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Letter to the editor

Comments on "Paleoproterozoic arc-continent collision in the North China Craton: Evidence from the Zanhuang Complex" by Li et al. (2016), Precambrian Research 286: 281–305

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In a recent article, Li et al. (2016) present questionable petrological, geochemical and zircon U-Pb and Lu-Hf data on a suite of rocks so-called granitoids, amphibolites, diorites, metavolcanics and metasediments (quartz-mica schist) in the Zanhuang Complex in the Central Orogenic Belt (called Trans-North China Orogen in Zhao et al. (2005)) of the North China Craton, and propose a sweeping model that the Zanhuang Complex is a Paleoproterozoic arc that collided with the Neoarchean continent of the Eastern Block of the North China Craton.

However, based on many years of detailed mapping, structural, and geochronological work, we object to most of the basic interpretations of field relationships, descriptions of rock types, quality and interpretations of geochronological data, and major conclusions in Li et al. (2016). First, the paper is devoid of any systematic field descriptions, structural context of where the samples were taken from, or any rigorous description of the samples, leaving the reader unsure whether the protoliths of the rocks are what the authors suggest. Second, the zircon age data is not of publishable quality, is poorly presented and interpreted, rendering it meaningless. Third, the paper entirely ignores the circa 2.5 Ga collisional event which has been well documented in the Zanhuang Complex in recently published work (Deng et al., 2013, 2014; Kusky et al., 2016; Wang et al., 2013, 2015, 2016, 2017a,b; Xiao et al., 2014) and which refutes their proposed tectonic model. Fourth, the paper is internally inconsistent between the conclusion and the description of the tectonic model, and does not present any field evidence for the so-called Paleoproterozoic arc-continent collision between the Zanhuang arc and Eastern Block continent. Fifth, the paper has abundant spelling and grammatical mistakes.

1) There are significant problems with the U-Pb dating and interpretation of the zircons. For the samples of the so-called diorite (ZH-20-2, ZH-21-1), we question why the samples shown have so much K-feldspar (if it is identified correctly). Most of the zircons from this rock are

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clearly metamorphic based on zircon cathodoluminescence (CL) images (their Fig. 15b and c in Li et al. (2016)). Li et al. (2016) have erroneously interpreted these zircons as igneous ones and used these metamorphic ages to incorrectly represent the formation age of the rock they call a diorite. These metamorphic zircons represent one or a mixture of the circa 2.3–1.8 Ga subsequent tectonic events following the early circa 2.5 Ga tectonic event (arc/continent collioion) rather than the formation age of so-called diorite. For the sample of the so-called metavolcanic rock (ZH-18-1, actually a quartz-hornblende schist), the field and petrographic data (their Fig. 5f) do not convincingly show that it is metavolcanic. It is obvious that 28 spots of zircons from sample ZH-18-1 were dated (see supplementary Table 3 in Li et al. (2016)). However, the authors only show 23 spots, and do not explain why they only publish part of the data. Among the published data from those 23 spots, the concordance of 22 zircon spots (one spot at 79%, one spot at 67%, one spot at 59%, the other 19 spots lower than 42% including 5 spots lower than 20%) is much lower than the accepted value of 95%. The concordance of only one spot ($^{207}Pb/^{206}Pb$ age = 2370 ± 31 Ma) is 98%. Therefore, the data are very poor, unpublishable and meaningless. Moreover, it is fallacious to use a weighted mean age (2302 ± 30 Ma) for these discordant data. The single concordant $^{207}Pb/^{206}Pb$ age of 2370 ± 31 Ma inadequately shows that the formation age of the so-called metavolcanic rock would be best-estimated as circa 2.4 Ga rather than 2.3 Ga as proposed in Li et al. (2016). In addition, the authors only obtained data from the somewhat rounded inherited cores of the zircons instead of the rather euhedral overgrowths of these zircons which can be explained to represent younger tectono-thermal events (their Fig. 16c). It is essential to understand what the rock types are that are used for dating and to understand zircon morphology, especially whether they are igneous, metamorphic, detrital, or hydrothermal (Wan et al., 2011; Wu and Zheng, 2004; Chen and Zheng, 2017). Otherwise, zircon U-Pb data can be misinterpreted as meaningful ages. In conclusion, these data are sub-standard and not reliable, and are insufficient to propose any circa 2.3 Ga tectono-thermal events for the Zanhuang Complex of the North China Craton, let alone a sweeping collision of arcs and continents.

