



## News &amp; Views

## Long-lived connection between the North China and North Australian cratons in supercontinent Nuna: paleomagnetic and geological constraints

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It has been proposed by Zhang et al. [1] that the northern part of the North China Craton (NCC) was connected to the north-western part of the North Australian Craton (NAC) in the Proterozoic, mainly based on the radial geometry of correlative ~1.32 Ga dyke swarms in the two cratons (Fig. 1a). While the hypothetical connection between the NCC and the NAC was thought to be paleomagnetically permissible at ~1.80–1.78 Ga but with a slightly different configuration [2], the exact duration of either configuration is uncertain (e.g., [2,3]). Here we present a comparison of up-to-date paleomagnetic poles, together with a detailed comparison of the geological records, of both cratons to evaluate a potential long-lasting connection between the NCC and the NAC throughout the Proterozoic.

To test the connection between the NCC and the NAC paleomagnetically, reliable paleopoles have been selected (Table S1 online). Some poles have precise ages and positive field tests, whereas others obtained from sedimentary rocks have large age uncertainties (Table S1 online). From Fig. 1b, we see that the ~1.78 Ga paleopole for the NCC falls close to the newly published ~1.79 Ga paleopole for the NAC in a revised NCC-NAC configuration, similar to the model proposed by Zhang et al. [1]. Although no other coeval poles exist for the two cratons (Fig. 1b), preliminary paleomagnetic evidence suggests for a similar configuration at ~1.32 Ga [4]. Therefore, the NCC and the NAC were likely connected to each other between ~1.78 and 1.32 Ga. In such a paleomagnetism-based reconstruction, coeval ~1.32 Ga mafic magmatic events in both cratons, including the orientation of mafic dykes, are interpreted to be the products of the same mantle plume (Fig. 1).

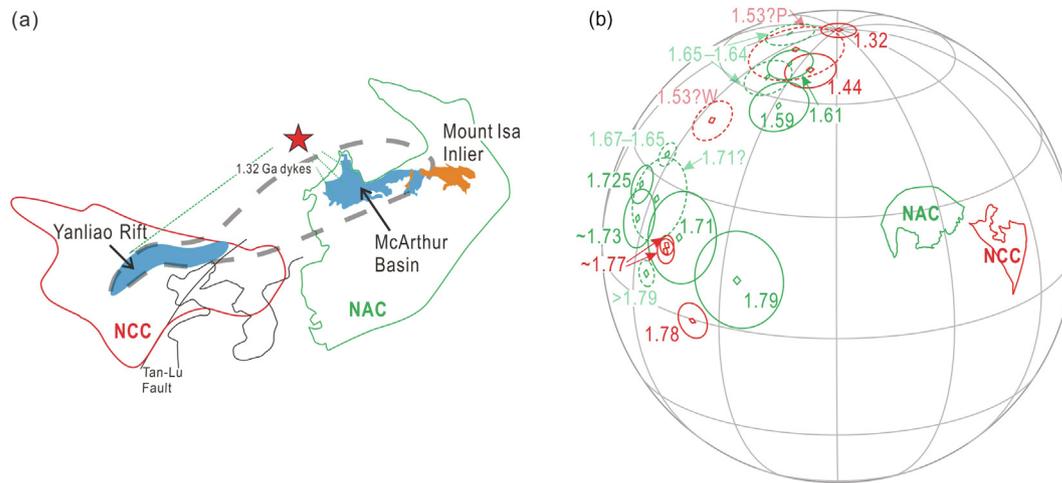
The McArthur Basin in the NAC was suggested to be correlative to the Yanliao Rift because of the presence of coeval ~1.32 Ga

