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Paleomagnetism of ca. 1.35 Ga sills in northern North China Craton and implications for paleogeographic reconstruction of the Mesoproterozoic supercontinent

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ABSTRACT

We report paleomagnetic data on precisely dated Mesoproterozoic sills, in zircon and baddeleyite $^{207}Pb/^{206}Pb$ ages of 1345 ± 12 and 1353 ± 14 Ma respectively, intruding the Xiamaling and Wumishan formations in North China with an aim of evaluating how the North China Craton (NCC) was involved in the evolution of the Columbia supercontinent from ca. 1.78 to 1.35 Ga. After systematic thermal demagnetization we isolate a high temperature characteristic remanence from 18 sites with a tilt-corrected site-mean direction of $D = 294.4^\circ$, $I = -31.7^\circ$ and $\alpha_{95} = 4.3^\circ$, corresponding to a mean paleomagnetic pole at $\lambda = 5.9^\circ$N, $\varphi = 359.6^\circ$E ($N = 18$) with angular standard deviation of 10.0° and $A_{95} = 4.3^\circ$. Rock magnetic experiments, light microscopy and scanning electron microscopy all indicate that the main magnetic minerals in the sampled sill rocks are medium sized titanomagnetites. The positive fold test and fresh titanomagnetite grains suggest that the characteristic remanence is likely to be a primary acquired at ca. 1.35 Ga. The preliminary paleogeography reconstruction based upon the well-matched apparent polar wander paths between the Laurentia–Baltica–Siberia united block and the NCC supports the interpretation that the NCC may have drifted together with this united block before ca. 1.35 Ga during the late history of the Columbia supercontinent. We argue that the NCC was located in low latitudes and kept tight connections with the Siberian and Indian cratons during the interval between ca. 1.8 and 1.35 Ga, and that the ca. 1.35 Ga sills widely developed in the Mesoproterozoic Xiamaling and Wumishan formations, as well as the ca. 1.3–1.2 Ga magma events well-developed in Siberia and northern margin of the NCC, may represent the complete fragmentation of the NCC with the neighboring cratons.

1. Introduction

The Paleo-Mesoproterozoic supercontinent Columbia (Nuna) has been discussed for more than a decade and is considered to have been an amalgamation of all cratons of the globe (Zhao et al., 2003a; G. Zhao et al., 2004). At present, it is widely considered that the Columbia supercontinent was amalgamated at ca. 2.0–1.8 Ga (Zhao et al., 2003a; Hawkesworth et al., 2009), and broke up at ca. 1.5–1.3 Ga (G. Zhao et al., 2004; Hou et al., 2008a). However, the evolvement of its configuration has been hotly debated and remains poorly constrained. Hitherto, there have been at least three main different models based on the distribution of ca. 2.1–1.8 Ga orogens (Condie, 2002; Rogers and Santosh, 2002; Zhao et al., 2003a; G. Zhao et al., 2004) with recent studies presenting some interesting suggestions on the basis of paleomagnetic data and geological correlations (Hou et al., 2008a; Evans and Mitchell, 2011). In a word, no consensus could be reached so far for the paleogeographic configuration of a possible Paleo-Mesoproterozoic supercontinent Columbia because of both geological complexities and paucity of high quality paleomagnetic data. The latter has been widely accepted to be the only a quantitative constraint on the paleogeographic reconstruction of supercontinent and the relationship of the North China Craton (NCC, Fig. 1) to neighboring cratons is still an enigma due to the lack of precise age-controlled high quality paleomagnetic data. Wilde et al. (2002) proposed that the NCC might be connected with the Baltica Craton in the light of lithologic correlation and the distribution of major crustal components, whilst Condie (2002) argued that it should be adjacent to the Siberian Craton, and Zhao et al. (2003b) regarded the Indian Craton as the NCC's neighbor. On the other hand, Wu et al. (2005) and Pei et al. (2006) reported respectively two ca. 1.35 Ga paleomagnetic poles for the NCC based on an $^{40}Ar–^{39}Ar$ dating age of the Yangzhuang Formation (Wang et al., 1995). Although these two

