1. Introduction

Arguably, the plate tectonic revolution started with the research on supercontinent cycles (Wegener, 1912, 1922; Wilson, 1966). The generation and biased preservation of the continental crust are also controlled by supercontinent cycles (Condie, 1998; Hawkesworth et al., 2009; Kemp et al., 2006; Spencer et al., 2018). The oldest known Palaeo-Mesoproterozoic Columbia supercontinent, contained almost all of Earth’s present continental blocks, was assembled during global 2.1 to 1.8 Ga collisional events, underwent long-lived, subduction-related accretion at key continental margins in the period of 1.8–1.3 Ga, commenced to fragment ~1.6 Ga ago, and finally broke up at ~1.3 Ga (Rogers & Santosh, 2002; Zhao et al., 2002, 2004, 2006, 2011). Lacking of sufficient and reliable geological, paleontologic, and palaeomagnetic data, the Columbia supercontinent has not been well configured as supercontinents Pangea and Rodinia, even though the increasingly stratigraphical, lithological, geochronological, and geochemical data (e.g., Girelli et al., 2018; Kohn et al., 2010; Rogers & Santosh, 2002; Singh et al., 2009; Zhao et al., 2002, 2004).

The Earth’s mantle is compositionally heterogeneous as the result of melt extraction and recycling of crustal components into the mantle throughout Earth history (Hager et al., 1985; Hofmann, 1988; Zindler et al., 1984). Spatially, isotopically heterogeneous exists from grain scale to regional or global scale (e.g., Jackson et al., 2007; Jackson & Hart, 2006; Paul et al., 2011; Rampone & Hofmann, 2012). Temporally, the regional mantle heterogeneous, such as long termly preserved ultradepleted mantle domain from mantle convective
stirring and rehomogenization (Liu et al., 2008), was successively recognized from Eoarchean Greenstone belt, tonalite-trondhjemite-granodiorites (TTGs), and komatiites to present-day abyssal peridotites and mid-ocean ridge basalts (MORBs; e.g., Byerly & Lassiter, 2014; Hoffmann et al., 2010; Hoffmann & Wilson, 2017; Puchtel et al., 2013; Stracke et al., 2011; Wang et al., 2015). Alternatively, though the temporal distribution and tectonic settings of mafic-ultramafic rocks (dyke swarms) become more prevalent on supercontinent reconstruction (e.g., Belica et al., 2014; Ernst et al., 2016; Goldberg, 2010; Hou et al., 2008; Pivarunas et al., 2018; Zhang et al., 2009; Zhao et al., 2006, 2011), their mantle sources, especially the signatures of mantle heterogeneity, have not yet been considered when reconstructing the supercontinent.

The Paleoproterozoic tectono-magmatic event in Cathaysia block is considered to be related to the assembly of Columbia supercontinent, though the scenario remains controversial (Chen et al., 2016; Liu et al., 2014; Xia et al., 2012; Yu et al., 2009). However, the Cathaysia block have not been well posited in the original configuration of Columbia (Rogers & Santosh, 2002; Zhao et al., 2002). A position adjacent to Lesser Himalaya of NW India in Columbia was proposed by Yu et al. (2012), on the basis of age spectra of detrital zircons and geochemical features of granitoids. Although less emphasized, the Paleoproterozoic meta-mafic rocks with ultradepleted mantle signals in Cathaysia block challenge such model (Li et al., 2000; Qi, 2006; Zhang, 2013) and suggest the affinity between North Australia Craton (NAC) and Cathaysia block. Hence, to constrain the early Precambrian evolution of Cathaysia, its position in the Columbia and its relationship with other continental blocks, more reliable data and clear elucidation are necessary.