mafic sills and comparable strata (e.g., the Xiamaling Formation with the Roper Group; Fig. 2) [1]. The Yanliao Rift consists of the Changcheng (~1.70–1.60 Ga) and Jixian (~1.60–1.40 Ga) groups, the Xiamaling Formation (~1.40–1.35? Ga), and the geochronologically poorly constrained Qingbaikou Group [5] (Fig. 2). The McArthur Basin is better documented and is broadly divided geographically into the southern and northern McArthur Basin [6]. Stratigraphically, the basin is sub-divided into five disconformity-bound packages according to lithofacies, age dating results and stratigraphic relationships [6]. It is generally considered that during deposition sedimentary units were continuous across most of the basin and are well correlated throughout [6]. We discuss the Katherine River (~1.82?–1.71 Ga) and Parsons Range (~1.71–1.67 Ga) groups from the northern McArthur Basin, and the McArthur (~1.67–1.60 Ga), Nathan (~1.60–1.58 Ga) and Roper (~1.5–1.35? Ga) groups from its southern and central regions [6]. Apart from those recognised by Zhang et al. [1], there are more comparable geological features between the two basins (Fig. 2) that are consistent with the proposed NCC-NAC connection during the Proterozoic.

(1) Strata and environmentally sensitive fossil record. Basins on both cratons dominantly received clastic sediments during ~1.70–1.60 Ga, with minor carbonates—the ~1.64 Ga dolostone in the Changcheng Group (Yanliao Rift) and the McArthur Group (McArthur Basin). Both basins also recorded mainly clastic sedimentation after ~1.40 Ga [5,6] (Fig. 2). Furthermore, the oldest eukaryotic microfossils *Valeria lophostriata*, showing complex wall structure and concentric striations, have been found in both the lower Changcheng Group of the Yanliao Rift and the Mallapunyah Formation of the McArthur Group (lower McArthur Basin) [7] (Fig. 2).

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**Fig. 1.** Reconstruction of the NCC and NAC from ~1.78 to 1.32 Ga. (a) Schematic paleogeography corresponding to the similar paleomagnetic reconstruction in (b). The comparable model of the ~1.32 Ga radial dykes and plume centre was first proposed by Zhang et al. [1]. (b) Selected ~1.80–1.30 Ga paleomagnetic poles from the NCC (red) and the NAC (green) showing the proposed configuration. Paleopoles are marked with ages in Ga (dashed poles have putative ages only). Data sources are shown in Table S1 (online). Euler rotations for ~1.32 Ga: NCC ( $-32.72^{\circ}\text{N}$ ,  $-44.19^{\circ}\text{E}$ ,  $-124.58^{\circ}$ ) and NAC ( $-4.44^{\circ}\text{N}$ ,  $-55.92^{\circ}\text{E}$ ,  $-178.78^{\circ}$ ). NCC–North China Craton, NAC–North Australian Craton.

Nonetheless, there are also differences between the two basins. In contrast to the Yanliao Rift, the McArthur Basin contains pre-1.70 Ga strata and ~1.58–1.50 Ga sediments are absent (Fig. 2). This depositional hiatus in the McArthur Basin was characterised by east-northeast to south-southwest shortening throughout the entire basin and is correlative with the ~1.60 to 1.50 Ga Isan Orogeny in the Mount Isa Inlier (to the east of the McArthur Basin, Fig. 1a) [8]. Other stratigraphic differences between the two cratons (Fig. 2) could be caused by lateral variations within large sedimentary system (e.g., [6]).

(2) Magmatic events. The ~1.73 Ga Miyun dolerite dykes intruded the Archean basement in the Yanliao Rift [9]. Similarly, in the McArthur Basin ~1.73 Ga Oenpelli dolerite sills were emplaced into sandstones of the Katherine River Group as well as the neighbouring Pine Creek Orogen to the northwest [10]. Furthermore, the ~1.72 Ga Jimbu Microgranite featuring abundant K-feldspar phenocrysts rimmed by albite intruded the Katherine River Group in northwestern McArthur Basin [6], which can be correlated with ~1.73–1.68 Ga rapakivis or K-rich granites, anorthosites, mangerites, and alkali granitoids emplaced in the basement of the Yanliao Rift (e.g., [11]). The Yanliao Rift recorded ~1.64 and 1.62 Ga volcanic eruptions [12] that might be coeval with tuffs layers in the McArthur Basin [6] (Fig. 2), and ~1.49–1.48 Ga tuffaceous layers are also found in both basins [6,12] (Fig. 2).

