Precambrian Research 255 (2014) 276–293

Contents lists available at ScienceDirect

Precambrian Research

journal homepage: www.elsevier.com/locate/precamres

Paleo-position of the North China craton within the supercontinent Columbia: Constraints from new paleomagnetic results

Huiru Xu[a,b,*], Zhenyu Yang[c,d], Peng Peng[a], Joseph G. Meert[e], Rixiang Zhu[a]

[a] State Key Laboratory of Lithospheric Evolution, Institute of Geology and Geophysics, Chinese Academy of Science, Beijing 100029, China
[b] University of Chinese Academy of Sciences, Beijing 100049, China
[c] Key Laboratory of Paleomagnetism and Tectonic Reconstruction, Ministry of Land and Resource, Beijing 100081, China
[d] Institute of Geomechanics, Chinese Academy of Geological Sciences, Beijing 100081, China
[e] Department of Geological Sciences, University of Florida, Gainesville, FL 32611, USA

ARTICLE INFO

Article history:
Received 22 February 2014
Received in revised form
30 September 2014
Accepted 3 October 2014
Available online 14 October 2014

Keywords:
North China craton
Mafic dyke swarm
Xiong'er volcanic rocks
Paleomagnetism
Columbia
Supercontinent

ABSTRACT

Several new paleomagnetic and geological studies focused on the reconstruction of the North China Craton (NCC) within the Paleo-Mesoproterozoic Columbia supercontinent. In spite of these new data, there are still widely divergent opinions regarding supercontinental reconstructions. In addition to qualitative correlations of orogenic belts, rift basin ages, stratigraphy and distribution of igneous provinces, paleomagnetic data can provide key constraints on the positioning of individual cratons on the globe. In this paper, we report a detailed paleomagnetic study on the coeval ~1780 Ma mafic dyke swarm and Xiong'er volcanic province, which extended for more than one thousand kilometers in the central NCC. Rock magnetic studies, including thermomagnetic curves, hysteresis loops and the progressive acquisition of isothermal remanence conducted in selected samples, indicate that the dominant magnetic carriers are PSD magnetite. Stepwise thermal demagnetization isolated higher-temperature components directed to NNE/SSW with shallow inclinations from 37 sampling sites (16 sites in Yinshan area, 13 sites in Taihang area and 8 sites in Xiaoshan area). A baked contact test conducted on two Yinshan dykes intruded by a younger dyke demonstrates the magnetization in the Yinshan dykes pre-dates 1320 Ma. The existence of dual-polarity magnetizations in both Taihang and Xiong'er areas support our contention that the ChRM was acquired during the cooling of the magma. The primary origin of the ChRM is also supported by a positive fold test on the Xiong'er data, and a coherent regional test between the results from the Taihang and Xiong'er areas. Two different site-mean directions were compiled from these new results along with previous publications. The first direction, from the Taihang and Xiong'er areas, yields Declination (D)/Inclination (I) = 12.4°/−3.7° (κ = 20.5, α_{95} = 4.3°, N = 57 sites). The second, from the Yinshan area is at (D) 36.7°/(I)−12.4° (κ = 86.8, α_{95} = 2.7°, N = 32 sites). We argue that the difference is due to Mesozoic and/or Cenozoic vertical-axis rotation of the Taihang and Xiong'er areas with respect to the fixed Yinshan-Ordos basin. The corresponding paleopoles for the Yinshan dykes falls at 245.2°E/35.5°N (A_{95} = 2.4°). A comparison between the NCC, Laurentia, Siberia and Baltica is consistent with possible links between these four blocks in a perhaps, even larger, continent. The proximity of Australia and India to the NCC is also evaluated.

1. Introduction

Although the proposition of a large Paleo-Mesoproterozoic supercontinent, named Columbia (or Nuna), was proposed more than a decade ago, its exact geometry, timing of amalgamation and timing of break-up are still contentious (Rogers, 1996; Meert, 2002, 2014; Rogers and Santosh, 2002; Zhao et al., 2002b; Pesonen et al., 2003, 2012; Zhao et al., 2004; Evans and Mitchell, 2011; Zhang et al., 2012a; Chen et al., 2013). As the only quantitative method to test the proposed configurations, systematic paleomagnetic studies of Paleo-Mesoproterozoic in different geological units are necessary. In spite of recent efforts to obtain reliable paleomagnetic data, the exact configuration of Columbia remains enigmatic.