2. Brief Introduction to Geological Background and Sample Description

The Cathaysia block, which is generally accepted that amalgamated with the Yangtze block during early Neoproterozoic to form the South China block (also called the South China craton by some geologists), is dominated by Phanerozoic igneous rocks, with only sporadically exposed Paleoproterozoic crystalline basement (Figure S1; Xia et al., 2014, 2016, 2018; Zhao & Cawood, 2012). Archean basement is barely exposed and largely inferred from the presence of minor inherited and/or xenocrystic zircons and Nd-Hf isotopic model ages (e.g., Wan et al., 2007; Xia et al., 2012; Yu et al., 2012; Zhao et al., 2014, 2015). The Paleoproterozoic migmatites, granitoid gneisses, and amphibolites (e.g., Badu, Mayuan, and Tianjingping complexes) form most of the basement (Figure S1 and Table S1 in the supporting information; Li et al., 2000; Wan et al., 2007; Xia et al., 2012; Yu et al., 2009, 2012; Zhao et al., 2015, 2017).

We have undertaken U-Pb age and Hf isotope, whole-rock major and trace element, and Nd isotope analyses for representative samples of Chatan amphibolite, Fenghuangshan granitic pluton, and felsic meta-volcanic rocks and meta-sedimentary rocks from Badu complex in Longquan area (Figure S1). Detailed geological background and sample petrography, analytical methods, and analytical results are provided in the supporting information and Table S2–S6.

3. Palaeoproterozoic Back-Arc Magmatism and Sedimentation in Cathaysia Block

Although the Palaeoproterozoic tectonic setting of Cathaysia block is still in debate (e.g., intraplate extensional (rift) and syn-collisional or early post-collisional), most researchers agree the existence of Palaeoproterozoic extensional regime in Cathaysia block (Chen et al., 2016; Li et al., 2000; Liu et al., 2014; Yu et al., 2009, 2012; Xia et al., 2012; Zhang, 2013), in accordance with the Palaeoproterozoic bimodal magmas that dominated by mafic and felsic volcanic or intrusive rocks (Figures S1 and S3b in the supporting information).

The Palaeoproterozoic mafic rocks in Cathaysia block include calc-alkaline and tholeiitic basaltic to basaltic andesitic rocks (i.e., amphibolites from Badu, Mayuan, and Tianjingping complexes) with varying FeO/TiO2/MgO values (Figure S1c). The growing obtained age data (Li, 1997; Li et al., 2010; Xiang et al., 2008; Zhang, 2013, and this study) indicate two episodes of mafic magmatisms at 1.88–1.85 and 1.78–1.77 Ga (Figure 2a and Table S1) with coherent geochemistry compositions. The Palaeoproterozoic calc-alkaline mafic rocks including Chatan amphibolite show relatively low Nb/Th and Nb/La ratios with arc-like rare earth element patterns and spidergrams (Figure S4a) and fall into the field of island arc basalts in both Hf/3-Th-Ta and V versus Ti diagrams (Figures 1a and 1b). Alternatively, the Palaeoproterozoic tholeiitic mafic rocks exhibit E-type or N-type MORB-like but more enriched patterns and spidergrams (Figure S4b).
S4a). Their relatively low Th/Ta and high Ti/V ratios are consistent with that of back-arc basin basalts (BABB) and MORB (Figures 1a and 1b). Such bimodal features of both arc-like and MORB for Palaeoproterozoic mafic rocks are typical for BABB (e.g., Lawton & McMillan, 1999; Pearce & Stern, 2006; Taylor & Martinez, 2003), where the early stage basalts exhibit arc-like signature due to more crustal contributions during mantle melting, whereas the later stage basalts exhibit MORB-like patterns due to subdued crustal influence. According to the extremely depleted Nd and Hf isotopic compositions (Figures 2d and 2e), the Palaeoproterozoic mafic magmas likely originated from an ultradepleted mantle. However, a prior refertilization of refractory depleted mantle is requested to promote the incompatible element concentration and reduce the melting solidus. Thus, the parental magmas of the Palaeoproterozoic mafic rocks were probably derived from metasomatized mantle wedge, which is also supported by the calc-alkaline basaltic rocks and the clinopyroxenite xenoliths found in Palaeoproterozoic Qiuyuan granite with a strong subduction-related affinity (Figures 1a and 1b; Li et al., 2011). Such highly depleted mantle wedge compositions have been recognized previously in some modern subduction-related settings (e.g., Tonga-Kermadec-Lau arc-back-arc system; Ewart et al., 1998).

