A paradigm shift: North China Craton's North Margin Orogen is the collisional suture with the Columbia Supercontinent

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Abstract

In a new study, Wu et al. (this issue) present a comprehensive study of the North Margin Orogen of the North China Craton, showing that older accreted rocks in this belt preserve a record of active margin magmatism from 2.2-2.0 Ga, followed by collisional tectonics, marked by mélange and mylonitic shear zones, then granulite facies metamorphism at 1.9-1.8 Ga, marking the final collision of the North China Craton with the Columbia Supercontinent. The multidisciplinary studies present in this work support earlier suggestions that the North China amalgamated during accretionary orogenesis in the Neoarchean to earlier Paleoproterozoic, and that the late widespread 1.85 Ga high-grade metamorphism is craton-wide in scale, and not confined to a narrow orogen in the center of the craton. This new understanding creates new possibilities for refining reconstructions of one of Earth's earliest, best documented supercontinents, showing a globally-linked plate network at 1.85 Ga, and suggests drastic new correlations and models for mineral resource exploration.

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Invited Commentary:

A paradigm shift: North China Craton's North Margin Orogen is the collisional suture with the Columbia Supercontinent

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Abstract

In a new study, Wu et al. (this issue) present a comprehensive study of the North Margin Orogen of the North China Craton, showing that older accreted rocks in this belt preserve a record of active margin magmatism from 2.2-2.0 Ga, followed by collisional tectonics, marked by mélange and mylonitic shear zones, then granulite facies metamorphism at 1.9-1.8 Ga, marking the final collision of the North China Craton with the Columbia Supercontinent. The multidisciplinary studies present in this work support earlier suggestions that the North China amalgamated during accretionary orogenesis in the Neoarchean to earlier Paleoproterozoic, and that the late widespread 1.85 Ga high-grade metamorphism is craton-wide in scale, and not confined to a narrow orogen in the center of the craton. This new understanding creates new possibilities for refining reconstructions of one of Earth's earliest, best documented supercontinents, showing a globally-linked plate network at 1.85 Ga, and suggests drastic new correlations and models for mineral resource exploration.

Key Points:

The Paleoproterozoic collisional orogen of the North China Craton with Columbia Supercontinent is positively identified

This "North Margin Orogen" changes reconstructions of the oldest well-established supercontinent

Correlations of the North Margin Orogen with the orogenic-gold-rich Birimian or West Africa suggest a new mineral exploration strategy for China

When the supercontinent cycle started on Earth is an important question, as formation of the first supercontinent may reveal the time that earlier forms of plate tectonics were able to build continents of sufficient size to emerge above sea level, begin the Wilson Cycle, and begin subaerial weathering, fomenting major changes in numerous chemical and physical systems on our planet (Mitchell et al., 2021). Pre-supercontinent cycle tectonics were likely dominated by submergent intra-oceanic subduction and arc systems, numerous oceanic spreading ridges, and probably a much greater total plate boundary length with smaller overall plate sizes, with arc magmatism being the biggest contributor to continental growth (Windley et al., 2021). Determination of the configuration of the first supercontinent is plagued with difficulties in making reconstructions the further back in time one goes, with the loss of fossils, sea-floor spreading records, and reliable paleomagnetic results, so we must rely on classical geologic analysis and correlation for earlier times (e.g., Şengör et al., 2020).

For decades, a scientific debate has raged as to where is the collisional orogen responsible for the regional high-grade metamorphism of the North China Craton at 1.85 Ga, presumably related to the North China craton's amalgamation with the earliest well-documented supercontinent, Columbia, with Nuna at its core. One school of thought has argued that a north-south belt of uplifts that runs through the center of the craton is the collisional orogen between the Eastern and Western Blocks on either side as the blocks jumbled and joined the Columbia Supercontinent, and this proposed orogen was named the Trans-North China Orogen, or TNCO (Zhao et al., 2001, 2005, 2012). In contrast, others have argued that the 1.85 Ga collisional orogen lies in an east-west belt along the north margin of the craton, marking the place where the North China Block joined the Columbia Supercontinent, after a long period of geographically wide Andean margin activity caused by subduction to the south under the craton. In this model, the 1.85 Ga continent/continent collision was Tibetan-in-scale, affecting most of the craton, but stronger in the north (Kusky et al., 2016; Xiao et al., 2021). The paper by Chen Wu et al. (2022a) is a potential paradigm shifter, as it is the first to clearly, quantitively, and comprehensively describe the orogen on the north margin of the craton, and link it with other collisional orogens globally-related to the formation of the planet's first clearly-documented supercontinent, Columbia. This has important implications, not only academically, but potentially economically.

