North China craton: The conjugate margin for northwestern Laurentia in Rodinia

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ABSTRACT

In the Rodinia supercontinent, Laurentia is placed at the center because it was flanked by late Neoproterozoic rifted margins; however, the conjugate margin for western Laurentia is still enigmatic. In this study, new paleomagnetic results have been obtained from 15 ca. 775 Ma mafic dikes in eastern Hebei Province, North China craton (NCC). Stepwise thermal demagnetization revealed a high-temperature component, directed northeast or southwest with shallow inclinations, with unblocking temperatures of as high as 580 \degree C. Rock magnetism suggests the component is carried by single-domain and pseudo-single-domain magnetite grains. Its primary origin is supported by a positive reversal test and regional remanence direction correlation test, and the paleomagnetic pole (29.0\degree S, 64.7\degree E, $A_{PM} = 5.4\degree$) is not similar to any published younger poles of the NCC. Matching the late Mesoproterozoic to early Neoproterozoic (ca. 1110–775 Ma) apparent polar wander paths of the NCC and Laurentia suggests that the NCC could have been the conjugate margin for northwestern Laurentia in Rodinia, rather than sitting off the northeast coast of the main Rodinian landmass. Geological data indicate that breakup of the NCC and Laurentia occurred between ca. 775 and 720 Ma.

INTRODUCTION

Laurentia is placed at the center of the Rodinia supercontinent because it is flanked by Neoproterozoic passive margins (Hoffman, 1991; Li et al., 2008, and references therein). The present eastern and southern margins of Laurentia could connect with Baltica, Amazonia, and Kalahari (Li et al., 2008; Meredith et al., 2017, and references therein), and its northern margin could connect with Siberia (Evans et al., 2016, and references therein); however, the continent(s) once adjacent to its present western margin are still enigmatic (Eyster et al., 2020). In earlier published papers for Rodinia reconstructions (Dalziel, 1991; Hoffman, 1991; Moores, 1991), Australia–Antarctica was linked to the western margin of Laurentia, named the “SWEAT” (southwestern United States and East Antarctica) model, but subsequent paleomagnetic data excluded a tight configuration of Australia against the western Laurentia margin (Li et al., 2008; Eyster et al., 2020, and references therein). Alternatively, the South China block was placed between eastern Australia and western Laurentia, known as the “missing link” model (Li et al., 2008), but more recent paleomagnetic studies suggested the South China block and Laurentia were separated by a large latitudinal gap ca. 800 Ma (Jing et al., 2020; Xian et al., 2020). Recently, Wen et al. (2017, 2018) suggested that the Tarim craton could have occupied a similar missing-link position based on new paleomagnetic data, although the Tarim craton is too small to match the entire length of Laurentia’s western margin. Alternative reconstruction models were also proposed to link other continents to the western margin of Laurentia, such as Siberia (Sears and Price, 2003), Congo–São Francisco (Maloof et al., 2006), or West Africa (Evans, 2009), but these models are not supported by available paleomagnetic data. Owing to a series of high-quality late Mesoproterozoic to early Neoproterozoic paleomagnetic and geochronological data reported from the North China craton (NCC), a ca. 1100–920 Ma connection of the northeastern NCC and northwestern Laurentia (present coordinates) was proposed (Fu et al., 2015; Zhao et al., 2020) but required rigorous testing by coeval pairs of high-quality poles with precise age constraints. In this study, we report a new high-quality paleomagnetic pole obtained from ca. 775 Ma mafic dikes in the eastern Hebei Province, NCC. This pole, combined with the late Mesoproterozoic to early Neoproterozoic (ca. 1110–775 Ma) paleomagnetic database of the NCC and Laurentia, supports an enduring NCC–northwestern Laurentia connection in Rodinia.