The Paleoproterozoic felsic rocks in Cathaysia block are mainly composed of I-type (1.91–1.86 Ga), S-type (1.93–1.83 Ga), A-type granitoids (1.88–1.79 Ga), and some felsic meta-volcanic rocks (e.g., quartzfeldspathic orthogneiss and leptynite; 1.88–1.79 Ga). The felsic meta-volcanic rocks show similar geochemical and isotopic compositions with those granitoids, indicating that both felsic volcanic and plutonic equivalents share similar source rocks. The S- and A-type granitoids, including Fenghuangshan A-type
granite, share similar Hf-Nd isotopic compositions (Figures 2d and 2e), suggesting sources similar to meta-sedimentary rocks of the Badu and Mayuan complexes with different proportions of juvenile material input (Chen et al., 2016; Liu et al., 2014; Xia et al., 2012; Yu et al., 2009). The recognized I-type granitoids, including Fenghuangshan I-type granite, are proposed to be originated from meta-felsic igneous rocks with or without injection of magma derived from old meta-sedimentary rocks (Liu et al., 2014). Most of the felsic igneous rocks also plot in volcanic arc field in the Rb/30-Hf-Ta*3 diagram (Figure 1c). In general, I-type granitoids are abundant in subduction-related context (Altherr & Siebel, 2002; Atherton & Ghani, 2002; Pearce, 1996; Pitcher, 1987), while A-type granitoids are connected to extensional settings (Bonin, 2007; Eby, 1992; Whalen et al., 1987), emphasizing a back-arc setting. However, compositions of granites essentially depend on the nature of their source rocks rather than the tectonic environment ( Förster et al., 1997; Pearce et al., 1984). Thus, during the interval between the mafic magmatism, the tectonic setting of the granitic magmatism is still enigmatic.

The meta-sedimentary rocks from the Badu and Mayuan complexes, which were the oldest clastic sedimentary rocks in Cathaysia block, underwent at least two episodes (1.89–1.85 and 0.25–0.23 Ga) of high-grade metamorphism, up to high amphibolite to granulite facies (Table S1 and references in it). The detrital zircons from these meta-sedimentary rocks give a bimodal age distribution with age peaks of circa 2.5 and 1.85 Ga (Figure 2c) and Hf model ages of 1.90–4.10 Ga (Yu et al., 2012; Zhao et al., 2015). Yu et al. (2012) argued that the protoliths of the meta-sedimentary rocks deposited at circa 2.5 Ga. However, there are still substantial 1.91–1.85 Ga detrital/inherited zircon cores in these meta-sedimentary rocks (Yu et al., 2012; Zhao et al., 2015). Their elevated initial \(^{176}\text{Hf} /^{177}\text{Hf}\) ratios than that of Neoarchean zircons excludes that these zircons are produced by the recrystallization of old detrital zircons. The indistinguishable maximum deposition age defined by the youngest detrital/inherited zircon ages of circa 1.91–1.85 Ga and metamorphism ages of 1.89–1.85 Ga (Figures 2a and 2c) plurally constrains that the protoliths of the meta-sedimentary rocks deposited at circa 1.90–1.85 Ga. In the La/Th versus Hf diagram (Figure 1d), these sedimentary rocks plot along the trend of arc source with different degrees of old sediment component contribution, consistent with the age distribution and Hf isotopes of detrital zircons (Wan et al., 2007; Yu et al., 2012; Zhao et al., 2015). A similar result appears in the K2O/Na2O versus SiO2 diagram (Figure 1e), in which the Paleoproterozoic clastic sedimentary rocks plot straddle the boundary between both active and passive continental margin fields. All these above evidences imply an arc basin setting, where the detritus from volcanic arc would be proximal accumulation and rapid subsidence. Therefore, the continental arc to back-arc basin is a probable tectonic setting for the Palaeoproterozoic Cathaysia.

