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Neoproterozoic paleogeography of the Tarim Block: An extended or alternative "missing-link" model for Rodinia?

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ABSTRACT

Recent reconstructions of the Rodinia supercontinent and its breakup incorporate South China as a "missing link" between Australia and Laurentia, and place the Tarim craton adjacent to northwestern Australia on the supercontinent's periphery. However, subsequent kinematic evolution toward Gondwana amalgamation requires complex geometric shuffling between South China and Tarim, which cannot be easily resolved with the stratigraphic records of those blocks. Here we present new paleomagnetic data from early Ediacaran strata of northwest Tarim, and document large-scale rotation at near-constant paleolatitudes during Cryogenian time. The rotation is coeval with Rodinia breakup, and Tarim's paleolatitudes are compatible with its placement between Australia and Laurentia, either by itself as an alternative "missing link" or joined with South China in that role. At the same time, indications of subduction-related magmatism in Tarim's Neoproterozoic record suggest that Rodinia breakup was dynamically linked to subduction retreat along its northern margin. Such a model is akin to early stages of Jurassic fragmentation within southern Gondwana, and implies more complicated subduction-related dynamics of supercontinent breakup than superplume impingement alone.

1. Introduction

The evolution of the Neoproterozoic supercontinent Rodinia was an integral part of the broader Earth system that also included extremes in paleoclimate (Kirschvink, 1992), ocean geochemistry (Halverson et al., 2010), and the emergence of complex life (McMenamin and McMenamin, 1990). However, much debate remains regarding the configuration of this supercontinent (e.g., Li et al., 2008; Evans, 2013). One main controversy is whether Australia–East Antarctica was directly connected to Laurentia, near the center of Rodinia (Hoffman, 1991; Li et al., 2008), and if so, in what specific configuration. Early Rodinia models postulated a tight fit of those cratons, establishing the standard "SWEAT" (Southwest U.S.–East Antarctic) connection (e.g., Dalziel, 1997). Simultaneously or shortly afterwards, alternative models were proposed, including the "AUSWUS" (Australia–Western United States) connection (Karlstrom et al., 1999), the "AUSMEX" (Australia–Mexico) juxtaposition (Wingate et al., 2002), and also the "Missing-link" model of South China inserted in between (Li et al., 1995). According to a comprehensive analysis of geological and paleomagnetic data (summarized by Li et al., 2008), only the "Missing-link" model was demonstrated to be viable by both geological correlations and ca. 1200–750 Ma paleomagnetic poles from Australia and Laurentia. For example, the ca. 750 Ma paleomagnetic data demanded either untenably early supercontinental breakup relative to the stratigraphic age of proposed rift–drift transitions on the Australian and Laurentian conjugate margins, or a sizable gap between the blocks (Wingate and Giddings, 2000). South China may have filled that gap, as its centrally located, Grenville-age Sibao (or Jiangnan) orogen could mark the suture between the Australia–proximal Yangtze block and the Laurentia-related Cathaysia block during Rodinia amalgamation (Li et al., 1995, 2008).

However, the basis for this "missing-link" position for South China faces some challenges. First, the timing of the assembly of Yangtze and Cathaysia, i.e., the age of the Sibao or Jiangnan orogen is probably younger than the type Grenville orogeny suggested by new chronologic data (e.g., Zhao et al., 2011; Wang et al., 2014), and the tectonic setting of the younger magmatism (ca. 830–750 Ma) in this block has different interpretations (e.g., Sun et al., 2008). Second, in order for South China to migrate from the "missing link" position to a likely early Paleozoic location adjacent to NW Australia, South China must have taken a circuitous path around northern Australia (Li et al., 2013)—

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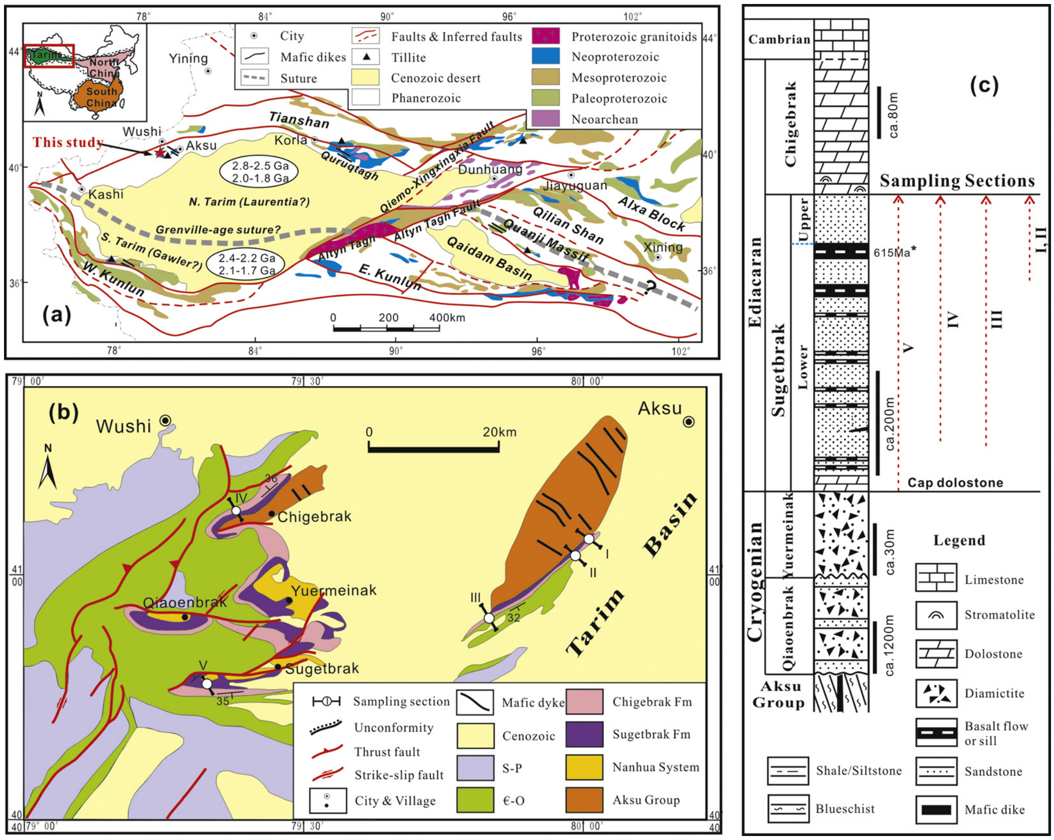