REGIONAL GEOLOGY AND SAMPLING

Two generations of unmetamorphosed Precambrian mafic dikes exist in the Lulong region, eastern Hebei Province, the northeastern NCC (Fig. 1). Both sets of dikes vertically or subvertically intruded into Archean–Paleoproterozoic gneisses (Figs. 1B and 1C; Fig. S1 in the Supplemental Material); Wang et al., 2016; Ding et al., 2020). Dikes of the older group are 10–30 m wide and were dated at 1236.4 ± 7.3 Ma (baddeleyite, Pb-Pb secondary ion mass spectrometry [SIMS] method; dike LL02, Fig. 1B; Wang et al., 2016). They are north-trending alkaline gabbro dikes (Wang et al., 2016) and carry paleomagnetic directions pointing east and downward with moderate inclinations (Ding et al., 2020). Dikes of the younger group are 5–15-m-wide, ENE-trending porphyritic diabase dikes, tholeiitic in geochemical features (Wang et al., 2016), and were dated at 775 ± 5 Ma (zircon, U-Pb SIMS method; Wang et al., 2016). Paleomagnetic results from two dikes of the younger group were reported previously, the remanence being...
obviously different to that of the ca. 1236 Ma dikes (Ding et al., 2020). In this study, we collected 214 paleomagnetic core samples from 13 additional ca. 775 Ma dikes. In order to conduct baked-contact tests, 24 samples from the baked and unbaked gneisses in the proximity of two dikes were also collected.

**PALEOMAGNETIC RESULTS**

The natural remanent magnetization intensities of the samples from the ca. 775 Ma mafic dikes range from 0.01 to 1.2 A/m. For most samples, after stepwise thermal demagnetization, two components can be isolated. The low-temperature component (LC) is identified mostly below 400 °C (Fig. 2). Directions of the LC distribute around the present geomagnetic field (PGF) direction in the region and are thus interpreted to be a viscous remanent magnetization. The high-temperature component (HC) is generally defined in higher-temperature steps up to ∼580 °C. This is consistent with

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**Figure 1.** (A) Schematic map showing the distribution of basement rocks, unmetamorphosed Precambrian mafic dikes, and locations of the study regions (blue rectangles) in the North China craton. (B,C) Simplified geological maps of the studied regions and distribution of studied dikes.
thermomagnetic and hysteresis curves (Fig. S2) that demonstrate the main magnetic carriers in the samples are single-domain and pseudo-single-domain magnetite grains. Some specimens from weathered rocks, however, hold only one component up to 580 °C, close to the PGF. The HC directions of 10 dikes point northeast, and of three dikes, southwest, both with shallow inclinations (Fig. 3A). The northeast directions are consistent with the data previously reported in Ding et al. (2020). Because the two generations of dikes have different trends but are all vertical or subvertical, no tilt correction is interpreted to be necessary for the paleomagnetic data. By averaging the total 13 virtual geomagnetic poles (VGPs) of this study plus the two from Ding et al. (2020), a mean pole for the ca. 775 Ma dikes is determined at 29.0°S, 64.7°E (A95 = 5.4°) (Fig. 3B), which yields a paleolatitude of 4.6° ± 5.4° for the sampling location (39.9°N, 119.0°E). This pole passes a reversal test at 95% confidence level (class C; McFadden and McElhinny, 1990), with the observed angular difference (γ0 = 10.7°) less than the critical angle (γc = 12.9°) (Table S1).

We conducted baked-contact tests for two dikes. The HC isolated from the baked gneisses surrounding dike LL18 (Fig. 1C) is similar to that of the dike (Fig. S3). Unfortunately, the samples from the unbaked gneisses display scattered demagnetization patterns, and the samples from the host rocks of dike LL13 all show scattered demagnetization patterns such that the baked-contact test is inconclusive. Nonetheless, the pole from the ca. 775 Ma dikes is different from that of the ca. 1236 Ma dikes in the same area, constituting a regional remanence direction correlation test (Buchan, 2013), and it is also dissimilar to all younger paleomagnetic poles of the NCC, supporting the interpretation that the HC component is a magnetization from the time of dike emplacement ca. 775 Ma. The 15 VGPs yield an angular dispersion of 11.0° with confidence interval 9.2°−12.8° (1σ). That value and its confidence interval overlap with the expected range of 9.7°−12.6° for paleolatitude of 4.6° according to the empirical paleosecular variation (PSV) model for 1.0–2.2 Ga (Smirnov et al., 2011) as well as the expected range of 9.6°−10.7° for 0.5–1.5 Ga (Veikkola-Len and Pesonen, 2014). The A95 (5.4°) is also within the expected envelope of 4.1°–14.9° that accounts for the uncertainty on the mean that could be expected to arise through secular variation (Deenen et al., 2011). Finally, the HC directions include dual polarities that pass the reversal test at the 95% confidence level. Taken together, these factors strongly suggest that the pole from the ca. 775 Ma dikes has averaged out PSV. In summary, the new pole fulfills six of the seven revised quality criteria for paleomagnetic poles (Meert et al., 2020), therefore it is considered as a reliable paleomagnetic pole for the NCC.
CONJUGATE MARGIN FOR NORTHWESTERN LAURENTIA

