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# **Geophysical Research Letters**<sup>\*</sup>

# **RESEARCH LETTER**

10.1029/2022GL099842

#### **Key Points:**

- Two new high-quality
  Paleoproterozoic paleopoles for the
  North Australian Craton are presented
- The new paleomagnetic data suggest a scissor-like assembly of the North Australian Craton
- Our new kinematic model proposes a situation prior to the formation of the first supercontinent related to a major slab-suction event

#### Supporting Information:

Supporting Information may be found in the online version of this article.

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#### Citation:

Kirscher, U., Mitchell, R. N., Liu, Y., Pisarevsky, S. A., Giddings, J., & Li, Z.-X. (2022). Paleomagnetic evidence for a Paleoproterozoic rotational assembly of the North Australian craton in the leadup to supercontinent formation. *Geophysical Research Letters*, 49, e2022GL099842. https://doi.org/10.1029/2022GL099842

Received 8 JUN 2022 Accepted 29 OCT 2022

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# Paleomagnetic Evidence for a Paleoproterozoic Rotational Assembly of the North Australian Craton in the Leadup to Supercontinent Formation

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**Abstract** The kinematics of the Paleoproterozoic assembly of Earth's first supercontinent, Nuna, are still debated. We present new paleomagnetic results from two Paleoproterozoic rock formations in the North Australia Craton (NAC) that exemplify cratonic assembly processes in the leadup to Nuna formation. Our new paleomagnetic data for the 1,825 Ma Plum Tree Creek Volcanics of the proto-NAC and the layered mafic-ultramafic 1,855 Ma Toby intrusion of the Kimberley Craton suggest their amalgamation just prior to ca. 1.8 Ga through a scissor-like ocean closure to form the NAC, in accord with geological records. Comparing these new results with extant poles from Australia and other major cratons suggests similarly minor relative plate motions between ca. 1.9 and 1.65 Ga during craton and supercontinent formation. A global reconstruction suggests that these events could be related to a major slab-suction event leading to Nuna formation.

**Plain Language Summary** Earth's evolution is characterized by the recurring assembly of most tectonic plates into one single supercontinent. There is mounting evidence that at least three supercontinents existed throughout Earth history. This cycle of supercontinents potentially played an important role for the evolution of life and is inextricably connected to plate tectonics. However, we still don't understand how and when exactly the supercontinent cycle initiated. We present here new paleomagnetic data allowing us the most precise paleogeographic reconstruction for the time interval before the first of the three known supercontinents formed. Our data reveals a small-scale collisional assembly of the Australian cratons in the vicinity of the formation of other major cratons at that time. Our global reconstruction using the most up to date paleomagnetic data set can be interpreted as evidence for a model where all cratons formed over a mantle downwelling structure that ultimately lead to the initiation of the supercontinent cycle.

# 1. Introduction

It is well-established that the recurring assembly and breakup of supercontinents over much of Earth's history has played an important role in the evolution of the Earth system (Nance et al., 2014). It has also become apparent that the supercontinent cycle is inextricably linked with fundamental mechanisms of mantle convection (Cao et al., 2021; Li & Zhong, 2009). Deciphering when and how the coupling between supercontinent cycles and whole mantle convection began carries implications for understanding the evolution of Earth's modern style of plate tectonics. There is mounting consensus that the Paleoproterozoic-Mesoproterozoic supercontinent Nuna (a.k.a., Columbia) represents the first of its kind (Mitchell et al., 2021). It has recently been proposed that the name ambiguity could be resolved by naming the precursor "megacontinent" at ca. 2-1.8 Ga "Nuna," while naming the final supercontinent at ca. 1.6 Ga "Columbia" (Wang et al., 2021). Given that it is the early assembly stage at ca. 1.85 Ga that is investigated in this paper, referring to Nuna herein is apt irrespective of the current debate over names. Despite proposals of an even older supercontinent, the most recent compilation of paleomagnetic data does not support a single large continental landmass for a prolonged period of time in the Archean (Liu et al., 2021). The configuration of the so-called extended core of Nuna (Evans & Mitchell, 2011; Kirscher, Mitchell, et al., 2021; Zhang et al., 2012) seems to have existed between ca. 1.6 and 1.3 Ga (Kirscher, Mitchell, et al., 2021). Prior to this, there is much more uncertainty and controversy surrounding the paleogeographic evolution during the leadup to the assembly of Earth's potential first supercontinent.





