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EDITED AND REVIEWED BY
Michel Grégoire,
UMR5563 Géosciences Environnement Toulouse (GET), France

*CORRESPONDENCE
Chen Zhao,
aaron198807@163.com
Jiahui Qian,
qianjh5@mail.sysu.edu.cn
Xiaoguang Liu,
liuxiaoguang@sdust.edu.cn

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Editorial: The World's ancient cratons: tectonics, metamorphism, magmatism and mineralization

Chen Zhao[1,2,3]*, Jiahui Qian[4]*, Xiaoguang Liu[5]*, Hossein Azizi[6], Scott Andrew Whattam[7] and Shenghong Yang[8]

[1]Shenyang Center of Geological Survey, China Geological Survey, Shenyang, China, [2]Northeast Geological S&T Innovation Center of China Geological Survey, Shenyang, China, [3]Geological Research Center of Eastern Continental Edge, China Geological Survey, Shenyang, China, [4]School of Earth Sciences and Engineering, Sun Yat-sen University, Zhuhai, China, [5]College of Earth Science and Engineering, Shandong University of Science and Technology, Qingdao, China, [6]Department of Mining Engineering, Faculty of Engineering, University of Kurdistan, Sanandaj, Iran, [7]Department of Geosciences, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia, [8]Oulu Mining School, University of Oulu, Oulu, Finland

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Editorial on the Research Topic
"The World's ancient cratons: tectonics, metamorphism, magmatism and mineralization"

1 Introduction

Earth exhibits a distinct bimodal distribution of continental and oceanic crust, a feature that differentiates it from other terrestrial planets in the solar system (Dilek and Polat, 2008; Dhuime et al., 2015). The continental crust plays a critical role in sustaining Earth's habitable surface conditions and climatic equilibrium (Lee et al., 2016; Rozel et al., 2017; Huang et al., 2021), while also serving as a significant repository of mineral resources (Rudnick and Gao, 2014; Tang, 2020). However, the continental crust is frequently subjected to significant destruction or reformation through subsequent weathering, erosion, and tectonic processes (Sobolev and Brown, 2019; Zhu et al., 2021; Cawood et al., 2022; Zhao et al., 2024), with only approximately 7% of the Archean crust remaining preserved across thirty-five ancient cratons (Rudnick and Gao, 2014; Wan et al., 2023). Furthermore, ancient cratons serve as repositories of numerous valuable pertaining to tectonic evolution, metamorphism, magmatism and metallic deposits (Sandiford et al., 2004; Moyen et al., 2006), which play crucial roles in sustaining the planet's resource base and habitability, and provide essential insights into the transition from pre-plate tectonic regimes to modern plate tectonics on Earth (Hamilton, 2011; Zhang et al., 2014; Gerya et al., 2015; Hasie et al., 2016; Cawood et al., 2018; Windley et al., 2021; Zhao et al., 2022; Zhao et al., 2025). Systematic studies on ancient cratons are essential, as they would enhance our understanding of global Precambrian geology and contribute to the exploration of early