The new ca. 775 Ma paleomagnetic pole and the updated paleomagnetic data from the NCC and Laurentia bolster the hypothesis (Fu et al., 2015; Zhao et al., 2020) that the NCC could have been the conjugate margin for western Laurentia. The new ca. 775 Ma pole suggests that the NCC was located at low latitudes; paleomagnetic poles from the Gunbarrel large igneous province (LIP; Northwest Territories, Canada) also yield a low paleolatitude for Laurentia at ca. 775 Ma (Eyster et al., 2020, and references therein). Moreover, combining this pole with the three poles (BNFa, BNFb, and BNFc; Table S2) from the Nanfen Formation and one pole (LHB; Table S2) from the lower Huaibei Group from the NCC, long-distance movement is implied for ca. 1110–775 Ma, similar to that of Laurentia over the same time interval (Swanson-Hysell et al., 2019, Eyster et al., 2020; Fig. 4A). The ca. 1110–775 Ma apparent polar wander paths (APWPs) for the NCC and Laurentia are established by eight and 25 paleomagnetic poles, respectively, the geometry of which permits a single possible (within uncertainty) relative reconstruction in both paleolatitude and paleolongitude via matching their APWPs. NCC poles of 930–890 Ma also match well with the Bactria poles of 950–850 Ma in typical Rodinia reconstructions (Gong et al., 2018; Figs. 4B and 4C).

The NCC–northwestern Laurentia connection finds geological support from the following points. Firstly, based on the reconstruction, the ca. 775 Ma dikes in the NCC and the ca. 775 Ma Gunbarrel dikes in Laurentia (Mackinder et al., 2019, and references therein) could have formed a radiating LIP (Fig. 4D), consistent with the paleomagnetic reconstruction. Secondly, ca. 1200–1000 Ma detrital zircons have been widely reported from late Mesoproterozoic to early Neoproterozoic strata in the eastern and northern NCC, despite a lack of abundant magmatic events of those ages across the NCC (Zhao et al., 2020, and references therein). These detrital zircons are likely sourced from other cratons that were once juxtaposed to the NCC; namely, they could be sourced from the Grenville orogen of eastern Laurentia, transported >3000 km by a pancontinental river system as previously suggested (Rainbird et al., 2017; Zhao et al., 2020, and references therein).

Published geochronological data suggest that ca. 800–760 Ma mafic dikes are widespread in northern Tarim (Zhang et al. 2009), but the available paleomagnetic data obtained from them could have been affected by late regional hydrothermal activity (Wen et al., 2017). Based on the reliable poles from the ca. 890 Ma Saijiazitange Group (Wen et al., 2018) and the ca. 750–740 Ma Baiyisi Formation (Huang et al., 2005), Wen et al. (2017, 2018) suggested Tarim could have remained close to southwestern Laurentia in Rodinia. If this model is correct, the ca. 800–760 Ma dikes in the Quruqtagh and Aksu regions of the Tarim craton could form another branch of the radiating dike swarm that the coeval dikes from the NCC and Laurentia formed (Fig. 4D), although some authors have suggested that the northern Tarim dikes were subduction associated (e.g., Tang et al., 2016). Moreover, ca. 780 Ma mafic dikes or plutons were also reported from the Yili block, which is 300 km to the north of Tarim and was possibly associated with Tarim during the Neoproterozoic (Wang et al., 2014). These results suggest the NCC, Tarim, and Yili block together could have formed the conjugate margin for western Laurentia.

