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# The Paleoproterozoic diorite dykes in the southern margin of the North China Craton: Insight into rift-related magmatism

Changming Wang [a,b,*], Yongjun Lu [b,c], Xinyu He [a], Qionghui Wang [d], Jing Zhang [a]

[a] State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences, Beijing 100083, China
[b] Centre for Exploration Targeting and Australian Research Council Centre of Excellence for Core to Crust Fluid Systems (CCFS), University of Western Australia, Perth, WA 6009, Australia
[c] Geological Survey of Western Australia, 100 Plain Street, East Perth, WA 6004, Australia
[d] Minmetals Exploration and Development CO., LTD, Beijing 100010, China

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ABSTRACT

The Xiong'er rift zone along the southern margin of the North China Craton (NCC) is characterized by exposure of a suite of volcanic rocks and associated mafic – intermediate dykes and sedimentary rocks. In this study, we report for the first time the newly identified late Paleoproterozoic diorite dykes from the Waifangshan Mountain in the Xiong'er rift zone and present results from the LA-ICP-MS zircon U–Pb dating, Sr–Nd–Hf isotope systematics, and whole-rock major and trace element geochemistry. The Wafang diorite dykes intruding into the upper part of the Xiong'er Group yielded emplacement mean ages of $^{207}Pb/^{206}Pb$ from 1746 ± 22 Ma to 1762 ± 11 Ma. These diorite dykes have extreme low MgO, Cr and Ni contents, and enriched in LREEs and LILEs but depleted in HFSEs (Nb, Ta, and Ti). They are characterized by having negative zircon $\varepsilon_{Hf}(t)$ values of −11.4 to −3.1, a whole-rock initial $^{87}Sr/^{86}Sr$ value of 0.70196 and $\varepsilon Nd(t)$ value of −8.7, and Pb isotopes ($^{206}Pb/^{20}4Pb$ = 16.072–16.295, $^{207}Pb/^{204}Pb$ = 15.275–15.293, $^{208}Pb/^{204}Pb$ = 36.538–37.255). These geochemical features, together with trace element modeling, suggest that the late Paleoproterozoic Wafang diorite dykes could be sourced from crustal melting with minor contribution of the mixing of mantle materials. These new data combined with previous studies on the late Paleoproterozoic the Xiong'er volcanism should have lasted for nearly 43 Ma ranging from 1789 Ma to 1746 Ma. Correspondingly, the initiation timing of the Xiong'er rift should be younger than 1831 Ma, but earlier than 1625. The Wafang diorite dykes formed in a rift environment, possibly related to breakup of the supercontinent Columbia.



## 1. Introduction

Columbia supercontinent was introduced by Rogers (2000) as a Paleoproterozoic supercontinent, the first coherent supercontinent on Earth. Since then, the "Columbia supercontinent" has drawn significant scientific attention on its evolution such as the amalgamation, rifting, fragmentation, and breakup in India, Antarctica, North America, Baltica, North China, and Amazon (e.g., Zhao et al., 2002a, 2004a; Condie, 2002; Rogers and Santosh, 2002, 2009; Ernst et al., 2008; Santosh et al., 2009, 2013; Santosh, 2010; Wang et al., 2014a; Belica et al., 2014; Rekha and Bhattacharya, 2014; Deng et al., 2014a,b,c). The NCC, the oldest craton in China, is an ideal region for investigating the geodynamic processes of the late Paleoproterozoic magmatism within the Columbia supercontinent (Wang et al., 2014b, 2015a; Deng et al., 2015a; Deng and Wang, 2015b). In the NCC, the Eastern and Western Blocks were amalgamated by the collision along the Trans-North China Orogen (TNCO) at ∼1.85 Ga (Zhao et al., 2001; Ratschbacher et al., 2003). Subsequently, the intracontinental extension resulted in the formation of the late Paleoproterozoic Xiong'er rift along the southern margins of the NCC (Fig. 1; Santosh et al., 2007; Trap et al., 2012). Different magmatic episodes are well preserved within the Xiong'er rift, but previous studies were focused on ∼1.78 Ga mafic dykes and the Xiong'er volcanic rocks (Xia et al., 1990, 2013; Zhao et al., 2002b, 2004b; Xu et al., 2007; He et al., 2008, 2009, 2010; Peng et al., 2004, 2007, 2008, 2014; Wang et al., 2004, 2010c, 2013b; Kusky et al., 2007a,b; Hou et al., 2008a; Cui et al., 2011, 2013; Lu et al., 2013, 2014; Ma et al., 2013; Zhang et al., 2013; Hu et al., 2014; Peng et al., 2014; Wang et al., 2014e; Zhou et al., 2014). However, the intermediate dykes within the rift are not studied previously,

