis of their similar ages and chemistry (Glikson et al., 1996). They crosscut the unnamed olivine dolerite dykes and Giles Event intrusions such as the Hinckley Range and Michael Hills intrusions. They are composed of medium-grained, intergranular to subophitic dolerite, but where recrystallized show polygonal granoblastic textures. The dolerite consists of pink cloudy plagioclase (labradorite, 55–60%), augite (30–40%), and late sulfide minerals (up to 5% pyrrhotite with accessory pyrite). Augite is commonly altered to amphibole and biotite is associated with the sulfide phases. In zones of deformation the dolerite is variably recrystallized, and contains micromylonite zones and warped plagioclase.

The dykes have slightly enriched primitive mantle-normalized incompatible trace-element profiles (La/Sm = 1.8 to 2.9) and a slight negative Nb anomaly (Fig. 2g).

Neodymium data for two dykes show ε_{Nd} values of +2.39 and +3.81 (calculated at t = 800 Ma), generally lower than the range of +3.1 to +4.9 for these dykes in the Northern Territory (Scrimgeour et al., 1999), but consistent with the ε_{Nd} values of +2.4 to +4.3 for the Amata Dolerite and the Gairdner Dykes Swarm of South Australia (Zhao et al., 1994).

LREE-depleted dykes (c. 750 Ma)

There are several metamorphosed mafic dykes north of the Mann Fault (BATES 1:100 000 map sheet) that are characterized by distinctive depleted incompatible trace-element geochemistry and high ε_{Nd} values. Their orientation varies where deformed, from east-northeast to northwest.

The dykes are medium grained, massive, ophitic to subophitic metagabbros. The well-preserved igneous textures are, however, accompanied by high-grade metamorphic reactions. Recrystallized dykes have polygonal granoblastic textures and well-foliated or mylonitic dykes have elongate granoblastic textures.

The major mineral assemblage consists of green clinopyroxene (sometimes as oikocrysts), orthopyroxene, euhedral plagioclase (30–35%), green hornblende, quartz (<5%), with or without garnet (porphyroblasts). Rutile, biotite, pentlandite, and pyrrhotite are accessory minerals. Fine-grained sulfides extend along grain boundaries, enclose plagioclase grains, and are common inclusions within garnet porphyroblasts. Metamorphic reactions include hornblende rims on clinopyroxene, biotite rims on opaque phases, and polygonal aggregates of biotite–garnet–clinopyroxene surrounding orthopyroxene.

The LREE-depleted dykes (Fig. 2h) have La/Sm ratios of 0.8 to 1.5 and flat heavy rare earth element (HREE) profiles (Gd/Yb = 1.3–1.7), compared with the other suites of dykes. They also have a slightly negative Nb anomaly and ε_{Nd} values ranging from +4.58 to +4.60.

A three-point Sm–Nd age determination yielded an age of 747 ± 48 Ma (GSWA unpublished data) suggesting that they are either a depleted component of the c. 800 Ma magmatic event that produced the Gairdner Dyke Swarm and Amata Dolerite of South Australia (Zhao et al., 1994) or a slightly younger suite, possibly contemporaneous with the 755 Ma Mundine Well dyke swarm of northwestern Australia (Wingate and Giddings, 2000). If the former is true, then they were extracted from a source that was more melt depleted than other dykes of that age. The LREE-depleted dykes show contrasting trace element characteristics to the LREE-enriched 755 Ma Mundine Well Dyke Swarm (Morris and Pirajno, 2005; Li et al., 2006).

Discussion

The trace element and isotope geochemistry of the six mafic dykes suites suggests that they were derived from distinct magma sources or incorporated distinct source components. All suites have higher La/Nb ratios than primitive mantle, in particular the Pitjantjatjarra Supersuite, the plagioclase-rich dykes, and the olivine dolerite dykes, which have the highest La/Nb ratios of more than 2. These high ratios indicate the involvement of either crustal contamination or subduction-enriched mantle sources.