4. Palaeoproterozoic Ultradepleted Mantle Reservoir Beneath Cathaysia Block

By integrating the Nd-Hf isotope data of the two episodic Paleoproterozoic mafic rocks in Cathaysia block from previous studies and this work, these mafic-derived magmas, either calc-alkaline or tholeiitic series, all possess extremely positive \(\varepsilon_{\text{Nd}}(t)\) and \(\varepsilon_{\text{Hf}}(t)\) values with whole-rock \(\varepsilon_{\text{Nd}}(t)\) values range from +4.0 to +11.4 and \(\varepsilon_{\text{Hf}}(t)\) values range from +14.6 to +23.7 (Figures 2d and 2e). The strong positive correlation between coupled whole-rock \(\varepsilon_{\text{Nd}}(t)\) and \(\varepsilon_{\text{Hf}}(t)\) values (\(\varepsilon_{\text{Hf}}(t) = 1.41\times \varepsilon_{\text{Nd}}(t) + 9.1; R^2 = 0.78;\) Qi, 2006 and this study) also precludes the disturbance due to subsequent hydrothermal overprinting events. Yet this study obtains apparently low \(\varepsilon_{\text{Hf}}(t)\) values of zircons (+5.9 to +11.8) related to whole rock (+23.7) from the Chatan amphibolite. Though the apparent contamination is absent (see below), the inherited zircons in Chatan amphibolite (supporting information) still imply minor country rock contamination. Such contamination will facilitate the crystallization of magmatic zircons, which tend to crystallize later in ultramafic-mafic magmas (Wang et al., 2016), and reduce \(^{176}\text{Hf} /^{177}\text{Hf}\) ratios of surrounding melt. Hence, the Hf isotopes of newly crystallized zircons, which equilibrated with their surrounding melts, would be biased to infer Hf isotopic compositions of primary melt.

The Paleoproterozoic tholeiitic basaltic rocks possess relatively high Nb/Th (7–13) and Nb/La ratios (0.7–1.1), slightly lower than the Nb/Th (14–20) and Nb/La ratios (commonly circa 1.3) for typical oceanic tholeiites (Niu & O'Hara, 2003; Sun & McDonough, 1989). Their weak linear correlations between \(\varepsilon_{\text{Nd}}(t)\) and \(\varepsilon_{\text{Hf}}(t)\) values together with Nb/Th and Nb/La ratios imply an insignificant influence of crustal contamination (Li et al., 2000; Qi, 2006; Zhang, 2013). The Paleoproterozoic calc-alkaline basaltic rocks, on the contrary, possess relatively low Nb/Th (1.4–3.1) and Nb/La ratios (0.4–1.2), more similar to average Nb/Th (2.6) and Nb/La ratios (0.3) of island arc basalts (Niu & O'Hara, 2003), indicating that they are likely derived from subduction-zone metasomatized mantle wedge. Hence, the Palaeoproterozoic ultradepleted mantle reservoir beneath the Cathaysia block is estimated to have whole-rock \(\varepsilon_{\text{Nd}}(t)\) (> +10) and \(\varepsilon_{\text{Hf}}(t)\) values (> +20) in terms of the samples with highest Nb/Th and Nb/La ratios, which can reach up to nearly twice as much as the average depleted mantle (DM) at that time (\(\varepsilon_{\text{Nd}}(t)1.80\text{ Ga}\) of circa +6.1 for Goldstein et al., 1984’s curve and circa +3.9 for DePaolo, 1981’s curve; \(\varepsilon_{\text{Hf}}(t)1.80\text{ Ga}\) of circa +10.6 for Vervoort and Blichert-Toft, 1999’s curve and circa +10.3 for Dhuime et al., 2011’s curve; Figures 2d and 2e).