* Corresponding author at: China University of Geosciences, No. 29, Xueyuan Road, Haidian District, Beijing 100083, China. Tel.: +86 10 82323761; fax: +86 10 82321006.
*E-mail address:* wangcm@cugb.edu.cn (C. Wang).

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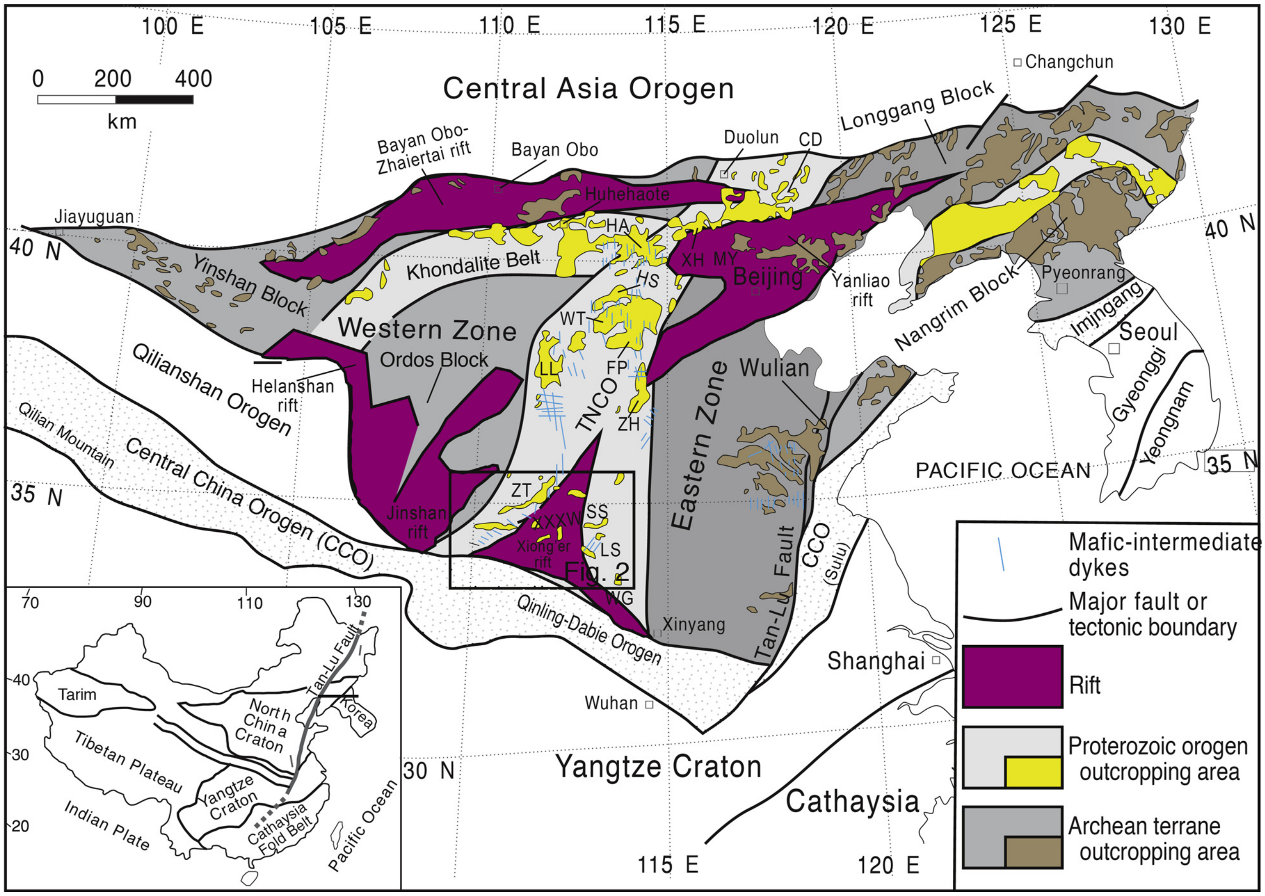