2) Deng et al. (2013, 2014) and Wang et al. (2013, 2015, 2016, 2017a,b) have documented a Neoarchean tectonic mélange in the Central Zanhuang Domain of the North China Craton. The mélange contains a structurally complex tectonic mixture of metapelites, metapsammites, marbles and quartzites mixed with exotic tectonic blocks of ultramafic and mafic rocks, metabasalts that locally include relict pillow structures, and TTG gneisses (Wang et al., 2013, 2016). The mélange is older than 2.5 Ga, since it is cross-cut by circa 2.5 Ga mafic dikes and coeval granitic plutons/dikes that cut across the mélange fabric (Deng et al., 2013, 2014; Wang et al., 2013, 2015, 2016, 2017a,b). The metasedimentary rocks including quartzite, marble and schist form a significant part of the Zanhuang mélange (Wang et al., 2013, 2016). LA-ICP-MS detrital zircon dating of quartzites shows that the metasedimentary rocks were deposited between 2.4 and 2.6 Ga, with a peak depositional age at circa 2.5 Ga and the deposition ceased by ca. 2.4 Ga (Wang et al., 2017b). Based on detailed field mapping and geochronological work on different units in the Zanhuang Complex. Wang et al. (2013, 2016) proposed that the Western Zanhuang Domain is part of the 1600 km long Wutai/Fuping arc (sensu Kusky et al., 2016), and the Eastern Zanhuang Domain represents a continental section including structurally imbricated basement, rift, passive margin, and foreland basin sequences that belong to the Eastern Block of the North China Craton. The Neoarchean (circa 2.5 Ga) Zanhuang tectonic mélange in between represents a suture zone between the Wutai/Fuping arc and the Eastern Block continent (Deng et al., 2013, 2014; Kusky et al., 2016; Wang et al., 2013, 2015, 2016, 2017a,b). It is clear that the circa 2.5 Ga event indeed exists in the Zanhuang Complex of the North China Craton. However, it is notable that the circa 2.5 Ga tectonic event is not the terminal tectonic event in the North China Craton. The North China craton was built by successive accretion of microblocks, island arcs and oceanic plateaus (Kusky and Li, 2003; Zhao et al., 2005; Zhai and Santosh, 2011; Kusky et al., 2016), and records several other important tectonic events after 2.5 Ga, specifically at 2.43 Ga, 2.3 Ga, 2.1 Ga, and a 1.9 ~ 1.8 Ga major granulite facies metamorphic event which is widely distributed in the whole North China Craton (Kusky, 2011; Kusky et al., 2016; Peng et al., 2014; Zhao et al., 2001a). The Eastern Block of the North China Craton was assembled by several small blocks between 2.7 Ga and 2.6 Ga (Kusky et al., 2007, 2016; Zhao et al., 2001b). A thick passive margin sequence was developed on the western margin of the assembled Eastern Block between 2.6 Ga and 2.5 Ga (Kusky, 2011; Kusky et al., 2016; Wang et al., 2013, 2016). At circa 2.5 Ga, The Wutai/Fuping arc collided with the margin of the Eastern Block over a west-dipping subducting slab (Trap et al., 2009; Wang et al., 2016), obducting ophiolites and ophiolitic mélanges over and imbricating the sequences of the Eastern Block. From south to north, this 2.5 Ga subduction and accretion event is marked by traces of the Zunhua-Zanhuang suture along the Dengfeng fore-arc subduction-accretion complex (Deng et al., 2016), the Zanhuang ophiolitic mélange (Wang et al., 2013), the Zunhua structural belt in eastern Hebei province (Kusky and Li, 2003), and the Jianping structural mélange in northern Liaoning province (Li et al., 2002). At circa 2.43 Ga, the remaining open ocean west of the accreted arc closed and collided with an oceanic plateau now preserved as the Western Block (Kusky and Mooney, 2015; Kusky et al., 2016). At circa 2.3 Ga, an arc collided with an Atlantic-type margin developed along the northern margin of the North China Craton (Kusky et al., 2016). The circa 2.1 Ga magmatic events related with rift or back-arc setting have been documented from the Zanhuang Complex (Du et al., 2016; Yang et al., 2011a,b; Peng et al., 2014). From 1.9 to 1.8 Ga, the whole North China Craton underwent a granulite facies metamorphic event with higher grade along the northern margin of the craton (Kusky and Li, 2003; Kusky and Santosh, 2009; Kusky et al., 2016; Peng et al., 2014; Zhai and Santosh, 2011). Kusky and Li (2003) and Kusky et al. (2016) suggest that the metamorphism was related to a continent-conti-

nent collision along the northern margin of the craton when the amalgamated North China Craton joined the Columbia continent. In conclusion, it is significant to evaluate the structural, metamorphic, and igneous history of the study area from published data before interpreting the questionable geochronological data.