The paper by Chen Wu and others (2022a) puts together a structural, geochronological, geochemical, and paleomagnetism-based plate reconstruction model that clearly documents the northern margin of the North China Craton as the 1.85 Ga collisional orogen, and the other belts (TNCO included) as zones of regional overprinting of older orogenic belts. Professor Chen Wu and his colleagues initially recognized a circa 1.9 Ga mélange along the north margin of the craton (Wu et al., 2018), then continued mapping and through detailed field studies (Wu et al., 2022a, b) have now documented many of the classical features of collisional orogens along the north margin of the craton, at 1.9-1.85 (extending to 1.78 Ga for post collisional magmatism), using long-established indicators of collisional orogens. Specifically, Wu et al. (2022a) document the presence of an east-west striking belt of 2.2-2.0 Ga continental margin magmatic arc rocks, an east-west striking 1.9-1.88 Ga tectonic mélange and mylonitic shear zones, and lower Paleoproterozoic strata folded by N-S contraction, all metamorphosed to granulite facies at 1.9-1.8 Ga. Analysis of a huge dataset of detrital zircons by Wu et al (2022a) is consistent with Neoarchean arc/continent collision in the older orogenic belt in the center of the craton, followed by active continental margin arc tectonics along the north margin of the craton from 2.2-1.85 Ga forming the Bayan Obo subduction/accretion mélange, then ridge subduction at 1.92 Ga, followed by collision with Columbia Supercontinent at 1.93-1.80 Ga, then post-collisional magmatism in the range of 1.87-1.80, with the final pulse of post-collisional lamprophyre dikes intruding at 1.78-1.77 Ga. The North Margin Orogen was then intruded by 1.87-1.78 plutons of the anorthosite – mangerite -charnockite -alkali feldspar granitoid suite (Peng et al., 2014), which are common in post-continental collisional settings such as the Rodinian Belts, including the Adirondacks the Grenville Province.

While the position of the North China Craton in the Columbia Supercontinent has been debated (Rogers and Santosh, 2002; Zhao et al., 2002; Meert, 2012), this is largely because most workers have been assuming the north-south striking TNCO in the center of the craton marked the collisional suture with Columbia. Since this turns out to not be true, confirmed by the new work reported by Wu et al. (2022a), one of the biggest reasons the NCC was so hard to fit into Columbia, was that these attempts were using the wrong orogen as the suture! The reconstruction of Kusky and Santosh (2009) used the North Margin Orogen to fit the NCC into Columbia, correlating this belt with the Trans-Amazonian of South America and Eburnian/Birimian orogens of West Africa. In a new greatly refined reconstruction of Columbia, Grenholm (2019) has fit together most cratons of Columbia into the "Atlantica" configuration, in which the North Margin Orogen of the NCC also correlates with the Birimian terrains amalgamated during the Eburnian orogeny (Fig. 1). Together, the North Margin Orogen of Wu et al. (2022a) and the Birimian terranes of West Africa as seen on this reconstruction to form a large 2.3-2.0 Ga accretionary orogen, that collided with the other blocks of Columbia in the Atlantica configuration at 1.85 Ga.