The North China craton is one of the oldest regions in the world, but its location within Columbia is still unresolved although

* Corresponding author at: Institute of Geology and Geophysics, CAS, No. 19, Beitucheng Xilu, Chaoyang District, Beijing, China. Tel.: +86 10 82998418.
E-mail address: zhuiri2080@gmail.com (H. Xu).

http://dx.doi.org/10.1016/j.precamres.2014.10.004
0301-9268/

several distinct proposals were made on the basis of geological considerations. Li et al. (1996) suggested a Mesoproterozoic connection between Siberia and the NCC based on geological similarities in coeval sedimentary sequences found on both cratons. Condie (2002) proposed that the NCC–Siberia connection extended into the Paleoproterozoic, but placed the NCC against Northeastern Siberia to align the Trans-North China Orogenic belt to the Akitkan orogenic belt in Siberia. The resemblance between the NCC and Baltica was first proposed by Qian (1997). He noted the geological similarities between the Precambrian of both cratons. Although not particularly diagnostic, both Baltica and the NCC stabilized during the Archean, exhibited rifting in Proterozoic that formed trondhjemitic–tonalitic–granodioritc (TTG) along with supracrustals and a volcano-sedimentary sequence in the upper part of the sequence. Wilde et al. (2002) supported this relationship based on coeval collisions at ~1.8 Ga recorded by the Trans-North China Orogen (TNCO) and Kola-Karelian Orogen (Berthelsen and Marker, 1986; Wilde et al., 2002; Zhao et al., 2001). Based on evidence from coeval magmatic activity, Kusky et al. (2007a) proposed a linkage between the NCC, Baltica and Amazonia, placing the eastern margin of the NCC next to southwestern Baltica and the western side of the NCC against Amazonia. As major crustal formation in both the NCC and Southern India are coeval at 2.6–2.5 Ga indicated by granulite facies metamorphism, Kröner et al. (1998) proposed that the two blocks were connected as part of a single active continental margin. Based on the alignment of orogenic belts, Zhao et al. (2002a) presented the western and eastern blocks of the NCC adjacent to Northern India and Southern India respectively by assuming the TNCO and the Central India Tectonic Zone (CITZ) evolved together. Peng et al. (2005) used the geometry of coeval mafic dyke swarms in both the NCC and the Dharwar craton of India as evidence for a NCC–Dharwar connection. Based on similar evidences, Hou et al. (2008) slightly changed the relative positions and connected the NCC to the Cuddapah Basin at the eastern margin of the India.

Paleomagnetic data were also used to evaluate the NCC's proximity to other cratons in Columbia. Halls et al. (2000) suggested that the NCC, Laurentia and Siberia maintain an integral geometry similar to their present-day configuration in Columbia starting at ~1800 Ma based on apparent polar wander paths (APWPs) from the three blocks. Piper et al. (2011) placed the northern NCC next to western India based on the APWPs around 1800 Ma. Zhang et al. (2012a) also supported this connection based on the comparison of APWPs in Paleo-Mesoproterozoic. However, Chen et al. (2013) placed the southwestern part of the NCC to eastern India. Recently obtained poles from Amazonia were used to place the NCC between Baltica and Amazonia (Bispo-Santos et al., 2008, 2012, 2014; D'Agrella-Filho et al., 2012).

Based on these previous models, the position of the NCC within the Columbia supercontinent is ambiguous. In an effort to provide additional constraints on the position of the NCC, we report new data from coeval mafic dykes and the Xiong'er volcanics in the central NCC for a systematic and detailed paleomagnetic study, in order to solve the "where" and "when" problems discussed above.