Generation of the extremely high \(\varepsilon_{\text{Nd}}(t)\) and \(\varepsilon_{\text{Hf}}(t)\) values needs a long-time incompatible element depletion mantle reservoir with highly fractionated Sm/Nd and Lu/Hf ratios, which requires an ancient continental crust extraction to deplete the upper mantle (Bennett et al., 1993; Salters & Hart, 1991). As for \(^{144}\text{Sm}\)–\(^{143}\text{Nd}\) isotope system, the relationship between light rare earth element enrichment or depletion as represented by the \(f\) value, and the change in the end value, is approximated by equation \(\Delta \varepsilon_{\text{Nd}} = f \times Q \times \Delta T\),
where $Q$ is a constant = 25.13 Ga$^{-1}$, $T$ is time (Ga), and $f = [^{147}\text{Sm} / ^{144}\text{Nd(source)}] / [^{147}\text{Sm} / ^{144}\text{Nd(chondrite)}] - 1$ (DePaolo & Wasserburg, 1976). We assume that the Cathaysia initial crust extracted from its precursor mantle source at around 3.0 Ga inferred by the Nd and Hf model ages, which is also the period of plate tectonics initiation (Chowdhury et al., 2017; Dhuime et al., 2012, 2015; Tang et al., 2016). To attain the $\varepsilon_{\text{Nd}}(t)$ values $> +10$ at circa 1.9 Ga, $f$ value should be no less than $+0.2$ (Figure 2e), which implies a mantle source with a time-averaged Sm/Nd from 3.0 to 1.9 Ga that was 20% higher than in the chondritic unfractionated reservoir and even higher than the present DM with a time-averaged $f$ value $\approx +0.1$ estimated by MORBs (Bennett et al., 1993). Thus, a large scale of partial melting of the mantle source at circa 3.0 Ga would be required to cause this amount of Sm/Nd fractionation.

5. Linking Cathaysia Block to North Australian Craton in Columbia Supercontinent

Yu et al. (2012) suggested a position for Cathaysia block adjacent to Lesser Himalaya of NW India in Columbia based on collisional orogeny at circa 1.9–1.8 Ga in both two blocks. However, competing Paleoproterozoic tectonic settings of north Indian continental margin have been proposed (e.g., anorogenic (rift) and continental arc; Kohn et al., 2010; Singh et al., 2009; Richards et al., 2005). In fact, the allanite ages and widespread felsic volcanic rocks do not support a Paleoproterozoic collision and attendant general metamorphic events in Lesser Himalaya (Kohn et al., 2010; Phukon et al., 2018). In the Paleo-Mesoproterozoic Columbia supercontinent, the 1.8 to 1.5 Ga accretionary orogens and subduction-related magmatic arc system bordering the present-day southern margin of North America, Greenland and Baltica, the western, eastern and southern margins of NAC and the eastern margin of Gawler Craton, the western margin of Amazonia Craton, and the southern margin of North China Craton (Figures 2b and 3a; Rogers & Santosh, 2002; Zhao et al., 2002, 2004). Compilations of crystallization ages for detrital zircons from both Cathaysia and southern margin of NAC, which is constituted by Arunta, Granites–Tanami (GT) terrane and southern part of Tennant Creek (TC), show remarkably similar patterns of peaks and troughs with all the detrital zircon ages cluster into two peaks of circa 1.85 and 2.5 Ga (Figure 2c), although with some variation in the relative amplitude of the peaks, implying the closest affinity between the proto-Cathaysia and southern margin of NAC.

The GT terrane contains isolated Neoarchean inliers (circa 2.51 Ga Billabong Complex; Figure 2b; Bagas et al., 2009; Crispe et al., 2007), and the inherited zircons and isotopic model ages also imply the existence...
of Archean relics in Cathaysia block (Figure 2a; Xia et al., 2012). The earliest stratigraphic constraint of ~1.86-1.84 Ga for the siliciclastic-dominated metasedimentary rocks from Tanami Group that is composed of the Dead Bullock Formation (the former Stubbins and Mount Charles formations; Bagas et al., 2014) and the overlying Killi Killi Formation in GT terrane and synchronous equivalents of Warramunga Group in TC terrane is generally overlapped but ensued that of Badu-Mayuan Complex in Cathaysia block (Figure 2c).