Figure 1. (a) Overview map of Australian cratons with both study areas indicated. NAC, WAC, and SAC–North, West, and South Australian cratons, respectively; KC–Kimberley Craton. (b) Geologic map of the Plum Tree Creek Volcanics based on Kruse et al. (1994) with sampling localities indicated. (c) Geologic overview map of the mafic intrusions of the Halls Creek Orogen based on Hoatson and Blake (2000). (d) Detailed geological map of the Toby Gabbro with sites along sampled transect indicated.

The assembly of Nuna is proposed to have occurred, depending on different approaches, between ca. 1.9 and 1.6 Ga (Evans & Mitchell, 2011; Pourteau et al., 2018; Zhao et al., 2002). Recently, Kirscher et al. (2019) interpret this prolonged timespan as a two-stage assembly, wherein an earlier ca. 1.8 Ga assembly of a majority of Nuna was followed by final assembly at ca. 1.6 Ga. A comprehensive understanding of the assembly of Nuna is of utmost importance because, if Nuna represents the first supercontinent, then its assembly marks the onset of supercontinent cycles and potentially also plate tectonics sensu stricto as a global network of interacting plate boundaries (Stern, 2018; Wan et al., 2020).

### 2. Geological Setting and Sampling

#### 2.1. Sampling

We present here new paleo- and rock magnetic as well as anisotropy data from two well-dated Paleoproterozoic magmatic complexes located within the North Australian Craton (NAC; Figure 1a). From the Kimberley craton (KC) that became sutured with the NAC along the ca. 1,832–1,808 Ma Halls Creek Orogen (Figure 1; Tyler et al., 2012), we collected a total of 265 oriented core samples from 20 sites in a detailed transect across the ca. 1,855 Ma Toby Gabbro and 1 site with 16 oriented core samples from the 1,843–1,830 Ma Wild Dog Creek Gabbro. From proto-NAC (NAC prior to the amalgamation with the KC), we collected 232 oriented block samples from 30 sites of the ca. 1,825 Ma Plum Tree Creek Volcanics (PTCV) of the Edith Falls syncline (Figures 1a and 1b; sites PCV 1–10, ERV 1–6, paleomagnetic sites of the PTCV of two field campaigns were named PCV: Plum tree Creek Volcanics and ERV: Edith River Volcanics) and the Seventeen-Miles Anticline (Figure 1b; sites PCV 11–15, ERV 16–24; Table S1 in Supporting Information S1). Comparison of the results from these two sectors of the NAC allows us to constrain the detailed kinematics of such cratonic assembly processes leading up to final supercontinent assembly.

### 2.2. The Plum Tree Creek Volcanics

The PTCV are located in the Central Domain of the ca. 2,030–1,780 Ma Pine Creek Orogen (PCO; Worden et al., 2008; Figure 1b). Within the PCO, the ca. 1,870–1,780 Top End Orogeny marks the final stage of orogenesis. The PTCV is a part of the Edith River Group, which represents the final sequences of syn-orogenic volcanics and associated sedimentary rocks of the Top End Orogeny (Worden et al., 2008). After the formation of the Edith River Group, the area was only affected by the Shoobridge low-grade metamorphic event at ca. 1.78 Ga along reactivated linear shear zones, and the intrusion of the Oenpelli Dolerite at ca. 1.69 Ga (Needham & Stuart-Smith, 1985). The PTCV represents an extensive subaerial ignimbrite sheet with minor basaltic and rhyolitic rocks. Near the city of Katherine, the Edith River Group and the overlying Kombolgie Formation are deformed into the genetically related Edith Falls Syncline and 17 Mile Anticline (Kruse et al., 1994). These folds are in places asymmetrical and strongly disrupted by faults and were probably generated during more than one phase of tectonism during the final stages of the PCO (Kruse et al., 1994). The PTCV are dated at  $1,825 \pm 4$  Ma by SHRIMP U-Pb zircon geochronology (Page, 1996). Two previous paleomagnetic studies reported results for the PTCV. The first study of the PTCV (which were then called the Edith River Volcanics) was conducted by Irving and Green (1958). Subsequently, Idnurm and Giddings (1988) presented additional preliminary results on the PTCV, including the mention of a positive fold test, but without providing sufficient detailed results. Thus, even though the PTCV might have potential for paleomagnetism, more study was required to acquire high-quality data.

