**Appendix A: Methods**

***Zircon U–Pb geochronology***

LA–ICP–MS zircon geochronology was done on epoxy resin-mounted zircon grains from sample 53810. Zircons were extracted from crushed rock by a combination of panning, magnetic and heavy liquid separation, then heat treated at 900 °C for 48 hours. Thermal annealing of zircon grains was done to improve cathodoluminescence (CL) response and to produce more accurate U–Pb ages (Nasdala et al. 2002; Solari et al. 2015). Mounted grains were imaged using a Gatan CL detector attached to a FEI Quanta 600 SEM at Adelaide Microscopy, University of Adelaide.

Zircon U–Pb data was collected at Adelaide Microscopy using a RESOlution LR 193 nm Excimer laser in a He ablation atmosphere, coupled to an Agilent 7700s ICP–MS for isotopic characterisation. Ablation was performed with a frequency of 5 Hz and spot sizes of both 19 and 29 μm, based on grain size. Data acquisition included 30 seconds of background measurement and 30 seconds of sample ablation.

Zircon isotopic data was reduced using Iolite software (Paton et al. 2011). Elemental fractionation and mass bias were corrected using the primary zircon standard GJ (TIMS data: 207Pb/206Pb = 607.7 ± 4.3 Ma, 206Pb/238U = 600.7 ± 1.1 Ma and 207Pb/235U = 602.0 ± 1.0 Ma; Jackson et al. 2004) with standards bracketing every 10 unknown analyses. Data accuracy was monitored using secondary zircon standards Plešovice (TIMS data: 206Pb/238U = 337.13 ± 0.37 Ma; Sláma et al. 2008) and 91500 (TIMS data: 206Pb/238U = 1065 ± 0.4 Ma; Wiedenbeck et al. 1995).

The weighted mean ages of external standards analysed over the course of this study were as follows: Plešovice: 207Pb/206Pb = 322 ± 15 Ma (*n* = 50, MSWD = 2.3), 206Pb/238U = 337 ± 0.71 Ma (*n* = 50, MSWD = 1.3), 207Pb/235U = 337 ± 1.6 Ma (*n* = 50, MSWD = 1.8); 91500: 207Pb/206Pb = 1032 ± 15 Ma (*n* = 50, MSWD = 1.8), 206Pb/238U = 1052 ± 2.4 Ma (*n* = 50, MSWD = 1.07), 207Pb/235U = 1052 ± 4.5 Ma (*n* = 50, MSWD = 1.7). The minor discrepancy between our calculated 91500 206Pb/238U age and the quoted TIMS age can likely be attributed to matrix effects (e.g. radiation dose, Pb & U ppm variations etc.). These effects commonly cause LA–ICP–MS ages to be systematically younger than the expected TIMS age by 3–4% (e.g. Orihashi et al. 2008)

***Monazite U–Pb geochronology***

LA–ICP–MS monazite geochronology was conducted *in situ* for samples 53816 and 53815. Monazites were first located in each thin section using a back-scattered electron (BSE) detector on a FEI Quanta 600 Scanning Electron Microscope (SEM) accompanied with Mineral Liberation Analysis (MLA) software. Selected grains were then imaged using a BSE detector on a Phillips XL30 SEM to characterise in finer detail their microstructural locations and compositional variability. BSE images and MLA maps were collected using an acceleration voltage of 15–25 kV, spot size of 4–6 and working distance of 10 mm.

Monazite U–Pb data were collected at Adelaide Microscopy using a RESOlution LR 193 nm Excimer laser in a He ablation atmosphere, coupled to an Agilent 7700s ICP–MS. Ablation was performed with a frequency of 5 Hz. A spot size of 13 μm was used for sample 53816, whereas sample 53815 was analysed using both 9 μm and 13 μm spot sizes due to variability in monazite grain size. Data acquisition included 30 seconds of background measurement and 30 seconds of sample ablation.

Monazite isotopic data was reduced using Iolite software (Paton et al. 2011). Elemental fractionation and mass bias for monazite geochronology was corrected using the primary standard MAdel (TIMS data: 207Pb/206Pb = 492.01 ± 0.77 Ma, 206Pb/238U = 517.9 ± 2.6 Ma and 207Pb/235U = 513.13 ± 0.20 Ma; updated from Payne et al. (2008) with additional TIMS analyses), with standards bracketing every 10–15 unknown analyses. Data accuracy was monitored using the in-house monazite standard 94-222/Bruna-NW (SHRIMP data: 206Pb/238U = 450.2 ± 3.4 Ma; Maidment 2005). Over the course of the study, 26 analyses of 94-222 yielded weighted mean ages of 207Pb/206Pb = 433 ± 11 Ma (MSWD = 0.50), 206Pb/238U = 450 ± 1.3 Ma (MSWD = 0.96) and 207Pb/235U = 449 ± 1.8 Ma (MSWD = 0.85).