3) One of the major conclusions in the paper by Li et al. (2016) is that the Western and Eastern Domains of the Zanhuang Complex represent Archean continental basement whereas the Central Zanhuang Domain is an accretionary complex developed during the subduction and collision process between the Western Zanhuang Domain and Eastern Zanhuang Domain during the Paleoproterozoic. In other words, the authors regard the Western Zanhuang Domain and Eastern Zanhuang Domain as continental blocks, and the Central Zanhuang Domain as a suture between the two continental domains. However, the authors refer the whole Zanhuang Complex as an arc in Section 5.4 where they describe the evolutionary history of the Zanhuang Complex. In the cartoon of their tectonic model, they also suggest that the Zanhuang Complex was an arc. It is obvious that the authors are self-conflicted. The totally different views make readers very confused. Both the Western and Eastern Domains of the Zanhuang Complex are mainly composed of deformed TTG gneisses that experienced partial melting (Trap et al., 2009; Wang et al., 2013). The protolith of the TTG gneisses in the Western Zanhuang Domain, predominantly tonalite, has undergone intense metamorphism, deformation and anatexis and is intimately associated with melanocratic dioritic gneiss and leucocratic trondhjemitic veins (HBGMR, 1996; Yang et al., 2013). The tonalitic gneiss has a SHRIMP zircon U-Pb age of circa 2692 ± 12 Ma (Yang et al., 2013). Metamorphic temperatures and pressures of the garnet-bearing TTG gneisses from the Western Zanhuang Domain are estimated to be between 550–700 °C and 5–10 kbar (HBGMR, 1989; Trap et al., 2009). The TTG gneisses in the Eastern Zanhuang Domain experienced amphibolite- to granulite-facies metamorphism (Trap et al., 2009). The protolith ages for the TTG gneisses are estimated to be late Archean (HBGMR, 1989, 1996; Trap et al., 2009; Wang et al., 2003; Wang et al., 2013). Apart from some lithological and metamorphic similarities, the structural and geochemical features of the TTG gneisses between the Western Zanhuang Domain and the Eastern Zanhuang Domain are very different (Trap et al., 2009; Wang et al., 2013; Yang et al., 2013). In addition, previously published work suggests that the TTG gneisses of the Western Zanhuang Domain represent the Fuping arc, whereas the TTG gneisses in the Eastern Zanhuang Domain represent an old continent that belongs to the Eastern Block of the North China Craton (Trap et al., 2009; Wang et al., 2013, 2016, 2017a,b). Therefore, the conclusion by Li et al. (2016) that the entire Zanhuang Complex is a single arc is misinformed. It is also unfounded to propose a back-arc between the Western Zanhuang Domian and Eastern Zanhuang Domian if, as Li et al. (2016) propose, the whole Zanhuang Complex was an arc. Furthermore, the authors do not present any field or any other evidence for the so-called arc-continent collision zone between the Zanhuang arc and Eastern Block continent. In conclusion, the authors did not evaluate the previous work including detailed field mapping, structural analysis, regional tectonic analysis, geochemical and geochronological works by other groups in this area (Trap et al., 2009; Wang et al., 2013, 2016, 2017a,b; Yang et al., 2013), and built a groundless tectonic model with no field data to support it.

4) The paper has a large number of careless spelling, grammatical and other mistakes. In the abstract, LA-CIPMS should be corrected to LA-ICPMS. The title for Section 2 is "Geological background and sampling". However, this section does not provide information about sampling at all. Instead, the sampling information is presented in results section (Section 4). In Section 4 (results), the data and interpretation are mixed together when the authors describe the petrography and geochemistry. The results and discussion should be separated. In addition, the authors do not describe the field contact relationships for all the rocks before starting to describe the petrography. Moreover, the authors do not show the typical optical characteristics of different minerals leading to confusion by the reader about the photomicrographs. For example, the plagioclase in Fig. 5e and f looks like quartz. The K-feldspar in Fig. 5a–d looks like quartz. The muscovite in Fig. 5e looks like biotite. The total estimated content of all the rock types is not 100%. Following Trap et al. (2009), the authors have mislabelled the longitude on their Fig. 3 as 144° rather than 114°. A final small point, the authors thank "Editor in Chief" Prof. Guochun Zhao for helpful comments during his handling of the paper, but the authors should note that the journal Precambrian Research does not have an "Editor in Chief", but rather, has two Editors, currently Guochun Zhao and Randall Parrish.

In summary, Li et al. (2016) did not provide necessary or sufficient data to constrain or even propose the existence of any Paleoproterozoic arc-continent collision in the Zanhuang Complex. The paper did not evaluate the previous work in the Zanhuang Complex (Deng et al., 2013, 2014; Trap et al., 2009; Wang et al., 2013, 2015, 2016, 2017a,b; Xiao et al., 2014) that refutes their proposed tectonic model. There is no field evidence showing that it is a Paleoproterozoic arc-continent collisional suture zone. The authors mixed up igneous and metamorphic zircons in their interpretations. The zircon U-Pb dating of the so-called metavolcanic rock is sub-standard and meaningless. Therefore, the interpretations and conclusions drawn from Li et al. (2016) are refuted.

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