#### 2.3. The Toby Gabbro

The KC, representing the western part of the NAC, is composed of the Paleoproterozoic–Mesoproterozoic Kimberley and Speewah basins. Within the deformed margins of the KC, in the Lamboo Province, two major orogenic events have been identified: (a) the ca. 1,870–1,850 Ma Hooper Orogeny accompanied by intrusion of the Paperbark supersuite and (b) the ca. 1,832–1,808 Ma Halls Creek Orogeny accompanied by the intrusion of the Sally Downs supersuite (Tyler et al., 2012). The Toby and Wild Dog Creek intrusions are parts of the Paperbark and Sally Downs supersuites, respectively. Whereas the Hooper Orogeny has been related to the collision of the KC with an oceanic arc, the Halls Creek Orogeny is regarded as representing the final collision of the KC with the proto-NAC (Phillips et al., 2016). The Toby Gabbro was dated using U-Pb geochronology, with  $^{207}Pb/^{206}Pb$  ages on 24 zircon grains yielding a mean age of  $1,855 \pm 2$  Ma (Hoatson & Blake, 2000). The age of the Wild Dog Creek Gabbro is constrained by the fact that it intrudes the ca. 1,843 Ma Koongie Park Formation and is cut by the 1,830 Ma McIntosh Suite, resulting in an age range for the Wild Dog Creek Gabbro of 1,843-1,830 Ma (Hoatson & Blake, 2000).

# 3. Methods and Results

In order to obtain the paleo- and rock magnetic information recorded in the volcanic rocks, a number of epxeriments were carried out on both collections. First, the anisotropy of magnetic susceptibility (AMS) was measured on one specimen of each sample. Subsequently, one specimen of each sample was thermally demagnetized after an initial bath in liquid nitrogen for low temperature demagnetization (Schmidt, 1993). Specimen of 50% of the samples were also treated with alternating field (AF) demagnetization. Small rock chips of representative lithologies were crushed and used for susceptibility versus temperature measurements to obtain information on the magnetic carriers within the rock samples.

### 3.1. Methods

For the PTCV, block samples were oriented with both magnetic and sun compasses. Sun-compass observations were made whenever possible to ensure an accurate measure of the local magnetic declination. From the six to eight oriented block samples from each site, two inch-diameter cores were drilled in the laboratory from each block and cut in standard sized cylinders. Magnetization directions were measured in three axes in a magnetically shielded room at Curtin University.

Magnetic components were computed for each sample using principal-component analysis (Kirschvink, 1980). All vectors were calculated using at least four successive steps with a maximum angular deviation <10°. In instances where stable-endpoints could not be reached, remagnetization great circles were fitted. Site-mean directions and mean virtual geomagnetic poles (VGPs) were calculated using Fisher statistics (Fisher, 1953) or the iterative approach combining great circles and magnetic vectors (McFadden & McElhinny, 1988).

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Whereas PCV1 represents a rhyolite outcrop, all other sites cover basaltic lava flows. One outcrop/site represents about 5–10 m of stratigraphic thickness. Bedding orientations were obtained on intercalated ignimbrites and the pillow basalt site PCV14. We interpreted the rhyolite site PCV-1 as a present-day overprint due to its similarity in in situ coordinates with the present-day field (IGRF12 of pmagpy for this locality for today:  $D = 3.8^\circ$ ,  $I = -42.1^\circ$ ). Additionally, we found three samples at site PCV-2 with a characteristic remanent magnetization (ChRM) component, which is very similar to the present-day direction of the magnetic field in in situ coordinates. Site PCV-11 reveals two clusters of directions, which are statistically distinct and were therefore treated independently (Table S2 in Supporting Information S1).