**Fig. 1.** Tectonic framework of the North China Craton showing the Eastern Block, Western Block, and Trans-North China Orogen (after Zhao et al., 2005). Abbreviations for metamorphic complexes: CD = Chengde; FP = Fuping; HA = Huai'an; HS = Hengshan; LL = Luliang; LS = Lushan; MY = Miyun; SS = Songshan; XXXW = Xiaoqinling–Xiaoshan–Xiong'ershan–Waifangshan; WG = Wugang; WT = Wutai; XH = Xuanhua; ZH = Zanhuang; ZT = Zhongtiaoshan.

which preclude a comprehensive understanding of the evolution of magmatic activities and genetic linkages with late Paleoproterozoic Xiong'er rift.

We present precise LA-ICP-MS zircon U–Pb ages, Sr–Nd–Hf isotope data, and whole rock major and trace element compositions from the Wafang diorite dykes in order to: (1) constrain opening and closing ages of the Xiong'er rift, (2) unravel the nature of the magma source region and magma evolution, (3) compare the north-south differences of the Trans-North China Orogen, and (4) investigate the tectonic setting and implications for breakup of the supercontinent Columbia.

## 2. Geological setting

The NCC can be subdivided into the Eastern and Western Blocks, which were amalgamated along the TNCO at ~1850 Ma (Fig. 1a; Zhao et al., 2001; Ratschbacher et al., 2003; Wang et al., 2013a). The Xiong'er volcanic belt within the southern margin of the North China Craton, is bounded to the northwest by the Jiangxian–Lintong fault and to the northeast by the Luoyang–Baofeng fault, and is separated from the Northern Qinling Orogen in the south by the Luonan–Luanchun fault (Fig. 2a).

The Mesoarchean to Paleoproterozoic Taihua Group is the metamorphosed basement exposed in the southern margin of the TNCO, which is unconformably overlain by the Paleoproterozoic Xiong'er Group, and Meso- to Neoproterozoic Guandaokou and Luanchuan Groups (Fig. 2; Peng et al., 2008; Zhao et al., 2009a,b; Deng et al., 2014a). The Taihua Group is divided into the basal Caoyugou Formation conformably overlain by the Shibangou, Longtangou, Longmendian, and Duangou formations, which is metamorphosed to amphibolite and granulite facies (Hacker et al., 1996). The Xiong'er Group is divided into the clastic Dagushi Formation at the base overlain by volcanic rocks assigned to the Xushan, Jidanping and Majiahe Formations (Fig. 3; Zhao et al., 1998, 2005). The Dagushi Formation is composed primarily of conglomerate, sandstone and mudstone. The Xushan Formation is dominated by andesites and basaltic andesites, with minor rhyolites, andesites and basalts, and locally intercalated with shales and sandstones. The Jidanping Formation consists of dacites and rhyolites, with local andesites, basaltic andesites, minor clastics and tuffs. The Majiahe Formation consists of andesites with minor trachyandesite and rhyolites, volcanic clastics and sandstones. Zhao et al. (2005) have suggested that the Dagushi Formation mostly belonged to a river–lake-facies, whereas the sediments in the Xushan and Jidanping Formations were deposited in continental-facies environment, and the Majiahe Formation was deposited in an oceanic setting.

The Wafang diorite dykes intruded the Majiahe and Jidanping Formations of the Xiong'er Group in the Songxian County, Henan Province (Fig. 2b). At the current level of exposure, diorite dykes have an average trend of NNE40°. The diorite dikes vary in size widely, with thickness generally ranging from 1 to 1500 m, and length ranging from 1 to 20 km. Six samples (WF1307-3, 04, 05, 06, 08, 09) were collected from the Wafang diorite dykes in this study (33°55′9″ N–33°56′13″ N; 112°03′40″ E–112°04′7″ E).

The diorite dykes are grayish green, typically massive with a hypidiomorphic granular texture, and composed of