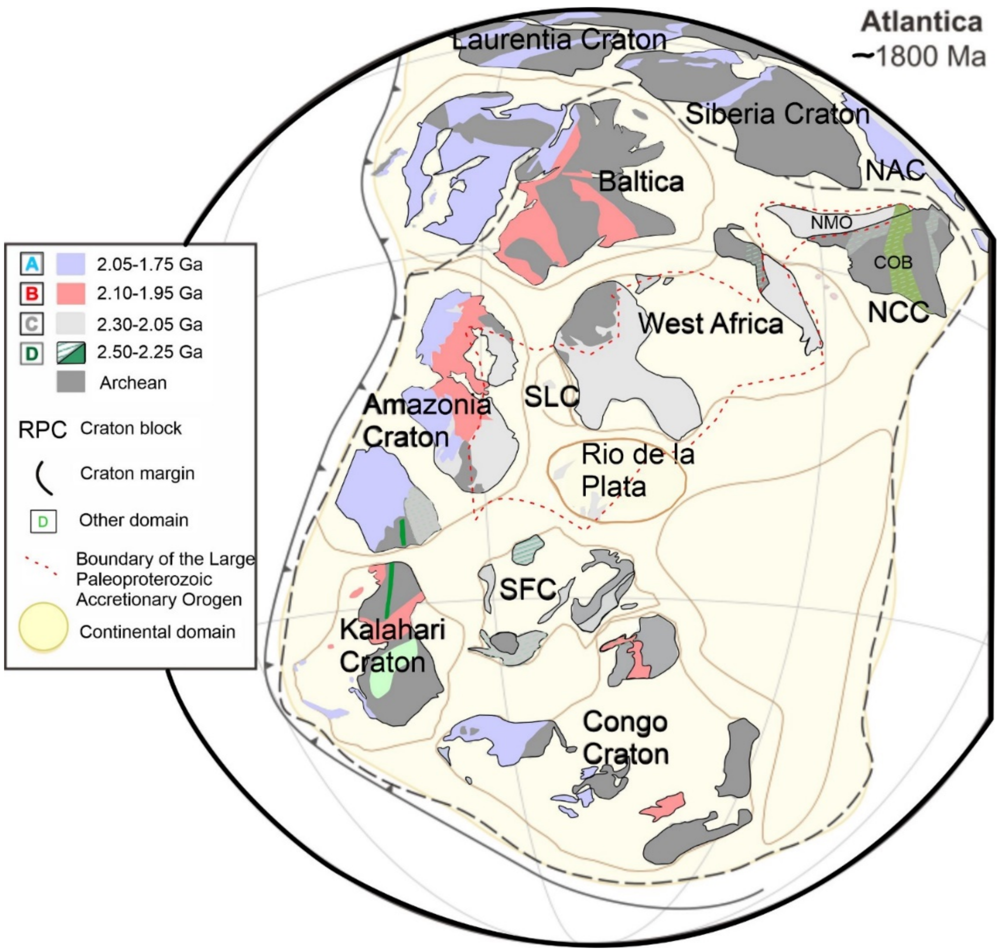

Fig. 1. "Atlantica" reconstruction of the Columbia Supercontinent, modified after Grenholm (2019). Note that the north margin of the North China Craton correlates with the gold-rich Birimian belts of the West Africa Craton. Abbreviations as follows: COB, Central Orogenic Belt; NAC, North Atlantic Craton; NCC, North China Craton; NMO, North Margin Orogen; SFC, São Francisco Craton; SLC, São Luis Craton.

The importance of using the correct orogen to fit the NCC into the Columbia Supercontinent reconstruction is more than academic. Workers who have been using the TNCO as the collisional orogen, and the reconstructions based on that have faced the challenge of finding no associated orogenic gold deposits, or other economically significant mineral deposits associated with their proposed orogen. The Birimian, in contrast, has recently been recognized as the world's premier Paleoproterozoic gold province, with > 10,000 metric tons gold endowment known, so far (Masurel et al., 2022). In fact, the West African Craton constitutes an extensive Paleoproterozoic accretionary orogen which contain numerous orogenic gold deposits (Bierlein et al., 2009) formed around ca. 2.27–1.96 Ga (Para-Avila 2016; Şengör et al., 2021b). The orogenic gold deposits are typically located in metamorphosed fore-arc and back-arc regions, as well as in the arc (Goldfarb et al., 2015) and show a close spatial relationship to lamprophyres and associated felsic porphyry dikes and sills (Rock et al., 1987), similar to those of the North Margin Orogen of the NCC. Additionally, the Paleoproterozoic Birimian encompasses volcanic greenstone belts, and granitic intrusions related to the Eburnean orogeny, with ages between 2.2 to 1.8 Ga (Grenholm, 2019), similar to parts of the North Margin Orogen. The deformation period during Eburnean orogenesis is focused at about 2.1 Ga (Para-Avila, 2017), similar to the period when the north margin of the NCC was an active Andean-type accretionary orogen margin (Kusky et al., 2016; Wu et al., 2018, 2022a, b).