#### 3.2. Anisotropy of Magnetic Susceptibility Results

#### **3.2.1.** Toby and Wild Dog Creek Intrusions

AMS mean values reveal dominantly lineated magnetic fabrics (Figure S2A in Supporting Information S1). The tilt of the K3 mean direction (Figure S2A in Supporting Information S1) is unlikely to be related to folding, for which there are no structural indications (Hoatson & Blake, 2000). We argue that our AMS signal is related to a proposed collapse of the upper part of the intrusion similar to downsagging during volcanic caldera formations (Branney, 1995), which led to a tilted withdrawal of magma. Accordingly, our AMS results support a primary fabric of the magnetic minerals in the intrusion.

#### 3.2.2. Plum Tree Creek Volcanics

AMS results of the PTCV reveal a less anisotropic signal (Figure S2d in Supporting Information S1) compared to the Toby Intrusion. The complicated AMS mean directions of the PTCV (Figure S2b in Supporting Information S1) can be explained by variations in bedding orientations and the low degree of anisotropy. In some cases (e.g., sites PCV10 and 11) the bedding orientation matches the AMS results (Figures S2f and S2g in Supporting Information S1). Combining ambiguous results of sites PCV1-8 also show this result (Figure S2e in Supporting Information S1). Accordingly, we interpret the PTCV AMS results as supporting the primary origin of the magnetic signal.

#### 3.3. Paleo and Rock Magnetic Results

Rock magnetic experiments of the PTCV and the Toby Gabbro indicate magnetite and/or Ti-poor titanomagnetite as the main magnetic phase in both units (Figure 2; Figure S1 in Supporting Information S1). The occasional presence of a Hopkinson peak (Figure S1c in Supporting Information S1) is indicative of single- or pseudo-single-domain (titano-magnetite), suggesting stable remanences. Whereas the results for the intrusions are roughly reversible (Figure 2; Figure S1 in Supporting Information S1), the volcanics show a more diverse behavior including the presence of a medium temperature component at ~380°C or lower, which could be related to the presence of pyrrhotite or Ti-rich titanomagnetite. AMS results of both units suggest magnetic fabrics typical of a primary magmatic origin (Figure S2 and Table S3 in Supporting Information S1). Thermal and AF demagnetization (Figure S3e in Supporting Information S1) of each of the Toby, Wild Dog Creek, and PTCV sample sets yield well-defined and self-consistent directional behavior leading to the isolation of high-stability ChRM directions (Figure 2; Tables S1 and S2 in Supporting Information S1) and clustered site-mean directions (Figure 2).

Demagnetization experiments of the Toby and Wild Dog intrusions reveal, in general, stable behavior (Figure 2; Figure S3 in Supporting Information S1). A total of 194 samples yields interpretable results. Three sites did show declinations close to 0° and inclinations between -44 and -70° (present-local field (PLF) for PLF in Table S1 in Supporting Information S1). Another five sites show directions with high inclination values between 58 and 84° (\* in Table S1 in Supporting Information S1). The remaining 15 sites yield a high-quality (HQ) remanence interpreted as primary. To check consistency of the HQ directional data of this plutonic intrusion the mean of all individual samples was calculated and is indistinguishable from the mean direction based on site mean values (mean direction of individual samples: D = 83.0°, I = 1.6° and  $\alpha_{05} = 6.1°$ ).



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**Figure 2.** Representative paleomagnetic and rock magnetic results. (a, b) Representative thermal demagnetization results. (c) Stereographic projection of site-mean directions of the Toby Gabbro shown with the  $\alpha_{95}$  error circles of each site (left) and overall mean direction with according error circles (right). Gray samples indicate sites with large  $\alpha_{95}$  and those sites that have been "reversed" are indicated as such. (a–c) Open (closed) circles represent projections on the upper (lower) hemisphere. (d) Stereographic projection of PTCV site mean direction in situ (IS) and tilt-corrected (TC) coordinates. (e) Parametric fold test of PTCV results. (f) Representative susceptibility versus temperature results.