Coeval ~1.32 Ga magmatic events are recorded in both basins (Fig. 2): the Datong dyke ( $1,326 \pm 4$  Ma) and Yanliao sills (peak age at ~1,323 Ma) in the NCC [1,9], and the Galiwinku dyke swarm ( $1,324$ – $1,329$  Ma) and Derim-Derim sills ( $1,324 \pm 4$  Ma) in the NAC [10]. The ~1.32 Ga magmatism in the NCC was interpreted to represent a large igneous province (LIP) because (i) it covers  $>1.2 \times 10^5$  km<sup>2</sup>; (ii) pre-magmatic uplift occurred 20 ma prior to the LIP, and (iii) the sills are typical of within-plate tectonic settings [1]. The Galiwinku dykes and the Derim-Derim sills also cover a large area [10] and could be plume products.

Zhang et al. [1] suggested that both the unconformity (or disconformity) between the Xiamaling Formation and the Qingbaikou Group (Yuxian uplift), and the unconformity between the Roper Group and the overlying Cambrian strata in the McArthur Basin,

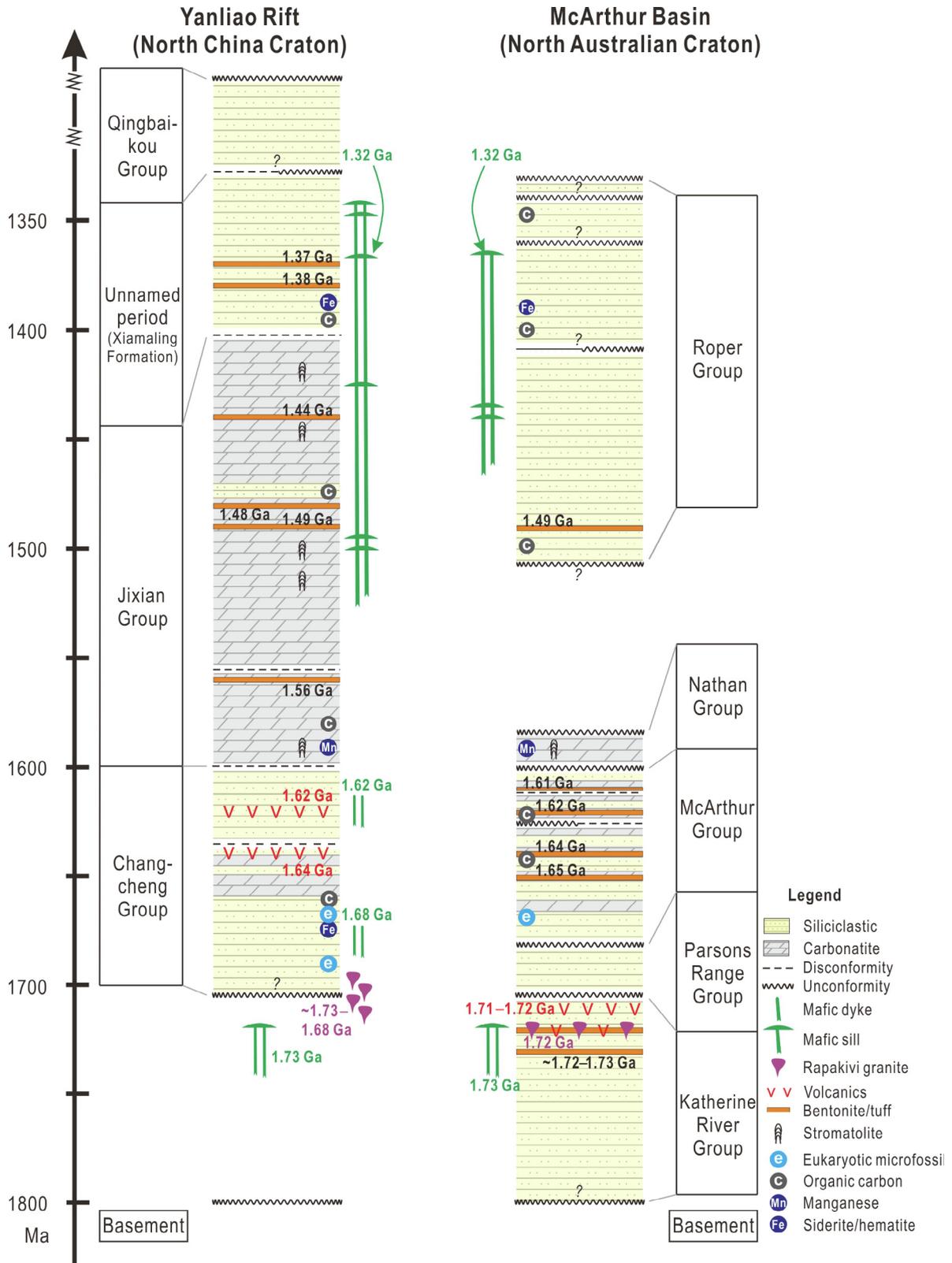
represent the same pre-magmatic uplift of the ~1.32 Ga LIP event, possibly related to the breakup of the supercontinent Nuna.