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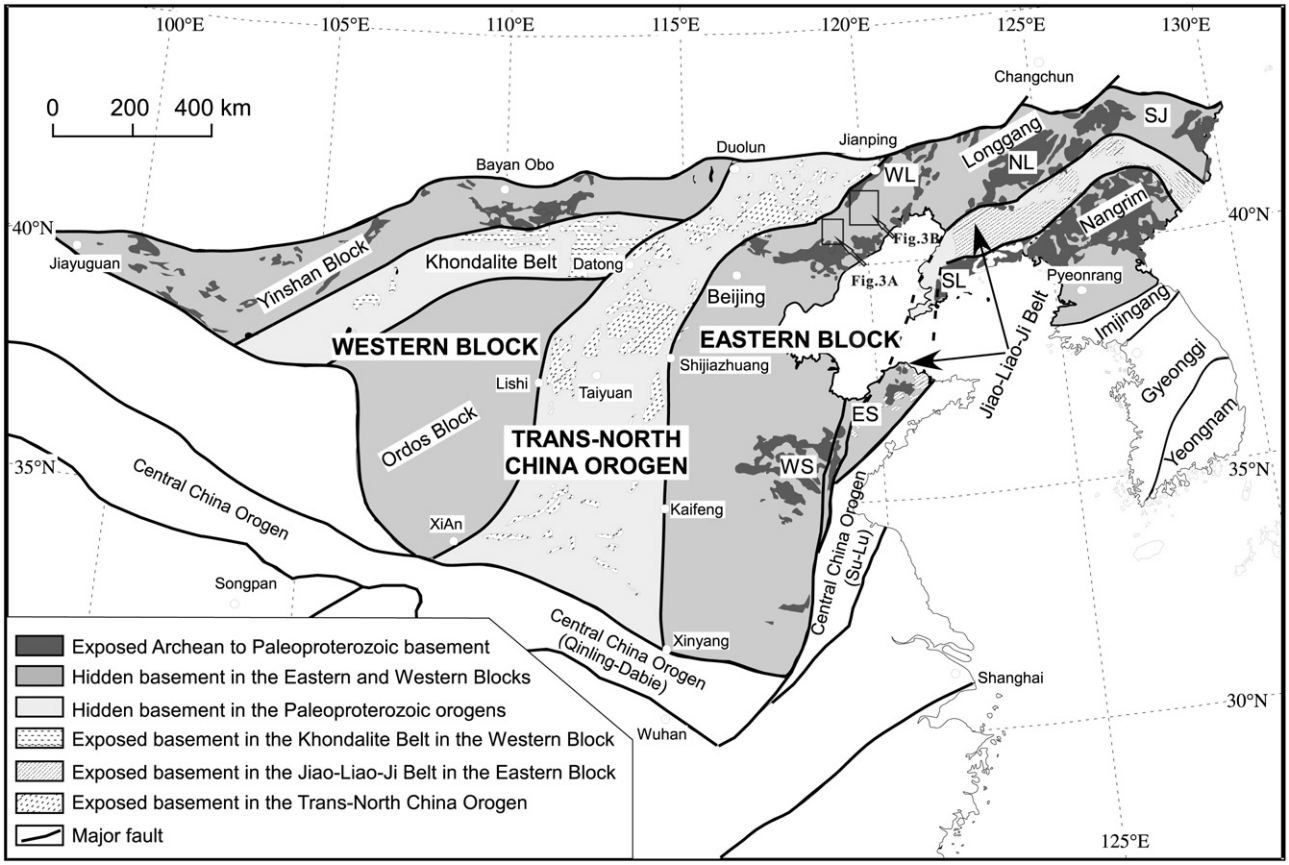

Fig. 1. Tectonic subdivision of the North China Craton (after Zhao et al., 2005).

ca. 1.35 Ga paleopoles are significantly different from each other, they suggest that the NCC may have remained in continuity with Baltica and Laurentia during the Mesoproterozoic. In particular, the quoted age of the Yangzhuang Formation is now problematic in the context of new results from the U–Pb dating method. A precise U–Pb zircon dating result (ca. 1.35 Ga) has recently been obtained by S.-H. Zhang et al. (2009) for sills emplaced into the Xiamaling and Wumishan formations overlying the Yangzhuang Formation (Fig. 2), suggesting that the ca. 1.35 Ga age assignment is too young for the underlying Yangzhuang Formation, and the significance of paleomagnetic poles obtained from this formation

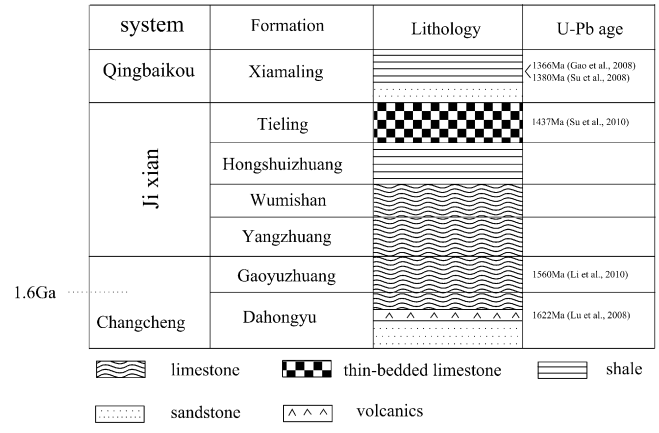

Fig. 2. Subdivision of Mesoproterozoic strata developed in the northern North China Craton with U–Pb age constraints (modified after S.-H. Zhang et al., 2009; Meng et al., 2011).

therefore need to be revised. In summary, the configuration of the NCC in the Columbia supercontinent is still actively debated and high quality Mesoproterozoic paleomagnetic data are clearly desirable. Here we report a ca. 1.35 Ga paleomagnetic pole from a suite of geochronologically dated Mesoproterozoic sills broadly intruding the Xiamaling and Wumishan formations in the northern NCC with an aim of providing a constraint to the configuration of the NCC in the Columbia supercontinent.

2. Geologic background

The NCC is divided into the Western and Eastern Blocks. The former is subdivided into the Yinshan Block in the north and the Ordos Block in the south, which may have amalgamated along the E–W trending Khondalite Belt at ~1.95 Ga (Fig. 1; Zhao et al., 2005; Xia et al., 2006a,b, 2008, 2009; Yin et al., 2009, 2011); whereas the latter is subdivided into the Longgang Block in the northwest and the Langrim Block in the southeast, separated by the Paleoproterozoic Jiao-Liao-Ji Belt (Fig. 1; Li et al., 2005, 2006, 2012; Lu et al., 2006, 2008; Li and Zhao, 2007; Zhou et al., 2008; Tam et al., 2011, 2012). The final amalgamation of the Eastern and Western Blocks to form the coherent basement of the NCC is considered to have occurred along the Trans-North China Orogen at about 1.85 Ga (Fig. 1; Zhao et al., 2000, 2001, 2010; Guo et al., 2002; J. Zhang et al., 2009; H. Li et al., 2010; S.Z. Li et al., 2010; Wang et al., 2010) and may have coincided with the global assembly of the Paleo-Mesoproterozoic Columbia supercontinent.

Following the final amalgamation of the NCC at ~1.8 Ga, a series of well-preserved unmetamorphosed or only weakly metamorphosed Precambrian sediments developed mainly over the central part of the NCC. These Paleo-Mesoproterozoic strata are