Nevertheless, new dating coverage in the Arunta terrane (e.g., Claoué-Long, Edgoose, et al., 2008; Claoué-Long & Edgoose, 2008; Neumann & Fraser, 2007) revealed that the oldest sedimentary succession is the Lander Package that precipitated later than ~1.84 Ga similar to the Ooradidgee Group in TC and the Killi Killi Formation in TG, and the earliest magmatic intrusions are dated to the ~1.81-1.80 Ga, significantly later than the onset of the subduction-related magmatism and sedimentation in GT, TC, and Cathaysia (Figures 2a–2c).

The ancient depletion signatures are broadly reported in Archean greenstone belts and TTG gneisses (e.g., Barberton, Napier, Anshan, and Norseman-Wiluna; Figures 2d and 2e; Bennett et al., 1993, 2007; Hoffmann et al., 2010; Puchtel et al., 2013; Smith & Ludden, 1989; Wang et al., 2015). On the contrary, the Paleoproterozoic ultradepleted mantle only recorded in Cathaysia, Arunta, and GT (Figures 2d and 2e; Lambeck et al., 2010; Li et al., 2000; Sivell & McCulloch, 1991; Qi, 2006; Zhang, 2013). In Arunta terrane, the circa 1.77 Ga back-arc basin tholeiites from the Harts Range metaigneous complex show high εNd(t) values (+2.9 to +8.3), especially the Harts Range metaigneous complex lower metatholeiites show exceptionally high εNd(t) values that range from +7.0 to +8.3 (Sivell & McCulloch, 1991). In Figure 2e, all these tholeiitic samples drop significantly above the DM curve. In GT terrane, the circa 1.86 Ga pillow basalts and sandstone from Dead Bullock Formation yield εNd(t) values up to +7.2 and +10.2, respectively, which is also much higher than the DM at that time and are interpreted to have been formed in a back-arc setting (Figure 2e; Bagas et al., 2008; Carson, 2013; Lambeck et al., 2010; Li et al., 2013). It is no coincidence that the two episodes of back-arc mafic magmatisms in Cathaysia block appear to be essentially synchronous with the BABB-like basaltic magmatism in Arunta and GT terranes, respectively. Moreover, the Earth’s mantle is chemically and isotopically heterogeneous in various scale from hand specimen to regional or global scale (Liu et al., 2008; Paul et al., 2011; Rampone & Hofmann, 2012). The approximate extents of hidden ultradepleted mantle domains beneath Cathaysia and southern margin of NAC are both around 500 km (according to present-day coordinates), making it appropriate to take the ultradepleted mantle as a guide to reconstruct the relative configuration of different blocks. All these above indicate that the proto-Cathaysia should be the best candidate to serve as the missing link between Arunta and GT terranes during Paleoproterozoic time (Figure 3a).

The circa 1.88 to 1.85 Ga magmatic arc would have lain along the western, eastern, and southern margins of NAC (Figure 3b; Blewett et al., 2012; Cawood & Korsch, 2008), which overlap with circa 1.91 to 1.85 Ga arc-back-arc magmatism in the Cathaysia block. Meanwhile, the Arunta terrane did not connect with the Cathaysia-GT-TC terrane due to the absent of the homochronous stratigraphic and magmatic records (Figures 2b and 2c; Bagas & Korsch, 2008). A long-lived overall east dipping resulted in accretion of the Tickalara arc and along strike correlatives of the Halls Creek (HC) and Pine Creek (PC) orogens, and overall west dipping resulted in accretion of the magmatic arcs of the Mount Isa (MI) orogen commenced around 1.88 Ga (Figure 3b; Cawood & Korsch, 2008). Nevertheless, the age and dip polarity of the back-arc related subduction zone in GT terrane are not known (Bagas et al., 2008). The earlier onset of the subduction-related magmatism in Cathaysia (Figure 2a) implies that the GT-Cathaysia was separated from Arunta by an overall north dipping subducting ocean basin during 1.91–1.85 Ga (Figure 3b). In response to changing rates of trench rollback (Scrimgeour, 2006) and/or slab dip (Giles et al., 2004), a back-arc basin (1.88 to 1.85 Ga) separated the proto-Cathaysia from GT with the first episode back-arc magmatism and sedimentation (Figures 2a and 2b).