Secular trends in composition towards generally decreasing concentrations of incompatible trace elements with decreasing age are evident from the trace element profiles of most dyke suites at a given MgO content and these trends most probably reflect differences in the magma sources. The Pitjantjatjarra Supersuite mafic intrusions show very LREE enriched trace element patterns and have high La/Nb ratios (3.2 to 4.2) indicative of a significant crustal component. The Alcurra Dolerite dykes show slightly less LREE enrichment, but significantly lower La/Nb ratios (1.3 to 1.8), suggesting more extensive fractionation of a less enriched source or of a relatively uncontaminated magma.

The difference in composition between the Alcurra Dolerite dykes and the unnamed plagioclase-rich dolerite dykes is the only exception to the secular enrichment trend. The plagioclase-rich dykes were either intruded in the latter stages of or after the Giles Event. Their low REE abundances, high MgO and Ni contents, and flat REE profiles may be due to a higher degree of melting of a slightly more refractory mantle source, following the extraction of large amounts of mafic magma from the mantle during the Giles Event. The relatively high La/Nb ratios of 2.1 to 7.6 still require the involvement of a crustal component, either in the mantle source or as a later magma contaminant.

The unnamed olivine dolerite dykes are LREE enriched with La/Nb ratios ranging from 2 to 4 and were possibly generated from a similar source to the plagioclase-rich dykes. However, the dykes of the Gairdner Dyke Swarm show no or only very slight LREE enrichment and much lower La/Nb ratios of 1.2 to 1.4, suggesting that their chemical characteristics reflect their mantle source and melting conditions and have not been significantly modified by crustal contamination. The large spatial extent of the Gairdner Dyke Swarm and Amata Dolerite dykes (and their extrusive equivalents) and their consistent geochemistry, (also supported by these data) are consistent with derivation from the uniform asthenospheric mantle plume proposed by Zhao et al. (1994). The LREE-depleted 750 Ma dykes have similar HREE abundances to the Gairdner Dyke Swarm and low La/Nb ratios, but are significantly LREE depleted. These dykes may have been produced from either a depleted component of the same mantle plume source or an unrelated mantle source.

The Nd isotope chemistry shows secular trends towards increasing ε_{Nd} values with decreasing age. The Pitjantjatjarra Supersuite mafic intrusions show ε_{Nd} values from –6.2 to –2.4 consistent with generation from a highly enriched mantle source or extensive crustal contamination, or both. The La/Nb values in the dykes overlap with or exceed those of average Pitjantjatjarra Supersuite granites (~3.2), suggesting that either the voluminous suite of granites was not the sole crustal contaminant or that an enriched (high La/Nb) mantle source is required, or both. Successively more positive ε_{Nd} from the Alcurra Dolerite dykes compared to the unnamed olivine dolerite dykes suggests derivation from either a successively less enriched mantle source, or successively less crustal contamination of mantle-derived magma, or some combination of these two processes. The most significant change in the Nd isotope chemistry is in the dykes of the Gairdner Dyke Swarm, which have significantly more positive ε_{Nd} values of +2.4 to +4.3. This change suggests that they were derived from a significantly less enriched source and is consistent with a mantle plume model. The LREE-depleted dykes have similar to slightly more positive ε_{Nd} values of +4.6, again reflecting a similar primitive, although slightly more depleted, source.

Many of the older mafic suites are exposed both north and south of the Mann Fault, such as the Pitjantjatjarra Supersuite dykes, the Giles Event-age layered intrusions and Alcurra Dolerite dykes, and the post-Giles Event plagioclase-porphyritic dykes. In contrast, the younger suites appear to be more provincial. For example, the Gairdner Dyke Swarm and unnamed olivine dolerite dykes are only exposed south of the Mann Fault (on BELL ROCK), whereas the LREE-depleted 750 Ma dykes appear to be confined to the area north of the Mann Fault (on BATES). This suggests that the younger dykes have intruded to very specific crustal levels and so their present distribution is controlled by the extensive post-Giles Event vertical displacements along the Mann Fault.

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