The recognition that the North Margin Orogen is an accretionary orogen correlated with the world's largest Paleoproterozoic gold province suggests the explorationists need to adopt a new geologic/tectonic model for exploration programs, and focus extra efforts on the North Margin Orogen of Wu et al. (2022a). If the erosion level of the North Margin Orogen is deeper than the typical greenschist-amphibolite facies orogenic gold deposits, then perhaps the orogenic gold should be searched for in the retro-arc and foreland basins, much like the detrital gold of the Witwatersrand. The paper by Wu et al. (2022a) is indeed a paradigm shifter, with implications for global tectonic configurations, and economic mineral deposit exploration.

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References Cited

Bierlein, F. P., Groves D. I., & Cawood P. A. (2009). Metallogeny of accretionary orogens — The connection between lithospheric processes and metal endowment. *Ore Geology Reviews, 36*, 282–292. https://doi.org/10.1016/j.oregeorev.2009.04.002

Goldfarb R. J., & Groves D. I. (2015). Orogenic gold: Common or evolving fluid and metal sources through time. *Geochemistry and Earth Systems – A Special Issue in Memory of Robert Kerrich, Lithos 233, 2–26.* https://doi.org/10.1016/j.lithos.2015.07.011

Grenholm, M. (2019). The Global Tectonic Context of the ca. 2.27 -1.96 Ga Birimian Orogen – Insights from Comparative Studies, with Implications for Supercontinent Cycles. *Earth -Science Reviews, 193*, 260–298. https://doi.org/10.1016/j.earscirev.2019.04.017

Kusky, T.M., & Santosh, M. (2009). The Columbia Connection in North China, in Reddy, S.M., Mazumder, R., Evans, D., and Collins, A.S., Paleoproterozoic

Supercontinents and Global Evolution. *Geological Society of London Special Publication 323*, 49-71. https://doi.org/10.1144/SP323.3

Kusky, T.M., Polat, A., Windley, B.F., Burke, K.C., Dewey, J.F., Kidd, W.S.F., Maruyama, S., Wang, J.P., Deng, H., & Wang, Z.S. (2016). Insights into the Tectonic Evolution of the North China Craton Through Comparative Tectonic Analysis: A Record of Outward Growth of Precambrian Continents. *Earth-Science Reviews 162*, 387-432. http://dx.doi.org/10.1016/j.earscirev.2016.09.002

Masurel, Q., Eglinger, A., & Thebaud, et al., (2022). Paleoproterozoic gold events in the sothern West African Cratons: review and synopsis, Mineralium Deposita 57, 513-537. https://doi.org/10.1007/s00126-021-01052-5

Meert, J. G. (2012). What's in a name? The Columbia (Paleopangaea/Nuna) supercontinent. *Gondwana Research*, *21*(4), 987-993. https://doi.org/10.1016/j.gr.2011.12.002

Mitchell R.N., Zhang, N., Salminen, J., Liu, Y., Spencer, C., Steinberger, B., Murphy, J.B., & Li, Z.X. (2021). The supercontinent cycle. *Nature Reviews Earth & Environment* **2**, 358-374. 10.1038/s43017-021-00160-0

Parra-Avila, L.A., Belousov, E., Fiorentini, M.L., Baratoux, L., Davisa, J., Millera, J., McCuaig, T.C. (2016). Crustal Evolution of the Paleoproterozoic Birimian Terranes of the Baoulé -Mossi Domain, Southern West African Craton : U–Pb and Hf -Isotope Studies of Detrital Zircons. *Precambrian Research 274,* (25–60). http://dx.doi.org/10.1016/j.precamres.2015.09.005.

Parra-Avila, L.A., Kemp, I.S., Fiorentinia, M.L., Belousova, E., Baratouxd, L., Blocke, S., Jessell, M., Bruguier, O., Begg, G.C., Miller, J., Davis, J., & McCuaig, T.C. (2017). The Geochronological Evolution of the Paleoproterozoic Baoulé -Mossi Domain of the Southern West African Craton. *Precambrian Research 300,* (1–27). http://dx.doi.org/10.1016/j.precamres. 2017. 07. 036.