(3) Ore deposits. Dolostone-hosted manganese deposits are found in both the Jixian Group of the Yanliao Rift [13] and the Nathan Group of the McArthur Basin [6] (Fig. 2). The deposits in both basins occur as irregular lenses or veinlets in strata, mainly hosted in shallow marine sediments, implying a similar genesis [6,13].

Correlative iron deposits are also found in both basins (Fig. 2). The Sherwin Formation (upper Roper Group, McArthur Basin) comprises shale, sandy mudstone and sandstone, within lenses of massive oolitic to pisolitic beds, interbedded with medium to rather coarse chamosite–siderite [6]. The iron ore of the Sherwin Formation consists of hematite and/or goethite, and greenalite ooids. Chamosite and hematite are partly replaced by siderite by post-diagenetic processes, producing the silica (chert) cement. The stratiform siderites with minor hematite have been reported from the middle part of the Xiamaling Formation (~1.40–1.35? Ga) in the Yanliao Rift [14]. The siderites of the Xiamaling Formation contain hematite inclusions, indicating iron reduction process during early diagenesis [14].

(4) Hydrocarbon-bearing potential. Several potential hydrocarbon source rocks have been reported from the McArthur and Roper groups of the McArthur Basin (Fig. 2). Among those, ~1.64 Ga mudstones have high Total Organic Carbon (TOC) contents (up to 8%) [6], whereas those from the middle Roper Group have TOC of 1%–3% (some up to 8%–12%) [6]. Similarly, rocks with hydrocarbon-bearing potential have also been discovered in the Yanliao Rift (Fig. 2). The middle Changcheng Group (~1.65? Ga) and the Xiamaling Formation have TOC values of 0.6%–15% (average 2%) and 3%–21% (average 5.2%), respectively [15].

In summary, by comparing the paleomagnetic poles and geological similarities (e.g., comparable strata, environmentally sensitive fossils, magmatism, ore deposits and hydrocarbon-bearing potential), we identified a number of intriguing similarities between the NCC and the NAC, and while more work needs to be done on this Proterozoic connection, it seems likely that the two cratons were together from at least ~1.78 to 1.32 Ga, covering the lifespan of the supercontinent Nuna.



**Fig. 2.** Time-space diagram outlining tectonostratigraphic correlations between the Yanliao Rift of the North China Craton and the McArthur Basin of the North Australian Craton. Columns of the Yanliao Rift and McArthur Basin are compiled after Su et al. [5] and Ahmad et al. [6], respectively.

## Conflict of interest

The authors declare that they have no conflict of interest.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.scib.2019.04.028>.

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