IMPLICATIONS

In the common Rodinian reference frame of the NCC adjacent to northwestern Laurentia proposed herein, the ca. 1220 Ma pole from the NCC and the ca. 1235 Ma pole from Laurentia are separated from each other (Fig. 4A; Fig. S4), suggesting that their assembly happened during ca. 1220–1110 Ma (Ding et al., 2020); however, the intervening orogenic belt has not yet been discovered in either western Laurentia or the northern NCC. We suggest that such a terrain has been dispersed among other smaller, unidentified blocks or recycled into the mantle, or that the...
assemblage could have amalgamated primarily by strike-slip movement. All of these possibilities require further investigation. After the NCC and Laurentia merged, they experienced long-distance motion across paleolatitudes when Rodinia formed during Grenvillian orogenesis. The NCC–northwestern Laurentia connection likely broke up during ca. 775–720 Ma, given that both the ca. 720 Ma Franklin LIP and the Sturtian glacial deposits—widespread across northwestern Laurentia—are absent from the NCC.

Nearly all previous Rodinia reconstructions placed the NCC along the supercontinent’s periphery as a peninsula jutting outward into the Mirovoi global ocean (Li et al., 2008; Meredith et al., 2017). Simplified concepts of global geodynamics posit a nearly continuous ring of subduction zones encircling a supercontinent (e.g., Li et al., 2019). In that context, the lack of early Neoproterozoic subduction records at the present-day northern margin of the NCC would be surprising. If the NCC was conjugate to northwestern Laurentia, however, the NCC would have occupied a less-protruding location within the Rodinia landmass. It may be of further interest that the remarkable geobiological records of eukaryotic development (Tang et al., 2020, and references therein) and marine geochemistry (Zhou et al., 2020, and references therein) from 15 ca. 775 Ma mafic dikes in the NCC. This new pole, combined with the late Mesoproterozoic and early Neoproterozoic paleomagnetic data from the NCC and Laurentia, suggests that the NCC could have been the conjugate margin for northwestern Laurentia in the supercontinent Rodinia. After the NCC and Laurentia assembled during ca. 1220–1110 Ma, they shared long-distance plate motions (ca. 1110–775 Ma) as part of Rodinia prior to breakup between ca. 775 and 720 Ma. The important Tonian geobiological and geochemical records documented by NCC strata are integral rather than peripheral to Rodinia.

CONCLUSIONS
A reliable paleomagnetic pole was obtained from 15 ca. 775 Ma mafic dikes in the NCC. This new pole, combined with the late Mesoproterozoic and early Neoproterozoic paleomagnetic data from the NCC and Laurentia, suggests that the NCC could have been the conjugate margin for northwestern Laurentia in the supercontinent Rodinia. After the NCC and Laurentia assembled during ca. 1220–1110 Ma, they shared long-distance plate motions (ca. 1110–775 Ma) as part of Rodinia prior to breakup between ca. 775 and 720 Ma. The important Tonian geobiological and geochemical records documented by NCC strata are integral rather than peripheral to Rodinia.

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REFERENCES CITED
Buchan, K.L., 2013, Key paleomagnetic poles and their use in Proterozoic continent and supercontinent reconstructions: A review: Precambrian Research, v. 238, p. 93–110, https://doi.org/10.1016/j.precamres.2013.09.018.
Dalziel, I.W.D., 1991, Pacific margins of Laurentia and East Antarctica–Australia as a conjugate rift pair:
Evidence and implications for an Eocambrian supercontinent: Geology, v. 19, p. 598–601, https://doi.org/10.1130/0091-7311.2001.009.<0598:PMOLAE>2.3.CO;2

Deenen, M.H., Langereis, C.G., van Hinsbergen, D.J., and Biggin, A.J., 2011, Geomagnetic secular variation and the statistics of palaeomagnetic direction: Geophysical Journal International, v. 186, p. 509–520, https://doi.org/10.1111/j.1365-246X.2011.05050.x.