Peng, P., Wang, X. P., Windley, B. F., Guo, J. H., Zhai, M. G., & Li, Y. (2014). Spatial distribution of ~1950–1800Ma metamorphic events in the North China craton: Implications for tectonic subdivision of the craton. *Lithos*, (202-203), 250–266. https://doi.org/10.1016/j.lithos.2014.05.033

Rock, N.M.S. (*1987*). The nature and origin of lamprophyres: an overview. *Geological Society, London, Special Publications 30,* (*1*) *191–226.* https://doi.org/10.1144/GSL.SP.1987.030.01.09

Rogers, J. J. W., & Santosh, M. (2002). Configuration of Columbia, a Mesoproterozoic supercontinent. *Gondwana Research*, *5*(1), 5–22. https://doi.org/10.1016/S1342-937X(05)70883-2

Şengör, A.M.C., Lom, N., Zabci, C. & Oner, T. (2020). Reconstructing orogens without biostratigraphy: The Saharides and continental growth during the final assembly of Gondwanaland. *Proceedings of the Natational Acadamies of Science 117,* (32278-32284). https://doi.org/10.1073/pnas.2015117117

Şengör, A. M. C., Lom, N., Zabcı, C., Sunal, G., & Öner, T. (2021b). The Saharides: Turkic -Type Orogeny in Afro-Arabia. *International Journal of Earth Sciences 111,* 2885-2924. https://doi.org/10.1007/s00531-021-02063-3.

Windley, B.F., Kusky, T.M., & Polat, A. (2021). Onset of plate tectonics by the early Archean. *Precambrian Research 352.* 105980. https://doi.org/10.1016/j.precamres.2020.105980.

Wu, C., Zhou, Z. G., Zuza, A. V., Wang, G. S., Liu, C. F., & Jiang, T. (2018). A 1.9 Ga mélange along the northern margin of the North China craton: Implications for the assembly of Columbia supercontinent. *Tectonics*, *37*(10), 3610–3646. https://doi.org/10.1029/2018TC005103

Wu, C., Wang, G. S., Zhou, Z. G., Zhao, X. Q., Haproff, P. J., Zuza, A.V., & Liu, W.Y. (2022a). Paleoproterozoic plate tectonics recorded in the Northern Margin Orogen, North China Craton, Geochemistry, Geophysics, Geosystems, e2022GC010662, https://doi.org/10.1029/2022GC010662

Wu, C., Wang, G. S., Zhou, Z. G., Zhao, X. Q., & Haproff, P. J. (2022b). Late Archean– Paleoproterozoic plate tectonics along the northern margin of the North China craton. *Geological Society of America Bulletin*, doi.org/10.1130/B36533.1

Xiao, D., Ning, W.B., Wang, J.P., Kusky, T., Wang, L., Deng, H., Zhong, Y.T., & Jiang, K. (2021). Neoarchean to Paleoproterozoic tectonothermal evolution of the North China Craton: Constraints from geological mapping and Th-U-Pb geochronology of zircon, titanite, and monazite in Zanhuang massif. *Precambrian Research, 359,* 106214. https://doi.org/10.1016/j.precamres.2021.106214

Zhao, G. C., Wilde, S. A., Cawood, P. A., & Sun, M. (2001). Archean blocks and their boundaries in the North China craton: Lithological, geochemical, structural and P-T path constraints and tectonic evolution. *Precambrian Research*, *107*(1-2), 45–73. https://doi.org/10.1016/S0301-9268(00)00154-6

Zhao, G. C., Cawood, P. A., Wilde, S. A., & Sun, M. (2002). Review of the global 2.1–1.8 Ga orogens: Implications for a pre-Rodinian supercontinent. *Earth-Science Reviews*, *59*(1-4), 125–162. https://doi.org/10.1016/S0012-8252(02)00073-9

Zhao, G., Cawood, P.A., Li, S.Z., Wilde, S.A., Sun, M., Zhang, J., He, Y.H., & Yin, C.Q. (2012). Amalgamation of the North China Craton: Key issues and discussion. *Precambrian Research 222,* 55-76. https://doi.org/10.1016/j.precamres.2012.09.016

Zhao, G., Sun, M., Wilde, S.A., & Li, S.Z. (2005). Late Archean to Paleoproterozoic evolution of the North China Craton: key issues revisited. *Precambrian Research 136* (2), 177-202. https://doi.org/10.1016/j.precamres.2004.10.002