Dual polarity HQ directions of the Toby Gabbro yielded separate mean directions of declination/inclination pairs of  $258.0^{\circ}/13.1^{\circ}$  (n = 2) and  $86.0^{\circ}/7.1^{\circ}(n = 13)$  with  $\alpha_{95}$  of  $11.6^{\circ}$  and  $6.8^{\circ}$ . This means a potential reversal test would be negative due to underrepresentation of westward oriented sample directions.

Site-mean directions of the PTCV are characterized by a single polarity and are generally directed up and south-east. Four sites were excluded from further analyses due to either proximity to the PLF direction or anomalous directions (Table S1 in Supporting Information S1). The remaining 28 site-mean directions yield an average mean direction of  $D = 124.2^{\circ}$  and  $I = 46.1^{\circ}$  before bedding correction, and  $D = 122.5^{\circ}$  and  $I = 34.1^{\circ}$  after bedding correction, with an increase of the precision parameter *k* from 6.5 to 10.4 and a decrease of  $\alpha_{95}$  from 11.7° to 8.9° upon unfolding, constituting a positive parametric fold test (Figure 2e; Tauxe & Watson, 1994). The resulting paleopole after 100% unfolding is located at Plat = 34.8°S, Plong = 209.3°E (A<sub>95</sub> = 7.7°).

The ChRMs of both the Toby and Wild Dog Creek intrusions exhibit predominantly shallow directions pointing east (Figure 2c) with a few directions of opposite polarity (data not sufficient to perform a positive reversal test; Text S1 in Supporting Information S1). Some sites show both the identified ChRM directions and directions that are close to the PLF direction (Table S2 in Supporting Information S1). Another anomalous mean direction has been observed with very steep inclinations, which could be related to the intrusion collapse. Combining 15 site-mean directions yields an overall mean direction for the Toby Gabbro of  $D = 86.7^{\circ}$ ,  $I = 1.8^{\circ}$ , and  $\alpha_{95} = 13.7^{\circ}$  with a corresponding paleopole of Plat = 2.9°, Plong = 215.6° ( $A_{95} = 9.7^{\circ}$ ). The one site of the Wild Dog Creek Gabbro yields a mean direction of  $D = 253.7^{\circ}$ ,  $I = 3.4^{\circ}$  ( $\alpha_{95}$  of 8.0°) with a VGP based on 12 individual sample directions of Plat = 16.1°, Plong = 214.2° ( $A_{95} = 5.7^{\circ}$ ).





**Figure 3.** Paleopoles of the North Australian Craton color-coded by sector (green: KC, blue: remaining NAC). (a) Present-day paleopoles from P(T)CV, Toby and Wild Dog Creek intrusions together with the Hart Dolerite pole. Also shown are Toby and Wild Dog Creek paleopoles before a suggested ~40° rotation in yellow that can be related to the rotational assembly of the entire NAC. Plum tree Creek Volcanics (PCV)\_82% is based on syn-folding mean directions of the P(T)CV for comparison (see Supporting Information S1 for more details). Toby<sup>1/2</sup> refers to paleopoles based on less sites using a stricter  $\alpha_{95}$  criterion. Inset shows the age uncertainties of the paleopoles and the two major orogenic events during the assembly of the NAC. (b) All paleopoles from the NAC for this time interval (1,860–1,650 Ma) corrected for relative rotation. The ages of all paleopoles used are color-coded by craton (Table S4 in Supporting Information S1). Mercator projections.