Fig. 1. (a) Tectonic framework of Tarim Block (NW China), showing the Grenville-age "Tarimian" sutures (after Lu et al., 2008; Z.Q. Xu et al., 2013) and study area in this work. The ovals mark the different age ranges of continental nucleus and igneous/metamorphic events in basements of Northern and Southern Tarim. (b) Geological map of the northwestern margin of Tarim Block (after Gao et al., 1985; XBGMR, 1993; Turner, 2010; Wen et al., 2015), showing the sampling sections. (c) The composite Precambrian stratigraphic column of the Aksu–Wushi area (after Gao et al., 1985; XBGMR, 1993; Turner, 2010; Zhu et al., 2011; B. Xu et al., 2013; Wen et al., 2015), schematically showing the sampling sections I to V that consist of the upper and lower part of the Sugetbrak Formation. Cross-section of each section is shown in Fig. S1. *, a U–Pb zircon age of basalt from B. Xu et al. (2013). Note variable thickness scales.

not only is this kinematically unusual, but it also predicts large-scale sinistral transform motion that is not readily compatible with the Ediacaran–Cambrian passive-margin tectonostratigraphic records of both blocks (e.g., Jiang et al., 2003). As an alternative to the "missing-link" position, South China has been proposed to remain near NW Australia at marginal regions of Rodinia during the evolution from Rodinia to Gondwana (Jiang et al., 2003; Zhang et al., 2013).

While South China has been placed on either side of Australia in Rodinia reconstructions, the Tarim craton has conventionally been positioned along Australia's northwestern margin at Rodinia's periphery. Such a location was initially proposed by Li et al. (1996) to account for (i) the allegedly minor role of Grenville-age tectonism in Tarim, (ii) plume-related magmatism at 830–750 Ma correlated with that in northwestern Australia, and (iii) similar Ediacaran–Cambrian stratigraphic records including late Neoproterozoic glacial deposits and Lower Cambrian volcanic rocks. Most subsequent work has adopted this model in the absence of additional constraints (e.g., Li et al., 2008); a notable exception is that of Lu et al. (2008), who instead joined Tarim with South China in the "missing link" location based on the tectonostratigraphic correlation including the ~820 Ma giant radiating dyke swarms in the center. Further work has demonstrated that the proposed location of Tarim adjacent to northwestern Australia may be ill-founded. A comprehensive study of deep-drill cores in Tarim has revealed that the Grenville-age (1.1–1.0 Ga) orogeny is in fact pervasive across the craton (Fig. 1a; Z.Q. Xu et al., 2013 and references therein). Furthermore, the 830–750 Ma magmatism in Tarim could be linked to either NW Australia, or many other locations around Australia or even other continents (Li et al., 2003, 2008). Meanwhile, the <750 Ma rifting-related magmatism that occurred in Tarim (Xu et al., 2005, 2009) is not present in northwestern Australia. And finally, the Cambrian mafic magmatism within sections of NE Tarim is found to be earliest Cambrian in age (Yao et al., 2005), and hence cannot be considered a match for the Early–Middle Cambrian Kalkarindji large igneous province in northern Australia (Glass and Phillips, 2006). Thus, the only point of distinctive geologic comparison between Tarim and northern Australia is the presence of mid–late Ediacaran glacial strata, which nonetheless lack precise age constraints and are among a handful of other enigmatic glaciogenic deposits of that age interval worldwide (Evans and Raub, 2011). Besides the geological mismatches, the other weakness for the Tarim–NW Australia juxtaposition is from the paleomagnetic constraints of Tarim. Chen et al. (2004), Zhan et al. (2007) and Zhao et al. (2014) together proposed a long connection between Tarim and NW Australia during most of the Neoproterozoic times. Not to mention its incompatibility with the geological records above, its paleolatitude is not easy to be reconciled with the paleomagnetic data obtained from the ca. 740 Ma Baiyisi volcanic rocks (Huang et al., 2005) and the Sturtian-age Qiaoenbrak Formation (Fm) sediments (Wen et al., 2013).

Apart from the oft-suggested connection to NW Australia, the other proposed paleoposition for Tarim is the eastern side of Australia (e.g., Lu et al., 2008). If so, whether the Tarim Block can act as an alternative missing link within Rodinia reconstructions? Also, the discrepancy among the available paleopoles for Tarim's paleogeography within this supercontinent emphasizes the need of more reliable paleomagnetic data. In this paper, we report high-