The circa 1.86 to 1.83 Ga tectonothermal activity (e.g., the HC Orogeny) occurs across the NAC (Figure 3b; e.g., PC, GT, TC, and MI), suggesting major plate kinematic readjustment associated with this collisional suturing event (Cawood & Korsch, 2008). Yet the final amalgamation age of the Arunta and GT has been debated, with both 1.85–1.83 Ga (Tanami Event; Crispe et al., 2007; Cross & Crispe, 2007) and 1.81–1.80 Ga (Stafford Event; Bagas et al., 2009; Li et al., 2014) proposed for the orogenic belts that weld the two terranes. Moreover, both two periods of tectonothermal events resulted in predominantly greenschist facies metamorphism in the GT (Cawood & Korsch, 2008), while the Cathaysia recorded
widespread S-type granitoids and up to high amphibolite to granulite facies metamorphism during circa 1.89–1.83 Ga (Yu et al., 2012; Zhao et al., 2018). Metamorphisms up to granulite grade related to the collision orogens were recognized in HC, PC, and MI. In general, the onset age of compression and metamorphic grade decreased inland, for instance, from the western to eastern zones of the HC orogen (Neumann & Fraser, 2007), implying that the southern NAC sutured with the Cathaysia orogenic belts instead of the previously called Tanami Orogen during 1.85–1.83 Ga (Figure 3b). Associated with intense compression and crustal shortening, the proto-Cathaysia was extruded eastward with sustaining A-type granitic magmatism (Figure 2a). After that, the Stafford Event (~1.81–1.80 Ga) and Yambah Event (~1.79–1.77 Ga) occurred related to north dipping subduction and back-arc opening (Giles et al., 2004; Hoatson et al., 2005) with circa 1.81 to 1.79 Ga island arc tholeiites, granites, and migmatises and circa 1.78 to 1.75 Ga subduction-related granitoids and back-arc basin tholeiites in Arunta and the second episodes of BABB-like mafic magmatism (1.78–1.77 Ga) in Cathaysia (Figures 2a and 2b). Then, Arc magmatism ceased around 1740 Ma at the start of the Strangways Event (1.74–1.69 Ga) with high grade metamorphism in Arunta and magmatism in Arunta, GT, and TC and no records in Cathaysia (Figures 2a and 2b; Neumann & Fraser, 2007). Thus, prior to Strangways Event, the proto-Cathaysia detached from NAC due to the opening of second back-arc basin (Figure 3b).

6. Conclusions

By integrating data from previous studies and this work, the Paleoproterozoic meta-mafic rocks with BABB affinity indicate two episodes of back-arc basin developed in the Cathaysia block at circa 1.88–1.85 and 1.78–1.77 Ga. These two episodic mafic rocks all possess extremely positive εNd(t) and εHf(t) values and are in favor of an ultra-depleted mantle reservoir with highly fractionated incompatible elements beneath Cathaysia due to the ancient continental crust extraction at ~3.0 Ga. The ultra-depleted mantle, continental arc to back-arc assemblages, metamorphisms, and detrital zircon age spectra are very similar to those of the Arunta and GT terranes in the southern margin of NAC, suggesting that the Cathaysia block should be posited between Arunta and GT in assembled Columbia supercontinent. This work highlights the mantle heterogeneity in supercontinent reconstruction.

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