***Mineral chemistry***

Mineral chemical analyses were obtained using a Cameca SXFive electron microprobe with five Wavelength Dispersive Spectrometers (WDS) at Adelaide Microscopy, using a beam current of 20 nA and an accelerating voltage of 15 kV. Calibration was performed on certified synthetic and natural mineral standards from Astimex Ltd and P&H Associates. Data calibration and reduction was carried out in Probe for EPMA, distributed by Probe Software Inc.

***Phase equilibria modelling***

Whole-rock chemical compositions for phase equilibria modelling were obtained by XRF analysis from Bureau Veritas, Perth. Phase equilibria models were calculated for samples 53815 and 53816 using THERMOCALC v3.40, using the latest internally-consistent thermodynamic dataset ‘ds62’ (Holland & Powell 1998; Holland & Powell 2011) in the model chemical system MnNCKFMASHTO (MnO–Na2O–CaO–K2O–FeO–MgO–Al2O3–SiO2–H2O–TiO2–O). Activity–composition models re-parameterised for metapelitic rocks in the MnNCKFMASHTO system were used (Powell et al. 2014; White et al. 2014a; White et al. 2014b). Temperature–molar oxygen (*T–M*o) models were used to constrain the oxidation state of the system, i.e. the amount of Fe2O3 versus FeO. The *T–M*o models were calculated at a pressure of 3.5 kbar, based on the presence of andalusite within the metasedimentary package. Importantly, the choice of pressure at which to calculate *T–M*o models does not need to correspond to the peak pressure (in part because peak pressure is not constrained until the *P–T* model is calculated), but should provide a high chance that the peak assemblage (used to constrain oxidation state) occurs as a field in a given *T–M*o model. Subsolidus metamorphism is typically interpreted to involve an aqueous fluid and therefore models were calculated with H2O set in excess.

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**Appendix B: Mineral chemistry results**

Representative electron microprobe mineral analyses are presented in Supplementary Data Table 4 and summarised below.

***Garnet***

Garnet grains in sample 53815 are predominantly almandine–spessartine mixtures with *X*alm [Fe2+/(Fe2+ + Mg + Ca + Mn)] varying between 0.701–0.703 and *X*sps [Mn/(Fe2+ + Mg + Ca + Mn)] values of 0.168–0.169. *X*grs [Ca/(Fe2+ + Mg + Ca + Mn)] varies from 0.043– 0.038 and *X*py [Mg/(Fe2+ + Mg + Ca + Mn)] from 0.087 to 0.078.

Garnet grains in sample 53816 are predominantly almandine–spessartine mixtures with *X*alm varying between 0.730–0.656 and *X*sps between 0.179–0.134. *X*grs varies from 0.033–0.069 and *X*py from 0.103–0.112.

***Biotite***

Biotite in both samples has relatively similar TiO2 content of 1.19–1.82 wt%. Fluorine content varies between 0.03–0.16 wt%, with biotite in sample 53815 having the lowest fluorine content of 0.03–0.08 wt%.

***Chlorite***

Chlorite in sample 53815 has *X*Fe [Fe2+/(Fe2+ +Mg)] values of 0.509–0.525 and sample 53816 has values of 0.481–0.492.

***Cordierite***

Cordierite porphyroblasts in sample 53815 have *X*Fe values of 0.355–0.369 and MnO values of 0.62–0.67 wt%.

***Staurolite***

Staurolite is present in both samples and has *X*Fe values of 0.716–0.840 and ZnO content of 0.16–0.29 wt% in sample 53815 and 1.20–1.36 wt% in sample 53816.

***Plagioclase***

Plagioclase is present in both samples. Sample 53815 and 53816 have similar *X*Ab [Na/(Na+ Ca + K)]values of 0.708–0.744.

***Ilmenite***

Ilmenite is present in both samples. TiO2 content in sample 53815 varies between 49.5–51.8 wt%, whereas sample 53816 has higher TiO2 content of 52.9–53.1 wt%. Sample 53815 has a MnO content of 2.20–3.82 wt% and sample 53816 has a lower MnO content of 0.99–1.11 wt%.