192892: mafic granulite, Lucy Hill

(Youanmi Terrane, Yilgarn Craton)

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Location and sampling

Hyden (SI 50-4), Hurlstone (2732)

MGA Zone 50, 723495E 6384109N

Warox Site FJKBGD192892

Sampled on 18 May 2009

This sample was collected from an outcrop on the south side of Lucy Hill, along the north side of the Hyden – Lake King Road, about 3.5 km northwest of Holt Rock and 2.7 km southeast from the junction with Di Russo Road. The sample was collected as part of the Yilgarn Craton Metamorphic Project (2003–14) undertaken by Ben Goscombe for the Geological Survey of Western Australia (GSWA), and referred to in that study as sample BG09-145a. The results from this project have not been released by GSWA, although select data have been published in Goscombe et al. (2019). This sample is not available in the GSWA collections; all observations are based on descriptions presented in Goscombe et al. (2019) and have not been directly verified.

Geological context

The unit sampled is a mafic granulite of the western Youanmi Terrane (Quentin de Gromard et al., 2021). This unit is part of a belt of Archean metasedimentary and gneissic rocks previously assigned to the South West Terrane and referred to informally by Wilde and Pidgeon (1987) as the 'Wheat Belt' region (cf. Wilde, 2001). However, a recent reinterpretation places the boundary between the South West and the Youanmi Terranes farther to the southwest than shown on older maps (Quentin de Gromard et al., 2021). The Youanmi Terrane contains both granite–greenstone and high-grade gneiss components with emplacement ages from 3010 to 2600 Ma (GSWA, 2020; Cassidy et al., 2006). Existing geochronological data from this part of the Youanmi Terrane is sparse. A biotite metagranodiorite, collected about 109 km to the south-southeast of this locality, yielded an igneous crystallization age of 2978 ± 5 Ma (GSWA 224357, Lu et al., 2018). Two samples of garnet-bearing alkali feldspar granite from Griffins Find about 109 km to the west-southwest yielded crystallization ages of c. 2636 Ma (Qiu and McNaughton, 1999). A quartzite also collected from Griffins Find yielded detrital zircon dates between c. 3812 and 2643 Ma, and a conservative maximum age of deposition of 2655 ± 11 Ma (GSWA 198580, Lu et al., 2015b). A pelitic gneiss from Griffins Find yielded detrital zircon dates between c. 2838 and 2629 Ma, and a conservative maximum depositional age of 2638 ± 2 Ma (GSWA 198578; Lu et al., 2015a), and another pelitic gneiss sample yielded a monazite age for high-grade metamorphism of 2641 ± 6 Ma (GSWA 198585, Fielding et al., 2021).

Petrographic description

The sample is a massive medium- to coarse-grained mafic granulite containing green–brown hornblende, clinopyroxene, plagioclase and ilmenite (Fig. 1). Titanite and quartz may be present but have not been verified. The sample has a weak grain-shape fabric and a polygonal granoblastic matrix. It is unknown whether the sample has undergone partial melting. Mineral compositions are provided in Table 1.

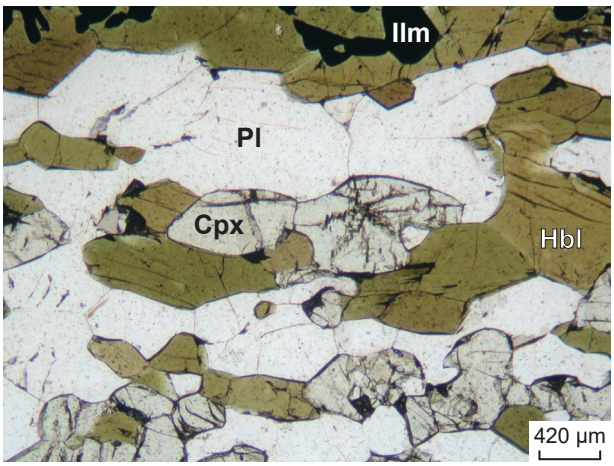

Figure 1. **Photomicrograph of sample 192892: mafic granulite, Lucy Hill in plane-polarized light. Mineral abbreviations are explained in the caption to Figure 2**