The PTCV results reveal a positive fold test (Figure 2e), indicating the age of the ChRM pre-dates folding in the area. Maximum clustering of directions is reached at a somewhat broad range of unfolding percentage (Figure 2e). This result can be explained by the fact that the ChRM directions being subparallel to that of the regional fold hinge (Figure 1b), where the clustering of the site-mean directions is not so sensitive to the bedding correction. Although we could not rule out the possibility of an early syn-folding magnetization for the ChRM, we deem it unlikely. This interpretation is further supported by the fact that the resulting PTCV poles show no similarity to the 1.79 Ga Hart Dolerite pole, making a syn-folding origin related to the ca. 1.78 Ga Shoobridge Event unlikely. Given the small age difference between the PTCV and its folding, we therefore conclude that the PTCV preserves a primary magnetic signal. No baked contact test was possible at the Toby Gabbro because no distinct contact with host rocks was observed. However, the identified ChRM directions of the Toby Gabbro differ from observed overprint directions related to the PLF or orogenic events in this region (Austin & Patterson, 2020), suggesting a primary origin for the magnetic signal. Furthermore, the consistency of the results from the Toby and Wild Dog Creek intrusions argues against post-emplacement rotations that may have affected other parts of this region (Austin & Patterson, 2020). Another argument is a positive paleo-secular variation test for both areas (Table S6 in Supporting Information S1, Deenen et al., 2011). In summary, based on the fact that these new paleomagnetic data are most parsimoniously interpreted as primary, two new paleopoles are obtained for two regions of the NAC for 1,855 and 1,825 Ma.

### 4. Discussion

#### 4.1. Assembly of the North Australian Craton

The two new results reported here represent the oldest-available, high-quality paleomagnetic data for the NAC and thus critically inform its assembly in the leadup to the formation of the supercontinent Nuna. Older data from Australia are exclusively based on rocks from the West Australian Craton (Kirscher, Nordsvan, & Schmidt, 2021). Our new poles plot in close proximity with other Australian data between 1888 and 1655 Ma (Figure 3). However, a distinct difference in pole positions is apparent between the Toby (1,855 Ma) and Wild Dog Creek (1,836 Ma) intrusions of the KC and the PTCV (1,825 Ma) of the proto-NAC, which is unexpected for two groupings of poles





**Figure 4.** (a) Paleogeographic reconstruction at ca. 1,855 Ma. Australian cratons (NAC–North Australian; WAC–West Australian; KC–Kimberley cratons; CLP–Central Lamboo Province) are shown together with Mawson, Siberia, India, North China craton (NCC), and the Laurentian cratons (depicted according to Swanson—Hysell et al., 2021). Suggested subduction zones: HO–Hooper Orogeny; HCO–Halls Creek Orogeny; YO–Yapungku Orogeny. Proposed rotation of KC between 1,855  $\pm$  2 Ma and 1,825  $\pm$  4 Ma is indicated. Cylindrical equidistant projection is used. (b) Paleopoles used for reconstruction color coded by craton. Pole labels, ages, and references are given in Table S4 in Supporting Information S1. Euler rotation parameters for reconstruction are given in Table S5 in Supporting Information S1. Orthographic projection.

so close in age (Figures 2 and 3a). The significant angular discrepancy can be accounted for by inferring a counterclockwise rotation of the KC (Toby and Wild Dog Creek intrusions) with respect to the proto-NAC (PTCV), where a counterclockwise rotation of  $\sim 40^{\circ}$  brings the broadly coeval paleopoles from the two different regions of the NAC into agreement (Figure 3b). The potential criticism that the Toby and PTCV poles are not precisely coeval for such a comparison is largely absolved by the consistency of the Toby pole with the Wild Dog Creek VGP that is closer in age with the PTCV. The inferred large rotation is interpreted to reflect the kinematics of the intervening Halls Creek orogeny during the assembly of the KC with proto-NAC (see also Text S2 in Supporting Information S1).

#### 4.2. Assembly of Supercontinent Nuna

Using the newly obtained data for the NAC, a global reconstruction for 1,855 Ma was established with a focus on the Australian cratons and its nearest neighbors, which include parts of Laurentia, Siberia, India, and North China. The widespread occurrence of major orogens such as the Trans-Hudson, the Halls Creek, the Trans-North China, and the North China–Siberia orogens could be related to the development of the proposed earliest global subduction network at this age (Figure 4, Wan et al., 2020). The positions of India and the WAC are loosely defined with paleomagnetic constraints and coeval magmatism at ca. 1.89 Ga (Liu et al., 2019), but because the assembly of the WAC and NAC occurs shortly after during the Yapunku Orogeny starting at 1.8 Ga (Johnson, 2014), proximity of the NAC and WAC seems to be likely.