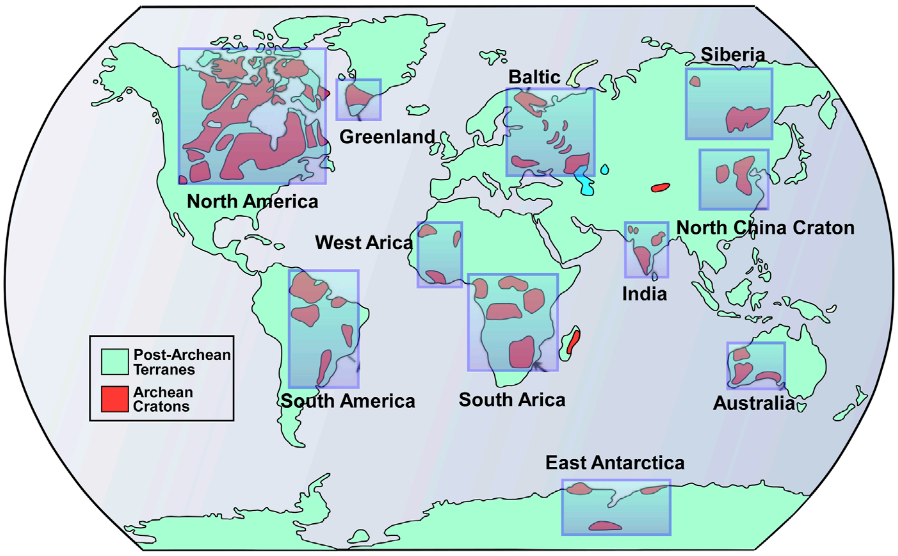

FIGURE 1
Spatial distribution of major cratons in the world.

Earth evolution. We therefore propose the Research Topic entitled "The World's Ancient Cratons: Tectonics, Metamorphism, Magmatism and Mineralization" in Frontiers in Earth Science.

A total of seven papers focusing on magmatism, metamorphism, and tectonic evolution within ancient cratons have been published in this Research Topic (Figure 1). Among these, four studies document the Paleoproterozoic metamorphic, structural, and magmatic evolution of the Khondalite Belt within the North China Craton. One study focuses on the Paleoproterozoic evolutionary history of the Jiao-Liao-Ji Belt. One study examines the metamorphosed supracrustal rocks and the associated Neoarchean tectonic regime of the eastern Hebei terrane within the Eastern Block of the North China Craton. One paper is related to the structural and metamorphic characteristics of the basement rocks in the Gida Ayana area of western Ethiopia. The brief introductions of the seven papers included in this Research Topic are summarized below.

2 Summary of papers

Hu et al. conducted a comprehensive review of field investigations, petrological analyses, zircon U-Pb dating, whole-rock geochemical studies, and electron probe mineral thermobarometric data derived from garnet-bearing pyroxenite and serpentinite-like dunite within the ultramafic rocks of the east-west oriented Khondalite Belt, North China Craton. The hornblende pyroxenite and serpentinized dunite in the Wuchuan area were emplaced approximately 1.9 Ga. The ages of 2.2 Ga and 2.5 Ga obtained from the surrounding garnet-K-feldspar gneiss and garnet-plagioclase two-pyroxene granulite represent the regional metamorphic age and the protolith depositional age of the Khondalite Belt, respectively. Tectonic analysis indicates that these ultramafic rocks formed during the post-orogenic extensional stage. The ultramafic rocks formed under conditions of 767.93 °C and 4.61 kbar, indicating a medium-pressure, high-temperature metamorphic environment. Furthermore, the lack of granulite-facies metamorphism induced by the intrusion of these ultramafic rocks suggests that the granulite-grade metamorphism observed within the Khondalite Belt is not directly associated with the post-orogenic extensional processes in the Inner Mongolia-Northern Hebei orogenic belt.

Wu et al. employed zircon and monazite geochronology in conjunction with thermodynamic modelling to elucidate the retrograde metamorphic evolution of medium-pressure (MP) pelitic granulites within the Qianlishan Complex, Khondalite Belt, North China Craton. The results demonstrate that all MP pelitic granulites exhibit comparable clockwise pressure-temperature (P-T) paths, characterized by well-constrained post-peak P-T conditions ranging from 775 °C to 825 °C and 4.9–6.5 kbar. Zircon and monazite U-Pb dating results constrain the metamorphic ages of the pelitic granulites at ca. 1.93 Ga, which indicate that a peak-pressure metamorphic event occurred between 1.96 and 1.94 Ga, followed by a period of decompression and retrograde cooling around 1.93 Ga. Furthermore, these findings provide support for the hypothesis that a continent-continent collision occurred in the Khondalite Belt approximately 1.95 Ga, followed by a rapid slab-breakoff at shallow depths, which induced the exhumation of pelitic granulites in the western Khondalite Belt to mid-crustal levels and their subsequent cooling at around 1.93 Ga.

Qiao et al. carried out field-based structural analysis and U-Pb geochronological investigations on the Helanshan ductile shear zones and Qianlishan ductile shear zones located within the western segment of the Khondalite Belt. A suite of monazite, titanite, and apatite U-Pb ages ranging from 1904 to 1801 Ma collectively constrain the timing of shear zone activity within the western Khondalite Belt. Furthermore, this study highlights that the post-collisional orogen-parallel ductile shear zones within the

Khondalite Belt developed during the time interval of approximately 1.90–1.80 Ga.