Table 1. Mineral compositions for sample 192892: mafic granulite, Lucy Hill

Mineral[a]	Hbl	Hbl	Cpx	Cpx	Pl	Pl	Ilm
Setting	Core	Rim	Core	Rim	Core	Rim	Matrix
wt%							
SiO_2	44.23	44.28	51.35	51.18	56.15	55.37	0.05
TiO_2	1.88	1.71	0.15	0.19	0.02	0.00	49.59
Al_2O_3	9.06	9.01	1.38	1.32	26.02	26.01	0.00
Cr_2O_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO	14.30	14.52	9.95	10.11	0.13	0.18	47.90
MnO	0.15	0.23	0.37	0.36	0.00	0.00	0.74
MgO	12.78	12.86	13.41	13.38	0.00	0.00	1.01
ZnO	0.00	0.02	0.05	0.00	0.04	0.00	0.08
CaO	11.10	11.36	21.76	21.90	8.68	9.01	0.00
Na_2O	1.76	1.61	0.34	0.36	6.44	6.29	0.02
K_2O	0.72	0.81	0.02	0.01	0.32	0.32	0.03
Total[b]	95.99	96.38	98.73	98.81	97.77	97.17	99.35
Oxygen	23	23	6	6	8	8	3
Si	6.56	6.55	1.94	1.94	2.57	2.55	0.00
Ti	0.21	0.19	0.00	0.01	0.00	0.00	0.94
Al	1.58	1.57	0.06	0.06	1.40	1.41	0.00
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe^{3+}[c]	0.74	0.78	0.07	0.09	0.00	0.00	0.13
Fe^{2+}	1.04	1.02	0.24	0.23	0.01	0.01	0.88
Mn^{2+}	0.02	0.03	0.01	0.01	0.00	0.00	0.02
Mg	2.83	2.84	0.76	0.75	0.00	0.00	0.04
Zn	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ca	1.76	1.80	0.88	0.89	0.43	0.45	0.00
Na	0.51	0.46	0.03	0.03	0.57	0.56	0.00
K	0.14	0.15	0.00	0.00	0.02	0.02	0.00
Total	15.39	15.39	4.00	4.00	5.00	5.00	2.00
Compositional variables							
XFe[d]	0.27	0.26	0.24	0.24	–	–	0.96

NOTES: – not applicable
(a) Mineral abbreviations explained in the caption to Figure 2
(b) Totals on anhydrous basis
(c) Hornblende cations calculated following Holland and Blundy (1994); Fe^{3+} contents for other minerals based on Droop (1987)
(d) XFe = $Fe^{2+}/(Fe^{2+} + Mg)$

Analytical details

Preliminary *P–T* estimates were obtained using multiple-reaction thermobarometry calculated from the mineral compositions (Table 1; Goscombe et al., 2019). These estimates were derived from the 'averagePT' module (avPT) in the program THERMOCALC version tc325 (Powell and Holland, 1988), using the internally consistent Holland and Powell (1998) dataset.

The metamorphic evolution of this sample has been subsequently re-evaluated using phase equilibria modelling, based on the bulk-rock composition (Table 2). The bulk-rock composition was determined by X-ray fluorescence spectroscopy, together with loss on ignition (LOI). The modelled O content (for Fe^{3+}) was set to be 20% of the measured total Fe; the modelled H_2O content was the measured LOI. The bulk composition was adjusted for the presence of apatite by applying a correction to CaO (Table 1). Thermodynamic calculations were performed in the NCKFMASHTO (Na_2O–CaO–K_2O–FeO–MgO–Al_2O_3–SiO_2–H_2O–TiO_2–O) system using THERMOCALC version tc340 (Powell and Holland, 1988; updated October 2013) and the internally consistent thermodynamic dataset of Green et al. (2016; version dataset tc-ds63, created January 2015). The activity–composition relations used in the modelling are detailed in Green et al. (2016), with the augite model used for clinopyroxene. Additional information on the workflow with relevant background and methodology are provided in Korhonen et al. (2020).

Table 2. Measured whole-rock and modelled compositions for sample 192892: mafic granulite, Lucy Hill

XRF whole-rock composition (wt%)[a]												
SiO_2	**TiO_2**	**Al_2O_3**	**Fe_2O_3[b]**	**FeO[b]**	**MnO**	**MgO**	**CaO**	**Na_2O**	**K_2O**	**P_2O_5**	**LOI**	**Total**
54.08	0.44	13.22	–	7.32	0.14	7.33	11.63	3.05	0.42	0.03	0.54	98.20
Normalized composition used for phase equilibria modelling (mol%)												
SiO_2	**TiO_2**	**Al_2O_3**	**O[c]**	**FeO^T[d]**	**MnO**	**MgO**	**CaO[e]**	**Na_2O**	**K_2O**	**–**	**H_2O[f]**	**Total**
55.98	0.34	8.06	0.57	5.70	–	11.31	12.85	3.06	0.27	–	1.86	100

NOTES: (a) Data and analytical details are available from the WACHEM database <http://geochem.dmp.wa.gov.au/geochem/>
(b) FeO content is total Fe
(c) O content (for Fe_2O_3) set to be 20% of measured FeO[b]
(d) FeO^T = moles FeO + 2 * moles O
(e) CaO modified to remove apatite: CaO(Mod) = CaO(Total) - (moles CaO(in Ap) = 3.33 * moles P_2O_5)
(f) H_2O content is the measured LOI
– not applicable

Results

The *P–T* pseudosection for sample 192892 was calculated over a *P–T* range of 2–8 kbar and 650–900 °C (Fig. 2). The solidus is located between 745 and 810 °C across the range of modelled pressures. Garnet is stable above 7.4 kbar at 650 °C and rutile is stable above 7 kbar at 800 °C. Orthopyroxene-absent assemblages are predicted between 720 and 860 °C across the range of modelled pressures. At temperatures above the solidus, orthopyroxene is restabilized, followed by the loss of quartz and hornblende as temperature increases.