Paleomagnetic data for the NCC is absent prior to 1.78 Ga, but a peak of detrital zircon ages around 2.5 Ga in sediments of the Kimberley and Speewah basins (Hollis et al., 2014), for which a local source remains to be identified, could be explained by the proximity of KC with eastern NCC, where these ages are common and zircons have similarly positive  $\varepsilon_{HF}$  values (Hollis et al., 2014; Wang & Liu, 2012). The juxtaposition of the NAC and NCC—with the KC providing the critical link—suggests that the rotational assembly of the NAC was related to its motion toward the Laurentian cratons, whereby an eastward-moving proto-NAC dragged KC, Mawson, and NCC with it, causing KC to rotate inward, finally forming the NAC as well as pushing NCC toward Siberia, where both sutures were fittingly complete by ca. 1.8 Ga (Tyler et al., 2012; Wan et al., 2015).

Our results shed new light on the critical cratonic assemblies leading up to the larger assembly of supercontinent Nuna (a.k.a., Columbia) by putting various collisional events in a global perspective. Such kinematic constraints for understanding the prolonged assembly of Earth's first supercontinent may offer additional insights into how the pivotal transition to the supercontinent cycle started on Earth. Our final reconstruction could also be seen as an



update for the proposed slab-suction style of assembly of proto-Laurentia (Faccenna et al., 2021; Hoffman, 2014; Mitchell et al., 2012). As Hoffman (2014) speculated, our paleogeographic model is in agreement with the Rae craton serving as the upper plate in Nuna assembly toward which other continents aggregated. We speculate that cratons aggregated over an underlying singularity of mantle downwelling associated with a long-lived degree-1 mantle convection system (Mitchell et al., 2021; Wang et al., 2021) that ultimately led to the formation of Earth's first supercontinent at ca. 1.6 Ga.

### 5. Conclusions

We present two new paleomagnetic studies for the 1,825 Ma PTCV and the layered mafic-ultramafic 1,855 Ma Toby intrusion of the North Australian Craton. Paleomagnetic directions of both studies agree roughly in terms of declination but show deviation in inclination. We explain this discrepancy by a scissor-like assembly of the proto-NAC with the KC during the Halls Creek Orogeny. Using the new results, we establish a global paleogeographic reconstruction for the time shortly prior to the assembly of Earth's first supercontinent Nuna at ca. 1.855 Ga. This paleogeographic model reveals that the assembly processes of several cratons (e.g., Laurentia, Australia, North China and Baltica) appear to have occurred in surprisingly close proximity with only minor amounts of relative motion required to ultimately assemble Nuna. This observation can perhaps be interpreted as supporting the slab-suction model of supercontinent formation, where a supercontinent eventually amalgamates over a mantle convective downwelling.

#### **Data Availability Statement**

All primary paleo- and rock magnetic data used in this study including data for compiling the reconstructions are available at https://zenodo.org/record/7271546 and are also given in the Supporting Information S1.

#### Acknowledgments

The Northern Territory Geological Survey (NTGS) kindly provided geological maps for the study regions. This work was supported by the Australian Research Council Laureate Fellowship Grant to ZXL (FL150100133) and by Grants from the National Natural Science Foundation of China (41888101 and 41890833) and the Chinese Academy of Sciences (IGGCAS-201905) to RNM. SAP was supported by the Ministry of Science and High Education of the Russian Federation (Grant 075-15-2019-1883). The authors thank Monika Korte for handling the manuscript and Michiel de Kock and one anonymous reviewer for very helpful and constructive comments that significantly improved the quality of the manuscript. The authors furthermore thank Chris Klootwijk for support during the first Edith River Volcanics field campaign and the owners of the Springvale Station for access to their land. Open access publishing facilitated by Curtin University, as part of the Wiley - Curtin University agreement via the Council of Australian University Librarians.

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