2. Geological setting

Several proposals exist for the tectonic subdivisions of the NCC although there is a general consensus that it had stabilized by ~1800 Ma (Wu and Zhong, 1998; Wu et al., 1998; Zhai et al., 2000; Li et al., 2000; Kusky and Li, 2003; Zhao et al., 2005). Among these models, the tripartite division proposed by Zhao et al. (2005) is widely accepted. In that model, the Precambrian blocks (i.e. the Western and Eastern Blocks) evolved independently and collided along the trans-North China Orogen (Zhao et al., 2001, 2005; Li et al., 2000). The Western Block was formed by the amalgamation of the Ordos Block in the south and the Yinshan Block to the north along the east-west-trending Khondalite belt. Collision between the Western and Eastern Blocks occurred at either ~1.85 Ga (Wilde et al., 2002; Zhao et al., 2001, 2002a, 2005; Kröner et al., 2005; Guo et al., 2005) or ~2.5 Ga (Li et al., 2000; Kusky and Li, 2003). After cratonization, as a result of amalgamation of Archean blocks, the NCC experienced remobilization and recratonization (e.g. rifting, collision and/or uplift; Li et al., 2000; Zhai et al., 2000; Kusky and Li, 2003; Zhai and Liu, 2003; Kusky et al., 2007a, 2007b; Zhai and Peng, 2007; Li et al., 2010). During this remobilization, at least two significant magmatic events took place. This includes the emplacement of mafic dyke swarms in the central and western of the NCC, and the Xiong'er volcanics along the south margin during the Paleoproterozoic (Peng et al., 2008). Following these magmatic events, the NCC was covered by a thick sequence of Meso-Neoproterozoic (Changcheng, Jixian and Qingbaikou Systems) volcanic and sedimentary rocks (HBGMR, 1982).

The mafic dyke swarm investigated in this study is related to either break-up (and plume activity; Peng et al., 2008) or a post-NCC assembly extensional episode (Zhao et al., 2002b). Most of the mafic dykes trend NNW, are vertical or sub-vertical and can be up to 60 km in length and 100 m in width, with most around 15 m wide. The dykes extend more than 1000 km across the central NCC and are gabbroic in composition and doleritic in texture with sharp, chilled contacts with the country rocks. The primary textures show increasing hydrous alteration (including saussuritization of feldspar, conversion of pyroxene to amphibole, and serpentinization of olivine) toward the south (Qian and Chen, 1987; Halls et al., 2000; Hou et al., 2001; Peng et al., 2005, 2008). The dykes in the Yinshan and Taihang areas are dated at around ~1780 Ma (Fig. 1 and Table 1) (Halls et al., 2000; Li et al., 2001; Wang et al., 2004; Peng et al., 2005, 2006).

The Xiong'er volcanics have a thickness of 3–7 km and extend in outcrop over an area of 60,000 km^2. The volcanic rocks are exposed in the Zhongtiao, Xiao, Xiong'er and Waifang Mountains and consist of lava and pyroclastic rocks interlayered with minor sedimentary rocks (Zhao et al., 2002b). Stratigraphically (from oldest to youngest) these rocks are subdivided into the Xushan Formation (Fm.), Jidanping Fm. and Majiahe Fm. The basal Xushan Fm. is composed of basaltic andesite and andesite with minor dacite, dacitic rhyolite, and basalt. The Jidanping Fm. contains dacite-rhyolite flows interbedded with basaltic andesite and andesite. The Majiahe Fm. is composed of basaltic andesite and andesite interlayered with voluminous sediments and pyroclastic rocks and minor rhyolite (Zhao et al., 2002b). The duration of volcanic activity related to the emplacement of the Xiong'er rocks was discussed by several authors (Table 1) (Zhao et al., 2004; He et al., 2009; Cui et al., 2010; Wang et al., 2010). The reported ages for Majiahe Fm. and Xushan Fm. are indistinguishable within uncertainty at around 1780 Ma (Fig. 1). Based on these data, we consider the paleomagnetic pole from the Xiong'er volcanic rocks as contemporary with the mafic dykes to its north.

3. Paleomagnetic experiments and results

3.1. Paleomagnetic sampling

Standard oriented cylindrical cores were collected with a portable, gasoline-powered rock drill from 18 sites (dykes) in the Yinshan area in Inner Mongolia, 27 sites (dykes) in the Taihang area of Shanxi and Hebei, and 26 sites (lavas) of the Xiong'er volcanics in the Xiaoshan area of Henan. The distribution of paleomagnetic sampling sites is shown in Fig. 1. Samples were oriented using both a sun and magnetic compass. Every core was cut into a single