Metamorphic *P–T* estimates (± 2σ uncertainty) calculated using multiple-reaction thermobarometry are 4.2 ± 0.5 kbar and 712 ± 25 °C (Goscombe et al., 2019). These calculations used the core compositions (Table 1) to estimate peak conditions.

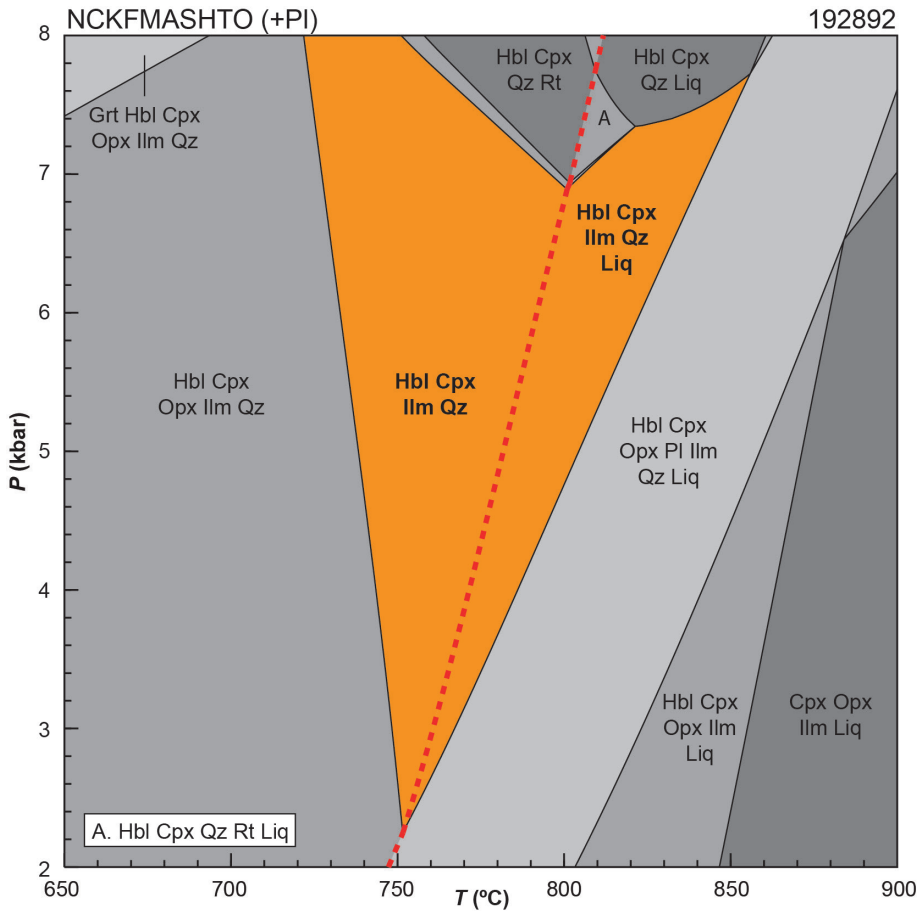

Figure 2. ***P–T*** **pseudosection calculated for sample 192892: mafic granulite, Lucy Hill. Assemblage fields corresponding to peak metamorphic conditions are delimited by bold text and orange shading. Red dashed line represents the solidus. Abbreviations: Cpx, clinopyroxene; Grt, garnet; Hbl, hornblende; Ilm, ilmenite; Liq, silicate melt; Opx, orthopyroxene; Pl, plagioclase; Qz, quartz; Rt, rutile**

Interpretation

The peak metamorphic assemblage is interpreted to be hornblende–clinopyroxene–plagioclase–ilmenite–quartz(–melt). There is uncertainty whether the sample has undergone partial melting. The subsolidus hornblende–clinopyroxene–plagioclase–ilmenite–quartz field is stable between 720 and 800 °C from 2.2 to pressures above 8 kbar, and the melt-bearing field is stable between 750 and 855 °C at 2.2 – 7.7 kbar (Fig. 2). Both fields are delimited by the stability of orthopyroxene at lower pressure and lower and higher temperatures, and the stability of rutile and absence of ilmenite at higher pressure.

The results determined from multiple-reaction thermobarometry are at lower *P–T* conditions than the calculated stability of the peak hornblende–clinopyroxene–plagioclase–ilmenite–quartz(–melt) fields. There is no information on the prograde and retrograde segments of the *P–T* path, and therefore the overall shape of the *P–T* path is not defined.

Based on the results of phase equilibria modelling, peak metamorphic conditions are poorly constrained, with estimates between 720–855 °C and 2.2 – 8 kbar. Mineral compositions are consistent with equilibration at 712 ± 25 °C, 4.2 ± 0.5 kbar, defining an apparent thermal between 150 and 190 °C/kbar.

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Links

Metamorphic history introduction document: Intro_2020.pdf

Recommended reference for this publication

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Grid references in this publication refer to the Geocentric Datum of Australia 1994 (GDA94). All locations are quoted to at least the nearest 100 m.

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Digital data related to WA Geology Online, including geochronology and digital geology, are available online at the Department's Data and Software Centre and may be viewed in map context at GeoVIEW.WA.

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