Ding, J., Zhang, S., Zhao, H., Xian, H., Li, H., Yang, T., Wu, H., and Wang, W., 2020, A combined geochronological and paleomagnetic study on ~1220 Ma mafic dikes in the North China Craton and the implications for the breakup of Nuna and assembly of Rodinia: American Journal of Science, v. 320, p. 125–149, https://doi.org/10.2475/02.2020.02.

Evans, D.A.D., 2009, The palaeomagnetically viable, long-lived and all-inclusive Rodinia supercontinent reconstruction, in Murphy, J.B., et al., eds., Ancient Orogens and Modern Analogues: Geological Society of London Special Publication 327, p. 371–404, https://doi.org/10.1144/SP327.16.

Evans, D.A.D., Veselovsky, R.V., Petrov, P.Y., Shatsilo, A.V., and Pavlov, V.E., 2016, Paleomagnetism of Mesoproterozoic margins of the Anabar Shield: A hypothesized billion-year partnership of Siberia and northern Laurentia: Precambrian Research, v. 281, p. 639–655, https://doi.org/10.1016/j.precamres.2016.06.017.

Eyster, A., Weiss, B.P., Karlstrom, K., and Macdonald, F.A., 2020, Paleomagnetism of the Chuar Group and evaluation of the late Tonian Laurentian apparent polar wander path with implications for the breakup of Rodinia: Geological Society of America Bulletin, v. 132, p. 710–738, https://doi.org/10.1130/B32012.1.

Fu, X., Zhang, S., Li, H., Ding, J., Yang, T., Wu, H., Yuan, H., and Lv, J., 2015, New paleomagnetic results from the Huaibei Group and Neoproterozoic mafic sills in the North China Craton and their paleogeographic implications: Precambrian Research, v. 269, p. 90–106, https://doi.org/10.1016/j.precamres.2015.08.013.

Gong, Z., Evans, D.A.D., Elming, S.-Å., Söderlund, U., and Salminen, J.M., 2018, Paleomagnetism, magnetic anisotropy and U-Pb baddeleyite geochronology of the early Neoproterozoic Blekelinge-Dalarna dyke swarm, Sweden: Precambrian Research, v. 317, p. 14–32, https://doi.org/10.1016/j.precamres.2018.08.019.

Hoffman, P.F., 1991, Did the breakup of Laurentia turn Gondwanaland inside-out?: Science, v. 252, p. 1409–1412, https://doi.org/10.1126/science.252.5011.1409.

Huang, B., Xu, B., Zhang, C., Li, Y.A., and Zhu, R., 2005, Paleomagnetism of the Baiyisi volcanic rocks (ca. 740 Ma) of Tarim, Northwest China: A continental fragment of Neoproterozoic Western Australia?: Precambrian Research, v. 142, p. 83–92, https://doi.org/10.1016/j.precamres.2005.09.006.

Jing, X., Yang, Z., Evans, D.A.D., Tong, Y., Xu, Y., and Wang, H., 2020, A pan-latitudean Rodinia in the Tonian true polar wander frame: Earth and Planetary Science Letters, v. 530, 115808, https://doi.org/10.1016/j.epsl.2019.115808.

Li, Z.X., et al., 2008, Assembly, configuration, and break-up history of Rodinia: A synthesis: Precambrian Research, v. 160, p. 179–210, https://doi.org/10.1016/j.precamres.2007.04.021.

Li, Z.X., Mitchell, R.N., Spencer, C.J., Ernst, R., Pisarevsky, S.A., Kirschner, U., and Murphy, J.B., 2019, Decoding Earth’s rhythms: Modulation of supercontinent cycles by longer superocean episodes: Precambrian Research, v. 323, p. 1–5, https://doi.org/10.1016/j.precamres.2019.01.009.

Mackinder, A., Cousins, B.L., Ernst, R.E., and Chamberlin, K.R., 2019, Geochemical, isotopic, and U-Pb zircon study of the central and southern portions of the 780 Ma Gunbrrel Large Igneous Province in western Laurentia: Canadian Journal of Earth Sciences, v. 56, p. 738–755, https://doi.org/10.1139/cjes-2018-0083.