Wang et al. conducted a comprehensive study of representative meta-mafic and felsic rock assemblages from the Daqingshan Complex within the Khondalite Belt of the North China Craton. The zircon U-Pb dating results indicate that the meta-mafic and felsic rock assemblages yield crystallization ages ranging from 2.47 to 2.39 Ga, along with metamorphic ages between 1.91 and 1.83 Ga. The zircon Lu-Hf isotopic composition indicates that the protoliths of the 2.47-2.39 Ga meta-mafic and felsic rock assemblages in the Daqingshan Complex originated from the depleted lithospheric mantle and/or juvenile continental crust. The trace element characteristics of the zircons indicate that they were formed in the continental arc-related/orogenic tectonic setting. In summary, it can be inferred that the Khondalite Belt underwent prolonged arc-continent accretion along the southern margin of the Yinshan Block during the late Neoarchean to Paleoproterozoic.

Chen et al. carried out geochronological and trace element analyses on mafic rocks derived from the Lieryu Formation of the Liaohe Group within the Jiao-Liao-Ji Belt, located in the eastern part of the North China Craton. Zircon U-Pb geochronology has been applied to reconstruct the geochronological framework of Lieryu mafic magmatism, constraining its temporal range to the interval of 2190–1995 Ma. Combined with field observations of the Lieryu Formation, the evidence suggests that the Liaohe Group does not represent a coherent stratigraphic succession, but rather constitutes a tectonically disrupted stratigraphic unit. Geochemical characteristics indicate that the mafic rocks belong to the calc-alkaline series and were derived from a transitional mantle source. Furthermore, it suggests the existence of ancient oceans during the Paleoproterozoic, and the Jiao-Liao-Ji Belt (JLJB) was formed during the subduction and final closure of the Paleoproterozoic oceanic realm.

Zu et al. conducted detailed field investigations, petrological analyses, phase equilibrium modeling, and zircon U-Pb geochronological studies on the metamorphosed supracrustal rocks of the Luanxian Group in the Sijiaying iron deposit area, located within the eastern Hebei terrane. Biotite-plagioclase gneisses in the Luanxian Group exhibit a clockwise P-T path characteristic of amphibolite facies metamorphism, which includes pre-peak heating and compression leading to peak P-T conditions of approximately 7.0 kbar/630 °C and 7.4 kbar/586 °C, followed by post-peak decompression and cooling. The protoliths of the Luanxian supracrustal rocks, which consist of pelitic rocks and greywackes, were deposited at approximately 2.55 Ga and subsequently experienced regional metamorphism. By integrating previous studies with geological observations of the "dome-and-keel" architecture, near-synchronous magmatism, sedimentation, and metamorphism, as well as characteristic P-T paths, we propose that the eastern Hebei terrane was dominated by a vertical tectonic regime during the Neoarchean.

Mihret et al. performed a comprehensive review of the structural and metamorphic characteristics of the basement rocks in the Gida Ayana area, located in western Ethiopia. The study area underwent polyphase deformations, involving at least three ductile deformation phases (D_1 to D_3), which were associated with two distinct metamorphic events (M_1 and M_2). The prograde metamorphism (M_1) occurred synchronously with the D_2 deformation phase. A retrograde metamorphism (M_2), potentially associated with uplift or fluid migration related to the D_3 shear zone, is inferred to have occurred. Furthermore, the Gida Ayana area is considered to be situated within the East African Orogen, representing its broader regional tectonic framework. The relationships between the metamorphic and deformational events in the Gida Ayana area and broader tectonic processes, such as continental collisions during the Pan-African Orogeny, have been identified.

Author contributions

CZ: Conceptualization, Funding acquisition, Visualization, Writing – original draft, Writing – review and editing. JQ: Writing – review and editing. XL: Writing – review and editing. HA: Writing – review and editing. SW: Writing – review and editing. SY: Writing – review and editing.

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