Malloof, A.C., Halverson, G.R., Kirschvink, J.L., Schrag, D.P., Weiss, B.P., and Hoffman, P.F., 2006, Combined paleomagnetic, isotopic, and stratigraphic evidence for true polar wander from the Neoproterozoic Akademikerkreen Group, Svalbard, Norway: Geological Society of America Bulletin, v. 118, p. 1099–1124, https://doi.org/10.1130/B25892.1.

McFadden, P.L., and McElhinny, M.W., 1990, Classification of the reversal test in paleomagnetism: Geophysical Journal International, v. 103, p. 725–739, https://doi.org/10.1111/j.1365-246X.1990.tb05683.x.

Meert, J.G., Pivaranas, A.F., Evans, D.A.D., Pisarevsky, S.A., Posenen, L.J., Li, Z.-X., Elming, S.-Å., Miller, S.R., Zhang, S., and Salminen, J.M., 2020, The magnificent seven: A proposal for modest revision of the Van der Voo (1990) quality index: Tectonophysics, https://doi.org/10.1016/j.tecto.2020.228549.

Merdith, A.S., et al., 2017, A full-plate global reconstruction of the Neoproterozoic: Gondwana Research, v. 50, p. 84–134, https://doi.org/10.1016/j.gr.2017.04.001.

Moore, E.M., 1991, Southwest U.S.–East Antarctic (SWEAT) connection: A hypothesis: Geology, v. 19, p. 425–428, https://doi.org/10.1130/0091-7311(1991)019<0425:SUSEAS>2.3.CO;2.

Rainbird, R.H., Rayner, N.M., Hadlari, T., Heaman, L.M., Ielpi, A., Turner, E.C., and MacNaughton, R.B., 2017, Zircon provenance data record the lateral extent of pancontinental, early Neoproterozoic, and erosional unroofing history of the Grenville orogen: Geological Society of America Bulletin, v. 129, p. 1408–1423, https://doi.org/10.1130/B31695.1.

Sears, J.W., and Price, R.A., 2003, Tightening the Siberian connection to western Laurentia: Geological Society of America Bulletin, v. 115, p. 943–953, https://doi.org/10.1130/B32529.1.

Smirnov, A.V., Tarduno, J.A., and Evans, D.A.D., 2011, Evolving core conditions ca. 2 billion years ago detected by paleosecular variation: Physics of the Earth and Planetary Interiors, v. 187, p. 225–231, https://doi.org/10.1016/j.pepi.2011.05.003.

Swanson-Hysell, N.L., Ramezani, J., Fairchild, L.M., and Rose, I.R., 2019, Failed rifting and fast drift in the equatorial Indian Ocean: Implications for Rodinia reconstruction: Precambrian Research, v. 356, 105494, https://doi.org/10.1016/j.precamres.2019.105494.

Zhang, C.-L., Li, Z.-X., Li, X.-H., and Ye, H.-M., 2009, Neoproterozoic mafic dyke swarms at the northern margin of the Tarim Block, NW China: Age, geochemistry, petrogenesis and tectonic implications: Journal of Asian Earth Sciences, v. 35, p. 167–179, https://doi.org/10.1016/j.jseaes.2009.02.003.

Zhou, Y., Zhang, C., Li, H., Yang, T., and Wu, H., 2020, Geochronological and palaeomagnetic investigation of the Madiyi Formation, lower Banxi Group, South China: Implications for Rodinia reconstruction: Precambrian Research, v. 363, 105494, https://doi.org/10.1016/j.precamres.2019.105494.

Tang, Q., Qian, L., Li, Z.-X., Li, X.-H., and Ye, H.-M., 2009, Neoproterozoic mafic dyke swarms at the northern margin of the Tarim Block, NW China: Age, geochemistry, petrogenesis and tectonic implications: Journal of Asian Earth Sciences, v. 35, p. 167–179, https://doi.org/10.1016/j.jseaes.2009.02.003.

Zhou, Y., and Liu, H., 2012, Geochemical and Sr isotopic Sr using calcite microspar: Geology, v. 40, p. 462–467, https://doi.org/10.1130/G34675.1.

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